Grand Prairie
TEXAS

City of Grand Prairie

City-Wide Drainage Master Plan for Arbor Creek

STATE OF TEXAS
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1-13-2012

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1-16-2012

O'Brien Engineering, Inc.
Hydraulics . Hydrology . Civil Engineering

January 13, 2012

RESOLUTION NO. 4539-2012

A RESOLUTION APPROVING THE CITY OF GRAND PRAIRIE'S CITY-WIDE DRAINAGE MASTER PLAN FOR ARBOR CREEK.

WHEREAS, The "City-Wide Drainage Master Plan for Arbor Creek" (the Plan) is about providing comprehensive, updated technical data for the management of the Arbor Creek watershed; and

WHEREAS, the Plan addresses existing flooding, erosion, and sedimentation problems within the watershed and provides planning alternatives and design concepts to help alleviate potential flood damages; and

WHEREAS, the Plan provides the City of Grand Prairie with the necessary updated drainage information to coordinate future development according to the City's drainage requirements to help minimize existing and potential flood damages within the Arbor Creek watershed; and

WHEREAS, any revisions to the floodplain and the floodways identified in these studies shall also include ultimate development conditions and shall be for the whole creek as determined in these studies and not for portions of it to ensure that there are no downstream adverse effects; required submittals to FEMA shall be for the whole creek (as determined in these studies) and not for portions of it; and

WHEREAS, the recommendations of this report shall be incorporated for all future development as well as CIP budget considerations.

NOW THEREFORE, BE IT RESOLVED, BY THE CITY COUNCIL OF THE CITY OF GRAND PRAIRIE, TEXAS THAT:

SECTION 1. That the City of Grand Prairie, Texas, having developed the "City-Wide Drainage Master Plan for Arbor Creek" to cost-effectively manage flood or storm waters within budgeting constraints, approves and adopts the "City-Wide Drainage Master Plan for Arbor Creek" thereby setting the standard for future drainage master plans, addressing existing flooding problems and providing planning recommendation, alternatives and design concepts for future development, to include CIP as well as possible developer participation projects.

PASSED AND APPROVED BY THE CITY COUNCIL OF THE CITY OF GRAND PRAIRIE, TEXAS ON THIS THE 3RD DAY OF JANUARY, 2012.

APPROVED:

Charles England, Mayor

ATTEST:

City Secretary

APPROVED AS TO FORM:

City Attorney

O'BrienEngineering, Inc.
Hydraulics · Hydrology · Civil Engineering

January 13, 2012

Mr. Romin Khavari, PE, CFM
City Engineer
City of Grand Prairie
206 W. Church Street
P.O. Box 534045
Grand Prairie, Texas 75053-4045

RE: City-Wide Drainage Master Plan Road Map
(Y#0879) Final Report – Arbor Creek

Dear Mr. Khavari:

O'Brien Engineering, Inc. is pleased to provide the Final Report for Arbor Creek portion of the City-Wide Drainage Master Plan Road Map (Y#0879). This report compiles existing and newly developed technical data for the Arbor Creek watershed into a single report. The discussion includes evaluation of the creek's ongoing nature-driven transformation to an urban stream, and enumerates and analyzes potential management practices and facilities to mitigate the process.

This report will provide the City with a valuable planning tool. The analytical tools – the hydrologic and hydraulic models and mapping will provide the City with a ready means to better manage the channel, floodplain and drainage ways. A CD-ROM containing HEC-HMS hydrologic models, HEC-RAS hydraulic models, the GIS shapefiles, and PDFs, is attached for City use.

It is our privilege to provide this important service to the City of Grand Prairie and its citizens. If you have any questions or require further information, please do not hesitate to contact us.

Sincerely,

O'BRIEN ENGINEERING, INC.

Jacob S. Lesué

Jacob S. Lesué, PE, CFM
Project Manager

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TABLE OF CONTENTS

TABLE OF CONTENTS i
EXECUTIVE SUMMARY viii
Preliminary Short-Term & Long Term Implementation Plan ix
CIP Location Map x

I. INTRODUCTION

A. Acknowledgements I-1
B. Authorization I-1
C. Purpose of Study I-1
D. City Ordinances and Development Requirements I-3
E. Watershed Description I-4
F. Principal Flooding Problems I-5
G. Channel Stability Assessment I-5
H. Pertinent Study and Technical Data Related to Watershed Prior to Arbor Creek CWDMP Preparation I-6

II. HYDROLOGIC STUDY

A. General II-1
B. Watershed II-2
C. Land Use II-5
D. Impervious Coverage II-9
E. Soil Types II-9
F. Loss Rates II-12
G. Synthetic Unit Hydrograph II-12
H. Rainfall II-14
I. Flood Routing II-14
J. Detention & Diversions II-15

III. HYDRAULIC STUDY

A. Hydraulic Analysis III-1
B. Cross Sections III-2
C. Parameter Estimation III-4
D. Modeling Considerations III-5

IV. HYDROLOGIC AND HYDRAULIC STUDY RESULTS

A. Hydrologic Study Results IV-1

B. Hydraulic Study Results IV-1
C. Quality Assurance / Quality control..... IV-5

V. FLOODPLAIN MAPPING
A. General..... V-1
B. FEMA Map Revisions V-1

VI. ROADWAY CROSSINGS
A. Evaluation of Existing Roadway Crossings VI-1
B. Evaluation of Proposed and Future Roadway Crossings VI-1

VII. ALTERNATIVES FOR STREAMS AND OPEN CHANNELS
A. Summary of Flooding Issues VII-1
B. Alternatives Analysis VII-2

VIII. STORM WATER INFRASTRUCTURE ANALYSIS

IX. CHANNEL STABILITY ASSESSMENT & EROSION HAZARD ANALYSIS
A. Introduction..... IX-1
B. Channel Stability Concepts IX-1
C. Findings of Channel Assessment IX-4
D. Areas of Concern..... IX-8
E. Non-Structural Measures (Erosion Hazard Setbacks)..... IX-15
F. Structural Measures IX-17
G. Inspection and Maintenance..... IX-43

X. DAMS / LEVEES / DETENTION / DRAINAGE REVIEWS
A. Dams, Levees, and Detention Facilities X-1
B. Drainage Reviews X-1

XI. STORM DRAIN OUTFALL ASSESSMENT
A. Assessment Resources..... XI-1
B. Condition and Criteria..... XI-4
C. Field Check XI-5
D. Outfall Conclusions/Recommendations..... XI-7

TABLE OF CONTENTS

XII. PRELIMINARY QUANTITIES / ESTIMATES OF PROBABLE COST

XIII. EVALUATION & PRIORITIZATION / PHASING & IMPLEMENTATION

A. Evaluation & Prioritization XIII-1
B. Phasing & Implementation XIII-1

XIV. SHORT TERM PRIORITIES & LONG TERM PLAN

A. Short-Term Priorities Implementation XIV-1
B. Long-Term Plan Implementation XIV-1

XV. MASTER PLAN STUDY WRAP-UP & RECOMMENDATIONS

A. Stream and Open Channel XV-1
B. Stream Stability XV-1
C. Improvement Project Prioritization XV-2
D. Storm Drain Outfalls XV-2
E. Other Drainage Facilities XV-2
F. Recommendations XV-3
G. Master Drainage Plan Maintenance XV-3

TABLES

Table II-1 Summary of Hydrologic Parameters II-3
Table II-2 Existing Development Land Use Summary II-6
Table II-3 Ultimate Development Land Use Summary II-6
Table II-4 Land Use Percent Impervious II-9
Table II-5 Rainfall Data in Inches II-14

Table III-1 Manning’s Roughness Coefficients by Type III-5

Table IV-1 Summary of Discharges for Arbor Creek IV-1
Table IV-2 Water Surface Elevation Comparison IV-2

Table VI-1 Existing Roadway Crossings Summary VI-3
Table VI-2 Proposed Alternatives for Existing Roadway Crossings .. VI-3

Table VII-1 Tarrant Road Alternative Summary of Concept Opinion of Probable Construction Costs VII-5

Table IX-1 Reach B Stream Stabilization Summary of Concept Opinion of Probable Construction Costs IX-29

Table IX-2 Reach C Stream Stabilization Summary of Concept Opinion of Probable Construction Costs IX-31

Table IX-3 Reach D Stream Stabilization Summary of Concept Opinion of Probable Construction Costs IX-32

Table IX-4 Reach E Stream Stabilization Summary of Concept Opinion of Probable Construction Costs IX-33

Table IX-5 Reach F Stream Stabilization Summary of Concept Opinion of Probable Construction Costs IX-39

Table IX-6 Reach G Stream Stabilization Summary of Concept Opinion of Probable Construction Costs IX-42

Table IX-7 Reach G Stream Stabilization Summary of Concept Opinion of Probable Construction Costs IX-42

Table XI-1 Storm Drain Outfall Assessment.................................... XI-6

Table XII-1 Conceptual Opinion of Probable Construction Cost (COPCC) – Tarrant Road 100-Yr Culvert Option: Existing Width.. XII-2

Table XII-2 COPCC – Arbor Creek Reach B Stream Stabilization: 1 Improved Culvert Outfall, 1 New Drop Structure, and 1 Improved Drop Structure... XII-3

Table XII-3 COPCC – Arbor Creek Reach C Stream Stabilization: 1 Improved Drop Structure and 2 Improved Drop Structures/Utility Crossings.. XII-4

Table XII-4 COPCC – Arbor Creek Reach D Stream Stabilization: 1 Sanitary Sewer Encasement...................................... XII-5

Table XII-5 COPCC – Arbor Creek Reach E Stream Stabilization: 1 Improved Drop Structure and 2 New Drop Structures . XII-6

Table XII-6 COPCC – Arbor Creek Reach F Stream Stabilization: 2 New Drop Structures, 1 Gabion Repair/Drop Structure, 1 Section of Bank Armoring XII-7

Table XII-7 COPCC – Arbor Creek Reach G Stream Stabilization: Stream Restoration of Entire Reach XII-8
Table XII-8 COPCC – Arbor Creek Reach G Bridge Stabilization: Scour Control Around Pedestrian Bridge........................ XII-9

Table XIII-1 Preliminary Short-Term & Long Term Implementation Plan VIII-3

FIGURES

Figure II-1 Watershed Map II-4
Figure II-2 Existing Conditions Land Use Map II-7
Figure II-3 Ultimate Conditions Land Use Map II-8
Figure II-4 Hydrologic Soils Map II-11

Figure V-1 Arbor Creek Floodplain Workmap..................................... V-2

Figure VI-1 City of Grand Prairie Master Thoroughfare Plan.............. VI-4

Figure VII-1 Tarrant Road Crossing Alternative - 1% AC Flood Capacity... VII-6

Figure IX-1 Channel Evolution Model IX-2
Figure IX-2 Channel Evolution Model from Dr. Allen's Channel Assessment Report IX-3
Figure IX-3 Approximate Location of Stream Stability Issues............. IX-6
Figure IX-4 Views of Exposed Utility Encasements at Station 71+64 (left), and Station 35+50 (right) IX-9
Figure IX-5 Views of Unstable Bank Sections at Station 71+50 (left), and Station 24+77 (right) IX-9
Figure IX-6 Typical Local Scour Problems at Tarrant Road (left), and Drop Structure Near Station 45+20 (right) IX-10
Figure IX-7 Potential and Observed Areas of Sedimentation IX-12
Figure IX-8 Views of Sediment in Existing Drop Structures at Station 51+50 (left), and Station 46+00 (right) IX-14

Figure IX-9 View of Sediment and Vegetation at Egyptian Way Culverts IX-15
Figure IX-10 Schematic for Determination of Erosion Hazard Setback Distances IX-16
Figure IX-11 Typical Profile of a Drop Structure Designed to Protect an Exposed Utility Encasement IX-19
Figure IX-12 Typical Profile of a Drop Structure IX-19
Figure IX-13 Typical Drop Structure Crest Section IX-20
Figure IX-14 Typical Gabion Wall with Tie-Backs IX-21
Figure IX-15 Typical Loose Riprap Installation at a Culvert Outfall IX-23
Figure IX-16 Proposed Project Locations IX-25
Figure IX-17 View of Scour at the Outfall of the Duncan Perry Road Culvert IX-27
Figure IX-18 Exposed Sanitary Sewer Line Encasement (Station 82+30) IX-28
Figure IX-19 Grouted Rock Riprap Drop Structure (Station 78+00) ... IX-28
Figure IX-20 Loose Rock Riprap Drop Structure (Station 67+90) IX-30
Figure IX-21 Encased Sanitary Sewer Crossing (Station 64+90) IX-31
Figure IX-22 Views of Meanders Close to SH 161 at Station 24+80 (left) and Station 30+50 (right) IX-34
Figure IX-23 Erosion at End of Gabion Mattress Channel Bottom (Station 37+00) IX-35
Figure IX-24 Exposed Sanitary Sewer Encasement Near Station 35+50 .... IX-36
Figure IX-25 Concept Cross Section of Proposed Bank and Channel Armoring Between Stations 35+70 and 34+80 .... IX-36
Figure IX-26 Concept of Proposed Drop Structure and Channel Armoring Between Stations 35+70 and 34+55 .... IX-37
Figure IX-27 Scour Adjacent to Gabion Armoring Near Station 26+50 .... IX-38
Figure IX-28 Concept Cross Section of Proposed Channel Armoring Between Stations 26+65 and 25+50 .... IX-38
Figure IX-29 Concept of Drop Structure Near Section 25+50 .... IX-39
Figure IX-30 Typical Section of Degraded Channel in Waggoner Park (Station 6+25) IX-40

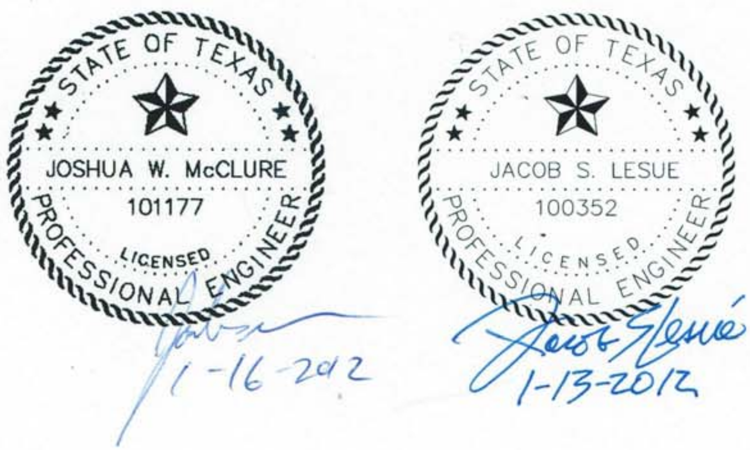
TABLE OF CONTENTS

Figure IX-31 Pedestrian Bridge with Substantial Scour (Station 3+50) IX-41

Figure XI-1 Storm Sewer Outfall Location Map XI-2

APPENDICES

Appendix A .... Hydrologic and Hydraulic Data
Appendix B .... Elevation Certificates
Appendix C .... Storm Drain Outfalls
Appendix D .... Arbor Creek Channel Assessment by Dr. Peter M. Allen
Appendix E .... CD-ROM



Executive Summary

The City-Wide Drainage Master Plan for Arbor Creek provides comprehensive, updated technical data for the management of the Arbor Creek watershed and storm water infrastructure. The analysis included updated hydrologic and hydraulic modeling of the watershed and channel, field observation based assessment of numerous drainage facilities, stream geomorphologic assessment, alternative solution development, and project priority ranking.

This report summarizes the analysis and findings. The CWDMP will provide the City of Grand Prairie a powerful, current tool which will prove beneficial in the expedient and cost-effective maintenance and upgrading of the infrastructure that comprises the storm drain, flood control, and erosion control systems in the City. It also provides the City with the tools to evaluate new development and other proposed projects to assure compliant design and construction.

Although there are no record flooding complaints relative to the Arbor Creek floodplain, Tarrant Road stands in need of immediate attention to repair substantial erosion. Alternatives and recommendations are detailed within.

Arbor Creek is approximately 82% urbanized. Whereas this fact indicates that development review is nearing an end for this watershed, it is one of the primary underlying reasons for the current rapid degradation of the Arbor Creek channel as the stream gravitates to a new equilibrium consistent with the developed characteristics of this unique watershed. Analysis of the Arbor Creek geomorphology is detailed within this study, in addition to the alternative effective means of mitigating the adverse impacts of the ongoing changes.

Table XIII-1 Preliminary Short-Term & Long-Term Implementation Plan

Arbor Creek

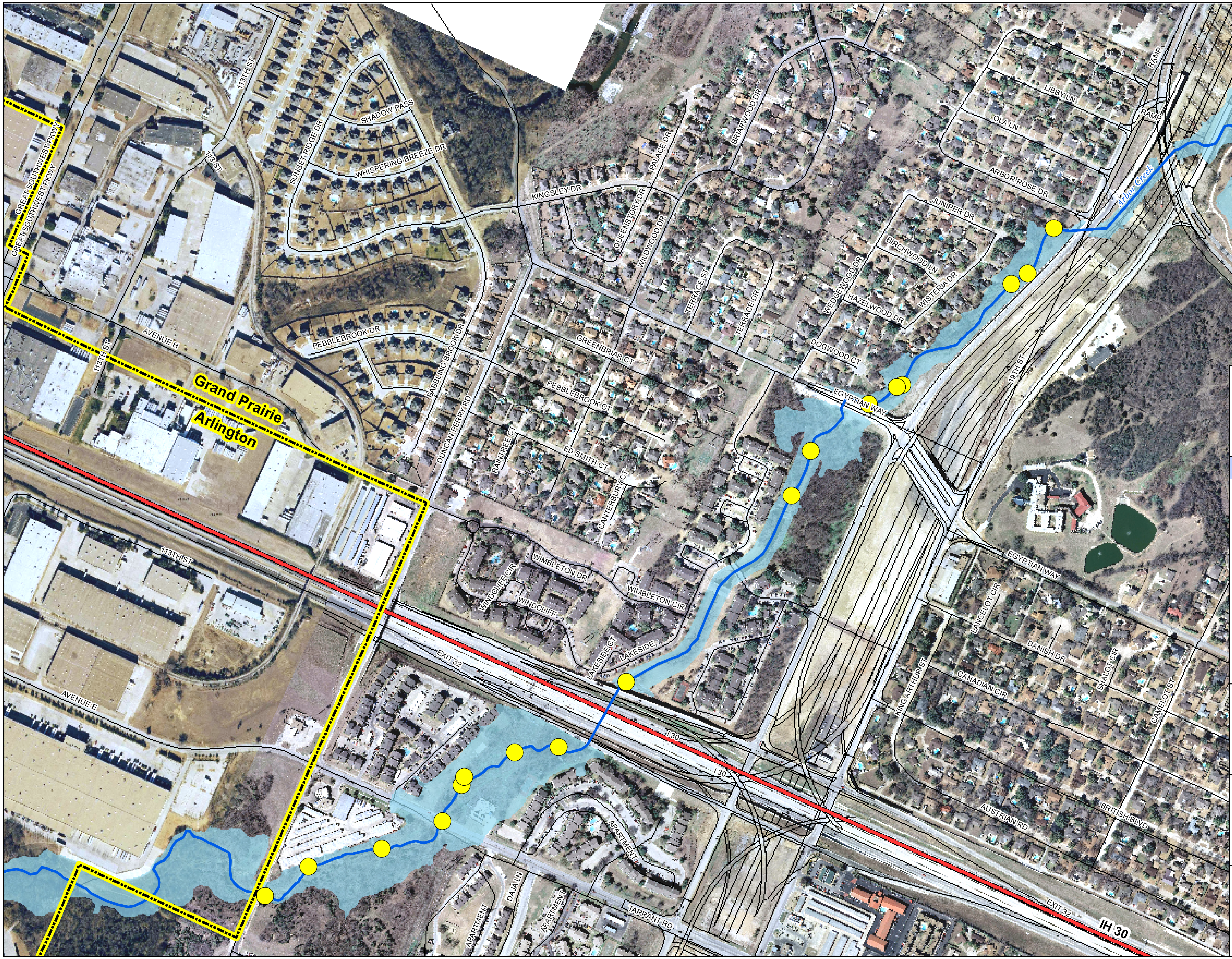
	Capital Improvement Project	Project Size & Short-Term/Long-Term	Step 1 - Initial Ranking Factor - Estimate of Probable Cost vs. # Structures Benefited [1]			Step 2 - Second Ranking Factor - Cost to Benefit of Roadway Number of Citizens Impacted [2]							Step 3 - Tax Value of Benefited Property Structures [7]		Sum of 1st, 2nd, and 3rd Factors - Step 4	Initial Rank - Step 4	100-Year Ultimate Discharge at CIP Location - Step 5		Final Rank - Step 6
			# Structures	Cost	1st Factor [1]	Type	Current Roadway Flood Event Protection	Roadway % Citizens Protected Currently.[4]	Roadway % Citizens Protected After Alt.[4]	Roadway # Citizens Impacted [5]	Cost to Benefit Roadway # Citizens Impacted [6]	2nd Factor	Tax Value of Property Structures Benefited	3rd Factor	Total	Rank [8]	Ultimate Q_{100}	Sorting [9]	Rank [10]
1	**Alt. 1 -** Tarrant Road	Large/Short-Term	0	$1,539,000	**5**	M4U	1	0%	100%	6760	$227.66	**1**	$0	**20**	**26**	**2**	4,130	**1**	1
5	**Alt. 2 -** Reach B Stream Stability Measures	Small/Long-Term	0	$176,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	4,130	**5**	5
2	**Alt. 3 -** Reach C Stream Stability Measures	Small/Short-Term	0	$232,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	2,630	**2**	2
3	**Alt. 4 -** Reach D Stream Stability Measures	Small/Short-Term	0	$18,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	2,890	**3**	3
6	**Alt. 5 -** Reach E Stream Stability Measures	Small/Long-Term	0	$126,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	2,890	**6**	6
4	**Alt. 6 -** Reach F Stream Stability Measures	Small/Short-Term	0	$360,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	3,440	**4**	4
8	**Alt. 7 -** Reach G Stream Rehabilitation	Large/Long-Term	0	$2,076,000	**5**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**27**	**3**	3,440	**8**	8
7	**Alt. 8 -** Reach G Pedestrian Bridge Impr.	Small/Long-Term	0	$244,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	3,440	**7**	7

1 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 1
2 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 2
3 Based on approximation, using logarithmic chart, with 1-Year Event coverage protecting 0% of traffic volume and 100-Year Event coverage protecting 100% of traffic volume
4 Percent Impacted = 100% minus % of Roadway Citizens Protected (approximate)
5 Number Impacted = % Impacted multiplied by [No. Lanes * 4 Hours Impacted * Hourly Volume Per Lane * Level of Service "C" Traffic Volume]
6 Cost of CIP divided by Roadway # Citizens Impacted
7 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 3
8 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 4
9 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 5 -- This ranking was modified because all alternatives are on the same stream. Instead of flow rate, the immediacy of the needs for each alternative and its costs were used create rankings.
10 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 6

Additional Notes:

a. Phased projects shall be ranked in order of Phasing (i.e. Phase 1 shall be ranked higher than Phase 2, etc.)

b. In Step 5, when comparing projects between two different watersheds: If two projects have same rank in Step 4 and need to be sorted, but have similar 100-Year Ultimate Discharges, then projects should be ranked in order of lowest cost estimate



CIP LOCATION MAP

KEY TO FEATURES

- CIP Alternative Locations (See Section VII)
- Grand Prairie City Limit
- Stream Centerline
- Floodplain - Ultimate 1% AC

0 250 500 1,000
Scale in Feet

Grand Prairie TEXAS

CWDMP for Arbor Creek

O'BrienEngineering, Inc.
Hydraulics • Hydrology • Civil Engineering
Texas Registered Engineering Firm F-3758

I. INTRODUCTION

A. Acknowledgements

O'Brien Engineering, Inc. would like to acknowledge the significant contributions of all City of Grand Prairie staff in preparation of the City-Wide Drainage Master Plan for Arbor Creek. In particular, the following individuals have provided invaluable input and assistance:

Romin Khavari – City Engineer
Gabriel Johnson – Floodplain Administrator

B. Authorization

The City of Grand Prairie authorized the Arbor Creek Master Drainage Study and FEMA CTP Mapping Project (Y#0879) and contracted with O'Brien Engineering, Inc. (OEI) for this work on December 13, 2010.

C. Purpose of Study

The City of Grand Prairie is a FEMA Cooperating Technical Partner (CTP). The City is committed to maintaining current flood maps as a CTP, and among other objectives, to developing a comprehensive studied and prioritized approach to flood and stormwater management, known as the City-wide Drainage Master Plan Road Map (Road Map). The Road Map is an efficient extension of the modeling required for the CTP mapping process, providing a basis for analysis of various frequency floods and hydraulic conditions and for evaluation of alternatives to specific flooding and drainage problems.

Specific objectives of the City that are addressed in this study include:

1. Development of a hydrologic model of the Arbor Creek Watershed. The model is based on US Army Corps of Engineers (USACE) hydrologic program, HEC-HMS.

2. Frequency analysis of the 10%, 4%, 2%, 1%, and 0.2% annual chance (AC) storms (10, 25, 50, 100 and 500-year frequencies) for the existing stage of watershed development.
3. Frequency analysis of the 50%, 20%, and 1% annual chance (AC) storms (2, 5, and 100 year frequencies) for the ultimate stage of watershed development.
4. Development of a hydraulic model of the Arbor Creek channel and floodplain. The model is based on USACE hydraulic program, HEC-RAS and incorporates recent improvements in the Arbor Creek system including:
    a. Improvements by TxDOT associated with the construction of SH-161, downstream of Egyptian Way, based on TxDOT's request for LOMR specific to the project,
    b. Drop structures and channel modifications between Egyptian Way and IH-30,
    c. Updated LiDAR topographic data throughout the remainder of the Arbor Creek system within City limits.
5. Preparation of updated Flood Insurance Rate Maps (FIRM) for Arbor Creek.
6. Development of alternative solutions to specific flooding and drainage problems in the watershed.
7. Preparation of stream geomorphologic study of Arbor Creek, detailing classification of stream evolution types, estimation of stream equilibrium conditions including stream and bank slopes and channel widths, and analysis of unstable and problematic areas
8. Preparation of flooding, erosion, and stream stability alternatives evaluation including conceptual opinions of probable construction cost.
9. Evaluation and prioritization of potential problem solution alternatives against the City's Road Map.

D. City Ordinances and Development Requirements

As part of this City-wide Drainage Master Plan study, the City Drainage Design Manual and existing development requirements were reviewed to determine their adequacy to prevent future flooding issues. The Arbor Creek watershed is mostly developed at this time and proper drainage requirements and responsible development of the watershed will help prevent future flood damage and unnecessary capital improvement costs.

The City of Grand Prairie is especially progressive in their storm water management program. The City's Drainage Design Manual was updated as recently as October of 2010 and is intended to "…protect the general health, safety, and welfare of the public by reducing flooding potential, controlling excessive runoff, minimizing erosion and siltation problems, and eliminating damage to public facilities resulting from uncontrolled storm water runoff."

Articles 14 and 15 of the Unified Development Code, included in the City's Drainage Design Manual, contain the City ordinances for Drainage and Floodplain Management, respectively. Requirements include the elevation of new construction a minimum of one foot above the ultimate 100-year floodplain or two feet above the existing conditions floodplain, whichever is higher. Construction of detention basins is required when downstream facilities are not adequately sized to convey a design storm based on current City criteria for hydraulic capacity. Post project peak flows are not allowed to exceed the existing conditions peak flows unless sufficient downstream capacity above existing discharge conditions is available. When required, detention facilities are to be designed such that peak discharges or velocities are not increased when compared to pre-project conditions for the 2-, 10- and 100-year floods.

The City ordinances allow for responsible development of the watershed such that flood risks to future structures can be minimized. The ordinances also allow for protection of existing structures so that future development will not increase the flooding hazard in areas that do not have the capacity to convey increased flood discharges. Upon review of the City's Drainage Design Manual and existing development requirements, it has been determined that the requirements in combination with the technical data provided in this report are adequate to properly manage the watershed going forward.

E. Watershed Description

Arbor Creek watershed is approximately 82% urbanized; the channel is crossed by roads at 9 locations. At present, industrial land uses comprise 31% of the watershed, while infrastructure and transportation make up another 30%. Residential development accounts for 12%, 8% is commercial, and 18% of the existing watershed is undeveloped or open space use. At full development of the watershed, it is estimated that residential will increase by 5%, industrial by 6%, and open space will decrease by 12%. Apart from crossings, more than 40% of the Arbor Creek stream channel has been modified by channelization, bank stabilization, erosion control structures, or other structural measures related to urbanization.

The nearly 2.45 mile length of Arbor Creek channel falls almost 80 feet from headwaters to outfall. 90% of the surface soils in the Arbor Creek watershed are classified as NRCS hydrologic soil group D, having high runoff potential. Eight percent are classed as B, with relatively low runoff potential. There are no significant detention structures in the basin; however, an undersized culvert at the IH-30 crossing impacts all calculated frequency hydrographs due to unintentional detention storage.

The Arbor Creek watershed is located both in Dallas and Tarrant Counties and also both in the City of Grand Prairie and the City of Arlington. Approximately 40% of the watershed is within the City limits of Grand Prairie, while approximately 70% of Arbor Creek that is not contained in a storm sewer system is within the city limits of Grand Prairie. Other unique attributes of Arbor Creek include, 1) a relatively small culvert to convey the 1% AC flood under I-30 which would cause substantial ponding, 2) two concrete drop structures, 3) a substantial bend immediately downstream of Egyptian Way, 4) three culverts in series as Arbor Creek passes under State Highway (SH) 161, 5) several bridge columns obstructing flow from the elevated main lanes of SH 161 as it runs parallel to Arbor Creek for approximately 1,000 feet, and 6) designation by FEMA as Stream JC-1 instead of Arbor Creek.

F. Principal Flooding Problems

1. Drainage Complaint Database

The City of Grand Prairie's Drainage Complaint Database indicates a number of problems relative to streets and storm drainage; however, there are no complaints relative to the Arbor Creek channel or floodplain.

2. Hot Spot Locations

No hot spot locations were evaluated as the database identified no problems relative to the Arbor Creek channel or floodplain.

3. Roadway Overtopping

Tarrant Road has been previously overtopped and the City has expressed an interest in upgrading this crossing. No other road overtopping is known to have occurred on Arbor Creek.

G. Channel Stability Assessment

Urbanization impacts numerous factors and changes the character and rate of response of a channel and floodplain to runoff. Although even pristine streams within pristine watersheds are under constant change, key characteristics, such as channel slope, bank slope, and channel bottom width tend to gravitate around equilibrium values even though they may fluctuate somewhat. When significant changes occur in the watershed however, these equilibrium values change, often dramatically.

Because the Arbor Creek watershed is highly urbanized, and somewhat recently so, the stream channel is in a state of transition, gradually edging toward equilibrium. In simple terms, this explains why many areas of the channel are experiencing aggressive transformations that, if not presently, will soon be threatening existing structures. Considerable attention is given to this issue and to the development of a strategy for managing the impacts of urbanization.

H. Pertinent Study and Technical Data Related to Watershed Prior to Arbor Creek CWDMP Preparation

1. 2004 Freese & Nichols Watershed Technical Report

Freese & Nichols, Inc. prepared a Watershed Technical Report for the City of Grand Prairie for several watersheds including Cottonwood Creek, Fish Creek, Cedar Creek, Arbor Creek, Barrett Creek, Turner Branch, and Gopher Branch. Hydrologic models were prepared for the 10, 50, and 100-year existing and ultimate land use conditions.

2. 2005 Halff Associates, Inc. Map Modernization Study

Halff Associates, Inc. (Halff) completed a hydraulic study in 2005 which was provided to FEMA as part of the Map Modernization Project for the production of the Digital Flood Insurance Rate Maps (DFIRM) and revised FIS for Dallas and Tarrant Counties. The area that was studied in detail included approximately 1.67 stream miles of Arbor Creek between Duncan Perry Road and the confluence of Arbor Creek and Johnson Creek. Cross Sections for this model were developed using the City of Grand Prairie 1999 aerial topography and field survey data prepared by Halff. Bridge and culvert data was obtained from Halff's survey, existing models, and record drawings. The Halff model was included in the preliminary version of the FIS and DFIRM panels released in June of 2007, which at this juncture have not become effective.

3. 2005 Halff Associates Tarrant Rd Drainage Improvements Study

Halff prepared a culvert improvement plan for Tarrant Road as it crosses Arbor Creek. The plan included field survey of structures in the vicinity, a hydraulic analysis, conceptual plan and profile drawing, and a cost estimate.

4. 2005 Halff Arbor Creek Urbanized Hydrology Study

The City of Grand Prairie engaged Halff in 2005 to prepare an Urbanized Hydrologic Study on Arbor Creek. Halff developed a new hydrologic model based on ultimate development and prepared a memo discussing their hydrologic analysis, methodologies, results, and comparisons to previous studies.

