SH 183/ SH 121
AIRPORT FREEWAY SCHEMATICS
WEST SECTION

PRELIMINARY DRAINAGE STUDY

STATE OF TEXAS
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LOCKWOOD, ANDREWS & NEWNAM, INC.

TXDOT - FORT WORTH DISTRICT

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LOCKWOOD, ANDREWS & NEWNAM, INC.

TXDOT - FORT WORTH DISTRICT

December 2003

I. EXECUTIVE SUMMARY

A. Purpose:

The study is a comparative review of the SH 121/SH 183 (Airport Freeway) cross drainage studies prepared utilizing differing methodologies. The intent is to aid TxDOT and local cities along the corridor with drainage feature fund programming in the development and planning of the Airport Freeway project. A summary of drainage feature construction costs presents a comparison between City Master Drainage Plan recommendations (Hurst, Bedford and Euless) and TxDOT policy and procedure recommendations.

B. Approach and Assumptions:

Airport Freeway is currently a 6-lane freeway with 2-lane frontage roads. The project limits are from IH 820 to County Line Road (at the Dallas County Line). The freeway extends generally from east to west and crosses cities of: North Richland Hills, Hurst, Bedford, Euless and Forth Worth.

There are four separate studies of the Airport Freeway cross drainage. The following descriptions are presented in chronological order. The first being the TxDOT initial design of the freeway drainage features for construction. Federal Emergency Management Agency Flood Insurance Rate Maps (FEMA/FIRM) and studies according to National Flood Insurance Program (NFIP) criteria. The Cities of Hurst, Euless and Bedford prepared master drainage studies that detailed the design of entire streams in their cities.

Nine major FEMA/FIRM studied waterways cross Airport Freeway and are tabulated below.

STREAM NAME	COMMUNITY	LANDMARK	FIRM MAP NO.
Lorean Branch	Hurst	Precinct Line Rd.	48439C0308H
Valley View Branch	Hurst/Bedford	Norwood	48439C0308H

Sulphur Branch	Bedford	Bedford Drive	48439C0309J
Stream SB-1	Bedford	Forest Ridge Drive	48439C0309J
Hurricane Creek	Bedford	At SH 121	48439C0330J
Stream HC-1	Bedford	Wilshire Drive	48439C0330J
Boyd Branch	Euless	Industrial Blvd	48439C0330J
Big Bear Creek	Fort Worth	International Pkwy	48439C0335J

The study approach is to analyze the existing cross drainage structures with TxDOT hydrology and hydraulic models to determine their current operations, and then design a replacement structure consistent with TxDOT and NFIP criteria. TxDOT hydraulic design criteria for a freeway prescribe a minimum 50 year design and analysis of the 100 year event to verify satisfaction of NFIP criteria. The 50 year design should consider probable future development and consistency with city master planning. The 100 year analysis used in this preliminary study were developed from TxDOT criteria. The hydrology was calculated using urban regression equation techniques. A more detailed approach will be used during detailed design phase. FEMA base floodway models will be obtained to perform the 100 year analysis of the proposed improvements.

Existing structures appear to be equivalent to 10 to 25 year design by current TxDOT practices. The resulting replacement structure is expected to operate hydraulically equal to or better than the one it replaces because designs will be based upon current 50 year hydrology. The replacement structure should not increase the base flood elevations. Generally, this applies directly to crossings in which either the roadway profile is lowered or the replacement structure is the same or larger than the existing structure. The replacement structures will convey the 50 year event under the new freeway through conduit or bridge. However, the 100 year event may pass over the roadway surface, but under no circumstances may the 100 year water surface profiles be higher than what the established floodway models allow. This approach is expected satisfy NFIP requirements for FEMA coordination.

City master drainage plans recommend solutions that fully convey 100 year events within culvert conduit or bridge opening. The modeled peak discharges were determined using Natural Resources Conservation Service (NRCS, formerly known as SCS) methods, which are more detailed than TxDOT regression methods and produce substantially higher peak discharges. Additionally, the purpose of the city studies are to model for future development to aid city planners and engineers in building their city. The city master drainage plans were developed with conservative assumptions of future development. The applied approaches are more conservative than that required by NFIP and TxDOT criteria. Generally, FEMA condones stricter design ordinances, but it does not require them. FEMA regulations specifically state that existing watershed conditions are to be the basis for establishing flood insurance rate zones, not future conditions. The city plan recommendations are in excess of FEMA regulations. Neither FHWA nor FEMA require states to comply with stricter city hydraulic design ordinances. On Federal-aid projects, FHWA will not fund costs in excess of those required for highways to meet basic FEMA criteria. If the design is to accommodate such ordinances, TxDOT requires that any cost in excess of what would be required to accommodate either FEMA basic criteria or TxDOT criteria be borne by the community or regional council enforcing such an ordinance unless otherwise mandated by federal or state law or policy. This rationale is consistent with both the hierarchical structure of government and the fact that TxDOT is responsible for ensuring equitable use of highway funds. This philosophy may not always result in additional cost to the local entity; a risk assessment involving a range of design alternatives possibly may yield a least total cost option that accommodates the provisions of the stricter ordinance.

The study is developed in the preliminary design stage of project development. Therefore, the level of detail has been limited to collection of available documents such as; as-built construction records, drainage studies, aerial photogrammetry, and site visits. Field survey data was not collected and considered beyond the scope of this preliminary design study. Also, detailed plans of adjacent property modifications were not obtained to determine their influences upstream and downstream of the project. The approach used herein is to analyze adequacy of existing cross drainage features and compare to proposed modifications designed to satisfy drainage area demand.

Some FIRMs appear outdated due to development adjacent to the ROW since initial construction of Airport Freeway. Land use changes and channel modifications are not reflected in FEMA FIRMs. Therefore, existing flood hazard boundaries do not reflect the observed stream hydraulic conditions. Airport Freeway reconstruction FIRM modification and subsequent Letters of Map Revisions (LOMR) will require additional modeling efforts due to the amount of stream modifications that may need to be performed downstream to adequately model the Airport Freeway improvements and satisfy FEMA LOMR requirements.

The general direction of the drainage flow of the area is from north to south which holds true for every culvert crossing Airport Freeway. Drainage area naming conventions followed designations found in the as-built plans to construct Airport Freeway. Drainage areas are designated from B to P and the last two areas are drainage areas for Bear Creek and structure #18 located just to the west of County Line road. General methods used to model the flows running through the culverts were: Dallas-Forth Worth Urban Regression Method and Rational Method, depending on the size of each drainage area and location.

TxDOT hydraulic design packages, Thysys Culvert and WinStorm, were used to analyze existing culvert operations and prepare preliminary design recommendations. The use of software ensures consistency with TxDOT methods and automates computations and documentation. Thysys Culvert V1.1 was used for Box culverts. WinStorm V3.05 was use to analyze storm systems that outfall to a culvert. Since each culvert is unique, the approach to analyze them in this study is discussed one by one to better explain the status of each culvert.

Drainage Areas B and C: Culvert B is the first culvert at the west limit of the project and is located opposite of the City of Hurst City Hall at Precinct Line Road. Culvert B was originally constructed as a multi-barrel box culvert that crossed the highway and flowed into an outfall channel. This channel connected to Lorean Branch, downstream from culvert C. Over time, development of the adjacent property resulted in culvert extensions for the full length of the outfall channel to its connection to Lorean Branch (culvert C outfall). Culvert B is undersized based on the culvert analysis. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Culvert C serves as cross drainage for Lorean Branch and is located nearly a quarter of a mile east of Precinct Line Road. Its capacity can be improved by adding more barrels of the same size in parallel. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Areas D, E, and F: These culverts have similar hydraulic issues. Drainage area D serves Valley View Branch. Its outfall is 500 feet east of Norwood at Grubbs Nissan. Drainage Area E serves Sulphur Branch. Its outfall is located 500 feet west of Bedford Road. And Drainage Area F serves tributary 1 of Sulphur Branch (stream SB-1). Its location is 500 feet west of Forest Ridge Drive. All culverts remain in their original configuration and they need capacity improvements to satisfy TxDOT requirements. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Areas G and G1: G and G1 serve as cross drainage for Hurricane Creek. The outfall is at the SH 121 interchange. Both current structures are double 9'x9' multi-barrel box culverts. G is located downstream of G1 and the headwater elevation for G was assumed to be the tailwater elevation for G1. Since they are both inadequate, new multiple box culverts were proposed. The minimum structure suggested for G is a 5 BBL - 10'x10' multiple box culvert. Regarding the magnitude of this structure, a bridge with equivalent or larger conveyance is a viable option. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Area H: Culvert H serves as cross drainage for a secondary tributary Hurricane Creek. The outfall condition of culvert H has a similar history as that of culvert B. The original culvert has been modified with a culvert extension that is assumed to connect to Hurricane Creek tributary 1 (Stream HC-1). The culvert will be analyzed using the as-built plans drainage area with the point of study being the end of the box culvert at the south ROW line. The detailed study of the culvert to its' confluence with Stream HC-1 will be considered beyond the scope of preliminary study. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Area I: Culvert I serves as cross drainage for Stream HC-1 and it is located approximately a half mile east of West Park Way (at Service King Collision Repair Center). The outlet headwall for this culvert is in its original configuration. However, approximately 10' downstream, development enclosed Stream HC-1 into to a 2 BBL MBC to accommodate the business' parking lot. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Area J: Culvert J serves as cross drainage for a secondary tributary of Stream HC-1 and it is located approximately a half mile west of Industrial Blvd. Again, the original culvert in the plans has been modified with a culvert extension. This study will assume it is connected to the culvert off-ROW at stream HC-1. The culvert will be analyzed using the as-built plan's drainage area with the point of study being the end of the box culvert at the south ROW line. The detailed study of the culvert to its' confluence with Stream HC-1 will be considered beyond the scope of preliminary study. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Area K: Culvert K serves as cross drainage for Boyd Branch and is located on the east side of the Industrial Blvd. Intersection with Airport Freeway. Adjacent ROW development has extended the length of this culvert, both upstream and downstream. The assumption is that the original double 10'x6' is still under the highway serving the same amount of drainage area. The culvert analysis was based on the as-built drawing configuration. Results indicate that the existing structure is adequate. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Area L: Culvert L serves as cross drainage for an unnamed tributary of Boyd Branch and it is located at Sheppard Drive. Analysis based upon pipe size, slope and culvert length obtain in as-built plans indicates the structure's capacity is adequate. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Area M: Culvert M serves as cross drainage for another unnamed tributary of Boyd Branch and it is located 200' east of Ector Dr. Capacity analysis indicates the existing structure is adequate. It should require some length adjustment and reconstruction at the inlet and outlet to accommodate the new frontage roads. The peak discharges were calculated using TxDOT Urban Regression Equation methods. Culvert hydraulics were calculated using Thysys Culvert.

Drainage Areas N, O, P: These drainage areas delineate a point of study for peak discharges from city storm sewer networks that cross Airport Freeway. Structure N is adequate but capacity analysis of structures O and P indicate a need for more capacity. The study assumes the network will be reconstructed to accommodate the new facility. The peak discharges were calculated using Rational method. Culvert hydraulics were calculated using Winstorm.

Bear Creek: A comparison of the as-built peak discharges to this study's calculated peak discharges indicates no conveyance improvements are required. The peak discharges were calculated using TxDOT Urban Regression Equation methods.

Drainage Areas # 17, 18, 23: These drainage areas serve the east project limit and combine to form the last culvert crossing Airport Freeway. The areas form a storm sewer network that connect into the main crossing trunk, a 3'x2' RCB. Capacity analysis indicates the system appears adequate with the exception of the downstream portion of the trunk that goes under the south frontage road. This portion could be changed into a 3'x3' RCB to accommodate the flow. The study assumes the network will be redesigned to accommodate the new facility. The peak discharges were calculated using Rational method. Culvert hydraulics were calculated using Winstorm.

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SUMMARY

LOCKWOOD, ANDREWS & NEWNAM, INC.
TXDOT - FORT WORTH DISTRICT
December 2003

SUMMARY

Table 1 - Peak Discharges

City	Drainage Area			TxDOT Methodology		City Drainage Studies	
	ID	Location	Area (acres)	Q_{50} (cfs)	Q_{100} (cfs)	Q_{100} (cfs)	Watershed
Hurst	B	STA 62+40 SH183	350	1036	1188	NA.	Lorean Branch
	C	STA 77+18 SH183	1455	2880	3325	5300	Lorean Branch
Bedford	D	STA 132+26 SH183	803	1934	2219	2770	Valley View Branch
	E	STA 170+05 SH183	1000	2334	2670	4514	Sulfur Branch
	F	STA 198+75 SH183	358	1054	1209	1825	Stream SB-1
	G1	STA 262+28 SH183	1149	2591	2963	4800	Hurricane Creek
	G	STA 262+28 SH183	1174	2634	3012	5240	Hurricane Creek
	H	STA 289+42 SH183	58	232	254		
	I	STA 297+66 SH183	368	1050	1208	2438	Stream HC-1
	J	STA 309+22 SH183	90	258	281		
Euless	K	STA 337+48 SH183	222	819	926	NA.	West Fork Trinity River
	L	STA 350+70 SH183	72	351	397	NA.	West Fork Trinity River
	M	STA 365+00 SH183	100	413	473	NA.	West Fork Trinity River
	N	STA 396+75 SH183	64	199	217	NA.	West Fork Trinity River
Forth Worth	O	STA 427+70 SH183	42	135	148	NA.	West Fork Trinity River
	P	STA 422+50 SH183	48	196	214	NA.	West Fork Trinity River
	BC	Bear Creek, between Amon Carter Blvd. & Valley View Ln.	51200	41907	48379	NA.	Bear Creek
	18	STA. 1025+07 SH183	8	68	75	NA.	Bear Creek

Note: City of Bedford Drainage Master plan study prepared June 1992.

Table 2 - Recommended Structures

	Drainage Area		Existing Structure			Proposed Structure			City Drainage Studies
ID	Location	Area (acres)	Culvert Size	Slope %	Length (ft)	Culvert size	Slope %	Length (ft)	Culvert size Recommendations
B	STA 62+40 SH183	350	2- 7'X3' MBC	0.53	1800	6-7'x3' MBC	0.53	332	No Recommendation
C	STA 77+18 SH183	1455	5- 7'X7' MBC	0.52	307	8- 7'X7' MBC	0.52	437	No Recommendation
D	STA 132+26 SH183	803	4- 6'X6' MBC	0.44	340	8- 6'X6' MBC	0.42	356	4-10'X10' MBC Proposed
E	STA 170+05 SH183	1000	4- 9'X6' MBC	0.50	344	5- 9'X6' MBC	0.50	490	2-10'X10' MBC Addition
F	STA 198+75 SH183	358	2- 7'X6' MBC	0.45	334	4- 7'X6' MBC	0.25	400	2-7'X6' MBC Addition
G1	STA 262+28 SH183	1149	2- 9'X9' MBC	0.83	465	4- 9'X9' MBC	0.83	490	2-10'X10' MBC Addition
G	STA 262+28 SH183	1174	2- 9'X9' MBC	0.84	76	5- 10'X10' MBC	0.83	120	25'X12' Proposed Bridge
HIJ	STA 297+66 SH183	368	1- 9'X6' RCB	1.21	340	2- 9'X6' MBC	1.48	365	5-10'X6' MBC Addition
K	STA 337+48 SH183	222	2- 10'X6' MBC	0.30	385	Existing is Adequate			
L	STA 350+70 SH183	72	1- 54" RCP	1.42	486	Existing is Adequate			
M	STA 365+00 SH183	100	2- 7'X3' MBC	0.37	374	Existing is Adequate			
N	STA 396+75 SH183	64	1-72" RCP	0.67	256	Existing is Adequate			
O	STA 427+70 SH183	42	1- 48" RCP	0.55	270	1- 60" RCP	0.55	270	
P	STA 422+50 SH183	48	1- 42" RCP	1.02	150	1- 60" RCP	1.02	150	
BC	Bear Creek, between Amon Carter Blvd. & Valley View Ln.	51200	Multiple Span Bridge						
18	STA. 1025+07 SH183	8	1- 3'X2' RCB	1.15	366	Last 33', 3'x3' RCB	1.15	33	

Table 3 - Existing Culvert Computations

	Drainage Area			Existing Structure				Flow		Headwater Elevation			
										Existing		Proposed	
ID	Station	Area	Culvert Size	Length	Fl_{in}	FL_{out}	Slope	Q_{50}	Q_{100}	HW_{100}	HW_{50}	HW_{100}	HW_{50}
		(acres)		(ft)	(ft)	(ft)		(cfs)	(cfs)	(ft)	(ft)	(ft)	(ft)
B	STA 62+40 SH183	350	2- 7'X3' MBC	1800	569.63	560.09	0.0053	1036	1188	612.97	602.96	574.65	574.14
C	STA 77+18 SH183	1455	5- 7'X7' MBC	307	554.50	552.90	0.0052	2880	3325	567.23	565.39	565.37	562.26
D	STA 132+26 SH183	803	4- 6'X6' MBC	340	560.50	559.00	0.0044	1934	2219	571.16	570.44	569.11	566.88
E	STA 170+05 SH183	1000	4- 9'X6' MBC	344	546.00	544.27	0.0050	2334	2670	555.00	553.74	556.60	553.63
F	STA 198+75 SH183	358	2- 7'X6' MBC	334	558.30	556.80	0.0045	1054	1209	567.28	567.00	567.60	567.02
G1	STA 262+28 SH183	1149	2- 9'X9' MBC	465	530.90	527.04	0.0083	2591	2963	544.96	543.45	542.64	539.98
G	STA 262+28 SH183	1174	2- 9'X9' MBC	76	525.82	525.18	0.0084	2634	3012	541.36	539.58	539.89	533.20
HIJ	STA 297+66 SH183	368	1- 9'X6' RCB	340	540.50	536.40	0.0121	1050	1208	548.42	548.18	551.40	550.16
K	STA 337+48 SH183	222	2- 10'X6' MBC	385	543.40	542.25	0.0030	819	926	550.45	549.87		
L	STA 350+70 SH183	72	1- 54" RCP	486	568.40	561.50	0.0142	351	397	570.18	570.18		
M	STA 365+00 SH183	100	2- 7'X3' MBC	374	564.94	563.54	0.0037	413	473	568.67	568.50		

	Drainage Area		Existing Structure			Flow		Capacity			
								Existing		Proposed	
ID	Station	Area	Culvert Size	Length	Slope	Q_{50}	Q_{100}	$*CAP_{100}$	CAP_{50}	CAP_{100}	CAP_{50}
		(acres)		(ft)		(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
N	STA 396+75 SH183	64	1-72" RCP	256	0.0067	199	217	347.19	347.19		
O	STA 427+70 SH183	42	1- 48" RCP	270	0.0055	135	148	106.54	106.54	193.18	193.18
P	STA 422+50 SH183	48	1- 42" RCP	150	0.0102	196	214	101.63	101.63	263.08	263.08
18	STA. 1025+07 SH183	8.3	1- 3'X2' RCB	366	0.0115	68	75	52.36	52.36	91.13	91.13

* 100-yr flow capacity

Table 4 - Cost Estimate

Drainage Area ID	Complete Reconstuction	Add Barrels Lengthen	Remove Existing Proposed Bridge	City Recommendations	Study Recommendations
B		$300,000			$300,000.0
C	$577,666	$171,846		-	$899,414
D		$20,774		$1,423,000	$24,929
E	$231,324	$275,648		$960,000	$608,367
F	$196,032	$32,345		$500,000	$274,053
G1	$613,646	$42,667		-	$787,575
G	$290,400			$1,053,000	$348,480
H,I,J	$169,952	$16,523		$1,410,000	$223,771
K,L	$88,010				
O	$48,895	$88,000			
P	$27,163	$89,000			
18	$72,330	$6,382			
Total Cost	$2,315,418	$1,043,185		$5,346,000	$3,466,588

SH 183/ SH 121
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WEST SECTION

PRELIMINARY DRAINAGE STUDY
PRELIMINARY HYDROLOGY

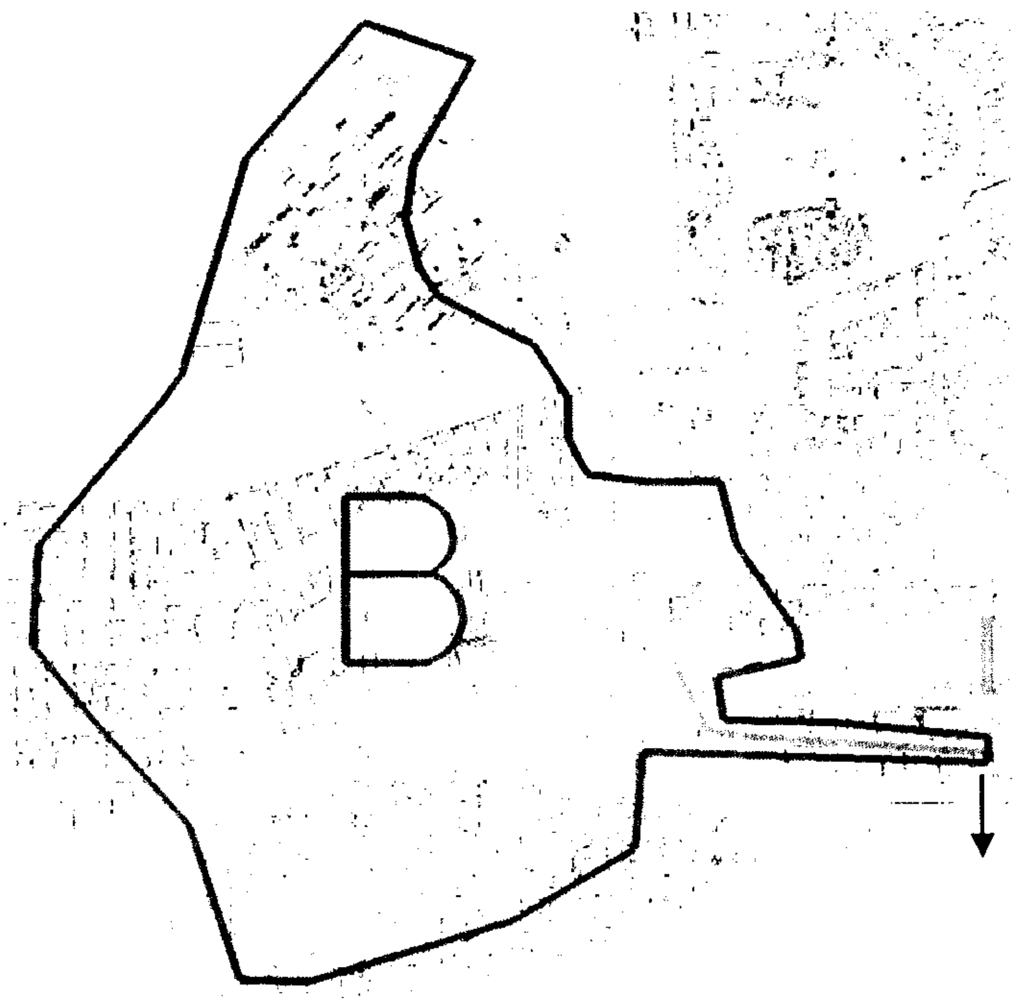
LOCKWOOD, ANDREWS & NEWNAM, INC.
TXDOT - FORT WORTH DISTRICT
December 2003

Runoff Calculations
Drainage Area - B

Culvert Location: West of Precinct Line Road
City: Hurst

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
B	STA 62+40 SH183	350	25	730	902	1036	1188

	UI COMPUTATIONS			
	FACTORS			TOTAL
SUBAREA	Storm Sewers	Curb and Gutter	Channel Rectification	
UPPER	3	3	1	7
MIDDLE	4	4	1	9
LOWER	4	4	1	9
URBANIZATION INDEX				25



Runoff Calculations
Drainage Area - C

Culvert Location: East of Precinct Line Road
City: Hurst

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
C	STA 77+18 SH183	1455	23	1964	2473	2880	3325

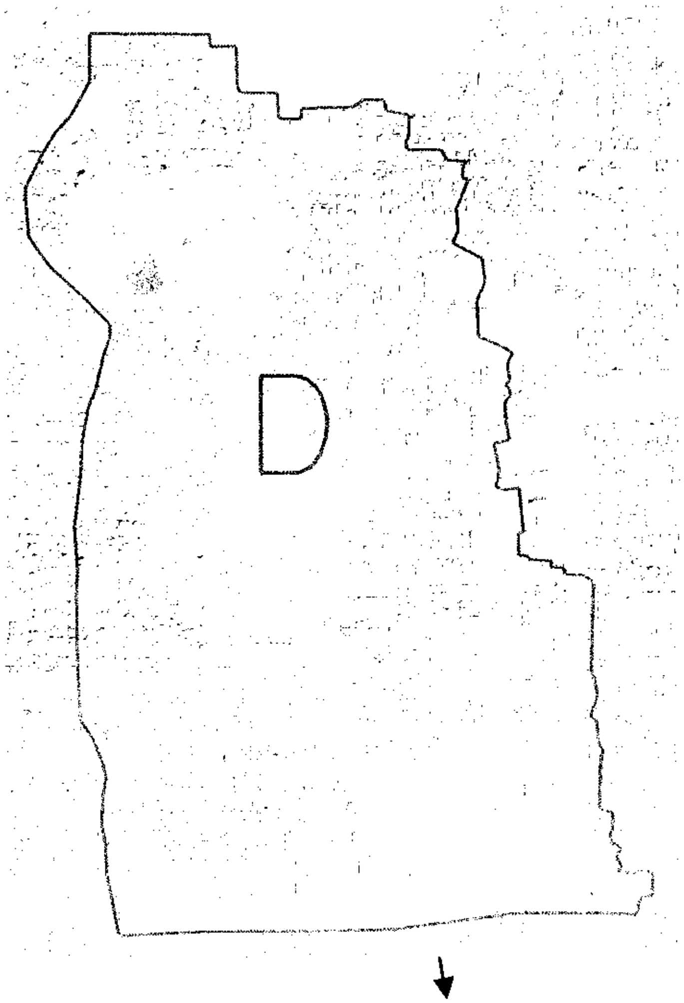
SUBAREA	UI COMPUTATIONS FACTORS			TOTAL
	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	3	3	1	7
MIDDLE	3	3	1	7
LOWER	4	4	1	9
URBANIZATION INDEX				23

Runoff Calculations
Drainage Area - D

Culvert Location: East of Norwood Drive
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	Acres		(cfs)	(cfs)	(cfs)	(cfs)
D	STA 132+26 SH183	803	25	1345	1674	1934	2219

SUBAREA	UI COMPUTATIONS			
	FACTORS			TOTAL
	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	3	3	1	7
MIDDLE	4	4	1	9
LOWER	4	4	1	9
URBANIZATION INDEX				25

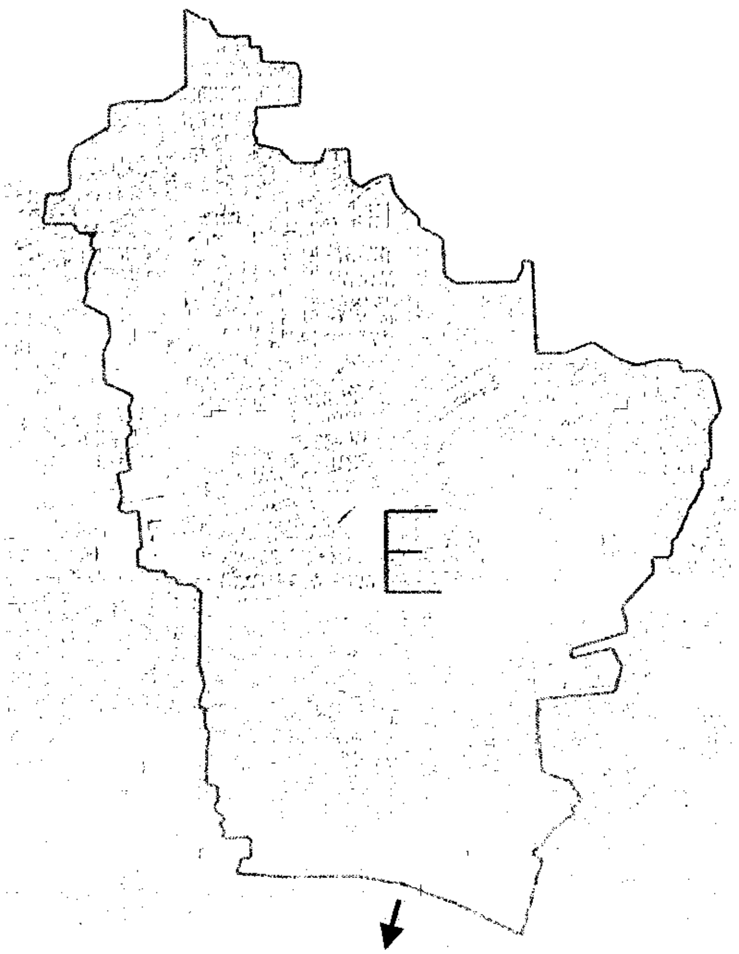


Runoff Calculations
Drainage Area - E

Culvert Location: West of Bedford Euless Road
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
E	STA 170+05 SH183	1000	26	1624	2021	2334	2670

	UI COMPUTATIONS			
	FACTORS			TOTAL
SUBAREA	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	4	4	1	9
MIDDLE	3	4	1	8
LOWER	4	4	1	9
URBANIZATION INDEX				26

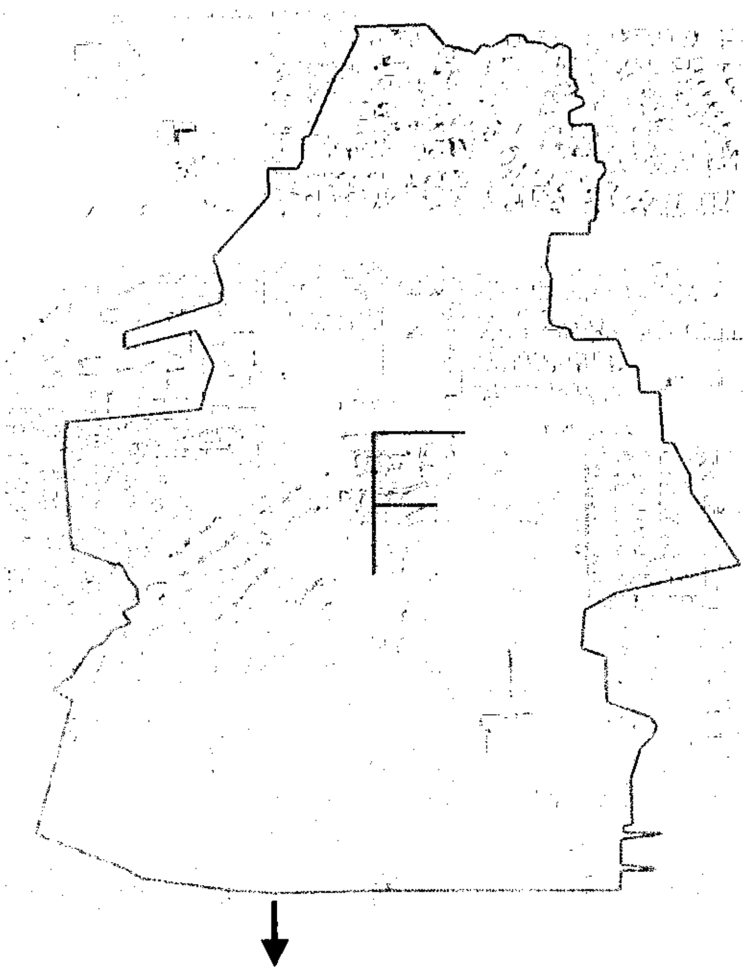


Runoff Calculations
Drainage Area - F

Culvert Location: West of Forest Ridge
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
F	STA 198+75 SH183	358	25	743	917	1054	1209

SUBAREA	UI COMPUTATIONS FACTORS			TOTAL
	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	4	4	1	9
MIDDLE	3	3	1	7
LOWER	4	4	1	9
URBANIZATION INDEX				25

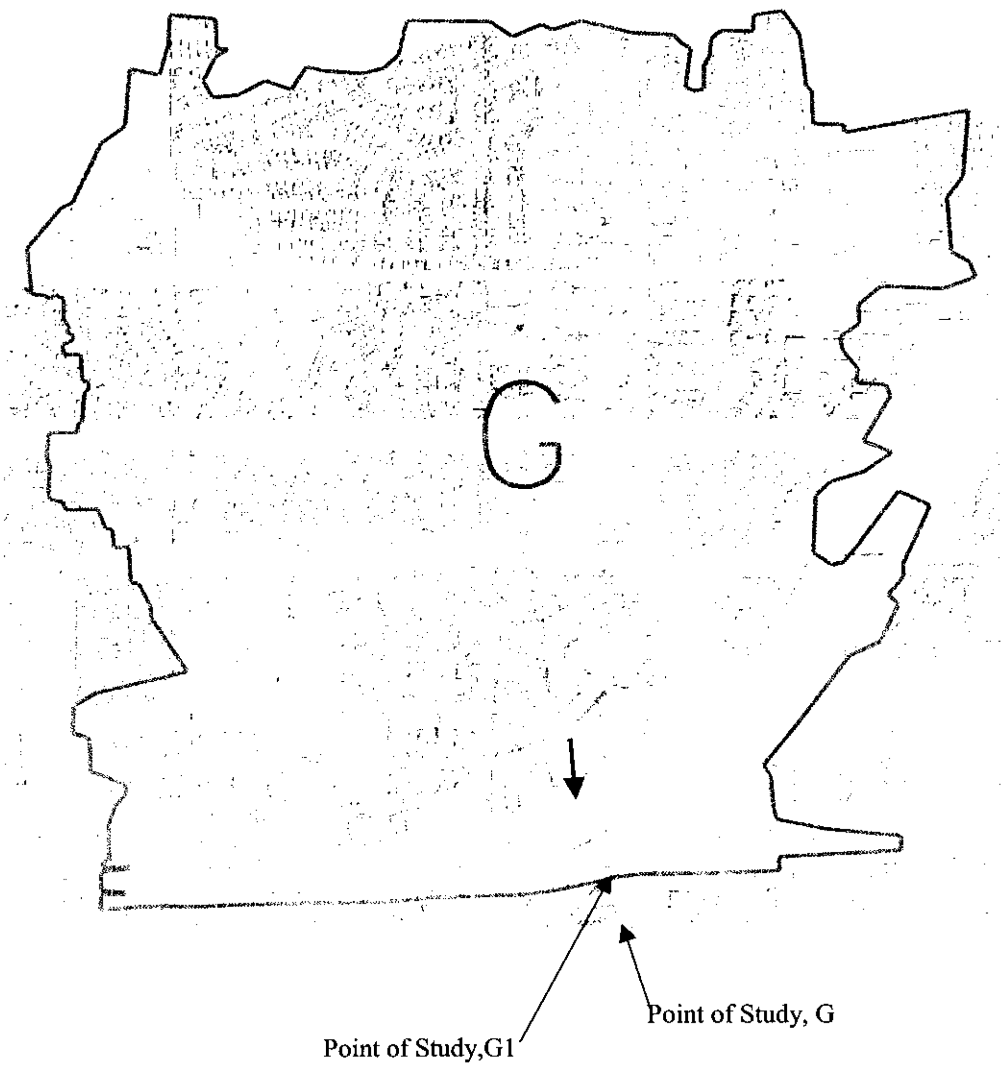


Runoff Calculations
Drainage Areas - G, G1

Culvert Location: West of Murphy Road
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
G-1	STA 262+28 SH183	1149	26	1798	2241	2591	2963
G	STA 262+28 SH183	1174	26	1827	2277	2634	3012

SUBAREA	UI COMPUTATIONS			
	FACTORS			TOTAL
	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	4	4	1	9
MIDDLE	3	4	1	8
LOWER	4	4	1	9
URBANIZATION INDEX				26



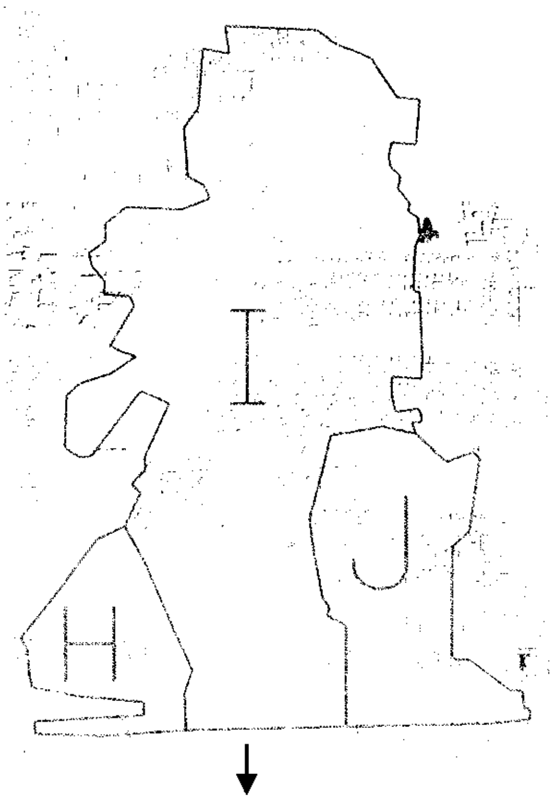
Runoff Calculations
Drainage Areas - H, I, J

Culvert Location: West of FM 157
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
I	STA 297+66 SH183	368	24	737	912	1050	1208

DRAINAGE AREA		AREA	C	T_c	I_{50}	I_{100}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(min)	(in/hr)	(in/hr)	(cfs)	(cfs)
H	STA 289+42 SH183	58	0.75	35.9	5.3	5.8	232	254
J	STA 309+22 SH183	90	0.75	60	3.8	4.2	258	281

	UI COMPUTATIONS FACTORS			TOTAL
SUBAREA	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	3	4	1	8
MIDDLE	3	4	1	8
LOWER	3	4	1	8
URBANIZATION INDEX				24



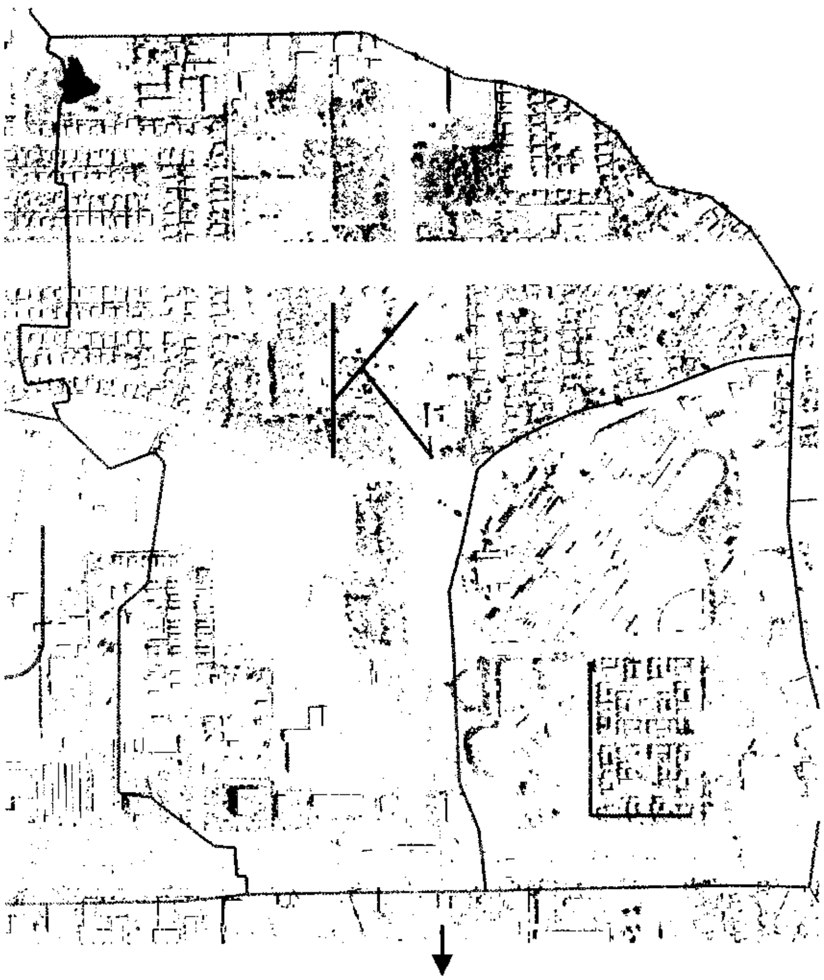
Note: Cyclone Branch
(Tributary of HC-1 of Hurricane Creek)

Runoff Calculations
Drainage Area - K

Culvert Location: East of FM 157
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
K	STA 337+48 SH183	222	30	594	721	819	926

	UI COMPUTATIONS			
	FACTORS			TOTAL
SUBAREA	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	4	4	2	10
MIDDLE	4	4	2	10
LOWER	4	4	2	10
URBANIZATION INDEX				30



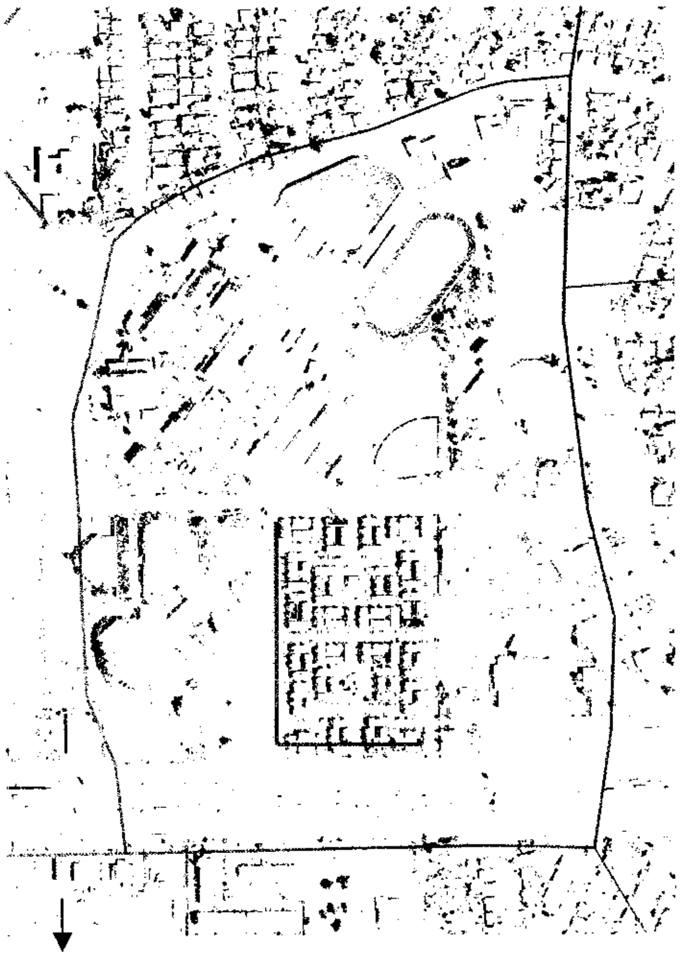
Runoff Calculations

Drainage Area - L

Culvert Location: East of FM 157
City: Bedford

DRAINAGE AREA			UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
L	STA 350+70 SH183	72	30	259	312	351	397

UI COMPUTATIONS				
	FACTORS			TOTAL
SUBAREA	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	4	4	2	10
MIDDLE	4	4	2	10
LOWER	4	4	2	10
URBANIZATION INDEX				30

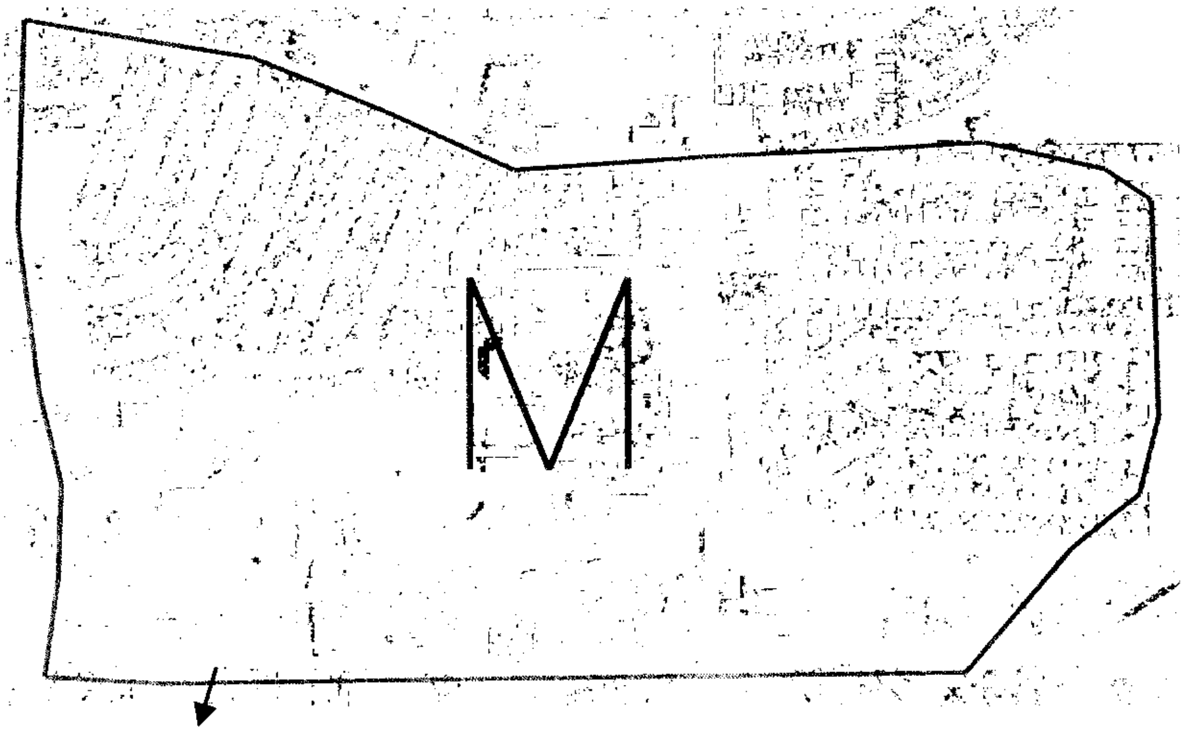


Runoff Calculations
Drainage Area - M

Culvert Location: West Ector Road
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
M	STA 365+00 SH183	100	26	299	363	413	473

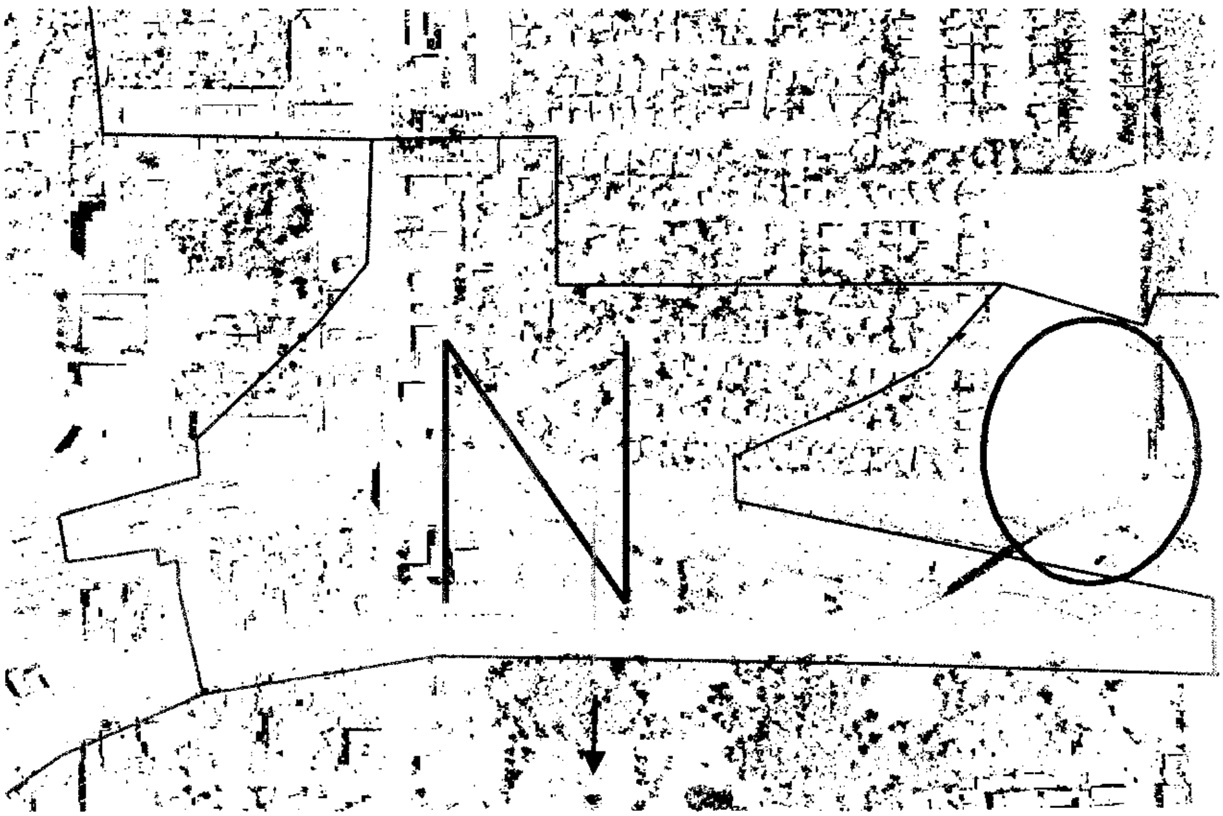
SUBAREA	UI COMPUTATIONS			
	FACTORS			TOTAL
	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	4	4	1	9
MIDDLE	3	4	1	8
LOWER	4	4	1	9
URBANIZATION INDEX				26



Runoff Calculations
Drainage Area - N

Culvert Location: East of Euless Main Street
City: Euless

DRAINAGE AREA		AREA	C	T_c	I_{50}	I_{100}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(min)	(in/hr)	(in/hr)	(cfs)	(cfs)
N	STA 396+75 SH183	64	0.7	47.8	4.4	4.8	199	217



Runoff Calculations

Drainage Area - O

Culvert Location: East of Euless Main Street
City: Euless

DRAINAGE AREA		AREA	C	T_c	I_{50}	I_{100}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(min)	(in/hr)	(in/hr)	(cfs)	(cfs)
O	STA 427+70 SH183	42	0.7	45.3	4.6	5.0	135	148

Runoff Calculations
Drainage Area - P

Culvert Location: East of Euless Main Street
City: Euless

DRAINAGE AREA		AREA	C	T_c	I_{50}	I_{100}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(min)	(in/hr)	(in/hr)	(cfs)	(cfs)
P	STA 422+50 SH183	48	0.7	31	5.8	6.4	196	214

Runoff Calculations
Drainage Area - BC

Culvert Location: West of Bedford Road
City: Bedford

DRAINAGE AREA		AREA	UI	Q_{10}	Q_{25}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(cfs)	(cfs)	(cfs)	(cfs)
BC	Bear Creek, between Amon Carter Blvd. & Valley View Ln.	51200	23	26900	35095	41907	48379

	UI COMPUTATIONS			
	FACTORS			TOTAL
SUBAREA	Storm Sewers	Curb and Gutters	Channel Rectification	
UPPER	3	3	1	7
MIDDLE	3	3	2	8
LOWER	2	2	4	8
URBANIZATION INDEX				23

Runoff Calculations
Drainage Area - 18

Culverts East of County Line Rd., City of Euless

DRAINAGE AREA		*AREA	C	T_c	I_{50}	I_{100}	Q_{50}	Q_{100}
ID	LOCATION	(acres)		(min)	(in/hr)	(in/hr)	(cfs)	(cfs)
18	STA. 1025+07 SH183	8.3	0.803	10.59	10.3	11.3	68	75

*Contributing drainage areas include Area 17, 18 and 23.
Drainage Area for each are respectively: 2.6, 2.9 and 2.8 acres.

SH 183/ SH 121
AIRPORT FREEWAY SCHEMATICS
WEST SECTION

PRELIMINARY DRAINAGE STUDY
PRELIMINARY HYDRAULICS

LOCKWOOD, ANDREWS & NEWNAM, INC.

TXDOT - FORT WORTH DISTRICT

December 2003

Preliminary Hydraulics

EXISTING B – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     W. Precinct Ln                 Input Units:  English
PROJECT NAME:     SH183                          Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing B

ANALYZE   MULTIPLE   OPENING    CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: STRAIGHT
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 YR    DISCHARGE:  1188.00 cfs  TAILWATER:    562.00 ft
FREQUENCY: 50 YR     DISCHARGE:  1036.00 cfs  TAILWATER:    562.00 ft


n value:  0.0120        Ke value:  0.7000

CULVERT RISE =  3.00 ft    CULVERT SPAN =   7.00 ft    BARRELS =    2

INLET  station:        0.00      elevation:     569.63 ft
OUTLET station:     1800.00      elevation:     560.09 ft

------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
------------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 YR

Barls. Qpb  Rise   Span  Length  Max.HW  Calc.HW  HW  Control   Veloc.Out.depth
                                  elev    elev
       cfs   ft     ft     ft      ft      ft      ft              ft/s     ft
------------------------------------------------------------------------------
  2 594.00  3.00  7.00 1800.00    0.00  612.97 43.34 Inlet    28.29    3.00

Inlet control depth  =     43.34 ft
Outlet control depth =     24.14 ft

Normal depth    =     3.00 ft    Culvert slope  =      0.00530
Critical depth =      6.07 ft    Critical slope =      0.00466
------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
------------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 YR

Barls. Qpb  Rise   Span  Length  Max.HW  Calc.HW  HW  Control   Veloc.Out.depth
                                  elev    elev
       cfs   ft     ft     ft      ft      ft      ft              ft/s     ft
------------------------------------------------------------------------------
```

```
  2 518.00  3.00  7.00 1800.00    0.00  602.96 33.33 Inlet    24.67    3.00

Inlet control depth  =      33.33 ft
Outlet control depth =      19.07 ft

Normal depth   =      3.00 ft    Culvert slope  =      0.00530
Critical depth =      5.54 ft    Critical slope =      0.00481
-------------------------------------------------------------------------------
 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED B – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     W. Precinct Ln               Input Units:  English
PROJECT NAME:     SH183                        Output Units: English
PROJECT CONTROL:  CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing B

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: BEVEL TO SLOPE
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 YR   DISCHARGE:  1188.00 cfs  TAILWATER:   570.00 ft
FREQUENCY: 50 YR    DISCHARGE:  1036.00 cfs  TAILWATER:   570.00 ft


n value:  0.0120       Ke value:  0.2000

CULVERT RISE =  3.00 ft    CULVERT SPAN =   7.00 ft    BARRELS =    6

INLET  station:       0.00      elevation:     569.56 ft
OUTLET station:     332.00      elevation:     567.80 ft

Road profile  (XY Coordinates)  ft
        X            Y           X            Y           X            Y
     6000.00       575.38     6100.00       574.79     6200.00       574.47
     6300.00       574.43     6400.00       574.64     6467.00       574.95

----------------------------------------------------------------------------
-

----------------------------------------------------------------------------
-
       CULVERT  OUTPUT      RUN NO =>  1
----------------------------------------------------------------------------
-
ANALYSIS for discharge frequency of :   100 YR

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.
Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
----------------------------------------------------------------------------
-
  6 191.43  3.00  7.00  332.00    0.00  574.65  5.09 Inlet    11.38    2.40

Inlet control depth  =      5.09 ft
Outlet control depth =      4.11 ft
```

```
Normal depth    =     2.40 ft    Culvert slope  =     0.00530
Critical depth =     2.85 ft    Critical slope =     0.00328
Road top width  => 30.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 2.97.

Toal Discharge                   =>  1188.00 cfs
Discharge per barrel             =>   191.43 cfs
Discharge over the road          =>    39.45 cfs
Average velocity over the road  =>     1.15 ft/sec
-----------------------------------------------------------------------------
-
-----------------------------------------------------------------------------
-
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
-
ANALYSIS for discharge frequency of :   50 YR

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.
Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------------------
-
  6 172.67  3.00  7.00  332.00    0.00  574.14  4.58 Inlet    11.09    2.22

Inlet control depth  =      4.58 ft
Outlet control depth =      3.83 ft

Normal depth    =     2.23 ft    Culvert slope  =     0.00530
Critical depth =     2.66 ft    Critical slope =     0.00322
Road top width  => 30.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 2.97.

No discharge over the road.
-----------------------------------------------------------------------------
-


 RUNING MESSAGES LIST:

*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING C – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     E. Precinct Ln                Input Units:  English
PROJECT NAME:     SH183                         Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing C

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 YR    DISCHARGE:  3325.00 cfs
FREQUENCY: 50 YR     DISCHARGE:  2880.00 cfs

TAILWATER ELEVATION (computed).

n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  7.00 ft    CULVERT SPAN =   7.00 ft    BARRELS =    5

INLET  station:        0.00      elevation:     554.50 ft
OUTLET station:      307.00      elevation:     552.90 ft

Cross section profile  (XY Coordinates)  ft
         X            Y            X            Y            X            Y
      100.00       563.00       147.22       562.00       149.79       561.00
      150.00       560.00       150.68       558.00       211.53       557.00
      214.37       556.00       220.10       550.00       223.23       549.00
      261.42       549.00       262.21       550.00       266.32       551.00
      269.00       552.00       271.00       553.00       272.60       554.00
      274.88       555.00       276.73       556.00       278.87       557.00
      324.15       558.00       386.65       559.00
-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------

TAILWATER ELEVATION:    558.21 ft (computed).

ANALYSIS for discharge frequency of :   100 YR

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
  5 665.00  7.00  7.00  265.00    0.00  567.23 12.84 Inlet    15.31    6.21

Inlet control depth  =     12.84 ft
```

```
Outlet control depth =     11.12 ft

Normal depth    =     6.21 ft    Culvert slope  =     0.00521
Critical depth =      6.55 ft    Critical slope =     0.00458
---------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
---------------------------------------------------------------------------

TAILWATER ELEVATION:    555.84 ft (computed).

ANALYSIS for discharge frequency of :   50 YR

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
---------------------------------------------------------------------------
  5 576.00  7.00  7.00  265.00    0.00  565.39 11.00 Inlet    14.86    5.54

Inlet control depth  =     11.00 ft
Outlet control depth =     10.00 ft

Normal depth    =     5.53 ft    Culvert slope  =     0.00521
Critical depth =      5.95 ft    Critical slope =     0.00435
---------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED C – THYSYS RESULTS

CULVERT HYDRAULIC COMPUTATIONS

CULVERT NAME: E. Precinct — Input Units: English
PROJECT NAME: SH 183 — Output Units: English
PROJECT CONTROL: CSJ:
COUNTY: Tarrant
DESCRIPTION: Proposed C

ANALYZE MULTIPLE OPENING CULVERT

MATERIAL: CONCRETE
SHAPE: CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE: STRAIGHT CULVERT

FREQUENCY: 100 yr DISCHARGE: 3325.00 cfs TAILWATER: 565.00 ft
FREQUENCY: 50 yr DISCHARGE: 2880.00 cfs TAILWATER: 556.55 ft

n value: 0.0120 Ke value: 0.5000

CULVERT RISE = 7.00 ft CULVERT SPAN = 7.00 ft BARRELS = 8

INLET station: 0.00 elevation: 554.94 ft
OUTLET station: 437.00 elevation: 552.69 ft

Road profile (XY Coordinates) ft

X	Y	X	Y	X	Y
35.00	563.50	100.00	563.50	104.25	564.00
127.50	565.00	161.80	564.00	169.90	565.00
175.62	565.00	182.60	567.00	226.20	568.00
231.10	568.20	235.10	568.00	249.50	568.00
296.60	567.00	320.90	566.00	336.60	565.00
351.10	563.00	390.70	562.00	404.00	562.00
437.00	561.50				

CULVERT OUTPUT RUN NO => 1

ANALYSIS for discharge frequency of : 100 yr

Barls.	Qpb cfs	Rise ft	Span ft	Length ft	Max.HW elev ft	Calc.HW elev ft	HW ft	Control	Veloc. ft/s	Out.depth ft
8	155.86	7.00	7.00	437.00	0.00	565.37	10.43	Outlet	3.18	7.00

Inlet control depth = 4.24 ft
Outlet control depth = 10.43 ft

Normal depth = 2.09 ft Culvert slope = 0.00515
Critical depth = 2.49 ft Critical slope = 0.00317
Road top width => 194.00 ft. Road pavement type => asphalt

```
Computed Weir Coefficient => 3.05.

Total Discharge                  =>  3325.00 cfs
Discharge per barrel            =>   155.86 cfs
Discharge over the road         =>  2078.13 cfs
Average velocity over the road  =>     4.32 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------------------
  8 354.38  7.00  7.00  437.00    0.00  562.26  7.32 Inlet    13.28    3.81

Inlet control depth  =      7.32 ft
Outlet control depth =      7.04 ft

Normal depth    =     3.82 ft    Culvert slope  =     0.00515
Critical depth =     4.30 ft    Critical slope =     0.00376
Road top width  => 194.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.03.

Total Discharge                  =>  2880.00 cfs
Discharge per barrel            =>   354.38 cfs
Discharge over the road         =>    45.00 cfs
Average velocity over the road  =>     1.86 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING D – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     E. Norwood                    Input Units:  English
PROJECT NAME:     SH 183                        Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing D

ANALYZE   MULTIPLE   OPENING    CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  2219.00 cfs  TAILWATER:   567.00 ft
FREQUENCY: 50 yr     DISCHARGE:  1934.00 cfs  TAILWATER:   565.00 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   6.00 ft    BARRELS =    4

INLET  station:       0.00      elevation:     560.50 ft
OUTLET station:     340.00      elevation:     559.00 ft

Road profile  (XY Coordinates)  ft
         X            Y            X            Y            X            Y
        0.00       568.00        4.60       570.00        46.40       571.00
       62.40       571.00       70.10       570.00        77.60       569.00
       82.30       569.00      112.10       574.00       209.90       574.00
      231.60       573.00      242.50       571.00       249.70       570.20
      279.40       571.00      297.80       570.00       331.20       569.00
      335.50       568.00      340.00       566.00
-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft      ft            ft/s     ft
-----------------------------------------------------------------------------
  4 385.72  6.00  6.00  340.00    0.00  571.16 10.66 Outlet   10.71    6.00

Inlet control depth  =       9.29 ft
Outlet control depth =      10.66 ft

Normal depth   =      5.11 ft    Culvert slope  =     0.00441
Critical depth =      5.05 ft    Critical slope =     0.00456
Road top width  => 24.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.08.
```

```
Total Discharge                => 2219.00 cfs
Discharge per barrel          =>  385.72 cfs
Discharge over the road       =>  676.10 cfs
Average velocity over the road =>    3.73 ft/sec
----------------------------------------------------------------------------
----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
----------------------------------------------------------------------------
  4 411.73  6.00  6.00  340.00    0.00  570.44  9.94 Inlet    11.44    6.00

Inlet control depth  =      9.94 ft
Outlet control depth =      9.17 ft

Normal depth   =     5.39 ft    Culvert slope  =     0.00441
Critical depth =     5.27 ft    Critical slope =     0.00466
Road top width  => 24.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.06.

Total Discharge                => 1934.00 cfs
Discharge per barrel          =>  411.73 cfs
Discharge over the road       =>  287.08 cfs
Average velocity over the road =>    3.59 ft/sec
----------------------------------------------------------------------------
----------------------------------------------------------------------------
NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED D – THYSYS RESULTS

```
                      CULVERT HYDRAULIC COMPUTATIONS
                      ------------------------------
CULVERT NAME:     E. Norwood                    Input Units:  English
PROJECT NAME:     SH 183                        Output Units: English
PROJECT CONTROL:  CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Proposed D

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  2219.00 cfs  TAILWATER:   567.00 ft
FREQUENCY: 50 yr     DISCHARGE:  1934.00 cfs  TAILWATER:   565.00 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   6.00 ft    BARRELS =    8

INLET  station:       0.00      elevation:     560.50 ft
OUTLET station:     356.00      elevation:     559.00 ft

Road profile  (XY Coordinates)  ft
         X           Y           X           Y           X           Y
       0.00       568.00       4.60       570.00       46.40       571.00
      62.40       571.00      70.10       570.00       77.60       569.00
      82.30       569.00     112.10       574.00      209.90       574.00
     231.60       573.00     242.50       571.00      249.70       570.20
     279.40       571.00     297.80       570.00      331.20       569.00
     335.50       568.00     340.00       566.00
-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
-
  8 273.04  6.00  6.00  356.00   0.00  569.11  8.61 Outlet    7.58    6.00

Inlet control depth  =      6.88 ft
Outlet control depth =      8.61 ft

Normal depth   =     3.96 ft    Culvert slope  =     0.00421
Critical depth =     4.01 ft    Critical slope =     0.00409
Road top width  => 24.00 ft.  Road pavement type => asphalt
```

```
Computed Weir Coefficient => 3.05.

Total Discharge                 =>  2219.00 cfs
Discharge per barrel           =>   273.04 cfs
Discharge over the road        =>    34.67 cfs
Average velocity over the road  =>     3.36 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                  elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------------------
  8 241.75  6.00  6.00  356.00    0.00  566.88  6.38 Outlet    6.72    6.00

Inlet control depth  =      6.29 ft
Outlet control depth =      6.38 ft

Normal depth    =     3.61 ft    Culvert slope  =     0.00421
Critical depth =     3.70 ft    Critical slope =     0.00396
Road top width  => 24.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.04.

No discharge over the road.
-----------------------------------------------------------------------------
NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING E – THYSYS RESULTS

```
                     CULVERT HYDRAULIC COMPUTATIONS
                     ------------------------------
CULVERT NAME:     W. Bedford                      Input Units:  English
PROJECT NAME:     SH 183                          Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Exisitng E

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  2670.00 cfs  TAILWATER:   553.00 ft
FREQUENCY: 50 yr     DISCHARGE:  2334.00 cfs  TAILWATER:   547.34 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   9.00 ft    BARRELS =    4

INLET  station:       0.00      elevation:     546.00 ft
OUTLET station:     344.00      elevation:     544.27 ft

Road profile  (XY Coordinates)  ft
         X            Y            X            Y            X            Y
       0.00        553.70        1.20        554.00        7.20        551.00
      40.50        552.00       52.00        553.00       83.20        575.00
      94.52        575.00       99.20        575.30      102.60        575.00
     108.64        574.00      138.30        575.00      150.70        576.00
     170.20        573.00      186.50        573.00      228.54        570.00
     236.90        569.00      277.30        557.00      283.80        556.00
     315.80        555.00      332.80        554.00      344.00        552.00

-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft      ft     ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
  4 417.19  6.00  9.00  344.00    0.00  555.00  9.00 Outlet     7.73     6.00

Inlet control depth  =      6.98 ft
Outlet control depth =      9.00 ft

Normal depth   =     3.40 ft    Culvert slope  =     0.00503
Critical depth =     4.06 ft    Critical slope =     0.00310
```

```
Road top width  => 169.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.05.

Total Discharge                 =>  2670.00 cfs
Discharge per barrel           =>   417.19 cfs
Discharge over the road        =>  1001.25 cfs
Average velocity over the road  =>     5.15 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------------------
  4 474.09  6.00  9.00  344.00    0.00  553.74  7.74 Inlet    13.98    3.77

Inlet control depth  =      7.74 ft
Outlet control depth =      7.04 ft

Normal depth   =     3.73 ft    Culvert slope  =     0.00503
Critical depth =     4.42 ft    Critical slope =     0.00318
Road top width  => 169.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.05.

Total Discharge                 =>  2334.00 cfs
Discharge per barrel           =>   474.09 cfs
Discharge over the road        =>   437.63 cfs
Average velocity over the road  =>     4.17 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED E – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     W. Bedford                     Input Units:  English
PROJECT NAME:     SH 183                         Output Units: English
PROJECT CONTROL:  CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Proposed E

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr   DISCHARGE:  2670.00 cfs  TAILWATER:   553.00 ft
FREQUENCY: 50 yr    DISCHARGE:  2334.00 cfs  TAILWATER:   547.34 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   9.00 ft    BARRELS =    5

INLET  station:       0.00       elevation:     546.09 ft
OUTLET station:     490.00       elevation:     543.64 ft

------------------------------------------------------------------------------

------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
------------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
------------------------------------------------------------------------------
  5 534.00  6.00  9.00  454.00    0.00  556.60 10.60 Outlet    9.89    6.00

Inlet control depth  =      8.59 ft
Outlet control depth =     10.60 ft

Normal depth   =     4.08 ft    Culvert slope  =     0.00500
Critical depth =     4.78 ft    Critical slope =     0.00327
------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
------------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
------------------------------------------------------------------------------
  5 466.80  6.00  9.00  454.00    0.00  553.63  7.63 Inlet    13.97    3.71
```

```
Inlet control depth  =      7.63 ft
Outlet control depth =      6.97 ft

Normal depth    =     3.70 ft    Culvert slope  =     0.00500
Critical depth =      4.37 ft    Critical slope =     0.00317
-----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING F – THYSYS RESULTS

```
                        CULVERT HYDRAULIC COMPUTATIONS
                        ------------------------------
CULVERT NAME:      W. Forest ridge               Input Units:  English
PROJECT NAME:      SH 183                        Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:            Tarrant
DESCRIPTION:       Existing F

ANALYZE   MULTIPLE   OPENING    CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  1209.00 cfs  TAILWATER:   561.00 ft
FREQUENCY: 50 yr     DISCHARGE:  1054.00 cfs  TAILWATER:   560.00 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   7.00 ft    BARRELS =    2

INLET  station:        0.00      elevation:     558.30 ft
OUTLET station:      334.00      elevation:     556.80 ft

Road profile  (XY Coordinates)  ft
         X           Y            X           Y           X           Y
        0.00       565.30        2.90      566.00       40.10      567.00
       43.60       567.00       56.50      567.00       95.70      579.00
      102.30       580.00      130.35      582.00      154.10      583.00
      189.40       584.00      210.10      585.00      229.70      585.00
      241.70       587.00      282.70      567.00      305.50      566.00
      331.20       565.00
-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
  2 434.48  6.00  7.00  334.00    0.00  567.28  8.98 Inlet    13.21    4.70

Inlet control depth  =      8.98 ft
Outlet control depth =      8.40 ft

Normal depth   =     4.70 ft    Culvert slope  =      0.00449
Critical depth =     4.93 ft    Critical slope =      0.00398
Road top width  => 99.30 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.05.
```

```
Total Discharge                   =>  1209.00 cfs
Discharge per barrel              =>   434.48 cfs
Discharge over the road           =>   340.03 cfs
Average velocity over the road    =>     3.22 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s      ft
-----------------------------------------------------------------------------
  2 420.47  6.00  7.00  334.00    0.00  567.00  8.70 Inlet    13.11     4.58

Inlet control depth  =      8.70 ft
Outlet control depth =      8.20 ft

Normal depth    =     4.58 ft    Culvert slope  =     0.00449
Critical depth =     4.82 ft    Critical slope =     0.00394
Road top width  => 99.30 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.05.

Total Discharge                   =>  1054.00 cfs
Discharge per barrel              =>   420.47 cfs
Discharge over the road           =>   213.06 cfs
Average velocity over the road    =>     3.07 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
*Computation: No hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED F – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     W. Forest Ridge                Input Units:  English
PROJECT NAME:     SH 183                         Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Proposed F

ANALYZE   MULTIPLE   OPENING    CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  1209.00 cfs  TAILWATER:   561.00 ft
FREQUENCY: 50 yr     DISCHARGE:  1054.00 cfs  TAILWATER:   560.00 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   7.00 ft    BARRELS =    4

INLET  station:       0.00       elevation:     561.00 ft
OUTLET station:     400.00       elevation:     560.00 ft

------------------------------------------------------------------------------

------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
------------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s      ft
------------------------------------------------------------------------------
  4 302.25  6.00  7.00  364.00    0.00  567.60  6.64 Outlet   11.16     3.87

Inlet control depth  =      6.61 ft
Outlet control depth =      6.64 ft

Normal depth    =     4.45 ft    Culvert slope  =     0.00250
Critical depth =      3.87 ft    Critical slope =     0.00361
------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
------------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s      ft
------------------------------------------------------------------------------
  4 263.50  6.00  7.00  364.00    0.00  567.02  6.07 Outlet   10.66     3.53
```

```
Inlet control depth  =      5.98 ft
Outlet control depth =      6.07 ft

Normal depth   =     4.01 ft    Culvert slope  =     0.00250
Critical depth =     3.53 ft    Critical slope =     0.00349
-----------------------------------------------------------------------------
*Computation: Tailwater elevation lower than outlet elevation.
*Computation: Minimum of normal/critical depth used.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING G – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     W. Murphy South              Input Units:  English
PROJECT NAME:     SH183                        Output Units: English
PROJECT CONTROL:  CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing G

ANALYZE   MULTIPLE   OPENING    CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  3012.00 cfs  TAILWATER:   539.00 ft
FREQUENCY: 50 yr     DISCHARGE:  2634.00 cfs  TAILWATER:   528.22 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  9.00 ft    CULVERT SPAN =   9.00 ft    BARRELS =    2

INLET  station:        0.00      elevation:     525.82 ft
OUTLET station:       76.00      elevation:     525.18 ft

Road profile  (XY Coordinates)  ft
         X           Y           X           Y           X           Y
       0.00       535.82       1.00       536.00       4.40       537.00
       9.40       538.00      15.30       539.00      24.80       539.00
      60.75       538.00      67.50       537.00      76.00       535.18

-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT       RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
  2 788.30  9.00  9.00   76.00    0.00  541.36 15.54 Outlet    9.73    9.00

Inlet control depth  =     10.70 ft
Outlet control depth =     15.54 ft

Normal depth    =     4.49 ft    Culvert slope  =     0.00842
Critical depth =      6.20 ft    Critical slope =     0.00362
Road top width  => 37.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.06.

Total Discharge                   =>  3012.00 cfs
```

```
Discharge per barrel             =>   788.30 cfs
Discharge over the road          =>  1435.41 cfs
Average velocity over the road  =>     5.74 ft/sec
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
--------------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs    ft    ft      ft     ft      ft     ft            ft/s     ft
--------------------------------------------------------------------------------
  21049.48  9.00  9.00   76.00    0.00  539.58 13.76 Inlet    17.98    6.48

Inlet control depth  =      13.76 ft
Outlet control depth =      11.21 ft

Normal depth   =      5.58 ft    Culvert slope  =      0.00842
Critical depth =      7.50 ft    Critical slope =      0.00396
Road top width  => 37.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.06.

Total Discharge                   =>  2634.00 cfs
Discharge per barrel             =>  1049.48 cfs
Discharge over the road          =>   535.03 cfs
Average velocity over the road  =>     4.30 ft/sec
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED G – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     W. Murphy S.                Input Units:  English
PROJECT NAME:     SH 183                      Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Proposed G

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  3012.00 cfs  TAILWATER:   539.00 ft
FREQUENCY: 50 yr     DISCHARGE:  2634.00 cfs  TAILWATER:   528.22 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  10.00 ft    CULVERT SPAN =   10.00 ft    BARRELS =    5

INLET  station:       0.00      elevation:     526.00 ft
OUTLET station:     120.00      elevation:     525.00 ft

-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------------------
  5 602.40 10.00 10.00   60.00    0.00  539.89 14.14 Outlet    6.02   10.00

Inlet control depth  =      8.13 ft
Outlet control depth =     14.14 ft

Normal depth   =      3.35 ft    Culvert slope  =     0.00833
Critical depth =      4.83 ft    Critical slope =     0.00306
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------------------
  5 526.80 10.00 10.00   60.00    0.00  533.20  7.45 Inlet    14.36    3.67
```

```
Inlet control depth  =      7.45 ft
Outlet control depth =      6.36 ft

Normal depth   =     3.05 ft    Culvert slope  =     0.00833
Critical depth =     4.42 ft    Critical slope =     0.00297
----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING G1 – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:      W. Murphy                   Input Units:  English
PROJECT NAME:      SH 183                      Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:            Tarrant
DESCRIPTION:       Existing G1

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr   DISCHARGE:  2963.00 cfs  TAILWATER:   541.36 ft
FREQUENCY: 50 yr    DISCHARGE:  2591.00 cfs  TAILWATER:   539.58 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  9.00 ft    CULVERT SPAN =   9.00 ft    BARRELS =    2

INLET  station:       0.00      elevation:     530.90 ft
OUTLET station:     465.00      elevation:     527.04 ft

Road profile  (XY Coordinates)  ft
         X           Y          X          Y          X          Y
        0.00       541.00      12.00      545.00      59.00      544.00
       71.80       543.10      73.53      544.00     120.70      558.00
      126.10       559.00     150.00      560.00     187.00      560.00
      291.00       560.20     297.74      561.00     323.30      561.00
      348.90       560.00     428.70      552.00     465.00      535.00

---------------------------------------------------------------------------

---------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
---------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
---------------------------------------------------------------------------
  2 839.13  9.00  9.00  465.00    0.00  544.96 14.06 Outlet   10.36    9.00

Inlet control depth  =     11.25 ft
Outlet control depth =     14.06 ft

Normal depth   =     4.73 ft    Culvert slope  =     0.00830
Critical depth =     6.46 ft    Critical slope =     0.00369
Road top width  => 24.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.09.
```

```
Total Discharge                    =>  2963.00 cfs
Discharge per barrel               =>   839.13 cfs
Discharge over the road            =>  1284.74 cfs
Average velocity over the road     =>     6.02 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
  2 870.41  9.00  9.00  465.00    0.00  543.45 12.55 Outlet   10.75    9.00

Inlet control depth  =     11.60 ft
Outlet control depth =     12.55 ft

Normal depth    =     4.87 ft    Culvert slope  =      0.00830
Critical depth =      6.62 ft    Critical slope =      0.00373
Road top width  => 24.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.09.

