Flood Protection Planning Study

City of Gainesville, Texas
and
Cooke County, Texas

FINAL REPORT

Prepared for
City of Gainesville, Texas
Texas Water Development Board

May 1999

STATE OF TEXAS
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GAINESVILLE
TEXAS

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Executive Summary

The primary objective of this Flood Protection Planning Study is to develop a plan to address the flood problems through a watershed planning approach to guide the City of Gainesville in implementing flood protection measures in a logical, cost-effective manner. The plan proposes non-structural and structural solutions for flood protection. Non-structural solutions include:

- Adoption of a Drainage Criteria and Design Manual,[1] developed as part of this study, for regulation of future development;
- Update of the existing 100-year floodplain mapping for the Elm Fork of the Trinity River, Pecan Creek, Wheeler Creek, and Dozier Creek and the inclusion of areas that were not mapped in detail in previous FEMA Flood Insurance Studies; and
- Acquisition of flood prone property that will be required for future implementation of flood control projects.

Structural solutions include a total of 30 projects that were identified to address the major flood problems that exist in the City. The total implementation cost for all of these projects is $30,839,000. The projects were prioritized based on criteria that included: severity of the problem; public safety; capital cost; preservation and enhancement of existing property values; development potential; social and economic impacts; and maintenance costs. Funding alternatives for the structural solutions are projected to primarily include revenue from the City's Municipal Drainage Utility (MDU) and potential federal assistance through the FEMA Flood Mitigation Assistance Program and the U.S. Army Corps of Engineers Local Flood Damage Reduction Program. Many of the projects will also involve coordination with the Texas Department of Transportation and the BN&SF Railroad Company.

An implementation plan is presented which illustrates a 10-year plan for completing various structural and non-structural measures for flood control. The plan assumes that the Municipal Drainage Utility will be the primary source of revenue for the City with rates increased to levels comparable to other cities in Texas. Revenue from the Municipal Drainage Utility is projected to fund two stages of capital improvements. The first stage, projected to occur in fiscal year 2000, includes an increase in MDU rates and the issuance of revenue bonds on the order of $2,500,0000 to fund immediate improvements. The second stage, projected to

[1] Drainage Criteria and Design Manual, Adopted by Ordinance by the City of Gainesville, March 2, 1999.

occur in fiscal year 2003, includes an additional increase in MDU rates and issuance of revenue bonds on the order of $3,700,000 to fund land acquisition, bridge replacements, and channel improvements on Pecan Creek and other smaller drainage projects. Projects that are projected to be completed in the first and second stages of the program include:

• Chestnut Channel Improvements[2]	$486,000
• Pecan Creek Channel Improvements[3]	$4,141,500
• Weaver St./Sante Fe Dr. – Phase 1 Storm Sewer Improvements	$490,000
• Laurel Road – Phase 1 Storm Sewer Improvements	$548,000
• Broadway Street West – Phase 1 Drainage Improvements	$92,000
• Refinery Road – Phase 1 Channel Improvements	$200,000
• College Avenue – Phase 1 Drainage Improvements	$40,000
• O'Neal Street – Phase 1 Storm Sewer Improvements	$440,000
• Airport Area – Phase 1 Drainage Improvements	$20,000
• Star Avenue Channel Improvements	$62,000

In order to fund any significant level of drainage improvements in the City of Gainesville, the rates for the City's Municipal Drainage Utility will have to be increased to levels comparable to other cities in Texas. As a comparison, the base residential rate required for Gainesville would increase from $0.50 to $2.00 per month in fiscal year 2000. The second stage of improvements would require a base residential rate on the order of $3.50 per month. These Municipal Drainage Utility rates are comparable to other cities in Texas, as shown in Table ES-1.

Table ES-1
Summary of Base Residential Rates for Municipal Drainage Utilities in Texas

City	1990 Population	Monthly Base Residential Rate
Gainesville	14,256	$0.50
Georgetown	14,842	$2.25
Grapevine	29,202	$4.00
Euless	38,149	$2.50
Bedford	43,762	$2.50
College Station	52,456	$3.50
Mesquite	101,484	$3.00
Garland	180,650	$2.40
Austin	456,622	$3.67

[2] Estimate of City's share of project cost. Funding is potentially available from the FEMA FMA Program.
[3] Estimate of City's share of project cost. Funding assumed to be available from the USCOE.

Section 1
Introduction

1.1 Background

The City of Gainesville and Cooke County are located in north Texas near the Texas-Oklahoma border. The City of Gainesville (City) has a population of approximately 14,000, about one-half the population of Cooke County. The City is the county seat and includes most of the major industry in the county: aircraft, steel fabrication, and tourism. The City's economy also includes agribusiness and the City's tourism amenities include a zoo, parks, Victorian homes, and walking tours.

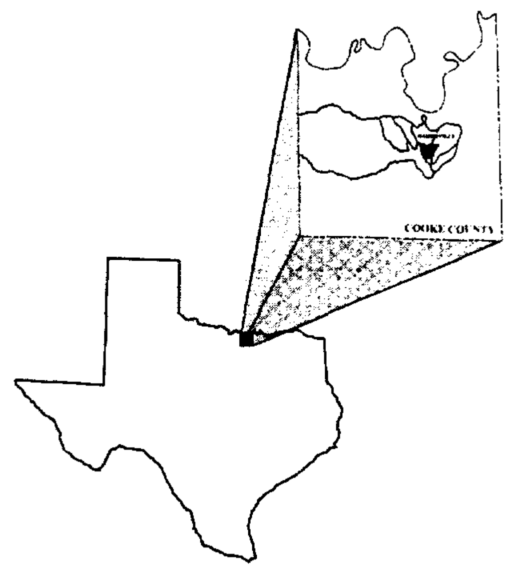
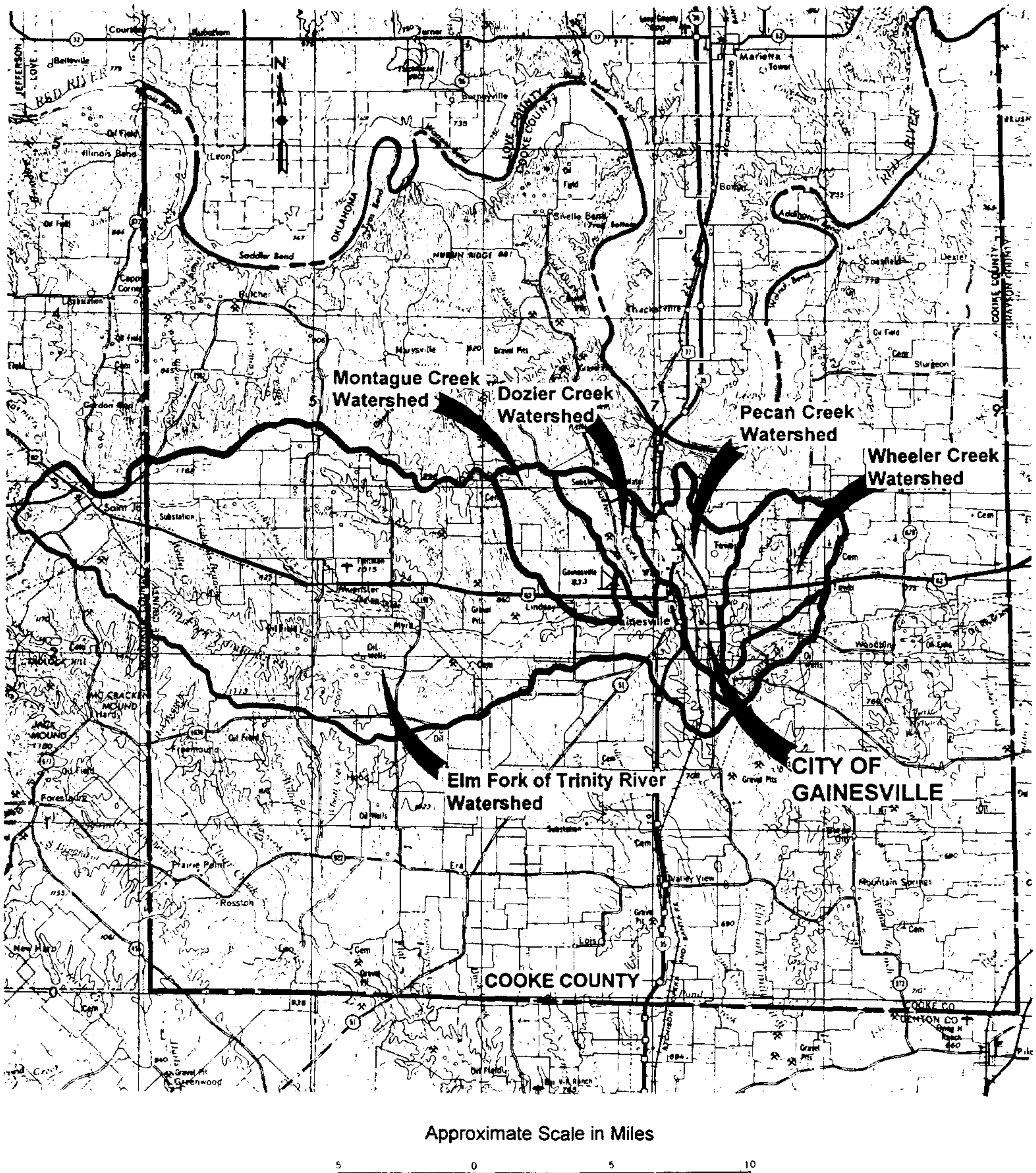


Figure 1.1-1
Study Area Location

Flood events resulting in substantial damage have occurred frequently in Gainesville and the surrounding Cooke County area. In the last 25 years, there have been significant flood events in 1977, 1979, 1981, 1989, 1990, and 1993. Flood events, occurring on average about once every four to five years, have resulted in costly damages to homes, local businesses, streets, parks, personal property, and other private and public facilities. The most damaging flooding in the Gainesville area generally occurs in the Pecan Creek, Wheeler Creek, and Elm Fork of the Trinity River watersheds. Other watersheds that contribute to flooding in the Gainesville area include Dozier Creek and Montague Creek watersheds (See Figure 1.0-2).

Pecan Creek flows through the heart of the City and floods that exceed the capacity of the Pecan Creek channel inundate many homes and businesses in the central business district of the City (See Figure 1.0-3). Wheeler Creek, a tributary to Pecan Creek, flows along the eastern portion of the City and produces flood problems primarily for local residences. Pecan Creek, Wheeler Creek, Dozier Creek, and Montague Creek all flow into the Elm Fork of the Trinity River near the City. Flood levels in the Elm Fork of the Trinity River also cause severe damage



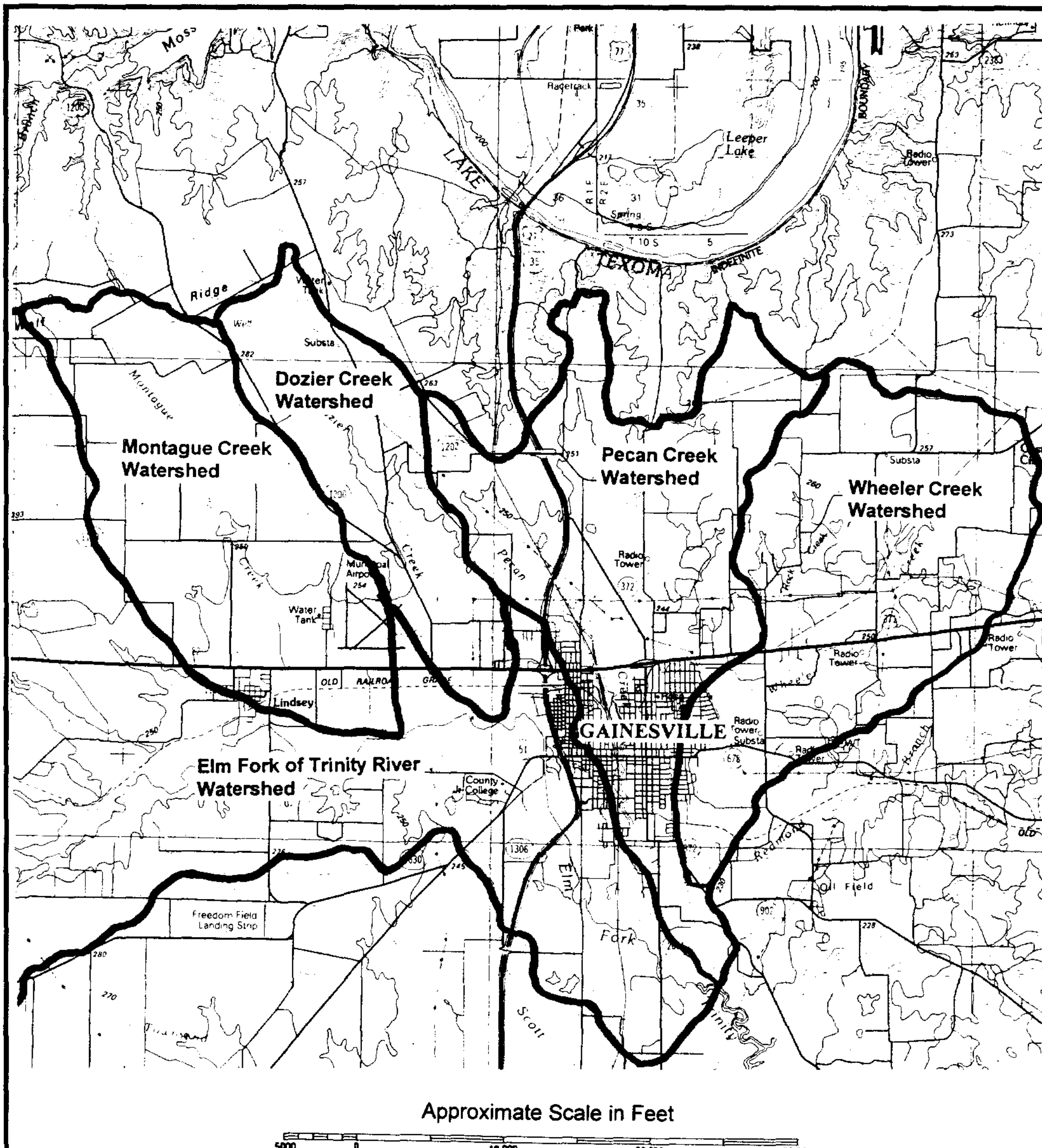
HDR Engineering, Inc.

CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

PLANNING AREA

FIGURE 1.1-2

MARCH, 1999



CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

LOCAL AREA WATERSHEDS

HDR

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FIGURE 1.1-3

MARCH, 1999

with backwater from major floods inundating several homes and businesses in the City and Cooke County area.

The City of Gainesville, in cooperation with Cooke County, applied to the Texas Water Development Board for a Flood Protection Planning Grant in August 1997. The Texas Water Development Board awarded the City and County a $125,000 matching grant in October 1997 to perform a planning study to address the flooding problems in the area. The City entered into an interlocal agreement with Cooke County to perform planning in the area of Cooke County, outside of the City's corporate limits and within the watershed study areas. The City entered into an agreement with HDR Engineering, Inc. to perform the planning study and the study was initiated in January 1998.

1.2 Goals and Objectives

The primary goal of the study is to develop a plan to address the flood problems through a watershed planning approach to help guide the City of Gainesville in implementing flood protection measures in a logical, cost-effective manner. The flood protection plan was developed by performing the following tasks:

1. Data Collection;
2. Hydrologic analysis;
3. Hydraulic analysis;
4. Development of flood control alternatives;
5. Economic analysis;
6. Report preparation; and
7. Public meetings.

The data collection task of the study included compiling existing information from a variety of sources including the Federal Emergency Management Agency (FEMA), City of Gainesville (City), Cooke County Appraisal District (CCAD), National Weather Service (NWS), U.S. Geological Survey (USGS), Natural Resource Conservation Service (NRCS), and the U.S. Army Corps of Engineers (USCOE). The data collection task also included a significant effort in obtaining field measurements of existing bridges and culverts in the planning area and compiling an inventory and preparing a map of the City's existing storm sewer system. The storm sewer inventory map was digitized electronically into the City's digital aerial topographic mapping system. The storm sewer system mapping will be a valuable tool for the City in complying with future EPA NPDES regulations as one of the first requirements will likely be identification of illicit discharges into the storm sewer system. The storm sewer system map will provide useful information for the City to locate illicit discharges.

The hydrologic analysis task included delineation of watershed boundaries for major and minor watersheds, computation of watershed parameters, development of rainfall-runoff models, analysis of streamflow gaging records, and computation of peak runoff rates at selected locations.

The hydraulic analysis task included development of stream hydraulic models for each major stream segment in the study area for which topographic information was available from the City's aerial topographic mapping, computation of water surface profiles for the 2-year through 500-year flood events, mapping of the 100-year flood plain area, and hydraulic analyses of existing and proposed storm sewer systems.

The task of development of flood control alternatives included evaluation of both structural and non-structural solutions. Problem areas were identified in the study area and various alternatives for mitigating existing and future flood problems were evaluated. Structural solutions generally included channel improvements, levees, flood control dams, bridge and culvert improvements, and storm sewer system improvements. Non-structural solutions included acquisition of flood prone properties, relocation, flood proofing, and ordinances and regulations.

Economic analyses were performed for each problem area. The economic analyses generally included preparation of capital cost estimates for each improvement plan and, in some cases, included an analysis of annual flood damages when data was available from other sources. The economic analysis task also included prioritizing each proposed improvement project and evaluation of potential financing and funding options for implementation of the plan.

The draft report was prepared at the conclusion of the study to document the study results, data, methods, and assumptions used. The draft report was distributed to the City and the Texas Water Development Board for review and comment and was made available to the general public. A final report will be issued upon receipt of comments on the draft report.

Public meetings were held during the course of the study to solicit input from the general public for the planning effort. A meeting was held near the beginning of the study to describe the goals and objectives of the study and solicit input on existing drainage problems in the study areas. Prior to the first meeting, a survey was mailed to each customer of the City inviting comments and suggestions related to the planning effort and to provide information related to specific flooding problems in the study area. A copy of the survey form and summary of responses is included in Appendix F. A second public meeting was held near the middle of the study effort in January 1999 to presents interim results including updated 100-year flood plain mapping and preliminary improvement plans for selected problem areas. A third and final meeting is scheduled in April 1999 at the conclusion of the study to present the results of the planning effort.

1.3 Organization of Planning Documents

The Flood Protection Planning Study Report is divided into six main sections. Section 1 provides an introduction, study goals and objectives, and description of historical flood events. Section 2 provides a description of the methodology used in the performance of this study including a description of the flood hydrology and stream hydraulic models, a discussion of the drainage criteria applied, a description of the methodology used to develop cost estimates of recommended improvements, and a description of how problem areas were identified. Section 3 includes individual sub-sections for each of the five major watersheds in the Gainesville area including the Elm Fork of the Trinity River, Pecan Creek, Wheeler Creek, Dozier Creek, and Montague Creek. Each watershed sub-section includes a description of the general characteristics of the watershed, flood hydrology results, hydraulic capacity of roadway and railroad crossings, identification of problem areas, conceptual improvement plans for flood mitigation, and cost estimates for each problem area. Section 4 provides a summary of improvements for each problem area and prioritization of each of the proposed projects. Section 5 presents alternatives for financing and funding of the recommended improvement plans and Section 6 presents an implementation plan and schedule for the City.

1.4 History of Flooding

The City of Gainesville has experienced frequent flooding over its history, including five significant floods in the last 17 years, all resulting in flooding of homes and businesses in the Gainesville area. Daily rainfall records are available for Gainesville since the late 1800s, and a review of these records reveals many major storm events over the 100-year period. Figure 1.4-1 presents a summary of the maximum daily rainfall for each calendar year for the period of 1900 to 1997.[1] Based on the rainfall records, two of the largest storm events occurred in 1903, with over 10.07 inches of rainfall recorded on July 2 and 9.95 inches recorded on September 30. In 1919, a major storm occurred on July 19, with 9.26 inches occurring in the 24-hour period. Recent history has included many major flood events since the 1960s, with the most catastrophic flooding occurring on October 13, 1981 and May 16, 1989. A summary of major flood events in the Gainesville area is presented chronologically since the 1960s in the following sections.

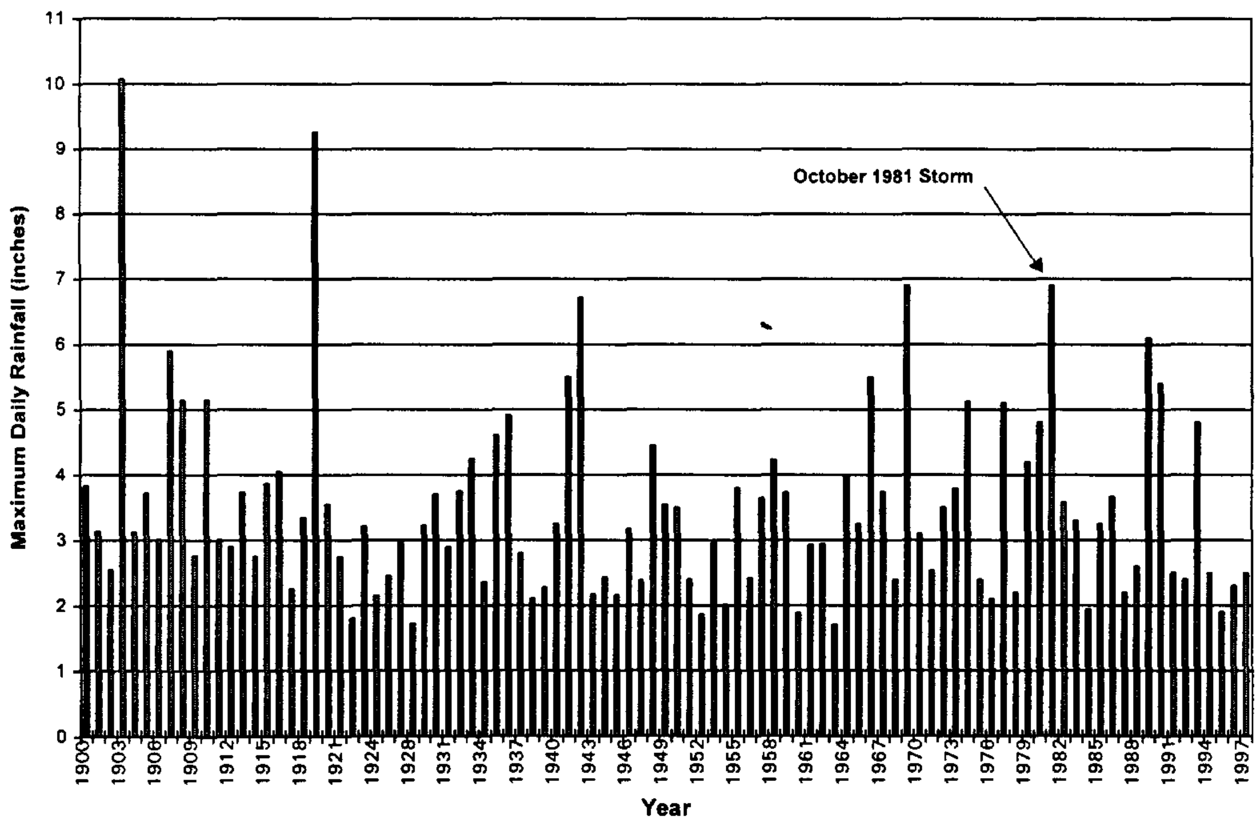
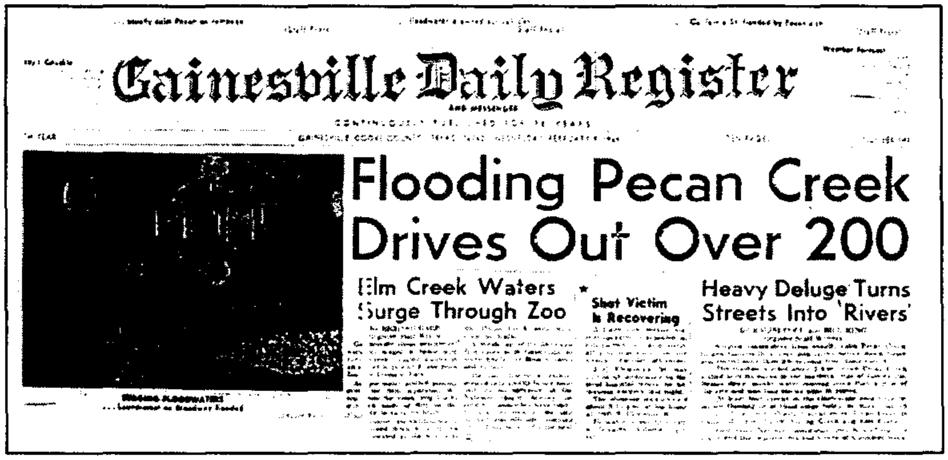


Figure 1.4-1. Summary of Maximum Daily Rainfall for Gainesville, Texas as Recorded by the National Weather Service (1900-1997)

[1] Texas Natural Resource Conservation Commission, Texas Water Oriented Data Bank, National Weather Service Precipitation for Gainesville, Texas, ID No. 00003415, Period of 1900 to 1997.

1.4.1 Flood of February 8-9, 1966

A significant flood event occurred on February 8-9, 1966 when the center of a storm crossed the northern portion of the City of Gainesville from west to east. Flooding was minor on the Elm Fork of the Trinity River; however, flooding on Pecan Creek caused considerable damage in the City of Gainesville. The Soil Conservation Service (SCS) prepared a Special Storm Report[2] for this flood event. Rainfall reports were received by the SCS from local citizens and SCS technicians within the Pecan Creek watershed. Reports reveal that the rainfall, accompanied by a violent electrical storm, started at about 8:00 p.m. on February 8, 1966. The heaviest rainfall occurred after 10:00 p.m. and continued until about 6:00 a.m. the next day. Approximately 6 inches of rainfall fell over the Pecan Creek watershed upstream of Gainesville during the 8-hour period. The storm was preceded by rain and snow over the watershed during the prior 3-week period, with soil moisture being characterized as medium-to-wet before the storm. A storm of this magnitude would be expected to occur about every 25 years, on average, based on the 8-hour period total of approximately 6 inches and regional rainfall statistics (Figure1.4-2). Flood damages were sustained by an estimated 60 homes and businesses in Gainesville. Other damages observed were to streets, bridges, fences, and personal property, such as automobiles and commercial vehicles. Flooding along the Elm Fork included damage to Frank Buck Zoo, including damage to zoo facilities and the loss of some of the smaller animals by drowning.


Gainesville Daily Register

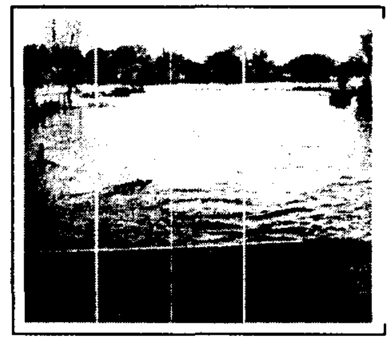
Flooding Pecan Creek Drives Out Over 200

Elm Creek Waters Surge Through Zoo

Shot Victim Is Recovering

Heavy Deluge Turns Streets Into 'Rivers'

2 Soil Conservation Service, Special Storm Report, Storm of February 8-9, 1966, Gainesville, Texas, Pecan Creek Tributary, Elm Fork Watershed, Upper Elm-Red Soil and Water Conservation District, Cooke County, Texas.



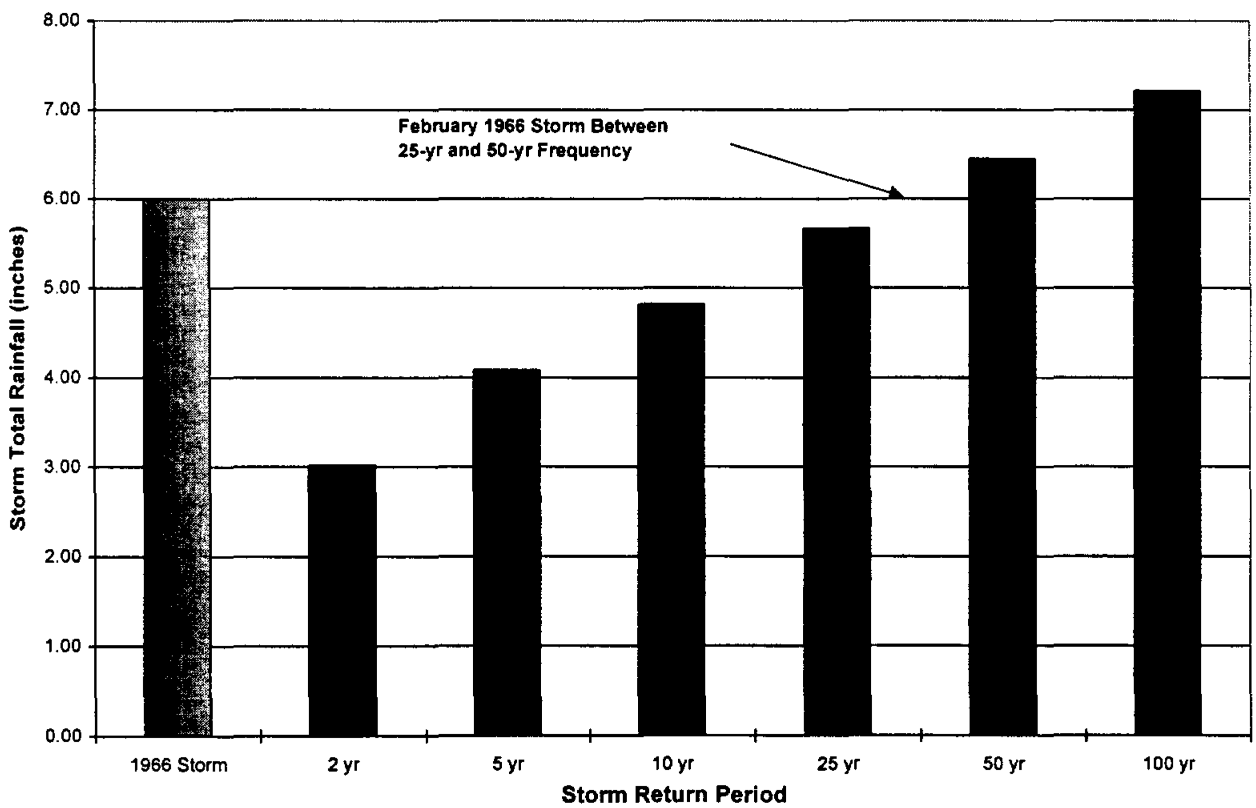


Figure 1.4-2. February 1966 Storm Frequency Comparison for 8-hour Duration

1.4.2 Flood of October 30-31, 1974

A storm event occurred on October 30-31, 1974 with over five inches of rainfall recorded during about a 20-hour period. The rainfall began at about noon on October 30 and continued until about 9:00 a.m. on October 31. Soil moisture conditions in the watersheds surrounding Gainesville were generally medium-to-wet, with rainfall occurring in each of the 4 days preceding this storm (total of 1.02 inches). Damage from this storm was relatively minor. A storm of this magnitude would be expected to occur about once every five years, based on the storm totals and regional rainfall statistics, as shown in Figure 1.4-3.

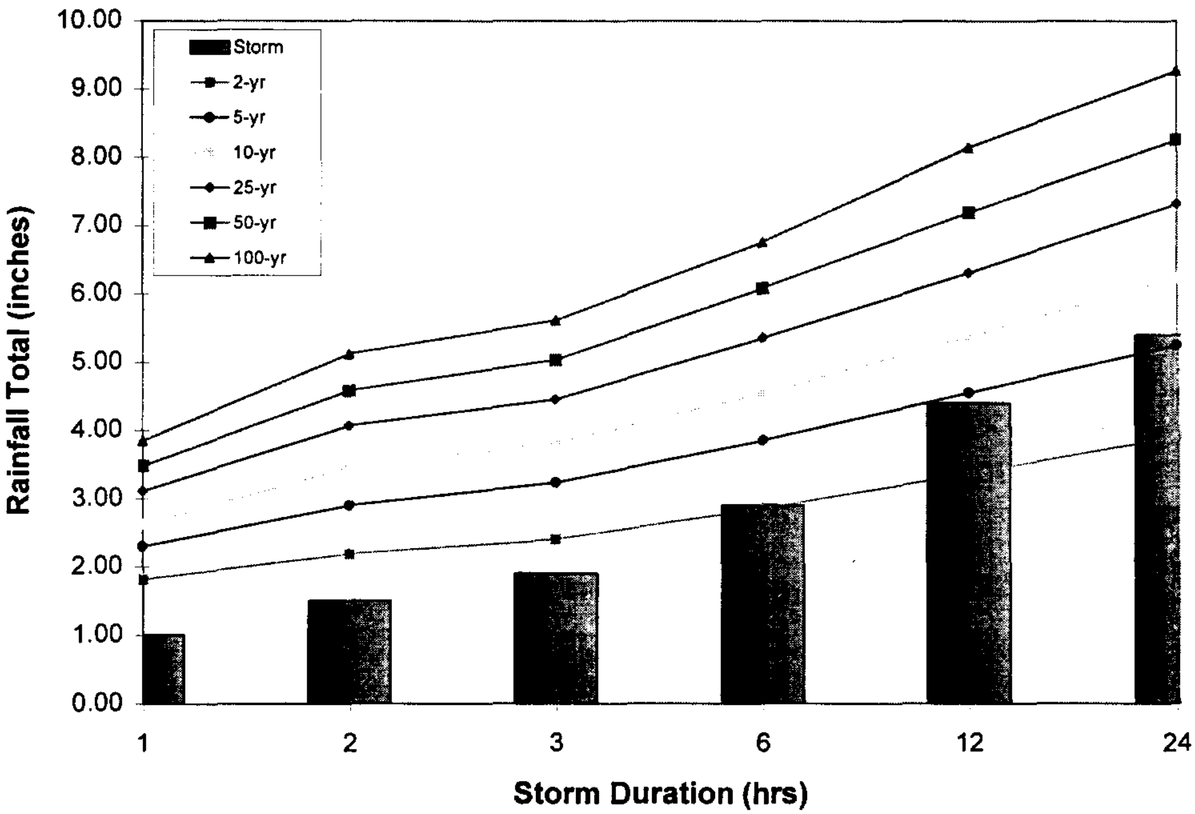


Figure 1.4-3. October 1974 Storm Frequency Comparison

1.4.3 Flood of March 19, 1979

A storm event occurred on March 19, 1979 causing minor flooding on Pecan Creek. Rainfall reports showed upwards of about 3 inches of rainfall occurred. This rain was preceded by rainfall over the previous 2 days, resulting in wet soil moisture conditions. Pecan Creek crested at a stage of about 10 feet, with flooding reported in low-lying areas around Myrtle, Olive, O'Neal, Anthony, Cole, Garnett, and Schopmeyer Streets and along Old Denton Road. There were no reports of water entering any homes, although flood waters were observed surrounding many residences in these locations. Street flooding was reported in many areas, and a small section of O'Neal Street near N. Grand Avenue was washed out and collapsed. The Elm Fork of the Trinity River reached a peak stage of over 20 feet. A storm of this magnitude would be expected to occur about once every five years, based on the reported rainfall totals and stream levels.

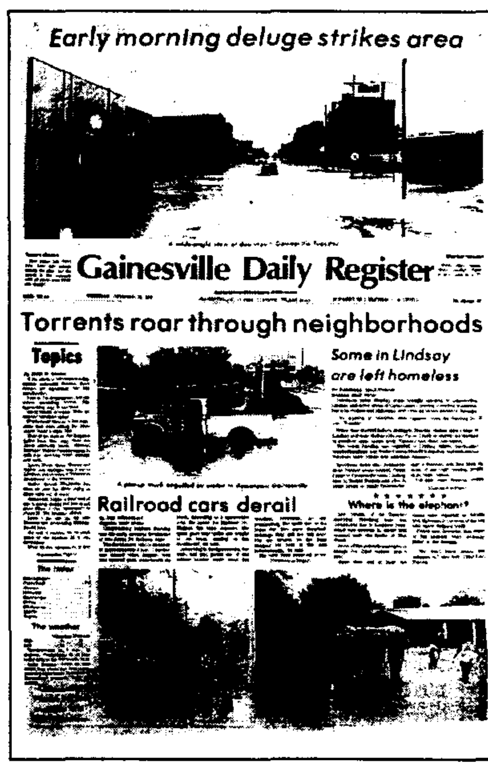
Gainesville Daily Register

High Wind and Heavy Rain Lash Cooke Area

Thunderstorms Roam Across Texas

1.4.4 Flood of October 12-14, 1981

The most catastrophic flood event in the Gainesville and Cooke County area occurred over the period of October 12-14, 1981. During the entire month of October 1981, total rainfall recorded at Gainesville was almost 26 inches. The storm of October 12-14 produced the most widespread damages. On October 5-7, rainfall amounts of 3.5 to 7.0 inches fell throughout the upper Trinity River watershed creating saturated soil moisture conditions and a high runoff potential. Due to the runoff from this earlier rainfall, many of the Soil Conservation Service floodwater retarding structures located in the upper Elm Fork watershed were filled to the principal spillway crest elevation and, in some cases, still had some storage in the flood detention pool when rainfall began on October 12.



Early morning deluge strikes area

Gainesville Daily Register

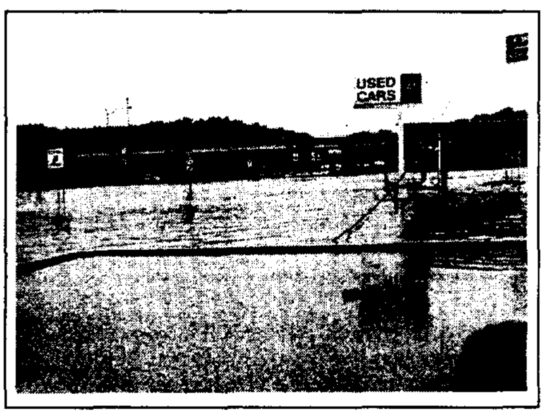
Torrents roar through neighborhoods

Topics

Some in Lindsay are left homeless

Railroad cars derail

The rain fell in a 36-hour period, with its greatest intensity over the majority of the area occurring in two 6-hour periods, including the early morning of October 12 and through noon on October 13. Reports of rainfall during this 36-hour period ranged from 7.5 inches to as high as 22.5 inches. The National Weather Service isohyetal map shown in Figure 1.4-4 displays the rainfall patterns in relation to the Cooke County area. The storm event produced runoff rates that engaged the emergency spillways of many of the SCS floodwater retarding structures in the Elm Fork watershed. In fact, the dam at one particular structure located on Montague Creek was overtopped by 0.4 feet. Significant erosion damage occurred to the dam, although the dam did not breach. This is the first time a SCS floodwater retarding structure had ever been overtopped in Texas out of 1,816 structures in place at that time, with many in service for over 30 years.




Gainesville Daily Register

Crews work in flood's wake

Waters leave mud, damage, hope despair

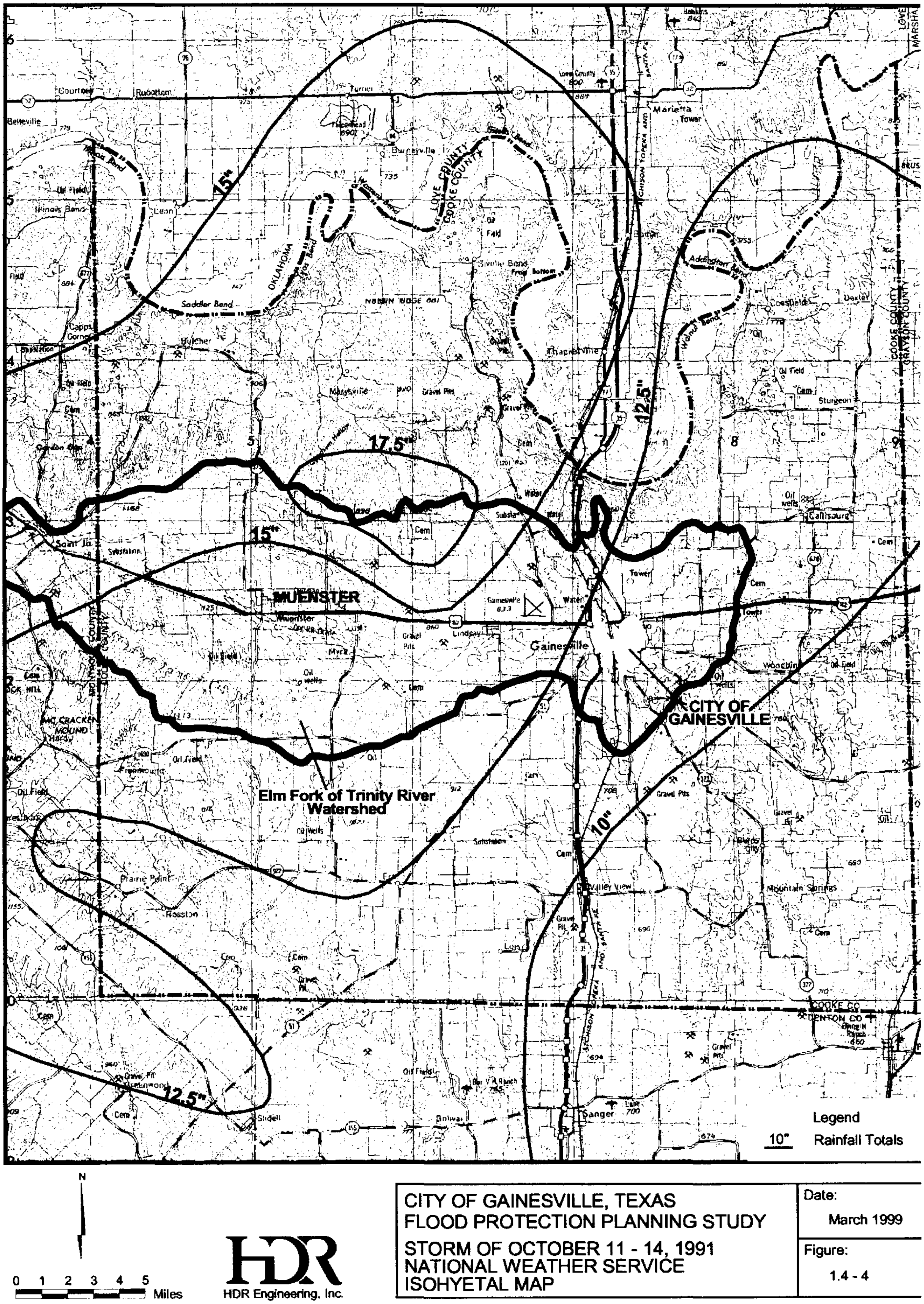
Zoo animals couldn't find ark

Evacuees come by vehicle, boat—on foot

Resident dies in accident

Today

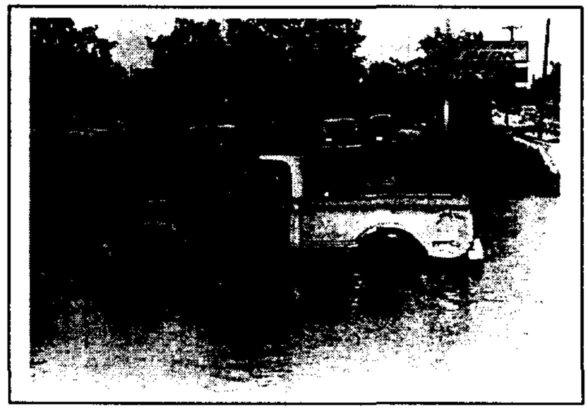
Flooding in Gainesville was widespread in all watersheds. The Elm Fork of the Trinity River reached a record stage, flooding a major portion of the southwestern portion of the City of Gainesville and inundating the Frank Buck Zoo. Based on local observations, the Elm Fork crested at a stage of about 28 feet. The estimated peak discharge at California Street based on this reported stage and gage measurements at Muenster and Sanger is on the order of 57,000 cfs. This is the largest flood of



HDR Engineering, Inc.

CITY OF GAINESVILLE, TEXAS FLOOD PROTECTION PLANNING STUDY	Date: March 1999
STORM OF OCTOBER 11 - 14, 1991 NATIONAL WEATHER SERVICE ISOHYETAL MAP	Figure: 1.4 - 4

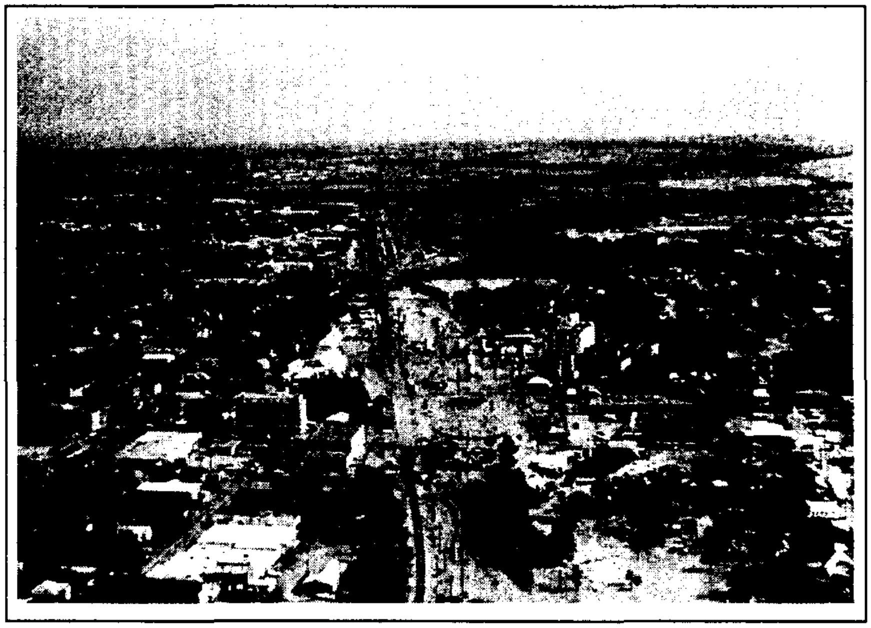
record on the Elm Fork since at least 1908. Overall, over 271 homes and businesses sustained damages from this flood in Gainesville. Flood damages in the Gainesville area were estimated to be over $19,000,000 and the Cooke County area was declared a Federal Disaster Area. A flood of this magnitude is unprecedented. Estimates of the return period of this event range from a 200-year event to in excess of a 500-year event.[3]

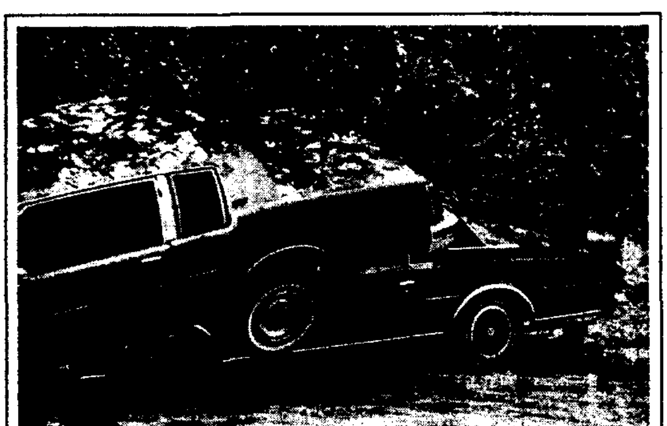


[3] Soil Conservation Service, "Performance of Floodwater Retarding Structures, Elm Fork of the Trinity River Watershed, During October 1981 Storm," U.S. Dept. of Agriculture, Temple, Texas, January 1983.

1.4.5 Flood of May 16, 1989

A storm event occurred on May 16, 1989 in the Gainesville area producing major flooding on Pecan Creek. Hourly rainfall records available from the National Weather Service show that 3.9 inches of rainfall occurred in the one-hour period of 10:00 a.m. to 11:00 a.m. on May 16, 1989. Over the 3-hour period of 10:00 a.m. to 1:00 p.m., rainfall totaled 5.8 inches. Most of the rainfall for this storm was concentrated on the Pecan Creek and Wheeler Creek watersheds, resulting in wide spread flooding of homes and buinesses along these two streams. The Elm Fork of the Trinity River crested at a stage of about 25.3 feet (24,000 cfs), well below its 1981 record level. Based on regional rainfall statistics, a storm of this magnitude would be expected to occur on average about once every 100 years. As shown in Figure 1-.4-5, the 1-hour, 2-hour, and 3-hour storm totals approach 100-year rainfall levels.





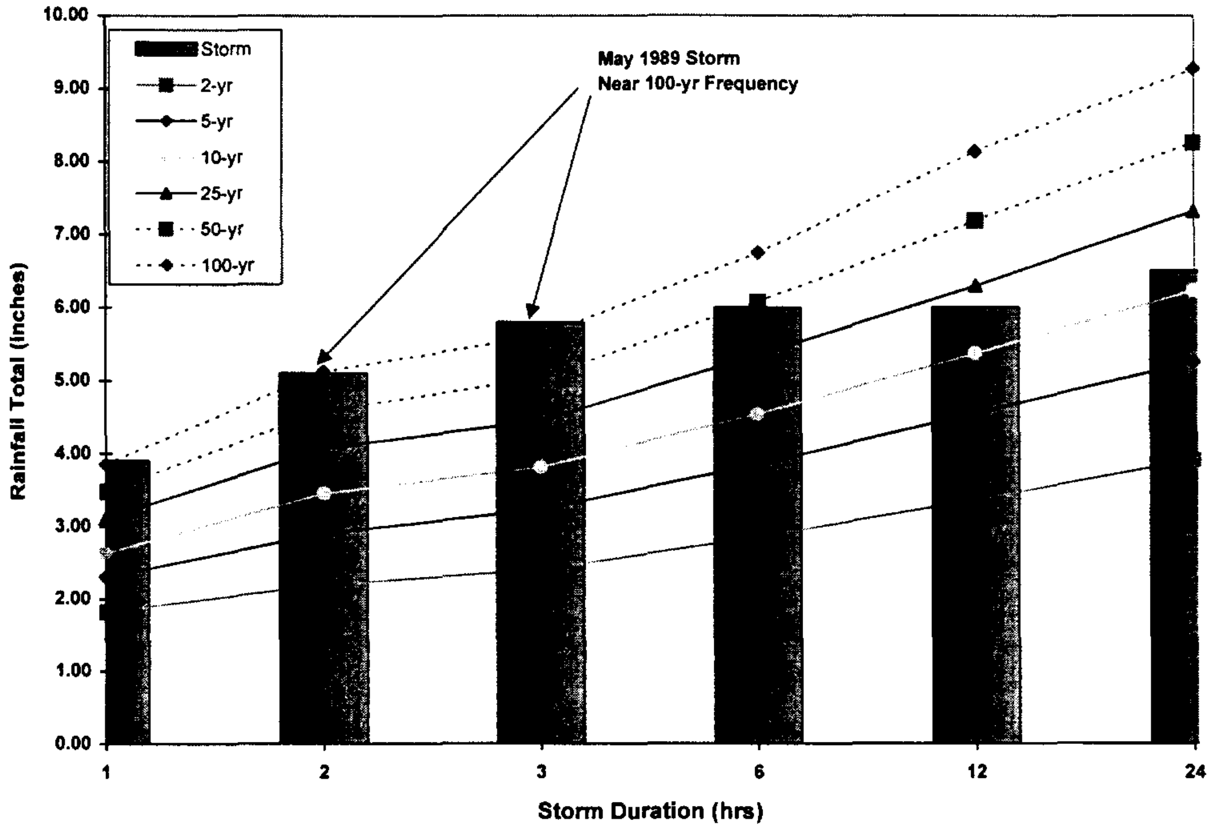
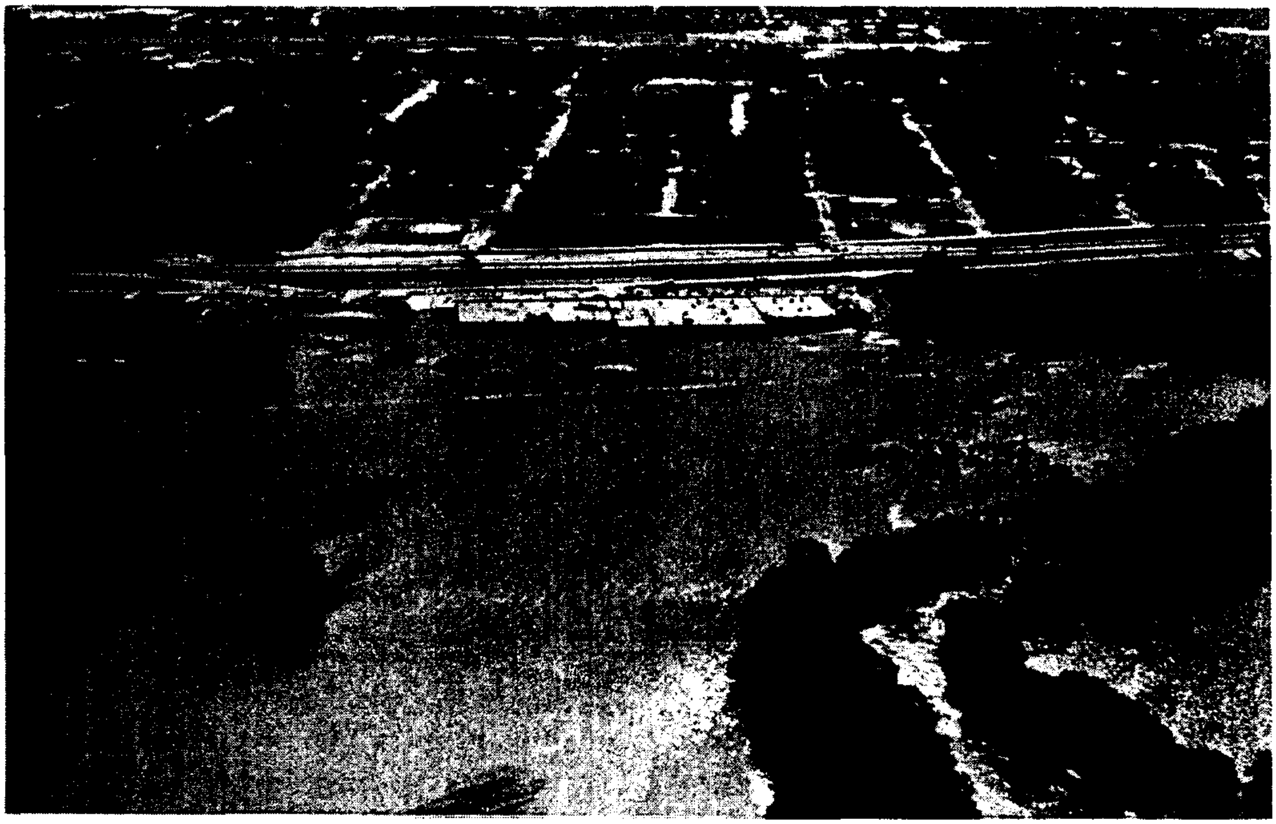
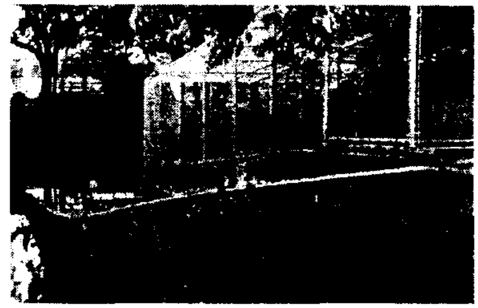


Figure 1.4-5. May 1989 Storm Frequency Comparison



1.4.6 Flood of April 25, 1990

A storm event occurred on April 25, 1990 that produced 5.35 inches of rainfall in a 21-hour period in Gainesville. Minor flooding resulted on Pecan Creek and the Elm Fork of the Trinity River. A storm event of the magnitude recorded at Gainesville would be expected to occur about every 5 years, on average, based on regional rainfall statistics as shown in Figure 1.4-6.

1.4.7 Flood of May 9, 1993

A storm event occurred on May 9, 1993 that produced about 3.9 inches of rainfall in a 4-hour period at Gainesville. The storm resulted in flooding of low-lying areas in Pecan Creek

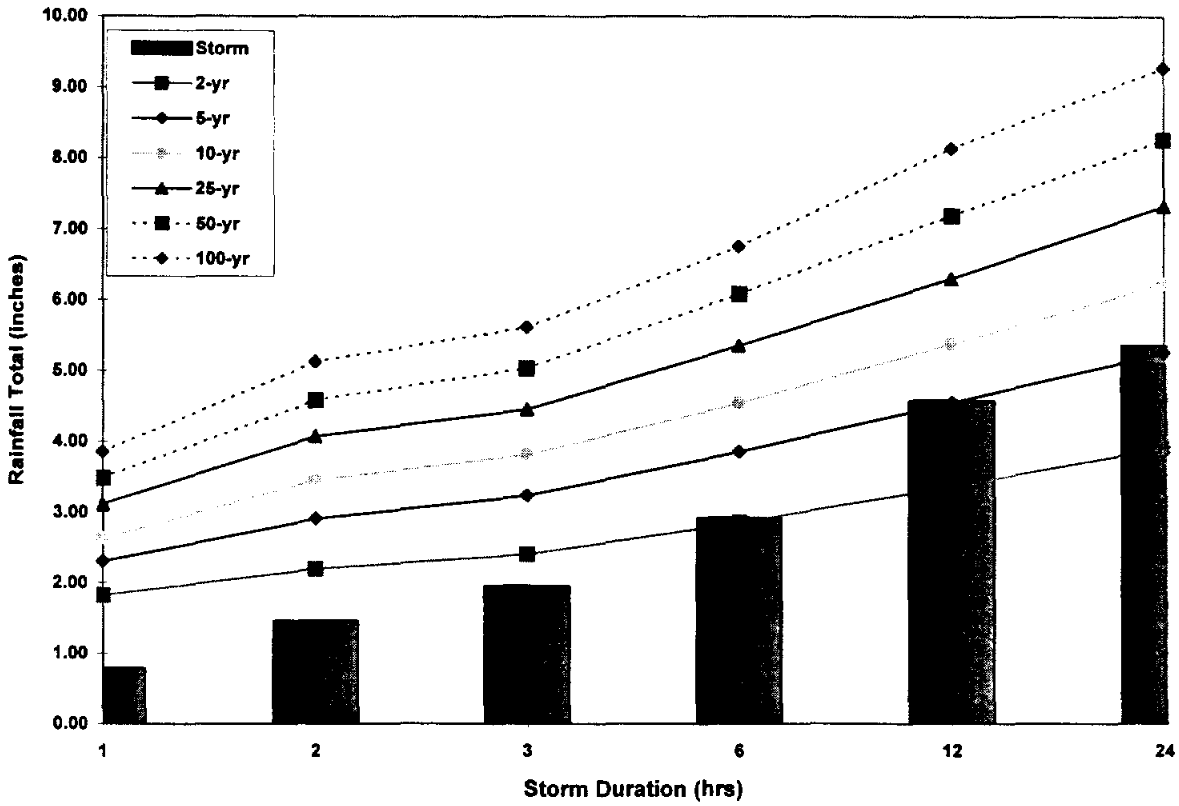


Figure 1.4-6. April 1990 Storm Frequency Comparison

and Wheeler Creek. The Elm Fork of the Trinity River crested at a stage of 22.7 feet (21,100 cfs) at the California Street bridge, just 1 to 2 feet below the top of the levee around Frank Buck Zoo, which had just been constructed. A storm event of this magnitude would be expected to occur about once every 5 years, on average, based on regional rainfall statistics. The resulting flood on the Elm Fork of the Trinity River would be expected to occur about once every 15 years based on available streamflow records.


Gainesville Daily Register

Dramatic rescue saves two women stranded in creek

Weather

Stormy weather

Storms, flash floods bring death, havoc

Gainesville Daily Register

TUESDAY, MAY 11, 1993 GAINESVILLE, COOKE COUNTY, TEXAS 76240 8 PAGES — 25 CENTS NUMBER 216

Ad-lib use of fire ladder keyed women's rescue

By LAURA J. FUHRMANN
Register Staff Writer

There was still a solemn softness in Fire Capt. Malcom Foster's voice Monday as he recalled the rescue of two women from Spring Creek.

Flood photos ——— page 2

On Sunday, Foster dangled at the end of a rope on a firetruck ladder in order to help hoist two potential victims to safety after the women became trapped in a vehicle with rising waters threatening to carry them away. Other emergency crew helped to manually hoist the rope and swing the truck's ladder horizontally — something the ladder isn't actually designed to do. Emergency personnel and others stood on the truck during the rescue to help equalize forces on both sides of the ladder.

"Things didn't go perfect, but they went as well as could be expected," Foster said. "It was scary. It was really scary."

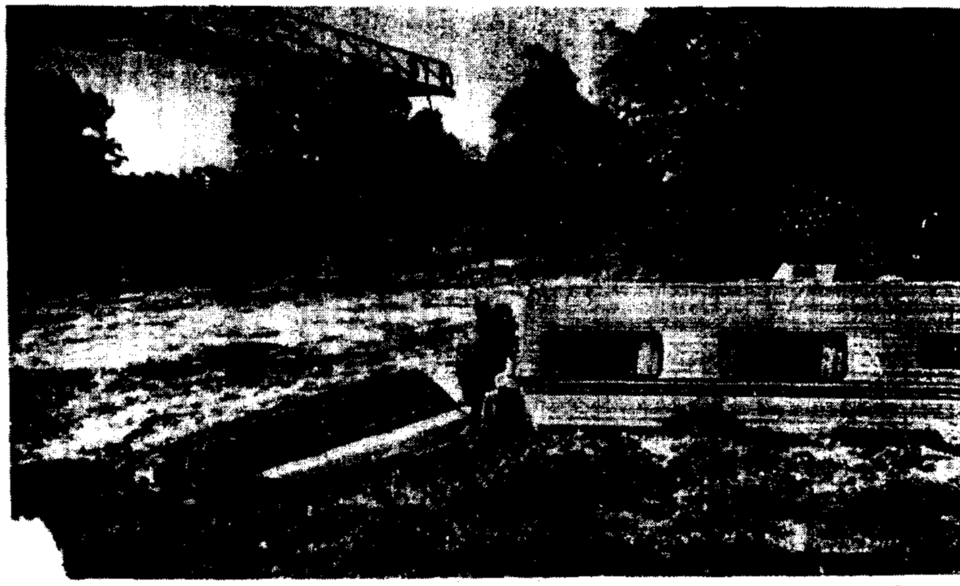
Foster said he was surprised the two women rescued — Marguerite Johnson, 76, of Whitesboro; and her daughter Judy Duncan, 48, of Little Elm — were as calm as they were. "They cooperated well," he said.

Foster said one never knows exactly what to expect when coming up on the scene of an emergency.

When he did find out about Sunday's scenario in which the Suburban with the two women in it was trapped in the rising creek with a trailer behind it, he said, "we thought there would be an easier way." There wasn't.

Normally, when a vehicle is stranded in water, it is a recovery, but this incident was a rescue, he said. And while training does help in such situations, Foster said part of knowing what to do is simply following common sense.

Foster, who took charge of the firefighters' operation Sunday at the low-water crossing on Highway 51



(Courtesy photo)

SAVED FROM THE FLOOD — Capt. Malcom Foster of the Gainesville Fire Department pulls one of two women trapped in their vehicle on a low-water crossing by a rising Spring Creek on Sunday. With help from volunteers including the Cooke County sheriff's department, Era volunteer fire department, Cooke County EMS, Department of Public Safety officers and others, the women were saved.

Section 2
Analysis Methodologies

The Flood Protection Planning Study includes a comprehensive analysis of stormwater runoff and flood conditions for the City of Gainesville (City) and the surrounding area. Historical streamflow conditions for the Elm Fork of the Trinity River (herein referred to as Elm Fork) were evaluated to determine statistics on the frequency of flooding. Flood hydrology models were developed for each major stream, incorporating the unique characteristics of each watershed (including land use, basin slope, channel characteristics, and existing reservoirs) to simulate runoff for specific storm events. Stream hydraulic models were developed for the stream segments included in the study, incorporating the channel and flood plain geometry derived from the City's aerial topographic maps,[1] existing ground survey data, roughness characteristics of the channel banks and flood plain, and the numerous bridges and culverts that cross the streams and affect flood levels. The following sections describe the analysis methodologies used in performance of this study.

2.1 Flood Hydrology

Flood hydrology was developed for major and minor watersheds in the study area for the purpose of evaluating flood conditions, including the capacity of channels, bridges, culverts, streets, and storm sewers. For major watersheds, which are generally defined as those with drainage areas greater than 200 acres, flood hydrology was developed using either historical streamflow data or rainfall-runoff computer models. For minor watersheds (less than 200 acres), flood hydrology was evaluated using more simplistic methods, such as the rational method or general relationships of peak runoff rate to drainage area. The following sections describe the methods and key elements involved in evaluating the flood hydrology for major and minor watersheds.

2.1.1 Major Watersheds

Flood hydrology was developed for the major watersheds in the study area, including the Elm Fork and Pecan, Wheeler, Dozier, and Montague Creeks. For the Elm Fork, historical

[1] City of Gainesville, Texas, Aerial Topographic Mapping, prepared by Dallas Aerial Mapping, Inc., January 1997.

streamflow data was utilized to develop relationships of flood frequency in terms of the probability of exceedance of calculated peak flows for any given year. For Pecan, Wheeler, Dozier, and Montague Creeks, where historical streamflow data is not available, rainfall-runoff computer models were created to develop relationships of flood frequency.

2.1.1.1 Historical Streamflow Data

Historical streamflow data has been collected by the U.S. Geological Survey (USGS) for many streams across Texas. The USGS has established gaging stations on the Elm Fork, near the City, for various periods of time. For purposes of determining flood frequency statistics for this area, the streamflow data was obtained and analyzed in accordance with guidelines for determining flood frequency.[2] These guidelines are incorporated into the computer program developed by the U.S. Army Corps of Engineers (USCOE) Hydrologic Engineering Center called HEC-FFA,[3] which was developed to analyze historical annual peak discharge data for the purpose of estimating flood flow frequency.

2.1.1.2 Rainfall-Runoff Models

For evaluating flood flow frequency for Pecan, Wheeler, Dozier, and Montague Creeks, rainfall-runoff models were developed to compute runoff hydrographs at various locations within each watershed. A rainfall-runoff model simulates the watershed response to precipitation. The USCOE Flood Hydrograph Package, HEC-1,[4] was used to model the flood hydrology in each of these watersheds. The model simulates the rainfall-runoff process and computes runoff hydrographs, peak discharges, and cumulative runoff volumes. The HEC-1 model has numerous options for generating and routing flood hydrographs. As recommended in the City's Drainage Criteria and Design Manual,[5] the Soil Conservation Service's (SCS) methodology[6] was deemed the most appropriate technique for generating flood hydrographs. Key data required by the HEC-1 model include: watershed area; precipitation depths; runoff curve number; unit

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[2] U.S. Geological Survey (USGS), "Guidelines for Determining Flood Flow Frequency," Bulletin #17B of the Hydrology Subcommittee, U.S. Water Council, March 1982.

[3] U.S. Army Corps of Engineers (USCOE), Hydrologic Engineering Center, "HEC-FFA Flood Frequency Analysis," User's Manual, May 1992.

[4] USCOE, Hydrologic Engineering Center, "HEC-1 — Flood Hydrograph Package," Users Manual, Davis, California, Revised, September 1990.