5. 2008 O'Brien Engineering, Inc. Flood Study for Repairs on Two Concrete Drop Structures

O'Brien Engineering, Inc. (OEI) prepared a flood study on Arbor Creek between Egyptian Way and Interstate 30 in 2008. The study used the Halff 2005 model as a base and made revisions to evaluate the two proposed concrete drop structures on Arbor Creek which have now been constructed. Cross sections were modified within the vicinity of the two drop structures using one-foot contours based on field survey prepared by SAM, Inc.

6. 2011 Texas Department of Transportation Hydraulic Study on Arbor Creek for Construction of State highway 161

The Texas Department of Transportation (TxDOT) prepared a flood study on Arbor Creek between Egyptian Way and Waggoner Park downstream of State Highway 161 between 2010 and 2011. This study also used the

Halff 2005 model as a base and made revisions to evaluate the construction of State Highway 161 which included the north and south frontage roads and the main lanes. Three new or modified crossings were evaluated in the model which included the culverts at Egyptian Way, SH 161 Southbound Frontage Road, and North Carrier Parkway. In addition, the project included stream realignment, channel improvements, and an elevated road structure with multiple bridge columns placed in the channel. The channel modeling utilized topographic data from multiple sources which included channel surveyed cross data completed by Lina T. Ramey & Associates, LLP (LTRA) and City of Grand Prairie funded LiDAR topography generated on a 1 foot contour interval.

II. HYDROLOGIC STUDY

A. General

A new hydrologic analysis of the Arbor Creek watershed was conducted for this study. The results of the analysis, along with all pertinent model parameters, were compared to two prior studies: one by Freese and Nichols, Inc. (FNI) and another by Halff Associates, Inc. (Halff). FNI completed their study of the Arbor Creek watershed in February 2005, and evaluated both, existing and ultimate land use conditions under a contract to the City of Grand Prairie. FNI used the USACE program HEC-HMS (version 2.2.2, May 2003) to perform the hydrologic analysis. Halff's study, completed in October 2005, included an analysis of the ultimate land use conditions hydrology for the Arbor Creek watershed using USACE programs, HEC-HMS to compute peak discharges and HEC-RAS to compute peak flood elevations for the study stream. The Arbor Creek HEC-HMS watershed models developed for the present study include analysis of both existing and ultimate land use conditions, using the SCS unit hydrograph method.

The Soil Conservation Service (SCS) Curve Number (CN) method was selected to evaluate the rainfall loss rates – evaporation, interception, depression storage, and infiltration – for this study. The CN method accounts for incremental rainfall losses for each time step, based on a coefficient that is calculated as a weighted average of the totality of varying land uses, soil types, and impervious areas within each sub-basin. Table 4.1a of the Drainage Design Manual for the City of Grand Prairie is a list of curve numbers for the various land uses in the City; a CN from this table was assigned to each land use within each sub-basin. The average CN was then calculated by weighting each land use CN proportionate to the area that they represent relative to the whole. Curve number is also affected by the moisture condition of the soil immediately prior to the storm, a factor referred to as the antecedent moisture condition or AMC. Three conditions are recognized: dry (AMC-I), moderately moist (AMC-II), and saturated (AMC-III). A condition of AMC-II was used for this study.

Several rainfall events were evaluated for this study including the 10%, 4%, 2%, 1%, and 0.2% annual chance (AC) storms (10, 25, 50, 100 and 500-year frequencies) for the existing land use conditions and the 50%, 20%, and 1% AC storms (2, 5 and 100-year frequencies) for the ultimate land use conditions. Detailed watershed delineations, existing and ultimate land use determinations, and the hydrologic soil coverage were used to develop HEC-HMS hydrologic computer models for the watershed. The City of Grand Prairie's current Drainage Design Manual (November 2009) along with Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55) Second Edition were used as guidelines for the new hydrologic analyses.

B. Watershed

Arbor Creek is a tributary to Johnson Creek and is located in northwestern Grand Prairie in Tarrant and Dallas County. Arbor Creek originates north east of the intersection of State Highway 360 and State Highway 180 in Arlington, Texas, and generally flows north-east to its confluence with Johnson Creek. The total contributing watershed draining to Johnson Creek is about 1.78 sq miles.

Arbor Creek is approximately 2.45 miles in length through the City Limits with an average slope of 0.6 %. Along Arbor Creek north of Interstate Highway-30, there are two concrete drop structures. Apart from these drop structures and several minor and major crossings, the creek is generally a natural earthen channel with some vegetation. The Arbor Creek Watershed is almost fully developed with high-density residential, commercial development and industrial areas.

The Arbor Creek watershed boundary was delineated using a combination of the City of Grand Prairie one-foot contours and the City of Arlington two-foot contours in ArcGIS 9.2. The watershed was subdivided into five sub-basins with its outfall at the confluence with Johnson Creek. These sub-basins range in drainage area size from 0.18 to 0.75 square miles. A detailed Watershed map is provided in Figure II-1. Table II-1 contains a summary of the various sub-basin areas for the Arbor Creek watershed.

Table II-1
Summary of Hydrologic Parameters

Basin Name	CN	Lag-Time (min)	Area (sq mi)
A1	93.6	15.1	0.75
A2	87.9	24.5	0.39
A3	89.5	16.5	0.18
A4	89.6	20.9	0.21
A5	88.5	25.2	0.25

Figure II-1

Watershed Map

KEY TO FEATURES

- ARBOR CREEK WATERSHED
- STREAM CENTERLINE
- STORM DRAIN
- CITY BOUNDARY
- INDEX CONTOUR

0 500 1,000 2,000

Scale in Feet

Grand Prairie TEXAS

CWDMP for Arbor Creek

O'Brien Engineering, Inc.

Hydraulics • Hydrology • Civil Engineering

Texas Registered Engineering Firm F-3758

C. Land Use

Land usage for the Arbor Creek watershed has been determined for both existing and ultimate watershed conditions.

1. Existing Conditions

The 2009 City of Grand Prairie aerial photography and North Central Texas Council of Government (NCTCOG) 2005 land use data were used to determine the existing land use. Existing land use in the Arbor Creek watershed consists almost entirely of industrial, commercial and residential development. The upper portion of the watershed, that portion which lies within the City of Arlington, is about 82% urbanized with a mix of industrial and commercial areas. The central portion of the watershed, which lies in the City of Grand Prairie, is developed with commercial and high-density residential use. Land use in the lower portion of the watershed, which is also in the City of Grand Prairie, ranges from residential complexes to wooded pastures and open spaces. The existing conditions land use map is provided in Figure II-2 and Table II-2 summarizes the existing land uses found in the Arbor Creek watershed. Including zoned open space, undeveloped land comprises approximately 18% of the watershed under existing conditions.

2. Ultimate Conditions

Ultimate watershed conditions were determined using the existing land use map as a platform and modifying the undeveloped areas according to the Cities' of Grand Prairie and Arlington future land use and zoning maps. Open spaces designated as parks or floodplain were not modified and were kept as undeveloped land use. The undeveloped areas in the City of Arlington are zoned for industrial land use, whereas the open spaces in the City of Grand Prairie are zoned for residential land use. The ultimate conditions land use map is provided in Figure II-3 and Table II-3 summarizes the ultimate land uses found in Arbor Creek. Under ultimate conditions the undeveloped land accounts for 6% of the watershed.

Table II-2
Existing Development Land Use Summary

Watershed/ Sub-Basin	Area (ac)	Land Use (percent)					
		Commercial	Government/ Education	Industrial	Infrastructure/ Transportation	Residential	Undeveloped
A1	478	16	0	46	29	0	9
A2	250	2	0	49	15	2	32
A3	114	6	0	10	30	33	21
A4	137	0	1	4	44	30	21
A5	162	2	3	0	43	35	17
Combined	1141	8	1	31	30	12	18

Table II-3
Ultimate Development Land Use Summary

Watershed/ Sub-Basin	Area (ac)	Land Use (percent)					
		Commercial	Government/ Education	Industrial	Infrastructure/ Transportation	Residential	Undeveloped
A1	478	19	0	52	29	0	0
A2	250	2	0	62	15	12	9
A3	114	6	0	13	30	42	9
A4	137	0	1	4	44	30	21
A5	162	2	3	0	43	36	16
Combined	1141	9	1	37	30	17	6

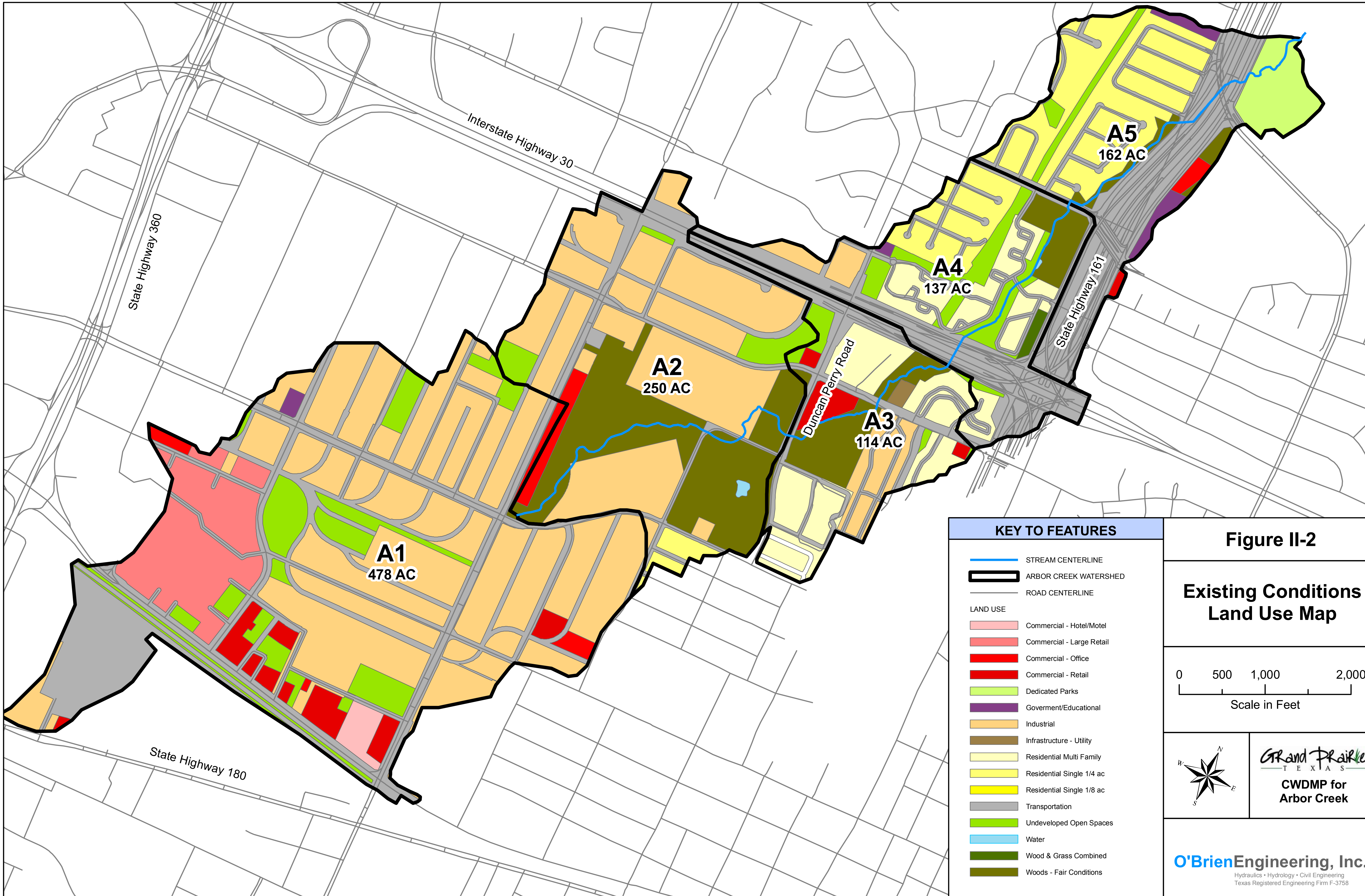


Figure II-2

Existing Conditions Land Use Map

Grand Prairie TEXAS

CWDMP for Arbor Creek

O'Brien Engineering, Inc.

Hydraulics • Hydrology • Civil Engineering
Texas Registered Engineering Firm F-3758

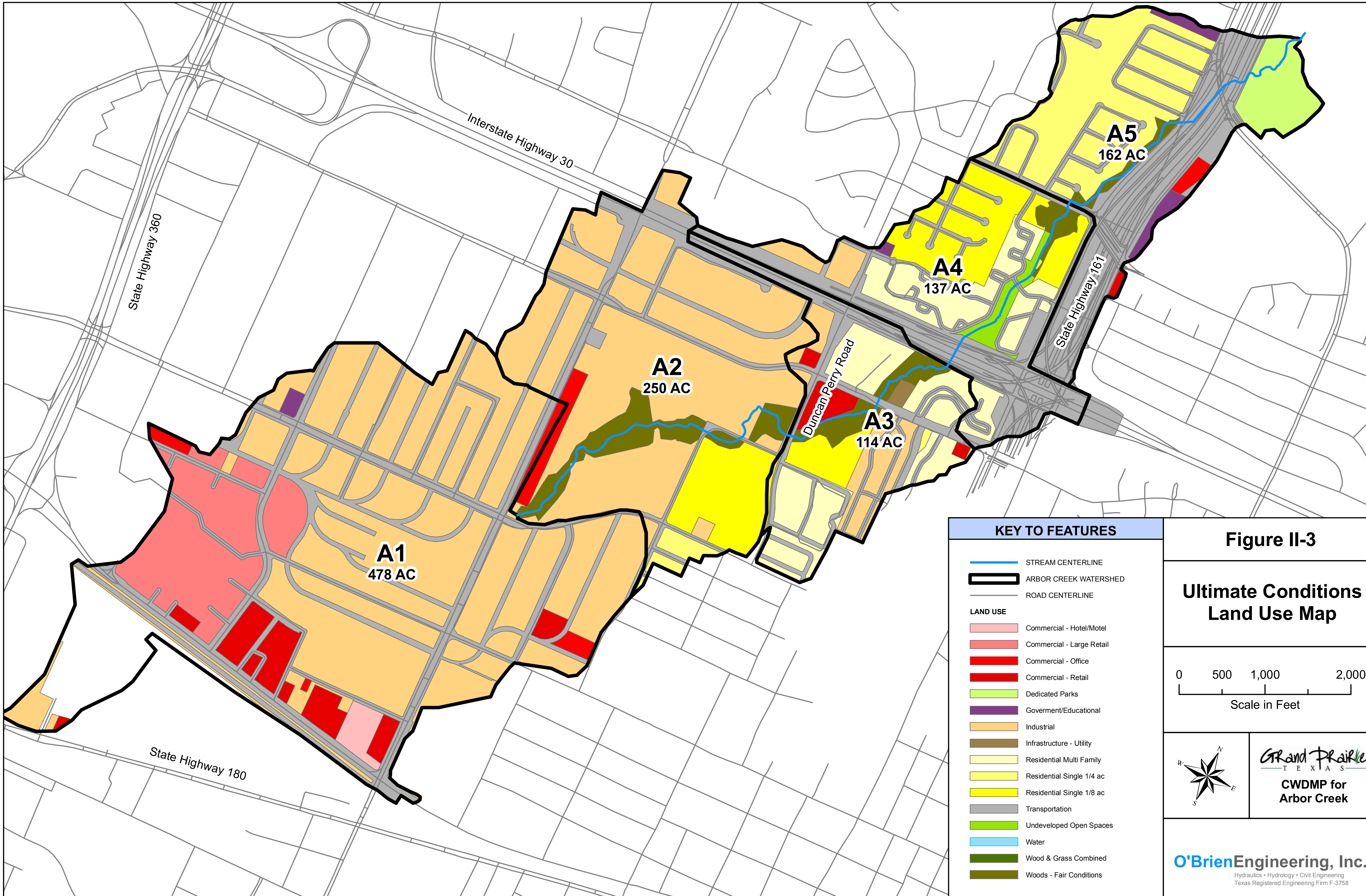


Figure II-3

Ultimate Conditions Land Use Map

D. Impervious Coverage

The SCS curve numbers typically account for the inherent imperviousness of a particular land use, but the imperviousness of atypical land uses should be assessed individually. A key factor is the degree to which impervious areas are interconnected so as to maintain surface flow, once generated. As appropriate, the interconnected impervious percentage of each sub-basin was assessed and factored into the calculation of the weighted CNs. Table II-4 lists the percent imperviousness values used for typical land uses found in Arbor Creek.

Table II-4
Land Use Percent Imperviousness

Land Use Classification	Percent Impervious
Single Family Residential (1/8 ac lots)	65
Single Family Residential (1/4 ac lots)	38
Multi-family Residential	65
Commercial, Office, Retail	85
Government, Education, Institutional	85
Industrial	72

E. Soil Types

Soil types for the watershed were obtained from the Natural Resource Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database for Tarrant and Dallas Counties dated February 1980. Figure II-4, Hydrologic Soils Map, highlights the various hydrologic soil groups found in the Arbor Creek watershed. About 90% of the watershed is covered with soils classified as hydrologic soil group D, which represents essentially clayey soils with low infiltration rates. Approximately 8% of the watershed contains soils classified as hydrologic soil group B, which represents soils with some content of gravel sand with moderate infiltration rates. The remaining 2% of the watershed contains soils classified as hydrologic soil group C, which indicates moderately fine soils with slow infiltration rates.

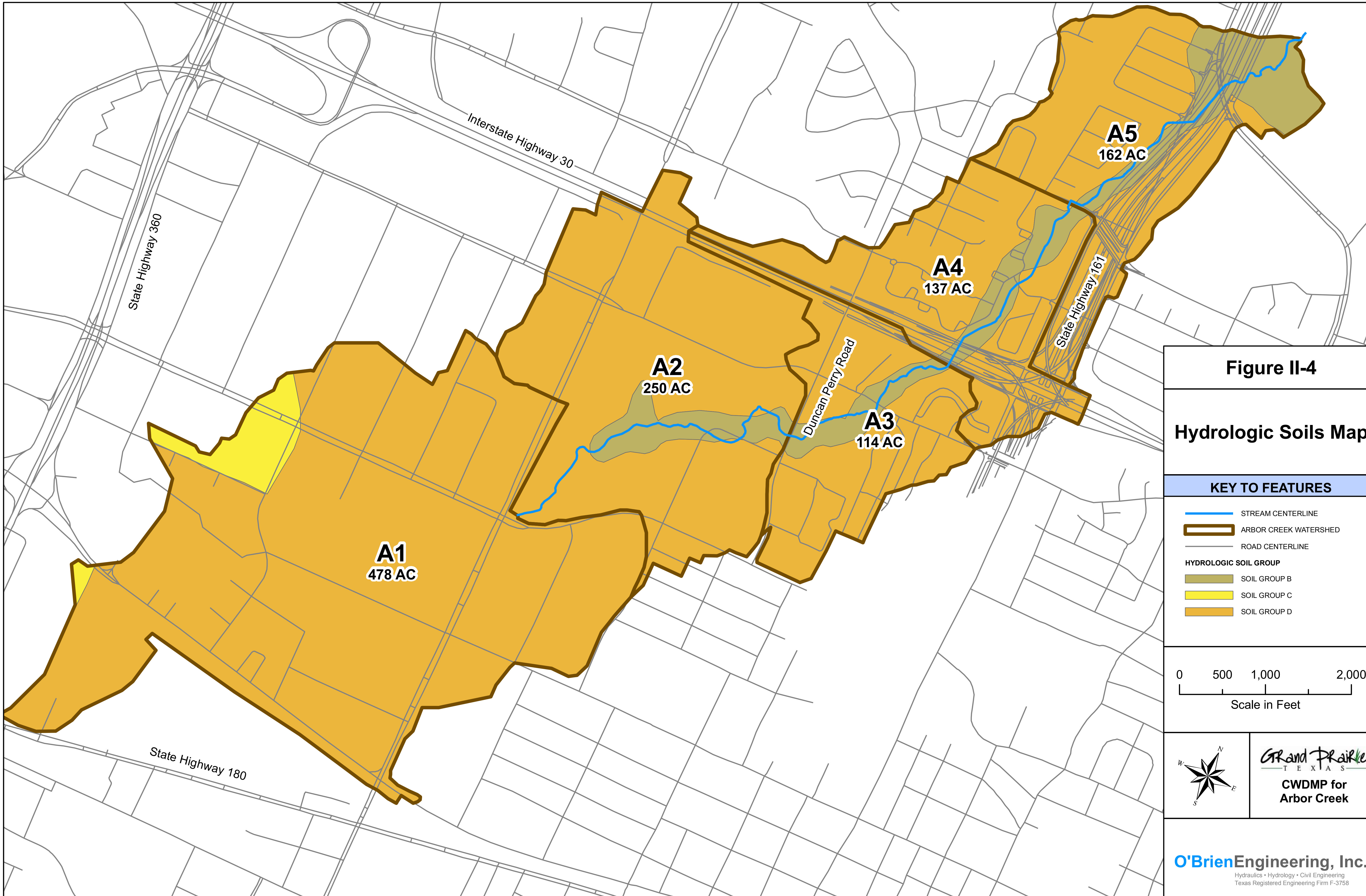


Figure II-4

Hydrologic Soils Map

F. Loss Rates

Rainfall infiltration losses primarily depend on soil characteristics and land use. The NRCS curve number method was selected for this study and uses a combination of soil conditions and land use to assign runoff curve numbers that represent the runoff potential of a sub-basin. Composite curve numbers were computed for each sub-basin using tools found in ArcGIS. Tables 2.2a, 2.2b, and 2.2c of the SCS Technical Release 55 (TR-55) and the City DDM were used as references to assign curve numbers to various land uses for each hydrologic soil group.

For curve number selection, the soil was assumed to have pre-storm moisture level consistent with Antecedent Moisture Condition (AMC) II. The computation process involved overlaying and intersecting GIS shapefiles of the watershed sub-basins, land uses, and soil types. The composite curve number was then computed by summing the intersected polygons with their respective weighted curve number for each sub-basin. The curve numbers for different land use and soils types based on AMC-II conditions are included in Tables 2.2a, b and c of TR-55 manual and Table 4.1a in the City of Grand Prairie Drainage Design Manual. A summary of curve numbers used for each sub-basin is included in Table II-1.

Initial abstraction is also a component of the curve number loss rate method. However, HEC-HMS automatically computes this value based on the assigned curve number using the following equation from TR-55:

$$IA = 0.2\left(\frac{1000}{CN} - 10\right)$$

G. Synthetic Unit Hydrograph

Rainfall excess is transformed to sub-basin runoff using unit hydrograph theory. For this study, the SCS dimensionless unit hydrograph method was used for the

Arbor Creek watershed. This method uses sub-basin area, curve number, and lag time to produce a unit hydrograph. Lag times were calculated as 60% of the computed times of concentration, which is the relationship suggested in the *NRCS National Engineering Handbook Section 4, Hydrology*.

Time of concentration is calculated as the total time taken for runoff to flow from the most remote point of the drainage area to the sub-basin outlet. SCS (now NRCS) TR-55 methodology of calculating the time of concentration was employed in this study. Depending on the sub-basin, time was estimated by dividing the flow path into three to four components, including *sheet flow*, *shallow concentrated flow*, *conduit flow* and/or *open channel flow*. *Sheet flow* lengths in the upper portions of sub-basins were limited to 100 feet (our experience indicates that in North Texas, which has relatively steep watersheds and soils that typically develop only a shallow layer of humus, shallow concentrated flow usually prevails beyond roughly 100 feet of surface flow) For *shallow concentrated flow* slope was obtained from the combined topography, whereas ground surface was determined (whether paved or unpaved) from aerial photography. For *conduit flow*, storm drain characteristics were extracted from GIS shapefile datasets obtained from the Cities of Arlington and Grand Prairie. Conduit travel times were calculated using Manning's equation assuming full flow condition. *Open channel flow* travel times were also calculated using Manning's equation based on bank-full flow conditions for channel sections that were extracted from the combined topography. The total time of concentration was an algebraic sum of each travel time component. Lag-times, as required for HEC-HMS input, were taken as 60% of the calculated times-of-concentration, which is the relationship suggested in the NRCS National Engineering Handbook Section 4, Hydrology. Table II-1 summarizes the lag-times used for the various sub-basins on Arbor Creek.

No separate calculation of times of concentration was made for ultimate watershed development due to the facts that the watershed is nearly 90%

urbanized and that urbanization of the remaining 10% will not substantively change flow paths. Therefore, calculated times of concentration and lag times are identical for existing and ultimate land use conditions.

H. Rainfall

Hypothetical point rainfall depths for the 50%, 20%, 10%, 4%, 2%, 1%, and 0.2% annual chance (AC) storms up to 24-hour duration were obtained from the December 2010 edition of the City of Grand Prairie Drainage Design Manual, (DDM). Table II-4 is a compilation of rainfall depths for storm durations of 5 minutes to 24 hours and frequencies of 2 to 500 years.

Table II-5
Rainfall Data in Inches

Storm Duration	Recurrence Interval (Years)						
	2	5	10	25	50	100	500
5 min	0.49	0.57	0.63	0.73	0.80	0.87	1.00
15 min	1.04	1.22	1.36	1.56	1.71	1.87	2.20
60 min	1.85	2.45	2.86	3.35	3.82	4.25	5.40
2 hrs	2.22	3.00	3.55	4.15	4.65	5.20	6.60
3 hrs	2.45	3.30	3.85	4.55	5.15	5.70	7.40
6 hrs	2.91	3.90	4.65	5.45	6.20	6.92	8.80
12 hrs	3.45	4.70	5.50	6.50	7.35	8.40	10.50
24 hrs	3.95	5.40	6.40	7.50	8.52	9.55	12.00

I. Flood Routing

The Modified Puls routing method was used to route the flood hydrographs through each segment of the Arbor Creek watershed. This method uses storage-discharge relationships for each routing reach that were generated using the USACE water surface profiles computer program, HEC-RAS. The HEC-RAS model was generated using procedures described below in Chapter III, and reflects existing conditions in the floodplain and channel.

J. Detention & Diversions

As it flows through the City, Arbor Creek crosses several roads starting from North Great Southwest Parkway upstream and continuing downstream towards Duncan Perry Road, Tarrant Road, and Interstate Highway 30 (IH-30). At IH-30 an undersized 2-8'x8' concrete box culvert results in considerable ponding upstream (the south side) of the culvert. The level pool reservoir routing method was used to account for the ponding in this area. Due to substantial differences in the level pool inundation limits, two sets of reservoir routing data were developed: one for the low flow 10% AC storm and one for high flows consisting of the 4%, 2%, 1% and 0.2% AC storms. The upstream channel routing storage-discharge relationships were adjusted accordingly. For example, the ponding effect was determined to extend from IH-30 to Tarrant Road for the low flow conditions while extending to Duncan Perry Road for the high flow conditions. No other detention ponds, either by design or unintentional, were identified or evaluated in the Arbor Creek watershed.

There were no diversions identified or modeled in the Arbor Creek watershed.

III. HYDRAULIC STUDY

A. Hydraulic Analysis

The hydraulic model developed for this study combines the data, modeling, and analysis of three recent separate studies into one comprehensive model for the entire Arbor Creek watershed. The combined model uses peak discharges computed from the HEC-HMS model for the existing 10%, 2%, 1% and 0.2% (10, 50, 100, and 500-year) floods and for the ultimate 50%, 20%, and 1% (2, 5, and 100-year) frequency floods. The results of the hydraulic modeling and computed water surface elevations are discussed in Chapter IV – Hydrologic and Hydraulic Results.

1. 2005 Halff Associates, Inc. Map Modernization Study

Halff Associates, Inc. (Halff) completed a hydraulic study in 2005 which was provided to FEMA as part of the Map Modernization Project for the production of the Digital Flood Insurance Rate Maps (DFIRM) and revised FIS for Dallas and Tarrant Counties. The area that was studied in detail included approximately 1.67 stream miles of Arbor Creek between Duncan Perry road and the confluence of Arbor Creek and Johnson Creek. Cross Sections for this model were developed using the City of Grand Prairie 1999 aerial topography and field survey data prepared by Halff. Bridge and culvert data was obtained from Halff's survey, existing models, and record drawings. The Halff model was included in the preliminary version of the FIS and DFIRM panels released in June of 2007, which at this juncture have not become effective.

2. 2008 O'Brien Engineering, Inc. Flood Study for Repairs on Two Concrete Drop Structures

O'Brien Engineering, Inc. (OEI) prepared a flood study on Arbor Creek between Egyptian Way and Interstate 30 in 2008. The study used the Halff 2005 model as a base and made revisions to evaluate the two proposed concrete drop structures on Arbor Creek which have now been constructed. Cross sections were modified within the vicinity of the two drop structures using one-foot contours based on field survey prepared by Sam, Inc.

3. 2011 Texas Department of Transportation Hydraulic Study on Arbor Creek for Construction of State highway 161

The Texas Department of Transportation (TxDOT) prepared a flood study on Arbor Creek between Egyptian Way and Waggoner Park downstream of State Highway 161 between 2010 and 2011. This study also used the Halff 2005 model as a base and made revisions to evaluate the construction of State Highway 161 which included the north and south frontage roads and the main lanes. Three new or modified crossings were evaluated in the model which included the culverts at Egyptian Way, SH 161 Southbound Frontage Road, and North Carrier Parkway. In addition, the project included stream realignment, channel improvements, and an elevated road structure with multiple bridge columns placed in the channel. The channel modeling utilized topographic data from multiple sources which included channel surveyed cross data completed by Lina T. Ramsey & Associates, LLP (LTRA) and City of Grand Prairie funded LiDAR topography generated on a 1 foot contour interval.

B. Cross Sections

1. Cross Sections Methodology

Cross sections on Arbor Creek for this study are located at about 100-200 feet intervals along the creek. A total of 95 cross sections ranging from cross section number 12941 to cross section number 281 were placed at representative locations throughout the creek and at locations where changes occur in discharge, slope, shape, roughness, and at the upstream and downstream faces of bridges/culverts and drop structures.

Cross section locations represented in the Arbor Creek model for this study are shown in Figure V-1 of Chapter V – Floodplain Mapping

The hydraulic cross sections contained in the models were developed using the City of Grand Prairie one-foot topography, the effective Arbor Creek hydraulic model, and on-the-ground field survey data from multiple studies. Field data for the lower portion of Arbor Creek, between Egyptian Way and the confluence with Johnson Creek was surveyed in 2009 and includes cross sections, structure elevations, and contours of the creek obtained from the Texas Department of Transportation (TxDOT) analysis of the construction of State Highway 161. Data for the portion of Arbor Creek between IH-30 and Egyptian Way included on-the-ground field data and LIDAR prepared by Sam, Inc. in 2008 for the OEI study of the two hydraulic drop structures. Data for the upper portion of Arbor Creek, upstream of IH-30, included field survey obtained from a 2005 Halff study of Arbor Creek. In addition, Marshall Lancaster & Associates, Inc. (MLAI), collected additional survey data as needed throughout the entire length of Arbor Creek.

A composite topographic contour shapefile consisting of the field survey and LIDAR data was prepared for this study to use for base mapping and floodplain delineation. From the contour shapefile, a triangulated irregular network (TIN) was created for Arbor Creek to use in extracting cross section geometry data using the USACE HEC-GeoRAS version 4.2.92 software package. Each extracted cross section was evaluated against data external to the TIN to determine the need for augmentation. Where needed, the TIN was merged with such external data, which included creek surveyed sections, structure elevations, 'as-built' plans, and record drawings. 'As-built' plans and record drawings for all the major crossings, including Duncan Perry Road, Tarrant Road, IH-30, Lakeside Drive, Egyptian Way and Carrier Parkway were obtained from the respective agencies or municipalities.

2. Bridges and Culverts

Detailed GPS field surveys of seven creek crossings (bridges or culverts) and two drop structures were conducted in January and February 2011 by MLAI. The data for the remainder of the structures found in the model were transferred from the effective model.

3. Location and Layout Consideration

Cross section data for this study was obtained either (1) entirely from a combination of topographic data and field survey, (2) from previous hydraulic models, or (3) from field surveyed section data only.

The cross section alignments from the previous study were imported into ArcGIS to create a polyline shapefile. The alignment and geometry of each cross section were evaluated to determine sufficiency for simulating flood conditions in the hydraulic model. Adjustments were made and additional cross sections were added to the GIS shapefile where necessary to represent the existing creek conditions not previously modeled, such as geometric transitions and structures. Each new section was developed following the procedures outlined above.

C. Parameter Estimation

Manning's roughness coefficients were determined from the 2009 aerial photographs and verified through field reconnaissance with reference to the guidelines outlined in the *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains Water-Supply Paper 2339*, by the United States Geological Survey, (1989) and to *Open-Channel Hydraulics* by Ven Te Chow (1959). Manning's roughness coefficients were entered into the model on each cross section using the horizontal variation method found in HEC-RAS.

The channel Manning's roughness coefficients range from 0.02 at concrete segments of the creek to 0.065 at significantly vegetated segments. The overbank values range from about 0.03 to 0.08. Table III-1 summarizes creek and floodplain conditions found in Arbor Creek and lists the respective Manning's roughness coefficients ("n" value) for each condition.