Total Discharge                    =>  2591.00 cfs
Discharge per barrel               =>   870.41 cfs
Discharge over the road            =>   850.17 cfs
Average velocity over the road     =>     6.24 ft/sec
-----------------------------------------------------------------------------
-----------------------------------------------------------------------------
NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED G1 – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:    W. Murphy                  Input Units:  English
PROJECT NAME:    SH 183                     Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:          Tarrant
DESCRIPTION:     Proposed G1

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  2963.00 cfs  TAILWATER:   539.89 ft
FREQUENCY: 50 yr     DISCHARGE:  2591.00 cfs  TAILWATER:   533.20 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  9.00 ft    CULVERT SPAN =   9.00 ft    BARRELS =    4

INLET  station:        0.00      elevation:     531.00 ft
OUTLET station:      490.00      elevation:     526.93 ft

-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
  4 740.75  9.00  9.00  436.00    0.00  542.64 11.87 Outlet    9.15    9.00

Inlet control depth  =      10.16 ft
Outlet control depth =      11.87 ft

Normal depth    =      4.31 ft    Culvert slope  =      0.00831
Critical depth =       5.95 ft    Critical slope =      0.00356
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft             ft/s     ft
-----------------------------------------------------------------------------
  4 647.75  9.00  9.00  436.00    0.00  539.98  9.21 Inlet    17.86    4.03
```

```
Inlet control depth  =      9.21 ft
Outlet control depth =      8.12 ft

Normal depth   =     3.90 ft    Culvert slope  =     0.00831
Critical depth =     5.44 ft    Critical slope =     0.00343
----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING I – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     W. FM157                      Input Units:  English
PROJECT NAME:     SH 183                        Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing I

ANALYZE   SINGLE     OPENING    CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  1208.00 cfs  TAILWATER:   546.00 ft
FREQUENCY: 50 yr     DISCHARGE:  1050.00 cfs  TAILWATER:   540.13 ft

TAILWATER ELEVATION (computed).

n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   9.00 ft    BARRELS =    1

INLET  station:       0.00      elevation:     540.50 ft
OUTLET station:     340.00      elevation:     536.40 ft

Cross section profile  (XY Coordinates)  ft
         X            Y            X            Y            X            Y
       0.00       548.00         9.60       547.00        18.20       545.00
      20.50       544.00        21.90       543.00        22.40       542.00
      23.40       541.00        24.00       540.00        26.70       537.00
      27.00       536.40        48.00       536.40        48.50       537.00
      50.50       540.00        51.10       541.00        52.50       542.00
      53.11       543.00        53.90       544.00        56.00       545.00
      64.80       547.00
Road profile  (XY Coordinates)  ft
         X            Y            X            Y            X            Y
       0.00       547.50         0.75       548.00         4.10       550.00
      34.60       551.00        53.80       551.00        57.50       550.40
      60.10       551.00       107.22       560.00       126.80       561.00
     158.60       562.00       166.50       562.10       176.10       562.00
     215.70       561.00       236.30       547.00       280.90       547.00
     283.80       546.20       287.70       547.00       325.00       547.00
     334.00       547.00       335.80       544.00       340.00       543.40

----------------------------------------------------------------------------


----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
----------------------------------------------------------------------------

TAILWATER ELEVATION:    542.78 ft (computed).
```

```
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb   Rise   Span   Length   Max.HW   Calc.HW   HW   Control   Veloc.Out.depth
                                     elev     elev
       cfs    ft     ft      ft       ft       ft      ft              ft/s     ft
-----------------------------------------------------------------------------------
  1 502.55  6.00   9.00   304.00    0.00   548.42   8.14 Inlet      9.31     6.00

Inlet control depth  =      8.14 ft
Outlet control depth =      6.57 ft

Normal depth    =     2.84 ft    Culvert slope  =     0.01206
Critical depth  =     4.59 ft    Critical slope =     0.00322
Road top width  => 190.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.05.

Total Discharge                  =>  1208.00 cfs
Discharge per barrel             =>   502.55 cfs
Discharge over the road          =>   705.45 cfs
Average velocity over the road   =>     3.99 ft/sec
-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------------

TAILWATER ELEVATION:    542.29 ft (computed).

ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb   Rise   Span   Length   Max.HW   Calc.HW   HW   Control   Veloc.Out.depth
                                     elev     elev
       cfs    ft     ft      ft       ft       ft      ft              ft/s     ft
-----------------------------------------------------------------------------------
  1 486.04  6.00   9.00   304.00    0.00   548.18   7.90 Inlet     18.11     2.98

Inlet control depth  =      7.90 ft
Outlet control depth =      6.38 ft

Normal depth    =     2.77 ft    Culvert slope  =     0.01206
Critical depth  =     4.49 ft    Critical slope =     0.00320
Road top width  => 190.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.05.

Total Discharge                  =>  1050.00 cfs
Discharge per barrel             =>   486.04 cfs
Discharge over the road          =>   563.96 cfs
Average velocity over the road   =>     3.76 ft/sec
-----------------------------------------------------------------------------------
-----------------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: No hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on supercritical depth at end of
culvert.
*Computation: Hydraulic jump occurs within culvert.
```

```
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

PROPOSED I – THYSYS RESULTS

```
                     CULVERT HYDRAULIC COMPUTATIONS
                     ------------------------------
CULVERT NAME:    W. FM157                     Input Units:  English
PROJECT NAME:    SH 183                       Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:          Tarrant
DESCRIPTION:     Proposed I

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:  1208.00 cfs  TAILWATER:   546.00 ft
FREQUENCY: 50 yr     DISCHARGE:  1050.00 cfs  TAILWATER:   540.13 ft


n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   9.00 ft    BARRELS =    2

INLET  station:        0.00      elevation:     542.00 ft
OUTLET station:      365.00      elevation:     536.59 ft

-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft     ft      ft      ft            ft/s     ft
-----------------------------------------------------------------------------
  2 604.00  6.00  9.00  329.00    0.00  551.40  9.66 Inlet    11.19    6.00

Inlet control depth  =      9.66 ft
Outlet control depth =      8.15 ft

Normal depth   =     3.01 ft    Culvert slope  =     0.01482
Critical depth =     5.19 ft    Critical slope =     0.00337
-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
-----------------------------------------------------------------------------
ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft     ft      ft      ft            ft/s     ft
-----------------------------------------------------------------------------
  2 525.00  6.00  9.00  329.00    0.00  550.16  8.42 Inlet    19.85    2.94
```

```
Inlet control depth  =      8.42 ft
Outlet control depth =      6.39 ft

Normal depth    =      2.72 ft    Culvert slope  =      0.01482
Critical depth =      4.73 ft    Critical slope =      0.00326
-----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING K – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     Existing K                       Input Units:  English
PROJECT NAME:     W. of Sheppard                   Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing K

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:   926.00 cfs
FREQUENCY: 50 yr     DISCHARGE:   819.00 cfs

TAILWATER ELEVATION (computed).

n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  6.00 ft    CULVERT SPAN =   10.00 ft    BARRELS =    2

INLET  station:       0.00      elevation:     543.40 ft
OUTLET station:     385.00      elevation:     542.25 ft

Cross section profile  (XY Coordinates)  ft
        X           Y           X           Y           X           Y
       0.00       550.25      25.50      542.25      47.50      542.25
      73.00       550.25
Road profile  (XY Coordinates)  ft
        X           Y           X           Y           X           Y
       0.00       574.00      34.00      574.00      92.80      573.00
     113.14       573.00     120.40      572.00     153.90      572.00
     186.20       574.00     201.00      576.00     216.90      577.00
     251.60       578.00     275.40      578.20     285.50      578.00
     341.10       578.00     341.10      577.00     350.40      576.00
     392.00       567.00     442.00      566.00     486.00      566.00

-----------------------------------------------------------------

-----------------------------------------------------------------
      CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------

TAILWATER ELEVATION:     544.26 ft (computed).

ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------
```

```
  2 463.00  6.00 10.00  385.00    0.00  550.45  7.05 Outlet   11.54    4.01

Inlet control depth  =      6.97 ft
Outlet control depth =      7.05 ft

Normal depth   =     4.01 ft    Culvert slope  =     0.00299
Critical depth =     4.05 ft    Critical slope =     0.00290
Road top width  => 254.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.00.

No discharge over the road.
------------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
------------------------------------------------------------------------------

TAILWATER ELEVATION:    544.12 ft (computed).

ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
------------------------------------------------------------------------------
  2 409.50  6.00 10.00  385.00    0.00  549.87  6.47 Outlet   11.17    3.67

Inlet control depth  =      6.35 ft
Outlet control depth =      6.47 ft

Normal depth   =     3.67 ft    Culvert slope  =     0.00299
Critical depth =     3.74 ft    Critical slope =     0.00285
Road top width  => 254.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.00.

No discharge over the road.
------------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING L – THYSYS RESULTS

```
                    CULVERT HYDRAULIC COMPUTATIONS
                    ------------------------------
CULVERT NAME:     Existing L                    Input Units:  English
PROJECT NAME:     W. of Sheppard                Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      Existing L

ANALYZE   SINGLE    OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    RCP CIRCULAR PIPE.
ENTRANCE: BEVEL 1:1
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:   397.00 cfs
FREQUENCY: 50 yr     DISCHARGE:   351.00 cfs

TAILWATER ELEVATION (computed).

n value:  0.0120       Ke value:  0.2000

CULVERT DIAM. =  4.50 ft   BARRELS =  1

INLET  station:       0.00      elevation:     568.40 ft
OUTLET station:     486.00      elevation:     561.50 ft

Cross section profile  (XY Coordinates)  ft
         X           Y           X           Y           X           Y
        0.00      566.00       25.50      561.50       35.00      561.50
       60.50      566.00
Road profile  (XY Coordinates)  ft
         X           Y           X           Y           X           Y
        0.00      574.00       34.00      574.00       92.80      573.00
      113.14      573.00      120.40      572.00      153.90      572.00
      186.20      574.00      201.00      576.00      216.90      577.00
      251.60      578.00      275.40      578.20      285.50      578.00
      341.10      578.00      341.10      577.00      350.40      576.00
      392.00      567.00      442.00      566.00      486.00      566.00

-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------

TAILWATER ELEVATION:    563.17 ft (computed).

ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
-----------------------------------------------------------------------------
```

```
 1 397.00  4.50  0.00  486.00    0.00  570.18  1.78 Inlet     0.00    1.67

Inlet control depth  =      1.78 ft
Outlet control depth =      0.01 ft

Normal depth   =     0.01 ft    Culvert slope  =     0.01420
Critical depth =     0.07 ft    Critical slope =     0.00000
Road top width  => 254.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.05.

No discharge over the road.

-----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
*Computation: Outlet velocity is based on tailwater conditions.
*Computation: Hydraulic jump occurs within culvert.
```

EXISTING M – THYSYS RESULTS

```
                   CULVERT HYDRAULIC COMPUTATIONS
                   ------------------------------
CULVERT NAME:     Culvert M                     Input Units:  English
PROJECT NAME:     SH183                         Output Units: English
PROJECT CONTROL: CSJ:
COUNTY:           Tarrant
DESCRIPTION:      E. Ector

ANALYZE   MULTIPLE   OPENING   CULVERT

MATERIAL: CONCRETE
SHAPE:    CONCRETE BOX.
ENTRANCE: FLARED 90:15
PROFILE:  STRAIGHT CULVERT

FREQUENCY: 100 yr    DISCHARGE:   473.00 cfs
FREQUENCY: 50 yr     DISCHARGE:   413.00 cfs

TAILWATER ELEVATION (computed).

n value:  0.0120       Ke value:  0.5000

CULVERT RISE =  3.00 ft    CULVERT SPAN =   7.00 ft    BARRELS =    2

INLET  station:        0.00      elevation:     564.94 ft
OUTLET station:      374.00      elevation:     563.54 ft

Cross section profile  (XY Coordinates)  ft
         X          Y          X          Y          X          Y
       0.00      567.10      35.70      563.54      52.90      563.54
      65.00      567.58
Road profile  (XY Coordinates)  ft
         X          Y          X          Y          X          Y
       0.00      569.50       5.60      570.00      11.60      570.00
      40.00      571.00      42.60      571.00      87.37      587.00
      96.50      590.00     128.40      591.00     173.00      591.70
     199.00      592.00     226.30      593.00     236.70      593.00
     251.40      589.00     253.30      590.00     293.90      570.00
     298.70      569.00     325.80      568.00     361.40      567.00
     366.70      567.00     374.40      567.54
-----------------------------------------------------------------------------

-----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  1
-----------------------------------------------------------------------------

TAILWATER ELEVATION:    565.59 ft (computed).

ANALYSIS for discharge frequency of :   100 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s      ft
-----------------------------------------------------------------------------
```

```
  2 124.72  3.00  7.00  374.00    0.00  568.67  3.73 Inlet     8.90    2.00

Inlet control depth  =      3.73 ft
Outlet control depth =      3.60 ft

Normal depth   =     2.00 ft    Culvert slope  =     0.00374
Critical depth =     2.14 ft    Critical slope =     0.00308
Road top width  => 210.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.04.

Total Discharge                  =>   473.00 cfs
Discharge per barrel            =>   124.72 cfs
Discharge over the road         =>   223.57 cfs
Average velocity over the road  =>     3.22 ft/sec
----------------------------------------------------------------------------
----------------------------------------------------------------------------
       CULVERT  OUTPUT      RUN NO =>  2
----------------------------------------------------------------------------

TAILWATER ELEVATION:    565.45 ft (computed).

ANALYSIS for discharge frequency of :   50 yr

Barls. Qpb  Rise  Span  Length  Max.HW  Calc.HW  HW  Control  Veloc.
Out.depth
                                 elev    elev
       cfs   ft    ft     ft      ft      ft     ft            ft/s     ft
----------------------------------------------------------------------------
  2 117.77  3.00  7.00  374.00    0.00  568.50  3.56 Inlet     8.75    1.92

Inlet control depth  =      3.56 ft
Outlet control depth =      3.47 ft

Normal depth   =     1.92 ft    Culvert slope  =     0.00374
Critical depth =     2.06 ft    Critical slope =     0.00306
Road top width  => 210.00 ft.  Road pavement type => asphalt
Computed Weir Coefficient => 3.04.

Total Discharge                  =>   413.00 cfs
Discharge per barrel            =>   117.77 cfs
Discharge over the road         =>   177.46 cfs
Average velocity over the road  =>     3.01 ft/sec
----------------------------------------------------------------------------
----------------------------------------------------------------------------
*Computation: Hydraulic jump occurs within culvert.

 NORMAL TERMINATION OF THYSYS,  CULVERT.
```

EXISTING N – WINSTORM RESULTS

PROJECT NAME : SH183
JOB NUMBER :
PROJECT DESCRIPTION : Existing N
DESIGN FREQUENCY : 50 Years
ANALYSYS FREQUENCY : 100 Years
MEASUREMENT UNITS: ENGLISH

OUTPUT FOR DESIGN FREQUENCY of: 50 Years

Runoff Computation for Design Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
N	0.75	64.00	30.00	30.00	5.96	0.000	286.306

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	Gutter n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
N	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
N	Grate	n/a	20.00	25.00	286.306	21.828	4.537	50.20	50.20

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
N	Grate	0.750	64.00	30.00	5.96	0.000	0.00	286.306
OUT	Outlt	0.750	64.00	30.00	5.96	0.000	0.00	286.306

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US	Flowline Elev. DS	Shape #	Span	Rise	Length	Slope	n_value

			(ft)	(ft)			(ft)	(ft)	(ft)	(%)	
1	N	OUT	4.00	2.28	Circ	1	0.00	6.00	256.00	0.67	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Actual (ft)	Velocity Unif. (f/s)	Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	8.17	6.45	0.457	4.17	4.17	13.64	13.64	286.31	347.19	0.000

OUTPUT FOR ANALYSYS FREQUENCY of: 100 Years

Runoff Computation for Analysis Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
N	0.75	64.00	30.00	30.00	6.51	0.000	312.502

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Trans (%)	Right-Slope Long (%)	Trans (%)	Gutter n	DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
N	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Right (ft)
N	Grate	n/a	20.00	25.00	312.502	21.828	5.405	51.90	51.90

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
N	Grate	0.750	64.00	30.00	6.51	0.000	0.00	312.502
OUT	Outlt	0.750	64.00	30.00	6.51	0.000	0.00	312.502

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	N	OUT	4.00	2.28	Circ 1	0.00	6.00	256.00	0.67	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	8.45	6.73	0.544	4.45	4.45	13.89	13.89	312.50	347.19	0.000

=====================================END=====================================

* Super critical flow.

NORMAL TERMINATION OF WINSTORM.

Warning Messages for current project:

Runoff Frequency of: 50 Years
Computed right ponded width exceeds allowable width at inlet Id= N
Computed left ponded width exceeds allowable width at inlet Id= N
Capacity of sag inlet exceeded at inlet Id= N
Tailwater set to uniform depth elevation = 6.45(ft)
Upstream hydraulic gradeline exceeds critical elevation at node Id= N

Runoff Frequency of: 100 Years
Computed right ponded width exceeds allowable width at inlet Id= N
Computed left ponded width exceeds allowable width at inlet Id= N
Capacity of sag inlet exceeded at inlet Id= N
Tailwater set to uniform depth elevation = 6.73(ft)
Upstream hydraulic gradeline exceeds critical elevation at node Id= N

EXISTING O – WINSTORM RESULTS

```
PROJECT NAME :  SH183
JOB NUMBER   :
PROJECT DESCRIPTION : Existing O
DESIGN FREQUENCY    :  50   Years
ANALYSYS FREQUENCY :  100   Years
MEASUREMENT UNITS:    ENGLISH
```

OUTPUT FOR DESIGN FREQUENCY of: 50 Years

Runoff Computation for Design Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
O	0.75	32.30	30.00	30.00	5.96	0.000	144.495

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	Gutter n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
O	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
O	Grate	n/a	20.00	25.00	144.495	21.828	1.763	38.85	38.85

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
O	Grate	0.750	32.30	30.00	5.96	0.000	0.00	144.495
OUT	Outlt	0.750	32.30	30.00	5.96	0.000	0.00	144.495

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US	Flowline Elev. DS	Shape #	Span	Rise	Length	Slope	n_value

			(ft)	(ft)			(ft)	(ft)	(ft)	(%)
1	O	OUT	6.00	4.52	Circ	1	0.00	4.00	270.00	0.55	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Actual (ft)	Velocity Unif. (f/s)	Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1	11.25	8.52	1.012	4.00	4.00	11.50	11.50	144.50	106.54	0.000

OUTPUT FOR ANALYSYS FREQUENCY of: 100 Years

Runoff Computation for Analysis Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
O	0.75	32.30	30.00	30.00	6.51	0.000	157.716

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
O	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
O	Grate	n/a	20.00	25.00	157.716	21.828	1.869	40.15	40.15

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
O	Grate	0.750	32.30	30.00	6.51	0.000	0.00	157.716
OUT	Outlt	0.750	32.30	30.00	6.51	0.000	0.00	157.716

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	O	OUT	6.00	4.52	Circ 1	0.00	4.00	270.00	0.55	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1	11.77	8.52	1.205	4.00	4.00	12.55	12.55	157.72	106.54	0.000

=====END=====

NORMAL TERMINATION OF WINSTORM.

Warning Messages for current project:

Runoff Frequency of: 50 Years
Computed right ponded width exceeds allowable width at inlet Id= O
Computed left ponded width exceeds allowable width at inlet Id= O
Capacity of sag inlet exceeded at inlet Id= O
Tailwater set to uniform depth elevation = 8.52(ft)
Run# 1 Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= O

Runoff Frequency of: 100 Years
Computed right ponded width exceeds allowable width at inlet Id= O
Computed left ponded width exceeds allowable width at inlet Id= O
Capacity of sag inlet exceeded at inlet Id= O
Tailwater set to uniform depth elevation = 8.52(ft)
Run# 1 Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= O

PROPOSED O – WINSTORM RESULTS

PROJECT NAME : SH183
JOB NUMBER :
PROJECT DESCRIPTION : Proposed O
DESIGN FREQUENCY : 50 Years
ANALYSYS FREQUENCY : 100 Years
MEASUREMENT UNITS: ENGLISH

OUTPUT FOR DESIGN FREQUENCY of: 50 Years

Runoff Computation for Design Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
O	0.75	32.30	30.00	30.00	5.96	0.000	144.495

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	Gutter n	DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
O	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
O	Grate	n/a	20.00	25.00	144.495	21.828	1.763	38.85	38.85

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
O	Grate	0.750	32.30	30.00	5.96	0.000	0.00	144.495
OUT	Outlt	0.750	32.30	30.00	5.96	0.000	0.00	144.495

Conveyance Configuration Data

Run# Node I.D. Flowline Elev.

	US	DS	US (ft)	DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	O	OUT	5.00	3.52	Circ 1	0.00	5.00	270.00	0.55	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Actual (ft)	Velocity Unif. (f/s)	Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	8.24	6.76	0.308	3.24	3.24	10.72	10.72	144.50	193.18	0.000

OUTPUT FOR ANALYSYS FREQUENCY of: 100 Years

Runoff Computation for Analysis Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
O	0.75	32.30	30.00	30.00	6.51	0.000	157.716

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	Gutter n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
O	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Right (ft)
O	Grate	n/a	20.00	25.00	157.716	21.828	1.869	40.15	40.15

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
O	Grate	0.750	32.30	30.00	6.51	0.000	0.00	157.716
OUT	Outlt	0.750	32.30	30.00	6.51	0.000	0.00	157.716

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	O	OUT	5.00	3.52	Circ 1	0.00	5.00	270.00	0.55	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	8.44	6.95	0.367	3.44	3.44	10.96	10.96	157.72	193.18	0.000

END

* Super critical flow.

NORMAL TERMINATION OF WINSTORM.

Warning Messages for current project:

Runoff Frequency of: 50 Years

Computed right ponded width exceeds allowable width at inlet Id= O
Computed left ponded width exceeds allowable width at inlet Id= O
Capacity of sag inlet exceeded at inlet Id= O
Tailwater set to uniform depth elevation = 6.76(ft)
Upstream hydraulic gradeline exceeds critical elevation at node Id= O

Runoff Frequency of: 100 Years

Computed right ponded width exceeds allowable width at inlet Id= O
Computed left ponded width exceeds allowable width at inlet Id= O
Capacity of sag inlet exceeded at inlet Id= O
Tailwater set to uniform depth elevation = 6.95(ft)
Upstream hydraulic gradeline exceeds critical elevation at node Id= O

EXISTING P – WINSTORM RESULTS

PROJECT NAME : SH183
JOB NUMBER :
PROJECT DESCRIPTION : Existing P
DESIGN FREQUENCY : 50 Years
ANALYSYS FREQUENCY : 100 Years
MEASUREMENT UNITS: ENGLISH

OUTPUT FOR DESIGN FREQUENCY of: 50 Years

Runoff Computation for Design Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
P	0.75	48.00	30.00	30.00	5.96	0.000	214.730

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
P	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
P	Grate	n/a	20.00	25.00	214.730	21.828	2.552	45.05	45.05

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
P	Grate	0.750	48.00	30.00	5.96	0.000	0.00	214.730
OUT	Outlt	0.750	48.00	30.00	5.96	0.000	0.00	214.730

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US	Flowline Elev. DS	Shape #	Span	Rise	Length	Slope	n_value

			(ft)	(ft)		(ft)	(ft)	(ft)	(%)	
1	P	OUT	6.50	4.97	Circ 1	0.00	3.50	150.00	1.02	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradelin US Elev (ft)	DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Actual (ft)	Velocity Unif. (f/s)	Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1	15.30	8.47	4.554	3.50	3.50	22.32	22.32	214.73	101.63	0.000

OUTPUT FOR ANALYSYS FREQUENCY of: 100 Years

Runoff Computation for Analysis Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
P	0.75	48.00	30.00	30.00	6.51	0.000	234.377

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Trans (%)	Right-Slope Long (%)	Trans (%)	Gutter n	DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
P	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	0.50	2.50

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Right (ft)
P	Grate	n/a	20.00	25.00	234.377	21.828	3.040	46.60	46.60

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
P	Grate	0.750	48.00	30.00	6.51	0.000	0.00	234.377
OUT	Outlt	0.750	48.00	30.00	6.51	0.000	0.00	234.377

```
Conveyance Configuration Data
===========================================================================
Run#  Node I.D.      Flowline Elev.
      US    DS         US      DS      Shape #  Span  Rise  Length  Slope
n_value
                      (ft)    (ft)              (ft)  (ft)   (ft)    (%)
---------------------------------------------------------------------------
1    P      OUT        6.50      4.97   Circ 1  0.00  3.50   150.00   1.02
0.013
---------------------------------------------------------------------------


Conveyance Hydraulic Computations.  Tailwater = 0.000 (ft)
===========================================================================
    Hydraulic Gradeline           Depth         Velocity                Junc
Run#   US Elev  DS Elev  Fr.Slope Unif. Actual  Unif. Actual   Q    Cap   Loss
        (ft)     (ft)      (%)     (ft)  (ft)   (f/s)  (f/s)  (cfs)(cfs)  (ft)
---------------------------------------------------------------------------
1     16.61    8.47  5.425    3.50   3.50   24.36  24.36 234.38 101.63  0.000
==================================END======================================

 NORMAL TERMINATION OF WINSTORM.

Warning Messages for current project:

        Runoff Frequency of: 50 Years
Computed right ponded width exceeds allowable width at inlet Id= P
Computed left ponded width exceeds allowable width at inlet Id= P
Capacity of sag inlet exceeded at inlet Id= P
Tailwater set to uniform depth elevation = 8.47(ft)
Run# 1  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= P

        Runoff Frequency of: 100 Years
Computed right ponded width exceeds allowable width at inlet Id= P
Computed left ponded width exceeds allowable width at inlet Id= P
Capacity of sag inlet exceeded at inlet Id= P
Tailwater set to uniform depth elevation = 8.47(ft)
Run# 1  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= P
```

PROPOSED P – WINSTORM RESULTS

PROJECT NAME : SH183
JOB NUMBER :
PROJECT DESCRIPTION : Proposed P
DESIGN FREQUENCY : 50 Years
ANALYSYS FREQUENCY : 100 Years
MEASUREMENT UNITS: ENGLISH

OUTPUT FOR DESIGN FREQUENCY of: 50 Years

Runoff Computation for Design Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
O	0.75	48.00	30.00	30.00	5.96	0.000	214.730

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	Gutter n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
P	Grate	20.00	25.00	0.50	2.00	0.50	2.00	0.014	n/a	2.50	

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
P	Grate	n/a	20.00	25.00	214.730	21.828	2.552	45.05	45.05

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
O	Grate	0.750	48.00	30.00	5.96	0.000	0.00	214.730
OUT	Outlt	0.750	48.00	30.00	5.96	0.000	0.00	214.730

Conveyance Configuration Data

Run# Node I.D. US	DS	Flowline Elev. US	DS	Shape #	Span	Rise	Length	Slope	n_value

```
                     (ft)    (ft)                (ft)   (ft)    (ft)     (%)
-----------------------------------------------------------------------------
1    P      OUT     5.00      3.47   Circ 1  0.00  5.00    150    1.02  0.013
-----------------------------------------------------------------------------


Conveyance Hydraulic Computations.  Tailwater = 0.000 (ft)
=============================================================================
      Hydraulic Gradeline          Depth          Velocity
Junc
Run#  US Elev  DS Elev  Fr.Slope Unif. Actual  Unif. Actual  Q    Cap     Loss
       (ft)     (ft)       (%)     (ft)  (ft)   (f/s)  (f/s) (cfs)(cfs)    (ft)
-----------------------------------------------------------------------------
1*     8.44     6.91  0.680    3.44    3.44   14.92   14.92 214.73 263.08  0.000

=============================================================================


         OUTPUT FOR ANALYSYS FREQUENCY of:  100   Years
         ============================================


Runoff Computation for Analysis Frequency.
=============================================================================
ID      C Value     Area     Tc     Tc Used     Intensity     Supply Q    Total Q
                   (acre)  (min)   (min)        (in/hr)       (cfs)       (cfs)
-----------------------------------------------------------------------------
P        0.75     48.00   30.00    30.00        6.51          0.000      234.377
-----------------------------------------------------------------------------


Sag Inlets Configuration Data.
=============================================================================
Inlet Inlet Length/ Grate  Left-Slope  Right-Slope    Gutter  Depth Critic
 ID   Type  Perim.  Area   Long Trans  Long Trans  n  DeprW  Allowed   Elev.
             (ft)    (sf)   (%)   (%)   (%)   (%)       (ft)    (ft)     (ft)
-----------------------------------------------------------------------------
P    Grate 20.00  25.00   0.50 2.00   0.50  2.00 0.014 n/a     0.50      2.50
-----------------------------------------------------------------------------

Sag Inlets Computation Data.
=============================================================================
Inlet   Inlet    Length     Grate       Total Q   Inlet     Total    Ponded Width
 ID     Type              Perim Area             Capacity   Head     Left   Right
                  (ft)    (ft)  (sf)    (cfs)     (cfs)     (ft)     (ft)   (ft)
-----------------------------------------------------------------------------
P       Grate      n/a  20.00 25.00  234.377   21.828    3.040    46.60   46.60
-----------------------------------------------------------------------------

Cumulative Junction Discharge Computations
=============================================================================
Node  Node Weighted  Cumulat. Cumulat. Intens.   User      Additional    Total
I.D. Type  C-Value   Dr.Area   Tc               Supply Q   Q in Node     Disch.
                     (acres)   (min)   (in/hr)    cfs)       (cfs)        (cfs)
-----------------------------------------------------------------------------
P    Grate   0.750     48.00   30.00     6.51    0.000          0.00    234.377
OUT  Outlt   0.750     48.00   30.00     6.51    0.000          0.00    234.377
```

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	P	OUT	5.00	3.47	Circ 1	0.00	5.00	150.00	1.02	0.013

Conveyance Hydraulic Computations. Tailwater = 0.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	8.67	7.14	0.810	3.67	3.67	15.17	15.17	234.38	263.08	0.000

END

* Super critical flow.

NORMAL TERMINATION OF WINSTORM.

Warning Messages for current project:

Runoff Frequency of: 50 Years
Computed right ponded width exceeds allowable width at inlet Id= O
Computed left ponded width exceeds allowable width at inlet Id= O
Capacity of sag inlet exceeded at inlet Id= O
Tailwater set to uniform depth elevation = 6.76(ft)
Upstream hydraulic gradeline exceeds critical elevation at node Id= O

Runoff Frequency of: 100 Years
Computed right ponded width exceeds allowable width at inlet Id= O
Computed left ponded width exceeds allowable width at inlet Id= O
Capacity of sag inlet exceeded at inlet Id= O
Tailwater set to uniform depth elevation = 6.95(ft)
Upstream hydraulic gradeline exceeds critical elevation at node Id= O

EXISTING 18 – WINSTORM RESULTS

PROJECT NAME : SH183
JOB NUMBER :
PROJECT DESCRIPTION : Existing 3'x2' RCB just west of Co. Lane
DESIGN FREQUENCY : 50 Years
ANALYSYS FREQUENCY : 100 Years
MEASUREMENT UNITS: ENGLISH

OUTPUT FOR DESIGN FREQUENCY of: 50 Years

Runoff Computation for Design Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
17	0.85	2.90	10.00	10.00	10.53	0.000	25.947
18	0.7	2.60	10.00	10.00	10.53	0.000	19.157
23	0.85	2.80	10.00	10.00	10.53	0.000	25.052

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
18	Grate	12.00	9.00	0.50	2.00	0.50	2.00	0.023	n/a	3.00	491.00

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
18	Grate	n/a	12.00	9.00	19.157	83.781	0.644	21.95	21.95

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
17	BoxMh	0.779	5.50	10.18	10.45	0.000	0.00	44.776
18	Grate	0.700	2.60	10.00	10.53	0.000	0.00	19.157
23	CircMh	0.803	8.30	10.59	10.27	0.000	0.00	68.464
M1	JnctBx	0.700	2.60	10.00	10.53	0.000	0.00	19.157
M2	JnctBx	0.779	5.50	10.18	10.45	0.000	0.00	44.776
M3	JnctBx	0.779	5.50	10.18	10.45	0.000	0.00	44.776
OUT	Outlt	0.803	8.30	10.59	10.27	0.000	0.00	68.464

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	18	M1	485.00	484.60	Box 1	3.00	2.00	35.75	1.12	0.013
2	M1	17	484.60	482.09	Box 1	3.00	2.00	70.00	3.59	0.013
3	17	M2	482.09	481.77	Box 1	3.00	2.00	128.00	0.25	0.013
4	M2	M3	481.77	479.27	Box 1	3.00	2.00	33.00	7.60	0.013
5	M3	23	479.27	478.38	Box 1	3.00	2.00	66.00	1.35	0.013
6	23	OUT	478.38	478.00	Box 1	3.00	2.00	33.00	1.15	0.013

Conveyance Hydraulic Computations. Tailwater = 480.500 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	485.85	485.68	0.154	0.81	1.08	7.86	5.90	19.16	51.61	0.000
2*	485.68	485.15	0.154	0.54	2.00	11.74	3.19	19.16	92.42	0.000
3	485.15	483.68	0.842	2.00	2.00	7.46	7.46	44.78	24.39	0.000
4*	483.68	481.71	0.842	0.75	2.00	19.87	7.46	44.78	134.48	0.000
5*	481.71	481.15	0.842	1.40	2.00	10.67	7.46	44.78	56.66	0.000
6	481.15	480.50	1.969	2.00	2.00	11.41	11.41	68.46	52.36	0.000

OUTPUT FOR ANALYSYS FREQUENCY of: 100 Years

Runoff Computation for Analysis Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
17	0.85	2.90	10.00	10.00	11.55	0.000	28.466
18	0.7	2.60	10.00	10.00	11.55	0.000	21.018
23	0.85	2.80	10.00	10.00	11.55	0.000	27.485

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)

18	Grate	12.00	9.00	0.50	2.00	0.50	2.00	0.023	n/a	3.00	491.00

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
18	Grate	n/a	12.00	9.00	21.018	83.781	0.685	22.70	22.70

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q (cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
17	BoxMh	0.779	5.50	10.17	11.47	0.000	0.00	49.128
18	Grate	0.700	2.60	10.00	11.55	0.000	0.00	21.018
23	CircMh	0.803	8.30	10.56	11.28	0.000	0.00	75.186
M1	JnctBx	0.700	2.60	10.00	11.55	0.000	0.00	21.018
M2	JnctBx	0.779	5.50	10.17	11.47	0.000	0.00	49.128
M3	JnctBx	0.779	5.50	10.17	11.47	0.000	0.00	49.128
OUT	Outlt	0.803	8.30	10.56	11.28	0.000	0.00	75.186

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape	#	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	18	M1	485.00	484.60	Box	1	3.00	2.00	35.75	1.12	0.013
2	M1	17	484.60	482.09	Box	1	3.00	2.00	70.00	3.59	0.013
3	17	M2	482.09	481.77	Box	1	3.00	2.00	128.00	0.25	0.013
4	M2	M3	481.77	479.27	Box	1	3.00	2.00	33.00	7.60	0.013
5	M3	23	479.27	478.38	Box	1	3.00	2.00	66.00	1.35	0.013
6	23	OUT	478.38	478.00	Box	1	3.00	2.00	33.00	1.15	0.013

Conveyance Hydraulic Computations. Tailwater = 481.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	485.91	485.75	0.186	0.87	1.15	8.08	6.09	21.02	51.61	0.000
2*	485.75	485.07	0.186	0.58	2.00	12.10	3.50	21.02	92.42	0.000
3	485.07	483.77	1.014	2.00	2.00	8.19	8.19	49.13	24.39	0.000
4*	483.77	482.45	1.014	0.80	2.00	20.43	8.19	49.13	134.48	0.000
5*	482.45	481.78	1.014	1.50	2.00	10.92	8.19	49.13	56.66	0.000
6	481.78	481.00	2.375	2.00	2.00	12.53	12.53	75.19	52.36	0.000

END

```
* Super critical flow.

 NORMAL TERMINATION OF WINSTORM.

Warning Messages for current project:

        Runoff Frequency of: 50 Years
Computed right ponded width exceeds allowable width at inlet Id= 18
Computed left ponded width exceeds allowable width at inlet Id= 18
Discharge decreased downstream node Id= M1 Previous intensity used.
Discharge decreased downstream node Id= M2 Previous intensity used.
Discharge decreased downstream node Id= M3 Previous intensity used.
Run# 6  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 23
Upstream hydraulic gradeline exceeds critical elevation at node Id= M3
Upstream hydraulic gradeline exceeds critical elevation at node Id= M2
Run# 3  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 17
Upstream hydraulic gradeline exceeds critical elevation at node Id= M1

        Runoff Frequency of: 100 Years
Computed right ponded width exceeds allowable width at inlet Id= 18
Computed left ponded width exceeds allowable width at inlet Id= 18
Discharge decreased downstream node Id= M1 Previous intensity used.
Discharge decreased downstream node Id= M2 Previous intensity used.
Discharge decreased downstream node Id= M3 Previous intensity used.
Run# 6  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 23
Upstream hydraulic gradeline exceeds critical elevation at node Id= M3
Upstream hydraulic gradeline exceeds critical elevation at node Id= M2
Run# 3  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 17
Upstream hydraulic gradeline exceeds critical elevation at node Id= M1
```

PROPOSED 18 – WINSTORM RESULTS

PROJECT NAME : SH183
JOB NUMBER :
PROJECT DESCRIPTION : Existing 3'x2' RCB just west of Co. Lane
DESIGN FREQUENCY : 50 Years
ANALYSYS FREQUENCY : 100 Years
MEASUREMENT UNITS: ENGLISH

OUTPUT FOR DESIGN FREQUENCY of: 50 Years

Runoff Computation for Design Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
17	0.85	2.90	10.00	10.00	10.53	0.000	25.947
18	0.7	2.60	10.00	10.00	10.53	0.000	19.157
23	0.85	2.80	10.00	10.00	10.53	0.000	25.052

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	N	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)
18	Grate	12.00	9.00	0.50	2.00	0.50	2.00	0.023	n/a	3.00	491.00

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
18	Grate	n/a	12.00	9.00	19.157	83.781	0.644	21.95	21.95

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User Supply Q cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
17	BoxMh	0.779	5.50	10.18	10.45	0.000	0.00	44.776
18	Grate	0.700	2.60	10.00	10.53	0.000	0.00	19.157
23	CircMh	0.803	8.30	10.59	10.27	0.000	0.00	68.464
M1	JnctBx	0.700	2.60	10.00	10.53	0.000	0.00	19.157
M2	JnctBx	0.779	5.50	10.18	10.45	0.000	0.00	44.776
M3	JnctBx	0.779	5.50	10.18	10.45	0.000	0.00	44.776
OUT	Outlt	0.803	8.30	10.59	10.27	0.000	0.00	68.464

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	18	M1	485.00	484.60	Box 1	3.00	2.00	35.75	1.12	0.013
2	M1	17	484.60	482.09	Box 1	3.00	2.00	70.00	3.59	0.013
3	17	M2	482.09	481.77	Box 1	3.00	2.00	128.00	0.25	0.013
4	M2	M3	481.77	479.27	Box 1	3.00	2.00	33.00	7.60	0.013
5	M3	23	479.27	478.38	Box 1	3.00	2.00	66.00	1.35	0.013
6	23	OUT	477.38	477.00	Box 1	3.00	3.00	33.00	1.15	0.013

Conveyance Hydraulic Computations. Tailwater = 480.500 (ft)

Run#	Hydraulic Gradeline US Elev ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	485.85	485.68	0.154	0.81	1.08	7.86	5.90	19.16	51.61	0.000
2*	485.68	485.15	0.154	0.54	2.00	11.74	3.19	19.16	92.42	0.000
3	485.15	483.68	0.842	2.00	2.00	7.46	7.46	44.78	24.39	0.000
4*	483.68	481.27	0.842	0.75	2.00	19.87	7.46	44.78	134.48	0.000
5*	481.27	480.71	0.842	1.40	2.00	10.67	7.46	44.78	56.66	0.000
6*	480.71	480.50	0.650	2.05	3.00	11.13	7.61	68.46	91.13	0.000

OUTPUT FOR ANALYSYS FREQUENCY of: 100 Years

Runoff Computation for Analysis Frequency.

ID	C Value	Area (acre)	Tc (min)	Tc Used (min)	Intensity (in/hr)	Supply Q (cfs)	Total Q (cfs)
17	0.85	2.90	10.00	10.00	11.55	0.000	28.466
18	0.7	2.60	10.00	10.00	11.55	0.000	21.018
23	0.85	2.80	10.00	10.00	11.55	0.000	27.485

Sag Inlets Configuration Data.

Inlet ID	Inlet Type	Length/ Perim. (ft)	Grate Area (sf)	Left-Slope Long (%)	Left-Slope Trans (%)	Right-Slope Long (%)	Right-Slope Trans (%)	n	Gutter DeprW (ft)	Depth Allowed (ft)	Critic Elev. (ft)

18	Grate	12.00	9.00	0.50	2.00	0.50	2.00	0.023	n/a	3.00	491.00

Sag Inlets Computation Data.

Inlet ID	Inlet Type	Length (ft)	Grate Perim (ft)	Grate Area (sf)	Total Q (cfs)	Inlet Capacity (cfs)	Total Head (ft)	Ponded Width Left (ft)	Ponded Width Right (ft)
18	Grate	n/a	12.00	9.00	21.018	83.781	0.685	22.70	22.70

Cumulative Junction Discharge Computations

Node I.D.	Node Type	Weighted C-Value	Cumulat. Dr.Area (acres)	Cumulat. Tc (min)	Intens. (in/hr)	User upply Q cfs)	Additional Q in Node (cfs)	Total Disch. (cfs)
17	BoxMh	0.779	5.50	10.17	11.47	0.000	0.00	49.128
18	Grate	0.700	2.60	10.00	11.55	0.000	0.00	21.018
23	CircMh	0.803	8.30	10.56	11.28	0.000	0.00	75.186
M1	JnctBx	0.700	2.60	10.00	11.55	0.000	0.00	21.018
M2	JnctBx	0.779	5.50	10.17	11.47	0.000	0.00	49.128
M3	JnctBx	0.779	5.50	10.17	11.47	0.000	0.00	49.128
OUT	Outlt	0.803	8.30	10.56	11.28	0.000	0.00	75.186

Conveyance Configuration Data

Run#	Node I.D. US	Node I.D. DS	Flowline Elev. US (ft)	Flowline Elev. DS (ft)	Shape #	Span (ft)	Rise (ft)	Length (ft)	Slope (%)	n_value
1	18	M1	485.00	484.60	Box 1	3.00	2.00	35.75	1.12	0.013
2	M1	17	484.60	482.09	Box 1	3.00	2.00	70.00	3.59	0.013
3	17	M2	482.09	481.77	Box 1	3.00	2.00	128.00	0.25	0.013
4	M2	M3	481.77	479.27	Box 1	3.00	2.00	33.00	7.60	0.013
5	M3	23	479.27	478.38	Box 1	3.00	2.00	66.00	1.35	0.013
6	23	OUT	477.38	477.00	Box 1	3.00	3.00	33.00	1.15	0.013

Conveyance Hydraulic Computations. Tailwater = 481.000 (ft)

Run#	Hydraulic Gradeline US Elev (ft)	Hydraulic Gradeline DS Elev (ft)	Fr.Slope (%)	Depth Unif. (ft)	Depth Actual (ft)	Velocity Unif. (f/s)	Velocity Actual (f/s)	Q (cfs)	Cap (cfs)	Junc Loss (ft)
1*	485.91	485.75	0.186	0.87	1.15	8.08	6.09	21.02	51.61	0.000
2*	485.75	485.07	0.186	0.58	2.00	12.10	3.50	21.02	92.42	0.000
3	485.07	483.77	1.014	2.00	2.00	8.19	8.19	49.13	24.39	0.000
4*	483.77	481.93	1.014	0.80	2.00	20.43	8.19	49.13	134.48	0.000
5*	481.93	481.26	1.014	1.50	2.00	10.92	8.19	49.13	56.66	0.000

```
6*  481.26   481.00  0.784    2.20   3.00   11.38   8.35  75.19  91.13  0.000
===================================END=====================================

* Super critical flow.

 NORMAL TERMINATION OF WINSTORM.

Warning Messages for current project:

        Runoff Frequency of: 50 Years
Computed right ponded width exceeds allowable width at inlet Id= 18
Computed left ponded width exceeds allowable width at inlet Id= 18
Discharge decreased downstream node Id= M1 Previous intensity used.
Discharge decreased downstream node Id= M2 Previous intensity used.
Discharge decreased downstream node Id= M3 Previous intensity used.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 23
Upstream hydraulic gradeline exceeds critical elevation at node Id= M3
Upstream hydraulic gradeline exceeds critical elevation at node Id= M2
Run# 3  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 17
Upstream hydraulic gradeline exceeds critical elevation at node Id= M1