[5] City of Gainesville, "Drainage Criteria and Design Manual," Section 2 - Storm Water Runoff, prepared by HDR Engineering, Inc., November 1998.

hydrograph and basin lag time; design storm characteristics; and channel and reservoir routing parameters.

The drainage basin areas were delineated and subdivided using the City's aerial topographic mapping. The 2-foot contour interval on the mapping provided useful information in determining the major watershed divides and sub-basin delineations. In watersheds bordering the City's aerial mapping limits, USGS 7.5-minute quadrangle maps were used to define the missing watershed boundaries.

In order to develop flood hydrographs for storm events with various return periods, rainfall depths corresponding to the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year recurrence intervals were used. The balanced triangular rainfall distribution with a 24-hour storm duration was used in the HEC-1 model to provide a temporal distribution of rainfall. Areal rainfall reduction factors were used in the hydrologic models to reduce the point rainfall depths where appropriate, as recommended in the National Weather Service's Technical Paper No. 40[7] and NWS HYDRO-35.[8] A point rainfall depth versus duration summary for the City is provided in Table 2-1.

Table 2-1.
Depth-Duration-Frequency Data for Gainesville, Texas

Duration (minutes)	*Rainfall Depth (inches)*					
	Storm Frequency					
	2-Year	*5-Year*	*10-Year*	*25-Year*	*50-Year*	*100-Year*
5	0.49	0.57	0.64	0.73	0.81	0.88
10	0.80	0.95	1.06	1.22	1.35	1.47
15	1.02	1.21	1.35	1.56	1.72	1.88
30	1.41	1.74	1.98	2.32	2.58	2.85
60	1.82	2.30	2.63	3.11	3.48	3.85
120	2.19	2.90	3.45	4.07	4.58	5.12
180	2.40	3.23	3.81	4.45	5.03	5.61
360	2.85	3.85	4.54	5.34	6.08	6.75
720	3.36	4.55	5.37	6.30	7.19	8.14
1,440	3.91	5.25	6.23	7.32	8.26	9.27

6 Soil Conservation Service (SCS), "National Engineering Handbook," Section 4 - Hydrology, 1971.
7 National Weather Service, "Rainfall Frequency Atlas of the United States," Technical Paper No. 40, U.S. Dept. of Commerce, Washington, D.C., 1961.
8 National Weather Service, "Five- to 60-Minute Precipitation Frequency for the Eastern and Central United States," National Oceanic and Atmospheric Administration, Silver Spring, MD, June 1977.

2.1.1.2.1 SCS Runoff Curve Number

The SCS runoff curve number procedure[9] is an accepted method for computing abstractions for storm rainfall. Abstractions are defined as the physical processes (such as soil infiltration and detention or retention by vegetation and/or other means) that effectively reduce the volume of precipitation that becomes runoff. The rainfall that is in excess of the abstractions and becomes runoff is referred to as the excess rainfall. Therefore, for a storm event as a whole, the excess rainfall is always less than or equal to the depth of precipitation. The SCS runoff curve number method relates soil types, antecedent soil moisture, and land use to precipitation abstractions. This method was used in conjunction with information from the Cooke County Soil Survey,[10] the City's aerial topographic maps, and the Drainage Criteria and Design Manual[11] to develop a runoff curve number for each sub-basin considered in the study. Curve numbers were developed for existing and ultimate land use conditions. The soils in the area are generally characterized as hydrologic soil group D, which have a high runoff potential and very low infiltration rates.[12] Generally, these soils consist chiefly of clays and soils with a large clay component. For the 2-year through 500-year flood events, average antecedent moisture conditions (AMC-II) were assumed.

2.1.1.2.2 SCS Unit Hydrograph

The unit hydrograph method is the component in the rainfall-runoff model that transforms the rainfall excess into a surface runoff hydrograph. The unit hydrograph is a typical hydrograph for a watershed. Since the physical characteristics of a watershed (e.g., shape, size, slope, etc.) are generally constant, it is expected that considerable similarity in the shape of runoff hydrographs from storms of similar rainfall characteristics will result. The unit hydrograph for a watershed is defined as a direct runoff hydrograph resulting from one inch of excess rainfall generated uniformly over the drainage area at a constant rate for an effective duration.[13]

The SCS unit hydrograph method relates hydrograph characteristics to a physical characteristic of the watershed, the basin time to peak (t_p). The parameter t_p is defined as the

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9 SCS, Op. Cit., 1971.
10 SCS, "Soil Survey of Cooke County, Texas," U.S. Dept. of Agriculture, May 1979.
11 City of Gainesville, Op. Cit., November 1998.
12 SCS, Op. Cit., 1971.
13 Chow, Ven Te, *et al.*, "Applied Hydrology," McGraw-Hill Book Co., 1988.

time from the beginning of the rainfall event to the time at which the peak runoff rate is observed at the watershed outlet. The time to peak of a basin can be estimated using the following empirical equation:

$$t_p = 0.6\ T_c$$

where:

T_c = Time of concentration for the watershed.

The time of concentration is defined as the time it takes for a drop of rain that falls on the most hydraulically remote point in the watershed to contribute to the flow at the drainage basin outlet. Times of concentration for each sub-basin within the drainage basins were computed using the City's aerial topographic mapping and procedures detailed in SCS Technical Release No. 55.[14] The SCS unit hydrograph method was utilized in the HEC-1 model for all drainage basins in the study.

2.1.1.2.3 Channel Routing

Routing of flood flows from the outlet of an upstream sub-basin to the next sub-basin outlet downstream was accomplished using the Modified Puls method in HEC-1.[15] The flow at the upstream end of a channel was routed to the downstream outlet using Normal Depth Storage techniques. Cross-section geometry, slopes, and Manning's roughness coefficients were obtained from the City's aerial topographic mapping and used as input for the hydrologic model. Computed storage-discharge relationships were used for specific channel reaches that were simulated with the stream hydraulic model (see Section 2.2).

2.1.1.2.4 Reservoir Routing

Reservoir routing was included in the model to account for the flood attenuation effects associated with reservoirs and detention basins. Existing flood control reservoirs were modeled in the Wheeler Creek and Montague Creek watersheds. In addition, potential flood control reservoirs were analyzed in the Pecan Creek watershed as proposed solutions to reduce flooding in the City. The HEC-1 Modified Puls routing routines were used to simulate flow through the

[13] Chow, Ven Te, *et al.*, "Applied Hydrology," McGraw-Hill Book Co., 1988.
[14] SCS, "Urban Hydrology for Small Watersheds," Technical Release No. 55, June 1986.
[15] USCOE, Op. Cit., September 1990.

reservoirs using the Level Pool Routing procedure. This procedure assumes that the reservoir water surface remains effectively level during the routing. Stage-storage-discharge relationships were developed for each reservoir by computing a stage-outflow relationship for each dam and spillway and combining it with the stage-storage relationship for the upstream reservoir pool. Stage-storage relationships were derived using the topographic data from the City's aerial topographic maps or from existing stage-storage relationships provided by the Natural Resource Conservation Service (NRCS, formerly the Soil Conservation Service). Stage-discharge rating tables were developed using information on the outlet works facilities (spillways) from as-built drawings provided by the NRCS.

2.1.2 Minor Watersheds

Flood hydrology was developed for minor watersheds in the study area. Minor watersheds are defined as watersheds with drainage areas of less than 200 acres that exist within the major watersheds of the study area. Minor watersheds are typically associated with a specific area with known drainage problems, such as flooding of homes and businesses due to overflow from streets, excessive street flooding, inadequate storm sewer systems, and/or flooding of minor channels. Flood hydrology for minor watersheds was analyzed using the Rational Method, as outlined in the Drainage Criteria and Design Manual.[16] The Rational Method is an empirical runoff formula that has gained wide acceptance because of its simple intuitive treatment of peak storm runoff rates in areas less than 200 acres. This method relates runoff to rainfall intensity, surface area and surface characteristics by the formula:

$$Q = C\ I\ A$$

where:

- Q = Peak runoff rate, in cubic feet per second (cfs);
- C = Runoff coefficient;
- I = Average rainfall intensity, for a duration equal to the time of concentration, in inches per hour; and
- A = Drainage area to the point under consideration, in acres.

The runoff coefficient (C) accounts for abstractions for losses between rainfall and runoff, which may vary with time for a given drainage area. These losses are caused by interception by vegetation, infiltration into permeable soils, retention in surface depressions, and evaporation and transpiration. Runoff coefficients used in the study are presented in the Drainage Criteria and Design Manual[17] for various types of areas. Rainfall intensity (I) is the average rate of rainfall in inches per hour. Intensity is selected on the basis of design frequency and rainfall duration. For the Rational Method, the critical rainfall intensity is the rainfall having a duration equal to the time of concentration of the drainage basin. Rainfall intensity curves for the City and the surrounding area are presented in the Drainage Criteria and Design Manual.[18]

The Rational Method was applied to minor watersheds in the study to compute peak runoff rates to analyze the capacity of existing systems and to size proposed facilities. Due to the number of minor watersheds required for analysis, the Rational Method was applied to a number of watersheds of various sizes and shapes for the purpose of developing general trends of peak runoff rate versus drainage area for selected return period storm events. These generalized peak runoff rates were used for evaluating the capacity of streets, minor channels, and storm sewer systems.

2.2 Stream Hydraulics

Hydraulic models were developed for each of the major streams in the City for the purpose of assessing flood conditions, including water surface elevations, channel capacities, and hydraulic capacities of existing drainage structures. Peak runoff rates computed as part of the rainfall-runoff analysis (Section 2.1) were used in conjunction with the City's aerial topographic mapping[19] and existing field data to develop the stream hydraulic models. Water surface profiles for each stream segment included in this study were computed for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flood events. The resulting flood plains were mapped for the 100-year flood event for existing and future development conditions using the aerial topographic maps as a base for flood plain delineation. A total of 42.6 miles of streams comprising the major storm drainage system in the study area were modeled. The following sections describe the key elements involved in hydraulic modeling of the stream segments in the study area.

[16] City of Gainesville, Op. Cit., November, 1998.
[17] Ibid.
[18] Ibid.
[19] City of Gainesville, Op. Cit., January 1997.

2.2.1 Selection of Stream Hydraulic Model

The USCOE Hydrologic Engineering Center (HEC) developed the computer model HEC-RAS[20] for the computation of water surface profiles. This model was developed as part of the HEC's "Next Generation" (NexGen) of hydrologic engineering software. HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics, and reporting facilities. The HEC-RAS software allows the user to perform one-dimensional steady flow calculations and is a successor to HEC-2.[21] HEC-RAS employs the standard step method and includes a variety of computation procedures for analyzing bridges, culverts, and other hydraulic structures that are encountered on most rivers and streams. The HEC-RAS model requires the following input data:

- Channel cross section geometry;
- Bridge/culvert geometry;
- Flow lengths;
- Manning's roughness coefficient estimates; and
- Streamflow.

Channel cross-section geometry and flow lengths were obtained from the City's aerial topographic mapping. Cross-section geometry was generated using the electronic versions of the City's maps and the BOSS-RMS[22] software, which electronically generates the basic HEC-RAS input data files within AutoCAD. The City's aerial topographic mapping was developed based on a 2-foot contour interval. Data from topographic mapping using National Map Standards is generally accurate within 1 foot of the actual ground elevation. Bridge and culvert geometry was obtained from a variety of sources, including the existing Federal Emergency Management Agency (FEMA) model, field measurements, and design plans for recently constructed structures. Manning's roughness coefficients were selected based primarily on field observations and interpretations from aerial mapping. Streamflows used in the hydraulic models were the

[20] USCOE, Hydrologic Engineering Center , "HEC-RAS River Analysis System," User's Manual, Davis, California, July 1995.
[21] USCOE, Hydrologic Engineering Center, "HEC-2, Water Surface Profiles," Users Manual, Davis, California, September 1991.
[22] BOSS International, "BOSS RMS for AutoCAD," User's Manual, Madison, WI, 1998.

peak flows computed for the 2-year through 500-year flood events, obtained from the flood hydrology model (Section 2.1).

2.2.2 Existing FEMA Model

The FEMA studies performed for the City were completed by Bovay Engineers, Inc.[23] using the hydraulic model HEC-2. The HEC-2 model for the City has been archived by FEMA onto microfiche and was not available electronically. The existing FEMA model only applies to certain areas of the Elm Fork and Pecan Creek, and for a very short reach of Wheeler Creek (Refer to Appendix A). Stream segments outside of these areas were not studied in detail and flood plains were delineated using approximate methods. For the purposes of this study, the HEC-RAS Water Surface Profiles model was used to compute water surface profiles for all stream segments studied. HEC-RAS is essentially an update of the HEC-2 model and utilizes comparable procedures for computing water surface profiles. HEC-RAS was selected due to its universal acceptance and because it offers certain advantages in stream hydraulic modeling.

2.2.3 Channel Improvements

Channel improvements were evaluated for a number of the problem areas identified in this study. HEC-RAS offers a convenient method for analyzing a range of channel improvement options and includes computational procedures for estimating excavation volumes and computing revised flood levels with the channel improvements in place. Earthen and concrete channel improvements were considered at many locations as a part of this study. Recommended channel improvements were based on the guidelines provided in the City's Drainage Criteria and Design Manual.[24]

2.3 Street Drainage

Streets and roadways in the urban areas of the study area serve an important and necessary drainage service even though their primary function is for the movement of traffic. Water will often tend to follow streets and roadways, therefore, the analysis of street drainage is

[23] Bovay Engineers, Inc., "Flood Insurance Study, City of Gainesville, Texas, Cooke County," Federal Emergency Management Agency, Community No. 480154, April 15, 1981.
[24] City of Gainesville, Op. Cit., November 1998.

an important part of the overall study in order to reduce drainage problems that occur due to excessive street flow.

2.3.1 Street Classification

Streets are classified based on their primary use and size. Streets are classified as one of three types including:

- Residential Streets;
- Residential Collector Streets; or
- Industrial and Arterial Streets.

Residential streets are generally located in single-family residential areas and are typically about 30 feet in width. Residential collector streets are also generally located in single-family residential areas that collect traffic from a number of residential streets and ultimately connect to an arterial or larger street. Residential collector streets are typically in the range of 36 feet in width. Industrial and arterial streets are large streets that serve to convey large volumes of traffic through an area. Industrial and arterial streets are typically multi-lane streets, larger than 36 feet. Examples of arterial streets in the City are California Street, Broadway Street, and Grand Avenue.

2.3.2 Street Hydraulic Capacity

The hydraulic capacity of streets is dependent on the street classification and design criteria (Section 2.4.3). The hydraulic capacity for straight crown roadways is based on a modified version for Manning's Equation to better describe the hydraulic radius of a gutter section. The equation in terms of cross slope and depth of flow at the curb is:

$$Q = 0.56\left[\frac{Z}{n}\right]S^{0.5}d^{2.67}$$

where:

Q = Discharge, in cubic feet per second;
Z = Reciprocal of cross slope, $1/S_x$, in feet per foot;
n = Manning's roughness coefficient;
S = Longitudinal slope, in feet per foot; and
d = Depth of flow at curb or deepest point, in feet.

2.3.3 Storm Sewer Systems

Storm sewer systems serve to remove excess street flow and convey it underground to a major drainageway. Storm sewer systems are located throughout the City, however, the size of the existing facilities does not provide for the streets to meet the street drainage criteria (Section 2.4.3). A field survey of the existing storm sewer facilities was conducted and the existing system was mapped on the City's aerial topographic mapping system. The size of inlets and the size of storm sewer pipes were measured, if accessible. Most of the storm sewer facilities will only convey frequently occurring storm events (less than a 2-year storm) so that the streets are not at curb full capacity.

2.3.4 Storm Sewer System Conceptual Design

Storm sewer systems were sized to meet the drainage criteria for streets and roadways to develop conceptual layouts and cost estimates for reducing drainage-related problems in the study area. Typically, peak runoff rates were determined using methods for minor watersheds (Section 2.1.2). Locations where the peak runoff rate exceeded the allowable street flow were determined and storm sewer facilities, including inlets and pipes, were sized. For purposes of this study, the slope of the storm sewer pipes was assumed to be equal to the slope of the natural ground or street where it is planned to be located. Inlet sizes were based on procedures outlined for computing the capacity of inlets in the Drainage Criteria and Design Manual. In general, curb-opening inlets were assumed for all storm sewer inlets. Standard size inlets (5-feet, 10-feet, 15-feet, 20-feet, etc.) were assumed for removing excess street runoff to desirable levels. Storm sewer pipes were assumed to be reinforced concrete pipe (RCP), and the hydraulic capacity was computed using Manning's equation, as outlined in the Drainage Criteria and Design Manual.

2.4 Drainage Criteria

In November 1998, a Drainage Criteria and Design Manual[25] was developed for use as a guidance document for designing and evaluating drainage facilities within the City's jurisdiction. As stated in the policies section of this manual, storm drainage systems shall be designed to convey the runoff from a specified design storm event. In addition to providing storm drainage facilities for the design storm runoff, the City's drainage policies dictate that provisions shall be made to prevent

[25] City of Gainesville, Op. Cit., November 1998.

significant property damage and loss of life from major storm runoff. The design storm event is dependent on the type of drainage facility under consideration. Streets, bridges, and culverts shall be designed for a 25-year storm event, which is defined as a storm event that has a four percent (1/25) chance of being equaled or exceeded in any given year. Open channels are specified to be designed for a 50-year storm event, which is defined as a storm event that has a two percent (1/50) chance of being equaled or exceeded in any given year. The major storm event is defined as a 100-year return period storm, which has a one percent (1/100) chance of being equaled or exceeded in any given year.

The following sections detail the drainage criteria specific to the facilities analyzed as a part of this study, which includes natural and improved open channels, bridges, culverts, streets, and storm sewer systems in the study area.

2.4.1 Open Channels

Open channels are recommended for the City's major drainage system because they typically exhibit significant advantages in terms of cost, capacity, multiple use for recreational and aesthetic purposes, and/or potential for instream storage as compared to other alternatives. Careful planning and design are needed to maximize the beneficial use of open channels. The City's Drainage Criteria states that open channels shall be designed such that: 1) flow is contained within channel banks for the 50-year storm; and 2) the minimum finished floor elevation for residential dwellings or public, commercial or industrial buildings shall not be less than 2 feet above the inundation level for the 100-year storm event, unless the building is floodproofed.

2.4.2 Bridges and Culverts

The function of a bridge or culvert is to safely pass flow under a roadway, railroad, or other feature without causing damage to the structure, or to property located upstream and downstream of the structure. The City's Drainage Criteria states that culverts and bridges shall be designed such that there is no overtopping of the associated roadway for the 25-year storm event. The criteria also specifies that, for the 100-year storm event, overtopping of residential streets shall not exceed 12 inches and overtopping of residential collector, neighborhood collector, industrial, and arterial streets shall not exceed 6 inches. In addition, for the 100-year storm event, the minimum finished floor elevation of residential dwellings or public, commercial and industrial buildings shall not be less than 2 feet above the inundation level caused by backwater from the drainage structure, unless the building is floodproofed.

2.4.3 Streets

Streets and roadways serve an important and necessary drainage service even though their primary function is for the movement of traffic. The City's drainage policies specify the transport of runoff on streets be based on a reasonable frequency of traffic interference. That is, depending on the street classification, certain traffic lanes can be fully inundated for the design storm event. The design storm for street drainage is specified as the 25-year storm event. Determination of street capacity of the design storm shall be based upon pavement encroachment. The pavement encroachment for the design storm shall be limited as set forth in Table 2-2. When the maximum encroachment in shown in the table is reached, a separate storm drainage system or additional storm drainage capacity shall be provided, sized on the basis of the design storm.

Table 2-2.
Design Storm Runoff Allowable Street Use

Street Classification	*Maximum Pavement Encroachment*
Residential Street	Flow of water in gutters shall be limited to a depth at the curb of 6 inches or wherever the street is just covered, whichever is the least depth.
Residential Collector Streets	Flow of water in gutters of a residential collector street shall be limited so that one standard lane will remain clear.
Industrial and Arterial Streets (widths above 36 feet)	Flow of water in gutters of industrial and arterial streets shall be limited so that two standard lanes will remain clear (at least one lane in each direction).

The intent of the drainage policy is to have the major storm runoff removed from public streets into major drainageways at frequent and regular intervals, however, it is recognized that water will often tend to follow streets and roadways. Therefore, streets and roadways often may be aligned so that they will provide a specific runoff conveyance function. Planning and design objectives for the major storm drainage system with respect to public streets shall be based upon the limiting criteria in Table 2-3.

Table 2-3.
Major Storm Runoff Allowable Street Inundation

Street Classification	Maximum Pavement Encroachment
Residential Street	Residential dwellings and public, commercial, and industrial buildings shall have a minimum finished floor elevation of not less than 1 foot above the level of inundation unless the buildings are floodproofed.
Residential Collector Streets, Industrial and Arterial Streets.	Residential dwellings and public, commercial, and industrial buildings shall have a minimum finished floor elevation of not less than 1 foot above the level of inundation unless the buildings are floodproofed. The depth of water at the street crown shall not exceed 6 inches in order to allow operation of emergency vehicles.
Note: Minimum finished floor elevations for residential dwellings and public, commercial, and industrial buildings located near open channels must also meet the criteria for open channels of being 2 feet above the level of inundation unless the buildings are floodproofed.	

2.4.4 Problem Area Identification

Problem areas were identified throughout the study area. The primary method of identifying problem areas is by reports from citizens through the public survey conducted near the beginning of this study and areas identified by city staff has having a history of drainage problems. The drainage policies outlined in the Drainage Criteria and Design Manual were used as a basis for determining the magnitude of existing problems and as a basis for developing plans and sizing facilities to mitigate the drainage problem.

2.5 Basis for Cost Estimates

Cost estimates were developed for recommended improvements at each of the problem areas identified in the study area. Component costs were estimated based on typical unit costs for construction applied to quantities of materials required for project implementation. Estimated capital costs for each project were based on costs for each component, plus 15 percent for construction contingencies and unlisted items and an additional 20 percent for engineering, legal, and surveying costs. Costs for acquisition of private property or easements for project implementation are not included in the cost estimates presented, unless specifically itemized in the cost estimates. For those alternatives that include costs for acquisition of private property, the land costs were based primarily on data obtained from the Cooke County Appraisal District (CCAD).

2.6 Evaluation of Flood Mitigation Measures

In developing a flood control plan, a full range of structural and nonstructural alternatives are considered. Structural alternatives are those measures constructed to contain, divert, or reduce the flow of water from flood prone areas and are intended to reduce or eliminate damage to property, loss of life, public health, and economic loss. Structural alternatives include measures such as channel improvements, bridge and culvert improvements, storm sewer systems, detention reservoirs, levees, and diversions of floodwaters. Nonstructural alternatives are those that propose management of flood plain lands by the removal or exclusion of damageable properties (residences, businesses, etc.) from flood prone areas. These measures do not affect the frequency or level of flooding within a flood plain, but affect flood plain activities. Nonstructural alternatives include regulatory measures, flood plain evacuation (acquisition), relocation, flood forecasting, and floodproofing.

2.6.1 Structural Alternatives

2.6.1.1 Channel Improvements

Channel improvements generally lower flood levels by improving the hydraulic efficiency of a stream channel by enlarging the channel, straightening the channel, reducing the channel friction by smoothing the contours and/or lining of the channel banks, and removing obstructions. The increase in channel velocity permits a given flow rate to be passed through a channel reach at a lower water surface elevation. The cross-sectional area of the channel is usually increased, which contributes to the lowering of the water surface elevation. Channel improvements generally reduce the area flooded for all flow rates, even those in excess of the design capacity. Evaluation of channel improvements usually includes different channel sizes, as well as grass-lined and concrete-lined channels.

2.6.1.2 Bridge and Culvert Improvements

Bridges and culverts span rivers, streams, and channels to convey vehicular traffic. In many cases, the structures are capable of passing low flows, however, they may have inadequate opening area to convey higher flow rates during flood conditions. Bridges and culverts that have insufficient area to convey higher flows tend to overtop frequently, preventing the passage of vehicles during high flow times, and cause excess backwater that may result in flooding of upstream properties. Bridges and culverts that overtop frequently poses a significant threat to public safety as many flood related deaths occur at these types of crossings. Enlargement of bridges and culverts was considered in order to improve the hydraulic capacity of the structure, reduce flooding of upstream properties, and reduce the frequency of overtopping.

2.6.1.3 Storm Sewer Improvements

Street flooding is a common occurrence in many areas of the City. Excessive street flow has caused flooding of residential and commercial structures, interruption of traffic flow, and damage to pavement. In most cases, the only feasible solution for reducing street flow in developed areas is by installing storm sewer systems to collect runoff and convey it underground to a receiving stream. This is due to the density of utilities, homes, and businesses generally associated with urban areas that restrict the construction of open channels and ditches.

2.6.1.4 Stormwater Detention

Stormwater detention reservoirs are a means of controlling stream flooding by temporarily impounding upstream floodwaters during significant storm events. The impounded floodwaters are released at a controlled rate to reduce the peak flow downstream and corresponding flood levels. Stormwater detention requires the availability of an upstream impoundment site capable of providing sufficient storage. Stormwater detention can include major impoundments for control of runoff from large watersheds and smaller, on-site detention structures to reduce the runoff rates from individual sites.

2.6.1.5 Levees

Levees confine out-of-bank flows to areas along rivers and streams to prevent flood damages to properties located in the natural flood plain. The confinement of floodwaters using levees considerably alters the characteristics of flood flows. Reduction of natural valley storage capacity in the flood plain can increase peak discharges for a given flood and increase flood damages downstream of a levee. Land must be reserved behind the levees for ponding areas and impounded water retained or pumped over the levee. Levees are most applicable where the flood plain is wide and development is located a considerable distance from the channel. Levees can cause catastrophic damage if overtopped by a flood greater than the design flood. Therefore, the design flood for levees is typically the 100-year flood, with additional freeboard to provide a very low risk of overtopping.

2.6.1.6 Stormwater Diversion

Diversion of floodwaters to an adjacent stream or channel or around an area to be protected may be economically viable in some cases when the receiving stream has adequate capacity to carry the additional flows. A typical diversion channel or tunnel would cross watershed boundaries which requires deep excavation cuts in order to cross over the higher elevation at a watershed divide. The deep excavation cuts and associated relocation of associated utilities and roadways usually requires diversions to be over a short distance in order to be economically feasible.

2.6.2 Nonstructural Alternatives

2.6.2.1 Regulatory Measures

Adoption of regulations by local governments are legal measures to control development in flood prone areas and to prevent the occurrence of future drainage related problems. Zoning of flood prone land ensures the property will be properly used in the best interest of public health, safety and welfare; however, it offers no relief for existing development. The City and Cooke County are participants in the National Flood Insurance Program, and regulations were adopted accordingly for flood plain regulation. The City also adopted a Drainage Criteria and Design Manual in March 1999, developed as part of this study, for regulation of future development in addition to the flood plain ordinances presently in effect.

2.6.2.2 Flood Plain Evacuation (Acquisition)

Permanent evacuation of developed flood plain areas is one method to eliminate flood damage potential to a selected frequency of flooding (i.e., 5-, 10-, 100-year, etc.). This alternative requires the acquisition of all privately-owned lands, residences, businesses, and other improvements. The improvements would be removed, the population relocated to areas outside the flood zone, and the land committed to parks, greenbelt areas, or other uses consistent with periodic flooding.

Evacuation and relocation alternatives are generally most cost effective in the zero- to 10-year frequency flood plain. If economic feasibility cannot be demonstrated in these areas, then it will not be feasible in areas of less frequent flooding (i.e., greater frequency than the 10-year event).

2.6.2.3 Flood Forecasting

Flood forecasts and temporary evacuation involves the determination of imminent flooding, implementation of a plan to warn the public, and organization of assistance in evacuating persons and some personal property. Notification of impending flooding can be made by radio, siren, individual notification, or by more elaborate means such as a remote sensor to detect rising water. While this alternative does not substantially reduce flood damages, it does prevent loss of life and may prevent damage to some portable property, including vehicles, by early warning. Flood forecasting can lead to a sense of low concern if warnings are issued and minor flooding or no damage occurs. Flood warnings should be a part of any plan, although consideration of forecasting beyond the present level was not considered further, due to the short warning time that exists in many of the watersheds.

2.6.2.4 Floodproofing

Floodproofing of residential and commercial structures consists of providing watertight coverings for door and window openings, raising structures in place, raising access roads and escape routes, constructing levees and floodwalls around individual buildings or groups of buildings, and waterproofing of walls of structures. Floodproofing is more easily applied to new construction and more applicable where flooding is of short duration, low velocity, infrequent, and of shallow depths. Floodproofing is also appropriate for locations where structural flood protection is not feasible. Implementation of floodproofing for most structures in the study area would require significant and costly modifications to existing structures.

Section 3
Study Areas

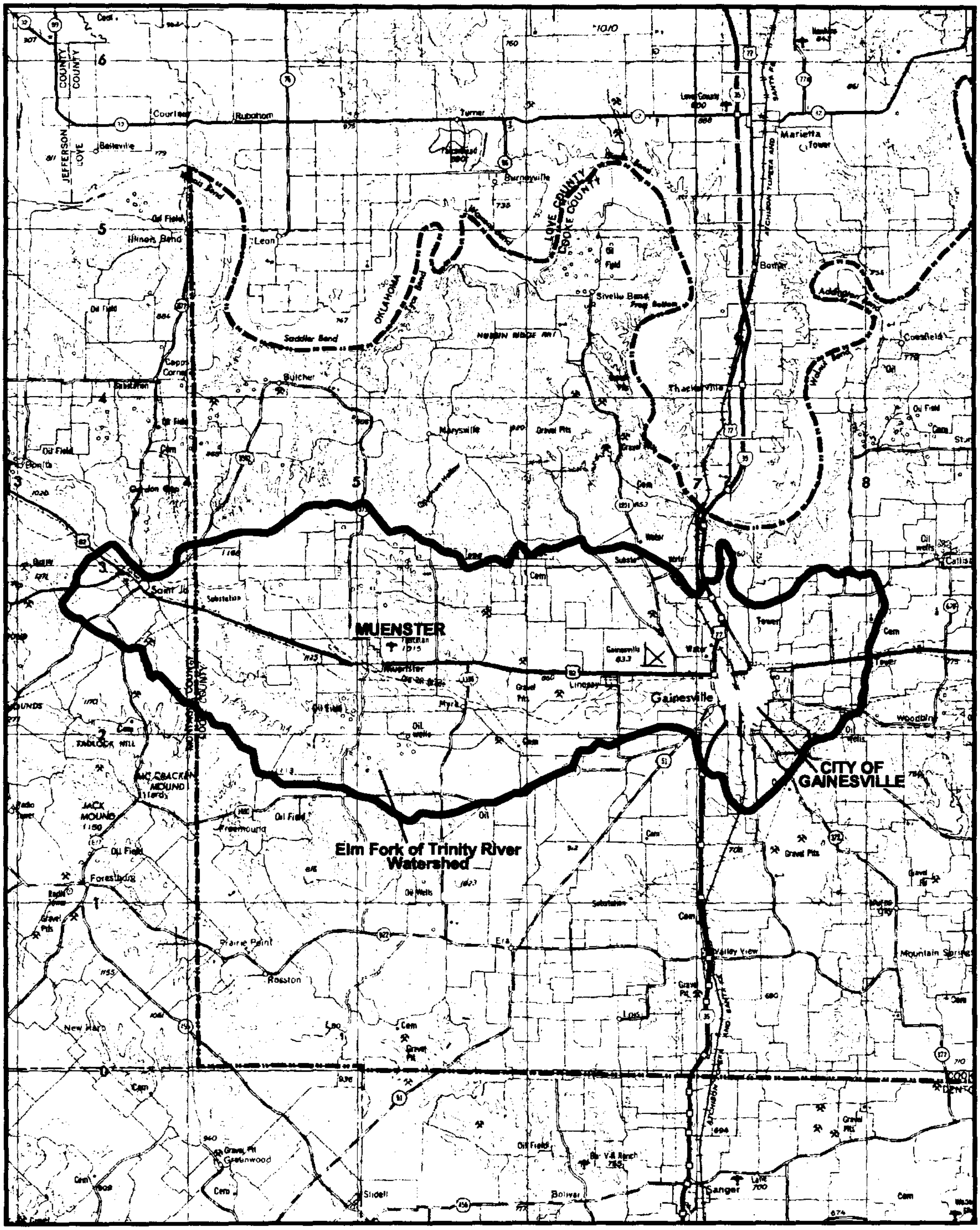
3.1 Elm Fork Watershed

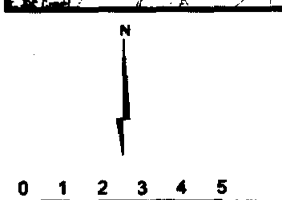
The Elm Fork flows along the south-southwest portion of the City and is the ultimate receiving stream of all of the tributary streams in the City, including Pecan, Wheeler, Dozier, and Montague Creeks. The Elm Fork watershed originates as far west as the community of Saint Jo in Montague County and covers a large portion of western Cooke County, as shown in Figure 3.1-1. The watershed covers 174 square miles (sq. mi.) at California Street (Highway 51) and about 221 sq. mi. at the Pecan Creek confluence south of the City. The Elm Fork flood plain extends across a vast portion of the southwest side of the City as backwater encroaches the City during large flood events. Land use within the Elm Fork watershed is predominantly rural, with a small percentage of urban development in the cities of Gainesville, Lindsay, Muenster, and Saint Jo. Land use in the Elm Fork watershed is expected to remain largely rural, due to the relative size of the watershed as compared to the potential for urban development.

South view of Elm Fork flooding in May 1989 at Frank Buck Zoo along west side of IH-35

Existing flood plain mapping for the Elm Fork was completed in 1981 by FEMA[1] and was limited to a segment extending from about 3,000 feet downstream of IH-35 at the south end of Weaver Street to about 5,500 feet upstream of California Street, as shown in Figure 3.1-2. This is the only segment of Elm Fork in which a detailed study was performed by FEMA to identify flood plain limits. Other segments of Elm Fork located outside of the City in Cooke

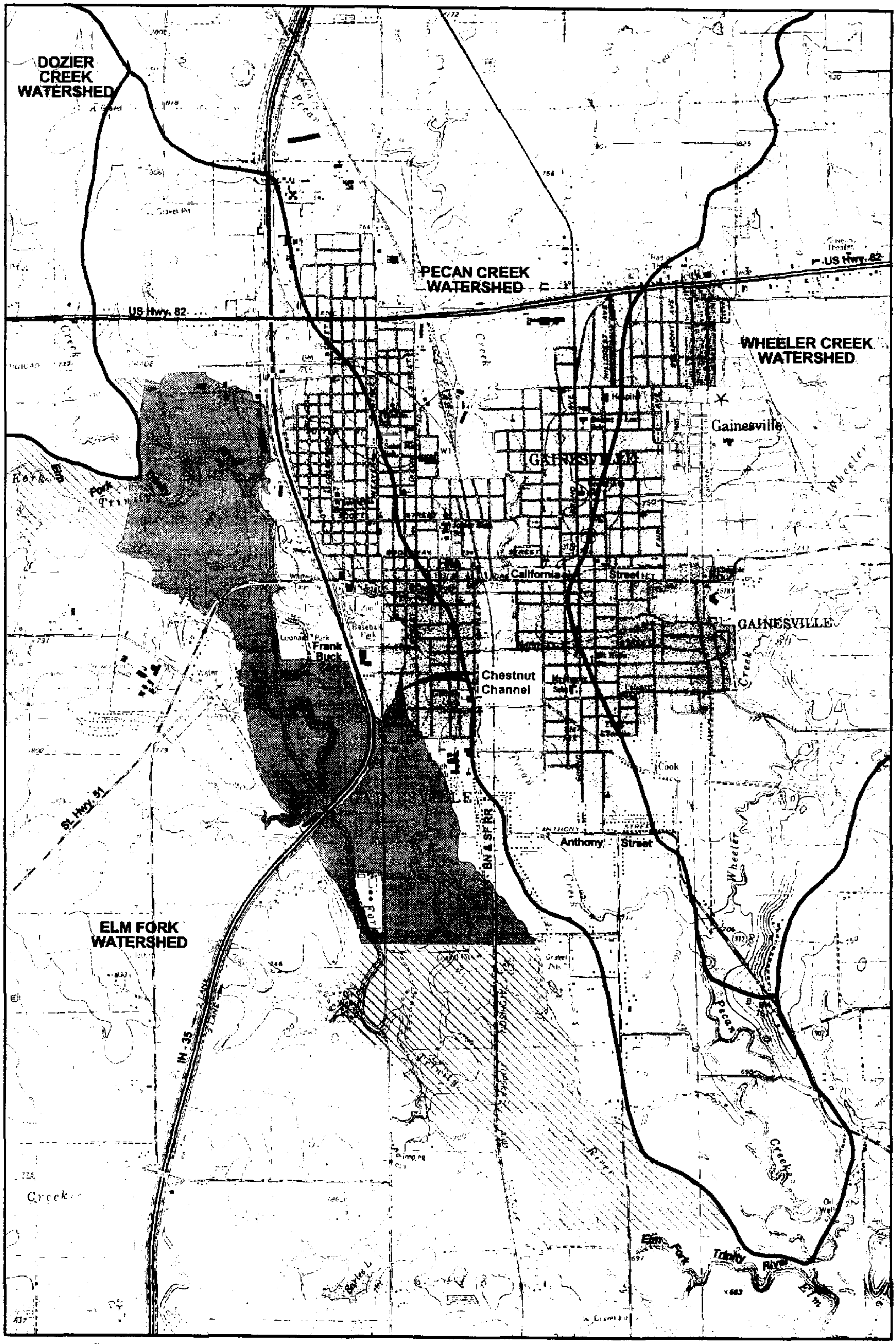
[1] Federal Emergency Management Agency (FEMA), Flood Insurance Study, City of Gainesville, Texas, Cooke County, Community No. 480154, April 15, 1981.





HDR Engineering, Inc.

CITY OF GAINESVILLE, TEXAS FLOOD PROTECTION PLANNING STUDY ELM FORK WATERSHED	Date: March 1999 Figure: 3.1-1



Scale - 1" equals 2000'
0 2000 4000 Feet

Legend
- FEMA Zone 'A' (approximate boundaries)
- FEMA Detailed Study Area
- Watershed Boundaries

HDR Engineering, Inc.

CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

ELM FORK WATERSHED
1981 FEMA FIS MAPPING

FIGURE: 3.1 - 2

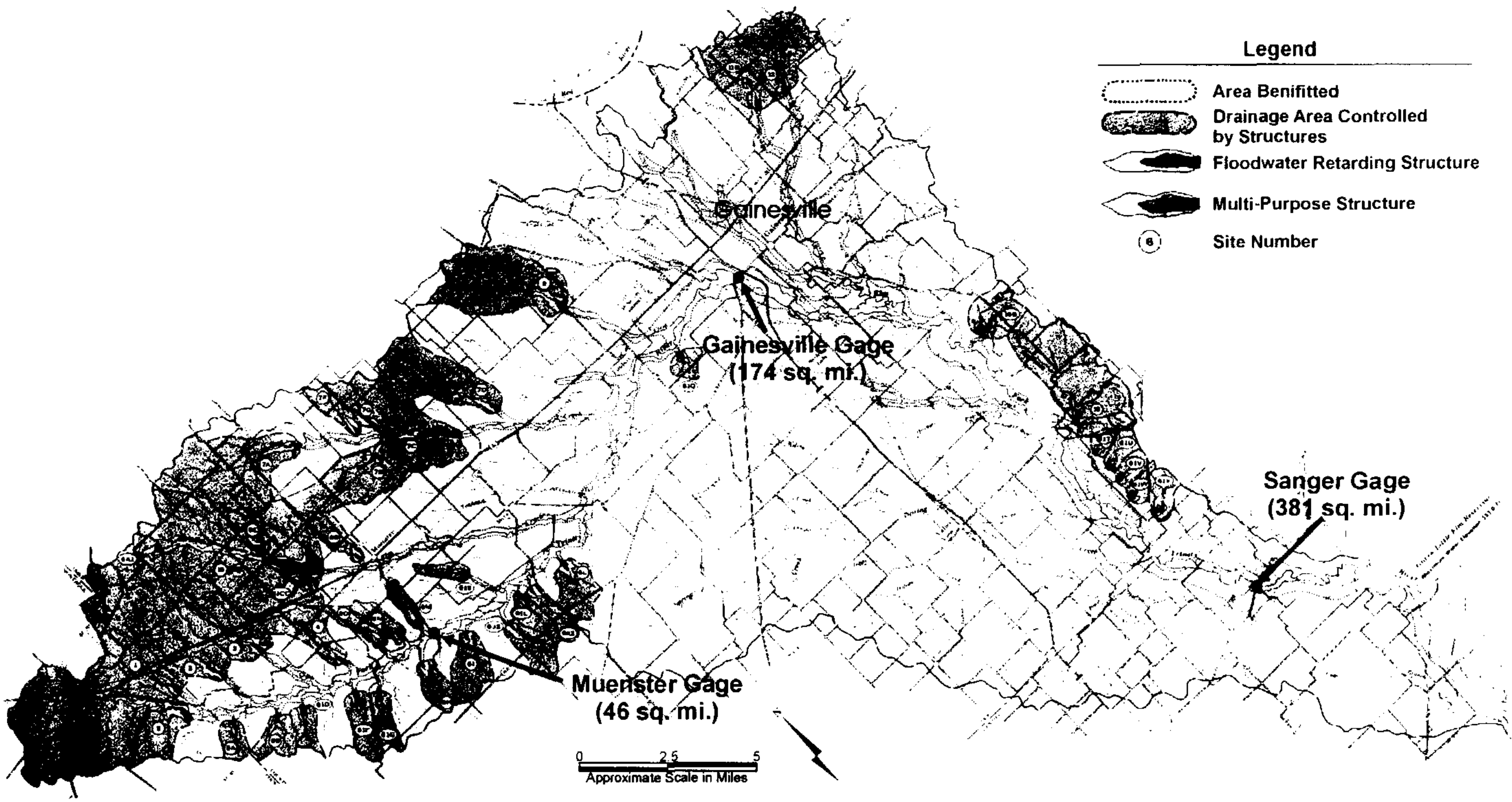
County[2] were not studied in detail, and mapping of flood plain limits were made in 1977 using approximate methods.

Flooding on the Elm Fork has been the source of some of the most catastrophic flooding occurring in both the City and Cooke County, with flooding of homes, businesses, streets, and other public facilities, such as the Frank Buck Zoo and the City's wastewater treatment plant. Flooding problems in the Elm Fork watershed are primarily associated with streamflow exceeding the capacity of the Elm Fork channel along the southwestern part of the City, and from backwater encroaching into the City from downstream of IH-35. The largest flood event of record on the Elm Fork occurred in October 1981 and caused extensive damage all across the southwestern area of the City. In addition to flooding on the main stem of the Elm Fork, minor watersheds in the City contributing to the Elm Fork also experience drainage problems. Street and local flooding along the Chestnut Channel frequently occur, damaging residences and commercial structures.

Flood control measures have been constructed in the Elm Fork watershed, which include implementation of a Watershed Control Plan[3] in the 1950s by the Soil Conservation Service (SCS, now the Natural Resource Conservation Service). A total of 41 floodwater-retarding structures have been constructed by the SCS to control runoff from the Elm Fork watershed, with an additional structure (Site 19) near Muenster being planned for implementation in the next few years for the dual purpose of flood control and water supply. Upstream of the City, these dams presently control approximately 78 sq. mi. (45 percent) of the 174 sq. mi. watershed at California Street, as shown in Figure 3.1-3. Typically, the SCS dams are designed to impound runoff from a 25- to 50-year storm event and offer flood control benefits for larger flood events, including the 100-year storm event. The City has implemented local flood protection measures along the Elm Fork to protect public facilities from flood damage. Levees have been constructed around the City's wastewater treatment plant and the Frank Buck Zoo to provide protection from large flood events. These two levees provide protection up to about the 25-year return period flood event.

[2] FEMA, Flood Hazard Boundary Map, Cooke County, Texas, Unincorporated Area, Community No. 480765, October 18, 1977.

[3] U.S. Dept. of Agriculture, Soil Conservation Service, Work Plan Elm Fork Watershed of the Trinity River Watershed, Montague, Cooke, and Denton Counties, Revised June 1956.



CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

HDR Engineering, Inc.

ELM FORK WATERSHED
NRCS FLOODWATER
RETARDING STRUCTURES

FIGURE 3.1-3 MARCH, 1999

3.1.1 Elm Fork Flood Hydrology

An analysis of historical streamflow for the Elm Fork watershed was performed to compute peak discharges for various return period flood events near the City. Historical streamflow records have been maintained by the USGS at three streamflow gaging stations located at Muenster, Gainesville, and Sanger (Figure 3.1-3). The period of record for each gaging station varies. The Muenster gage is located 2.5 miles south of Muenster at FM 373 and has a period of record extending from 1957 to 1973, when it was discontinued. The gaged area is approximately 46 sq. mi., with 33.5 sq. mi. (73 percent) of the watershed controlled by SCS floodwater-retarding structures. The Gainesville gage is located at the California Street bridge just upstream of the Frank Buck Zoo, and has been maintained by the USGS since 1986. The gaged area is 174 sq. mi., with SCS structures controlling 78 sq. mi. (45 percent) of the upstream watershed. The Sanger gage was the first gage installed in the Elm Fork watershed (in 1949). Records were maintained from 1949 to 1984. The gage is located at FM 455, about 5.4 miles northeast of Sanger, and has a watershed area of 381 sq. mi. Upstream of the Sanger gage, SCS structures control 94.7 sq. mi. (25 percent) of the watershed. A review of historical streamflow records for each of the three gages shows that the October 1981 flood event was the largest flood of record since 1903. The only gaging station in operation for the 1981 flood was the Sanger gage; however, a peak stage was measured near the Gainesville gaging station. At the Sanger gaging station, the October 1981 flood event recorded a peak discharge of 150,000 cfs and a stage of 33.5 feet. Table 3.1-1 provides a summary of annual peak floods for each gaging station for their respective periods of record.

In order to determine the magnitude of various return period flood events (e.g., 10-, 25-, 50-, 100-year, etc.), statistical analyses were performed using the gage records. Using a variety of methods, peak streamflows were estimated at the Gainesville gage for the period of 1949 to 1984, when the gage was not in operation. For each year from 1949 to 1984, the amount of uncontrolled area at each gaging station was determined based on construction completion dates of each SCS floodwater-retarding structure. Table 3.1-2 lists the year and amount of uncontrolled area for each of the three gaging stations for the period of 1949 to 1997. For the period of 1949 to 1956, when only the Sanger gage was in service, the peak streamflow at

Table 3.1-1.
Summary of Historical Flood Events

Water Year[1]	Muenster Gage 46 sq. mi. Peak Flow (cfs)	Muenster Gage 46 sq. mi. Peak Stage (ft)	Gainesville Gage 174 sq. mi. Peak Flow (cfs)	Gainesville Gage 174 sq. mi. Peak Stage (ft)	Sanger Gage 381 sq. mi. Peak Flow (cfs)	Sanger Gage 381 sq. mi. Peak Stage (ft)
1949					6,960	24.1
1950					20,100	27.1
1951					4,800	22.2
1952					2,710	18.3
1953					1,980	14.6
1954					3,530	19.1
1955					11,000	26.2
1956					424	8.15
1957	3,480	15.2			20,800	27.5
1958	5,900	20.2			27,500	29.1
1959	33	4.0			20,000	27.6
1960	4,160	16.7			9,850	25.3
1961	710	7.4			3,580	19.6
1962	1,310	10.5			22,500	28.1
1963	1,260	10.3			7,880	24.3
1964	970	9.1			6,300	22.9
1965	3,440	16.7			17,500	27.1
1966	3,020	15.6			35,000	27.7
1967	1,500	11.1			12,600	26.1
1968	1,580	11.3			12,000	26.1
1969	3,140	15.9			13,400	26.3
1970	941	9.0			14,300	26.4
1971	3,690	17.3			3,740	19.5
1972	1,490	11.1			15,100	26.5
1973	1,740	12.0			15,900	26.5
1974					6,260	23.5
1975					50,000	29.1
1976					5,230	22.2
1977					25,700	27.8
1978					1,880	14.0
1979					7,900	14.8
1980					11,000	26.0
1981					8,230	24.7
1982				28.8	150,000	33.5
1983					2,980	20.7
1984					5,770	N/A
1985						
1986			10,300	19.6		
1987			10,500	19.8		
1988			4,980	13.8		
1989			24,000	25.3		
1990			21,300	22.8		
1991			5,920	15.0		
1992			11,300	18.7		
1993			21,100	22.7		
1994			8,190	17.0		
1995			12,900	19.5		
1996			6,040	15.0		
1997			21,000	22.7		

1 Water Year is defined from October 1 of the preceding year to September 30 (e.g., WY 1997 is from 10/1/96 to 9/30/97).

Table 3.1-2.
Summary of Watershed Area Controlled by SCS Floodwater Retarding Structures

Years	USGS Streamflow Gaging Station					
	Muenster Watershed Area = 46 sq. mi.		Gainesville Watershed Area = 174 sq. mi.		Sanger Watershed Area = 381 sq. mi.	
	Area Controlled (sq. mi.)	Percent of Watershed	Area Controlled (sq. mi.)	Percent of Watershed	Area Controlled (sq. mi.)	Percent of Watershed
1947-1953	0.0	0%	0.0	0%	0.0	0%
1954	7.4	16%	7.4	4%	7.4	2%
1955	15.1	33%	15.1	9%	15.1	4%
1956	29.1	63%	29.1	17%	29.1	8%
1957	31.0	67%	41.1	24%	41.1	11%
1958	31.0	67%	54.7	31%	60.1	16%
1959	31.0	67%	56.5	32%	61.8	16%
1960	31.0	67%	62.1	36%	67.4	18%
1961	31.0	67%	62.1	36%	75.5	20%
1962	31.0	67%	75.0	43%	88.5	23%
1963	33.5	73%	78.0	45%	94.7	25%
1964-1999	33.5	73%	78.0	45%	94.7	25%

Gainesville was estimated based on the ratio of uncontrolled area at Gainesville to the uncontrolled area at Sanger, expressed as:

$$Q_p Gainesville = \left(\frac{A_U Gainesville}{A_U Sanger} \right) \times Q_p Sanger$$

where:

Q_p Gainesville = Peak flow at Gainesville gage (cfs);
A_UGainesville = Uncontrolled area at Gainesville gage (sq. mi.);
Q_p Sanger = Peak flow at Sanger gage (cfs); and
A_USanger = Uncontrolled area at Sanger gage (sq. mi.).

For the period of 1957 to 1973, when the Muenster and Sanger gages were in service, the peak flow at Gainesville was estimated based on the incremental uncontrolled area between Muenster and Sanger, expressed as:

$$Q_pGainesville = Q_pMuenster + \left(\frac{A_UGainesville - A_UMuenster}{A_USanger - A_UMuenster}\right) \times \left(Q_pSanger - Q_pMuenster\right)$$

where:

Q_p Gainesville	=	Peak flow at Gainesville gage (cfs);
Q_p Muenster	=	Peak flow at Muenster gage (cfs);
Q_p Sanger	=	Peak flow at Sanger gage (cfs);
A_U Gainesville	=	Uncontrolled area at Gainesville gage (sq. mi.);
A_U Muenster	=	Uncontrolled area at Sanger gage (sq. mi.); and
A_USanger	=	Uncontrolled area at Sanger gage (sq. mi.).

For the period of 1974 to 1984, the peak flow at Gainesville was based on the same relationship as for the period of 1949 to 1956, when only the Sanger gage was in service. An exception to this was for the October 1981 flood event. A peak stage observation was noted for the October 1981 flood event by the USGS at the California Street bridge. Based on the results of a stream hydraulic model for the Elm Fork near Gainesville, the peak flow for the October 1981 flood at the Gainesville gage was estimated to be 56,800 cfs. No data was available for 1985 due to the absence of the Gainesville gage and the discontinuation of the Sanger in 1984. For the period of 1986 to the present, actual streamflow records were available at the Gainesville gaging station. Table 3.1-3 provides a summary of the year, peak flow, amount of uncontrolled area for each of the three gaging stations, and the estimated peak flow at Gainesville for 1949 to 1997. A summary of the estimated and gaged peak flows at Gainesville is presented in Figure 3.1-4.

Statistical analyses were performed for the Elm Fork at Gainesville using methods in accordance with Bulletin 17B of the U.S. Water Resources Council[4] and included in the

[4] U.S. Geological Survey, Guidelines for Determining Flood Flow Frequency, Bulletin #17B of the Hydrology Subcommittee, March 1982.

Table 3.1-3
Elm Fork of the Trinity River.
Summary of Actual and Estimated[1] Peak Flows

	Muenster Gage 46 sq. mi.		Gainesville Gage 174 sq. mi.		Sanger Gage 381 sq. mi.	
Water Year	Uncontrolled Area (sq.mi.)	Peak Stage (ft)	Uncontrolled Area (sq.mi.)	Peak Flow (cfs)	Uncontrolled Area (sq.mi.)	Peak Flow (cfs)
1949	46.0		174.0	*3,179*	381.0	6,960
1950	46.0		174.0	*9,180*	381.0	20,100
1951	46.0		174.0	*2,192*	381.0	4,800
1952	46.0		174.0	*1,238*	381.0	2,710
1953	46.0		174.0	*904*	381.0	1,980
1954	38.6		166.6	*1,574*	373.6	3,530
1955	30.9		158.9	*4,777*	365.9	11,000
1956	16.9		144.9	*175*	351.9	424
1957	15.0	3,480	132.9	*9,766*	339.9	20,800
1958	15.0	5,900	119.3	*13,262*	320.9	27,500
1959	15.0	33	117.5	*6,761*	319.2	20,000
1960	15.0	4,160	111.9	*6,007*	313.6	9,850
1961	15.0	710	111.9	*1,668*	305.5	3,580
1962	12.5	1,310	99.0	*7,724*	292.5	22,500
1963	12.5	1,260	96.0	*3,279*	286.3	7,880
1964	12.5	970	96.0	*2,596*	286.3	6,300
1965	12.5	3,440	96.0	*7,728*	286.3	17,500
1966	12.5	3,020	96.0	*11,900*	286.3	35,000
1967	12.5	1,500	96.0	*4,885*	286.3	12,600
1968	12.5	1,580	96.0	*4,080*	286.3	12,000
1969	12.5	3,140	96.0	*6,269*	286.3	13,400
1970	12.5	941	96.0	*5,015*	286.3	14,300
1971	12.5	3,690	96.0	*3,705*	286.3	3,740
1972	12.5	1,490	96.0	*5,134*	286.3	15,100
1973	12.5	1,740	96.0	*6,059*	286.3	15,900
1974	12.5		96.0	*2,099*	286.3	6,260
1975	12.5		96.0	*16,764*	286.3	50,000
1976	12.5		96.0	*1,754*	286.3	5,230
1977	12.5		96.0	*8,617*	286.3	25,700
1978	12.5		96.0	*630*	286.3	1,880
1979	12.5		96.0	*2,649*	286.3	7,900
1980	12.5		96.0	*3,688*	286.3	11,000
1981	12.5		96.0	*2,759*	286.3	8,230
1982	12.5		96.0	*56,800*	286.3	150,000
1983	12.5		96.0	*999*	286.3	2,980
1984	12.5		96.0	*1,935*	286.3	5,770
1985	12.5		96.0	N/A	286.3	
1986	12.5		96.0	10,300	286.3	
1987	12.5		96.0	10,500	286.3	
1988	12.5		96.0	4,980	286.3	
1989	12.5		96.0	24,000	286.3	
1990	12.5		96.0	21,300	286.3	
1991	12.5		96.0	5,920	286.3	
1992	12.5		96.0	11,300	286.3	
1993	12.5		96.0	21,100	286.3	
1994	12.5		96.0	8,190	286.3	
1995	12.5		96.0	12,900	286.3	
1996	12.5		96.0	6,040	286.3	
1997	12.5		96.0	21,000	286.3	

1 Estimated peak flows for the Gainesville gage are shown in italics for the period of 1949 to 1984.

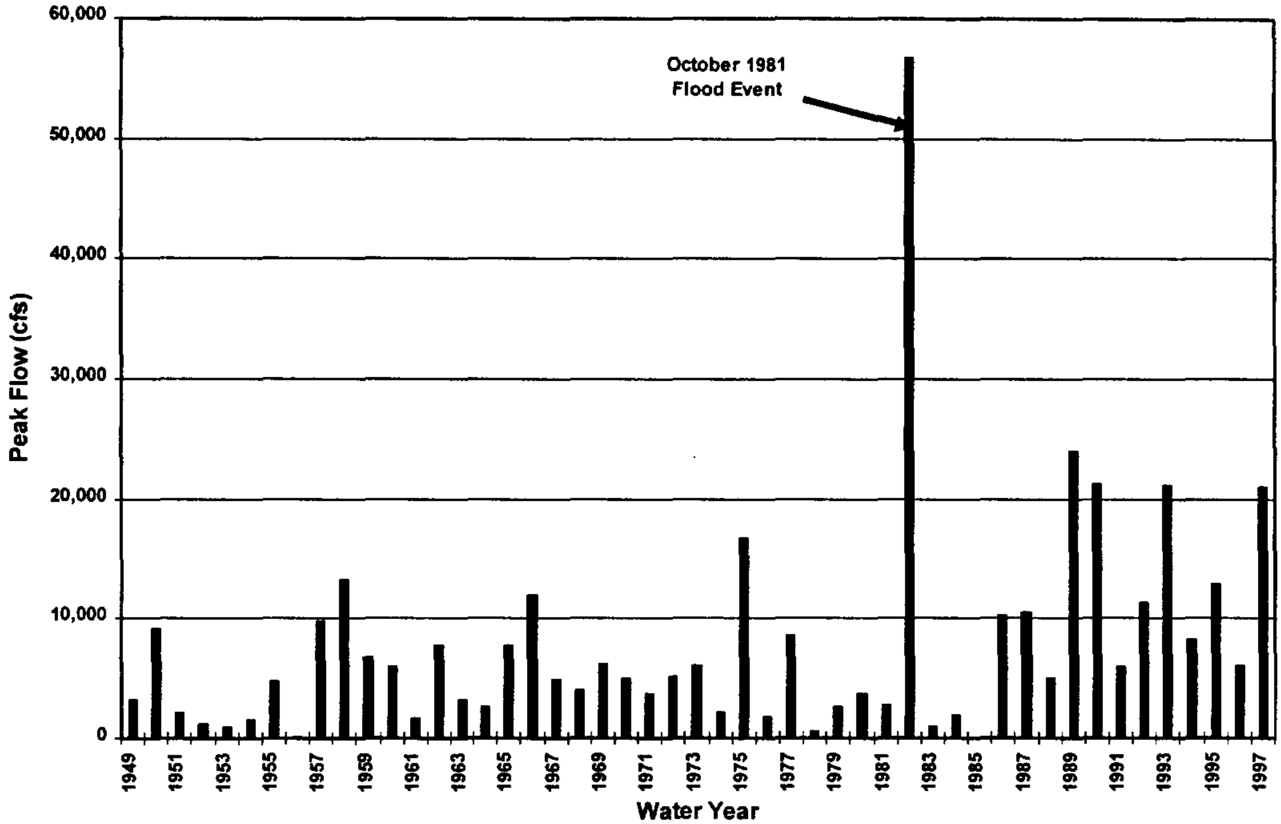


Figure 3.1-4. Summary of Estimated and Gaged Peak Flows at Gainesville Gage Station

computer program HEC-FFA (Flood Frequency Analysis).[5] These analyses were performed to estimate various return period flood events using four different sets of data. The first set of data used was an analysis of the annual peak flows recorded at the Gainesville gage for its period of record (1986 to 1997). This analysis was severely limited by the short period of record (12 years), which results in greater uncertainty in the analysis. The second set of data analyzed included peak flows recorded at the Sanger gage for the 1949 to 1984 period of record. The magnitude of various return period flood events at Gainesville were estimated based on a drainage area ratio of the uncontrolled area at Gainesville and the uncontrolled area at Sanger. The third set of data analyzed included the peak flows estimated at Gainesville for the period of 1964 to present. This analysis represents the peak flows since all of the current SCS floodwater-retarding structures have been in place and controlling runoff. The fourth set of data used included the peak flows estimated at Gainesville for the period of 1949 to present, including the period when the watershed was not controlled or only partially controlled by SCS structures. The results of each of the statistical analyses is presented in Table 3.1-4, which shows the computed peak flow rates for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood events.

Table 3.1-4
Elm Fork of the Trinity River
Summary of Statistical Flood Analyses

	Peak Flow (cfs) at Gainesville Gage (California Street)			
	Data Set No. 1	Data Set No. 2	Data Set No. 3	Data Set No. 4
Return Period Flood Event	Actual Flows Gainesville Gage (1986 to Present)	Gainesville Gage Prorated from Sanger Gage (1949 to1984)	Estimated Flows Gainesville Gage (1964 to Present)	Estimated Flows Gainesville Gage (1949 to Present)
2-year	11,600	3,100	6,000	5,200
5-year	19,300	6,800	13,000	11,200
10-year	25,800	10,500	19,300	16,800
25-year	36,000	17,000	29,000	26,000
50-year	46,200	24,000	38,300	34,300
100-year	58,700	33,000	48,800	44,300
500-year	102,000	66,000	80,200	74,900

The results of the analyses of the four individual sets of data a wide disparity in the peak flows for each return period flood event. The results of the analysis for Data Set No. 1, which include an analysis of the peak annual streamflows recorded at the Gainesville gage for the actual period of record (1986 to present), are significantly higher than any of the other methods. The higher results are due to the greater uncertainty caused by the relatively short 12-year period of record. The results using Data Set No. 2, based on an analysis of the peak flows at Sanger and then prorated for the ratio of uncontrolled areas at Gainesville and Sanger, are significantly less than any of the other three methods. This is primarily a result of the larger drainage area and the lower unit runoff rates that will occur for storm events over larger areas. Data Sets No. 3 and 4 appear to provide the more reliable flood frequency estimates and the resulting peak flows are relatively similar (within 15 percent). Logically, one would expect the results of Data Set No. 3, which includes an analysis of only the period of record since implementation of the SCS

[5] U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-FFA Flood Frequency Analysis, User's Manual, May 1992.

floodwater-retarding structures, to be less than the results of Data Set No. 4, which includes the period prior to and after implementation of the SCS structures. However, due to the shorter period of record available for Data Set No. 3 and the greater uncertainty inherent to the shorter record, the analysis yielded slightly higher peak flows. Based on the fact that the regulation of runoff by the SCS structures should produce lower magnitude floods, the results using Data Set No. 4 were selected as most representative of the hydrologic conditions at Gainesville.

The 1981 FEMA Flood Insurance Study for the City provided flood frequency estimates for the 10-, 50-, 100-, and 500-year return period flood events. A method published by the USGS[6] in 1977 was used in the FEMA study to estimate the peak flow for each flood event. This method is based on regional relationships of flood frequency to drainage area and watershed slope, and is generally applicable to natural, uncontrolled watersheds. The Elm Fork watershed at Gainesville is largely controlled, and application of the regional relationships would be expected to overestimate peak flows. Table 3.1-5 presents a comparison of the peak flows for 10-, 50-, 100-, and 500-year flood events, as computed in this study and the 1981 FEMA Flood Insurance Study.

Table 3.1-5
Elm Fork of the Trinity River at Gainesville, TX
Comparison of Computed Peak Flows to
FEMA Flood Insurance Study Peak Flows

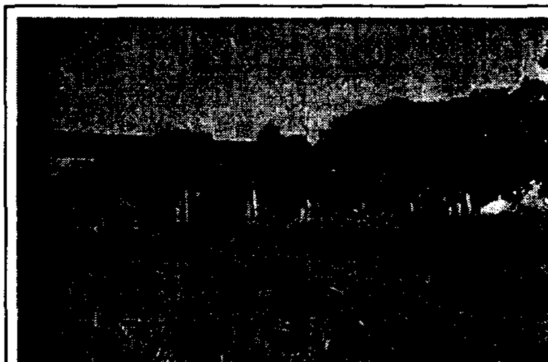
	Peak Flows (cfs) at Gainesville Gaging Station	
Flood Event	***Computed***	***1981 FEMA F.I.S.***
10-year	16,800	22,400
50-year	34,300	43,400
100-year	44,300	54,100
500-year	74,900	86,000

[6] U.S. Geological Survey, Techniques for Estimating the Magnitude and Frequency of Floods in Texas, Open File Report 77-110, 1977.

3.1.2 Stream Hydraulics

HEC-RAS[7] was used to develop a stream hydraulic model to simulate flow in the Elm Fork channel and flood plain area near the City. The stream hydraulic model used the peak flows from the hydrologic analysis and computed water surface profiles (flood levels) for each flood event for 12.5 miles of stream channel. Cross sections of stream segments were obtained using the City's aerial topographic mapping[8] and supplemented with field measurements at hydraulic structures.

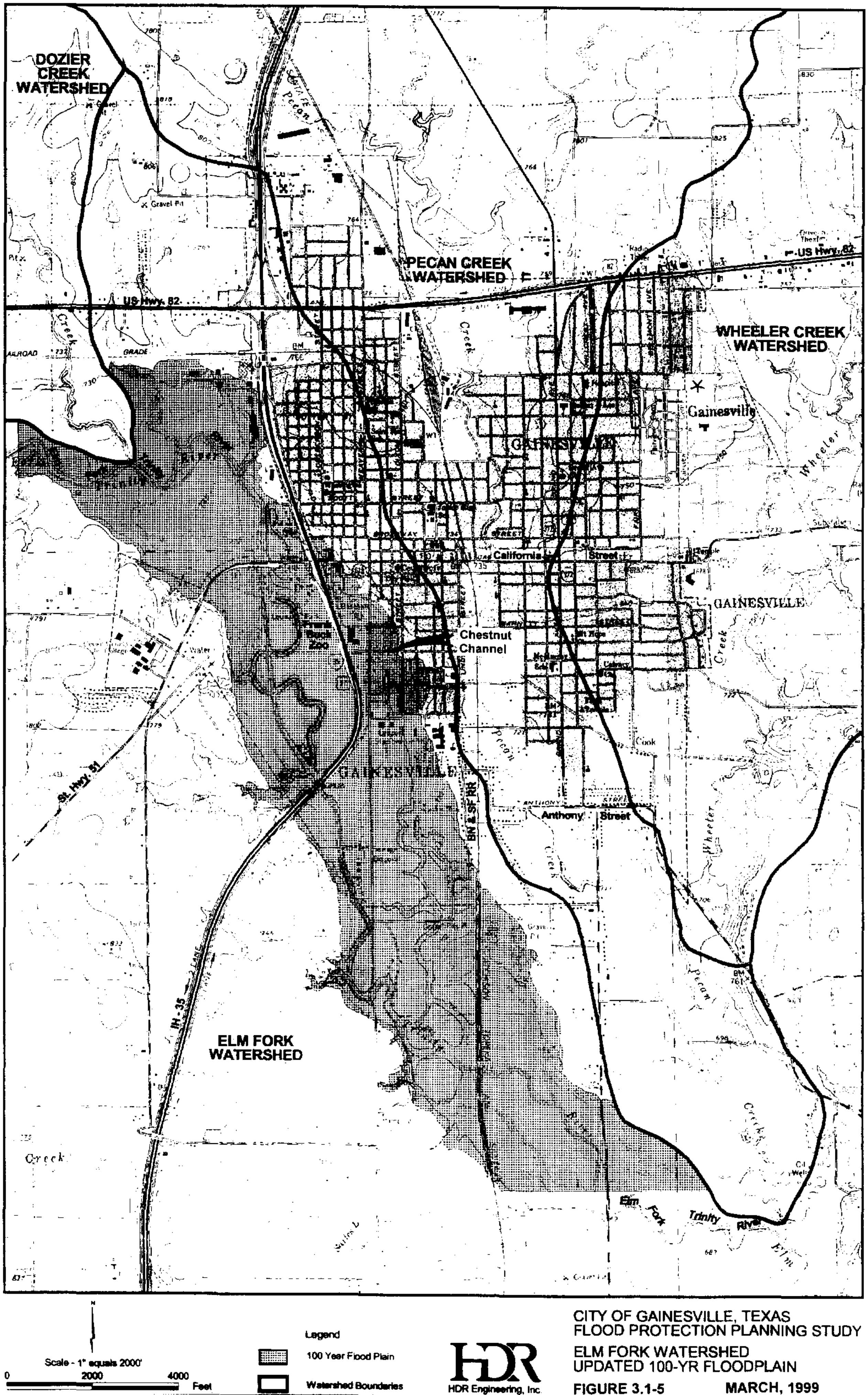
The stream hydraulic model Elm Fork extends from its confluence with Pecan Creek, downstream of the BN&SF Railroad, to 3.2 miles upstream of the confluence with Dozier Creek, as shown in Figure 3.1-5. The stream hydraulic model extends well beyond the limits of the existing FEMA flood plain mapping which was limited to a 3.2 mile segment from just downstream of the City's wastewater treatment plant to the confluence with Dozier Creek (Figure 3.1-2). The HEC-RAS model, developed as part of this study provides a more accurate representation of flood levels in the Elm Fork than the 1981 FEMA study, due to new data available at the USGS gaging station at California Street, which was not available in 1981. The USGS gage at California Street has been maintained since 1986, and the USGS has measured the discharge and peak stage at the downstream face of the bridge for several flood events. This data was used to calibrate the HEC-RAS model to insure that the results of the hydraulic model were representative of this segment of the Elm Fork. The results of the calibration provide a more accurate representation of flood levels in the City.