Table III-1
Manning's Roughness Coefficients by Type

	Channel "n" Values	**Overbank "n" Values**
Concrete channels	0.013	
Concrete pilot with maintained grass banks	0.025	
Maintained grass	0.035	
Weeds and brush, irregular channel (overflow)	0.055	
Medium tree canopy	0.065	
Heavy tree canopy	0.075	
Grass		0.045
Gravel, construction		0.055
Scattered trees, flow obstructions		0.060
Light to medium tress with some open space		0.070
Medium tree cover		0.080
Medium residential with large streets in flow direction		0.090
Heavy tree cover with some open space		0.090
Industrial, commercial with some open space (no fencing)		0.090
Heavy tree cover, residential with some open space		0.100
Dense residential (small, fenced lots)		0.120

D. Modeling Considerations

1. Starting Water Surface Elevation

Normal depth was selected as the starting boundary condition for Arbor Creek. Hydraulic slope was taken to be equal to the channel slope of the lower reach.

2. Structure/Road Crossing Modeling

The portion of Arbor Creek within the City of Grand Prairie contains 3 bridges, 7 culverts, and 2 drop structures. The drop structures were modeled as in-line weirs with model input data including stream distances to upstream model cross sections, weir profile data, and typical broad crested weir coefficients. The bridges were modeled by coding the high and low chord profile data, bridge width, and the overtopping weir coefficient. The standard step energy method was selected for low flow computation while pressure flow was selected for high flow computation using a submerged inlet coefficient of 0.8. The culverts were modeled by entering the roadway profile data, roadway width, overtopping weir coefficient, and culvert dimensions.

3. Islands and/or Flow Splits

Arbor Creek does not have islands or other conditions where split flows may occur and therefore split flow was not considered in the hydraulic model.

4. Ineffective Flow Areas

Ineffective flow limits were determined using a typical 1:1 contraction ratio and a 2:1 expansion ratio and were placed in the model upstream and downstream of existing structures, buildings, and other significant obstructions, or where the topography indicates conditions of sudden expansion or contraction of flow. Contraction and expansion coefficients of 0.1 and 0.3, respectively were used at normal sections. At locations impacted by constrictions, the contraction and expansion coefficients were increased according to recommendations provided in the HEC-RAS User's Manual.

5. Supercritical Flow Condition

At several locations in the HEC-RAS model, the water surface was calculated as critical depth. This is a typical result when the model cannot solve for depth in a given number of trials or as a default when, during the iteration process, the calculated depth of flow goes below critical depth. Every instance of critical depth calculation is located at a bridge or structure where subcritical flow is typically anticipated, rather than in unprotected channel sections. FEMA's *Guidelines and Specifications for Flood hazard Mapping Partners* in these cases (section C.3.4.4) suggest always using the subcritical flow regime for natural streams.

A CD-ROM containing copies of all hydraulic computer models, GIS shapefiles, and figures used in preparation of this report is included in Appendix E.

IV. HYDROLOGIC AND HYDRAULIC STUDY RESULTS

A. HYDROLOGIC STUDY RESULTS

As previously discussed in Chapter II – Hydrologic Study, undeveloped or open space land accounts for approximately 18% of the watershed under existing conditions and approximately 6% of the watershed under ultimate conditions. Consequently, ultimate urbanization of the watershed would result in average increases in peak flood discharges across the watershed of approximately only 1%. Table IV-1 is a summary of peak flood discharges for Arbor Creek at various locations in the watershed for various storms.

Table IV-1
Summary of Discharges for Arbor Creek

Location	Drainage Area (sq mi)	Peak Discharges (cfs)							
		EX 10% AC	EX 4% AC	EX 2% AC	EX 1% AC	EX 0.2% AC	ULT 50% AC	ULT 20% AC	ULT 1% AC
Great Southwest Pkwy	0.75	2060	2430	2720	3000	3660	1250	1740	3020
Duncan Perry Rd	1.14	2590	2950	3230	3450	3990	1470	2200	3500
D/S of Tarrant Rd	1.32	2500	3380	3730	4040	4770	1570	2330	4110
IH-30	1.32	2090	2210	2370	2520	2790	1380	1850	2540
Egyptian Way	1.53	2220	2470	2360	2780	3150	1470	1990	2810
Confl w/ Johnson Creek	1.78	2500	2990	3330	3430	3670	1430	1900	3450

B. HYDRAULIC STUDY RESULTS

The computed peak flood discharges were used for computing water surface elevations for the existing conditions 10%, 4%, 2%, 1%, and 0.2% AC floods and for the ultimate conditions 50%, 20%, and 1% AC floods. Table IV-2 compares the differences in computed flood water surface elevations between existing and ultimate conditions for the 1% AC flood. Refer to Appendix A for a complete listing of computed flood water surface elevations for all other flood profiles on Arbor Creek. When comparing the 1% AC flood water surface elevations between the existing and ultimate conditions, the average increase is less than

0.1 feet. A maximum increase of 0.2 – 0.3 feet would occur between Interstate 30 and Duncan Perry Road. A CD-ROM included in Appendix E contains all of the hydraulic models and mapping shapefiles developed as part of this report. Flood profiles (existing and ultimate conditions) are included in Appendix A of this report for all the previously specified flood profiles.

Table IV-2
Water Surface Elevation Comparison

Location	River Station	Water Surface Elevation (ft)		
		EX 1% AC	ULT 1% AC	Difference (ULT – EX)
Grand Prairie City Limits	10104	516.19	516.23	0.04
	9724	509.71	509.74	0.03
	9278	508.66	508.69	0.03
	8972	507.22	507.25	0.03
	8754	505.44	505.53	0.09
U/S Duncan Perry Rd	8659	504.21	504.55	0.34
D/S Duncan Perry Rd	8562	503.78	504.10	0.32
	8487	501.83	502.06	0.23
	7948	501.84	502.07	0.23
	7510	501.55	501.80	0.25
U/S Tarrant Rd	7444	501.35	501.62	0.27
D/S Tarrant Rd	7348	501.12	501.38	0.26
	7164	500.36	500.58	0.22
	6841	500.42	500.65	0.23
	6479	500.41	500.64	0.23
U/S Interstate 30	6360	500.38	500.61	0.23
D/S Interstate 30	5980	500.05	500.28	0.23
	5908	484.97	485.00	0.03
	5826	485.07	485.10	0.03
	5597	484.90	484.93	0.03
	5407	483.47	483.50	0.03
	5230	482.29	482.32	0.03
U/S Drop Structure #1	5199	481.73	481.76	0.03

Table IV-2 Water Surface Elevation Comparison				
		Water Surface Elevation (ft)		
Location	**River Station**	**EX 1% AC**	**ULT 1% AC**	**Difference (ULT – EX)**
	5155	481.72	481.74	0.02
	5106	477.34	477.39	0.05
U/S Lakeside Dr	5053	477.41	477.46	0.05
D/S Lakeside Dr	5007	477.04	477.09	0.05
	4847	475.11	475.14	0.03
	4699	475.02	475.04	0.02
	4647	474.41	474.43	0.02
U/S Drop Structure #2	4628	474.08	474.10	0.02
	4600	474.17	474.20	0.03
	4529	472.88	472.91	0.03
	4519	472.89	472.92	0.03
	4490	470.62	470.67	0.05
	4286	470.59	470.65	0.06
	3977	470.34	470.39	0.05
U/S Egyptian Way	3908	470.23	470.29	0.06
D/S Egyptian Way	3828	469.91	469.96	0.05
	3795	469.08	469.11	0.03
	3767	468.54	468.57	0.03
	3729	467.15	467.18	0.03
	3695	467.08	467.10	0.02
	3610	466.54	466.56	0.02
	3556	466.64	466.66	0.02
	3278	466.45	466.47	0.02
	3056	465.39	465.41	0.02
	2845	464.60	464.63	0.03
	2659	462.99	463.01	0.02
	2477	461.98	462.01	0.03
	2383	461.03	461.06	0.03
	2162	460.92	460.95	0.03
	2140	457.60	457.61	0.01
U/S SH 161 South Bound Frontage Rd	2109	457.30	457.33	0.03

Table IV-2
Water Surface Elevation Comparison

Location	River Station	Water Surface Elevation (ft)		
		EX 1% AC	ULT 1% AC	Difference (ULT – EX)
D/S SH 161 South Bound Frontage Rd	1952	456.46	456.51	0.05
	1942	454.94	454.96	0.02
	1934	454.98	455.01	0.03
	1882	454.90	454.93	0.03
	1868	454.33	454.36	0.03
	1862	454.28	454.31	0.03
	1815	453.65	453.67	0.02
	1767	453.57	453.60	0.03
	1761	453.55	453.57	0.02
	1712	452.19	452.22	0.03
	1669	452.13	452.16	0.03
	1663	452.16	452.19	0.03
	1596	451.02	451.05	0.03
	1526	450.98	451.02	0.04
	1520	451.05	451.08	0.03
U/S Carrier Pkwy	1511	450.53	450.56	0.03
D/S Carrier Pkwy	1353	450.53	450.57	0.04
	1335	449.62	449.63	0.01
	1328	449.58	449.60	0.02
	1262	449.30	449.32	0.02
	1188	449.17	449.19	0.02
	1105	448.65	448.66	0.01
	1100	448.71	448.72	0.01
	1037	448.57	448.58	0.01
	1032	448.56	448.57	0.01
	971	448.53	448.53	0.00
	884	448.49	448.50	0.01
U/S Waggoner Park Pedestrian Bridge #1	750	448.36	448.37	0.01
D/S Waggoner Park Pedestrian Bridge #1	730	448.14	448.15	0.01
	570	448.10	448.11	0.01
U/S Waggoner Park Pedestrian Bridge #2	359	447.93	447.93	0.00

Table IV-2 Water Surface Elevation Comparison				
		Water Surface Elevation (ft)		
Location	**River Station**	**EX 1% AC**	**ULT 1% AC**	**Difference (ULT – EX)**
D/S Waggoner Park Pedestrian Bridge #2	338	447.62	447.63	0.01
	281	447.55	447.56	0.01

C. QUALITY ASSURANCE / QUALITY CONTROL

Quality assurance / quality control for the 2011 hydrologic and hydraulic studies was performed by a third party reviewer (Halff Associates) in October 2011. The QC comments and responses are included in Appendix A of this report.

V. FLOODPLAIN MAPPING

A. General

As part of the City-Wide Drainage Master Plan for Arbor Creek, O'Brien Engineering, Inc. (OEI) remapped the floodplain on Arbor Creek using the City of Grand Prairie 2009 LiDAR topography. Mapping included delineations for the floodway, the existing 1% AC and 0.2% AC floodplains, and the ultimate 1% AC floodplain. The effective FEMA flood zone designation for Arbor Creek is zone AE and includes floodways. For this study, the flood zone will remain as a zone AE and will include modifications to both the floodway and floodplain. Figure V-1 illustrates the detailed floodplain delineation, floodway, base flood elevations (BFE), and model cross section locations. Floodplain and other mapping and model shapefiles are included on the CD-ROM in Appendix E.

B. FEMA Map Revisions

A separate study and report is currently underway to prepare hydrologic modeling, hydraulic modeling, floodplain mapping, Digital Flood Insurance Rate Map (DFIRM) production, and revised Flood Insurance Study (FIS) for FEMA. This separate study is conducted by the City of Grand Prairie under the Cooperating Technical Partners (CTP) Program. Existing conditions base models created for and utilized in both the CTP study and this CWMDP are identical. The affected map panels on Arbor Creek will be revised in the CTP study and are not a part of this CWMDP.

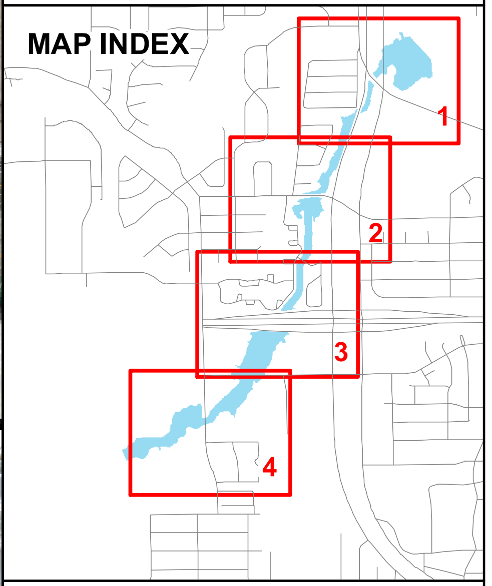
Figure V-1

ARBOR CREEK FLOODPLAIN WORKMAP (1 of 4)

KEY TO FEATURES

- Base Flood Elevation (BFE)
- GRAND PRAIRIE CITY LIMIT
- ARBOR CREEK CENTERLINE
- CROSS SECTION
- FLOODWAY
- STREET CENTERLINE
- EXISTING 1% AC FLOODPLAIN
- ULTIMATE 1% AC FLOODPLAIN

MAP INDEX



0 100 200 400

Scale in Feet

N S E W

Grand Prairie TEXAS

CWDMP for Arbor Creek

O'Brien Engineering, Inc.
Hydraulics • Hydrology • Civil Engineering
Texas Registered Engineering Firm F-3758

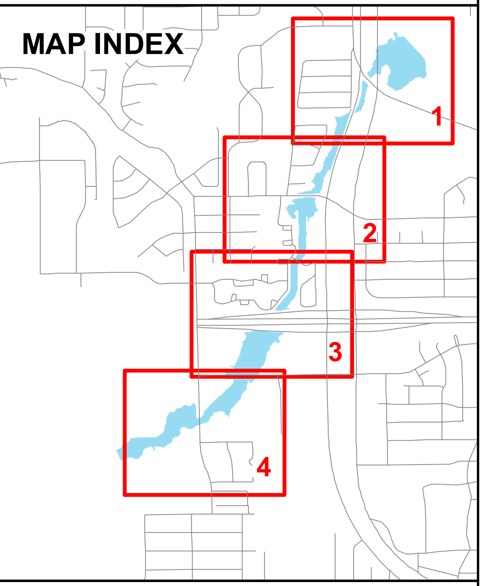
Figure V-1

ARBOR CREEK FLOODPLAIN WORKMAP (2 of 4)

KEY TO FEATURES

- Base Flood Elevation (BFE)
- GRAND PRAIRIE CITY LIMIT
- ARBOR CREEK CENTERLINE
- CROSS SECTION
- FLOODWAY
- STREET CENTERLINE
- EXISTING 1% AC FLOODPLAIN
- ULTIMATE 1% AC FLOODPLAIN

MAP INDEX



0 100 200 400

Scale in Feet

Grand Prairie TEXAS

CWDMP for Arbor Creek

O'Brien Engineering, Inc.

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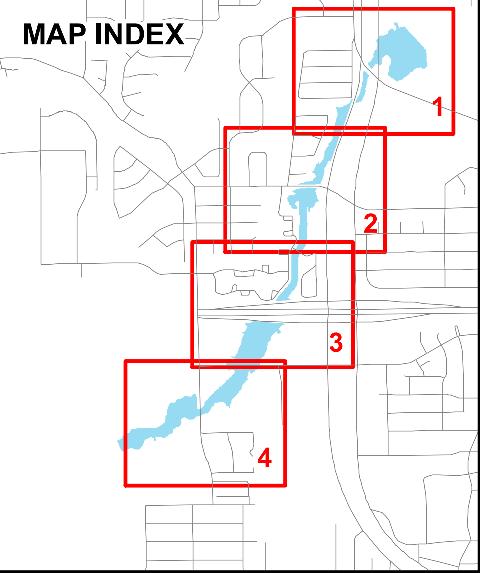
Figure V-1

ARBOR CREEK FLOODPLAIN WORKMAP (3 of 4)

KEY TO FEATURES

- Base Flood Elevation (BFE)
- GRAND PRAIRIE CITY LIMIT
- ARBOR CREEK CENTERLINE
- CROSS SECTION
- FLOODWAY
- STREET CENTERLINE
- EXISTING 1% AC FLOODPLAIN
- ULTIMATE 1% AC FLOODPLAIN

MAP INDEX



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Scale in Feet

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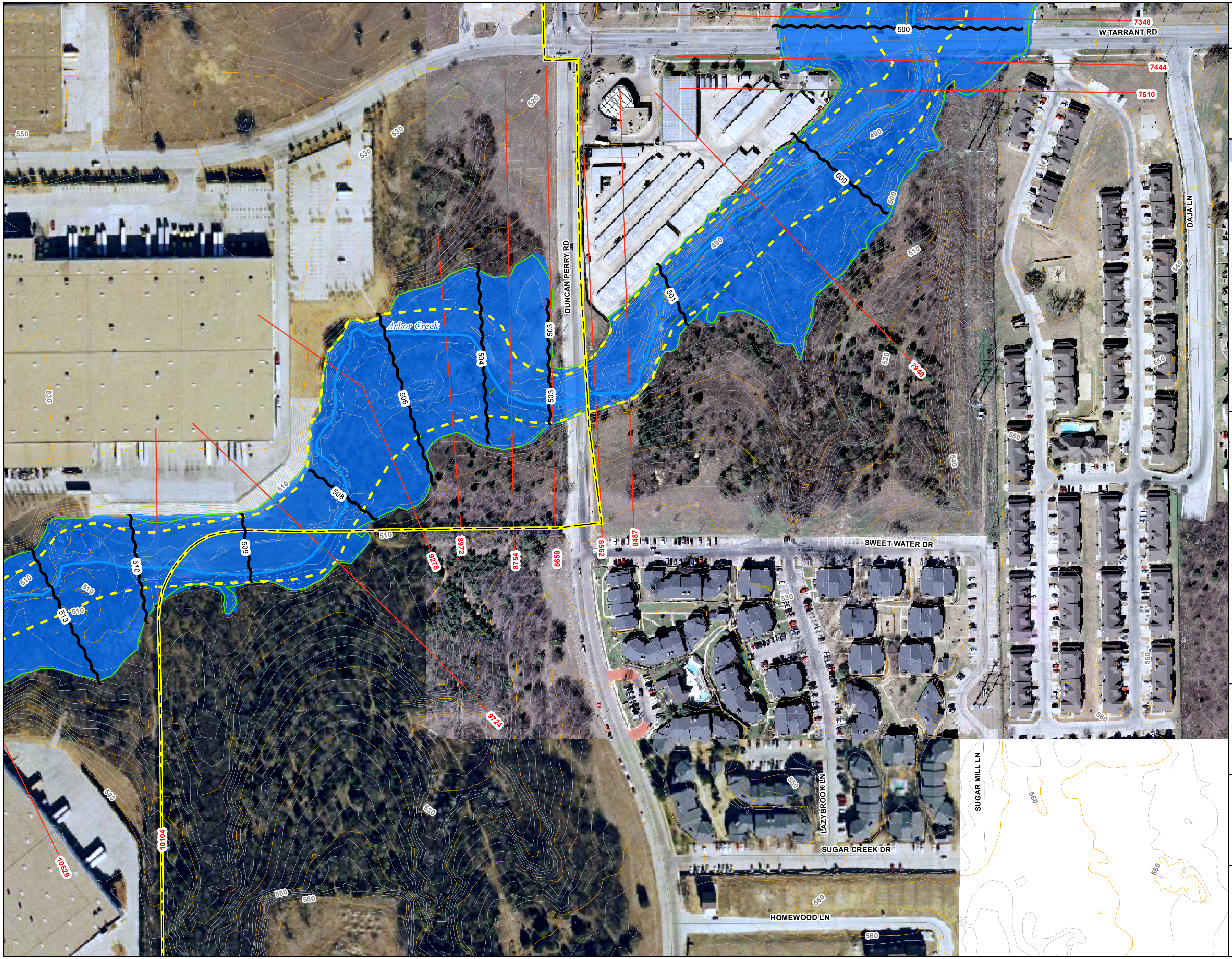


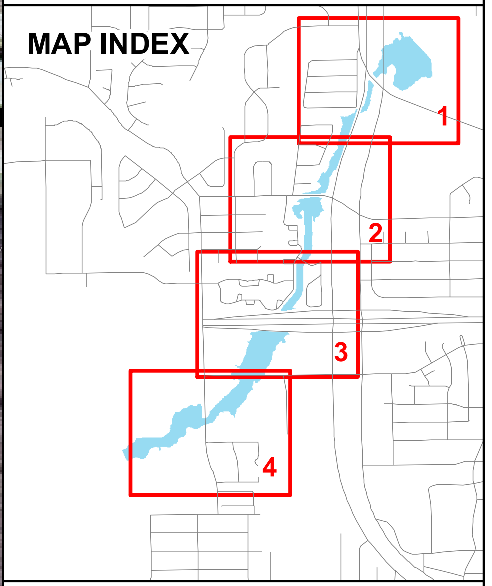
Figure V-1

ARBOR CREEK FLOODPLAIN WORKMAP (4 of 4)

KEY TO FEATURES

- Base Flood Elevation (BFE)
- GRAND PRAIRIE CITY LIMIT
- ARBOR CREEK CENTERLINE
- CROSS SECTION
- FLOODWAY
- STREET CENTERLINE
- EXISTING 1% AC FLOODPLAIN
- ULTIMATE 1% AC FLOODPLAIN

MAP INDEX



0 100 200 400

Scale in Feet

N S E W

Grand Prairie TEXAS

CWDMP for Arbor Creek

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VI. ROADWAY CROSSINGS

A. Evaluation of Existing Roadway Crossings

Existing road crossings of Arbor Creek were evaluated to determine the potential for overtopping during 50%, 10%, or 1% AC ultimate development flood events. Table VI-1 lists the road crossings, associated river station, minimum top of the roadway, and peak water surface elevations (WSEL) for the various frequency floods. The WSEL are reported at the upstream face of the structure.

Only Tarrant Road would be overtopped by floods as or more frequent than the 1% AC flood; it would even be overtopped by floods as frequent as the 50% AC flood. In fact, this road has reportedly been overtopped in recent years. The principal cause of flooding at this road is backwater from the undersized culverts under IH-30, which can extend past Tarrant Road. For vehicular and pedestrian safety, consideration should be given to raising Tarrant Road and increasing the flood capacity of the crossing. Table VI-2 shows the improvements necessary to protect against the 1% AC flood events. Section VII provides more detailed descriptions of the proposed conceptual road crossing Improvements.

B. Evaluation Of Proposed And Future Roadway Crossings

The City of Grand Prairie's Master Thoroughfare Plan indicates that several new or improved roads are planned in the Arbor Creek watershed. Most of these are associated with the SH-161 project and have been completed, or are near completion. Of the planned road improvements that cross Arbor Creek, only three have yet to be designed: Duncan Perry Road, Tarrant Road, and Egyptian Way. The planned improvements include increasing the size and traffic capacity along the same alignment. This makes upgrading the flood capacity of any undersized crossing even more important. Figure VI-1 shows the Master Thoroughfare Plan roads overlaid with the Arbor Creek watershed map showing existing and future crossings.

1. Design of Future Thoroughfare Crossings

When possible, future thoroughfare crossings, or improved crossings, should be designed to pass an ultimate development 1% AC flood event without creating adverse impacts to the upstream or downstream properties. It is desirable for these roadway crossings to span the entire 1% AC floodplain; however, in mostly developed floodplains such as this one, this is not typically feasible or even profitable as there is already substantial encroachment into the natural floodplain by the existing crossings and adjacent properties.

As discussed in the previous section, Tarrant Road is the only roadway crossing on Arbor Creek that is not currently adequately sized to pass a 1% AC flood without overtopping. The needed Tarrant Road improvements were discussed in the previous section. City staff has indicated that Tarrant Road is not likely to be widened in the foreseeable future; therefore, no consideration has been given to the effects of widening the roadway on the floodplain. A slight upsizing of the proposed culverts might be necessary for future widening to offset the increase in culvert length.

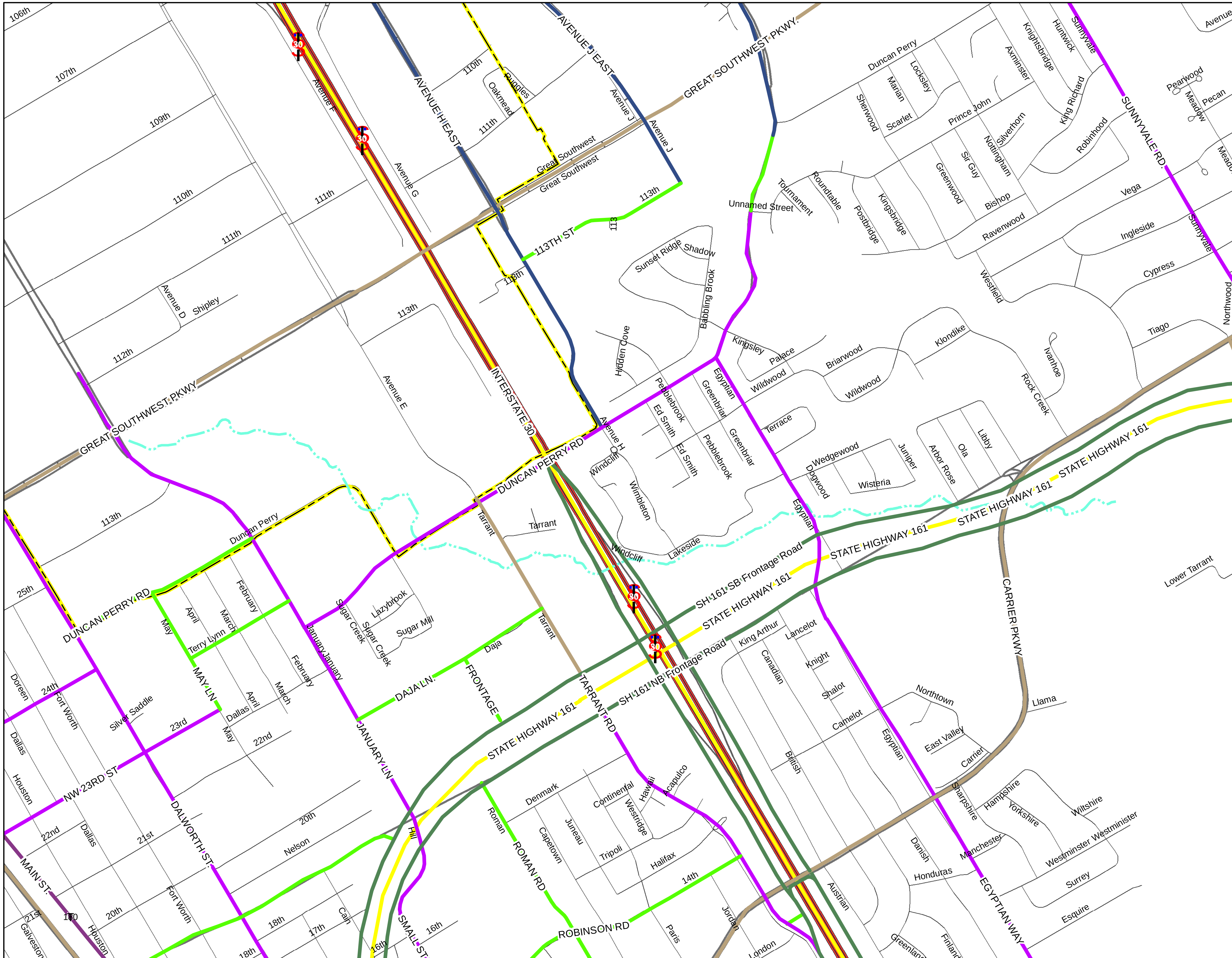
The crossing at Egyptian Way is adequately sized to pass a 1% AC flood event; however, the current configuration is less than ideal, as it is not aligned with the stream channel. This has resulted in an area of low velocity that tends to silt up and a sharp bend that creates erosive conditions for other portions of the crossing. A more detailed discussion of this area is included in Chapter IX – Channel Stability Assessment. Design for future improvements to the Egyptian Way crossing should take these issues into account.

Table VI-1					
Existing Roadway Crossings Summary					
Road Name	**Stream Station**	**Minimum Top of Road Elevation**	**Water Surface Elevation at Crossing**		
			50% AC	**20% AC**	**1% AC**
Duncan Perry Road	8610	504.79	500.07	501.42	503.48
Tarrant Road	7400	494.30	495.61	496.65	500.71
IH-30	6200	505.00	489.17	493.25	500.32
Lakeside Drive	5035	481.63	474.48	475.43	476.81
Egyptian Way	3875	471.14	465.01	466.24	470.02
SH-161 South Bound Frontage Road	2000	459.38	451.72	452.83	456.15
SH-161 (Lowest Point of Main Lanes)	1865	474.54	49.81	450.64	452.71
Carrier Parkway	1450	451.24	447.78	448.75	450.57
SH-161 North Bound Frontage Road	1103	455.36	447.26	448.13	448.68

Table VI-2										
Proposed Alternatives for Existing Roadway Crossings										
			Existing Condition				**Proposed Condition**			
Road Name	**Alternative Option**	**Stream Station**	**Flood Frequency Safely Passed**	**Minimum Top of Road Elevation**	**Size of Opening/ Culverts**	**1% AC WSEL at US XS**	**Flood Frequency Safely Passed**	**Minimum Top of Road Elevation**	**Size of Opening/ Culverts**	**1% AC WSEL at US XS**
Tarrant Road	Alternative 1	74+00	<50% AC	494.30	2 - 8'x5' Boxes	500.71	1% AC	501.70	6 - 10'x10' Boxes	501.62

Figure VI-1

CITY OF GRAND PRAIRIE MASTER THOROUGHFARE PLAN



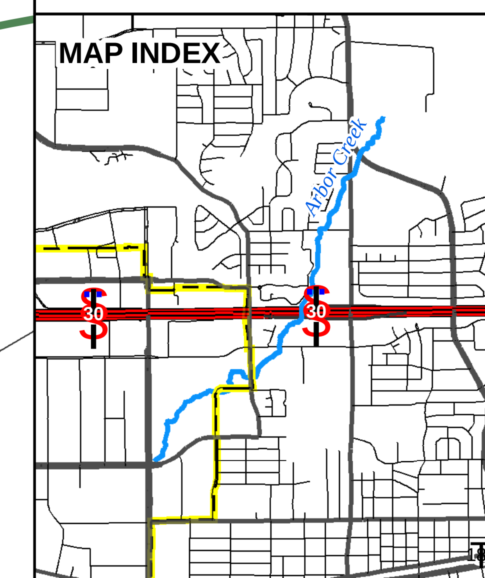
KEY TO FEATURES

- ARBOR CREEK CENTERLINE
- GRAND PRAIRIE CITY LIMIT

Planned Thoroughfare Class

- C2U
- HWY
- M3U
- M4U
- M5U
- P3U
- P4D
- P6D
- P7U

MAP INDEX



0 500 1,000 2,000

Scale in Feet

Grand Prairie TEXAS

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VII. ALTERNATIVES FOR STREAMS AND OPEN CHANNELS

A. Summary of Flooding Issues

1. Known Flooding Issues

A drainage complaint database was provided by the City of Grand Prairie. This database contained no riverine flooding issues in the Arbor Creek watershed. Tarrant Road is known to have overtopped in the past and the City has expressed an interest in making improvements to this crossing.

2. Roadway Flooding Issues

As discussed in Chapter VI, Tarrant Road is the only road that would overtop in a 1% AC flood event. Alternatives for improving this crossing are discussed in Section B of this chapter.

3. Structure Flooding Issues

To evaluate the potential for flooding of structures, the floodplain was evaluated against available structure data. The City of Grand Prairie provided LiDAR GIS data collected in 2009 that includes building outlines. These building outlines were overlaid with the ultimate development floodplain delineation to identify buildings that may potentially be below the Base Flood Elevation (BFE).

In this manner, a total of fourteen structures were identified within the floodplain; of these, eight are considered to be significant habitable structures (two houses and six apartment buildings). Two of the other structures are commercial storage buildings and two others are facilities associated with the Waggoner Park baseball fields. The remaining structures appear to be home storage buildings.

To determine whether these structures are below the BFE, the City contracted separately for the preparation of Elevation Certificates for each potentially affected structure, using addresses and other pertinent information provided by OEI. Elevation certificates for these eight structures were prepared based on the floodplain elevations developed as part of the Cooperating Technical Partner (CTP) remapping effort, which is also being conducted by OEI as part of this same contract. These BFEs will become effective once FEMA has approved the floodplain maps developed under the CTP study. Copies of the elevation certificates are included in Appendix B.

Several structures were determined to be mapped within the 1% AC floodplain. Elevation Certificates were prepared for each of these structures to determine whether or not the lowest adjacent grade for each structure was elevated above or below the effective BFE and the BFE determined under the CTP study. Most of these structures are in the apartment complexes located between IH-30 and Tarrant Road. Alternatives for improvements to this area are discussed below. The other structures are in low-lying areas for which there are no economically viable ways to reduce the BFE sufficiently to remove the structures from the floodplain. As there have been no reported flooding problems with these structures, further consideration has not been given to flood reduction or buy-outs.

B. Alternatives Analysis

Proposed concept alternatives were considered for all existing roadway crossings that appear to have a reasonable likelihood of impacting structure or roadway flooding. These concept alternatives are discussed below. Some of these alternatives were introduced in Section VI and concept opinion of probable construction costs for each flood control alternative can be found in Section XII of this report. Refer to Table VI-2 for a summary of proposed conceptual existing bridge crossing improvements. Total annual costs, including construction and design, are based on a 50-year project life and a 7% discount rate.