        Runoff Frequency of: 100 Years
Computed right ponded width exceeds allowable width at inlet Id= 18
Computed left ponded width exceeds allowable width at inlet Id= 18
Discharge decreased downstream node Id= M1 Previous intensity used.
Discharge decreased downstream node Id= M2 Previous intensity used.
Discharge decreased downstream node Id= M3 Previous intensity used.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 23
Upstream hydraulic gradeline exceeds critical elevation at node Id= M3
Upstream hydraulic gradeline exceeds critical elevation at node Id= M2
Run# 3  Insufficient capacity.
Upstream hydraulic gradeline exceeds critical elevation at node Id= 17
Upstream hydraulic gradeline exceeds critical elevation at node Id= M1
```

SH 183/ SH 121
AIRPORT FREEWAY SCHEMATICS
WEST SECTION

PRELIMINARY DRAINAGE STUDY
APPENDIX A - DRAINAGE MASTER PLANS

CITY OF BEDFORD
CITY OF EULESS
CITY OF HURST
December 2003

DRAINAGE MASTER PLAN

FOR THE

CITY of BEDFORD

FIRST INTERIM REPORT

JUNE, 1992

PREPARED BY:

KNOWLTON-ENGLISH-FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth-Dallas

KNOWLTON-ENGLISH-FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth-Dallas

June 1, 1992

Honorable Mayor and City Council
City of Bedford
P.O. Box 157
Bedford, Texas 76095-0157

Re: ***29-232, CITY OF BEDFORD, DRAINAGE MASTER PLAN, FIRST INTERIM REPORT***

Presented herein is the Engineering Report on recommended drainage improvements within the corporate city limits of Bedford, Texas which constitutes the basis for a Drainage Master Plan. This First Interim Report is an extensive study and plan for improvements to all the major channels within the watersheds of Valley View Branch, Sulphur Branch, Bedford Creek, Boyd Branch and Little Bear Creek. A discussion of design criteria and estimated current construction costs of the proposed improvements are included.

The data presented in this report can be used immediately for identifying flood hazard areas, and we strongly recommend that the City adopt a general plan to improve the Major Channels of a particular watershed first, starting from the most downstream location and working upstream. After the major channels are improved, the City can shift the priorities to the Minor Channels and Storm Drains within each watershed.

The Second Interim Report will be an extensive study of all the minor channels and storm drains, both existing and proposed in the City, and it will be presented later. This phase of the Drainage Master Plan will provide the grid maps of the City and depict the topographic features; division of the watersheds, tributary and subdrainage areas; delineation of the major flood plain limits; inventory of existing storm drains, structures and channels; and analysis of additional systems with recommendations of proposed improvements required to meet the design criteria.

The drawings shown in this First Report depict the recommended improvements, their location, alignment, size, etc. However, they are basically schematic in nature and are intended for general planning purposes only. Even though this study represents the product of detailed field surveys, hydraulic computations and an analysis of project alternatives; actual construction should not be initiated without additional preliminary construction planning of the proposed drainage facilities. The plan shown is flexible and deviations from it may be required as further detailed design data become available.

Due to the abundant traffic on Airport Freeway (S.H. 183), the State is currently planning the expansion of this highway corridor. We strongly urge the City to write and meet with the Texas Department of Transportation and have them design all the existing drainage structures under Airport Freeway for a 100-year frequency storm. The existing culverts were designed and built for a 25-year frequency storm around 1970, and can only carry a 10-year frequency flow with current development.

We are available to answer any questions you may have concerning this First Report and stand ready to assist you in the implementation of the proposed improvements.

STATE OF TEXAS
MARK E. RIDDLE
43805
REGISTERED
PROFESSIONAL ENGINEER

MARK E. RIDDLE, P.E.

STATE OF TEXAS
KENNETH E. ENGLISH
26082
REGISTERED
PROFESSIONAL ENGINEER

KENNETH E. ENGLISH, P.E.

MER/lld

xc: Mr. Jim W. Walker, City Manager
Mr. J.E. Powell, P.E., City Engineer

DRAINAGE MASTER PLAN

ACKNOWLEDGEMENTS

Knowlton-English-Flowers, Inc. wishes to extend their appreciation and gratitude for all the valuable assistance and help received from the many individuals and organizations who made the preparation of this report possible:

1) the Bedford City Administrative Staff;
2) the Bedford Public Works Staff;
3) the U.S. Army Corps of Engineers, Fort Worth District;
4) the City of Bedford Residents;
5) the Metropolitan Aerial Surveys Staff; and
6) the employees of K-E-F, Inc.

The efforts of everyone who may have helped in the performance of this Drainage Master Plan are greatly appreciated.

DRAINAGE MASTER PLAN

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DRAINAGE MASTER PLAN

LIST OF DRAWINGS

DRAINAGE MASTER PLAN

SECTION 1 -- INTRODUCTION

PURPOSE AND SCOPE

As authorized by letter dated July 5, 1990 we have performed this drainage study of the entire City of Bedford which analyzes the capacity of the existing drainage systems and presents a master plan of recommended improvements needed to minimize the potential for flooding. The master plan will serve as an overall guide for planning and budgeting of drainage improvements throughout the City.

The study has consisted of, but was not limited to:

1. A delineation of the fully urbanized, 100-year frequency flood plain limits within the major watersheds, along with plots of the corresponding water surface profiles.

2. An inventory of existing storm drains and analysis of the sub-drainage areas to evaluate and identify the total capacity of underground storm drains required to conform to the drainage criteria outlined in the City of Bedford Subdivision Ordinance.

3. An analysis of channel and other watershed improvements required to contain the fully urbanized 100-year frequency flood (or indicate where channel containment is neither feasible nor desired to maintain an urban greenbelt) along with plots of the corresponding water surface profiles showing proposed flood plain elevations relative to existing area finished floor elevations.

4. Preparation of pre-design Capital Improvement cost estimates for construction of channel, bridge, culvert, storm drain and other drainage improvements recommended within each watershed area.

HYDROLOGY

Major Channels

The discharges used in this study for computing flood plain limits and water surface profiles were computed using the program "HEC-1" on our PC based Haestad Methods program. Discharges noted on the plan-profile sheets include existing and proposed conditions at fully urbanized flows. The fully urbanized flows were used in this study for establishing the 100-year flood plain limits and for channel improvements design calculations.

Minor Channels and Storm Drains

Discharges used in analysis and design of the minor channels and storm drainage systems were developed from calculations using the Rational Formula. This procedure is outlined hereinafter and in the City's Subdivision Ordinance. Drainage areas and grades were obtained from the City's new 100-scale aerials and topographic maps prepared by Metropolitan Aerial Surveys from January, 1990 aerial photographs and captured in digital format. We would note that while these maps supplemented by some field data are sufficient for this type of preliminary over-all plan, additional detailed field surveys must be made prior to the preparation of construction plans in order to provide the necessary accuracy for horizontal as well as vertical control.

HYDRAULICS

Major Channels

Flood plain limits and water surface profiles were computed using the program "HEC-2" on our in-house Prime 2755 digital computer system and on our PC based "Haestad Methods" program. Channel cross section data used by the "HEC-2" program were obtained from the Corps of Engineers, Flood Plain Management Department. Supplemental topographical data were developed by our firm and incorporated in this study, including finished floor elevations of some homes, businesses and other structures located within the flood plain limits.

Bridges and Culverts

Bridges and culverts were sized using the computer program "THYSIS" developed by the Texas Department of Transportation.

Minor Channels and Storm Drains

Minor channels and storm drains were sized using the computer program "SSSSG" developed by Forrest and Cotton, Inc., Consulting Engineers for use in designing storm drain systems for the Dallas-Fort Worth Regional Airport. Modifications have been incorporated into this program based on the Fort Worth/Tarrant County area rainfall frequency curves and computation procedures. The program "SEWER" developed by our firm was used to compute the hydraulic gradient elevations in the design of the storm drains.

ANALYSIS

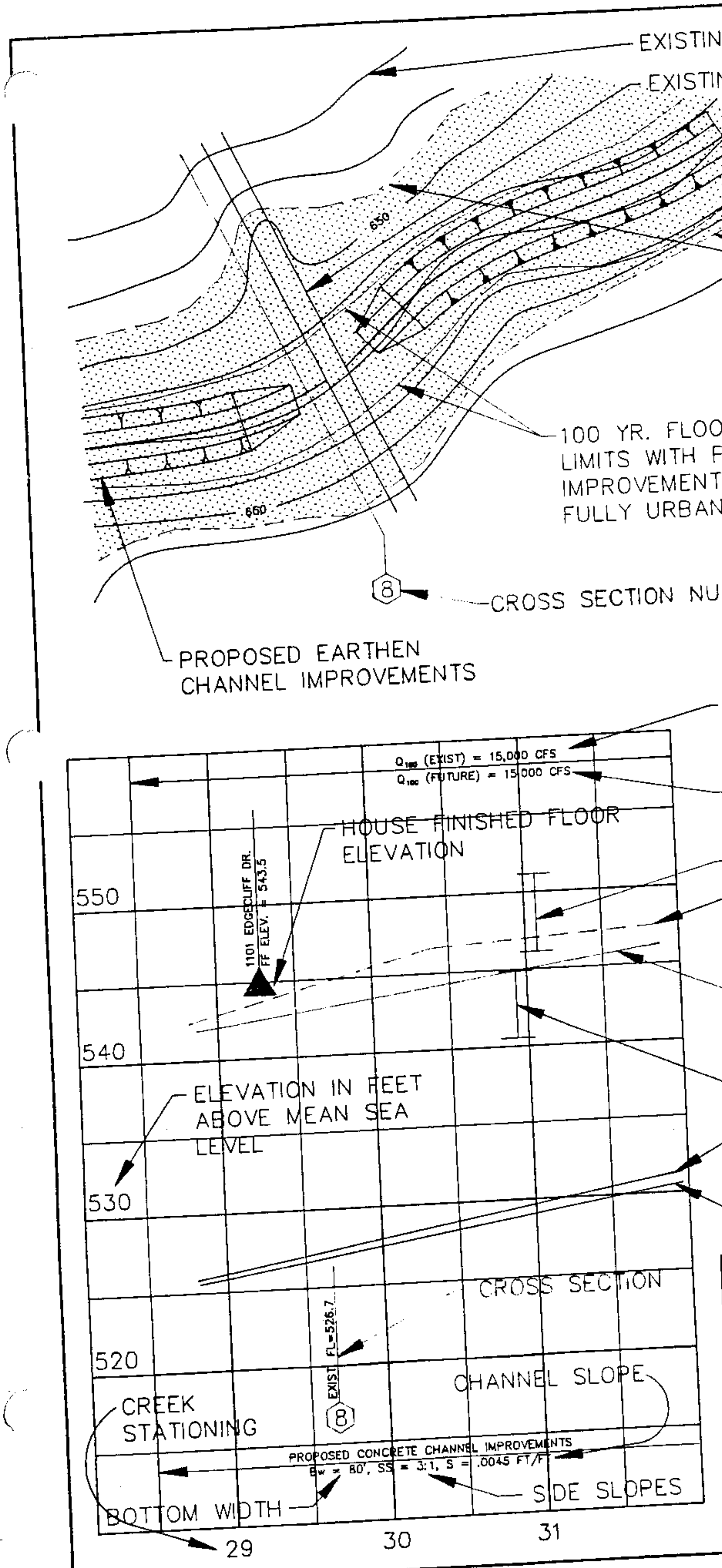
Major Channels

The Plan-Profile Sheets each consist of two parts - a continuous plan view of the channel system and a continuous profile view of the channel system for each major stream and selected tributaries. Existing topographical features are shown in black. The existing 100-year flood plain limits and flood profile are shown in dashed blue lines in the plan and profile views, respectively. The existing channel flowline is shown in black in the profile. The proposed channel improvements and proposed flowline are shown in red in the plan and profile views. The proposed 100-year flood plain limits and computed water surface profile based on fully urbanized flows and recommended channel improvements are shown in a solid blue line. The types of recommended improvements are noted in red at the bottom of each profile sheet. Selected finished floor elevations (shown in black) are noted in the plan view and also shown as triangles in the profiles. A legend of plan-profile data is presented on the Plan-Profile Legend, Plate No. 1.

Design improvements are based on increasing existing bridge, culvert and channel capacity as required to contain the fully urbanized flows within the banks of the channel. Where such containment is not possible or practical, design is based on optimum improvements which would lower the flood plain below the lowest existing finished floor elevations in each channel reach.

Minor Channels and Storm Drains

Each major watershed is divided into many drainage (tributary) areas which are in turn divided into sub-drainage areas. All watersheds and their sub-drainage areas have been assigned identifying codes used to organize the system components and identify system elements. All channels and storm drains have been assigned unique numbers. A legend of typical drainage area identification and numbering codes used in this study is included.



DRAINAGE MASTER PLAN
PLAN-PROFILE LEGEND
CITY OF BEDFORD

KNOWLTON-ENGLISH-FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth-Dallas

DESIGNED BY: MER		DATE: SEPTEMBER 1991
DRAWN BY: DLD		JOB NO: 29-232
CHECKED BY:		PLATE NO. 1

DESIGN CRITERIA

The design criteria used in this study is based upon the City of Bedford Subdivision Ordinance where applicable. Additional criteria has been incorporated in this study based on experience and good engineering judgment.

<u>Major Channels</u>

Major channels should be designed to convey the 100-year discharge based on ultimate development of the watershed. If sufficient right-of-way is available, earthen or grassed lined improvements may be preferable. A concrete pilot channel in all major streams is recommended primarily for maintenance purposes. If channel access ramps are not provided for these channels then at least 15 feet of right-of-way or easement should be located along the top bank for maintenance access. An additional 5 foot minimum easement should be provided along the opposite channel bank.

Where major channels are located in a developed area within a narrow or constricted right-of-way and homes along the channel are presently subject to flooding from the 100-year storm, then full concrete channel liner improvements are recommended. The concrete channel should be designed to convey the full 100-year discharge without overtopping the banks. Where such full conveyance construction is not possible because of excessive additional right-of-way requirements, or other obstacles exist which prevent full required channel widening, then the channel should be made as large as possible to keep the 100-year water surface below the finished floor elevations of as many homes and other structures as possible along the channel.

A detailed description of each major channel reach is included in this report and the basis for the proposed improvements is explained. Cost estimates for each channel reach are also provided elsewhere in this report.

<u>Bridges and Culverts</u>

All bridges and culverts shall be designed based on the 100-year frequency storm based on ultimate development of the watershed regardless of right-of-way constraints and other obstacles which might prevent a full 100-year design.

In addition to the 100-year conveyance criteria, bridges and culverts constructed to provide crossings of streams and open channels shall provide a clear waterway having at least the same width as the downstream channel and shall have a clear height (free board) of one foot above the calculated upstream water depth unless otherwise approved by the City of Bedford. Bridges shall have concrete lined bottoms and slopes, and both bridges and culverts shall have upstream and downstream slope protection in the form of concrete headwalls or wingwalls. Transition structures between trapezoidal channels and vertical wall sections at box culverts which minimize entrance and exit head losses are preferred.

Recommended culvert and bridge improvements are presented in this report based on these criteria. New bridges and culverts at new street crossings, if not shown in this report, should be designed based on full 100-year conveyance criteria using the design discharges presented on the Channel Plan-Profile Sheets for the applicable reach.

Minor Channels and Storm Drains

In general, the analysis of existing storm drains has been approached assuming that no parallel lines are considered and the storm drains required to conform a system to the Subdivision Ordinance of the City of Bedford have been plotted in red. For example, a proposed 30" storm drain (red line) plotted alongside an existing 24" storm drain (black line) illustrates that adequate capacity is not provided in the existing system.

Minor channels and storm drains generally convey less than 1000 acres of runoff area. These systems have been sized utilizing the Rational Formula:

$$Q = C\ I\ A$$

where,

Q = Design flow in cubic feet per second at a given design point.

C = Runoff coefficient or ratio of maximum rate of runoff to the average rate of rainfall.

The following runoff coefficients have been used in this study:

Highways, C = 0.95

Service Commercial, Light Commercial, Heavy Commercial,
Business, Retail, Restaurants, CBD,
C = 0.90

Central Business District,
C = 0.90

Light Industrial, C = 0.85

Medium Density - 1,2,3,4, Multi-Family, Townhomes,
Motels, Condominiums
C = 0.75

Schools, Churches, C = 0.70

Residential - 9000, 7500, 6500, Zero-Lot Line,
C = 0.55

Parks, Open Area, C = 0.30

The original data received on land uses included the May 1982 Future Land Use Plan prepared by Carter & Burgess, Inc., Engineers-Planners along with the City's existing zoning map.

Land uses are based on the City of Bedford Assumed Land Use Map (Preliminary), revised by Knowlton-English-Flowers with City data and input.

I = The average intensity of rainfall in inches per hour for the calculated time of concentration at the design point.

The rainfall intensity-frequency curves used in this study were compiled by the U.S. Department of Commerce Weather Bureau in Technical Paper No. 40 dated May, 1961.

The times of concentration were computed based on the criteria outlined in the City's Subdivision Ordinance or other methods where applicable.

A = Drainage area in acres that is tributary to the storm drain design point.

Drainage areas were computed using the relational data of AutoCAD software to circumscribe the area divides delineated on the Grid Maps presented in this report.

Storm Sewer Design Frequency, (General Guidelines):

5 Year -- Drainage areas less than 50 acres;

10 Year -- Drainage areas between 50 and 100 acres;

25 Year -- Drainage areas between 100 and 200 acres, all storm drains at low points with maintainable overland relief;

50 Year -- Drainage areas between 200 and 500 acres;

100 Year -- Drainage areas greater than 500 acres, all storm drains greater than 72-inch diameter and all storm drains in sumps without maintainable overland relief.

The above frequency criteria may be reduced if sufficient overland relief above the storm drainage system is available to convey the excess 25-year storm within the street right-of-way, and the 100-year storm through the subdivision without flooding any homes or businesses. Some discretionary variances from this criteria have been made in this study where necessary generally in favor of up-sizing.

The hydraulic capacity of a given street for a 5-year storm is controlled by the permissible spread of water flowing in the gutters, thus controlling the design of the storm drainage system. The permissible spread of water in gutters of major divided thoroughfares will be limited so that one traffic lane on each side remains clear; collector streets will be limited so that one standard traffic lane remains clear; and minor streets will be limited by the curb height.

All storm drains in sump areas with overland relief will be designed to carry a minimum capacity of a 25-year frequency storm. Where no overland relief is available or may not be maintained, then all storm drains in sumps will be designed to carry the 100-year frequency storm.

Storm Sewer Sizing:

Sizing is based on the Mannings Equation of Flow:

$$Q = 1.486/n\ A\ R^{2/3}\ S^{1/2}$$

and the Continuity Equation:

$$Q = AV$$

where,

Q	=	Discharge in cubic feet per second
n	=	Mannings Roughness Coefficient

n	=	0.013 Concrete pipe
n	=	0.015 Concrete lined channel
n	=	0.035 Grassed or earthen channel

A	=	Cross-sectional area of flow in square feet
R	=	Hydraulic Radius in feet (Area/Wetted Perimeter)
S	=	Slope of hydraulic gradient in feet per foot
V	=	Mean velocity of flow in feet per second

Storm sewer pipes shall be designed so that the average velocity of flow shall not be less than 3 feet per second and not more than 15 feet per second, and the velocity at the discharge end of all storm drains shall not exceed 6 feet per second. The minimum size of storm drains shall be 18 inches in diameter or equivalent cross-sectional area.

DRAINAGE MASTER PLAN

SECTION 2 -- VALLEY VIEW BRANCH WATERSHED

GENERAL

Portions of the Valley View Branch Watershed are located in the southwest and northwest sector of Bedford. This watershed originates in Colleyville and flows through Bedford and Hurst to its confluence with Walker Branch, and then into the West Fork of the Trinity River. The Valley View Branch Watershed has a drainage area of 3.1 square miles. The drainage area above Bedford Road at the city limits of Bedford is approximately 1.6 square miles. The watershed shape is generally long and narrow, having an average width of about 0.8 miles and a length slightly less than 5 miles.

The study area is located generally north of Hurst Drive, west of Brown Trail and south of the Hurst south city limits line north of Airport Freeway near the L.D. Bell High School facility in the southwest sector of Bedford. In the northwest sector of Bedford, the study area is located from the Hurst north city limits line, south of Harwood Road between Block 42 and 57 of the Mayfair Addition northward into the city limits of Colleyville at Quail Run. Residential units dominate this watershed with some commercial and multi-family units.

Several buildings lie within the 100-year flood plain limits and some are below the 100-year water surface profile. Backwater effects caused by box culverts do not pose a serious problem, instead channel capacity is inadequate to carry very large stormwater flows and result in overbank flooding.

RECOMMENDATIONS

1 VALLEY VIEW BRANCH MAIN CHANNEL

The Main Channel of Valley View Branch and the proposed improvements are shown on Plan-Profile Sheet No. 1.

1.1 Bedford Road To Airport Freeway

This reach consists of an existing earthen channel with homes and businesses on both sides. Five (5) buildings are below the 100-year water surface profile at the existing conditions. To remove these buildings from the 100-year flood plain, the existing channel is proposed to be a concrete lined trapezoidal channel with a 42 foot wide bottom and 1:1 side slopes. The estimated cost of this improvement is about $940,000.

In another drainage Master Plan, the existing box culvert at Bedford Road in the City of Hurst was proposed to be replaced as required to convey the future 100-year frequency storm. This, would further relieve the potential for upstream flooding caused by backwater in this reach. No other improvements are proposed in this reach.

1.2 Airport Freeway

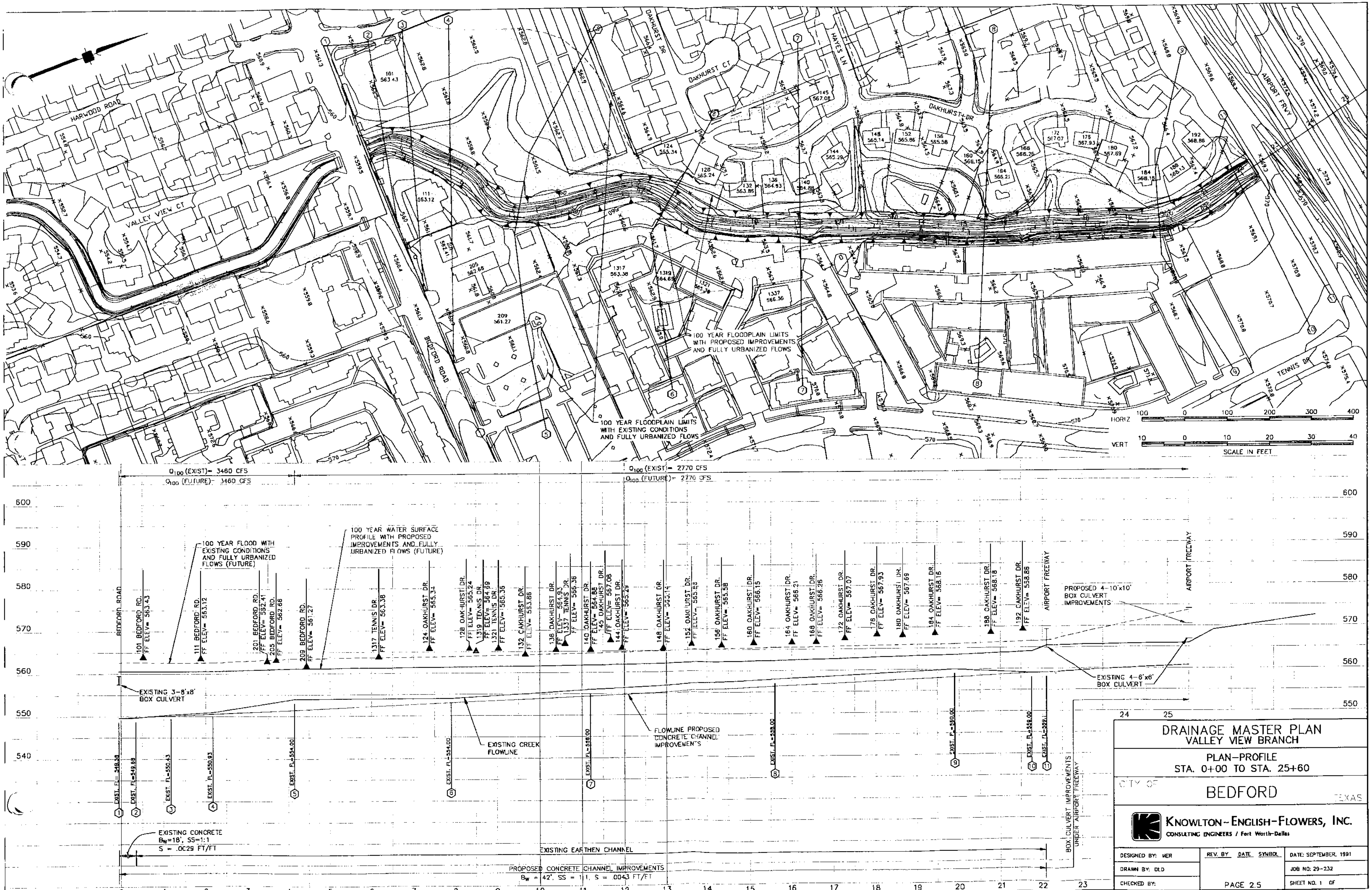
The existing 4-barrel 6'x6' box culvert at Valley View Branch and Airport Freeway is undersized and should be replaced by at least a 4-barrel 10'x10' box culvert. The estimated cost to remove the old culvert and construct the new culvert is approximately $1,423,000.

1.3 Airport Freeway To Hurst City Limits Line

This reach consists of about 595 feet of unimproved earthen channel across the L.D. Bell High School tract of land. In another drainage Master Plan, the upstream channel is proposed to be a 12 foot wide concrete pilot channel centered in a 50 foot wide bottom earthen channel with 3:1 side slopes and we concur with this design for this reach. The estimated cost for this improvement is approximately $105,000.

1.4 Hurst City Limits Line To Harwood Road

This reach consists of approximately 350 feet of unimproved earthen channel across a vacant tract of land. In another drainage Master Plan, the downstream channel is proposed to consist of a 12 foot wide concrete pilot channel centered in a 50 foot wide bottom earthen channel with 3:1 side slopes. The above described improvements are also proposed in this reach. The estimated cost of this improvement is $70,000.



DRAINAGE MASTER PLAN
VALLEY VIEW BRANCH
PLAN–PROFILE
STA. 0+00 TO STA. 25+60
CITY OF BEDFORD TEXAS
KNOWLTON–ENGLISH–FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth–Dallas
DESIGNED BY: WER
DRAWN BY: DLD
CHECKED BY:
REV. BY DATE SYMBOL
DATE: SEPTEMBER, 1991
JOB NO: 29-232
SHEET NO. 1 OF
PAGE 2.5
SCALE IN FEET
HORIZ 100 0 100 200 300 400
VERT 10 0 10 20 30 40
AIRPORT FRWY
TENNIS DR
OAKHURST DR
OAKHURST CT
HAYES LN
BEDFORD ROAD
HARWOOD ROAD
VALLEY VIEW CT
100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND FULLY URBANIZED FLOWS
Q_{100} (EXIST)= 3460 CFS
Q_{100} (FUTURE)= 3460 CFS
Q_{100} (EXIST)= 2770 CFS
Q_{100} (FUTURE)= 2770 CFS
100 YEAR FLOOD WITH EXISTING CONDITIONS AND FULLY URBANIZED FLOWS (FUTURE)
100 YEAR WATER SURFACE PROFILE WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS (FUTURE)
BEDFORD ROAD
101 BEDFORD RD. FF ELEV= 563.43
111 BEDFORD RD. FF ELEV= 563.12
201 BEDFORD RD. FF ELEV= 562.41
205 BEDFORD RD. FF ELEV= 562.66
209 BEDFORD RD. FF ELEV= 561.27
1317 TENNIS DR. FF ELEV= 563.38
124 OAKHURST DR. FF ELEV= 565.34
128 OAKHURST DR. FF ELEV= 565.24
1319 TENNIS DR. FF ELEV= 564.69
1321 TENNIS DR. FF ELEV= 565.35
132 OAKHURST DR. FF ELEV= 553.86
136 OAKHURST DR. FF ELEV= 561.93
1337 TENNIS DR. FF ELEV= 566.36
140 OAKHURST DR. FF ELEV= 564.88
145 OAKHURST DR. FF ELEV= 567.08
144 OAKHURST DR. FF ELEV= 565.29
148 OAKHURST DR. FF ELEV= 563.14
152 OAKHURST DR. FF ELEV= 565.86
156 OAKHURST DR. FF ELEV= 565.58
160 OAKHURST DR. FF ELEV= 566.15
164 OAKHURST DR. FF ELEV= 566.21
168 OAKHURST DR. FF ELEV= 566.26
172 OAKHURST DR. FF ELEV= 567.07
176 OAKHURST DR. FF ELEV= 567.93
180 OAKHURST DR. FF ELEV= 567.69
184 OAKHURST DR. FF ELEV= 568.16
188 OAKHURST DR. FF ELEV= 568.18
192 OAKHURST DR. FF ELEV= 558.86
AIRPORT FREEWAY
PROPOSED 4–10'x10' BOX CULVERT IMPROVEMENTS
EXISTING 4–6'x6' BOX CULVERT
EXISTING 3–8'x8' BOX CULVERT
EXISTING CREEK FLOWLINE
FLOWLINE PROPOSED CONCRETE CHANNEL IMPROVEMENTS
EXIST. FL=548.58
EXIST. FL=549.88
EXIST. FL=550.43
EXIST. FL=550.93
EXIST. FL=554.00
EXIST. FL=554.00
EXIST. FL=558.00
EXIST. FL=558.00
EXIST. FL=560.00
EXIST. FL=559.00
EXIST. FL=559.1
BOX CULVERT IMPROVEMENTS UNDER AIRPORT FREEWAY
EXISTING CONCRETE B_W=18', SS=1:1 S = .0029 FT/FT
EXISTING EARTHEN CHANNEL
PROPOSED CONCRETE CHANNEL IMPROVEMENTS B_W = 42', SS = 1:1, S = .0043 FT/FT

SECTION 3 -- SULPHUR BRANCH WATERSHED

GENERAL

Sulphur Branch flows southward from Huntwich Drive in Camelot Estates in Bedford, then flows through the Cities of Bedford, Euless and Hurst until it merges with Walker Branch in an unincorporated part of Fort Worth, then flows into the West Fork of the Trinity River. The drainage area of the Sulphur Branch Watershed is 5.9 square miles and within the study area of Bedford is approximately 3.6 square miles. This watershed is generally shaped like a long and narrow right triangle, having a width at its base of about 2 miles and a length of about 4.4 miles.

The study area is located from Pipeline Road northward to Huntwich Drive near the north city limits of Bedford. The segment between Pipeline Road and Airport Freeway is 100 percent developed with single-family units and some commercial units. The segment north of Airport Freeway is well developed with a mix of residential homes, townhomes, apartments, commercial buildings, schools and churches, and only a small portion of vacant land exists, most of which is located in the Central Business District (CBD).

As a minimum, regrading and realigning the existing earthen channels for hydraulic and maintenance considerations is a must for the extensive development along this watershed. A 12 foot wide concrete pilot channel will be adequate for the main channel south of Bedford Road and full concrete lining in the congested developments is recommended north of Bedford Road.

RECOMMENDATIONS

1 SULPHUR BRANCH MAIN CHANNEL

This channel and the proposed improvements are shown on Plan-Profile Sheets No. 1 through 7.

1.1 Pipeline Road to Rankin Drive

This reach consists of an unimproved existing earthen channel that meanders around the west side of Brookhollow Park and is experiencing a serious erosion problem. The 100-year flood plain limits encompass the entire park area due to the backwater effects caused by the existing Pipeline Road box culvert. The proposed improvements in this reach consists of realigning the channel and constructing a 12 foot wide concrete pilot channel centered in a 50 foot wide bottom earthen channel with 4:1 side slopes or flatter. This improvement will cost an estimated $975,000.

1.2 Rankin Drive

The existing 4-barrel 10'x6' box culvert at Sulphur Branch and Rankin Drive is of inadequate capacity to convey the 100-year flow. This box culvert should be replaced by a 5-barrel 10'x10' box culvert which will raise the road surface about 9 inches. The estimated cost to remove the old culvert and construct the new culvert is approximately $220,000.

If the proposed box culvert is extended an additional 100 feet southward from Rankin Drive, then the surface area above the structure could provide additional parking for Brookhollow Park and the channel access ramp could be relocated on the west side of the downstream channel. This extension could cost an estimated $180,000.

1.3 Rankin Drive To Existing Concrete Channel at Sta. 30+34

This reach consists of an existing earthen channel in a 100 foot wide drainage easement, with residential homes along both sides of the channel. Several homes along the west side of the channel are below or at the 100-year water surface profile and the proposed improvement will contain the 100-year flood. The improvement consists of a 12 foot wide concrete pilot channel centered in a 50 foot wide bottom earthen channel with 3:1 side slopes for an estimated cost of $300,000.

1.4 Sta. 30+34 to End of Existing Concrete at Sta. 34+64

This section consists of existing concrete channel liner 42 feet wide with 1:1 side slopes and a 4-barrel 10'x10' box culvert at Circle Lane. One split level house is below the 100-year flood elevation in this section, therefore the existing channel and culvert should be modified. The north side of the existing channel should be extended to 57 feet wide with a vertical wall and a 10'x10' box culvert should be added to the north side of the existing culvert. The estimated cost of these improvements are about $150,000.

1.5 Sta. 34+64 to Bedford Road

This reach consists of a meandering earthen channel to Bedford Road. No residential dwellings are presently subject to flooding from the 100-year frequency flood. Regrading and realigning the channel to an improved 12 foot wide concrete pilot channel centered in a 42 foot wide bottom earthen channel with 3:1 side slopes could contain the 100-year flood within the channel banks. The estimated cost of this improvement is approximately $880,000.

1.6 Bedford Road

The existing 3-barrel 10'x8' box culvert at Bedford Road and Sulphur Branch is inadequate to carry the 100-year frequency flood without the backwater flooding some upstream residential homes. The box culvert should be replaced by a 5-barrel 10'x10' box culvert. This proposed box culvert will cost an estimated $300,000 including the removal of the old box culvert.

1.7 Bedford Road to Airport Freeway

This reach consists of approximately 265 feet of concrete channel with a 30 foot wide bottom and 1:1 side slopes, and about 469 feet of earthen channel. The existing concrete channel would be adequate to carry the 100-year flow, however should the State of Texas expand the existing 4-barrel box culvert under Airport Freeway, then the channel would be to small to carry the 100-year flow. Therefore, this reach should be improved with a 52.7 foot wide concrete channel bottom with vertical walls at an estimated cost of about $440,000.

1.8 Airport Freeway

The existing 4-barrel 9'x6' box culvert at Sulphur Branch and Airport Freeway will not carry the 100-year flow without flooding approximately 26 homes upstream. This structure should be modified by adding a 2-barrel 10'x10' box culvert to the west side of the existing 4-barrel box culvert. This modification could cost an estimated $960,000.

1.9 Airport Freeway to End of Existing Concrete at Sta. 83+60

This reach consists of an existing concrete channel that is 38 foot wide in the bottom and has 1:1 side slopes. This section of channel should be modified to a 60-foot wide channel bottom with vertical walls, to match the modified box culvert under Airport Freeway. This channel improvement could cost an estimated $306,000.

1.10 Sta. 83+60 to Existing Concrete Channel at Sta. 90+60

This reach consists of an existing earthen channel with residential homes congested along both sides of the channel. The proposed improvements consist of a 38 foot wide concrete channel bottom with vertical walls. This concrete channel will cost an estimated $635,000.

1.11 Sta. 90+60 to Shady Lane

This section consists of existing concrete channel liner 30 feet wide with 1:1 side slopes. The proposed improvements should be a 38-foot wide channel with vertical walls to match the downstream section. These improvements could cost an estimated $210,000.

1.12 Shady Lane

The existing 3-barrel 10'x7' box culvert at Sulphur Branch and Shady Lane is inadequate to carry the 100-year flood without topping the roadway. This box culvert should be replaced with a 3-barrel 10'x8' box culvert at an estimated cost of $70,000.

1.13 Shady Lane to Shady Lake Drive

This section consists of an existing concrete channel liner 30-foot wide and 1:1 side slopes. Since the 100-year flood plain is below all finished floor elevations in this section, then no channel improvements are recommended along this reach.

1.14 Shady Lake Drive

The existing 3-barrel 10'x6' box culvert at Sulphur Branch and Shady Lake Drive is adequate to carry the 100-year flood; however, the flowline of this culvert is about 3 feet higher than it should be. This is a substantial loss of grade that is needed upstream, therefore, the existing culvert should be replaced with a new 3-barrel 10'x10' box culvert for an estimated cost of $100,000.

1.15 Shady Lake Drive to Springdale Road

This reach consists of an existing earthen channel in which 7 homes are in the 100-year flood plain limits. The proposed improvement would remove these homes from the flood plain. A concrete lined trapezoidal channel with a 31.3 foot wide bottom and 1:1 side slopes is recommended. The estimated cost is approximately $415,000.

The cost for a new pedestrian walkway bridge over Sulphur Branch for the school-kids to crossover to the Shady Brook Elementary School, is not included in the above estimated channel cost.

1.16 Springdale Road

The existing 2-barrel 10'x5' box culvert at Springdale Road is inadequate to carry the 100-year frequency flood without topping the road and causing significant backwater effects. This box culvert should be replaced by a 3-barrel 10'x7' box culvert. The estimated cost to remove the old culvert and construct the new culvert is about $160,000.

1.17 Springdale Road to Harwood Road

This reach consists of an existing earthen channel along which several residential homes and multiplexes are in the 100-year flood plain limits. A concrete lined trapezoidal channel with a 31.3 foot wide bottom and 1:1 side slopes would remove all these structures from the flood plain limits. The cost for this channel improvement is an estimated $260,000.

1.18 Harwood Road

The existing 2-barrel 10'x6' box culvert at Sulphur Branch and Harwood Road is inadequate to carry the 100-year flood without topping the roadway. However, this box culvert can be modified by adding a single 10'x7' box culvert to one side of the existing double box culvert and lowering the existing flowline 1 foot in order to have an improved 3-barrel 10'x7' box culvert. This modification could cost an estimated $160,000.

1.19 Harwood Road to Spring Lake Drive

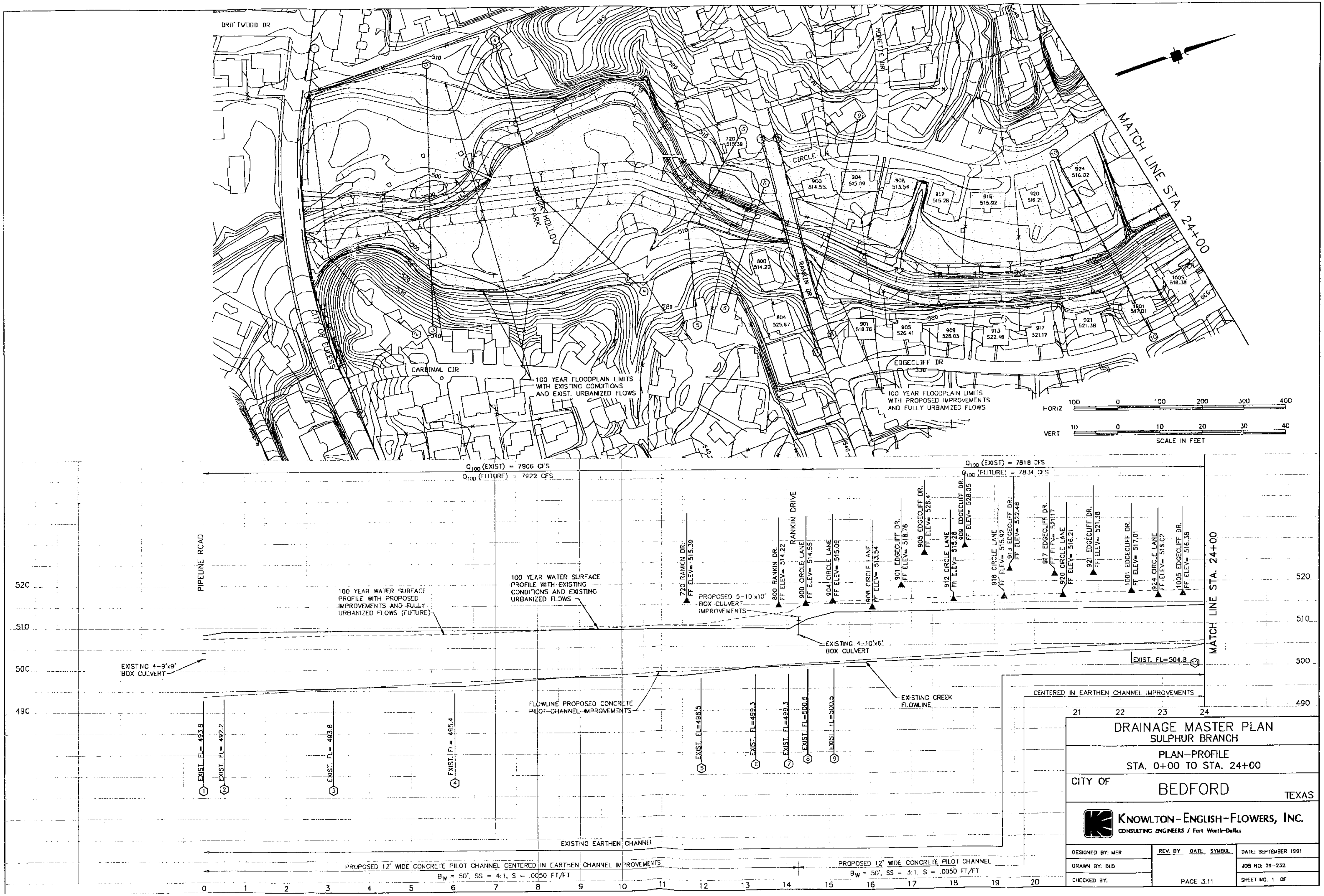
This reach consists of an existing earthen channel along which 2 or 3 residential homes are in the 100-year flood plain limits. The 100-year flood can be contained in a concrete lined trapezoidal channel that is 20.7 foot wide at the bottom and has 1:1 side slopes. This channel would cost an estimated $300,000.

1.20 Spring Lake Drive

The existing 2-barrel 7'x6' box culvert at Spring Lake Drive should be widened to carry the upstream 100-year frequency flow. This existing box culvert is centered in the existing drainageway and cannot be modified by adding a single 6'x6' box culvert to either side without additional right-of-way transition of the channel through the culvert. Therefore, the existing culvert should be removed and replaced by a new 2-barrel 10'x6' box culvert. The estimated cost for this new box culvert is approximately $140,000.

1.21 Spring Lake Drive to End of Channel

This final reach consists of approximately 112 feet of existing concrete channel liner, approximately 375 feet of concrete riprap on the west side of an existing earthen channel, and existing earthen channel to the end. The existing 100-year flood plain width is about 200 feet wide and several residential homes on the west side of the channel are within these flood plain limits. This reach should be fully concrete lined with a variable width bottom from 20.7 feet to 10 feet and variable side slopes from 1:1 to 3:1. These improvements would cost an estimated $330,000.



DRIFTWOOD DR
MONETTE DR
CIRCLE LN
RANKIN DR
EDGECLIFF DR
CARDINAL CIR
CITY OF EULESS
MATCH LINE STA. 24+00
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND EXIST. URBANIZED FLOWS
100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS
HORIZ 100 0 100 200 300 400
VERT 10 0 10 20 30 40
SCALE IN FEET
Q_{100} (EXIST) = 7906 CFS
Q_{100} (FUTURE) = 7922 CFS
Q_{100} (EXIST) = 7818 CFS
Q_{100} (FUTURE) = 7834 CFS
PIPELINE ROAD
100 YEAR WATER SURFACE PROFILE WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS (FUTURE)
100 YEAR WATER SURFACE PROFILE WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS
PROPOSED 5-10'x10' BOX CULVERT IMPROVEMENTS
EXISTING 4-10'x6' BOX CULVERT
EXISTING 4-9'x9' BOX CULVERT
FLOWLINE PROPOSED CONCRETE PILOT CHANNEL IMPROVEMENTS
EXISTING CREEK FLOWLINE
720 RANKIN DR. FF ELEV= 515.39
800 RANKIN DR. FF ELEV= 514.22
RANKIN DRIVE
900 CIRCLE LANE FF ELEV= 514.55
904 CIRCLE LANE FF ELEV= 515.09
908 CIRCLE LANE FF ELEV= 513.54
901 EDGECLIFF DR. FF ELEV= 518.76
905 EDGECLIFF DR. FF ELEV= 526.41
912 CIRCLE LANE FF ELEV= 515.28
909 EDGECLIFF DR. FF ELEV= 528.05
916 CIRCLE LANE FF ELEV= 515.92
913 EDGECLIFF DR. FF ELEV= 522.48
917 EDGECLIFF DR. FF ELEV= 521.17
920 CIRCLE LANE FF ELEV= 516.21
921 EDGECLIFF DR. FF ELEV= 521.38
1001 EDGECLIFF DR. FF ELEV= 517.01
924 CIRCLE LANE FF ELEV= 516.02
1005 EDGECLIFF DR. FF ELEV= 516.38
EXIST. FL= 493.8
EXIST. FL= 492.2
EXIST. FL= 493.8
EXIST. FL= 495.4
EXIST. FL=498.5
EXIST. FL=499.3
EXIST. FL=499.3
EXIST. FL=500.5
EXIST. FL=500.5
EXIST. FL=504.8
CENTERED IN EARTHEN CHANNEL IMPROVEMENTS
EXISTING EARTHEN CHANNEL
PROPOSED 12' WIDE CONCRETE PILOT CHANNEL CENTERED IN EARTHEN CHANNEL IMPROVEMENTS
B_W = 50', SS = 4:1, S = .0050 FT/FT
PROPOSED 12' WIDE CONCRETE PILOT CHANNEL
B_W = 50', SS = 3:1, S = .0050 FT/FT
DRAINAGE MASTER PLAN
SULPHUR BRANCH
PLAN-PROFILE
STA. 0+00 TO STA. 24+00
CITY OF BEDFORD TEXAS
KNOWLTON-ENGLISH-FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth-Dallas
DESIGNED BY: MER
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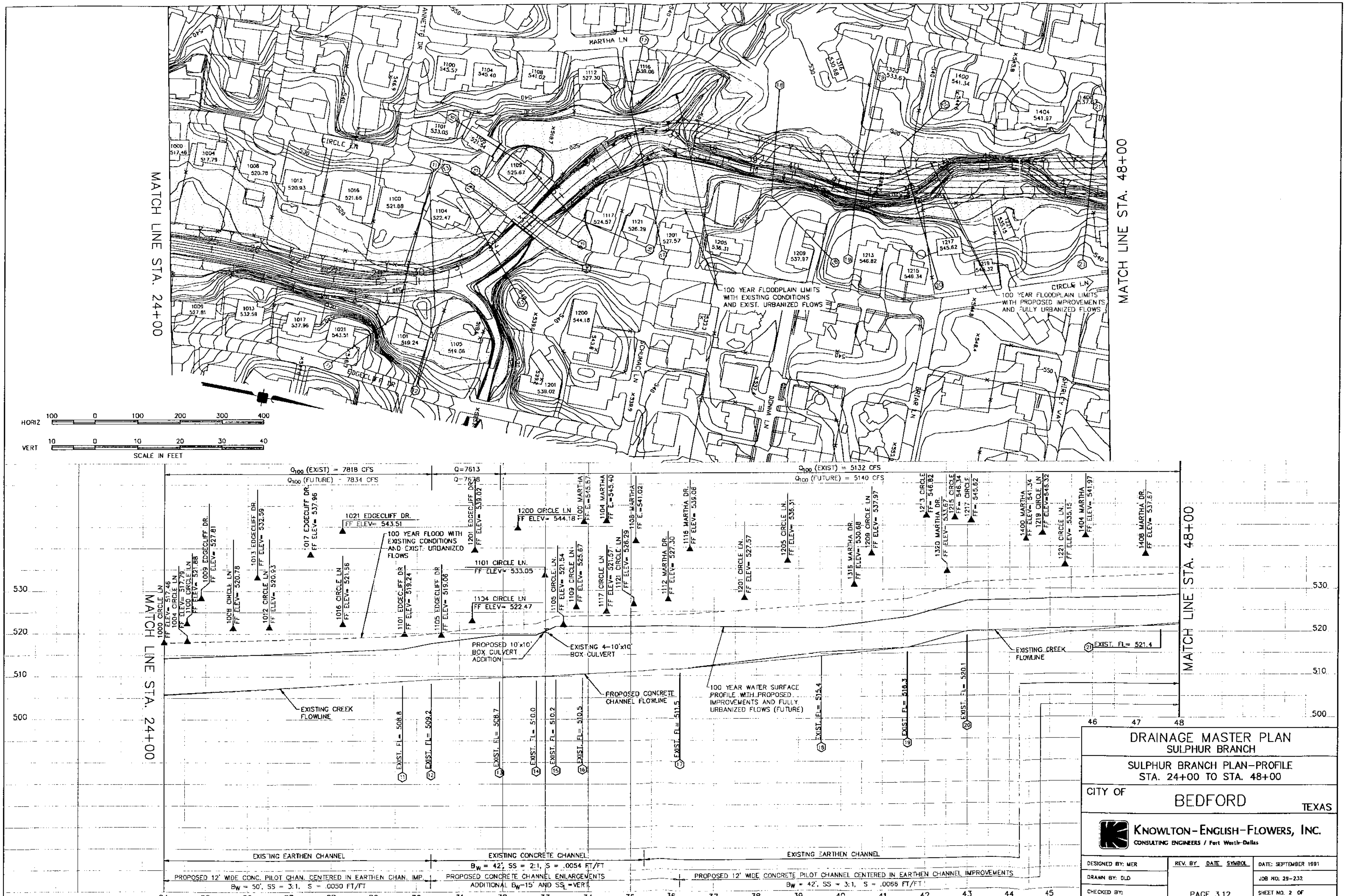
SHEET NO. 1 OF



DRAINAGE MASTER PLAN
SULPHUR BRANCH

SULPHUR BRANCH PLAN-PROFILE
STA. 24+00 TO STA. 48+00

CITY OF BEDFORD TEXAS

KNOWLTON-ENGLISH-FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth-Dallas

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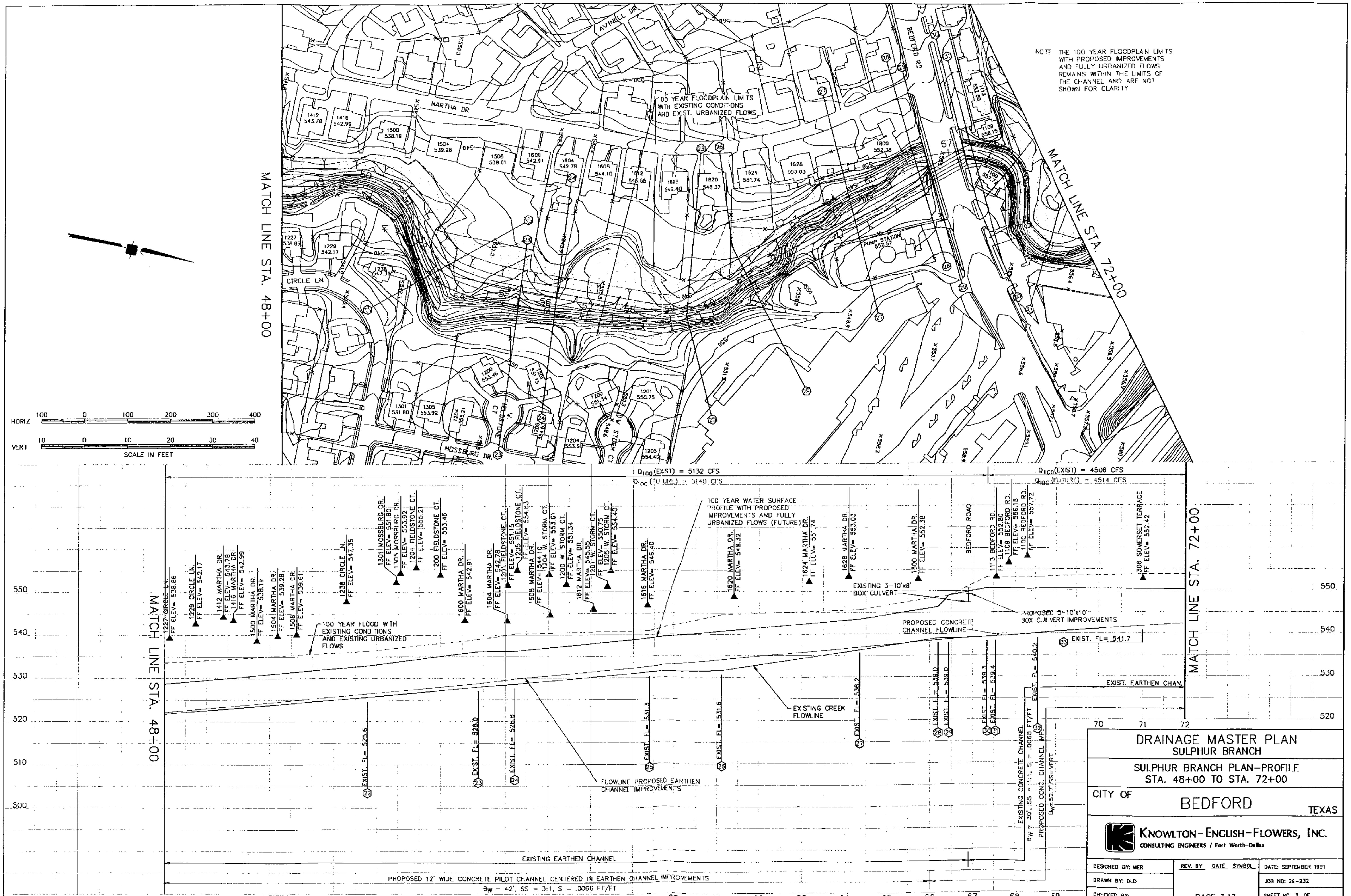

NOTE THE 100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS REMAINS WITHIN THE LIMITS OF THE CHANNEL AND ARE NOT SHOWN FOR CLARITY
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND EXIST. URBANIZED FLOWS
MATCH LINE STA. 48+00
MATCH LINE STA. 72+00
MARTHA DR
BEDFORD RD
CIRCLE LN
AVINELL DR
MOSSBURG DR.
W. FIELDSTONE CT
W. STORM CT
PUMP STATION 552.57
SCALE IN FEET
HORIZ 100 0 100 200 300 400
VERT 10 0 10 20 30 40
Q_{100}(EXIST) = 5132 CFS
Q_{100}(FUTURE) = 5140 CFS
Q_{100}(EXIST) = 4506 CFS
Q_{100}(FUTURE) = 4514 CFS
100 YEAR WATER SURFACE PROFILE WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS (FUTURE)
100 YEAR FLOOD WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS
1227 CIRCLE LN. FF ELEV= 538.86
1229 CIRCLE LN. FF ELEV= 542.17
1412 MARTHA DR. FF ELEV= 543.78
1416 MARTHA DR. FF ELEV= 542.99
1500 MARTHA DR. FF ELEV= 538.19
1504 MARTHA DR. FF ELEV= 539.28
1508 MARTHA DR. FF ELEV= 539.61
1238 CIRCLE LN. FF ELEV= 547.36
1301 MOSSBURG DR. FF ELEV= 551.80
1305 MOSSBURG DR. FF ELEV= 553.92
1204 FIELDSTONE CT. FF ELEV= 555.21
1200 FIELDSTONE CT. FF ELEV= 553.46
1600 MARTHA DR. FF ELEV= 542.91
1604 MARTHA DR. FF ELEV= 542.78
1201 FIELDSTONE CT. FF ELEV= 551.15
1205 FIELDSTONE CT. FF ELEV= 554.63
1608 MARTHA DR. FF ELEV= 544.10
1204 W. STORM CT. FF ELEV= 553.61
1200 W. STORM CT. FF ELEV= 551.34
1612 MARTHA DR. FF ELEV= 545.55
1201 W. STORM CT. FF ELEV= 550.75
1205 W. STORM CT. FF ELEV= 554.40
1616 MARTHA DR. FF ELEV= 546.40
1620 MARTHA DR. FF ELEV= 548.32
1624 MARTHA DR. FF ELEV= 551.74
1628 MARTHA DR. FF ELEV= 553.03
1300 MARTHA DR. FF ELEV= 552.38
BEDFORD ROAD
1113 BEDFORD RD. FF ELEV= 552.80
1109 BEDFORD RD. FF ELEV= 556.15
1100 BEDFORD RD. FF ELEV= 557.72
1306 SOMERSET TERRACE FF ELEV= 552.42
EXISTING 3-10'x8' BOX CULVERT
PROPOSED 3-10'x10' BOX CULVERT IMPROVEMENTS
PROPOSED CONCRETE CHANNEL FLOWLINE
EXIST. FL= 541.7
EXIST. EARTHEN CHAN.
EXISTING CREEK FLOWLINE
FLOWLINE PROPOSED EARTHEN CHANNEL IMPROVEMENTS
EXIST. FL= 525.6
EXIST. FL= 528.0
EXIST. FL= 528.6
EXIST. FL= 531.3
EXIST. FL= 531.6
EXIST. FL= 536.2
EXIST. FL= 539.0
EXIST. FL= 539.0
EXIST. FL= 539.3
EXIST. FL= 539.4
EXIST. FL= 540.2
EXISTING CONCRETE CHANNEL
Bw = 30', SS = 1:1, S = .0068 FT/FT
PROPOSED CONC. CHANNEL IMP.
Bw=52.7',SS=VERT.
EXISTING EARTHEN CHANNEL
PROPOSED 12' WIDE CONCRETE PILOT CHANNEL CENTERED IN EARTHEN CHANNEL IMPROVEMENTS
B_W = 42', SS = 3:1, S = .0066 FT/FT
550
540
530
520
510
500
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
DRAINAGE MASTER PLAN
SULPHUR BRANCH
SULPHUR BRANCH PLAN-PROFILE
STA. 48+00 TO STA. 72+00
CITY OF BEDFORD TEXAS
KNOWLTON-ENGLISH-FLOWERS, INC.
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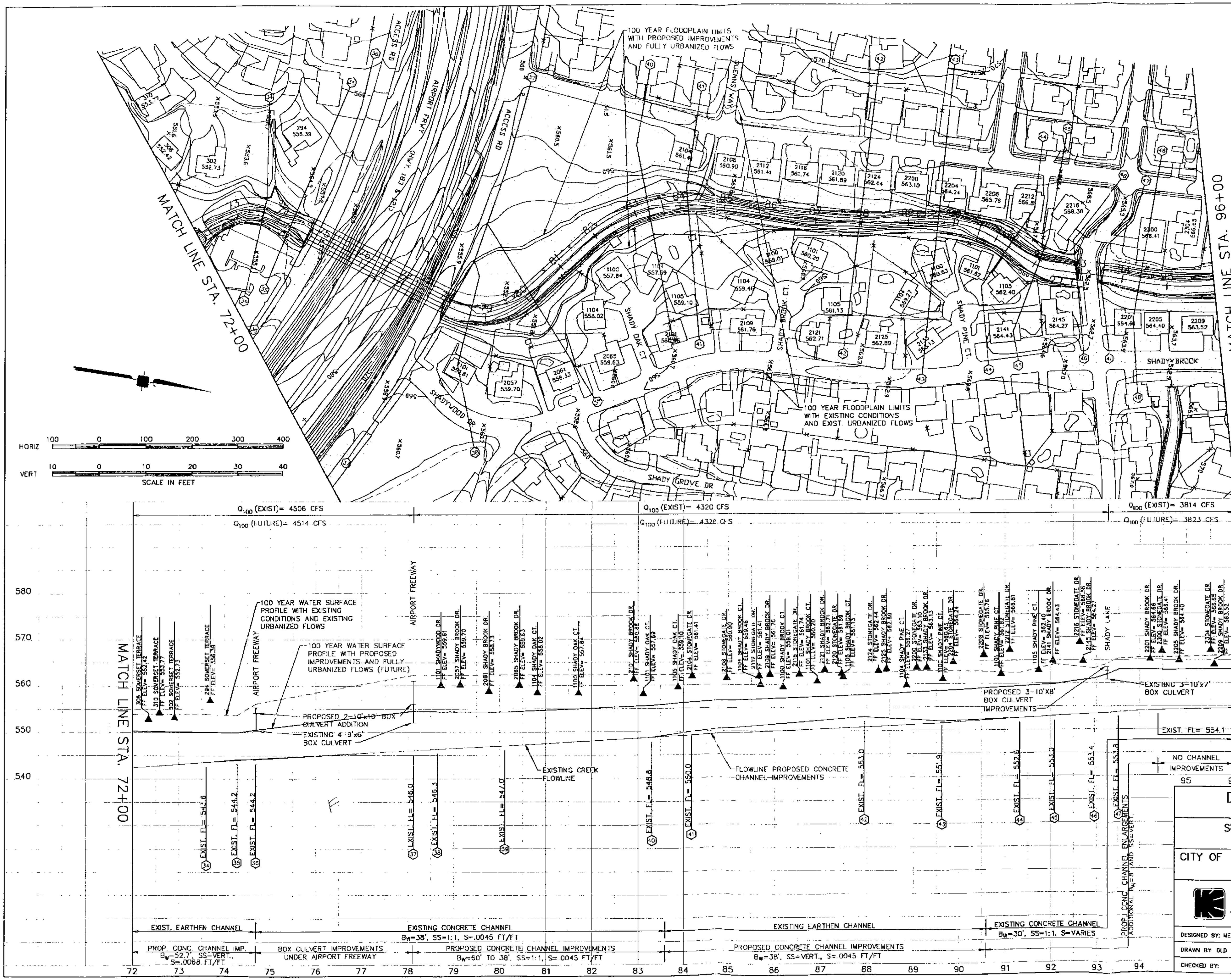

DRAINAGE MASTER PLAN
SULPHUR BRANCH

SULPHUR BRANCH PLAN-PROFILE
STA. 72+00 TO STA. 96+00

CITY OF BEDFORD TEXAS

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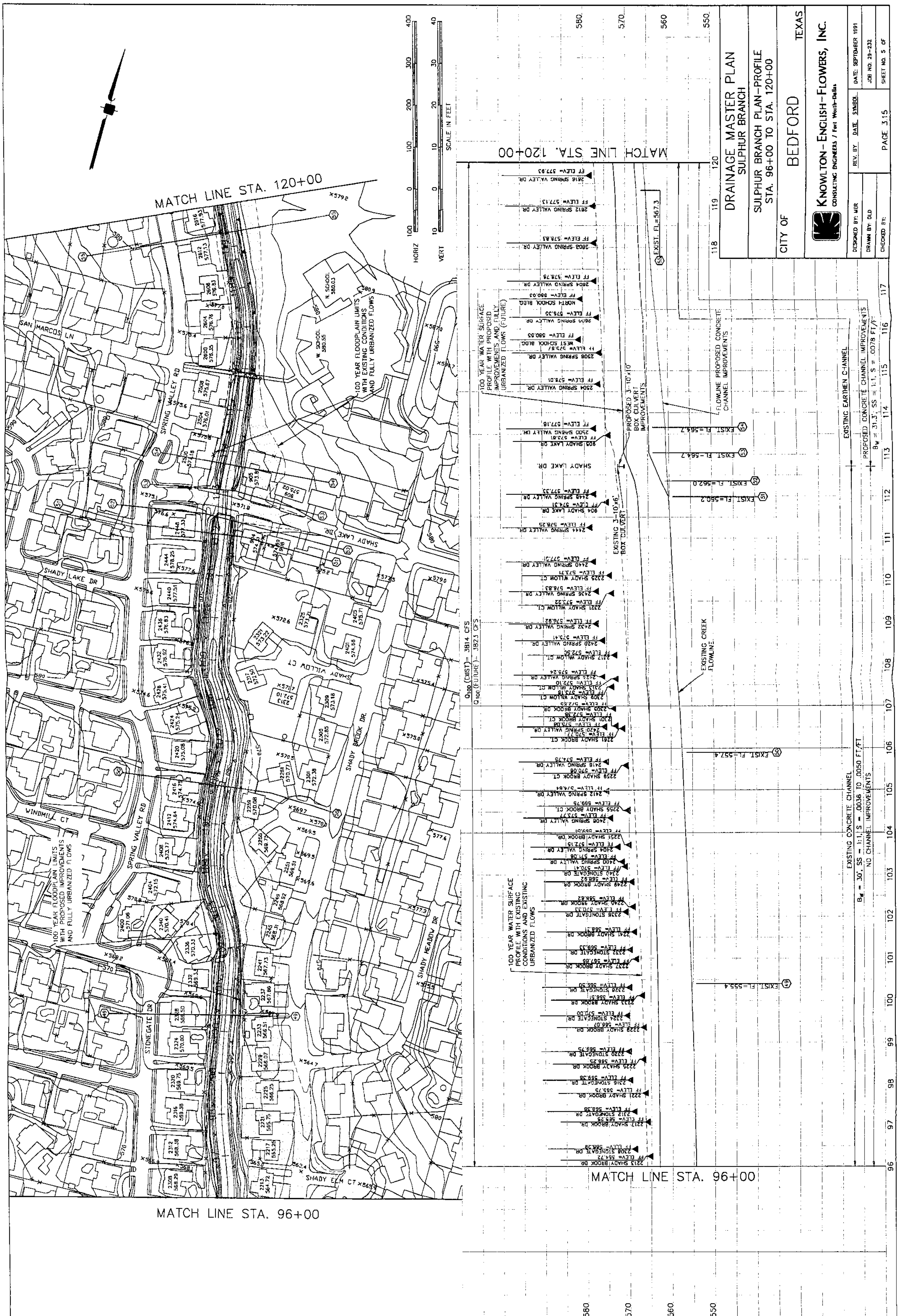
MATCH LINE STA. 120+00
MATCH LINE STA. 96+00
SCALE IN FEET
HORIZ 100 0 100 200 300 400
VERT 10 0 10 20 30 40
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND FULLY URBANIZED FLOWS
100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS
SPRING VALLEY RD
SHADY LAKE DR
SHADY WILLOW CT
SHADY BROOK DR
SHADY MEADOW DR
SHADY ELM CT
STONEGATE DR
WINDMILL CT
SAN MARCOS LN
N. SCHOOL 580.03
W. SCHOOL 580.55
100 YEAR WATER SURFACE PROFILE WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS (FUTURE)
100 YEAR WATER SURFACE PROFILE WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS
PROPOSED 3-10'x10' BOX CULVERT IMPROVEMENTS
EXISTING 3-10'x6' BOX CULVERT
FLOWLINE PROPOSED CONCRETE CHANNEL IMPROVEMENTS
EXISTING CREEK FLOWLINE
Q_{100} (EXIST) = 3814 CFS
Q_{100} (FUTURE) = 3823 CFS
EXIST. FL=567.3
EXIST. FL=564.7
EXIST. FL=564.7
EXIST. FL=562.0
EXIST. FL=560.2
EXIST. FL=557.4
EXIST. FL=555.4
EXISTING EARTHEN CHANNEL
PROPOSED CONCRETE CHANNEL IMPROVEMENTS
B_W = 31.3', SS = 1:1, S = .0078 FT/FT
EXISTING CONCRETE CHANNEL
B_W = 30', SS = 1:1, S = .0036 TO .0050 FT/FT
NO CHANNEL IMPROVEMENTS
580
570
560
550
96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120
DRAINAGE MASTER PLAN
SULPHUR BRANCH
SULPHUR BRANCH PLAN-PROFILE
STA. 96+00 TO STA. 120+00
CITY OF BEDFORD TEXAS
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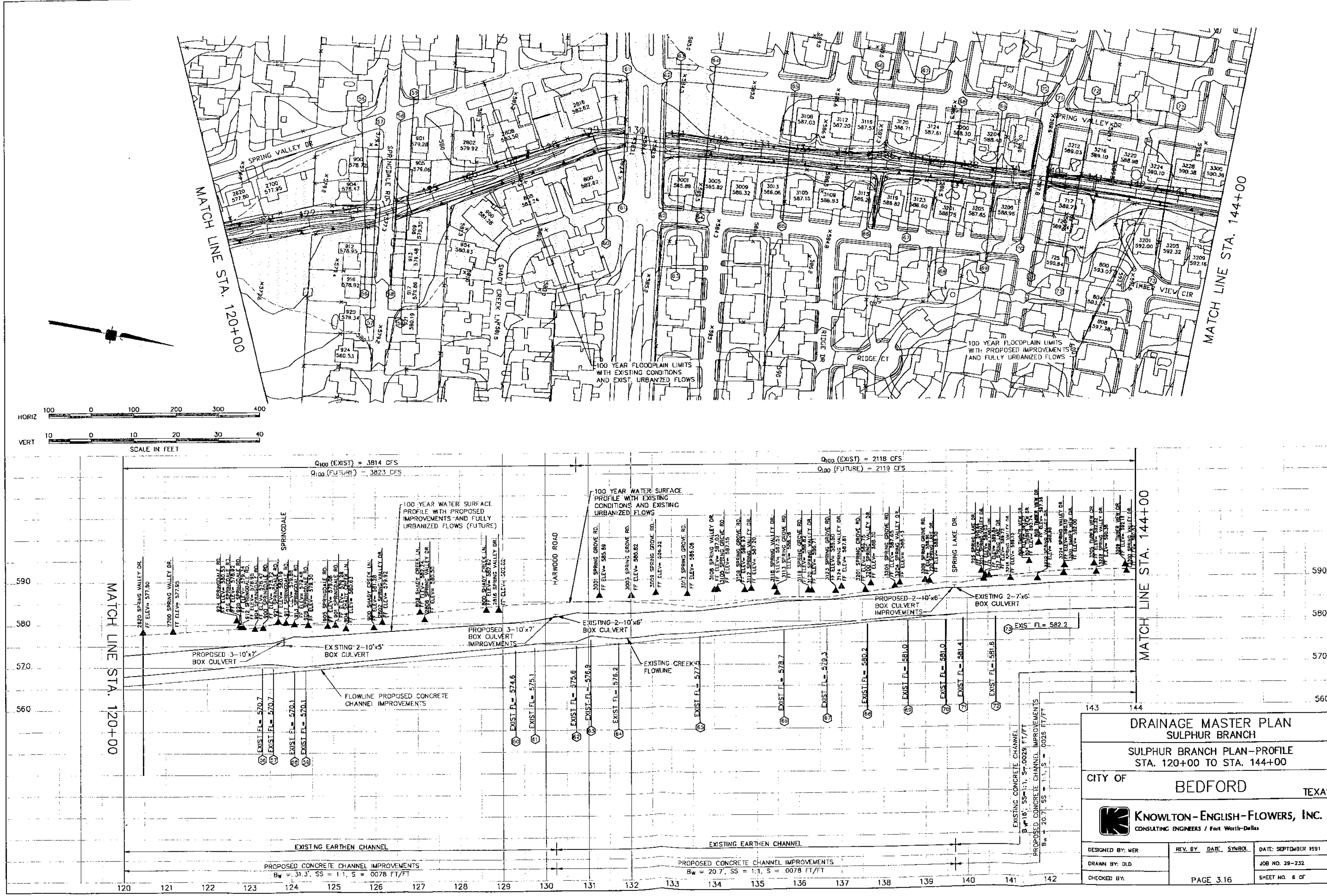
PAGE 3.15



DRAINAGE MASTER PLAN
SULPHUR BRANCH

SULPHUR BRANCH PLAN-PROFILE
STA. 120+00 TO STA. 144+00

CITY OF BEDFORD TEXAS

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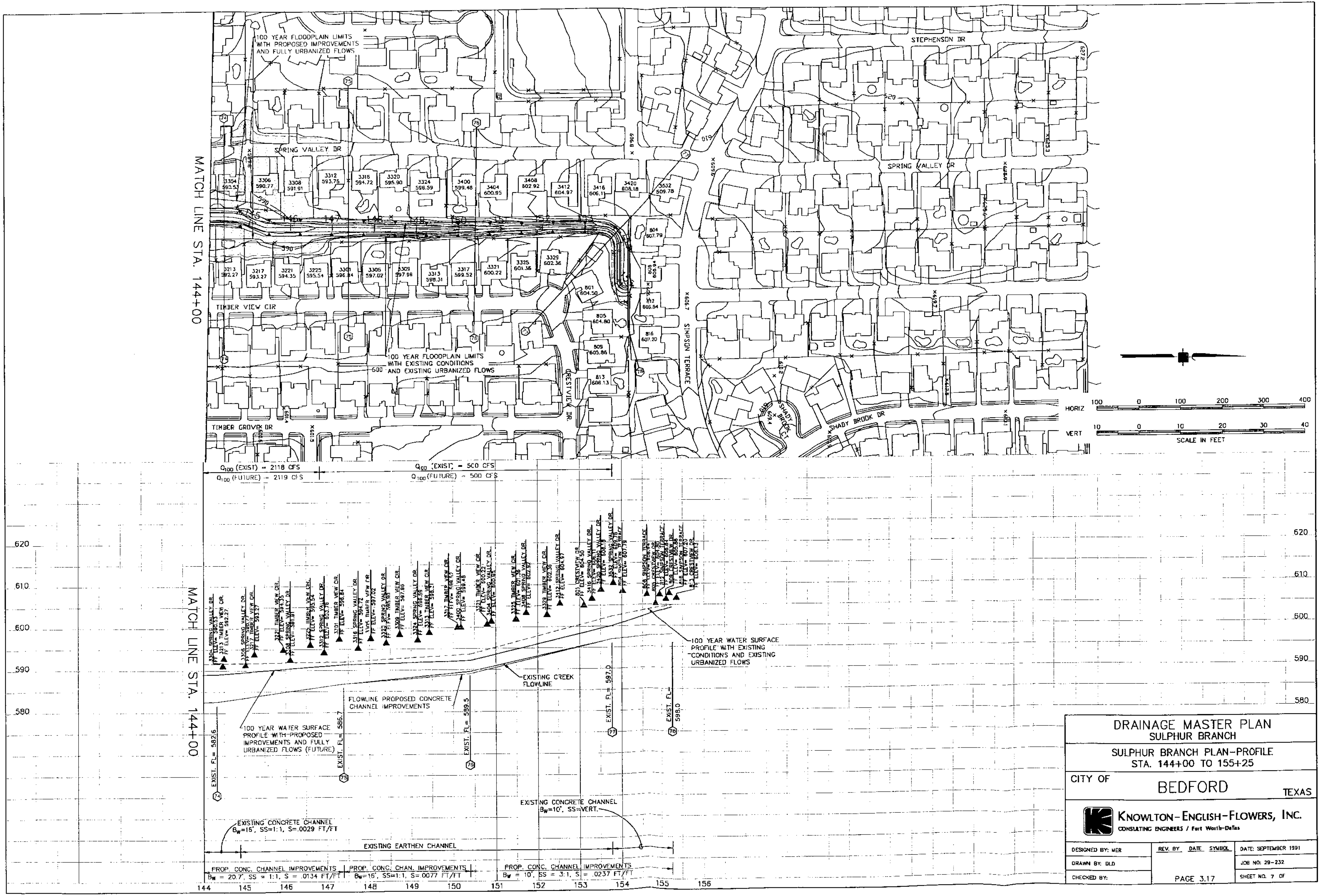

DRAINAGE MASTER PLAN
SULPHUR BRANCH

SULPHUR BRANCH PLAN-PROFILE
STA. 144+00 TO 155+25

CITY OF BEDFORD TEXAS

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2 SULPHUR BRANCH TRIBUTARY

This tributary extends from the Sulphur Branch Main Channel at Station 30+34, upstream to Airport Freeway and continuing northward through the Central Business District to its end, east of Parkwood Drive. The proposed improvements are shown on Plan-Profile Sheets No. 1 through 3.

2.1 Confluence to Edgecliff Drive

This reach consists of an existing 15-foot to 10-foot wide concrete channel bottom and 1.5:1 to 1:1 side slopes. This reach is inadequate to carry the 100-year flood and should be modified to an additional 21 feet wide with a vertical wall along the south side of the channel. These improvements could cost an estimated $100,000.

2.2 Edgecliff Drive

The existing 3-barrel 10'x7' box culvert at the Sulphur Branch Tributary and Edgecliff Drive does not adequately carry the 100-year flood. This box culvert should be modified by adding a single 10'x7' box culvert to the north side of the existing box culvert. The estimated cost for this modification is approximately $30,000.

2.3 Edgecliff Drive to Overhill Street

This reach consists of an existing 10-foot wide concrete trapezoidal channel with 1:1 side slopes. The existing north channel wall should be modified to a vertical wall to enlarge the channel for additional capacity. This could cost an estimated $52,000.

2.4 Overhill Street

The existing 3-barrel 10'x7' box culvert at the Sulphur Branch Tributary and Overhill Street does not adequately carry the 100-year flood without topping the roadway. This box culvert can be modified by adding a single 10'x7' box culvert to the north side of the existing box culvert. The estimated cost for this modification is approximately $30,000.

2.5 Overhill Street to Sta. 8+00

This reach consists of an existing 31-foot wide concrete channel and 2:1 side slopes. This section of the channel is adequate to carry the 100-year flood and only minor channel reshaping is needed to fit the modified box culvert at Overhill Street. This cost is estimated at $20,000.

2.6 Sta. 8+00 to Shumac Lane

This reach consists of an unimproved existing earthen channel that meanders to Shumac Lane and is experiencing erosion and flooding problems. This section should be improved to a 30-foot wide concrete lined channel with a 1:1 side slope and a vertical wall. These improvements cost an estimated $196,000.

2.7 Shumac Lane to Circle Lane

This reach consists of several unimproved existing earthen channels that meander from street to street, with residential homes congested along both sides of the channels, a double 10'x8' box culvert at Donna Lane and Briar Lane, a double 10'x7' box culvert at Shirley Way and a double 10'x6' box culvert at Circle Lane. All these box culverts will carry the 100-year flood; however, the channels should be improved to a 20-foot wide concrete lined channel with vertical walls. These improvements could cost an estimated $782 per linear foot of channel section or $1,474,070.

2.8 Circle Lane to Airport Freeway

This reach consists of an unimproved existing earthen channel through a commercial area, and no businesses are in the existing 100-year flood plain. A low maintenance concrete channel should be constructed 15-foot wide with 1:1 side slopes. This could cost an estimated $207,000.

2.9 Airport Freeway

The existing 2-barrel 7'x6' box culvert at the Sulphur Branch Tributary and Airport Freeway will not carry the 100-year flow without flooding several businesses and apartment units upstream. This structure can be modified by adding a 2-barrel 7'x6' box culvert to the one side of the existing 2-barrel box culvert. This modification could cost an estimated $500,000.

2.10 Airport Freeway to Sta. 48+80

This reach consists of an existing concrete lined ditch between the Airport Freeway box culvert and a 4-barrel 5'x5' box culvert under the parking lot of Harrigan's restaurant. Only minor channel reshaping is needed to fit the modified box culvert at Airport Freeway. This cost is estimated at $20,000.

2.11 Sta. 48+80 to Forest Ridge Drive

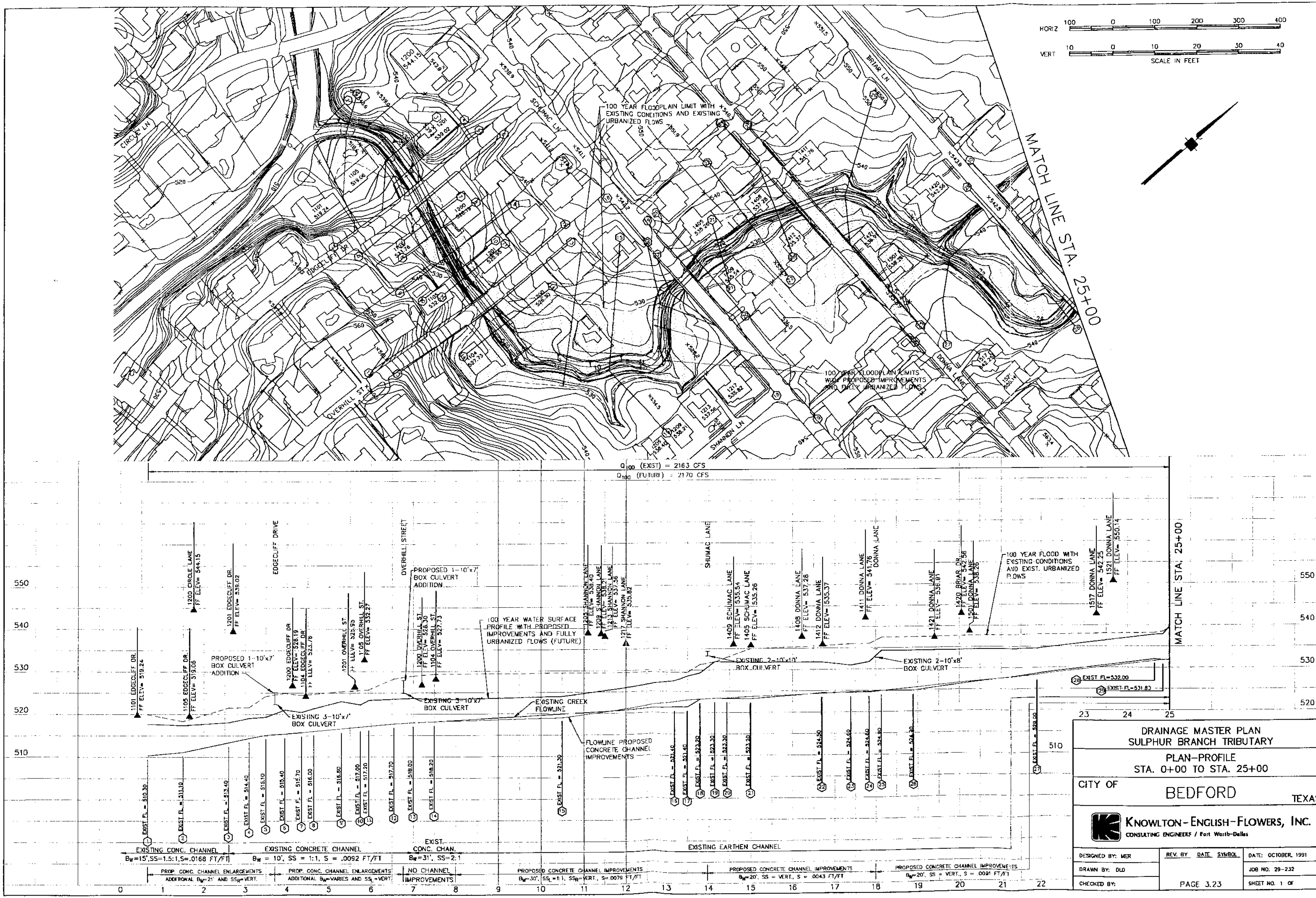
This reach consists of an existing unimproved earthen channel that is overgrown with vegetation and trees. This section could be realigned and regraded to a 15-foot wide concrete pilot channel centered in a 21.5-foot wide bottom earthen channel with 4:1 side slopes. The estimated cost for this improvement is approximately $1,670,000.

2.12 Forest Ridge Drive to Municipal Parkway

This reach consists of an improved and maintained earthen channel, an existing 2-barrel 10'x6' box culvert at the Sulphur Branch Tributary and Forest Ridge Drive, and an existing 2-barrel 7'x4' box culvert at Municipal Parkway. These box culverts will carry the 100-year flood and no homes or apartment units are in the 100-year flood plain. This section could be improved to contain the 100-year flow and maintain the channel by constructing a 15-foot wide concrete bottom with 4:1 earthen side slopes. This could cost an estimated $57,000.

2.13 Municipal Parkway to Parkwood Drive

This reach consists of an unimproved, undefined earthen swale across an undeveloped tract of land. When development of this tract occurs, the 100-year flow could be contained in a 15-foot wide concrete bottom channel with 4:1 earthen side slopes for an estimated cost of $102 per linear foot.



DRAINAGE MASTER PLAN
SULPHUR BRANCH TRIBUTARY

PLAN-PROFILE
STA. 0+00 TO STA. 25+00

CITY OF BEDFORD TEXAS

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DRAINAGE MASTER PLAN
SULPHUR BRANCH TRIBUTARY

PLAN-PROFILE
STA. 25+00 TO STA. 50+00

CITY OF BEDFORD TEXAS

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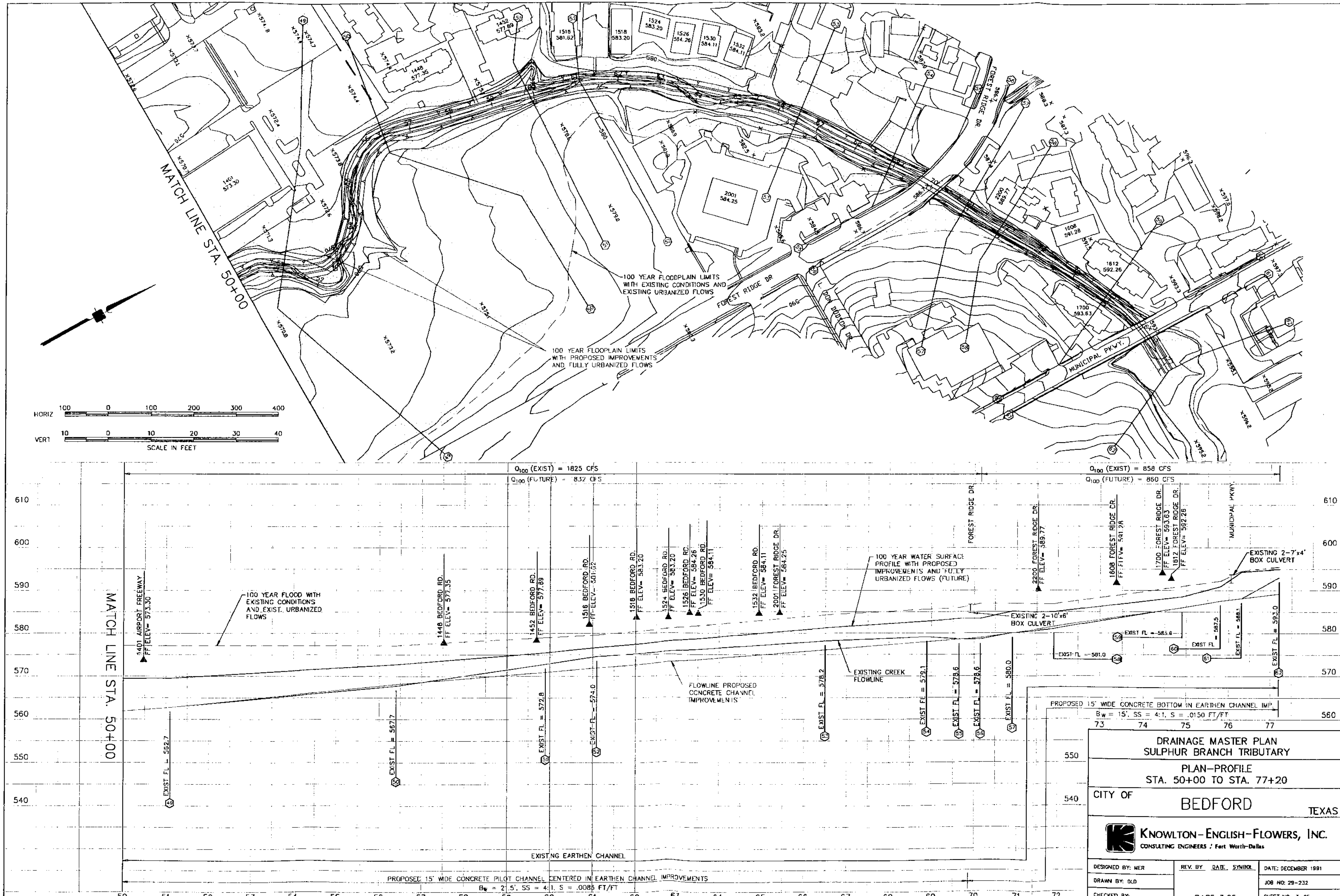

DRAINAGE MASTER PLAN
SULPHUR BRANCH TRIBUTARY

PLAN-PROFILE
STA. 50+00 TO STA. 77+20

CITY OF BEDFORD TEXAS

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SECTION 4 -- BEDFORD CREEK WATERSHED

GENERAL

The Bedford Creek Watershed consists of approximately 5.5 square miles of drainage area, of which 3.2 square miles are within the City of Bedford. The watershed is generally rectangular shaped, having an average width of 1.7 miles and a length of about 3.7 miles, and flows southerly from Bedford through Euless to the West Fork of the Trinity River.