BN&SF Railroad relief bridge for Elm Fork

Three bridges exist in this stream segment including the BN&SF Railroad, IH-35, and California Street (Hwy 51). Each of these bridge crossings were analyzed to determine their respective hydraulic capacity and to quantify the effect of the structures on water surface elevations in the City. The BN&SF Railroad crossing of the Elm Fork

[7] USCOE, Hydrologic Engineering Center, "HEC-RAS River Analysis System," User's Manual, Davis, California, July, 1995.
[8] City of Gainesville, Texas, Aerial Topographic Mapping, prepared by Dallas Aerial Mapping, Inc., January, 1997.



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ELM FORK WATERSHED
UPDATED 100-YR FLOODPLAIN

FIGURE 3.1-5 MARCH, 1999

includes four individual bridges: a 402-ft span bridge over the main channel and three relief bridges with spans of 112-ft, 161-ft, and 181-ft in the floodplain. The BN&SF Railroad structures were found to pass the 500-year flood event without overtopping the railroad embankment. A hydraulic simulation was performed to determine the amount of backwater the bridges cause by simulating conditions with and without the structure using the HEC-RAS model. The analysis showed that the BN&SF Railroad bridges cause about 1.2 feet of backwater just upstream of the railroad for the 100-year flood event and less than 0.1 feet of backwater at IH-35. A similar analysis was performed for the IH-35 bridge over the Elm Fork. The IH-35 bridge will pass the 500-year flood event without overtopping at the structure, and the bridge was estimated to produce approximately 1.3 feet of backwater just upstream of the bridge for the 100-year flood event. The California Street bridge was calculated to pass the 500-year flood event without overtopping the bridge. However, a section of California Street at the IH-35 overpass is depressed, and allows overbank flows from the Elm Fork to spill into the City for flood events exceeding a 25-year return period. Spills that enter the City under the IH-35 overpass at California Street are conveyed back to the Elm Fork through the Chestnut Channel area, which does not have adequate capacity to convey the large flow rates that occur when the Elm Fork is at high flood stage. Upstream of California Street, the HEC-RAS model showed that the IH-35 road embankment will not overtop for the 100-year flood event. The embankment did overtop in the October 1981 flood, however, this flood has an estimated return period exceeding a 100-year event. A summary of the hydraulic capacity for each crossing is presented in Table 3.1-6.

Table 3.1-6
Elm Fork of the Trinity River Watershed
Summary of Hydraulic Capacity of Stream Crossings

Location	Hydraulic Capacity[1] Return Period Flood Event	Notes
California Street (Hwy 51)	10-year	389-ft bridge
IH-35	500-year	467-ft bridge
BN&SF Railroad[2]	500-year	402-ft bridge

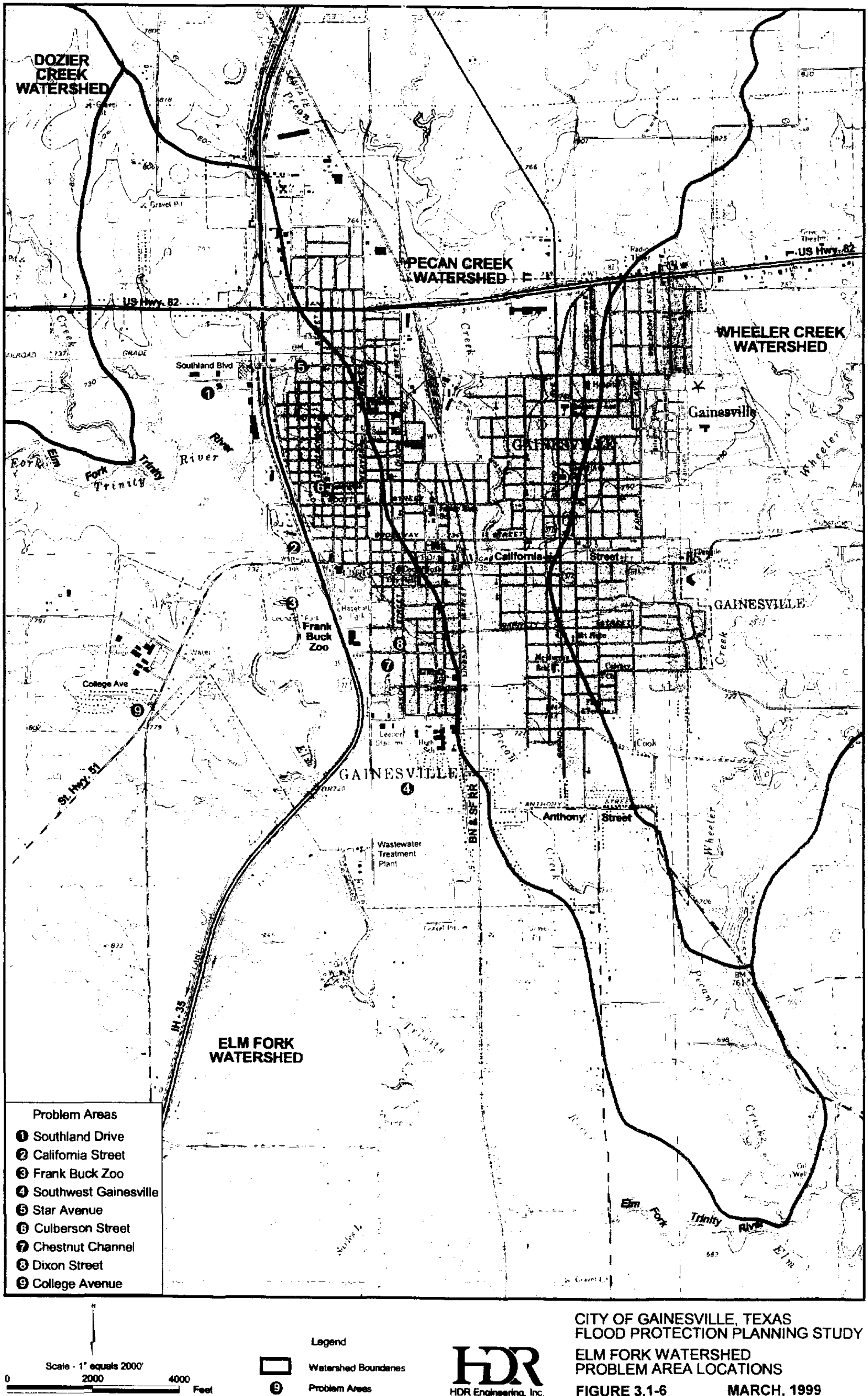
[1] Hydraulic capacity at top of road or top of railroad embankment.
[2] BN&SF Railroad includes a 402-ft bridge over the main channel and three relief bridges with lengths of 112-ft, 161-ft, and 181-ft.

3.1.3 Problem Areas

The flood hydrology and stream hydraulic models provide the results needed for identification of areas that are not in compliance with the City's Drainage Criteria (Section 2.3). Areas identified along the Elm Fork and its major tributaries that do not meet the Drainage Criteria are shown in Figure 3.1-6 and summarized in Table 3.1-7 from the upstream end to the downstream end of the study area. The major flood problem along Elm Fork is backwater, which floods several residential and commercial structures during major flood events. In addition, areas in the City that contribute to the Elm Fork also incur flood problems related to local flows exceeding the capacity of smaller channels, undersized culverts, and street flooding. The problem areas were divided into major and minor watershed categories. Major watershed problem areas are associated with flooding from the main channel of the Elm Fork, while minor watershed problem areas are associated with drainage problems for smaller areas contributing to the Elm Fork channel. A description of each of the identified problem areas is presented in the following sections, as well as an improvement plan and estimated cost for resolving the drainage problem.

Major Watershed

The primary flooding problems along the Elm Fork in the City is inundation of residential and commercial structures from backwater from the Elm Fork channel. Areas flooded by the Elm Fork include the Southland Boulevard area, California Street, Frank Buck Zoo, and a large area in the southwest part of the City that includes the Chestnut Channel and Shadowood area as well as the City's wastewater treatment plant. A description of each of the problem areas and a recommended plan for flood prevention is provided in the following sections.



CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

ELM FORK WATERSHED
PROBLEM AREA LOCATIONS

FIGURE 3.1-6 MARCH, 1999

Table 3.1-7
Elm Fork of the Trinity River Watershed
Problem Area Summary

Problem Area	Watershed Category	Description
Southland Boulevard	Major	Flooding of an industrial park area from backwater from the Elm Fork. Flooding is estimated to occur for a 10-year return period flood event.
California Street	Major	Flooding overtops an existing levee that parallels the Elm Fork channel north (upstream) of California Street for a 50-year flood event. Flow that overtops this levee spills into the Moffet Park area, through the IH-35 overpass over California Street, and into the Chestnut Channel and Shadowood areas.
Frank Buck Zoo	Major	Flooding on the Elm Fork overtops an existing levee and damages the zoo and park facilities. The existing levee is estimated to provide protection for the 25-year return period storm event.
Southwest Gainesville	Major	Backwater from the Elm Fork floods a large area of southwest Gainesville including the City's wastewater treatment plant and numerous residences. The existing levee surrounding the wastewater treatment plant is estimated to provide protection from a 25-year return period flood event. Residences begin to be impacted for about a 10-year return period flood event.
Star Avenue	Minor	Minor flood damages resulting from inadequate channel capacity and culvert capacity for a small channel upstream of Star Avenue.
Culberson Street	Minor	Frequent street flooding along Culberson Street from near Fletcher Street to California Street with damages reported to local businesses along California Street.
Chestnut Channel	Minor	Flooding of local residences along Chestnut Channel due to inadequate channel capacity and undersized culvert crossings. Backwater from the Elm Fork also impacts this area.
Dixon Street	Minor	Street flooding along Dixon Street near the Hird Street intersection.
College Avenue	Minor	Street flooding along College Avenue and flooding at the culvert crossing at California Street (Hwy 51). Frequent flooding at the California Street culvert blocks the only access to the residential area.

Notes:
1. Major watershed problem areas includes those areas primarily impacted by flooding from the main channel . Minor watershed problem areas includes those primarily impacted by flooding from smaller areas contributing runoff to the main channel.

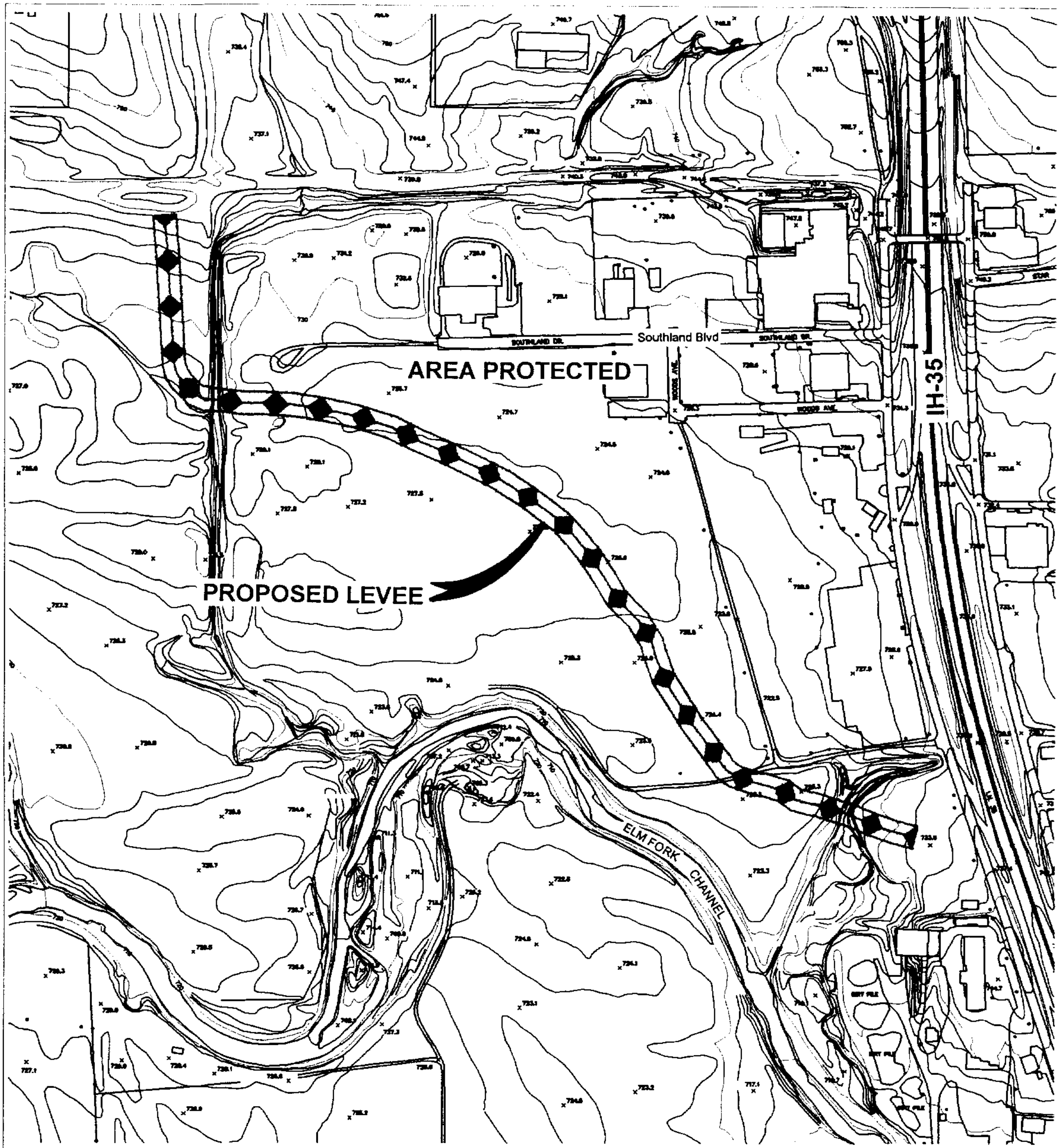
3.1.3.1 Southland Boulevard Problem Area

The Southland Boulevard Problem Area is located in the northwest part of the City along IH-35 and south of Highway 82. Flood problems in this area are related to overbank flooding from the Elm Fork that floods a commercially developed area along Southland Boulevard and IH-35. This area has experienced flooding in the past including 1981 and 1989. In 1981, floodwaters from the Elm Fork spilled over the IH-35 road embankment and into areas along the east side of IH-35. Flood damage to developed property in the Southland Boulevard area is estimated to begin occurring for a 10-year flood event. The only feasible alternatives for preventing flood damages to this area are permanent evacuation of the flood plain area or construction of a levee to prevent overbank flows from entering the area. The cost for implementation of a levee plan is presented in this study to provide the information necessary to determine if protection of the property in this area is economically feasible.

Elm Fork flooding in Southland Drive area in May 1989. Looking east toward IH-35 with Elm Fork channel at right.

The alignment of the proposed levee is shown in Figure 3.1-7. The proposed levee would be approximately 3,850 feet long, extending just north of the City's Public Works facilities to an area just south of Highway 82 across from the Floral Drive intersection. The levee would have a maximum height of about 12 feet on the Elm Fork flood plain and a total embankment volume of approximately 60,500 cubic

Flooding at Southland Blvd in Oct. 1981. Looking west along Southland Blvd.



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SOUTHLAND BOULEVARD
LEVEE IMPROVEMENTS

FIGURE 3.1-7 MARCH, 1999

yards. The capital cost for implementation of the levee is estimated to be $777,000, including engineering and construction contingencies, as shown in Table 3.1-8. Cost for land required for construction of the levee is not included.

Table 3.1-8
Southland Boulevard Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Borrow Excavation	cubic yard	60,500	$2.00	$121,000
Embankment/Levee Fill	cubic yard	60,500	$3.00	$181,500
Clearing and Grubbing	acre	8	$4,000	$32,000
Stripping	cubic yard	10,000	$1.50	$15,000
Seeding/Vegetation	square yard	39,650	$0.45	$17,843
Soil Retention Blanket	square yard	39,650	$1.00	$39,650
Outlet Structure – 60-inch RCP	linear feet	150	$165	$24,750
Outlet Structure – 72-inch RCP	linear feet	150	$210	$31,500
Headwall	each	4	$2,500	$10,000
Backflow Prevention Valve – 60"	each	1	$37,500	$37,500
Backflow Prevention Valve – 72"	each	1	$52,500	$52,500
Subtotal				$563,243
Contingencies & Miscellaneous			15%	$84,486
Construction Cost				$647,729
Engineering, Surveying, Legal			20%	$129,546
Total Project Cost				$777,275

3.1.3.2 California Street Problem Area.

The California Street Problem Area is located in the west central portion of the City at the intersection of California Street and IH-35. Flooding problems in this area are associated with overbank flows from the Elm Fork overtopping an existing levee along the east bank of the Elm Fork, north of California Street. Flow that overtops this area spills across Moffet Park and through the California Street

Flow from Elm Fork overtopping existing levee upstream of California Street along Moffet Park.

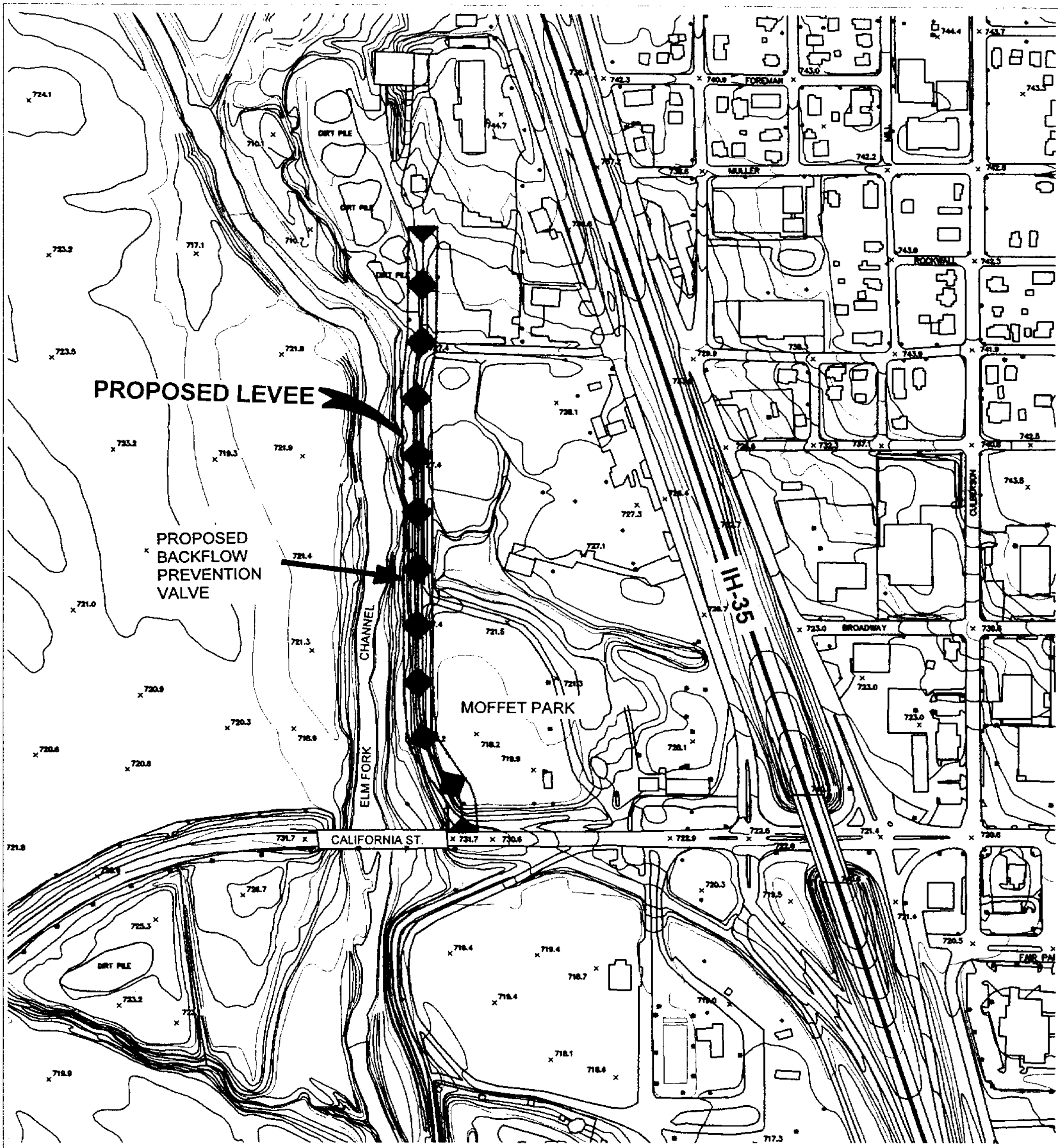
underpass at IH-35 into the Chestnut Channel and Shadowood areas along the east side of IH-35. This condition is expected to occur only for large flood events exceeding a 50-year return period. Overbank flooding occurred in this area during the October 1981 flood event.

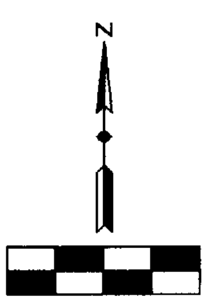
The recommended plan to prevent overbank flooding through the California Street underpass at IH-35 is to raise the existing levee that extends from the east side of the California Street bridge north to higher ground at the City's Public Works facilities, as shown in Figure 3.1-8. The top of the existing levee serves as an access road to the City's Public Works facilities and it is required to be raised by about 3 feet. In addition, the proposed improvements would include realignment of the access road at the intersection with California Street, and installation of backflow prevention valves on an existing drainage pipe to prevent floodwaters from the Elm Fork from backing up into the Moffet Park area and the east side of IH-35. The capital cost for implementation of the proposed levee plan is estimated to be $173,000, including engineering and construction contingencies, as presented in Table 3.1-9.

Floodwaters from Elm Fork spilling through California St./IH-35 overpass into area of City on east side of IH-35.

Table 3.1-9
California Street Problem Area
Project Cost Estimate

Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Borrow Excavation	cubic yard	7,500	$2.00	$15,000
Embankment/Levee Fill	cubic yard	7,500	$3.00	$22,500
Stripping	cubic yard	1,930	$1.50	$2,895
Seeding/Vegetation	square yard	29,700	$0.45	$13,365
Soil Retention Blanket	square yard	29,700	$1.00	$29,700
Backflow Prevention Valve – 48"	each	1	$19,500	$19,500
Asphalt Paving	square feet	1,500	$3.50	$5,250
Gravel Paving	square feet	11,250	$1.50	$16,875
Subtotal				$125,085
Contingencies & Miscellaneous			15%	$18,763
Construction Cost				$143,848
Engineering, Surveying, Legal			20%	$28,770
Total Project Cost				$172,617





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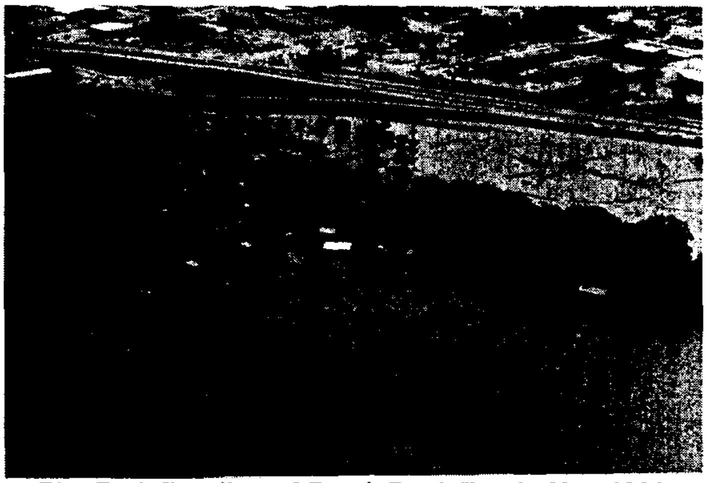
CALIFORNIA STREET
LEVEE IMPROVEMENTS

FIGURE 3.1-8 **MARCH, 1999**

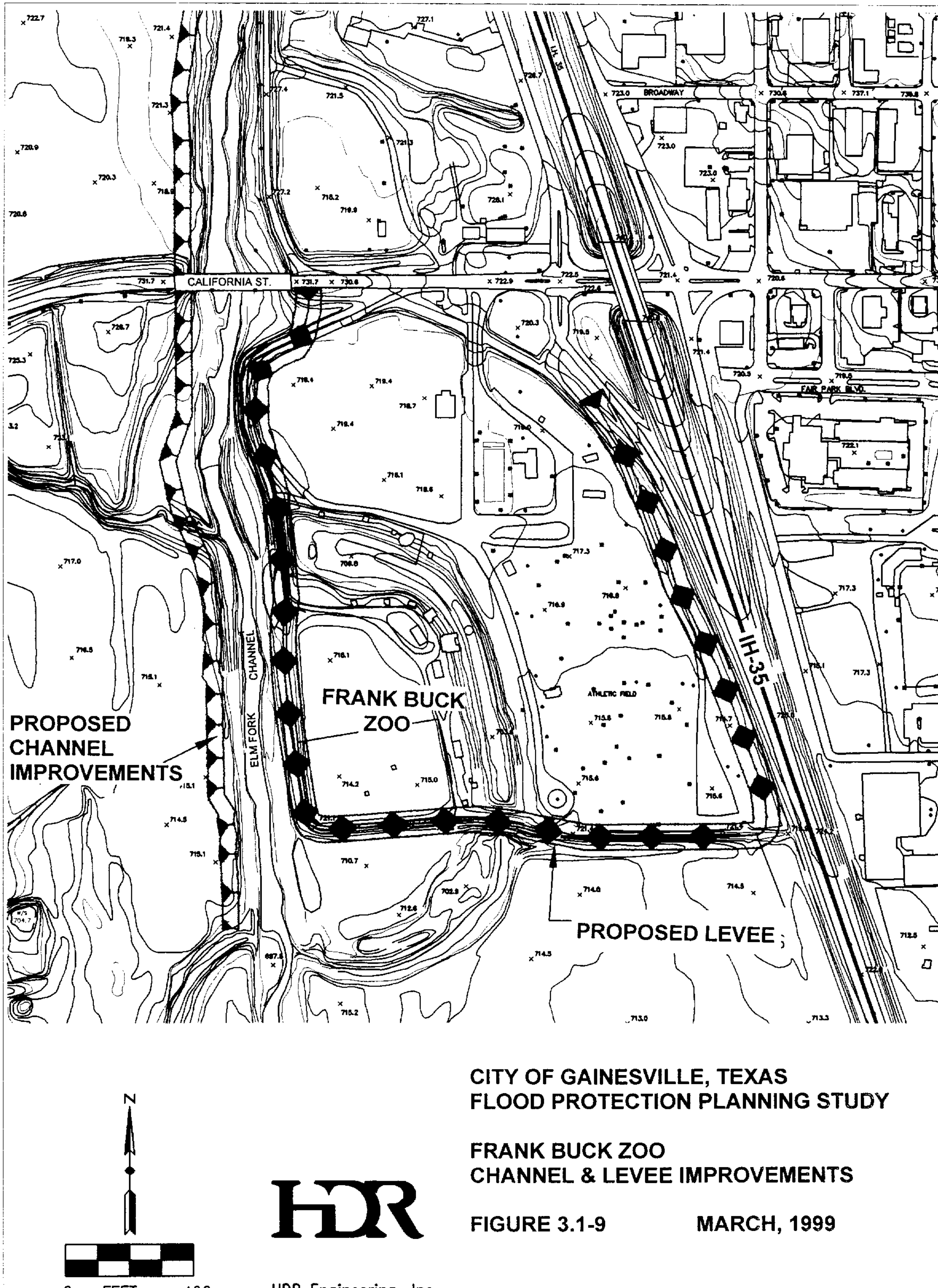
3.1.3.3 Frank Buck Zoo Problem Area

The Frank Buck Zoo is located just south of California Street and west of IH-35 along the east bank of the Elm Fork. Flooding problems in this area are associated with overbank flooding of the zoo area from the Elm Fork during large flood events. The zoo has a history of flood damages, with the October 1981 flood being the most catastrophic event. In 1993, the City constructed a levee along the perimeter of the zoo from the California Street road embankment to the IH-35 service road embankment, as shown in Figure 3.1-9. The elevation of the levee was based on 100-year flood levels published in the 1981 FEMA Flood Insurance Study. The elevation of the top of the levee ranges from 724 feet-mean sea level (ft-msl) at the north end near California Street to 721 ft-msl at the south end. In May 1993, just as the levee project was being completed, a flood event occurred that came within about 1 foot of overtopping the levee. The USGS streamflow gaging station recorded a peak discharge for the May 1993 flood event of about 21,100 cfs and a peak stage of 722.7 ft-msl at the downstream face of the California Street bridge, which is the upstream end of the zoo levee. The stream hydraulic model developed as part of this study shows that the FEMA Flood Insurance Study flood levels are approximately 5 feet too low, based on the updated model and data recorded at the USGS gaging station at California Street. Current estimates show that the levee around the zoo would overtop for a peak discharge of approximately 22,000 cfs, which corresponds to approximately the 25-year return period event.



Elm Fork flooding of Frank Buck Zoo in May 1989. Looking northeast at zoo area with intersection of IH-35 and California St. in background of photo.

In order to provide 100-year flood protection for the Frank Buck Zoo, the existing levee is required to be raised by about 4 feet. At the south end of the levee, the existing elevation is approximately 721 ft-msl, and the proposed elevation would be 725 ft-msl, based on the



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FLOOD PROTECTION PLANNING STUDY

FRANK BUCK ZOO
CHANNEL & LEVEE IMPROVEMENTS

FIGURE 3.1-9 **MARCH, 1999**

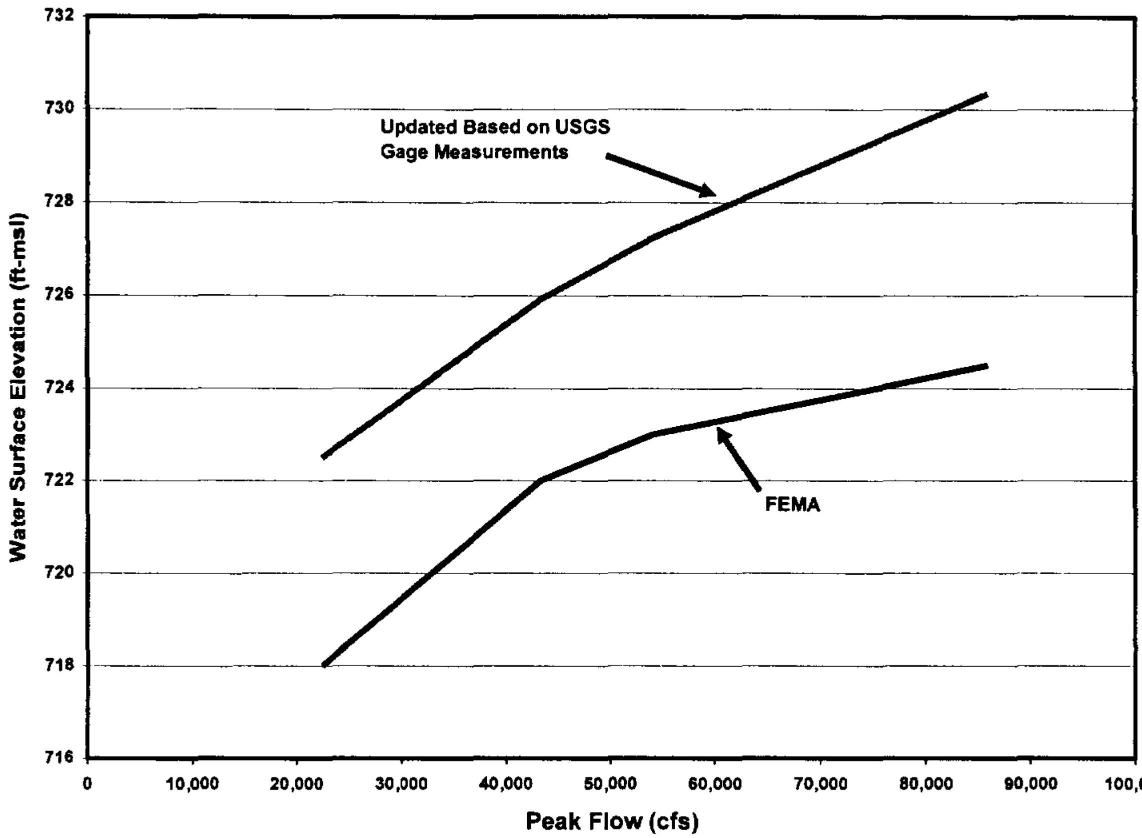


Figure 3.1-10. Water Surface Elevation vs. Peak Flow for the Elm Fork at California St.

hydraulic model. In order to raise the levee at the south end to this higher elevation, the levee will have to be continued north, parallel to the IH-35 service road embankment, for a distance of about 700 feet until it joins with a natural ground elevation of 725 ft-msl. The total embankment volume for the incremental raise of the levee and the new segment along IH-35 is approximately 17,000 cubic yards. Raising the existing levee at the zoo and upstream of California Street will prevent flood damages by restricting flow in the Elm Fork to west of IH-35. By restricting the flow at California Street, there would be an increase in water surface elevation upstream of California Street that would flood additional property for the 100-year flood event. In order to mitigate the increase in water surface elevation, channel improvements along the west bank of the Elm Fork downstream of California Street are recommended to provide additional flow capacity. The channel improvements include widening the bottom width of the existing channel by a maximum of 30 feet. The capital cost for implementation of the proposed levee and channel improvement plan is estimated to be $653,000, including engineering and contingencies, as presented in Table 3.1-10.

Table 3.1-10
Frank Buck Zoo Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	25,100	$6.25	$156,875
Embankment/Levee Fill	cubic yard	17,000	$3.00	$51,000
Stripping	cubic yard	4,250	$1.50	$6,375
Clearing and Grubbing	acres	2.3	$8,000	$18,365
Seeding/Vegetation	square yard	130,000	$0.45	$58,500
Soil Retention Blanket	square yard	130,000	$1.00	$130,000
Asphalt Paving	square feet	7,200	$3.50	$25,200
Gravel Paving	square feet	11,250	$1.50	$27,000
Subtotal				$473,315
Contingencies & Miscellaneous			15%	$70,997
Construction Cost				$544,313
Engineering, Surveying, Legal			20%	$108,863
Total Project Cost				$653,175

3.1.3.4 Southwest Gainesville Problem Area

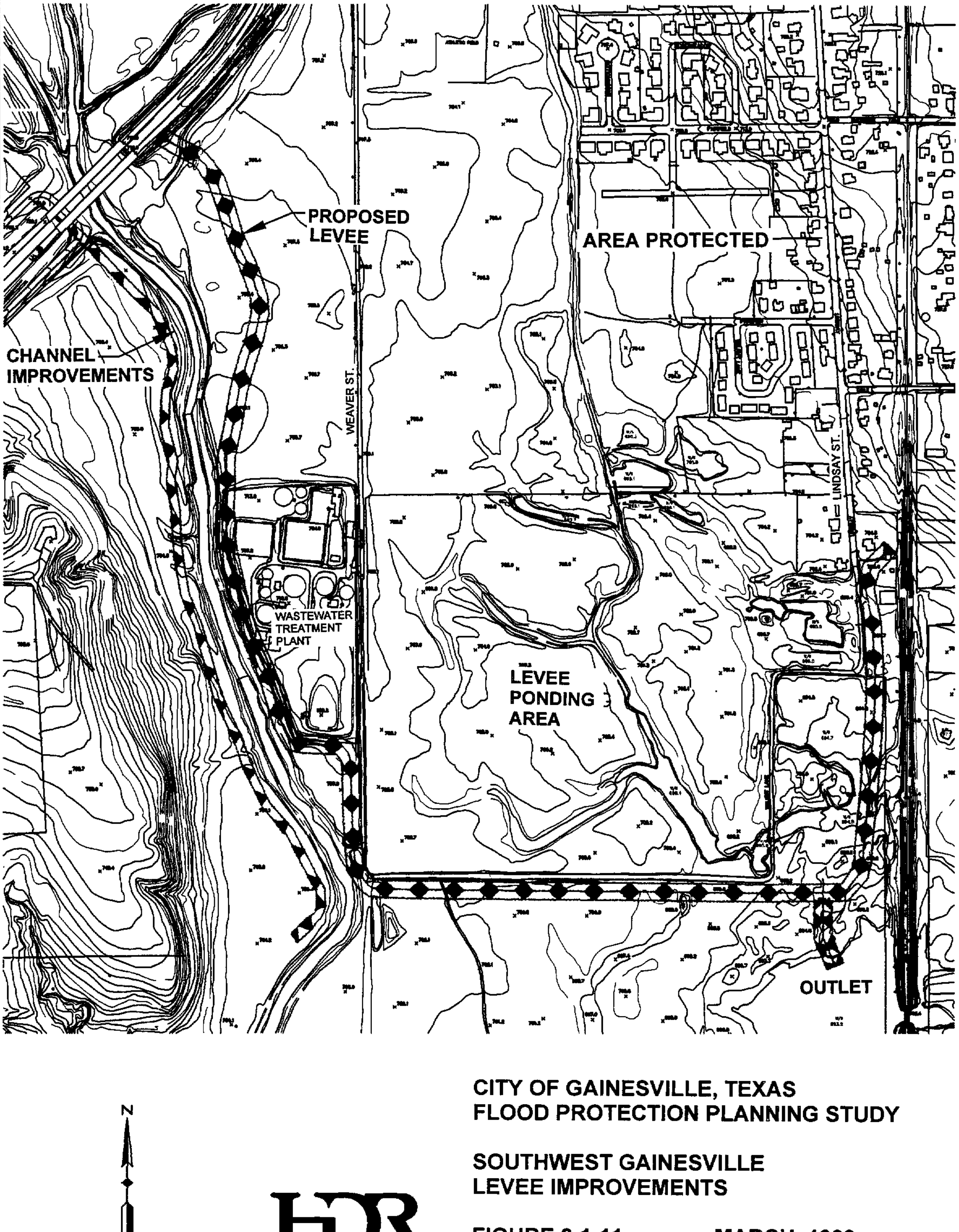
The Southwest Gainesville Problem Area includes a large area defined as south of California Street, west of Lindsay Street, north of Walnut Lane, and east of the Elm Fork channel and IH-35. Flooding problems in this area are associated with overbank flows from the Elm Fork downstream of the IH-35 bridge and backwater into the Chestnut Channel and Shadowood areas. The area also includes the City's wastewater treatment plant, which is protected by an existing levee. Overbank flooding and backwater from the Elm Fork for large flood events


Backwater from Elm Fork at Hird Street in Southwest Gainesville. Flood of Oct. 1981.

Backwater from Elm Fork flooding residence along Fairfield Drive.

will result in inundation of several residences and commercial structures, and potential overtopping of the levee at the City's wastewater treatment plant. Current estimates based on the updated stream hydraulic model show that the existing levee for the wastewater treatment plant would overtop at a peak discharge of approximately 27,000 cfs, or about the 25-year return period flood event. Flooding of this area did occur as a result of the October 1981 flood, which is estimated to have exceeded the magnitude of the 100-year return period flood event. The recommended flood protection plan is construction of a levee to prevent overbank flows and backwater from the Elm Fork for entering the area. In its 1987 study of the Elm Fork, the U.S. Army Corps of Engineers (USCOE)[9] concluded that permanent evacuation of the flood plain was not economically feasible and recommended a levee plan to prevent flooding in this area. The proposed plan presented by the USCOE was reviewed as part of this study, and revisions have been recommended based on recent activities in the City. The City is developing a park area (Kennestoe Park) between the south ends of Weaver Street and Lindsay Street. The original levee plan proposed by the USCOE would cross through the park area and would interfere with the City's plan for park development. A revised plan is recommended for this area, which includes a levee from the IH-35 road embankment on the east side of the existing bridge over the Elm Fork to the west side of the City's wastewater treatment plant, as shown in Figure 3.1-11. The levee is proposed to provide 100-year flood protection with 3 feet of freeboard. The west side of the City's existing wastewater treatment plant levee would be raised by approximately 4 feet, and the levee would be continued to a point near the south end of Weaver Street. From this point the levee would turn east and continue for approximately 2,400 feet to near the BN&SF Railroad right-of-way. The levee would turn north and follow the BN&SF Railroad right-of-way to connect to higher ground at the north end. The proposed levee is approximately 8,000 feet long, has a maximum height of 19 feet, an average height of about 10 feet, and includes a total embankment volume of

[9] U.S. Army Corps of Engineers, Fort Worth District, Elm Fork of the Trinity River, Gainesville, Texas, Definite Project Report, October 1987.



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SOUTHWEST GAINESVILLE
LEVEE IMPROVEMENTS

FIGURE 3.1-11 MARCH, 1999

140,000 cubic yards. Construction of the levee would require acquisition of residential structures and storage buildings at the south end of Lindsay Street. The estimated land acquisition costs, based on data from the Cooke County Appraisal District and the City's aerial topographic mapping, is approximately $100,000. The plan includes interior drainage structures at the southwest and southeast corners of the levee to drain interior runoff. The interior drainage structures include discharge pipes through the levee, sized for the 100-year peak runoff rate, with backflow prevention valves to prevent backwater from the Elm Fork from entering the area. The proposed drainage structures on Chestnut Channel at the southeast end of the proposed levee were sized as two, 84-inch diameter concrete pipes. No pumping stations are included in the plan. For large flood events, flood levels in the Elm Fork may prevent interior flows from being passed through the discharge pipes as the backflow prevention valves would close. If the backflow prevention valves closed due to high flood levels in the Elm Fork, interior flows would be impounded behind the proposed levee in the park area until such time as flood levels in the Elm Fork dropped below levels on the interior side of the levee. The storage volume upstream of the levee in the park area is adequate to store up to a local 500-year storm event without damage to existing structures. The 500-year flood level on the interior side of the levee is approximately 703.3 ft-msl, which is 0.7 feet lower than the lowest structure.

The proposed levee plan provides protection from flooding on the Elm Fork for a large area of southwest Gainesville, including the City's wastewater treatment plant. However, the proposed levee does reduce conveyance in the flood plain area that would result in increased flood levels upstream of the IH-35 bridge. In order to mitigate the increased flood levels, channel improvements to the west bank of the Elm Fork channel from IH-35 to downstream of the City's wastewater treatment plant are recommended. The channel improvements include excavation of the west bank to provide additional conveyance capacity to maintain or reduce existing flood levels upstream of the proposed project. The total excavation volume for the channel improvements is approximately 100,000 cubic yards, and it is expected that a significant portion of the material would be utilized in construction of the proposed levees.

The capital cost for implementation of the recommended plan is estimated to be $2,605,000, including engineering, construction contingencies, and land acquisition, as shown in Table 3.1-11.

Table 3.1-11
Southwest Gainesville Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	100,000	$6.25	$625,000
Embankment/Levee Fill	cubic yard	140,000	$3.00	$420,000
Clearing & Grubbing	acre	17	$3,000	$51,000
Stripping	cubic yard	14,722	$1.00	$14,722
Seeding/Vegetation	square yard	160,000	$0.45	$72,000
Soil Retention Blanket	square yard	160,000	$1.00	$160,000
Outlet Structure – 84-inch RCP	linear feet	250	$325	$81,250
Outlet Structure – 36-inch RCP	linear feet	100	$55	$5,500
Headwalls	each	4	$2,500	$10,000
Backflow Prevention Valve – 84"	each	2	$58,000	$116,000
Backflow Prevention Valve – 36"	each	1	$13,500	$13,500
Gravel Paving	square feet	79,500	$1.50	$119,250
Subtotal				$1,688,222
Contingencies & Miscellaneous			15%	$253,233
Construction Cost – Subtotal				$1,941,455
Engineering, Surveying, Legal			20%	$388,291
Land Acquisition	lump sum	1	$100,000	$100,000
Mitigation Area	lump sum	1	$175,000	$175,000
Total Project Cost				$2,604,746

Minor Watersheds

Minor watersheds in the Elm Fork watershed in the City were analyzed for the interior drainage facilities needed to convey runoff to prevent flood damages to the local areas. A number of problem areas were identified in the study area through the public survey and engineering analyses of runoff rates and street flow capacity. Five problem areas associated with minor watersheds in the Elm Fork were identified, as previously shown in Table 3.1-7 and Figure 3.1-6.

The problem areas associated with the minor watersheds are primarily associated with street flooding, inadequate channel capacity, and undersized bridges and culverts. In the cases of street flooding, the recommended plan will be construction of underground storm sewer systems to remove surface runoff from the streets. Storm sewer systems are usually the only option due to dense urban development and limited right-of-way available for construction of more economical alternatives, such as open channels. Storm sewer systems are expensive to implement, especially in a scenario involving retrofitting to an already developed area. The cost of the system is increased due to the cost of restoring the street after construction and coordination with other existing utilities. Benefits of the proposed improvements include:

- Reduction in flood damages to existing residences and businesses;
- Reduction in risk to public health and safety; and
- Increased life of street pavements as a direct result of improved drainage.

In the cases of inadequate channel capacity and undersized bridges and culverts, the recommended plan will usually include channel improvements along the existing alignment and replacement or enlargement of the existing bridges and culverts. Alternatives for diversion and/or detention of floodwaters were also investigated, however, it was determined that these alternatives were not feasible, due to the lack of available right-of-way and/or cost of construction.

3.1.3.5 Star Avenue Problem Area

The Star Avenue Problem Area is located in the northwest part of the City, east of IH-35 and north of California Street as shown in Figure 3.1-6. Drainage problems in this area have been reported along Star Avenue due to flooding along an existing channel. The channel flows along the downstream side of an abandoned railroad embankment behind the existing homes and then crosses under Star Avenue. Star Avenue includes two 27-inch diameter concrete culverts to pass runoff under the roadway. Drainage problems in this area are a result of inadequate channel capacity and flood damages have included flooding of homes and damage to fences and landscaping as reported by the local residents.

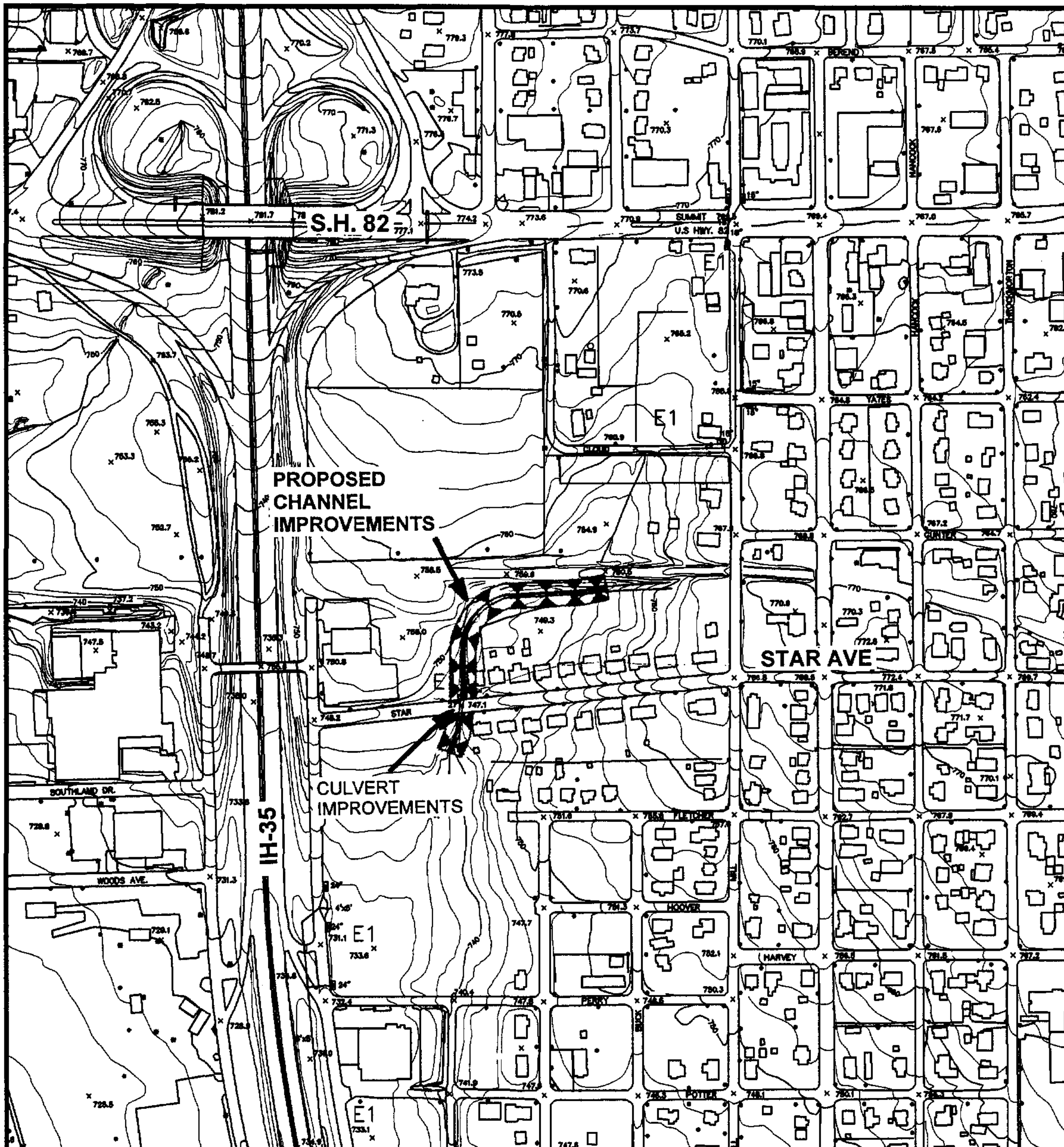
Existing channel upstream of Star Ave.

The recommended plan for improving drainage in this area includes channel improvements near Star Avenue to the upstream railroad embankment, as well as enlargement of the existing culvert at Star Avenue, as shown in Figure 3.1-12. It is recommended that the existing channel be enlarged to a minimum 10-ft bottom width with 4:1 (horizontal:vertical) side slopes. The average depth of the channel is proposed to be on the order of 4 to 5 feet. The Star Avenue culverts are recommended to be replaced with a 6-ft by 4-ft concrete box culvert. The capital cost of the recommended plan is estimated to be $62,000, including engineering and contingencies, as shown in Table 3.1-12.

Existing 27-inch RCP culverts at Star Avenue.

Table 3.1-12
Star Avenue Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	1,960	$6.25	$12,250
Road Excavation/Backfill	cubic yard	156	$12.00	$1,872
Pavement Cut/Repair	square feet	900	$3.50	$3,150
Topsoil (4")	square yard	3,560	$1.15	$4,094
Seeding/Vegetation	square yard	3,560	$0.45	$1,602
Soil Retention Blanket	square yard	3,560	$1.00	$3,560
Structural Concrete – Box Culvert	cubic yard	22	$400	$8,800
Headwall	each	2	$1,500	$3,000
Concrete Riprap	square feet	1,250	$5.50	$6,876
Subtotal				$45,203
Contingencies & Miscellaneous			15%	$6,780
Construction Cost				$51,983
Engineering, Surveying, Legal			20%	$10,397
Total Project Cost				$62,380



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CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

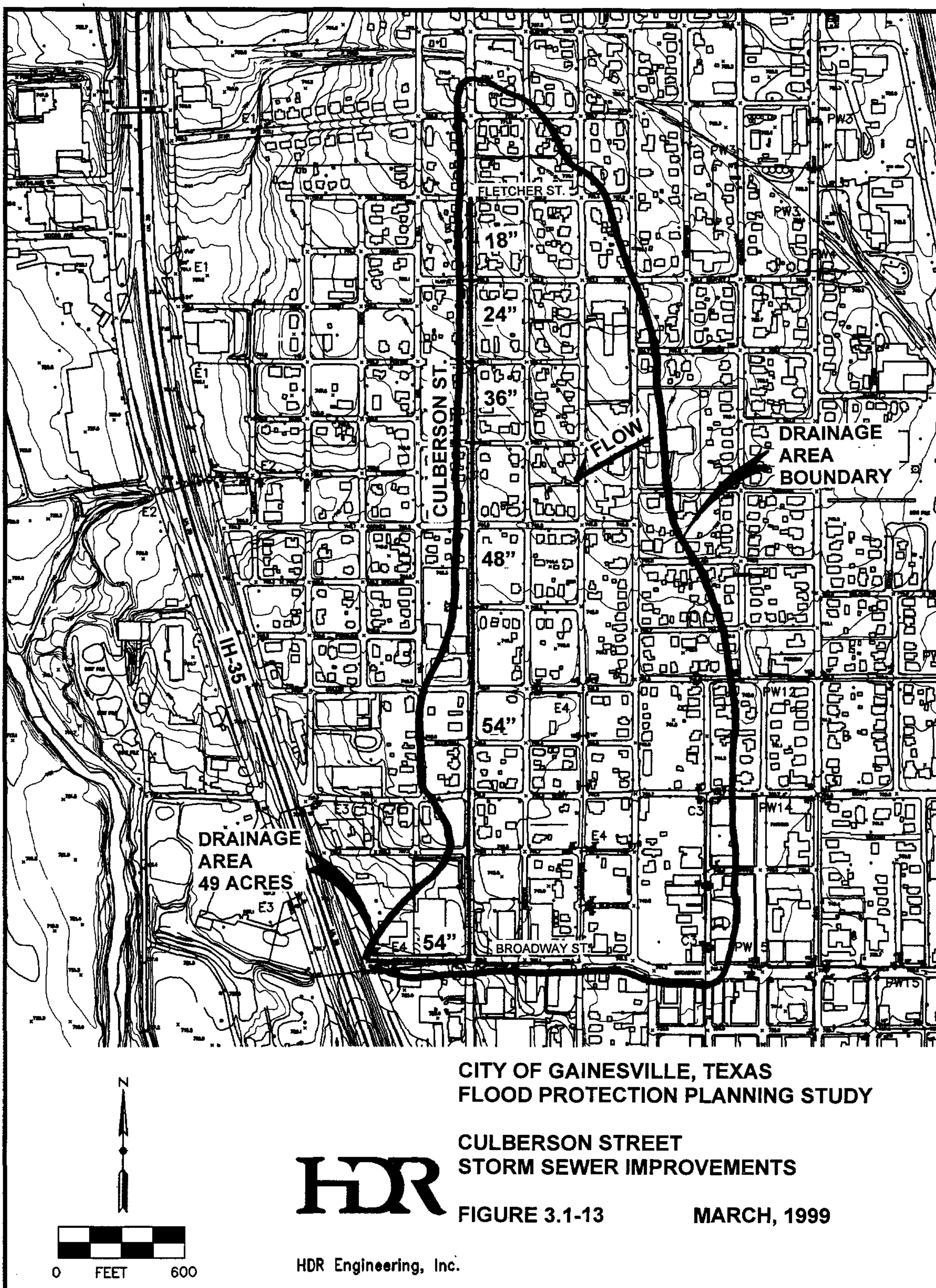
STAR AVENUE
DRAINAGE IMPROVEMENTS

FIGURE 3.1-12 **MARCH, 1999**

3.1.3.6 Culberson Street Problem Area

The Culberson Street Problem Area is located in the west part of the City, north of California Street and east of IH-35. Excessive street flooding occurs along Culberson Street, especially near the Broadway and California Street intersections. The street receives runoff from as far north (upstream) as Star Avenue and intercepts additional flow from the east as it flows downstream (south) to Broadway Street and California Street. All runoff on Culberson Street flows on the surface as no underground storm sewer presently exists along the street. Flood damages are primarily limited to street flooding, however. The peak runoff rate for the 25-year storm event is as much as four to five times the hydraulic capacity of Culberson Street at various locations. For example, near Belcher Street, the hydraulic capacity of Culberson Street at the top of curb level is approximately 30 cfs. The 25-year peak runoff rate at the intersection of Culberson Street and Belcher Street is 145 cfs, exceeding the street capacity by 115 cfs, which results in severe flooding of the street. The current capacity of Culberson Street at the top of curb level is estimated to be less than the 2-year return period storm event.

The recommended plan for improving drainage on Culberson Street includes installation of a storm sewer system beginning upstream (north) at Fletcher Street and extending south to Broadway Street and IH-35 (Figure 3.1-13). The storm sewer pipe size would begin at 18 inches in diameter at Fletcher Street and increase to 54-inches in diameter at its outfall near Broadway Street. The proposed storm sewer system would discharge into the upstream end of a 5-ft by 4-ft box culvert located at IH-35 that eventually conveys water to the Elm Fork channel. The total length of the storm sewer system is 4,100 feet. The capital cost of the proposed system is estimated to be $767,000, including engineering and construction contingencies, as shown in Table 3.1-13.



CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

CULBERSON STREET
STORM SEWER IMPROVEMENTS

FIGURE 3.1-13 **MARCH, 1999**

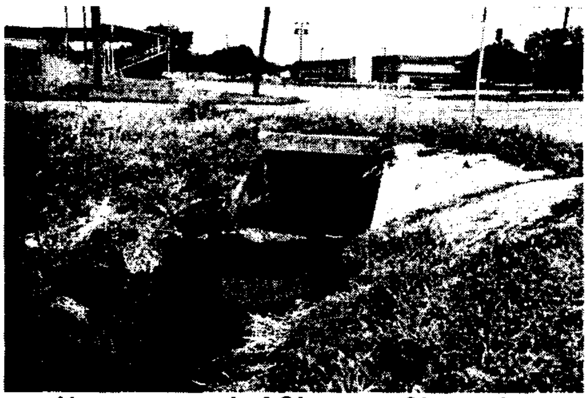
HDR Engineering, Inc.

Table 3.1-13
Culberson Street Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Road Excavation	cubic yard	5,520	$12.00	$66,240
Pavement Cut/Repair	square feet	20,300	$3.50	$71,050
Trench Safety	linear feet	4,100	$3.50	$14,350
Storm Sewer Inlet (10-ft)	each	21	$2,100	$44,100
Storm Sewer Inlet (20-ft)	each	2	$4,000	$8,000
Manhole	each	8	$4,000	$32,000
18-inch RCP	linear feet	400	$29	$11,600
24-inch RCP	linear feet	400	$32	$12,800
36-inch RCP	linear feet	400	$55	$22,000
48-inch RCP	linear feet	800	$80	$64,000
54-inch RCP	linear feet	2,100	$100	$210,000
Subtotal				$556,140
Contingencies & Miscellaneous			15%	$83,421
Construction Cost				$639,561
Engineering, Surveying, Legal			20%	$127,912
Total Project Cost				$767,473

3.1.3.7 Chestnut Channel Problem Area

The Chestnut Channel Problem Area is located in the southwest part of the City, south of California Street and east of IH-35 (Figure 3.1-6). Chestnut Channel is a grass-lined drainage channel that begins near the intersection of Weaver Street and Church Street near the Holiday Inn and extends downstream to the Elm Fork channel. At the downstream end, the channel becomes less defined as it enters a wide, flat area of the Elm Fork flood plain. Drainage problems in the area are primarily due to inadequate channel capacity and undersized culvert crossings. There are numerous reports of frequent flooding along the channel, especially in the Shadowood area, where the channel is small and residences are located adjacent to the channel. The channel segment between Garnett Street and the north end of Shadowood Drive is lined with large trees, with small pedestrian bridges crossing the channel at various locations. The remaining portion of the channel segment is relatively clear of trees and obstructions, however, it has inadequate channel capacity to convey the design discharge without flooding adjacent residences.

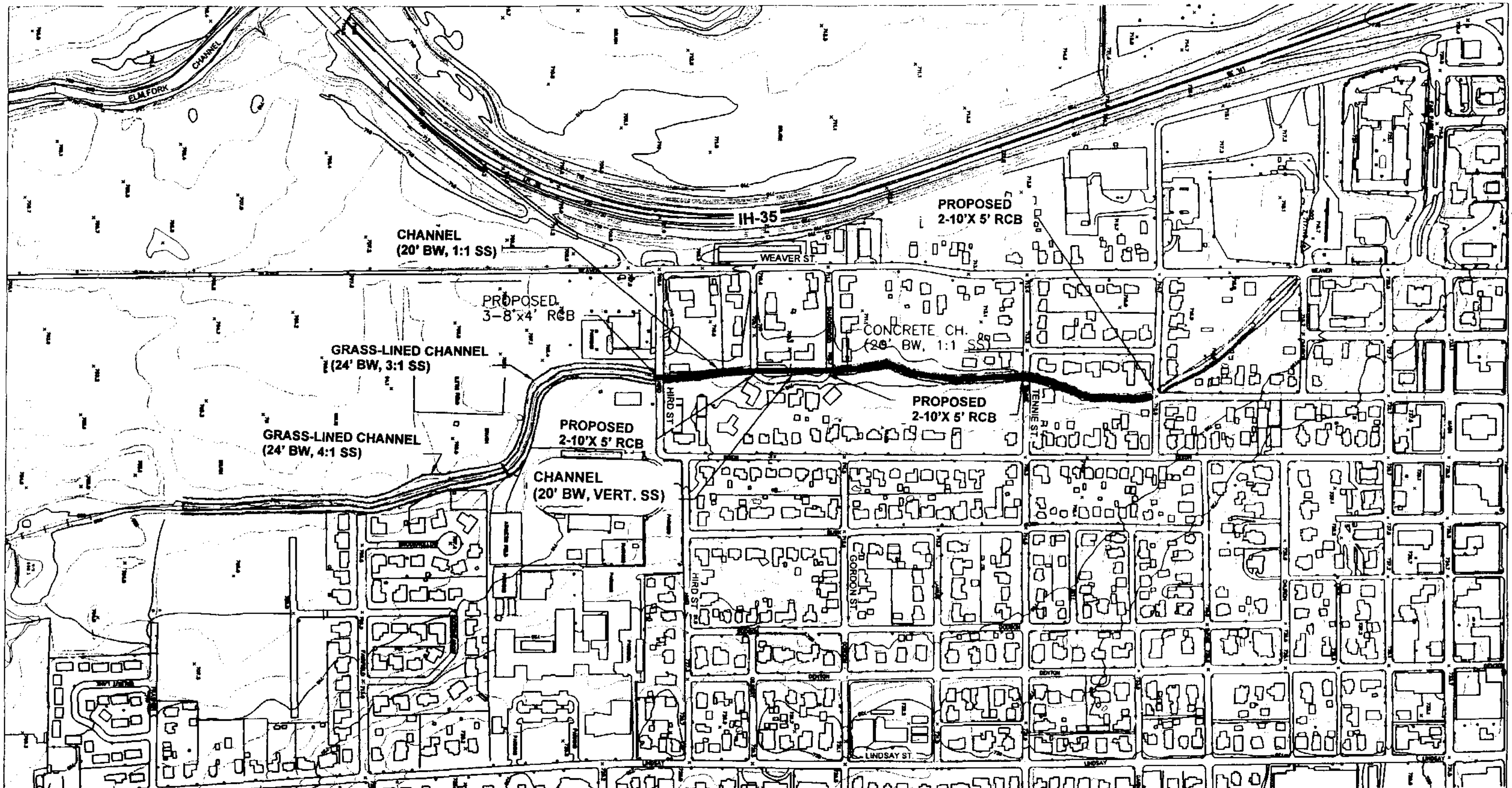


Upstream end of Chestnut Channel at Weaver St. and Church St.

Chestnut Channel upstream of Tennie Street

The recommended plan for the Chestnut Channel is to improve the channel from Weaver Street to about 2,300 feet south of Hird Street, as shown in Figure 3.1-14. Improvements to the existing channel include a grass-lined, trapezoidal channel with a 20-ft bottom width and 3:1 side slopes between Weaver Street and Garnett Street. Downstream of Garnett Street to Hird Street, the 20-ft bottom width was maintained. The side slopes of the channel were set to near vertical in this segment to reduce the top width in order to align the channel between existing structures, limit the amount of tree removal required, and maintain the aesthetics of the area. Downstream of Hird Street, the channel would transition back to a grass-lined, trapezoidal channel with a 24-ft bottom width and 3:1 side slopes. In addition to the recommended channel improvements, several culvert crossings are recommended to be enlarged at Garnett Street, Tennie Street, Shadowood Drive (two crossings), an existing residential driveway, and Hird Street. Each culvert crossing, except for Hird Street, is recommended to be replaced with a two-barrel, 10-ft by 5-ft box culvert. Hird Street is presently equipped with a two-barrel, 8-ft by 4-ft box culvert and the existing culvert is recommended to be expanded by adding an additional 8-ft by 4-ft box culvert. The capital cost for the recommended plan is estimated to be $923,000, including engineering and construction

Chestnut Channel upstream of Hird St.



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CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

CHESTNUT CHANNEL
DRAINAGE IMPROVEMENTS

FIGURE 3.1-14 MARCH, 1999

contingencies, as shown in Table 3.1-14. The capital costs do not include the costs for land acquisition or easements that would be required for implementation of the recommended project.