Any improvements in the FEMA floodway that cause an increase in the BFE will require a Conditional Letter of Map Revision (CLOMR) from FEMA. Before approving the CLOMR, FEMA will want to see the following information:

- An evaluation of alternatives that would not result in a BFE increase above that permitted and a demonstration of why these alternatives are not feasible;
- Notification of affected property owners explaining the impact of the proposed project on their property;
- Concurrence of the Chief Executive Officer (CEO) and any other communities affected by the proposed actions; and
- Certification that no structures are located in areas that would be impacted by the increased base flood elevation.

Arbor Creek and any adjacent wetlands would be considered waters of the United States; therefore, any construction that impacts the channel and associated wetlands would require permitting through the U.S. Army Corps of Engineers (USACE) under Section 404 of the Clean Water Act. Depending on the nature of the improvements, bridge improvements can typically be permitted under Nationwide Permit 14 (NWP 14) for Linear Transportation Crossings to satisfy the USACE requirements. Other improvements can be covered under nationwide permits for work such as streambank armoring, maintenance of existing structures, and aquatic habitat enhancements. A delineation of waters of the US is required to assess the feasibility of claiming a particular Nationwide Permit.

1. IH-30 Crossing (Stream Station 62+00)

The culverts beneath IH-30 are significantly undersized causing a substantial backwater condition under high flows. This backwater would be responsible for most of the potential structure flooding during a 1% AC flood. It would also partially responsible for the inability of Tarrant Road to handle even the 10% AC flood. Adding an additional 8 foot diameter culvert would lower the BFE nearly 7 ft at the upstream face of IH-30, remove a number of structures from the floodplain, and substantially reduce the needed improvements to Tarrant Road.

Adding the additional culverts to the IH-30 crossing would increase the flow downstream of IH-30 by reducing the detention effect caused by the existing undersized culverts. This would cause some additional flooding downstream. A number of detention alternatives were considered to offset this impact, but a viable option was not found when considering the necessary volume of detention that would be required, available land, and construction costs.

Tunneling the approximately 475 feet beneath IH-30 appears to be technically feasible, but costly. TxDOT is currently completing construction to this area that is associated with the SH-161 project. Considering their recent activities, it is unlikely that TxDOT will be interested in pursuing such a project in the near future. Further consideration of this alternative will require coordination with TxDOT to evaluate the technical feasibility, allowable materials, and cost sharing. No additional design or cost data is provided for this alternative as the City has indicated that this is not a feasible option in the near term.

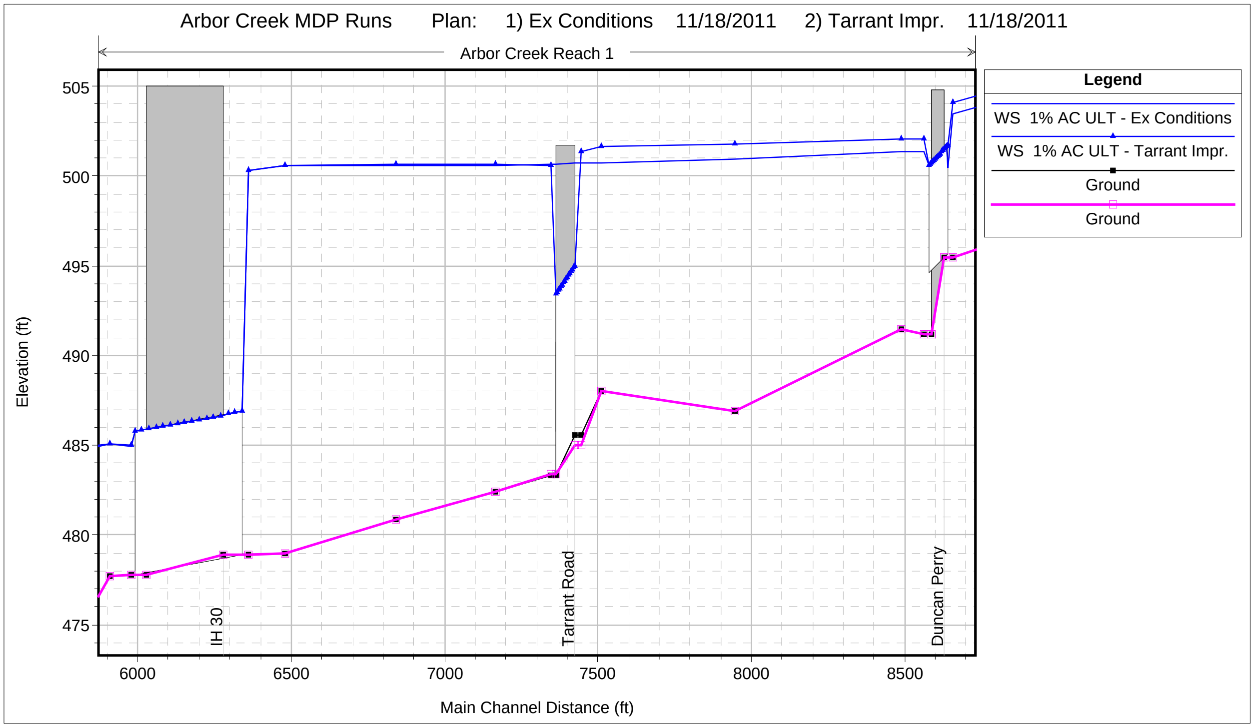
2. Tarrant Road (Stream Station 74+00)

The existing culvert beneath Tarrant Road is a double barrel 8 foot by 5 foot concrete box culvert with a capacity less than the 50% AC flood event, and the 1% AC flood event would overtop by more than 6 feet. As summarized in Table IV-2, it is suggested that Tarrant Road be improved by raising the road to at least 501.7 ft and installing a 6 barrel - 10 foot by 10 foot box culvert. Figure VII-1 shows a concept of this alternative with the existing and proposed section view and the impact to the stream profile in the vicinity of the bridge.

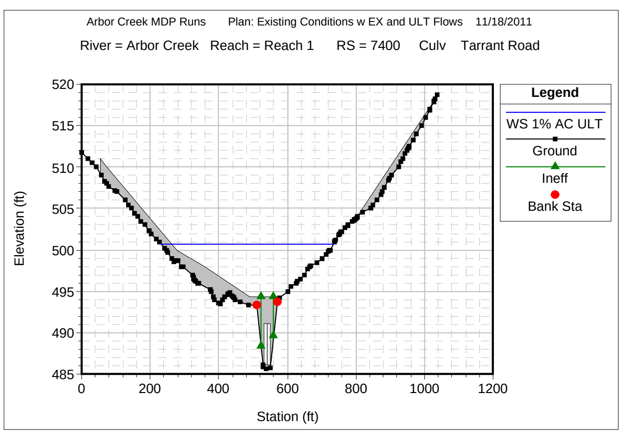
A summary of the concept opinion of probable construction costs is shown in Table VII-1. Section XII provides a more detailed breakdown of the concept opinion of probable construction costs. If this alternative were implemented, Tarrant Road would no longer be overtopped by a 1% AC ultimate development flood event. These improvements could cause an increase in the BFE upstream of Tarrant Road of approximately 0.9 feet, which would not appear to cause flooding of any structures. Larger, or additional, culverts could help reduce the upstream impact, but at additional costs. Because the construction would occur in the floodway, and there would be an increase in the BFE, a CLOMR would be required before construction. After construction, a Letter of Map Revision (LOMR) would be necessary to incorporate the floodplain and floodway mapping revisions into the FEMA mapping.

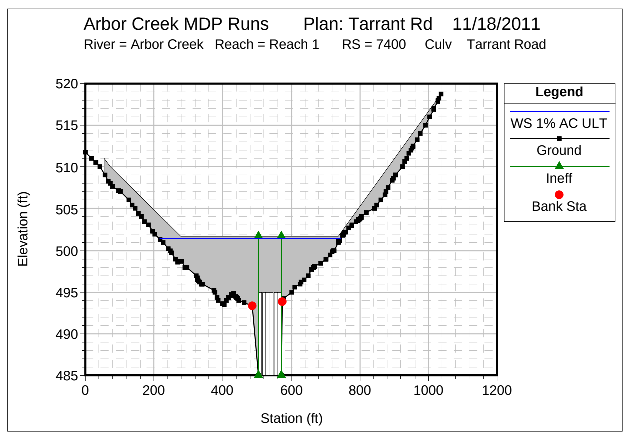
Table VII-1	
Tarrant Road Alternative Summary of Concept Opinion of Probable Construction Costs	
Construction Subtotal	$ 1,118,870.00
Approximately 25% Contingency	$ 280,130.00
Construction Total	$ 1,399,000.00
Appr. 10% for Engineering and Survey	$ 140,000.00
Total	**$ 1,539,000.00**

Tarrant Road Alternative 1 Profile Comparison



Tarrant Road Alternative 1 Bridge Comparison





Existing **Proposed**

Figure VII-1. Tarrant Road Crossing Alternative - 1% AC Flood Capacity

VIII. STORM WATER INFRASTRUCTURE ANALYSIS

Analysis of the storm water infrastructure in the Arbor Creek watershed was not included as part of this contract.

IX. CHANNEL STABILITY ASSESSMENT & EROSION HAZARD ANALYSIS

A. Introduction

Streams are dynamic systems that evolve and react to changes in their watershed. This is often evident in urban areas where streams deepen and widen over time, often threatening structures and infrastructure in the process. To help assess how Arbor Creek is responding to urbanization of its watershed, Peter Allen, PhD, PG, of Baylor University, was engaged to perform a channel assessment of Arbor Creek.

This channel assessment looked at a number of features of the watershed and channel to estimate ultimate channel parameters, such as stable slopes, bank width and depth, meander migration rates, and times needed to obtain a new equilibrium. These estimates are based on field measurements of existing channel dimensions, bed and bank material testing, visual observations, computer models, existing literature, and experience with similar channels in the area. This Chapter will briefly discuss channel stability concepts and the results of this channel assessment, Dr. Allen's full report is attached in Appendix D.

B. Channel Stability Concepts

Stable streams represent a state of equilibrium between stream flows and sediment. As long as these two factors remain steady, the stream will remain stable; however, stable does not mean static. Even a stable stream will migrate over time, particularly in the bend of meanders. Urbanization alters this equilibrium, principally through increasing runoff, which causes the stream to react and adjust.

One of the most popular models for stream response is the Channel Evolution Model, as graphically depicted in Figure IX-1. Type I is a stable channel before urbanization. As flows increase due to urbanization, the channel moves to Type II, and begins downcutting. When the bank heights increase they become unstable and begin slumping into the channel (Type III). This process continues and the channel widens (Type IV). Eventually the channel reaches a new equilibrium condition with a larger channel inside of a deepened floodplain.

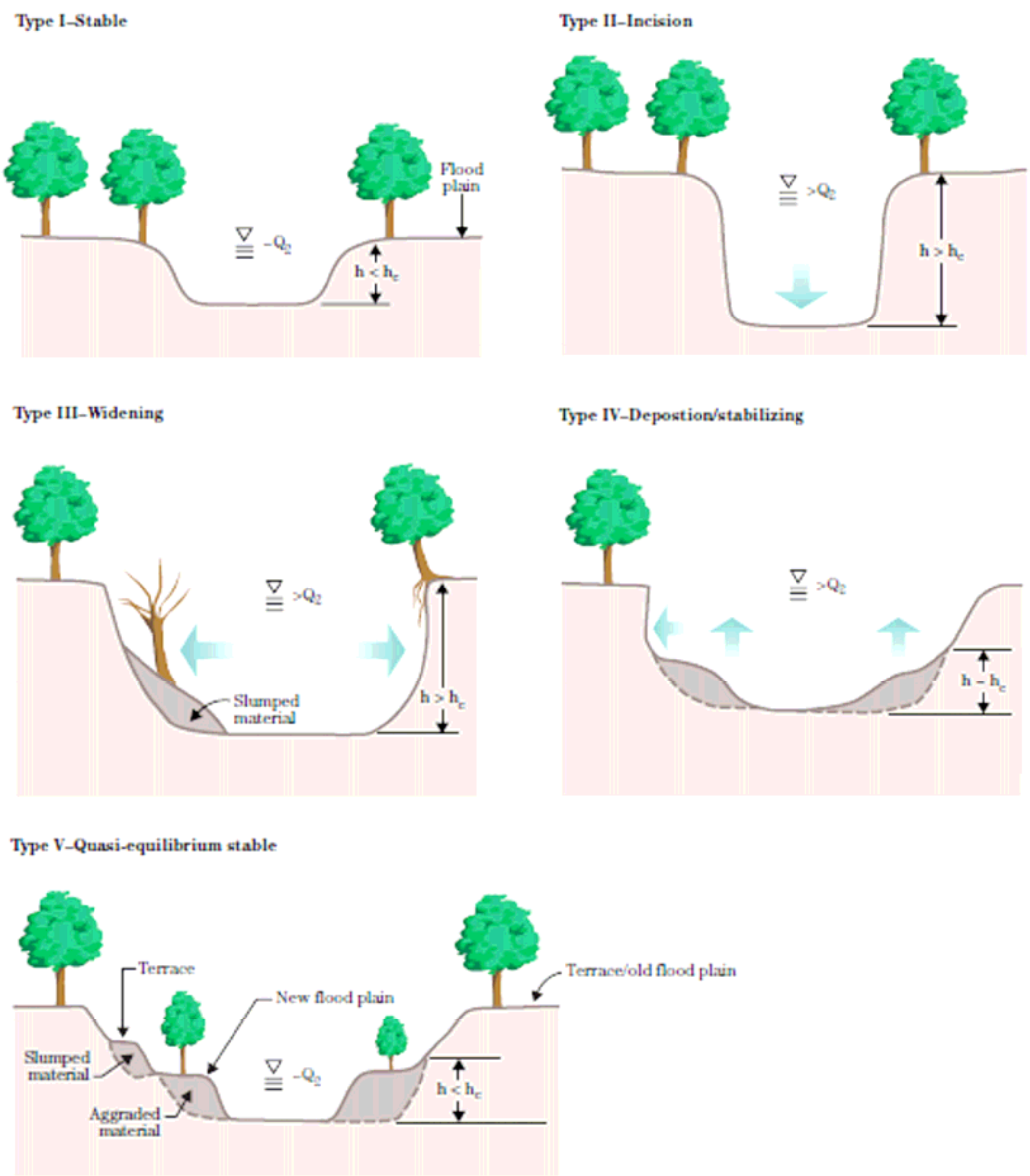


Figure IX-1. Channel Evolution Model (NEH 654, Adapted from Schumm, Harvey, and Watson (1981))

Dr. Allen has adapted the channel evolution model for streams in the DFW Metroplex as shown in Figure IX-2. This figure shows greater detail of the indicators of the evolutionary stages of a channel reach. Many of these signs are evident in Arbor Creek and will be discussed in more detail in the following sections.

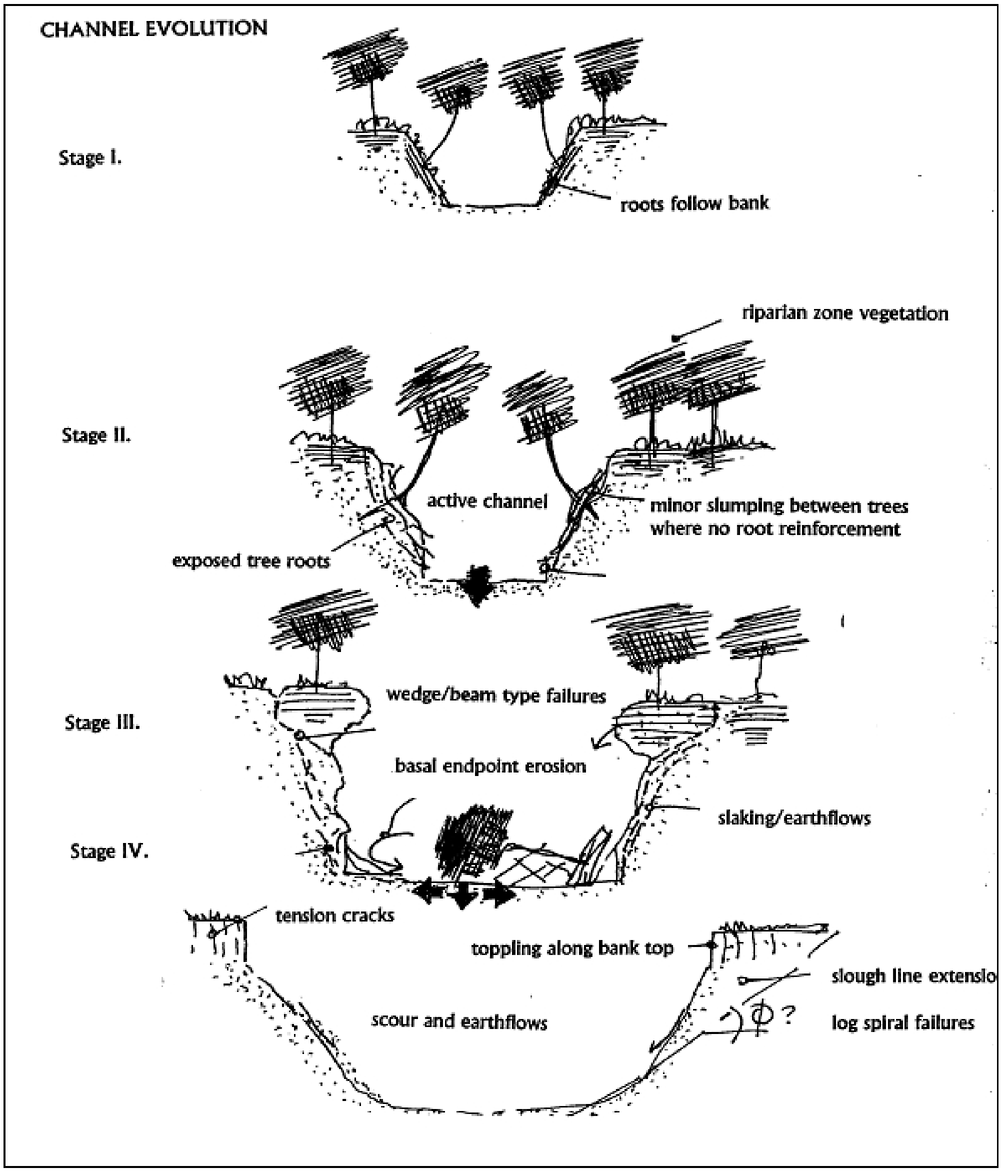


Figure IX-2. Channel Evolution Model from Dr. Allen's Channel Assessment Report (Appendix D)

C. Findings of Channel Assessment

Arbor Creek channel soils are generally clay and highly plastic clay soils. In some areas these soils are underlain by the Eagle Ford Shale formation, while in other areas there are limestone outcroppings. Many portions of the channel and banks contain substantial gravel from past alluvial deposits.

These clay soils are prone to shrinking and swelling with varying moisture conditions, which enhances their erodibility. The shale bedrock, where it is exposed, is subject to substantial slaking due to changes in moisture content, which can result in erosion rates comparable to those of bare soils.

Most of the bed materials are mobile even in a 50% AC flood event. Smaller flows will carry away fine materials, leaving a gravel armor, but larger flows will be able to move the gravel armoring downstream. This means that the channel will be able to downcut without substantial resistance.

Many of the bank areas are covered in trees or tall grasses. While this helps resist erosion and lessen velocities near the banks, undercutting of the trees will result in them falling into the channel. This will accelerate bank erosion and potentially cause damage to nearby facilities from the fallen trees.

Multiple tests are available for determining which portions of the stream are subject to erosion. The City of Grand Prairie Drainage Design Manual provides a table of maximum velocities for various soils. Table 5 in the Stream Assessment Report in Appendix D provides a USACE table for critical shear stresses on various bed materials. Dr. Allen provided two additional criteria for potential erosion areas in Arbor Creek: stream power and Froude number. Areas of the channel with stream power exceeding 80 Watts/square meter may be subject to erosion. Froude numbers in excess of 0.35 can also indicate high risks of erosion.

Current channel slopes in the Arbor Creek watershed vary from 0.0023 to 0.0075 feet/feet. Based on an analysis of multiple models, the final equilibrium slope for Arbor Creek is estimated to be 0.00075 feet/feet, which is substantially lower than the existing slopes. This indicates that the channel will downcut until this equilibrium slope is reach, at which time the channel will obtain a quasi-equilibrium state.

Channel downcutting is currently limited by hardpoints, such as road crossings, utility crossings, and drop structures. Without these hardpoints, the channel would downcut as much as 25 feet at the City limits near Duncan Perry Road. Even with the current hardpoints, the channel is expected to downcut more than 6 feet in some reaches. Such downcutting will undermine existing hardpoints such as culverts and utility crossings; therefore, it is recommended that additional drop structures be constructed to prevent downcutting and damage to existing infrastructure. The following sections will discuss needed drop structures in more detail.

If the predicted downcutting continues, additional bank failures will occur and the channel will widen. Dr. Allen has predicted that without control measures, the channel will widen by 10 to 20 feet, to a final width of about 30 feet. During this process, unarmored banks higher than approximately 8 feet will begin failing. Lower banks can also fail, although typically less severely. This can be especially true along the outer bend of meanders, which have been estimated to migrate 1 to 2 feet per year, without countermeasures. Measures should be taken, as discussed in the following sections, to protect structures and infrastructure from such bank failures. Such protection could include structural measures as well as setbacks for future construction. In improved areas, unarmored banks should not have slopes in excess of 4:1 (horizontal to vertical).

Figure IX-3

APPROXIMATE LOCATION OF STREAM STABILITY ISSUES (1 OF 2)

KEY TO FEATURES

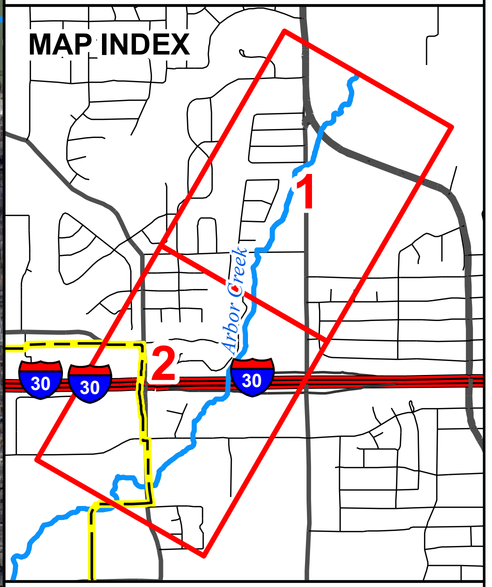
- Storm Drain Lines
- Wastewater Lines
- Water Lines
- GRAND PRAIRIE CITY LIMIT

Stream Stability Issues

Type

- Sedimentation
- Structure Damage
- Structure/Utility Scour
- Unstable Banks

MAP INDEX



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Scale in Feet

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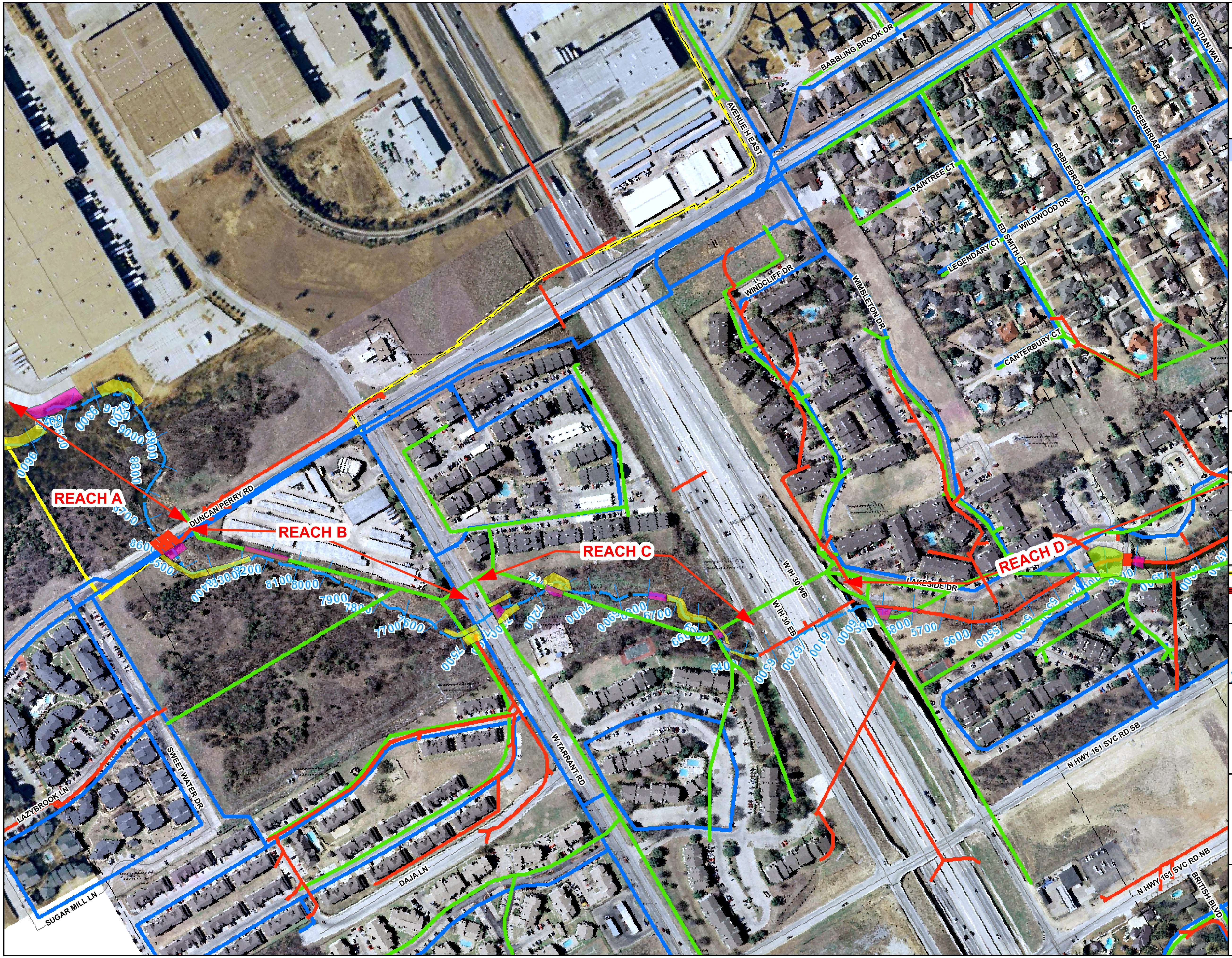


Figure IX-3

APPROXIMATE LOCATION OF STREAM STABILITY ISSUES (2 OF 2)

KEY TO FEATURES

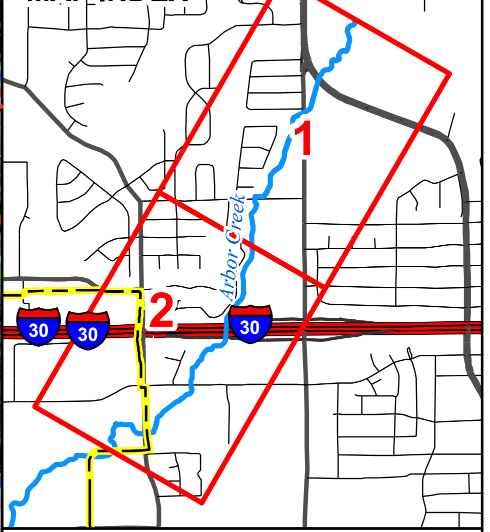
- Storm Drain Lines
- Wastewater Lines
- Water Lines
- GRAND PRAIRIE CITY LIMIT

Stream Stability Issues

Type

- Sedimentation
- Structure Damage
- Structure/Utility Scour
- Unstable Banks

MAP INDEX



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The time it takes for the estimated channel changes to take place is highly dependent on climate and future watershed changes. Based on model results and experience in the area, it has been estimated that, if left unaltered, these changes would take about 30 years to fully develop; however, a number of structures and utilities will likely be damaged much sooner than that, based on current conditions. The following sections discuss specific areas of concern and proposed measures to prevent damage to existing structures and infrastructure.

D. Areas of Concern

During the stream assessment, a number of existing stream stability concerns were noted as shown in the Stream Assessment Report in Appendix D. Figure IX-3 shows the approximate locations and limits of the areas of concern. These concerns are focused on the stream and stream crossings. Issues associated with storm sewer outfall structures are addressed in Chapter XI.

1. Utilities

There are a number of utility crossings and utility exposures on Arbor Creek. Most of these have been encased in concrete and some are deeper than the channel bottom. Many of the utility lines have been exposed by either bank erosion and/or downcutting of the channel. Figure IX-4 shows examples of two endangered utilities. Halting the downcutting and scour around these utilities appears to be the most effective means of protecting them, without relocating them. Section F below discusses the recommended structural measures to protect the exposed utilities.

2. Bank Instability

There are a number of portions of the stream bank that are unstable due to bank height; instability of other portions is due to their position on the outside of meanders (cut banks). Figure IX-5 shows two typical cases of unstable banks along Arbor Creek. The instability in most of these areas is due to stream downcutting. Strategically located drop structures, could halt or slow this process, thus preventing future areas from becoming unstable. The City of Grand Prairies has expressed a desire to focus the consideration of improvements to those areas that threaten existing facilities. Section E below, recommends non-structural measures to help protect future development near the stream from bank instability. Structural measures needed to protect existing threatened structures and infrastructure are discussed in Section F.

Figure IX-4. Views of Exposed Utility Encasements at Station 71+64 (left), and Station 35+50 (right).

Figure IX-5. Typical Unstable Bank Sections at Station 71+50 (left), and Station 24+77 (right)

3. Localized Scour

Areas of localized scour are typically associated with bridge crossings, culverts outfalls, some utility crossings, and interfaces between hard and soft materials. In some cases, local scour may be partially attributable to downcutting or bank instability, and distinguishing between them can be difficult. As discussed in Section F, many of the recommended measures address both local scour from a culvert as well as future downcutting. Figure IX-6 shows a typical local scour problem associated with a culvert crossing.

Figure IX-6. Typical Local Scour Problems at Tarrant Road (left), and Drop Structure Near Station 45+20 (right)

4. Sedimentation

As discussed in Section C, much of the bed materials would be mobile in a significant runoff event. Throughout most of the stream, power, tractive force, and velocity exceed the calculated minimums necessary to move the bed materials; however, certain portions of the stream have low velocities and/or localized calm zones that could allow substantial amounts of sediment and bed materials to settle out, even during higher flow events. Excess buildup of sediment can lead to vegetation establishment, consequently restricting flow.

Figure IX-7 shows areas that have the potential to deposit significant sediment as well as those areas that were observed to have significant sediment deposition. Although a sediment transport study has not been performed, the areas of potential sedimentation were determined by examining areas where the hydraulic models showed shear stresses below the critical shear stress of coarse gravel (0.25 pound per foot squared) and where the velocity is less than 2 feet per second for a wide range of flood frequencies.

There are five potential areas of deposition based on the hydraulic model analysis. The first is associated with the area upstream of IH-30 and is due to the high tailwater caused by the undersized culverts. While deposition is feasible during these higher flow events, the smaller more frequent flows have adequate velocities and tractive forces to erode most sediment deposits. No substantial amounts of sediment were noted in this reach, and the stream stability analysis indicates that this area will downcut over time to reach a shallower stable slope.

Two other areas are those associated with the drop structures between IH-30 and Egyptian Way. These drop structures were designed to slow the water and sedimentation is expected in them, and has been observed as shown in Figure IX-8. This sediment should reach an equilibrium point over time; however, some maintenance is recommended as discussed in Section G.