The study area is divided into two (2) areas, Bedford Creek Main Channel and East Branch Bedford Creek. The Bedford Creek Main Channel flows from Harwood Road, south across Bedford Road through the Central Business District, across Airport Freeway, along the east side of Harris Methodist H-E-B Hospital and into the City of Euless at Tibbets Drive. The East Branch Bedford Creek flows from Harwood Road at State Highway 121, south along the Whisperwood Addition, across Bedford Road through Bedford Forum and across Airport Freeway into Euless. These two areas are mixed with residential homes, apartments, commercial and industrial businesses, and vacant land.

RECOMMENDATIONS

1 BEDFORD CREEK MAIN CHANNEL (HURRICANE CREEK)

This channel and the proposed improvements are shown on Plan-Profile Sheets No. 1 through 3.

1.1 Tibbets Drive

The existing 2-barrel 10'x10' box culvert at Bedford Creek and Tibbets Drive does not adequately carry the 100-year flow without topping the roadway. This box culvert should be replaced by a 25-foot span bridge that is 17 feet above the flowline of the channel. This bridge will raise the roadway about 4 feet. The estimated cost to remove the old culvert and construct the new bridge is approximately $100,000.

This drainage structure is divided in half by the corporate limits line between the Cities of Euless and Bedford.

1.2 Tibbets Drive to Airport Freeway

This reach consists of an existing unimproved earthen channel and a well maintained earthen channel which will carry the 100-year flood; therefore, no channel improvements are recommended along this reach.

1.3 Airport Freeway

This reach at Bedford Creek and Airport Freeway consists of 2 existing drainage structures that will not carry the 100-year flow without topping the frontage roadways and the main driving lanes. The south frontage road structure is a 2-barrel 10'x9' box culvert, and the other structure under the main lanes and the north frontage road is a 2-barrel 9'x9' box culvert. The double 10'x9' box culvert should be replaced by a 25-foot span bridge that is 12 feet above the channel flowline. This bridge will raise the roadway about 4 feet. The other drainage structure can be modified by adding a 2-barrel 10'x10' box culvert to one side of the existing box culvert. The estimated cost for these improvements is approximately $1,053,000.

1.4 Airport Freeway to Bedford Road

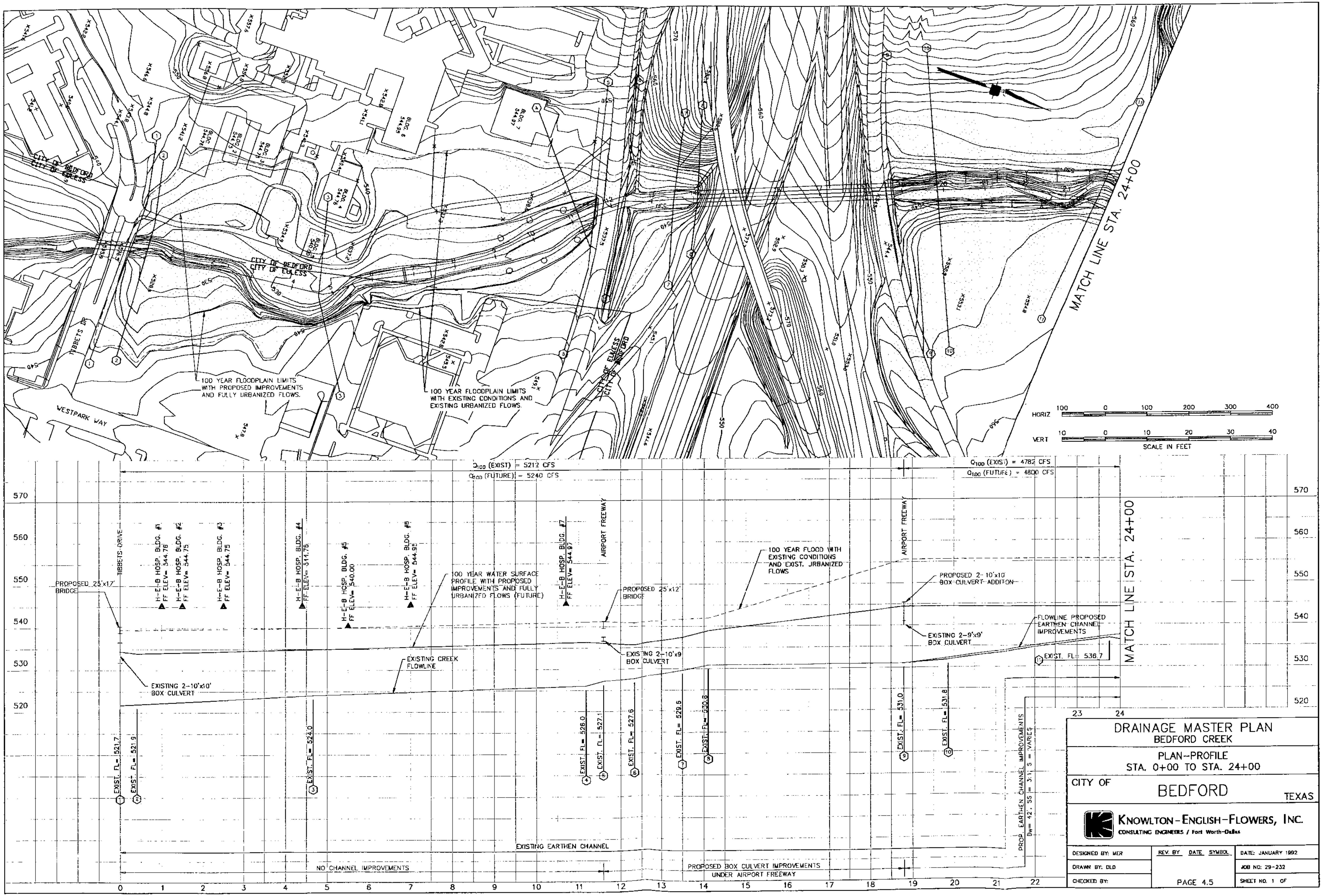
This reach consists of 2 unimproved earthen channels that meander from Airport Freeway to L. Don Dodson Drive to Bedford Road, and a 4-barrel 10'x10' box culvert at L. Don Dodson Drive. The box culvert will carry the 100-year flow; however, the channels could be improved to a 42-foot wide bottom earthen channel with 3:1 side slopes so that additional land can be reclaimed for development. The cost of these improvements is an estimated $493,000.

1.5 Bedford Road

The existing 10'x4' box culvert at Bedford Creek and Bedford Road will not carry the 100-year flow without overtopping the roadway and causing upstream flooding. This box culvert should be replaced by a 5-barrel 10'x8' box culvert, which will raise the roadway about 2-feet. The estimated cost to remove the old culvert and construct the new culvert is approximately $325,000.

1.6 Bedford Road to Harwood Road

This reach consists of an existing channel that is at various stages of improvement. Some sections are just an unimproved meandering stream, while others have some concrete slope protection. Several residential homes and apartment units are in the existing 100-year flood plain and can be removed from the flood plain by improving the channel to a 52.7-foot and 40-foot wide bottom concrete lined channel with vertical walls. These improvements will cost and estimated $1,645,000.



MATCH LINE STA. 24+00
CITY OF BEDFORD
CITY OF EULESS
TIBBETS DR
WESTPARK WAY
BLDG. 7 544.97
BLDG. 6 544.95
BLDG. 4 544.76
BLDG. 5 540.00
BLDG. 3 544.75
BLDG. 2 544.75
BLDG. 1 544.76
100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS.
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS.
HORIZ 100 0 100 200 300 400
VERT 10 0 10 20 30 40
SCALE IN FEET
Q_{100} (EXIST) = 5212 CFS
Q_{100} (FUTURE) = 5240 CFS
Q_{100} (EXIST) = 4782 CFS
Q_{100} (FUTURE) = 4800 CFS
TIBBETS DRIVE
PROPOSED 25'x17' BRIDGE
H-E-B HOSP. BLDG. #1 FF ELEV= 544.76
H-E-B HOSP. BLDG. #2 FF ELEV= 544.75
H-E-B HOSP. BLDG. #3 FF ELEV= 544.75
H-E-B HOSP. BLDG. #4 FF ELEV= 544.76
H-E-B HOSP. BLDG. #5 FF ELEV= 540.00
H-E-B HOSP. BLDG. #6 FF ELEV= 544.95
H-E-B HOSP. BLDG. #7 FF ELEV= 544.97
AIRPORT FREEWAY
100 YEAR WATER SURFACE PROFILE WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS (FUTURE)
PROPOSED 25'x12' BRIDGE
100 YEAR FLOOD WITH EXISTING CONDITIONS AND EXIST. URBANIZED FLOWS
PROPOSED 2-10'x10' BOX CULVERT ADDITON
EXISTING 2-9'x9' BOX CULVERT
FLOWLINE PROPOSED EARTHEN CHANNEL IMPROVEMENTS
EXISTING CREEK FLOWLINE
EXISTING 2-10'x9 BOX CULVERT
EXISTING 2-10'x10' BOX CULVERT
EXIST. FL= 521.7
EXIST. FL= 521.9
EXIST. FL= 524.0
EXIST. FL= 526.0
EXIST. FL= 527.1
EXIST. FL= 527.6
EXIST. FL= 529.5
EXIST. FL= 530.8
EXIST. FL= 531.0
EXIST. FL= 531.8
EXIST. FL= 536.7
PROP. EARTHEN CHANNEL IMPROVEMENTS Bw= 42', SS = 3:1, S = VARIES
EXISTING EARTHEN CHANNEL
NO CHANNEL IMPROVEMENTS
PROPOSED BOX CULVERT IMPROVEMENTS UNDER AIRPORT FREEWAY
570 560 550 540 530 520
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
DRAINAGE MASTER PLAN
BEDFORD CREEK
PLAN--PROFILE
STA. 0+00 TO STA. 24+00
CITY OF BEDFORD TEXAS
KNOWLTON-ENGLISH-FLOWERS, INC.
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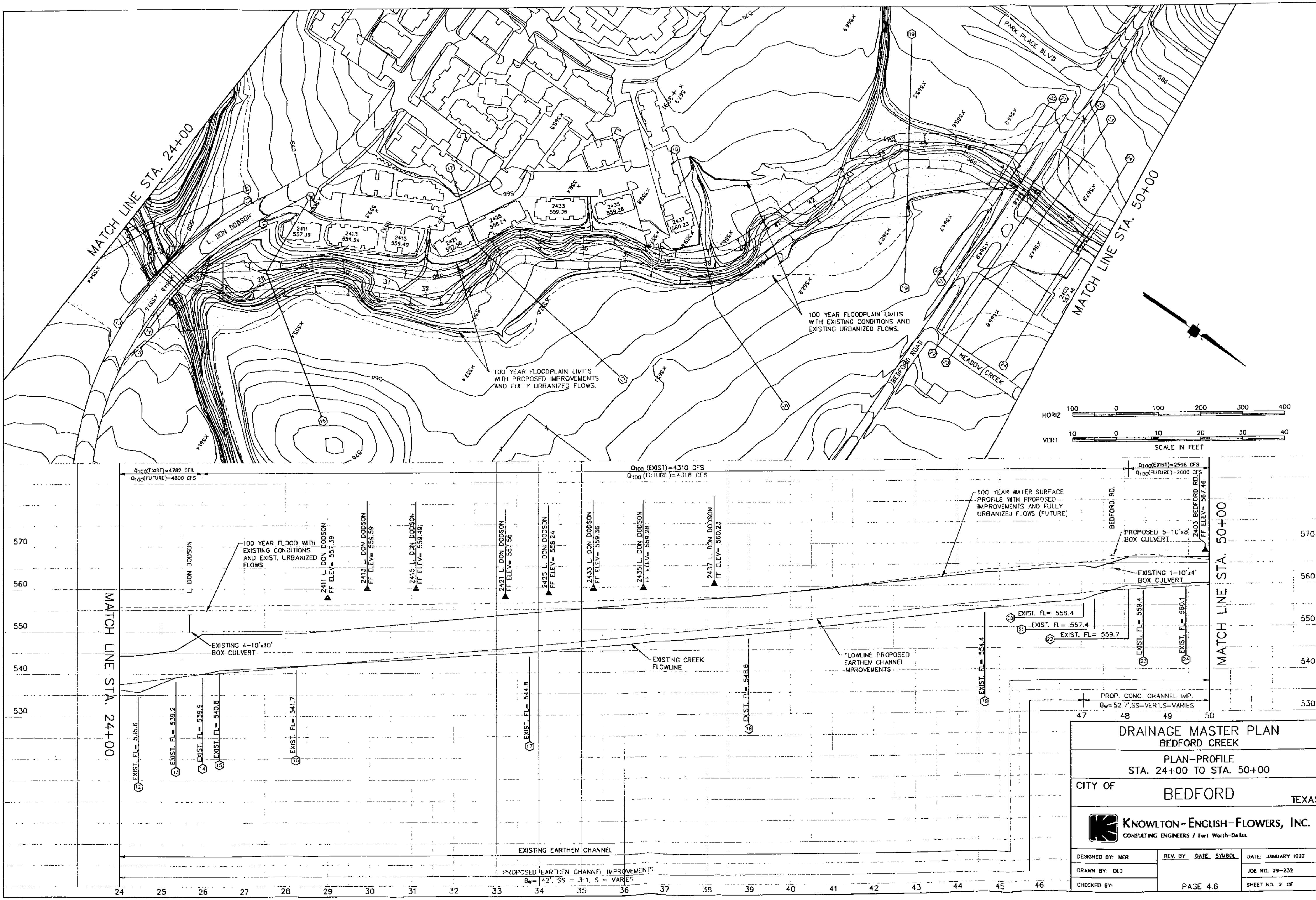
MATCH LINE STA. 24+00
MATCH LINE STA. 50+00
PARK PLACE BLVD
L. DON DODSON
BEDFORD ROAD
MEADOW CREEK
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS.
100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS.
HORIZ
VERT
SCALE IN FEET
Q_{100}(EXIST)=4782 CFS
Q_{100}(FUTURE)=4800 CFS
Q_{100} (EXIST)=4310 CFS
Q_{100} (FUTURE)=4318 CFS
Q_{100}(EXIST)=2598 CFS
Q_{100}(FUTURE)=2600 CFS
100 YEAR FLOOD WITH EXISTING CONDITIONS AND EXIST. URBANIZED FLOWS
100 YEAR WATER SURFACE PROFILE WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS (FUTURE)
EXISTING 4-10'x10' BOX CULVERT
PROPOSED 5-10'x8' BOX CULVERT
EXISTING 1-10'x4' BOX CULVERT
EXISTING CREEK FLOWLINE
FLOWLINE PROPOSED EARTHEN CHANNEL IMPROVEMENTS
2411 L. DON DODSON FF ELEV= 557.39
2413 L. DON DODSON FF ELEV= 559.59
2415 L. DON DODSON FF ELEV= 559.49
2421 L. DON DODSON FF ELEV= 557.56
2425 L. DON DODSON FF ELEV= 558.24
2433 L. DON DODSON FF ELEV= 559.36
2435 L. DON DODSON FF ELEV= 559.28
2437 L. DON DODSON FF ELEV= 560.23
2403 BEDFORD RD. FF ELEV= 567.46
EXIST. FL= 535.6
EXIST. FL= 539.2
EXIST. FL= 539.9
EXIST. FL= 540.8
EXIST. FL= 541.7
EXIST. FL= 544.8
EXIST. FL= 548.6
EXIST. FL= 554.4
EXIST. FL= 556.4
EXIST. FL= 557.4
EXIST. FL= 559.7
EXIST. FL= 559.4
EXIST. FL= 560.1
EXISTING EARTHEN CHANNEL
PROPOSED EARTHEN CHANNEL IMPROVEMENTS B_W= 42', SS = 3:1, S = VARIES
PROP. CONC. CHANNEL IMP. B_W=52.7',SS=VERT,S=VARIES
DRAINAGE MASTER PLAN
BEDFORD CREEK
PLAN-PROFILE
STA. 24+00 TO STA. 50+00
CITY OF BEDFORD TEXAS
KNOWLTON-ENGLISH-FLOWERS, INC.
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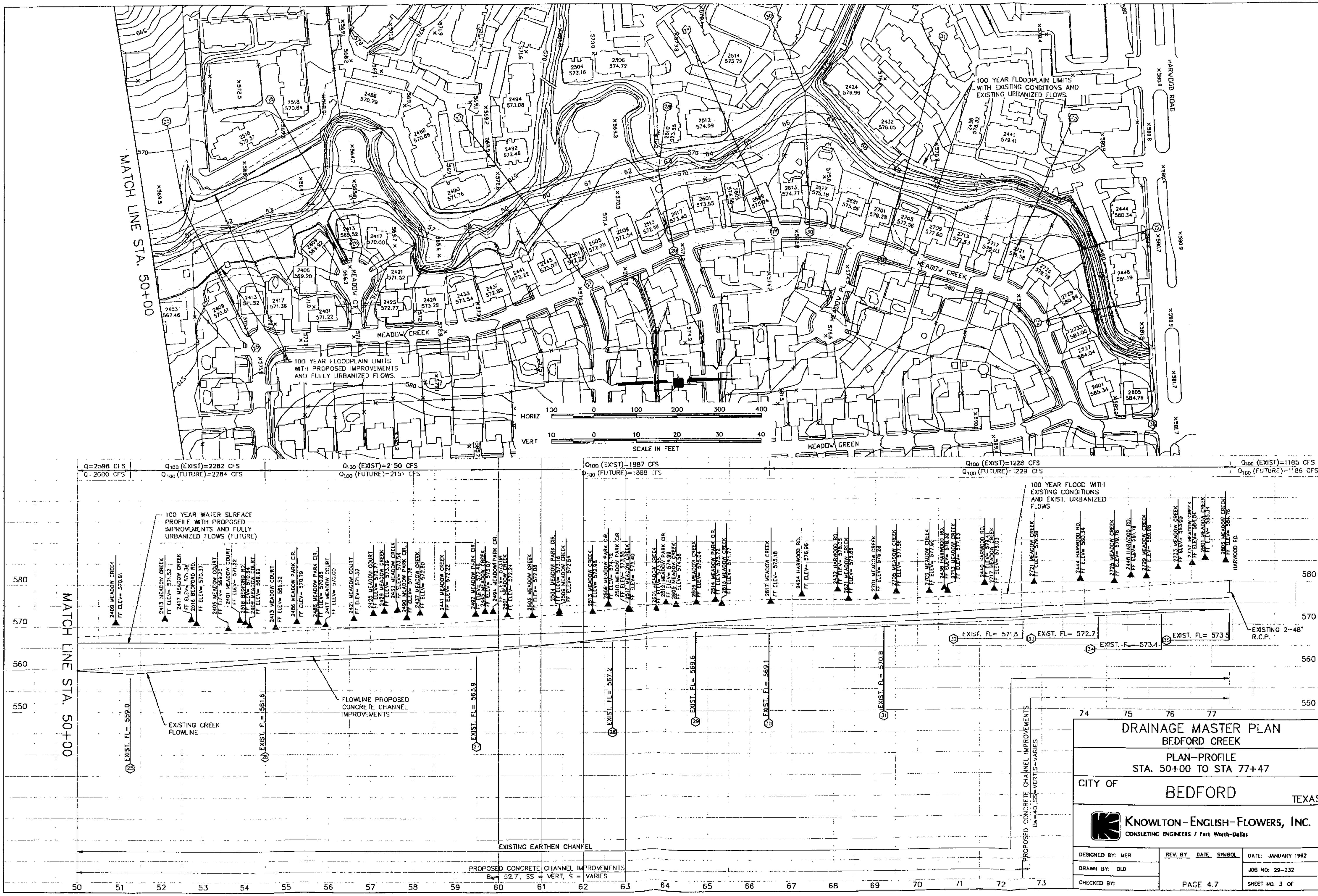

DRAINAGE MASTER PLAN
BEDFORD CREEK

PLAN–PROFILE
STA. 50+00 TO STA 77+47

CITY OF BEDFORD TEXAS

KNOWLTON–ENGLISH–FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth–Dallas

DESIGNED BY: MER	REV. BY DATE SYMBOL	DATE: JANUARY 1992
DRAWN BY: DLD		JOB NO: 29-232
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HC-1

2 EAST BRANCH BEDFORD CREEK

This tributary extends from its confluence with Bedford Creek (Hurrican Creek) Main Channel in the City of Euless approximately 3,500 feet southeast of Tibbets Drive, upstream to Airport Freeway and continuing northward through the Bedford Forum Industrial Development to its end at Harwood Road and State Highway No. 121. The proposed improvements are shown on Plan-Profile Sheets No. 1 through 2.

2.1 Airport Freeway

The existing 10'x6' box culvert at East Branch Bedford Creek and Airport Freeway will not adequately carry the 100-year flow without overtopping the north frontage roadway and flooding local businesses. This box culvert can be modified by adding a 5-barrel 10'x6' box culvert to one side of the existing box culvert. This would cost an estimated $1,410,000.

2.2 Airport Freeway to Commerce Place

This reach consists of an unimproved earthen ditch that is overgrown with vegetation and trees. This section does not contain the 100-year flow and should be improved as development occurs to a minimum 34-foot wide bottom earthen channel and 3:1 side slopes. This improvement will cost an estimated $139,000.

2.3 Commerce Place to Sta. 47+25

This reach consists of 2 existing improved earthen channels, a 4-barrel 8'x5' box culvert at Commerce Place and a 3-barrel 10'x8' box culvert at Bedford Road. These existing drainage improvements can adequately carry the 100-year flow without flooding any residential homes or apartment units or businesses. No channel or culvert improvements are recommended along this reach.


MATCH LINE STA. 23+00
AIRPORT FREEWAY (ST HWY 183)
STATE HWY 183 ACCESS RD
PLAZA PKWY
COMMERCE PL
1800
564.26
2008 560.48
2012
561.54
2120
570.95
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS
100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS
HORIZ
VERT
SCALE IN FEET
Q_{100} (EXIST.)=2423 CFS
Q_{100} (FUTURE)=2438 CFS
Q_{100} (EXIST.)=1632 CFS
Q_{100} (FUTURE)=1639 CFS
AIRPORT FREEWAY
1800 PLAZA PKWY. FF ELEV= 564.26
SHED AT 2008 FF ELEV= 554.22
2008 PLAZA PKWY. FF ELEV= 560.43
2012 PLAZA PKWY. FF ELEV= 561.64
2120 PLAZA PKWY. FF ELEV= 570.95
COMMERCE PLACE
100 YEAR WATER SURFACE PROFILE WITH PROPOSED IMPROVEMENTS AND FULLY URBANIZED FLOWS (FUTURE)
100 YEAR FLOOD WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS
EXISTING 4-8'X5' BOX CULVERT
EXISTING CREEK FLOWLINE
PROPOSED 5-10'X6' BOX CULVERT ADDITION
EXISTING 10'X6' BOX CULVERT
FLOWLINE PROPOSED EARTHEN CHANNEL IMPROVEMENTS
EXIST. FL = 541.5
EXIST. FL = 541.4
EXIST. FL = 545.0
EXIST. FL = 548.5
EXIST. FL = 550.5
EXIST. FL = 554.0
EXIST. FL = 557.6
EXIST. FL = 558.2
EXIST. FL = 558.2
EXIST. FL = 558.7
EXIST. FL = 558.7
EXIST. FL = 558.8
EXIST. FL = 559.0
EXIST. FL = 560.0
EXISTING EARTHEN CHANNEL
PROPOSED EARTHEN CHANNEL IMPROVEMENTS
B_W= 34', SS = 3:1, S = .0114 FT/FT
NO CHANNEL IMPROVEMENTS
DRAINAGE MASTER PLAN
EAST BRANCH BEDFORD CREEK
PLAN-PROFILE
STA. 0+00 TO STA. 23+00
CITY OF
BEDFORD
TEXAS
KNOWLTON-ENGLISH-FLOWERS, INC.
CONSULTING ENGINEERS / Fort Worth-Dallas
DESIGNED BY: MER
DRAWN BY: DLO
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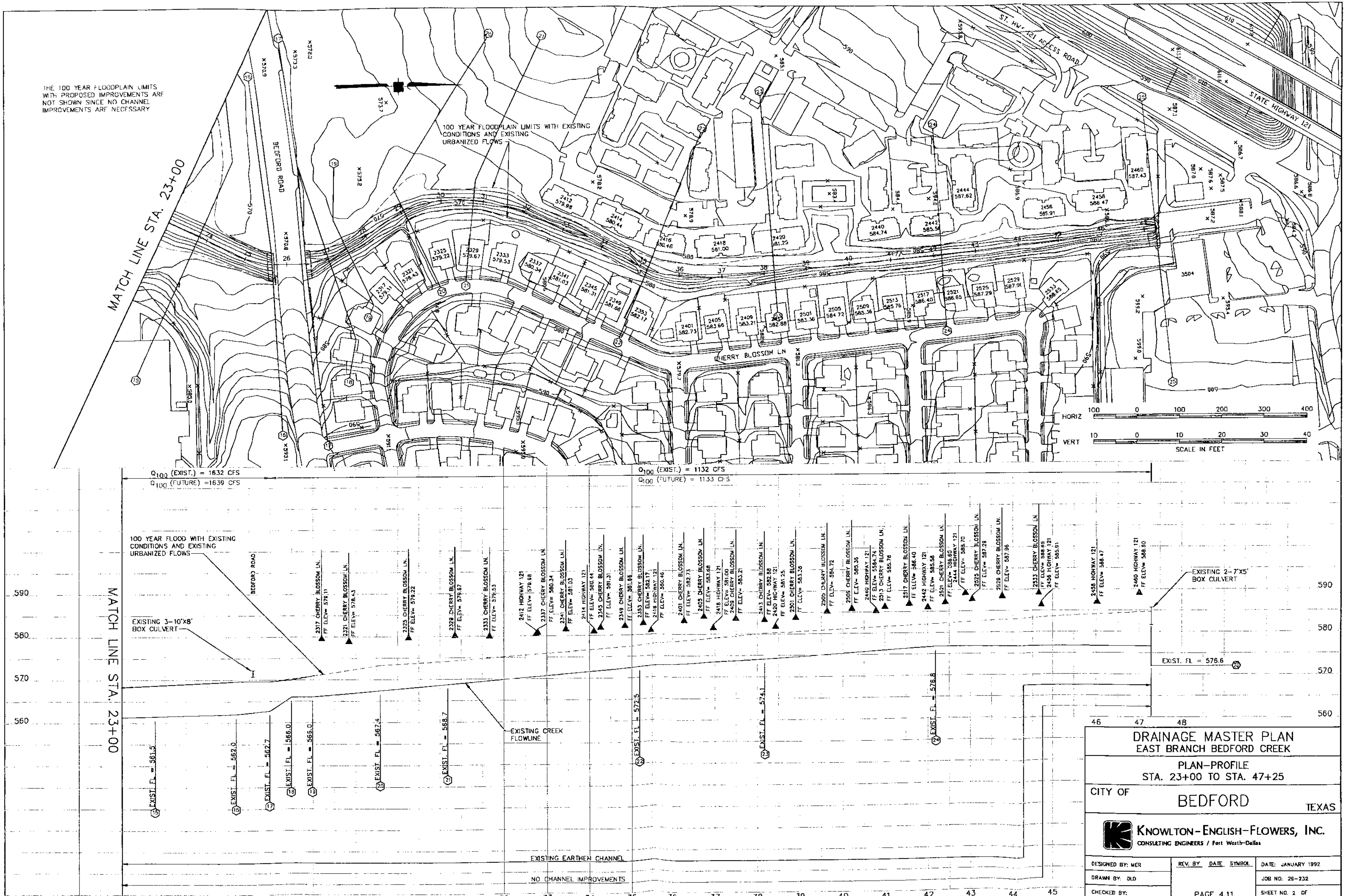
DATE: JANUARY 1992
JOB NO: 29-232
SHEET NO. 1 OF


THE 100 YEAR FLOODPLAIN LIMITS WITH PROPOSED IMPROVEMENTS ARE NOT SHOWN SINCE NO CHANNEL IMPROVEMENTS ARE NECESSARY
100 YEAR FLOODPLAIN LIMITS WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS
MATCH LINE STA. 23+00
BEDFORD ROAD
CHERRY BLOSSOM LN
ST. HWY. 121 ACCESS ROAD
STATE HIGHWAY 121
HORIZ
VERT
SCALE IN FEET
Q100 (EXIST.) = 1632 CFS
Q100 (FUTURE) =1639 CFS
Q100 (EXIST.) = 1132 CFS
Q100 (FUTURE) = 1133 CFS
100 YEAR FLOOD WITH EXISTING CONDITIONS AND EXISTING URBANIZED FLOWS
EXISTING 3-10'X8' BOX CULVERT
EXISTING 2-7'X5' BOX CULVERT
EXISTING CREEK FLOWLINE
EXIST. FL = 576.6
EXISTING EARTHEN CHANNEL
NO CHANNEL IMPROVEMENTS
DRAINAGE MASTER PLAN
EAST BRANCH BEDFORD CREEK
PLAN-PROFILE
STA. 23+00 TO STA. 47+25
CITY OF BEDFORD TEXAS
KNOWLTON-ENGLISH-FLOWERS, INC.
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PAGE 4.11

SECTION 5 -- BOYD BRANCH WATERSHED

GENERAL

Boyd Branch flows in a southerly direction from Harwood Road through Stormy Jones Park, across Bedford Road and parallel to Farm Market 157 in an existing State of Texas drainage easement/right-of-way and flows into the City of Euless at Airport Freeway. The flow continues southerly through Euless and into an unincorporated portion of Fort Worth to the Chicago Rock Island and Pacific Railroad, then easterly through and unincorporated part of Fort Worth until it merges with the West Fork of the Trinity River. The drainage area of the Boyd Branch Watershed is approximately 3.1 square miles of which 0.3 square mile is contained within the corporate limits of Bedford. However, 0.14 square mile drain into the City of Bedford north of Bedford Road from Euless. The general shape of the watershed is long and narrow, having an average width of 1 mile and a length of about 3.1 miles.

The study area in Bedford is less than 250 acres and is sparsely developed with about 72 acres of residential homes and apartments, and about 68 acres of commercial businesses. The remainder of the land is vacant and overgrown with trees and vegetation (approximately 90 acres).

RECOMMENDATIONS

Due to the small size of the Boyd Branch Watershed drainage area in Bedford, this study area will be analyzed using the Rational Method, therefore no major channel improvements are recommended for this area.

SECTION 6 -- LITTLE BEAR CREEK WATERSHED

GENERAL

A portion of the Little Bear Creek Watershed is located in the northern sector of Bedford. This watershed originates in Keller at Whitley Road and Rapp Road, and flows easterly through the Cities of Keller, North Richland Hills, Hurst, Colleyville and Euless to its confluence with Big Bear Creek at Minters Chapel Road. This watershed is about 1.7 miles wide approximately 13 miles in length. The general shape is very long and narrow, consisting of approximately 23 square miles of drainage area, of which 2.2 square miles are contained within the City of Bedford.

The study area in Bedford is divided into eight (8) separate minor subdrainage areas, from the west subdivision line of Bedford Place II eastward to the west right-of-way line of Farm Market 157. All these areas flow to the north into the Cities of Colleyville and Euless. Four of the areas are fully developed with residential homes, three areas are partially developed with residential homes and vacant land, and one area is vacant of any development.

RECOMMENDATIONS

Each of these eight (8) subdrainage areas are less than 400 acres and will be analyzed using the Rational Method. No major channel improvements are recommended for these areas.

SECTION 7 -- COST ESTIMATES

GENERAL

Estimated costs of the various proposed bridge, culvert and major channel storm drainage improvements are presented in this section. Cost estimates of the proposed improvements are divided by watershed for each major channel reach. The cost of each portion of the proposed improvements has been estimated without regard to priority of construction so that each project may be considered separately. Cost estimates on the individual culvert, bridge and channel improvements are available upon request.

Based on current construction costs in the Fort Worth area, the unit prices used in this report have been developed to aid in the preparation of the project cost estimates. The unit prices presented in this report were estimated using the average unit costs for items of similar work in 1991 dollars when the "Engineering News Record" Construction Cost Index was approximately 4,891. The estimated costs contain allowances for engineering and contingencies; however, the actual costs may vary from the estimated cost depending on the size of the contract, market conditions and job difficulty. The cost estimates do not include the cost of easements or right-of-way.

The total estimated cost of all major channel improvements equals approximately \$12,389,070 and approximately \$7,161,000 is the total estimated cost of all bridge and culvert improvements.

SECTION 8 -- DESIGN CALCULATIONS

GENERAL

Printouts of computer runs generated by the programs "HEC-1" and "HEC-2" which present hydrologic and hydraulic data on all major channels and streams in the City of Bedford are available for review. Printouts of channel hydraulic data before and after proposed improvements are available to the City Staff and may be obtained from the office of the Engineer.

HEC-2 SUMMARY DATA DESCRIPTION

Summary output data from all "HEC-2" runs is available as listed below along with other detailed section data and hydraulics parameters computed in the analysis and design calculations:

SECNO -- Cross section identification number.

Q -- Discharge, in Cubic Feet per Second (CFS).

CWSEL -- Computed water surface elevation, in elevation Mean Sea Level (MSL).

DIFWSX -- Difference in water surface elevation between sections, in Feet.

XLCH -- Channel reach length, in Feet.

ELTRD -- Minimum elevation from top of road profile, in MSL.

ELLC -- Maximum low chord elevation of bridge or culvert, in MSL.

ELMIN -- Minimum flowline elevation in cross section, in MSL.

HV -- Mean velocity head across the entire cross section, in Feet.

HL -- Energy loss due to friction.

TIME -- Travel time from the first cross section to the present cross section, in Hours.

VOL -- Cumulative volume of water in the stream from the first cross section, in Acre-Feet.

QCH -- Amount of flow in the channel, in CFS.

VCH -- Mean velocity in the channel, in Feet Per Second.

XNCH -- Mannings "n" for the channel area (times 1,000).

DEPTH -- Depth of flow, in Feet.

TOPWID -- Cross section width at the calculated water surface elevation, in Feet.

CLSTA -- Centerline Station of the trapezoidal excavation.

BW -- Bottom width of the trapezoidal excavation, in Feet.

XLBEL -- Left bank elevation, in MSL.

RBEL -- Right bank elevation, in MSL.

DRAINAGE MASTER PLAN

SECTION 9 -- REFERENCES

1. "HEC-1 FLOOD HYDROGRAPH PACKAGE, USER MANUAL" and "HEC-2 WATER SURFACE PROFILES, USERS MANUAL", U.S. Army Corps of Engineers, The Hydrologic Engineering Center, 609 Second Street, Davis, California 95616, dated September, 1981 and September, 1982, respectively, Phone (916) 440-2105 or (FTS) 448-2105, Al Montalvo or Richard Hayes. Note: Ft. Worth Corps Phone 334-3312, Craig Loftin.

2. "FLOOD INSURANCE STUDY", City of Bedford, Texas, Tarrant County, Federal Emergency Management Agency, Community Number 480585, dated June 4, 1990.

3. "FUTURE LAND USE PLAN OF BEDFORD TEXAS", prepared by Carter and Burgess Inc., Fort Worth, Texas, May, 1982.

4. "SUBDIVISION ORDINANCE; BEDFORD, TEXAS," Revised Ordinance No. 1193, October 9, 1990.

5. "DRAINAGE MASTER PLAN FOR THE CITY OF KELLER", Knowlton-English-Flowers, Inc., Consulting Engineers, dated June, 1991.

6. "DRAINAGE MASTER PLAN FOR THE CITY OF NORTH RICHLAND HILLS", Knowlton-English-Flowers, Inc., Consulting Engineers, dated March, 1985.

7. "DRAINAGE MASTER PLAN FOR THE CITY OF BEDFORD; PHASE I, SULPHUR BRANCH WATERSHED", Knowlton-Ratliff-English-Flowers, Inc., Engineers-Architects-Planners, dated March 1, 1975.

8. "DRAINAGE MASTER PLAN FOR THE CITY OF FORT WORTH", Knowlton-English-Flowers, Inc., Consulting Engineers, 1967.

9. "A STORM DRAINAGE STUDY OF MAJOR STREAMS IN HURST, TEXAS", Albert H. Halff Associates, Inc., Engineers and Scientists, Fort Worth, Texas, November, 1983.

10. "DRAINAGE STUDY SULPHUR BRANCH; MORRISDALE ESTATES ADDITION; EULESS, TEXAS", Elliott and Hughes, Inc., Engineers/Planners, March 1988.

11. "STORMWATER MANAGEMENT HANDBOOK", Stormwater Estimation and Management Techniques for North Central Texas, North Central Texas Council of Governments, 1984 Edition.

12. "COMPUTER ASSISTED FLOODPLAIN HYDROLOGY AND HYDRAULICS", Daniel H. Hoggan, McGraw-Hill Publishing, New York-New York, 1989.

13. "FLOOD PLAIN AND MAIN CHANNEL FLOW INTERACTION", Donald W. Knight and John D. Demetriou, Journal of Hydraulic Engineering, Vol. 109, No. 8, August, 1983.

14. "CRITICAL SCOUR: NEW BED PROTECTION DESIGN METHOD", Marten B. DeGroot and Abraham J. Bliek, Journal of Hydraulic Engineering, Vol. 114, No. 10, October, 1988.

15. "SSSSG COMPUTER PROGRAM", Forrest and Cotton, Inc., Consulting Engineers, Dallas, Texas.

16. "SEWER COMPUTER PROGRAM", Knowlton-English-Flowers, Inc., Consulting Engineers, March, 1984.

17. "THYSYS COMPUTER PROGRAM", Texas Department of Transportation, 1977.

18. "HEC2 INPUT DATA AND 100-YEAR FLOOD DATA", U.S. Army Corps of Engineers, Hydrology and Hydraulic Branch, Fort Worth District, Mr. Jimmy D. Baggett, Mr. Craig Loftin, Mr. Bill Black.

19. HEC-1, HEC-2 and THYSYS hydrology and hydraulic software programs for PC computers by Haestad Methods, Inc., 37 Brookside Road, Waterbury, CT 06708, Phone (800) 727-6555 or Fax (203) 597-1488.

APPENDIX A -- BEDFORD SUBDIVISION ORDINANCE

ARTICLE VI - IMPROVEMENTS

Section 6.1:

A. All grading and drainage improvements necessary for the proper use of streets, highways, and rights-of-way, for public safety, shall be in accordance with the current City of Bedford's Street and Drainage standards and specifications.

B. All streets within or abutting the proposed subdivision shall be paved with curbs and gutters installed, in accordance with the City of Bedford's standards and specifications. All paving shall be to the width specified on the Master Thoroughfare Plan and shall be constructed under the supervision of the Public Works Department. The construction cost of all street improvements shall be borne by the developer, except that the City may participate in the cost of over-width streets, based on zoning, and if funds are available. This determination will be made by the City Manager.

C. Underground utilities required in the subdivision shall be placed under or across all streets after the rough grades are made, but prior to the paving being placed. Paving operations will not be allowed to start until all underground utility work is completed and accepted by the City.

D. Street grades shall be such that excessive sand deposition from too low a water velocity or pavement scouring from too high a velocity is to be avoided as far as possible. The minimum street grade permitted shall be 0.50%. The maximum street grade permitted shall be 8.00%. Any diversion from this range of permissible grades shall require the approval of the City Engineer, Director of Public Works, and the City Manager.

E. Standard roadway widths from face of curb to face of curb are thirty feet (30') in a fifty foot (50') right-of-way, forty feet (40') in a sixty foot (60') right-of-way, and sixty feet (60') in an eighty foot (80') right-of-way.

F. Standard reinforced concrete curb height and width is six inches (6") with a twenty-four inch (24") integral gutter section, measured form the face of the curb. Any diversion from this section will require the approval of the City Engineer and Director of Public Works.

G. Minimum horizontal curvature radii for design of street center lines shall be as follows:

Major Thoroughfares	800 ft.
Collectors	400 ft.
Residential	200 ft.

H. In order to maintain an adequate sight distance, the minimum "K" values for the formula L=KA, where L is the length of the vertical curve (in feet), and A is the algebraic difference of street grades in percent (%) are listed below:

Design Speed	Crest Vertical Curve "K" Value	Sag Vertical Curve "K" Value
30	28	35
40	50	50
50	80	70

I. The minimum radius for curb returns at intersections shall be twenty feet (20') to the face of the curb.

J. All cul-de-sacs shall have a turnaround provided, having a minimum outside roadway radius of forty feet (40') to the face of the curb.

K. A tangent of at least one hundred feet (100') long shall be introduced between reverse curves on arterial and collector streets.

L. Right-of-way lines at street intersections shall be rounded with a minimum radius of ten feet (10') or a comparable corner clip.

Section 6.2 - Water Mains:

A. Water systems shall have a sufficient number of outlets and shall be of sufficient size to furnish adequate domestic service, to provide adequate fire protection to all lots, and to conform to the City of Bedford's current Master Water Plan.

B. All water system installations shall be in accordance with the current City of Bedford's Water Standards and Specifications.

C. All portions of the water system must be controlled by a maximum three (3) valve shutdown. All tee intersections of public water mains shall include at least two (2) gate valves. All cross intersections of public water mains shall include at least three (3) gate valves.

D. The minimum size water main in a residential area shall be six inches (6") in diameter, except in cul-de-sacs which are less than four hundred feet (400') in length, and do not require a fire hydrant installation. These type cul-de-sacs can be served by a four inch (4") diameter water meter.

E. The minimum size water main in commercial, industrial, and other non-residential areas shall be eight inches (8") in diameter.

F. Residential water services shall not be directly connected to water mains sixteen inches (16") in diameter or greater. Parallel water mains are required in these cases.

G. All water services shall be placed at the lot line, between lots, where possible.

Section 6.3 - City Participation in Oversize Water and Sewer Lines:

A. Water and/or sewer mains may be extended to serve property which has been subdivided or platted for development and resale, on the following basis and in accordance with the minimum standards and procedures:

1. On-site extensions totally within property to be developed. A developer shall defray the entire cost of water and sewer mains and all appurtenances that lie totally within a subdivision, except that the City will refund ninety percent (90%) of the evaluated oversize cost of any main larger than necessary to serve the property to be developed, provided, however, the City shall not participate in the cost of any main except those larger than six inches (6"). Size of mains necessary for adequate service shall be determined by the City. Refunds for oversize and along-site cost will be made upon final acceptance of the system by the City.

2. Along-site mains lying along one or more sides of a subdivided tract serving property other than the subdivision for which the extensions are made. For water mains six inches (6") and smaller and for sewer mains six inches (6") and smaller constructed along side subdivided tract and serving property other than a subdivision for which the extensions are made, the developer will be refunded one half (1/2) of the actual cost of the size main constructed. Such refunds will be made at the time the adjoining property connects to said line.

3. Off-site extensions totally outside of property to be developed. Where water and/or sewer facilities are not available to a tract to be developed, mains may at the discretion of the City be extended to the subdivision at the expense of the developer requiring such extension. The City will refund ninety percent(90%) of the oversize cost of such line upon final acceptance of the installation by the City. The balance of the cost of such line will be refunded at the time the property fronting said line is connected, provided, however, the City shall not be obligated to pay more than the amount of actual pro-rata charges which it has collected for connections to said line, nor shall refunds be made contrary to section 3.

B. Water and Sewer Extension Fund:

1. Any and all sums of money hereinafter collected for water an/or sewer extensions, at the rates set out in this article shall be credited to the water and sewer extension fund of the City and all refunds shall be paid from said fund.

2. In no event shall the City be obligated to proceed under the terms of this article if funds are not available or if in the determination of the City Council the extension may not be practical.

C. <u>Refunding Procedure:</u> Except as otherwise provided, all refunds provided for in this article shall be made on April 1st and October 1st of each year, and shall include funds then accrued to the credit of the developers and others. A refund contract entered into by any property owner and the City under the provisions of this article shall be effective only for a period of seven (7) years after the date of such contract. No refunds will be made by the City to any applicant or contracting party after this seven (7) year period has expired nor shall the City ever be liable for payment of interest in any deposits or refunds provided for herein.

Section 6.4 - Sewer Mains:

A. Sanitary sewer facilities shall be provided to adequately service each lot or tract of the subdivision, and shall conform to the City of Bedford's current Master Sanitary Sewer Plan.

B. All sanitary sewer system installations shall be in accordance with the current City of Bedford's Sanitary Sewer Standards and Specifications.

C. All services shall be placed at the center of each lot.

Section 6.5 - Fire Hydrants:

A. In all single-family, triplex, and quadruplex subdivisions, fire hydrant spacing shall not exceed five hundred feet (500') hose lay as measured along public rights-of-way or emergency access easements.

B. In all multi-family apartments, commercial, industrial, and other non-residential subdivisions, fire hydrant spacing shall not exceed three hundred feet (300') hose lay as measured along public rights-of-way or emergency access easement and shall be placed within 300 feet (300') of any fire department connection that serves a fire sprinkler system.

Section 6.6 - Drainage Improvements:

A. <u>General:</u> The criteria herein provided shall govern the design of storm drainage improvements within the City of Bedford. Improvements shall include streets, alleys, storm sewers, channels, culverts, bridges, swales, and any other facility through which storm water flows. All drainage improvements shall be constructed in accordance with current City Specifications and be in dedicated right-of-way, easement, or floodway easement.

B. <u>Basis of Design:</u>

1. <u>Rational Method:</u> The method of calculation for storm runoff for drainage areas less than 1,000 acres will be the Rational Method. This method is expressed by the following equation:

$$Q = CIA$$

Q = storm discharge at the design point in cubic feet per second.

C = runoff coefficient representing the ratio of peak runoff to the rainfall.

I = average rainfall intensity for the time of concentration at the design point in inches per hour.

A = area contributing runoff to the point of design in acres.

2. Unit Hydrograph Method: Peak discharges for drainage areas exceeding 1,000 acres shall be determined by using the unit hydrograph method. The unit hydrograph for this method shall be developed by using the criteria as outlined in "Flood- Hydrograph Analysis and Computation", U.S. Army Corp. of Engineers, Engineering and Design Manuals, EM 110-2-1405, Washington, D.C. dated August 31, 1959. A unit period of 15 minutes should be used for the determination of the unit hydrograph.

3. Runoff Coefficient: Storm drainage improvements shall be designed based on drainage areas being fully developed. The zoning as shown on the current City Zoning maps or the City's Master Land Use Plan, whichever is more restrictive, shall determine the particular coefficient value selected. Table VI - 1 indicates the runoff coefficient for the different land uses.

Table VI -1

Runoff Coefficient "C"

Business & Commercial & CBD	0.90
Industrial	0.85
Apartments	0.75
Residential	
Lots < 0.25 Acres	0.60
0.25 Acre ≤ Lots < Acre	0.55
Lots ≥ 1 Acre	0.50
Parks or Open Area	0.30

4. Time of Concentration: The time of concentration shall be defined as the time it takes a drop of water to flow from the upper limit of a drainage area to the point of concentration. Times of concentration shall be calculated for all inlets, pipe junctions, and other critical design points in the proposed storm sewer systems. The following minimum inlet times of concentration may be used in place of calculated times. When calculating inlet times, consider overland flow channelled at such time as the distance traveled exceeds 100 feet.

Table VI - 2

Minimum Inlet Time of Concentration

Type of Area	Minimum Inlet Time
CBD	5 min.
Business & Commercial	10 min.
Industrial	10 min.
Apartments	10 min.
Residential	15 min.
Parks or Open Area	20 min.

5. Rainfall Intensity - Duration - Frequency: The rainfall intensity-duration-frequency information compiled in Technical Paper No. 40 by the U.S. Weather Bureau, Department of Commerce shall be utilized in computing rainfall intensity.

6. Design Storm Frequency: Storm frequency to be used in design shall be as shown in the following table:

Table VI - 3

Design Storm Frequency

Type of Frequency	Minimum Design Frequency
Storm Sewers (with inlets on grade)	5 years
Street	5 years
Storm Sewers(with low point inlets)	25 years
Culverts, Bridges, Channels, Underpasses, and Creeks	100 years

A storm sewer shall be designed to pick up flow from the street when the runoff from a 5 year frequency storm exceeds the capacity of the street and right-of-way and/or drainage easement and the storm sewer pipe shall be adequate to safely convey the runoff from a 100 year frequency storm.

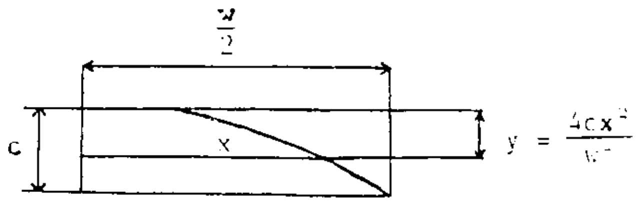
7. Flow in Streets:

a. Street capacity shall be determined utilizing Mannings equation:

$$Q = \frac{1.486}{n} A R^{2/3} S_o^{1/2}$$

Q = discharge in c.f.s.
n = Mannings roughness coefficient, use 0.016 for pavement and gutters
A = cross-section area of flow in square feet
R = hydraulic radius in feet
S = street or gutter slope in feet per foot

b. For parabolic crown streets, the cross slope shall be represented by the following formula:



8. <u>Storm Drain Inlets:</u>

a. The capacity of a depressed curb inlet on grade will be based on the following equation:

$$q_L = 0.7 \left[\frac{1}{H_1 - H_2}\right] \left[(H_1)^{5/2} - (H_2)^{5/2}\right]$$

q_L = discharge into inlet per foot of inlet opening in c.f.s./ft.

$H_1 = a + y_o$

$H_2 = a$ = gutter depression in feet

y_o = depth of flow in approach gutter in feet

b. The capacity of low point or drop inlets will be designed based on the broadcrested weir formula:

$$q_L - 3.0 \, (H_1)^{3/2}$$

9. Storm Sewer Systems:

a. Storm sewer shall be designed using the continuity equation and Manning's equation.

$Q = AV$ and

$$Q = \frac{1.486}{n} A R^{2/3} S_f^{1/2}$$

Q = Discharge in c.f.s.

A = cross-section flow area normal to pipe in square feet

V = mean velocity of flow in feet per second

n = Manning's roughness coefficient

R = hydraulic radius in feet

S_f = friction slope in feet per foot

b. The coefficient of roughness to be used in design shall be as shown below:

Pipe Material	n
Reinforced concrete pipe	0.012
Corrugated metal pipe:	
Annular, unpaved with bituminous coating	0.024
" , 25% paved with bituminous coating	0.021
" , 100% paved with bituminous coating	0.013
Helical, unpaved with bituminous coating	0.014-0.026
" , 100% paved with bituminous coating	0.013

*To be determined by diameter and size of corrugations.

c. Storm sewer pipes shall be designed so that the mean velocity of flow is equal to or greater than 2.5 feet per second and equal to or less than 15 feet per second.

d. The appropriate hydraulic grade line shall be plotted for all storm drainage design. In plotting the hydraulic grade line it shall never fall below the inside top of pipe. The elevation of the hydraulic grade line shall in no case be closer to the gutter flow line than 1.5 feet.

C. Drainage Features and Policies

1. The three (3) different types of basic drainage features are as follows:

(a) Closed systems.
(b) Reinforced concrete lined channels.
(c) Natural Channels.

2. Storm water runoff shall be carried in a closed system when either of the following apply:

   (a) The runoff can be carried in a pipe of seventy-two (72) inches in diameter or smaller; or

   (b) Where it is necessary for the protection of adjacent facilities that the storm water be carried in a closed system. Head walls shall be constructed at the outfall of all closed systems. When it is mutually agreeable to both the City and the owner, a concrete lined channel may be used in lieu of a closed system.

3. Reinforced concrete lined channels should be used when the criteria outlined above is exceeded. Reinforced concrete lined channels shall conform to the following:

   (a) Channels draining an area with a "CA" factor of two hundred fifty (250) or less shall be lined with reinforced concrete in an a manner which will contain the design frequency storm plus one foot (1') of freeboard within the concrete lining.

   (b) Channels draining an area with a "CA" factor of more than two hundred fifty (250) but not more than five hundred (500) shall be concrete lined to contain the runoff from a five (5) year return frequency storm with the balance of the required design frequency storm contained within grassed slopes no steeper than three feet (3') horizontal to one foot (1') vertical and with a minimum of one foot (1') of freeboard.

   (c) Channels draining an area with a "CA" factor of more than five hundred (500) but not more than two thousand (2,000) shall be constructed with a reinforced concrete pilot channel not less than twelve feet (12') in width and having at least six inch (6") curbs and a four inch (4") depressed invert. The remainder of the channel shall consist of grassed slopes not steeper than three (3) to one (1).

   (d) Channels draining an area having a "CA" factor of more than two thousand (2,000) shall be governed by the criteria outlined in Category 4 below, or according to plans that have obtained special approval of the City Manager.

4. Natural channels, with the City Manager's approval, may be preserved when the criteria of Section (C)(3)(d) above are met. The following criteria shall apply when natural channels are to be preserved. An application for preservation of a natural channel shall be submitted to the City Engineer for review and comment prior to approval of the preliminary plat or preliminary/final plat or final plat or submission of construction plans, whichever is appropriate. This application shall contain the following information furnished by the developer:

(a) Topographic, hydrologic and hydraulic information sufficient to properly evaluate the proposal and showing that: (i) all land having an elevation below the twenty-five (25) year return frequency flood elevation is contained within an easement dedicated to the public for the purpose of providing drainage; (ii) the channel easement has a minimum hydraulic capacity to accommodate a twenty-five (25) year return frequency storm based on a fully developed water shed; (iii) that all channel improvements, such as reshaping, realignment, etc., are protected with sodding, backsloping, cribbing or other bank protection that is designed and constructed to control ponding and erosion from the twenty-five (25) year return frequency flood by allowing a maximum downstream discharge velocity not to exceed six feet (6') per second. An analysis shall also be made to determine the effects of the one hundred (100) year flood.

(b) When the natural channel to be preserved is one which has been designated as a flood plain, the one hundred (100) year return frequency storm shall be as shown on the maps furnished by the Federal Emergency Management Agency and City of Bedford Ordinance #985 (Flood Damage Prevention). All requirements contained in this ordinance shall be applicable in addition to the requirements outlined above.

5. A perpetual maintenance agreement in the form prescribed by the City shall be executed by all parties owning any interest in the property abutting upon, adjacent to, or included within a drainage channel or easement provided for in this ordinance. Such perpetual maintenance agreement shall be filed of record with the Tarrant County Clerk of Records and shall establish an affirmative burden, charge and duty on the part of all existing and future parties owning any interest in the property abutting upon, adjacent to, or included within such drainage channel or easement for the maintenance of the channel or easement with regard to vegetation, insects, pooling water, erosion control, and the control of trash and debris. The right, without a duty to do so, shall be given the City to enforce such perpetual maintenance agreement, and, if is so elects, to perform necessary maintenance, the pro-rata cost of which may be charged as a priority lien and assessment against the property and the owners thereof abutting upon, adjacent to, or included within such channel or easement. The perpetual maintenance agreement shall also include provisions that the owners of the property shall provide certification by a licensed engineer registered in the State of Texas every year, that the channel continues to meet or exceed F.E.M.A. and/or City of Bedford requirements and regulations for drainage channels.

D. Bridges and Culverts

1. All bridges and culverts shall be designed in accordance with the current edition of "Hydraulic Manual" prepared by the Texas Highway Department, Bridge Division. The one hundred (100) year

frequency storm hydraulic grade line shall be plotted. All culverts shall have head walls and wing walls upstream and downstream.

2. All culverts shall pass the one hundred (100) year frequency storm runoff without allowing runoff to pass over the road.

3. All bridges shall have channel bottom and slopes concrete lined. The lowest point on a bridge structure shall be one foot (1') above the one hundred (100) year frequency storm runoff.

E. Lot Grading

1. Lot grading shall be conducted in a manner which will not allow runoff to cross more than two (2) lots, including the lot on which it originates. If this is not possible, then a drainage easement and any necessary facilities shall be provided by the developer.

2. Finished floor elevations shall be set at least two feet (2') above the one hundred (100) year base flood elevation.

F. Off-site Drainage

1. The owner or developer of property to be developed shall be responsible for all storm drainage flowing on such person's property. This responsibility includes the drainage directed to that property by prior development as well as drainage naturally flowing through the property by reason of topography. All off-site drainage shall be carried in a seventy-two inch (72") pipe. In the event that such a pipe is inadequate to carry the design frequency storm runoff, the City may participate in the cost of the off-site drainage. The City may participate when adequate bond financing is available. The City's participation shall be based on drainage area contributions from property that is not under the control or ownership of he developer. Any such participation shall be upon order of the City Council.

2. Adequate consideration shall be given by the owner in the development of property to determine how the discharge leaving the proposed development will affect downstream property, with the velocity of said downstream drainage not to exceed six feet (6') per second. That portion of the drainage that comes from undeveloped land will be considered to be one hundred percent (100%) developed in accordance with the City's approved zoning plan and the velocity will be based on that assumption. Six feet (6') per second applies only where the developer is draining onto natural ground.

3. On lots or tracts of three (3) acres or more where storm water runoff has been collected or concentrated, drainage from such lot or tract onto adjacent property, shall not be permitted except in existing creeks, channel or storm sewers unless proper drainage easements are provided.

4. (a) In the event that the subdivision is physically located in a drainage area that requires oversized facilities, the developer will be responsible for the design and installation of such oversized facilities. The developer shall pay the entire cost of construction with reimbursement coming from upstream or downstream developers as connections are made to the system. The reimbursement will be calculated on the actual cost of construction and will be based on drainage area contributions.

(b) Any and all sums of money hereinafter collected by the City for drainage improvements, at the cost as outlined in Appendix C, shall be credited to the Street & Drainage Fund of the City and all refunds shall be paid from said fund.

(c) Except as otherwise provided, all refunds provided for in this ordinance shall be made on April 1st and October 1st of each year, and shall include funds then accrued to the credit of the developers and others. A refund contract entered into by any property owner and the City under the provisions of this document shall be effective only for a period of seven (7) years after the date of such contract. No refunds will be made by the City to any contracting party after this seven (7) year period has expired nor shall the City ever be liable for payment of interest in any deposits or refunds provided for herein. In the event the developer cannot be located after the exercise of due diligence by the City in searching for said developer, any refunds collected in the seven year period shall revert back to the City's drainage fund. No owner that connects to such a system after the expiration of the seven year period shall be required to reimburse the developer for the oversized facilities.

5. Where it is anticipated that additional runoff incident to the development of the subdivision will overload an existing downstream drainage facility, whether natural or man-made, and result in hazardous conditions, the planning commission may withhold approval of the subdivision plat until appropriate provisions have been made by the developer to accommodate the problem. Plans shall be provided by the developer and shall include all necessary off-site improvements, including storm sewer systems, channel grading, driveway adjustments, culvert improvements, etc.

G. Subdivision and/or Unimproved Tract Abutting Unimproved Drainage Ways and/or Tributaries

1. Where the proposed subdivision plat and/or unimproved tract abuts only one (1) side of an unimproved drainage way, and where, in the City Manager's judgment, it is not feasible to construct the drainage way at the time of development of the subdivision and/or undeveloped tract, the City shall permit the developer to pay into escrow, for the construction and/or improvements of said drainage

way, an amount of money equal to the developer's share of the cost of said improvements as a condition precedent to the acceptance of said utilities and street or streets of said subdivision and/or unimproved tract.

(a) The drainage way to be constructed and/or improved, or the amount of money to be placed in escrow will be based on the drainage area contribution, by the development, or one half (1/2) of the appropriate improvements, whichever is greater.

(b) All improvements shall be constructed in accordance with the City of Bedford Street and Drainage Specifications.

(c) The amount of money for escrow shall be determined by the estimates as to the cost of improvements as provided by the Engineer of the City and as adopted by the City Council. Said estimates as to the cost of improvements are attached hereto as Appendix C.

Section 6.7 Construction Plan Requirements: All construction plans for proposed public water, sanitary sewer, streets, and drainage improvements shall adhere to the following requirements:

A. Plans to be designed, signed, and sealed, and dated by a professional Civil Engineer registered in the State of Texas.

B. Plan and profile sheets to be 36 inches wide by 24 inches high.

C. Horizontal scale shall be 1 inch equals 40 feet or larger. Verticle scale shall be 1 inch equals 4 feet.

D. Appropriate hydraulic grade line or water surface profile shall be plotted with all drainage design. Capacity, design discharge, friction slope, velocity, and velocity head shall be noted on each segment of drainage facility whenever one or more of these parameters changes.

Section 6.8 - Miscellaneous:

A. The developer shall furnish all easements and rights-of-way necessary for construction of electrical, gas, cable T.V., and telephone service to the subdivision.

B. The developer will furnish a street lighting plan as part of his construction plans for review and approval by the City Engineer and the Director of Special Services. The Developer shall pay for the number of street lights required in the subdivision. Street lights will be placed at each intersection and at mid block if block is over 1200 feet long. In no case shall the street lights be placed farther than 600 feet apart. After acceptance of the subdivision, service charges for electricity will be paid by the City.

C. The developer shall be responsible for all damages to existing improvements caused during installation of utilities.

D. All utilities shall be installed underground.

Section 6.9 - Tree Preservation:

A. The purposes of this section are to establish rules and regulations governing the protection of trees within the City of Bedford and to encourage the protection of healthy trees.

B. Definitions:

1. Buildable area: That portion of a building site exclusive of the required yard areas on which a structure or building improvements may be erected, and including the actual structure, driveway, parking lot, pool, and other construction as shown on a site plan.

2. Drip line: A vertical line run through the outermost portion of the crown of a tree and extending to the ground.

3. Tree: Any self-supporting woody perennial plant which has a trunk diameter of three (3) inches or more when measured a at the point of four and one-half (4½) feet above ground level and which normally attains an overall height of at least twenty (20) feet at maturity usually with one (1) main stem or trunk and may branches. It may appear to have several stems or trunks as in several varieties of oak.