Existing culvert across Chestnut Channel at Shadowood Circle

Chestnut Channel along Shadowood Circle

Table 3.1-14
Chestnut Channel Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	21,000	$6.25	$131,250
Road Excavation/Backfill	cubic yard	1,500	$12.00	$18,000
Clearing & Grubbing	acre	2.5	$8,000	$20,000
Topsoil (4")	square yard	20,000	$1.15	$23,000
Seeding/Vegetation	square yard	20,000	$0.45	$9,000
Soil Retention Blanket	square yard	20,000	$1.00	$20,000
Pavement Cut/Repair	square feet	4,500	$3.50	$15,750
Modular Concrete Retaining Wall	square feet	25,800	$12.00	$309,600
Culvert (10-ft x 5-ft RCB)	linear feet	320	$275	$88,000
Culvert (8-ft x 4-ft RCB)	linear feet	35	$210	$7,350
Headwall	each	10	$2,500	$25,000
Subtotal				$669,050
Contingencies & Miscellaneous			15%	$100,358
Construction Cost				$769,408
Engineering, Surveying, Legal			20%	$153,882
Total Project Cost				$923,300

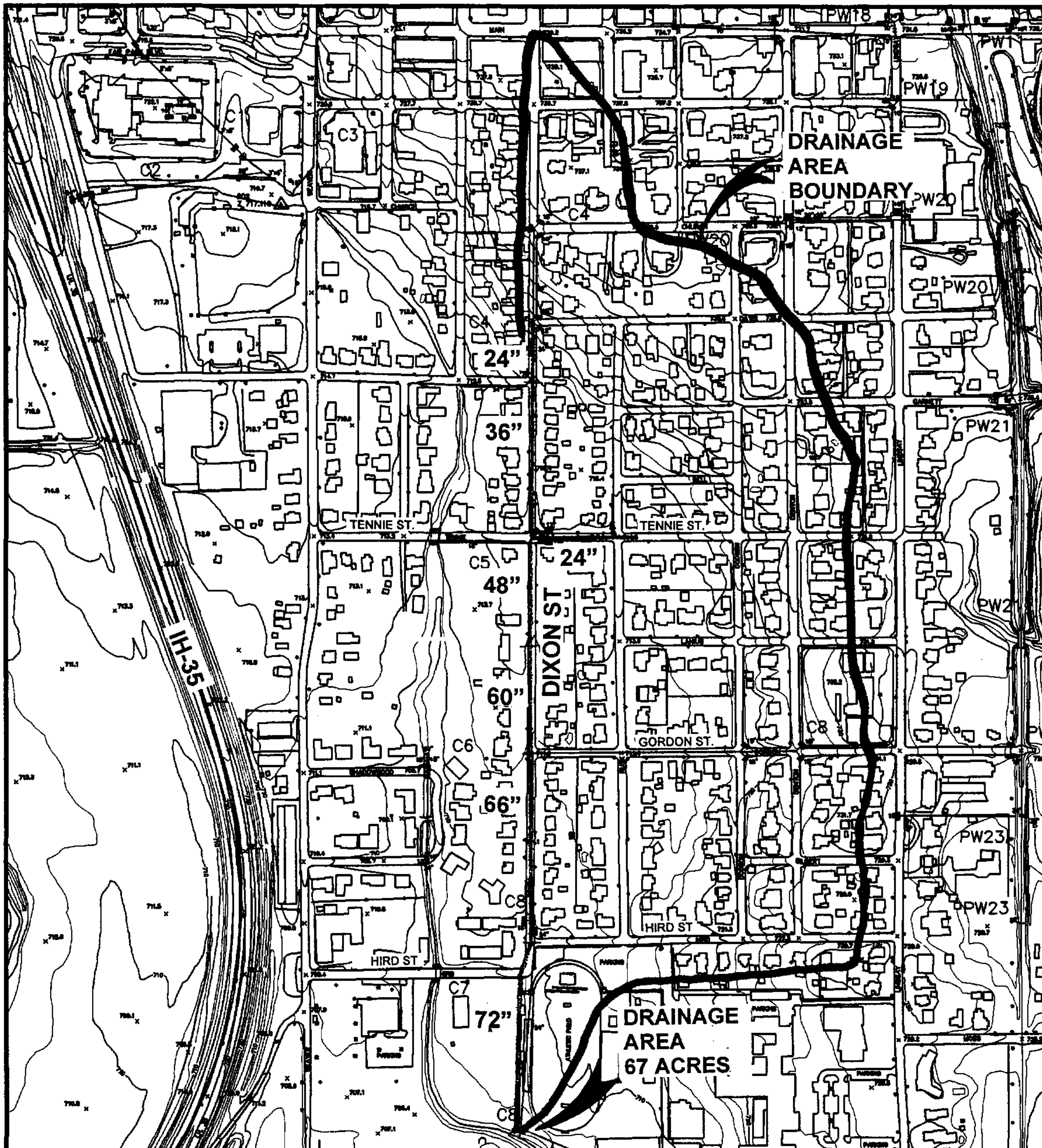
3.1.3.8 Dixon Street Problem Area

The Dixon Street Problem Area is located in the west part of the City, south of California Street and east of IH-35. Street flooding occurs as runoff travels west from near Denton Street and is intercepted by Dixon Street, which redirects the flow south. Drainage problems have been reported by local residences at the downstream (south) end of Dixon Street at the intersection with Hird Street. All runoff that travels to Dixon Street is conveyed on the surface, as no underground storm sewer system presently exists. The existing hydraulic capacity of Dixon Street ranges from around 30 cfs to 40 cfs, depending on the slope of the street. The total drainage area for Dixon Street at the Gordon Street intersection is approximately 49 acres, and the estimated 25-year peak runoff rate is 160 cfs. The street hydraulic capacity at this location was calculated to be 30 cfs at the top of curb level, which is exceeded by 130 cfs for the 25-year storm event. The estimated hydraulic capacity of Dixon Street at the top of curb level is less than a 2-year storm event.

The recommended plan to reduce street flooding along Dixon Street is installation of an underground storm sewer system from the Davis Street intersection at the north (upstream) end to its ultimate discharge point in the Chestnut Channel, about 550 feet downstream of Hird Street (Figure 3.1-15). Implementation of the plan will reduce street flooding along Dixon Street, as well as reduce the amount of runoff that currently enters the Chestnut Channel south of Garnett Street when the Dixon Street capacity is exceeded. The capital cost of the recommended plan is estimated to be $979,000, including engineering and construction contingencies, as shown in Table 3.1-15.

3.1.3.9 College Avenue Problem Area

The College Avenue Problem Area is located in the far west portion of the City, west of the Elm Fork channel near the North Central Texas College campus (Figure 3.1-6). Drainage problems have been reported along College Avenue near the intersection with California Street (Hwy 51). Runoff from the residential areas flows east along College Avenue to a divided intersection at California Street. An existing 5-ft by 3-ft box culvert conveys flow under California Street and flow continues downstream to Black Hills Drive. Runoff from the



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FLOOD PROTECTION PLANNING STUDY

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DIXON STREET
STORM SEWER IMPROVEMENTS

HDR Engineering, Inc.

FIGURE 3.1-15 **MARCH, 1999**

Table 3.1-15
Dixon Street Problem Area
Project Cost Estimate

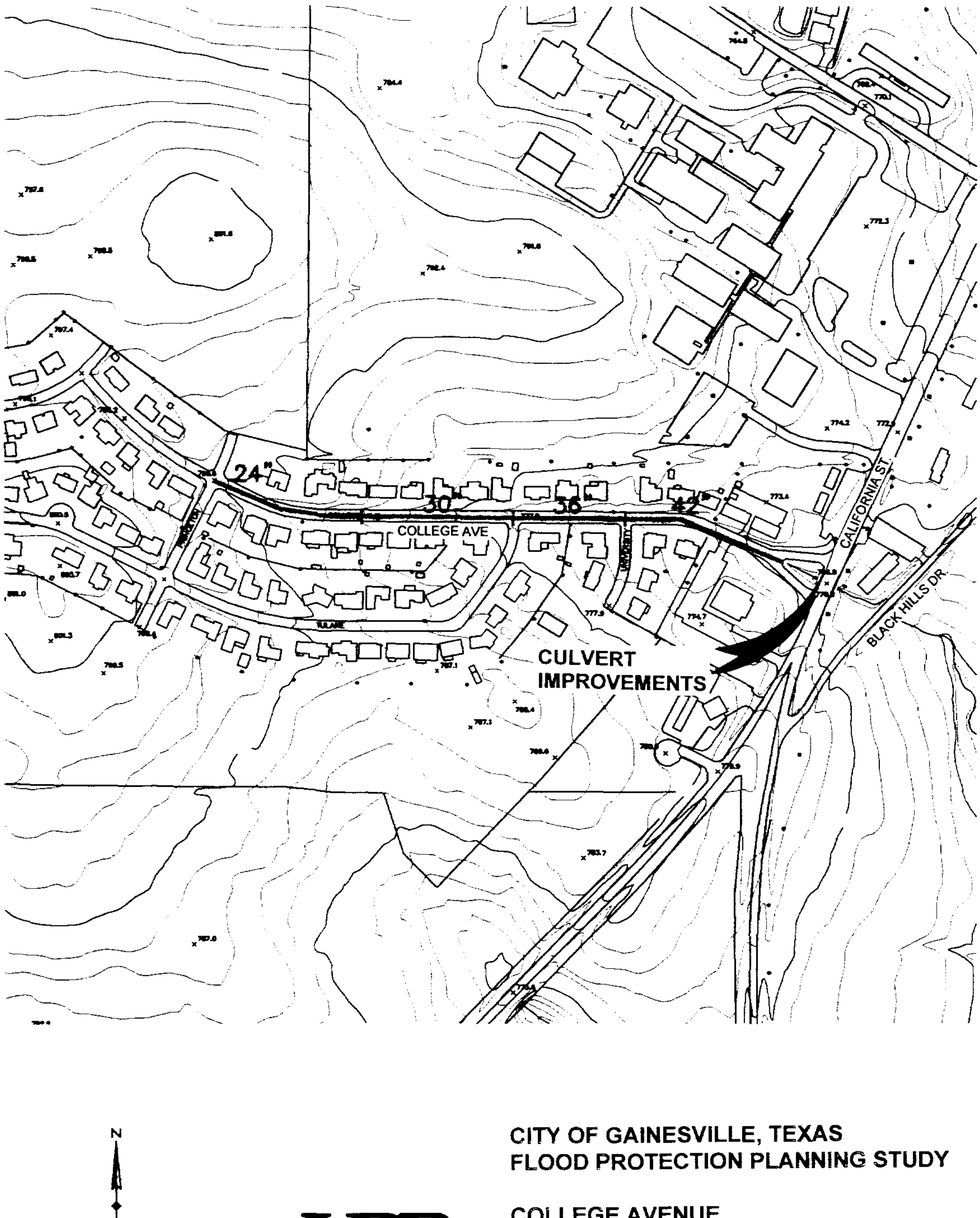
Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Road Excavation	cubic yard	6,900	$12.00	$82,800
Pavement Cut/Repair	square feet	24,000	$3.50	$84,000
Trench Safety	linear feet	4,030	$3.50	$14,105
Storm Sewer Inlet (10-ft)	each	20	$2,100	$42,000
Storm Sewer Inlet (20-ft)	each	4	$4,000	$16,000
Manhole	each	5	$4,000	$20,000
Headwall	each	1	$1,500	$1,500
18-inch RCP	linear feet	360	$29	$10,440
24-inch RCP	linear feet	750	$32	$24,000
36-inch RCP	linear feet	1,660	$55	$91,300
54-inch RCP	linear feet	150	$100	$15,000
66-inch RCP	linear feet	1,070	$180	$192,600
72-inch RCP	linear feet	550	$210	$115,500
Subtotal				$709,245
Contingencies & Miscellaneous			15%	$106,387
Construction Cost				$815,632
Engineering, Surveying, Legal			20%	$163,126
Total Project Cost				$978,758

residential area is conveyed on the surface of the street, as no underground storm sewer exists in the College Avenue area. The hydraulic capacity of the street is calculated to be on the order of 40 cfs at the top of curb level, based on the street slope. The peak runoff rate for the 25-year storm event for College Avenue near the Tulane Street intersection was estimated to be over 100 cfs for the 28-acre drainage area. The current street capacity for College Avenue at the top of curb level is less than a 2-year storm event.

The recommended plan for the College Avenue Problem Area includes enlargement of the existing culvert at California Street and installation of a storm sewer system along College Avenue to collect street flow and prevent the frequent street flooding (Figure 3.1-16). The existing 5-ft by 3-ft box culvert under California Street is proposed to be tripled in size by adding two additional 5-ft by 3-ft barrels. The proposed storm sewer system along College Avenue is proposed to begin at the Princeton Street intersection and continue downstream to the California Street intersection. Pipe sizes for the College Avenue system range from 24-inches in diameter at Princeton Street to 42-inches in diameter at the outlet near California Street.

Existing 5-ft by 3-ft box culvert at College Avenue and California Street

The existing corrugated metal pipe culverts under Black Hills Drive are also proposed to be enlarged by also adding two additional 5-ft by 3-ft box culverts. Implementation of additional culverts at California Street and College Avenue will need to be coordinated with and constructed by the Texas Dept. of Transportation. Increasing the size of the culverts will significantly improve drainage in the area by alleviating flooding at the intersection, which serves as the only access to the subdivision. The capital cost for the recommended plan is estimated to be $384,000, including engineering and contingencies, as shown in Table 3.1-16. The California Street culvert improvements are estimated to cost $80,000, with the remaining improvements having an estimated capital cost of $304,000.



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FLOOD PROTECTION PLANNING STUDY

COLLEGE AVENUE
DRAINAGE IMPROVEMENTS

FIGURE 3.1-16 MARCH, 1999

Table 3.1-16
College Avenue Problem Area
Project Cost Estimate

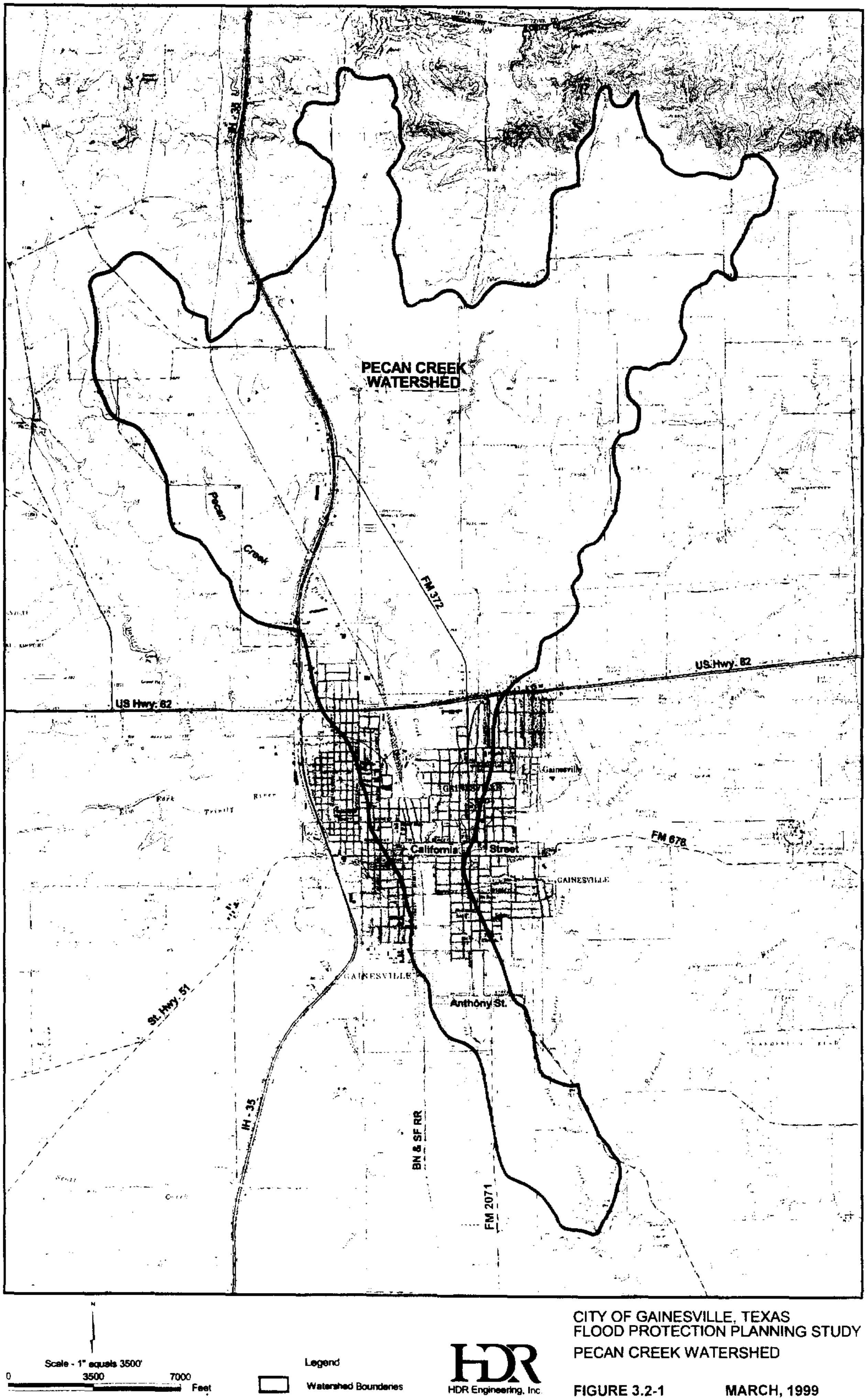
Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Road Excavation	cubic yard	2,345	$12.00	$28,140
Channel Excavation	cubic yard	100	$6.25	$625
Pavement Cut/Repair	square feet	10,165	$3.50	$35,578
Trench Safety	linear feet	2,440	$3.50	$8,540
Structural Concrete (Box Culverts)	cubic yard	119	$400	$47,600
Storm Sewer Inlet (5-ft)	each	1	$1,300	$1,300
Storm Sewer Inlet (10-ft)	each	13	$2,100	$27,300
Storm Sewer Inlet (20-ft)	each	1	$4,000	$4,000
Manhole	each	3	$4,000	$12,000
Headwall	each	8	$1,500	$12,000
18-inch RCP	linear feet	210	$29	$6,090
24-inch RCP	linear feet	680	$32	$21,760
30-inch RCP	linear feet	460	$55	$20,700
36-inch RCP	linear feet	320	$55	$17,600
42-inch RCP	linear feet	540	$65	$35,100
Subtotal				$278,333
Contingencies & Miscellaneous			15%	$41,750
Construction Cost				$320,082
Engineering, Surveying, Legal			20%	$64,016
Total Project Cost				$384,099

3.1.4 Summary

A summary of the problem areas, recommended improvements, and capital costs for the Elm Fork watershed is provided in Table 3.1-17. The total capital cost for all the recommended improvements in this watershed is $7,665,000.

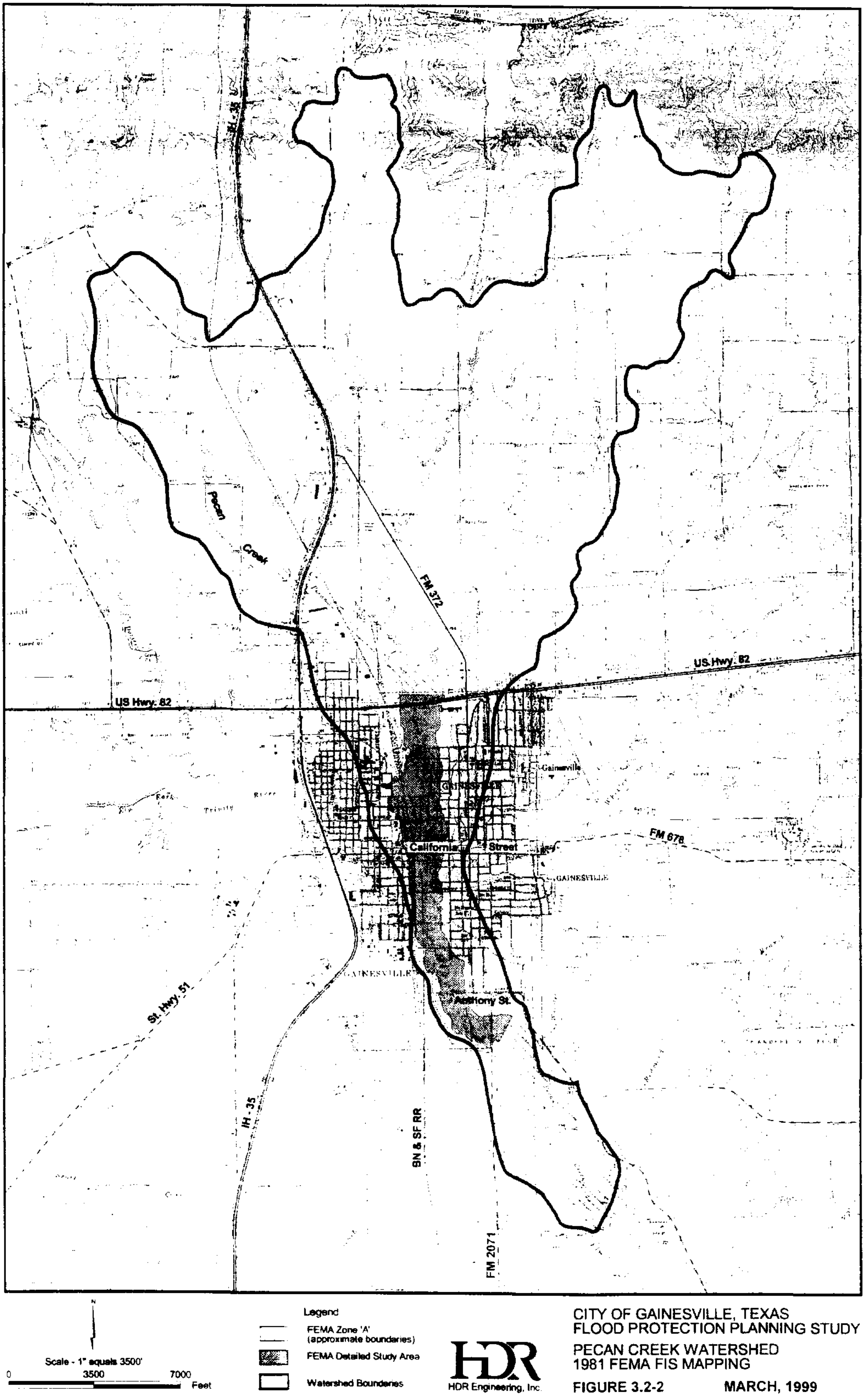
Table 3.1-17
Elm Fork Watershed
Summary of Recommended Improvements

Problem Area	Watershed Category	Recommended Improvements	Estimated Capital Cost
Southland Boulevard	Major	Levee improvements to protect the Southland Boulevard and IH-35 area from flooding from the Elm Fork.	$777,000
California Street	Major	Levee improvements upstream of California Street to prevent floodwaters from the Elm Fork from overflowing through the California Street underpass at IH-35 and into the area of the City east of IH-35.	$173,000
Frank Buck Zoo	Major	Levee improvements around the perimeter of Frank Buck Zoo and channel improvements along the Elm Fork to prevent the zoo area from flooding for a 100-year flood event.	$653,000
Southwest Gainesville	Major	Levee and channel improvements to prevent backwater from the Elm Fork from flooding several residences in southwest Gainesville	$2,605,000
Star Avenue	Minor	Channel and culvert improvements along Star Avenue to contain floodwaters and reduce overtopping of Star Avenue.	$62,000
Culberson Street	Minor	Storm sewer improvements along Culberson Street from Fletcher Street to Broadway Street to reduce frequent and severe street flooding.	$1,109,000
Chestnut Channel	Minor	Channel and culvert improvements along the Chestnut Channel from Weaver Street to about 2,300 feet downstream of Hird Street.	$923,000
Dixon Street	Minor	Storm sewer improvements along Dixon Street from Davis Street to 550 feet downstream of Hird Street.	$979,000
College Avenue	Minor	Storm sewer improvements along College Avenue and culvert improvements at the College Avenue and California Street (Hwy 51) intersection.	$384,000
		Total	**$7,665,000**



CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY
PECAN CREEK WATERSHED

FIGURE 3.2-1 MARCH, 1999



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CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

PECAN CREEK WATERSHED
1981 FEMA FIS MAPPING

FIGURE 3.2-2 MARCH, 1999

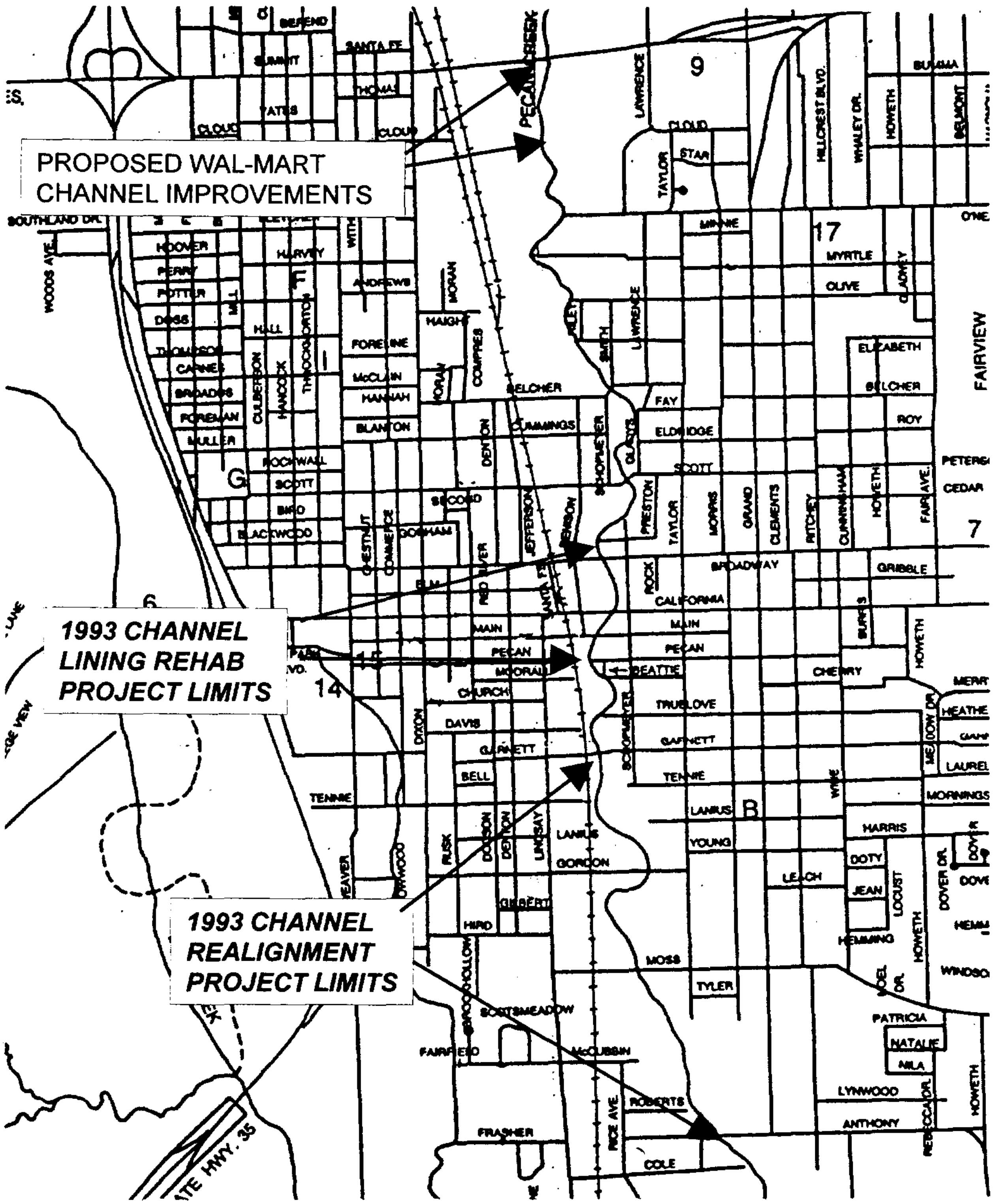
of Pecan Creek and major tributaries to Pecan Creek located outside of the City in Cooke County[10] were not studied in detail and mapping of flood plain limits were made in 1981 using approximate methods.

Flooding problems in the Pecan Creek watershed are primarily associated with streamflow exceeding the capacity of the Pecan Creek channel and flooding of the overbank areas in the City. In addition, areas along Pecan Creek in the City do not have adequate drainage systems to convey runoff in residential and commercial areas into the creek. This results in street flooding, and in some cases, causes damage to adjacent homes and businesses. Few flood control measures have been implemented in the Pecan Creek watershed. Flood control measures that have been implemented consist primarily of minor channel modifications along segments of the creek in the City. The Pecan Creek channel was improved through the central portion of the City in the 1930s as part of the Federal Government sponsored Works Projects Administration (WPA) program. The channel was lined with rock riprap extending from Garnett Street to Scott Street (see Figure 3.2-3). In 1993, the City completed a channel realignment project and a channel lining rehabilitation project on Pecan Creek. The channel realignment project was implemented at the southern end of Pecan Creek and included straightening the channel at several locations to prevent erosion at bridge crossings and clearing dense vegetation from the channel. The channel lining rehabilitation project was implemented to repair the existing rock riprap lining in the pilot channel between Main Street and Broadway Street, which had been damaged after several years of service. Both of the 1993 projects provided a slight increase in the channel capacity and increased the efficiency of the channel by removing debris and straightening the

1930s WPA Program Channel Lining Upstream of Broadway

1993 Channel Lining Project Upstream of California Street

[10] FEMA, Op. Cit., October 18, 1977.



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CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

PECAN CREEK
EXISTING FLOOD CONTROL IMPROVEMENTS

FIGURE 3.2-3 MARCH, 1999

meanders of the main channel. Although the 1993 channel improvement project did provide some additional hydraulic capacity, it produces only a minor reduction in the 100-year flood plain limits. Current estimates show that hydraulic capacity of the Pecan Creek channel in the City is approximately 2,000 cfs, or 25 percent of the estimated 100-year peak runoff rate of about 8,000 cfs. Channel improvements are also being completed just downstream of Highway 82 associated with the Wal-Mart expansion. The channel improvements include widening of the existing channel to a bottom width ranging from 80 to 200 feet for the purpose of mitigating Wal-Mart's encroachment on the flood plain. Other flood control measures that have been considered, but not implemented, in the Pecan Creek watershed include flood control dams upstream of Highway 82 and major channel improvements on Pecan Creek from Highway 82 to Anthony Street. Flood control dams have been evaluated by the Natural Resource Conservation Service[11] (NRCS, formerly the Soil Conservation Service) and major channel improvements have been evaluated by the U.S. Army Corps of Engineers.[12] Investigations of these alternatives are addressed in Sections 3.2.3.1 and 3.2.3.2.

1993 Channel Lining Project Upstream of Main Street

3.2.1 Pecan Creek Flood Hydrology

A flood hydrology model was developed to simulate the rainfall-runoff process for the Pecan Creek watershed. The HEC-1 Flood Hydrograph Package[13] was utilized to compute the peak runoff rates at key points in the drainage basin for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flood events. Runoff hydrographs were developed for each storm event for existing and future development conditions. Future development conditions were based on ultimate development, as shown in the City's Comprehensive Land Use Plan. Peak runoff rates for future development conditions are expected to increase due to an increase in impervious cover and to future modifications to the drainage system. For example, future peak runoff rates

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[11] U.S. Department of Agriculture, Soil Conservation Service, Work Plan Elm Fork Watershed of the Trinity River Watershed, Montague, Cooke and Denton Counties, Texas, June 1956.

[12] U.S. Army Corps of Engineers, Fort Worth District, Pecan Creek, Gainesville, Texas, Detailed Project Report, May 1987.

[13] U.S. Army Corps of Engineers, Hydrologic Engineering Center, "HEC-1 Flood Hydrograph Package," Users Manual, Davis, CA, Revised 1990.

at California Street for the 100-year flood event are expected to increase from 8,300 cfs to 10,200 cfs, a 23 percent increase. Table 3.2-1 provides a summary of existing and future peak runoff rates for selected storm events at key locations in the Pecan Creek watershed. Detailed results of the HEC-1 model are provided in Appendix C.

Table 3.2-1.
Pecan Creek Watershed
Summary of Peak Runoff Rates

Location	Drainage Area (sq. mi.)	Peak Runoff Rates (cfs)					
		10-year		25-year		100-year	
		Existing	Future	Existing	Future	Existing	Future
IH-35	3.0	1,720	1,930	2,140	2,390	2,820	3,100
Highway 82	12.4	4.630	4,680	5,930	5,930	8,220	8,090
Belcher Street	14.0	5,360	5,700	6,330	7,220	8,890	9,670
California Street	14.5	4,440	6,030	5,980	7,630	8,300	10,190
Anthony Street	15.0	4,340	6,280	5,870	7,970	7,960	10,500
Wheeler Creek (u/s)[1]	15.4	4,190	5,480	5,510	7,010	8,050	10,030
Wheeler Creek (d/s)[2]	33.5	7,970	9,640	10,530	12,450	15,460	17,660
Elm Fork (u/s)[3]	34.3	7,530	8,630	9,650	11,130	13,960	15,840

[1] Location is just upstream of Wheeler Creek confluence.
[2] Location is just downstream of Wheeler Creek confluence.
[3] Location is just upstream of Elm Fork confluence.

3.2.2 Stream Hydraulics

HEC-RAS[14] was used to develop a stream hydraulic model to simulate flow in Pecan Creek and selected tributaries, and through the many bridges and culverts that exist in the study area. The stream hydraulic model used the peak runoff rates from the hydrologic model and computed water surface profiles (flood levels) for each storm event for 18.7 miles of stream studied in the Pecan Creek watershed. Cross-sections of stream segments were obtained using the City's aerial topographic mapping[15] and supplemented with field measurements at structures.

The stream hydraulic model was developed for several segments of Pecan Creek that had not been mapped in detail in past studies. The existing FEMA flood plain mapping is limited to

[14] U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-RAS River Analysis System, User's Manual, 1995.
[15] City of Gainesville, Texas, Aerial Topographic Mapping, prepared by Dallas Aerial Mapping, Inc., January, 1997.

the segment between FM 2071 and Highway 82. The stream hydraulic model was extended as part of this study from just upstream of the confluence with the Elm Fork to 2.4 miles upstream of IH-35, as shown in Figure 3.2-4. In addition, three tributaries to Pecan Creek were also modeled: the north tributary; the east tributary; and the northeast tributary. The north tributary was modeled from its confluence with the main channel of Pecan Creek to 0.4 miles upstream of County Road (CR) 134. The east tributary was modeled from its confluence with the main channel of Pecan Creek to 1.5 miles upstream of CR 135, and the northeast tributary was modeled from its confluence with the north tributary to 0.75 miles upstream of CR 135.

The most damaging flooding along Pecan Creek has historically occurred in the central area of the City from FM 2071 to Highway 82. The hydraulic capacity of the channel for this segment was determined to be on the order of 2,000 cfs. Based on the channel capacity and the results of the hydrologic models, flooding would be expected to occur on average every 2 to 5 years. At California Street, for example, the peak runoff rate for the 2-year and 5-year storm events are 1,750 cfs and 3,280 cfs, respectively. Figure 3.2-5 provides a comparison of the Pecan Creek channel capacity in the City to the peak runoff rates for various return period storm events.

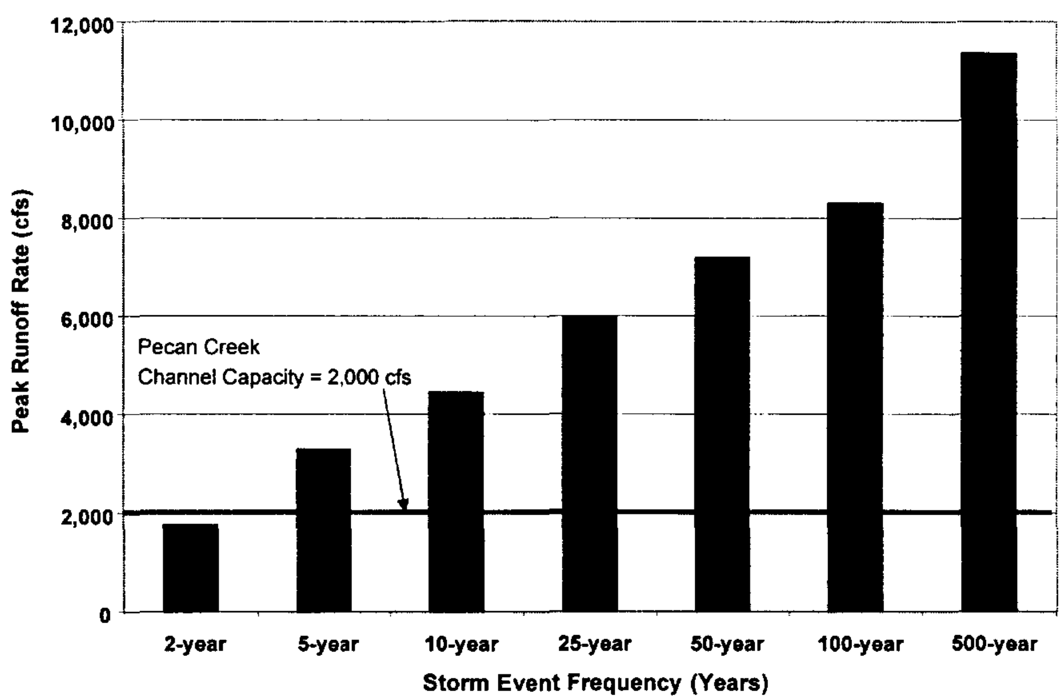


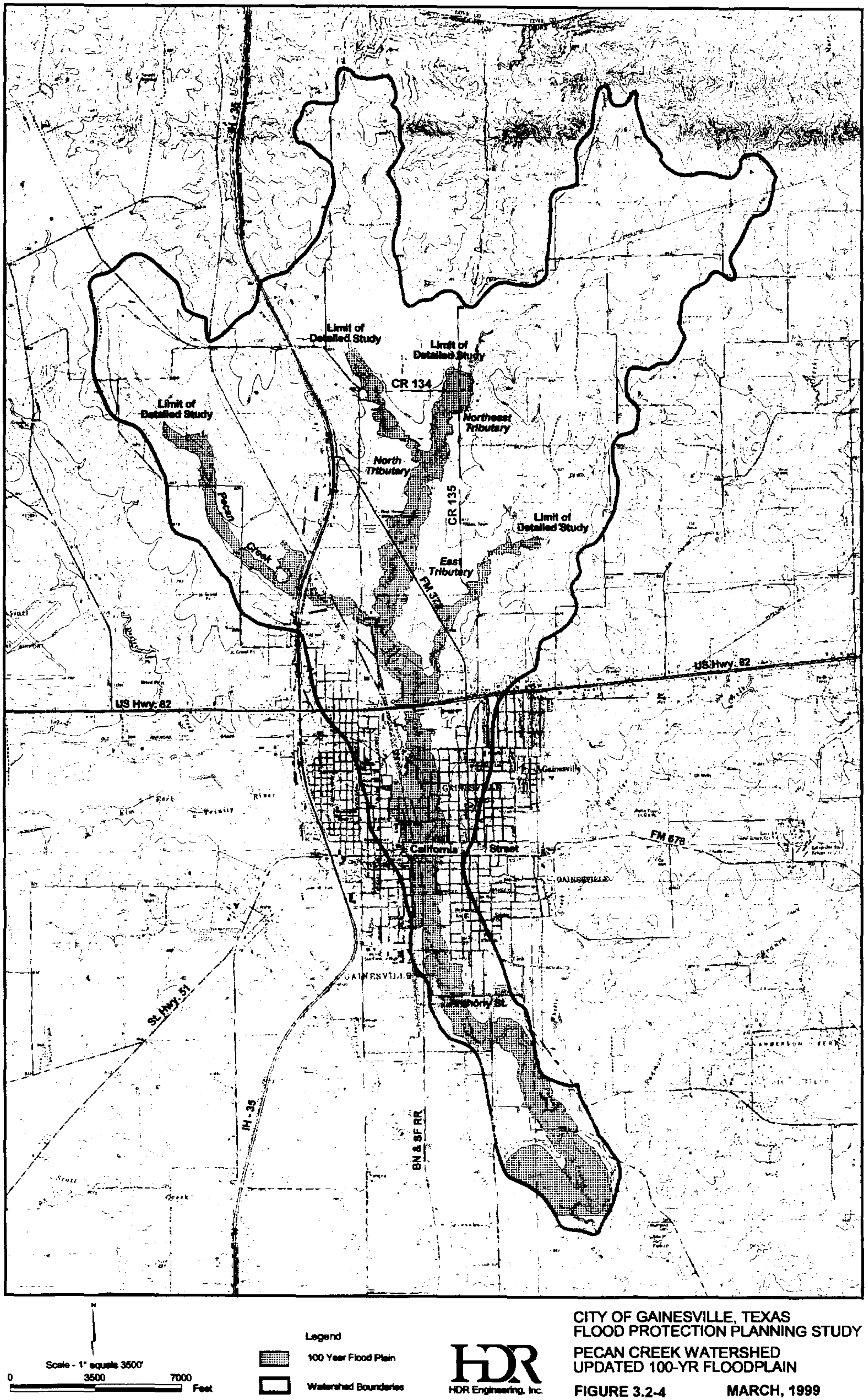
Figure 3.2-5. Comparison of Pecan Creek Channel Capacity and Peak Runoff Rates

A total of 20 road and railroad crossings were analyzed in the Pecan Creek watershed. Fifteen of these crossings in the Pecan Creek watershed do not meet the City's drainage criteria of passing the 25-year flood event without overtopping the roadway for existing and future conditions. A summary of the hydraulic capacity for each crossing is presented in Table 3.2-2.

Table 3.2-2.
Pecan Creek Watershed
Summary of Hydraulic Capacity of Stream Crossings

Location	Stream	Hydraulic Capacity Return Period Flood Event[1]	Notes[3]
CR 401 North	Pecan	< 2-year	7-ft CMP
CR 401 South	Pecan	2-year	18-ft x 7.5-ft RCB
IH-35	Pecan	500-year	5-barrel, 8-ft x 7-ft RCB
BN&SF Railroad	Pecan	500-year	111-ft bridge
Weaver Street[2]	Pecan	< 2-year	19-ft bridge
Highway 82	Pecan	25-year	150-ft bridge
Belcher Street[2]	Pecan	2-year	67-ft bridge
Scott Street[2]	Pecan	5-year	60-ft bridge
Broadway Street[2]	Pecan	5-year	68-ft bridge
California Street	Pecan	25-year	58-ft bridge
Main Street[2]	Pecan	10-year	90-ft bridge
Garnett Street[2]	Pecan	5-year	78-ft bridge
Moss Street[2]	Pecan	10-year	61-ft bridge
Anthony Street	Pecan	10-year	120-ft bridge
FM 2071	Pecan	2-year	88-ft bridge
CR 134	North Tributary	< 2-year	6-ft CMP
FM 372	North Tributary	>500-year	81-ft bridge
FM 135	Northeast Tributary	2-year	43-ft bridge
FM 135 (Clements)	East Tributary	2-year	2-barrel, 6-ft CMP
FM 372 (Old Hwy 77)	East Tributary	25-year	2-barrel, 8-ft x 8-ft RCB

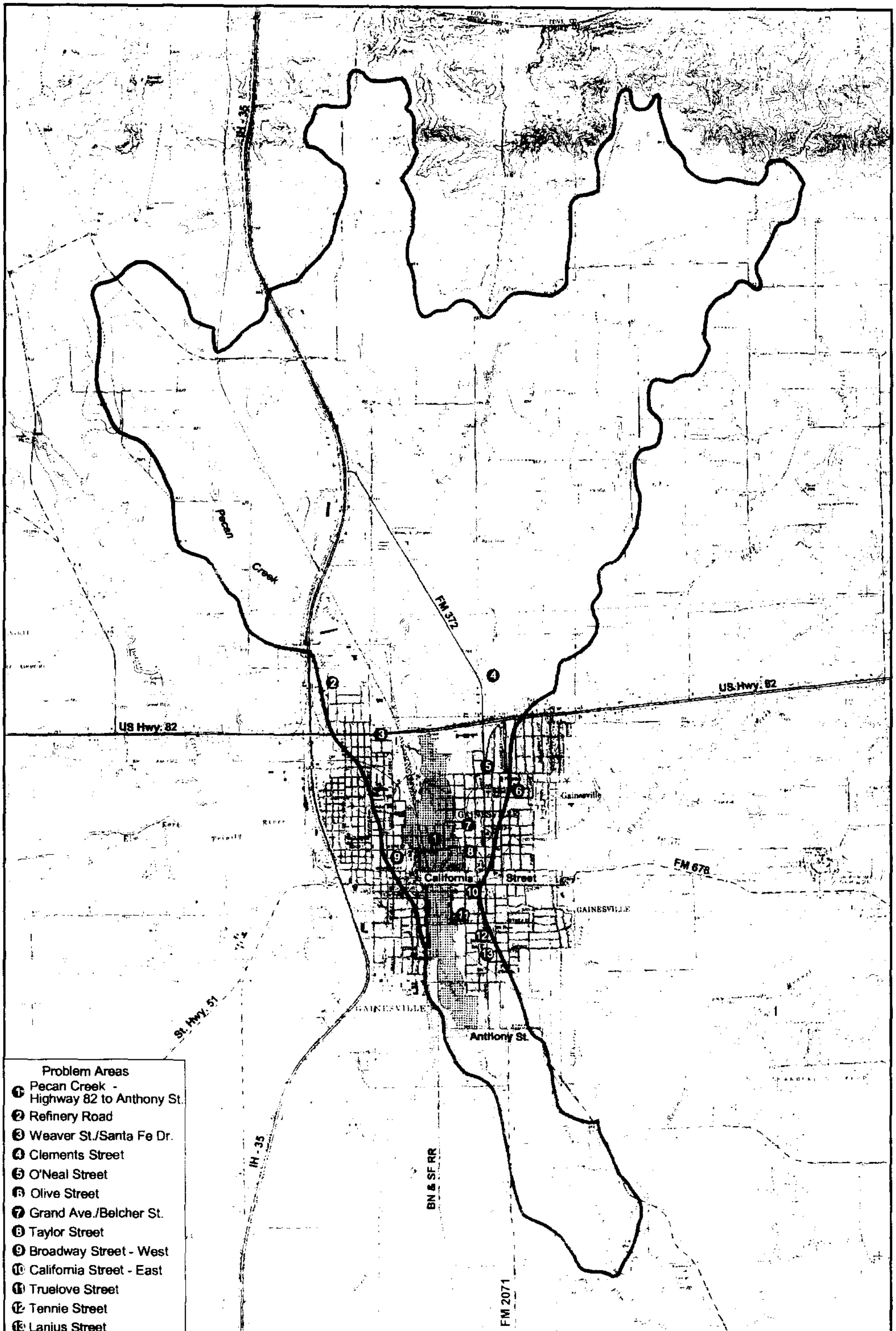
1 Hydraulic capacity at top of road or top of railroad embankment.
2 Maintained by City of Gainesville.
3 RCB – reinforced concrete box culvert, CMP – corrugated metal pipe.



CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

PECAN CREEK WATERSHED
UPDATED 100-YR FLOODPLAIN

FIGURE 3.2-4 MARCH, 1999



Scale - 1" equals 3500'
0 3500 7000 Feet

Legend
Watershed Boundaries
9 Problem Areas

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FLOOD PROTECTION PLANNING STUDY

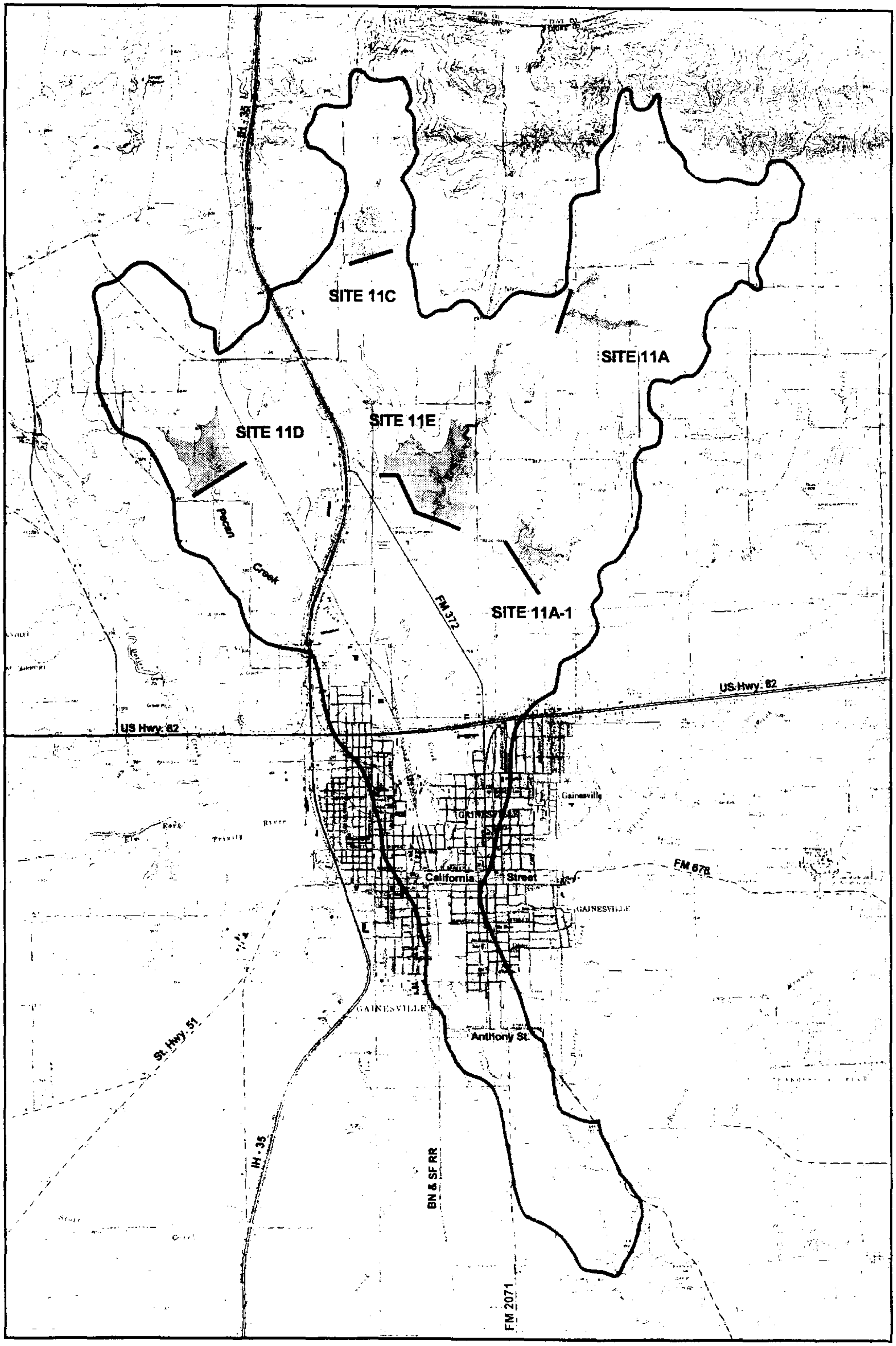
PECAN CREEK WATERSHED
PROBLEM AREA LOCATIONS

FIGURE 3.2-6 MARCH, 1999

Table 3.2-3.
Pecan Creek Watershed
Problem Area Summary

Problem Area	Watershed Category[1]	Description
Pecan Creek Hwy 82 to Anthony St.[2]	Major	Channel segment experiences frequent flooding of overbank areas. Residential and commercial structures inundated by less than a 10-year flood.
Belcher St. Bridge at Pecan Creek[2]	Major	Bridge and roadway overtopped for a 5-year return period flood event
Scott St. Bridge at Pecan Creek[2]	Major	Bridge and roadway overtopped for a 10-year return period flood event.
Broadway St. Bridge at Pecan Creek[2]	Major	Bridge and roadway overtopped for a 10-year return period flood event.
Main St. Bridge at Pecan Creek[2]	Major	Bridge and roadway overtopped for a 25-year return period flood event.
Garnett St. Bridge at Pecan Creek[2]	Major	Bridge and roadway overtopped for a 10-year return period flood event.
Moss St. Bridge at Pecan Creek[2]	Major	Bridge and roadway overtopped for a 25-year return period flood event.
Refinery Road	Minor	Street flooding along Refinery Road south of Old Sivells Bend Road. Runoff from Refinery Road area enters a residential area along Buck Street and Walter Road causing additional street flooding
Weaver Street Santa Fe Drive	Minor	Street flooding along Weaver Street extending from near Lynch Street to Santa Fe Drive. Street flooding and flooding of commercial structures along Santa Fe Drive and Dixon Street. Backwater from BN&SF Railroad culvert at Dixon Street.
Clements Street	Minor	Unpaved road (Eastridge Addition) overtops frequently due to poor drainage. Clements Street overtops frequently at a low are just north of Highway 82 and south of Meadowlark Lane.
O'Neal Street	Minor	Street flooding at the intersection of Grand Avenue and O'Neal Street and at other locations along O'Neal Street. Street flooding along Clements Street north of O'Neal Street.
Olive Street	Minor	Street flooding and flooding of residences along Howeth Strand Whaley Dr Street from runoff originating north of Highway 82. Street flooding at intersection of Whaley Dr. and O'Neal Street and along O'Neal St east of Hillcrest Blvd. Flooding of residences along Fair Ave and Elizabeth St. from runoff from west side of cemetery area.
Grand Ave/Belcher St,	Minor	Street flooding along Grand Avenue near Belcher Street
Taylor Street	Minor	Street flooding along Morris Street and Taylor Street.
Broadway Street West	Minor	Street flooding along Broadway Street and at intersection of Dixon Street and Scott Street. Flooding at BN&SF Railroad culvert between Main Street and Garnett Street.
California Street East	Minor	Street flooding on California Street from Grand Ave to Pecan Creek.
Truelove Street	Minor	Street flooding along Grand Ave from California St to Truelove St. and along Truelove St. from Grand Ave to Pecan Creek.
Tennie Street	Minor	Street flooding along Tennie Street at the Grand Ave intersection
Lanius Street	Minor	Street flooding along Lanius Street from Wine St. to Pecan Creek

Notes:
1. Major watershed problem areas include those areas impacted by flooding on the main channel and Minor watershed problem areas are impacted by flooding in areas contributing to the main channel.
2. Projects were analyzed as a single Major watershed problem area.



Scale - 1" equals 3500'
0 3500 7000 Feet

Legend
Dam Sites
Watershed Boundaries

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FLOOD PROTECTION PLANNING STUDY

PECAN CREEK WATERSHED
POTENTIAL FLOOD CONTROL DAM SITES

FIGURE 3.2-7 MARCH, 1999

The rainfall-runoff model (HEC-1) developed for the Pecan Creek watershed was used to evaluate each of the potential dams individually and collectively. The results of the HEC-1 model show that only Site 11E would provide significant flood reduction benefits to the City. The other sites provided some flood reduction benefits, but not to any degree that would warrant further economic analysis as was found in the previous NRCS study. Table 3.2-5 and Figure 3.2-8 summarize the resulting peak flows with implementation of individual dam sites and various combinations of dam sites. The peak flow rates are summarized in Table 3.2-5 for various points of interest in the City, including IH-35, Highway 82, and California Street. Figure 3.2-7 provides a graphical summary of the 100-year peak flow rates at California Street in the central portion of the City with and without the flood control dams.

Table 3.2-5. Summary of Peak Flow Reduction for Flood Control Dams in the Pecan Creek Watershed

Alternative	Watershed Area Controlled (sq. mi.)	Peak Flow (cfs)					
		IH-35		Highway 82		California Street	
		10-yr Flood	100-yr Flood	10-yr Flood	100-yr Flood	10-yr Flood	100-yr Flood
Existing Conditions[1]	**0.0**	**1,670**	**2,790**	**4,630**	**8,220**	**4,430**	**8,280**
Dam 11A (only)	2.2	1,670	2,790	4,530	7,770	4,230	7,840
Dam 11C (only)	0.9	1,670	2,790	4,670	8,130	4,500	8,200
Dam 11D (only)	1.5	1,630	2,590	4,620	7,930	4,340	7,950
Dam 11E (only)	5.8	1,670	2,790	3,450	5,900	3,430	6,200
Dams 11A, 11C	3.1	1,630	2,590	4,480	7,520	4,150	7,590
Dams 11A, 11C, 11D	4.6	1,630	2,590	4,480	7,520	4,150	7,590
Dams 11D, 11E	7.3	1,630	2,590	3,410	5,760	3,400	6,020

[1] Existing conditions without implementation of any flood control dams.

Figure 3.2-9 shows a detailed plan view of the Site 11E project using the City's aerial topographic mapping. The proposed dam for Site 11E is approximately 4,300 feet long and has a maximum height of 32 feet. The dam controls approximately 5.8 sq. mi. of the Pecan Creek watershed and is proposed to have a flood storage volume of 1,630 acre-feet or 5.3 inches of runoff. The dam will reduce the 100-year flood peak flow at the site from 5,650 cfs to 80 cfs. The total cost of the structure is estimated to be $1,870,000, including engineering and

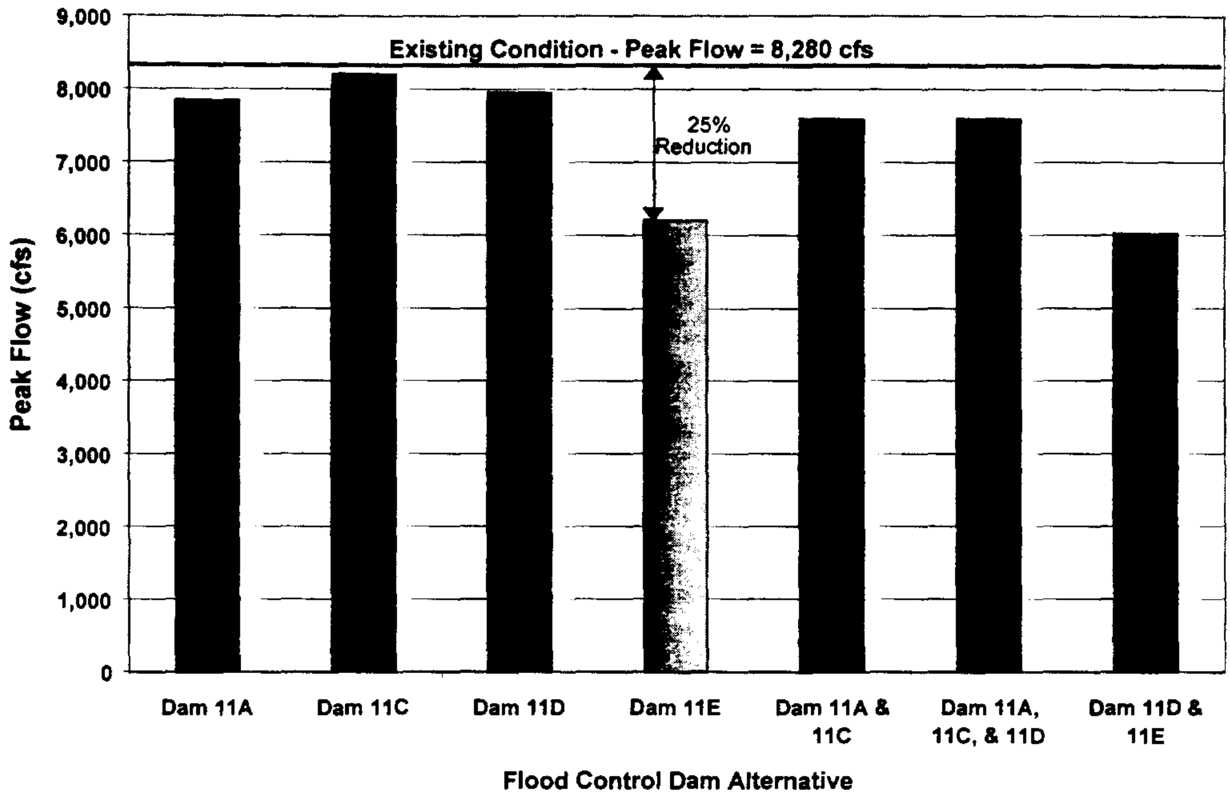
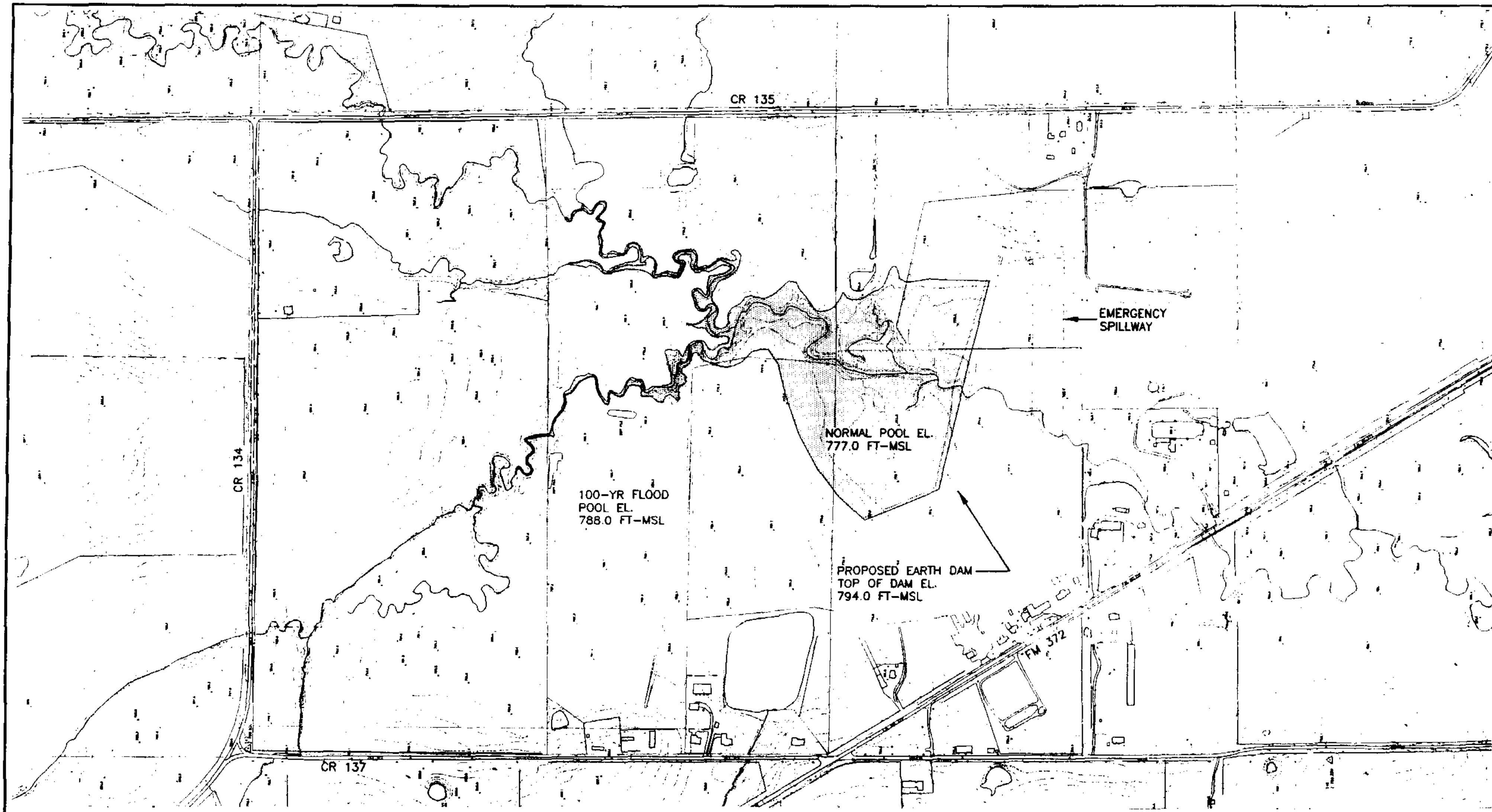


Figure 3.2-8
100-Year Peak Flow Reduction at California Street for Potential Flood Control

contingencies, as shown in Table 3.2-6. The total area of land required for implementation of Site 11E is approximately 250 acres. Research at the Cooke County Appraisal District (CCAD) showed that this area is owned by 11 individual landowners and appraised values of the impacted property range from $1,000 to $1,300 per acre. The total cost for land acquisition is estimated to be $406,000, as shown in Table 3.2-7, which assumes that the land will be acquired at the CCAD appraised values plus 25 percent for administration, legal, and surveying costs. The total project cost for implementation of Site 11E is estimated to be $2,276,000.

The benefits of implementation of Site 11E would be a 25 percent reduction in the 100-year flood peak flow rate in the City. However, the channel capacity of Pecan Creek would still be exceeded by flood events greater in magnitude than the 5-year flood event. In order to significantly reduce the 100-year flood plain area and flood damages in the City, channel improvements on Pecan Creek in the City would still be required.



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PECAN CREEK WATERSHED
POTENTIAL FLOOD CONTROL DAM
SITE 11 E

FIGURE 3.2-9 MARCH, 1999

Table 3.2-6.
Pecan Creek Flood Control Dam - Site 11E
Construction Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Earth Embankment - Zone 1	cubic yard	53,302	$3.00	$159,905
Earth Embankment - Zone 2	cubic yard	158,955	$2.00	$317,911
Earth Embankment - Zone 4	cubic yard	17,006	$20.00	$340,117
Excavation	cubic yard	18,603	$3.00	$55,809
Stripping	cubic yard	21,345	$1.00	$21,345
Riprap	cubic yard	6,088	$25.00	$152,208
Outlet Pipe - 24 inch RCCP	linear feet	239	$125.00	$29,875
Intake Tower - Structural Concrete	cubic yard	73	$400	$29,232
Outlet Stabilization - Concrete	cubic yard	200	$300	$60,000
Emergency Spillway	each	1	$80,000	$80,000
Subtotal				$1,246,402
Contingencies & Miscellaneous			20%	$249,280
Construction Cost				$1,495,682
Engineering, Surveying, Legal			25%	$373,920
Total Project Cost[1]				$1,869,602

Notes:
1. Land acquisition costs not included.

Table 3.2-7.
Pecan Creek Flood Control Dam - Site 11E
Land Acquisition Cost Estimate

Item	Total Cost
Total Land Value - 246 acres from Cooke Co. Appraisal District	$304,081
Total Value of Improvements - from Cooke Co. Appraisal District	$20,416
Subtotal	$324,497
Administration, Damages, Relocation Assistance (25%)	$81,124
Total Cost	$405,621

3.2.3.2 Pecan Creek Channel Improvements

In a study performed in 1987, the U.S. Army Corps of Engineers (USCOE)[17] investigated the Pecan Creek segment in the City extending from Highway 82 to FM 2071. This study evaluated structural and non-structural alternatives for mitigating flood damages along this segment of Pecan Creek, including permanent evacuation (buyout) of damageable properties in the flood plain, flood-proofing, channel improvements, levees, and detention reservoirs. The USCOE study included a hydrologic and hydraulic analysis of the Pecan Creek watershed and an economic study of the area impacted. The study showed that flood events of various magnitudes would cause extensive damage across the City. Estimates of single occurrence flood losses for flood events ranging from the 5-year to 100-year event were presented in the study and are summarized in Table 3.2-8. As shown in this table, the estimate of flood damage that would result from a 100-year flood event was approximately $11,214,000.

Table 3.2-8.
Summary of Single Occurrence Flood Losses for Pecan Creek[1]
1987 USCOE Study

Flood Event	Flood Losses (1987 Dollars)
5-year	$913,500
10-year	$4,530,200
25-year	$5,623,600
50-year	$8,864,200
100-year	$11,214,300

[1] Flood losses computed for Pecan Creek segment extending from Highway 82 to FM 2071 in the City

From the estimates of single occurrence flood losses for the Pecan Creek segment, the USCOE was able to compute the average annual damages. Average annual flood damages for the Pecan Creek segment in 1987 were estimated to be approximately $1,126,500. A substantial portion of the damages were estimated to occur at or below a 10-year flood event, as shown in Table 3.2-9.