Figure IX-7

POTENTIAL AND OBSERVED AREAS OF SEDIMENTATION (1 OF 2)

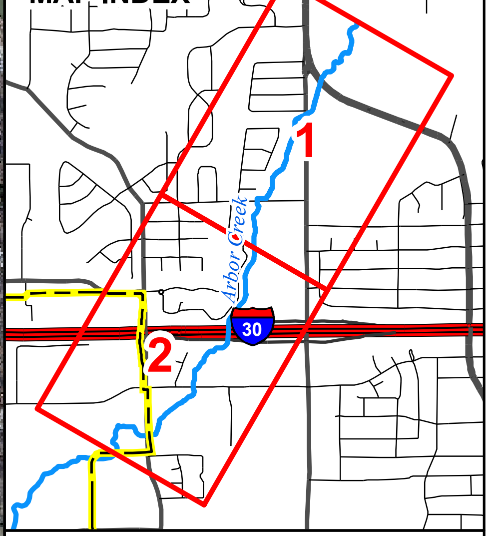
KEY TO FEATURES

- ARBOR CREEK CENTERLINE
- GRAND PRAIRIE CITY LIMIT
- STREET CENTERLINE

Sedimentation Issues

- Observed
- Potential

MAP INDEX



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Scale in Feet

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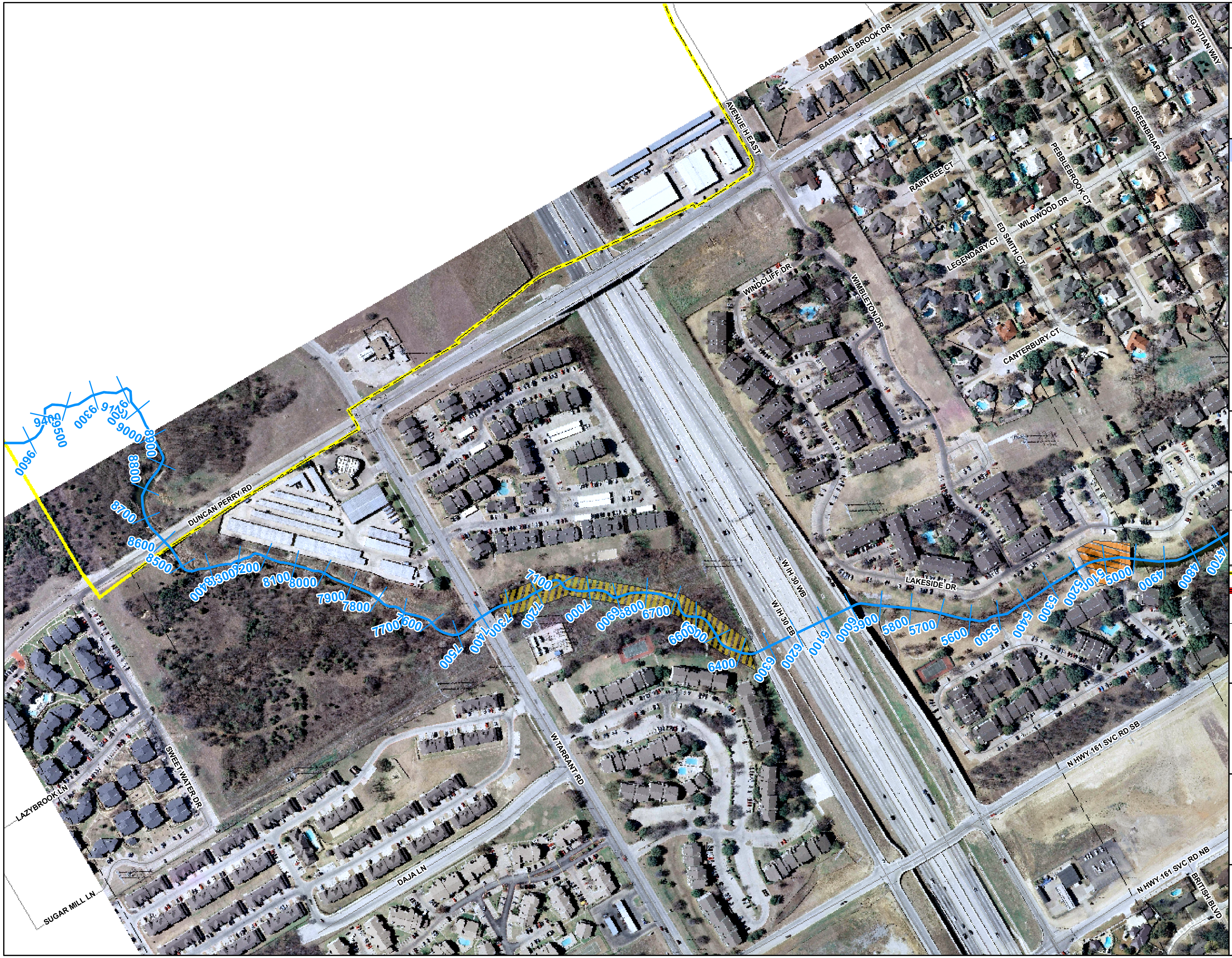
Figure IX-7

POTENTIAL AND OBSERVED AREAS OF SEDIMENTATION (2 OF 2)

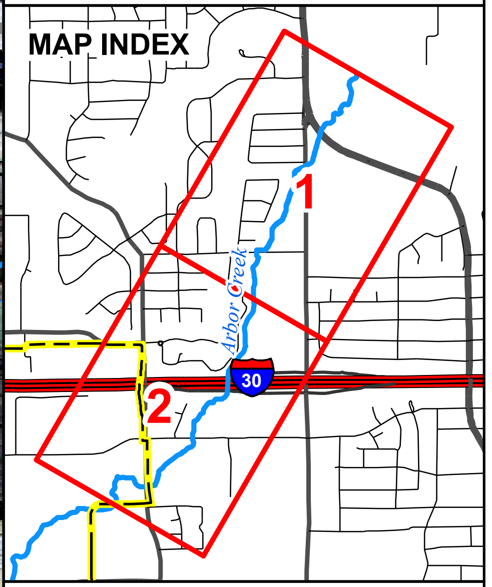


KEY TO FEATURES

- ARBOR CREEK CENTERLINE
- GRAND PRAIRIE CITY LIMIT
- STREET CENTERLINE

Sedimenation Issues

- Observed
- Potential



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Scale in Feet

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Figure IX-8. View of Sediment in Existing Drop Structures at Station 51+50 (left), and at Station 46+00 (right).

The culverts at Egyptian Way represent another area of both potential and observed sedimentation. The design of the culverts spreads the flow out over a wide area, thus slowing the water. The sharp bend on the downstream side of the culverts encourages areas of ineffective flow on the outside culverts. Once coarse materials, such as gravel settles out, then finer materials begin to get entrained in the gravel. Since most flood events aren’t adequate to move this material, it begins to build, blocking the culverts and allowing vegetation to become established. Figure IX-9 shows the existing and past sedimentation and vegetation in this area. The construction of these culverts was completed by TxDOT within the last three years and according the City of Grand Prairie, there are no near-term plans to replace this crossing; therefore, the sedimentation will have to be addressed through routine maintenance as discussed in Section G.

Figure IX-9. View of Sediment and Vegetation at the Egyptian Way Culverts.

The final area of potential sedimentation, based on hydraulic model analysis, is beneath the SH-161 bridges, particularly downstream of Carrier Parkway. This area is determined to be marginally at risk of sedimentation and will likely be flushed out during higher flow events. No substantial sedimentation was observed in this area, but it should be monitored routinely to note excessive buildup.

E. Non-Structural Measures (Erosion Hazard Setbacks)

Some areas of existing or potential bank instability may not warrant immediate attention, as there are no structures or infrastructure threatened by bank failures. In these areas, the City of Grand Prairie has expressed a desire to focus on non-structural measures to address potential future damage. Erosion hazard setbacks can be an effective way to protect structures and infrastructure by ensuring that future construction is located far enough away from the channel banks that it will not be threatened by channel erosion, widening, or bank instability.

The Drainage Design Manual provides a procedure for determining such setbacks. It should be considered that the necessary setback distance will vary based on the existing bank heights, anticipated channel downcutting, slopes of the surrounding area, and anticipated final channel width. Figure IX-10 shows a schematic of a typical setback. DEG30 and W30 are the expected channel elevation and widths after 30 years. These are based on the stable slope and expected downcutting previously discussed. Installation of structural measures, as discussed in the following section, can limit the amount of downcutting and widening, but cannot completely eliminate them.

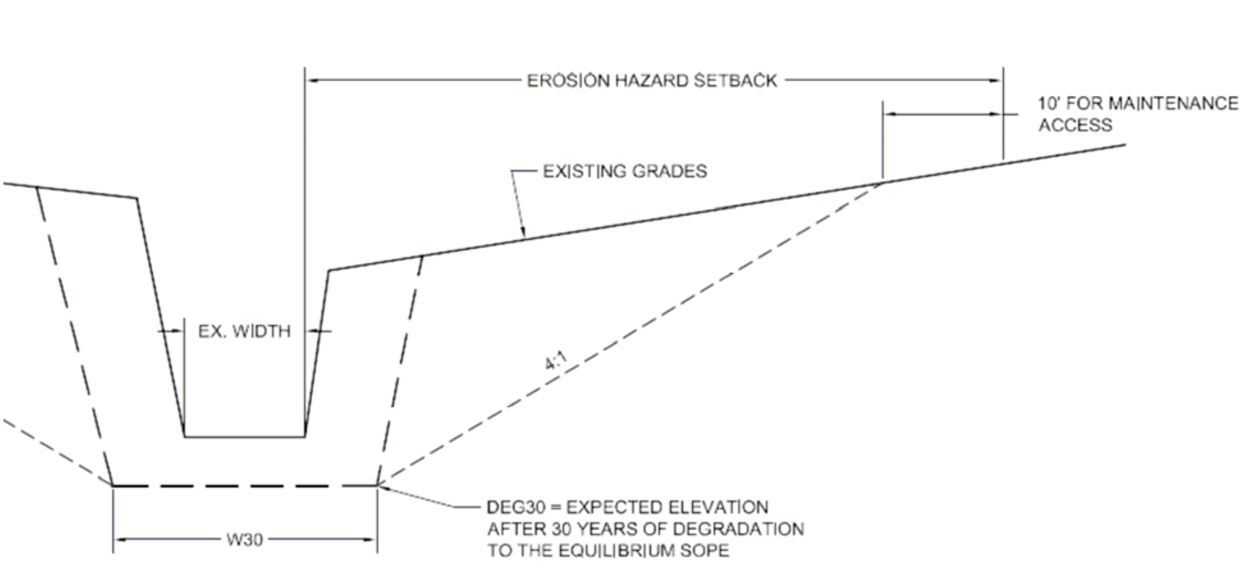


Figure IX-10. Schematic for Determination of Erosion Hazard Setback Distances.

As discussed previously, stable side slopes for Arbor Creek have been estimated to be 4:1, or about 14 degrees. To determine the setback, a 4:1 line should be drawn from the expected final toe location to where it meets the existing grade. An additional 10 feet should be added to allow for maintenance.

Some sites will require additional considerations; particularly those that have the potential for local scour or are on the outer bends of a meander. Local scour can substantially increase the bank height and require additional setbacks. Since meander bends can migrate 1 to 2 feet in a typical year, setbacks should be set with an adequate buffer to allow for the expected migration.

Due to the unique situation for each location, the setback distances will require site-specific analysis. Determination of the necessary setback distance should be performed by a licensed engineer with experience in streambank stability.

The data and recommendations contained in this Arbor Creek CWMDP should be taken into account before designing or approving erosion hazard setback distances. Some land parcels may be overly burdened by a potential setback distance; elsewhere, meander rates and directions or other factors may be indeterminate. In these and similar instances, structural measures may be warranted to limit the setback distance or improve confidence in the final result. The following section discusses some structural measures that can be used.

F. Structural Measures

While setbacks can help prevent future structures and infrastructure from becoming threatened by stream erosion, existing facilities built within these setbacks can still be threatened. For these areas, structural measures are necessary to reduce or eliminate damage. Structural measures can protect existing facilities, but they can also reduce the potential for future damage to areas not yet threatened and reduce the size of erosion hazard setbacks. By reducing the size of setbacks, more potentially developable or otherwise useable land is available.

Section D provides information of problem areas, some of which could benefit from structural measures. Section 1 will discusses typical designs for the most common structural measures needed on Arbor Creek. Subsection 2 provides additional details and costs associated with each proposed improvement location.

1. Common Structural Improvements

This section provides typical designs and general design guidelines for each type of common structural improvement. Each location will ultimately require detailed design. Subsection 2 will provide additional details for each specific location.

Drop Structures

Drop structures help control downcutting of the stream by providing a hardpoint that does not erode. There are numerous potential designs for drop structures; the design considered herein is a composite of common NRCS designs and similar designs recently utilized in Grand Prairie, such as have been implemented on Kirby Creek and elsewhere.

There are numerous existing utility crossings along Arbor Creek, many of which have been exposed. For most locations, the drop structures should be positioned in such a manner as to optimize protection of the affected facility, structure or utility, while focusing erosive flows away from vulnerable areas.

The concept design shown in Figure IX-11 incorporates an existing encased utility-crossing that has been exposed. A concrete cutoff wall is added to prevent piping and undermining beneath the structure. Loose riprap is utilized at each end of the structure since it has the ability to adjust to the downcutting that can occur as the reach upstream and downstream attain their equilibrium slopes. The length of the downstream riprap section is chosen to provide a maximum 5:1 slope once the downstream equilibrium slope is reached. On the upstream side, the length is adequate for a final riprap slope of 4:1 max.

Placement of drop structures is partially determined by the location of the existing crossings, but also in consideration of the goal to limit individual drops to a height of about 3 feet. The three-foot drop provides a balance between the number of required drops, the cost of each installation, and the allowable downcutting.

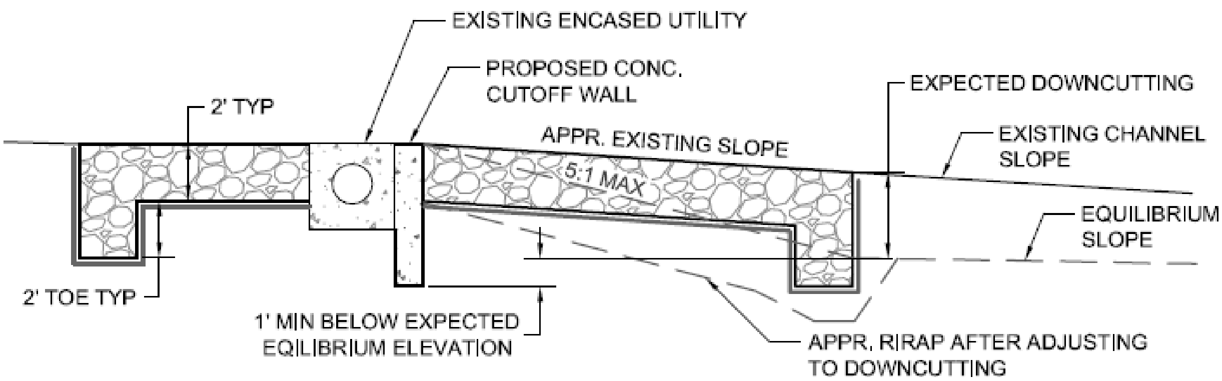


Figure IX-11. Typical Profile of a Drop Structure Designed to Protect an Exposed Utility Encasement.

Some drops that are not associated with a utility crossing, or where the utility is not exposed, may utilize some other type of cutoff wall, such as a similar depth of grouted riprap (see Figure IX-12). Other recommended drop locations have been chosen corresponding with exposed utility encasements that run generally parallel with the stream and have been exposed by downcutting. By locating the drop structure at the utility, further downcutting in the vicinity of the utility can be minimized and the encasement can be incorporated into the structure.

The drop structure cross section is generally configured to concentrate flows toward the center of the channel and away from the channel toes, thus further reducing the erosive potential in these sensitive areas (see Figure IX-13).

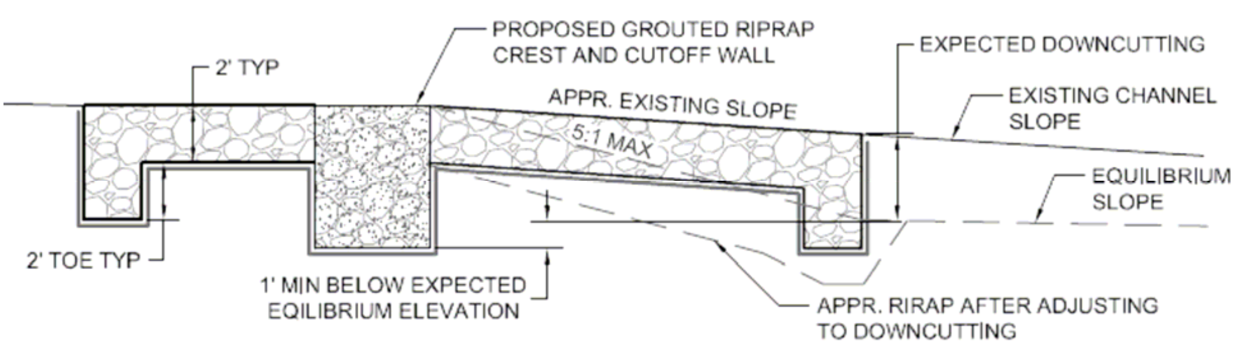


Figure IX-12. Typical Profile of a Drop Structure.

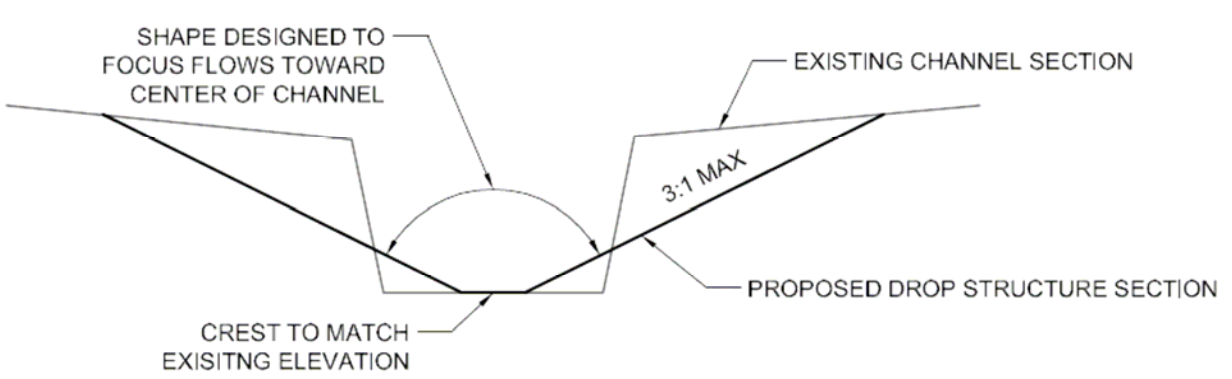


Figure IX-13. Typical Drop Structure Crest Section.

Bank Armoring

Bank armoring is recommended in locations where bank instability is likely to threaten houses or infrastructure. While bank heights vary considerably, most affected locations will be sufficiently stabilized by gabion walls with tie-back anchorages. Figure IX-14 shows a typical concept design for such a structure.

Gabion walls are constructed by interconnecting and stacking rock-filled gabion baskets, which consist of heavy gage wire that is twisted or welded into a mesh and shaped to form basket segments. The most common basket segment configuration is 3 feet tall by 3 feet deep and 6 feet long. Each length of basket is divided into 3-foot cells to limit rock movement in the basket. The baskets are filled with a hard durable stone, which provides mass to the wall and helps prevent erosion of the underlying material.

For gabion walls, the baskets are typically underlain and backed by a layer of gravel that allows water to drain from the soils behind the wall while retaining the soil in place. This drainage layer also helps provide an additional barrier between the moving water and the underlying soil.

The bottom basket should be placed below the anticipated scour depth, which should consider local scour issues as well as anticipated downcutting from the stream. This depth can be minimized by judicious use of drop structures. Above the existing grade, each new row of baskets is typically stepped back one half a basket width, into the slope.

Depending on the soil parameters and the structures and facilities that are behind the wall, certain rows may have reinforcing beams installed. Tie-back anchors will typically pass-through and be tensioned against this beam to anchor the wall. Using anchors minimizes the need to excavate, reduces the size of the thickness of the wall, and can minimize disturbance to nearby facilities.

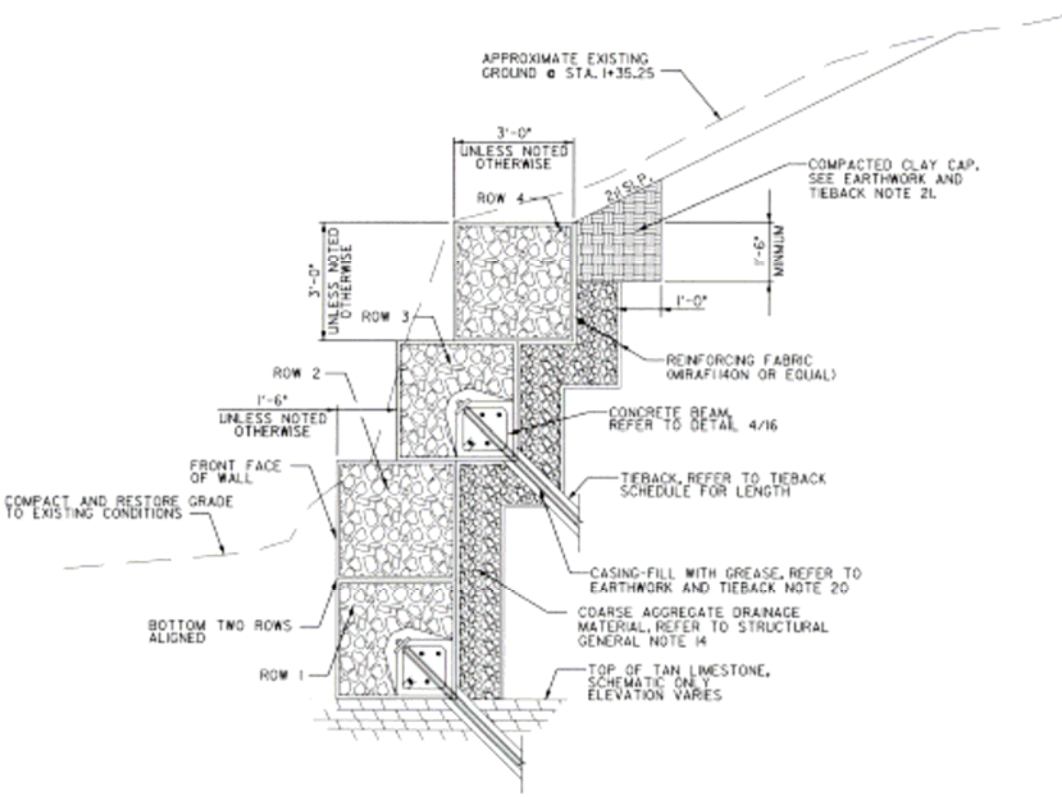


Figure IX-14. Typical Gabion Wall with Tie-Backs.

Local Scour Protection

Local scour problems can vary greatly, but are typically associated with culvert outfalls and transitions between hard and soft materials, such as the end of a concrete drop structure. Solutions to these problems can vary just as greatly.

At some scour locations, drop structures are being recommended, but for most locations, loose riprap is recommended. Loose riprap remains flexible, thus adjusting to stream downcutting and limited scour where it transitions to natural channel materials. Rigid armor, such as concrete or grouted riprap, does not allow for movement and can be undercut. Loose riprap has the added benefit of being fairly easy to install and maintain.

Figure IX-15 shows a typical loose riprap installation on the end of a culvert. A hard, durable, angular stone should be utilized. Using stones with a range of sizes and with an angular shape allows the stones to lock together, typically yielding a greater resistance to scour. The smaller stones also help fill in gaps that would allow higher water velocities jetting through to the base material. Geotextile fabric helps prevent the rocks from settling into the soil beneath them and provides a filter to prevent soil particles from being scoured or piped from beneath the riprap.

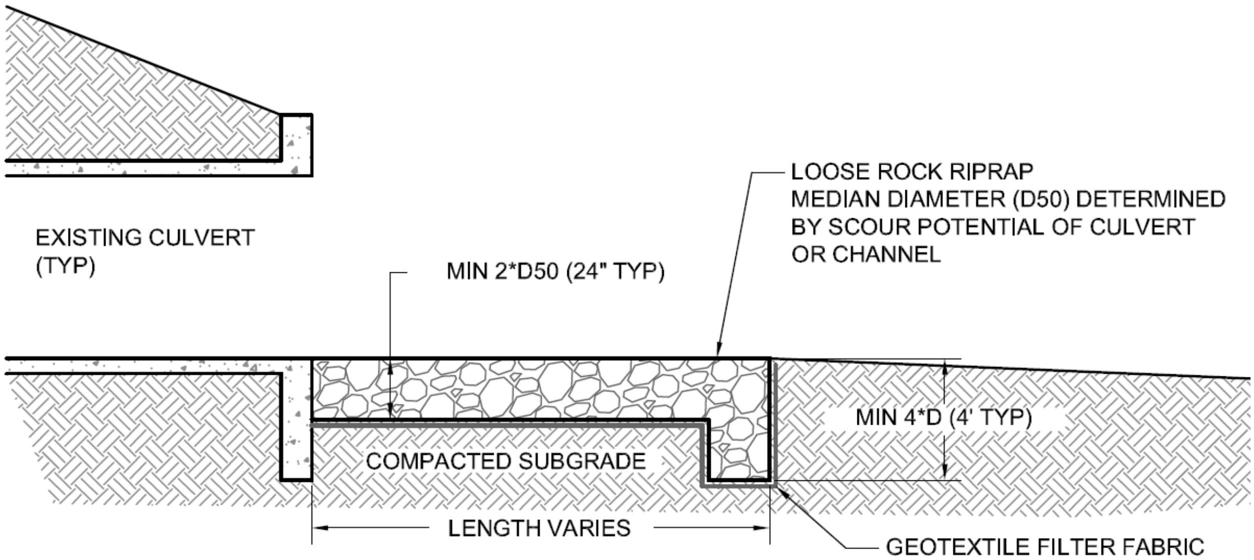


Figure IX-15. Typical Loose Riprap Installation at a Culvert Outfall.

2. Locations and Costs

As discussed in the previous sections, many of the stream stability issues experienced along Arbor Creek are caused by downcutting of the channel as it approaches a new equilibrium. This downcutting has been partially controlled by existing hardpoints, some of which are fairly permanent, such as road crossings, while others are being undermined and are at risk of failing, particularly at utility crossings. Because many of the structural measures will work together, such as drop structures that prevent undermining of walls, it is proposed that groups of structural measures be installed as a single project. This helps minimize mobilization costs, but also minimizes the design requirements and costs for each individual project.

Figure IX-16 shows the proposed locations for each structural improvement. All related projects within a reach have been grouped. These reaches generally stretch from one road crossing or major drop structure to the next. The following sections will discuss the structural measures, as grouped by reach.

Some structural measures are warranted, but are not specifically proposed herein. These generally correspond to portions of the channel that would fall under NTTA or TxDOT jurisdiction and are not expected to be the responsibility of the City of Grand Prairie. Structural measures for these areas will be briefly discussed, but no concept designs or costs have been determined for them.

Reach A - Upstream of Duncan Perry Road

No structures or infrastructure within the City of Grand Prairie were noted in this reach. To avoid future stream stability problems, future development in this area should consider the erosion hazard setback requirements as previously discussed.

Reach B - Duncan Perry Road to Tarrant Road

As discussed in Section D, several stream stability issues were noted within Reach B. A number of streambank erosion issues were noted, but because no structures or infrastructure appear to be at risk in these areas, no structural measures are considered. Future development should consider the erosion hazard setbacks previously discussed. The drop structure improvements discussed below will help slow the rate of degradation of some bank sections.

Scour is evident at the outfall of the culverts under Duncan Perry Road. The scour at this culvert outfall should be addressed by increasing the particle size and quantity of riprap. Final design should consider a pre-formed scour hole to help offset the cost of additional riprap.

Figure IX-16

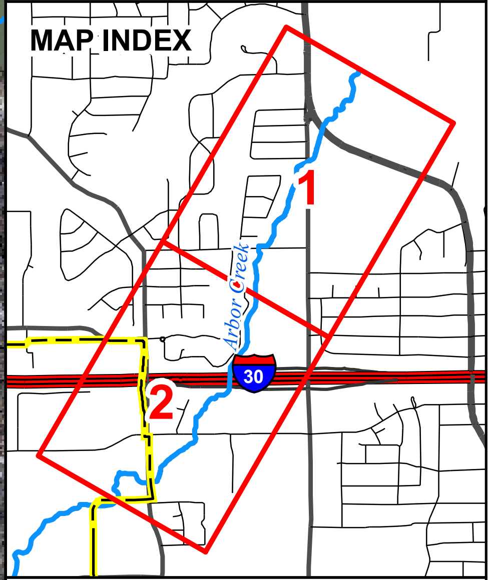
PROPOSED PROJECT LOCATIONS (1 OF 2)

KEY TO FEATURES

Improvement Locations

- Drop Structure
- Encasement
- Outfall Protection
- Scour Protection
- Proposed_Bank_Armoring
- ARBOR CREEK CENTERLINE
- GRAND PRAIRIE CITY LIMIT
- STREET CENTERLINE

MAP INDEX



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Scale in Feet

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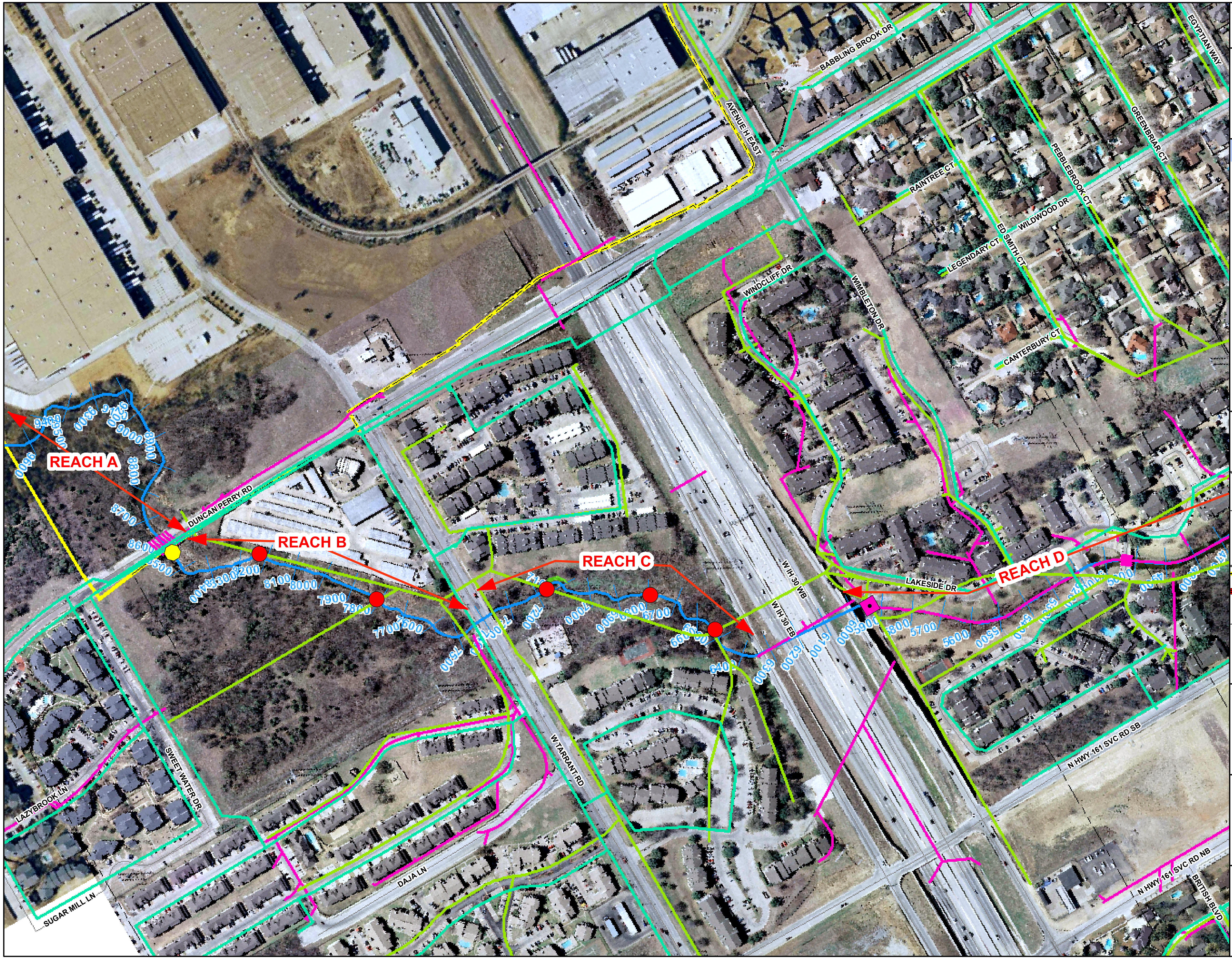


Figure IX-16

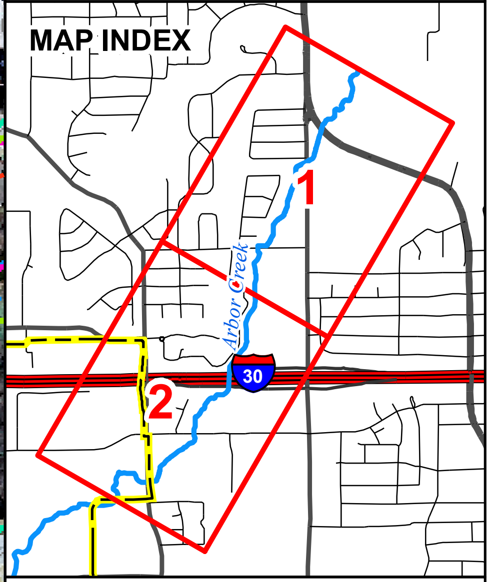
PROPOSED PROJECT LOCATIONS (2 OF 2)

KEY TO FEATURES

- Arbor Creek Centerline
- Grand Prairie City Limits
- Street Centerline
- Water Line
- Wastewater
- Storm Sewer

Proposed Improvement Locations

- Drop Structure
- Encasement
- Outfall Protection
- Scour Protection
- Proposed Bank Armoring



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Scale in Feet

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Figure IX-17. View of Scour at the Outfall of the Duncan Perry Road Culvert.