4. Yard area: The front, side and rear yard areas as required under the comprehensive zoning code and the zoning district requirement applicable thereto.

C. Applicability: The terms and provisions of this section shall apply to real property as follows:

1. All vacant and undeveloped property.

2. All unimproved property.

3. All easements and right-of-ways except those included in a plat approved by the Planning and Zoning Commission.

D. No person, directly or indirectly, shall cut down, destroy, remove or move, or effectively destroy through damaging, any tree situated on property described above without first obtaining a tree removal permit unless an exception specified herein is met.

E. Application: Permits for removal of trees covered herein shall be obtained by making application on a form prescribed by the City to the Building Department and shall pay a nonreturnable fee of five dollars ($5.00) for each acre or fraction thereof for a maximum of $200.00. The application shall be accompanied by a preliminary plat showing the exact location, size (trunk diameter and height), common name of all trees to be removed. The application shall also be accompanied by a written document indicating the reasons for removal of trees and two copies of a legible site plan drawn to the largest practicable shall indicating the following:

1. Location of all existing or proposed structures, improvements and site uses, properly dimensioned and referenced to property lines, and setback and yard requirements.

2. Existing and proposed site elevations, grades and major contours.

3. Location of existing and proposed utility easements.

4. The location of trees on the site to be removed.

5. Tree information required above shall be summarized in legend form on the plan and shall include the reason for the proposed removal.

6. Aerial photographs, at an appropriate scale, may be substituted, at the discretion of the Building Official, for a site plan if adequate site information is supplied on the aerial photographs.

F. Application Review: Upon receipt of a proper application, the Building Official shall review the application and consider the effect of the removal or relocation of any tree upon the drainage, topography, safety hazards, health of tree, and the natural resources prior to the granting or denying of any application. Said review may include a field inspection of the site, and the application may be referred to such department as deemed appropriate for review and recommendations. If the application is made in conjunction with a site plan submitted for approval, the application will be considered as part of the site plan, and no permit shall be issued without site plan approval.

G. Tree Removal Permits:

1. No tree removal permits shall be issued unless one of the following conditions exist:

    a. The tree is located where structures, buildings, utilities, or other improvements are to be placed and the removal of such tree is essential for the proper development of the tract and the relocation of the tree is not feasible.

    b. The tree is dead, diseased, injured, in danger of falling, interferes with utility service, creates unsafe vision clearance, dangerously close to existing or proposed structures or buildings, or conflicts with other ordinances or regulations.

    c. Under no circumstances shall there be clear cutting of trees on a property prior to the issuance of a tree removal permit.

2. Upon issuance of a tree removal permit, the developer shall be allowed to remove trees located on the buildable area of the property. Trees located in required yard areas, buffers and open

space areas shall be maintained. The buildable area shall include sufficient adjacent area to allow the normal operation of construction equipment as determined by the Building Official.

3. Permit(s) for tree removal not issued in connection with a building permit or a site plan shall become void ninety (90) days after the issue date on the permit. Permits for tree removal issued in connection with a building permit or site plan shall be valid for the period of that building permit's or site plan's validity.

H. Replacement:

1. In the event that it is necessary to remove tree(s) outside the buildable area, the developer, as condition to issuance of a tree removal permit, may be required to replace the tree(s) being removed with comparable trees somewhere within the site.

2. A sufficient number of trees shall be planted to equal, in caliper, the diameter of the tree removed. Said replacement trees shall be a minimum of 3" caliper and 7 feet in height when planted, and shall be selected from the list of approved replacement trees created and maintained by the Building Official.

3. At the time of application review, the person responsible for replacement, time of replacement and location will be determined by the Building Official.

I. Tree Protection:

1. During any construction or land development, the developer shall clearly mark all trees to be maintained and all such trees or groups of trees. The developer shall not allow the movement of equipment or the storage of equipment, materials, debris or fill to be placed within the drip line of any tree.

2. During the construction stage of development, the developer shall not allow cleaning of equipment or material under the canopy drip line of any tree or group of trees to remain. Neither shall the developer allow the disposal of any waste material such as, but not limited to, paint, oil, solvents, asphalt, concrete, mortar, etc., under the canopy of any tree or group of trees to remain.

3. No attachments or wires of any kind, other than those of a protective nature, shall be attached to any tree.

4. No structure or impervious paving shall be located within a 6" radius of a trunk perimeter of any tree.

J. Appeals: Any person aggrieved by a decision of the Building Official under this Section of the Subdivision Ordinance shall have the right to make an appeal to the Building Commission, or any successor thereof, as provided in Section 6-9 of the City of Bedford Code of Ordinances.

K. Exceptions:

1. In the event that any tree shall be determined to be in a hazardous or dangerous condition so as to endanger the public health, welfare or safety, and require immediate removal without delay, authorization may be given by the Building Official and the tree may then be removed without obtaining a written permit as herein required.

2. During the period of an emergency such as a tornado, storm, flood, or other act of God, the requirements of this ordinance may be waived as may be deemed necessary the Building Official.

3. All licensed plant or tree nurseries shall be exempt from the terms and provision of this section only in relation to those trees planted and growing on the premises of said licensee which are so planted and growing for the sale or intended sale to the general public in the ordinary course of said licensee's business.

4. Utility companies franchised by the city may remove trees which endanger public safety and welfare by interfering with utility service, except that where such trees are on owner-occupied properties developed for one-family use, disposal of such trees shall be at the option of the property owner. Utility companies shall file with the Building Official the standards and specifications used by such company for the removal and/or pruning of trees. Such standards and specifications must be filed with the Building Official within thirty (30) days after the enactment of this Ordinance. If such plans and specifications are approved by the Building Official, a utility tree removal permit shall be issued. Such utility removal permit shall be good for any tree removal or pruning work of the utility company for a period of one year from the issuance date.

5. The provisions and requirements of this Section of the Subdivision Ordinance shall not apply to projects of the City of Bedford; provided, however, that all City of Bedford projects that may affect trees shall preserve, replace, and relocate trees whenever feasible.

DRAINAGE MASTER PLAN

APPENDIX B -- SUPPORT DATA

THIS RUN EXECUTED 28MAY92 17:08:14

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HEC-2 WATER SURFACE PROFILES

Version 4.6.0; February 1991
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

PROPOSED IMPROVEMENTS FOR VALLEY VIEW BRANCH
100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	1165.000	3810.00	482.17	.00	.00	.00	.00	477.60	.09	.00	.00	.00
	1770.000	3810.00	485.20	3.03	605.00	.00	.00	481.30	.21	3.09	.05	19.96
*	1820.000	3810.00	489.21	4.01	50.00	489.20	485.80	482.00	.40	.51	.05	21.03
*	1850.000	3810.00	489.86	.65	30.00	489.20	485.80	482.00	.12	.29	.05	21.76
	1920.000	3810.00	490.04	.18	70.00	.00	.00	482.20	.16	.20	.06	23.94
*	2490.000	3810.00	491.29	1.25	570.00	.00	.00	483.20	.81	1.57	.08	36.76
	2880.000	3810.00	493.23	1.94	390.00	.00	.00	483.50	.89	1.99	.09	41.77
	2930.000	3810.00	493.47	.24	50.00	.00	.00	485.00	.92	.25	.10	42.38
*	3010.000	3810.00	493.85	.38	80.00	.00	.00	485.80	1.21	.52	.10	43.36
*	3060.000	3810.00	501.31	7.46	50.00	516.00	496.50	485.80	.08	6.33	.11	44.83
	3195.000	3810.00	501.42	.11	135.00	.00	.00	486.30	.02	.03	.14	53.77
*	3700.000	3810.00	501.54	.12	505.00	.00	.00	486.80	.07	.15	.21	89.17
*	4210.000	3810.00	501.73	.19	510.00	.00	.00	487.90	1.25	.78	.23	105.72
	4270.000	3810.00	502.02	.28	60.00	.00	.00	490.80	1.84	.58	.23	106.28
*	4380.000	3810.00	506.49	4.48	110.00	506.20	498.80	490.80	.89	3.53	.23	107.76
	4475.000	3810.00	506.62	.13	95.00	.00	.00	492.20	.82	.04	.24	109.28
	4925.000	3810.00	506.76	.13	450.00	.00	.00	493.50	1.07	.26	.25	116.88

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	5000.000	3810.00	507.32	.56	75.00	.00	.00	493.60	.67	.04	.26	118.63
*	5040.000	3810.00	507.68	.35	40.00	505.10	502.70	493.60	.59	.28	.26	119.76
	5090.000	3810.00	507.69	.01	50.00	.00	.00	493.90	.60	.02	.26	121.22
	5300.000	3810.00	508.08	.39	210.00	.00	.00	494.10	.34	.06	.27	128.89
*	5520.000	4200.00	507.87	-.21	220.00	.00	.00	495.30	.94	.08	.28	136.52
	5620.000	4200.00	507.91	.05	100.00	.00	.00	495.60	.98	.07	.29	138.89
	5670.000	4200.00	509.11	1.20	50.00	507.40	504.30	496.10	.77	.99	.29	140.24
	5720.000	4200.00	509.10	-.01	50.00	.00	.00	496.10	.86	.03	.29	141.72
*	6510.000	4200.00	510.32	1.22	790.00	.00	.00	500.50	3.12	.93	.31	155.46
*	7080.000	4200.00	513.07	2.75	570.00	.00	.00	501.30	1.80	1.04	.32	161.50
	7130.000	4200.00	513.12	.05	50.00	.00	.00	501.60	1.87	.06	.32	162.18
*	7170.000	4200.00	514.48	1.36	40.00	513.20	519.90	501.70	1.61	1.10	.32	162.71
	7230.000	4200.00	514.48	.00	45.00	.00	.00	502.90	1.86	.05	.32	163.28
	7250.000	4200.00	514.32	-.16	20.00	.00	.00	504.10	2.81	.03	.32	163.50
*	7290.000	4200.00	516.89	2.56	40.00	.00	.00	506.80	2.29	.10	.33	164.00
*	7325.000	4200.00	518.04	1.16	35.00	.00	.00	508.30	2.36	.09	.33	164.54
*	8140.000	4200.00	524.13	6.09	815.00	.00	.00	513.30	2.92	2.09	.34	175.28
*	8240.000	4200.00	524.83	.70	100.00	.00	.00	514.00	2.92	.25	.35	176.39
*	8310.000	4200.00	525.60	.77	25.00	.00	.00	514.60	2.78	.06	.35	176.67
*	8890.000	4200.00	528.84	3.23	580.00	.00	.00	518.20	2.96	1.43	.36	182.69
*	8955.000	4200.00	533.42	4.59	65.00	.00	.00	519.20	.11	.03	.36	184.29
	8995.000	4200.00	533.53	.10	40.00	530.00	527.00	520.00	.18	.17	.37	185.72
*	9035.000	4200.00	533.43	-.09	40.00	.00	.00	520.20	.72	.02	.37	186.97
	9350.000	4200.00	533.73	.29	315.00	.00	.00	521.50	1.12	.37	.38	195.66
	9535.000	4200.00	533.99	.27	185.00	.00	.00	522.90	1.47	.34	.39	199.81
*	9760.000	4200.00	535.31	1.31	225.00	.00	.00	524.30	2.17	.54	.39	203.09

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	9955.000	4200.00	537.85	2.55	195.00	.00	.00	526.80	3.05	.66	.40	205.53
*	10010.000	4200.00	542.63	4.77	55.00	.00	.00	526.80	.07	.01	.40	207.23
	10060.000	3460.00	542.63	.00	50.00	537.50	535.91	527.60	.07	.00	.41	209.65
	10110.000	3460.00	542.58	-.04	50.00	.00	.00	527.90	.31	.00	.41	211.88
*	10510.000	3460.00	542.59	.00	400.00	.00	.00	530.80	.72	.08	.43	225.98
*	10855.000	3460.00	543.23	.65	345.00	.00	.00	533.31	1.87	.21	.44	232.64
*	10935.000	3460.00	544.03	.80	80.00	.00	.00	534.20	2.43	.10	.44	233.48
*	10985.000	3460.00	546.37	2.33	50.00	546.60	543.70	534.20	.81	.72	.45	234.26
	11020.000	3460.00	546.39	.02	35.00	.00	.00	534.25	.80	.01	.45	235.08
	11210.000	3460.00	546.31	-.09	190.00	.00	.00	535.25	1.25	.09	.45	238.83
	11440.000	3460.00	546.13	-.18	230.00	.00	.00	536.20	2.20	.20	.46	241.71
*	11530.000	3460.00	546.04	-.09	90.00	.00	.00	536.90	3.16	.13	.46	242.38
*	11605.000	3460.00	550.39	4.35	75.00	.00	.00	536.95	.07	.02	.47	243.95
	11645.000	3460.00	550.29	-.10	40.00	546.20	545.70	537.20	.25	.09	.47	245.25
	11700.000	3460.00	550.27	-.02	55.00	.00	.00	537.45	.48	.03	.48	246.50
	11860.000	3460.00	550.33	.06	160.00	.00	.00	538.20	.84	.13	.48	249.82
*	11915.000	3460.00	551.33	1.00	55.00	.00	.00	538.20	.24	.03	.49	251.02
	11965.000	3460.00	551.45	.13	50.00	547.80	547.30	538.80	.19	.08	.49	252.40
	12025.000	3460.00	551.44	-.01	60.00	.00	.00	539.05	.35	.02	.49	254.06
	12300.000	3460.00	551.54	.10	275.00	.00	.00	540.40	.58	.15	.51	261.56
*	12625.000	3460.00	551.75	.21	325.00	.00	.00	542.10	1.26	.35	.52	266.69
	12685.000	3460.00	551.86	.10	60.00	.00	.00	542.38	1.28	.11	.52	267.23
*	12715.000	3460.00	553.15	1.30	30.00	552.80	551.80	542.30	.94	.96	.52	267.51
	12775.000	3460.00	553.21	.06	60.00	.00	.00	542.81	1.05	.08	.52	268.11
	13000.000	3460.00	553.53	.32	225.00	.00	.00	543.80	1.11	.33	.53	270.71
	13200.000	3460.00	553.82	.29	200.00	.00	.00	544.76	1.46	.37	.54	272.99

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	13440.000	3460.00	554.36	.54	240.00	.00	.00	545.66	1.63	.57	.54	275.03
	13710.000	3460.00	555.09	.73	270.00	.00	.00	546.90	1.90	.78	.55	277.09
	13940.000	3460.00	555.86	.77	230.00	.00	.00	548.21	2.24	.84	.55	278.67
	14155.000	3460.00	556.75	.89	215.00	.00	.00	549.17	2.29	.90	.56	280.09
*	14225.000	3460.00	558.85	2.10	70.00	.00	.00	549.17	1.08	.17	.56	280.67
*	14295.000	3460.00	559.84	.99	70.00	560.50	559.50	549.58	.61	.51	.56	281.53
	14335.000	3460.00	559.86	.02	40.00	.00	.00	549.68	.65	.03	.57	282.09
	14417.000	3460.00	559.90	.05	82.00	.00	.00	550.43	.77	.07	.57	283.15
	14517.000	3460.00	560.00	.09	100.00	.00	.00	550.93	.87	.11	.57	284.31
	14715.000	2770.00	560.70	.70	198.00	.00	.00	552.60	.56	.21	.58	286.60
	15090.000	2770.00	561.03	.33	375.00	.00	.00	552.80	.69	.35	.60	290.75
	15420.000	2770.00	561.41	.39	330.00	.00	.00	554.20	.85	.42	.61	293.89
	15860.000	2770.00	562.21	.80	440.00	.00	.00	555.80	1.04	.83	.63	298.10
	16290.000	2770.00	563.40	1.19	430.00	.00	.00	557.50	1.16	1.22	.64	301.84
	16475.000	2770.00	564.05	.65	185.00	.00	.00	559.00	2.09	.84	.64	303.03
*	16510.000	2770.00	565.60	1.54	35.00	.00	.00	559.10	1.20	.12	.64	303.25
*	16850.000	2770.00	565.95	.36	340.00	571.10	570.70	560.70	2.63	1.79	.65	305.31
*	16910.000	2770.00	569.13	3.18	60.00	.00	.00	561.60	2.25	1.31	.65	305.62
*	17390.000	2770.00	575.24	6.11	480.00	.00	.00	567.20	.36	3.09	.68	311.90
	17790.000	2770.00	576.37	1.13	400.00	.00	.00	567.70	.35	1.12	.71	319.50
*	17845.000	2770.00	576.79	.42	55.00	.00	.00	567.70	.14	.08	.71	320.60
	17895.000	2770.00	576.91	.12	50.00	573.80	573.40	567.70	.12	.10	.72	321.75
	17945.000	2770.00	576.93	.02	50.00	.00	.00	568.40	.29	.05	.72	322.80
*	18130.000	2770.00	577.31	.38	185.00	.00	.00	570.30	.64	.46	.73	325.44
	18725.000	2770.00	580.36	3.05	595.00	.00	.00	573.50	.70	3.06	.75	332.15
	19150.000	2770.00	582.69	2.33	425.00	.00	.00	574.20	.25	1.60	.78	338.21

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	19180.000	2770.00	582.72	.03	30.00	.00	.00	574.20	.28	.04	.79	338.70
*	19230.000	2770.00	583.66	.94	50.00	581.60	579.50	574.20	.11	.78	.79	339.72
*	19280.000	2770.00	583.53	-.13	50.00	.00	.00	574.50	.99	.05	.79	340.58
	19400.000	2770.00	584.19	.66	120.00	.00	.00	576.00	1.49	.76	.80	341.61
*	19500.000	2770.00	586.49	2.30	100.00	.00	.00	577.30	.25	.31	.80	342.98
*	19790.000	2770.00	587.10	.61	290.00	.00	.00	578.90	.43	.65	.82	348.15
	20100.000	2770.00	588.25	1.15	310.00	.00	.00	579.50	.59	1.18	.83	352.30
	20225.000	2770.00	588.85	.60	125.00	.00	.00	580.40	.70	.62	.84	353.63
	20350.000	2770.00	589.55	.70	125.00	.00	.00	581.10	.70	.70	.84	354.87
	20550.000	2770.00	590.71	1.16	200.00	.00	.00	581.70	.59	.98	.85	357.03
	20700.000	2770.00	591.38	.68	150.00	.00	.00	582.50	.64	.69	.86	358.73
	20900.000	2770.00	592.63	1.24	200.00	.00	.00	583.30	.30	.70	.87	361.53
	21080.000	2770.00	593.14	.51	180.00	.00	.00	584.10	.35	.52	.88	364.49

100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
	1165.000	439.65	482.17	4.16	45.00	4.57	1099.03	.00	.01	482.50	481.70
	1770.000	731.58	485.20	5.10	45.00	3.90	825.89	.00	.01	482.40	483.50
*	1820.000	432.58	489.21	5.67	45.00	7.21	879.95	.00	.01	489.20	489.20
*	1850.000	249.94	489.86	2.80	45.00	7.86	967.78	.00	.01	489.20	489.20
*	1920.000	1686.26	490.04	4.04	45.00	7.84	490.52	.00	.01	488.40	487.90
*	2490.000	3461.57	491.29	7.51	45.00	8.09	192.49	.00	.01	489.60	488.80
	2880.000	3785.94	493.23	7.60	45.00	9.73	133.95	.00	.01	492.40	492.50
	2930.000	3220.54	493.47	8.23	45.00	8.47	142.78	.00	.01	490.00	490.00
*	3010.000	3409.85	493.85	9.27	55.00	8.05	134.72	.00	.01	490.80	490.80
*	3060.000	2176.80	501.31	2.80	55.00	15.51	275.00	.00	.01	490.80	490.80
	3195.000	1186.34	501.42	1.61	60.00	15.12	584.20	.00	.01	495.40	497.90
*	3700.000	1837.22	501.54	2.77	60.00	14.74	525.45	.00	.01	496.10	499.60
*	4210.000	3810.00	501.73	8.99	60.00	13.83	48.99	.00	.01	504.20	506.40
	4270.000	3509.43	502.02	11.28	60.00	11.22	49.69	.00	.01	492.90	495.90
*	4380.000	3507.84	506.49	7.88	20.00	15.69	292.06	.00	.01	492.90	495.90
	4475.000	3720.57	506.62	7.34	20.00	14.42	133.71	.00	.01	504.60	500.50
	4925.000	3469.16	506.76	8.69	20.00	13.26	305.39	.00	.01	502.00	502.00
	5000.000	3235.14	507.32	7.10	20.00	13.72	342.51	.00	.01	502.20	502.20
*	5040.000	3177.51	507.68	6.72	20.00	14.08	327.35	.00	.01	502.20	502.20
	5090.000	3186.21	507.69	6.78	20.00	13.79	347.16	.00	.01	502.20	502.20
	5300.000	2762.95	508.08	5.51	20.00	13.98	371.25	.00	.01	502.60	502.60
*	5520.000	3679.56	507.87	8.30	20.00	12.57	273.43	.00	.01	503.80	503.80
	5620.000	3673.64	507.91	8.49	20.00	12.31	272.85	.00	.01	504.10	504.10
	5670.000	3298.76	509.11	7.93	20.00	13.01	300.09	.00	.01	503.80	503.80

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
	5720.000	3381.40	509.10	8.27	20.00	13.00	297.74	.00	.01	504.60	504.60
*	6510.000	4149.72	510.32	14.26	20.00	9.82	120.10	.00	.01	509.00	509.00
*	7080.000	4008.42	513.07	11.02	20.00	11.77	279.14	.00	.01	508.80	508.80
	7130.000	3994.17	513.12	11.26	20.00	11.52	283.67	.00	.01	509.10	509.10
*	7170.000	4116.19	514.48	10.28	20.00	12.78	228.63	.00	.01	509.20	509.20
	7230.000	4056.21	514.48	11.14	20.00	11.58	224.18	.00	.01	509.50	509.50
	7250.000	4134.32	514.32	13.56	20.00	10.22	195.88	.00	.01	512.00	512.00
*	7290.000	3464.39	516.89	13.35	20.00	10.09	194.69	.00	.01	513.80	514.00
*	7325.000	3406.85	518.04	13.65	20.00	9.74	178.11	.00	.01	515.30	515.30
*	8140.000	3980.75	524.13	14.09	20.00	10.83	171.97	.00	.01	521.30	521.30
*	8240.000	3980.94	524.83	14.09	20.00	10.83	171.91	.00	.01	522.00	522.00
*	8310.000	3932.36	525.60	13.82	20.00	11.00	198.42	.00	.01	524.10	521.20
*	8890.000	4066.24	528.84	14.04	20.00	10.64	159.34	.00	.01	526.20	526.20
*	8955.000	1500.04	533.42	3.64	25.00	14.22	385.57	.00	.01	527.20	527.20
	8995.000	1581.76	533.53	4.52	25.00	13.53	340.01	.00	.01	527.00	526.90
*	9035.000	2831.76	533.43	8.26	25.00	13.23	336.54	.00	.01	527.00	526.90
	9350.000	3088.86	533.73	9.88	25.00	12.23	319.67	.00	.01	529.00	529.00
	9535.000	3178.71	533.99	11.14	25.00	11.09	289.67	.00	.01	529.00	529.90
*	9760.000	3577.19	535.31	12.79	25.00	11.01	258.98	.00	.01	531.30	531.30
*	9955.000	3913.00	537.85	14.51	25.00	11.05	132.24	.00	.01	533.90	533.80
*	10010.000	1223.27	542.63	3.00	20.00	15.83	497.18	.00	.01	533.90	533.80
	10060.000	1300.47	542.63	2.89	20.00	15.03	544.37	.00	.01	536.50	536.50
	10110.000	2375.54	542.58	5.39	15.00	14.68	542.10	.00	.01	536.50	536.50
*	10510.000	2639.15	542.59	7.76	15.00	11.79	368.33	.00	.01	539.30	539.30
*	10855.000	3159.70	543.23	11.49	15.00	9.92	294.56	.00	.01	541.81	541.81
*	10935.000	3422.97	544.03	12.58	15.00	9.83	215.07	.00	.01	543.35	543.25

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	10985.000	2840.13	546.37	7.97	15.00	12.17	364.90	.00	.01	543.35	543.25
	11020.000	2829.16	546.39	7.95	15.00	12.14	366.85	.00	.01	543.35	543.25
	11210.000	3038.58	546.31	9.58	15.00	11.06	260.90	.00	.01	544.25	544.25
	11440.000	3384.58	546.13	12.05	15.00	9.93	164.07	.00	.01	544.70	544.70
*	11530.000	3431.73	546.04	14.32	15.00	9.14	103.46	.00	.01	545.00	545.00
*	11605.000	935.28	550.39	2.79	25.00	13.44	472.11	.00	.01	544.95	544.95
*	11645.000	1900.24	550.29	5.01	25.00	13.09	341.89	.00	.01	545.45	545.45
	11700.000	2443.86	550.27	6.57	25.00	12.82	340.18	.00	.01	545.45	545.45
	11860.000	2826.07	550.33	8.13	25.00	12.13	317.09	.00	.01	546.30	546.30
*	11915.000	1890.06	551.33	4.95	25.00	13.13	384.45	.00	.01	546.30	546.30
	11965.000	2200.84	551.45	4.24	25.00	12.65	393.19	357.00	30.00	546.78	547.00
	12025.000	2736.71	551.44	5.34	25.00	12.39	363.19	360.00	30.00	548.00	547.82
	12300.000	2965.19	551.54	6.57	25.00	11.14	276.88	437.00	30.00	548.90	548.90
*	12625.000	3448.58	551.75	9.03	25.00	9.65	99.43	369.00	30.00	550.81	550.94
	12685.000	3460.00	551.86	9.10	25.00	9.48	49.00	485.50	30.00	552.72	552.74
*	12715.000	3457.01	553.15	7.80	25.00	10.85	73.40	470.00	30.00	552.93	552.85
	12775.000	3458.58	553.21	8.23	25.00	10.40	77.20	470.00	30.00	552.92	552.85
	13000.000	3318.00	553.53	8.62	25.00	9.73	307.60	519.00	30.00	552.30	552.34
	13200.000	3441.04	553.82	9.73	25.00	9.06	289.49	492.00	30.00	553.26	553.54
	13440.000	3455.07	554.36	10.26	25.00	8.70	141.68	412.00	30.00	554.16	554.16
	13710.000	3460.00	555.09	11.06	25.00	8.19	46.38	430.40	30.00	557.41	556.00
	13940.000	3460.00	555.86	12.01	25.00	7.65	45.31	376.00	30.00	556.71	556.71
	14155.000	3460.00	556.75	12.14	25.00	7.58	45.17	555.00	30.00	558.04	557.67
*	14225.000	3277.67	558.85	8.57	25.00	9.68	169.63	555.00	30.00	558.04	557.67
*	14295.000	3381.46	559.84	6.31	25.00	10.26	230.17	860.00	42.00	558.99	559.56
	14335.000	3439.68	559.86	6.48	25.00	10.18	234.42	860.00	42.00	558.99	559.56

SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
14417.000	3450.52	559.90	7.07	25.00	9.47	276.03	790.00	42.00	559.46	559.53
14517.000	3459.53	560.00	7.47	25.00	9.07	327.01	675.00	42.00	559.94	559.93
14715.000	2714.53	560.70	6.05	25.00	8.10	195.40	1213.00	42.00	560.06	558.00
15090.000	2760.33	561.03	6.69	25.00	8.23	106.63	421.00	42.00	560.11	560.42
15420.000	2753.28	561.41	7.44	25.00	7.21	99.71	338.00	42.00	562.50	560.00
15860.000	2644.87	562.21	8.37	25.00	6.41	170.23	291.00	42.00	562.00	560.13
16290.000	2770.00	563.40	8.65	25.00	5.90	82.26	210.00	42.00	564.00	564.00
16475.000	2770.00	564.05	11.59	25.00	5.05	53.95	363.00	42.00	568.30	565.50
* 1610.000	2770.00	565.60	8.78	25.00	6.50	55.26	1350.00	42.00	566.62	566.10
* 16850.000	2770.00	565.95	13.01	45.00	5.25	51.02	1975.00	.00	566.70	566.70
* 16910.000	2770.00	569.13	12.03	45.00	7.53	52.19	1975.00	.00	572.50	571.73
* 17390.000	1848.22	575.24	5.80	45.00	8.04	575.04	1975.00	-385.00	573.60	573.80
17790.000	2198.53	576.37	5.29	45.00	8.67	419.46	1975.00	-275.00	575.20	571.50
17845.000	1439.14	576.79	3.23	45.00	9.09	516.09	1975.00	-275.00	575.20	571.50
17895.000	1382.71	576.91	3.05	45.00	9.21	544.25	1975.00	-275.00	575.20	571.50
17945.000	2261.96	576.93	4.73	45.00	8.53	259.83	1975.00	-505.00	572.00	572.00
* 18130.000	2750.18	577.31	6.47	45.00	7.01	139.82	1975.00	-598.00	576.40	576.60
18725.000	2330.69	580.36	7.28	45.00	6.86	321.69	1975.00	-275.00	577.40	578.70
19150.000	962.28	582.69	4.45	45.00	8.49	253.58	1975.00	.00	585.50	585.73
* 19180.000	502.20	582.72	2.31	45.00	8.52	256.51	1975.00	.00	585.50	585.73
* 19230.000	461.14	583.66	1.72	45.00	9.46	539.33	1975.00	.00	585.50	585.73
* 19280.000	2466.76	583.53	8.43	45.00	9.03	151.22	1975.00	-325.00	580.00	580.00
19400.000	2608.85	584.19	10.08	45.00	8.19	103.44	1975.00	-325.00	581.50	581.50
* 19500.000	2178.92	586.49	4.44	45.00	9.19	290.08	1975.00	-675.00	583.30	584.60
* 19790.000	2351.27	587.10	5.69	45.00	8.20	297.97	1975.00	-675.00	584.90	586.20
20100.000	2716.55	588.25	6.25	45.00	8.75	231.28	1975.00	-675.00	587.40	587.00

SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
20225.000	2749.95	588.85	6.74	45.00	8.45	175.82	1975.00	-675.00	588.30	587.90
20350.000	2750.07	589.55	6.74	45.00	8.45	175.55	1975.00	-675.00	589.00	588.60
20550.000	2706.28	590.71	6.23	45.00	9.01	300.00	1975.00	-675.00	590.30	589.40
20700.000	2733.81	591.38	6.46	45.00	8.88	300.00	1975.00	-675.00	591.10	590.20
20900.000	1475.20	592.63	5.41	45.00	9.33	198.97	1975.00	-475.00	585.60	594.20
21080.000	1519.04	593.14	5.86	45.00	9.04	173.06	1975.00	-475.00	586.40	595.00

THIS RUN EXECUTED 13FEB92 12:03:20

****
HEC-2 WATER SURFACE PROFILES

Version 4.6.0; February 1991
****

NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

PROPOSED IMPROVEMENTS FOR SULPHUR BRANCH (MAIN CHANNEL)
100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	11290.000	8661.00	500.94	.00	.00	.00	.00	488.70	2.72	.00	.00	.00
*	11590.000	8661.00	501.91	.97	300.00	.00	.00	489.70	2.69	.33	.01	10.00
*	11790.000	8661.00	502.55	.64	200.00	.00	.00	490.40	2.68	.22	.01	16.76
*	11990.000	8661.00	503.61	1.06	200.00	.00	.00	491.00	3.66	.24	.02	22.05
	12040.000	8661.00	506.32	2.70	50.00	.00	.00	491.00	2.88	.06	.02	23.40
*	12090.000	7922.00	508.33	2.01	50.00	504.10	502.80	493.80	.87	.00	.02	25.65
	12100.000	7922.00	508.29	-.04	10.00	.00	.00	493.90	.92	.00	.02	26.20
	12140.000	7922.00	509.10	.81	40.00	.00	.00	494.10	.20	.01	.02	28.61
	12390.000	7922.00	509.23	.13	250.00	.00	.00	495.50	.14	.06	.05	47.15
*	12685.000	7922.00	509.21	-.02	260.00	.00	.00	497.00	.38	.10	.06	63.90
*	13255.000	7922.00	509.26	.05	410.00	.00	.00	499.40	1.22	.47	.07	77.82
	13400.000	7922.00	509.37	.12	145.00	.00	.00	500.20	1.88	.44	.08	80.57
	13440.000	7922.00	508.93	-.44	40.00	.00	.00	500.50	3.14	.19	.08	81.20
*	13478.000	7922.00	509.04	.11	38.00	.00	.00	500.70	3.82	.12	.08	81.70
*	13522.000	7834.00	511.42	2.38	44.00	511.90	510.90	500.90	2.00	.56	.08	82.30
	13552.000	7834.00	511.54	.12	30.00	.00	.00	501.00	1.92	.02	.08	82.84
	13585.000	7834.00	512.90	1.36	33.00	.00	.00	501.20	.90	.03	.08	83.64

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	14315.000	7834.00	513.59	.69	730.00	.00	.00	505.00	2.25	1.64	.10	99.56
	14665.000	7834.00	515.27	1.68	350.00	.00	.00	506.80	2.28	1.70	.11	105.12
*	15040.000	7834.00	516.32	1.05	375.00	.00	.00	508.80	2.72	1.05	.12	111.00
*	15070.000	7834.00	517.78	1.46	30.00	.00	.00	509.00	1.62	.04	.12	111.52
	15107.000	7628.00	517.64	-.14	37.00	.00	.00	509.20	1.98	.04	.12	112.19
	15157.000	7628.00	517.66	.02	50.00	.00	.00	509.40	2.08	.07	.12	112.96
	15207.000	7628.00	517.74	.07	50.00	.00	.00	509.50	2.09	.07	.12	113.73
*	15265.000	5140.00	519.69	1.95	58.00	.00	.00	509.70	.61	.04	.12	114.73
	15310.000	5140.00	519.69	.00	45.00	.00	.00	509.90	.65	.01	.12	115.58
	15354.000	5140.00	519.69	.01	44.00	.00	.00	510.00	.66	.01	.13	116.39
*	15406.000	5140.00	521.66	1.96	52.00	522.00	520.20	510.20	.35	1.66	.13	117.77
	15470.000	5140.00	521.57	-.08	64.00	.00	.00	510.50	.53	.01	.13	119.89
	15670.000	5140.00	521.55	-.02	200.00	.00	.00	511.50	.67	.05	.14	124.84
	16000.000	5140.00	521.03	-.52	330.00	.00	.00	514.50	2.53	.26	.15	129.66
*	16100.000	5140.00	521.98	.95	100.00	.00	.00	515.40	2.49	.80	.15	130.59
*	16200.000	5140.00	523.51	1.53	100.00	.00	.00	516.30	3.07	.82	.15	131.48
*	16270.000	5140.00	524.18	.68	70.00	.00	.00	517.00	3.07	.59	.15	132.07
*	16340.000	5140.00	527.26	3.08	70.00	.00	.00	517.60	.88	.23	.16	132.93
*	16570.000	5140.00	527.50	.24	230.00	.00	.00	519.60	1.51	.56	.16	136.19
*	16830.000	5140.00	528.29	.78	230.00	.00	.00	521.70	2.43	1.21	.17	138.70
	17090.000	5140.00	530.79	2.50	260.00	.00	.00	524.10	1.84	1.73	.17	141.48
*	17350.000	5140.00	532.93	2.14	260.00	.00	.00	526.40	2.47	1.65	.18	144.30
*	17480.000	5140.00	533.95	1.03	130.00	.00	.00	527.60	2.42	.96	.18	145.56
*	17610.000	5140.00	536.22	2.27	130.00	.00	.00	528.80	1.14	.60	.19	147.13
	17665.000	5140.00	536.38	.15	55.00	.00	.00	529.30	1.20	.19	.19	147.97
	17720.000	5140.00	536.28	-.09	55.00	.00	.00	529.80	1.90	.25	.19	148.74

SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
17870.000	5140.00	537.88	1.59	150.00	.00	.00	530.80	1.29	.81	.20	150.99
* 18190.000	5140.00	539.19	1.31	165.00	.00	.00	532.60	2.48	.98	.20	153.17
* 18240.000	5140.00	540.72	1.53	170.00	.00	.00	534.10	2.22	1.20	.20	155.01
18395.000	5140.00	542.53	1.81	155.00	.00	.00	535.50	1.47	.83	.21	157.18
* 18550.000	5140.00	543.46	.93	155.00	.00	.00	536.90	2.00	.40	.21	159.73
* 18705.000	5140.00	545.20	1.74	155.00	.00	.00	538.30	2.05	.30	.22	161.89
* 18730.000	5140.00	546.30	1.10	25.00	.00	.00	538.60	2.67	.05	.22	162.21
* 18755.000	5140.00	548.99	2.70	25.00	.00	.00	538.80	.43	.01	.22	162.66
18845.000	4514.00	550.69	1.70	90.00	550.80	549.30	539.30	.39	1.65	.22	164.60
18865.000	4514.00	550.67	-.03	20.00	.00	.00	539.40	.43	.00	.22	165.08
18985.000	4514.00	550.55	-.12	120.00	.00	.00	540.20	.67	.02	.23	167.99
19200.000	4514.00	550.54	-.01	215.00	.00	.00	541.70	.81	.07	.24	172.15
19340.000	4514.00	550.48	-.06	140.00	.00	.00	542.70	1.01	.07	.24	174.58
* 19480.000	4514.00	550.06	-.41	140.00	.00	.00	543.60	1.91	.12	.25	176.40
19540.000	4514.00	549.91	-.16	60.00	.00	.00	544.00	2.32	.09	.25	176.93
19585.000	4514.00	550.53	.62	45.00	.00	.00	544.30	1.87	.07	.25	177.34
* 19927.000	4328.00	554.55	4.02	342.00	561.00	554.00	546.00	.85	3.01	.26	181.25
19977.000	4328.00	554.42	-.13	50.00	.00	.00	546.30	1.07	.02	.26	181.93
* 20130.000	4328.00	554.33	-.09	153.00	.00	.00	547.00	1.97	.12	.27	184.13
* 20480.000	4328.00	555.67	1.34	350.00	.00	.00	548.80	2.10	.55	.27	188.59
* 20560.000	4328.00	556.32	.65	80.00	.00	.00	549.20	2.69	.15	.28	189.35
* 20740.000	4328.00	557.12	.80	185.00	.00	.00	550.00	2.47	.29	.28	191.31
* 20935.000	4328.00	557.74	.62	190.00	.00	.00	550.80	2.98	.32	.28	193.16
* 21080.000	4328.00	558.53	.79	145.00	.00	.00	551.50	2.89	.29	.29	194.25
* 21240.000	4328.00	559.47	.95	160.00	.00	.00	552.60	3.07	.33	.29	195.40
* 21280.000	4328.00	559.66	.19	40.00	.00	.00	552.80	3.08	.08	.29	195.69

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	21320.000	4328.00	559.86	.20	40.00	.00	.00	553.00	3.08	.08	.29	195.97
*	21365.000	4328.00	560.07	.20	45.00	.00	.00	553.20	3.08	.09	.29	196.29
*	21405.000	4328.00	560.98	.91	40.00	.00	.00	553.40	3.53	.08	.29	196.57
*	21465.000	3823.00	562.96	1.98	60.00	562.70	561.80	553.80	1.55	.00	.30	197.03
	21550.000	3823.00	562.86	-.10	85.00	.00	.00	554.10	1.85	.11	.30	197.76
	22160.000	3823.00	563.33	.48	610.00	.00	.00	555.40	2.50	.93	.31	202.34
*	22435.000	3823.00	563.68	.35	275.00	.00	.00	556.40	3.08	.51	.32	204.15
*	22710.000	3823.00	564.69	1.01	275.00	.00	.00	557.40	3.07	.59	.32	205.87
*	23015.000	3823.00	566.08	1.40	305.00	.00	.00	558.80	3.08	.65	.33	207.77
*	23265.000	3823.00	567.19	1.10	250.00	.00	.00	559.90	3.08	.54	.33	209.33
*	23320.000	3823.00	567.49	.30	55.00	.00	.00	560.20	3.08	.12	.33	209.67
	23362.000	3823.00	568.14	.65	42.00	.00	.00	560.40	2.56	.08	.33	209.94
*	23418.000	3823.00	570.65	2.52	56.00	571.80	570.70	560.70	1.34	1.30	.34	210.40
	23475.000	3823.00	570.67	.02	57.00	.00	.00	560.80	1.36	.04	.34	210.94
*	23755.000	3823.00	570.27	-.41	280.00	.00	.00	563.00	2.86	.32	.34	213.16
*	24040.000	3823.00	572.33	2.06	285.00	.00	.00	565.20	3.02	.61	.35	214.98
*	24245.000	3823.00	573.92	1.59	205.00	.00	.00	566.80	3.03	.44	.35	216.26
*	24450.000	3823.00	575.52	1.60	205.00	.00	.00	568.40	3.03	.44	.36	217.55
*	24475.000	3823.00	575.72	.20	25.00	.00	.00	568.60	3.03	.05	.36	217.71
*	24525.000	3823.00	577.20	1.47	50.00	577.00	576.00	569.00	2.10	.54	.36	218.06
	24550.000	3823.00	577.08	-.11	25.00	.00	.00	569.20	2.31	.04	.36	218.25
*	24600.000	3823.00	576.85	-.24	50.00	.00	.00	569.60	2.84	.09	.36	218.60
*	24820.000	3823.00	578.47	1.63	220.00	.00	.00	571.30	2.72	.45	.37	220.10
*	25020.000	3823.00	580.01	1.54	200.00	.00	.00	572.90	3.04	.41	.37	221.44
*	25045.000	3823.00	580.22	.21	25.00	.00	.00	573.10	3.03	.05	.37	221.60
*	25095.000	3823.00	580.52	.30	50.00	.00	.00	573.40	3.03	.11	.37	221.91

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	25185.000	2119.00	582.32	1.80	90.00	582.10	581.10	574.10	1.23	.00	.37	222.44
	25220.000	2119.00	582.24	-.08	35.00	.00	.00	574.40	1.39	.03	.37	222.62
	25285.000	2119.00	582.07	-.17	65.00	.00	.00	574.90	1.74	.08	.38	222.94
*	25385.000	2119.00	581.89	-.18	100.00	.00	.00	575.70	2.52	.18	.38	223.36
*	25485.000	2119.00	582.57	.68	100.00	.00	.00	576.40	2.54	.23	.38	223.74
*	25585.000	2119.00	583.37	.80	100.00	.00	.00	577.20	2.53	.23	.38	224.12
*	25685.000	2119.00	584.75	1.38	100.00	.00	.00	578.00	1.77	.24	.39	224.54
*	25785.000	2119.00	585.01	.26	100.00	.00	.00	578.80	2.22	.23	.39	224.99
*	25885.000	2119.00	585.94	.93	100.00	.00	.00	579.60	2.26	.22	.39	225.42
*	25985.000	2119.00	586.62	.68	100.00	.00	.00	580.30	2.19	.22	.39	225.85
*	26073.000	2119.00	587.45	.84	88.00	.00	.00	581.20	1.99	.18	.39	226.27
*	26108.000	2119.00	587.57	.12	35.00	588.10	587.40	581.40	2.56	.07	.40	226.43
	26148.000	2119.00	587.66	.09	40.00	.00	.00	581.50	2.56	.09	.40	226.59
*	26185.000	2119.00	587.75	.09	37.00	.00	.00	581.60	2.56	.08	.40	226.73
*	26385.000	2119.00	589.46	1.71	200.00	.00	.00	582.10	1.25	.26	.40	228.13
*	26550.000	2119.00	589.08	-.38	165.00	.00	.00	582.60	2.13	.19	.41	229.43
*	26700.000	500.00	591.42	2.35	150.00	.00	.00	584.60	.05	.06	.43	230.94
*	26850.000	500.00	591.33	-.09	150.00	.00	.00	586.70	.20	.01	.44	232.27
*	27000.000	500.00	591.17	-.16	150.00	.00	.00	587.90	.54	.08	.45	232.66
*	27150.000	500.00	592.13	.96	150.00	.00	.00	589.00	1.05	.25	.46	232.91
*	27315.000	500.00	596.02	3.89	165.00	.00	.00	592.90	1.07	.45	.46	233.13
*	27485.000	500.00	600.12	4.10	170.00	.00	.00	597.00	1.06	.46	.47	233.37
*	27630.000	500.00	604.41	4.29	145.00	.00	.00	598.00	.94	.32	.47	233.78

00% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	11290.000	7297.41	500.94	14.41	15.00	12.24	404.43	1243.00	25.00	496.26	497.40
*	11590.000	7245.55	501.91	14.37	15.00	12.21	408.54	1243.00	25.00	497.15	498.30
*	11790.000	7205.80	502.55	14.39	15.00	12.15	411.01	1243.00	25.00	497.74	498.90
*	11990.000	8192.89	503.61	15.79	15.00	12.61	247.34	1242.00	25.00	496.96	502.04
*	12040.000	6473.52	506.32	15.71	15.00	15.32	363.76	1242.00	.00	496.90	501.90
*	12090.000	6206.86	508.33	8.43	15.00	14.53	400.11	1242.00	37.50	496.98	502.09
	12100.000	6120.36	508.29	8.75	15.00	14.39	399.39	1242.00	40.00	496.98	502.02
	12140.000	6805.68	509.10	3.86	30.00	15.00	413.96	1242.00	50.00	538.64	502.71
	12390.000	4740.94	509.23	3.73	30.00	13.73	503.35	1080.00	50.00	509.25	500.00
*	12685.000	6941.24	509.21	5.29	30.00	12.21	414.38	1408.00	50.00	504.00	501.25
*	13255.000	7913.30	509.26	8.89	30.00	9.86	157.68	1150.00	50.00	508.00	508.59
	13400.000	7848.14	509.37	11.04	30.00	9.17	124.29	1118.00	50.00	506.91	509.42
	13440.000	7381.80	508.93	14.68	30.00	8.43	107.34	1118.00	51.50	501.84	509.24
*	13478.000	7922.00	509.04	15.69	15.00	8.34	66.93	1118.00	52.70	501.85	509.24
*	13522.000	7834.00	511.42	11.34	15.00	10.52	74.00	1141.00	52.70	510.80	505.20
	13552.000	7621.89	511.54	11.27	15.00	10.54	204.29	1141.00	51.50	510.76	504.92
	13585.000	7432.75	512.90	7.81	30.00	11.70	250.21	1141.00	50.00	510.53	508.11
*	14315.000	7834.00	513.59	12.04	30.00	8.59	104.51	1118.00	50.00	513.50	513.53
	14665.000	7668.28	515.27	12.24	30.00	8.47	215.76	1118.00	50.00	513.13	513.32
*	15040.000	7783.65	516.32	13.28	15.00	7.52	148.66	1095.00	50.00	515.48	513.40
*	15070.000	7705.97	517.78	10.31	15.00	8.78	193.32	1095.00	53.50	515.55	513.40
	15107.000	7624.61	517.64	11.29	15.00	8.44	149.58	1085.00	57.00	517.85	517.00
	15157.000	7624.20	517.66	11.59	15.00	8.26	149.99	1085.00	57.00	517.85	517.00
	15207.000	7622.97	517.74	11.60	15.00	8.24	153.00	1085.00	57.00	517.84	517.00

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	15265.000	5135.25	519.69	6.28	15.00	9.99	128.98	1090.00	57.00	518.74	519.18
	15310.000	5134.90	519.69	6.45	15.00	9.79	128.88	1090.00	57.00	518.74	519.14
	15354.000	5140.00	519.69	6.51	15.00	9.69	102.18	1090.00	57.30	518.74	519.13
*	15406.000	4707.14	521.66	4.96	15.00	11.46	269.49	1320.00	57.30	515.72	522.79
	15470.000	4588.16	521.57	6.20	15.00	11.07	242.34	1320.00	57.30	515.68	522.55
	15670.000	5078.19	521.55	6.61	15.00	10.05	137.64	1305.00	57.30	524.34	518.46
*	16000.000	5140.00	521.03	12.78	30.00	6.53	80.60	1290.00	42.00	526.51	520.83
*	16100.000	5140.00	521.98	12.65	30.00	6.58	80.74	1290.00	42.00	526.55	521.73
*	16200.000	5138.52	523.51	14.06	30.00	7.21	64.24	1019.00	40.00	542.50	522.83
*	16270.000	5125.85	524.18	14.07	30.00	7.18	68.89	1019.00	40.00	542.50	522.60
*	16340.000	5130.12	527.26	7.51	30.00	9.66	109.43	1165.00	42.00	544.62	525.86
*	16570.000	5097.43	527.50	9.91	30.00	7.90	106.00	1165.00	42.00	544.38	525.64
*	16830.000	5139.63	528.29	12.51	30.00	6.59	90.76	1090.00	42.00	537.99	528.00
	17090.000	4993.26	530.79	11.03	30.00	6.69	126.92	1090.00	42.00	537.39	528.00
*	17350.000	5057.91	532.93	12.70	30.00	6.53	92.89	1120.00	42.00	546.00	530.00
*	17480.000	4965.94	533.95	12.69	30.00	6.35	94.93	1120.00	42.00	546.00	530.00
*	17610.000	4860.82	536.22	8.77	30.00	7.42	145.01	1160.00	42.00	548.59	532.00
	17665.000	4820.14	536.38	9.06	30.00	7.08	145.03	1160.00	42.00	548.49	532.00
	17720.000	4405.31	536.28	11.84	30.00	6.48	141.63	1072.00	42.00	546.80	532.07
	17870.000	3513.14	537.88	10.68	30.00	7.08	160.88	1072.00	42.00	546.76	531.10
*	18190.000	5117.37	539.19	12.66	30.00	6.59	104.88	1276.00	42.00	546.45	537.94
*	18240.000	4854.58	540.72	12.29	30.00	6.62	143.31	1261.00	42.00	548.07	537.63
	18395.000	4286.47	542.53	10.56	30.00	7.03	191.69	1261.00	42.00	547.56	537.52
*	18550.000	4533.35	543.46	12.06	15.00	6.56	254.95	1281.00	42.00	545.00	538.05
*	18705.000	5061.35	545.20	11.58	15.00	6.90	132.66	1310.00	36.00	542.50	554.50
*	18730.000	4542.02	546.30	13.94	15.00	7.70	138.16	1310.00	38.50	551.50	554.50

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	18755.000	5140.00	548.99	5.29	15.00	10.19	121.54	1285.00	52.70	542.50	552.45
	18845.000	4514.00	550.69	4.99	15.00	11.39	92.74	1255.00	52.70	542.50	553.13
	18865.000	4222.51	550.67	5.46	15.00	11.27	200.49	1240.00	52.70	542.50	551.90
	18985.000	4285.31	550.55	6.76	15.00	10.35	122.88	1215.00	52.70	544.53	554.00
	19200.000	4267.02	550.54	7.41	15.00	8.84	218.31	1110.00	52.70	553.66	546.00
	19340.000	4226.52	550.48	8.34	15.00	7.78	214.31	1110.00	52.70	553.41	546.00
*	19480.000	4514.00	550.06	11.08	15.00	6.46	75.86	1225.00	56.50	554.06	550.00
	19540.000	4514.00	549.91	12.23	15.00	5.91	68.33	1418.00	56.50	553.50	552.74
	19585.000	4514.00	550.53	10.96	15.00	6.23	72.44	1418.00	60.00	553.54	552.82
*	19927.000	4328.00	554.55	7.40	15.00	8.55	75.66	1500.00	60.00	554.57	553.11
	19977.000	4277.93	554.42	8.36	15.00	8.12	182.05	1500.00	55.00	554.17	553.08
*	20130.000	3860.43	554.33	11.91	15.00	7.33	284.05	1500.00	38.00	551.70	550.90
*	20480.000	4295.62	555.67	11.67	15.00	6.87	134.47	1116.00	38.00	553.93	554.70
	20560.000	4242.42	556.32	13.30	15.00	7.12	142.73	1400.00	38.00	554.13	554.00
*	20740.000	4116.08	557.12	12.93	15.00	7.12	194.04	1400.00	38.00	554.10	554.00
*	20935.000	4308.76	557.74	13.89	15.00	6.94	87.90	1475.00	38.00	556.22	556.65
*	21080.000	4327.98	558.53	13.65	15.00	7.03	56.85	1360.00	38.00	558.39	560.00
*	21240.000	4326.68	559.47	14.06	15.00	6.87	56.06	1133.00	38.00	558.72	558.50
*	21280.000	4326.43	559.66	14.10	15.00	6.86	56.31	1133.00	38.00	558.86	558.63
*	21320.000	4326.42	559.86	14.09	15.00	6.86	56.34	1133.00	38.00	559.06	558.83
*	21365.000	4326.71	560.07	14.08	15.00	6.87	55.99	1133.00	38.00	559.33	559.10
*	21405.000	4328.00	560.98	15.09	15.00	7.58	40.94	1133.00	31.30	558.38	558.05
*	21465.000	3820.89	562.96	10.00	15.00	9.16	106.84	1350.00	31.30	562.20	563.60
	21550.000	3821.59	562.86	10.93	15.00	8.76	85.72	1350.00	30.00	562.20	563.60
	22160.000	3823.00	563.33	12.70	15.00	7.93	45.87	1141.00	30.00	566.51	568.70
*	22435.000	3823.00	563.68	14.09	15.00	7.28	44.55	1141.00	30.00	566.43	568.70

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	22710.000	3823.00	564.69	14.07	15.00	7.29	44.57	1240.00	30.00	569.78	574.00
*	23015.000	3823.00	566.08	14.08	15.00	7.28	44.57	1240.00	30.00	569.74	574.00
*	23265.000	3823.00	567.19	14.07	15.00	7.29	44.57	1427.00	30.00	573.72	576.10
*	23320.000	3823.00	567.49	14.07	15.00	7.29	44.57	1427.00	30.00	573.71	576.10
	23362.000	3823.00	568.14	12.83	15.00	7.74	46.27	1427.00	30.80	573.72	576.10
*	23418.000	3823.00	570.65	9.28	15.00	9.95	52.25	1317.00	31.30	570.00	570.30
	23475.000	3822.76	570.67	9.38	15.00	9.87	56.75	1317.00	31.30	570.00	570.28
*	23755.000	3822.93	570.27	13.58	15.00	7.27	52.69	1317.00	31.30	570.00	570.00
*	24040.000	3823.00	572.33	13.96	15.00	7.13	45.56	1292.00	31.30	575.90	576.71
*	24245.000	3823.00	573.92	13.98	15.00	7.12	45.54	1292.00	31.30	575.90	576.70
*	24450.000	3823.00	575.52	13.97	15.00	7.12	45.54	1384.00	31.30	577.29	578.10
*	24475.000	3823.00	575.72	13.97	15.00	7.12	45.54	1384.00	31.30	577.28	578.10
*	24525.000	3817.59	577.20	11.64	15.00	8.20	67.95	1400.00	31.30	576.00	576.00
	24550.000	3819.51	577.08	12.21	15.00	7.88	64.78	1400.00	31.30	576.10	576.10
*	24600.000	3821.67	576.85	13.53	15.00	7.25	59.68	1400.00	31.30	576.20	576.20
*	24820.000	3804.11	578.47	13.27	15.00	7.17	76.56	1400.00	31.30	576.70	576.70
*	25020.000	3823.00	580.01	14.00	15.00	7.11	45.52	1612.00	31.30	582.06	582.10
*	25045.000	3823.00	580.22	13.97	15.00	7.12	45.55	1612.00	31.30	582.05	582.10
*	25095.000	3823.00	580.52	13.98	15.00	7.12	45.54	1612.00	31.30	582.56	582.60
*	25185.000	2119.00	582.32	8.91	15.00	8.22	37.14	1442.00	20.70	583.70	583.40
	25220.000	2119.00	582.24	9.47	15.00	7.84	36.38	1442.00	20.70	583.70	583.40
	25285.000	2119.00	582.07	10.60	15.00	7.17	35.05	1400.00	20.70	583.30	584.20
*	25385.000	2119.00	581.89	12.74	15.00	6.19	33.07	1400.00	20.70	583.30	584.20
*	25485.000	2119.00	582.57	12.78	15.00	6.17	33.04	1400.00	20.70	584.10	584.00
*	25585.000	2119.00	583.37	12.77	15.00	6.17	33.05	1400.00	20.70	584.10	584.00
*	25685.000	2118.18	584.75	10.67	15.00	6.75	64.01	1400.00	20.70	584.70	584.10

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	25785.000	2108.82	585.01	11.99	15.00	6.21	57.39	1399.00	20.70	584.40	583.40
*	25885.000	2114.39	585.94	12.08	15.00	6.34	57.49	1399.00	20.70	584.80	585.20
*	25985.000	2108.32	586.62	11.92	15.00	6.32	65.84	1400.00	20.70	585.60	585.50
*	26073.000	2074.89	587.45	11.44	15.00	6.25	81.63	1400.00	20.70	585.60	585.50
*	26108.000	2119.00	587.57	12.84	15.00	6.17	31.44	1401.00	20.70	586.56	586.98
	26148.000	2113.26	587.66	12.85	15.00	6.16	43.68	1401.00	20.70	586.55	586.96
*	26185.000	2111.86	587.75	12.87	15.00	6.15	44.56	1401.00	20.70	586.54	586.94
*	26385.000	1889.73	589.46	9.50	15.00	7.36	179.89	1400.00	20.70	587.41	586.21
*	26550.000	2061.45	589.08	11.87	15.00	6.48	131.18	1397.00	20.70	587.81	586.80
*	26700.000	380.02	591.42	2.09	15.00	6.82	210.00	1397.00	20.70	587.76	586.80
*	26850.000	500.00	591.33	3.61	15.00	4.63	43.79	1170.00	16.00	592.12	592.00
*	27000.000	500.00	591.17	5.91	15.00	3.27	35.65	1170.00	16.00	592.05	592.00
*	27150.000	500.00	592.13	8.24	15.00	3.13	28.78	1167.00	10.00	598.10	598.00
*	27315.000	500.00	596.02	8.29	15.00	3.12	28.70	1167.00	10.00	598.00	598.00
*	27485.000	500.00	600.12	8.28	15.00	3.12	28.72	1228.00	10.00	604.60	602.84
*	27630.000	359.17	604.41	9.14	15.00	6.41	129.59	.00	.01	602.00	602.00

THIS RUN EXECUTED 9APR92 9:23:36

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HEC-2 WATER SURFACE PROFILES

Version 4.6.0; February 1991
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

PROPOSED IMPROVEMENTS FOR SULPHUR BRANCH TRIBUTARY

100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	65.000	2170.00	517.64	.00	.00	.00	.00	510.30	.68	.00	.00	.00
	155.000	2170.00	517.40	-.24	85.00	.00	.00	511.10	1.11	.06	.00	.59
*	275.000	2170.00	518.10	.70	110.00	.00	.00	513.40	2.12	.15	.01	1.15
*	325.000	2170.00	519.05	.96	50.00	.00	.00	514.40	2.17	.12	.01	1.37
	365.000	2170.00	519.34	.28	40.00	.00	.00	515.10	2.00	.10	.01	1.54
*	410.000	2170.00	520.98	1.65	45.00	524.20	522.40	515.40	1.10	.75	.01	1.77
*	450.000	2170.00	520.49	-.49	40.00	.00	.00	515.70	2.10	.06	.01	1.97
*	480.000	2170.00	521.35	.86	30.00	.00	.00	516.00	2.25	.07	.01	2.10
*	545.000	2170.00	523.01	1.65	65.00	.00	.00	516.60	.81	.07	.01	2.46
*	590.000	2170.00	522.19	-.81	45.00	.00	.00	517.00	2.04	.05	.01	2.71
*	610.000	2170.00	523.24	1.05	20.00	.00	.00	517.20	1.11	.03	.01	2.81
	670.000	2170.00	523.54	.30	60.00	.00	.00	517.70	.88	.05	.02	3.19
	715.000	2170.00	523.76	.23	45.00	527.70	524.90	518.00	.91	.25	.02	3.49
*	765.000	2170.00	523.32	-.45	50.00	.00	.00	518.20	1.62	.05	.02	3.77
*	1065.000	2170.00	523.99	.67	300.00	.00	.00	519.00	2.09	.59	.03	5.15
*	1380.000	2170.00	527.50	3.51	270.00	.00	.00	522.60	1.64	.52	.03	6.93
*	1410.000	2170.00	528.61	1.11	30.00	.00	.00	523.00	2.18	.06	.04	7.14

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	1440.000	2170.00	529.32	.70	30.00	.00	.00	523.20	2.43	.07	.04	7.28
*	1475.000	2170.00	531.90	2.59	35.00	534.40	533.30	523.30	1.00	1.15	.04	7.46
	1505.000	2170.00	531.88	-.03	30.00	.00	.00	523.30	1.07	.02	.04	7.64
	1560.000	2170.00	531.81	-.06	55.00	.00	.00	523.70	1.22	.04	.04	7.96
	1730.000	2170.00	531.73	-.09	170.00	.00	.00	524.40	1.60	.18	.04	8.87
	1800.000	2170.00	531.89	.16	70.00	.00	.00	524.70	1.53	.09	.05	9.28
	1835.000	2170.00	531.70	-.19	45.00	.00	.00	524.80	1.88	.06	.05	9.53
*	1865.000	2170.00	534.34	2.63	30.00	534.70	532.90	524.90	.68	1.43	.05	9.71
	1940.000	2170.00	534.30	-.04	75.00	.00	.00	525.60	.88	.10	.05	10.25
*	2240.000	2170.00	534.51	.21	300.00	.00	.00	528.30	2.46	.59	.06	11.85
*	2600.000	2170.00	537.82	3.31	350.00	.00	.00	531.60	1.94	.73	.07	13.67
*	2620.000	2170.00	537.89	.07	20.00	.00	.00	531.80	2.46	.04	.07	13.77
*	2662.000	2170.00	541.08	3.19	42.00	540.80	540.20	532.20	.79	1.52	.07	14.01
	2780.000	2170.00	540.96	-.11	120.00	.00	.00	533.30	1.09	.09	.07	14.98
*	2980.000	2170.00	541.37	.41	200.00	.00	.00	535.10	1.85	.26	.08	16.33
*	3210.000	2170.00	543.24	1.87	230.00	.00	.00	537.10	2.40	.49	.08	17.47
*	3285.000	2170.00	544.38	1.14	75.00	.00	.00	537.80	1.89	.17	.09	17.83
*	3335.000	2016.00	547.04	2.66	50.00	545.90	545.20	538.20	.57	1.34	.09	18.17
*	3410.000	2016.00	546.46	-.58	75.00	.00	.00	539.40	1.46	.05	.09	18.73
*	3550.000	2016.00	547.77	1.31	140.00	.00	.00	541.80	2.31	.21	.09	19.42
*	3605.000	2016.00	548.56	.79	55.00	.00	.00	542.70	2.34	.12	.09	19.64
*	3675.000	2016.00	551.39	2.83	50.00	550.10	551.30	545.30	1.50	.11	.10	19.89
*	3750.000	2016.00	553.40	2.01	75.00	.00	.00	546.40	2.66	.16	.10	20.26
*	3840.000	2016.00	554.68	1.28	90.00	.00	.00	547.70	2.68	.22	.10	20.57
*	3890.000	2016.00	555.29	.61	50.00	.00	.00	548.40	2.78	.12	.10	20.75
*	4010.000	2016.00	557.30	2.01	120.00	.00	.00	550.20	1.77	.29	.10	21.26

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	4410.000	2016.00	561.65	4.35	400.00	.00	.00	556.00	1.77	.92	.11	23.28
*	4460.000	2016.00	563.13	1.48	50.00	.00	.00	556.70	.67	.05	.12	23.58
*	4790.000	1832.00	567.05	3.92	330.00	571.70	564.10	564.00	.78	.28	.13	26.38
*	4860.000	1832.00	567.04	-.01	70.00	.00	.00	564.00	1.07	.13	.13	27.14
*	5075.000	1832.00	569.48	2.44	215.00	566.60	565.90	560.90	.22	1.59	.15	29.86
*	5160.000	1832.00	569.51	.03	230.00	.00	.00	562.70	.45	.19	.16	32.51
*	5840.000	1832.00	572.76	3.25	530.00	.00	.00	568.10	1.48	1.51	.18	36.10
	6200.000	1832.00	575.60	2.84	350.00	.00	.00	570.90	1.48	2.83	.19	37.69
*	6320.000	1832.00	576.69	1.10	120.00	.00	.00	571.90	1.77	.94	.19	38.23
	6860.000	1832.00	581.28	4.59	540.00	.00	.00	576.10	1.42	4.19	.21	40.50
*	7100.000	1832.00	582.81	1.53	240.00	.00	.00	578.00	1.74	.89	.21	41.51
*	7175.000	1832.00	583.42	.61	75.00	.00	.00	578.60	1.74	.17	.21	41.81
*	7225.000	860.00	583.42	.00	50.00	586.70	584.90	578.90	.26	.00	.22	42.03
	7300.000	860.00	585.06	1.65	75.00	.00	.00	580.00	.20	.10	.22	42.47
*	7400.000	860.00	584.94	-.13	100.00	.00	.00	581.50	1.18	.29	.23	42.92
*	7700.000	860.00	588.56	3.63	300.00	.00	.00	586.00	1.03	1.32	.24	43.75
*	7840.000	860.00	590.94	2.37	100.00	.00	.00	587.50	1.18	.25	.24	44.02
	7890.000	860.00	594.32	3.38	50.00	593.70	592.10	588.10	.18	2.39	.24	44.23
*	7980.000	860.00	594.92	.60	90.00	.00	.00	589.20	.18	.60	.25	44.77
*	8420.000	860.00	596.53	1.61	440.00	.00	.00	594.20	.02	1.43	.36	49.89
*	8720.000	860.00	600.78	4.25	300.00	.00	.00	598.10	.38	1.44	.37	53.10
*	8770.000	860.00	602.20	1.42	50.00	.00	.00	598.70	.02	.26	.39	53.61
*	8790.000	860.00	603.93	1.73	20.00	602.80	602.10	599.90	.00	1.71	.40	54.14
	8840.000	860.00	603.94	.01	50.00	.00	.00	599.90	.00	.01	.42	55.97

100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
	65.000	2163.72	517.64	6.61	15.00	7.34	106.18	45.00	36.00	516.30	516.59
	155.000	2169.94	517.40	8.46	15.00	6.30	54.07	37.00	36.00	523.77	517.25
*	275.000	2170.00	518.10	11.68	15.00	4.70	43.78	45.00	36.00	519.72	518.90
*	325.000	2170.00	519.05	11.81	15.00	4.65	42.98	51.00	36.00	521.54	521.55
	365.000	2170.00	519.34	11.34	15.00	4.24	48.35	95.50	42.00	524.73	522.61
*	410.000	2170.00	520.98	8.42	15.00	5.58	50.37	165.70	42.00	524.48	524.25
*	450.000	2170.00	520.49	11.62	15.00	4.79	44.79	23.50	33.00	520.37	522.70
*	480.000	2170.00	521.35	12.03	15.00	5.35	40.38	26.50	27.00	524.67	522.70
*	545.000	2170.00	523.01	7.21	15.00	6.41	55.01	120.50	39.00	525.09	523.60
*	590.000	2170.00	522.19	11.45	15.00	5.19	42.98	38.00	30.00	532.33	530.13
*	610.000	2170.00	523.24	8.44	15.00	6.04	50.11	36.00	35.00	529.53	530.17
	670.000	2170.00	523.54	7.54	15.00	5.84	56.60	153.70	42.00	527.84	528.77
	715.000	2170.00	523.76	7.65	15.00	5.76	56.41	160.70	42.00	528.49	528.29
*	765.000	2170.00	523.32	10.22	15.00	5.12	51.69	83.60	31.20	525.20	525.20
*	1065.000	2170.00	523.99	11.60	15.00	4.99	44.97	280.00	30.00	526.00	526.00
*	1380.000	1915.62	527.50	10.94	15.00	4.90	181.80	1262.00	30.00	525.30	525.16