[17] U.S. Army Corps of Engineers, Fort Worth District, Pecan Creek, Gainesville, Texas, Detailed Project Report, May 1987.

Table 3.2-9.
Annual Average Flood Damages for Pecan Creek[1]
1987 USCOE Study

Flood Zone	*Average Annual Damages (1987 Dollars)*
Channel Bank to 10-year	$921,000
10-year to 25-year	$69,300
25-year to 50-year	$16,800
50-year to 100-year	$95,800
100-year to Standard Project Flood	$23,600
Total	$1,126,300

[1] Average annual damages computed for Pecan Creek segment extending from Highway 82 to FM 2071 in the City

Each potential flood control alternative was evaluated in terms of the annual costs and benefit-to-cost ratio. For example, permanent evacuation of all developed properties in the flood plain (bank to 10-year) was estimated to cost $27,810,000. The annual costs of this plan including debt service were computed based on a federal discount rate of 8.875% over a 50-year period. The annual costs for the proposed plan were estimated to be $2,504,000 and the average annual benefits were estimated to be $921,000 based on flood loss reduction. The benefit to cost ratio for permanent evacuation was computed to be 0.36 to 1 and, therefore, was not economically feasible. In addition to the permanent evacuation alternative, the USCOE also removed levees, detention reservoirs, and flood proofing from further consideration based on their assessment that these solutions were not feasible for implementation.

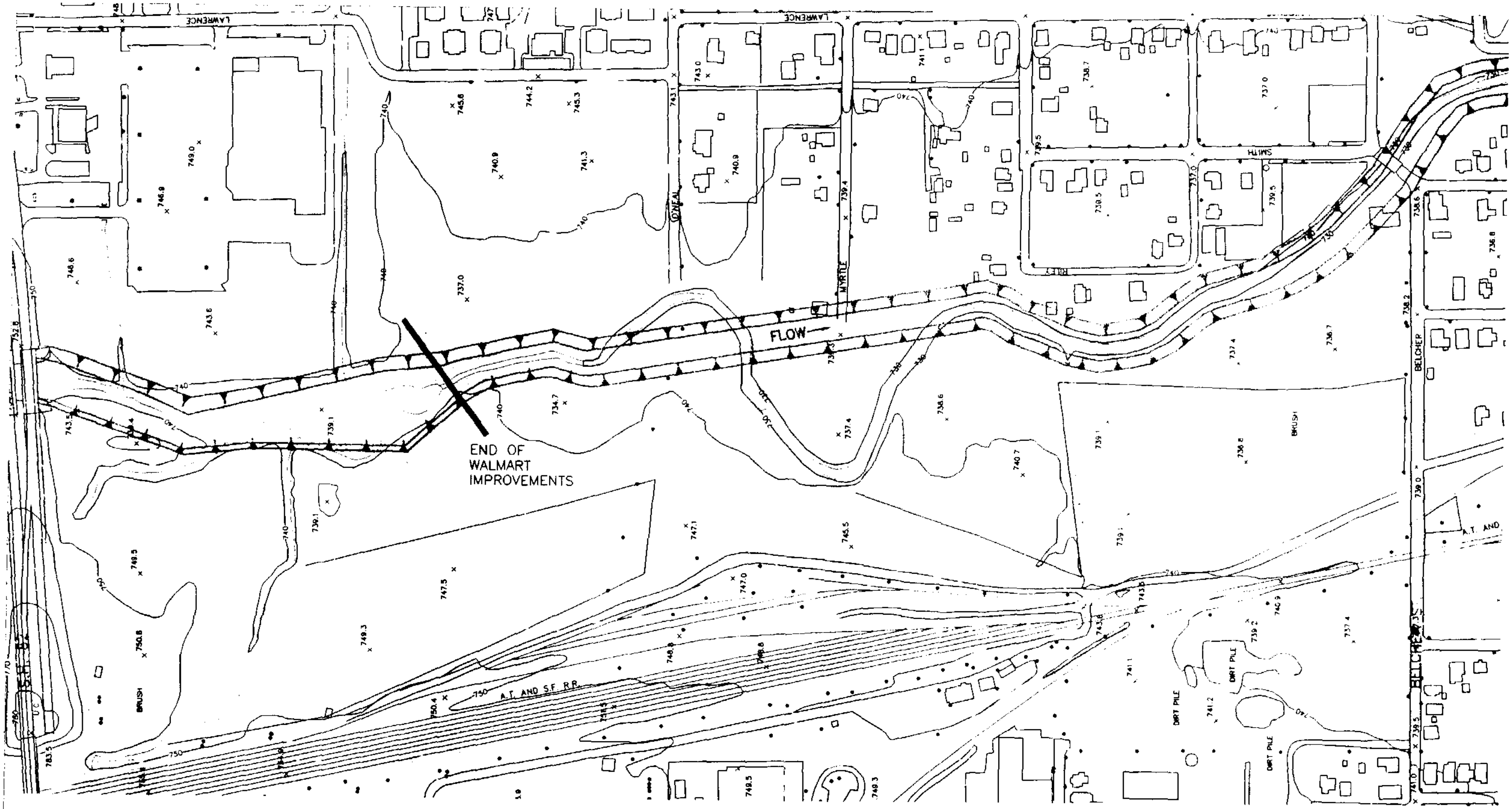
Channel improvements to Pecan Creek were identified by the USCOE as the most feasible solution to reducing flood damages in the City. The recommendation of the study was to widen the existing channel from Highway 82 to Anthony Street to a 65-foot bottom width, grass-lined, trapezoidal channel with 3:1 (horizontal:vertical) side slopes. Assuming an average depth of 12 feet, the total top width of the proposed project would be on the order of about 140 feet. All of the bridges in the channel segment upstream of Anthony Street were proposed for replacement, including Belcher, Scott, Broadway, California, Main, Garnett, and Moss Streets. The total project cost estimate for the Pecan Creek Project presented in the 1987 study was $7,418,000, which included land acquisition, bridge replacements, utility relocations, channel improvements, and engineering and administration. The annual costs associated with the project, including operation and maintenance were estimated to be $688,000 compared to annual flood reduction benefits of $1,139,000. The benefit-to-cost ratio of the project was estimated to be 1.6 to 1.

The Pecan Creek channel improvement project was reevaluated in this study and the results were similar to the 1987 USCOE study with minor revisions. Revisions to the 1987 USCOE study include building upon the Pecan Creek channel improvements that were constructed by the City in 1993, taking advantage of the existing concrete lining that presently exists, and revising the upper project limits to transition from the Wal-Mart channel improvements to the proposed project.

The HEC-RAS stream hydraulic model developed as part of this study was used to evaluate various options for channel improvements along Pecan Creek. Channel improvement options were evaluated and a recommended plan for improvements for various segments was developed. The objectives of the recommended plan for improvements included:

1. Significantly reduce flood damages along Pecan Creek;
2. Minimize the capital cost and long-term maintenance cost of the proposed improvements;
3. Minimize the amount of private property required for project implementation; and
4. Include recreational amenities and benefits in combination with flood control benefits.

A plan view of the proposed channel improvements is included in Figures 3.2-10 through 3.2-12, and representative cross sections of Pecan Creek for existing and proposed conditions at selected locations are presented in Figure 3.2-13. Implementation of the project will require acquisition of some existing residences, commercial businesses, and storage buildings, along with vacant property along the creek. Land acquisition costs were based upon data obtained from the CCAD and communication with local real estate professionals. The total quantity of excavation for the channel improvements is estimated to be on the order of 380,000 cubic yards. As presented in Table 3.2-10, the total cost for the proposed project is estimated to be $8,633,000, which is about 16 percent more than the original 1987 project cost estimate. The small increase in cost since 1987 is less than might be expected due, in part, to lower land acquisition costs than were projected in the 1987 study and accounting for channel improvements that have been implemented by the City in the interim period since 1987. Overall, the project would be expected to have a positive benefit to cost ratio, potentially even higher than the 1.6 to 1.0 ratio



PROPOSED
CHANNEL
IMPROVEMENTS

Z

0 FEET 250

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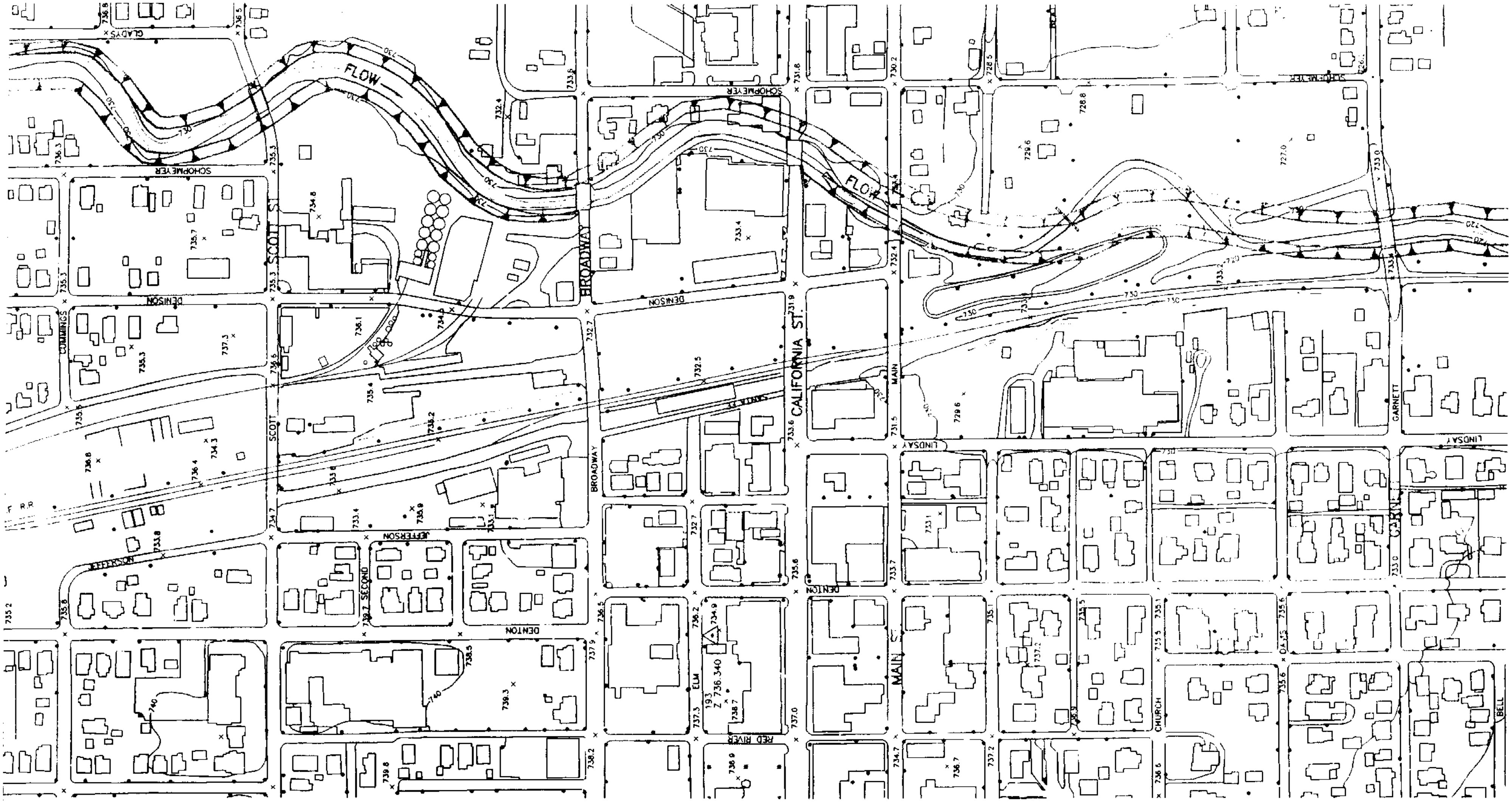
FLOOD PROTECTION PLANNING STUDY

PECAN CREEK
CHANNEL IMPROVEMENTS - 1 OF 3

FIGURE 3.2-10 **MARCH, 1999**



PROPOSED CHANNEL IMPROVEMENTS

Z

0 FEET 250

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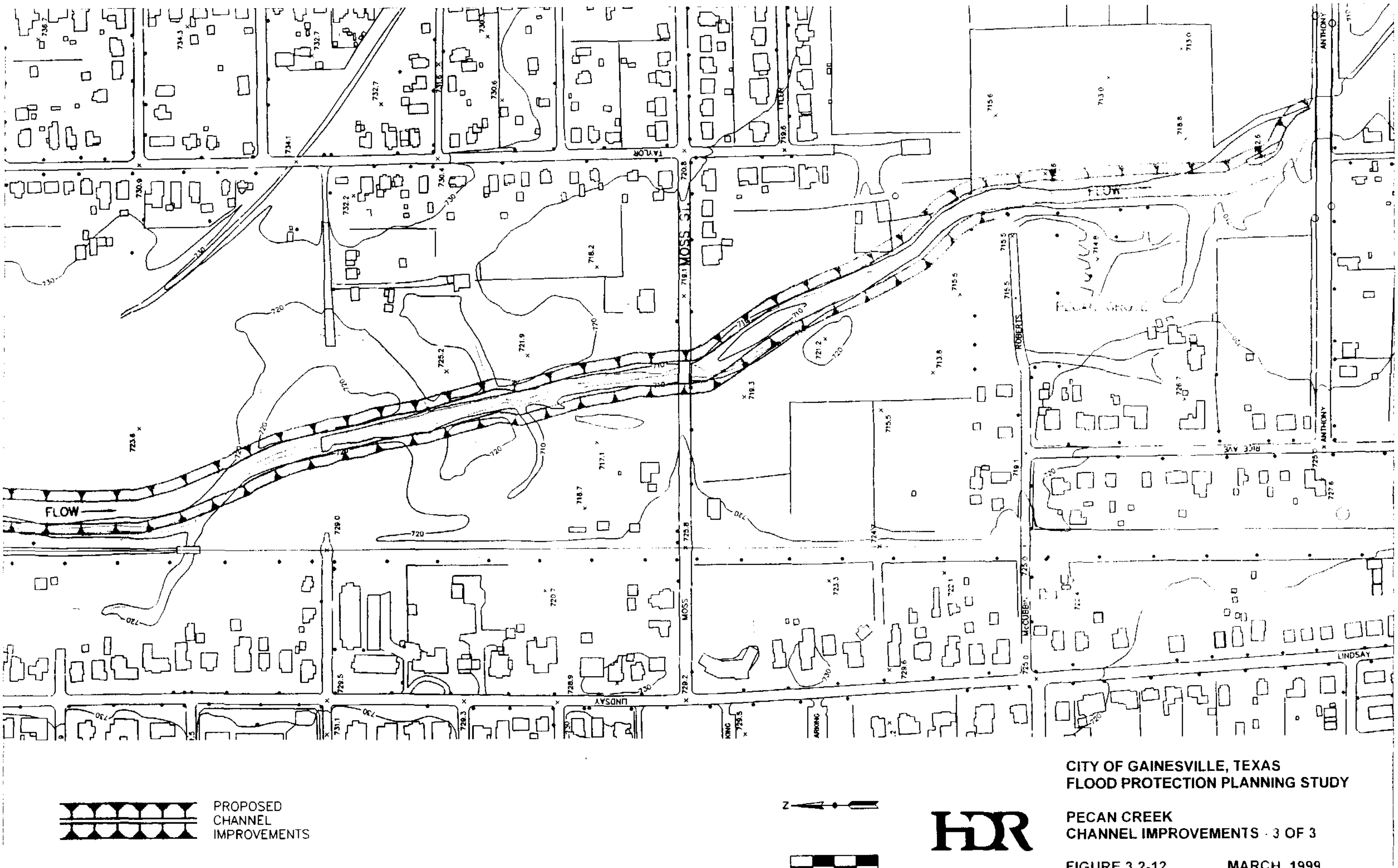
PECAN CREEK
CHANNEL IMPROVEMENTS - 2 OF 3

FIGURE 3.2-11 **MARCH, 1999**



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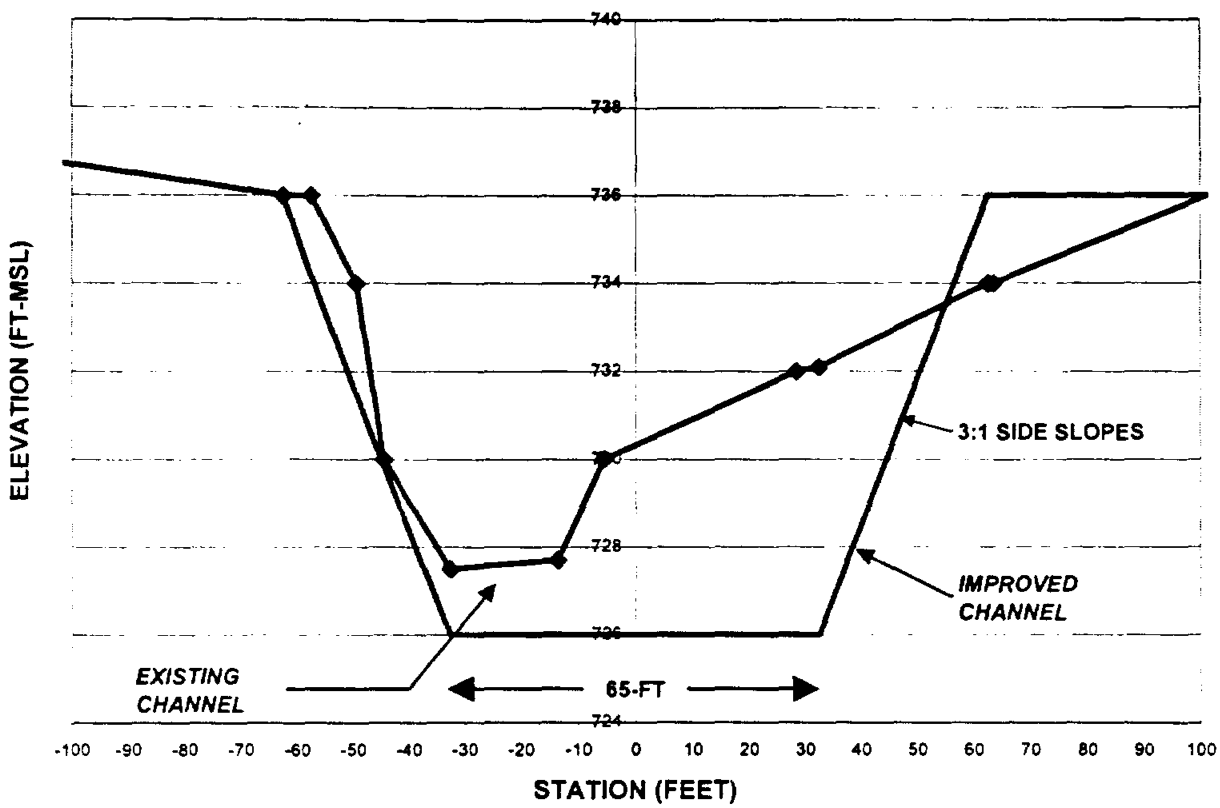
PECAN CREEK
CHANNEL IMPROVEMENTS - 3 OF 3

FIGURE 3.2-12 MARCH, 1999



IMPROVED CHANNEL
BETWEEN BELCHER STREET AND SCOTT STREET

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PECAN CREEK
IMPROVED CHANNEL SECTION

FIGURE 3.2-13 MARCH, 1999

calculated in the 1987 study. This assessment is based on the assumption that overall property values have likely appreciated since 1987 and a federal discount rate that is significantly lower today (6.875 percent) than it was in 1987 (8.875 percent). The lower discount rate will produce annual debt service costs about 22 percent less than the 1987 discount rate. Annual costs for the Pecan Creek Project were calculated to be $647,000, based on the current federal discount rate, revised project cost estimate, and annual operation and maintenance costs ($30,000 per year). Assuming average annual flood loss reduction benefits would remain at the 1987 level of $1,139,000, the benefit-to-cost ratio of the updated project would be about 1.8 to 1.

Implementation of a flood control dam (Site 11E) on Pecan Creek would reduce peak flow rates in the City and would therefore require less extensive channel improvements. An analysis of the channel improvements that would be required, in combination with the flood control dam to achieve a similar level of flood protection as the 65-ft bottom width channel, was performed. Based on estimates of peak flow reduction of about 25 percent as a result of implementation of the flood control dam, the size of the proposed channel improvements would be reduced to a bottom width of 45-ft to accomplish the same objectives. The project cost for implementation of a 45-ft bottom width channel was estimated to be $7,536,000 as shown in Table 3.2-11. The total project cost of the flood control dam alternative, including implementation of the Site 11E flood control dam ($2,276,000) and the 45-ft bottom width channel improvements ($7,536,000) is estimated to be $9,812,000. Annual costs for this alternative for debt service (6.875% for 50 years) and operation and maintenance were calculated to be $736,000. Assuming average annual flood loss reduction benefits of $1,139,000, the benefit-to-cost ratio of this alternative would be 1.5 to 1. A comparison of the benefits and costs for the 65-ft bottom width channel improvement alternative and the flood control dam with 45-ft bottom width channel improvements is presented in Figure 3.2-14.

Table 3.2-10.
Pecan Creek Channel Improvement Project
65-ft Bottom Width Channel
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Amount
LANDS & DAMAGES				
Project Lands	acre	54	$2,000	$108,000
Improvements	lump sum	1	$570,000	$570,000
Damages	lump sum	1	$80,000	$80,000
Relocation Assistance	lump sum	1	$100,000	$100,000
Mitigation Land	acre	70	$2,500	$175,000
Administration	lump sum	1	$100,000	$100,000
TOTAL – Lands & Damages				$1,133,000
RELOCATIONS				
Bridges				
-Belcher Street	square feet	4,500	$40	$180,000
-Scott Street	square feet	4,500	$40	$180,000
-Broadway Street	square feet	4,500	$40	$180,000
-California Street	square feet	7,500	$40	$300,000
-Main Street	square feet	5,100	$40	$204,000
-Garnett Street	square feet	4,500	$40	$180,000
-Moss Street	square feet	4,500	$40	$180,000
Removal of Existing Bridges	square feet	35,100	$5	$175,500
Utilities				
-Water	linear feet	720	$20	$14,400
-Sewer	linear feet	1,490	$31	$46,190
-Gas	linear feet	905	$12	$10,860
-Electric & Telephone	lump sum	1	$35,000	$35,000
Subtotal – Bridges & Utilities				$1,685,950
Contingencies (20%)				$337,190
TOTAL – Relocations				$2,023,140
CHANNEL CONSTRUCTION				
Excavation				
-Overburden	cubic yard	250,000	$5	$1,250,000
-Rippable Rock	cubic yard	130,000	$8	$1,040,000
Compacted Fill	cubic yard	20,000	$3	$60,000
Clearing & Grubbing	acre	54	$2,000	$108,000
Seeding, Vegetation & Blanket	acre	54	$4,000	$216,000
Care of Water	lump sum	1	$100,000	$100,000
Concrete Riprap	square feet	100,000	$3	$300,000
Bedding	cubic yard	2,000	$40	$80,000
Top Soil	cubic yard	20,000	$8	$160,000
Chutes	lump sum	1	$150,000	$150,000
Subtotal – Channel Construction				$3,464,000
Contingencies (20%)				$692,800
TOTAL – Channel Construction				$4,156,800
ENGINEERING & DESIGN				$820,000
SUPERVISION & ADMIN.				$500,000
TOTAL PROJECT COST				**$8,632,940**

Table 3.2-11.
Pecan Creek Channel Improvement Project
45-ft Bottom Width Channel
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Amount
LANDS & DAMAGES				
Project Lands	acre	48	$2,000	$96,000
Improvements	lump sum	1	$570,000	$570,000
Damages	lump sum	1	$80,000	$80,000
Relocation Assistance	lump sum	1	$100,000	$100,000
Mitigation Land	acre	64	$2,500	$160,000
Administration	lump sum	1	$100,000	$100,000
TOTAL – Lands & Damages				$1,106,000
RELOCATIONS				
Bridges				
-Belcher Street	square feet	3,900	$40	$156,000
-Scott Street	square feet	3,900	$40	$156,000
-Broadway Street	square feet	3,900	$40	$156,000
-California Street	square feet	6,500	$40	$260,000
-Main Street	square feet	4,420	$40	$176,800
-Garnett Street	square feet	3,900	$40	$156,000
-Moss Street	square feet	3,900	$40	$156,000
Removal of Existing Bridges	square feet	30,420	$5	$152,100
Utilities				
-Water	linear feet	720	$20	$14,400
-Sewer	linear feet	1,490	$31	$46,200
-Gas	linear feet	900	$12	$10,800
-Electric & Telephone	lump sum	1	$35,000	$35,000
Subtotal – Bridges & Utilities				$1,475,350
Contingencies (20%)				$295,070
TOTAL – Relocations				$1,770,420
CHANNEL CONSTRUCTION				
Excavation				
-Overburden	cubic yard	185,000	$5	$925,000
-Rippable Rock	cubic yard	90,000	$8	$720,000
Compacted Fill	cubic yard	20,000	$3	$60,000
Clearing & Grubbing	acre	48	$2,000	$96,000
Seeding, Vegetation & Blanket	acre	48	$4,000	$192,000
Care of Water	lump sum	1	$100,000	$100,000
Concrete Riprap	square feet	100,000	$3	$300,000
Bedding	cubic yard	2,000	$40	$80,000
Top Soil	cubic yard	20,000	$8	$160,000
Chutes	lump sum	1	$150,000	$150,000
Subtotal – Channel Construction				$2,783,000
Contingencies (20%)				$556,600
TOTAL – Channel Construction				$3,339,600
ENGINEERING & DESIGN				$820,000
SUPERVISION & ADMIN.				$500,000
TOTAL PROJECT COST				**$7,536,020**

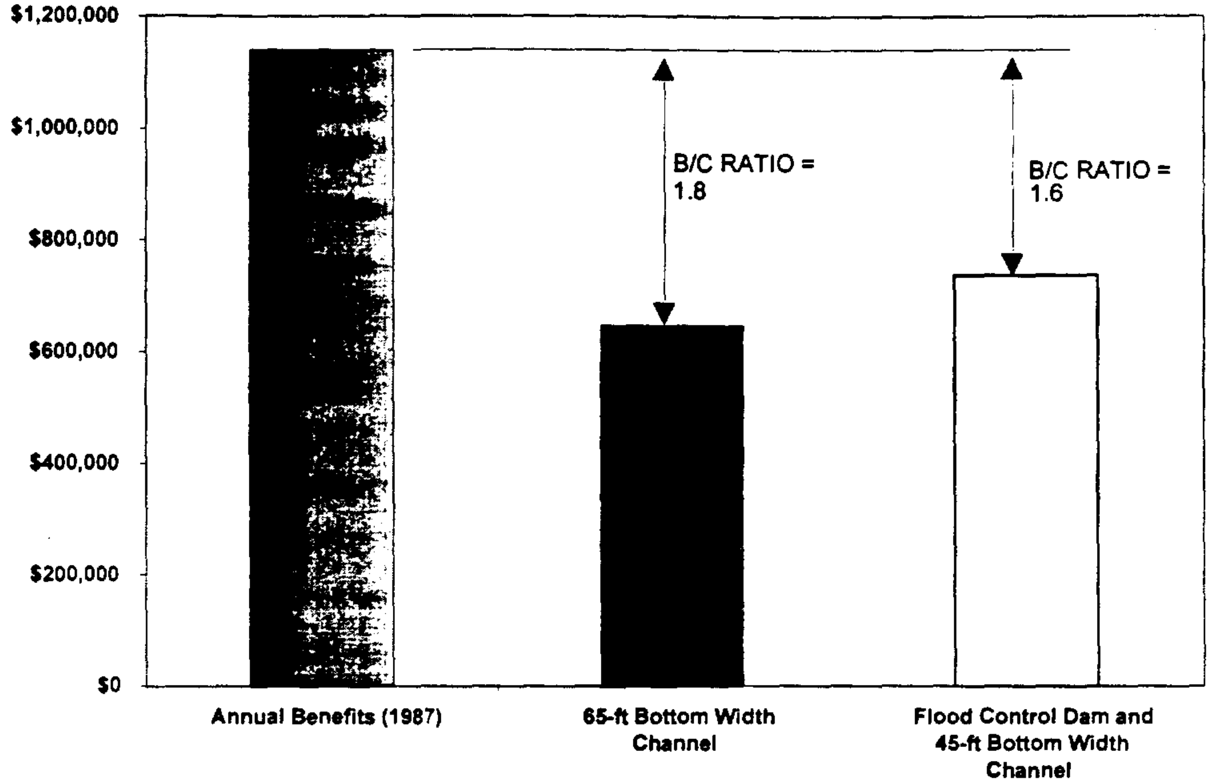


Figure 3.2-14. Comparison of Annual Benefits and Annual Costs for Pecan Creek Improvement Alternatives

Based on the estimated costs of implementation of the flood control dam in combination with channel improvements as compared to the estimated costs for implementation of a larger channel improvement project, the 65-ft bottom width channel option is the recommended plan for Pecan Creek. No other improvements are recommended along the main stem of Pecan Creek upstream of Highway 82 or downstream of Anthony Street. Existing flood damage potential does not warrant structural solutions and non-structural solutions are most economical for those areas outside of the project limits. Non-structural solutions for areas outside of the project limits include enforcement of existing flood plain development ordinances and the City's Drainage Criteria and Design Manual. The Pecan Creek Improvement Project may be eligible for partial federal funding through the USCOE. Funding options for implementation of the project are presented in Section 5.

Minor Watersheds

Minor watersheds in the Pecan Creek watershed in the City were analyzed for the interior drainage facilities needed to convey runoff to the main channel of Pecan Creek. A number of problem areas were identified in the study area through the public survey and engineering analyses of runoff rates and street flow capacity. A total of 12 problem areas associated with minor watersheds in Pecan Creek were identified, as previously shown in Table 3.2-3 and Figure 3.2-5.

The problem areas associated with minor watersheds are primarily associated with street flooding. In most areas, the recommended plan will be construction of underground storm sewer systems to remove surface runoff from the streets and convey it to Pecan Creek. Storm sewer systems are usually the only option due to dense urban development and limited right-of-way available for construction of more economical alternatives such as open channels. Storm sewer systems are expensive to implement, especially in a scenario involving retrofitting to an already developed area. The cost of the system is increased due to the cost of restoring the street after construction and coordination with other existing utilities. Benefits of the proposed improvements will be far reaching including:

- Reduction in flood damages to existing residences and businesses;
- Reduction in risk to public health and safety; and
- Increased life of street pavements as a direct result of improved drainage.
-

Many of these recommended plans are predicated on improvements to Pecan Creek to lower flood levels at the outlet of the proposed systems. Without improvements to Pecan Creek, the effectiveness of the proposed systems will be limited due to backwater from the creek during significant storm events.

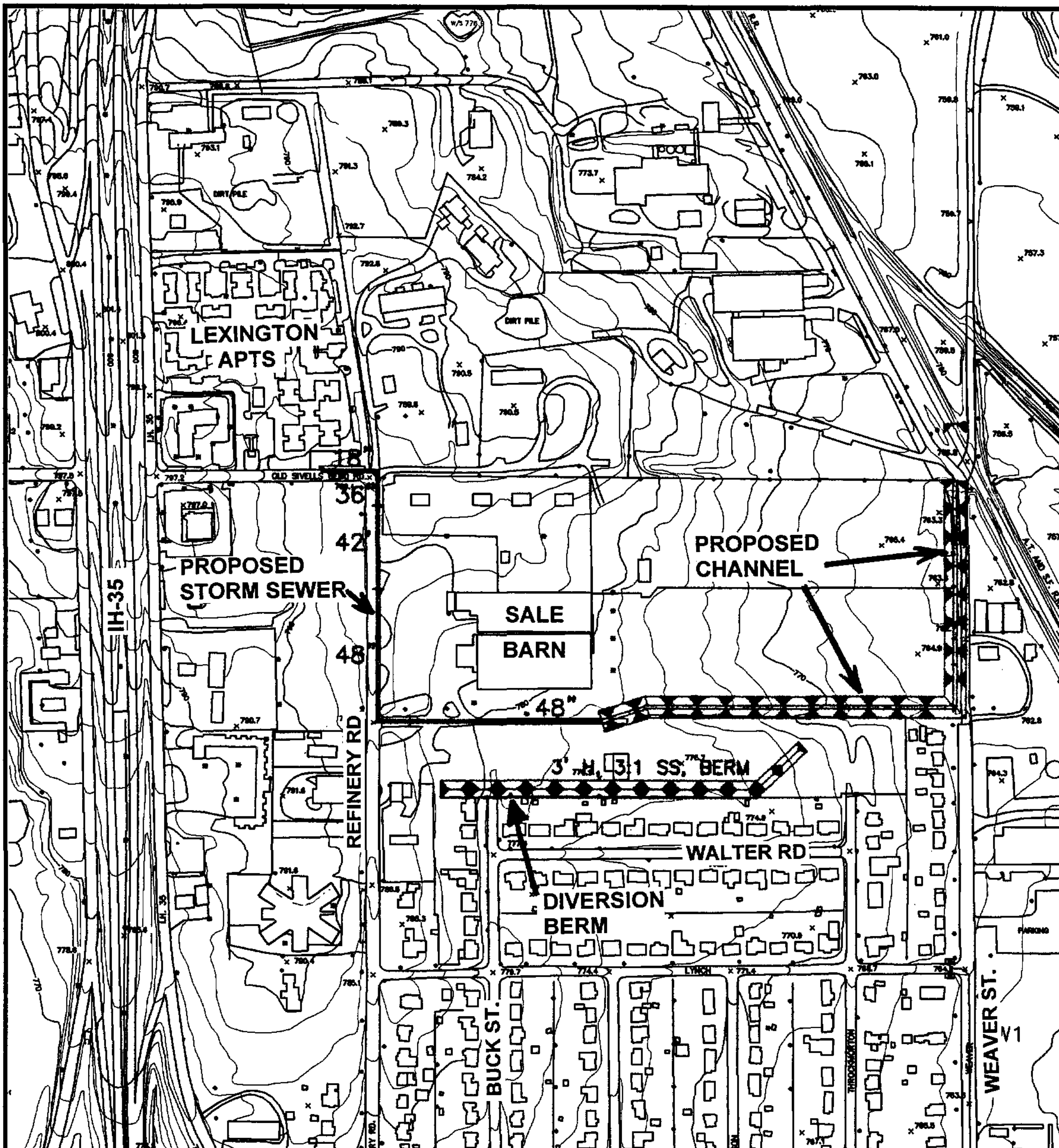
3.2.3.3 Refinery Road Problem Area

The Refinery Road Problem Area is located in the northwest part of the City, north of Highway 82 and west of the BN&SF Railroad (Figure 3.2-6). The primary drainage problem at the this location is excess street flow along Refinery Road that collects in a low area at Ward Street. Runoff to this area originates from the west between IH-35 and Refinery Road and from just north of Old Sivells Bend Road (Lexington Apartments). Runoff from these areas produces street flooding along the east end of Old Sivells Bend Road and along Refinery Road, especially at a low area (Ward Street) located about 650 feet south of Old Sivells Bend Road. Runoff collects at this low area and travels east across an open field through an existing swale that conveys it to the northern end of Buck Street. A portion of the runoff that enters Buck Street turns and travels east along Walter Road to Throckmorton Street, eventually flowing to Weaver Street and continuing downstream to Sante Fe Street, Dixon Street, BN&SF Railroad, and into Pecan Creek. Street flooding occurs along Buck Street and the Walter Road area as a result of runoff from the upstream area. In addition to excessive runoff entering Buck Street and the Walter Road area, the water quality is poor. The poor water quality is due to a large portion of the runoff that flows across property used as a livestock auction facility and picks up various contaminants.

Street Flooding along Buck Street and Walter Road

The recommended plan for mitigating this drainage problem is construction of a storm sewer and channel system, as shown in Figure 3.2-15, beginning near Old Sivells Bend Road and extending south along Refinery Road to the existing low area. Storm sewer pipe sizes for this system range from 18-inches in diameter at the upstream end to 48-inches in diameter at the downstream (south) end. The proposed system discharges into a proposed channel along the alignment of an existing drainage swale and conveys the runoff to Weaver Road. The proposed channel was sized as a 4-ft bottom width, 3:1 side

Low Area at Refinery Road and Ward Street



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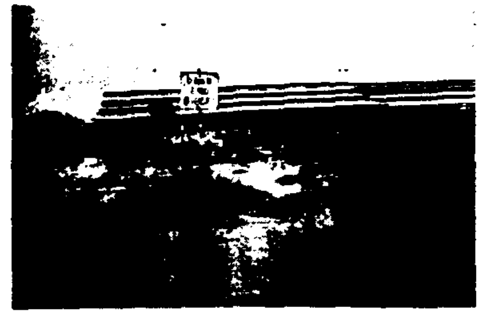
REFINERY ROAD
DRAINAGE IMPROVEMENTS

FIGURE 3.2-15 MARCH, 1999

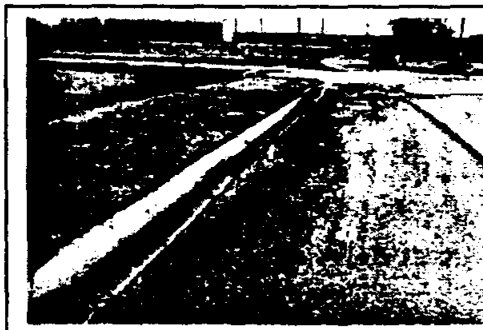
slope, grass-lined, trapezoidal channel with a minimum depth of three feet. At Weaver Street, the existing 24-inch diameter culverts are proposed to be replaced with larger pipes to pass the flow under the roadway. The runoff will then flow under the BN&SF Railroad immediately downstream of Refinery Road through an existing 48-inch steel pipe. In addition to these improvements, a small diversion berm is proposed to be placed along the north boundary of a residential area to prevent runoff from the livestock auction area from entering the residential area. Overall, the proposed plan will provide the following benefits:



Runoff entering Buck Street from Sale Barn area.

- Divert runoff originating upstream of the livestock auction area which reduces the volume of water crossing the livestock area which, in turn, lessens the quantity of poor quality runoff leaving the site;
- Reduce the quantity of street flow on Refinery Road which will reduce pavement damage and extend the life of the street; and
- Reduce the quantity of street flow on streets located downstream of this area including Buck Street, Walter Road, Lynch Street, Throckmorton Street, Weaver Street, Santa Fe Street, and Dixon Street.

The capital cost of the proposed plan is estimated to be $318,000 including engineering and construction contingencies, as shown in Table 3.2-12. It should be noted, however, that significant improvements to drainage in the area can be accomplished without implementation of the storm sewer system. Other less costly options for improving drainage for this area include construction of a swale near the low area on Refinery Road to convey the runoff that collects at that point to the east and construction of the small diversion berm to prevent runoff from the livestock area from entering the residential area. Periodic street flooding will still occur along Refinery Road if the storm sewer system is not constructed, however, street flooding in this area does not directly cause damage to existing residential or



Pavement Damage at Old Sivells Bend Road and Refinery Road

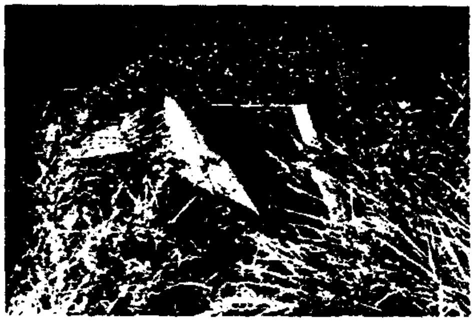
commercial structures. Eliminating the storm sewer system and constructing a swale and channel to convey flow at the low area of Refinery Road will reduce the capital cost of the plan by 32 percent to approximately $215,000.

Table 3.2-12.
Refinery Road Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	8,637	$6.25	$53,981
Trench Excavation	cubic yard	1,793	$4.25	$7,620
Road Excavation/Backfill	cubic yard	162	$12.00	$1,944
Embankment/Levee Fill	cubic yard	360	$3.00	$1,080
Seeding/Vegetation	square yard	5,675	$0.45	$2,554
Soil Retention Blanket	square yard	5,675	$1.00	$5,675
Pavement Cut/Repair	square feet	2,000	$3.50	$7,000
Trench Safety	linear feet	1,835	$3.50	$6,423
Storm Sewer Inlet (10-ft)	each	9	$2,100	$18,900
Storm Sewer Inlet (20-ft)	each	1	$4,000	$4,000
Storm Sewer (18-in RCP)	linear feet	330	$29	$9,570
Storm Sewer (24-in RCP)	linear feet	80	$32	$2,560
Storm Sewer (36-in RCP)	linear feet	120	$55	$6,600
Storm Sewer (42-in RCP)	linear feet	270	$65	$17,550
Storm Sewer (48-in RCP)	linear feet	950	$80	$76,000
Culvert (36-in RCP)	linear feet	80	$55	$4,400
Culvert Headwall	each	3	$1,500	$4,500
Subtotal				$230,357
Contingencies & Miscellaneous			15%	$34,554
Construction Cost				$264,910
Engineering, Surveying, Legal			20%	$52,982
Total Project Cost				$317,892

3.2.3.4 Weaver Street/Santa Fe Drive Problem Area

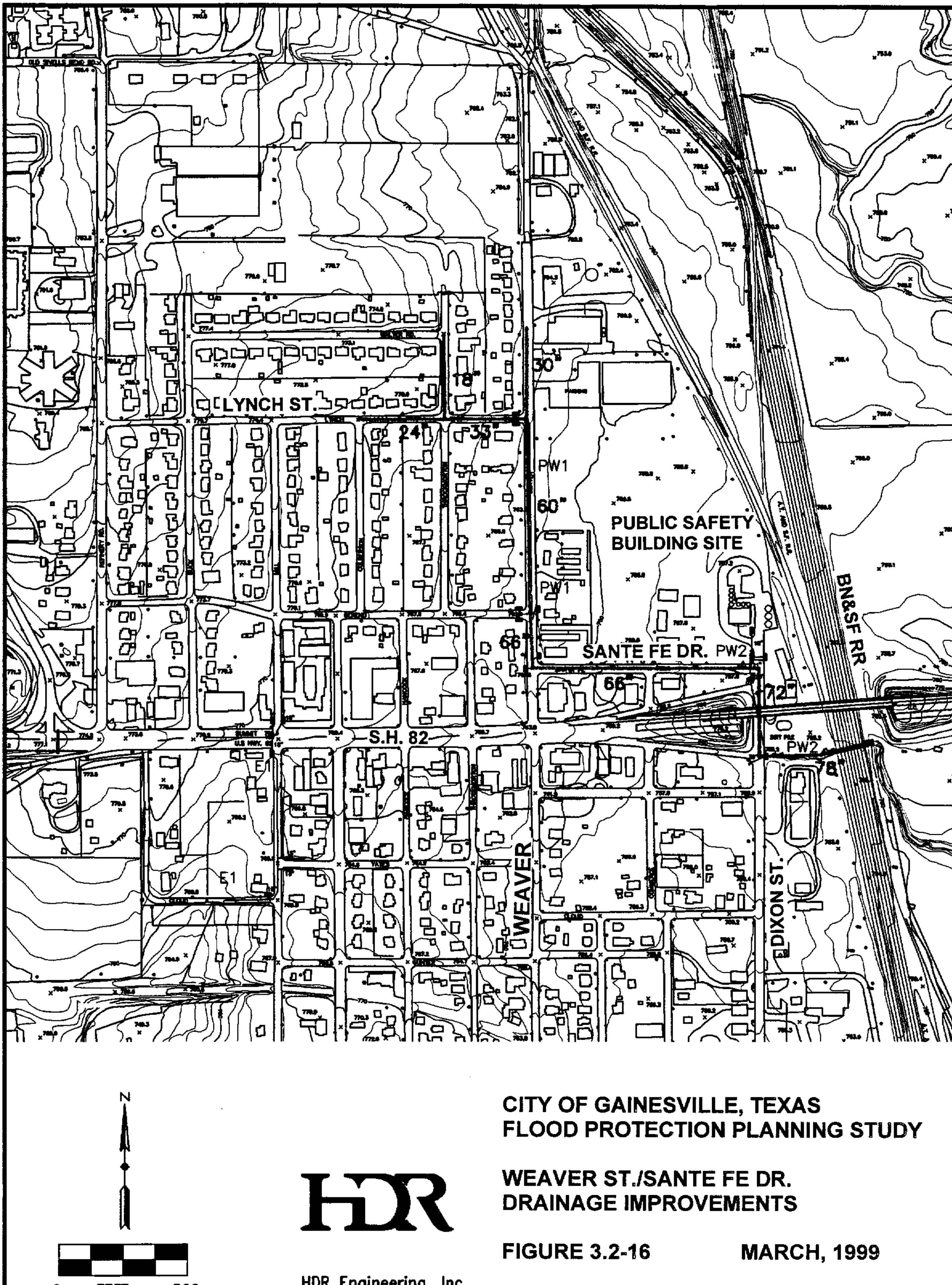
The Weaver Street/Santa Fe Drive Problem Area is located in the northwest part of the City just north of Highway 82 and west of the BN&SF Railroad (Figure 3.2-6). The area is located downstream (south) of the Refinery Road Problem Area. The primary drainage problem for this area is excess street flow along Weaver Street, Santa Fe Drive, and Dixon Street. At Dixon Street, runoff passes under the BN&SF Railroad which is presently equipped with a 4-ft by 4-ft box culvert. Drainage problems have been reported by local businesses, especially along Santa Fe Drive and along Dixon Street as flow crosses under the Highway 82 and enters the BN&SF Railroad culvert and by residences along Lynch Street and Culberson Street. The City's new public safety building is presently under construction on Santa Fe Drive and it will be important to reduce street flooding to ensure that emergency vehicle access to Highway 82 during severe storm events.



Upstream Face of BN&SF Railroad Culvert

The recommended plan for improving drainage in this area is construction of a storm sewer system along Weaver Street to collect runoff and convey it underground to Santa Fe Drive, as shown in Figure 3.2-16. The proposed storm sewer system will be continued along Santa Fe Drive, under Highway 82 along Dixon Street, and to the a new proposed culvert under the railroad to discharge into Pecan Creek. The proposed storm sewer system will upgrade a smaller storm sewer system that presently exists in this area along Weaver Street and extends to the BN&SF Railroad. The total cost for the proposed storm sewer system is $1,056,000, including engineering and construction contingencies, as shown in Table 3.2-13.

Santa Fe Drive between Weaver St. and Dixon St.



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WEAVER ST./SANTE FE DR.
DRAINAGE IMPROVEMENTS

FIGURE 3.2-16 **MARCH, 1999**

Table 3.2-13.
Weaver Street/Santa Fe Drive Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Road Excavation/Backfill	cubic yard	7,000	$12.00	$84,000
Pavement Cut/Repair	square feet	22,800	$3.50	$79,800
Trench Safety	linear feet	4,460	$3.50	$15,600
Storm Sewer Inlet (10-ft)	each	42	$2,100	$88,200
Manhole	each	9	$4,000	$36,000
Storm Sewer (18-in RCP)	linear feet	810	$29	$23,500
Storm Sewer (24-in RCP)	linear feet	330	$32	$10,600
Storm Sewer (30-in RCP)	linear feet	360	$45	$16,200
Storm Sewer (33-in RCP)	linear feet	330	$50	$16,500
Storm Sewer (60-in RCP)	linear feet	760	$165	$125,400
Storm Sewer (66-in RCP)	linear feet	1,090	$180	$196,200
Storm Sewer (72-in RCP)	linear feet	350	$210	$73,500
Storm Sewer (78-in RCP)	linear feet	430	$270	$116,100
Subtotal				$765,500
Contingencies & Miscellaneous			15%	$114,800
Construction Cost				$880,300
Engineering, Surveying, Legal			20%	$176,000
Total Project Cost				$1,056,300

3.2.3.5 Clements Street Problem Area

The Clements Street Problem Area is located in the north part of the City north of Highway 82 and east of Pecan Creek (Figure 3.2-6). The primary drainage problem in this area is overtopping of an unpaved road (Eastridge Addition) and overtopping of Clements Street at an existing culvert location between Highway 82 and Meadowlark Lane. Drainage in this area is conveyed through wide swales and the channels are poorly defined. No drainage structure exists at the Eastridge Addition crossing as runoff from approximately 80 undeveloped acres travels across the road leaving it impassable

Clements Street north of Hwy 82
Pavement damage from overtopping

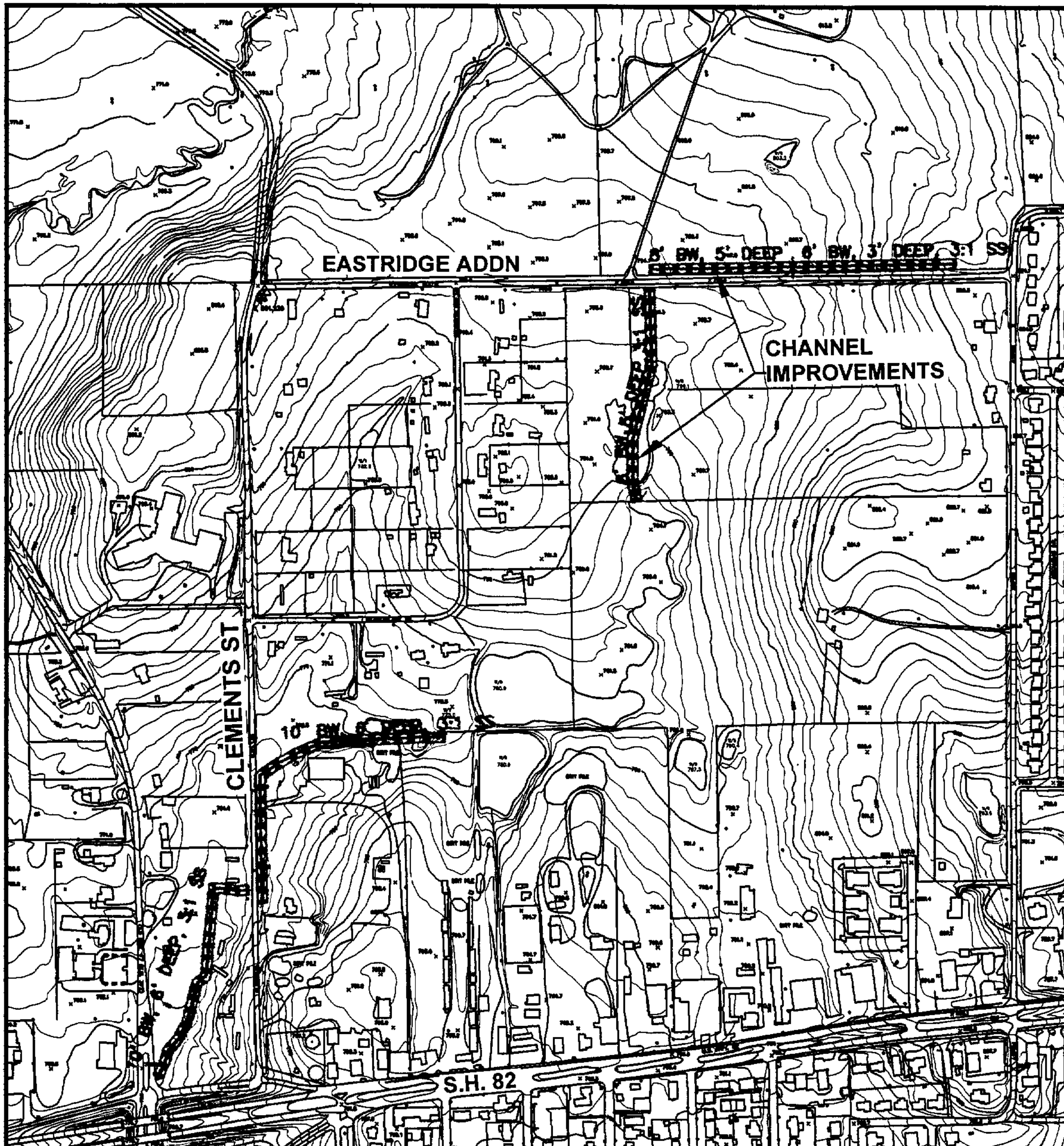
during storm events. The culvert at Clements Street is undersized and runoff from the 260 acre drainage area overtops the street frequently causing damage to the existing pavement.

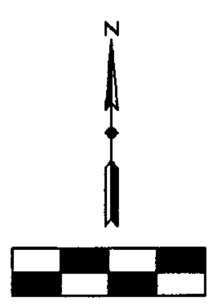
The recommended plan for improving drainage in this area is construction of a drainage channel along the north side of the Eastridge Addition road and installation of a 10-ft by 4-ft box culvert at a low area in the road to pass runoff underneath the roadway (See Figure 3.2-17). Channel improvements are required at the downstream end of the proposed culvert to convey the flow to an existing pond. Channel improvements are also recommended to begin downstream of the pond to Clements Street and downstream of Clements Street to Highway 82. The Clements Street culvert is recommended to be replaced with a three-barrel, 10-ft by 6-ft box culvert to pass the 25-year peak runoff rate without overtopping. The capital cost of the proposed improvements is estimated to be $328,000, including engineering and construction contingencies, as shown in Table 3.2-14. Much of the system between Eastridge Addition Road and Clements Street could be delayed and implemented at such time as the property is developed. Implementation of the culvert at Clements Street and channel improvements immediately upstream and downstream of the culvert is estimated to cost approximately $161,000.

Eastridge Addition unpaved road

Table 3.2-14.
Clements Street Problem Area
Project Cost Estimate

Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Road Excavation/Backfill	cubic yard	21,800	$12.00	$136,250
Pavement Cut/Repair	square feet	1,400	$3.50	$4,900
Seeding/Vegetation	square yard	20,800	$0.45	$9,360
Soil Retention Blanket	square yard	20,800	$1.00	$20,800
Headwall	each	4	$2,500	$10,000
Culvert (10-ft x 4-ft RCB)	linear feet	50	$260	$13,000
Culvert (10-ft x 6-ft RCB)	linear feet	150	$290	$43,500
Subtotal				$237,810
Contingencies & Miscellaneous			15%	$35,672
Construction Cost				$273,482
Engineering, Surveying, Legal			20%	$54,696
Total Project Cost				$328,178





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CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

CLEMENTS STREET
DRAINAGE IMPROVEMENTS

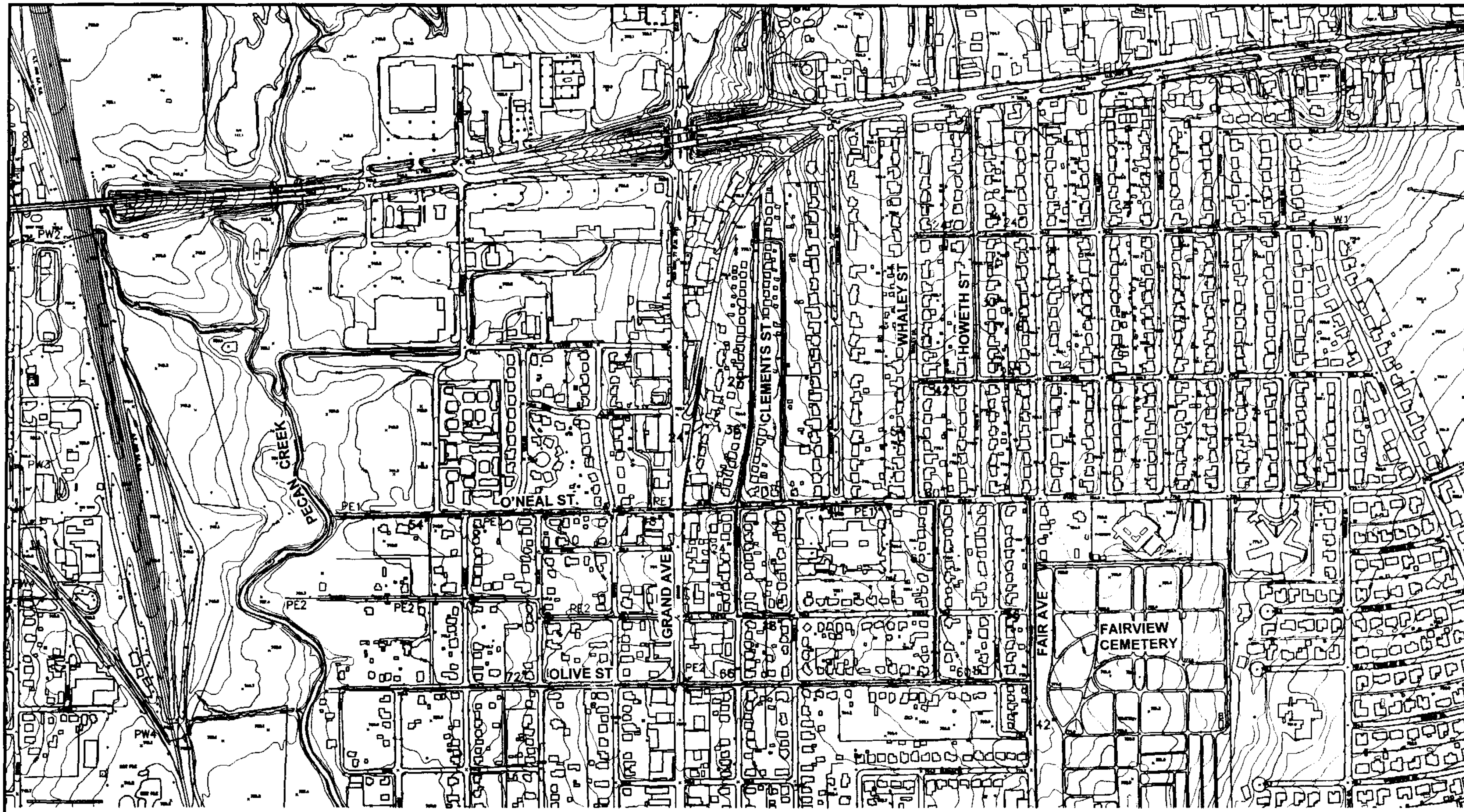
FIGURE 3.2-17 **MARCH, 1999**

3.2.3.6 O'Neal Street Problem Area

The O'Neal Street Problem Area covers a rather large area of the northern portion of the City located just south of Highway 82 and east of Pecan Creek (Figure 3.2-6). Flooding problems in this area are associated with excessive street flooding along O'Neal Street, especially near the Grand Avenue intersection. Presently, storm water runoff originating north of O'Neal Street along Highway 82 and extending east to Howeth and Whaley Streets travels down O'Neal Street. The runoff from this large drainage area exceeds the hydraulic capacity of the street on a frequent basis, flooding O'Neal Street at several locations. Flooding at the Howeth and Whaley Street intersections is planned to be alleviated by a separate system (Olive Street System, Section 3.2.3.7). Street flooding that occurs west of Whaley Drive and extending to Pecan Creek is addressed by a proposed storm sewer system along O'Neal Street. The recommended plan includes the construction of a new storm sewer system along O'Neal Street extending from just west of Whaley Drive to Pecan Creek (See Figure 3.2-18). Storm sewer pipe sizes are proposed to range from 18 inches in diameter at the upper end to 54 inches in diameter at the outlet into Pecan Creek. Various storm sewer systems that are proposed to collect runoff on side streets including Clements Street and Grand Avenue are also included. The total cost for the proposed system is estimated to be $801,000 including engineering and construction contingencies, as shown in Table 3.2-15.

3.2.3.7 Olive Street Problem Area

The Olive Street Problem Area includes a number of smaller areas that have frequent flooding problems including flooding of homes and street flooding. All of these smaller areas have had numerous reports of flooding and include the areas of Whaley Street, Howeth Street, Fair Avenue, and portions of O'Neal Street (Figure 3.2-6). The intersections of Whaley Street at O'Neal Street and Howeth Street at O'Neal Street flood frequently from runoff generated from Highway 82. During minor storms, the hydraulic capacity of the streets at these locations is exceeded and runoff continues west and contributes to flooding at Grand Avenue and other locations along the route. Fair Avenue near Olive Street also has experienced frequent flooding as runoff from the western portion of Fair Cemetery collects in a low area and travels through the yards of several residences located along Elizabeth Street and occasionally floods the homes.



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CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

HDR

O'NEAL STREET & OLIVE STREET
STORM SEWER IMPROVEMENTS

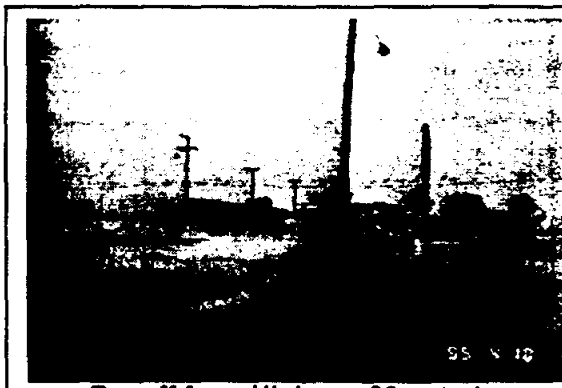
HDR Engineering, Inc.

FIGURE 3.2-18 MARCH, 1999

Table 3.2-15.
O'Neal Street Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Road Excavation/Backfill	cubic yard	5,461	$12.00	$65,532
Pavement Cut/Repair	square feet	21,795	$3.50	$76,283
Trench Safety	linear feet	5,545	$3.50	$19,408
Storm Sewer Inlet (10-ft)	each	39	$2,100	$81,900
Manhole	each	9	$4000	$36,000
Storm Sewer (18-in RCP)	linear feet	330	$29	$9,570
Storm Sewer (24-in RCP)	linear feet	1,300	$32	$41,600
Storm Sewer (27-in RCP)	linear feet	630	$39	$24,570
Storm Sewer (36-in RCP)	linear feet	500	$55	$27,500
Storm Sewer (48-in RCP)	linear feet	1,080	$80	$86,400
Storm Sewer (54-in RCP)	linear feet	1,120	$100	$112,000
Subtotal				$580,762
Contingencies & Miscellaneous			15%	$87,114
Construction Cost				$667,876
Engineering, Surveying, Legal			20%	$133,575
Total Project Cost				$801,452

The recommended plan is the construction of a comprehensive storm sewer system extending into each of these areas, as shown in Figure 3.2-18. The primary storm sewer pipeline is planned to be placed in Olive Street that will ultimately convey all of the runoff from these smaller areas to Pecan Creek. The proposed storm sewer system will convey runoff underground from near Highway 82 to O'Neal Street and then to the Olive Street trunk line. A separate storm sewer system is planned to be constructed along Fair Avenue to intercept runoff from the cemetery area and prevent flooding of existing residences along Elizabeth Street. The runoff collected at Fair Avenue will be conveyed to the Olive Street trunk line. The large drainage areas that contribute at each of the locations require large storm sewer pipes to effectively convey the runoff and eliminate the frequent flooding that occurs.



Runoff from Highway 82 entering Howeth Street for a minor storm event

Storm sewer pipe sizes range from 24 inches to 54 inches in diameter in the Howeth Street and Whaley Street areas. The Fair Avenue system includes storm sewer pipes ranging in size from 36 inches to 42 inches in diameter. The primary trunk line along Olive Street begins at 60-inches in diameter at the upstream (east) end and increase to 72 inches in diameter at the outlet at Pecan Creek. The total cost for the Olive Street storm sewer system is estimated to be $2,483,000 including engineering and construction contingencies, as shown in Table 3.2-16. Overall, the system includes over 10,000 feet of storm sewer pipe. Although the system is one of the more expensive storm sewer systems proposed, it effectively eliminates the frequent flooding that occurs in several areas and diverts a large portion of the runoff that presently contributes to flooding along O'Neal Street including the Grand Avenue intersection.

Table 3.2-16.
Olive Street Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Road Excavation/Backfill	cubic yard	15,968	$12.00	$191,616
Pavement Cut/Repair	square feet	53,818	$3.50	$188,363
Trench Safety	linear feet	10,665	$3.50	$37,328
Storm Sewer Inlet (10-ft)	each	55	$2,100	$115,500
Manhole	each	12	$4000	$48,000
Storm Sewer (18-in RCP)	linear feet	825	$29	$23,925
Storm Sewer (24-in RCP)	linear feet	1,050	$32	$33,600
Storm Sewer (30-in RCP)	linear feet	700	$45	$31,500
Storm Sewer (36-in RCP)	linear feet	1,750	$55	$96,250
Storm Sewer (42-in RCP)	linear feet	700	$65	$45,500
Storm Sewer (54-in RCP)	linear feet	650	$100	$65,000
Storm Sewer (60-in RCP)	linear feet	1,630	$165	$268,950
Storm Sewer (66-in RCP)	linear feet	1,740	$180	$313,200
Storm Sewer (72-in RCP)	linear feet	1,620	$210	$340,200
Subtotal				$1,798,932
Contingencies & Miscellaneous			15%	$269,840
Construction Cost				$2,068,771
Engineering, Surveying, Legal			20%	$413,754
Total Project Cost				$2,482,525

3.2.3.8 Grand Avenue/Belcher Street Problem Area

The Grand Avenue/Belcher Street Problem Area is located in the north central part of the City north of California Street and east of Pecan Creek (Figure 3.2-6). The primary drainage problem at this location is street flooding along Grand Avenue near Belcher Street and along Morris Street at the Fay Street intersection. The total contributing drainage area at Morris Street and Fay Street is about 18 acres. The 25-year storm peak runoff rate was calculated to be approximately 62 cfs or about twice the estimated street capacity of 35 cfs. As flow travels west along Fay Street, the 25-year storm peak runoff rate was calculated to increase to 105 cfs or three times the estimated street capacity.

The recommended plan for improving drainage in this area is construction of a storm sewer system along Belcher Street and Fay Street to collect a large portion of the runoff and convey it underground to Pecan Creek, as shown in Figure 3.2-19. The proposed storm sewer system will parallel an existing storm sewer system along Eldridge Street. The Eldridge Street storm sewer system captures runoff at Grand Avenue and conveys it west to Pecan Creek. The maximum pipe diameter for the existing Eldridge Street system is 24 inches which is too small to convey the 25-year storm peak runoff rate for its contributing area. The proposed storm sewer system will intercept a large part of the runoff that presently overwhelms the Eldridge Street storm sewer system in order to alleviate street flooding for the areas that both systems serve. Pipe sizes for the main trunk lines for the proposed system range from 27-inches to 36-inches in diameter. The total cost for the proposed Grand Avenue/Belcher Street storm sewer system is estimated to be $201,000 including engineering and construction contingencies, as shown in Table 3.2-17.