About 100 foot of exposed and encased sanitary sewer line runs parallel to the channel at about Station 82+30. A drop structure that would utilize the encasement as one bank is proposed at this location. The crest and cutoff wall of the drop would be constructed of grouted rock riprap with a connection to the concrete encasement. The upstream and downstream ends of the drop structure would be constructed with loose rock riprap, roughly at existing grades. This drop, combined with improvements to the existing downstream drop structure, should halt further downcutting at, and exposure of, the sanitary sewer encasement.

The existing drop structure at Station 78+00 is constructed of grouted rock riprap and appears to correspond to a sanitary sewer crossing. The structure appears to be in good condition with minimal scour observed. Addition of loose rock riprap is recommended to allow the structure to adjust to future downcutting without the risk of undermining the rigid grouted riprap.

Figure IX-18. Exposed Sanitary Sewer Line Encasement (Station 82+30)

Figure IX-19. Grouted Rock Riprap Drop Structure (Station 78+00)

There is a number of stream stability issues associated with the Tarrant Road crossing. These are addressed by the improvements discussed in Chapter VII and are, therefore, not discussed further in this section.

Estimated costs for the recommended structural measures within Reach B are briefly summarized in Table IV-1. A more detailed concept opinion of probable construction costs is provided in Chapter XII and a project prioritization is included in Chapter XIII.

Table IX-1		
Reach B Stream Stabilization **Summary of Concept Opinion of Probable Construction Costs**		
1 Improved Culvert Outfall, 1 New Drop Structure, and 1 Improved Drop Structure		
Construction Subtotal	$	117,625.00
Approximate25% Contingency	$	29,375.00
Construction Total	$	147,000.00
Appr. 20% for Engineering, Survey, and Environmental Services	$	29,000.00
Total	**$**	**176,000.00**

Reach C - Tarrant Road to IH-30

As discussed in Section D, several stream stability issues were noted within Reach C. A number of streambank erosion issues were noted, but because no structures or infrastructure appear to be at immediate risk in these areas, no structural measures are considered. Future development should consider the erosion hazard setbacks previously discussed. The drop structure improvements discussed below will help slow the rate of degradation of some bank sections. The City should consider periodically inspecting the unstable bank areas to ensure that the potential for damage to existing facilities is detected early and measures to prevent such damage can be considered.

The Tarrant Road culvert outfall area is in poor condition. This area will be addressed by the improvements discussed in Chapter VII and are, therefore, not discussed further in this section.

There is substantial scour evident at the sanitary sewer crossing at Station 71+64. The encased sewer is being undercut and substantial bank erosion is evident (See Figure IX-4). A drop structure is proposed that would incorporate the encased sanitary sewer line that would be similar to the concept shown in Figure IX-11. Due to the severity of the bank erosion and its proximity to the proposed drop structure, a gabion wall is proposed to stabilize the outside of the channel meander.

A loose rock riprap drop structure is located at Station 67+90. It is in fair condition, but appears to be inadequately sized to handle potential downcutting. This structure should be improved by increasing the quantity of riprap to allow for future downcutting and by grouting a central riprap cutoff wall as shown in Figure IX-12.

Figure IX-20. Loose Rock Riprap Drop Structure (Station 67+90)

Near Station 64+90, there is an existing sanitary sewer encasement that is in poor condition. It also appears to have been incorporated into a drop structure, but downcutting and scour have placed the sewer at risk. A drop structure, similar to the concept shown in Figure IX-11, is proposed. This would also help alleviate the bank instability problems just upstream of this area.

Figure IX-21. Encased Sanitary Sewer Crossing (Station 64+90)

Estimated costs for the recommended structural measures within Reach C are briefly summarized in Table IV-2. A more detailed concept opinion of probable construction costs is provided in Chapter XII and a project prioritization is included in Chapter XIII.

Table IX-2	
Reach C Stream Stabilization **Summary of Concept Opinion of Probable Construction Costs**	
1 Improved Drop Structure and 2 Improved Drop Structures/ Utility Crossings	
Construction Subtotal	$ 161,785.00
Approximate 25% Contingency	$ 40,215.00
Construction Total	$ 202,000.00
Appr. 15% for Engineering, Survey, and Environmental Services	$ 30,000.00
Total	**$ 232,000.00**

Reach D – IH-30 to Drop Structure at Station 46+00

No significant stream stability issues were noted in Reach D. This is largely due to the function of the two drop-structures, which were repaired in 2009. A sanitary sewer line is exposed at Station 58+00. It is proposed that a portion of this line be encased to prevent damage.

Estimated costs for the recommended structural measures within Reach D are briefly summarized in Table IV-3. A more detailed concept opinion of probable construction costs is provided in Chapter XII and a project prioritization is included in Chapter XIII.

Table IX-3	
Reach D Stream Stabilization **Summary of Concept Opinion of Probable Construction Costs**	
1 Sanitary Sewer Encasement	
Construction Subtotal	$ 11,690.00
Approximate 25% Contingency	$ 3,310.00
Construction Total	$ 15,000.00
Appr. 20% for Engineering, Survey, and Environmental Services	$ 3,000.00
Total	**$ 18,000.00**

Reach E - Drop Structure at Station 46+00 to Egyptian Way

As discussed in Section D, several stream stability issues were noted within Reach E. No significant streambank erosion issues were noted. Future development in this reach should consider the erosion hazard setbacks previously discussed.

Scour is evident at the outfall of the existing drop structure (See Figure IX-6). It is proposed that this be addressed with the addition of loose rock riprap at the end of the structure that would surround the existing grouted riprap. This would reduce the potential for local scour and mitigate damage as the stream downcuts.

It is estimated that this reach could downcut by more than 5 feet. To prevent damage to the existing concrete drop structure, one additional drop structures is proposed at Station 42+00. A drop structure consisting only of loose rock riprap is proposed, at grade. This is due to the relatively stable limestone present, which has a fairly low erosion rate and has less risk of being undercut.

Estimated costs for the recommended structural measures within Reach E are briefly summarized in Table IV-4. A more detailed concept opinion of probable construction costs is provided in Chapter XII and a project prioritization is included in Chapter XIII.

Table IX-4	
Reach E Stream Stabilization **Summary of Concept Opinion of Probable Construction Costs**	
1 Improved Drop Structure and 2 Improved Drop Structures/ Utility Crossings	
Construction Subtotal	$ 84,285.00
Approximate 25% Contingency	$ 20,715.00
Construction Total	$ 105,000.00
Appr. 20% for Engineering, Survey, and Environmental Services	$ 21,0000.00
Total	**$ 126,000.00**

Reach F - Egyptian Way to SH-161

As discussed in Section D, several stream stability issues were noted within Reach F. This reach is in the worst condition of all study reaches in terms of degradation and threatened facilities.

TxDOT has recently completed construction on the SH-161 overpass through this area, including service roads, the Egyptian Way crossing of Arbor Creek, and the Carrier Parkway crossing of Arbor Creek. The Egyptian Way crossing configuration has resulted in sediment accumulation and vegetation growth that partially obstructs the culvert flows. Some of the gabion structures have been damaged and are risk of failure. In two locations, near Stations 24+80 and 30+50, the stream is meandering to within 10 feet of the southbound service road. It does not appear that these walls are designed to prevent undercutting by channel scour forces. NTTA has now taken control of SH-161. Because these channel stability issues are associated with the TxDOT and NTTA, no specific concept designs or costs have been prepared. A number of the structural measures discussed for this reach will help reduce the rate of degradation, but are not designed to address the risks to the NTTA facilities.

Figure IX-22. Views of Meanders Close to SH-161 at Station 24+80 (left) and Station 30+50 (right).

To address future downcutting, it is recommended that loose rock riprap be added to the end of the gabion mattress channel bottom near Station 37+00. This will provide flexible channel armoring that can adjust to future downcutting and mitigate undercutting of the gabion mattress.

Figure IX-23. Erosion at End of Gabion Mattress Channel Bottom (Station 37+00)

An existing encased sanitary sewer line makes up the channel bank for a portion of the channel near Station 35+50 (See Figure IX-24). Some bank scour is evident on the opposite side of the channel. To prevent further downcutting and exposure of the sanitary sewer line, a drop structure near the north end of the exposed encasement should be considered as shown in the concept drawing in Figures IX-25 and IX-26. The crest would consist of grouted rock riprap and be doweled into the existing concrete encasement. The downstream end would be constructed of loose rock riprap that can adjust to stream downcutting without undermining the grouted riprap. Two rows of gabion baskets are proposed to armor the western bank to protect fences and trees in this area. Because a significant amount of the sanitary sewer encasement is exposed, grouted riprap would be used to line the channel bottom along the exposed length. This will minimize further downcutting and cover a portion of the exposed encasement.

There is a steep bank near Station 22+15 that is at risk of failure. A house and fence are located within the potential failure zone. This location is situated on the outside of a meander and will most likely continue to deteriorate. It is proposed that an approximately 100-foot long gabion wall of a similar design as the concept presented in Figure IX-14 be constructed at this location.

Figure IX-24. Exposed Sanitary Sewer Encasement Near Station 35+50.

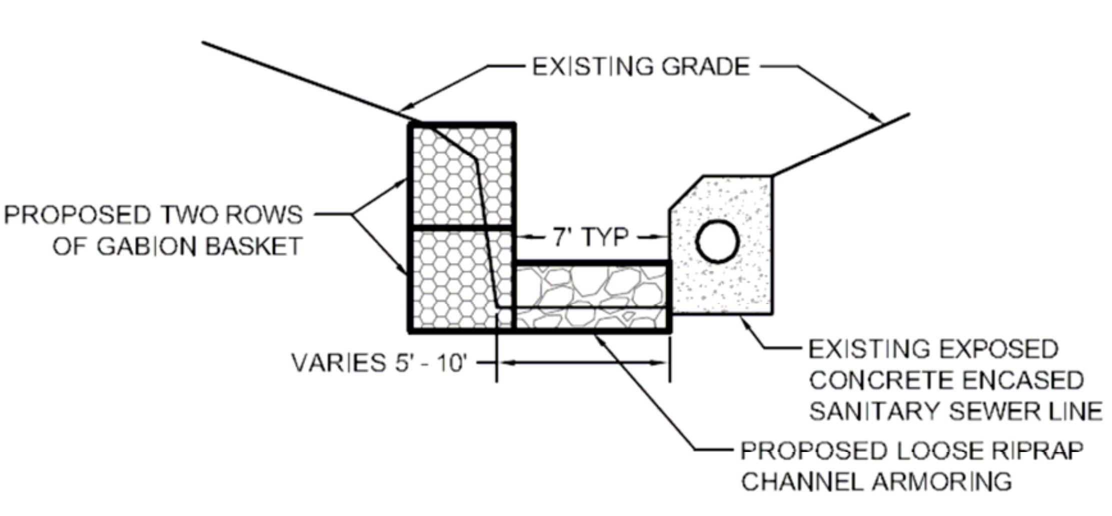


Figure IX-25. Concept Cross Section of Proposed Bank and Channel Armoring between Stations 35+70 and 34+80.

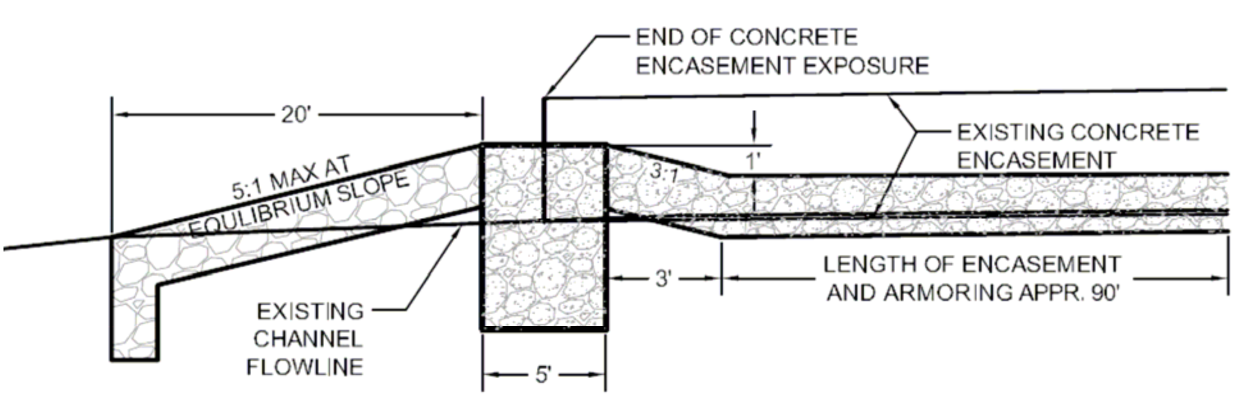


Figure IX-26. Concept Profile of Proposed Drop Structure and Channel Armoring between Stations 35+70 and 34+55.

Near Station 26+65, one half of the channel was armored with gabion mattresses and gabion baskets. Over time, the channel has downcut adjacent to the toe of this protection and has exposed about 3 feet of the gabion toe wall (See Figure IX-27). Further downcutting will endanger the entire gabion system and cause more rapid deterioration of the upstream banks. To prevent further downcutting, additional gabion channel armoring should be considered as shown in Figure IX-28. A gabion mattress that would be tied into the gabion toe wall, would extend up the eastern bank. At the north end, a straight concrete drop structure (see concept profile in Figure IX-29) is proposed that would seal the end of the gabions from piping and provide a controlled drop down to existing grade. Loose rock riprap on the downstream end of the concrete would allow for further downstream downcutting.

Estimated costs for the recommended structural measures within Reach F are briefly summarized in Table IV-5. A more detailed concept opinion of probable construction costs is provided in Chapter XII and a project prioritization is included in Chapter XIII.

Figure IX-27. Scour Adjacent to Gabion Armoring near Station 26+50

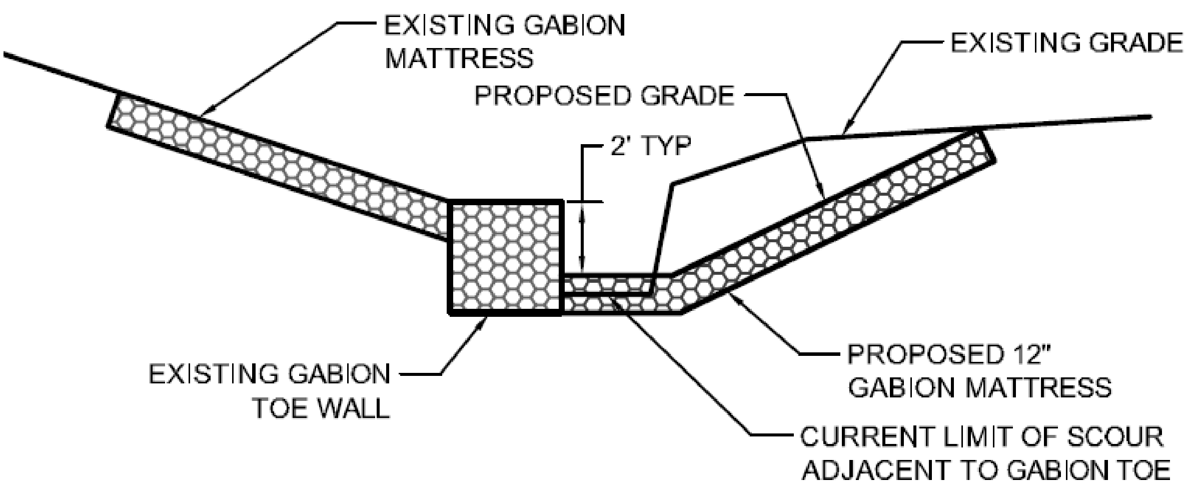


Figure IX-28. Concept Cross Section of Proposed Channel Armoring between Stations 26+65 and 25+50

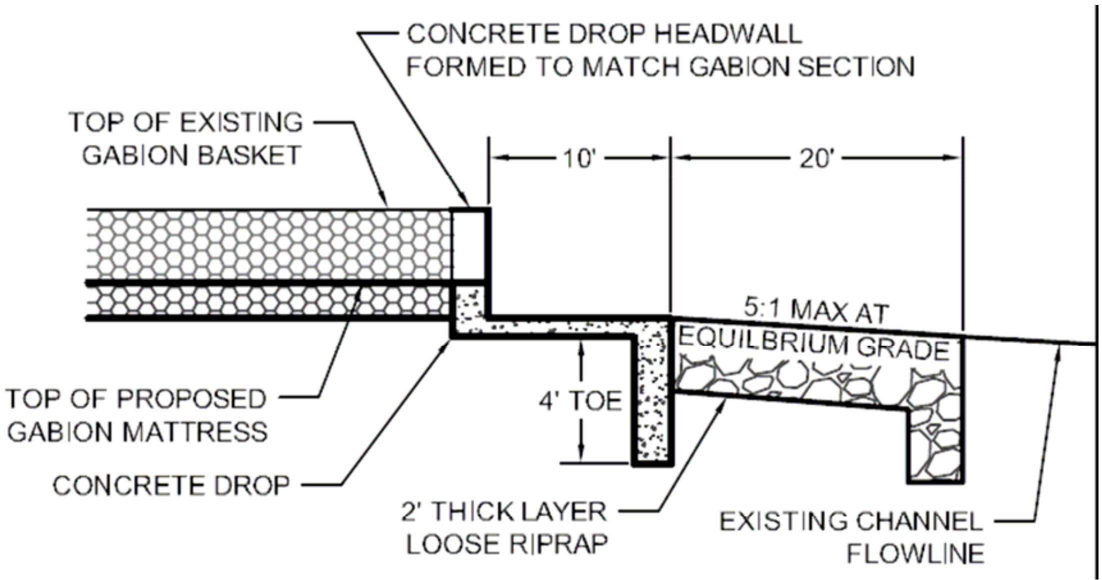


Figure IX-29. Concept Profile of Drop Structure near Section 25+50.

Table IX-5	
Reach F Stream Stabilization **Summary of Concept Opinion of Probable Construction Costs**	
1 Improved Culvert Outfall, 1 New Drop Structure, and 1 Improved Drop Structure	
Construction Subtotal	$ 250,620.00
Approximate 25% Contingency	$ 62,380.00
Construction Total	$ 313,000.00
Appr. 15% for Engineering, Survey, and Environmental Services	$ 47,000.00
Total	**$ 360,000.00**

Reach G - SH-161 to Johnson Creek

As discussed in Section D, several stream stability issues were noted within Reach G. This reach is in the worst physical condition of the studied reaches, but because it is located in a park, there are few significant threats to existing facilities.

The entire reach through Waggoner Park is substantially degraded, with significant downcutting and subsequent bank failures evident or imminent. This portion of the channel has reached Stages III and IV of the channel evolution model discussed in Section C. As a result, addressing channel stability through drop structures or other low costs means is no longer feasible. Instead, the entire reach (Station 1+00 to 9+50) needs to be rehabilitated. This would include widening the channel bottom such that it is close to the estimated equilibrium width of 25 feet. The eastern bank, which is fairly close to a driveway at a number of locations, would need to be fully armored with gabion baskets. The western bank would have a gabion-armored toe, with the overburden slope cut back to a 4:1 slope. Trees and native riparian vegetation should be considered along the banks to provide natural armoring and be able to survive in wet and dry conditions.

Figure IX-30. Typical Section of Degraded Channel in Waggoner Park (Station 6+25)

Figure IX-31. Pedestrian Bridge with Substantial Scour (Station 3+50)

Two drop structures would need to be added to achieve the equilibrium slope, one at the pedestrian bridge near Station 3+50 (as discussed below) and one near station 5+50. A modified version of the concept design previously discussed should be considered for this drop that would employ a gabion crest that can be tied into the gabion walls. Loose rock riprap should again be employed to allow the drop structure to adjust to potential downcutting.

The pedestrian bridge at Station 3+50 (Figure IX-31) warrants special consideration as it is at risk of structural failure due to downcutting and scour of the abutments. A driveway is also threatened near the bridge due to bank instability. To address the stability of this bridge and protect the nearby driveway, limited bank armoring with an incorporated drop structure is recommended.

Approximately 60 feet of gabion bank armoring along both sides of the channel beneath the bridge will be necessary, with an additional 75 feet along the eastern bank to protect the driveway. A drop structure, similar to those recommended for the rest of this reach, should be incorporated to prevent additional downcutting.

Estimated costs for the recommended structural measures within Reach G are briefly summarized in Tables IV-6 And IV-7. The bridge protection is included in the full stream restoration option and as a separate project since it needs more immediate attention. A more detailed concept opinion of probable construction costs is provided in Chapter XII and a project prioritization is included in Chapter XIII.

Table IX-6	
Reach G Stream Stabilization **Summary of Concept Opinion of Probable Construction Costs**	
Stream Restoration of Entire Reach	
Construction Subtotal	$ 1,509,960.00
Approximate 25% Contingency	$ 377,040.00
Construction Total	$ 1,887,000.00
Appr. 10% for Engineering, Survey, and Environmental Services	$ 189,000.00
Total	**$ 2,076,000.00**

Table IX-7	
Reach G Stream Stabilization **Summary of Concept Opinion of Probable Construction Costs**	
Stabilization of Pedestrian Bridge Only	
Construction Subtotal	$ 195,500.00
Approximately 25% Contingency	$ 48,500.00
Construction Total	$ 244,000.00
Appr. 15% for Engineering, Survey, and Environmental Services	$ 37,000.00
Total	**$ 281,000.00**

G. Inspection and Maintenance

The City of Grand Prairie should consider implementation of a routine field inspection program to monitor the status of the stream stability issues discussed herein. Such a program should focus on problem areas noted. These inspections can be used to help prioritize the necessary improvements and provide the City staff with more detailed knowledge of the stream and impacted facilities. It may be possible to temporarily address or prevent stream stability issues through maintenance, when those issues are detected early through routine inspections.

Most of the areas requiring structural measures described above are too degraded to be addressed by maintenance measures alone; however, there are a number of structures in fair to good condition for which routine inspection and maintenance should substantially minimize degradation. Such maintenance may include removal of vegetation, sealing of concrete joints, clearing of accumulated debris, or adding riprap.

Areas of potential sedimentation should be inspected and cleaned out as appropriate. This is especially true of the Egyptian Way culverts, which have the potential to become blocked to a significant degree. Vegetation and sediment should be removed from this area at regular intervals and before it becomes an issue.

Existing and future gabion walls should be inspected for debris damage and repaired according to the manufacturer's recommendations. Major damage, such as spilled rocks or misaligned baskets, will require an engineer's involvement.

X. DAMS / LEVEES / DETENTION / DRAINAGE REVIEWS

A. Dams, Levees, And Detention Facilities

Data was requested form the City of Grand Prairie concerning known dams, levees, and detention facilities. The City knew of no such facilities within the Arbor Creek watershed. Aerial images and contours were reviewed to look for these facilities; none were identified. During watershed reconnaissance, no such facilities were noticed. Based on this review, it does not appear that any dams, levees, or detention facilities are present in the Arbor Creek watershed.

B. Drainage Reviews

City of Grand Prairie indicated that no drainage reviews were available for the Arbor Creek watershed. This is likely due to the age of the developments within the watershed.

XI. STORM DRAIN OUTFALL ASSESSMENT

The portion of Arbor Creek watershed within the city limits of Grand Prairie (City) contains 15 storm sewer systems that drain into Arbor Creek. Arbor Creek also has 7 culverts from road crossings and 13 concrete flumes draining other developed commercial or residential areas. The condition at the outfall of each drainage element was assessed and ranked according to condition and urgency. The results of this assessment are listed in Table XI-1 highlighting each outfall's condition, assessment criteria category, and ranking. Figure XI-1, the Storm Sewer Outfall Location Map displays the horizontal location of each outfall referenced to the 2009 City aerial photography. A Photograph of each outfall is contained in Appendix C Storm Drain Outfalls. Of note here is that observations of the inlets of each of the 7 road crossing culverts revealed that all appear to be in good condition; no further assessment is included for the inlets, herein.

A. Assessment Resources

The initial ranking of each outfall was determined by referencing several resources. These references include:

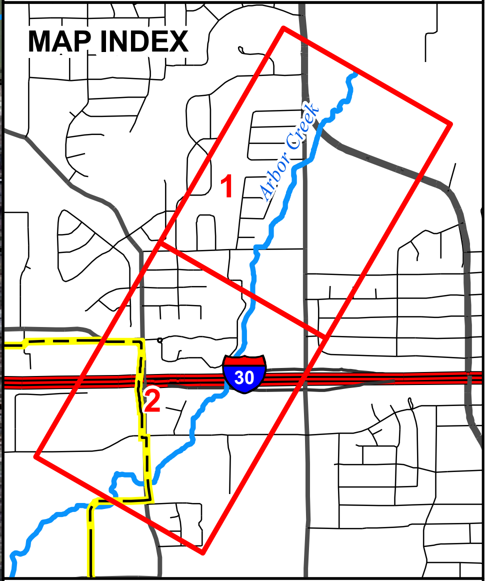
- The City Drainage Design Manual, which notes City requirements for storm drain outfalls
- The City database of field-checked storm drain outfalls, which provided information about the condition of documented outfalls
- Photos obtained from field observations by both OEI and the City provided an up to date assessment of the condition
- City 2009 aerial photos facilitated the creation of an overall vicinity and location map of each outfall

Figure XI-1

STORM SEWER OUTFALL LOCATION MAP (1 OF 2)

KEY TO FEATURES

- STORM SEWER OUTFALL PHOTO ID
- STORM SEWER
- GRAND PRAIRIE CITY LIMIT
- ARBOR CREEK CENTERLINE
- STREET CENTERLINE



0 150 300 600

Scale in Feet

Grand Prairie
TEXAS

CWDMP for Arbor Creek

O'Brien Engineering, Inc.

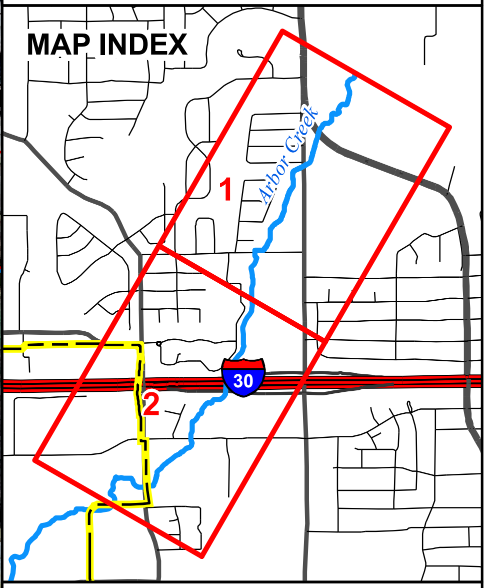
Hydraulics • Hydrology • Civil Engineering
Texas Registered Engineering Firm F-3758

Figure XI-1

STORM SEWER OUTFALL LOCATION MAP (2 OF 2)

KEY TO FEATURES

- STORM SEWER OUTFALL PHOTO ID
- STORM SEWER
- GRAND PRAIRIE CITY LIMIT
- ARBOR CREEK CENTERLINE
- STREET CENTERLINE



0 150 300 600

Scale in Feet

Grand Prairie TEXAS

CWDMP for Arbor Creek

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B. Condition and Criteria

Each storm drain outfall was assigned a condition and an assessment criteria category based on recommendations provided in the 2010 City-Wide Drainage Master Plan Road Map. The four conditions included **1) Good** (requires no remedial maintenance/continued normal inspections, **2) Fair** (may require some remedial maintenance/not immediate), **3) Poor** (requires immediate remedial maintenance), and **4) Failure** (requires design and/or construction in order to correct the problem).

The assessment criteria category assigned to each outfall included one of the following: Structural, No Headwall, RipRap/Scour, Siltation, or Aesthetics. The criteria was assigned by answering various questions including: “Is there a threat to the structural integrity of the outfall?”; “Does the outfall have a headwall?”; “Is erosion control needed at the outfall?”; “Is there siltation at the outfall limiting its conveyance?”; “Is the outlet structure of concern aesthetically?” After each storm drain outfall was assessed based on condition and criteria a number ranking was assigned based on the need for repair (1 being the highest priority). A brief description of each category is provided below.

1. Structural Criteria Category

Outfalls were assigned to the Structural criteria category if the outfall had experienced a structural failure or visible significant degradation of the structure, including large cracks and spalls or exposed steel.

2. RipRap/Scour Criteria Category

Outfalls were assigned to the RipRap/Scour criteria category if the outfall was experiencing erosion or scour either from storm water draining from the storm sewer system or from flows in the receiving creek.

3. Siltation Criteria Category

Outfalls were assigned to the Siltation criteria category if the conveyance in the storm sewer conduit would be restricted due to existing silt deposition.

4. No Headwall Criteria Category

Outfalls were assigned to the No Headwall criteria category if the outfall was constructed without a headwall on the outfall pipe. The City Drainage Design Manual requires all inlets and outfalls on closed conduits to be constructed with City standard or TxDOT standard headwalls.

5. Aesthetics Criteria Category

Outfalls were assigned to the Aesthetics criteria category if the appearance of the structure was significantly and negatively impacted, requiring maintenance. Some examples would be a downed tree near the outfall structure, loose rock, debris, or signs of vandalism.

C. Field Check

Field observations of each outfall were made in July of 2011 to take photographs and document current conditions. Table XI-1, is a summary of the condition assessment of each outfall.

Table XI-1 Storm Drain Outfall Assessment						
Overall Ranking	**Map Photo ID**	**Photo Date**	**Type**	**Condition**	**Criteria**	**Comments**
1	30	7/8/11	Culvert	Failure	Structural	Cracked Headwall Significant Scour
2	1	7/8/11	Flume	Failure	Structural	Structural Damage Significant Erosion
3	12	7/8/11	Storm Sewer Outfall	Poor	Siltation	Significant Siltation
4	13	7/8/11	Culvert	Poor	Siltation	Significant Siltation
5	26	7/8/11	Storm Sewer Outfall	Poor	Aesthetics	Tree/Significant Vegetation
6	32	7/8/11	Flume	Poor	Structural	Significant Erosion Structure OK
7	35	7/8/11	Culvert	Fair	RipRap/Scour	Moderate Scour
8	9	7/8/11	Storm Sewer Outfall	Fair	Aesthetics	Significant Vegetation
9	11	7/8/11	Storm Sewer Outfall	Fair	Aesthetics	Significant Vegetation
10	27	7/8/11	Flume	Fair	Siltation	Significant Vegetation
11	6	7/8/11	Storm Sewer Outfall	Fair	Siltation	Moderate Siltation
12	10	7/8/11	Flume	Fair	Aesthetics	Moderate Vegetation
13	28	7/8/11	Storm Sewer Outfall	Fair	Siltation	Moderate Siltation
14	31	7/8/11	Storm Sewer Outfall	Fair	Aesthetics	Moderate Vegetation and Debris
15	4	7/8/11	Storm Sewer Outfall			Could Not Verify in Field
16	8	7/8/11	Flume			Could Not Verify in Field
17	15	7/8/11	Flume			Could Not Verify in Field
18	33	7/8/11	Flume	Good		
19	2	7/8/11	Storm Sewer Outfall	Good		
20	3	7/8/11	Culvert	Good		
21	5	7/8/11	Culvert	Good		
22	7	7/8/11	Storm Sewer Outfall	Good		
23	14	7/8/11	Storm Sewer Outfall	Good		
24	16	7/8/11	Storm Sewer Outfall	Good		
25	17	7/8/11	Culvert	Good		

Table XI-1 Storm Drain Outfall Assessment						
26	18	7/8/11	Flume	Good		
27	19	7/8/11	Storm Sewer Outfall	Good		
28	20	7/8/11	Flume	Good		
29	21	7/8/11	Storm Sewer Outfall	Good		
30	22	7/8/11	Flume	Good		
31	23	7/8/11	Flume	Good		
32	24	7/8/11	Flume	Good		
33	25	7/8/11	Flume	Good		
34	29	7/8/11	Culvert	Good		
35	34	7/8/11	Storm Sewer Outfall	Good		

D. Outfall Conclusions/Recommendations

The outfall with the highest ranking/priority is located at Tarrant Road, which should be addressed with recommendations provided in Chapters 6 and 7. Significant settlement and erosion has occurred on the eastern part of the downstream headwall and embankment slope. However, if the recommendations in Chapters 6 and 7 will not be implemented immediately, the City should consider maintenance to the part of the headwall and embankment slope experiencing significant erosion and settlement. The northern traffic lane of Tarrant Road appears to be at risk of undermining by significant erosion or settlement which would lead to pavement failure and disruption of traffic on Tarrant Road.

A second outfall categorized as 'Failure' is part of a surface system located in Waggoner Park, which drains surface water runoff from the adjacent ball fields, roads, and parking lots. The foundation of the downstream toe of this concrete flume has eroded and sloughed off into Arbor Creek. Significant undercutting of the remaining flume threatens further collapse of the structure. Due to the proximity and accessibility of this structure to Waggoner Park, OEI recommends immediate repairs to this structure to avoid potential collapse and protection to park visitors within the immediate vicinity of the structure.