*	1410.000	2125.95	528.61	11.98	15.00	5.61	70.40	1262.00	25.00	530.00	527.14
*	1440.000	2170.00	529.32	12.52	15.00	6.12	35.99	222.00	20.70	532.75	532.03
*	1475.000	2170.00	531.90	8.02	15.00	8.60	42.21	1400.40	20.70	533.57	534.88
	1505.000	2170.00	531.88	8.30	15.00	8.58	41.19	1400.40	20.00	533.57	534.85
	1560.000	2168.84	531.81	8.88	15.00	8.11	48.54	1447.00	20.00	530.91	536.20
	1730.000	2170.00	531.73	10.15	15.00	7.33	38.32	1447.00	20.00	532.34	536.20
	1800.000	2062.54	531.89	10.18	15.00	7.19	91.50	1130.00	20.00	527.05	532.45
	1835.000	2170.00	531.70	11.00	15.00	6.90	35.66	1130.00	20.70	527.09	532.46

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	1865.000	2170.00	534.34	6.62	15.00	9.44	106.00	272.00	20.70	534.00	534.00
	1940.000	2168.90	534.30	7.54	15.00	8.70	143.04	272.00	20.00	534.00	534.00
*	2240.000	2170.00	534.51	12.59	15.00	6.21	35.52	147.00	20.00	538.00	538.00
*	2600.000	2080.80	537.82	11.42	15.00	6.22	115.69	1098.00	20.00	536.51	535.70
*	2620.000	2170.00	537.89	12.59	15.00	6.09	35.92	657.70	20.70	540.00	540.00
*	2662.000	2162.74	541.08	7.16	15.00	8.88	104.18	657.70	20.70	540.00	540.00
	2780.000	2035.73	540.96	8.63	15.00	7.66	99.66	1226.00	20.00	537.90	540.78
*	2980.000	2154.75	541.37	10.95	15.00	6.27	85.79	154.00	20.00	540.00	546.54
*	3210.000	2085.46	543.24	12.67	15.00	6.14	62.31	1189.00	20.00	538.93	542.43
*	3285.000	2170.00	544.38	11.03	15.00	6.58	54.00	388.70	20.70	544.00	544.00
*	3335.000	1989.76	547.04	6.09	15.00	8.84	142.74	388.70	20.70	544.00	544.00
*	3410.000	1976.33	546.46	9.79	15.00	7.06	68.22	1123.00	20.00	550.20	542.80
*	3550.000	2007.41	547.77	12.22	15.00	5.97	63.53	1154.00	20.00	546.00	547.05
*	3605.000	2016.00	548.56	12.27	15.00	5.86	35.35	471.50	20.70	550.00	550.00
*	3675.000	1971.74	551.39	9.93	15.00	6.09	159.45	471.50	20.70	550.00	550.00
*	3750.000	2016.00	553.40	13.10	15.00	7.00	29.00	198.00	15.00	554.00	554.00
*	3840.000	2016.00	554.68	13.14	15.00	6.98	28.96	188.00	15.00	556.00	556.00
*	3890.000	2016.00	555.29	13.38	15.00	6.89	28.77	188.00	15.00	556.00	556.00
*	4010.000	1994.46	557.30	10.75	15.00	7.10	99.35	265.00	15.00	556.00	556.00
*	4410.000	1966.99	561.65	10.81	15.00	5.65	73.18	1236.00	15.00	558.39	560.20
*	4460.000	2016.00	563.13	6.56	15.00	6.43	58.98	1236.00	30.30	559.53	560.20
*	4790.000	1170.24	567.05	8.73	15.00	3.05	348.85	1236.00	-228.85	564.00	564.00
*	4860.000	1369.55	567.04	9.59	15.00	3.04	300.98	1236.00	-262.25	564.00	564.00
*	5075.000	1775.27	569.48	3.83	30.00	8.58	237.69	366.00	21.50	567.02	568.17
*	5160.000	1696.47	569.51	5.56	30.00	6.81	114.82	1364.00	21.50	567.81	566.00
*	5840.000	1832.00	572.76	9.78	30.00	4.66	67.08	1255.00	21.50	572.70	573.70

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
	6200.000	1797.62	575.60	9.85	30.00	4.70	98.82	1544.00	21.50	574.60	574.04
*	6320.000	1826.90	576.69	10.70	30.00	4.79	56.74	1544.00	21.50	576.71	575.73
	6860.000	1832.00	581.28	9.55	30.00	5.18	52.58	122.00	21.50	582.00	582.10
*	7100.000	1832.00	582.81	10.59	15.00	4.81	50.37	109.00	21.50	584.00	584.03
*	7175.000	1832.00	583.42	10.57	15.00	4.82	50.41	132.50	21.50	586.03	586.01
*	7225.000	860.00	583.42	4.08	30.00	4.52	61.95	132.50	21.50	586.06	586.03
	7300.000	698.12	585.06	3.91	30.00	5.06	103.42	288.00	15.00	586.22	586.16
*	7400.000	860.00	584.94	8.70	30.00	3.44	42.50	224.00	15.00	587.44	588.90
*	7700.000	814.24	588.56	8.35	15.00	2.56	88.03	224.00	15.00	586.00	593.40
*	7840.000	860.00	590.94	8.71	15.00	3.44	42.49	313.00	15.00	592.23	592.05
	7890.000	845.84	594.32	3.46	75.00	6.22	119.35	359.00	15.00	594.03	593.01
*	7980.000	818.54	594.92	3.52	75.00	5.72	174.62	210.00	10.00	594.00	594.00
*	8420.000	164.61	596.53	1.25	75.00	2.33	463.02	1254.00	10.00	594.50	595.00
*	8720.000	428.92	600.78	5.76	75.00	2.68	290.74	1254.00	10.00	600.30	600.73
*	8770.000	220.19	602.20	1.43	75.00	3.50	452.78	1254.00	10.00	600.30	600.77
*	8790.000	153.26	603.93	.61	75.00	4.03	573.24	.00	.01	600.30	600.80
	8840.000	153.21	603.94	.61	75.00	4.04	573.45	.00	.01	600.30	600.80

THIS RUN EXECUTED 28JAN92 15:38:31

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HEC-2 WATER SURFACE PROFILES

Version 4.6.0; February 1991
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

PROPOSED IMPROVEMENTS FOR BEDFORD CREEK (MAIN CHANNEL)
100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	15530.000	5240.00	530.00	.00	.00	.00	.00	509.50	.06	.00	.00	.00
	15550.000	5240.00	530.01	.01	20.00	.00	.00	509.50	.05	.00	.00	2.47
	15580.000	5240.00	530.01	-.01	30.00	518.90	518.20	509.50	.06	.00	.01	6.21
*	15630.000	5240.00	530.00	-.01	50.00	.00	.00	509.50	.07	.00	.02	11.88
	15920.000	5240.00	530.08	.08	290.00	.00	.00	511.00	.03	.03	.08	42.72
	16020.000	5240.00	530.10	.02	100.00	.00	.00	511.50	.03	.02	.10	53.36
*	16620.000	5240.00	530.25	.15	600.00	.00	.00	513.60	.14	.23	.16	100.06
	16670.000	5240.00	530.30	.05	50.00	.00	.00	513.60	.13	.05	.17	102.79
	16760.000	5240.00	530.30	.00	90.00	526.50	525.00	513.60	.13	.00	.18	107.72
	16900.000	5240.00	530.44	.14	140.00	.00	.00	513.20	.15	.15	.19	113.99
*	17620.000	5240.00	532.35	1.92	720.00	.00	.00	518.50	.53	2.18	.23	139.04
*	17730.000	5240.00	531.67	-.69	110.00	.00	.00	521.20	3.05	.32	.23	141.16
*	17770.000	5240.00	534.39	2.72	40.00	.00	.00	521.40	.60	.02	.23	142.06
	17850.000	5240.00	534.38	-.01	80.00	.00	.00	521.70	.64	.02	.23	144.42
*	17890.000	5240.00	533.95	-.43	40.00	.00	.00	521.90	1.27	.02	.24	145.42
*	18360.000	5240.00	534.89	.94	470.00	.00	.00	524.00	1.19	.86	.25	153.59
*	19090.000	5240.00	536.31	1.42	730.00	.00	.00	526.00	1.64	1.73	.27	163.41

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	19130.000	5240.00	536.12	-.20	40.00	.00	.00	527.10	1.97	.04	.27	163.86
	19200.000	5240.00	535.78	-.34	70.00	.00	.00	527.60	2.59	.10	.27	164.57
*	19320.000	5240.00	537.43	1.65	120.00	.00	.00	529.60	2.56	.23	.28	165.71
*	19390.000	5240.00	538.93	1.51	70.00	.00	.00	529.60	1.53	.17	.28	166.47
*	19850.000	4800.00	544.44	5.50	460.00	554.00	540.50	531.00	.31	4.28	.31	174.89
	19950.000	4800.00	544.43	.00	100.00	.00	.00	531.80	.33	.01	.31	177.36
*	20360.000	4800.00	544.15	-.29	410.00	.00	.00	531.80	.86	.08	.33	186.72
*	20430.000	4800.00	544.32	.18	70.00	.00	.00	538.00	2.41	.05	.33	187.75
*	20530.000	4800.00	545.50	1.17	100.00	.00	.00	539.20	2.43	.20	.33	188.64
*	20595.000	4318.00	549.38	3.88	65.00	553.60	549.90	539.90	.65	2.10	.33	189.42
	20625.000	4318.00	549.36	-.02	30.00	.00	.00	540.10	.69	.01	.34	189.87
*	20780.000	4318.00	549.42	.07	185.00	.00	.00	541.50	.89	.20	.34	192.46
*	21400.000	4318.00	554.12	4.70	620.00	.00	.00	546.20	.54	4.31	.37	202.16
	22000.000	4318.00	557.74	3.62	600.00	.00	.00	550.70	.96	3.92	.39	211.37
*	22700.000	4318.00	562.93	5.19	700.00	.00	.00	556.00	.73	4.94	.42	223.01
	22950.000	4318.00	564.36	1.44	250.00	.00	.00	557.90	.77	1.46	.43	227.85
*	23000.000	4318.00	563.84	-.53	25.00	.00	.00	558.30	1.98	.08	.43	228.19
*	23080.000	2600.00	566.36	2.52	80.00	567.10	566.70	558.70	.31	.86	.44	229.07
	23090.000	2600.00	566.36	.00	35.00	.00	.00	558.90	.32	.01	.44	229.57
	23190.000	2600.00	566.34	-.02	100.00	.00	.00	559.40	.39	.02	.45	231.01
*	23525.000	2284.00	566.37	.03	335.00	.00	.00	560.90	.52	.12	.46	235.19
*	23700.000	2151.00	566.02	-.35	305.00	.00	.00	562.50	1.41	.27	.47	237.79
*	24700.000	1888.00	567.90	1.88	500.00	.00	.00	564.90	1.11	1.17	.49	240.62
*	25020.000	1888.00	568.89	.99	320.00	.00	.00	566.50	1.10	.82	.50	242.37
*	26140.000	1888.00	570.59	1.70	200.00	.00	.00	567.40	1.40	.49	.51	243.39
	26311.000	1229.00	571.88	1.28	171.00	.00	.00	568.20	.43	.22	.51	244.24

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
*	26620.000	1229.00	572.04	.16	278.00	.00	.00	569.60	1.10	.31	.52	245.46
*	26680.000	1229.00	574.06	2.02	330.00	.00	.00	571.20	1.22	.84	.53	246.54
*	26820.000	1229.00	574.85	.79	170.00	.00	.00	572.00	1.23	.43	.54	247.08
*	27130.000	1229.00	575.65	.80	150.00	.00	.00	572.80	1.22	.38	.54	247.55
*	27160.000	1186.00	576.29	.64	150.00	.00	.00	573.50	1.20	.38	.55	248.02
*	27161.000	1186.00	578.59	2.30	.00	.00	.00	573.50	1.60	.00	.55	248.02

100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
	15530.000	2812.69	530.00	2.60	20.00	20.50	586.36	.00	.01	519.10	518.30
	15550.000	3409.38	530.01	2.17	20.00	20.51	586.59	.00	.01	519.10	518.30
	15580.000	3059.63	530.01	2.44	20.00	20.51	586.57	.00	.01	519.10	518.30
*	15630.000	3050.23	530.00	2.82	25.00	20.50	550.37	.00	.01	519.10	518.30
*	15920.000	1518.80	530.08	1.96	55.00	19.08	623.18	.00	.01	521.40	519.80
	16020.000	1321.30	530.10	1.76	70.00	18.60	603.46	.00	.01	521.90	520.30
*	16620.000	3260.53	530.25	3.57	70.00	16.65	574.32	.00	.01	521.20	525.70
	16670.000	3238.68	530.30	3.53	70.00	16.70	575.84	.00	.01	521.20	525.70
	16760.000	3238.66	530.30	3.53	70.00	16.70	575.84	.00	.01	521.20	525.70
	16900.000	2050.71	530.44	4.26	70.00	17.24	423.41	.00	.01	522.30	523.00
*	17620.000	1589.12	532.35	8.02	70.00	13.85	282.38	.00	.01	524.00	526.40
*	17730.000	4710.61	531.67	14.78	15.00	10.47	175.42	1237.00	6.00	525.87	527.81
*	17770.000	4766.89	534.39	6.50	15.00	12.99	238.71	1447.00	25.00	526.34	535.67
	17850.000	4736.87	534.38	6.74	15.00	12.68	237.37	1447.00	25.00	526.37	535.64
*	17890.000	4716.87	533.95	9.52	15.00	12.05	179.09	1447.00	10.00	527.57	535.14
*	18360.000	2462.72	534.89	10.69	75.00	10.89	146.06	.00	.01	541.40	528.70
*	19090.000	5234.90	536.31	10.27	15.00	10.31	98.54	1418.00	19.00	535.13	534.75
	19130.000	5235.45	536.12	11.27	15.00	9.02	90.11	1418.00	25.00	535.05	534.60
	19200.000	5240.00	535.78	12.92	15.00	8.18	74.10	1760.00	25.00	544.01	536.00
*	19320.000	5233.76	537.43	12.84	15.00	7.83	92.87	.00	.01	538.00	536.00
*	19390.000	5240.00	538.93	9.93	30.00	9.33	80.00	.00	.01	538.00	536.00
*	19850.000	4800.00	544.44	4.49	15.00	13.44	109.19	2055.00	40.70	544.00	540.83
	19950.000	4789.65	544.43	4.64	15.00	12.63	173.78	1543.00	42.00	542.40	543.02
*	20360.000	4409.21	544.15	7.78	15.00	12.35	164.48	1543.00	42.00	542.40	531.80

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	20430.000	4800.00	544.32	12.45	15.00	6.32	79.93	1271.00	42.00	546.20	544.44
*	20530.000	4800.00	545.50	12.52	15.00	6.30	79.78	1393.00	42.00	550.00	553.56
*	20595.000	4318.00	549.38	6.47	15.00	9.48	98.87	1380.00	42.00	551.03	551.90
	20625.000	4318.00	549.36	6.68	15.00	9.26	97.55	1379.00	42.00	551.16	552.00
*	20780.000	4318.00	549.42	7.57	45.00	7.92	184.50	1245.00	42.00	550.06	549.70
*	21400.000	4064.09	554.12	6.04	45.00	7.92	247.86	1330.00	42.00	548.30	553.60
*	22000.000	4315.32	557.74	7.87	45.00	7.04	177.89	1286.00	42.00	558.11	557.40
*	22700.000	3206.83	562.93	7.83	45.00	6.93	281.44	1408.00	42.00	560.63	559.48
	22950.000	3142.41	564.36	8.09	45.00	6.46	248.79	1358.00	42.00	564.35	562.06
*	23000.000	4318.00	563.84	11.28	15.00	5.54	83.17	1356.00	52.70	565.67	562.92
*	23080.000	2600.00	566.36	4.49	15.00	7.66	96.34	1493.00	52.70	565.00	567.08
	23090.000	2576.31	566.36	4.60	15.00	7.46	212.52	1493.00	52.70	565.00	567.08
	23190.000	2573.76	566.34	5.02	15.00	6.94	209.66	1493.00	52.70	565.00	567.06
*	23525.000	2246.76	566.37	5.81	15.00	5.47	207.24	1493.00	52.70	565.00	567.00
*	23700.000	2114.32	566.02	9.60	15.00	3.52	120.57	1359.00	52.70	565.90	564.41
*	24700.000	1883.39	567.90	8.46	15.00	3.00	112.89	1266.00	52.70	566.70	569.34
*	25020.000	1863.50	568.89	8.46	15.00	2.39	120.66	1266.00	52.70	566.70	569.21
*	26140.000	1888.00	570.59	9.49	15.00	3.19	71.87	1243.00	52.70	574.40	575.30
	26311.000	1229.00	571.88	5.24	15.00	3.68	74.77	1243.00	52.70	574.40	575.30
*	26620.000	1229.00	572.04	8.41	15.00	2.44	67.32	1356.00	52.70	577.16	575.48
*	26680.000	1229.00	574.06	8.85	15.00	2.86	57.16	1356.00	40.00	576.74	578.90
*	26820.000	1229.00	574.85	8.88	15.00	2.85	57.10	1045.00	40.00	579.94	580.33
*	27130.000	1229.00	575.65	8.87	15.00	2.85	57.11	1045.00	40.00	579.80	581.13
*	27160.000	1186.00	576.29	8.78	15.00	2.79	56.76	1045.00	40.00	580.26	581.83
*	27161.000	1186.00	578.59	10.14	15.00	5.09	37.75	.00	.01	579.50	578.50

THIS RUN EXECUTED 4FEB92 13:05:14

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HEC-2 WATER SURFACE PROFILES

Version 4.6.0; February 1991
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NOTE- ASTERISK (*) AT LEFT OF CROSS-SECTION NUMBER INDICATES MESSAGE IN SUMMARY OF ERRORS LIST

PROPOSED IMPROVEMENTS FOR EAST BRANCH BEDFORD CREEK
100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	4010.000	2438.00	540.00	.00	.00	.00	.00	528.80	.13	.00	.00	.00
*	4940.000	2438.00	543.50	3.50	930.00	.00	.00	534.60	.26	3.59	.06	18.45
*	5360.000	2438.00	545.93	2.43	420.00	.00	.00	537.20	.18	2.34	.10	25.02
*	5800.000	2438.00	548.11	2.18	440.00	.00	.00	537.50	.90	2.68	.11	31.07
	5820.000	2438.00	548.46	.36	20.00	.00	.00	537.50	.76	.20	.11	31.24
*	6160.000	2438.00	549.69	1.23	340.00	560.40	546.70	540.70	.28	.75	.13	35.09
*	6225.000	2438.00	549.63	-.06	65.00	.00	.00	541.40	.40	.02	.14	35.88
*	6472.000	2438.00	549.73	.10	247.00	.00	.00	544.20	1.18	.65	.15	38.04
*	6720.000	2438.00	551.77	2.04	248.00	.00	.00	547.10	1.83	2.15	.15	39.48
	6990.000	2438.00	555.03	3.26	270.00	.00	.00	550.20	1.69	3.10	.16	40.90
	7160.000	2438.00	556.87	1.84	170.00	.00	.00	552.10	1.74	1.88	.16	41.81
*	7530.000	2438.00	561.07	4.20	370.00	.00	.00	556.30	1.47	3.70	.17	44.04
*	7615.000	2438.00	561.82	.75	85.00	.00	.00	557.30	1.83	.34	.18	44.52
*	7630.000	2438.00	562.57	.75	53.00	.00	.00	557.90	1.83	.12	.18	44.80
*	7705.000	1639.00	565.09	2.52	75.00	564.60	563.40	558.70	.95	1.64	.18	45.17
	7707.000	1639.00	565.40	.31	2.00	.00	.00	558.70	.72	.01	.18	45.18
*	7710.000	1639.00	566.16	.77	3.00	.00	.00	558.80	.03	.01	.18	45.23

	SECNO	Q	CWSEL	DIFWSX	XLCH	ELTRD	ELLC	ELMIN	HV	HL	TIME	VOL
	7755.000	1639.00	566.22	.06	45.00	.00	.00	559.00	.04	.06	.19	46.41
	8128.000	1639.00	566.66	.44	373.00	.00	.00	560.00	.04	.45	.24	53.29
*	8500.000	1639.00	567.31	.65	372.00	.00	.00	561.40	.08	.67	.27	58.99
*	8890.000	1639.00	568.10	.79	191.00	.00	.00	562.00	.68	1.09	.28	61.26
	8970.000	1133.00	568.10	.00	80.00	570.80	570.70	562.70	.46	.00	.29	61.68
*	9020.000	1133.00	568.80	.70	50.00	.00	.00	566.00	.31	.29	.29	61.94
*	9070.000	1133.00	570.86	2.06	50.00	.00	.00	566.00	.70	1.59	.29	62.20
*	9230.000	1133.00	573.29	2.43	160.00	.00	.00	567.40	.19	1.87	.30	63.24
	9390.000	1133.00	574.14	.85	160.00	.00	.00	568.70	.34	.96	.31	64.44
	9840.000	1133.00	577.52	3.38	450.00	.00	.00	572.50	1.02	3.86	.33	66.74
*	10140.000	1133.00	580.17	2.65	300.00	.00	.00	574.10	.54	2.12	.34	67.89
	10540.000	1133.00	582.10	1.93	400.00	.00	.00	576.80	.75	2.08	.36	69.55
	11050.000	651.00	584.76	2.66	510.00	.00	.00	576.60	.17	2.03	.40	71.80
*	11170.000	651.00	587.66	2.89	120.00	.00	.00	585.90	.29	.92	.41	72.31

100% URBAN, 100-YR FREQ.

SUMMARY PRINTOUT

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
	4010.000	1124.75	540.00	3.99	70.00	11.20	380.00	.00	.01	533.90	534.20
*	4940.000	546.58	543.50	6.15	70.00	8.90	293.92	.00	.01	547.20	538.90
*	5360.000	845.00	545.93	4.87	70.00	8.73	315.07	.00	.01	540.20	539.00
*	5800.000	2391.65	548.11	7.67	70.00	10.61	139.42	.00	.01	546.90	547.50
	5820.000	2339.56	548.46	7.14	70.00	10.96	185.28	.00	.01	546.90	547.50
*	6160.000	2438.00	549.69	4.24	15.00	8.99	64.00	1712.00	64.00	548.00	548.80
*	6225.000	2438.00	549.63	5.04	35.00	8.23	83.40	1693.00	34.00	556.60	550.30
*	6472.000	2438.00	549.73	8.70	35.00	5.53	67.21	1333.00	34.00	551.14	551.27
*	6720.000	2438.00	551.77	10.87	35.00	4.67	62.04	1333.00	34.00	555.04	554.84
	6990.000	2438.00	555.03	10.42	35.00	4.83	62.96	1348.00	34.00	557.70	557.15
	7160.000	2438.00	556.87	10.57	35.00	4.77	62.64	1257.00	34.00	560.06	560.00
*	7530.000	2270.03	561.07	10.06	35.00	4.77	136.46	1222.00	34.00	559.00	560.60
*	7615.000	2438.00	561.82	10.86	15.00	4.52	61.15	1408.00	34.00	565.16	565.02
*	7630.000	2438.00	562.57	10.87	15.00	4.67	62.04	1408.00	34.00	565.15	565.02
*	7705.000	1637.44	565.09	7.84	35.00	6.39	113.66	.00	.01	565.00	565.00
	7707.000	1613.29	565.40	6.88	40.00	6.70	294.80	.00	.01	565.00	565.00
*	7710.000	162.81	566.16	2.05	80.00	7.36	510.95	.00	.01	561.80	561.20
	7755.000	171.33	566.22	2.21	80.00	7.22	498.87	.00	.01	562.00	561.40
	8128.000	179.89	566.66	2.24	80.00	6.66	399.11	.00	.01	563.00	562.80
*	8500.000	230.64	567.31	3.27	75.00	5.91	337.67	.00	.01	564.40	564.20
*	8890.000	1639.00	568.10	6.62	55.00	6.10	58.63	.00	.01	570.00	570.00
	8970.000	1133.00	568.10	5.45	35.00	5.40	49.74	.00	.01	572.00	572.00
*	9020.000	100.21	568.80	5.94	75.00	2.80	143.91	.00	.01	566.00	566.00
*	9070.000	861.53	570.86	7.46	75.00	4.86	157.69	.00	.01	574.10	569.70

	SECNO	QCH	CWSEL	VCH	K*XNCH	DEPTH	TOPWID	CLSTA	BW	XLBEL	RBEL
*	9230.000	700.12	573.29	4.15	55.00	5.89	216.42	.00	.01	575.50	571.10
	9390.000	784.69	574.14	5.42	45.00	5.44	190.53	.00	.01	576.80	572.40
	9840.000	1133.00	577.52	8.11	35.00	5.02	54.17	.00	.01	579.90	577.40
*	10140.000	1133.00	580.17	5.90	35.00	6.07	69.87	.00	.01	580.60	581.00
	10540.000	1122.55	582.10	6.98	35.00	5.30	60.00	.00	.01	582.60	581.00
	11050.000	638.54	584.76	3.37	60.00	8.16	108.24	.00	.01	584.00	586.00
*	11170.000	26.98	587.66	2.59	60.00	1.76	280.66	.00	.01	587.70	588.00

STORM DRAINAGE MASTER PLAN
PHASE III

HURRICANE CREEK WATERSHED
MAIN CHANNEL
(INCLUDING CYCLONE BRANCH)

FOR

THE CITY OF

EULESS

PREPARED BY

TEAGUE NALL AND PERKINS INC.
CONSULTING ENGINEERS
Developing Creative Engineering
Solutions for Our Communities

Celebrating 20 Years of Service

OCTOBER 1996

STORM DRAINAGE MASTER PLAN PHASE III

HURRICANE CREEK WATERSHED-MAIN CHANNEL

(INCLUDING CYCLONE BRANCH)

for the

CITY OF EULESS

PREPARED BY:

TEAGUE NALL AND PERKINS, INC.

2001 W. IRVING BLVD.

IRVING, TEXAS 75061

(214) 251-1627

OCTOBER 1996

CITY OF EULESS STORM DRAINAGE MASTER PLAN - PHASE III
HURRICANE CREEK WATERSHED - MAIN CHANNEL

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EXECUTIVE SUMMARY

PURPOSE

This study is a tool to be used in planning for the protection of the environment, the natural value of park and recreational land, and the existing residences along Hurricane Creek. It can also be used in planning future developments along the channel. A tributary of Hurricane Creek included in this study is Cyclone Branch (referred to by COE as HC-1).

HYDROLOGY

The term "ultimate development unmitigated" as used in this report refers to the complete development of the watershed according to future land use maps, but without any drainage improvements to accomodate the increase in flows. Given that the "ultimate development unmitigated" model does not consider drainage improvements, the model will typically contain flow values lower than the "ultimate developed" model, due to slower velocities and greater stream storage capacities. For Hurricane Creek, the ultimate developed unmitigated base flood flowrates range up to 29% higher than the Flood Insurance Study (FIS) flowrates. Those for Cyclone Branch range up to 53% higher.

The term "ultimate developed" includes future land use, channelization, and road crossing improvements which are proposed to mitigate the effects of flooding. Such drainage improvements increase stream velocities and decrease stream storage, consequently increasing flowrates. For Hurricane Creek, the ultimate developed base flood flowrates range up to 46% higher than the FIS flowrates; those for Cyclone Branch range up to 69% higher.

FLOODING PROBLEMS

Urbanization of the Hurricane Creek watershed without the improvements proposed in this study will cause flood elevations to be higher than the effective base flood elevations within the City of Euless by as much as 3.8 feet along the main stream and 4.2 feet along Cyclone Branch.

The base flood elevations calculated in the FIS indicate that twelve (12) existing residences are in the floodplain. The ultimate developed unmitigated floodplain will contain twenty-four (24) existing residences. All of these residences are upstream of SH 10. No other types of insurable structures appear to be in the floodplain.

Under both FIS and ultimate conditions in the Hurricane Creek watershed, Mosier Valley Road, South Pipeline Road, State Highway 10, Marlene Drive, and Westpark Way will be overtopped along the main stream during the 100-yr storm. Along Cyclone Branch under FIS conditions, Kynette will be overtopped, and under ultimate conditions both Marlene and Kynette will be overtopped.

FLOODING SOLUTIONS

All of the flooding of residences and road crossings can be eliminated by channelization, culvert, and bridge improvements. The estimated cost of these improvements is $5,248,767.

GOLF COURSE

Because no drainage improvements are recommended along the golf course, the ultimate developed floodplain is as much as 2.9 feet higher than the FIS floodplain along this reach. Based on the golf course grading plan, some of the tees and greens will be as much as six (6') feet below the ultimate developed floodplain.

TRINITY BOULEVARD

The preliminary design by the Texas Department of Transportation (TxDOT) indicates that the two bridge structures at the future Trinity Boulevard crossing should be 3 - 45' spans. The preliminary hydrology prepared by the TxDOT shows the ultimate base flood flowrate to be less than the FIS base flood flowrate. This hydrology contributes to the apparent undersizing of the structure. Using the flowrates determined in this study, this structure would increase the ultimate developed base flood by 1.3 feet. The resulting ultimate developed floodplain will be 2.6 feet above the effective floodplain. We believe it would be in the best interests of the City to present the findings of this study to TxDOT, in order to attempt to persuade the State to consider upsizing the Trinity Boulevard Bridge.

SOUTH PIPELINE ROAD

The proposed removal of the existing crossing at South Pipeline Road will have no appreciable effect on the ultimate floodplain. This structure spans only the channel and has no approach embankments which could impede floodwater.

WESTPARK WAY

The existing crossing at Westpark Way is a two-barrel 10' x 10' multiple box culvert (MBC). The FIS models this crossing as a three-barrel 10' x 10' MBC. With downstream channel improvements, a four-barrel 10' x 10' MBC will pass the ultimate developed 100-yr storm without overtopping. If these improvements are made without the downstream channel improvements, some overtopping may still occur. This MBC improvement alone has negligible effect on the downstream peak flowrates. Above the confluence with Cyclone Branch, ultimate developed unmitigated 100-yr flow is increased by 1.4%. At SH 10, the increase is <1%. The lower frequency storms yield similar increases. The net effect on base flood elevations is negligible.

DETENTION

The feasibility of a detention facility immediately upstream of SH 10 was evaluated. The evaluation was made assuming the floodplain between SH 10 and the confluence with Cyclone Branch would be the limits of grading for detention. The result is that only the lower frequency storms experience any appreciable attenuation. Because of the lack of adequate detention storage, the base flood flowrate is not reduced and the existing SH 10 structure would continue to overtop. Detention is not recommended.

CHECKDAMS

Two checkdams can be constructed between South Pipeline Road and SH 10. These five-foot high checkdams can retain water for aesthetic purposes in the channel along holes 17 and 18 of the Texas Star golf course. These checkdams have a negligible effect on the floodplain because most of the floodplain capacity is outside of the channel. The opinion of probable cost of these improvements is $92,710.

CITY OF EULESS STORM DRAINAGE MASTER PLAN - PHASE III
HURRICANE CREEK WATERSHED - MAIN CHANNEL

A. INTRODUCTION

PURPOSE

This study is a tool to be used in the planning for the protection of the environment, the natural value of park and recreational land, and the existing residences along Hurricane Creek. It can also be used in planning future developments along the channel.

GOALS

1. Develop hydrologic and hydraulic models for ultimate developed watershed conditions.
2. Assess the flooding problems along Hurricane Creek and Cyclone Branch.
3. Determine channel and road crossing improvements which will alleviate flooding and which can be used to plan future development along the channel.
4. Evaluate the concept of detention/retention facilities immediately upstream of SH 10.
5. Evaluate the future Trinity Boulevard crossing to determine the bridge span needed to pass the ultimate developed 100-yr. storm.
6. Determine the impact on the ultimate developed floodplain of removing the bridge crossing at South Pipeline Road.
7. Evaluate the impact of checkdams on the ultimate developed floodplain between South Pipeline Road and SH 10.

ASSUMPTIONS

1. The ultimate development hydrology developed for the City of Bedford will be used for the portion of the Hurricane Creek watershed upstream of Euless. The assumptions concerning impervious area and stream storage upstream of SH 121 will be evaluated and revised as required.
2. There will be no proposed channel improvements downstream of Euless Boulevard (SH 10) because of the golf course. However, the proposed grading for the golf course dated 8/25/95, as provided by Keith Foster, will be included in the analysis insofar as it affects the ultimate developed floodplain.
3. The existing crossings at South Pipeline Road, Mosier Valley Road, and Missouri-Kansas-Texas Railroad will remain a part of the ultimate developed floodplain analysis, and no improvements will be recommended.

B. METHODOLOGY

1. HYDROLOGY

GENERAL

The hydrologic analysis was prepared to provide flow values for the Hurricane Creek hydraulic model. In this study a range of storm frequencies from the 2-year through 500-year were computed. The HEC-1 Flood Hydrograph Package (ref. 4) was used to estimate the ultimate flows during the various storm frequencies.

A model was prepared to show the effects of fully urbanized land use in the watershed, but with no additional channel improvements. These conditions are referred to as "ultimate developed unmitigated" conditions because no improvements are proposed to mitigate the effects of flooding. The fully urbanized land use is based on the City's Future Land Use Plan (ref. 7).

A second model was prepared to reflect not only the effects of urbanized land use, but also the effects of drainage improvements. Improvements to channels and road crossings causes increased velocity and decreased stream storage. These changes result in higher peak flows. The term "ultimate developed" includes future land use, channelization, and road crossing improvements which are proposed to mitigate the effects of flooding.

EXISTING INFORMATION

Previous analysis by others relative to hydrology was considered in the preparation of this analysis. The Flood Insurance Study was prepared by the U.S. Army Corps of Engineers (COE). Even though the current Flood Insurance Rate Maps (FIRM) are dated 1995, the hydrologic and hydraulic analyses for Hurricane Creek were completed in 1984 (ref. 10). The COE used their NUDALLAS computer program to model the hydrology (ref. 6). In 1992, the COE prepared an evaluation of fully urbanized conditions peak discharge at the request of the City Engineer of Bedford. The results of this analysis was transmitted in a letter dated 10/5/92 (see appendix).

The City of Bedford is situated in the headwaters of the Hurricane Creek watershed. A Master Drainage Plan was prepared for the City of Bedford by Knowlton-English-Flowers Consulting Engineers (KEF) in 1992. This study analyzed ultimate developed flows and proposed drainage improvements including channelization and culvert improvements. KEF used the HEC-1 Flood Hydrograph Package to prepare the hydrology (ref. 4).

The Texas Department of Transportation has prepared preliminary hydrology for the design of the future Trinity Boulevard bridge. They used the Urban Regression Equation method.

RAINFALL

Rainfall amounts for storms up to and including the 100-year event were obtained from information provided in TP-40 (ref. 2) and Hydro-35 (ref. 3) of the National Weather Service. Rainfall amounts for the 500-year event were extrapolated from TP-40.

RUNOFF

For the Hurricane Creek watershed in Bedford, KEF used the initial and uniform loss method to compute runoff in the HEC-1 model. This method requires direct input of the percentage of impervious area. The impervious values used for the sub-basins in Bedford range from 36% for the area upstream of Harwood Road to 93% for the area between SH 121 and Tibbets. The area just upstream of SH 121 is modeled as 87% impervious. These impervious values appear to be adequate for ultimate conditions.

For the Hurricane Creek watershed in Euless, the SCS Curve Number method was used to compute runoff. This method allows determination of runoff from a given storm based on consideration of the soils, vegetative cover, cover condition, and antecedent moisture condition of the basin. These parameters are used to generate Curve Numbers (CN) which are used in an empirical calculation to determine runoff. Urbanized CN as used in this study were taken from TR-55 (ref. 12).

The four hydrologic soil groups used in this method are labeled A, B, C and D. An "A" soil has low runoff potential and is generally characterized by a higher sand content than the other soil types. Soil "D" is characterized by a high clay content, and has the greatest runoff potential of the four soils. The specific hydrologic soils groups within the Hurricane Creek watershed were taken from SCS Soil Survey for Tarrant County (ref. 9).

The type of vegetation or ground cover in an area affects the runoff from an area because of the impact on a soil's ability to infiltrate or store surface water. The portion of an area that is impervious because of roofs, pavement, or some other impervious surface treatment overrides other soil considerations. Almost all the rainfall to an impervious area results in runoff.

The amount of moisture in a soil prior to a rainfall event can significantly affect the rate and amount of runoff. SCS describes three Antecedent Moisture Conditions (AMC). Generally, AMC-I is a dry condition, AMC-II is "average" and AMC-III is saturated. In the growing season, the SCS defines AMC-III as a condition created when there has been more than 2.1 inches of rainfall in the five days preceding a storm event. AMC-III conditions are used for the Hurricane Creek analysis. The AMC-II CNs are used with initial abstraction based on AMC-III (ref. 1).

UNIT HYDROGRAPH

Lag times (t_p) for the Hurricane Creek watershed in Euless were calculated using the NUDALLAS methodology (ref. 6). The Fort Worth District of the COE developed a method of computing t_p using urbanization curves. Curves were prepared for sand and clay soils. Interpolation between the curves is based on the percent sand in the watershed.

The typical Snyder's peaking coefficient (C_p) used by the COE for the D/FW Metroplex area is typically 0.72.

STREAM ROUTING

Stream routing was performed in HEC-1 using the Modified Puls method. For the Hurricane Creek watershed in Bedford, KEF used the Normal-Depth Storage and Outflow method. This method uses a typical channel section of the stream reach, Manning's equation, and normal depth to compute the stream storage. The limitation of this method is that the effect of downstream conditions cannot be considered.

A more detailed method of preparing data for the Modified Puls method is to provide the storage-discharge relationship as direct input to HEC-1. This data can be obtained from a HEC-2 model prepared for the stream being studied. The advantage of this method is that downstream conditions can be considered, as well as the effects of proposed improvements. This is the method used in this study for Hurricane Creek.

A portion of the HEC-1 run prepared for the City of Bedford was modified with more detailed stream routing information. The routing reaches below sub-areas 3 and 4 were revised. These reaches extend from Tibbets upstream through SH 121 and northwesterly to Don Dodson Street in Bedford. The stream storage for these reaches is based on the drainage improvements proposed in the Bedford Master Drainage Plan.

The ultimate developed *unmitigated* hydrology is based on existing stream storage. The flows used for proposed improvements is based on the loss of stream storage caused by the improvements. The only difference between ultimate developed unmitigated and ultimate developed is the change in stream storage.

Table B-1 is a summary of the methods used for hydrology as discussed above.

TABLE B-1. HYDROLOGIC METHODS SUMMARY		
No.	**Description**	**Method**
1	Runoff Computations	Initial and Uniform Loss SCS Curve Number
2	Rainfall	Hydro-35, TP-40
3	Unit Hydrograph	Snyder
4	Hydraulic Routing	Modified Puls

For the purposes of this study, the following HEC-1 models were developed:

FILENAME	DESCRIPTION
HC-UDUF.IH1	Ultimate developed watershed conditions. Stream storage based on existing hydraulic conditions. This model provides the flowrates which will occur if the watershed is developed with no additional drainage improvements.
HC-ULT.IH1	Ultimate developed watershed conditions. Stream storage based on proposed channel and culvert improvements. This model provides the flowrates which will occur if the watershed is developed, and the drainage improvements proposed in this study are constructed.

2. HYDRAULICS

EXISTING INFORMATION

The hydraulic model used in the Flood Insurance Study (FIS) was "HEC-2 Water Surface Profiles," (updated 1982), a computer program developed by the U.S. Army Corps of Engineers (ref. 5). The FIS model was completed in 1982, and is the basis of the effective floodplain and floodway limits as shown on the Flood Insurance Rate Map (FIRM) panels.

PREPARATION OF NEW MODELS

The hydraulic model used in this study is "HEC-2 Water Surface Profiles" Version 4.6.2, dated May 1991.

The cross-sections reflecting existing conditions were taken from field surveys conducted in July and December, 1995, and the City's 1993 topography. Cross-sections reflecting proposed improvements in Bedford were taken from information provided by KEF. Cross-sections showing the impact of the Texas Star golf course were taken from the grading plan dated 8/25/95 prepared by Keith Foster. The finished floor elevations of insurable structures in or near the floodplain were surveyed in January, 1996.

Most of the topographic data contained in the FIS has been replaced in this study by more current data. This study uses the same cross-section locations as the FIS, with some additional locations within the study area. The roughness coefficients used in the FIS for undeveloped floodplain areas were used in this study in areas which remain undeveloped. New roughness coefficients are used to reflect improved conditions.

At Westpark Way, the FIS modeled the crossing as a three-barrel 10'x 10' MBC. The existing structure is actually a two barrel 10' x 10' MBC. The sizes of other bridges and culverts along the main channel are correct as modeled in the FIS.

The models prepared to represent ultimate watershed conditions with and without improvements include future improvements in Bedford. These improvements include improvements to the Tibbets and SH 121 crossings, and earthen channel improvements upstream of SH 121.

For the purposes of this study, the following models were developed:

FILENAME	DESCRIPTION
HC-UDUF.IH2	Hurricane Creek main stream. Ultimate developed watershed conditions. Future improvements at Trinity Boulevard, upstream in the City of Bedford, and Texas Star golf course. This model establishes the floodplain if the watershed is developed, but no additional drainage improvements are constructed in the City of Euless.
HC-IMP.IH2	Hurricane Creek main stream. Ultimate developed watershed conditions. Future improvements at Trinity Boulevard, upstream in the City of Bedford, and Texas Star golf course. This model establishes the floodplain if the watershed is developed and the drainage improvements proposed in this study are constructed.
CB-UDUF.IH2	Cyclone Branch (also known as HC-1). Ultimate developed watershed conditions. This model establishes the floodplain if the watershed is developed, but no additional drainage improvements are constructed in the City of Euless.

CB-IMP.IH2 — Cyclone Branch (also known as HC-1). Ultimate developed watershed conditions. This model establishes the floodplain if the watershed is developed and the drainage improvements proposed in this study are constructed.

3. FLOODING

Evaluation of flooding according to the FIS was made by plotting the calculated base flood elevations on the 1993 City topography and by comparing computed base flood elevations with surveyed finished floor elevations.

The evaluation of potential flooding due to urbanization was based on the new hydrologic and hydraulic models described above. The 100-year storm was used to evaluate flooding under ultimate developed unmitigated conditions. In order to determine the extent of flooding, the 100-year BFE was plotted on 1993 City topography. Also, the computed base flood elevations were compared with surveyed finished floor elevations.

The survey of finished floor elevations was conducted for the insurable structures which appear on the City topography. This topography shows insurable structures which existed when the aerial photographs were taken in 1993. Therefore, the evaluation of flooding is limited to the presence of insurable structures at the time the topography was prepared.

C. RESULTS

1. HYDROLOGY

DRAINAGE AREA

The Hurricane Creek watershed is about 4.5 miles long. With the headwaters in Bedford, it extends across Euless, Fort Worth, and Arlington corporate boundaries. The watershed covers an area of about 5.6 square miles at the lowest study point taken at the Missouri-Kansas-Texas Railroad. Hurricane Creek discharges into the West Fork Trinity River. The watershed is not yet fully urbanized. See the DRAINAGE AREA MAP exhibit for sub-area delineations. The areas of the sub-basins are summarized in Tables C-1 and C-2.

RUNOFF

The parameters used to develop the ultimate hydrology for the Hurricane Creek basin in the City of Bedford are summarized in Table C-1. These parameters were reviewed, but not modified for use in this study.

The Initial and Uniform Loss Rate Method was used by KEF for the Bedford sub-areas. The initial rainfall loss was taken as 0.90 inches. The uniform rainfall loss was taken as 0.10 inches. These values were used for all Bedford sub-areas. The remaining loss rate parameter is the percentage of impervious ground cover, which varies by sub-basin.

TABLE C-1. HURRICANE CREEK SUB-BASIN SUMMARY (BEDFORD)

SUB-BASIN	AREA (s.m.)	IMPERVIOUS (%)	LAG TIME (hr.)
1	0.21	36.00	0.19
2	0.51	45.00	0.49
3	0.69	65.00	0.62
4	0.20	87.00	0.64
5	0.20	93.00	0.74
8	0.15	74.00	0.31
9	0.13	51.00	0.41
10	0.16	89.00	0.46
11	0.25	89.00	0.51

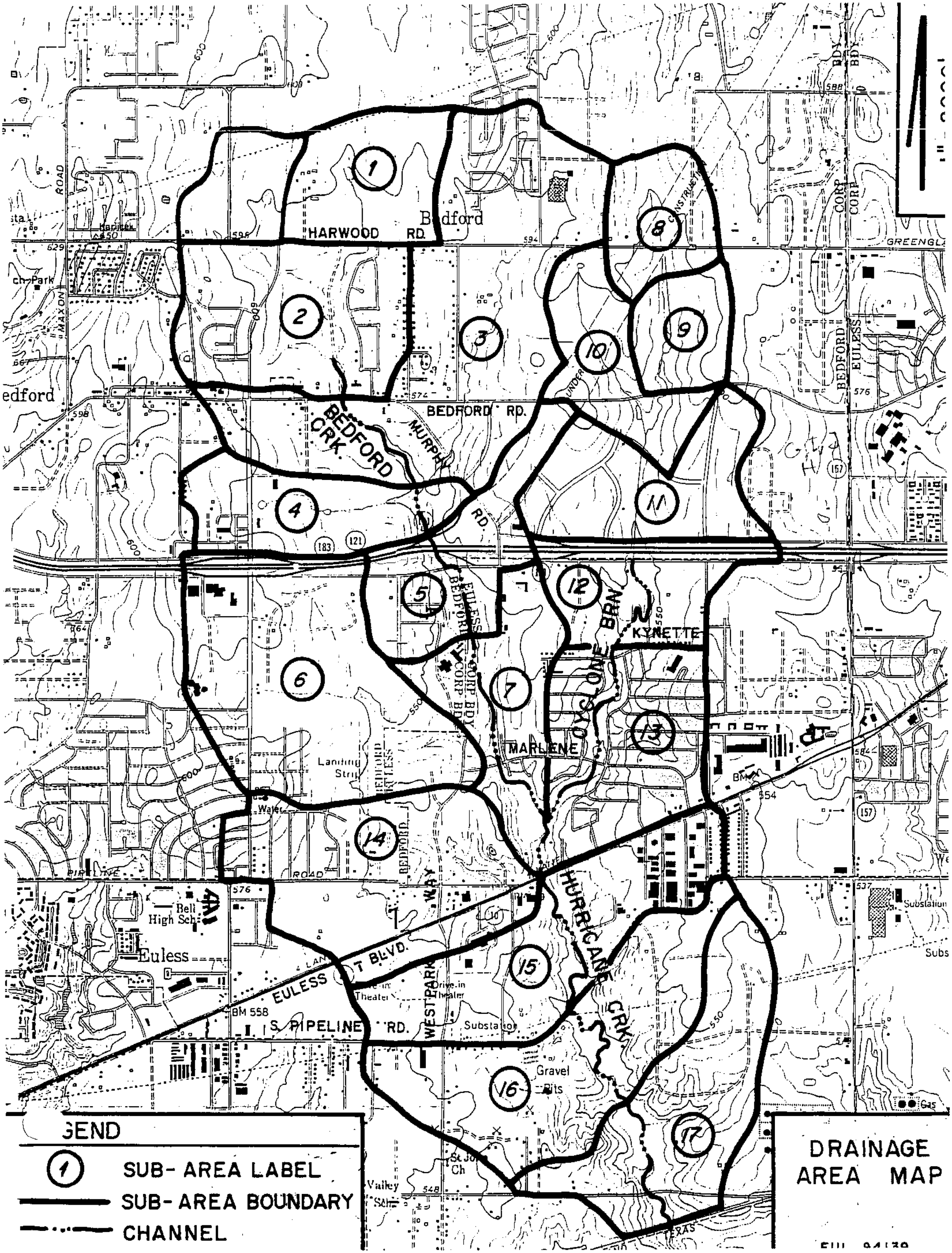
AT·7.5

The parameters developed to model the Hurricane Creek sub-basins in the City of Euless are summarized in Table C-2. Even though different methods for computing loss rates are used for areas within Bedford and Euless, the methods are compatible because both provide information used by the Snyder Unit Hydrograph method.

TABLE C-2. HURRICANE CREEK SUB-BASIN SUMMARY (EULESS)

BASIN	AREA (s.m.)	CURVE NUMBER	INITIAL ABSTRACTION (in.)	LAG TIME (hr.)
6	0.55	87	0.11	0.36
7	0.26	84	0.15	0.29
12	0.20	89	0.09	0.19
13	0.33	81	0.17	0.30
14	0.46	82	0.17	0.33
15	0.47	85	0.13	0.22
16	0.46	77	0.24	0.26
17	0.37	77	0.24	0.47

3.1



DRAINAGE AREA MAP

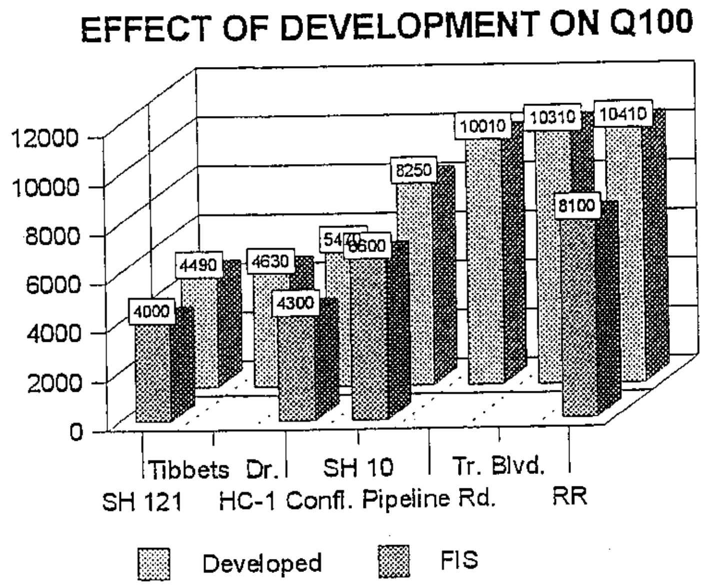
RAINFALL

The rainfall amounts for the watershed were derived from Hydro-35 and TP-40. Since the watershed is relatively small, no reduction due to aerial extent is applied to the rainfall values. A summary of the amounts, duration and frequency of the storms is given in Table C-3.

TABLE C-3. STORM RAINFALL DATA

STORM DURATION	STORM FREQUENCY						
	2 YR. (in.)	5 YR. (in.)	10 YR. (in.)	25 YR. (in.)	50 YR. (in.)	100 YR. (in.)	500 YR. (in.)
5 minute	0.49	0.58	0.63	0.73	0.8	0.87	1
15 minute	1.06	1.23	1.36	1.56	1.71	1.87	2.2
60 minute	1.93	2.35	2.86	3.35	3.79	4.25	5.4
2 hour	2.35	3.04	3.49	4.12	4.63	5.13	6.6
3 hour	2.55	3.33	3.85	4.5	5.1	5.65	7.4
6 hour	3.02	3.96	4.62	5.43	6.1	6.88	8.8
12 hour	3.50	4.70	5.48	6.43	7.3	8.25	10.5
24 hour	4.1	5.46	6.33	7.48	8.52	9.47	12.00

COMPARISON OF FLOWS



As a reliability check, the ultimate developed unmitigated flows (UDUF) should be compared with the flows used in the FIS, particularly since the FIS hydrology was prepared with a different computer model. This comparison will show the effect of development on the base flood flowrates. Because the watershed as modeled in the FIS was not fully developed, the ultimate developed flows should be somewhat higher than FIS flows. The higher flows will be due strictly to the change in land use, because the ultimate developed unmitigated discharge values do not include the impact of channelization. The effect of drainage improvements is discussed later. Along the main stream of Hurricane Creek, the ultimate developed unmitigated base (100-yr) flood ranges up to 29% higher than flows given in the FIS (see graph above). Similarly, the Cyclone Branch (HC-1) base flood increases by up to 53% over the FIS. Comparisons of base flood discharges and drainage areas are given in Table C-4. The computed ultimate developed unmitigated flows are within the expected ranges as compared to the FIS.

The Texas Department of Transportation (TxDOT) has computed ultimate developed flows along Hurricane Creek. Mr. John Terry of the TxDOT reported on 11/14/95 that in using the Urban Regression Equations method, they have computed an urbanized 100-yr discharge of 7500 cfs at the future Trinity Boulevard crossing. An interpolation of the FIS flows based on contributing drainage area yields a 100-yr discharge of 7800 cfs at the same location. This means that the urbanized 100-yr discharge is computed by the TxDOT to be less than the FIS which represented a partially-developed watershed. Assuming the accuracy of the FIS hydrology, this would not be reasonable, so the calculations in this study are not modified due to the previous work of the TxDOT.

The Corps of Engineers (COE) has also computed ultimate developed flows at points along Hurricane Creek. The COE reported an ultimate developed flow of 4250 at SH 121 and 3000 at Westpark Way. This shows a significant decrease in flows downstream, presumably due to extensive storage. The ultimate developed unmitigated flows in this study assume the improvements proposed in the Bedford Master Drainage Plan at SH 121 have been implemented. These improvements minimize the stream storage. Because of the apparent difference in assumptions, the calculations in this study are not modified due to the previous work of the COE.

TABLE C-4. BASE FLOOD DISCHARGE SUMMARY				
STUDY POINT	FIS		UDUF	
	DA (sm)	Q_{100} (cfs)	DA (sm)	Q_{100} (cfs)
SH 121	1.63	4000	1.62	4490
TIBBETS DRIVE			1.81	4630
ABOVE CONFLUENCE OF HC-1	2.55	4300	2.62	5470
SH 10	3.8	6600	3.84	8250
S. PIPELINE ROAD			4.77	10010
TRINITY BOULEVARD			5.23	10310
RAILROAD	5.5	8100	5.60	10410
WEST BRANCH	0.32	950	0.55	1770
HC-1 AT KYNETTE	0.9	1500	0.89	2300
HC-1 AT CONFLUENCE	1.3	2400	1.22	2900

The reach of Hurricane Creek that extends through the Texas Star golf course will not be channelized. However, channelization and road crossing improvements will be required upstream of the golf course in order to mitigate flooding. These drainage improvements will reduce the available stream storage and increase the velocity of floodwater. These factors will have the effect of increasing the peak flows (see graph at right). Table C-5 summarizes the effects of such drainage improvements on the ultimate developed base flood discharge at various locations along the main stream.

EFFECT OF IMPROVEMENTS ON Q100

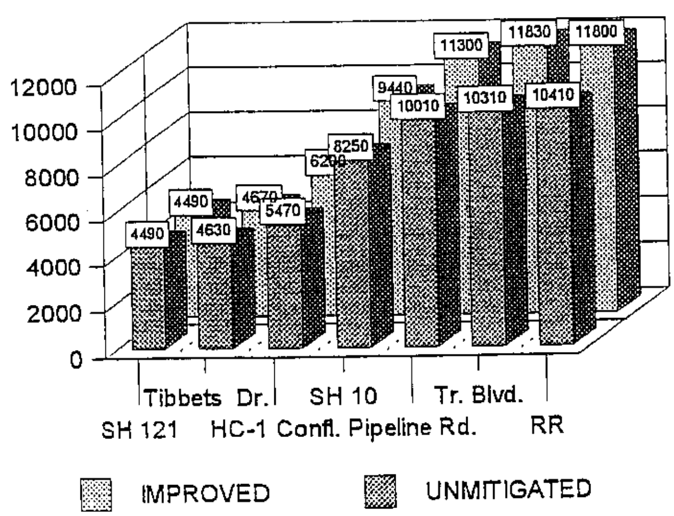


TABLE C-5. EFFECT OF IMPROVEMENTS ON BASE FLOOD FLOWRATES			
STUDY POINT	UDUF Q_{100} (cfs)	ULT. DEV. Q_{100} (cfs)	INCREASE (%)
SH 121	4490	4490	0
TIBBETS DRIVE	4630	4670	1
ABOVE CONFLUENCE OF HC-1	5470	6200	13
SH 10	8250	9440	14
S. PIPELINE ROAD	10010	11300	13
TRINITY BOULEVARD	10310	11830	15
RAILROAD	10410	11800	13
WEST BRANCH	1770	1770	0
HC-1 AT KYNETTE	2300	2530	10
HC-1 AT CONFLUENCE	2900	3310	14

UDUF = Ultimate Developed Unmitigated Flood (ultimate watershed development, no drainage improvements).
ULT. DEV. = Ultimate Developed Flood (ultimate watershed development with drainage improvements).

The peak discharge for various storm frequencies was computed based on ultimate developed conditions with drainage improvements. The results of these computations are presented in Table C-6.

TABLE C-6. ULTIMATE DEVELOPED FLOWRATES BY FREQUENCY							
STUDY POINT	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	500-YEAR
SH 121	1860	2510	3050	3600	4040	4490	5550
TIBBETS DRIVE	2010	2670	3240	3820	4290	4670	5660
ABOVE CONFLUENCE OF HC-1	2490	3410	4190	4980	5630	6200	7390
SH 10	3660	5110	6320	7530	8480	9440	11530
S. PIPELINE ROAD	4020	5920	7450	8930	10080	11300	14250
TRINITY BOULEVARD	3970	5960	7550	9330	10680	11830	14960
RAILROAD	3880	5950	7540	9210	10600	11800	14930
WEST BRANCH	620	910	1140	1380	1570	1770	2240
HC-1 AT KYNETTE	1020	1400	1720	2040	2300	2530	3180
HC-1 AT CONFLUENCE	1190	1720	2180	2620	2960	3310	4170
These flowrates are based on ultimate development in the watershed with proposed channelization and road crossing improvements.							

SUMMARY

This hydrologic study provides a current analysis by which to evaluate drainage needs along Hurricane Creek. The results of this hydrologic analysis are flow rates which have been used in the hydraulic analysis of the stream.

Urbanized flowrates have been calculated previously by the TxDOT and the COE. The flowrates computed by these agencies are somewhat lower than the flowrates computed in this study. The justification for proceeding with the higher flowrates is given above.

This evaluation includes a model of the effects of ultimate development and drainage improvements. The term "ultimate development unmitigated" as used in this report refers to the complete development of the watershed according to future land use maps, but with no drainage improvements except those proposed in the Master Drainage Plan for the City of Bedford and the future Trinity Boulevard bridge. For Hurricane Creek, the ultimate developed unmitigated base flood flowrates range up to 29% higher than the Flood Insurance Study (FIS) flowrates. Those for Cyclone Branch range up to 53% higher.

"Ultimate developed" refers to complete urbanization and development of the watershed including the drainage improvements proposed in this study. For Hurricane Creek, the ultimate developed base flood flowrates range up to 46% higher than the FIS flowrates. Those for Cyclone Branch range up to 69% higher.

2. DETENTION

The effects of a detention structure immediately upstream of SH 10 were evaluated. The limit of grading for the detention pond was assumed to be the effective floodplain per the FIS. The side slopes were assumed to be 3:1 down to the depth of the existing flowline of the channel. The assumption was made that the existing structure at SH 10 would be the control structure, and the channel downstream of SH 10 would remain unchanged.

The stage-discharge curve was prepared using a HEC-2 run so that the effect of high tailwater on the SH 10 structure could be evaluated. The stage-storage data was prepared in two ways for reliability. First, the HEC-1 model was revised to calculate the storage based on planimetered areas. The second method was to prepare a HEC-2 run with revised sections in the proposed basin in order to compute the storage-discharge curve for direct input into the HEC-1 model. Both of these approaches yielded similar results for stage-storage data.

The result is that only the lower frequency storms experience any appreciable detention effect. The reason for this is that even with detention, the 100-yr storm overtops the existing roadway by over two (2) feet. This causes extensive weir flow over the top of the road. With such a high discharge over the top of the road, little water is held back in the detention structure. Specifically, the 2-yr storm is reduced by 17%. The 5-yr storm is reduced by 7%. The 10-yr storm is reduced by 1%. The higher frequencies are not attenuated by this detention scenario. Another way to state the result is that the detention storage volume assumed is inadequate and the structure is adversely affected by high tailwater.

The effect of detention could be improved with either channel improvements downstream of SH 10, improvements to the SH 10 structure, increased detention storage volume, or some combination of these three. However, in the larger picture, there appear to be no insurable structures in the ultimate floodplain downstream of SH 10. The only benefit of detention would be to improve conditions at downstream crossings at S. Pipeline Road, Trinity Boulevard, and Mosier Valley Road. But even this benefit would likely not be cost-effective due to the extensive grading and improvements required to construct the detention facility.

Because of the minimal effect and benefit, no further consideration should be given to a proposed detention facility based on the assumptions stated above.

3. HYDRAULICS

The hydraulic model for the FIS indicates that in the 100-year storm, super-critical flow exists in portions of the existing concrete-lined channel. In the main stream, the reach downstream of Marlene has supercritical flow as well as most of the improved Cyclone Branch channel. Some scour at the tops of the concrete channel lining might be expected due to the high velocities of flows which overtop the channel. In ultimate developed conditions, most of the existing concrete-lined channel will experience high velocities associated with supercritical flow.