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FLOOD PROTECTION PLANNING STUDY

GRAND AVE/BELCHER ST.
STORM SEWER IMPROVEMENTS

FIGURE 3.2-19 **MARCH, 1999**

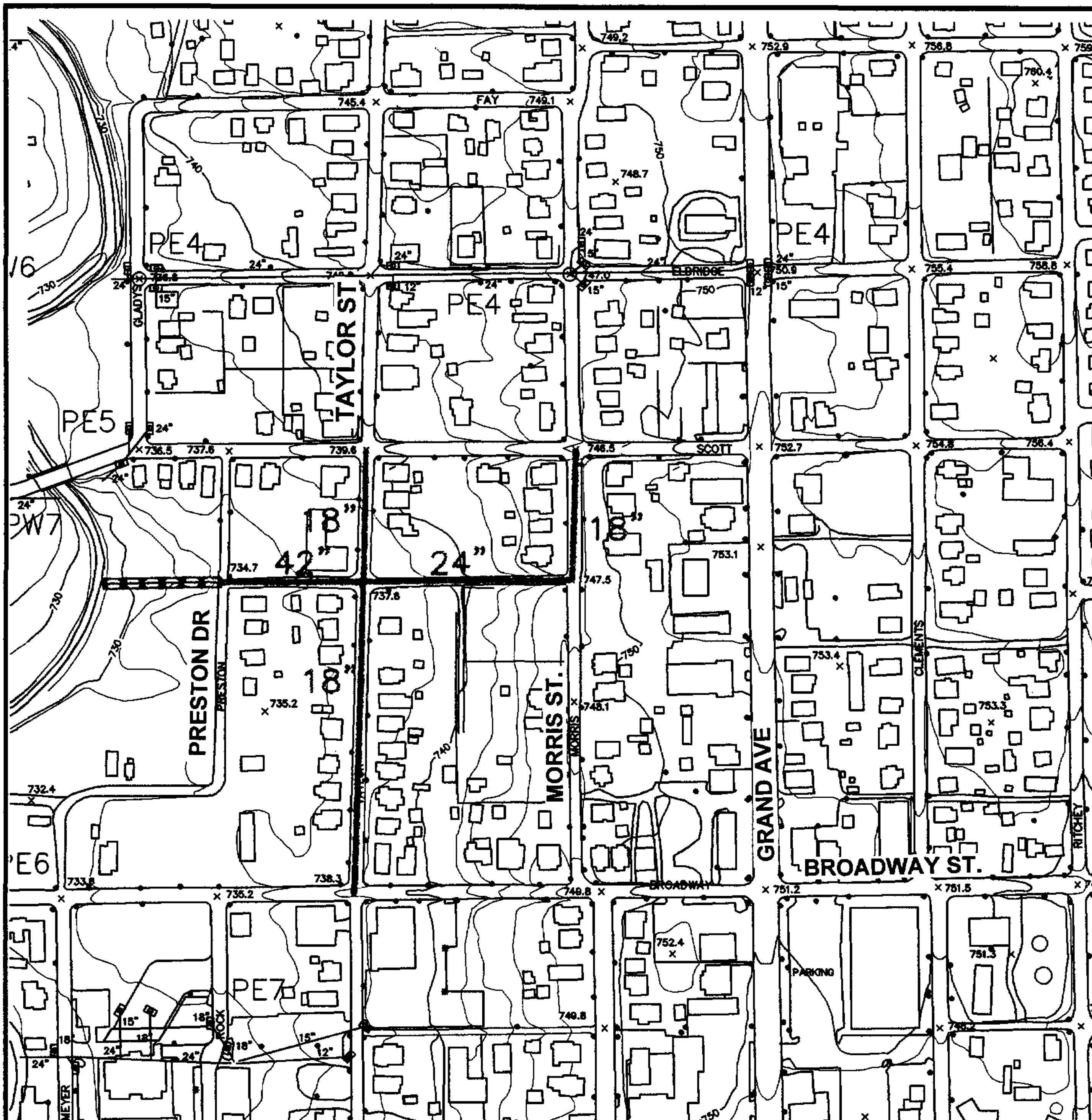
Table 3.2-17.
Grand Avenue/Belcher Street Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Road Excavation/Backfill	cubic yard	1,345	$12.00	$16,140
Pavement Cut/Repair	square feet	5,795	$3.50	$20,283
Trench Safety	linear feet	1,565	$3.50	$5,478
Storm Sewer Inlet (10-ft)	each	9	$2,100	$18,900
Manhole	each	2	$4000	$8,000
Storm Sewer (18-in RCP)	linear feet	135	$29	$3,915
Storm Sewer (27-in RCP)	linear feet	350	$39	$13,650
Storm Sewer (36-in RCP)	linear feet	1,080	$55	$59,400
Subtotal				$145,765
Contingencies & Miscellaneous			15%	$21,865
Construction Cost				$167,630
Engineering, Surveying, Legal			20%	$33,526
Total Project Cost				$201,156

3.2.3.9 Taylor Street Problem Area

The Taylor Street Problem Area is located in the north central part of the City north of California Street and east of Pecan Creek (Figure 3.2-6). The primary drainage problem for this area is excessive street flow along Morris Street and Taylor Street between Scott Street and Broadway Street. Drainage problems are primarily located near the Cedar Street intersection. At the Morris Street and Cedar Street intersection, the total drainage area is approximately 13 acres. The 25-year storm peak runoff rate for this area was estimated to be 43 cfs, nearly three times the street flow capacity of 16 cfs. At Taylor Street, the drainage area increases to 26 acres. The 25-year storm peak runoff rate for this area is on the order of 100 cfs, almost nine times the estimated street flow capacity of 11 cfs.

The recommended plan for improving drainage in this area is construction of a storm sewer system and outfall channel along Morris Street, Taylor Street, and Cedar Street to collect runoff and convey it underground to Preston Drive, as shown in Figure 3.2-20. From Preston



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TAYLOR STREET
STORM SEWER IMPROVEMENTS

FIGURE 3.2-20 **MARCH, 1999**

Drive, a grass-lined channel is proposed to convey the runoff to Pecan Creek. Pipe sizes for the main trunk lines for the proposed system range from 24-inches to 42-inches in diameter. Lateral lines of 18-inches in diameter are also proposed along Morris Street and Taylor Street to collect and convey runoff to the main trunk lines. The total cost for the proposed storm sewer system is estimated to be $214,000 including engineering and contingencies, as shown in Table 3.2-18.

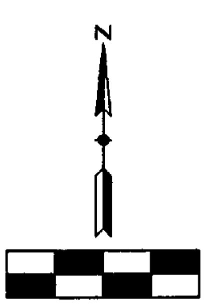
Table 3.2-18.
Taylor Street Problem Area
Project Cost Estimate

Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Channel Excavation	cubic yard	1,533	$6.25	$9,581
Road Excavation/Backfill	cubic yard	1,252	$12.00	$15,024
Pavement Cut/Repair	square feet	6,038	$3.50	$21,133
Seeding/Vegetation	square yard	1,500	$0.45	$675
Soil Retention Blanket	square yard	1,500	$1.00	$1,500
Trench Safety	linear feet	2,065	$3.50	$7,228
Storm Sewer Inlet (10-ft)	each	9	$2,100	$18,900
Manhole	each	2	$4000	$8,000
Storm Sewer (18-in RCP)	linear feet	1,305	$29	$37,845
Storm Sewer (24-in RCP)	linear feet	430	$32	$13,760
Storm Sewer (42-in RCP)	linear feet	330	$65	$21,450
Subtotal				$155,096
Contingencies & Miscellaneous			15%	$23,264
Construction Cost				$178,360
Engineering, Surveying, Legal			20%	$35,672
Total Project Cost				$214,032

3.2.3.10 Broadway Street West Problem Area

The Broadway Street West Problem Area is located in the west central part of the City north of California Street and west of Pecan Creek (Figure 3.2-6). The primary drainage problem at this location is street flooding along Broadway Street and along Dixon Street including the intersection with Broadway Street and Scott Street. In addition, flooding has been reported along the west side of the BN&SF Railroad embankment at an existing culvert that drains runoff from the Broadway Street area into Pecan Creek. There are small storm sewer systems in the immediate vicinity of Broadway Street including along Broadway Street from Commerce Street to near the BN&SF Railroad. However, the pipe sizes for the main trunk lines of these systems are small, on the order of 12-inches to 15-inches in diameter, and are effective only for very minor storm events. All of the existing storm sewer systems from this area drain into a 4-ft by 4-ft box that discharges into a channel at the south side of Main Street, just west of the BN&SF Railroad. All runoff from the area converges at this channel, whether it's conveyed through the storm sewer system or on the surface of the streets, and is passed under the BN&SF Railroad to Pecan Creek through two 48-inch diameter culverts. In addition to the two 48-inch diameter culverts, a 36-inch diameter culvert exists farther south near Garnett Street. The total drainage area at the BN&SF Railroad culverts is approximately 150 acres of densely developed area.

The recommended plan for improving drainage in this area is to install a new storm sewer system along Dixon Street and Broadway Street to reduce street flooding in this area, as shown in Figure 3.2-21. The existing storm sewer inlets and new inlets will be connected to the new system. Due to the relatively flat slopes in the area, the storm sewer pipe sizes ranged from 30-inches to 48-inches in diameter in order to convey the 25-year peak runoff rate. The proposed storm sewer system will outlet at the south side of Main Street, adjacent to the existing system outlet. The existing channel, extending from Main Street to the railroad culverts, would be cleared and expanded to provide improved drainage. The existing 48-inch culverts at the BN&SF Railroad are proposed to be replaced with two 10-ft by 6-ft box culverts in order to pass the runoff from the upstream area to Pecan Creek. The existing 36-inch diameter culvert under the railroad is proposed to remain and the channel is proposed to be graded from this area to flow north to the new box culverts. The capital cost of the proposed improvements is estimated to be $784,000 including engineering and construction contingencies as shown in Table 3.2-19. It should be noted that the effectiveness of the new culverts at the BN&SF Railroad is dependent on flood levels in Pecan Creek and the capacity of the culverts will be significantly improved with improvements to the Pecan Creek channel as discussed in Section 3.2.3.2.



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BROADWAY STREET WEST
DRAINAGE IMPROVEMENTS

FIGURE 3.2-21 **MARCH, 1999**

Table 3.2-19.
Broadway Street West Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	500	$6.25	$3,125
Road Excavation/Backfill	cubic yard	4,300	$12.00	$51,600
Seeding/Vegetation	square yard	9,722	$0.45	$4,375
Pavement Cut/Repair	square feet	16,200	$3.50	$56,700
Trench Safety	linear feet	3,565	$3.50	$12,478
Storm Sewer Inlet (10-ft)	each	8	$2,100	$16,800
Manhole	each	3	$4000	$12,000
Headwall	each	1	$2,500	$2,500
Storm Sewer (18-in RCP)	linear feet	315	$29	$9,135
Storm Sewer (30-in RCP)	linear feet	300	$45	$13,500
Storm Sewer (36-in RCP)	linear feet	400	$55	$22,000
Storm Sewer (48-in RCP)	linear feet	2,550	$80	$204,00
Railroad Box Culvert (10'x 6' RCB)	linear feet	120	$1,200	$144,000
Subtotal				$568,213
Contingencies & Miscellaneous			15%	$85,232
Construction Cost				$653,444
Engineering, Surveying, Legal			20%	$130,689
Total Project Cost				$784,133

3.2.3.11 California Street East Problem Area

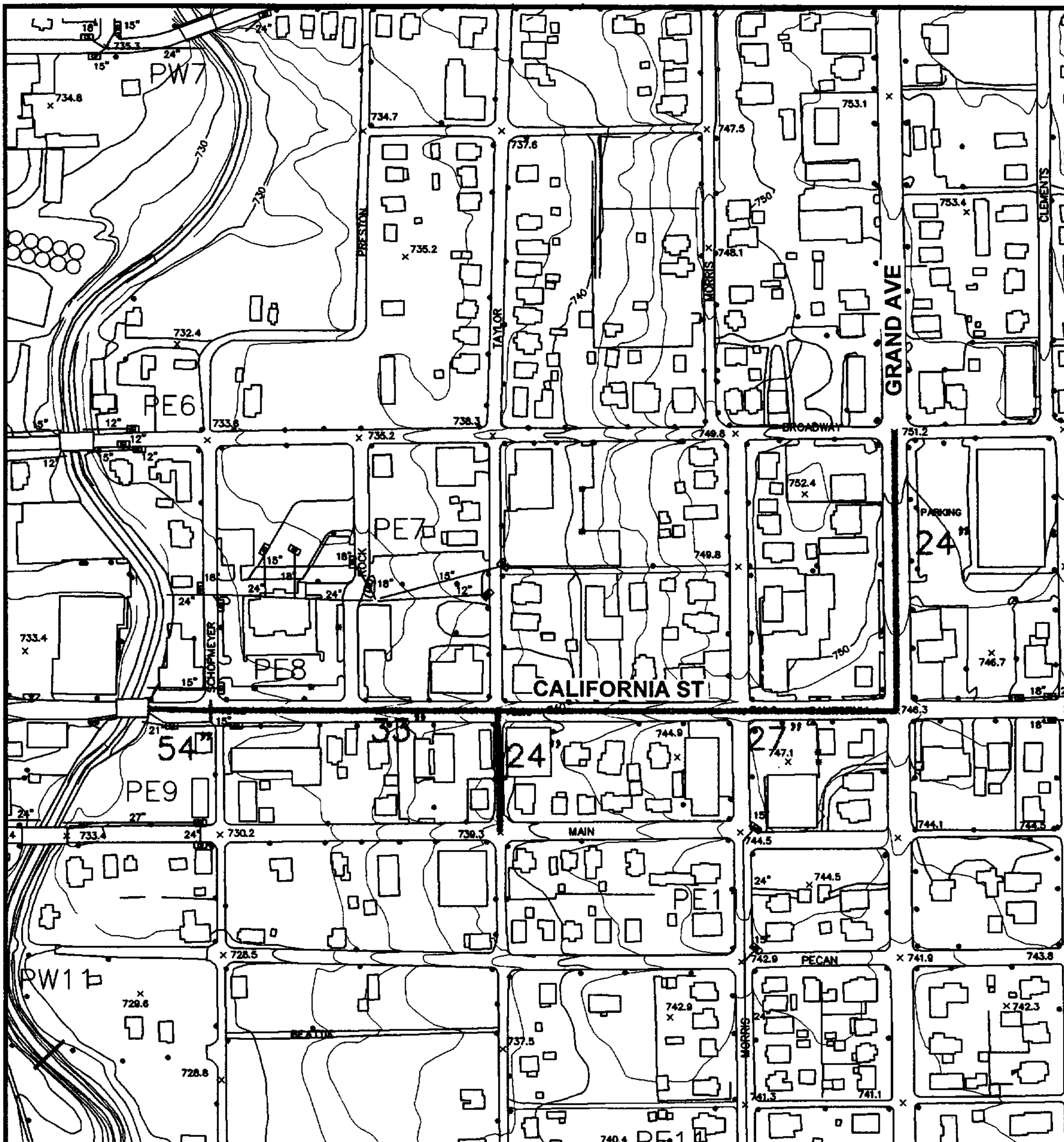
The California Street East Problem Area is located in the central portion of the City along California Street just east of Pecan Creek (Figure 3.2-6). The primary drainage problem for this area is recurring street flooding on California Street between Pecan Creek and Grand Avenue. Runoff travels south along Grand Avenue and enters the California Street intersection. The drainage area contributing to this intersection extends north along Grand Avenue to about Scott Street and includes a total area of about 10.5 acres. Grand Avenue is considered an arterial street, therefore two lanes are required to remain open for a 25-year storm event based on the City's Drainage Criteria. Applying this criteria, the street flow capacity of Grand Avenue would be on the order of about 10 cfs based on the longitudinal slope of the street. The 25-year storm peak runoff rate was calculated to be 34 cfs or over three times the allowable street flow rate.

Therefore, a storm sewer system is required to prevent the street flow capacity from being exceeded.

The recommended plan includes a storm sewer system beginning at the Grand Avenue and Broadway Street intersection (24-inch diameter pipe) and extending south along Grand Avenue to California Street (See Figure 3.2-22). The main trunk line would then increase in size to a 27-inch diameter pipe and convey runoff west to Pecan Creek. The trunk line is proposed to increase in size near each major street intersection where additional inlets would be located to reduce flow in the intersection to allowable levels. The proposed system is planned for streets that are presently maintained by TxDOT, therefore implementation of this plan would require coordination and implementation by TxDOT. The total cost for the proposed storm sewer system is $312,000, including engineering and construction contingencies, as shown in Table 3.2-20.

Table 3.2-20.
California Street East Problem Area
Project Cost Estimate

Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Road Excavation/Backfill	cubic yard	2,000	$12.00	$24,000
Pavement Cut/Repair	square feet	9,080	$3.50	$31,780
Trench Safety	linear feet	2,725	$3.50	$9,538
Storm Sewer Inlet (10-ft)	each	17	$2,100	$35,700
Manhole	each	3	$4000	$12,000
Storm Sewer (18-in RCP)	linear feet	255	$29	$7,395
Storm Sewer (24-in RCP)	linear feet	895	$32	$28,640
Storm Sewer (27-in RCP)	linear feet	825	$39	$32,175
Storm Sewer (33-in RCP)	linear feet	600	$50	$30,000
Storm Sewer (54-in RCP)	linear feet	150	$100	$15,000
Subtotal				$226,228
Contingencies & Miscellaneous			15%	$33,934
Construction Cost				$260,162
Engineering, Surveying, Legal			20%	$52,032
Total Project Cost				$312,194



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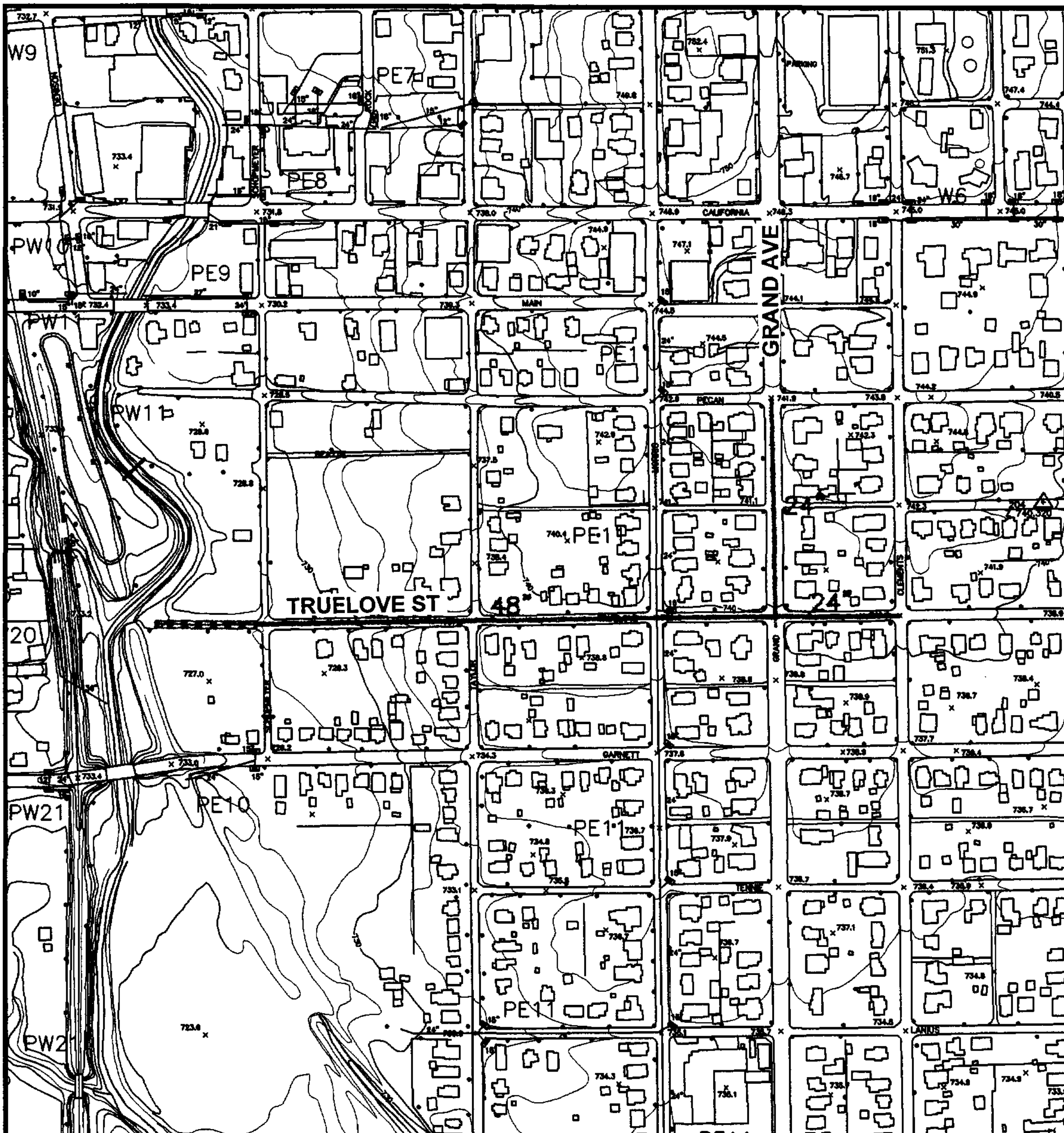
CALIFORNIA STREET EAST
STORM SEWER IMPROVEMENTS

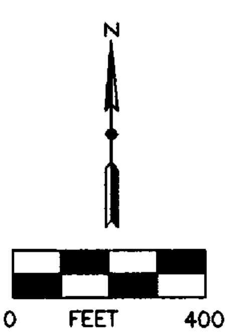
FIGURE 3.2-22 MARCH, 1999

3.2.3.12 Truelove Street Problem Area

The Truelove Street Problem Area is located in the central portion of the City just south of California Street and east of Pecan Creek (Figure 3.2-5). The primary drainage problem in this area is street flooding along Grand Avenue from California Street to Truelove Street and along Truelove Street from Grand Avenue to Pecan Creek. The drainage area for Grand Avenue south of California Street at the Truelove Street intersection is approximately 11 acres. The 25-year storm peak runoff rate at this location was calculated to be on the order of 40 cfs, as compared to an allowable street flow of less than 10 cfs for Grand Avenue based on its longitudinal street slope and arterial street classification. Along Truelove Street, the drainage area west of Grand Avenue at Schopmeyer Street is about 10 acres which produces a 25-year storm peak runoff rate of 34 cfs. The allowable street flow for Truelove Street is about 22 cfs, which is less than the design storm runoff rate. In order to meet the City's Drainage Criteria for allowable street flow, an underground storm sewer system is required to convey the surface runoff for Grand Avenue and Truelove Street.

The recommended plan consists of an underground storm sewer system along Grand Avenue and along Truelove Street to convey the surface runoff to Pecan Creek, as shown in Figure 3.2-23. The system would begin near the intersection of Grand Avenue and Pecan Street and extend south to Truelove Street. From the intersection of Grand Avenue and Truelove Street, the system would extend west to Pecan Creek. The proposed storm sewer pipe along Truelove would also intercept flow from the existing Morris Street storm sewer. This will increase the ability of the Morris Street storm sewer system to capture additional runoff downstream (south) of Truelove Street. The total cost of the proposed storm sewer system is $416,000 including engineering and construction contingencies, as shown in Table 3.2-21.





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FLOOD PROTECTION PLANNING STUDY

TRUELOVE STREET
STORM SEWER IMPROVEMENTS

FIGURE 3.2-23 **MARCH, 1999**

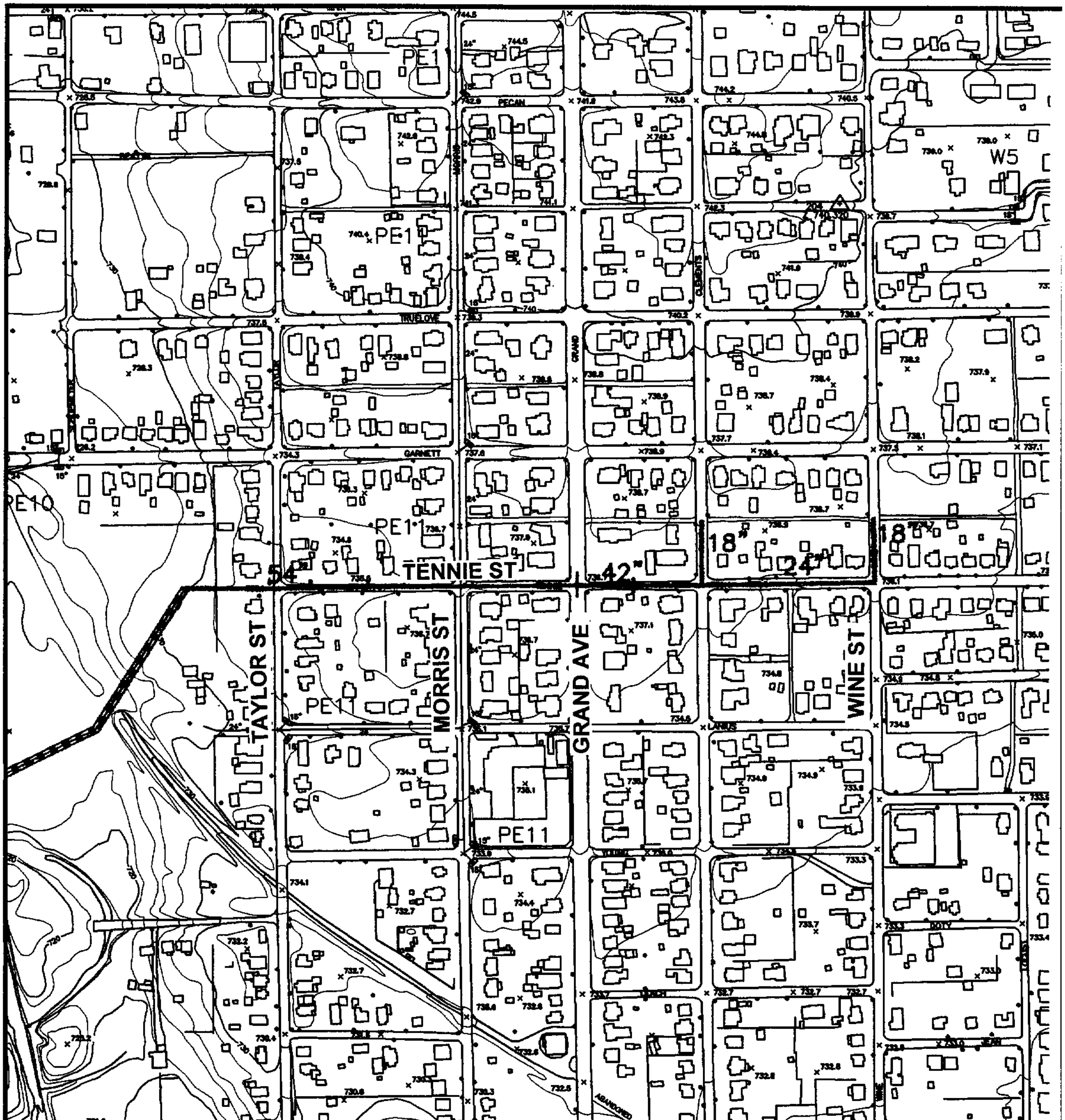
Table 3.2-21.
Truelove Street Problem Area
Project Cost Estimate

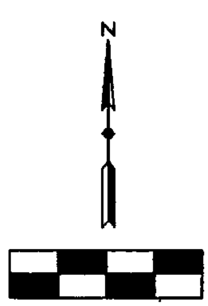
Item	Units	Quantity	Unit Cost	Total Cost
Trench Excavation	cubic yard	347	$4.25	$1,475
Road Excavation/Backfill	cubic yard	2,700	$12.00	$32,400
Pavement Cut/Repair	square feet	11,800	$3.50	$41,300
Trench Safety	linear feet	2,845	$3.50	$9,958
Storm Sewer Inlet (10-ft)	each	13	$2,100	$27,300
Manhole	each	4	$4000	$16,000
Storm Sewer (18-in RCP)	linear feet	195	$29	$5,655
Storm Sewer (24-in RCP)	linear feet	930	$32	$29,760
Storm Sewer (48-in RCP)	linear feet	1,720	$80	$137,600
Subtotal				$301,447
Contingencies & Miscellaneous			15%	$45,217
Construction Cost				$346,664
Engineering, Surveying, Legal			20%	$69,333
Total Project Cost				$415,997

3.2.3.13 Tennie Street Problem Area

The Tennie Street Problem Area is located in the south central portion of the City about six blocks south of California Street and east of Pecan Creek (Figure 3.2-5). The primary drainage problem associated with this problem area is excessive street flow along Tennie Street and at the Grand Avenue intersection. The Tennie Street problem area actually stretches across the watershed divide between Pecan Creek and Wheeler Creek. The problem area was extended in order to address street flooding along Wine Street that presently would continue to flow south to the abandoned railroad grade and then east to Wheeler Creek. Drainage problems have been reported in this area along Grand Avenue and along Tennie Street at various locations.

The recommended plan for this area is to construct an underground storm sewer system along Tennie Street extending from Wine Street to Taylor Street, as shown in Figure 3.2-24. From Taylor Street, a grass-lined channel is proposed to convey the runoff to Pecan Creek. The proposed system is designed to alleviate flood problems along Tennie Street, Grand Avenue, Wine Street, and Taylor Street by collecting surface runoff at each of the main intersections. The





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FLOOD PROTECTION PLANNING STUDY

TENNIE STREET
STORM SEWER IMPROVEMENTS

FIGURE 3.2-24 **MARCH, 1999**

proposed storm sewer system includes trunk lines that begin at 24-inches in diameter at Wine Street, increasing to 42-inches and 54-inches in diameter west of Clements Street. Similar to the proposed Truelove Street system (Section 3.2.3.12), the Tennie Street system will intercept flow in the existing Morris Street storm sewer system that is presently severely undersized. The total cost for the proposed storm sewer system is estimated to be $455,000, including engineering and construction contingencies, as shown in Table 3.2-22.

Table 3.2-22.
Tennie Street Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	6,018	$6.25	$37,613
Trench Excavation	cubic yard	240	$4.25	$1,020
Road Excavation/Backfill	cubic yard	2,533	$12.00	$30,396
Pavement Cut/Repair	square feet	10,530	$3.50	$36,855
Seeding/Vegetation	square yard	5,820	$0.45	$2,619
Soil Retention Blanket	square yard	5,820	$1.00	$5,820
Trench Safety	linear feet	2,500	$3.50	$8,750
Storm Sewer Inlet (10-ft)	each	12	$2,100	$25,200
Manhole	each	4	$4000	$16,000
Storm Sewer (18-in RCP)	linear feet	540	$29	$15,660
Storm Sewer (24-in RCP)	linear feet	500	$32	$16,000
Storm Sewer (42-in RCP)	linear feet	350	$65	$22,750
Storm Sewer (54-in RCP)	linear feet	1,110	$100	$111,000
Subtotal				$329,683
Contingencies & Miscellaneous			15%	$49,452
Construction Cost				$379,135
Engineering, Surveying, Legal			20%	$75,827
Total Project Cost				$454,962

3.2.3.14 Lanius Street Problem Area

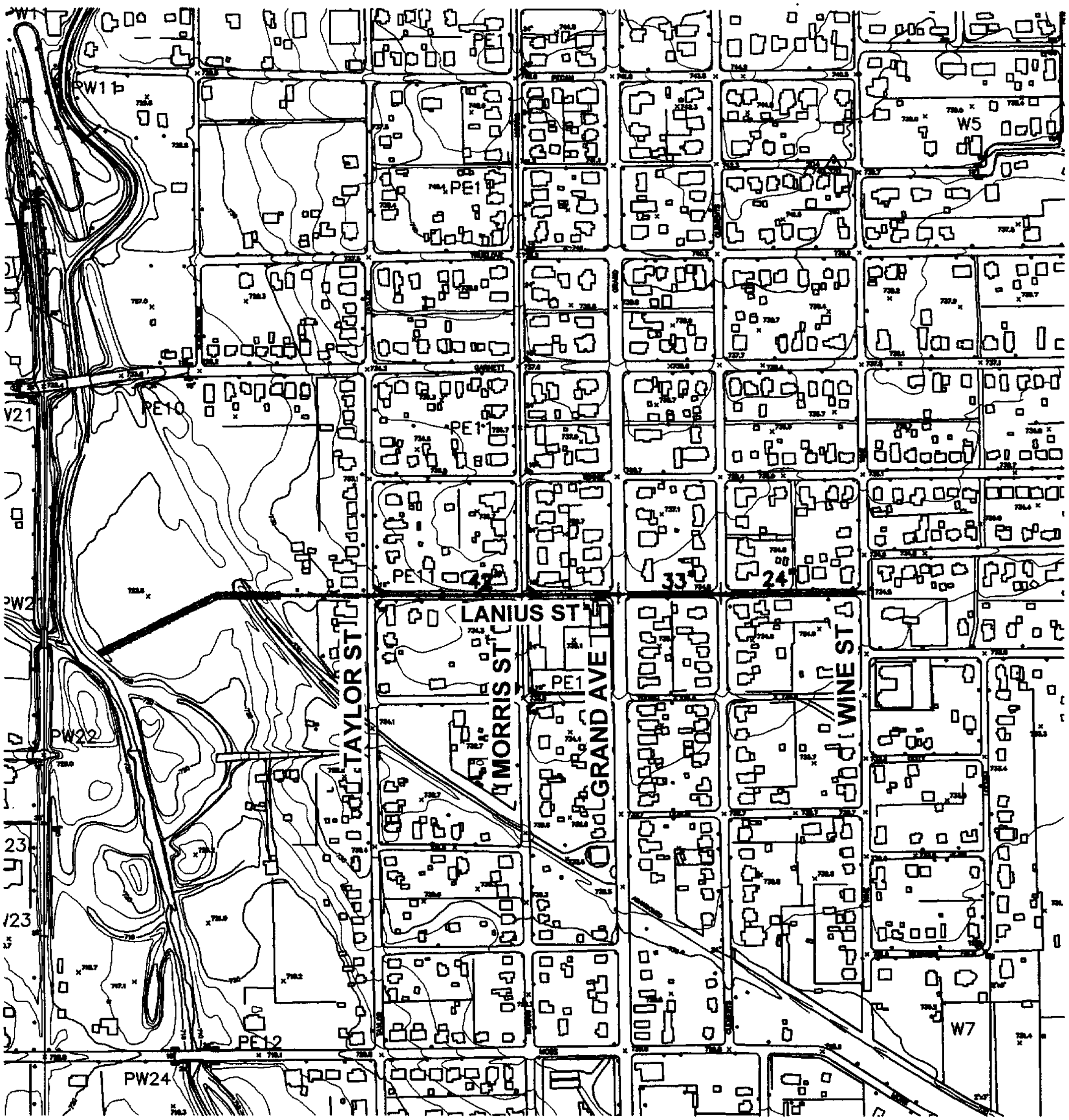
The Lanius Street Problem Area is located in the south central portion of the City about seven blocks south of California Street and east of Pecan Creek (Figure 3.2-6). The primary drainage problem associated with the Lanius Street Problem Area is excess street flow at various intersections along Lanius Street. Flow along each of the streets intersecting Lanius Streets in this area is to the south. Street flooding has been reported by local residents at the Grand

Avenue and Wine Street intersections, although analyses also show that street flow would also exceed the capacity at the Clements Street, Morris Street, and Taylor Street intersections.

The recommended plan for this area includes an underground storm sewer system to remove excess street flow and convey it underground to Pecan Creek, as shown in Figure 3.2-25. The proposed system would extend along Lanius Street from Wine Street west to Taylor Street. At Taylor Street, the storm sewer system would discharge into a grass-lined channel which would converge with grass-lined channel from the Tennie Street system and then flow would enter Pecan Creek downstream of the abandoned railroad grade. The trunk lines for the proposed system would begin at 24-inches in diameter at Wine Street increasing to 42-inches in diameter at the discharge near Taylor Street. The Lanius Street system was planned to connect to the existing Morris Street storm sewer system and parallel the existing 24-inch diameter trunk line along Lanius Street. The total cost for the proposed Lanius Street System is estimated to be $284,000 including engineering and construction contingencies, as shown in Table 3.2-23.

Table 3.2-23.
Lanius Street Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	3,470	$6.25	$21,668
Trench Excavation	cubic yard	312	$4.25	$1,326
Road Excavation/Backfill	cubic yard	1,520	$12.00	$18,240
Pavement Cut/Repair	square feet	7,575	$3.50	$26,513
Seeding/Vegetation	square yard	3,120	$0.45	$1,404
Soil Retention Blanket	square yard	3,120	$1.00	$3,120
Trench Safety	linear feet	1,940	$3.50	$6,790
Storm Sewer Inlet (10-ft)	each	6	$2,100	$12,600
Manhole	each	3	$4000	$12,000
Storm Sewer (18-in RCP)	linear feet	90	$29	$2,610
Storm Sewer (24-in RCP)	linear feet	475	$32	$15,200
Storm Sewer (33-in RCP)	linear feet	350	$50	$17,500
Storm Sewer (42-in RCP)	linear feet	1,025	$65	$66,625
Subtotal				$205,615
Contingencies & Miscellaneous			15%	$30,842
Construction Cost				$236,457
Engineering, Surveying, Legal			20%	$47,291
Total Project Cost				$283,749



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LANIUS STREET
STORM SEWER IMPROVEMENTS

FIGURE 3.2-25 **MARCH, 1999**

3.2.4 Summary

A summary of the problem areas, recommended improvements, and capital costs for the Pecan Creek watershed is provided in Table 3.2-24. The total capital cost of all of the recommended improvements is $16,285,000.

Table 3.2-24.
Pecan Creek Watershed
Summary of Recommended Improvements

Problem Area	Watershed Category	Recommended Improvements	Estimated Capital Cost
Pecan Creek Hwy 82 to Anthony St.	Major	Pecan Creek channel improvements from Highway 82 to Anthony St. consisting of a 65-ft bottom width, trapezoidal channel, with 3:1 side slopes. Bridge replacements at Belcher St., Scott St., Broadway St., California St., Main St., Garnett St., and Moss St.	$8,633,000
Belcher St. Bridge	Major		
Scott St. Bridge	Major		
Broadway St. Bridge	Major		
California St. Bridge	Major		
Main St. Bridge	Major		
Garnett St. Bridge	Major		
Moss St. Bridge	Major		
Refinery Rd.	Minor	Storm sewer system improvements on Refinery Rd. Channel improvements east of Refinery Rd. to Weaver St. Culvert replacement at Weaver St.	$318,000
Weaver St. Santa Fe Dr.	Minor	Storm sewer system on Weaver St. from near Lynch St. to Santa Fe Dr., Dixon St., and BN&SF Railroad.	$1,056,000
Clements St.	Minor	Channel improvements north of Eastridge Addition Rd. and upstream and downstream of Clements St. Installation of new culverts at Eastridge Addition Rd. and Clements St.	$328,000
O'Neal St.	Minor	Storm sewer system improvements along Clements St., Grand Ave., and O'Neal St.	$801,000
Olive St.	Minor	Storm sewer system improvements along Howeth St., Whaley St., O'Neal St., Fair Ave., and Olive St.	$2,483,000
Grand Ave. Belcher St.	Minor	Storm sewer system improvements on Grand Ave. and Belcher St.	$201,000
Taylor St.	Minor	Storm sewer system improvements on Taylor St., Scott St., and Morris St.	$214,000
Broadway St. West	Minor	Storm sewer system improvements on Dixon St. and Broadway St. and channel improvements south of Main St. Replacement of BN&SF Railroad culvert south of Main St.	$784,000
California St. East	Minor	Storm sewer system improvements on California St. from Grand Ave. to Pecan Creek.	$312,000
Truelove St.	Minor	Storm sewer system improvements on Truelove St. from Clements St. and Grand Ave. to Pecan Creek.	$416,000
Tennie St.	Minor	Storm sewer system improvements on Tennie St. from Wine St. to Pecan Creek.	$455,000
Lanius St.	Minor	Storm sewer system improvements on Lanius St. from Wine St. to Pecan Creek.	$284,000
		TOTAL	**$16,285,000**

3.3 Wheeler Creek Watershed

Wheeler Creek originates in the northeastern portion of Cooke County and extends downstream along the eastern edge of the City of Gainesville, as shown in Figure 3.3-1. The Wheeler Creek flood plain extends across the east side of the City causing flood problems at a few areas. The watershed covers about 15.6 sq. mi. at FM 678 (California Street) at the north end of the City and 18.0 sq. mi. at its confluence with Pecan Creek at the south end of the City. The land use within the watershed is predominantly rural upstream of Highway 82. Downstream of Highway 82, some residential development has occurred and is expected to continue to expand in the future. Based on the City of Gainesville's Comprehensive Land Use Plan,[14] future growth in the watershed near the City is planned primarily for residential use with some commercial development planned along the Highway 82 corridor. Outside of the City's current ETJ, land use was assumed to remain predominantly rural with some residential development.

Wheeler Creek downstream of Harris Street

Existing flood plain mapping for Wheeler Creek was completed in 1981 by FEMA[15] and was limited in the City of Gainesville to a very small segment extending from FM 678 to a point approximately 2,000 feet upstream, as shown in Figure 3.1-2. This is the only segment of Wheeler Creek in which a detailed study was performed by FEMA to identify flood plain limits. Other segments of Wheeler Creek and its major tributaries located outside of the City in Cooke County[16] were not studied in detail and mapping of flood plain limits were made in 1977 using approximate methods.

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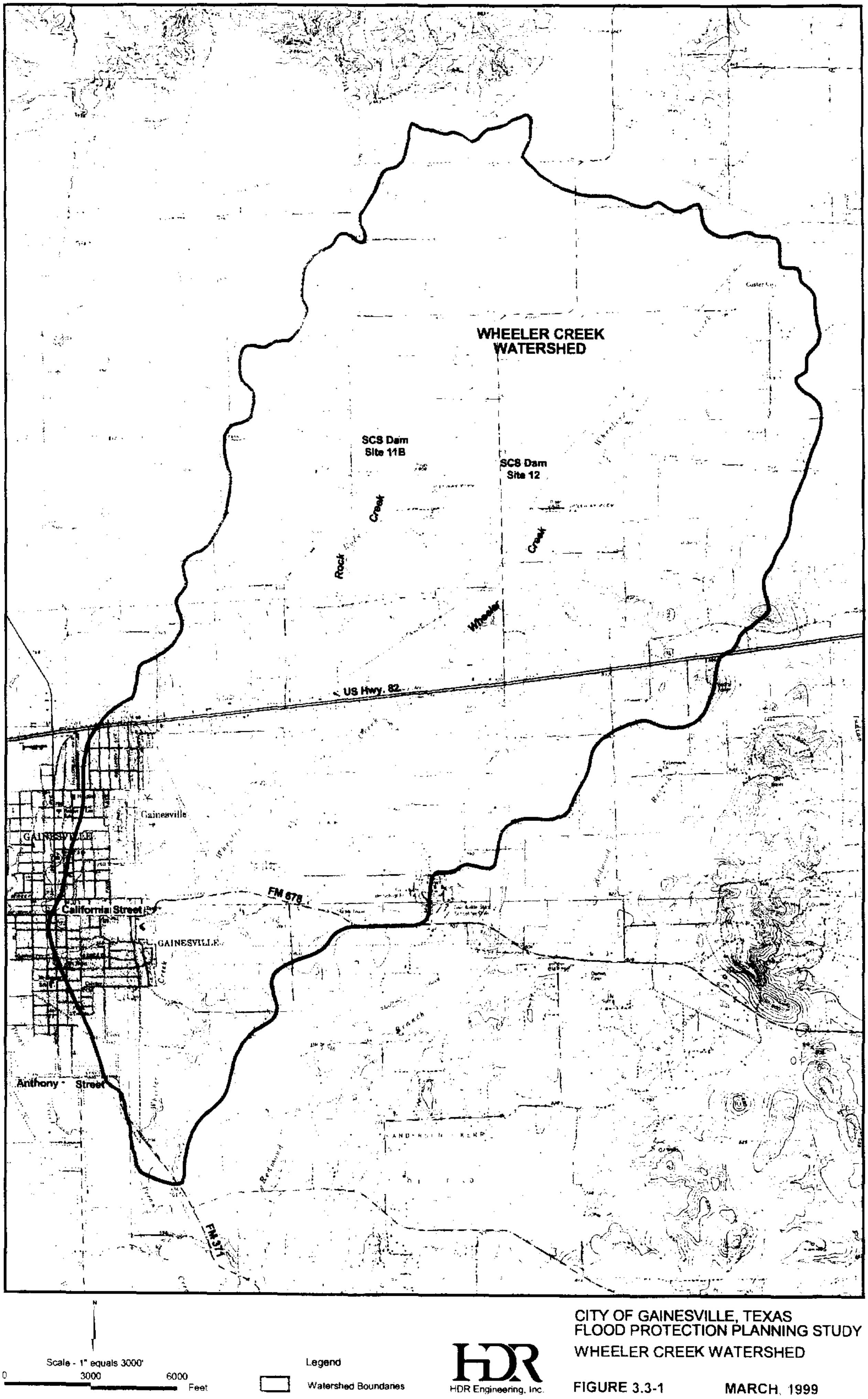
[14] Municipal Planning Resources Group, Inc., Op. Cit., October 1997.
[15] FEMA, Op. Cit., April 15, 1981.
[16] FEMA, Op. Cit., October 18, 1977.



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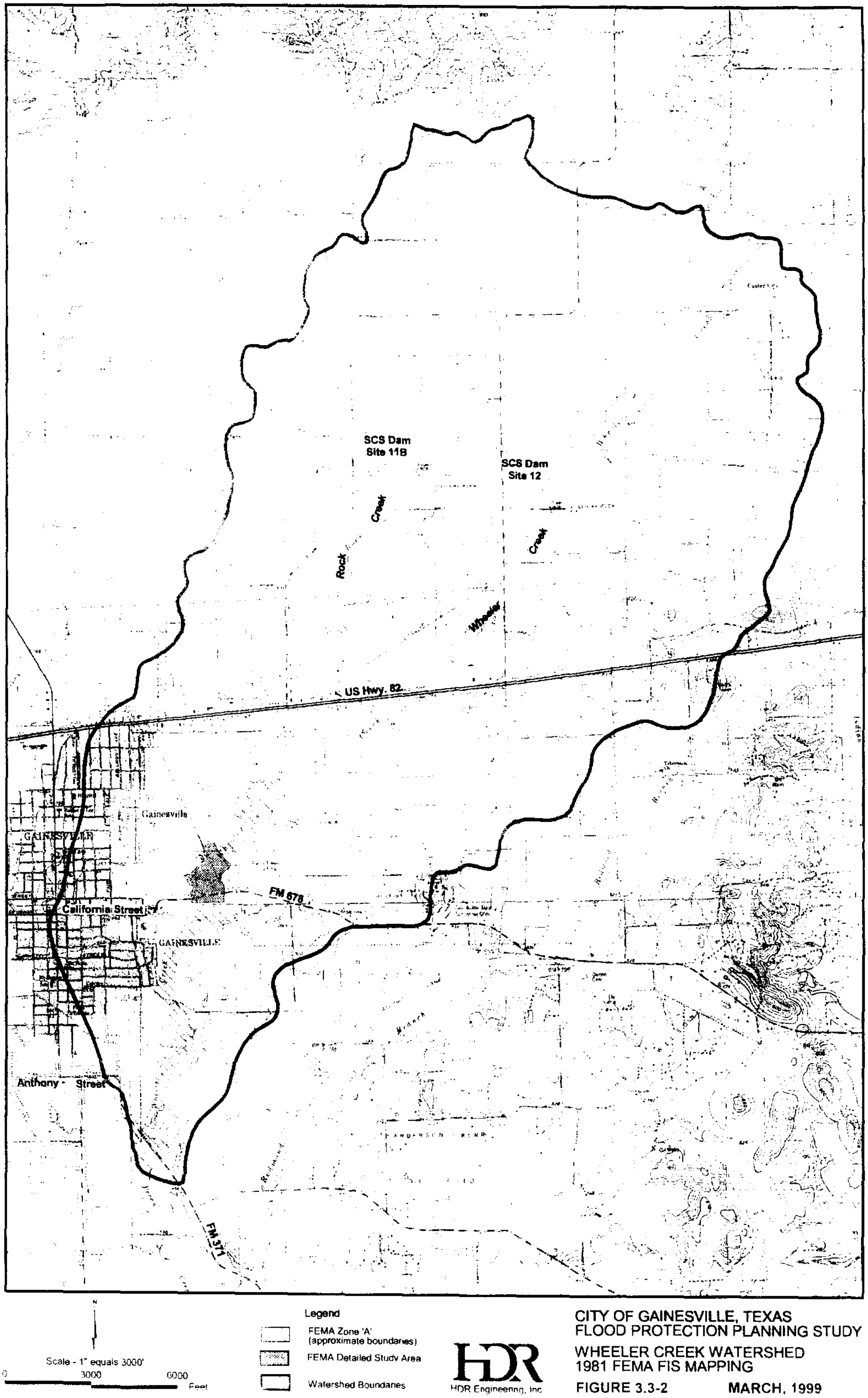
WHEELER CREEK WATERSHED

FIGURE 3.3-1 MARCH, 1999



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FLOOD PROTECTION PLANNING STUDY

WHEELER CREEK WATERSHED
1981 FEMA FIS MAPPING

FIGURE 3.3-2 MARCH, 1999

Flooding problems in the Wheeler Creek watershed are primarily associated with streamflow exceeding the capacity of the Wheeler Creek channel along the eastern fringe of the City. In addition, many other areas contributing to Wheeler Creek in the City of Gainesville do not have adequate drainage systems, which results in street flooding, and in some cases, causes damage to adjacent homes and businesses. Flood control measures have been implemented in the Wheeler Creek watershed including construction of flood control dams and channel improvements. Two flood control dams were constructed by the SCS in the Wheeler Creek watershed in the 1950s as part of the Watershed Plan for the Elm Fork Watershed.[17] SCS flood control dams were constructed in the headwaters of the Wheeler Creek (Figure 3.3-1) on the main stem of Wheeler Creek (Site 12) and on Rock Creek (Site 11B), a tributary to Wheeler Creek. Site 12 controls 3.4 sq. mi. of the Wheeler Creek watershed and Site 11B controls 2.0 sq. mi. of the Rock Creek watershed. The two flood control dams impound floodwaters from a combined total of 5.4 sq. mi. of watershed area, or 46 percent of the total watershed area (11.7 sq. mi.) at Highway 82. In addition to the flood control dams, the City is completing construction of channel improvements along a tributary to Wheeler Creek located just north of Wheeler Creek Drive in the northeast part of the City. The channel improvements consist of a concrete-lined, trapezoidal channel and were designed[18] to convey the 100-year peak runoff rate to Wheeler Creek just upstream of FM 678. The total contributing watershed for the tributary channel is about 144 acres (0.22 sq. mi.) and the channel improvements are designed to alleviate existing flooding problems along the drainage channel.

3.3.1 Flood Hydrology

A flood hydrology model was developed to simulate the rainfall-runoff process for the Wheeler Creek watershed. The HEC-1 Flood Hydrograph Package[19] was utilized to compute the peak runoff rates at key points in the drainage basin for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flood events. Runoff hydrographs were developed for each storm event

[17] U.S. Dept. of Agriculture, Soil Conservation Service, Work Plan Elm Fork Watershed of the Trinity River Watershed, Montague, Cooke, and Denton Counties, Revised June 1956.

[18] Biggs and Matthews, Inc., Wheeler Creek Drainage Improvements Project, City of Gainesville, Texas, December 1995.

[19] U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Users Manual, Davis, CA, Revised 1990.

for existing and future development conditions. Future development conditions were based on ultimate development as shown in the City of Gainesville's Comprehensive Land Use Plan. Peak runoff rates for future development conditions are expected to increase slightly due to future development in the Wheeler Creek watershed. For example, future peak runoff rates for the 100-year storm event at the confluence of Wheeler Creek and Rock Creek, just downstream of Highway 82, are expected to increase from 7,950 cfs to 8,750 cfs, a 10 percent increase. Table 3.3-1 provides a summary of existing and future peak runoff rates for selected storm events at key locations in the Wheeler Creek watershed. Detailed results of the HEC-1 model are provided in Appendix C.

Table 3.3-1.
Wheeler Creek Watershed
Summary of Peak Runoff Rates

Location	Drainage Area (sq. mi.)	Peak Runoff Rates (cfs)					
		10-year		25-year		100-year	
		Existing	Future	Existing	Future	Existing	Future
Wheeler Creek							
Site 12 Inflow	3.4	2,690	2,690	3,500	3,500	4,810	4,810
Site 12 Outflow	3.4	20	20	20	20	20	20
Highway 82	7.0	1,890	2,200	2,500	2,840	3,510	3,900
FM 678	15.6	4,400	5,050	5,720	6,260	7,710	8,100
Harris Street	17.0	4,580	5,090	6,290	6,590	8,550	8,780
Pecan Creek Conf[1].	18.0	5,010	5,290	5,330	5,580	7,640	7,890
Rock Creek							
Site 11B Inflow	2.0	1,750	1,750	2,230	2,230	2,990	2,990
Site 11B Outflow	2.0	15	15	16	16	140	140
Highway 82	4.7	1,990	2,300	2,530	2,880	3,410	3,780

[1] Location is just upstream of Pecan Creek confluence.

The SCS Flood Retardation Structures in the Wheeler Creek watershed (Site 11B and Site 12) provide significant flood reduction benefits to the City. As shown in Table 3.3-1, the peak flow at each of the dam sites is reduced to minimal levels for even the 100-year flood event. The peak flow reduction effects are translated downstream to areas within the City. Figure 3.3-3 shows the impact of the two dams on reducing the peak flow for Wheeler Creek at California

Street. If the dams were not in existence, the computed 100-year peak flow at California Street would be 11,800 cfs. The computed 100-year peak flow rate at California Street for existing conditions (with the dams in place) is 7,710 cfs, a 35 percent reduction.

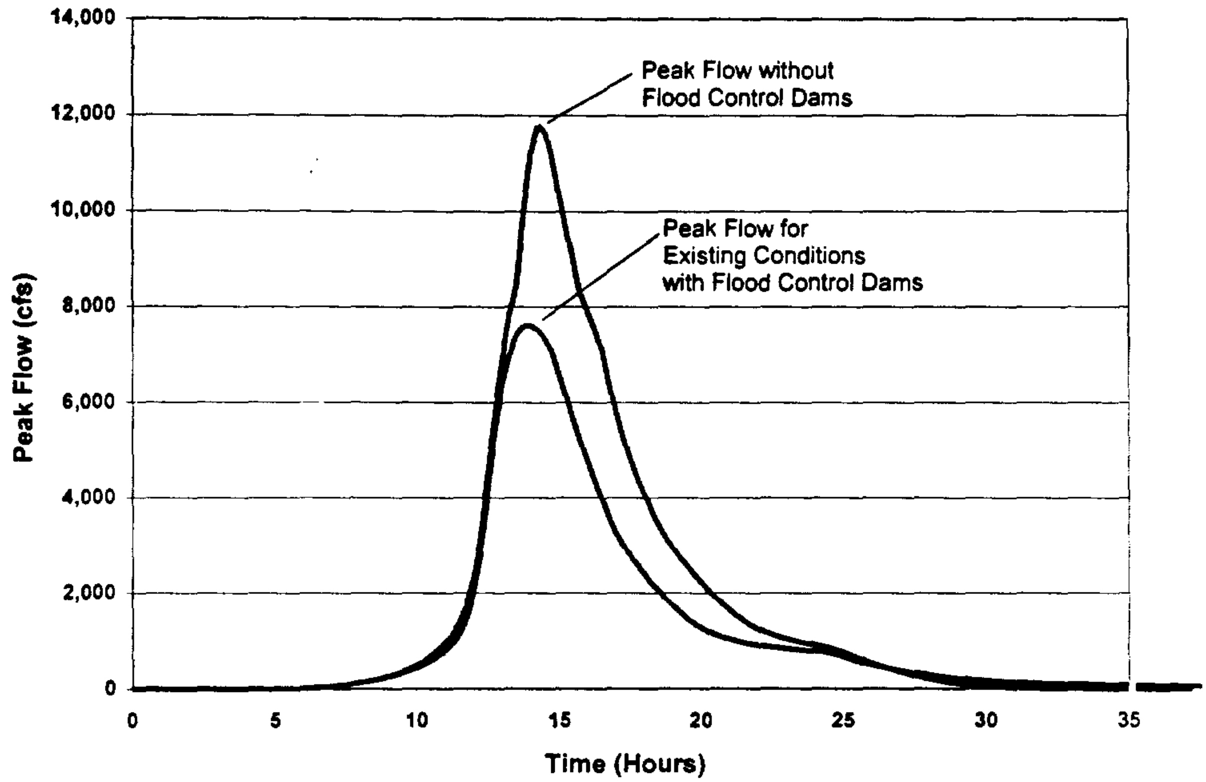


Figure 3.3-3. 100-Year Flood Peak Reduction for Existing SCS Flood Control Dams in the Wheeler Creek Watershed

3.3.2 Stream Hydraulics

HEC-RAS[20] was used to develop a stream hydraulic model to simulate flow in Wheeler Creek and selected tributaries and through the many bridges and culverts that exist in the study area. The stream hydraulic model used the peak runoff rates from the hydrologic model and computed water surface profiles (flood levels) for each storm event for 11.0 miles of stream studied in the Wheeler Creek watershed. Cross-sections of stream segments were obtained using

[20] U.S. Army Corps of Engineers, Hydrologic Engineering Center, "HEC-RAS River Analysis System," User's Manual, Davis, CA, 1995.

the City of Gainesville aerial topographic mapping[21] and supplemented with field measurements at hydraulic structures.

The stream hydraulic model was developed for several segments of Wheeler Creek that have not been mapped in detail in past studies. The existing FEMA flood plain mapping is limited to a 2,000 feet segment upstream of FM 678. The stream hydraulic model for this study extends from the confluence with Pecan Creek to about 4,000 feet upstream of Highway 82. In addition, tributaries to Wheeler Creek were also modeled including Rock Creek and other minor tributaries, as shown in Figure 3.3-4.

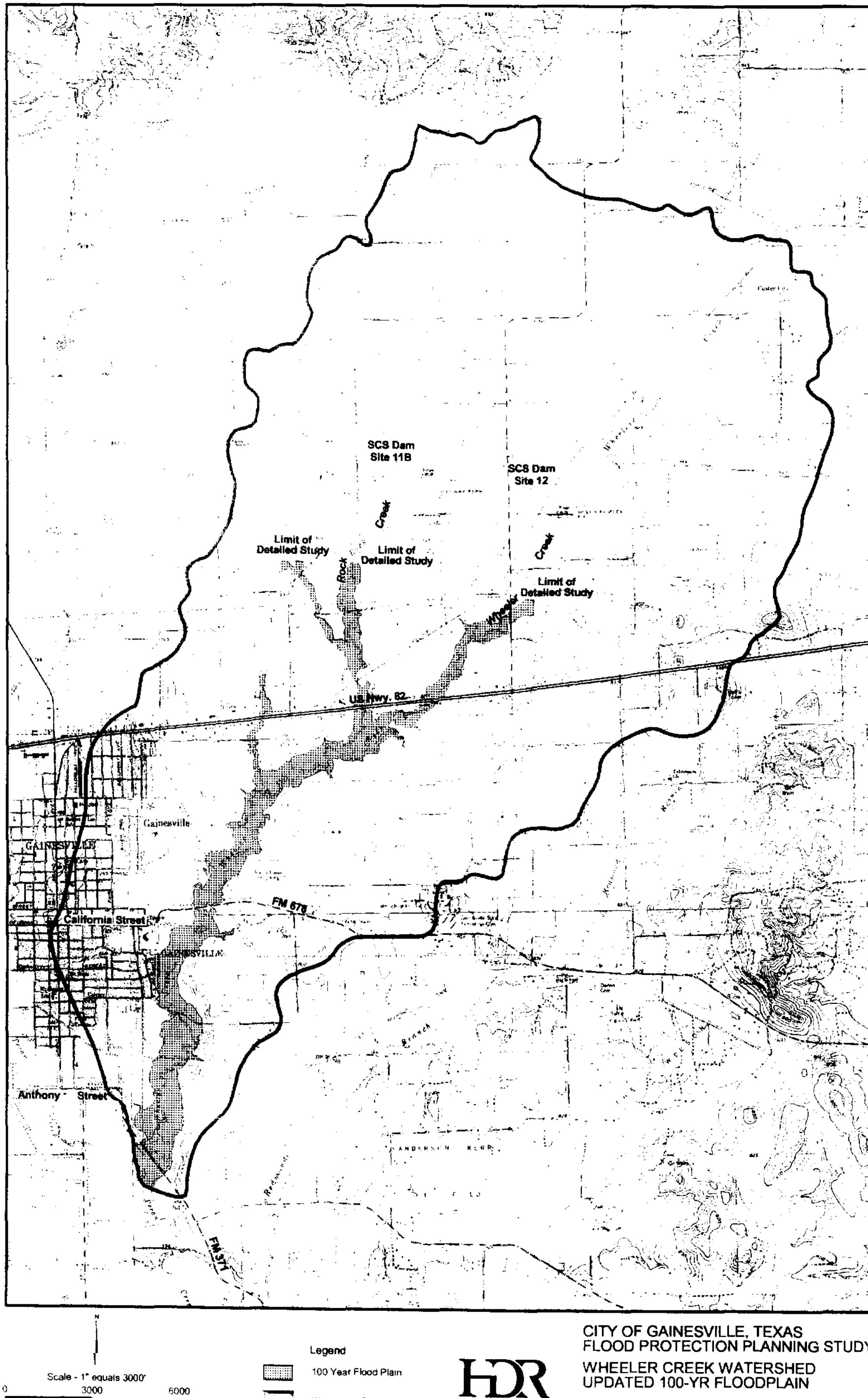
A total of 12 road and railroad crossings were analyzed in the Wheeler Creek watershed. Eight of these crossings in the Wheeler Creek watershed do not meet the City's Drainage Criteria of passing the 25-year flood event without overtopping the roadway for existing conditions. A summary of the hydraulic capacity for each crossing is presented in Table 3.3-2.

Table 3.3-2.
Wheeler Creek Watershed
Summary of Hydraulic Capacity of Stream Crossings

Location	Stream	Hydraulic Capacity[1] Return Period Flood Event Existing Conditions	Hydraulic Capacity[1] Return Period Flood Event Future Conditions	Notes[2]
CR 123	Wheeler	10-year	10-year	4b, 9-ft x 7-ft RCB
US 82	Wheeler	500-year	500-year	130-ft bridge
FM 3092	Wheeler	5-year	5-year	93-ft bridge
FM 678	Wheeler	100-year	50-year	86-ft bridge
Harris Street	Wheeler	< 2-year	< 2-year	96-ft bridge
FM 372	Wheeler	5-year	5-year	65-ft bridge
CR 138	Rock Creek	< 2-year	< 2-year	23-ft bridge
US 82	Rock Creek	500-year	500-year	104-ft bridge
CR 131	Rock Creek West	2-year	< 2-year	8-ft CMP
CR 138	Rock Creek West	< 2-year	< 2-year	6-ft CMP
US 82	Shipley Creek	25-year	5-year	2b, 6-ft x 6-ft RCB
Shipley St.	Shipley Creek	< 2-year	< 2-year	4-ft x 4-ft RCB

1 Hydraulic capacity at top of road elevation.
2 RCB – reinforced concrete box culvert, RCP – reinforced concrete pipe culvert, CMP – corrugated metal pipe.

[21] City of Gainesville, Texas, Aerial Topographic Mapping, prepared by Dallas Aerial Mapping, Inc. January, 1997.



CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

WHEELER CREEK WATERSHED
UPDATED 100-YR FLOODPLAIN

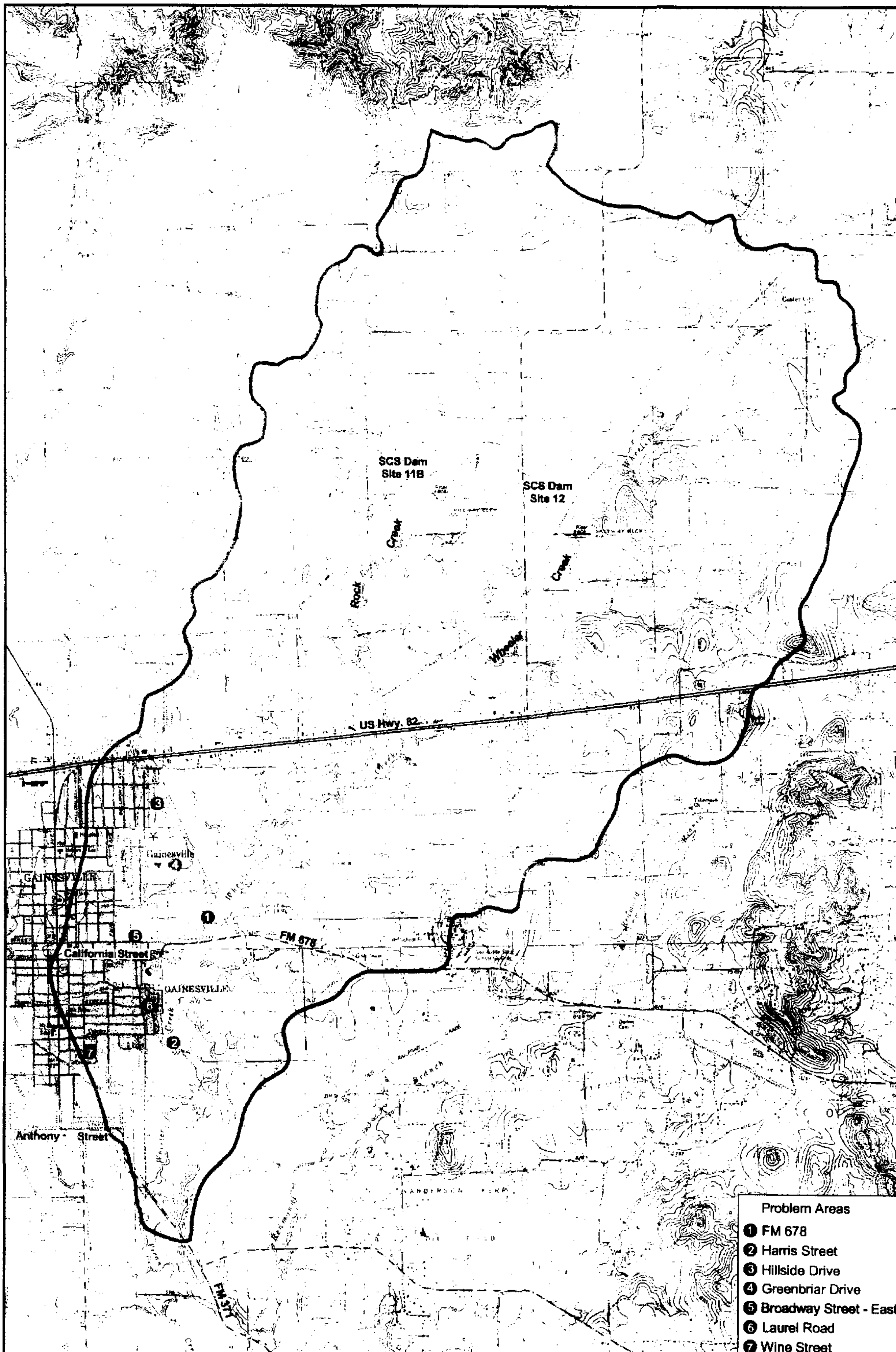
FIGURE: 3.3 - 4 MARCH, 1999

3.3.3 Problem Areas

The flood hydrology and stream hydraulic models provide the results needed for identification of areas that are not in compliance with the City's Drainage Criteria (see Section 2.4). Areas identified along Wheeler Creek and its major tributaries that do not meet the Drainage Criteria are shown in Figure 3.3-5 and summarized in Table 3.3-3 from the upstream end to the downstream end of the study area. Problem areas along Wheeler Creek include flooding of residential and commercial structures and street flooding. The problem areas were divided into major watershed and minor watershed categories. Major watershed problem areas area associated with flooding on the main channel of Wheeler Creek while minor watershed problem areas are associated with drainage problems for smaller areas contributing to Wheeler Creek. A description of each of the identified problem areas is presented in the following sections as well as an improvement plan and estimated cost for resolving the drainage problem.