The City should proceed with maintenance of the remaining outfalls along Arbor Creek classified as 'Poor' (four, in total). These structures appear to be at risk of either structural damage or reduced flood capacity due to significant silt deposition. Remedial maintenance of the 'Fair' outfalls and continued field inspection of the 'Good' outfalls should be conducted as part of a regular scheduled cycle determined by the City.

1. Recommended Maintenance Activities

i. Structural

Evaluate necessary structural repairs to determine whether outfall replacement is necessary. Restore outfall to adequate operable condition and install erosion protection to prevent future or additional undermining. Design of any replacement structure or structure repairs should be in accordance with the City of Grand Prairie standards.

Estimated Cost: $5,000 - $25,000 per outfall

ii. Siltation/Scour/RipRap

Siltation blocking or restricting flow from the outfall should be removed. Scour protection should be designed to adequately protect structural integrity of the outfall and to prevent erosion and siltation downstream. The *City of Grand Prairie Drainage Design Manual Section 8.9 – Outfall Design Guidelines* contains design criteria and a list of acceptable solutions for outfall protection. Another reference for outfall design is the *North Central Council of Governments iSWM Technical Manual Section 4.0.*

Estimated Cost: $1,000 - $5,000 per outfall

iii. Aesthetics

Remove accumulated debris including vegetation, trees, garbage, and the like from the outfall structure. Repair superficial defects to the outfall structure which could include displaced riprap, vandalism, or overgrown vegetation.

Estimated Cost: $500 - $1,500 per outfall

iv. Continued Monitoring

All outfalls, whether already repaired, scheduled for repair, or categorized as 'Good' in this report should be monitored on a regularly scheduled cycle as determined by the City to ensure that repairs are adequate and to determine where additional maintenance is needed.

XII. PRELIMINARY QUANTITIES/ESTIMATES OF PROBABLE COST

Concept opinions of probable construction costs were prepared for the alternatives discussed in Chapter VII and for the proposed structural channel stability measures discussed in Chapter IX. For the stream stability structural measures, costs were grouped by reach, as discussed in Chapter IX.

The following concept opinions of probable construction costs are based on recent bid tabulations, discussions with contractors, and experience with similar projects in this area. These quantities are based on concept designs, which will require additional analysis and permitting before final design and construction. This process is likely to change the final design and thus the actual construction costs.

All construction cost estimates include a 25 percent contingency cost added as shown. Design fees were based on percentages of the construction cost with contingencies. The design fee percentage varies based on the project cost, since the smaller projects will require a higher percentage for design than the larger projects.

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TABLE XII-1
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: November 17, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Tarrant Road 100-Yr Culvert Option - Existing Width

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 25,000.00	$ 25,000.00
2	Erosion Control	1	LS	$ 15,000.00	$ 15,000.00
3	Traffic Control	1	LS	$ 20,000.00	$ 20,000.00
4	ROW Preparation	1	LS	$ 20,000.00	$ 20,000.00
5	Remove Existing Pavement, Sidewalks, and Driveways	4000	SY	$ 6.50	$ 26,000.00
6	Remove Existing Culverts and Headwalls	1	LS	$ 50,000.00	$ 50,000.00
7	Excavation and Disposal of Ex. Soils	1500	CY	$ 7.00	$ 10,500.00
9	6-10x10 Box Culverts	60	LF	$ 3,800.00	$ 228,000.00
10	Headwalls	130	CY	$ 750.00	$ 97,500.00
11	Select Fill	5,300	CY	$ 17.00	$ 90,100.00
12	8" Thick Concrete Pavement and Stabilized Base	3,200	SY	$ 33.00	$ 105,600.00
13	Pedestrian Guard Rail	300	LF	$ 80.00	$ 24,000.00
14	Concrete Retaining Walls	2,100	SF	$ 40.00	$ 84,000.00
15	Gabion Walls	180	SY	$ 520.00	$ 93,600.00
16	Grouted Riprap Armoring 18" Thick	500	CY	$ 150.00	$ 75,000.00
17	36" Storm Sewer Pipe (Typical)	600	LF	$ 78.00	$ 46,800.00
18	Curb Inlets	6	EA	$ 2,750.00	$ 16,500.00
19	4' Sidewalks	1,120	LF	$ 16.00	$ 17,920.00
20	Curb and Gutter	1,200	LF	$ 24.00	$ 28,800.00
21	Adjust Utilities	1	LS	$ 115,000.00	$ 115,000.00
22	Block Sod and 4" of Top Soil	2,500	SY	$ 2.80	$ 7,000.00
23	Turn Reinforcing Mat	600	SY	$ 3.50	$ 2,100.00
24	Hydromulch	600	SY	$ 0.75	$ 450.00
	Construction Subtotal				$ 1,118,870.00
	Approximate 25% Contigency				$ 280,130.00
	Construction Total				$ 1,399,000.00
	Engineering, Survey, and Environmental for Design	Approximately	10%		$ 140,000.00
	Project Total				$ 1,539,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 111,600.00

Quantities are based on a concept design and are subject to plan revisions and field conditions.

Unit prices shown herein are from recent bid tabulations of projects in the general area of the subject project and input from contractors with experience in this type work. Because of the size and nature of this project, unit prices (and therefore the total cost) are subject to substantial variation, dependant on market conditions, ar current availability of qualified, interested contractors, as well as other typical factors.

This document is released for the purpose of providing a concept opinion of probable construciton cost. It is not to be used for construction, bidding, or permit purposes.

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TABLE XII-2
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: September 16, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Arbor Creek Reach B Stream Stabilization

1 Improved Culvert Outfall, 1 New Drop Structure, and 1 Improved Drop Structure

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 15,000.00	$ 18,000.00
2	Temporary access road	225	LF	$ 25.00	$ 5,625.00
3	Erosion control	1	LS	$ 6,000.00	$ 6,000.00
4	Traffic control	5	DAY	$ 500.00	$ 2,500.00
5	Divert water	1	LS	$ 5,000.00	$ 5,000.00
6	Clear and grub	1000	SY	$ 3.00	$ 3,000.00
7	Tree removal	4	EA	$ 550.00	$ 2,200.00
8	Reinforced concrete	0	CY	$ 700.00	$ -
9	Grouted riprap 24" thick	30	CY	$ 150.00	$ 4,500.00
10	Loose riprap 12" rock, 24" thick	500	CY	$ 115.00	$ 57,500.00
11	Gabions with tie-backs	0	CY	$ 520.00	$ -
12	Gabions without tie-backs	0	CY	$ 400.00	$ -
13	Gabion matttress 12"	0	CY	$ 300.00	$ -
14	Gabion matttress 12", with anchors	0	CY	$ 400.00	$ -
15	Grading - Fill	0	CY	$ 20.00	$ -
16	Grading- Cut	350	CY	$ 15.00	$ 5,250.00
17	Grading - Misc	250	CY	$ 12.00	$ 3,000.00
18	Hydromulch	250	SY	$ 3.00	$ 750.00
19	Plant mixed vegetation	400	SY	$ 10.00	$ 4,000.00
20	Plant trees	4	EA	$ 75.00	$ 300.00
	Construction Subtotal				$ 117,625.00
	Approximate 25% Contigency				$ 29,375.00
	Construction Total				$ 147,000.00
	Engineering, Survey, and Environmental for Design	Approximately		20%	$ 29,000.00
	Project Total				$ 176,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 12,800.00

Quantities are based on a concept design and are subject to plan revisions and field conditions.

Unit prices shown herein are from recent bid tabulations of projects in the general area of the subject project and input from contractors with experience in this type work. Because of the size and nature of this project, unit prices (and therefore the total cost) are subject to substantial variation, dependant on market conditions, ar current availability of qualified, interested contractors, as well as other typical factors.

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TBALE XII-3
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: September 16, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Arbor Creek Reach C Stream Stabilization

1 Improved Drop Structure and 2 Improved Drop Structures/ Utility Crossings

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 15,000.00	$ 15,000.00
2	Temporary access road	825	LF	$ 25.00	$ 20,625.00
3	Erosion control	1	LS	$ 6,000.00	$ 6,000.00
4	Traffic control	4	DAY	$ 500.00	$ 2,000.00
5	Divert water	1	LS	$ 6,000.00	$ 6,000.00
6	Clear and grub	1300	SY	$ 3.00	$ 3,900.00
7	Tree removal	20	EA	$ 500.00	$ 10,000.00
8	Reinforced concrete	23	CY	$ 700.00	$ 16,100.00
9	Grouted riprap 24" thick	30	CY	$ 150.00	$ 4,500.00
10	Loose riprap 12" rock, 24" thick	221	CY	$ 120.00	$ 26,520.00
11	Gabions with tie-backs	70	CY	$ 520.00	$ 36,400.00
12	Gabions without tie-backs	0	CY	$ 400.00	$ -
13	Gabion matttress 12"	0	CY	$ 300.00	$ -
14	Gabion matttress 12", with anchors	0	CY	$ 400.00	$ -
15	Grading - Fill	200	CY	$ 20.00	$ 4,000.00
16	Grading- Cut	0	CY	$ 15.00	$ -
17	Grading - Misc	270	CY	$ 12.00	$ 3,240.00
18	Hydromulch	900	SY	$ 3.00	$ 2,700.00
19	Plant mixed vegetation	330	SY	$ 10.00	$ 3,300.00
20	Plant trees	20	EA	$ 75.00	$ 1,500.00
	Construction Subtotal				$ 161,785.00
	Approximate 25% Contigency				$ 40,215.00
	Construction Total				$ 202,000.00
	Engineering, Survey, and Environmental for Design	Approximately		15%	$ 30,000.00
	Project Total				$ 232,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 16,800.00

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TABLE XII-4
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: September 16, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Arbor Creek Reach D Stream Stabilization

1 Sanitary Sewer Encasement

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 2,500.00	$ 2,500.00
2	Temporary access road	0	LF	$ 25.00	$ -
3	Erosion control	0	LS	$ 5,000.00	$ -
4	Traffic control	0	DAY	$ 500.00	$ -
5	Divert water	1	LS	$ 2,000.00	$ 2,000.00
6	Clear and grub	20	SY	$ 10.00	$ 200.00
7	Tree removal	0	EA	$ 500.00	$ -
8	Reinforced concrete	12	CY	$ 550.00	$ 6,600.00
9	Grouted riprap 24" thick	0	CY	$ 150.00	$ -
10	Loose riprap 12" rock, 24" thick	0	CY	$ 120.00	$ -
11	Gabions with tie-backs	0	CY	$ 520.00	$ -
12	Gabions without tie-backs	0	CY	$ 400.00	$ -
13	Gabion matttress 12"	0	CY	$ 300.00	$ -
14	Gabion matttress 12", with anchors	0	CY	$ 400.00	$ -
15	Grading - Fill	0	CY	$ 20.00	$ -
16	Grading- Cut	16	CY	$ 15.00	$ 240.00
17	Grading - Misc	0	CY	$ 12.00	$ -
18	Sod	30	SY	$ 5.00	$ 150.00
19	Plant mixed vegetation	0	SY	$ 10.00	$ -
20	Plant trees	0	EA	$ 75.00	$ -
	Construction Subtotal				$ 11,690.00
	Approximate 25% Contigency				$ 3,310.00
	Construction Total				$ 15,000.00
	Engineering, Survey, and Environmental for Design	Approximately		20%	$ 3,000.00
	Project Total				$ 18,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 1,300.00

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TABLE XII-5
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: November 20, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Arbor Creek Reach E Stream Stabilization

1 Improved Drop Structure and 1 New Drop Structures

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 15,000.00	$ 15,000.00
2	Temporary access road	200	LF	$ 25.00	$ 5,000.00
3	Erosion control	1	LS	$ 8,000.00	$ 8,000.00
4	Traffic control	0	DAY	$ 500.00	$ -
5	Divert water	1	LS	$ 6,000.00	$ 6,000.00
6	Clear and grub	500	SY	$ 3.00	$ 1,500.00
7	Tree removal	10	EA	$ 500.00	$ 5,000.00
8	Reinforced concrete	0	CY	$ 700.00	$ -
9	Grouted riprap 24" thick	0	CY	$ 150.00	$ -
10	Loose riprap 12" rock, 24" thick	300	CY	$ 120.00	$ 36,000.00
11	Gabions with tie-backs	0	CY	$ 520.00	$ -
12	Gabions without tie-backs	0	CY	$ 400.00	$ -
13	Gabion matttress 12"	0	CY	$ 300.00	$ -
14	Gabion matttress 12", with anchors	0	CY	$ 400.00	$ -
15	Grading - Fill	0	CY	$ 20.00	$ -
16	Grading- Cut	125	CY	$ 15.00	$ 1,875.00
17	Grading - Misc	200	CY	$ 12.00	$ 2,400.00
18	Hydromulch	65	SY	$ 4.00	$ 260.00
19	Plant mixed vegetation	250	SY	$ 10.00	$ 2,500.00
20	Plant trees	10	EA	$ 75.00	$ 750.00
	Construction Subtotal				$ 84,285.00
	Approximate 25% Contigency				$ 20,715.00
	Construction Total				$ 105,000.00
	Engineering, Survey, and Environmental for Design	Approximately		20%	$ 21,000.00
	Project Total				$ 126,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 9,100.00

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TABLE XII-6
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: September 7, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Arbor Creek Reach F Stream Stabilization

2 New Drop Structures, 1 Gabion Repair/Drop Structure, 1 Section of Bank Armoring

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 20,000.00	$ 20,000.00
2	Temporary access road	235	LF	$ 25.00	$ 5,875.00
3	Erosion control	1	LS	$ 10,000.00	$ 10,000.00
4	Traffic control	5	DAY	$ 500.00	$ 2,500.00
5	Divert water	1	LS	$ 8,000.00	$ 8,000.00
6	Clear and grub	1100	SY	$ 4.00	$ 4,400.00
7	Tree removal	25	EA	$ 500.00	$ 12,500.00
8	Reinforced concrete	10	CY	$ 700.00	$ 7,000.00
9	Grouted riprap 24" thick	65	CY	$ 150.00	$ 9,750.00
10	Loose riprap 12" rock, 24" thick	150	CY	$ 120.00	$ 18,000.00
11	Gabions with tie-backs	180	CY	$ 520.00	$ 93,600.00
12	Gabions without tie-backs	70	CY	$ 400.00	$ 28,000.00
13	Gabion matttress 12"	0	CY	$ 300.00	$ -
14	Gabion matttress 12", with anchors	35	CY	$ 400.00	$ 14,000.00
15	Grading - Fill	0	CY	$ 20.00	$ -
16	Grading- Cut	200	CY	$ 15.00	$ 3,000.00
17	Grading - Misc	460	CY	$ 12.00	$ 5,520.00
18	Hydromulch	250	SY	$ 4.00	$ 1,000.00
19	Plant mixed vegetation	560	SY	$ 10.00	$ 5,600.00
20	Plant trees	25	EA	$ 75.00	$ 1,875.00
	Construction Subtotal				$ 250,620.00
	Approximate 25% Contigency				$ 62,380.00
	Construction Total				$ 313,000.00
	Engineering, Survey, and Environmental for Design	Approximately	15%		$ 47,000.00
	Project Total				$ 360,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 26,100.00

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TABLE XII-7
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: November 20, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Arbor Creek Reach G Stream Stabilization

Stream Restoration of Entire Reach

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 20,000.00	$ 20,000.00
2	Temporary access road	0	LF	$ 25.00	$ -
3	Erosion control	1	LS	$ 20,000.00	$ 20,000.00
4	Traffic control	1	DAY	$ 500.00	$ 500.00
5	Divert water	1	LS	$ 15,000.00	$ 15,000.00
6	Clear and grub	3500	SY	$ 3.00	$ 10,500.00
7	Tree removal	20	EA	$ 450.00	$ 9,000.00
8	Reinforced concrete	20	CY	$ 700.00	$ 14,000.00
9	Grouted riprap 24" thick	0	CY	$ 150.00	$ -
10	Loose riprap 12" rock, 24" thick	150	CY	$ 120.00	$ 18,000.00
11	Gabions with tie-backs	2,400	CY	$ 520.00	$ 1,248,000.00
12	Gabions without tie-backs	25	CY	$ 400.00	$ 10,000.00
13	Gabion matttress 12"	0	CY	$ 300.00	$ -
14	Gabion matttress 12", with anchors	0	CY	$ 400.00	$ -
15	Grading - Fill	0	CY	$ 20.00	$ -
16	Grading- Cut	15,620	CY	$ 8.00	$ 124,960.00
17	Grading - Misc	0	CY	$ 12.00	$ -
18	Hydromulch	1,500	SY	$ 2.00	$ 3,000.00
19	Plant mixed vegetation	1,000	SY	$ 9.00	$ 9,000.00
20	Plant trees	20	EA	$ 400.00	$ 8,000.00
	Construction Subtotal				$ 1,509,960.00
	Approximate 25% Contigency				$ 377,040.00
	Construction Total				$ 1,887,000.00
	Engineering, Survey, and Environmental for Design	Approximately	10%		$ 189,000.00
	Project Total				$ 2,076,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 150,500.00

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TABLE XII-8
CONCEPTUAL OPINION OF PROBABLE CONSTRUCTION COST

DATE: September 16, 2011

City of Grand Prairie Master Drainage Plan for Arbor Creek

Arbor Creek Reach G Bridge Stabilization

Scour Control Around Pedestrian Bridge

ITEM No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE	TOTAL
	Base Items				
1	Mobilization	1	LS	$ 7,500.00	$ 7,500.00
2	Temporary access road	0	LF	$ 25.00	$ -
3	Erosion control	1	LS	$ 5,000.00	$ 5,000.00
4	Traffic control	1	DAY	$ 500.00	$ 500.00
5	Divert water	1	LS	$ 3,500.00	$ 3,500.00
6	Clear and grub	500	SY	$ 4.00	$ 2,000.00
7	Tree removal	7	EA	$ 500.00	$ 3,500.00
8	Reinforced concrete	12	CY	$ 700.00	$ 8,400.00
9	Grouted riprap 24" thick	0	CY	$ 150.00	$ -
10	Loose riprap 12" rock, 24" thick	0	CY	$ 120.00	$ -
11	Gabions with tie-backs	300	CY	$ 520.00	$ 156,000.00
12	Gabions without tie-backs	0	CY	$ 400.00	$ -
13	Gabion matttress 12"	0	CY	$ 300.00	$ -
14	Gabion matttress 12", with anchors	0	CY	$ 400.00	$ -
15	Grading - Fill	0	CY	$ 20.00	$ -
16	Grading- Cut	0	CY	$ 8.00	$ -
17	Grading - Misc	300	CY	$ 12.00	$ 3,600.00
18	Hydromulch	0	SY	$ 2.00	$ -
19	Plant mixed vegetation	200	SY	$ 10.00	$ 2,000.00
20	Plant trees	7	EA	$ 500.00	$ 3,500.00
	Construction Subtotal				$ 195,500.00
	Approximate 25% Contigency				$ 48,500.00
	Construction Total				$ 244,000.00
	Engineering, Survey, and Environmental for Design	Approximately	15%		$ 37,000.00
	Project Total				$ 281,000.00
	Total Annual Cost (7% Interest for 50 yrs)				$ 20,400.00

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XIII. EVALUATION & PRIORITIZATION/PHASING & IMPLEMENTATION

A. Evaluation & Prioritization

Eight total improvement alternatives have been developed for Arbor Creek to address issues such as road overtopping and stream stability. The first alternative is for improvements to Tarrant Road that would raise the road and increase the number and size of culverts such that the crossing can handle the 1% AC flood without overtopping. The other seven alternatives are structural measures to address stream stability issues.

Each alternative was ranked based on the process described in Section II.G of the *City of Grand Prairie City-Wide Drainage Master Plan Road Map*. Table XIII-1 shows a summary of the ranking process. The Step 4 initial ranking process produced several ties. Step 5 in the ranking process is designed to break these ties, but is not helpful for deciding between two or more tying projects on the same reach of stream and it gives no weight to varying urgencies. Ties in the initial rankings, therefore, were instead broken by factors including cost and exigency. Also, some stream stability issues need repairs sooner than others, which fact is not accounted for in the standard Road Map method.

B. Phasing & Implementation

1. Final Short-term Priorities Implementation

The City Road Map suggests that short-term priority Capital Improvement Projects (CIPs) could generally be described as those projects with an initial ranking factor of 1, 2, or 3. Only one of the projects considered here meets that requirement. Other considerations are warranted, particularly the likelihood of damage to infrastructure caused by an extended delay in consideration. It is recommended that the potential for damage caused by delay be considered in ranking projects. Ultimately, the projects discussed herein will need to be compared to those in the Master

Drainage Plans for the other watersheds to fully and properly prioritize them. It is recommended that the projects with a final ranking of *one* through *four* be given short-term consideration.

2. Final Long-term Plan Implementation

The projects with a final ranking of *five* or greater can be delayed in implementation and should therefore be given a long-term priority. These projects should be monitored to determine the need to adjust their priorities. Phasing of portions of some of these projects may be warranted, particularly to protect utility crossings, when the full project cannot be immediately implemented.

The following considerations should be given to projects that cannot be implemented in the short-term:

- Consider use of the flood warning system to protect citizens from road overtopping events until adequate funding can be obtained for road crossing improvements
- Consider buy-outs of structures threatened by bank instability
- Maintenance of threatened utilities to help mitigate damage
- Routine inspection of facilities in and near the channel to detect potential problems and avert failure
- Consider removal of certain facilities threatened by stream instability rather than implementing structural measures to protect them

Table XIII-1 Preliminary Short-Term & Long-Term Implementation Plan

Arbor Creek

	Capital Improvement Project	Project Size & Short-Term/Long-Term	Step 1 - Initial Ranking Factor - Estimate of Probable Cost vs. # Structures Benefited [1]			Step 2 - Second Ranking Factor - Cost to Benefit of Roadway Number of Citizens Impacted [2]							Step 3 - Tax Value of Benefited Property Structures [7]		Sum of 1st, 2nd, and 3rd Factors - Step 4	Initial Rank - Step 4	100-Year Ultimate Discharge at CIP Location - Step 5		Final Rank - Step 6
			# Structures	Cost	1st Factor [1]	Type	Current Roadway Flood Event Protection	Roadway % Citizens Protected Currently.[4]	Roadway % Citizens Protected After Alt.[4]	Roadway # Citizens Impacted [5]	Cost to Benefit Roadway # Citizens Impacted [6]	2nd Factor	Tax Value of Property Structures Benefited	3rd Factor	Total	Rank [8]	Ultimate Q_{100}	Sorting [9]	Rank [10]
1	**Alt. 1 -** Tarrant Road	Large/Short-Term	0	$1,539,000	**5**	M4U	1	0%	100%	6760	$227.66	**1**	$0	**20**	**26**	**2**	4,130	**1**	1
5	**Alt. 2 -** Reach B Stream Stability Measures	Small/Long-Term	0	$176,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	4,130	**5**	5
2	**Alt. 3 -** Reach C Stream Stability Measures	Small/Short-Term	0	$232,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	2,630	**2**	2
3	**Alt. 4 -** Reach D Stream Stability Measures	Small/Short-Term	0	$18,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	2,890	**3**	3
6	**Alt. 5 -** Reach E Stream Stability Measures	Small/Long-Term	0	$126,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	2,890	**6**	6
4	**Alt. 6 -** Reach F Stream Stability Measures	Small/Short-Term	0	$360,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	3,440	**4**	4
8	**Alt. 7 -** Reach G Stream Rehabilitation	Large/Long-Term	0	$2,076,000	**5**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**27**	**3**	3,440	**8**	8
7	**Alt. 8 -** Reach G Pedestrian Bridge Impr.	Small/Long-Term	0	$244,000	**3**	NA	NA	NA	NA	NA	NA	**2**	$0	**20**	**25**	**1**	3,440	**7**	7

1 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 1
2 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 2
3 Based on approximation, using logarithmic chart, with 1-Year Event coverage protecting 0% of traffic volume and 100-Year Event coverage protecting 100% of traffic volume
4 Percent Impacted = 100% minus % of Roadway Citizens Protected (approximate)
5 Number Impacted = % Impacted multiplied by [No. Lanes * 4 Hours Impacted * Hourly Volume Per Lane * Level of Service "C" Traffic Volume]
6 Cost of CIP divided by Roadway # Citizens Impacted
7 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 3
8 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 4
9 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 5 -- This ranking was modified because all alternatives are on the same stream. Instead of flow rate, the immediacy of the needs for each alternative and its costs were used create rankings.
10 Refer to City-Wide Drainage Master Plan Road Map, Section II.G - Implementation Plan - Step 6

Additional Notes:

a. Phased projects shall be ranked in order of Phasing (i.e. Phase 1 shall be ranked higher than Phase 2, etc.)

b. In Step 5, when comparing projects between two different watersheds: If two projects have same rank in Step 4 and need to be sorted, but have similar 100-Year Ultimate Discharges, then projects should be ranked in order of lowest cost estimate

XIV. SHORT TERM PRIORITIES & LONG TERM PLAN

A. Short-Term Priorities Implementation

None of the projects involve structure flooding, and are thus given lower priority in the Road Map methodology; however, all of the projects considered for Arbor Creek involve infrastructure, such as sanitary sewer lines, or they affect public safety, such as the Tarrant Road improvements. This fact resulted in many ties in the project rankings, as discussed in Chapter XII. Ultimately the project priority was determined based on its exigency, the relative cost of the repair (e.g. a very inexpensive repair is ranked higher), and the amount of public benefit.

Based on this analysis, the projects with final rankings of *one* through *four* should be considered short-term projects. These all have some sort of public infrastructure that is at risk of failing and/or a residence that is threatened. The costs of these projects are likely to grow, if not addressed in the short-term, as additional damage occurs. If it is not feasible to complete these projects, as proposed, on a short-term basis, then consideration should be given to other means of its accomplishment or to removing the need of the project altogether. These options could include removal or relocation of the infrastructure in question, buy-outs of homes, phasing the project, or regular maintenance to address deterioration on an ongoing basis.

While improvements to Tarrant Road are being considered, a flood warning system should be considered to help protect citizens during an overtopping event. Such a system could utilize the rain gage and stream gaging station that has been previously installed at that location.

B. Long-Term Plan Implementation

The proposed projects with final rankings of *five* through *eight* can be considered long-term projects, but will still need to be addressed in a reasonable time frame. Routine inspection and maintenance of these areas should be considered as having the benefit of requiring a minimal expense to delay a much greater expense, of course, but also of providing early indication of accelerating degradation and the need for adjusting priorities. Some projects may need to be pursued in phases or split up if the threat to the infrastructure increases.

The lowest ranked alternatives are improvements to the stream in Waggoner Park. These received lowest priority due to cost and the lack of critical infrastructure. This should not be taken as an indication that there is no threat to existing infrastructure. As previously discussed, there is serious channel degradation that threatens a pedestrian bridge (Alternative 8 would repair just the bridge area) and adjacent driveways (Alternative 7 would restore the entire reach). These alternatives should be considered in coordination with other relevant City departments to determine an appropriate course of action to protect the park infrastructure.

As with short-term projects, consideration should be given to routine inspection that would allow for early detection of immediate threats to infrastructure. Immediate threats may warrant remedial maintenance, increasing the project's priority, or consideration of phasing the project to address the more immediate needs. Other approaches may eliminate the need for certain portions of the projects, such as buy-outs of structures or relocation of infrastructure.

XV. MASTER PLAN STUDY WRAP-UP & RECOMMENDATIONS

The purpose of this City-Wide Drainage Master Plan for Arbor Creek is to evaluate the watershed and assess conditions relating to flooding and channel stability, and to suggest measures to address and mitigate problem areas. This Plan provides details of the watershed and modeling results for the 1% AC floodplain under ultimate development conditions. A geomorphologic study was completed based on the modeling results above and field measurements and observations. Results from these analyses were utilized to develop a set of improvement recommendations to address issues related to road overtopping, scour, and channel instability. These recommendations, when combined with those from the other watersheds, can be used as the basis for a capital improvement program. The following sections summarize the recommendations in the rest of the report.

A. Streams and Open Channels

Floodplain mapping developed in this study shows that 14 structures are in the 1% AC floodplain. Most of these structures are apartments in the reaches upstream of IH-30. The culverts beneath IH-30 are undersized and will cause a substantial backwater condition during high flows. This same backwater contributed to the overtopping of Tarrant Road, even during flood events as low as the 50% AC (2-year) flood. Consideration was given to improvements to this area for reducing flooding and for mitigating the overtopping of Tarrant Road. These improvements are discussed in Chapter VII.

B. Stream Stability

The geomorphologic analysis of the stream provided valuable information that can be used in evaluating current and future stream stability issues. These included equilibrium channel slopes, meander migration rates, and stable side slopes. With this information, erosion hazard setback distances can be determined for future development so that additional problem areas can be minimized.

A number of stream stability issues were found during this study, mostly caused by downcutting of the channel as it approaches its equilibrium slope. Concept designs for structural measures to address these issues were prepared, along with cost estimates. Because many of the structural measures are inter-related, they were grouped together by reach, with each reach treated as a single project. Most of the measures considered are drop structures, which will help control downcutting and reduce the chances of additional stability problems in the future. When installed at utility crossings, the drop structures can also help protect existing utilities. Chapter IX discusses stream stability issues and protective measures in greater detail.

C. Improvement Project Prioritization

The proposed stream stability and bridge improvement projects were ranked based on criteria discussed in the City-Wide Drainage Master Plan Road Map. Details of these rankings are provided in Chapter XIII.

D. Storm Drain Outfalls

Storm drain outfalls were assessed based on the current condition and then prioritized based on their maintenance requirements. Chapter XI provides more information on this process and the results.

E. Other Drainage Facilities

Data on the Arbor Creek watershed was assessed to look for the presence of other drainage facilities, such as detention ponds, dams, and levees. No such facilities were found to be present based on the available data. Analysis of the storm sewer systems was not included in this study. Data on existing reviews of drainage systems was not available for analysis.

F. Recommendations

Based on the analyses performed in this study the following recommendations are made. Each section in this report provides additional detail for these recommendations.

- The City should enforce its floodplain development standards to ensure that new flooding problems are minimized.
- Future development near the channel should consider the erosion hazard setback procedures outlined in Chapter IX, which are a modification of those discussed in the Drainage Manual.
- The City should consider the proposed improvements projects, which have been ranked in Chapter XIII. Many of these projects will prevent additional problems from forming by stabilizing the channel.
- Consideration should be given to routine inspection to find problems early and assess project priority in the future.
- Maintenance of outfalls, utility crossings, and other areas can help prevent future problems and prolong the life of existing facilities until they can be addressed through the proposed projects.
- If projects cannot be completed in a timely manner, then consideration should be given to phasing the projects to allow higher priority portions to be addressed sooner.
- Consideration of buy-outs or removing/relocating facilities may be warranted if it proves less costly than the proposed improvements.

G. Master Drainage Plan Maintenance

The City-Wide Drainage Master Plan should be maintained to keep it relevant and accurate. Future field assessments, flood studies, LOMRs, detention ponds, storm drain studies, improvements, and the like should be incorporated or added as appropriate.