The ultimate developed unmitigated base flood elevations (BFE) are higher than the effective base flood elevations by up to 3.8 feet along the main stream and 4.2 feet along Cyclone Branch. Table C-9 compares the ultimate and effective BFE at various stream sections. The ULTIMATE DEVELOPED UNMITIGATED FLOODPLAIN exhibit (six sheets) shows the floodplain location.

4. FLOODING

STRUCTURAL FLOODING

Using the methods described above, the effective floodplain contains 12 insurable structures. These structures are all existing single-family residences. They are located above the confluence of the main stream and Cyclone Branch on the following streets: Canyon Ridge, Live Oak, and Westcliff.

Without mitigation, the floodplain will include 12 additional insurable structures for a total of 24 structures in the ultimate developed floodplain. Table C-7 summarizes the flooding of insurable structures in the ultimate developed unmitigated flood. The ULTIMATE DEVELOPMENT UNMITIGATED FLOODPLAIN exhibit (six sheets) shows the insurable structures which are within the floodplain.

TABLE C-7. STRUCTURAL FLOODING

NUMBER OF INSURABLE STRUCTURES	FLOODING DEPTH
14	one foot or less
10	more than one foot

ROADWAY FLOODING

All road crossings in the City of Euless along Hurricane Creek and the Kynette crossing at Cyclone Branch are inundated by the effective floodplain. Under ultimate developed unmitigated conditions, the flooding worsens to include the Marlene crossing at Cyclone Branch. The overtopping depths at each crossing are listed in Table C-8.

TABLE C-8. ROADWAY FLOODING

STREET NAME	Q_{100} OVERTOPPING DEPTH (ft)	
	FIS	UDUF
Mosier Valley Road	4.6	6.3
South Pipeline Road	3.8	4.9
SH 10	3.0	2.8
Marlene (main stream)	1.3	4.9
Marlene (Cyclone Br.)	N/A	1.6
Westpark Way	0.6	2.5
Kynette	1.8	4.1

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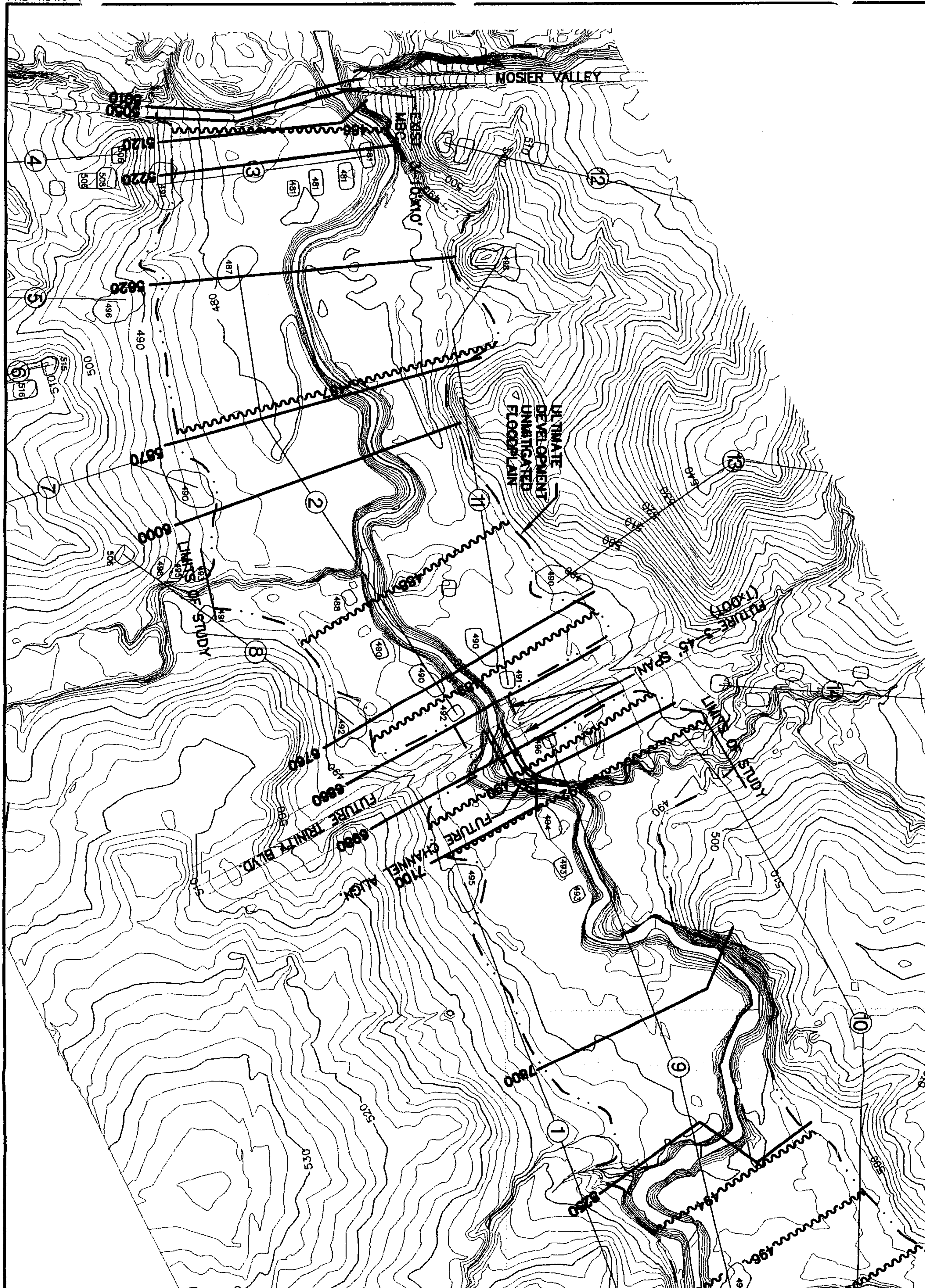

STORM DRAINAGE MASTER PLAN PHASE III

1: ULTIMATE DEVELOPMENT UNMITIGATED FLOODPLAIN

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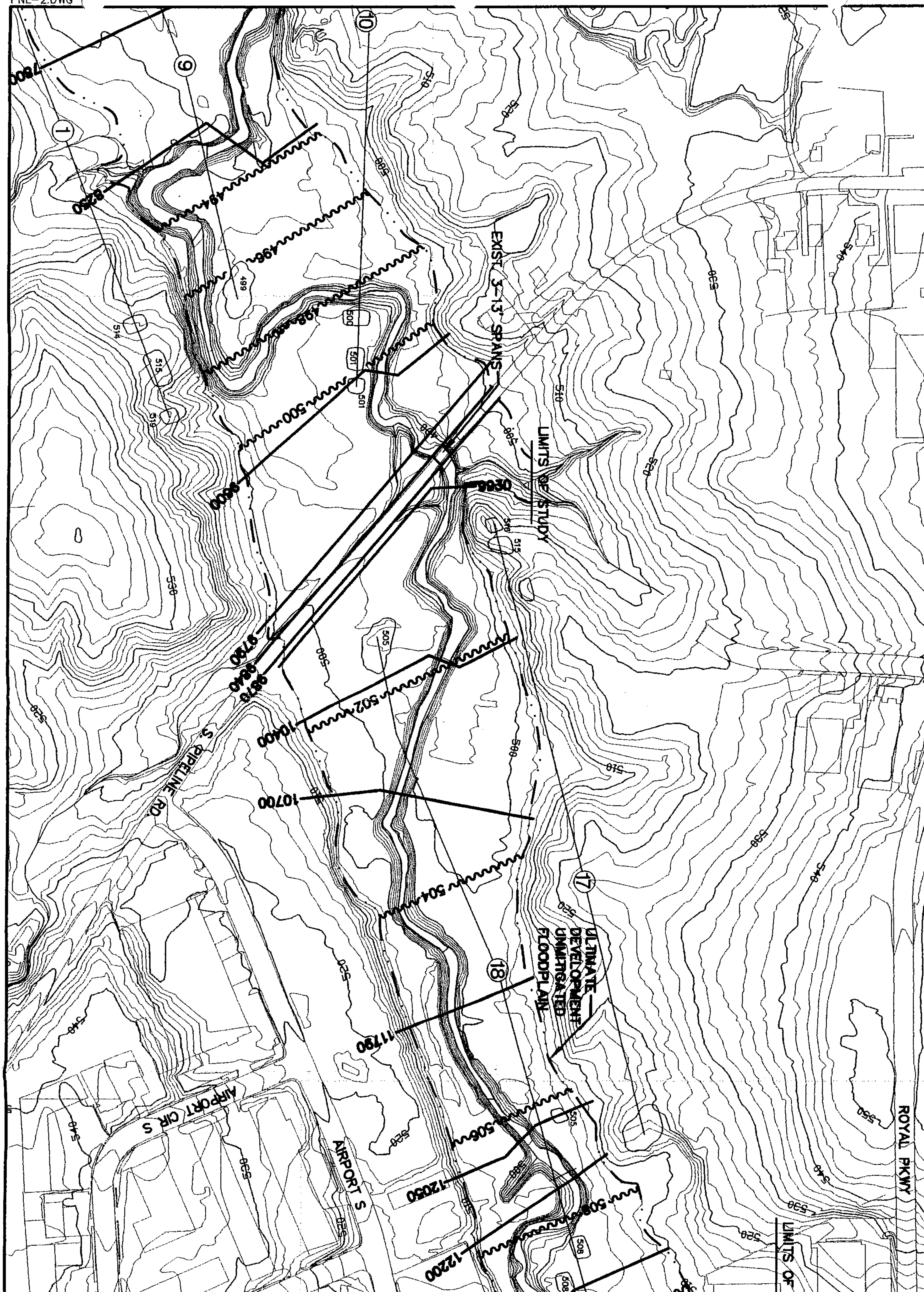

STORM DRAINAGE MASTER PLAN PHASE III

2: ULTIMATE DEVELOPMENT UNMITIGATED FLOODPLAIN

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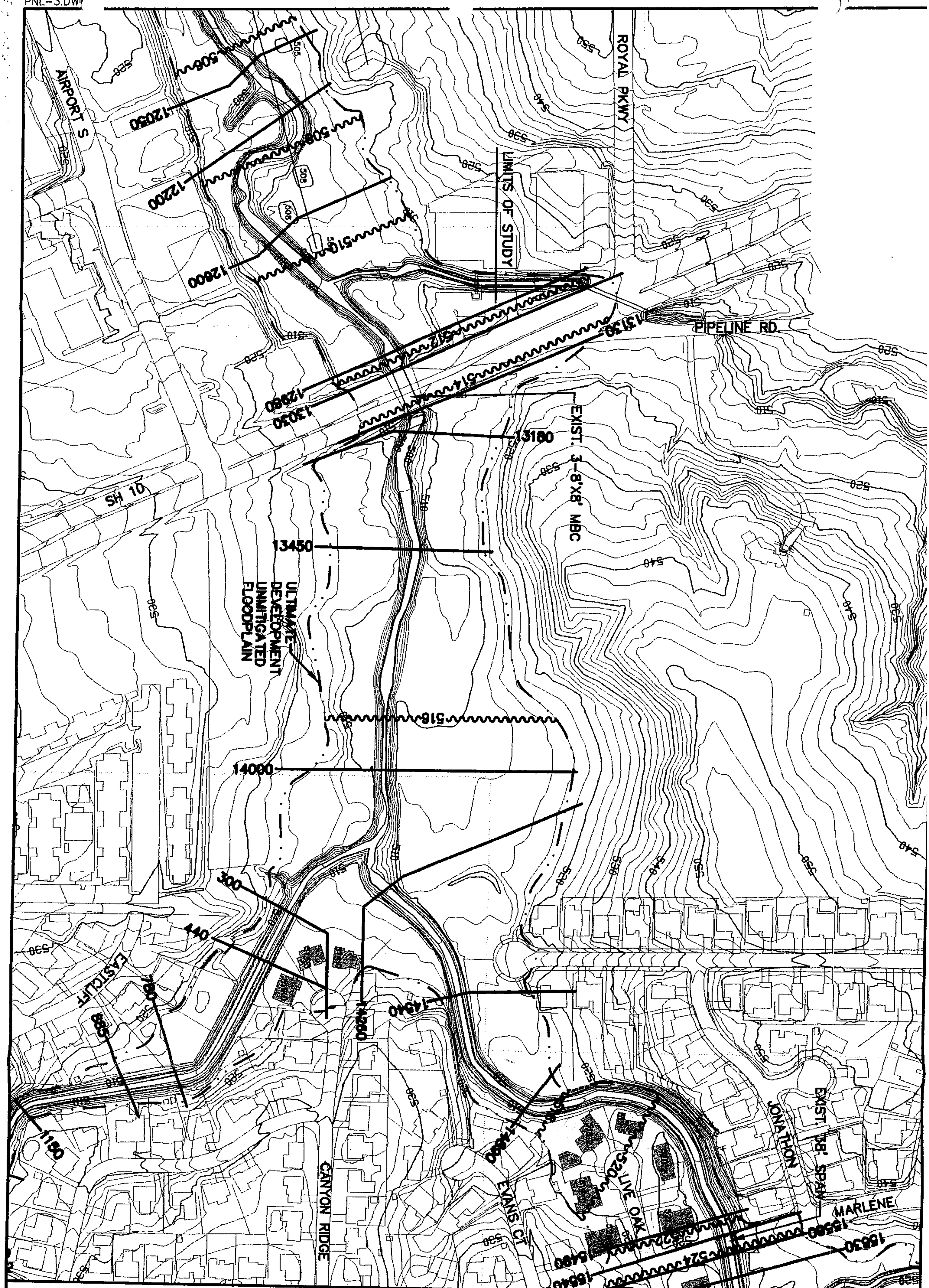

STORM DRAINAGE MASTER PLAN PHASE III

3: ULTIMATE DEVELOPMENT UNMITIGATED FLOODPLAIN

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STORM DRAINAGE MASTER PLAN PHASE III

4: ULTIMATE DEVELOPMENT UNMITIGATED FLOODPLAIN

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STORM DRAINAGE MASTER PLAN PHASE III
5: ULTIMATE DEVELOPMENT UNMITIGATED FLOODPLAIN
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PNL-5.DWG
KYNETTE
SIGNET
WINDLEA
TOPLEA
NORTHCLIFF
MARLENE
CANYON RIDGE
EVANS
MESA
WESTCLIFF
EASTCLIFF
SIERRA
SAGEBRUSH TRAIL
TYLER
MARY
GREENBRIAR
DEBRA
EXIST. 3-8'X4' MBC
PROP. 3-10' x 7' MBC
PROP. CONCRETE - LINED CHANNEL B=20'
ULTIMATE DEVELOPMENT UNMITIGATED FLOODPLAIN
VERTICAL - WALL CHANNEL UNDER BRIDGE
EXIST. 2-24' SPANS
PROP. CONCRETE - LINED CHANNEL B=15'
3465
3180
2770
2455
2270
1940
1810
1655
1560
1550
1520
1470
1310
1150
885
780
440
300
14540
14260

5. DRAINAGE IMPROVEMENTS

In general, drainage improvements are proposed to eliminate flooding of insurable structures and overtopping of road crossings, and to provide planning guidelines for channelization in areas that will be developed in the future. In most cases, road crossing improvements must be constructed along with downstream channel improvements in order to achieve the desired capacity. The DRAINAGE IMPROVEMENTS (six sheets) and TYPICAL CHANNEL SECTIONS exhibits provide details of the conceptual design of the proposed drainage improvements. Table C-9 summarizes the effect of these proposed drainage improvements on the base flood elevations.

The first reach of proposed improvements is SH 10 and downstream. A combination of high tailwater and lack of culvert capacity cause the overtopping of the road. The proposed solution includes channelization downstream of the crossing and replacement of the existing box culverts with a bridge span. The proposed channel will be subject to erosive velocities. The proposed channel should be lined with either rock rip-rap or gabions.

The reach between SH 10 and Marlene on the main stream is partially undeveloped and has existing single-family residences that are in the floodplain. The existing concrete channel adjacent to the development is inadequate for the ultimate developed flood. A concrete-lined channel is proposed which will convey the 100-year storm through the undeveloped section and lower the flood elevations as needed to remove the residences from the floodplain.

The reach from Marlene on the main stream to Westpark Way is partially undeveloped and has existing single-family residences that are in the floodplain. The existing bridge span at Marlene and the existing concrete channel adjacent to the development are inadequate for the ultimate developed base flood. The bridge can be replaced with a multiple box culvert to provide adequate capacity. A concrete-lined channel is proposed which will convey the ultimate development base flood through the undeveloped section and lower the flood elevations as needed to remove the residences from the floodplain.

From Westpark Way to Tibbets, the areas adjacent to the floodplain are partially developed, but no existing structures are in the ultimate floodplain. The existing multiple box culvert is inadequate for the ultimate developed base flood, but additional barrels can be added to the structure to provide the needed capacity. (See C.9. Westpark Way for additional discussion.) A concrete-lined channel is proposed which will lower the ultimate developed flood to FIS levels or below. Because of the visibility of this channel, an alternate solution is to line the channel with gabions.

On Cyclone Branch, the Marlene crossing is overtopped in the ultimate developed flood. The existing bridge structure can be preserved with channel improvements under the bridge and downstream which will provide the additional capacity needed to prevent overtopping. Additional evaluation of the structural details of the bridge may indicate that replacement of the bridge will be required by the channel work under the bridge.

Cyclone Branch overtops Kynette and floods downstream single-family residences in the ultimate developed base flood. The high tailwater on the road crossing, together with lack of culvert capacity, causes the overtopping of the road. The multiple box culvert can be replaced with a larger MBC if the channel is lowered and the road is raised. A concrete-lined channel is proposed which will lower the tailwater and convey the 100-year storm as needed to remove the residences from the ultimate developed floodplain.

Cyclone Branch between Kynette and SH 183 is in a largely undeveloped area, currently zoned for commercial and multi-family development. A concrete-lined channel is proposed which will convey the ultimate developed base flood through the undeveloped stream reach and lower the channel to accommodate the proposed Kynette crossing.

The tributary extended to the northeast will be carried underground in a 7'x 5' box culvert. This culvert is shown approximately 300' south of the frontage road, to permit room for commercial development along the road. It's location, however, is flexible, and can be adjusted to accommodate development.

The ultimate developed runoff for this tributary was determined by prorating the peak runoff for Cyclone Branch at Kynette.

	Area (Sq. Mi.)	Q_{100} (cfs)
Kynette	0.89	2,530
East Trib	0.16	455
East Trib (above SH 183)	0.11	313
Cyclone Branch (above East Trib)	0.57	1,620

A hydraulic gradient for the proposed box is shown below, including the existing 6'x 4' box culvert under S.H. 183.

DIST TO NEXT DP	"Q" (cfs)	FRICTION GRADIENT SLOPE (f/f)	HGL ELEVATIONS UP STREAM	HGL ELEVATIONS DOWN STREAM	V 1 IN (fps)	V 2 OUT (fps)	HEAD LOSS V 1^2 ----- 2g	HEAD LOSS V 2^2 ----- 2g	K*	K V 1^2 ----- 2g	h (ft)	HG ELEV @ DESIGN POINT	COMMENTS
320	313.0	0.0102	559.00	555.75		13.0		2.64	1.25	3.30	3.30	562.30	Ex. 6'x 4' Box
350	313.0	0.0037	555.30	554.01	13.0	8.9	2.64	1.24	0.30	0.79	0.45	555.75	7'x 5' Box
900	455.0	0.0078	551.76	544.76	8.9	13.0	1.24	2.62	0.30	0.37	2.25	554.01	7'x 5' Box
70	455.0	0.0078	542.93	542.38	13.0	13.0	2.62	2.62	0.30	0.79	1.84	544.76	7'x 5' Box

TABLE C-9. COMPARISON OF BASE FLOOD ELEVATIONS					
SECTION	FIS BFE	UDUF BFE	CHANGE FROM FIS TO UDUF	ULTIMATE BFE	CHANGE FROM FIS TO ULT.
HURRICANE CREEK - MAIN STREAM					
5050	484.16	485.92	1.76	487.07	2.91
5120	484.24	486.05	1.81	487.17	2.93
5220		486.28		487.35	
5620		486.43		487.48	
5870		486.99		487.92	
6000	486.51	487.12	0.61	488.01	1.50
6760		488.39		488.98	
6860		489.22		489.44	
6980		489.22		489.44	
7100		492.01		492.73	
7800	492.48	493.71	1.23	494.35	1.87
8250		493.74		494.37	
9600		500.08		500.39	
9790	500.21	501.31	1.10	501.74	1.53
9840	500.32	501.47	1.15	501.90	1.58
9870	500.38	501.53	1.15	501.96	1.58
9930	500.48	501.53	1.05	501.95	1.47
10400		502.05		502.46	
10700		502.91		503.35	
11790	504.99	505.43	0.44	505.81	0.82
12050				504.88	
12200		506.27		508.02	
12600		509.83		508.45	
12980	511.13	510.59	-0.54	509.11	-2.02
13030	511.60	510.47	-1.13	510.21	-1.39
13130	514.36	514.15	-0.21	511.26	-3.10
13180	514.37	514.13	-0.24	510.87	-3.50
13450	514.25	514.87	0.62	510.92	-3.33

TABLE C-9. COMPARISON OF BASE FLOOD ELEVATIONS					
SECTION	FIS BFE	UDUF BFE	CHANGE FROM FIS TO UDUF	ULTIMATE BFE	CHANGE FROM FIS TO ULT.
14000	515.41	516.31	0.90	510.83	-4.58
14260	515.44	516.61	1.17	513.18	-2.26
14540	515.46	515.98	0.52	512.91	-2.55
14890	516.90	517.29	0.39	514.03	-2.87
15490	520.64	521.87	1.23	516.93	-3.71
15540	520.47	524.22	3.75	517.01	-3.46
15580	520.48	524.08	3.60	518.26	-2.22
15630	521.24	523.90	2.66	518.46	-2.78
15750		523.80		518.96	
15920	522.08	523.70	1.62	519.66	-2.42
16100	522.80	523.29	0.49	520.53	-2.27
16480		527.02		521.88	
16530	525.26			522.05	-3.21
16630	525.41	527.10	1.69	524.15	-1.26
16730	527.03	528.94	1.91	525.45	-1.58
16900	527.24	529.40	2.16	525.42	-1.82
17300		529.93		527.16	
17620	530.70	530.92	0.22	529.03	-1.67
17730	531.64	531.64	0.00	530.13	-1.51
17770	531.94	531.56	-0.38	531.14	-0.80

TABLE C-9. COMPARISON OF BASE FLOOD ELEVATIONS					
SECTION	FIS BFE	UDUF BFE	CHANGE FROM FIS TO UDUF	ULTIMATE BFE	CHANGE FROM FIS TO ULT.
CYCLONE BRANCH (HC-1)					
440	515.24	516.63	1.39	513.12	-2.12
780	515.65	516.47	0.82	512.94	-2.71
885	515.39	516.50	1.11	514.03	-1.36
1150	515.22	516.42	1.20	514.93	-0.29
1310	515.60	517.44	1.84	516.47	0.87
1470	517.28	519.08	1.80	517.29	0.01
1520	518.29	522.52	4.23	519.88	1.59
1550	518.67	522.73	4.06	520.65	1.98
1590	519.01	522.22	3.21	520.65	1.64
1655	519.07	523.27	4.20	523.34	4.27
1810	519.05	523.25	4.20	523.31	4.26
1940		522.60		523.37	
2270	524.42	524.84	0.42	525.47	1.05
2455	526.00	526.89	0.89	527.51	1.51
2770	528.89	528.76	-0.13	527.12	-1.77
3185	532.58	532.14	-0.44	530.15	-2.43
3485	533.82	534.45	0.63	532.22	-1.60
3510	534.90	537.21	2.31	532.09	-2.81
3550	534.91	537.21	2.30	533.38	-1.53
3600	535.12	536.72	1.60	533.13	-1.99
3675		537.72		533.30	
3780	536.23	538.15	1.92	533.72	-2.51
4010	537.08	538.50	1.42	535.72	-1.36
4440		540.27		537.92	
4940	543.67	543.01	-0.66	539.72	-3.95
5360	544.76	546.06	1.30	541.52	-3.24
5800	546.09	548.74	2.65	544.52	-1.57

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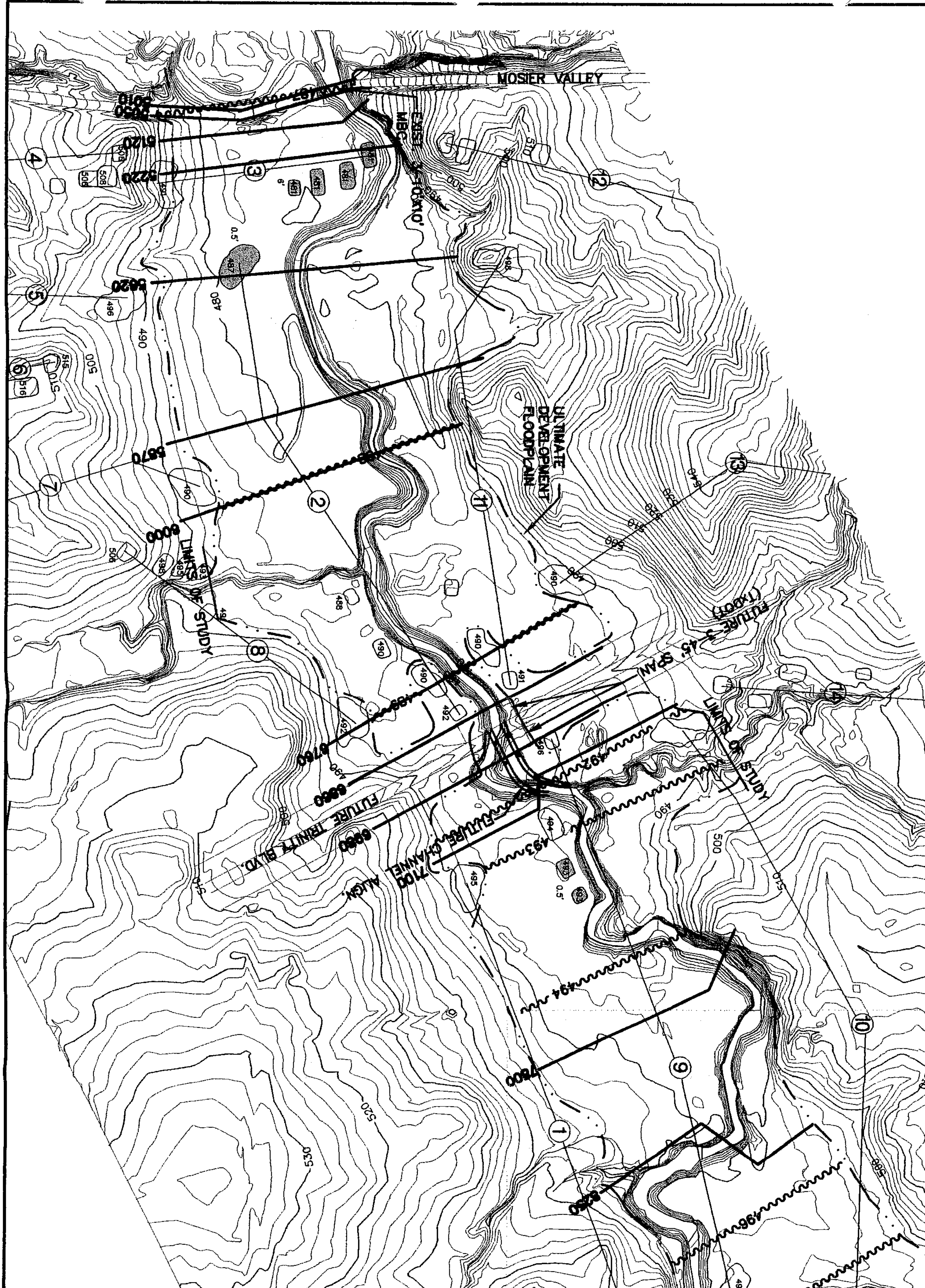

STORM DRAINAGE MASTER PLAN PHASE III

1: DRAINAGE IMPROVEMENTS

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STORM DRAINAGE MASTER PLAN PHASE III

2: DRAINAGE IMPROVEMENTS

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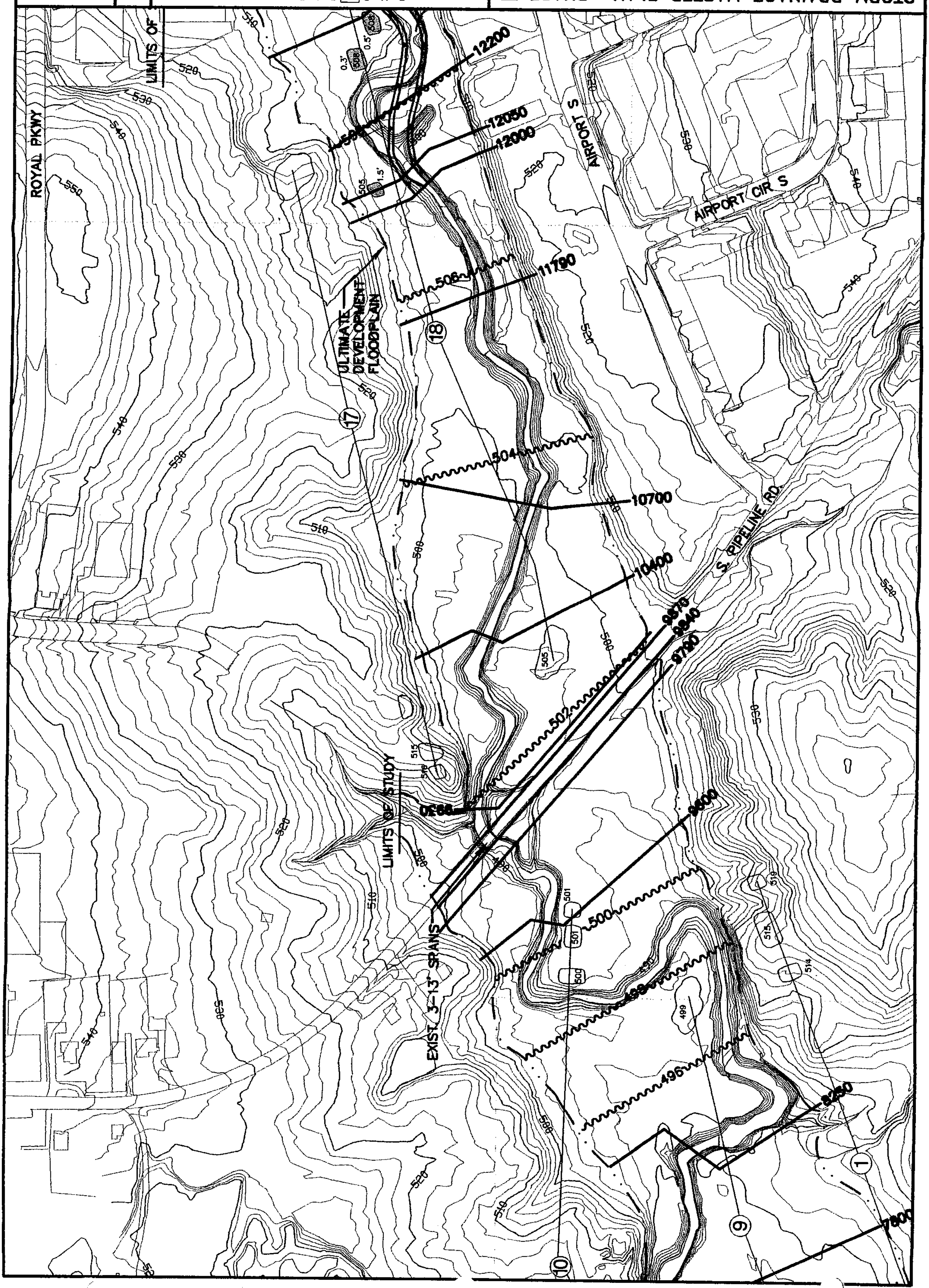

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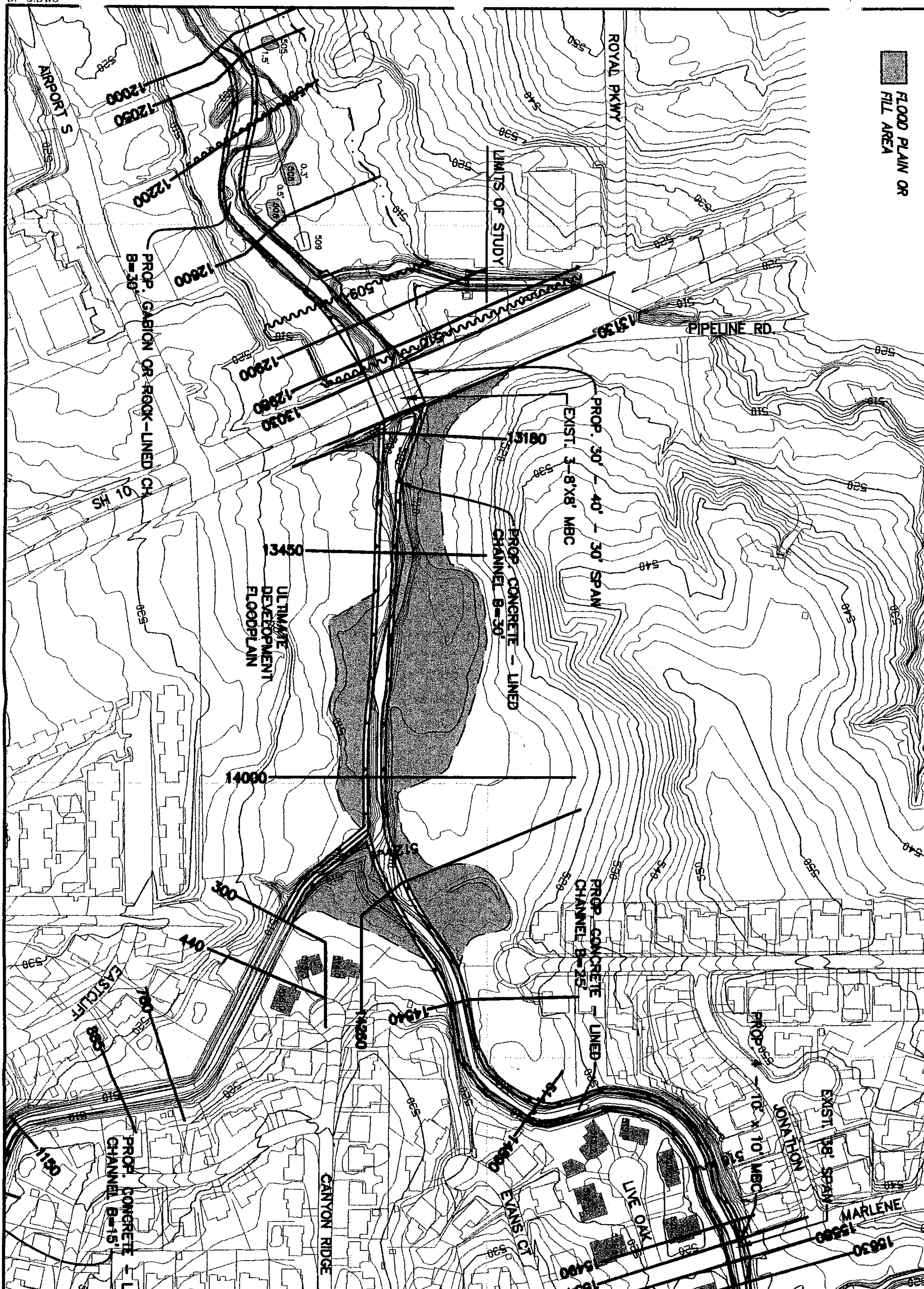
DI-3.DWG



STORM DRAINAGE MASTER PLAN PHASE III

3: DRAINAGE IMPROVEMENTS

PAGE	PANEL INDEX		
32	JAN 1996	1 2 3 4 5 6	W.E.F. DESIGNED M.D.S. DRAWN

THE CITY OF EULESS

TEAGUE NALL AND PERKINS
CONSULTING ENGINEERS

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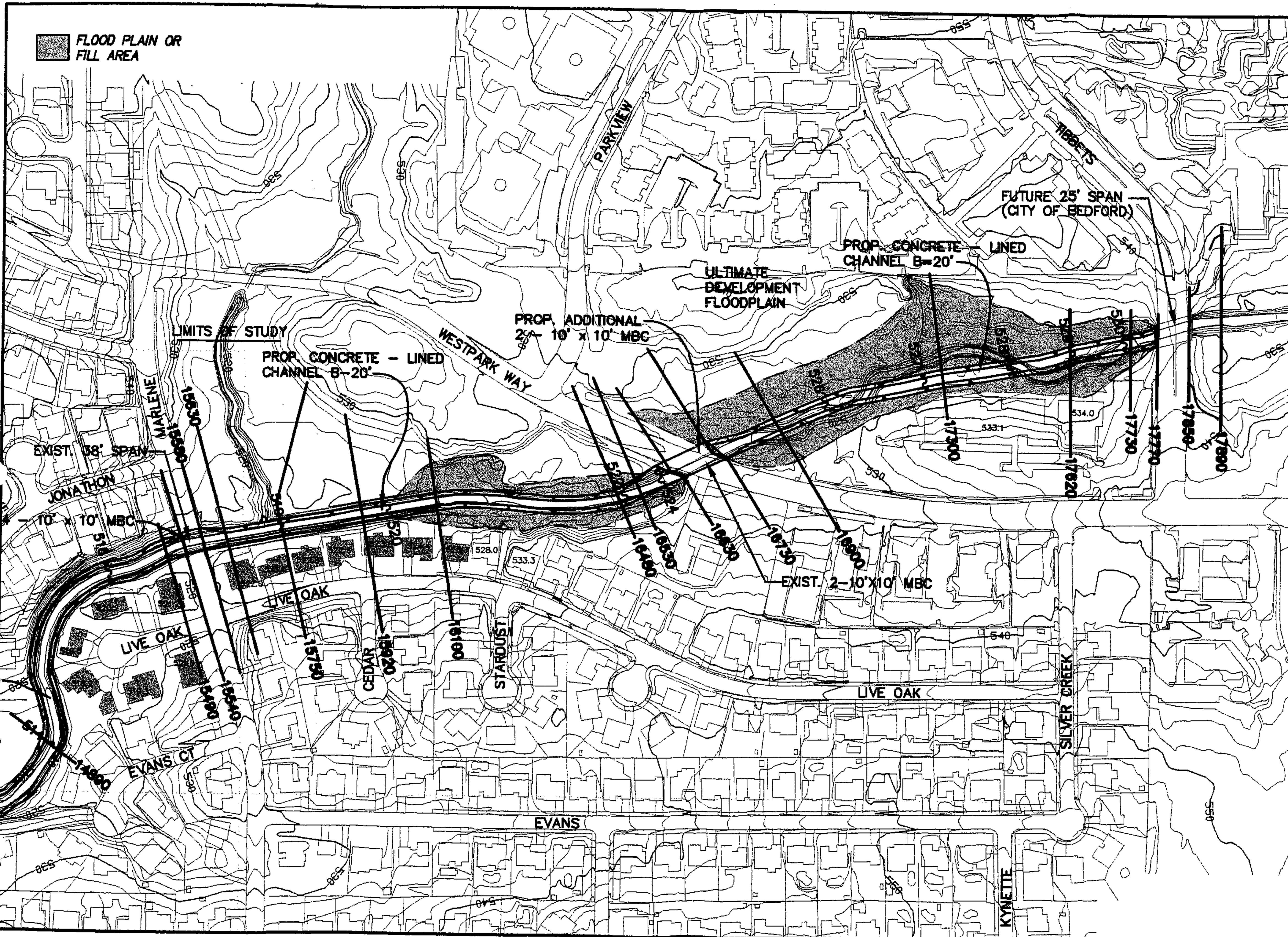

STORM DRAINAGE MASTER PLAN PHASE III

4: DRAINAGE IMPROVEMENTS

THE CITY OF EULESS

TEAGUE NALL AND PERKINS CONSULTING ENGINEERS

W.E.F. DESIGNED

M.D.S. DRAWN

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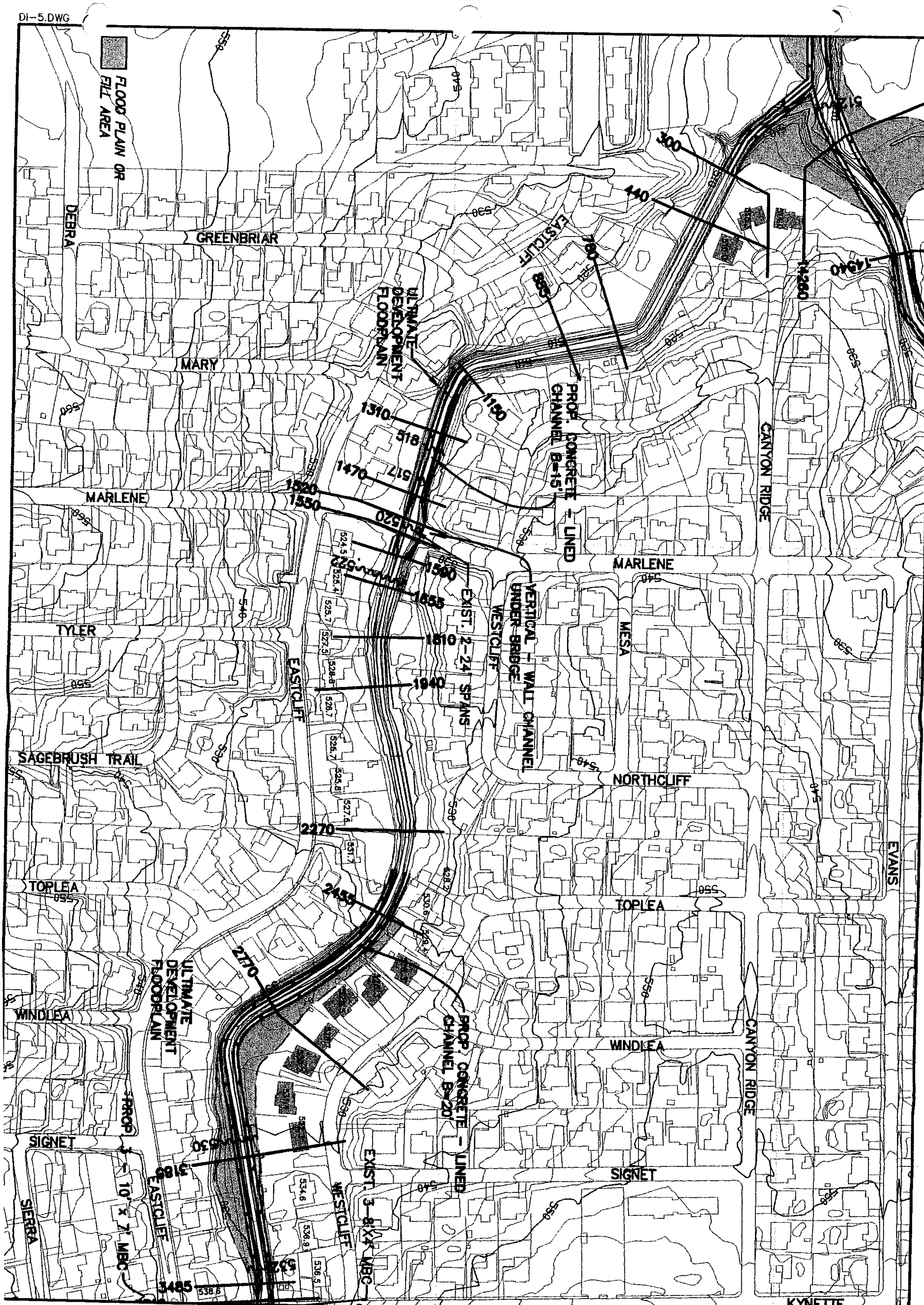

STORM DRAINAGE MASTER PLAN PHASE III

5: DRAINAGE IMPROVEMENTS

JAN 1996

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PANEL INDEX

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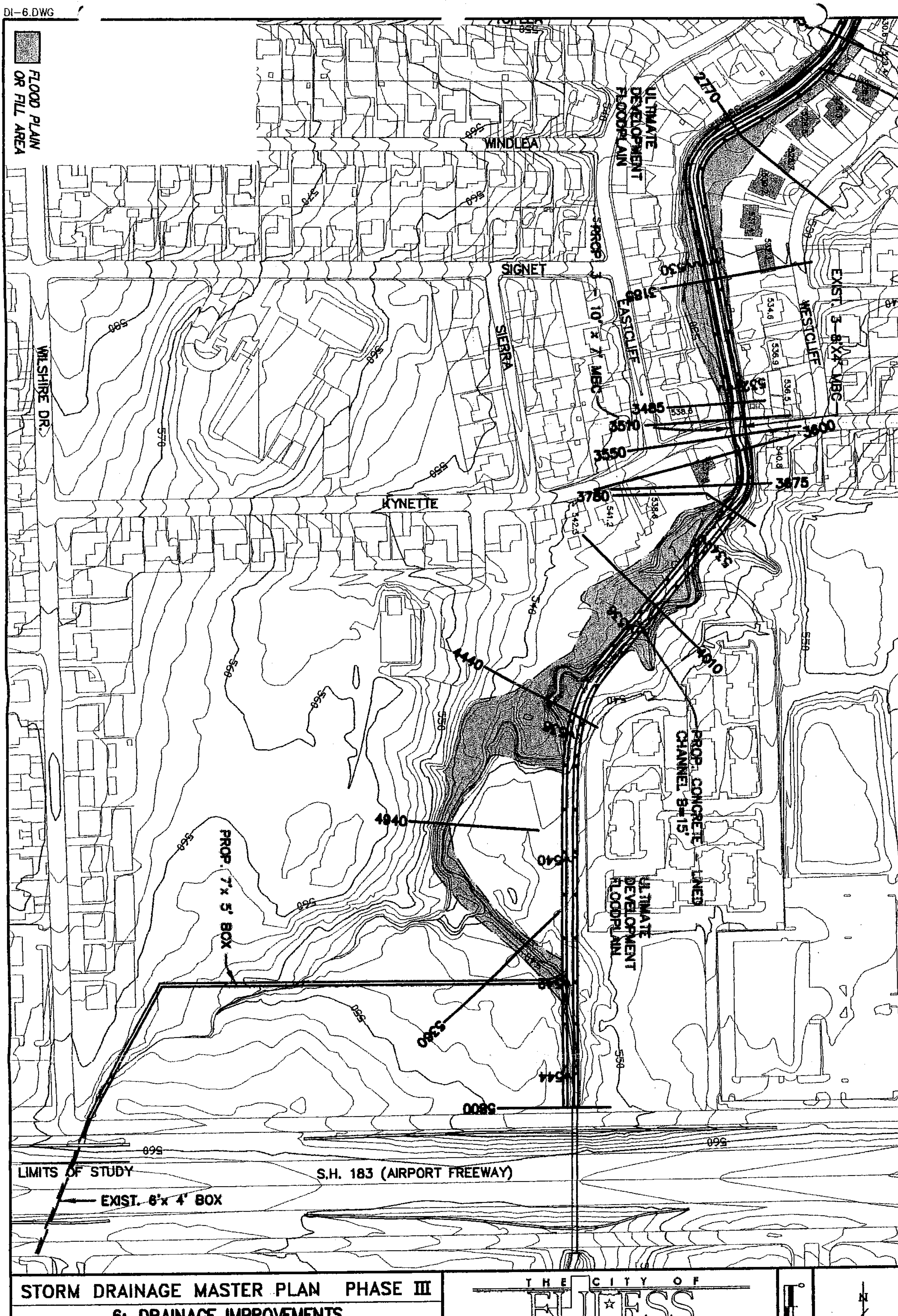
THE CITY OF EULESS

TEAGUE NALL AND PERKINS
CONSULTING ENGINEERS



STORM DRAINAGE MASTER PLAN PHASE III

6: DRAINAGE IMPROVEMENTS

JAN 1996	PAGE 35	PANEL INDEX	W.E.F. DESIGNED	M.D.S. DRAWN

THE CITY OF EULESS

TEAGUE NALL AND PERKINS CONSULTING ENGINEERS

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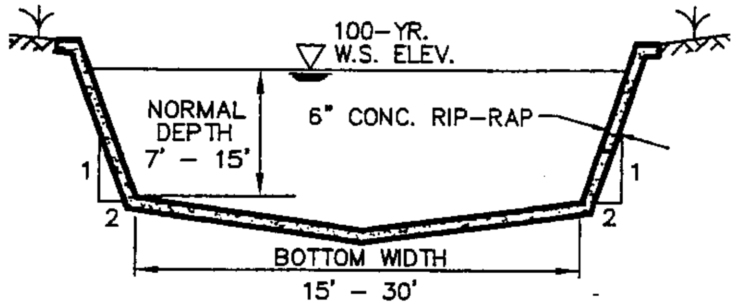
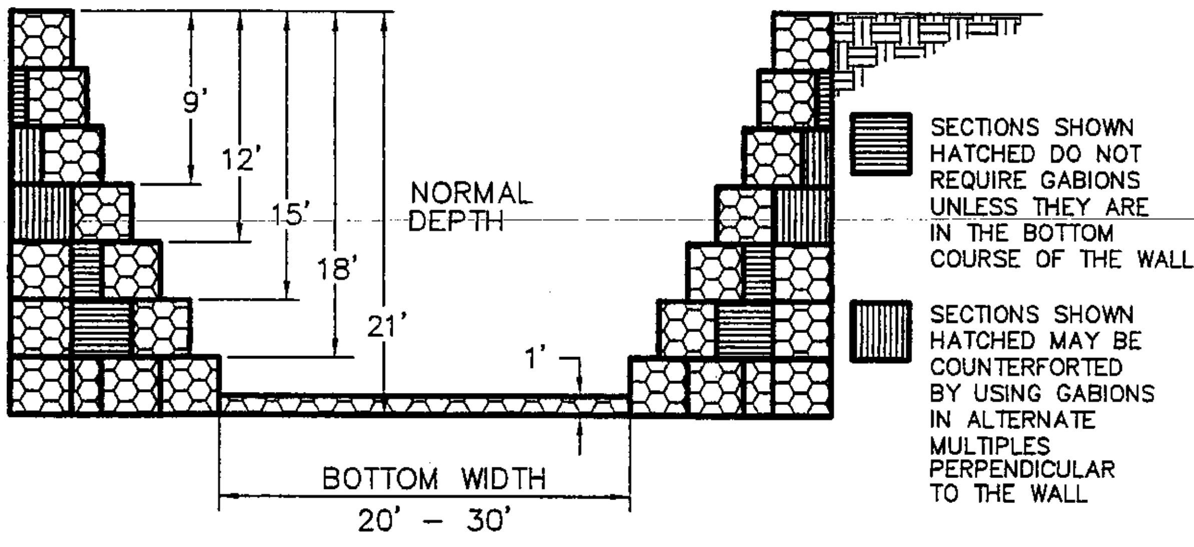


CONCRETE-LINED CHANNEL SECTION



NOTES:

1. TYPICAL UNSURCHARGED WALL TAKEN FROM INFORMATION PROVIDED BY GABION NORTH AMERICA, INC. AND IS GENERAL IN NATURE.
2. ACTUAL WALL DESIGN SHOULD FOLLOW STANDARD ENGINEERING PRACTICES.

GABION CHANNEL SECTION

THE CITY OF EULESS

TEAGUE NALL AND PERKINS
CONSULTING ENGINEERS

STORM DRAINAGE MASTER PLAN PHASE III

TYPICAL CHANNEL SECTIONS

W.E.F.
DESIGNED

T.D.M.
DRAWN

DATE
FEB. 1996

XSEC-1.DWG

6. GOLF COURSE

Because no drainage improvements are recommended along the Texas Star golf course, the ultimate developed floodplain is as much as 2.9 feet higher than the FIS floodplain along this reach. Based on the golf course grading plan, some of the tees and greens will be below the ultimate developed floodplain. The degree of flooding in the golf course will vary according to final grading. The extent of damage to tees and greens due to the ultimate developed flood conditions is difficult to predict. Even though some tees and greens will be inundated in the 100-yr storm, they may still have a statistically high degree of protection which may preclude the need for mitigation. The following table summarizes the approximate depth of flooding along the golf course in the ultimate developed base flood with upstream drainage improvements.

TABLE C-10. GOLF COURSE FLOODING

LOCATION	FLOODING DEPTH
Green 2	0.5'
Tee 3	6.4'
Green 9	0.5'
Green 18	1.5'

In addition to flooding, another potential problem through the golf course is erosion of the channel. The increasing flows due to urbanization will cause higher velocities. For the purposes of this study, channel reaches which have velocities in excess of eight (8) feet per second were considered for instability. Based on this criteria, potential erosion problems are indicated for several reaches.

The channel immediately upstream and downstream of the future Trinity Boulevard bridge as proposed by TxDOT has erosive velocities even in the 2-year storm event. The highest channel velocity in the 100-year storm event is 15.0 feet per second in this reach. These high velocities are the result of the grading for the golf course as well as the bridge size. These erosive velocities should be addressed as part of the bridge design.

The channel reach in the vicinity of the hole 10 tee and the hole 9 green has velocities up to 9.5 feet per second. The most likely location of instability will be in the numerous bends in this reach. More detailed soils investigations may indicate that these higher velocities may be tolerable. More detailed surveying and modeling of the areas in question, including evaluation of soil shear stress, may be required. The best approach in this reach may be to address erosion problems as they arise, unless access will be limited by golf course improvements.

The channel adjacent to and upstream of the hole 18 green has been realigned from its natural course. This could be the cause of velocities which range up to 10.3 feet per second. Since the reach is straight, erosion may not occur. The next downstream curve in the channel has velocities of approximately seven feet per second (7 fps). Some erosion may occur in the approach curve near section 10700. As a part of this study, checkdams were evaluated for this reach. These checkdams would provide some degree of erosion control.

The channel reach in the vicinity of hole 18 tee has a natural 'S' curve, and the natural floodplain narrows in this area. The golf course grading for the hole 18 tee tends to constrict the flows even more. These conditions contribute to high velocities and high tailwater on the SH 10 crossing. A solution as described above under 5. DRAINAGE IMPROVEMENTS will address the potential erosion problems due to high velocities in this reach. Also, this channel reach would be affected by the checkdams which were evaluated in this study.

7. TRINITY BOULEVARD

The Texas Department of Transportation has prepared preliminary hydrology and has developed a preliminary bridge size of 3-45' spans for each of the two 44' wide structures for the future Trinity Boulevard crossing. The size of the bridge structure will be finalized in early 1996 according to Mr. John Terry of TxDOT.

The preliminary hydrology prepared by the TxDOT shows the ultimate base flood flowrate to be less than the FIS base flood flowrate. The Urban Regression Equation method was used for this calculation of flowrates. The TxDOT preliminary hydrology appears to yield a low flowrate (see C.Results, 1.Hydrology, Comparison of Flows). This hydrology contributes to the apparent undersizing of the structure. The TxDOT intends to design the bridge for the urbanized 25-year storm with 2' of freeboard. Their design will include a check to insure a maximum one-foot (1') rise in the effective floodplain.

Using the ultimate developed flowrates determined in this study, the structures proposed by TxDOT would cause the ultimate developed base flood to increase by 1.3 feet. The resulting ultimate developed floodplain will be 2.6 feet above the effective base flood elevation.

8. SOUTH PIPELINE ROAD

The future extension of Trinity Boulevard may eliminate the need for South Pipeline Road. The study investigated the potential effect on the floodplain of removing the existing crossing at South Pipeline Road. The profiles published in the FIS show a minimal rise in the floodplain at South Pipeline Road. This evidence would indicate that the removal of the structure should have a minimal effect on the floodplain.

To evaluate the removal of the crossing, the ultimate development hydraulic model with drainage improvements (HC-IMP.IH2) was modified to remove the structure. The shape of the natural stream channel was maintained as it passes through the crossing reach.

The actual result is as anticipated. The removal of the existing crossing at South Pipeline Road has no appreciable effect on the ultimate floodplain. The reason for this result is that the structure spans only the channel and has no approach embankments which could impede floodwater.

9. WESTPARK WAY

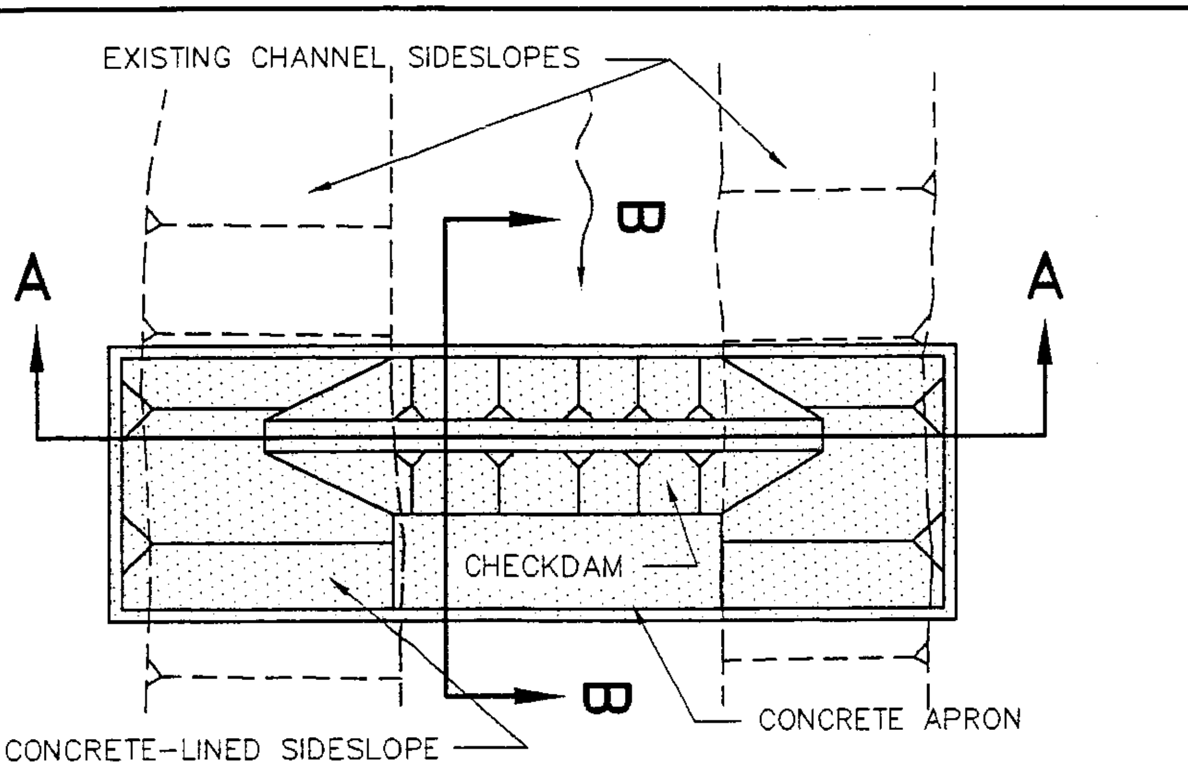
The existing crossing at Westpark Way is a two-barrel 10' x 10' multiple box culvert (MBC). The FIS models this crossing as a three-barrel 10' x 10' MBC. With downstream channel improvements, a four-barrel 10' x 10' MBC will pass the ultimate developed 100-yr storm without overtopping. If these improvements are made without the downstream channel improvements, some overtopping will still occur. This MBC improvement alone has negligible effect on the downstream peak flowrates. Above the confluence with Cyclone Branch, the ultimate developed unmitigated 100-yr flow is increased by 1.4%. At SH 10, the increase is <1%. The lower frequency storms yield similar increases. The net effect on base flood elevations is negligible.

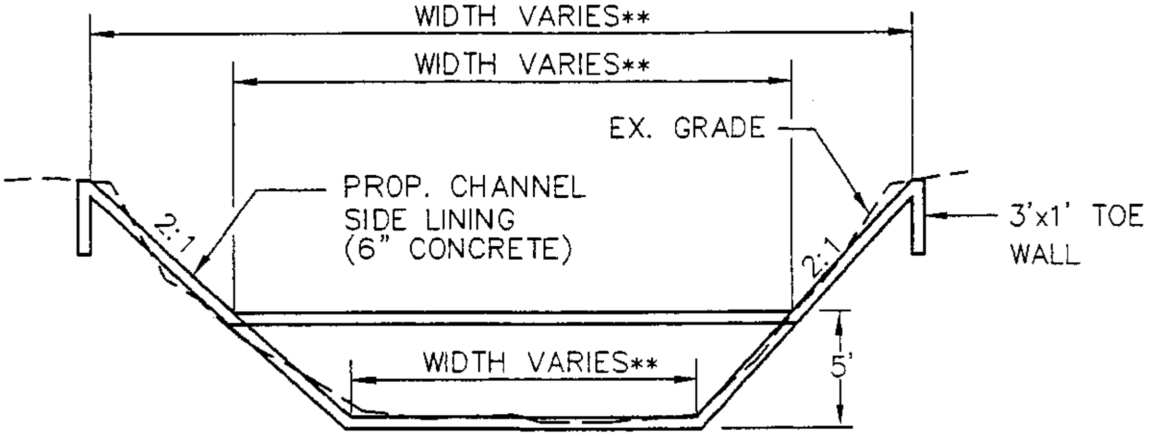
10. CHECKDAMS

The construction of check dams within the channel along a reach of Hurricane Creek along holes 17 and 18 of the Texas Star golf course, between South Pipeline Road and SH 10 was investigated. The purpose of the check dams is to create a ponding area along the channel to enhance the aesthetics of the golf course. Additional benefits could include improved plant and wildlife habitat and improved water quality along the creek.

Two checkdams five (5') feet high will retain water along most of the reach. The hydraulic effect of these dams was found to be negligible during the 100-yr storm event. The reason for this result is that most of the hydraulic capacity for the base flood is outside the channel in this reach.

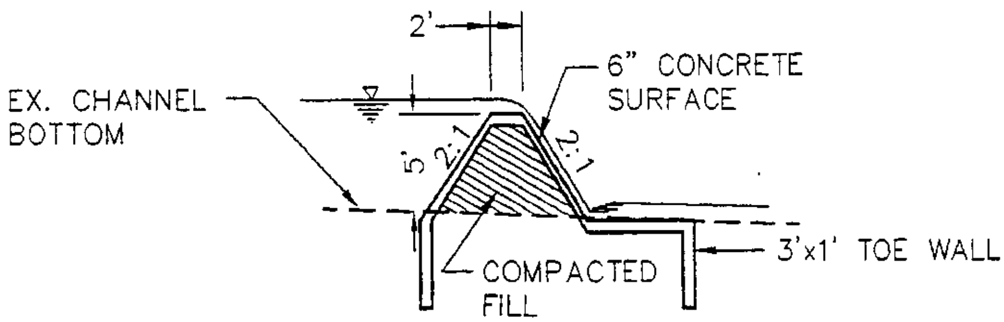
A gravity dam was selected for the checkdams as opposed to a cantilever type due to the longer anticipated useful life. The Check Dam Schematic exhibit illustrates the typical check dam used in preparing the cost estimate for this structure.





** WIDTH WILL VARY DEPENDING ON EXISTING CHANNEL GEOMETRY.

SECTION A-A



SECTION B-B

N.T.S.

THE CITY OF EULESS

TEAGUE NALL AND PERKINS
CONSULTING ENGINEERS

STORM DRAINAGE MASTER PLAN PHASE III

CHECK DAM SCHEMATIC

DESIGNED	R.W.D.
DRAWN	T.D.M.
DATE	FEB. 1996

CHECKDAM.DWG

D. REFERENCES

1. SCS National Engineering Handbook, Section 4, Hydrology, United States Department of Agriculture Soil Conservation Service, 1969.

2. Technical Paper No. 40, Rainfall Frequency Atlas of the United States, National Weather Service, 1961.

3. Technical Memorandum HYDRO-35, National Oceanic and Atmospheric Administration, June, 1977.

4. HEC-1 Flood Hydrograph Package, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, California, September, 1990.

5. HEC-2 Water Surface Profiles, U.S. Army Corps of Engineers, Hydrologic Engineering Center, 609 Second Street Suite D, Davis, California, 95616-4687.

6. NUDALLAS Documentation and Supporting Appendices, U.S. Army Corps of Engineers, Fort Worth, Texas, September, 1986.

7. General Future Land Use Plan, Planning and Zoning Commission of the City of Euless, 1983.

8. Drainage Master Plan, City of Bedford, Texas, Knowlton-English-Flowers, Inc., 1992.

9. Soil Survey of Tarrant County, Texas, USDA Soil Conservation Service, 1981.

10. Flood Insurance Study, Tarrant County, Texas, Federal Emergency Management Agency, August 2, 1995.

11. Technical Release No. 55, Urban Hydrology for Small Watersheds, U.S. Department of Agriculture Soil Conservation Service, June, 1986.

12. Flood Insurance Study Guidelines and Specification for Study Contractors, Federal Emergency Management Agency, March, 1993.

APPENDIX 1.

COE ULTIMATE HYDROLOGY LETTER

JOB NO. Corr.
FILING 29-232
KEE | TEN
BPF | GRP
RWA | MER
GHB | BSS
DHC | JVS
EWC | SLS
GWF

DEPARTMENT OF THE ARMY
FORT WORTH DISTRICT, CORPS OF ENGINEERS
P. O. BOX 17300
FORT WORTH, TEXAS 76102-0300

REPLY TO
ATTENTION OF

October 5, 1992

Hydrology and Hydraulics Branch
Engineering Division

Mr. J. E. Powell, P.E.
City Engineer
City of Bedford
P.O. Box 157
Bedford, Texas 76095-0157

Dear Mr. Powell:

Thank you for your letter of July 11, 1991 concerning the development of fully urbanized condition peak discharge versus frequency relationships for streams within your community. The Corps of Engineers has recently completed a hydrologic study on three streams in Bedford: Valley View Branch, Sulphur Branch, and Hurricane Branch. These streams were studied to determine ultimate discharges with a fully developed watershed.

The enclosed reports show the comparison of discharges for existing conditions and two different ultimate condition scenarios. The first ultimate condition scenario ("ultimate 1") was computed using existing stream channels and encroachment on the stream to the FEMA Floodway to determine storage for the hydrologic model. The existing hydrologic model was altered to represent a fully developed watershed by inserting the new storage and increasing the percent urbanization and percent impervious values. The second ultimate condition scenario ("ultimate 2") was computed using improved channels to determine storage and then inserting these storages into the hydrologic model. The assumptions which were used for the improved channels were that they would be concrete lined with side slopes of 1 on 1 and bottom widths ranging from 20 feet to 40 feet. The change in water surface elevation is the increase in elevation at selected points between an existing conditions model and an existing channel model using "ultimate 2" discharges.

We hope the information provided addresses your request and will help you in the development of your community.

Sincerely,

Jimmy D. Baggett

JIMMY D. BAGGETT, P.E.
Chief, Hydraulics and Hydrology Branch

Enclosure

Bedford Creek

	Drainage Area (sq.mi.)		10-yr	50-yr	100-yr	500-yr
D/S Westpark Way	1.96	existing	2450	2950	3100	3450
		ultimate1	2590	3000	3140	3420
		ultimate2	2600	2930	3000	3430
Highway 121	1.63	existing	2700	3600	4000	5100
		ultimate1	2910	3850	4250	5200
		ultimate2	2910	3850	4250	5200
Above Trib x-sec 20780	1.06	existing	1850	2500	2750	3500
		ultimate1	1870	2470	2730	3320
		ultimate2	1870	2470	2730	3320
Bedford Rd.	0.84	existing	1500	1950	2150	2750
		ultimate1	1480	1950	2150	2620
		ultimate2	1480	1950	2150	2620
x-sec 24700	0.55	existing	1000	1300	1450	1800
		ultimate1	970	1300	1420	1725
		ultimate2	970	1300	1420	1725
x-sec 26140	0.30	existing	550	700	750	1000
		ultimate1	525	700	760	930
		ultimate2	525	700	760	930

ultimate1 - existing chanels fully urbanized
ultimate2 - fully chanelized and urbanized

APPENDIX 2.

OPINION OF PROBABLE COST - CONCEPTUAL DESIGN

Index

TEAGUE NALL AND PERKINS

CONSULTING ENGINEERS

OPINION OF PROBABLE COST

CONCEPTUAL DESIGN

OWNER: CITY OF EULESS
PROJECT: HURRICANE CREEK

DATE: 09/19/96
PROJECT #: EUL94139

ITEM NO.	DESCRIPTION OF ITEMS	QUANTITY	UNIT	UNIT PRICE	COST
	ROAD CROSSING AT S.H. 10				
1	Remove Exist. Box Culvert	1	EA	14,000.00	14,000
2	Bridge (100' x 100' Span)	1	EA	740,000.00	740,000
3	Unclassified Excavation	2,300	CY	6.00	13,800
4	Traffic Control	1	EA	20,000.00	20,000
5	Erosion Control	1	EA	3,000.00	3,000
	Subtotal				$790,800
	Eng. & Survey @ 10%				79,080
	Contingency @ 15%				118,620
	Total				$988,500
	ROAD CROSSING AT MARLENE				
1	Remove Exist. Bridge	1	EA	15,000.00	15,000
2	4 - 10' x 10' Box Culvert	40	LF	1,125.00	45,000
3	Traffic Control	1	EA	2,000.00	2,000
	Subtotal				$62,000
	Eng. & Survey @ 12%				7,440
	Contingency @ 15%				9,300
	Total				$78,740
	ROAD CROSSING AT WESTPARK WAY				
1	2 - 10' x 10' Precast Box Culvert	100	LF	788.00	78,800
2	Traffic Control	1	EA	5,000.00	5,000
	Subtotal				$83,800
	Eng. & Survey @ 12%				10,056
	Contingency @ 15%				12,570
	Total				$106,426

TEAGUE NALL AND PERKINS

CONSULTING ENGINEERS

OPINION OF PROBABLE COST

CONCEPTUAL DESIGN

OWNER: CITY OF EULESS

PROJECT: HURRICANE CREEK

DATE: 09/19/96

PROJECT #: EUL94139

ITEM NO.	DESCRIPTION OF ITEMS	QUANTITY	UNIT	UNIT PRICE	COST
	GABION-LINED CHANNEL				
1	Unclassified Excavation	4,750	CY	6.00	28,500
2	Gabion Lining	4,100	CY	150.00	615,000
3	Gabion Mattress	1,150	CY	100.00	115,000
4	Hydromulch	4,000	SY	1.00	4,000
	Subtotal				$762,500
	Eng. & Survey @ 12%				91,500
	Contingency @ 15%				114,375
	Total				$968,375
	CONCRETE-LINED CHANNEL				
1	Unclassified Excavation	18,000	CY	6.00	108,000
2	6" Concrete Lining	35,800	SY	35.00	1,253,000
3	Hydromulch	44,000	SY	1.00	44,000
	Subtotal				$1,405,000
	Eng. & Survey @ 12%				168,600
	Contingency @ 15%				210,750
	Total				$1,784,350
	CHECKDAMS (COST FOR TWO)				
1	Compacted Fill	180	CY	10.00	1,800
2	Concrete Surface	604	SY	50.00	30,200
3	Toe Wall	50	CY	300.00	15,000
4	Drainage	2	LS	3,000.00	6,000
5	Temporary Diversion	2	LS	10,000.00	20,000
	Subtotal				$73,000
	Eng. & Survey @ 12%				8,760
	Contingency @ 15%				10,950
	Total				$92,710

TEAGUE NALL AND PERKINS

CONSULTING ENGINEERS

OPINION OF PROBABLE COST

CONCEPTUAL DESIGN

OWNER: CITY OF EULESS

PROJECT: CYCLONE BRANCH

DATE: 09/19/96

PROJECT #: EUL94139

ITEM NO.	DESCRIPTION OF ITEMS	QUANTITY	UNIT	UNIT PRICE	COST
	ROAD CROSSING AT MARLENE				
1	Remove Exist. RipRap	185	SY	6.00	1,110
2	Unclassified Excavation	200	CY	10.00	2,000
3	6" Concrete Lining	150	CY	350.00	52,500
4	Erosion Control	1	EA	2,000.00	2,000
	Subtotal				$57,610
	Eng. & Survey @ 12%				6,913
	Contingency @ 15%				8,642
	Total				$73,165
	ROAD CROSSING AT KYNETTE				
1	Remove Exist. Box Culvert	1	EA	5,500.00	5,500
2	3 - 10' x 7' Box Culvert	66	CY	330.00	21,780
3	Pavement Removal	450	SY	6.00	2,700
4	Compacted Fill	200	CY	5.00	1,000
5	6" Concrete Pavement	450	SY	30.00	13,500
6	Traffic Control	1	EA	2,000.00	2,000
	Subtotal				$46,480
	Eng. & Survey @ 12%				5,578
	Contingency @ 15%				6,972
	Total				$59,030
	CONCRETE-LINED CHANNEL				
1	Unclassified Excavation	17,400	CY	6.00	104,400
2	6" Concrete Lining	23,250	SY	35.00	813,750
3	Hydromulch	19,000	SY	1.00	19,000
	Subtotal				$937,150
	Eng. & Survey @ 12%				112,458
	Contingency @ 15%				140,573
	Total				$1,190,181

IV. LOREAN BRANCH

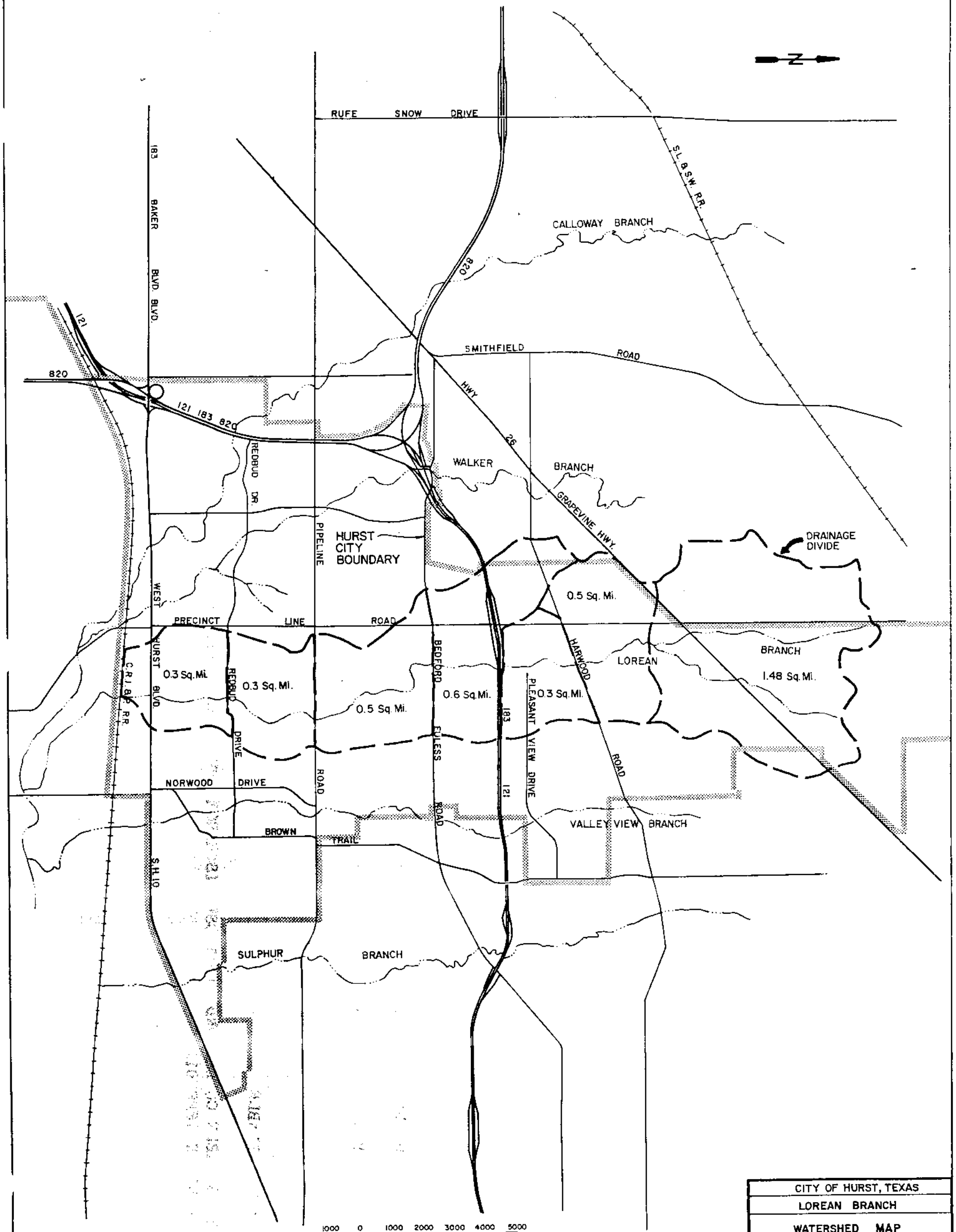
The Lorean Branch watershed is almost completely within the City of Hurst and drains the central portion of the City. Lorean Branch flows in a southerly direction from upstream of State Highway 26 to the Chicago, Rock Island, and Pacific Railroad (see Figure L-I). At the railroad the watershed drainage area is 4.0 square miles. The shape of the watershed is generally long and narrow with land use being primarily residential and commercial. Projected future urbanization and channelization is expected to increase the existing 100-year discharges by 20-45% for the various reaches (see Table L-1).

Lorean Branch has a channel length of about 5.5 miles with an average slope along the channel of approximately 0.5%. The reaches from Cullum Street to Central Park and from Pipeline Road to Hurstview Drive are concrete lined. Immediately downstream of Cullum Street and from Bedford-Euless Road to State Highway 121, the stream has improved earthen channels with concrete pilot channels. The remaining reaches are earthen channels. There are thirteen bridges on Lorean Branch between State Highway 26 and the Chicago, Rock Island, and Pacific Railroad. Table L-2 contains pertinent elevations for each of these bridges.

Lorean Branch has a history of flooding problems with homes located on Myrtle Drive, Bowles Court, and Cullum Drive which were damaged by flooding in 1971, 1974, and 1981. Potential flooding areas along the stream are depicted on Sheets L-1 and L-8 where the 100-year floodplain is delineated, depicting existing channel and bridge conditions with future flood discharges, based on a fully urbanized and channelized watershed. About 150 buildings were found to lie within the 100-year floodplain.

Since the existing channel and bridges cannot adequately carry the future 100-year discharges, a number of channel improvement and bridge replacement recommendations were made. These recommendations can be found in the following Tables L-3 to L-4. Initial recommendations for improvements to Lorean Branch totalled $7,027,000 and include the reaches between the Chicago, Rock Island, and Pacific Railroad and Cullum Street, and from Hurstview Drive to Cannon Drive. The ultimate recommendations for Lorean Branch totalled $10,772,000 and includes the reaches from the Chicago, Rock Island, and Pacific Railroad to Cannon Drive. The ultimate costs would include the initial recommendations cost estimates. See Appendix B for preliminary cost estimates.

At this time (November 1983), the Corps of Engineers is studying Lorean Branch under a Federal Flood Control Authority and will be making design recommendations independent of those prepared for this study.



CITY OF HURST, TEXAS

LOREAN BRANCH

WATERSHED MAP

ALBERT H. HALFF ASSOC., INC.	
DATE	A/O 7392
SCALE AS SHOWN	SHEET L-I

TABLE L-1

**PEAK FLOOD DISCHARGES
LOREAN BRANCH

LOCATION	DRAIN AREA (sq.mi.)	EXISTING CONDITIONS Q (cfs) 10-YR	*25-YR	50-YR	100-YR	500-YR	FULLY URBANIZED & CHANNELIZED CONDITIONS Q (cfs) 5-YR	10-YR	25-YR	50-YR	100-YR	500-YR
Above Cannon Dr	1.48	2,200	-	2,950	3,300	4,150	2,400	2,750	3,250	3,650	4,050	5,100
Above Harwood Dr	1.96	2,450	-	3,300	3,700	4,650	3,050	3,500	4,150	4,600	5,050	6,150
Above Highway 121	2.28	2,550	-	3,450	3,850	4,850	3,500	3,900	4,300	4,750	5,300	6,950
Above Bedford-Euless Road	2.85	3,300	-	4,400	4,900	6,150	4,400	4,850	5,500	6,000	6,600	8,350
Above Pipeline Rd	3.36	3,850	-	4,800	5,300	6,600	5,100	5,700	6,250	6,700	7,350	9,350
Above Redbud Dr	3.70	4,000	-	5,100	5,650	6,900	5,350	6,050	6,800	7,300	7,850	9,550
Above CRI&P RR	4.04	4,100	-	5,200	5,700	7,000	5,650	6,350	7,100	7,650	8,300	9,950

* NOT AVAILABLE

** THIS TABLE CORRESPONDS TO THOSE DISCHARGES WHICH WERE USED IN THE HYDRAULIC MODELS. ADDITIONAL DISCHARGES CAN BE FOUND IN APPENDIX C.

TABLE L-2

BRIDGE TABLE
LOREAN BRANCH

IDENTIFICATION	FLOWLINE ELEVATION	LOW* CHORD	TOP OF* ROAD	100-YEAR FLOOD WATER SURFACE ELEV @ US FACE	DESCRIPTION
C.R.I. & P. RR	495.2	515.2	519.0	510.4	Wood trestle
State Hwy 10	497.3	504.0	509.9	513.3	Multiple concrete box culverts
Cullum Street	499.5	508.0	510.0	514.3	Concrete w/piers
Redbud Drive	502.3	511.3	512.1	515.0	Concrete, single span
Hurstview Drive	507.8	514.0	516.8	520.6	Concrete, single span
Elm Street	511.3	520.8	522.0	522.0	Concrete w/piers
Pipeline Road	524.0	532.8	534.6	539.5	Concrete w/piers
Sheri Lane	525.5	532.6	533.6	539.6	Concrete w/piers
Hurstview Drive	527.9	533.7	535.7	540.8	Concrete w/piers
Bedford-Euless Rd	544.3	555.9	555.3	558.9	Concrete w/piers
Airport Frwy (121)	552.0	561.7	567.3	568.6	Multiple concrete box culverts
Harwood Road	563.0	572.7	575.0	575.0	Multiple concrete box culverts
Cannon Drive	575.0	580.6	582.6	584.6	Multiple concrete box culverts

* APPROXIMATE ELEVATIONS (FEET ABOVE MEAN SEA LEVEL)

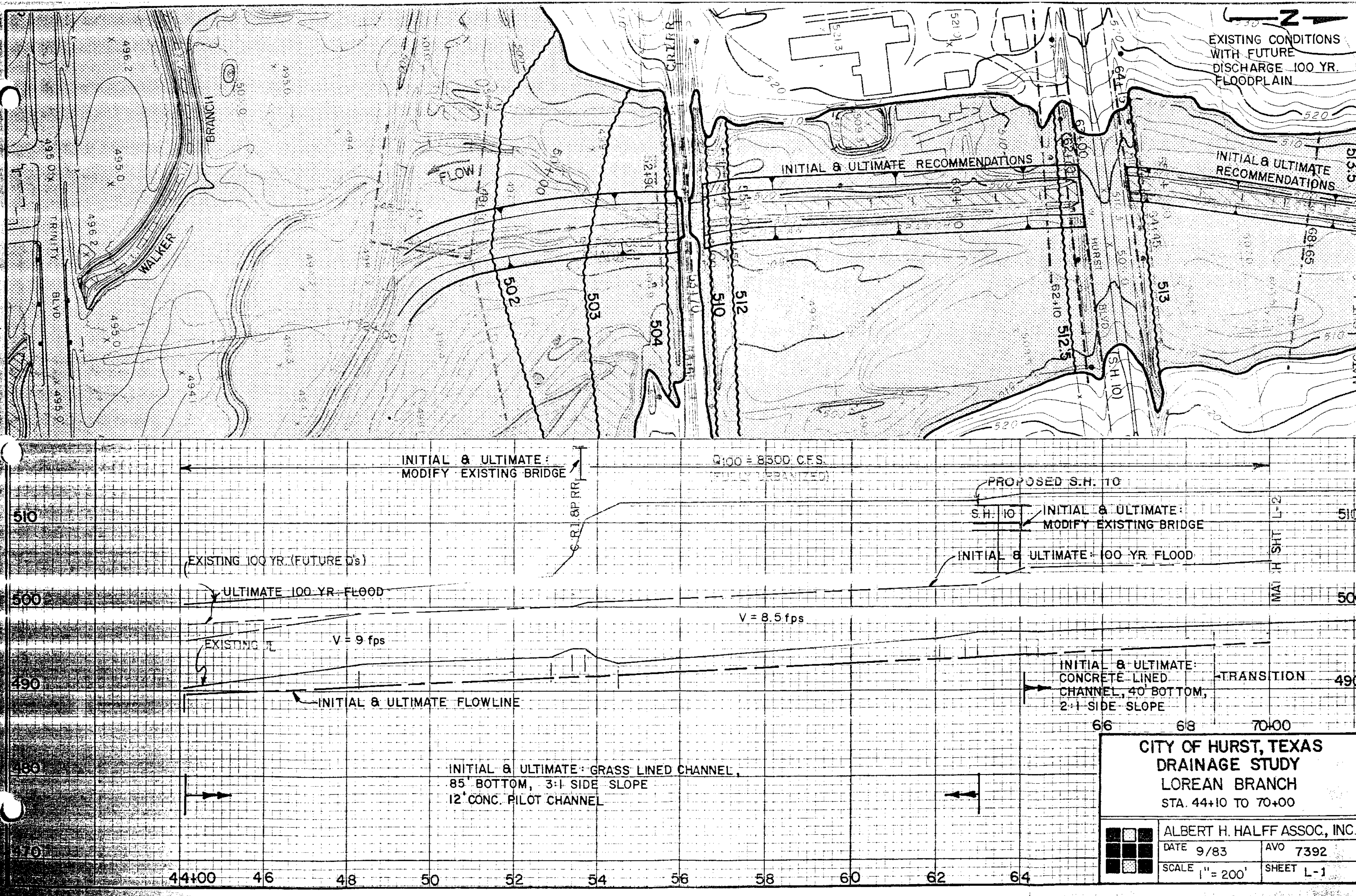
TABLE L-3

LOREAN BRANCH
INITIAL RECOMMENDATIONS

	REACH STATION	DESCRIPTION	DESCRIPTION OF IMPROVEMENTS	ESTIMATED COST
1)	44+10–63+00	DS of CRI&P RR to Hwy 10	– Earthen Channel with 12' concrete pilot channel, 85' BW, 3:1 SS modify existing bridge	$1,552,000
2)	63+00–80+20	Hwy 10 to US of Cullum	– Fully lined concrete channel 40' BW, 2:1 SS, modify exist culverts at Hwy 10	1,350,000
3)	133+10–167+70	Hurstview Drive to Bedford-Euless Rd	– Fully lined concrete channel 60' BW, 1:1 SS and 50' BW, 1:1 SS, lower flowline at Hurstview Drive bridge	1,961,000
4)	168+40–187+45	Bedford-Euless Rd to Airport Frwy	– Earthen channel with 12'concrete pilot channel, 60' BW, 3:1 SS, 1 drop structure	492,000
2205 5)	$479.82 190+55–212+60	$240 Airport Frwy to Harwood Road	– Fully lined concrete channel 35' BW, 2:1 SS	1,058,000
6)	213+70–241+20	Harwood Road to Cannon Drive	– 12' concrete pilot channel with earthen SS, 50' BW, 3:1 SS, 1 drop structure, lower flow-line of existing bridge at Cannon	614,000

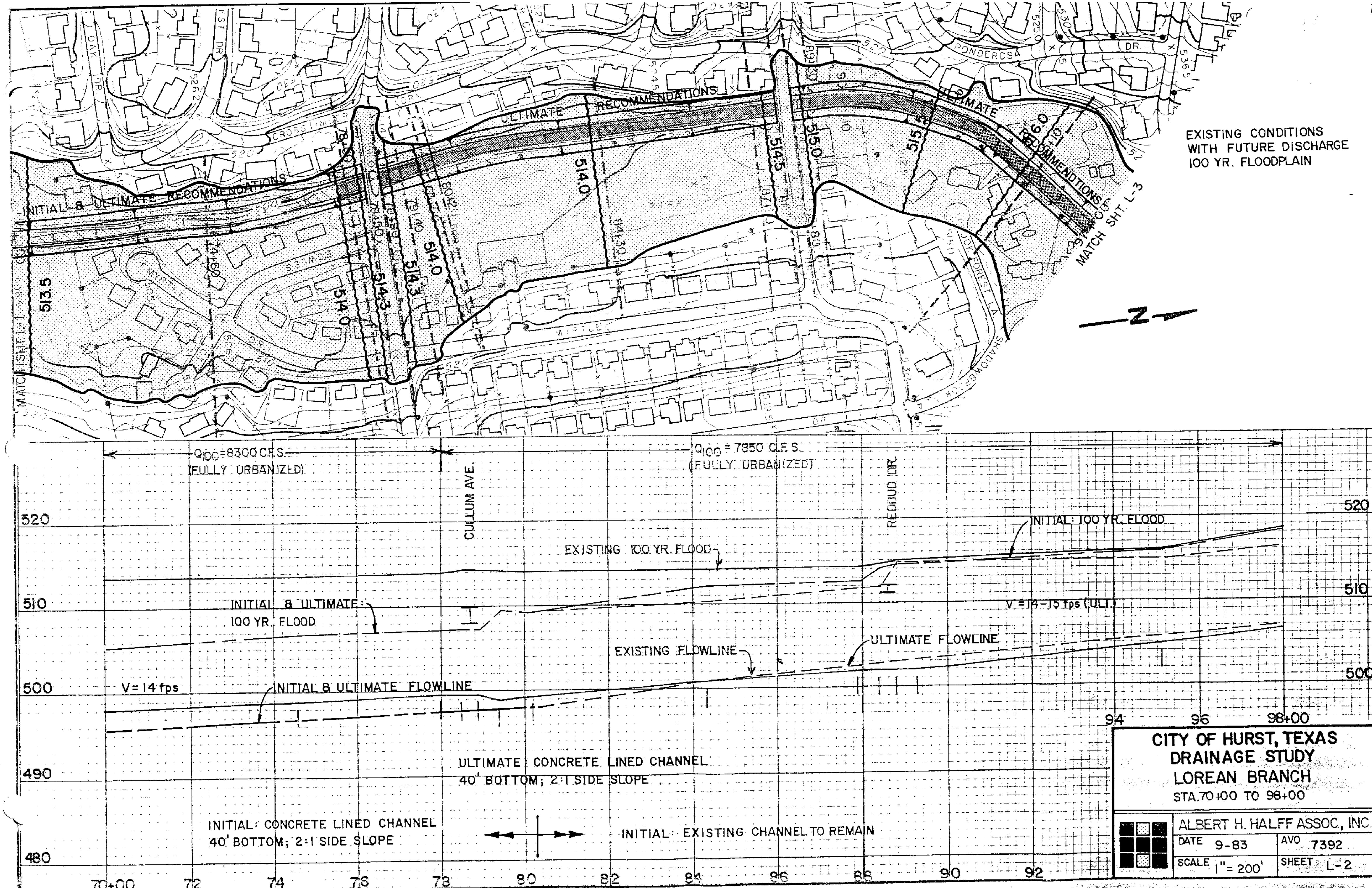
TABLE L-4
LOREAN BRANCH
ULTIMATE RECOMMENDATIONS

	REACH STATION	REACH DESCRIPTION	DESCRIPTION OF IMPROVEMENTS	ESTIMATED COST
1)	44+10-63+00	DS of CRI&PRR to Hwy 10	- 12' concrete pilot channel w/ earthen SS, 85' BW, 3:1 SS, modify existing bridge	$1,552,000
2)	63+00-78+50	Hwy 10 to Cullum Street	- Fully lined concrete channel 40' BW, 2:1 SS, modify exist Hwy 10 culverts	1,350,000
3)	78+50-88+40	Cullum Street to Redbud Drive	- Fully lined concrete channel 40' BW, 2:1 SS	535,000
4)	88+40-98+55	Redbud Drive to Hurstview Drive	- Fully lined concrete channel 40' BW, 2:1 SS, new bridge at Redbud Drive	719,000
5)	98+55-105+20	Hurstview Drive to Elm Street	- Fully lined concrete channel 40' BW, 2:1 SS, new bridge at Hurstview Drive	537,000
6)	118+37-124+60	DS of Pipeline to Sheri Street	- Fully lined concrete channel 50' BW, 2:1 SS and 60' BW, 1:1 SS, new bridge at Pipeline Road, 1 drop structure	793,000
7)	124+60-133+10	Sheri Street to Hurstview Drive	- Fully lined concrete channel 60' BW, 1:1 SS, new bridge at Sheri Street	709,000
8)	133+10-167+70	Hurstview Drive to Bedford-Euless Rd	- Fully lined concrete channel 60' BW, 1:1 SS and 50' BW, 1:1 SS, new bridge at Hurstview Drive	2,250,000
9)	168+40-187+45	Bedford-Euless Rd to Airport Frwy	- 12' concrete pilot channel with earthen SS, 60' BW, 3:1 SS, 1 drop structure	492,000
10)	190+55-212+60	Airport Frwy to Harwood Road	- Fully lined concrete channel 35' BW, 2:1 SS	1,058,000
11)	213+70-241+20	Harwood Road to Cannon Drive	- 12' concrete pilot channel with earthen SS, 50' BW, 3:1 SS, 1 drop structure, new bridge at Cannon	777,000

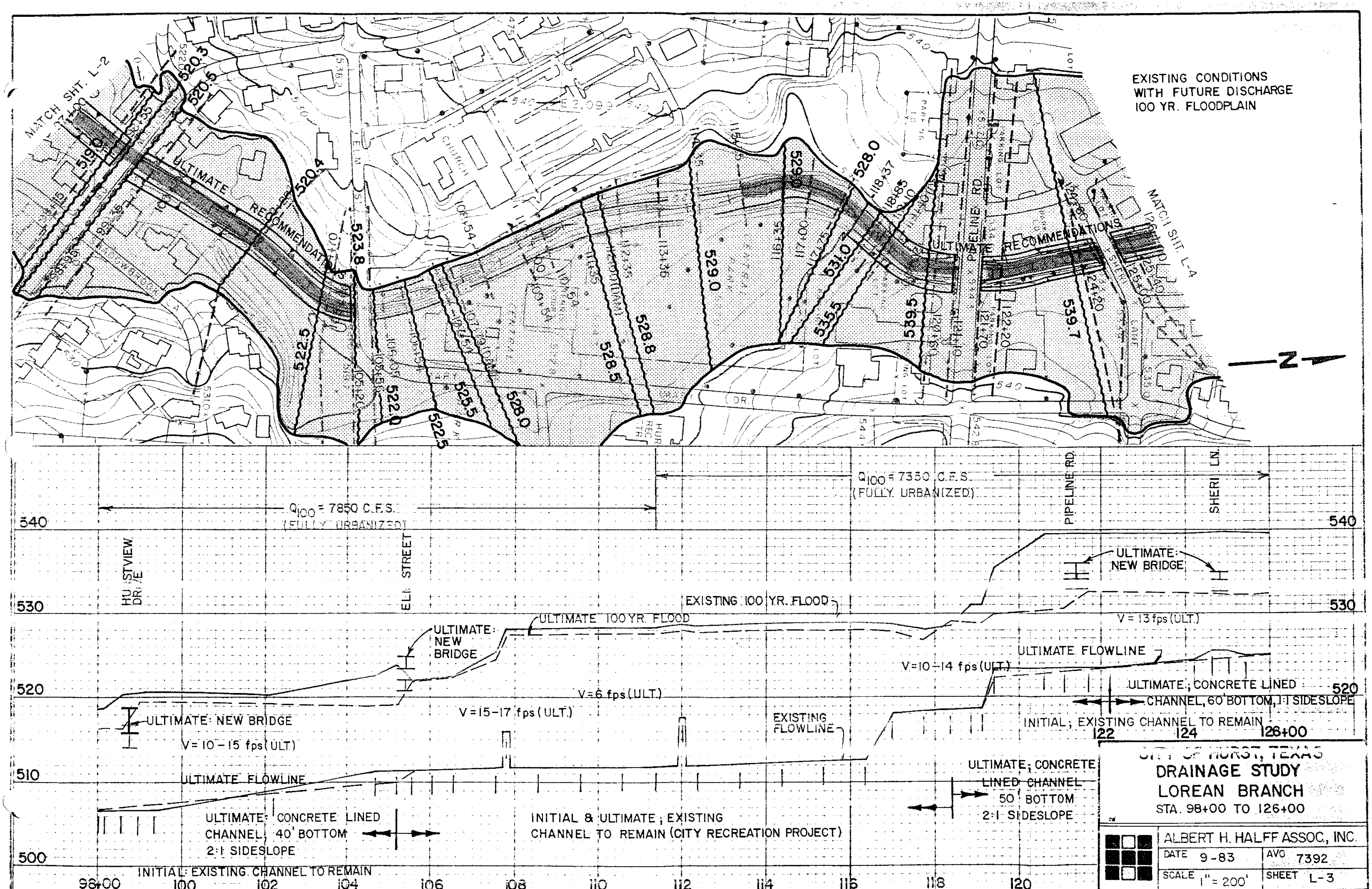


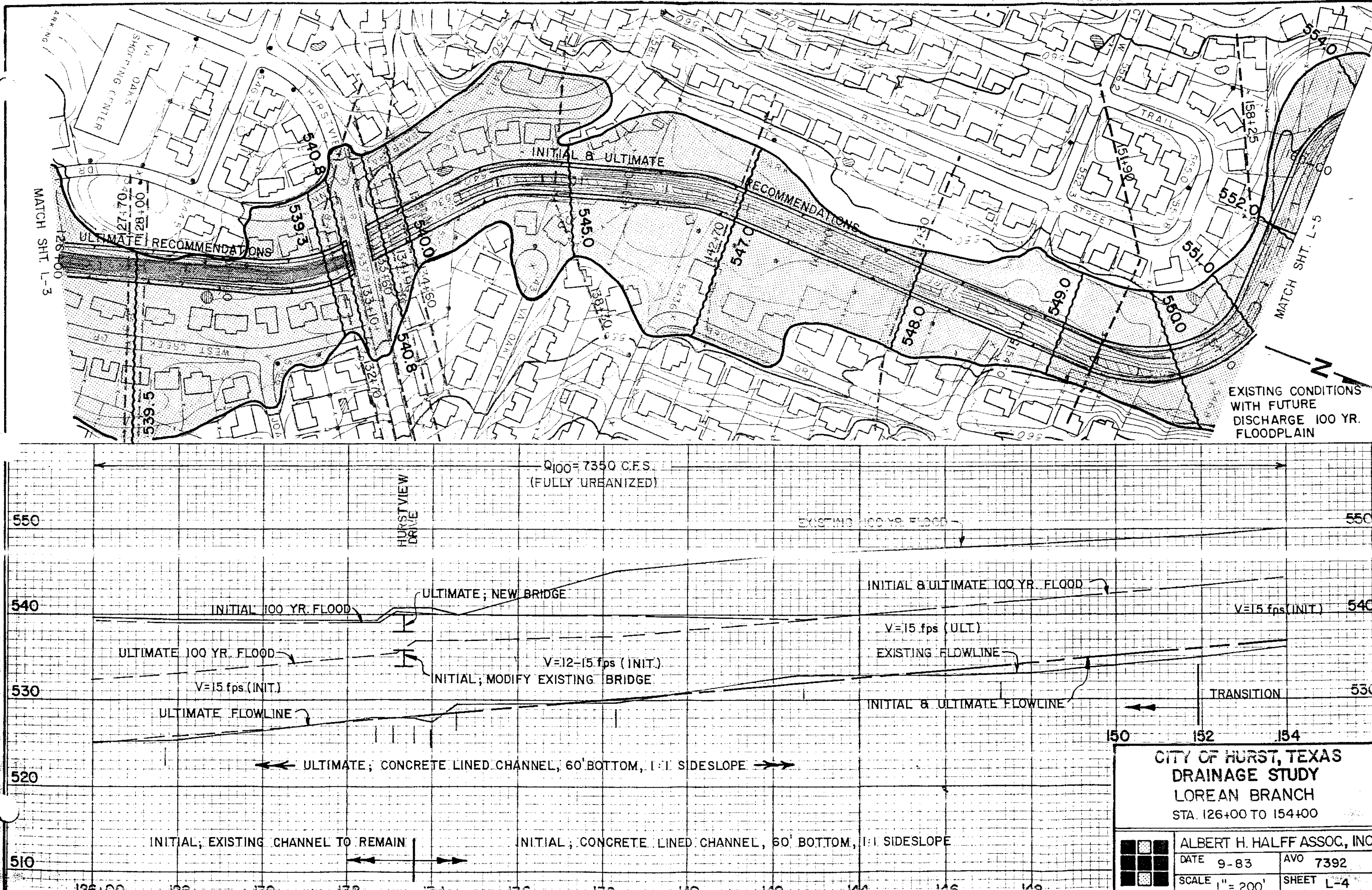
CITY OF HURST, TEXAS
DRAINAGE STUDY
LOREAN BRANCH
STA. 44+10 TO 70+00

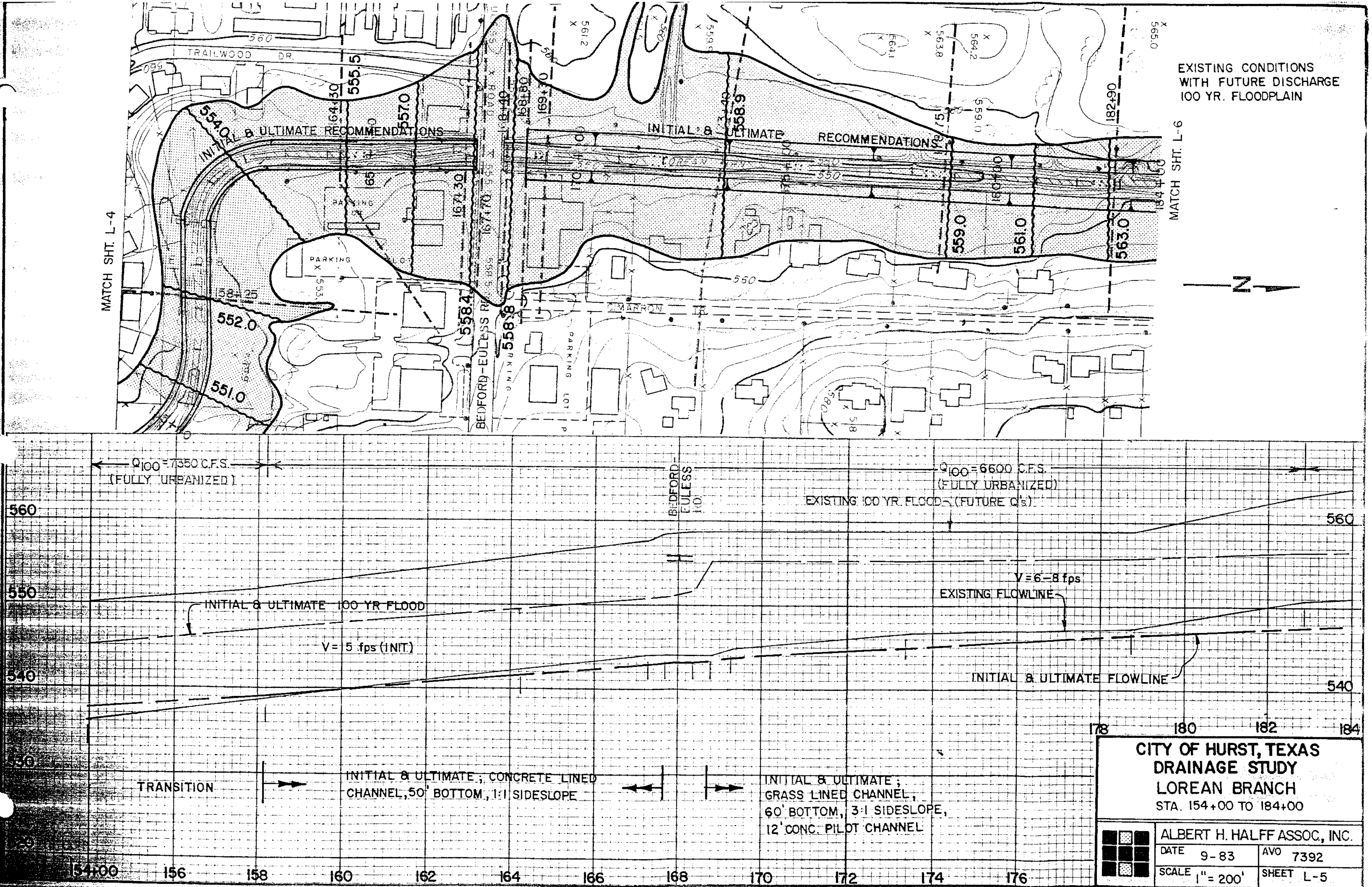
ALBERT H. HALFF ASSOC., INC.	
DATE 9/83	AVO 7392
SCALE 1" = 200'	SHEET L-1



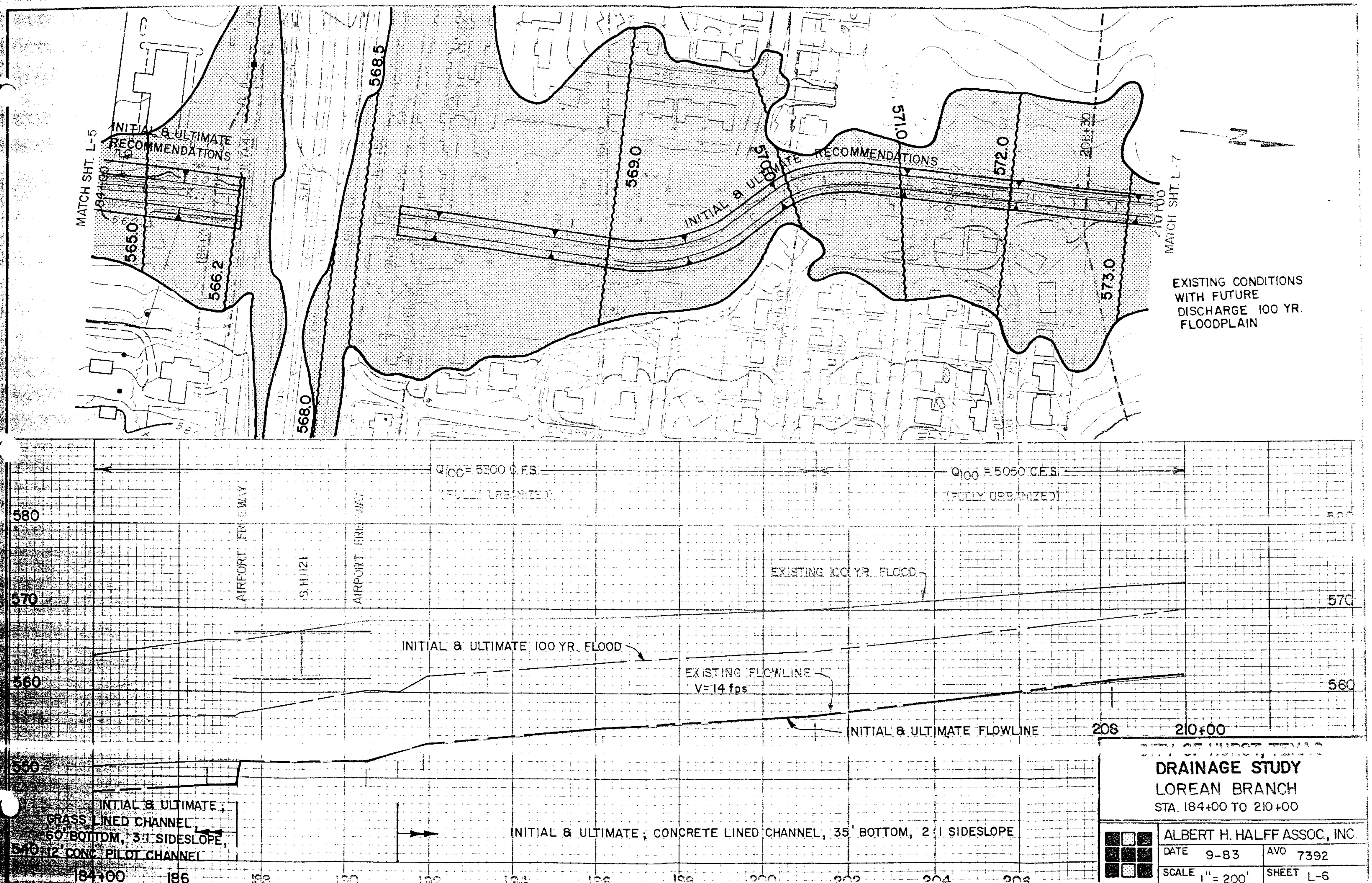
EXISTING CONDITIONS
WITH FUTURE DISCHARGE
100 YR. FLOODPLAIN
MATCH SHT. L-3
INITIAL & ULTIMATE RECOMMENDATIONS
ULTIMATE RECOMMENDATIONS
PONDEROSA DR.
OAK DR.
CROSSTIMBERS
MYRTLE
JOY FOREST LA.
SHADOWBROOK
513.5
514.0
514.3
514.3
514.0
514.0
514.0
514.5
515.0
515.5
516.0
74+60
78+50
79+40
80+21
84+30
87+
89+30
MATCH SHT. L-1
N
Q_{100} = 8300 C.F.S.
(FULLY URBANIZED)
Q_{100} = 7850 C.F.S.
(FULLY URBANIZED)
CULLUM AVE.
REDBUD DR.
EXISTING 100 YR. FLOOD
INITIAL 100 YR. FLOOD
INITIAL & ULTIMATE 100 YR. FLOOD
V = 14-15 fps (ULT.)
ULTIMATE FLOWLINE
EXISTING FLOWLINE
V = 14 fps
INITIAL & ULTIMATE FLOWLINE
ULTIMATE: CONCRETE LINED CHANNEL
40' BOTTOM; 2:1 SIDE SLOPE
INITIAL: CONCRETE LINED CHANNEL
40' BOTTOM; 2:1 SIDE SLOPE
INITIAL: EXISTING CHANNEL TO REMAIN
520
510
500
490
480
70+00
72
74
76
78
80
82
84
86
88
90
92
94
96
98+00
CITY OF HURST, TEXAS
DRAINAGE STUDY
LOREAN BRANCH
STA. 70+00 TO 98+00
ALBERT H. HALFF ASSOC., INC.
DATE 9-83
AVO 7392
SCALE 1" = 200'
SHEET L-2

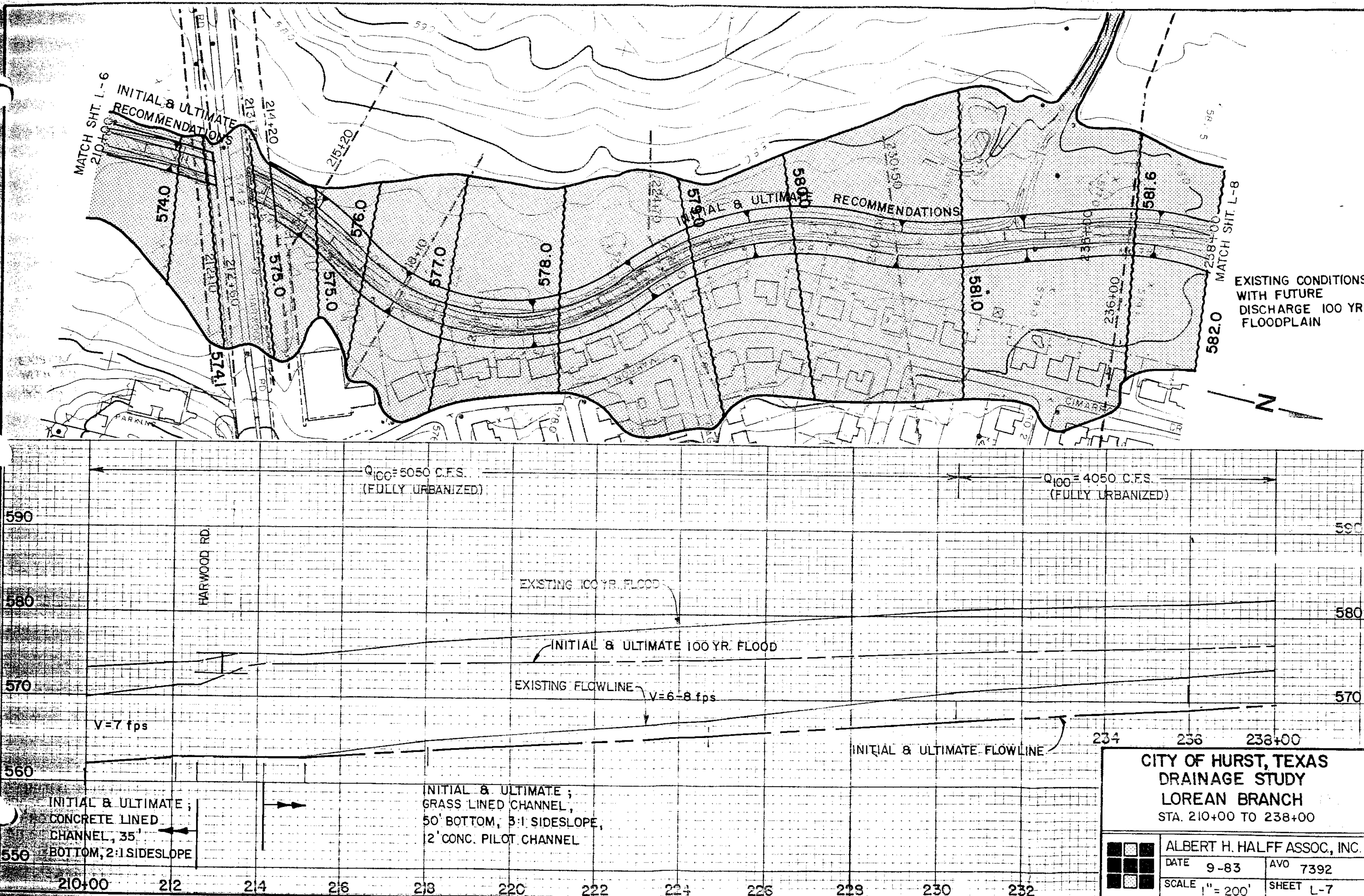

EXISTING CONDITIONS
WITH FUTURE DISCHARGE
100 YR. FLOODPLAIN
MATCH SHT. L-2
MATCH SHT. L-4
ULTIMATE RECOMMENDATIONS
PIPELINE RD.
CHURCH
519.0
520.3
520.5
520.4
523.8
522.5
522.0
525.5
528.0
528.5
528.8
529.0
531.0
535.5
539.5
539.7
Q_{100} = 7850 C.F.S.
(FULLY URBANIZED)
Q_{100} = 7350 C.F.S.
(FULLY URBANIZED)
HURSTVIEW DRIVE
ELM STREET
PIPELINE RD.
SHERI LN.
EXISTING 100 YR. FLOOD
ULTIMATE 100 YR. FLOOD
ULTIMATE: NEW BRIDGE
V = 13 fps (ULT.)
ULTIMATE FLOWLINE
V=10-14 fps (ULT.)
ULTIMATE; CONCRETE LINED CHANNEL, 60' BOTTOM, 1:1 SIDESLOPE
INITIAL; EXISTING CHANNEL TO REMAIN
V=6 fps (ULT.)
V=15-17 fps (ULT.)
EXISTING FLOWLINE
V=10-15 fps (ULT.)
ULTIMATE: CONCRETE LINED CHANNEL, 40' BOTTOM 2:1 SIDESLOPE
INITIAL & ULTIMATE; EXISTING CHANNEL TO REMAIN (CITY RECREATION PROJECT)
ULTIMATE; CONCRETE LINED CHANNEL 50' BOTTOM 2:1 SIDESLOPE
INITIAL: EXISTING CHANNEL TO REMAIN
98+00
100
102
104
106
108
110
112
114
116
118
120
122
124
126+00
500
510
520
530
540
DRAINAGE STUDY
LOREAN BRANCH
STA. 98+00 TO 126+00
ALBERT H. HALFF ASSOC., INC.
DATE 9-83
AVO 7392
SCALE 1" = 200'
SHEET L-3

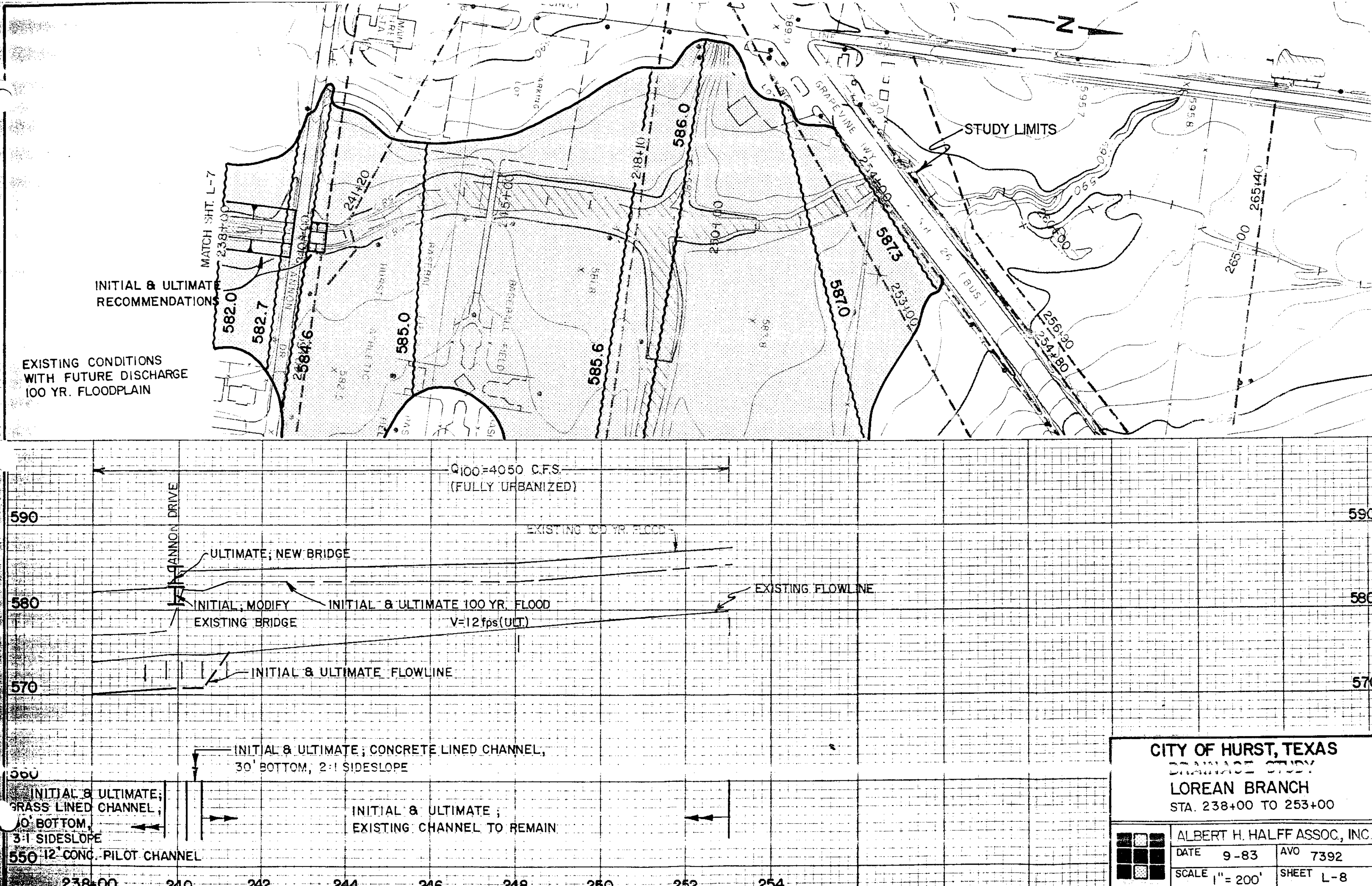

EXISTING CONDITIONS WITH FUTURE DISCHARGE 100 YR. FLOODPLAIN
MATCH SHT. L-3
MATCH SHT. L-5
INITIAL & ULTIMATE RECOMMENDATIONS
ULTIMATE RECOMMENDATIONS
VAL OAKS SHOPPING CENTER
HURSTVIEW
VAL OAK CT.
TRAIL
STREET
126+00
127+70
128+00
132+70
133+10
133+60
134+60
138+70
142+70
151+90
158+25
539.5
539.3
540.8
540.8
540.0
545.0
547.0
548.0
549.0
550.0
551.0
552.0
554.0
Q_{100} = 7350 C.F.S.
(FULLY URBANIZED)
HURSTVIEW DRIVE
EXISTING 100 YR. FLOOD
ULTIMATE; NEW BRIDGE
INITIAL 100 YR. FLOOD
INITIAL & ULTIMATE 100 YR. FLOOD
V=15 fps (INIT.)
V=15 fps (ULT.)
ULTIMATE 100 YR. FLOOD
V=12-15 fps (INIT.)
INITIAL; MODIFY EXISTING BRIDGE
EXISTING FLOWLINE
V=15 fps (INIT.)
ULTIMATE FLOWLINE
INITIAL & ULTIMATE FLOWLINE
TRANSITION
ULTIMATE; CONCRETE LINED CHANNEL, 60' BOTTOM, 1:1 SIDESLOPE
INITIAL; EXISTING CHANNEL TO REMAIN
INITIAL; CONCRETE LINED CHANNEL, 60' BOTTOM, 1:1 SIDESLOPE
550
540
530
520
510
126+00
128
130
132
134
136
138
140
142
144
146
148
150
152
154
CITY OF HURST, TEXAS
DRAINAGE STUDY
LOREAN BRANCH
STA. 126+00 TO 154+00
ALBERT H. HALFF ASSOC., INC.
DATE 9-83
AVO 7392
SCALE 1" = 200'
SHEET L-4



EXISTING CONDITIONS
WITH FUTURE DISCHARGE
100 YR. FLOODPLAIN
N
MATCH SHT. L-4
MATCH SHT. L-6
TRAILWOOD DR.
INITIAL & ULTIMATE RECOMMENDATIONS
INITIAL & ULTIMATE RECOMMENDATIONS
554.0
555.5
557.0
558.4
558.8
558.9
559.0
561.0
563.0
552.0
551.0
164+30
167+30
167+70
168+40
168+80
169+30
182+90
158+25
BEDFORD-EULESS RD.
CIMARRON TR.
PARKING
PARKING LOT
565.0
564.2
563.8
564.1
561.2
559.0
Q100=7350 C.F.S.
(FULLY URBANIZED)
Q100=6600 C.F.S.
(FULLY URBANIZED)
BEDFORD-EULESS RD.
EXISTING 100 YR. FLOOD (FUTURE Q's)
V=6-8 fps
EXISTING FLOWLINE
INITIAL & ULTIMATE 100 YR FLOOD
V=5 fps (INIT.)
INITIAL & ULTIMATE FLOWLINE
560
550
540
154+00
156
158
160
162
164
166
168
170
172
174
176
178
180
182
184
TRANSITION
INITIAL & ULTIMATE; CONCRETE LINED CHANNEL, 50' BOTTOM, 1:1 SIDESLOPE
INITIAL & ULTIMATE; GRASS LINED CHANNEL, 60' BOTTOM, 3:1 SIDESLOPE, 12' CONC. PILOT CHANNEL
CITY OF HURST, TEXAS
DRAINAGE STUDY
LOREAN BRANCH
STA. 154+00 TO 184+00
ALBERT H. HALFF ASSOC., INC.
DATE 9-83
AVO 7392
SCALE 1" = 200'
SHEET L-5


MATCH SHT. L-5
INITIAL & ULTIMATE RECOMMENDATIONS
184+00
565.0
566.2
568.0
568.5
569.0
570.0
INITIAL & ULTIMATE RECOMMENDATIONS
571.0
572.0
208+30
573.0
210+00
MATCH SHT. L-7
N
EXISTING CONDITIONS WITH FUTURE DISCHARGE 100 YR. FLOODPLAIN
Q_{100} = 5300 C.F.S.
(FULLY URBANIZED)
Q_{100} = 5050 C.F.S.
(FULLY URBANIZED)
AIRPORT FREEWAY
S.H. 121
AIRPORT FREEWAY
EXISTING 100 YR. FLOOD
INITIAL & ULTIMATE 100 YR. FLOOD
EXISTING FLOWLINE
V=14 fps
INITIAL & ULTIMATE FLOWLINE
INITIAL & ULTIMATE ; GRASS LINED CHANNEL, 60' BOTTOM, 3:1 SIDESLOPE, 12' CONC. PILOT CHANNEL
INITIAL & ULTIMATE ; CONCRETE LINED CHANNEL, 35' BOTTOM, 2:1 SIDESLOPE
580
570
560
550
540
184+00
186
188
190
192
194
196
198
200
202
204
206
208
210+00
DRAINAGE STUDY
LOREAN BRANCH
STA. 184+00 TO 210+00
ALBERT H. HALFF ASSOC., INC.
DATE 9-83
AVO 7392
SCALE 1" = 200'
SHEET L-6


MATCH SHT. L-6
210+00
INITIAL & ULTIMATE RECOMMENDATIONS
574.0
574.1
575.0
575.0
576.0
577.0
578.0
579.0
580.0
581.0
581.6
582.0
INITIAL & ULTIMATE RECOMMENDATIONS
MATCH SHT. L-8
238+00
236+00
214+20
215+20
230+50
PARKING
RD
CIMARR
N
EXISTING CONDITIONS WITH FUTURE DISCHARGE 100 YR. FLOODPLAIN
Q100 = 5050 C.F.S. (FULLY URBANIZED)
Q100 = 4050 C.F.S. (FULLY URBANIZED)
HARWOOD RD.
EXISTING 100 YR. FLOOD
INITIAL & ULTIMATE 100 YR. FLOOD
EXISTING FLOWLINE
V=6-8 fps
V=7 fps
INITIAL & ULTIMATE FLOWLINE
INITIAL & ULTIMATE ; CONCRETE LINED CHANNEL, 35' BOTTOM, 2:1 SIDESLOPE
INITIAL & ULTIMATE ; GRASS LINED CHANNEL, 50' BOTTOM, 3:1 SIDESLOPE, 12' CONC. PILOT CHANNEL
590
580
570
560
550
210+00
212
214
216
218
220
222
224
226
228
230
232
234
236
238+00
CITY OF HURST, TEXAS
DRAINAGE STUDY
LOREAN BRANCH
STA. 210+00 TO 238+00
ALBERT H. HALFF ASSOC., INC.
DATE 9-83
AVO 7392
SCALE 1" = 200'
SHEET L-7

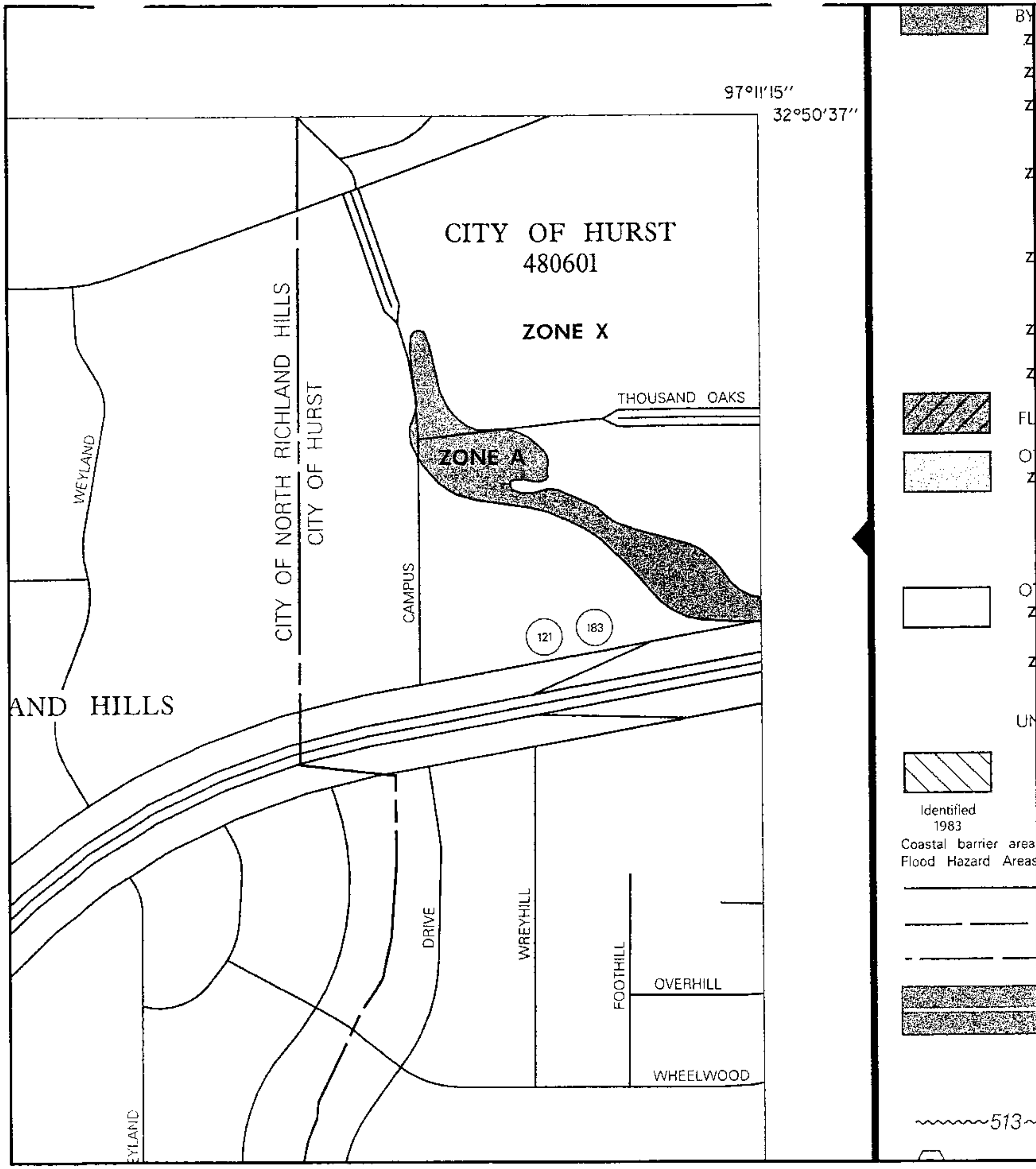


N
STUDY LIMITS
MATCH SHT. L-7
INITIAL & ULTIMATE RECOMMENDATIONS
EXISTING CONDITIONS WITH FUTURE DISCHARGE 100 YR. FLOODPLAIN
582.0
582.7
584.6
585.0
585.6
586.0
587.0
587.3
238+00
240+00
241+20
245+00
248+10
250+00
253+00
254+00
254+80
256+90
260+00
265+00
265+40
GRAPEVINE HWY
S.H. 26 (BUS.)
CANNON DR.
BASEBALL FIELD
HURST ATHLETIC
PARKING LOT
MAIN FIRE STA.
589.9
595.7
595.8
583.8
581.8
582.5
Q100=4050 C.F.S. (FULLY URBANIZED)
CANNON DRIVE
ULTIMATE; NEW BRIDGE
INITIAL; MODIFY EXISTING BRIDGE
INITIAL & ULTIMATE 100 YR. FLOOD
V=12 fps (ULT)
EXISTING 100 YR. FLOOD
EXISTING FLOWLINE
INITIAL & ULTIMATE FLOWLINE
INITIAL & ULTIMATE; CONCRETE LINED CHANNEL, 30' BOTTOM, 2:1 SIDESLOPE
INITIAL & ULTIMATE; GRASS LINED CHANNEL, 30' BOTTOM, 3:1 SIDESLOPE 12' CONC. PILOT CHANNEL
INITIAL & ULTIMATE; EXISTING CHANNEL TO REMAIN
590
580
570
560
550
238+00
240
242
244
246
248
250
252
254
CITY OF HURST, TEXAS
LOREAN BRANCH
STA. 238+00 TO 253+00
ALBERT H. HALFF ASSOC., INC.
DATE 9-83
AVO 7392
SCALE 1" = 200'
SHEET L-8

SH 183/ SH 121
AIRPORT FREEWAY SCHEMATICS
WEST SECTION

PRELIMINARY DRAINAGE STUDY
APPENDIX B - FLOOD INSURANCE RATE MAPS

FEDERAL EMERGENCY MANAGEMENT AGENCY
(FEMA)
December 2003



APPROXIMATE SCALE IN FEET

500 0 500

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

TARRANT COUNTY,
TEXAS AND
INCORPORATED AREAS

PANEL 304 OF 595

(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
HURST, CITY OF	480601	0304	J
NORTH RICHLAND HILLS, CITY OF	480607	0304	J
RICHLAND HILLS, CITY OF	480608	0304	J

MAP NUMBER
48439C0304 J

MAP REVISED:
AUGUST 23, 2000

Federal Emergency Management Agency

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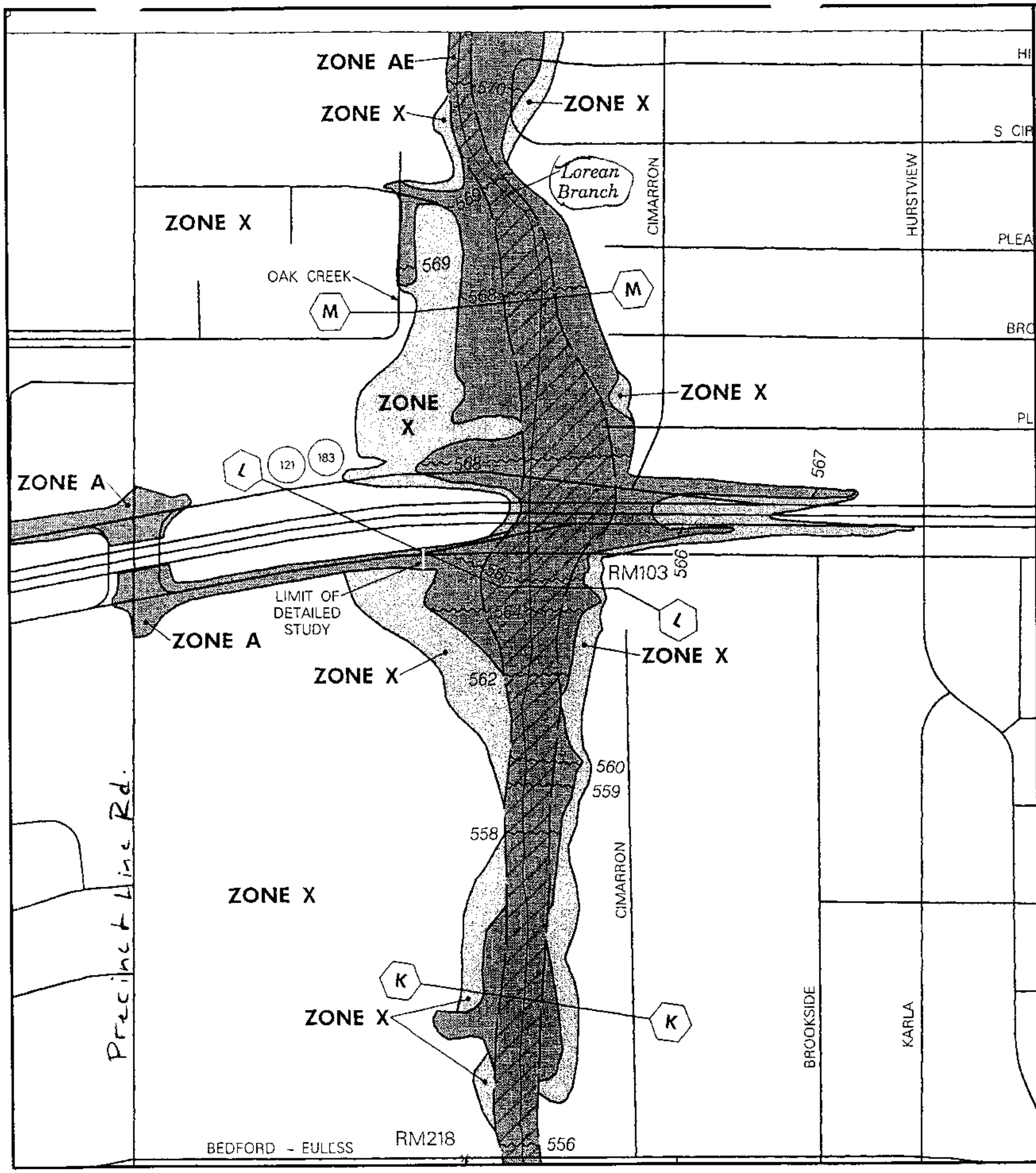
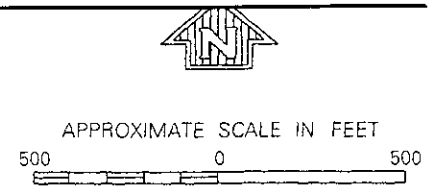




NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

TARRANT COUNTY, TEXAS AND INCORPORATED AREAS

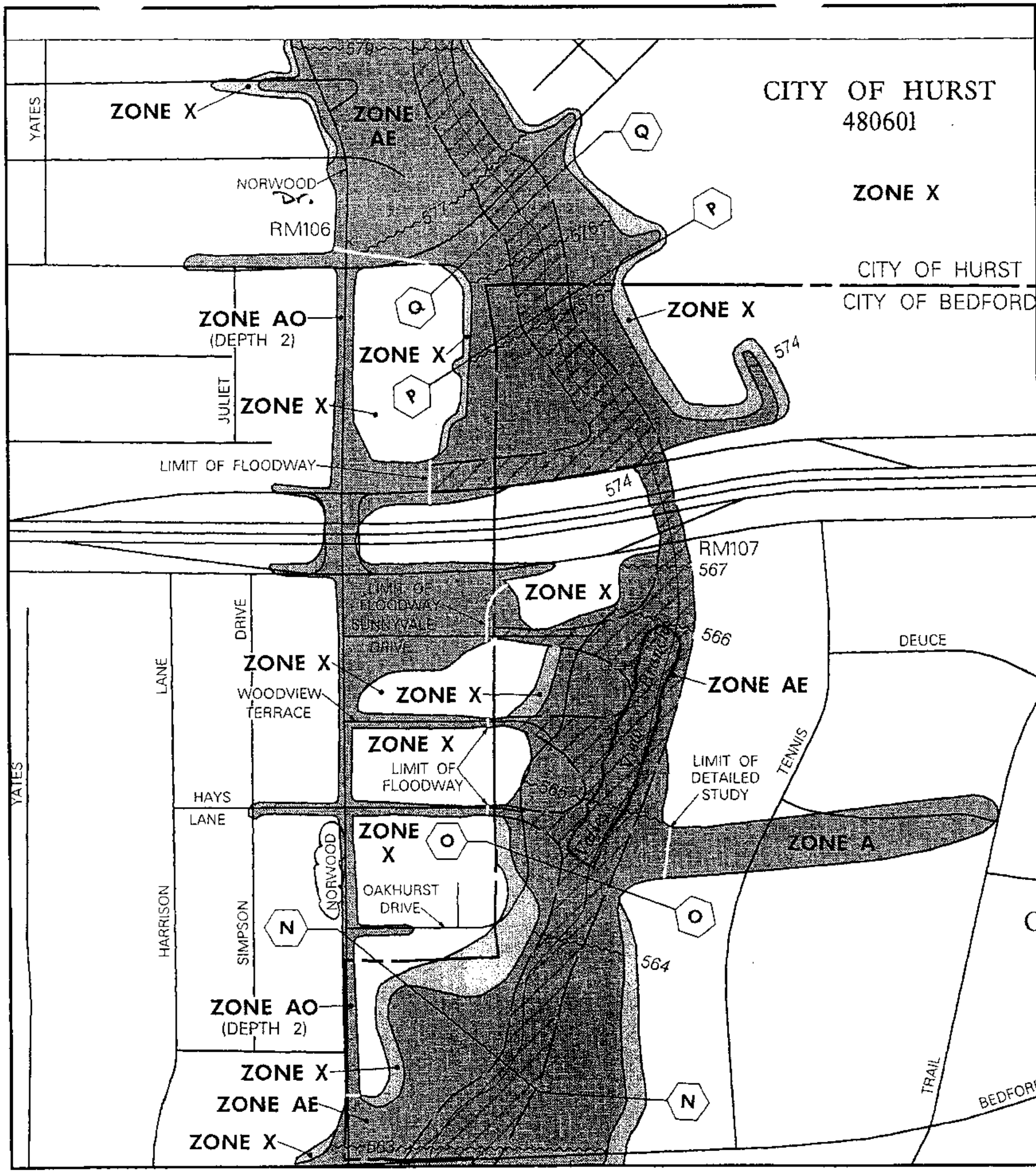
PANEL 308 OF 595
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS: COMMUNITY	NUMBER	PANEL	SUFFIX
BEDFORD, CITY OF	480585	0308	H
HURST, CITY OF	480601	0308	H

MAP NUMBER
48439C0308 H

MAP REVISED:
AUGUST 2, 1995

Federal Emergency Management Agency



NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

TARRANT COUNTY, TEXAS AND INCORPORATED AREAS

PANEL 308 OF 595

(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS: COMMUNITY	NUMBER	PANEL	SUFFIX
BEDFORD, CITY OF	480585	0308	H
HURST, CITY OF	480601	0308	H

MAP NUMBER 48439C0308 H

MAP REVISED: AUGUST 2, 1995

Federal Emergency Management Agency

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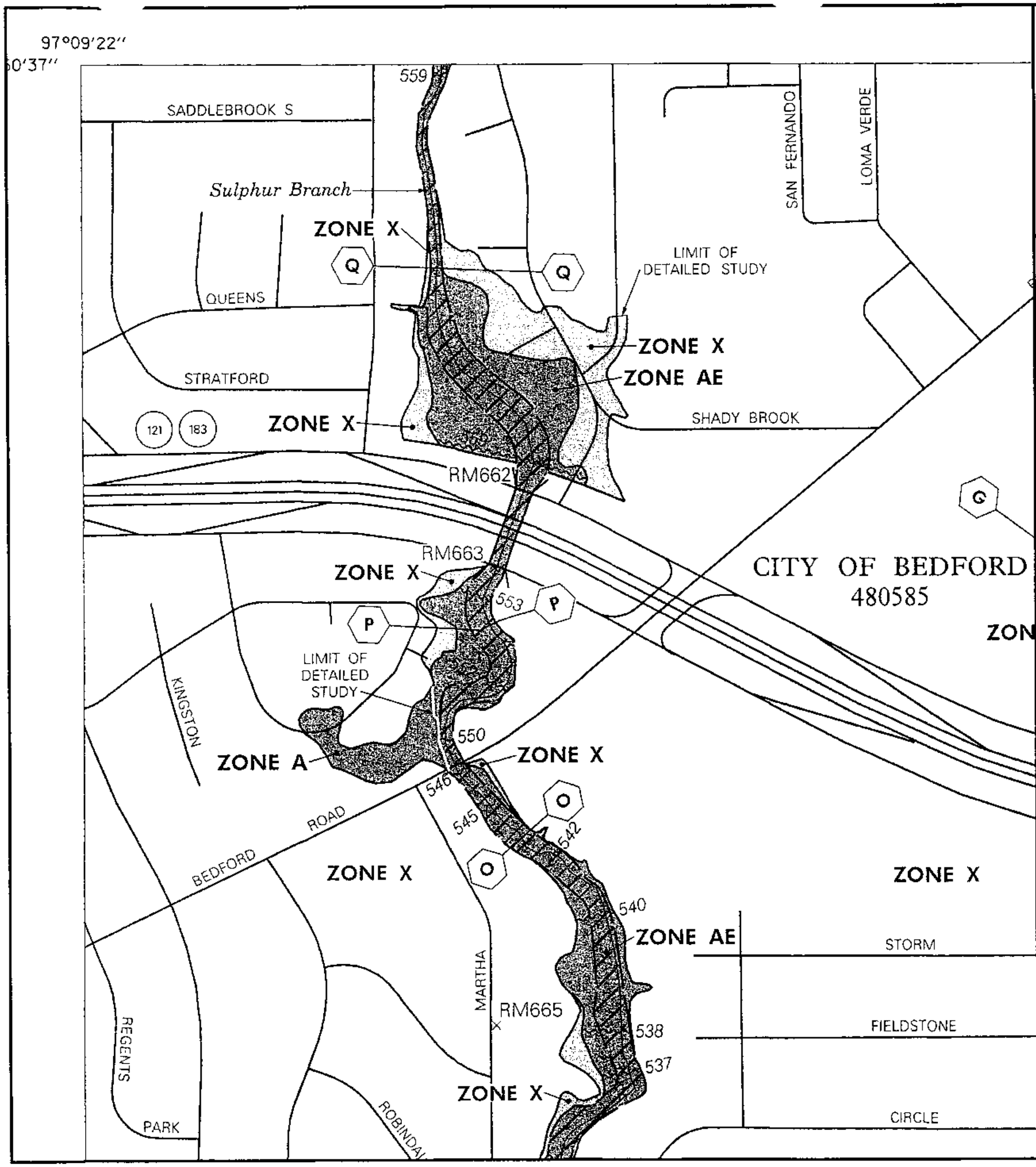
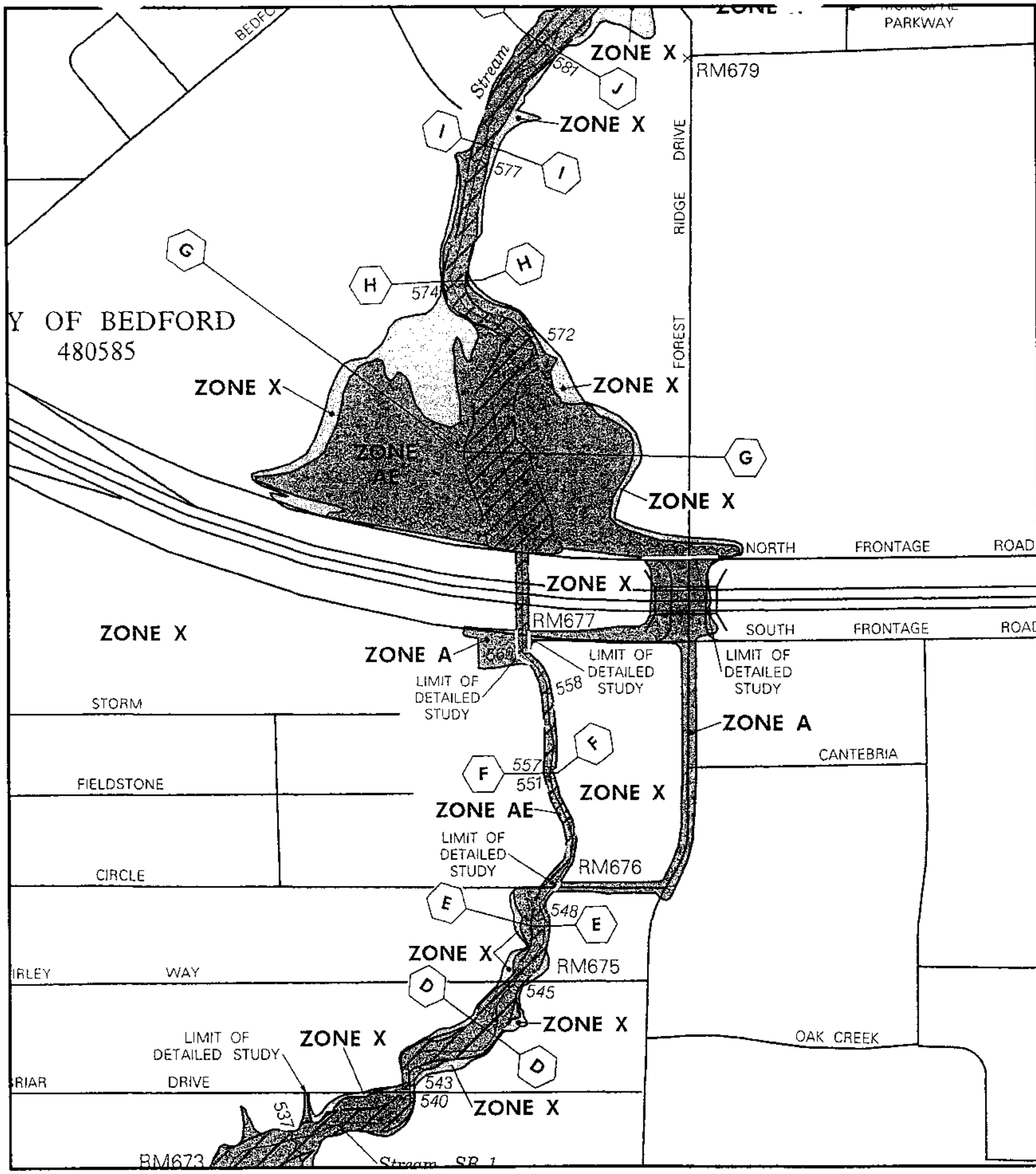


97°09'22"
0'37"
559
SADDLEBROOK S
Sulphur Branch
ZONE X
Q
Q
QUEENS
STRATFORD
121
183
ZONE X
LIMIT OF
DETAILED STUDY
ZONE X
ZONE AE
SHADY BROOK
SAN FERNANDO
LOMA VERDE
RM662
RM663
ZONE X
553
P
P
LIMIT OF
DETAILED
STUDY
KINGSTON
ZONE A
550
ZONE X
546
545
542
O
O
BEDFORD
ROAD
ZONE X
CITY OF BEDFORD
480585
G
ZON
ZONE X
540
ZONE AE
STORM
MARTHA
RM665
FIELDSTONE
538
537
ZONE X
CIRCLE
REGENTS
PARK
ROBINDAL



APPROXIMATE SCALE IN FEET

500 0 500

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TARRANT COUNTY, TEXAS AND INCORPORATED AREAS

PANEL 309 OF 595
(SEE MAP INDEX FOR PANELS NOT PRINTED)

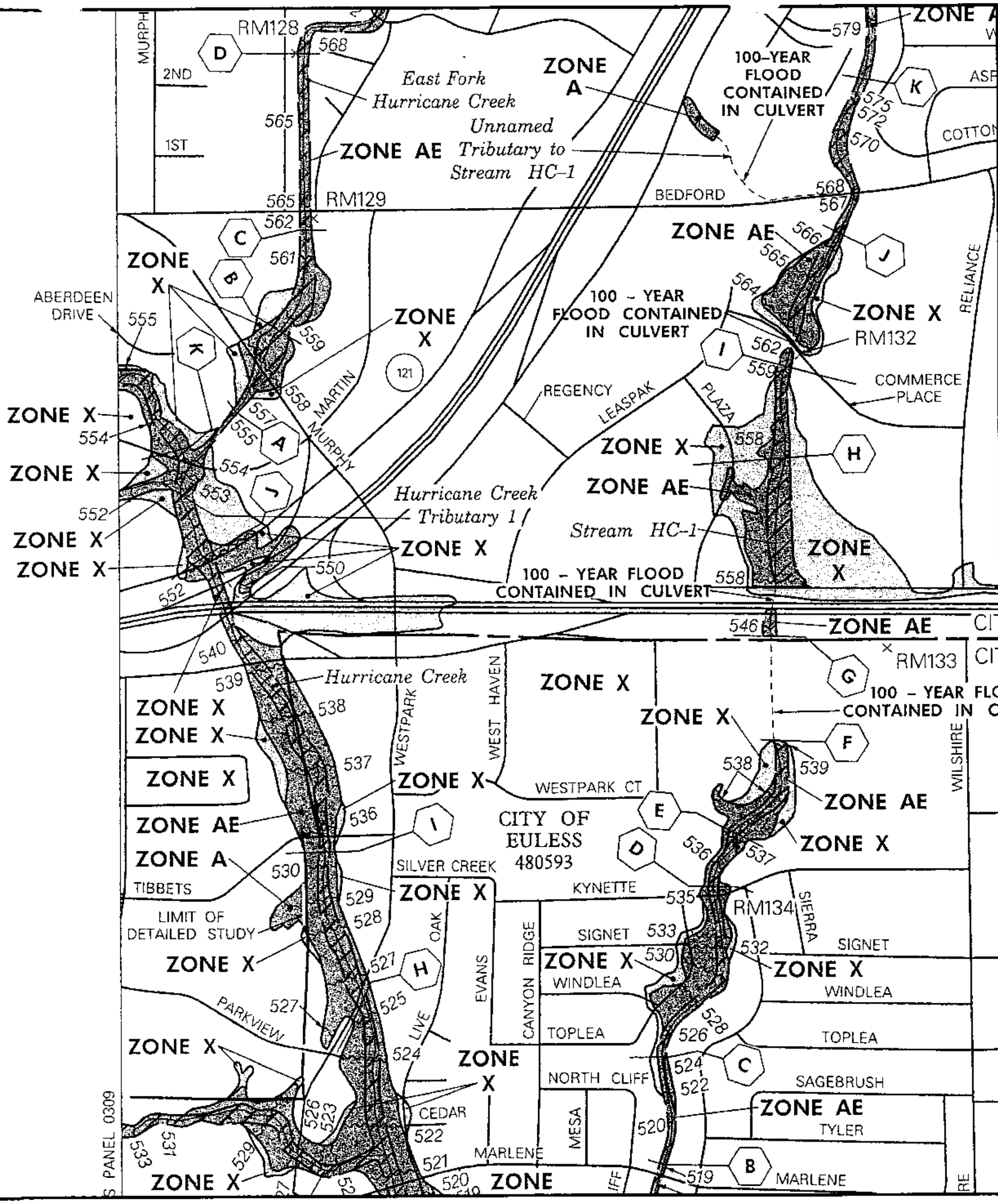
CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BEDFORD, CITY OF	480585	0309	J
EULESS, CITY OF	480593	0309	J
FORT WORTH, CITY OF	480596	0309	J
HURST, CITY OF	480601	0309	J

MAP NUMBER
48439C0309 J

MAP REVISED:
AUGUST 23, 2000

Federal Emergency Management Agency



NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TARRANT COUNTY,
TEXAS AND
INCORPORATED AREAS

PANEL 330 OF 595
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
BEDFORD, CITY OF	480585	0330	J
COLLEYVILLE, CITY OF	480590	0330	J
EULESS, CITY OF	480593	0330	J
FORT WORTH, CITY OF	480596	0330	J
ARLINGTON, CITY OF	485454	0330	J

MAP NUMBER
48439C0330 J

MAP REVISED:
AUGUST 23, 2000

Federal Emergency Management Agency

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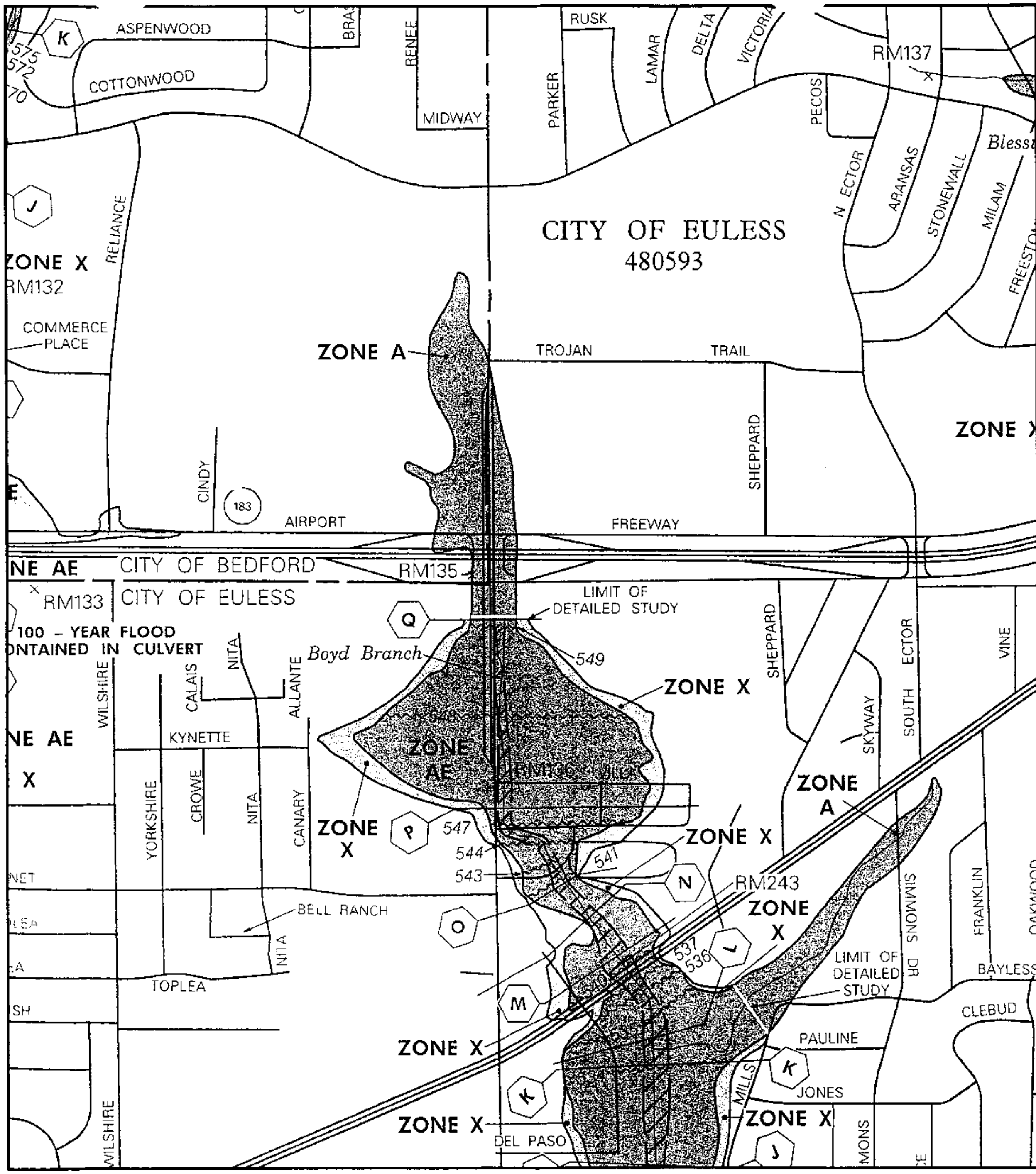


APPROXIMATE SCALE IN FEET

1000 0 1000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM
FLOOD INSURANCE RATE MAP

TARRANT COUNTY,
TEXAS AND
INCORPORATED AREAS

PANEL 330 OF 595
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

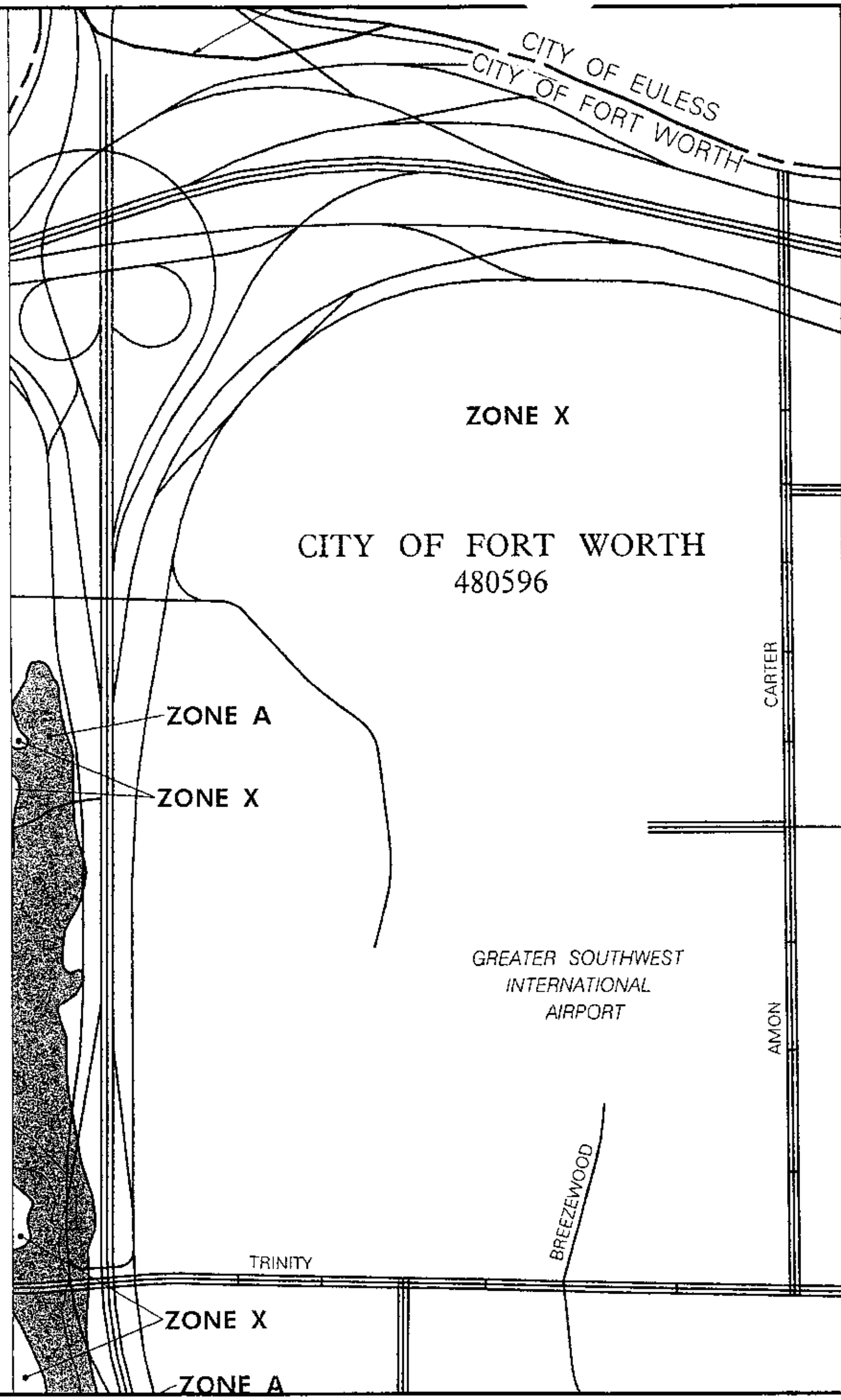
COMMUNITY	NUMBER	PANEL	SUFFIX
BEDFORD, CITY OF	480585	0330	J
COLLEYVILLE, CITY OF	480590	0330	J
EULESS, CITY OF	480593	0330	J
FORT WORTH, CITY OF	480596	0330	J
ARLINGTON, CITY OF	485454	0330	J

MAP NUMBER
48439C0330 J

MAP REVISED:
AUGUST 23, 2000

Federal Emergency Management Agency

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov



APPROXIMATE SCALE IN FEET

1000 0 1000

NATIONAL FLOOD INSURANCE PROGRAM

FIRM

FLOOD INSURANCE RATE MAP

TARRANT COUNTY,
TEXAS AND
INCORPORATED AREAS

PANEL 335 OF 595
(SEE MAP INDEX FOR PANELS NOT PRINTED)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
EULESS, CITY OF	480593	0335	J
FORT WORTH, CITY OF	480596	0335	J
ARLINGTON, CITY OF,	485454	0335	J

MAP NUMBER
48439C0335 J

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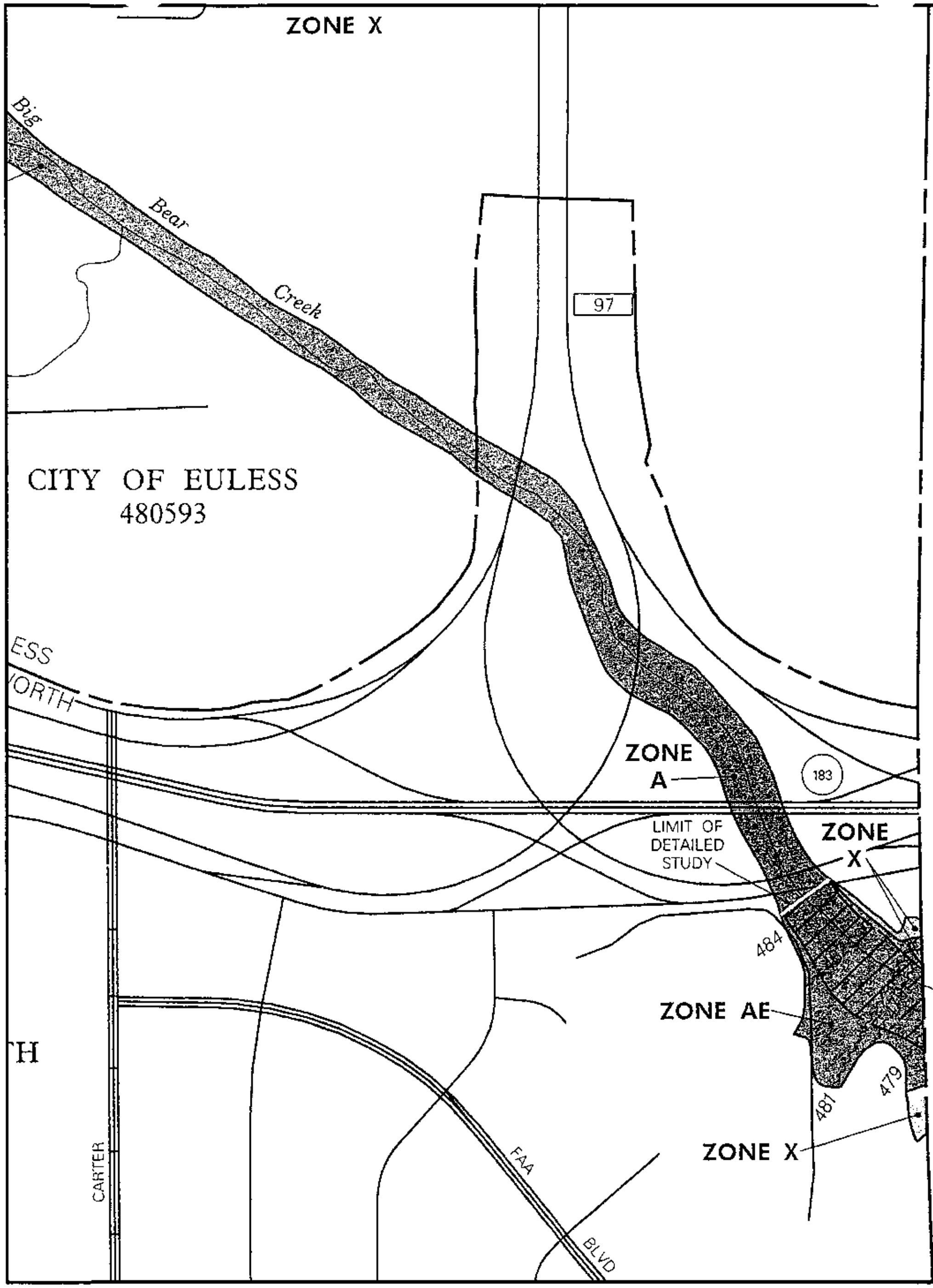

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Federal Emergency Management Agency

SH 183/ SH 121
AIRPORT FREEWAY SCHEMATICS
WEST SECTION

PRELIMINARY DRAINAGE STUDY
<u>APPENDIX C - DESIGN SUMMARY REPORT</u>

TEXAS DEPARTMENT OF TRANSPORTATION
FORT WORTH DISTRICT
December 2003

DESIGN SUMMARY REPORT (DSR)

The DSR summarizes a basic project information in one document. Use judgment in completing the report since it covers a wide range of items that may not apply to all projects.

This report can be partially completed during the *Preliminary* Design Conference and updated throughout project development. The DSR will be reviewed in detail during the Design Conference.

Highway No. SH 183

CSJ. 0364-01-054

County Tarrant

Length 10.05

Project No. ________

Limits From IH 820

To SH 360

Is project on National Highway System (NHS)? ☒ Yes ☐ No
If yes, is project ☐ State oversight ☒ Federal oversight

Type of work ________

Layman's description ________

Estimated construction cost ________ Date of estimate ________

Estimated right of way cost ________ Date of estimate ________

TABLE OF CONTENTS

PROGRAMMING AND FUNDING DATA

Work Program ______________ Authorized Funds ______________ STIP Year __________

Breakdown of Funding Participation

	Preliminary Engineering		**Construction**		**Right of Way**		**Eligible Utility Relocation**	
	%	**$**	**%**	**$**	**%**	**$**	**%**	**$**
Federal								
State								
County								
City								
Totals	0	0	0	0	0	0	0	0

Sidewalk funded by ______________________________

Curb and gutter funded by ______________________________