Table 3.3-3.
Wheeler Creek Watershed
Problem Area Summary

Problem Area	Watershed Category	Description
FM 678 at Wheeler Creek	Major	Potential flooding of residential area upstream of FM 678 for 100-year flood event.
Harris Street at Wheeler Creek	Major	Flooding of residences upstream of Harris Street for 100-year flood event.
Hillside Drive	Minor	Excessive street flooding and flooding of residences along Hillside Drive, Rosedale Drive, Belcher Street, Aspen Drive, and O'Neal Street from runoff originating from Highway 82.
Greenbriar Drive	Minor	Street flooding along Woodlawn Drive, Everglade Drive, and Greenbriar Drive from runoff from cemetery area.
Broadway Street East	Minor	Excessive street flooding along Broadway Street from Fair Avenue to California Street. Street flooding along Fair Avenue and Belcher Street.
Laurel Road	Minor	Excessive street flooding along Laurel Road, Bridle Lane, Cherry Lane, and Howeth Street. Frequent flooding of residences at east end of Laurel Road and Bridle Lane.
Wine Street	Minor	Street flooding along Wine St. near Hemming St.



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Scale - 1" equals 3000'

0 3000 6000 Feet

Legend

Watershed Boundaries

Problem Areas

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FLOOD PROTECTION PLANNING STUDY

WHEELER CREEK WATERSHED
PROBLEM AREA LOCATIONS

FIGURE 3.3-5 MARCH, 1999

Major Watershed

The primary flooding problems along the Wheeler Creek channel in the City of Gainesville are located in the vicinity of major road crossings where residences have been constructed within or near the flood plain. These locations are just upstream of FM 678 along Wheeler Creek Drive and upstream of Harris Street along Laurel Road. These problem areas can be addressed by local channel improvements to lower flood levels or through permanent evacuation (buy out) of the affected structures. Improvement plans and project cost estimates for lowering flood levels at these locations are presented in this study. However, permanent evacuation or buy out of the affected structures should be considered prior to implementation of any of the plans.

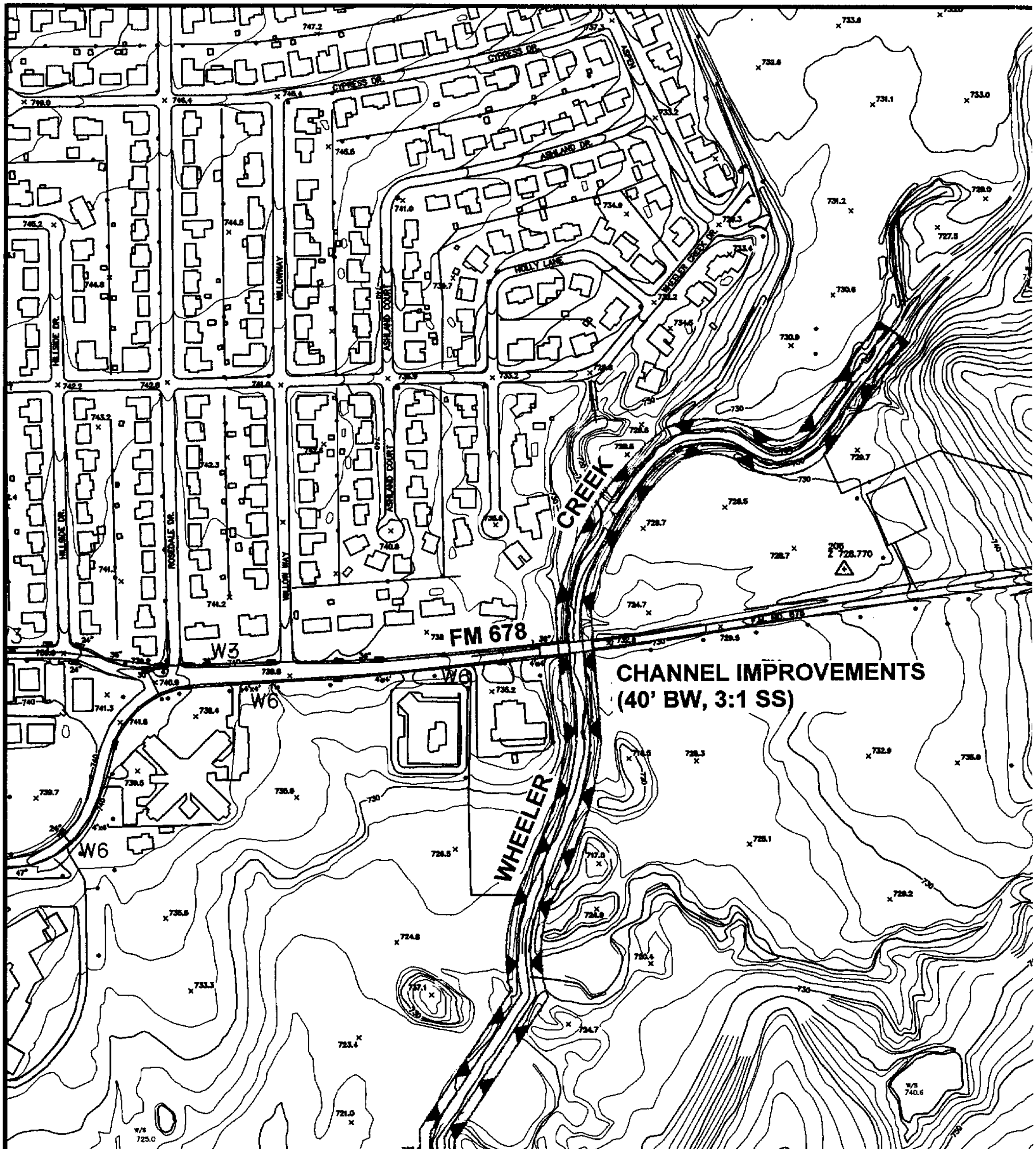
3.3.3.1 FM 678 Problem Area

The FM 678 Problem Area is defined as an area along Wheeler Creek extending from FM 678 to about 1,500 feet upstream. The primary drainage problem in this area consists of backwater from Wheeler Creek during major storm events that potentially causes flood damages

Wheeler Creek upstream of FM 678

Wheeler Creek behind residences along Wheeler Creek Drive

to about seven residences along Wheeler Creek Drive. The recommended plan for mitigating this problem is channel improvements for a 3,200 feet segment extending from 1,700 feet downstream of FM 678 to a point approximately 1,500 feet upstream. The improved channel would consist of a 40-ft bottom width, trapezoidal, grass-lined channel, as shown in Figure 3.3-6, to increase the hydraulic capacity of the creek and lower flood levels at this location. The total



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FLOOD PROTECTION PLANNING STUDY

FM 678
CHANNEL IMPROVEMENTS

FIGURE 3.3-6 **MARCH, 1999**

excavation volume for the channel improvements was estimated to be on the order of 32,500 cubic yards. The capital cost for the proposed plan is estimated to be $361,000, including engineering and contingencies, as shown in Table 3.3-4.

Table 3.3-4.
FM 678 Problem Area — Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	32,500	$6.25	$203,125
Clearing & Grubbing	acre	5.85	$3,000	$17,562
Seeding/Vegetation	square yard	28,300	$0.45	$12,735
Soil Retention Blanket	square yard	28,300	$1.00	$28,300
Subtotal				$261,722
Contingencies & Miscellaneous			15%	$39,258
Construction Cost				$300,980
Engineering, Surveying, Legal			20%	$60,199
Total Project Cost				$361,176

3.3.3.2 Harris Street Problem Area

The Harris Street Problem Area is located along Wheeler Creek extending from Harris Street approximately 2,200 feet upstream. The primary drainage problem in this area consists of backwater from Wheeler Creek for major storm events that impacts about ten residences along Laurel Road and Bridle Lane. A significant bend in the channel occurs just upstream of Harris Street which reduces the conveyance of the channel. The recommended plan for mitigating this problem is channel improvements for the segment extending from 300 feet downstream of Harris Street to a point upstream of Bridle Lane as shown in Figure 3.3-7. The channel improvements consist of a 40-ft wide bottom width,

Backwater from Wheeler Creek behind residences on Laurel Road upstream of Harris St.

trapezoidal, grass-lined channel to improve the hydraulic capacity of the existing channel and reduce the 100-year flood to an allowable level. The total excavation volume for the channel improvements was estimated to be on the order of 33,150 cubic yards. The capital cost of the proposed plan is estimated to be $350,000, including engineering and contingencies, as shown in Table 3.3-5.

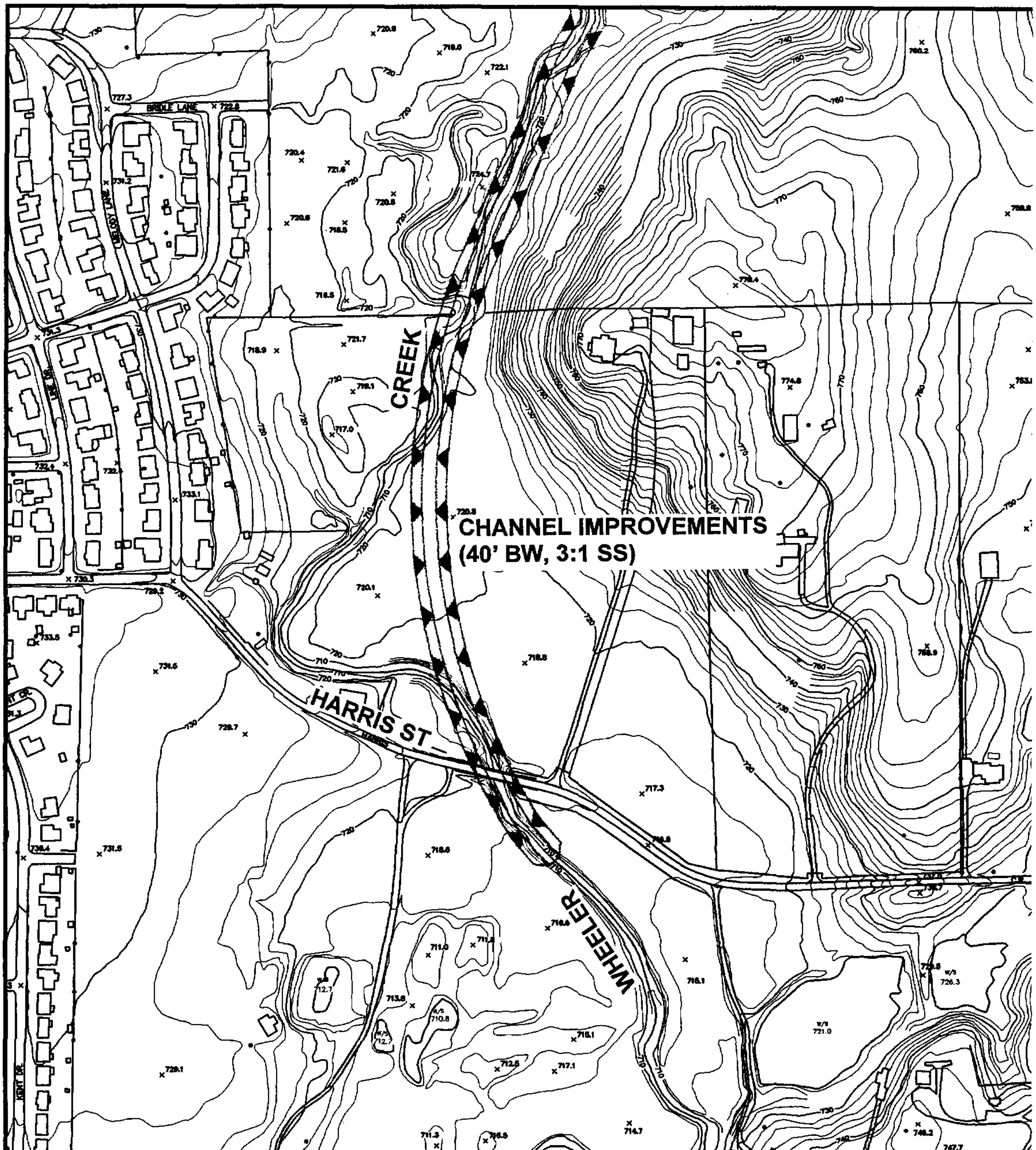
Table 3.3-5.
Harris Street Problem Area — Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	33,150	$6.25	$207,188
Clearing & Grubbing	acre	4.6	$3,000	$13,800
Seeding/Vegetation	square yard	22,300	$0.45	$10,035
Soil Retention Blanket	square yard	22,300	$1.00	$22,300
Subtotal				$253,323
Contingencies & Miscellaneous			15%	$37,998
Construction Cost				$291,321
Engineering, Surveying, Legal			20%	$58,264
Total Project Cost				$349,585

Minor Watersheds

Minor watersheds contributing runoff to Wheeler Creek in the City of Gainesville were analyzed for the interior drainage facilities needed to properly convey runoff to the main channel Wheeler Creek. A number of problem areas were identified in the study area through the public survey and engineering analyses of runoff rates compared to system capacity. A total of five problem areas associated with minor watersheds in Wheeler Creek were identified as summarized in Table 3.3-3 and shown in Figure 3.3-5.

The problem areas associated with minor watersheds are primarily resulting from street flooding. In most areas, the recommended plan will be construction of underground storm sewer systems to remove surface runoff from the streets and convey it to Wheeler Creek. Storm sewer systems are usually the only feasible solution due to dense urban development and limited right-of-way available for construction of more economical alternatives such as open channels. Storm sewer systems are expensive to implement, especially in a scenario involving retrofitting an



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HARRIS STREET
CHANNEL IMPROVEMENTS

FIGURE 3.3-7 MARCH, 1999

already developed area. The cost of the system is increased due to the cost of restoring the street after construction and coordination with other existing utilities. Benefits of the proposed improvements will be far reaching including:

- Reduction in flood damages to existing residences and businesses;
- Reduction in risk to public health and safety; and
- Increased life of street pavements as a direct result of improved drainage.

3.3.3.3 Hillside Drive Problem Area

The Hillside Drive Problem Area is located in the northeast part of the City of Gainesville, south of Highway 82 and east of Grand Avenue (Figure 3.3-5). Drainage problems in this area have been reported along Hillside Drive between Summa Street and Beecher Street, Rosedale Street, Beecher Street, Aspen Drive, and O'Neal Street. Problems reported in this area include street flooding originating from the Highway 82 area that flows south along Magnolia Street and exceeds the capacity of the street. Flow above curb level has been reported at several locations in the area and has resulted in flooding of homes along Hillside Drive and Rosedale Street. Runoff originating from the Highway 82 area travels south to O'Neal Street. At O'Neal Street, flow generally travels east to a small tributary of Wheeler Creek near The Creek subdivision. The total drainage area at O'Neal Street and Aspen Street is approximately 94 acres and the 25-year and 100-year storm peak runoff rates were estimated to be approximately 250 cfs and 340 cfs, respectively. The estimated street capacity of O'Neal Street near the Aspen Street intersection is approximately 40 cfs to 50 cfs at the top of curb level. Similarly, the 25-year storm event was found to produce peak runoff rates that exceed four to five times the street capacity at several other locations in the area.

The recommended plan for mitigating this drainage problem is construction of a storm sewer system to convey runoff underground along Magnolia Street, Beecher Street, O'Neal Street, and Aspen Street, as shown in Figure 3.3-8. A storm sewer system is essentially the only feasible solution for alleviating flood problems in this area due to the level of development that presently exists and the lack of available right-of-way to construct other alternatives such as open channels. The storm sewer system will include underground pipes that range in diameter from 42-inches in diameter near Highway 82 to 60-inches in diameter at Aspen Street near the lower

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HILLSIDE DRIVE
STORM SEWER IMPROVEMENTS

FIGURE 3.3-8 MARCH, 1999

end of the problem area. The outlet for the storm sewer system will be located at the tributary channel at the end of O'Neal Street near The Creek subdivision. Implementation of the plan will also relieve flooding that occurs along Summa Street. A small storm sewer system exists in Summa Street and upstream runoff currently overwhelms the system's capacity. The proposed plan will divert water from the Summa Street system through the proposed storm sewer system and reduce runoff to the existing Summa Street system. The capital cost of the proposed plan is estimated to be $1,300,000, including engineering and construction contingencies, as shown in Table 3.3-6.

Table 3.3-6.
Hillside Drive Problem Area
Project Cost Estimate

Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Road Excavation	cubic yard	8,350	$12.00	$100,200
Pavement Cut/Repair	square feet	29,000	$3.50	$101,500
Trench Safety	linear feet	5,410	$3.50	$18,935
Storm Sewer Inlet (10-ft)	each	31	$2,100	$65,100
Storm Sewer Inlet (20-ft)	each	5	$4,000	$20,000
Manhole	each	7	$4,000	$28,000
18-inch RCP	linear feet	590	$29	$17,110
24-inch RCP	linear feet	650	$32	$20,800
36-inch RCP	linear feet	430	$55	$23,650
42-inch RCP	linear feet	410	$65	$26,650
48-inch RCP	linear feet	400	$80	$32,000
54-inch RCP	linear feet	1,950	$100	$195,000
60-inch RCP	linear feet	650	$165	$107,250
7-ft x 5-ft RCB	linear feet	600	$310	$186,000
Subtotal				$942,195
Contingencies & Miscellaneous			15%	$141,329
Construction Cost				$1,083,524
Engineering, Surveying, Legal			20%	$216,705
Total Project Cost				$1,300,229

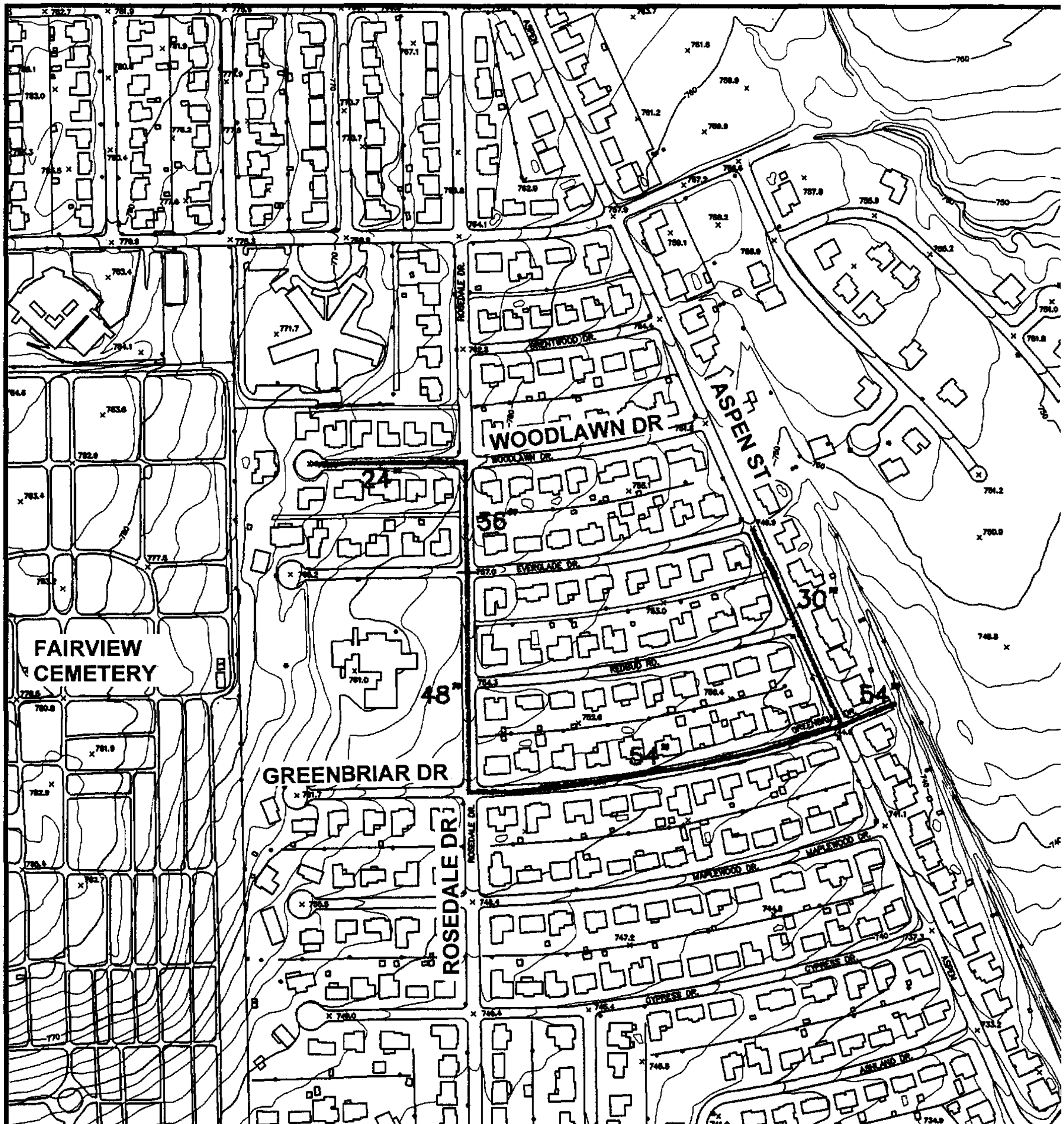
3.3.3.4 Greenbriar Drive Problem Area

The Greenbriar Drive Problem Area is located in the northeast part of the City of Gainesville south of Highway 82 and east of Fair Avenue (Figure 3.3-5). The area is located east of the City cemetery and runoff originating from the cemetery flows east through the area. Drainage problems have been reported along Woodlawn Drive, Everglade Drive, and Greenbriar Drive and primarily consist of severe street flooding. At the intersection of Greenbriar Drive and Rosedale Drive, the total drainage area is approximately 40 acres. The 25-year and 100-year storm peak runoff rates were estimated to be on the order of 140 cfs and 200 cfs, respectively. The flow capacity of Greenbriar Drive at this location is approximately 40 cfs at curb level.

The recommended plan for improving drainage in this area is construction of a storm sewer system along Woodlawn Drive, Rosedale Drive, Greenbriar Drive, and Aspen Drive, as shown in Figure 3.3-9. A storm sewer system is essentially the only feasible solution for improving drainage as this area is heavily developed and there is limited right-of-way available for construction of open channels. The storm sewer system is proposed to have underground pipes ranging in size from 24-inches to 54-inches in diameter. The outlet of the system is proposed to be located in the concrete-lined channel that is being constructed just east of Aspen Drive. The plan will not significantly increase the peak runoff rate in the channel as it does not alter the drainage path for existing conditions. The total cost for the proposed storm sewer system is estimated to be $600,000, including engineering and construction contingencies, as shown in Table 3.3-7.

3.3.3.5 Broadway Street East Problem Area

The Broadway Street East Problem Area covers a rather large area of the east-central portion of the City of Gainesville located north of California Street and east of Grand Avenue, (Figure 3.3-5). Flooding problems in this area are associated with excessive street flooding at several locations including Broadway Street, Beecher Street, Fair Avenue, and Hillside Drive. The intersection of Broadway Street and Fair Avenue is an area that floods on a frequent basis. Under existing conditions, runoff originating as far north as O'Neal Street flows to the Broadway



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GREENBRIAR DRIVE
STORM SEWER IMPROVEMENTS

FIGURE 3.3-9 MARCH, 1999

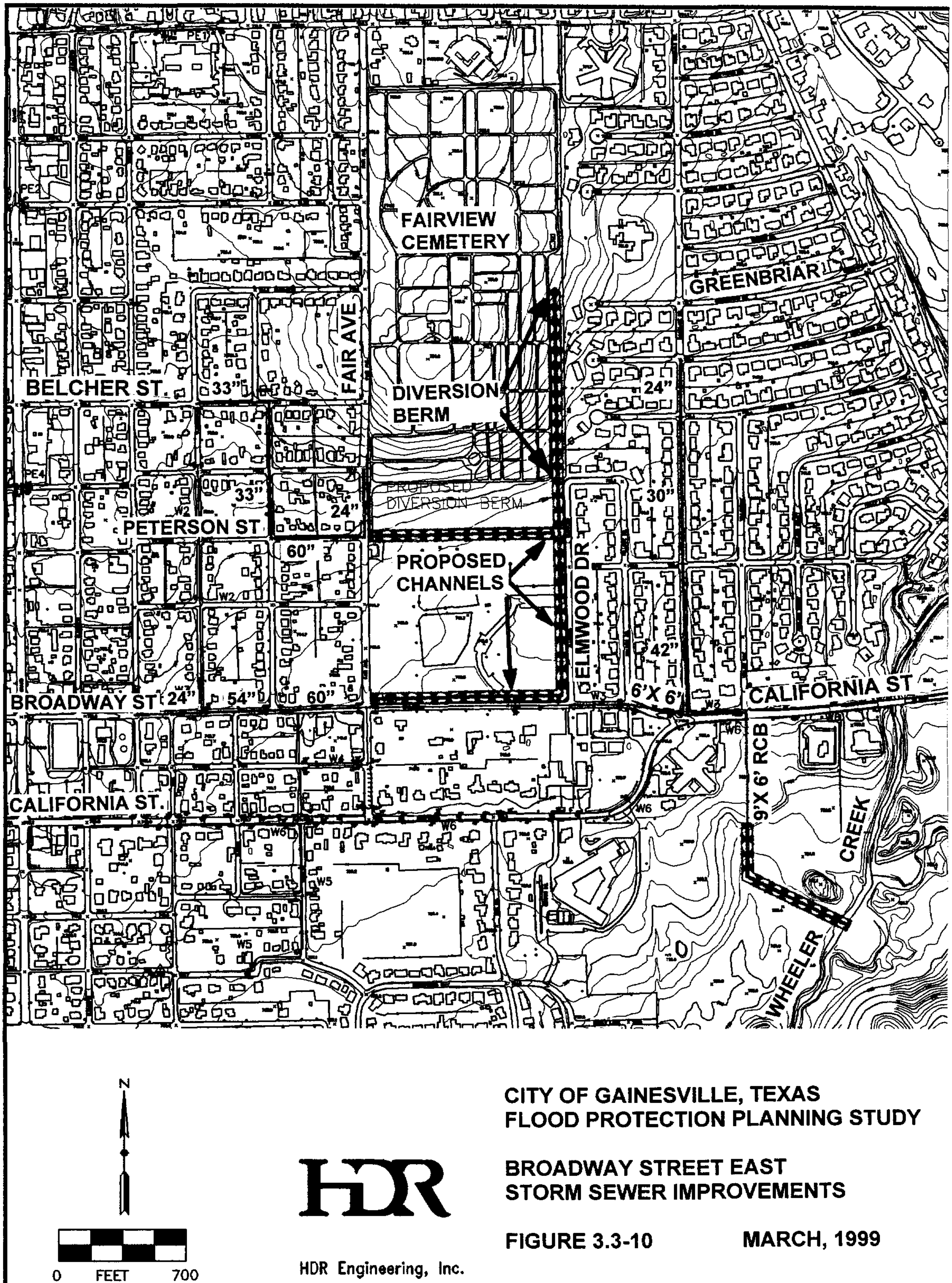
Table 3.3-7.
Greenbriar Drive Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Road Excavation/Backfill	cubic yard	4,056	$12.00	$48,672
Pavement Cut/Repair	square feet	15,525	$3.50	$54,338
Trench Safety	linear feet	3,150	$3.50	$11,025
Storm Sewer Inlet (10-ft)	each	28	$2,100	$58,800
Storm Sewer Inlet (20-ft)	each	3	$4,000	$12,000
Manhole	each	4	$4,000	$16,000
Storm Sewer (18-in RCP)	linear feet	270	$29	$7,830
Storm Sewer (24-in RCP)	linear feet	450	$32	$14,400
Storm Sewer (30-in RCP)	linear feet	600	$45	$27,000
Storm Sewer (36-in RCP)	linear feet	300	$55	$16,500
Storm Sewer (48-in RCP)	linear feet	600	$80	$48,000
Storm Sewer (54-in RCP)	linear feet	1,200	$100	$120,000
Subtotal				$434,565
Contingencies & Miscellaneous			15%	$65,185
Construction Cost				$499,749
Engineering, Surveying, Legal			20%	$99,950
Total Project Cost				$599,699

Street and Fair Avenue intersection. The proposed Olive Street storm sewer system (see Section 3.2.3.7) is planned to remove that portion of flow from the Broadway Street area and convey it to Pecan Creek. Broadway Street also receives a large amount of runoff from the cemetery area located to the north. An existing storm sewer system is located along Broadway Street that removes some of the surface runoff and conveys it east to Wheeler Creek. However, the maximum pipe size for this system is 36-inches in diameter from Fair Avenue to Wheeler Creek and the system capacity is exceeded on a frequent basis. Runoff that exceeds the capacity of the existing storm sewer system flows east from the intersection of Broadway Street and Fair Avenue to the intersection of Broadway Street and California Street. The street slope along this segment of Broadway Street is extremely flat at less than six inches of elevation decrease over 1,100 feet. This results in wide spread flooding and slow drainage. TxDOT constructed a storm sewer system along California Street extending from near Clements Street to Wheeler Creek in 1996. The California Street storm sewer system has decreased street flooding along California Street including the intersection of Broadway Street and California Street. The California Street storm sewer system is significantly larger than the existing Broadway Street system with three times the number of storm sewer inlets and larger underground pipes to convey runoff to Wheeler Creek.

The recommended plan for this area is to construct a new storm sewer system at several locations in combination with open channels in areas that have adequate right-of-way available, as shown in Figure 3.3-10. The proposed storm sewer system would begin near the intersection of Beecher Street and Cunningham Street and extend downstream along Howeth Street and Peterson Street to the intersection of Fair Avenue and Peterson Street. An open channel is proposed to begin at the intersection of Fair Avenue and Peterson Street to convey flow east to near Elmwood Street by crossing an open area south of and parallel to an existing fence for the cemetery to near Elmwood Street. The channel is proposed to cross an area that is proposed for future cemetery expansion and culverts may be constructed across the channel in the future for vehicular and pedestrian traffic when the cemetery is expanded to the south. This portion of the proposed plan will alleviate street flooding along Beecher Street and Fair Avenue as well as divert a significant portion of the runoff that presently enters the intersection of Broadway Street and Fair Avenue. A small diversion berm is proposed to be constructed along the east boundary of the cemetery area extending from just north of Greenbriar Drive to near Elmwood Drive at the south end. The purpose of the diversion berm is to prevent runoff from the cemetery area from flooding homes near Maplewood Drive and to prevent street flooding along Elmwood Drive. Flow travelling south along the diversion berm is planned to enter a new open channel that will parallel Elmwood Drive and convey flow south to the intersection of Broadway Street and Elmwood Drive. The open channel along Elmwood Drive would also intercept flow from the open channel originating at the intersection of Fair Avenue and Peterson Street. A new storm

Proposed route of new channel from Fair Ave to Elmwood St.



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BROADWAY STREET EAST
STORM SEWER IMPROVEMENTS

FIGURE 3.3-10 MARCH, 1999

sewer system is also proposed along Broadway Street extending from the Ritchey Street intersection to the Fair Avenue intersection. At the Fair Avenue intersection, the Broadway Street storm sewer system would discharge into a proposed open channel located parallel to and north of Broadway Street in an existing park area. The proposed open channel would be grass-lined with 3:1 side slopes and would be eight feet in depth. The channel will convey runoff originating north and west of Fair Avenue to the Elmwood Drive intersection as well as intercept runoff from the upstream park area. At the intersection of Broadway Street and Elmwood Drive, the open channels would enter an underground system (6-ft by 6-ft RCB) to convey the flow under Broadway Street to near the intersection of California Street and Willow Way Drive. A secondary storm sewer system is proposed along Rosedale Street to alleviate street flooding in that area and convey it to the proposed Broadway Street system. At the intersection of Willow Way Drive and California Street, the proposed Broadway Street system would combine with TxDOT's California Street storm sewer system. A new 9-foot by 6-foot reinforced concrete box would convey the combined flows south across an open field approximately 600 feet to a point where it would discharge into an open channel and flow south into Wheeler Creek.

Proposed location of outlet of new system at California Street near Willow Way Drive.

The proposed Broadway Street system is extensive, but it will also mitigate drainage problems in a number of areas that experience frequent flooding. The proposed system could also be constructed in phases and certain elements of the plan could be delayed such as the Rosedale Street storm sewer and the Beecher Street, Howeth Street, and Peterson Street systems. It should be noted that excluding elements of the plan will reduce the capacity of other segments, however, drainage conditions will be vastly improved compared to existing conditions. The capital cost of the proposed Broadway Street system is estimated to be $2,300,000, including engineering and construction contingencies, as shown in Table 3.3-8. If the open channel along Broadway Street were preferred to be replaced with an underground system, it would require installation of a 6-ft by 6-ft concrete box and additional inlets. The capital cost of the system would be estimated to increase by $444,000 to $2,744,000 for this option.

Table 3.3-8.
Broadway Street East Problem Area
Project Cost Estimate

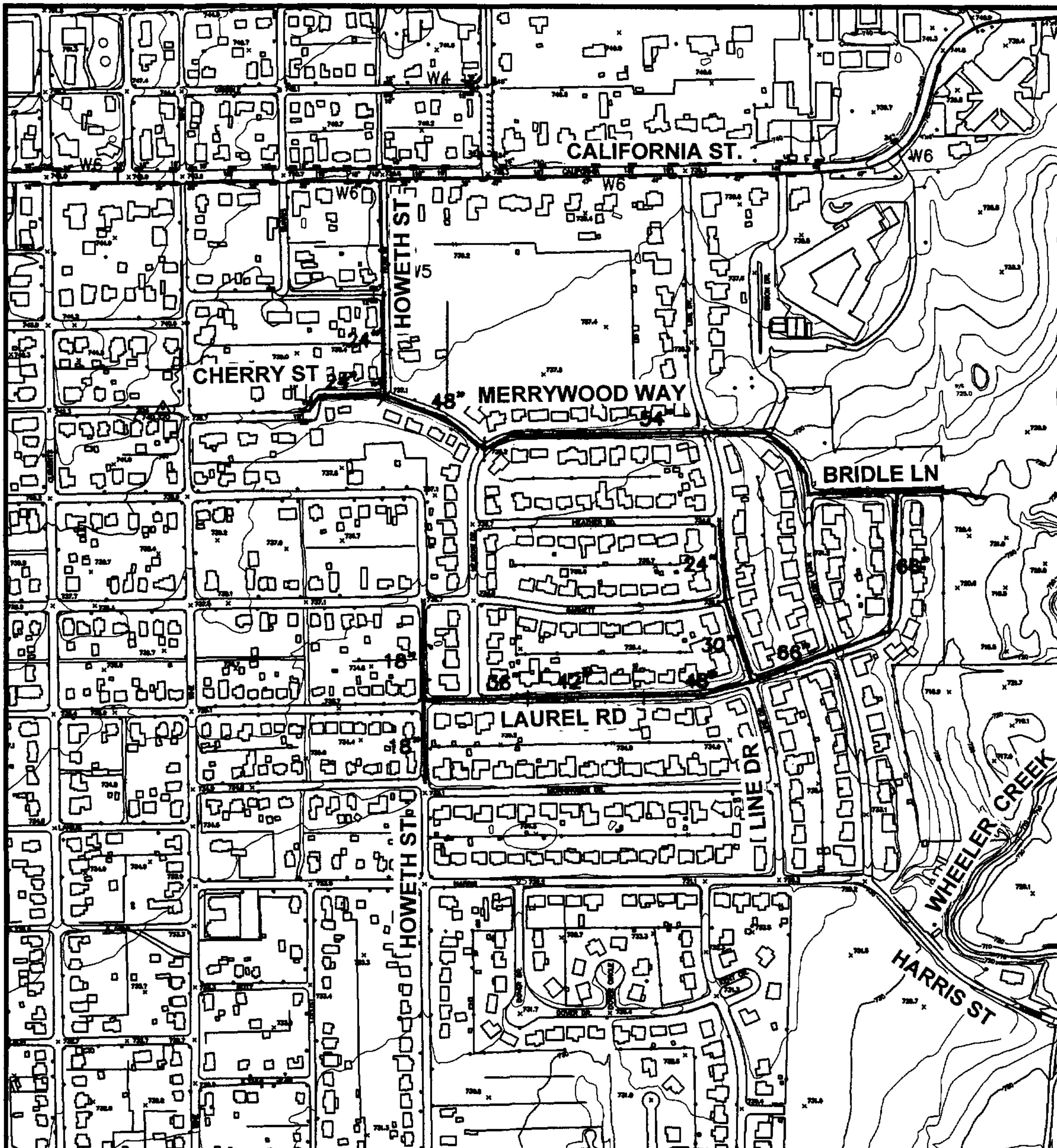
Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	32,900	$6.25	$205,625
Trench Excavation/Backfill	cubic yard	2,300	$4.25	$9,775
Road Excavation/Backfill	cubic yard	8,990	$12.00	$107,880
Seeding/Vegetation	square yard	25,800	$0.45	$11,610
Soil Retention Blanket	square yard	25,800	$1.00	$25,800
Concrete Riprap	square feet	5,400	$5.50	$29,700
Pavement Cut/Repair	square feet	33,000	$3.50	$115,500
Trench Safety	linear feet	7,220	$3.50	$25,270
Storm Sewer Inlet (10-ft)	each	36	$2,100	$75,600
Storm Sewer Inlet (20-ft)	each	8	$4,000	$32,000
Manhole	each	9	$4,000	$36,000
Storm Sewer (18-in RCP)	linear feet	270	$29	$7,830
Storm Sewer (24-in RCP)	linear feet	1,050	$32	$33,600
Storm Sewer (30-in RCP)	linear feet	830	$45	$37,350
Storm Sewer (33-in RCP)	linear feet	1,350	$50	$67,500
Storm Sewer (42-in RCP)	linear feet	840	$65	$54,600
Storm Sewer (54-in RCP)	linear feet	400	$100	$40,000
Strom Sewer (60-in RCP)	linear feet	1,080	$165	$178,200
Storm Sewer (6-ft x 6-ft RCB)	linear feet	1,020	$297	$306,000
Storm Sewer (9-ft x 6-ft RCB)	linear feet	650	$410	$266,500
Subtotal				$1,666,340
Contingencies & Miscellaneous			15%	$249,951
Construction Cost				$1,916,291
Engineering, Surveying, Legal			20%	$383,258
Total Project Cost				$2,299,549

3.3.3.6 Laurel Road Problem Area

The Laurel Road Problem Area is located in the southeast part of the City of Gainesville south of California Street and east of Grand Avenue (Figure 3.3-5). Drainage problems in the area include street flooding at several locations and flooding of residences at the east end of Laurel Road. In general, surface runoff in this area flows in the streets to the east, converges near the intersection of Laurel Road and Bridle Lane, and then flows into a small natural channel to Wheeler Creek. No storm sewer systems exist in the area and all of the surface runoff is conveyed on the streets to the Wheeler Creek channel. Residences along the east side of Laurel Road experience frequent flooding as runoff from the upstream drainage area of about 59 acres exceeds the top of curb level. The peak runoff rate for the 25-year storm event for Laurel Road near the Bridle Lane intersection was estimated to be on the order of 180 cfs compared to an estimated street capacity of about 30 cfs. Based on the estimated street capacity, flooding would be estimated to occur even for storm events as small as a 2-year return period. The peak runoff rate for the 25-year storm event for Bridle Lane upstream of the Laurel Road intersection was estimated to be on the order of 160 cfs for the 47-acre drainage area. The estimated street capacity for Bridle Lane is also on the order of 30 cfs and Bridle Lane also experiences frequent flooding. The combined drainage area at the intersection of Laurel Road and Bridle Lane is 106 acres and the estimated 25-year storm peak runoff rate is approximately 280 cfs.

Street flooding along Laurel Road for a minor storm event

The recommended plan for alleviating flooding in this area is construction of a storm sewer system to convey the surface runoff underground to Wheeler Creek. Limited right-of-way availability precludes other alternatives such as open channels. The proposed storm sewer system extends from Cherry Lane and Howeth Street to Merrywood Way and to Bridle Lane, as shown in Figure 3.3-11. A storm sewer system is also proposed to begin along Howeth Street at



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LAUREL ROAD
STORM SEWER IMPROVEMENTS

FIGURE 3.3-11 MARCH, 1999

the west end of Laurel Road and extend east to the Bridle Lane intersection. At the intersection of Laurel Road and Bridle Lane, the two systems would converge and discharge into an open channel that would convey the flow to Wheeler Creek. The total cost for the Laurel Road storm sewer system is estimated to be $1,465,000, including engineering and construction contingencies, as shown in Table 3.3-9.

Table 3.3-9.
Laurel Road Problem Area
Project Cost Estimate

Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Road Excavation/Backfill	cubic yard	9,300	$12.00	$111,600
Pavement Cut/Repair	square feet	32,900	$3.50	$115,150
Trench Safety	linear feet	6,340	$3.50	$22,190
Storm Sewer Inlet (10-ft)	each	35	$2,100	$73,500
Storm Sewer Inlet (20-ft)	each	5	$4,000	$20,000
Manhole	each	8	$4000	$32,000
Storm Sewer (18-in RCP)	linear feet	650	$29	$18,850
Storm Sewer (24-in RCP)	linear feet	930	$32	$29,760
Storm Sewer (30-in RCP)	linear feet	300	$45	$13,500
Storm Sewer (36-in RCP)	linear feet	370	$55	$20,350
Storm Sewer (42-in RCP)	linear feet	400	$65	$26,000
Storm Sewer (48-in RCP)	linear feet	770	$80	$61,600
Storm Sewer (54-in RCP)	linear feet	800	$100	$80,000
Storm Sewer (60-in RCP)	linear feet	800	$165	$132,000
Storm Sewer (66-in RCP)	linear feet	1,000	$180	$180,000
Storm Sewer (8-ft x 6-ft RCB)	linear feet	320	$390	$124,800
Subtotal				$1,061,300
Contingencies & Miscellaneous			15%	$159,195
Construction Cost				$1,220,495
Engineering, Surveying, Legal			20%	$244,099
Total Project Cost				$1,464,594

3.3.3.7 Wine Street Problem Area

The Wine Street Problem Area is located in the southeast part of the City of Gainesville east of Grand Avenue and north of Moss Street (Figure 3.3-5). Drainage problems in this area are primarily street flooding along Wine Street at Moss Street just east of Clements Street. Surface runoff that enters Wine Street from as far north as Truelove Street currently flows south to the abandoned railroad grade near Moss Street. Storm sewer systems proposed along Tennie Street and Lanius Street (se Sections 3.2.3.13 and 3.2.3.14) will divert a portion of this runoff to Pecan Creek. The remaining portion of the runoff in Wine Street will still exceed the street capacity at the south end of Wine Street. The total drainage area at the south end of Wine Street is approximately 25 acres assuming runoff north of Lanius Street is diverted by the proposed Lanius Street system. The 25-year storm peak runoff rate for this area is approximately 100 cfs and the estimated street capacity for Wine Street is on the order of 20 cfs at top of curb level. In order to alleviate street flooding in this area, a storm sewer system is required.

The recommended plan for the Wine Street Problem Area is construction of a storm sewer system along Leach Street, Doty Street, and Wine Street to intercept surface runoff and convey it underground to the existing drainage channel along the abandoned railroad grade, as shown in Figure 3.3-12. Minor channel modifications along the abandoned railroad grade are recommended. It is also recommended that the existing 48-inch diameter culvert under Howeth Street near Moss Street be expanded by installing an additional 48-inch diameter barrel. The capital cost for the proposed Wine Street system is estimated to be $362,000, including engineering and contingencies, as shown in Table 3.3-10.

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WINE STREET
DRAINAGE IMPROVEMENTS

FIGURE 3.3-12 MARCH, 1999

Table 3.3-10.
Wine Street Problem Area
Project Cost Estimate

Item	Units	Quantity	Unit Cost	Total Cost
Channel Excavation	cubic yard	1,750	$6.25	$10,938
Road Excavation/Backfill	cubic yard	2,300	$12.00	$27,600
Seeding/Vegetation	square yd	2,600	$0.45	$1,170
Soil Retention Blanket	square yd	2,600	$1.00	$2,600
Pavement Cut/Repair	square feet	9,250	$3.50	$32,375
Trench Safety	linear feet	2.385	$3.50	$8,348
Storm Sewer Inlet (10-ft)	each	9	$2,100	$18,900
Storm Sewer Inlet (20-ft)	each	2	$4,000	$8,000
Manhole	each	3	$4000	$12,000
Storm Sewer (18-in RCP)	linear feet	330	$29	$9,570
Storm Sewer (24-in RCP)	linear feet	830	$32	$26,560
Storm Sewer (33-in RCP)	linear feet	475	$50	$23,750
Storm Sewer (54-in RCP)	linear feet	750	$100	$75,000
Headwall	each	1	$1,500	$1,500
Culvert (48-in RCP)	linear feet	35	$80	$2,800
Subtotal				$262,610
Contingencies & Miscellaneous			15%	$39,392
Construction Cost				$302,002
Engineering, Surveying, Legal			20%	$60,400
Total Project Cost				$362,402

3.3.4 Summary

A summary of the problem areas, recommended improvements, and capital costs for the Wheeler Creek watershed is provided in Table 3.3-11. The total capital cost of all the recommended improvements is $6,738,000.

Table 3.3-11.
Wheeler Creek Watershed
Summary of Recommended Improvements

Problem Area	Watershed Category	Recommended Improvements	Estimated Capital Cost
FM 678 at Wheeler Creek	Major	Channel improvements upstream of FM 678 to reduce flood levels along Wheeler Creek Addition.	$361,000
Harris St at Wheeler Creek	Major	Channel improvements and realignment upstream of Harris St. to reduce flood levels upstream of Harris St.	$350,000
Hillside Drive	Minor	Storm sewer system improvements along Magnolia St., Belcher St., O'Neal St., and Aspen St. to reduce street flooding and flooding of area residences	$1,300,000
Greenbriar Drive	Minor	Storm sewer system improvements along Everglade Drive and Greenbriar Drive to reduce street flooding and potential flooding of adjacent residences.	$600,000
Broadway Street East	Minor	Storm sewer system improvements along Howeth St., Peterson St., Fair Ave, Broadway St. and Rosedale Dr. Channel improvements along Broadway St. and Fair Ave. to reduce street flooding and flooding of local residences.	$2,300,000
Laurel Road	Minor	Storm sewer system improvements along Laurel Road and Bridle Lane to reduce street flooding and flooding of homes along Laurel Road and Bridle Lane.	$1,465,000
Wine Street	Minor	Storm sewer system improvements along Wine St. to reduce street flooding.	$362,000
		Total	**$6,738,000**

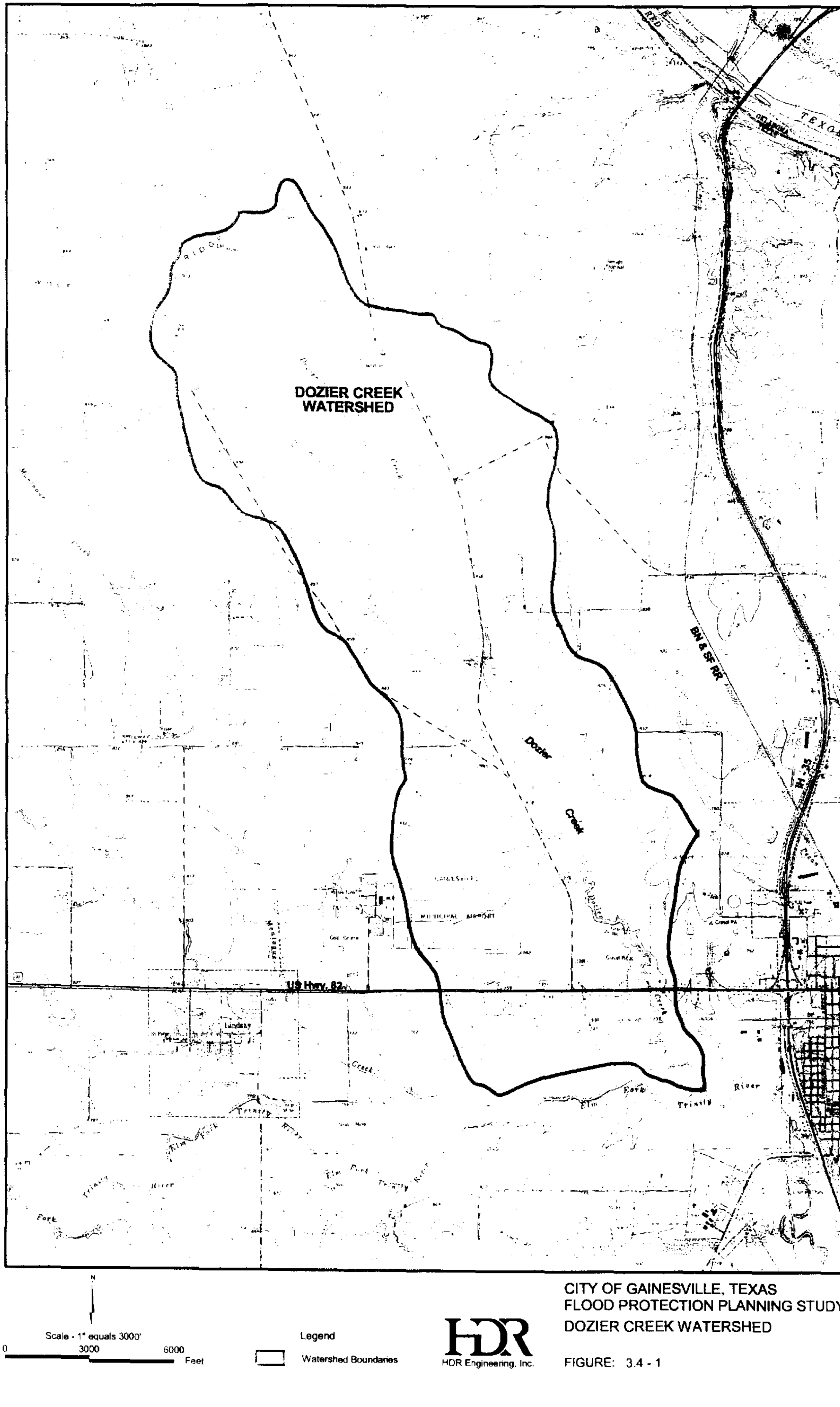
3.4 Dozier Creek Watershed

Dozier Creek originates in the north-central portion of Cooke County and extends downstream along the western edge of the City of Gainesville, as shown in Figure 3.4-1. The Dozier Creek floodplain extends across the west side of the City causing no significant flood problems. The watershed covers about 8.3 sq. mi. at Highway 82 and 10.2 sq. mi. at its confluence with the Elm Fork. The land use within the watershed is predominantly rural upstream of Highway 82 with some commercial development along the Highway 82 corridor. The primary development that has occurred in the Dozier Creek watershed is the Municipal Airport that is located along the western watershed boundary. Based on the City of Gainesville's Comprehensive Land Use Plan,[14] future growth in the watershed near the City is planned primarily for residential use with some additional commercial development planned along the Highway 82 corridor. Outside of the City's current ETJ, land use was assumed to remain predominantly rural with some residential development.

Highway 82 at Dozier Creek

Existing floodplain mapping for Dozier Creek was completed in 1977 as part of the Cooke County Flood Insurance Study.[15] The stream segment studied (See Figure 3.4-2) was not studied in detail and mapping of floodplain limits were made using approximate methods. Flooding problems in the Dozier Creek watershed are relatively minor as residential and commercial development has not occurred within the 100-year floodplain and no significant flood control measures have been implemented in the watershed.

[14] Municipal Planning Resources Group, Inc., Op. Cit., October 1997.
[15] FEMA, Op. Cit., October 18, 1977.



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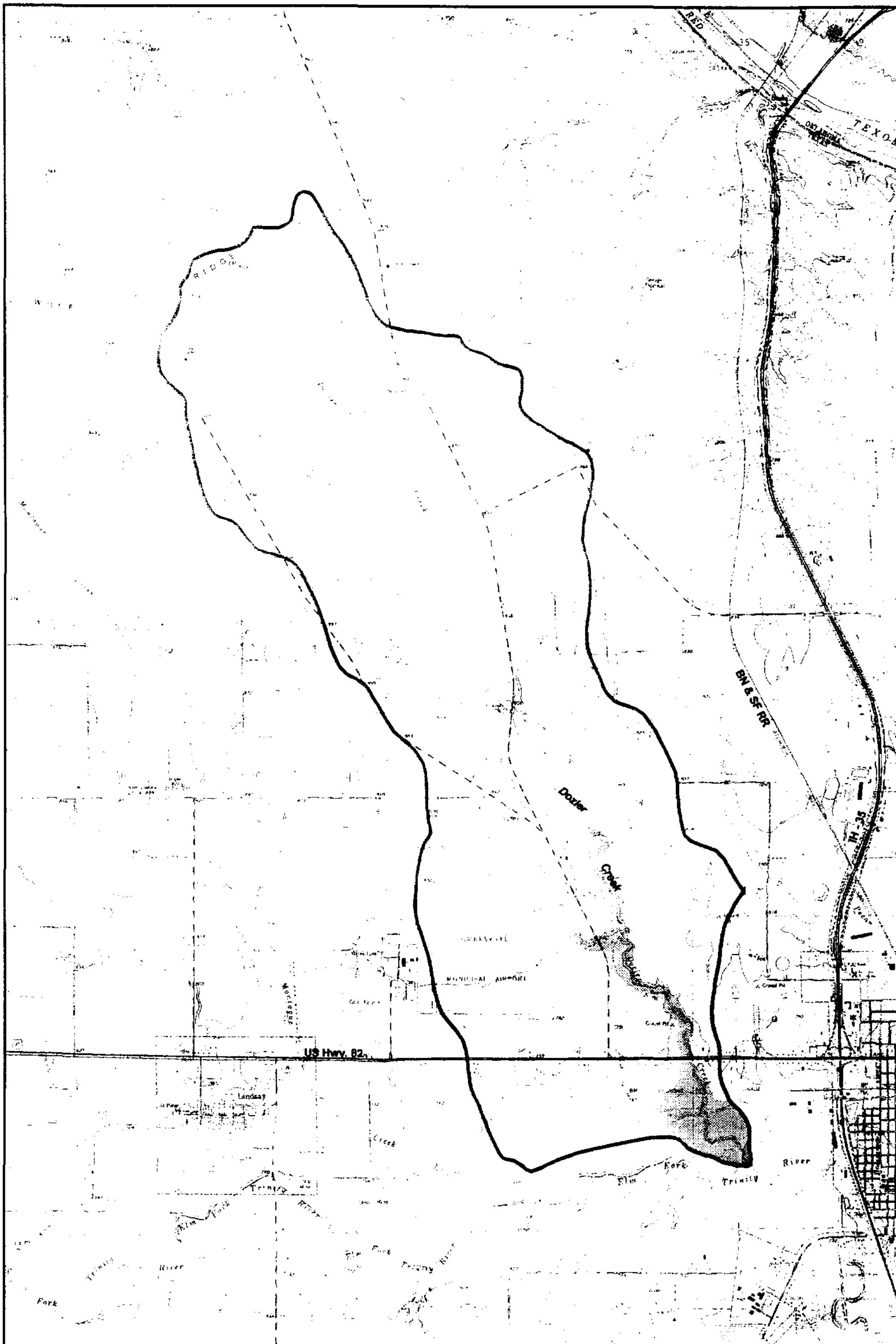
FLOOD PROTECTION PLANNING STUDY
DOZIER CREEK WATERSHED

FIGURE: 3.4 - 1



N

Scale - 1" equals 3000'

0 3000 6000 Feet

Legend

FEMA Zone 'A' (approximate boundaries)

FEMA Detailed Study Area

Watershed Boundaries

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FLOOD PROTECTION PLANNING STUDY

DOZIER CREEK WATERSHED
1981 FEMA FIS MAPPING

FIGURE: 3.4 - 2

3.4.1 Dozier Creek Flood Hydrology

A flood hydrology model was developed to simulate the rainfall-runoff process for the Dozier Creek watershed. The HEC-1 Flood Hydrograph Package[16] was utilized to compute the peak runoff rates at key points in the drainage basin for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flood events. Runoff hydrographs were developed for each storm event for existing and future development conditions. Future development conditions were based on ultimate development as shown in the City of Gainesville's Comprehensive Land Use Plan. Peak runoff rates for future development conditions are expected to increase slightly due to future development in the Dozier Creek watershed. For example, future peak runoff rates for the 100-year storm event at Highway 82 are expected to increase from 9,540 cfs to 10,080 cfs, a six percent increase. Table 3.4-1 provides a summary of existing and future peak runoff rates for selected storm events at key locations in the Dozier Creek watershed. Detailed results of the HEC-1 model are provided in Appendix C.

Table 3.4-1.
Dozier Creek Watershed
Summary of Peak Runoff Rates

Location	Drainage Area (sq. mi.)	Peak Runoff Rates (cfs)					
		10-year		25-year		100-year	
		Existing	Future	Existing	Future	Existing	Future
FM 1201	4.3	3,010	3,300	3,770	4,070	5,000	5,290
Highway 82	8.3	5,410	5,930	6,960	7,480	9,540	10,080
Elm Fork[1]	10.2	6,820	7,400	8,700	9,300	11,840	12,430

[1] Location is just upstream of the Elm Fork confluence.

[16] U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Users Manual, Davis, CA, Revised 1990.

3.4.2 Stream Hydraulics

HEC-RAS[17] was used to develop a stream hydraulic model to simulate flow in Dozier Creek and selected tributaries and through the bridges and culverts that exist in the study area. The stream hydraulic model used the peak runoff rates from the hydrologic model and computed water surface profiles (flood levels) for each storm event for 4.4 miles of stream studied in the Dozier Creek watershed. The stream segment studied was based on the availability of topographic data. Cross-sections of stream segments were obtained using the City of Gainesville aerial topographic mapping[18] and supplemented with field measurements at hydraulic structures.

The existing FEMA floodplain mapping was based on approximate methods to define the boundaries. The HEC-RAS model provides detailed flood level results for the stream segment studied which extends upstream from the Elm Fork confluence to near the FM 1201 crossing (See Figure 3.4-3).

Two road crossings were analyzed in the Dozier Creek watershed including Highway 82 and County Road (CR) 412. The Highway 82 bridge was determined to pass the 500-year flood event without overtopping and the CR 412 bridge will pass less than the 2-year flood event without overtopping A summary of the hydraulic capacity for each crossing is presented in Table 3.4-2.

Table 3.4-2.
Dozier Creek Watershed
Summary of Hydraulic Capacity of Stream Crossings

Location	Stream	Hydraulic Capacity[1] Return Period Flood Event Existing Conditions	Hydraulic Capacity[1] Return Period Flood Event Future Conditions	Notes[2]
CR 412	Dozier	< 2-year	< 2-year	49-ft bridge
Highway 82	Dozier	> 500-year	> 500-year	182-ft bridge

[1] Hydraulic capacity at top of road elevation.
[2] RCB – reinforced concrete box culvert, RCP – reinforced concrete pipe culvert, CMP – corrugated metal pipe.

[17] U.S. Army Corps of Engineers, Hydrologic Engineering Center, "HEC-RAS River Analysis System," User's Manual, Davis, CA, 1995.
[18] City of Gainesville, Texas, Aerial Topographic Mapping, prepared by Dallas Aerial Mapping, Inc. January, 1997.

3.4.3 Problem Areas

No significant problem areas were identified in the stream segment studied nor were any found for contributing areas. Non-structural solutions are recommended for Dozier Creek including:

- Enforcement of existing floodplain development ordinances for the City and Cooke County; and
- Enforcement of the City's Drainage Criteria and Design Manual to reduce the impact of future development, limit any increase in peak runoff rates, and ensure that new development is planned and designed according to the City's standards.

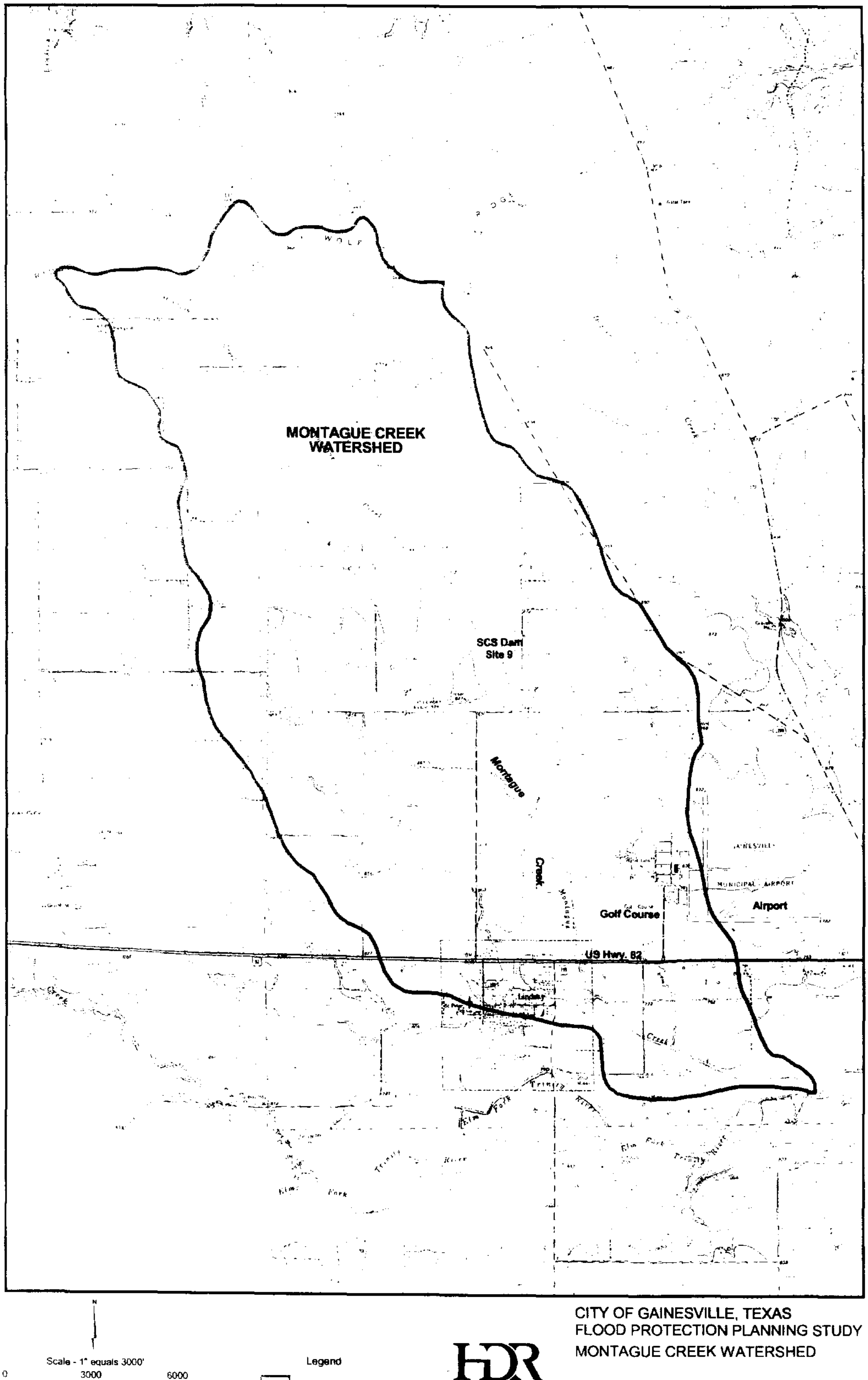
3.5 Montague Creek Watershed

Montague Creek originates in the north-central portion of Cooke County and extends downstream along the western edge of the City of Gainesville, as shown in Figure 3.5-1. The watershed covers about 7.1 sq. mi. at Highway 82 for the main stem. Two tributary streams join the main stem downstream of Highway 82 before the confluence with the Elm Fork. The west tributary flows through the City of Lindsay and the east tributary flows through the City of Gainesville's Municipal Golf Course. The total watershed area for Montague Creek at its confluence with the Elm Fork is 13.6 sq. mi. Land use within the watershed is predominantly rural upstream of Highway 82 with more urban development along the west tributary in the City of Lindsay and the east tributary in the vicinity of the City of Gainesville' Municipal Airport. Based on the City of Gainesville's Comprehensive Land Use Plan,[14] future growth in the watershed near the City is planned primarily for residential use with some commercial development planned along the Highway 82 and near the airport. Outside of the City's current ETJ, land use was assumed to remain predominantly rural with some residential development.

Existing flood plain mapping for Montague Creek was completed in 1977 as part of the Cooke County Flood Insurance Study.[15] The stream channels in this study were not studied in detail and mapping of flood plain limits were made using approximate methods. No significant flooding problems were noted within the City of Gainesville's ETJ in the Montague Creek watershed, primarily due to the low density of development

A flood control dam (Site 9) was constructed by the SCS in the Montague Creek watershed in the 1950s as part of the Watershed Plan for the Elm Fork Watershed.[16] The SCS constructed the Site 9 dam on the main stem of Montague Creek (Figure 3.5-1) and the dam controls approximately 5.6 sq. mi. of the watershed area, providing significant flood control benefits for the Montague Creek watershed. The peak runoff rates for the watershed upstream of the dam are substantially reduced even for storms as large as the 100-year storm event. The Site

[14] Municipal Planning Resources Group, Inc., Op. Cit., October 1997.
[15] FEMA, Op. Cit., October 18, 1977.
[16] U.S. Dept. of Agriculture, Soil Conservation Service, Work Plan Elm Fork Watershed of the Trinity River Watershed, Montague, Cooke, and Denton Counties, Revised June 1956.



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FLOOD PROTECTION PLANNING STUDY
MONTAGUE CREEK WATERSHED

FIGURE: 3.5 - 1

9 dam results in peak runoff rate reductions of almost 60 percent for the main stem channel at Highway 82.

3.5.1 Flood Hydrology

A flood hydrology model was developed to simulate the rainfall-runoff process for the Montague Creek watershed. The HEC-1 Flood Hydrograph Package[17] was utilized to compute the peak runoff rates at key points in the drainage basin for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year return period flood events. Runoff hydrographs were developed for each storm event for existing and future development conditions. Future development conditions were based on ultimate development as shown in the City of Gainesville's Comprehensive Land Use Plan. Peak runoff rates for future development conditions are expected to increase slightly due to future development in the Montague Creek watershed. For example, future peak runoff rates for the 100-year storm event at the Elm Fork confluence are expected to increase from 8,490 cfs to 8,830 cfs, a 4 percent increase. Table 3.5-1 provides a summary of existing and future peak runoff rates for selected storm events at key locations in the Montague Creek watershed. Detailed results of the HEC-1 model are provided in Appendix C.

3.5.2 Stream Hydraulics

The City of Gainesville aerial topographic mapping[18] did not provide coverage of the Montague Creek watershed. Therefore, no topographic data was available for development of a stream hydraulic model for the watershed.

3.5.3 Problem Areas

The low density of development in the watershed results in no significant flood-related problems along Montague Creek. It will be important for the City to prevent future flood and drainage-related problems from occurring in the watershed by implementing non-structural solutions including:

[17] U.S. Army Corps of Engineers, Hydrologic Engineering Center, HEC-1 Flood Hydrograph Package, Users Manual, Davis, CA, Revised 1990.
[18] City of Gainesville, Texas, Aerial Topographic Mapping, prepared by Dallas Aerial Mapping, Inc. January, 1997.

Table 3.5-1.
Montague Creek Watershed
Summary of Peak Runoff Rates

Location	Drainage Area (sq. mi.)	Peak Runoff Rates (cfs)					
		10-year		25-year		100-year	
		Existing	Future	Existing	Future	Existing	Future
Montague Creek							
Site 9 Inflow	5.6	4,310	4,710	5,430	5,840	7,220	7,620
Site 12 Outflow	5.6	40	40	41	107	480	640
Highway 82	7.1	1,660	1,730	2,070	2,140	2,700	2,780
Elm Fork Confluence[1]	13.6	5,100	5,420	6,360	6,700	8,490	8,830
West Tributary							
Highway 82	18.0	5,010	5,290	5,330	5,580	7,640	7,890
East Tributary							
Highway 82	2.0	1,750	1,750	2,230	2,230	2,990	2,990
Site 11B Outflow	2.0	15	15	16	16	140	140
Highway 82	4.7	1,990	2,300	2,530	2,880	3,410	3,780

[1] Location is just upstream of Elm Fork confluence.

- Enforcement of existing floodplain development ordinances for the City and Cooke County; and
- Enforcement of the City's Drainage Criteria and Design Manual to reduce the impact of future development, limit any increase in peak runoff rates, and ensure that new development is planned and designed according to the City's standards.

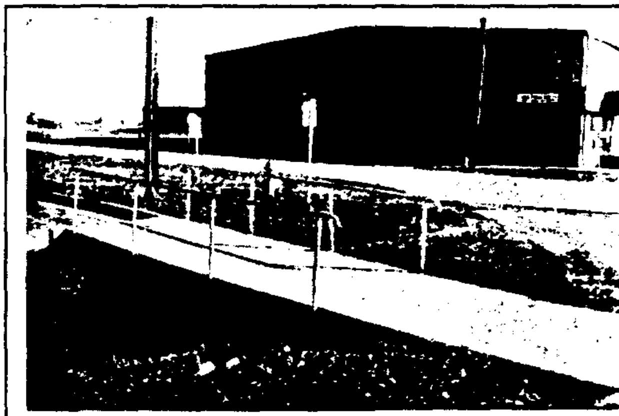
The public survey conducted at the beginning of the study identified one area near the City's Municipal Airport that experienced frequent flooding and poor drainage. A description of this problem area and the recommended improvements is provided in the following section.

3.5.3.1 Airport Area

The Airport Problem Area is located along in the northwestern part of the City, north of Highway 82 along Weber Road. Drainage problems in have been reported along Weber Road and Bonnavilla Drive consisting of poor drainage along the streets and inadequate culvert

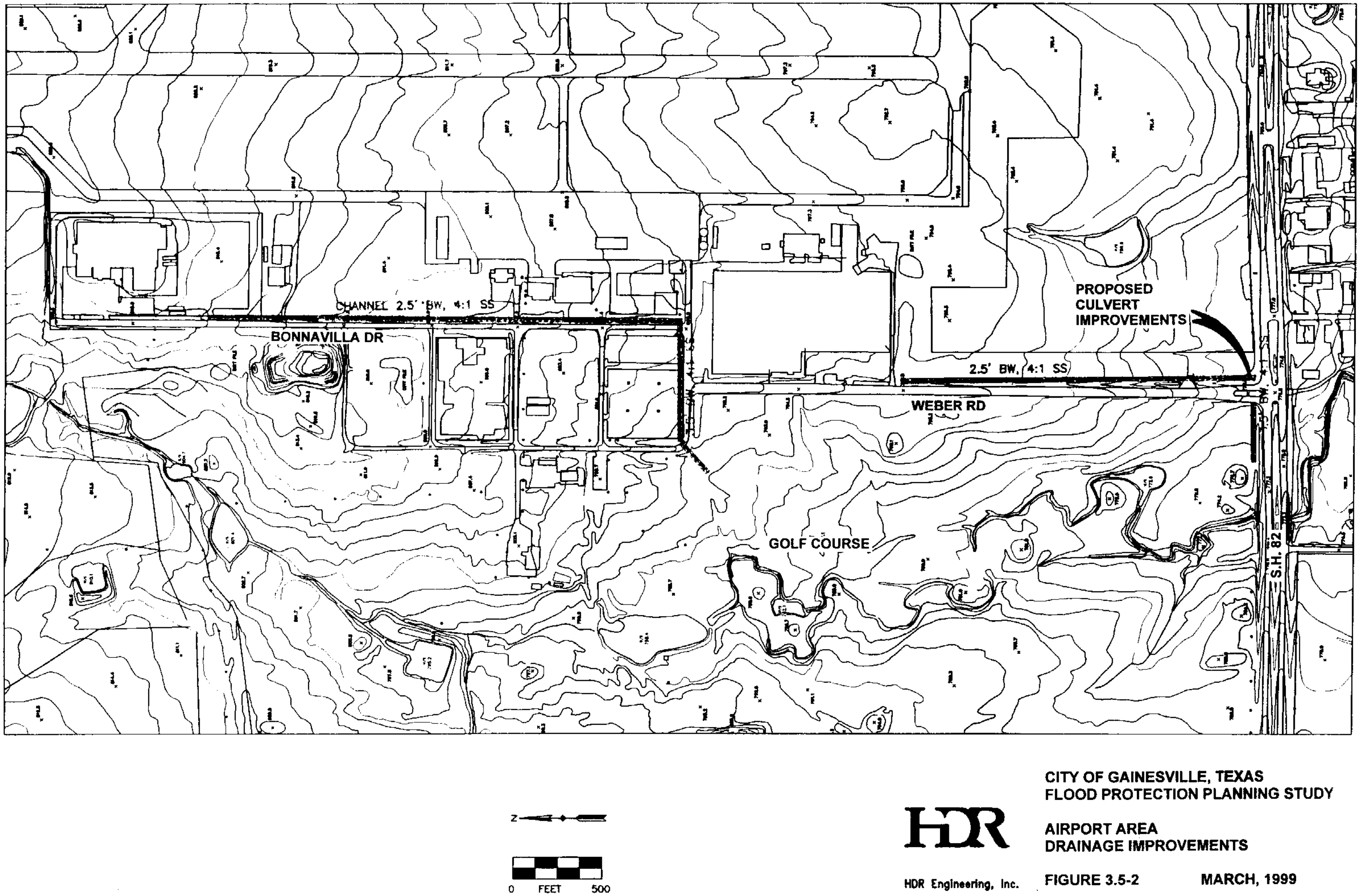
Weber Road culvert near Highway 82

capacity at the intersection of Weber Road and Highway 82. Street runoff in this area is conveyed by side ditches to the east tributary of Montague Creek. The existing ditches are small and have several driveway and sidewalk crossings. These crossings typically include very small culverts, some less than 12-inches in diameter, that restrict flow in the ditch and result in poor drainage of the site. The main problem for this area is at the intersection of Weber Road and Highway 82 where flow frequently overtops the roadway. Weber Road serves as the only access to the Airport and industrial area. A significant portion of the upstream drainage area flows south along the east side of Weber Road to the Highway 82 intersection. At the intersection, flow must travel under Weber Road through an existing 48-inch arch, corrugated metal pipe (CMP). The existing pipe entrance was found to be filled with sediment and the hydraulic capacity was severely limited.



Small culverts along Bonnavilla Drive

Recommended improvements in the Airport area include replacement of the Weber Road culverts at Highway 82 with two, 48-inch diameter reinforced concrete pipes, and channel, ditch, and culvert improvements parallel to Bonnavilla Drive and Weber Road as shown in Figure 3.5-2. The proposed improvements will require coordination with TxDOT related to replacement of the Weber Road culvert along Highway 82. The capital cost of the proposed improvements is estimated to be $143,000 including engineering and construction contingencies, as shown in Table 3.5-2. The City would likely be able to reduce the cost significantly by performing construction using its own staff and equipment.



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CITY OF GAINESVILLE, TEXAS
FLOOD PROTECTION PLANNING STUDY

AIRPORT AREA
DRAINAGE IMPROVEMENTS

FIGURE 3.5-2 MARCH, 1999

Table 3.5-2.
Airport Area Problem Area
Project Cost Estimate

Item	*Units*	*Quantity*	*Unit Cost*	*Total Cost*
Channel Excavation	cubic yard	4,600	$6.25	$28,750
Seeding/Vegetation	square yard	11,600	$0.45	$5,220
Pavement Cut/Repair	square feet	4,400	$3.50	$15,400
Culvert (18-IN RCP)	linear feet	80	$29	$2,320
Culvert (24-IN RCP)	linear feet	210	$31	$6,510
Culvert (30-IN RCP)	linear feet	450	$45	$20,250
Culvert (48-IN RCP)	linear feet	240	$80	$19,200
Headwall	each	2	$3,000	$6,000
Subtotal				$103,650
Contingencies & Miscellaneous			15%	$15,548
Construction Cost				$119,198
Engineering, Surveying, Legal			20%	$23,840
Total Project Cost				$143,037

Section 4
Recommendations

Recommendations for flood control in the City of Gainesville include both structural and non-structural solutions. Most of the recommended improvement plans presented for each watershed (Section 3) involve structural solutions, such as channel improvements, bridge and culvert improvements, levees, and storm sewer systems. Non-structural solutions include acquisition of damageable properties and adoption of ordinances and standards to prevent areas of future development from experiencing drainage and flood-related problems.

4.1 Non-Structural Recommendations

A number of properties were identified that presently exist in flood prone areas that are required to be removed for implementation of various structural improvements. Immediate acquisition of these properties is recommended in order to reduce future flood damages and to secure the property necessary for future project implementation. Implementation of these future projects will result in flood damage reduction for a number of other commercial and residential structures in the area.

The City's existing ordinances related to drainage and flood plain development were reviewed as part of this study. A number of recommendations were made to improve the existing ordinance, including higher standards for street drainage and storm sewer design, adoption of a "no net increase" policy related to peak runoff rates for new development, and adoption of various design standards and methodology for consistent application across the City. All of the proposed recommendations were included in a Drainage Criteria and Design Manual. The City adopted the Drainage Criteria and Design Manual on March 2, 1999 as part of this study.

Updated hydraulic models were developed for all of the major streams in the study area where topographic information was available. These models provide detailed hydraulic information for stream segments that have not been studied in detail by FEMA and are presently mapped using only approximate methods. The updated hydraulic models provide the City with detailed information on flood levels that can be used in the planning and regulation of future development that were not available before. The updated flood level data and enforcement of the

Drainage Criteria and Design Manual standards will ensure that future developed areas do not experience drainage and flood related problems. The City should consider submitting the updated hydraulic model data to FEMA for revision of the existing floodplain maps, especially for the Elm Fork where significant changes in flood levels were calculated based on the new gage data.

4.2 Structural Recommendations

The total cost of all of the structural improvement plans presented for each watershed is $30,839,000, which is an overwhelming financial burden for a City the size of Gainesville. Obviously, not all of the drainage improvement projects can be implemented by the City in a short period of time. The improvement plans will have to be undertaken by the City over a long period of time as funding becomes available. The first step in developing a plan for implementation of the proposed projects is to establish priorities. Although numerous criteria could be used to rank the proposed projects, the following criterion (arranged in order of decreasing importance) were considered herein:

1. Severity of existing problem;
2. Public Safety;
3. Capital cost;
4. Preserving/enhancing existing property values;
5. Development potential;
6. Social/economic impacts; and
7. Maintenance/operating costs.

The severity of the existing problem is an indication of the frequency and degree of flooding that a particular area incurs. A problem area that experiences flooding on average every two years would be ranked higher than a project that experiences flooding on average every 10 or 25 years. Likewise, areas that incur extensive damage when the capacity of a channel, street, or storm sewer is exceeded were also ranked higher than those that receive only minor damages. Public safety issues that were considered included the potential for loss of life which may exist for an area and any other public health issues related to frequent flooding. Areas where flooding could potentially wash vehicles off of roadways or where flooding would limit emergency vehicle access were given a higher priority. The capital cost of each improvement plan was an important factor in ranking projects as the most expensive projects to implement would reduce the amount of funding available to other areas. Projects with higher capital costs as compared to the size of the area being benefited were given a lower priority. Preservation and enhancement of existing property values was also considered in the prioritization of potential projects. This criteria is a reflection of the apparent benefit-to-cost ratio of each project. Implementation of drainage improvements will preserve or enhance property values in the benefited area and, in turn, provide an increase in property tax revenue to the City, County, and local school district. In addition, the area may also benefit from lower flood insurance rates depending on the location of the area and type of project being implemented. The potential for future development of an area was also considered in the ranking. A project was given a higher priority if it was located in an area where the City and County would likely experience additional growth. Social and economic impacts were evaluated based on several factors. These included the potential for loss of business, loss of employee wages, and the overall disruption that an area may receive due to the nature of the flooding problem. The last criteria considered in the ranking was the cost to maintain or operate the project. Projects that involved more maintenance effort and expense were given a lower ranking than those projects that involved little or no maintenance.

Each of the seven categories listed above were scored, from one to ten, for each problem area with a higher score indicating a higher priority for each individual category. The score for each individual category was weighted and a weighted average score for each project was calculated. The weight, or percentage of the average score, that each category was given is shown in Table 4-1. As shown in Table 4-1, the severity of the existing problem, public safety, and capital cost issues comprised 70 percent of the total score for each project.

The projects were ranked based on the weighted average score. For the most part, flooding of residential, commercial, and industrial structures were given the highest priority for implementation of improvement projects. The ranking of each individual project does not necessarily indicate the order for implementation of each project. In some cases, funding issues will dictate when a project can be implemented, and some projects are required to be

Table 4-1
Priority of Recommended Improvements

Category	Weight
Severity of existing problem	25%
Public safety	25%
Capital cost	20%
Preserving/enhancing existing property values	15%
Development potential	5%
Social/economic impacts	5%
Maintenance/operating costs	5%
Total	100%

implemented prior to other projects based on their relative location. For example, increasing the hydraulic capacity of a channel at an upstream location may increase the runoff rates for a downstream area causing additional and more frequent flooding at the downstream location. In this case, the downstream improvements should be implemented first, regardless of their overall priority. This is most common for projects discharging directly into Pecan Creek where it will be important to make improvements to Pecan Creek prior to implementing projects that are located in or adjacent to the Pecan Creek flood plain. A summary of the individual scoring and ranking of each improvement project is presented in Table 4-2.

The Pecan Creek improvement project was considered the most important project for the City to implement due to its far reaching impacts across the City and its relatively high benefit to cost ratio (See Section 3.2). However, the capital cost of this project is significant, and the project will likely only be constructed if funding from other sources can be secured. Section 5 presents various funding alternatives and methods by which the City can reduce its financial burden, and Section 6 presents an implementation plan and discusses how selected projects can be implemented in phases.

Table 4-2
Summary of Project Rankings

Rank	Project	Watershed	Watershed Category	Description	Total Project Cost	City Funding	Other Funding	Severity of Existing Problem 25%	Public Safety 25%	Capital Cost 20%	Preserving and Enhancing Existing Property Values 15%	Development Potential 5%	Social & Economic Impacts 5%	Maintenance Costs 5%	Composite Score 100%
1	Pecan Creek	Pecan Creek	Major	Channel and bridge improvements	$8,983,000	$4,141,500	$4,841,500	10	9	6	8	5	7	3	7.90
2	Chestnut Channel	Elm Fork	Minor	Channel and culvert improvements	$923,000	$646,000	$277,000	8	8	6	6	2	3	4	6.55
3	College Avenue	Elm Fork	Minor	Storm sewer and culvert improvements	$384,000	$304,000	$80,000	7	7	6	6	7	3	7	6.45
4	Refinery Road	Pecan Creek	Minor	Storm sewer, channel improvements, and diversion berm.	$318,000	$318,000	$0	6	7	7	5	4	2	5	5.95
5	Weaver Street/Sante Fe Drive	Pecan Creek	Minor	Storm sewer improvements	$1,056,000	$901,000	$155,000	6	8	5	4	3	4	8	5.85
6	Broadway Street East	Wheeler Creek	Minor	Storm sewer and channel improvements	$2,300,000	$2,300,000	$0	8	6	3	6	3	5	6	5.70
7	Laurel Road	Wheeler Creek	Minor	Storm sewer improvements	$1,465,000	$1,465,000	$0	8	6	3	6	3	3	7	5.65
8	Culberson Street	Elm Fork	Minor	Storm sewer improvements	$767,000	$767,000	$0	6	6	5	4	2	6	8	5.40
9	Airport Area	Montague Creek	Minor	Channel and culvert improvements	$143,000	$100,000	$43,000	5	5	7	4	7	5	5	5.35
10	Olive Street	Pecan Creek	Minor	Storm sewer improvements	$2,483,000	$2,403,000	$80,000	7	7	2	4	2	3	7	5.10
11	Southwest Gainesville	Elm Fork	Major	Levee and channel improvements	$2,605,000	$2,605,000	$0	6	6	2	7	4	4	4	5.05
12	Hillside Drive	Wheeler Creek	Minor	Storm sewer improvements	$1,300,000	$1,300,000	$0	7	4	5	4	2	3	8	5.00
13	O'Neal Street	Pecan Creek	Minor	Storm sewer improvements	$801,000	$721,000	$80,000	6	6	4	3	2	4	8	4.95
14	Broadway Street West	Pecan Creek	Minor	Storm sewer and channel improvements	$784,000	$645,000	$139,000	7	4	4	4	2	5	7	4.85
15	Greenbriar Drive	Wheeler Creek	Minor	Storm sewer improvements	$600,000	$600,000	$0	6	4	5	4	2	3	8	4.75
16	California Street East	Pecan Creek	Minor	Storm sewer improvements	$312,000	$0	$312,000	5	5	5	3	1	4	7	4.55
17	Star Avenue	Elm Fork	Minor	Channel and culvert improvements	$62,000	$62,000	$0	5	3	7	5	0	1	5	4.45
18	California Street Levee	Elm Fork	Major	Levee improvements and installation of backflow prevention valve	$173,000	$100,000	$73,000	2	4	6	6	2	7	6	4.35
19	Clements Street	Pecan Creek	Minor	Channel and culvert improvements	$328,000	$328,000	$0	5	5	3	3	7	2	6	4.30
20	Harris Street	Wheeler Creek	Major	Channel improvements	$350,000	$350,000	$0	5	3	4	2	7	2	3	3.70
21	Grand Avenue/Belcher Street	Pecan Creek	Minor	Storm sewer improvements	$201,000	$171,000	$30,000	3	4	4	2	2	3	8	3.50
22	FM 678	Wheeler Creek	Major	Channel improvements	$361,000	$361,000	$0	3	3	4	3	7	2	4	3.40
23	Frank Buck Zoo	Elm Fork	Major	Levee and channel improvements	$653,000	$653,000	$0	3	2	5	5	0	2	6	3.40
24	Wine Street	Wheeler Creek	Minor	Storm sewer improvements	$362,000	$362,000	$0	4	3	3	3	2	3	7	3.40
25	Taylor Street	Pecan Creek	Minor	Storm sewer improvements	$214,000	$214,000	$0	4	3	3	2	2	2	8	3.25
26	Lanius Street	Pecan Creek	Minor	Storm sewer improvements	$284,000	$256,000	$28,000	4	3	3	2	2	2	8	3.25
27	Truelove Street	Pecan Creek	Minor	Storm sewer improvements	$416,000	$374,000	$42,000	4	3	3	2	2	2	8	3.25
28	Tennie Street	Pecan Creek	Minor	Storm sewer improvements	$455,000	$409,000	$46,000	4	3	3	2	2	2	8	3.25
29	Dixon Street	Elm Fork	Minor	Storm sewer improvements	$979,000	$979,000	$0	3	3	2	5	2	2	8	3.25
30	Southland Blvd	Elm Fork	Major	Levee improvements to protect Southland Blvd and IH-35 industrial areas	$777,000	$777,000	$0	5	1	1	5	1	3	6	2.95
				TOTAL	$30,839,000	$24,612,500	$6,226,500								

Section 5
Funding Alternatives

Implementation of major drainage improvements in the Gainesville area will require commitment of significant local resources. There are several options for funding drainage improvements, including use of local resources and acquiring funds from outside resources including state and federal agencies. Funding alternatives described in this section include alternatives for generation of funds from local sources and the potential for funding from other sources such as state and federal agencies.

5.1 Local Funding Alternatives

Historically, many cities and towns in Texas have financed municipal drainage improvements with tax proceeds through their General Fund. However, this traditional approach has not continued to function well for many entities in addressing the modern day drainage needs. Over time, as rapid growth has occurred and the cost of such projects has risen, new methods for funding drainage improvements have arisen and been legally defined by Legislative action. These newer methods of drainage financing seek to: (1) acknowledge the drainage problem as a formal utility function, and (2) seek to place a greater financial burden for remediation of drainage and flooding problems upon those activities contributing to the problem. A brief overview of these approaches follows:

5.1.1 Tax-based/General Revenue Funding

Typically, with this method of funding, drainage activities and improvements are one of many "line items" in a municipality's General Fund that are supported with the combined pool of general revenues from ad valorem taxes, sales taxes, and other revenue. Capital financing is typically accomplished through cash transfers for small projects and general obligation bonds for major improvements. Operational activities are typically funded with general revenues.

Advantages of the simple General Revenue funding approach include:

- broad base of financial support (all taxpayers pay), and
- local taxes can be deducted from Federal income taxes.

Disadvantages include:

- competition for funding with other general services,
- inequities arising from tax liabilities not equating with contribution to drainage problems.

5.1.2 Capital Recovery Fees

When rapid growth in the late 1970's and early 1980's hit many Texas municipalities, a noticeable number of municipalities implemented capital recovery (impact) fee programs for new water and wastewater connections. Some implemented such fees for drainage as well. These fees were targeted at making new growth "pay for itself." The intent of these up-front fees were to gather cash for the purpose of partial or full financing of public capital improvements attributable to new growth. However, concerns from the development community over real or perceived abuses of fee levies, use of proceeds, and lack of any specific lawful authority for such charges prompted the passage of new law (Texas Local Government Code Section 395) in 1989. This Act not only legalized the levy of such fees, but also provided considerable definition on a public process and methods for calculating and utilizing such fee proceeds.

Advantages of the Capital Recovery Fee approach include:

- the partial or full funding of growth-induced drainage problems is borne by new development,
- specific funding becomes available for the sole use of drainage capital projects, and
- by incorporation into the mortgage financing, the interest is Federally tax deductible.

Disadvantages include:

- raises the cost of new homes and lessens the financial eligibility for home buyers,
- may relocate some new development to nearby communities with lower or no fees,
- takes time to accumulate enough fee revenue to make substantial contribution to new project financing when needs may be immediate,
- can create double-charge inequities arising from "growth" having paid once up-front for drainage improvements and again over the long-term through taxes,
- still leaves "existing" drainage and flooding problems subject to the difficulties of General Fund financing mentioned above.

5.1.3 Municipal Drainage Utility

At about the same time as the passage of law authorizing the levy of capital recovery fees for water, wastewater, and drainage purposes, the Texas Legislature also enacted further law (Texas Local Government Code Sections 402.042-402.054) specifically authorizing the creation of municipal drainage utilities. This Act allowed drainage utilities to be formed as an enterprise fund function of municipal government on a par with the financial and operational capabilities of municipal water/wastewater and electric utility funds. Typically, separate revenue and (capital and operating) expense accounting is maintained with fund income arising from drainage fee (rate) revenue and transfers from other funds. Most common is a periodic drainage fee (i.e. rate charge) that is usually made monthly and included on the water/wastewater billing. This monthly drainage fee usually reflects a flat charge for single family residential or a unit charge per amount of impervious cover for multi-family, commercial, and industrial land uses. The drainage fee levies should be equitable, related to the extent of problem drainage caused by the land use, and produce a targeted level of overall revenue recovery for the drainage utility. The income of a drainage utility can also include the drainage capital recovery levy previously described.

Advantages of the Municipal Drainage Utility approach include:

- provides continuing stream of income for on-going drainage improvements and operational activities,
- allows for the issuance of utility revenue bonds to fund capital improvements,
- with proper fee design, a reasonable charge can be levied that is equitable between new development and longer-term residents and also equitable among differing land uses, and
- raises the chronic drainage issue to a higher profile level and better targets needed actions.

Disadvantages include:

- in gathering revenues as a monthly rate charge, this source of financing is not deductible by rate-payers on Federal tax returns, and
- the City may incur slightly more administrative overhead due to the separate enterprise fund accounting and potentially expanded drainage programs.

5.1.4 Existing Local Funding Methods

Presently, the City of Gainesville funds drainage improvements through annual revenue generated through its Municipal Drainage Utility. The City's Municipal Drainage Utility was created by City Ordinance in 1993 and levies a monthly unit charge of $0.50 per standard residential unit (SRU) for residential and commercial properties. A standard residential unit in the City of Gainesville is defined as having 1,895 square feet of impervious cover. Properties with large quantities of impervious cover incur a monthly rate charge defined as $0.50 per 1,895 square feet of impervious cover. Annual revenue from the City's Municipal Drainage Utility is on the order of $137,000 based on the current rate structure and a breakdown of the source of revenue by customer category is illustrated in Table 5-1. The City does not currently collect Capital Recovery Fees for new development, and the City utilizes little or no funds from General Revenue for financing drainage improvements. Revenue from the Municipal Drainage Utility is expected to be the principal source of local funds for financing future projects.

Table 5-1

Existing Municipal Drainage Utility Revenue

Customer Category	Size Range[1]	Number of Accounts	Average SRU Size[2]	Average Monthly Fee	Annual Revenue	Percent of Annual Revenue
Non-Residential	0 to 1 SRU	42	0.50	$0.25	$126	0.1%
Residential	1 SRU	5,354	1.00	$0.50	$32,124	23.4%
Non-Residential	1 to 3 SRU	172	1.83	$0.92	$1,889	1.4%
Non-Residential	3 to 10 SRU	265	5.73	$2.87	$9,111	6.7%
Non-Residential	10 to 20 SRU	134	14.29	$7.15	$11,489	8.4%
Non-Residential	20 to 100 SRU	167	40.71	$20.36	$40,791	29.8%
Non-Residential	100 to 999 SRU	25	275.44	$137.72	$41,316	30.2%
Total		6,159			$136,979	100.0%

Notes:
1. SRU – Standard Residential Unit equal to 1,895 square feet of impervious area.
2. Average SRU size based on average size of all existing accounts within the size range.

In order to fund significant drainage improvements in the City using the Municipal Drainage Utility, an increase in the monthly drainage fees will be required. The amount of increase in rates will be based on the level of program that the City decides is affordable. A utility rate model was developed as part of this study to project annual revenues for various degrees of rate increases. Currently, the City's fee structure is based on a unit rate of $0.50 per 1,895 sq.ft. Future rate increases based on a set unit charge may be viewed as an inequitable to larger customers. Therefore, a decreasing block rate structure will likely be a more acceptable means of assessing drainage fees for funding drainage improvements. A comparison of potential rate structures is presented in Table 5-2, including the existing rate structure. Table 5-2 shows the existing and projected annual revenues for various categories of customers and the monthly drainage fees for an average customer in each category. The range of potential rate structures presented was based on monthly drainage fees that are typical of other cities in Texas. The base residential rate structures shown in Table 5-2 are comparable to rate structures that are being used by other Texas cities for funding drainage improvement programs.

5.2 State and Federal Participation

State and federal funding may be available for some of the recommended improvement projects. State and federal funding may be derived from several sources including the following:

- Low interest loans for flood control projects from the Texas Water Development Board;
- Participation by the Texas Department of Transportation (TXDOT) in drainage projects involving TXDOT owned and maintained roadways such as California Street, Grand Avenue, and IH-35;
- Matching grants from the Federal Emergency Management Agency (FEMA) Flood Mitigation Assistance (FMA) Program; and
- Local Flood Damage Reduction Program of the U.S. Army Corps of Engineers as authorized in Section 205 of the 1948 Flood Control Act.

Utilization of state, federal, and other funding will be important in order for the City to implement the larger flood protection projects and still maintain a reasonable monthly drainage fee for its customers. Acquisition of state and federal funding will require planning and coordination with each of the agencies to ensure that funds are available and projects are completed in a timely manner. An overview of various state and federal funding options is presented in the following sections.

Table 5-2
Summary of Existing and Potential Municipal Drainage Utility Rate Structures

Rate Alternative	Item	Category: Non-Residential 0 SRU to 1 SRU	Residential 1 SRU	Non-Residential 1 SRU to 3 SRU	Non-Residential 3 SRU to 10 SRU	Non-Residential 10 SRU to 20 SRU	Non-Residential 20 SRU to 100 SRU	Non-Residential 100 SRU to 999 SRU	Total
	No. of Accounts	42	5,354	172	265	134	167	25	6,159
	Average Size in Range	0.5	1	1.83	5.73	14.29	40.71	275.44	
	Rate per SRU	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	$0.50	
Existing	Average Monthly Fee	$0.25	$0.50	$0.92	$2.87	$7.15	$20.36	$137.72	
Rates	Annual Revenue	$126	$32,124	$1,889	$9,111	$11,489	$40,791	$41,316	$137,000
	% of Total Revenue	0.09%	23.45%	1.38%	6.65%	8.39%	29.77%	30.16%	100.00%
Option A	Rate per SRU	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	
Existing	Average Monthly Fee	$0.50	$1.00	$1.83	$5.73	$14.29	$40.71	$275.44	
Rates	Annual Revenue	$252	$64,248	$3,777	$18,221	$22,978	$81,583	$82,632	$274,000
x 2	% of Total Revenue	0.09%	23.45%	1.38%	6.65%	8.39%	29.77%	30.16%	100.00%
Option B	Rate per SRU	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	$2.00	
Existing	Average Monthly Fee	$1.00	$2.00	$3.66	$11.46	$28.58	$81.42	$550.88	
Rates	Annual Revenue	$504	$128,496	$7,554	$36,443	$45,957	$163,166	$165,264	$547,000
x 4	% of Total Revenue	0.09%	23.49%	1.38%	6.66%	8.40%	29.83%	30.21%	100.00%
Option C	Rate per SRU	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	$3.00	
Existing	Average Monthly Fee	$1.50	$3.00	$5.49	$17.19	$42.87	$122.13	$826.32	
Rates	Annual Revenue	$756	$192,744	$11,331	$54,664	$68,935	$244,749	$247,896	$821,000
x 6	% of Total Revenue	0.09%	23.48%	1.38%	6.66%	8.40%	29.81%	30.19%	100.00%
Option D	Rate per SRU	$2.00	$2.00	$2.00	$1.50	$1.00	$0.50	$0.50	
Decreasing	Average Monthly Fee	$2.00	$2.00	$3.66	$10.09	$20.79	$36.85	$154.22	
Block	Annual Revenue	$1,008	$128,496	$7,561	$32,083	$33,441	$73,863	$46,262	$323,000
Rate	% of Total Revenue	0.31%	39.78%	2.34%	9.93%	10.35%	22.87%	14.32%	100.00%
Option E	Rate per SRU	$3.50	$3.50	$3.00	$2.50	$2.00	$1.50	$1.00	
Decreasing	Average Monthly Fee	$3.50	$3.50	$5.99	$16.32	$35.58	$78.06	$342.44	
Block	Annual Revenue	$1,764	$224,868	$12,373	$51,882	$57,236	$156,464	$102,724	$607,000
Rate	% of Total Revenue	0.29%	37.05%	2.04%	8.55%	9.43%	25.78%	16.92%	100.00%

5.2.1 Texas Water Development Board Loan Assistance

Loans are available from the Texas Water Development Board for the planning, design, and construction of flood control projects. The Texas Water Development Fund is used to provide loans to eligible applicants for construction of flood control projects. The Texas Water Development Fund consists of several accounts including the Flood Control Account. The Flood Control Account provides financing for structural and non-structural flood protection improvements such as construction of stormwater retention basins; enlargement of stream channels; modification or reconstruction of bridges; acquisition of floodplain land for use as public open space, acquisition and removal of buildings located in a floodplain, relocation of residents of buildings removed from a floodplain, public beach renourishment, flood warning systems; control of coastal erosion; and development of floodplain management plans. The interest rate on a Texas Water Development Fund loan varies depending on the cost of TWDB funds. The lending rate scales are set 0.35 percent above the TWDB's borrowing cost. The lending rates are intended to provide reasonable rates to its customers while covering the TWDB's cost of funds and risk exposure. Current interest rates for tax exempt bonds for flood control are 5.64 percent (for week ending March 25, 1999). Repayment periods for loans from the Texas Water Development Fund generally range from 20 to 25 years.

5.2.2 Texas Department of Transportation

Many of the recommended projects involve coordination with the Texas Department of Transportation (TXDOT) as the projects involve modifications or improvements to TXDOT maintained roadways. These roadways primarily include California Street, Grand Avenue, and IH-35. TXDOT funds a variety of projects through its annual budgeting process. It will be important for the City to coordinate improvement projects with the County Resident, Area, and District offices of TXDOT. Funding for projects by TXDOT will be based on the amount of funds available and the priority of the project with respect to other projects in the District.

5.2.3 FEMA Flood Mitigation Assistance Program

The Flood Mitigation Assistance (FMA) Program was established by FEMA to assist state and local governments in funding projects that will reduce or eliminate the long-term risk of flood damage to buildings, manufactured homes, and other structures that are insured or are insurable under the National Flood Insurance Program. The FMA Program may provide grant funds for no more than 75 percent of the total cost of the following types of projects:

- acquisition of insured structures and real property and easements restricting property use;
- relocation of insured structures;
- demolition and removal of insured structures;
- elevation of insured structures;
- other activities to bring insured structures into flood plain management compliance;
- minor physical flood mitigation projects; and
- beach nourishment activities.

A community is available for project grants if it is not on probation or suspended under the NFIP, and if it has received FEMA approval of its flood mitigation plan. The FMA Program requires a 25 percent local cost share of which not more than one-half may be in-kind services. The FMA Program is administered in Texas by the Texas Water Development Board. Application for project grant funds are received by the TWDB each year and are evaluated based on the following criteria:

- the extent the project reduces future NFIP claims;
- projects with the highest benefit/cost ratio;
- projects which benefit the greatest number of NFIP-insured structures;
- the extent the project results in a long-term flooding solution and requires minimum maintenance;
- whether the project affects structures in an identified floodway or flood plain;
- the extent to which the sponsor is providing greater than the required 25 percent cost share;
- whether the applicant or community participates in the Community Rating System; and
- the multi-objective nature of the project.

The applications are evaluated by the TWDB and recommendations for grant award are forwarded to FEMA. FEMA currently restricts the amount of funds available. No community can receive more than $3,300,000 per five-year period. Due to the limited funds available for projects each year, the TWDB evaluates the applications and prioritizes for FEMA only those applications that meet the federal requirements. Acquisition of funds from the FMA Program is competitive and, in recent years, the amount of funding available to the state has been on the order of $1,000,000 for all communities. Projects involving acquisition of insured or insurable structures are generally ranked higher than other types of requests. Applications for funding are accepted year round, however, the evaluation of all applications for the next fiscal year are typically performed in August or September of each year. The Texas Water Development Board of Directors receives and approves the rankings to be forwarded to FEMA. The recommended projects are funded by FEMA based on the amount of funds made available to the state. Funds are typically disbursed the following January.

5.2.4 U.S. Army Corps of Engineers Local Flood Damage Reduction Program

The U.S. Army Corps of Engineers (USCOE) may provide federal funding of local flood control projects under Section 205 of the 1948 Flood Control Act (as amended). The Local Flood Damage Reduction Program provides for USCOE assistance in the planning, design, and construction of economically feasible, environmentally acceptable, and locally supported projects, subject to the availability of Federal funds. In order for the USCOE to conduct investigations and eventually construct a Federal flood damage reduction project, the local entity must request assistance from the USCOE. The process is completed in three phases once a request for assistance is made. These phases include:

- Feasibility Study;
- Plans and Specifications; and
- Construction.

The Feasibility Study is initiated once the request is received and approved by the USCOE and is completed within 24 months. Funding for the Feasibility Study is shared by the Federal Government and the local sponsor. The first $100,000 is a Federal expense and study costs in excess of $100,000 are cost-shared (50/50) between the Federal Government and the local sponsor. The steps involved in the Feasibility Study include:

- Define the flood problem;
- Evaluate alternatives to reduce flood damages including structural and non-structural solutions;
- Recommend a project for implementation if one is found to be technically and economically feasible, environmentally acceptable, and supported by the local sponsor; and
- Complete a project design as a basis for preparing plans and specifications.

Plans and Specifications are prepared for the recommended project upon completion of the Feasibility Study and authorization from the local sponsor. A Project Cooperation Agreement is executed between the USCOE and the local sponsor. The USCOE prepares contract documents and drawings for the project and the local sponsor obtains all lands, easements, rights-of-way, relocation, and disposal areas (LERRD's) that are necessary to implement the project. The Plans and Specifications phase is completed within 24 months, including contract advertisement and award, and is initially Federally financed (including real estate acquisitions). Upon award of the construction contract, the Construction Phase begins and the completion time varies depending on the extent of the project.

Cost sharing between the Federal Government and local sponsor depends on several factors. The minimum contribution from the local sponsor is 35 percent of the total project cost and the maximum contribution is 50 percent, provided the total project cost does not exceed $10,000,000. The maximum contribution by the Federal Government is limited to $5,000,000. The local sponsor must provide funding for the total cost of lands, easements, rights-of-way, relocations, and disposal areas and contribute 5 percent of the total project cost (Plans and Specifications, LERRD's, construction and management) in cash. If the sum of the 5 percent cash contribution and the value of the LERRD's is less than 35 percent of the total project cost, additional cash is required to meet the 35 percent minimum. Local contributions in excess of 50 percent of the total project cost are reimbursed by the Federal Government.

The Fort Worth District of the U.S. Army Corps of Engineers would be responsible for coordinating any Local Flood Damage Reduction Projects in the immediate vicinity of the City of Gainesville. The Fort Worth District performed Feasibility Studies on Pecan Creek and the Elm Fork at the request of the City of Gainesville in 1987. Projects were recommended for flood control for each area; however, the City elected not to pursue the projects due to funding limitations at that time. Preliminary meetings with the USCOE staff in February 1999 indicated that Federal funds would probably be available to reevaluate the previous projects and potentially fund construction, if the City were to request their assistance. If the City were to request funding through the USCOE for either the Pecan Creek or Elm Fork projects, the Feasibility Study would have to be updated. The Feasibility Study costs for a re-study by the USCOE may be on the order of $350,000. The City's cost share for the re-study would be $125,000. If the City were to request assistance from the USCOE for the Pecan Creek Project, the schedule from initiation of the Feasibility Study to completion of construction may be as long as six years.

Section 6
Implementation

6.0 Implementation

Development of an implementation plan for drainage improvements is not necessarily based on the recommended priority for each project as presented in Section 4. The plan and schedule for implementation of the recommendations is impacted by funding issues, coordination with other state and federal agencies, and availability of lands. In order to develop an implementation plan for the City, funding and coordination issues need to be understood for each project, and the potential for phased construction of projects should be considered. Phased construction of projects may provide a more affordable means of implementation for the City that allows for flood reduction benefits to be realized without compromising the ultimate scope and objective of the project.

Table 6-1 provides a summary of the 20 highest priority projects and the various issues that will dictate how and when each project may be implemented as well as a discussion on opportunities for phased construction. As shown in Table 6-1, a number of the recommended projects will involve coordination with state and federal agencies, the BN&SF Railroad, and other private utilities. Funding and coordination issues for the larger, higher priority projects, such as the Pecan Creek channel improvements project, will likely delay their implementation for a few years. Therefore, other projects may be completed ahead of their respective ranking in order for the City to make progress in implementing the overall plan. Table 6-2 presents a summary of implementation costs by projected source of funding and potential construction phases. As shown in Table 6-2, a number of the projects can be constructed in phases to significantly improve drainage in a number of areas.

Development of an implementation plan and schedule is primarily dependent on the level of funding support the City is willing to provide. An implementation plan was developed as part of this study, assuming that the principal source of local funding will be derived from the City's Municipal Drainage Utility. A funding scenario was assumed based on the amount of funds needed to make significant improvements and the amount of revenue that may be generated assuming comparable rate structures in use by other cities in Texas. The implementation plan is

Table 6-1
Implementation Issues for Recommended Projects

Project	Capital Cost	Funding and Coordination Issues	Phased Construction Opportunities
Pecan Creek	$8,983,000	Funding issues related to the potential acquisition of matching grants through the FEMA FMA Program, USCOE Local Flood Damage Reduction Program, and potential participation from TXDOT and Cooke County. Acquisition of right-of-way and easements for project implementation. Obtaining permits for construction of the recommended project.	1. Acquisition of improved properties and lands, easements, and right-of-way for project implementation. 2. Construction of recommended project.
Chestnut Channel	$923,000	Funding issues related to potential acquisition of matching grant through the FEMA FMA Program. Acquisition of right-of-way and easements for project implementation.	3. Construction of channel improvements from Hird St. to Shadowood Cr. (north). 4. Construction of channel improvements from Shadowood Cr. (north) to Garnett St. 5. Construction of channel improvements remaining from south of Hird St. to Weaver St.
College Avenue	$384,000	Participation and coordination with TXDOT for culvert improvements at Hwy 51 and College Avenue.	6. Construction of culvert and intersection drainage improvements at Hwy 51 and College Ave. 7. Construction of storm sewer system along College Avenue.
Refinery Road	$318,000	Acquisition of easements and right-of-way for project implementation.	8. Construction of channel improvements and diversion berm from Refinery Rd to Weaver St. 9. Construction of storm sewer system along Refinery Rd.
Weaver St/Sante Fe Dr.	$1,056,000	Participation and coordination with BN&SF Railroad for culvert improvements near Dixon St.	10. Construction of storm sewer system along Sante Fe Dr. from Weaver St. to Dixon St. 11. Construction of culvert improvements at BN&SF Railroad crossing east of Dixon St. 12. Construction of storm sewer system along Weaver St.
Broadway Street East	$2,300,000	Participation and coordination with TXDOT for storm sewer improvements required at California Street. Acquisition of right-of-way and easements for discharge channel to Wheeler Creek.	13. Construction of storm sewer system on Broadway St. from Fair Ave to Wheeler Creek and construction of channel improvements and diversion berm along Elmwood St. 14. Construction of Fair Ave storm sewer system and channel improvements from Fair Ave to Elmwood St.
Laurel Road	$1,465,000	Acquisition of right-of-way and easements for discharge channel to Wheeler Creek.	15. Construction of storm sewer system along Laurel Rd and Bridle Ln from Line Dr. to Wheeler Creek. 16. Construction of upstream storm sewer system along Merrywood Way, Line Drive, Howeth St., and Laurel Rd.
Culberson Street	767,000	Coordination with TXDOT for storm sewer discharge at IH-35 culvert entrance near Broadway Street.	17. Construction of lower storm sewer system from Hall St. to Broadway St. 18. Construction of upper storm sewer system from Fletcher St. to Hall St.
Airport Area	$143,000	Participation and coordination with TXDOT for culvert improvements at Weber Rd and Hwy 82.	19. Construction of culvert improvemetns at Weber Rd and Hwy 82. 20. Construction of channel and driveway culvert improvements along Weber Rd and Bonnavilla Dr.
Olive Street	$2,483,000	Participation and coordination with TXDOT for storm sewer improvements at Grand Ave and Olive St.	21. Constructinn of storm sewer system for Fair Ave and Olive St. 22. Construction of storm sewer system for Howeth St. and Whaley St.
Southwest Gainesville	$2,606,000	Funding issues related to the potential acquisition of matching grants through the FEMA FMA Program or the USCOE Local Flood Damage Reduction Program. Coordination with TXDOT for connection to the IH-35 road embankment. Acquisition of right-of-way, easements, and borrow areas for construction. Project needs to be constructed in conjunction with California St. levee improvements and Frank Buck Zoo channel improvements.	23. Acquisition of right-of-way, easements, and borrow areas. 24. Construction of recommended project.
Hillside Drive	$1,044,000	None	25. Construction of Magnolia St., Beecher St., and Aspen St. storm sewer system. 26. Construction of O'Neal St. storm sewer system.
O'Neal Street	$801,000	Participation and coordination with TXDOT for storm sewer improvements at Grand Ave and O'Neal St.	27. Construction of O'Neal St. storm sewer system. 28. Construction of storm sewer system along Clements St.
Broadway Street West	$784,000	Participation and coordination with TXDOT for storm sewer improvements at California St. and Sante Fe Dr. Participation and coordination with the BN&SF Railroad for channel and culvert improvements between Main St. and Garnett St.	29. Construction of BN&SF Railroad culvert and channel improvements from Main St. to Garnett St. 30. Construction of Broadway St. storm sewer system.
Greenbriar Drive	$600,000	None	31. Construction of Greenbriar Dr. storm sewer from Rosedale Dr. to Aspen St. 32. Construction of Rosedale Dr. and Aspen St. storm sewer systems.
California Street East	$312,000	Participation and coordination with TXDOT for storm sewer improvements on California Street.	No phased construction plan recommended.
Star Avenue	$62,000	Acquisition of right-of-way and easements for channel improvements.	No phased construction plan recommended.
California Street Levee	$173,0000	Funding issues related to the potential acquisition of matching grants through the FEMA FMA Program or the USCOE Local Flood Damage Reduction Program. Coordination with TXDOT for connection to California St. (Hwy 51) road embankment. Needs to be constructed in conjunction with Frank Buck Zoo channel improvements.	1. Install backflow prevention valve on existing drainage pipe. 2. Construction of California St. levee improvements.
Harris Street	$350,000	Acquisition of right-of-way and easements for channel improvements.	No phased construction plan recommended.
FM 678	$361,000	Acquisition of right-of-way and easements for channel improvements	No phased construction plan recommended.

Table 6-2
Summary of Estimated Implementation Costs

Project	Total Capital Cost	Estimate Cost Share: City Cost Share	Federal Cost Share	TXDOT Cost Share	BN&SF RR Cost Share	Implementation Costs for City by Phase: Phase 1	Phase 2	Phase 3
Pecan Creek	$8,983,000[1]	$4,141,500[1]	$4,541,500[1]	$300,000	$0	$373,000[2]	$125,000[3]	$3,643,500[4]
Chestnut Channel	$923,000	$646,000	$277,000	$0	$0	$128,000	$358,000	$160,000
College Avenue	$384,000	$304,000	$0	$80,000	$0	$40,000	$264,000	N/A
Refinery Road	$318,000	$318,000	$0	$0	$0	$200,000	$118,000	N/A
Weaver St/Sante Fe Dr.	$1,056,000	$901,000	$0	$0	$155,000	$490,000	$411,000	N/A
Broadway St. East	$2,300,000	$2,300,000	$0	$0	$0	$1,333,000	$967,000	N/A
Laurel Road	$1,465,000	$1,465,000	$0	$0	$0	$548,000	$500,000	$417,000
Culberson St.	$767,000	$767,000	$0	$0	$0	$634,000	$133,000	N/A
Airport Area	$143,000	$100,000	$0	$43,000	$0	$20,000	$80,000	N/A
Olive Street	$2,483,000	$2,403,000	$0	$80,000	$0	$1,584,000	$819,000	N/A
Southwest Gainesville	$2,605,000	$1,302,500	$1,302,500	$0	$0	$50,000	$1,252,500	N/A
Hillside Drive	$1,300,000	$1,300,000	$0	$0	$0	$1,147,000	$153,000	N/A
O'Neal Street	$801,000	$721,000	$0	$80,000	$0	$440,000	$281,000	N/A
Broadway Street West	$784,000	$645,000	$0	$0	$139,000	$92,000	$553,000	N/A
Greenbriar Drive	$600,000	$600,000	$0	$0	$0	$300,000	$300,000	N/A
California Street East	$312,000	$0	$0	$312,000	$0	$0	N/A	N/A
Star Avenue	$62,000	$62,000	$0	$0	$0	$62,000	N/A	N/A
California St. Levee	$173,000	$100,000	$73,000	$0	$0	$27,000	$73,000	N/A
Harris Street	$350,000	$350,000	$0	$0	$0	$350,000	N/A	N/A
FM 678	$361,000	$361,000	$0	$0	$0	$361,000	N/A	N/A
Total	***$26,237,000***	***$18,598,000***	***$6,194,000***	***$895,000***	***$294,000***	***$7,990,000***	***$6,387,500***	***$4,220,500***

Notes:
1. Includes cost of study phase estimated to be $350,000 with City funds of $125,000 and USCOE funds of $225,000.
2. Property acquisition cost for City.
3. Study cost for City.
4. Construction, relocation, land acquisition, engineering, and administration costs for City.
5. Capital costs include construction cost, construction contingencies (15%), and engineering, legal, and surveying costs (20%).

flexible and can be adjusted to be more or less comprehensive depending on the actual level of funding desired by the City. The implementation plan assumes that $2,500,000 in revenue bonds will be issued in fiscal year 2000 to fund the first stage of drainage improvements and a second issuance of bonds in the amount of $3,700,000 in fiscal year 2003 to fund the Pecan Creek channel improvements and other smaller projects. Drainage fee increases will be required in each of these years to support the annual bond payments and maintain adequate funding for annual operation and maintenance. The projects selected for the first stage of drainage improvements were based on the overall project rankings, outside funding and coordination issues, and land acquisition requirements. The projects are identified in Table 6-3 and the estimated schedule and annual revenue and expenditures for each fiscal year are also tabulated. The implementation plan is based on 1999 dollars and does not account for inflation of costs over time, nor does it account for future increases in revenue as the City expands.

A detailed summary of the recommended implementation steps for remaining part of fiscal year 1999 and for the next five years is provided below. Steps that are not completed in any given year will delay implementation of the project and, likewise, steps completed ahead of schedule may expedite implementation of the particular project.

Fiscal Year 1999

- Adopt the Flood Protection Planning Study Final Report and submit it to the Texas Water Development Board and FEMA for approval as the City's Flood Mitigation Plan.
- Negotiate easements for the Chestnut Channel Improvement Project.
- Begin negotiations for acquisition of improved properties along limits of Pecan Creek Channel Improvement Project.
- Prepare and submit applications for funding from the FEMA FMA Program for the Phase 1 of the Chestnut Channel Improvement Project.
- Acquire easements for the Refinery Road Project.
- Prepare construction plans and specifications for the Refinery Road Project.
- Begin coordination with TXDOT for culvert improvements at Hwy 51 (California Street) and College Avenue as part of Phase 1 of the College Avenue Project.
- Begin coordination with the BN&SF Railroad for culvert improvements at the railroad crossing near Sante Fe Drive and Dixon Street.

Table 6-3
Summary of Projected Implementation Costs

Project	Project Costs: Capital Cost	Project Costs: City Funding	Project Costs: Other Funding[1]	Projected Annual Costs: FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010
Pecan Creek	$8,983,000	$4,141,500	$4,841,500	$25,000[4]	$348,000[4]	$125,000[5]			$1,822,000	$1,822,000					
Chestnut Channel	$923,000	$646,000	$277,000		$168,000	$318,000					$160,000				
College Avenue	$384,000	$304,000	$80,000			$40,000									
Refinery Road	$318,000	$318,000	$0	$30,000	$170,000										
Weaver St/Sante Fe Dr.	$1,056,000	$901,000	$155,000		$80,000	$410,000									
Broadway St. East	$2,300,000	$2,300,000	$0												
Laurel Road	$1,465,000	$1,465,000	$0			$548,000									
Culberson Street	$767,000	$767,000	$0												
Airport Area	$143,000	$100,000	$43,000				$20,000								
Olive Street	$2,483,000	$2,403,000	$80,000												
Southwest Gainesville	$2,605,000	$1,302,500	$1,302,500												
Hillside Drive	$1,300,000	$1,300,000	$1,300,000												
O'Neal Street	$801,000	$721,000	$80,000								$440,000				
Broadway St. West	$784,000	$645,000	$139,000			$92,000									
Greenbriar Drive	$600,000	$600,000	$0												
California Street East	$312,000	$0	$312,000												
Star Avenue	$62,000	$62,000	$0				$62,000								
California Street Levee	$173,000	$100,000	$73,000			$27,000									
Harris Street	$380,000	$380,000	$0												
FM 678	$393,000	$393,000	$0												
Annual O&M				$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000	$50,000
Annual Debt Service[2]				$0	$104,167	$208,333	$208,333	$362,500	$516,667	$516,667	$516,667	$516,667	$516,667	$516,667	$516,667
C.I.P. Bond Proceeds				$0	$2,500,000			$3,700,000							
Municipal Drainage Utility Revenue[3]				$137,000	$323,000	$323,000	$323,000	$607,000	$607,000	$607,000	$607,000	$607,000	$607,000	$607,000	$607,000
Total Income				$137,000	$2,823,000	$323,000	$323,000	$4,307,000	$607,000	$607,000	$607,000	$607,000	$607,000	$607,000	$607,000
Total Expenditures				$105,000	$920,167	$1,818,333	$340,333	$412,500	$2,388,667	$2,388,667	$1,166,667	$566,667	$566,667	$566,667	$566,667
Balance				$32,000	$1,934,834	$439,500	$422,167	$4,316,667	$2,535,000	$753,334	$193,667	$234,000	$274,334	$314,667	$355,000

Notes:
1. Other funding sources potentially include FEMA, U.S. Army Corps of Engineers, TXDOT, and the BN&SF Railroad.
2. Annual debt service based on an assumed annual interest rate of 5.5 percent and a financing period of 20 years.
3. Municipal Drainage Utility Revenue based on existing rate structure for FY 1999 and future potential rate increases in FY 2000 and FY 2003.
4. Land acquisition costs.
5. Estimate of City's share of cost for restudy of Pecan Creek Channel Improvements Project by the U.S. Army Corps of Engineers

FY 2000

- Increase Municipal Drainage Utility Fees and issue $2,500,000 in capital improvement bonds for drainage improvements.
- Construct Refinery Road Project.
- Prepare construction plans and specifications for Chestnut Channel Improvement Project (Phase 1)subject to availability of funds through the FEMA FMA Program.
- Prepare application for funding from the FEMA FMA Program for Phase 2 of the Chestnut Channel Improvement Project.
- Prepare application for funding from the FEMA FMA Program for acquisition of improved properties along the limits of Pecan Creek Channel Improvement Project.
- Coordinate with BN&SF Railroad for culvert and channel improvements between Main Street and Garnett Street as part of Phase 1 of the Broadway Street West Project.
- Prepare construction plans and specifications for Phase 1 of the Weaver Street/Sante Fe Drive Storm Sewer Improvement Project.
- Issue request for assistance and negotiate planning study costs with the U.S. Army Corps of Engineers for the Pecan Creek Channel Improvements Project, subject to the availability of Federal funding.
- Coordinate future funding with TxDOT for replacement of California Street bridge over Pecan Creek as part of the Pecan Creek Channel Improvement Project.
- Coordinate other funding sources such as Cooke County for bridge replacements as part of the Pecan Creek Channel Improvement Project.

FY 2001

- Construct culvert improvements at Hwy 51 and College Avenue as part of Phase 1 of the College Avenue Project.
- Prepare construction plans and specifications for Phase 1 of the Laurel Road Storm Sewer Improvements Project.
- Construct Phase 1 of the Laurel Road Storm Sewer Improvements Project.
- Construct channel improvements and culvert improvements along the BN&SF Railroad as part of Phase 1 of the Broadway Street West Project.
- Prepare construction plans and specifications for Phase 1 of the California Street Levee Project for installation of a backflow prevention valve on an existing drainage pipe.
- Install backflow prevention valve on an existing drainage pipe at California Street Levee.
- Coordinate with TXDOT for culvert improvements at S.H. 82 and Weber Road.
- Complete U.S. Army Corps of Engineers Planning Study for the Pecan Creek Channel Improvements Project and authorize preparation of plans and specifications for construction of the project, subject to the availability of funding.

FY 2002

- Construct culvert and culvert improvements at S.H. 82 and Weber Road as part of the Airport Area Project.
- Prepare plans and specifications for culvert and channel improvements at Star Avenue.
- Construct culvert and channel improvements at Star Avenue.
- Acquire right-of-way, easements, and disposal areas required for construction of the Pecan Creek Channel Improvement Project.

FY 2003

- Increase Municipal Drainage Utility Fees and issue $3,700,000 in capital improvement bonds for drainage improvements.
- Continue with preparation of plans and specifications for Pecan Creek Channel Improvement Project.
- Continue with right-of-way, easement, and disposal area acquisition as part of the Pecan Creek Channel Improvement Project.

FY 2004

- Begin construction of Pecan Creek Channel Improvement Project.

FY 2005

- Complete construction of Pecan Creek Channel Improvement Project.
- Issue FEMA Floodplain Map revisions for Pecan Creek.
- Begin preparation of construction plans and specifications for Phase 3 of the Chestnut Channel Improvement Project.
- Begin preparation of construction plans and specifications for O'Neal Street Storm Sewer Improvements.

Current revenue from the Municipal Drainage Utility is approximately $137,000 per year. In order to produce annual revenues sufficient to support the funding levels presented in the implementation plan, an increase in the monthly drainage fees will be required. As previously discussed in Section 5, various levels of increases in drainage fees were analyzed using a rate model developed as part of this study. In order to support the first bond issue of $2,500,000 in fiscal year 2000 and annual operation and maintenance costs of approximately $50,000 per year, the base residential drainage fee will need to be increased from $0.50 per month to $2.00 per month. Similarly, as shown in Table 5-2, commercial rates would also be increased although a decreasing block rate structure would be recommended to equitably distribute the costs. A second bond issuance would be expected to occur in fiscal year 2003 in order to fund the Pecan Creek Project and other smaller projects, subject to availability of funds through the U.S. Army

Corps of Engineers. A second increase in the base residential rates would be required at this stage, increasing from $2.00 per month to approximately $3.50 per month. These base residential rates and corresponding non-residential rate structures are comparable to other rate structures in place for other Texas municipalities as shown in Table 6-4. A summary of the projected revenue and monthly drainage fees by customer category for each of the potential rate increases is also presented in Table 6-5. The revenue projections presented in Table 6-5 and previously in Table 5-2 provide a guide for the City to select the extent of drainage improvements and the level of funding that is affordable for its citizens.

Table 6-4
Summary of Base Residential Rates for Cities in Texas

City	1990 Population	Monthly Base Residential Fee
Gainesville	14,256	$0.50
Georgetown	14,842	$2.25
Grapevine	29,202	$4.00
Euless	38,149	$2.50
Bedford	43,762	$2.50
College Station	52,456	$3.50
Mesquite	101,484	$3.00
Garland	180,650	$2.40
Austin	456,622	$3.67

Table 6-5
Summary of Projected Annual Revenues for Potential Municipal Drainage Utility Rate Structures for the City of Gainesville

Category	Average SRU Size	No. of Acct.	Existing Rates $0.50 Base Residential: Monthly Drainage Fee	Existing Rates $0.50 Base Residential: Projected Annual Revenue	FY 2000 Option $2.00 Base Residential: Monthly Drainage Fee	FY 2000 Option $2.00 Base Residential: Projected Annual Revenue	FY 2003 Option $3.50 Base Residential: Monthly Drainage Fee	FY 2003 Option $3.50 Base Residential: Projected Annual Revenue
Non-Residential 0 to 1 SRU	0.50	42	$0.25	$126	$2.00	$1,008	$3.50	$1,764
Residential 1 SRU	1.00	5,354	$0.50	$32,124	$2.00	$128,496	$3.50	$224,868
Non-Residential 1 to 3 SRU	1.83	172	$0.92	$1,889	$3.66	$7,561	$5.99	$12,373
Non-Residential 3 to 10 SRU	5.73	265	$2.87	$9,111	$10.09	$32,083	$16.32	$51,882
Non-Residential 10 to 20 SRU	14.29	134	$7.15	$11,489	$20.79	$33,441	$35.58	$57,236
Non-Residential 20 to 100 SRU	40.71	167	$20.36	$40,791	$36.85	$73,863	$78.06	$156,464
Non-Residential 100 to 999 SRU	275.44	25	$137.72	$41,316	$154.22	$46,262	$342.44	$102,724
Total		**6,159**		**$137,000**		**$323,000**		**$607,000**

Notes:
1. SRU – Standard Residential Unit equal to 1,895 square feet of impervious area.
2. Average SRU size based on average of all accounts in each individual category.

City of Gainesville
Flood Protection Planning Study
Summary of Survey Responses

No.	Last Name	First Name	Problem Location	Type of Flood Problem: Home Flooding	Business Flooding	Street Flooding	Yard Flooding	Standing Water	Problem Description	Source of Problem	Flood Damages	Flood Insurance	F.I. Cost Per Year	I.D.
1	Alexander	Dale & Dorothy	729 South Weaver	X			X		Home flooded in 1981	Elm Fork	$1,000	No		5
2	Algar	Rebecca	Harris Street on west side of Wheeler Creek			X			Street Floods	Excess Street Flow		No		1
3	Allman	Jack	Street flooding at Belcher Street			X				Flooded by Wheeler Creek	None	No		4
4	Alsup	R E.	Garnett Street	X			X		Backwater		$10,000	No		2
5	Andrews	Hubert H.	Corner of Commerce & Garnett Streets				X		Northeast corner of property floods		None	No		3
6	Bagwill	Milton D.	910 N Clements Street	X		X	X		Home, Street flooding	Poor drainage east and northeast	$3,000	No		19
7	Blagg	Frank	706 Melody Lane	X			X		Cabin flooded, banks eroding.	Wheeler Creek		No		12
8	Blanton	Ken	207 Melody Lane			X	X		Flow from Schopmeyer,Tennie,Taylor Streets	Excess street flow		No		18
9	Bloom	Barbara	Near FM 372 and Weaver Street			X	X		Street overtopped, yard flooded	Inadequate channel capacity		No		17.5
10	Bob Smith Coachworks		Hwy 82 and Floral Drive		X	X			Business flooded, street flooding	Excess street flow & creek on east	$252	No		133
11	Bonin	Stephen & Carmen	Intersection of College Ave/California Street			X	X		Entrance to subdivision floods	Excess Street Flow		No		13
12	Boone Trading Post		300 N. Commerce	X	X	X	X		Business & home flooded, Street flooding	Pecan Creek		No		7
13	Bransford	Bob	1810 E. Broadway	X		X	X		Street flooding, garage flooded	Poor street drainage	None	No		16
14	Brooks	Lonnie & Debbie	1821 Lindsay Street	X		X	X			Elm Fork, excess street flow	$28,000	No		9
15	Brown	Bob & Dava	1908 Laurel Road	X			X	X	Yard Floods, standing water, street flooding, garage flooded		$2,000	Yes	$380	8
16	Burt	Delbert	607 Melody Lane	X		X	X				None	No		15
17	Bush	James & Dorothy	717 E. Scott Street	X		X	X		Cars flooded, home flooded (2), street flooding	Pecan Creek	$20,000	Yes	$550	10
18	Carrigan	Maggie	501 Fair Ave	X		X	X		Home flooded	Excess street flow		No		22
19	Cartwright	Richard	2 Brookhollow	X			X		Home flooded	Elm Fork flooding	$85,000	Yes	$855	33
20	Cason	Jess S.	1711 Old Denton Road	X			X		Home flooded	Pecan Creek	$80,000	Yes	$685	23
21	Chapman	Jo	909 Smith Street	X		X	X		Home, yard, street flooding	Pecan Creek	$18,000	No		24
22	Chef Mauric		721 Belcher Street	X			X		Home flooded	Pecan Creek	$12,000	Yes		94
23	Childress	Mary Louise	805 Gosset Street	X		X	X		Home, yard, street flooding	Pecan Creek, excess street flow		No		20
24	Childress	Robert	523 N. Chestnut			X	X	X	Yard flooding, street flooding, standing water	Excess street flow		No		29
25	Christine	Frank H	1809 N Weaver Street			X			Street flooding, damage to driveway	Excess street flow		No		30
26	Church of Jesus Christ		1612 E Broadway Street			X			Street flooding, sewer backup	Excess street flow				25
27	Clure	Joy A & Sarah	420 Hillside Drive	X		X	X		Homes, autos, street flooding	Cemetary runoff, excess street flow		No		27
28	Comer	Sue	601 Walter Road			X			Street flooding	Runoff from sale barn, Lexington Apts		No		32
29	Cook	Michael	701 Moss Street	X		X	X		Home, auto, barns flooded	Pecan Creek	$8,000	No		26
30	Cooke Co. Roofing		2202 E. Hwy 82				X		Business yard flooding	Excess runoff from Hwy 82/Aspen St.		No		108
31	Cooke Co. Youth Center		315 W. Hird			X		X	Street flooding, standing water	Excess street flow		Yes	$900	151
32	Covington	Morton Vern	515 Cole Street			X	X		Yard floods, street flooding	Inadequate capacity at railroad		No		21
33	Cowan	Olita	407 Fair Avenue				X		Yard flooded	Cemetary runoff, excess street flow		No		28
34	Crockett	Cathy	905 W. Star	X			X		Dry creek floods, yards flood, home flooding	Inadequate channel capacity		No		31
35	Davis	George M.	209 Melody Lane	X		X	X		Street flooding, yard flooded, porch flooded	Excess street flow		Yes	$166	39
36	Davis	Martha	1305 & 1307 E. Tennie Str.	X		X	X		Yard flooding, foundation damage	Excess runoff		No		40
37	Dickerman	Eldean	1403 Hancock Street			X	X		Street, yard flooded, foundation damage	Excess street flow		No		36
38	Dillard	Dolly Doty	411 S. Grand Ave			X	X		Street, yard flooded. Standing water, foundation damage	Excess street flow		No		34
39	Doty	Donna G	Oneil & N Grand Ave			X	X		Excess runoff, sewer backup	Excess runoff		No		37
40	Dudley	Jeff	Intersection of University West/Tulane			X		X	Street flooding, standing water	Poor street drainage		No		35
41	Duncan	Russell	628 Lindsay Street	X		X	X		Home flooded, auto damage, street flooding	Pecan Creek	$60,000	Yes	$400	38
42	Eberhart	June	1321 E Tennie Str.	X			X		Home flooding, yard flooding			No		42
43	Enderby	J A	508 S Chestnut	X			X		Home flooded	Elm Fork flooding	$18,000	Yes	$450	43
44	Estes	Norma Jane	214 W Tennie Street	X			X		Home flooded	Elm Fork flooding	$14,543	Yes	$345	44
45	Estes Exterm	Ray G	212 W Tennie Str.	X		X	X		Home flooded, street flooding	Excess street flow	$20,500	Yes	$275	41
46	Felderhoff	Marge	800 S Rusk Street	X		X	X		Home flooded, street flooding		$25,000	Yes	$75	47
47	Felphs	Bernice	Oneil & Whale Drive			X			Street flooding	Excess street flow		No		45
48	First State Bank		801 E California Street		X				Business flooded	Pecan Creek		Yes	$287	46
49	First State Bank		800 E Garnett Street	X			X		Home flooded	Pecan Creek				46
50	Flietman	Allen	213 W Tennie Str	X			X		Home flooded	Elm Fork flooding	$6,000	No		48
51	Foster	Barbara	1305 Moss Street			X			Street flooding	Excess street flow	None	No		49
52	Freewood Products Co., Inc.		1101 Woods Ave		X				Business flooded	Elm Fork flooding	$200,000	No		51
53	Fulton Supply & Recycling		Scott & Dennison Str.		X				Business flooded	Pecan Creek	$1,000	No		50
54	Gainesville Municipal Airport		A P Terminal, Hangar, Weber Aircraft			X			Street flooding	Inadequate ditch capacity				142