Storm drain system funded by ______________________________

Illumination to be maintained by ______________________________

List and describe active Minute Orders and agreements ______________________________

____

Are advance funding agreements required? ☐ yes ☐ no

If yes, describe ______________________________

____

Is unusual financing required? ☐ yes ☐ no

If yes, explain ______________________________

____

If program estimate differs from authorized amount, explain overrun/underrun ______________

____

____

See attached copy of current cost estimate.

Tentative letting date ______________________

Date of PS&E submission to District Design ______________________

Should letting date be rescheduled? ☐ yes ☐ no

If yes, recommended letting date ______________________________

(and notify all affected offices if letting date is changed) ______________________________

EXISTING ELEMENTS

A. Existing typical section
1. No. of traffic lanes
2. Lane Width
3. Shldr. Width
4. Median width
5. Curb & gutter ☐ yes ☐ no

B. Existing bridge data (including bridge-class culverts)

Stream Name	Structure Number	Structure Length	Structure Type	Date of Construction	Sidewalk Width	Clear Rdwy. Width	Sufficiency Rating

C. Existing cross drainage culvert data

Station	Number of Barrels	Sizes	Type (shape & material)

D. Stream data
1. Will channel work be required? ☐ yes ☐ no
   If yes, linear feet disturbed? permits needed? ☐ yes ☐ no
2. If bridges shafts must be drilled in channel or stream bed, how will drilling rigs gain access? (e.g., cofferdams, drilling pads, or access roads) ____________________

E. Other (e.g., stock pass) ____________________

F. ROW data
1. Existing ROW width
2. Estimated number of land owners
3. Predominant land use
4. Soil types

G. Existing constraints
1. Eligible historical structures ____________________
2. Schools ____________________
3. Parks ____________________
4. Archeological sites ____________________
5. Potential hazardous material sites ____________________
6. Ecological (wetlands, habitats, etc.) ____________________
7. Other ____________________

H. Highway-railroad (RR) grade crossings
1. Owner of RR: ☐ UP RR ☐ BNSF RR ☐ KCS RR ☐ Other ____________
2. Type of RR crossing surface material ☐ concrete ☐ rubber ☐ wood
3. Type of warning devices: ☐ passive ☐ cantilever flashing lights ☐ lights and gates ☐ mast signals
4. Do opportunities exist for consolidating or closing RR crossings? ☐ yes ☐ no
5. Is there a highway-RR grade crossing adjacent (i.e., within about 500 feet (152 m)) to a signalized highway intersection? ☐ yes ☐ no
   If yes, responsible office for determining the need for preemption ____________________

I. Has a crash analysis been performed? ☐ yes ☐ no

ADVANCED PROJECT DEVELOPMENT ELEMENTS

A. Surveying

1. Is planimetric needed? ☒ yes ☐ no
2. Status of aerial photography: ☒ complete ☐ in progress ☐ not started ☐ not proposed
3. Status of field surveys: ☐ complete ☐ in progress ☐ not started
4. Has vertical and horizontal control been established on the ground? ☒yes ☐ no
5. Additional elements to be surveyed (drainage channels, intersecting streets, etc.)
   Yes
6. Is existing ROW staking required? ☒ yes ☐ no
   Status: ☐ complete ☐ in progress ☒ not started Responsible Office: TPD/ROW
7. Comments __________

B. Schematic development

1. Is a geometric schematic required? ☒ yes ☐ no If yes, responsible office TPD
2. Is a signing schematic required? ☒ yes ☐ no
3. Schematic status
   a. Percent complete 40 % b. Approval authority: ☒ FHWA ☐ DES ☐ District
   c. Need prelim. schematic by d. Need approved schematic by
   e. Approval date
4. Comments

C. Environmental Commitments & Issues

1. Anticipated type of environmental document required ☐ CE ☒ EA ☐ EIS
2. Office responsible for preparing environmental document TPD
3. Has environmental document been approved? ☐ yes ☒ no Status Draft
4. Public meetings ☒ proposed ☐ not proposed ☐ scheduled ☒ held ☐ MAPO
   Date(s) __________
5. Public hearing: ☐ scheduled ☐ opp. afforded ☐ held ☐ not required Date:
6. Environmental commitments
   a. Noise __________
   b. Air quality __________
   c. Wetlands/Section 404 Permit __________
      1. Individual permit required? __________
      2. Nationwide permit required? __________
   d. Water Quality __________
   e. Coast Guard __________
   f. Natural Resources __________
      1. Vegetation __________
      2. Endangered species __________
      3. Other __________
   g. Cultural resources __________
      1. archeology __________
      2. historical __________
   h. Social, economic, environmental justice __________
   i. 4f, 6f __________
   j. Other __________
7. Are hazardous materials issues anticipated? ☐ yes ☐ no
8. Environmental Issues Permits Commitments Sheet (EIPC) completed? ☐ yes ☐ no
9. Office(s) responsible for fulfilling commitments __________
10. Comments __________

PROPOSED RIGHT OF WAY & UTILITY ELEMENTS

A. Right of way elements
1. Usual ROW width ____________________
2. Additional ROW needed to accommodate design features (side slopes, sound walls, etc.)
   HOV Lanes, Additional Capacity to SOV lanes
3. Have adjacent property owners been identified? ☒ yes ☐ no
4. Is additional ROW required? ☒yes ☐ no
5. How many parcels will be involved in ROW acquisition? ____________________
6. Are easements required (drainage or construction)? ☐ yes ☐ no
7. Is control of access needed? ☒ yes ☐ no
8. Have ROW map/plats/descriptions been prepared for parcels? ☐ yes ☒ no
9. Is relocation assistance required? ☒ yes ☐ no
   a. Number of residences tbd
   b. Number of businesses tbd
   c. Other improvements ____________________
10. Comments ____________________

B. Major utility facilities
1. Preliminary utility inventory

Utility	Type	Describe potential conflict

2. Have utility conflicts been determined? ☐ yes ☒ no
3. Has Subsurface Utility Engineering been requested or performed to locate utilities? ☐ yes ☒ no
4. Have utility agreements been prepared through district ROW office? ☐ yes ☒ no
   Comments ____________________

PROPOSED GEOMETRIC DESIGN ELEMENTS

Note: Design features listed in tables may not apply to every project.

Functional classification:

☒ freeway ☐ arterial ☐ major collector ☐ minor collector ☐ local

Highway type:

☒ urban freeway ☐ urban frontage road ☐ rural freeway ☐ rural frontage road

☐ rural multilane ☐ rural two-lane ☐ suburban roadway ☐ urban street ☐ bike/pedestrian trail

Proposed work: ☒ 4R/new construction ☐ 3R ☐ 2R Terrain: ☒ level ☐ rolling

A. Traffic

Street	Existing ADT	ADT (letting year)	ADT (design year)
	See TPP Corridor		
	Report		

Unless TxDOT-TPP provides this data, submit five-year and twenty-year forecasts of average daily traffic volumes including traffic loadings by axle load spectrum or vehicle classifications as defined by the FHWA on existing and proposed roads and streets within or affected by the facility.

B. Design criteria

Design Elements	Design Guidelines			Existing Value	Proposed Value
	Minimum	Desirable	Figure/Table		
Design speed	50		T. 3-17		70
Max. horiz. curvature	1055'		T. 2-3		3405
Max. superelevation rate	.06		T. 2-3		.06
K value – sag	96		F. 2-9		181
K value – crest	84		F. 2-7		247
Maximum grade	4		T. 2-9		3%
Minimum grade					0.5%
Other					

C. Roadside features **(See attached typical sections.)**

Roadside Feature	Unit	Value	Comments
Border	width	20'	
Sidewalk Location: TBD	width		
Cross slope – sidewalk	%	.02	
Ditch front slope – usual	ratio	6:1	
Ditch front slop – maximum	ratio	6:1	
Ditch back slope – usual	ratio	N/A	
Ditch back slope – maximum	ratio	N/A	
Maximum fill height before retaining wall	height		
Clear zone	width	30	
Other			

PROPOSED GEOMETRIC DESIGN ELEMENTS (continued)

D. Roadway surface features **(See attached typical sections.)**

Roadway Feature		Dimension	Comments
Thru Lanes	**Proposed**		
	Ultimate	**60'**	**5-12' Lanes**
Other Longitudinal elements	**Bike Lane (on-street)**	**N/A**	
	Parking	**N/A**	
	Bridge Width	**Varies**	
	Curb offset	**1'**	
Shoulders (ML)	**Inside**	**10'**	
	Outside	**10'**	
Median	**Raised**		
	Flush		
	Depressed		
	Opening spacing		
	Opening width		
Speed Change Lanes	**Lane width**		
	Storage Length		
	Taper Length		
	Shoulders		
Cross Slopes	**Thru lanes**	**.02/.025**	
	Shoulders	**.025**	
Structure clearances	**Horizontal**	**Varies**	**16'-30' Clear Zone**
	Vertical	**16.5'**	**Minimum**

E. Connecting roadways **(See attached typical sections.)**

Design Element	Ramps	Direct Connectors	Crossroads
Design speed	50 TL gore/ 40 ftg gore	50	40
Max. horizontal curve	1055'/835'	1055'	675/ (no super)
Maximum grade	5%	5%	7%f
Minimum grade	0.5%	0.5%	0.5%
Prop. number of lanes	1-2	varies	4 min.
Lane width	14'/2-12'	14'/2-12'	12'
Inside shoulder	2'	2'	N/A
Outside shoulder	8'	8'	N/A
Other			

F. Are design exceptions/waivers required? ☐ yes ☒ no
If yes, what design elements? ______________________

PROPOSED BRIDGE DESIGN DATA

A. Design data for structures

Structure Number	**Structure Location**	**Clearance** horiz.	vert.	**Clear Rdwy. width**	**Length**	**Over-pass OR under-pass**	**Foundation type**	**Super-structure type**	**Sub-structure type**

Structure Number (repeat from above)	**Railroad crossing?** (yes/no)	**Type of Exist. Rail**	**Type of Prop. Rail**	**Proposed approach treatment**	**Turn-arounds provided?** (width)	**Retaining walls proposed?** (type)	**Bridge widening** (describe exist. & proposed)	**Are bridge design exceptions/waivers required? If yes, for what design elements?**

B. Bridge widths are for: ☐ proposed number of lanes ☐ ultimate number of lanes

C. Are bridge widths controlled by traffic handling? ☐ yes ☐ no

PROPOSED HYDRAULIC ELEMENTS

A. TxDOT design frequency

Notes:
Table shown below is in the TxDOT Hydraulic Design Manual

Shaded boxes denote recommended design frequencies.

When multiple design frequencies are given, select a frequency by checking a box (o).

Federal law requires interstate highways to be provided with protection from the 50-year flood event, and facilities such as underpasses and depressed roadways where no overflow relief is available should be designed for the 50-year event.

Functional Classification and Structure Type	**Design Frequency** (years)					**Check 100-yr Flood?**
	2	5	10	25	50	
Freeways (main lanes)	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐	☐ (shaded)	yes
Bridges	☐	☐	☐	☐	☐ (shaded)	yes
Principal arterials	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐ (shaded)	☐	yes
Small bridges	☐	☐	☐	☐ (shaded)	☐	yes
Major river crossings	☐	☐	☐	☐	☐ (shaded)	yes
Minor arterials and collectors (including frontage roads)	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐ (shaded)	☐	yes
Small bridges	☐	☐	☐	☐ (shaded)	☐	yes
Major river crossings	☐	☐	☐	☐	☐ (shaded)	yes
Local roads and streets (off-system projects)	☐	☐	☐	☐	☐	
Culverts	☐	☐	☐	☐	☐	yes
Small bridges	☐	☐	☐	☐	☐	yes
Storm drain systems	☐	☐	☐	☐	☐	
Interstate and controlled access highways (main lanes)	☐	☐	☐	☐	☐	yes
inlets and drain pipe	☐	☐	☐ (shaded)	☐	☐	yes
inlets for depressed roadways	☐	☐	☐	☐	☐ (shaded)	yes
Other highways and frontage	☐	☐	☐	☐	☐	
inlets and drain pipe	☐	☐	☐	☐	☐	yes
inlets for depressed roadways	☐	☐	☐	☐	☐	yes
Other	☐	☐	☐	☐	☐	

PROPOSED HYDRAULIC ELEMENTS (continued)

B. If design frequency is other than TxDOT guidelines, where it is to be used and the reason (e.g., to use in designing off system facilities or to comply with FEMA requirements) ____________________

____

C. Comments on special hydrologic considerations (e.g. Basin is regulated by reservoirs, unit hydrograph and routing techniques in HEC-HMS used in lieu of regression equations)

____

D. Safety end treatment proposed
Parallel drainage structures ____
Cross drainage structures ____

E. Will outfall channels be provided? ☐ yes ☐ no
If yes, by whom? ______________________________

F. Will outfall channels be maintained by others? ☐ yes ☐ no
If yes, by whom? ______________________________

G. Will others have to approve hydraulic design? ☐ yes ☐ no
If yes, by whom? ______________________________

H. Will others participate in funding hydraulic structures (e.g., joint ditch agreements with railroads)?
☐ yes ☐ no
If yes, who? ______________________________

I. For storm drain design, is there potential for future development that may redirect flows normally away from the project back to the project? ☐ yes ☐ no
If yes, will the actual "modified" contributing drainage area be used if known or will an estimate of a 150' wide area be used instead when the actual modification is not known?

____

J. Will pump stations be required? ☐ yes ☐ no
If yes, approximate locations ____

K. Is this an evacuation route where roadway elevation is critical? ☐ yes ☐ no
If yes, explain ____

L. Is the design of any special drainage facility required? ☐ yes ☐ no
If yes, explain ____

____

M. Which hydraulic programs will be required for analysis? ____________________

____

N. Are flood insurance study streams within project limits? ☐ yes ☐ no
If yes, which streams and what type of may is designated (e.g. Flood Hazard and Boundary Map)?

____

O. Informal FEMA coordination should always be initiated early in project development to identify any pertinent issues such as the availability or loss of the accumulative 1-foot rise to previous development. Has the informal FEMA coordination revealed any special issues that may require formal coordination (e.g., such as a no remaining rise or the presence of a designated floodway)? ☐ yes ☐ no

P. Is the any existing development in the floodplain that may be impacted at any stage by changes (no matter how small) brought about by the project, regardless of whether the project meets FEMA standards? ☐ yes ☐ no

PROPOSED PAVEMENT STRUCTURE ELEMENTS

A. Describe existing pavement ______________________________

B. Is existing roadway load zoned? ☐ yes ☐ no
Limits From ______________________________
To ______________________________

C. Has pavement design been prepared? ☐ yes ☐ no Been approved? ☐ yes ☐ no
Responsible office ______________________________

D. Proposed pavement structure **(See attached typical sections.)**
Describe thickness and material type of each layer.

Pavement Structure Element	Roadway	Shoulder
Widen existing		
Mainlanes		
Frontage roads		
Direct connectors		
Ramps		
Detours		
Crossroads		
Others		

PROPOSED TRAFFIC OPERATIONS ELEMENTS

A. Are signing, delineation, and pavement markings to be included in const. plans? ☐ yes ☐ no
If yes, responsible office ______________________________

B. Is signalization proposed? ☐ yes ☐ no
If yes, are traffic signals warranted? ☐ yes ☐ no Resp. office for developing plans

C. Is there a highway-railroad grade crossing adjacent (i.e., within about 500-feet, (152 m)) to a signalized highway intersection? ☐ yes ☐ no
If yes, responsible office for determining the need for pre-emption ______________________________

D. Is safety lighting proposed? ☐ yes ☐ no
If yes, is illumination warranted? ☐ yes ☐ no Resp. office for developing plans

E. Is continuous lighting proposed? ☐ yes ☐ no
If yes, is illumination warranted? ☐ yes ☐ no Resp. office for developing plans

F. Are Intelligent Transportation System (ITS) items proposed? ☐ yes ☐ no
If yes, are proposed ITS items included in the regional ITS plan? ☐ yes ☐ no
Comments ______________________________

PROPOSED MISCELLANEOUS ELEMENTS

A. Geotechnical exploration
   1. Roadway
      Is geotechnical investigation needed? ☐ yes ☐ no
      Is geotechnical investigation available? ☐ yes ☐ no
      If yes, explain ______________________
   2. Bridges (list bridges requiring foundation exploration)
      ____
   3. Walls (list retaining walls or noise walls requiring foundation exploration)
      ____
   4. Storm drains
      ____
   5. Miscellaneous (e.g., overhead sign bridges, high mast illumination)
      ____
   6. Office responsible for geotechnical exploration (borings) ______________________
   7. Is a D_{50} (grain size determination) for scour analysis on the proposed structure at the stream crossing required from the lab? ☐ yes ☐ no

B. Sequence of construction (Outline probable stages. **See attached typical sections.**)
   1. Stage I ______________________
   2. Stage II ______________________
   3. Additional stages ______________________

C. Will median openings require approval by others? ☐ yes ☐ no If yes, by whom?

D. Are requirements satisfied for the Americans with Disabilities Act Accessibility Guidelines (ADAAG) and the Texas Accessibility Standards (TAS)? ☐ yes ☐ no
   Comments ______________________

E. Are railroad agreements needed? ☐ yes ☐ no If yes, where?

F. Are airway/highway clearance permits required? ☐ yes ☐ no
   1. For roadway ______________________
   2. For other (e.g., high mast illumination ______________________

G. What type of erosion control is proposed?
   1. Fills ______________________
   2. Is a stormwater pollution prevention plan (SW3P) proposed? ☐ yes ☐ no
      Required? ☐ yes ☐ no
   3. Other ______________________

H. What end treatment is proposed for metal beam guard fence? ______________________

I. Is a Safety Review Committee (or multi-discipline team) review required? ☐ yes ☐ no

J. Does design address requirements of environmental permits and env. concerns? ☐ yes ☐ no

K. Comments ______________________

ACCELERATED CONSTRUCTION PROCEDURES

A. Are accelerated contracting procedures required?

(The following types of projects will require the use of accelerated construction contract provisions. Check all that apply to this project:)

- ☐ Interstate or freeway project with lane closures during one or more phases of construction
- ☐ Bridge closure (either as the entire project or a portion of a larger project)
- ☐ Road closure
- ☐ Added Capacity projects
- ☐ Non-freeway with ADT >10,000 and lane closures during one or more phases of construction
- ☐ Provides access to a nearby school, emergency services (hospital, fire, etc.), or major traffic generator
- ☐ Project affects access to adjacent businesses
- ☐ Other (Projects that are time critical such as traffic signal work at high accident locations)

  Explain:

- ☐ None of the above (Acceleration provisions are not required)

  Type of Work:

B. Is an exception request to DES needed? ☐ Yes ☐ No

(Note: If the project meets any of the above criteria and accelerated contract provisions are not utilized, Design Division approval will be required. Request for approval to not utilize accelerated contract provisions should be submitted in advance of PS&E submission for letting.)

Request submitted: (date)

Approval Received: (date)

C. What type of accelerated contract procedure will be used?

(Check the accelerated contract provision(s) to be used on this project.)

- ☐ Calendar Day Definition for Working Day
- ☐ Incentive Using Contract Administrative Cost
- ☐ Increased Liquidated Damages
- ☐ Milestones with Incentives/Disincentives
- ☐ Substantial Completion Incentives/Disincentives
- ☐ Lane Rental Disincentive
- ☐ A+B Provisions

D. What technique will be used to calculate road user costs?

- ☐ FREQ, CORSIM or HCS models
- ☐ PASSER models
- ☐ Manual technique
- ☐ Other

E. Who will perform road user costs calculations?

☐ consultant ☐ interagency agreement ☐ district

APPENDIX

COMMENTS AND CONCURRENCE

District Comments ______________________________

____

____

____

______________________________ Signed ______________ Date

______________________________ Title

Design Division Comments ______________________________

____

____

____

______________________________ Signed ______________ Date

______________________________ Title

FHWA Comments

____

____

____

______________________________ Signed ______________ Date

______________________________ Title

Note: Concurrence with this report does not imply approval of any design exceptions or waivers referred to herein.

SUGGESTED ATTENDANCE

Date of conference ________________ Location of conference ________________

	INVITED (name)	**ATTENDED** (name)
TxDOT district and area office staff		
advanced project dev. engineer		
area engineer		
area maintenance supervisor		
bicycle coordinator		
bridge engineer		
construction engineer		
dir. of trans. planning & dev.		
district engineer		
district design engineer		
environmental coordinator		
landscape architect		
maintenance engineer		
pavement engineer		
pedestrian coordinator		
planner		
programming & sched. mgr.		
railroad coordinator		
right of way administrator		
utility coordinator		
traffic engineer		
TxDOT division offices		
FHWA		
bicycle groups		
city and county		
consultants		
environmental resource agencies		
federal transit authority		
MPO director or staff		
transit operators		
trucking industry		
utility companies		
others (e.g., chamber of commerce)		

SUGGESTED AGENDA

Prior to the Preliminary Design Conference, experienced district representatives from traffic operations, design, construction and maintenance should visit the site together to review existing conditions.

Background
- existing elements
- funding
- surveys, studies, and data
- agreements and permits
- problematic features
- Feasibility Study or Major Investment Study findings

Project Scope

Corridor issues
- mobility & transportation
- operations & maintenance
- planned/funded projects

Environmental issues

Multimodal issues

Alternatives

Schematics

Public Involvement Plan
- stakeholders
- public meeting and public hearing

Environmental Documents and Commitments made

Detailed Design Criteria

Project development criteria
- Level of Service
- control of access
- geometric design
- hydraulic design
- bridge design
- pavement design
- traffic operations design
- landscape and aesthetic design
- constructibility

Right of Way
- new ROW required
- easements required
- utility adjustments
- control of access

Maintenance

Permits, agreements, and coordination with:
- outside entities
- Federal, State, City, or County
- railroads

SUGGESTED REPORT MATERIAL

Consider attaching the following to this report:

PURPOSE AND NEED STATEMENT

*

DRAFT ALTERNATIVES SCREENING AND EVALUATION CRITERIA

*

PUBLIC INVOLVEMENT PLAN

*

PROJECT DEVELOPMENT SCHEDULE

*

DESCRIPTION OF KEY STAFF ROLES AND RESPONSIBILITIES

*

AGREEMENTS REACHED BETWEEN
CONFERENCE PARTICIPANTS

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ATTACHMENTS

Conference minutes or notes
Typical Sections
Page 3 of Form 1002
Location Map (optional)

SH 183/ SH 121
AIRPORT FREEWAY SCHEMATICS
WEST SECTION

PRELIMINARY DRAINAGE STUDY
<u>APPENDIX D - FEMA POLICY AND PROCEDURE</u>

FEDERAL EMERGENCY MANAGEMENT AGENCY
(FEMA)
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Section 5. FEMA Policy and Procedure

National Flood Insurance Program

The amended National Flood Insurance Act of 1968 (42 U.S.C. 4001 et seq.) established the National Flood Insurance Program (NFIP), which requires communities--whether city, county, or state--to adopt adequate land use and control measures to qualify for flood insurance in riverine flood-prone areas. When the Administrator of the Federal Insurance Administration has identified the flood-prone area, the community must require that, until a floodway has been designated, no use, including land fill, be permitted within the floodplain area having special flood hazards for which base flood elevations have been provided unless it is demonstrated that the cumulative effect of the proposed use, when combined with all other existing and reasonably anticipated uses of a similar nature, will not increase the water surface elevation of the 100-year flood more than 1 ft. (0.3 m) at any point within the community.

After the floodplain area has been identified and the water surface elevation for the 100-year flood and floodway data have been provided, the community may designate a floodway that will convey the 100-year flood without increasing the water surface elevation of the flood more than 1 ft. (0.3 m) at any point. Also, the community must prohibit, within the designated floodway, fill, encroachments, and new construction and substantial improvements of existing structures that would result in any increase in flood heights within the community during the occurrence of the 100-year flood discharge.

The participating cities or counties agree to regulate new development in the designated floodplain and floodway through regulations adopted in a floodplain ordinance. The ordinance should require that development in the designated floodplain be consistent with the intent, standards and criteria set by the NFIP. Failure on their behalf to enforce basic requirements can result in losing their status in the program.

The highway designer needs to be familiar with FEMA NFIP requirements because meeting them may either control the design of a facility within a floodplain or, when encroachments (any physical object placed in a floodplain that hinders flow) are proposed, necessitate considerable analysis, coordination, and expense to acquire FEMA approval of the project. Incorporate considerations concerning FEMA rules and procedures early in the project planning stages. (See Task 2200 and Task 5080 of the *Project Development Process Manual* for more information.)

Determining the status of a community 's participation in NFIP and reviewing applicable NFIP maps and ordinances are essential first steps in conducting location hydraulic studies and preparing environmental documents. Information of community participation in NFIP is provided in the National Flood Insurance Program Status of Participating Counties, published semi-annually for each state, and available through Federal Emergency Management Agency (FEMA) headquarters and the Texas Natural Resources and Conservation Commission (TNRCC).

NFIP Maps

Where NFIP maps are available, their use is mandatory in determining whether a highway location alternative will include an encroachment on the base floodplain. The following three types of NFIP map are published:

- Flood Hazard Boundary Map (FHBM) -- An FHBM does not generally originate from a detailed hydraulic study, and, therefore, the floodplain boundaries shown are approximate.
- Flood Boundary and Floodway Map (FBFM) -- An FBFM generally originates from a detailed hydraulic study. These hydraulic data are available through the FEMA regional office and should provide reasonably accurate information. This study is normally in the form of computer input data records or hand data for calculating water surface profiles.
- Flood Insurance Rate Map (FIRM) -- The FIRM identifies base flood elevations and rate zones for flood insurance and is generally produced at the same time as the FBFM using the same hydraulic model.

Flood Insurance Study

A Flood Insurance Study (FIS) documents methods and results of a detailed hydraulic study. The report includes the following information:

- name of community
- hydrologic analysis methods
- hydraulic analysis methods
- floodway data including areas, widths, average velocities, base flood elevations, and regulatory elevations
- water surface profile plots

NFIP Participation Phases

A community can be in the emergency program or the regular program, in the process of converting from the emergency program to the regular program, or not participating in NFIP. The emergency program is intended to provide a "first layer " amount of insurance on an emergency basis on all insurable structures before a risk study can be performed. Approximate flood boundaries are shown on a FHBM. The regular program provides a "second layer " coverage, which is offered only after the Floodplain Administrator has completed a risk study for the community. (The Floodplain Administrator is the mayor, county judge, or delegate responsible for the administration and enforcement of the floodplain management ordinances of a community participating in the NFIP.) A detailed hydraulic study has usually been performed and the results published in the FIS report, FIRM, and FBFM.

Regulated FloodPlain Components

Figure 2-1 illustrates the basic components of an FEMA-regulated floodplain. The floodplain is established by the base flood, which is the extent of inundation resulting from flood flow having a one percent exceedance probability in any given year (100-year flood). The floodplain is divided into a regulatory floodway (RFW) and floodway fringes. Another component of the regulated floodplain is differences in projects.

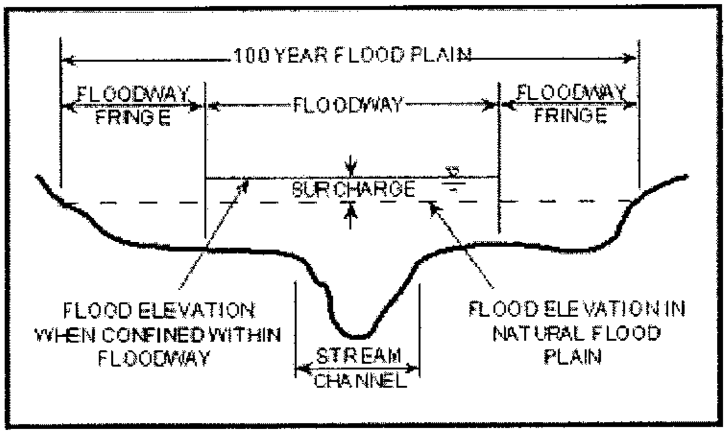

Figure 2-1. Basic Constituents of FEMA-NFIP-Regulated Floodplain

The regulatory floodway is the main stream channel and any floodplain areas that must be kept free of encroachment so that the base flood can be carried without a considerable increase in water surface elevations. The maximum increase above the base flood elevation (BFE) is usually 1 ft. (0.3 m). Existing insurable buildings, the potential for hazardous velocities, or other conditions may result in lower allowable increases.

The floodway fringe is the remaining area between the floodway and the floodplain boundary. Theoretically, the floodway fringe can be completely obstructed without increasing the water surface elevation of the base flood by more than 1 ft. (0.3 m) at any point.

Projects Requiring Coordination with FEMA

Several possible conditions may apply in a participating community and corresponding regulations apply to each, as shown in the "FEMA Requirements for Applicable Conditions" table below. You are responsible for determining the status of the waterway and taking the appropriate action.

FEMA Requirements for Applicable Conditions

Type of Map	WS Elev	RFW	Coastal Hazard Area	NFIP Section	Requirements
None	No	No	No	60.3(a)	♦ Permits to determine if flood prone
FHBM	No	No	No	60.3(b)	♦ Permits within Flood Hazard Areas ♦ Notify adjacent communities and FEMA before alteration or relocation of watercourse

					♦ Assure capacity is maintained
FIRM	Yes	No	No	60.3(c)	♦ Permits within Flood Hazard Areas ♦ Notify adjacent communities and FEMA before alteration or relocation of watercourse ♦ Assure capacity is maintained ♦ No construction until RFW is designated unless WS will not increase over 1 ft (0.3 m) ♦ Amend FIRM when WS increases over 1 ft (0.3 m)
FIRM	Yes	Yes	No	60.3(d)	♦ Permits within Flood Hazard Areas ♦ Notify adjacent communities and FEMA before alteration or relocation of watercourse ♦ Assure capacity is maintained ♦ No construction until RFW is designated, unless WS won't increase over 1 ft (0.3 m) ♦ No encroachment within RFW unless WS will not increase over 1 ft (0.3 m) ♦ Amend FIRM and RFW when WS increases over 1 ft (0.3 m)
FIRM	Yes	Yes	Yes	60.3(e)	♦ Permits within Flood Hazard Areas ♦ Notify adjacent communities and FEMA before alteration or relocation of watercourse ♦ Assure capacity is maintained ♦ Amend FIRM and RFW when WS increases over 1 ft (0.3 m) ♦ No alteration of sand dunes or mangrove stands within coastal hazard areas that would increase potential flood damage

Note. FEMA criteria are designated in English units.

TxDOT coordinates with FEMA in situations where administrative determinations are needed involving a regulatory floodway or where flood risks in NFIP communities are significantly impacted. The circumstances ordinarily requiring coordination with FEMA include the following:

- When a proposed crossing encroaches on a regulatory floodway and, as such, requires an amendment to the floodway map.
- When a proposed crossing encroaches on a floodplain where a detailed study has been performed but no floodway designated and the maximum 1-ft. (0.3-m) increase in the base flood elevation would be exceeded.
- When a local community is expected to enter into the regular program within a reasonable period and detailed floodplain studies are underway.
- When a local community is participating in the emergency program and base FEMA flood elevation in the vicinity of insurable buildings is increased by more than 1 ft. (0.3 m). Where insurable buildings are not affected, simply notify FEMA of changes to base flood elevations as a result of highway construction.

In many situations, it is possible to design and construct cost-effective highways such that their components are excluded from the floodway. This is the simplest way to be consistent with the standards and should be the initial alternative evaluated. If a project element encroaches on the floodway but has a minor effect on the floodway water surface elevation (such as piers in the floodway) and hydraulic conditions can be improved so that no water surface elevation increase is reflected in the computer printout for the new conditions, then the project may normally be considered consistent with standards.

The draft Environmental Impact Statement or Environmental Assessment (EIS/EA) should indicate the NFIP status of affected communities, the encroachments anticipated, and the need for floodway or floodplain ordinance amendments. Coordination means furnishing to FEMA the draft EIS/EA and, upon selection of an alternative, furnishing to FEMA, through the community, a preliminary site plan and water surface elevation information and technical data in support of a floodway revision request as required. If a FEMA determination would influence the selection of an alternative, obtain a commitment from FEMA prior to the final Environmental Impact Statement (FEIS) or a finding of no significant impact (FONSI). Otherwise, this later coordination may be postponed until the design phase. Refer to the Environmental Affairs Division for more details.

Floodway Revisions and NFIP

Where it is not cost-effective to design a highway crossing to avoid encroachment on an established floodway, consider modifying the floodway itself. Often, the community is willing to accept an alternative floodway configuration to accommodate a proposed crossing, provided NFIP limitations on increases in the base flood elevation are not exceeded. This approach is useful where the highway crossing does not cause more than a 1-ft. (0.3-m) rise in the base flood elevation. In some cases, it may be possible to enlarge the floodway or otherwise increase conveyance in the floodway above and below the crossing in order to allow greater encroachment. Such planning is best accomplished when the floodway is first established. However, where the community is willing to amend an established floodway to support this option, the floodway may be revised.

The responsibility for demonstrating that an alternative floodway configuration meets NFIP requirements rests with the community. However, this responsibility may be borne by the agency proposing to construct the highway crossing. FEMA prefers that floodway revisions be based on the hydraulic model used to develop the currently effective floodway but updated to reflect existing encroachment conditions. This allows determining the increase in the base flood elevation caused by encroachments since the original floodway was established. You may then analyze alternate floodway configurations. Reference increases in base flood elevations to the profile obtained for existing conditions when the floodway was first established.

Allowable Floodway Encroachment

When it is inappropriate to design a highway crossing to avoid encroachment on the floodway and where the floodway cannot be modified to exclude the structure, FEMA will approve an alternate floodway with backwater in excess of the 1-ft. (0.3-m) maximum only when the following conditions have been met:

- A location hydraulic study has been performed in accordance with FHWA, "Location and Hydraulic Design of Encroachments on Floodplains " (23 CFR §650, Subpart A), and FHWA finds the encroachment is the only practicable alternative.
- TxDOT has made appropriate arrangements with affected property owners and the community to obtain flooding easements or otherwise compensate them for future flood losses due to the effects of backwater greater than 1 ft. (0.3 m).
- TxDOT has made appropriate arrangements to assure that the National Flood Insurance Program and Flood Insurance Fund will not incur any liability for additional future flood losses to existing structures that are insured under the program and grandfathered under the risk status existing prior to the construction of the structure.
- Prior to initiating construction, TxDOT provides FEMA with revised flood profiles, floodway and floodplain mapping, and background technical data necessary for FEMA to issue revised Flood Insurance Rate Maps and Flood Boundary and Floodway Maps for the affected area, upon completion of the structure.

For more information on floodplain encroachments, see the Federal Aid Policy Guide.

Floodplain with a Detailed Study (FIRM). In NFIP participating communities where a detailed flood insurance study has been performed but no regulatory floodway is designated, design the highway crossing to allow no more than a 1-ft. (0.3-m) increase in the base flood elevation based on technical data from the flood insurance study. Submit technical data supporting the increased flood elevation to the local community and, through them, to FEMA for their files.

Floodplain Indicated on a FHBM. In NFIP-participating communities where detailed flood insurance studies have not been performed, TxDOT must generate its own technical data to determine the base floodplain elevation and design encroachments in accordance with the Federal Aid Policy Guide. Base floodplain elevations shall be furnished to the community and coordination carried out with FEMA as outlined previously where the increase in base flood elevations in the vicinity of insurable buildings exceeds 1 ft. (0.3 m).

Unidentified Floodplains. Design encroachments outside of NFIP communities or NFIP-identified flood hazard areas in accordance with the FAPG and TxDOT guidance. (See FAPG.)

Replacing Existing Structures

If an existing structure is replaced in a floodplain of an NFIP-participating community, the replacement structure is considered consistent with the NFIP criteria if it is hydraulically equal to or better than the one it replaces. That is, the replacement structure does not increase the base flood elevations. Generally, this applies directly to crossings in which either the roadway profile is lowered or the replacement structure is the same as or larger than the existing structure. In such instances, the designer may base the design solely on normal TxDOT design procedures. However, many bridge replacements combine an increase in structure size with an increase in the roadway profile elevation or a deeper bridge deck. If such changes constitute additional obstruction in the floodway, FEMA coordination is required.

Applicability of NFIP Criteria to TxDOT

Consistency with NFIP criteria is mandated for all TxDOT projects involving encroachments in floodplains of communities participating in NFIP. The following list identifies some typical conditions that must be checked for consistency with the requirements:

- NO X Replacement of existing bridge with smaller opening area, e.g., shorter length, deeper deck, higher or less hydraulically efficient railing.
- maybe X Replacement of bridge and approach roadway with an increase in the roadway profile.
- X Safety project involving addition of safety barrier. maybe
- √ Rehabilitation of roadway resulting in a higher profile.
- X Highway crossing at a new location.
- X Longitudinal encroachment of highway on floodplain (with or without crossing).
- X Storage of materials in floodplain.
- X TxDOT buildings in floodplain.

Some communities and regional councils have adopted floodplain ordinances that are more restrictive than basic FEMA criteria. Examples include the following:

- No increase ordinances that preclude any encroachment on the floodplain (i.e., no floodway).
- Design to accommodate ultimate watershed development.
- Roadway profiles to be set above 100-year flood elevation.

Generally FEMA condones stricter ordinances, but it does not require them. In fact, FEMA regulations specifically state that existing watershed conditions are to be the basis for establishing flood insurance rate zones, not future conditions. The implication of an ordinance with such stricter requirements is that highway crossings would have to span and clear the 100-year flood elevation. Neither FHWA nor FEMA require states to comply with stricter ordinances. On Federal-aid projects, FHWA will not fund costs in excess of those required for highways to meet basic FEMA criteria.

If the design is to accommodate such ordinances, TxDOT requires that any cost in excess of what would be required to accommodate either FEMA basic criteria or TxDOT criteria be borne by the community or regional council enforcing such an ordinance unless otherwise mandated by federal or state law or policy. This rationale is consistent with both the hierarchical structure of government and the fact that TxDOT is responsible for ensuring equitable use of highway funds. This philosophy may not always result in additional cost to the local entity; a risk assessment involving a range of design alternatives possibly may yield a least total cost option that accommodates the provisions of the stricter ordinance.

FEMA NFIP Map Revisions

Currently, FEMA publishes the following forms of map revision:

- Conditional Letter of Map Revision (CLOMR -- This letter from FEMA provides comments on a proposed project as to the need for a revised FIRM if the project is constructed. It indicates whether or not the project meets NFIP criteria.
- Letter of Map Revision (LOMR) -- Issued by FEMA with an accompanying copy of an annotated FIRM, this acknowledges changes in the base flood elevation, floodplain boundary, or floodway based on post-construction or revised conditions.
- Physical Map Revision -- This reprint of the FIRM reflects changes to the base flood elevations, floodplain boundary, or floodway based on revised conditions.

Normally, a TxDOT request for a CLOMR requires a follow up request for a LOMR after construction is complete unless the response to a request for a CLOMR indicates that a map revision is not required. FEMA determines the need for a physical map revision. The other map revision topics discussed below are the following:

- Typical conditions requiring FEMA map revision
- Hydrologic data for FEMA map revisions
- Hydraulic analyses for FEMA map revisions
- NFIP map revision request procedure
- FEMA 's response
- FEMA fees

You may submit any proposed project with a request for a CLOMR. FEMA will then determine need for a map revision. However, an application for a CLOMR is necessary when any of the following conditions is true:

- Proposed construction encroaches in the floodway and there is any increase in the base flood elevation associated with the floodway encroachment.
- Construction in the floodplain (not just floodway) changes the base flood elevation more than 1 ft (0.3 m).
- A floodway revision is desired to ensure other development does not obstruct a proposed bridge opening.

- New hydrologic and hydraulic analyses demonstrate that the existing study is not accurate.

The same is true of LOMR 's that apply to post-construction conditions. FEMA considers a LOMR to apply to any existing construction that may have occurred since the imposition of the floodway.

No map revisions are necessary under the following conditions:

- All proposed construction is outside the floodway boundary, and bridge lowchords are above the regulatory floodway elevation.
- Construction occurs within the floodway (e.g., piers), but the base flood elevations are the same or lower due to compensatory excavation or other improvement measures within the floodway, and the floodway does not need to be revised.

Hydrologic Data for FEMA Map Revisions

The hydrologic data used for the most current NFIP maps should be used in the hydraulic models for checking FEMA compliance and requesting map revisions. The only exception is when TxDOT is contesting the validity of the existing hydrologic data. FEMA will only consider new hydrologic data if it can be demonstrated to be more accurate than the existing data. The following methods acceptable to FEMA are shown in order of their preference:

1. Statistical analysis of peak annual gauged discharges
2. Regional regression equations
3. Rainfall-runoff modeling (e.g., NRCS methods).

When a request for a CLOMR or LOMR is necessary, under most circumstances, the designer needs to develop the following computer models, with exceptions as noted. All models must tie into the effective FIS profile upstream and downstream of the revised reach using sound hydraulic engineering practices to avoid discontinuities in the profile. The distance will vary depending on the magnitude of the requested floodway revision and the hydraulic characteristics of the stream.

- Duplicate effective model of the natural and floodway conditions. Rerun the original study model using the same computer program used for the original study to ensure that the base line is accurate. If the effective model is not available, an alternate model must be developed. The model should be run confining the effective flow area to the currently established floodway and calibrated to reproduce, within 0.10 ft. (0.03 m), the "with floodway " elevations provided in the Floodway Data Table for the current floodway. The alternate model should be based on floodplain geometry that existed when the original model was developed.
- Corrected effective model of the natural and floodway conditions. Many original studies may have technical errors, inaccuracies associated with not having enough cross-sections, or inaccurate cross-section data, or they did not include bridges or other structures that existed at the time of the original study. Also, an updated version of the computer program may provide more

accurate bridge modeling. The newer version of the same computer program may be used to show how the results would have appeared at the time of the original study if the newer technology had been used. With adequate justification, FEMA may consider this as the base line by which to compare the impacts of any changes that have occurred since the original model was developed. If the designer considers no such changes to have occurred that may detrimentally affect the TxDOT design, this model will not be necessary. FEMA may accept an alternative computer model to the original one if the original model is unavailable, inappropriate, or the alternative model is justified as providing more accurate results.

- Updated effective model reflecting changes in the floodplain that may have occurred since the original model was established. It is not the charter of TxDOT to provide studies for map revisions for changes other than those proposed by TxDOT. Often, either the community may not have requested map revisions or non-permitted activities may have changed base flood elevations. TxDOT does not consider itself responsible for such changes unless they were the result of TxDOT construction. However, such changes may either adversely affect the design of the TxDOT project or it is possible that the TxDOT project will incur no additional increase in the base flood elevation when accounting for these changes. Therefore, the need for development and submission of a pre-project model is left to the discretion of the designer.
- Post-project model reflecting the changes to the floodplain and floodway conditions anticipated by the proposed construction. This determines the impact of the project. FEMA only requires the duplicate effective model and the post-project model. The additional models (corrected and pre-project models) may be necessary to prove to FEMA that the existing effective model is not accurate and a new model should be the basis for comparison.

NFIP Map Revision Request Procedure

Generally, for TxDOT projects, an application for a CLOMR or LOMR should be prepared by TxDOT and submitted to FEMA by the participating community, TxDOT having provided supporting documentation. The procedural outline below assumes that a CLOMR or LOMR is needed.

1. Contact the FEMA coordinator for the participating community to discuss the need for map revision, to identify any conflicts, and to establish areas of cooperation.
2. Obtain detailed data for the FIS from FEMA. This will include the hydrologic and hydraulic analyses, current mapping, and active CLOMRs and LOMRs. The community may have this information. However, the source for the most current data is FEMA 's Technical Evaluation Contractor.
3. Acquire cross section survey data and establish existing field conditions in the floodplain at the proposed site.
4. Document the results of the hydraulic models.

5. Acquire and complete Form MT-2 "Application/Certification Forms for Conditional Letters of Map Revision, Letters of Map Revision, and Physical Map Revisions. "
6. Provide the participating community with the application and supporting documentation. Send the application and supporting documentation to the participating community with a request to submit the package to FEMA. Request the community to confirm the submittal and notify TxDOT of FEMA 's response.

FEMA response is usually a request for additional data, issuance of a map revision, or an indication that no map revision is required.

Fees associated with the application and review process are revised periodically. In 2001 these totaled about $5,400 for a CLOMR and follow-up LOMR and did not include the cost of retrieving the original FIS data. All associated fees for TxDOT projects should be assigned to engineering costs.