Appendix A
Hydrologic and Hydraulic Data

Hydrologic Parameters & Calculations

Rainfall Depths
County: Dallas-Tarrant

Duration	Return Period							
	1	2	5	10	25	50	100	500
5 min	0.39	0.49	0.57	0.63	0.73	0.80	0.87	1
15 min	0.76	1.04	1.22	1.36	1.56	1.71	1.87	2.2
60 min	1.49	1.85	2.45	2.86	3.35	3.82	4.25	5.40
2 hrs	1.81	2.22	3.00	3.55	4.15	4.65	5.20	6.60
3 hrs	1.99	2.45	3.30	3.85	4.55	5.15	5.70	7.40
6 hrs	2.41	2.91	3.90	4.65	5.45	6.20	6.92	8.80
12 hrs	2.80	3.45	4.70	5.50	6.50	7.35	8.40	10.50
24 hrs	3.21	3.95	5.40	6.40	7.50	8.52	9.55	12.00

* Obtained from City of Grand Prairie Drainage Design Manual

Time of Concentration Computation
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n		End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)	
A5									
SHEET	50	0.0100	0.41	GRASS, BERMUDA				0.231	
SHALLOW	1221	0.0440	0.025	PAVED				0.080	Along Egyptian Way (no Ditch)
CHANNEL	2640	0.0072	0.045		81.50	70.40	3.09	0.237	U/S of 161 XS 1136 from RAS (B2B)
CHANNEL	891	0.0011	0.060		216.30	78.34	1.62	0.153	D/S of 161 XS 2562 from RAS (B2B)
							Time of Conc (hrs)	0.701	
							Lag Time (hrs)	**0.420**	
							Lag Time (min)	25.218	
A4									
SHEET	100	0.01	0.41	GRASS, BERMUDA				0.461	
SHALLOW	300	0.023	3.9	PAVED				0.027	First 300 feet along I-30
CHANNEL	1337	0.02	0.013		3	6.32	9.773	0.038	Channel flow V-ditch along I-30, 1' deep, 6' wide
CHANNEL	432	0.046	0.013		5.94	8.64	20	0.006	33-inch RCP along I-30
CHANNEL	2150	0.021	0.045		520.08	125.28	12.442	0.048	Arbor Creek XS 4832 - Uniform channel
							Time of Conc (hrs)	0.58	
							Lag Time (hrs)	**0.348**	
							Lag Time (min)	20.880	
A3									
SHEET	50	0.01	0.41	GRASS, BERMUDA				0.265	
SHALLOW	670	0.075		PAVED				0.033	
CHANNEL	1157	0.029	0.013		3.14	6.28	12.36	0.026	24-inch RCP
CHANNEL	705	0.039	0.045		60	15.42	16.319	0.012	
CHANNEL	1633	0.005	0.045		136.8	68.6	3.718	0.122	D/S of Tarrant Rd XS 6968 from RAS (B2B)
							Time of Conc (hrs)	0.458	
							Lag Time (hrs)	**0.275**	
							Lag Time (min)	16.488	
A2									
SHEET	25	0.01	0.41	GRASS, BERMUDA				0.152	
SHALLOW	360	0.013		PAVED				0.043	
SHALLOW	300	0.013		UNPAVED				0.045	
CHANNEL	150	0.005	0.013		81	36	13.9	0.003	9 by 9 Box Culvert
CHANNEL	1100	0.01	0.013		7.07	9.42	9.549	0.032	36-inch RCP (assumed)
CHANNEL	1350	0.0254	0.06		255.62	218.18	4.412	0.085	Unnamed Tributary - XS extracted
CHANNEL	2122	0.008	0.06		270	65	5.723	0.103	Arbor Creek XS 9526 - Uniform channel - B2B
							Time of Conc (hrs)	0.463	
							Lag Time (hrs)	**0.278**	
							Lag Time (min)	16.668	
A1									
SHEET	100	0.01	0.011	SMOOTH SURFACE				0.024	
SHALLOW	643	0.0031	0.025	PAVED				0.158	
CHANNEL	1057	0.0095	0.013		9.62	10.99	10.125	0.029	48 - inch RCP
CHANNEL	1177	0.021	0.013		28.27	18.85	21.796	0.015	72-inch RCP
CHANNEL	2118	0.0052	0.045		89.85	51.24	3.481	0.169	XS Extracted - B2B
CHANNEL	700	0.0091	0.013		28.27	18.85	14.957	0.013	72-inch RCP
CHANNEL	779	0.0128	0.013		50.26	25.13	19.672	0.011	96-inch RCP
							Time of Conc (hrs)	0.419	
							Lag Time (hrs)	**0.251**	
							Lag Time (min)	15.084	

Land Use-Curve Number Reference Table
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

LU Code	Category	Landuse	A	B	C	D
111.1	Residential - 1/8 ac lots	Single Family	77	85	90	92
111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87
112	Residential	Multi-family	77	85	90	92
121	Commercial	Office	89	92	94	95
122	Commercial	Retail	89	92	94	95
122.1	Commercial	Large Retail	98	98	98	98
123	Government/Education	Institutional	89	92	94	95
124	Commercial	Hotel/Motel	89	92	94	95
131	Industrial	Industrial	81	88	91	93
141	Infrastructure	Transportation	98	98	98	98
143	Infrastructure	Utilities	89	92	94	95
171	Dedicated	Parks	39	61	74	80
300	Undeveloped	Vacant - open space	25	55	70	78
500	Water	Water	100	100	100	100
600	Woods	Grass combination	43	65	76	82
610	Woods	Fair	36	60	73	79

Curve Number Computations (Existing Conditions)
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

NAME	LU Code	Category	Landuse	A	B	C	D	Selected CN	HYDGRP	Basin Area (Acres)	Poly Area (Acres)	Weighted CN
A1	121	Commercial	Office	89	92	94	95	94	C	478.09	1.75	0.34
A1	121	Commercial	Office	89	92	94	95	95	D	478.09	4.22	0.84
A1	122	Commercial	Retail	89	92	94	95	95	D	478.09	17.41	3.46
A1	122.1	Commercial	Large Retail	98	98	98	98	98	C	478.09	3.88	0.80
A1	122.1	Commercial	Large Retail	98	98	98	98	98	D	478.09	44.63	9.15
A1	123	Government/Education	Institutional	89	92	94	95	94	C	478.09	1.15	0.23
A1	123	Government/Education	Institutional	89	92	94	95	95	D	478.09	0.20	0.04
A1	124	Commercial	Hotel/Motel	89	92	94	95	95	D	478.09	5.45	1.08
A1	131	Industrial	Industrial	81	88	91	93	91	C	478.09	7.10	1.35
A1	131	Industrial	Industrial	81	88	91	93	91	C	478.09	0.05	0.01
A1	131	Industrial	Industrial	81	88	91	93	93	D	478.09	211.82	41.20
A1	141	Infrastructure	Transportation	98	98	98	98	98	C	478.09	6.69	1.37
A1	141	Infrastructure	Transportation	98	98	98	98	98	C	478.09	1.55	0.32
A1	141	Infrastructure	Transportation	98	98	98	98	98	D	478.09	128.36	26.31
A1	300	Undeveloped	Vacant - open space	25	55	70	78	70	C	478.09	0.49	0.07
A1	300	Undeveloped	Vacant - open space	25	55	70	78	70	C	478.09	0.24	0.04
A1	300	Undeveloped	Vacant - open space	25	55	70	78	78	D	478.09	42.81	6.98
A1	610	Woods	Fair	36	60	73	79	79	D	478.09	0.29	0.05
											478.09	**93.64**
A2	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	87	D	249.66	4.89	1.70
A2	121	Commercial	Office	89	92	94	95	95	D	249.66	5.24	1.99
A2	131	Industrial	Industrial	81	88	91	93	88	B	249.66	4.17	1.47
A2	131	Industrial	Industrial	81	88	91	93	93	D	249.66	117.01	43.59
A2	141	Infrastructure	Transportation	98	98	98	98	98	B	249.66	1.08	0.42
A2	141	Infrastructure	Transportation	98	98	98	98	98	D	249.66	36.29	14.25
A2	300	Undeveloped	Vacant - open space	25	55	70	78	78	D	249.66	10.05	3.14
A2	500	Water	Water	100	100	100	100	100	D	249.66	0.58	0.23
A2	610	Woods	Fair	36	60	73	79	60	B	249.66	15.22	3.66
A2	610	Woods	Fair	36	60	73	79	79	D	249.66	55.13	17.44
											249.66	**87.90**
A3	112	Residential	Multi-family	77	85	90	92	85	B	114.04	0.37	0.28
A3	112	Residential	Multi-family	77	85	90	92	92	D	114.04	37.48	30.24
A3	122	Commercial	Retail	89	92	94	95	92	B	114.04	0.44	0.35
A3	122	Commercial	Retail	89	92	94	95	95	D	114.04	5.91	4.92
A3	131	Industrial	Industrial	81	88	91	93	88	B	114.04	0.02	0.02
A3	131	Industrial	Industrial	81	88	91	93	93	D	114.04	11.32	9.23
A3	141	Infrastructure	Transportation	98	98	98	98	98	B	114.04	1.34	1.15
A3	141	Infrastructure	Transportation	98	98	98	98	98	D	114.04	32.02	27.52
A3	143	Infrastructure	Utilities	89	92	94	95	92	B	114.04	0.66	0.53
A3	143	Infrastructure	Utilities	89	92	94	95	95	D	114.04	0.64	0.53
A3	300	Undeveloped	Vacant - open space	25	55	70	78	78	D	114.04	3.99	2.73
A3	610	Woods	Fair	36	60	73	79	60	B	114.04	10.77	5.67
A3	610	Woods	Fair	36	60	73	79	79	D	114.04	9.08	6.29
											114.04	**89.46**
A4	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	87	D	137.16	19.31	12.25
A4	112	Residential	Multi-family	77	85	90	92	85	B	137.16	3.46	2.14
A4	112	Residential	Multi-family	77	85	90	92	92	D	137.16	18.44	12.37
A4	122	Commercial	Retail	89	92	94	95	95	D	137.16	0.00	0.00
A4	123	Government/Education	Institutional	89	92	94	95	95	D	137.16	0.51	0.35
A4	131	Industrial	Industrial	81	88	91	93	93	D	137.16	5.34	3.62
A4	141	Infrastructure	Transportation	98	98	98	98	98	B	137.16	5.03	3.59
A4	141	Infrastructure	Transportation	98	98	98	98	98	D	137.16	55.88	39.93
A4	300	Undeveloped	Vacant - open space	25	55	70	78	55	B	137.16	4.48	1.80
A4	300	Undeveloped	Vacant - open space	25	55	70	78	78	D	137.16	12.85	7.31
A4	500	Water	Water	100	100	100	100	100	B	137.16	0.12	0.09
A4	500	Water	Water	100	100	100	100	100	D	137.16	0.05	0.04
A4	600	Woods	Grass combination	43	65	76	82	82	D	137.16	1.62	0.97
A4	610	Woods	Fair	36	60	73	79	60	B	137.16	4.74	2.07
A4	610	Woods	Fair	36	60	73	79	79	D	137.16	5.33	3.07
											137.16	**89.59**

Curve Number Computations (Existing Conditions)
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

NAME	LU Code	Category	Landuse	A	B	C	D	Selected CN	HYDGRP	Basin Area (Acres)	Poly Area (Acres)	Weighted CN
A5	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	75	B	162.21	2.38	1.10
A5	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	87	D	162.21	54.50	29.23
A5	121	Commercial	Office	89	92	94	95	95	D	162.21	1.95	1.14
A5	122	Commercial	Retail	89	92	94	95	95	D	162.21	0.80	0.47
A5	123	Government/Education	Institutional	89	92	94	95	92	B	162.21	0.76	0.43
A5	123	Government/Education	Institutional	89	92	94	95	95	D	162.21	4.14	2.42
A5	141	Infrastructure	Transportation	98	98	98	98	98	D	162.21	0.00	0.00
A5	141	Infrastructure	Transportation	98	98	98	98	98	B	162.21	17.20	10.39
A5	141	Infrastructure	Transportation	98	98	98	98	98	D	162.21	52.11	31.48
A5	171	Dedicated	Parks	39	61	74	80	61	B	162.21	15.42	5.80
A5	171	Dedicated	Parks	39	61	74	80	80	D	162.21	2.00	0.99
A5	300	Undeveloped	Vacant - open space	25	55	70	78	78	D	162.21	5.24	2.52
A5	610	Woods	Fair	36	60	73	79	60	B	162.21	2.25	0.83
A5	610	Woods	Fair	36	60	73	79	79	D	162.21	3.46	1.69
											162.21	**88.49**

Curve Number Computations (Ultimate Conditions)
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

NAME	LU Code	Category	Landuse	A	B	C	D	Selected CN	HYDGRP	Basin Area (Acres)	Poly Area (Acres)	Weighted CN
A1	121	Commercial	Office	89	92	94	95	95	D	478.09	4.2190	0.84
A1	121	Commercial	Office	89	92	94	95	94	C	478.09	1.7530	0.34
A1	122	Commercial	Retail	89	92	94	95	95	D	478.09	22.7066	4.51
A1	122.1	Commercial	Large Retail	98	98	98	98	98	D	478.09	54.3590	11.14
A1	122.1	Commercial	Large Retail	98	98	98	98	98	C	478.09	3.8799	0.80
A1	123	Government/Education	Institutional	89	92	94	95	95	D	478.09	0.2003	0.04
A1	123	Government/Education	Institutional	89	92	94	95	94	C	478.09	1.1484	0.23
A1	124	Commercial	Hotel/Motel	89	92	94	95	95	D	478.09	5.4495	1.08
A1	131	Industrial	Industrial	81	88	91	93	93	D	478.09	239.9770	46.68
A1	131	Industrial	Industrial	81	88	91	93	91	C	478.09	7.5965	1.45
A1	131	Industrial	Industrial	81	88	91	93	91	C	478.09	0.2897	0.06
A1	141	Infrastructure	Transportation	98	98	98	98	98	D	478.09	128.3968	26.32
A1	141	Infrastructure	Transportation	98	98	98	98	98	C	478.09	6.6889	1.37
A1	141	Infrastructure	Transportation	98	98	98	98	98	C	478.09	1.5484	0.32
A1	610	Woods	Fair	36	60	73	79	79	D	478.09	0.0066	0.00
											478.09	**95.17**
A2	111.1	Residential - 1/8 ac lots	Single Family	77	85	90	92	92	D	249.66	25.2624	9.31
A2	111.1	Residential - 1/8 ac lots	Single Family	77	85	90	92	85	B	249.66	0.0775	0.03
A2	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	87	D	249.66	4.9017	1.71
A2	121	Commercial	Office	89	92	94	95	95	D	249.66	5.2427	1.99
A2	131	Industrial	Industrial	98	98	98	98	98	D	249.66	150.0784	58.91
A2	131	Industrial	Industrial	98	98	98	98	98	B	249.66	4.1301	1.62
A2	141	Infrastructure	Transportation	98	98	98	98	98	D	249.66	36.2968	14.25
A2	141	Infrastructure	Transportation	98	98	98	98	98	B	249.66	1.0828	0.43
A2	610	Woods	Fair	36	60	73	79	79	D	249.66	7.4720	2.36
A2	610	Woods	Fair	36	60	73	79	60	B	249.66	15.1927	3.65
											249.66	**94.26**
A3	111.1	Residential - 1/8 ac lots	Single Family	77	85	90	92	92	D	114.04	7.3691	5.94
A3	111.1	Residential - 1/8 ac lots	Single Family	77	85	90	92	85	B	114.04	2.0092	1.50
A3	112	Residential	Multi-family	77	85	90	92	92	D	114.04	37.6508	30.37
A3	112	Residential	Multi-family	77	85	90	92	85	B	114.04	0.3743	0.28
A3	122	Commercial	Retail	89	92	94	95	95	D	114.04	5.9139	4.93
A3	122	Commercial	Retail	89	92	94	95	92	B	114.04	0.4362	0.35
A3	131	Industrial	Industrial	81	88	91	93	93	D	114.04	15.0977	12.31
A3	131	Industrial	Industrial	81	88	91	93	88	B	114.04	0.0226	0.02
A3	141	Infrastructure	Transportation	98	98	98	98	98	D	114.04	32.0259	27.52
A3	141	Infrastructure	Transportation	98	98	98	98	98	B	114.04	1.3435	1.15
A3	143	Infrastructure	Utilities	89	92	94	95	95	D	114.04	0.6446	0.54
A3	143	Infrastructure	Utilities	89	92	94	95	92	B	114.04	0.6617	0.53
A3	610	Woods	Fair	36	60	73	79	79	D	114.04	1.7698	1.23
A3	610	Woods	Fair	36	60	73	79	60	B	114.04	8.7669	4.61
											114.04	**91.2890**
A4	111.1	Residential - 1/8 ac lots	Single Family	77	85	90	92	92	D	137.16	31.3552	21.03
A4	111.1	Residential - 1/8 ac lots	Single Family	77	85	90	92	85	B	137.16	1.3331	0.83
A4	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	87	D	137.16	0.0862	0.05
A4	112	Residential	Multi-family	77	85	90	92	92	D	137.16	22.6581	15.20
A4	112	Residential	Multi-family	77	85	90	92	85	B	137.16	3.4607	2.14
A4	122	Commercial	Retail	89	92	94	95	95	D	137.16	0.0003	0.00
A4	123	Government/Education	Institutional	89	92	94	95	95	D	137.16	0.5129	0.36
A4	131	Industrial	Industrial	81	88	91	93	93	D	137.16	5.3406	3.62
A4	141	Infrastructure	Transportation	98	98	98	98	98	D	137.16	57.5093	41.09
A4	141	Infrastructure	Transportation	98	98	98	98	98	B	137.16	5.0267	3.59
A4	610	Woods	Fair	36	60	73	79	79	D	137.16	1.8879	1.09
A4	610	Woods	Fair	36	60	73	79	60	B	137.16	8.0066	3.50
											137.16	**92.50**

Curve Number Computations (Ultimate Conditions)
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

NAME	LU Code	Category	Landuse	A	B	C	D	Selected CN	HYDGRP	Basin Area (Acres)	Poly Area (Acres)	Weighted CN
A5	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	87	D	162.21	58.7964	31.53
A5	111.2	Residential - 1/4 ac lots	Single Family	61	75	83	87	75	B	162.21	2.1143	0.98
A5	121	Commercial	Office	89	92	94	95	95	D	162.21	1.9554	1.15
A5	122	Commercial	Retail	89	92	94	95	95	D	162.21	0.8026	0.47
A5	123	Government/Education	Institutional	89	92	94	95	95	D	162.21	4.1418	2.43
A5	123	Government/Education	Institutional	89	92	94	95	92	B	162.21	0.7617	0.43
A5	141	Infrastructure	Transportation	98	98	98	98	98	D	162.21	54.1620	32.72
A5	141	Infrastructure	Transportation	98	98	98	98	98	B	162.21	13.4713	8.14
A5	171	Dedicated	Parks	39	61	74	80	80	D	162.21	1.3861	0.68
A5	171	Dedicated	Parks	39	61	74	80	61	B	162.21	4.4796	1.68
A5	600	Woods	Grass combination	43	65	76	82	82	D	162.21	3.0005	1.52
A5	600	Woods	Grass combination	43	65	76	82	65	B	162.21	17.1917	6.89
											162.21	**88.62**

Modified Puls Routing Data
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

RTE1 - E Randoll Mill Road to Duncan Perry Road							
		Volume (ac-ft)			Avg Travel Time - based on stream velocity (hours)		
Profile	Q (cfs)	Section 12941	Section 8659	Total	Section 12941	Section 8659	Difference
PF 1	200	23.79	15.04	8.75	1.33	0.91	0.42
PF 2	400	39.29	24.53	14.76	1.11	0.76	0.35
PF 3	600	53.73	33.82	19.91	1.01	0.69	0.32
PF 4	800	71.41	46.78	24.63	0.97	0.68	0.29
PF 5	1000	90.79	61.13	29.66	0.97	0.69	0.28
PF 6	1400	129.83	90.98	38.85	0.94	0.68	0.26
PF 7	1800	183.16	136.17	46.99	0.99	0.74	0.25
PF 8	2200	224.89	167.05	57.84	1.01	0.76	0.25
PF 9	2600	312.31	241.16	71.15	1.15	0.89	0.26
PF 10	3000	436.48	339.45	97.03	1.39	1.10	0.29
PF 11	3400	478.49	367.76	110.73	1.34	1.03	0.31
PF 12	3800	509.68	388.77	120.91	1.27	0.97	0.30
PF 13	4200	540.40	410.10	130.30	1.21	0.92	0.29
						AVG	0.30

RTE2 - Duncan Perry Road to W Tarrant Road							
		Volume (ac-ft)			Avg Travel Time - based on stream velocity (hours)		
Profile	Q (cfs)	Section 12941	Section 8659	Total	Section 12941	Section 8659	Difference
PF 1	200	14.99	12.44	2.55	0.90	0.76	0.14
PF 2	400	24.45	19.82	4.63	0.75	0.62	0.13
PF 3	600	33.71	27.07	6.64	0.69	0.57	0.12
PF 4	800	46.64	36.90	9.74	0.68	0.54	0.14
PF 5	1000	60.97	48.33	12.64	0.69	0.54	0.15
PF 6	1400	90.77	74.45	16.32	0.67	0.53	0.14
PF 7	1800	135.92	116.57	19.35	0.74	0.61	0.13
PF 8	2200	166.76	142.79	23.97	0.76	0.63	0.13
PF 9	2600	240.75	194.14	46.61	0.89	0.68	0.21
PF 10	3000	338.02	261.46	76.56	1.08	0.80	0.28
PF 11	3400	366.06	286.43	79.63	1.02	0.76	0.26
PF 12	3800	386.87	305.30	81.57	0.96	0.72	0.24
PF 13	4200	407.99	324.61	83.38	0.91	0.69	0.22
						AVG	0.18

Modified Puls Routing Data
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

RTE3 - I-30 to Egyptian Way							
		Volume (ac-ft)			Avg Travel Time - based on stream velocity (hours)		
Profile	Q (cfs)	Section 12941	Section 8659	Total	Section 12941	Section 8659	Difference
PF 1	200	10.90	6.20	4.70	0.65	0.40	0.25
PF 2	400	17.23	10.17	7.06	0.53	0.34	0.19
PF 3	600	23.42	14.40	9.02	0.48	0.31	0.17
PF 4	800	32.14	21.27	10.87	0.46	0.30	0.16
PF 5	1000	41.67	29.02	12.65	0.45	0.30	0.15
PF 6	1400	62.10	46.01	16.09	0.43	0.30	0.13
PF 7	1800	89.98	70.51	19.47	0.47	0.35	0.12
PF 8	2200	91.48	68.23	23.25	0.41	0.29	0.12
PF 9	2600	100.53	73.40	27.13	0.37	0.25	0.12
PF 10	3000	117.98	86.69	31.29	0.38	0.26	0.12
PF 11	3400	136.66	100.54	36.12	0.38	0.26	0.12
PF 12	3800	151.24	109.67	41.57	0.37	0.25	0.12
PF 13	4200	166.39	118.64	47.75	0.36	0.25	0.11
						AVG	0.14

RTE4 - Egyptian Way to Confluence w/ Johnson Cr							
		Volume (ac-ft)			Avg Travel Time - based on stream velocity (hours)		
Profile	Q (cfs)	Section 12941	Section 8659	Total	Section 12941	Section 8659	Difference
PF 1	200	6.18	0.00	6.18	0.39	0.00	0.39
PF 2	400	10.13	0.00	10.13	0.33	0.00	0.33
PF 3	600	14.33	0.00	14.33	0.31	0.00	0.31
PF 4	800	21.19	0.00	21.19	0.30	0.00	0.30
PF 5	1000	28.93	0.00	28.93	0.30	0.00	0.30
PF 6	1400	45.90	0.00	45.90	0.29	0.00	0.29
PF 7	1800	70.38	0.00	70.38	0.34	0.00	0.34
PF 8	2200	68.09	0.00	68.09	0.29	0.00	0.29
PF 9	2600	73.25	0.00	73.25	0.25	0.00	0.25
PF 10	3000	86.54	0.00	86.54	0.26	0.00	0.26
PF 11	3400	100.39	0.00	100.39	0.26	0.00	0.26
PF 12	3800	109.51	0.00	109.51	0.25	0.00	0.25
PF 13	4200	118.47	0.00	118.47	0.24	0.00	0.24
						AVG	0.29

Modified Puls Routing Subreaches
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

Routing Reach	Length (feet)	Time Step (sec)	*Average Flood Wave Velocity (fps)	Sub reaches
RTE1	4282	60.00	6.66	11
RTE2	1119	60.00	2.94	6
RTE3	2072	60.00	6.63	5
RTE4	3547	60.00	5.60	11

*Grand Prairie Drainage Design Manual suggests the average flood wave velocity is typically 60% of the computed hydraulic channel velocity

Storage Volumes U/S of I-30
OEI Job # 196.006
Grand Prairie CWDMP for Arbor Creek Y#0879

High Flows				
Elevation (ft)	Area (sq-ft)	Area (acres)	Volume (cub-ft)	Volume (ac-ft)
480	1123.84	0.03	611.94	0.01
481	2793.33	0.06	2735.31	0.06
482	4629.54	0.11	6579.71	0.15
483	9922.52	0.23	14297.27	0.33
484	16738.74	0.38	28293.96	0.65
485	24828.68	0.57	49409.71	1.13
486	35965.84	0.83	79114.01	1.82
488	96260.90	2.21	209583.23	4.81
490	159665.31	3.67	464801.78	10.67
492	236099.36	5.42	860875.73	19.76
494	330262.56	7.58	1411755.21	32.41
496	452746.94	10.39	2195364.45	50.40
498	529969.68	12.17	3167037.53	72.71
500	614712.99	14.11	4291557.94	98.52
502	764040.31	17.54	5639539.95	129.47
504	947404.62	21.75	7415535.09	170.24

Low Flows				
Elevation (ft)	Area (sq-ft)	Area (acres)	Volume (cub-ft)	Volume (ac-ft)
480	1123.84	0.03	611.94	0.01
481	2793.33	0.06	2735.31	0.06
482	4629.54	0.11	6579.71	0.15
483	9922.52	0.23	14297.27	0.33
484	16738.74	0.38	28293.96	0.65
485	24828.68	0.57	49409.71	1.13
486	35906.39	0.82	79091.86	1.82
488	90565.99	2.08	205675.60	4.72
490	138361.67	3.18	434806.13	9.98
492	184711.15	4.24	758834.32	17.42
494	230014.13	5.28	1163354.75	26.71
496	280788.06	6.45	1666729.24	38.26
498	318071.67	7.30	2257974.27	51.84
500	359199.57	8.25	2923117.81	67.11
502	443241.18	10.18	3707141.21	85.10
504	507580.25	11.65	4671140.10	107.23

Soil Conservation Service
Technical Release 55
Tables 2-2a and 2-2c

Table 2-2a Runoff curve numbers for urban areas [1]

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area [2]	A	B	C	D
Fully developed urban areas (vegetation established)					
Open space (lawns, parks, golf courses, cemeteries, etc.) [3]:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) [4]		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82
Developing urban areas					
Newly graded areas (pervious areas only, no vegetation) [5]	77	86	91	94	
Idle lands (CN's are determined using cover types similar to those in table 2-2c).					

1 Average runoff condition, and $I_a = 0.2S$.

2 The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.

3 CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.

4 Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.

5 Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table 2-2c Runoff curve numbers for other agricultural lands [1/]

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing . [2/]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element. [3/]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4/]	48	65	73
Woods—grass combination (orchard or tree farm). [5/]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. [6/]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4/]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and I_a, = 0.2S.
2 *Poor:* <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.
3 *Poor*: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.
4 Actual curve number is less than 30; use CN = 30 for runoff computations.
5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.
6 *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

HEC-RAS Summary Output

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	10629	10% AC EX	2590.00	508.91	515.47	514.38	516.30	0.013497	7.63	374.10	187.14	0.60
Reach 1	10629	4% AC EX	2950.00	508.91	515.79	514.68	516.71	0.013823	8.05	405.68	194.47	0.62
Reach 1	10629	2% AC EX	3230.00	508.91	516.02	514.90	517.01	0.014062	8.36	429.18	199.64	0.63
Reach 1	10629	1% AC EX	3450.00	508.91	516.19	515.08	517.23	0.014344	8.61	446.00	202.65	0.64
Reach 1	10629	0.2% AC EX	3990.00	508.91	516.71	515.48	517.82	0.013794	8.94	499.66	212.41	0.63
Reach 1	10629	50% AC ULT	1470.00	508.91	514.22	513.24	514.77	0.012782	6.12	258.80	153.99	0.56
Reach 1	10629	20% AC ULT	2200.00	508.91	515.09	514.01	515.82	0.013149	7.14	337.58	178.74	0.59
Reach 1	10629	1% AC ULT	3500.00	508.91	516.23	515.11	517.28	0.014409	8.66	449.74	203.30	0.64
Reach 1	10104	10% AC EX	2590.00	501.36	509.09	508.82	510.15	0.010268	8.63	347.60	139.28	0.73
Reach 1	10104	4% AC EX	2950.00	501.36	509.36	509.11	510.49	0.010301	9.00	386.11	146.71	0.74
Reach 1	10104	2% AC EX	3230.00	501.36	509.56	509.32	510.74	0.010308	9.26	415.60	152.15	0.75
Reach 1	10104	1% AC EX	3450.00	501.36	509.71	509.46	510.92	0.010269	9.44	438.57	155.14	0.75
Reach 1	10104	0.2% AC EX	3990.00	501.36	510.04	509.83	511.42	0.010891	10.14	491.88	209.21	0.78
Reach 1	10104	50% AC ULT	1470.00	501.36	508.05	507.28	508.83	0.010083	7.11	217.70	107.08	0.69
Reach 1	10104	20% AC ULT	2200.00	501.36	508.77	508.47	509.75	0.010263	8.19	303.94	130.56	0.72
Reach 1	10104	1% AC ULT	3500.00	501.36	509.74	509.50	510.96	0.010260	9.47	443.74	155.78	0.75
Reach 1	9724	10% AC EX	2590.00	499.75	508.11	506.25	508.34	0.002525	4.68	712.28	202.85	0.31
Reach 1	9724	4% AC EX	2950.00	499.75	508.35	506.41	508.62	0.002671	4.93	761.43	204.83	0.32
Reach 1	9724	2% AC EX	3230.00	499.75	508.53	506.56	508.82	0.002776	5.10	797.87	206.28	0.33
Reach 1	9724	1% AC EX	3450.00	499.75	508.66	506.64	508.97	0.002855	5.24	825.47	207.37	0.33
Reach 1	9724	0.2% AC EX	3990.00	499.75	509.02	506.93	509.36	0.002940	5.48	899.30	210.27	0.34
Reach 1	9724	50% AC ULT	1470.00	499.75	507.20	505.55	507.34	0.001907	3.72	534.15	188.98	0.26
Reach 1	9724	20% AC ULT	2200.00	499.75	507.82	506.01	508.02	0.002344	4.39	654.51	198.96	0.30
Reach 1	9724	1% AC ULT	3500.00	499.75	508.69	506.67	509.01	0.002871	5.26	831.77	207.62	0.33
Reach 1	9278	10% AC EX	2590.00	495.59	506.70	505.36	506.85	0.010561	0.69	986.77	379.84	0.05
Reach 1	9278	4% AC EX	2950.00	495.59	506.92	505.49	507.09	0.010081	0.69	1072.61	382.58	0.05
Reach 1	9278	2% AC EX	3230.00	495.59	507.09	505.60	507.27	0.009769	0.70	1136.88	384.39	0.05
Reach 1	9278	1% AC EX	3450.00	495.59	507.22	505.66	507.40	0.009572	0.70	1185.38	385.61	0.05
Reach 1	9278	0.2% AC EX	3990.00	495.59	507.72	505.84	507.90	0.007401	0.64	1380.23	390.47	0.04
Reach 1	9278	50% AC ULT	1470.00	495.59	505.92	504.23	506.02	0.012950	0.70	693.40	369.62	0.05
Reach 1	9278	20% AC ULT	2200.00	495.59	506.44	505.18	506.58	0.011251	0.70	888.79	376.70	0.05
Reach 1	9278	1% AC ULT	3500.00	495.59	507.25	505.68	507.44	0.009480	0.70	1197.99	385.92	0.05
Reach 1	8972	10% AC EX	2590.00	498.00	504.93	503.27	505.10	0.008366	0.54	959.58	317.23	0.05
Reach 1	8972	4% AC EX	2950.00	498.00	505.14	503.42	505.33	0.008815	0.57	1026.44	323.72	0.05
Reach 1	8972	2% AC EX	3230.00	498.00	505.30	503.53	505.50	0.009096	0.60	1078.58	329.20	0.05
Reach 1	8972	1% AC EX	3450.00	498.00	505.44	503.62	505.65	0.009089	0.61	1126.92	334.20	0.05
Reach 1	8972	0.2% AC EX	3990.00	498.00	506.70	503.79	506.84	0.004339	0.49	1571.64	368.87	0.04
Reach 1	8972	50% AC ULT	1470.00	498.00	504.11	502.71	504.21	0.007318	0.44	707.02	298.41	0.04
Reach 1	8972	20% AC ULT	2200.00	498.00	504.67	503.10	504.82	0.007998	0.51	879.40	311.16	0.04
Reach 1	8972	1% AC ULT	3500.00	498.00	505.53	503.63	505.73	0.008673	0.60	1155.52	337.12	0.05
Reach 1	8754	10% AC EX	2590.00	496.00	502.35	501.82	503.16	0.014328	8.15	455.17	195.70	0.63
Reach 1	8754	4% AC EX	2950.00	496.00	502.98	501.99	503.63	0.010562	7.55	600.69	267.83	0.55
Reach 1	8754	2% AC EX	3230.00	496.00	503.45	502.00	503.99	0.008327	7.06	739.53	321.83	0.50
Reach 1	8754	1% AC EX	3450.00	496.00	504.21	501.99	504.54	0.004918	5.85	1014.80	396.85	0.39
Reach 1	8754	0.2% AC EX	3990.00	496.00	506.37	502.90	506.47	0.001275	3.56	1929.88	443.01	0.21
Reach 1	8754	50% AC ULT	1470.00	496.00	500.54	500.54	501.72	0.030297	8.92	189.78	105.17	0.85
Reach 1	8754	20% AC ULT	2200.00	496.00	501.66	501.52	502.63	0.019571	8.66	340.76	151.58	0.72
Reach 1	8754	1% AC ULT	3500.00	496.00	504.55	502.50	504.81	0.003743	5.27	1155.23	409.53	0.34
Reach 1	8659	10% AC EX	2590.00	495.50	502.08	498.97	502.47	0.002497	5.01	516.93	114.83	0.35
Reach 1	8659	4% AC EX	2950.00	495.50	502.66	499.25	503.08	0.002407	5.22	565.08	120.04	0.35
Reach 1	8659	2% AC EX	3230.00	495.50	503.09	499.46	503.54	0.002348	5.37	601.18	140.59	0.35
Reach 1	8659	1% AC EX	3450.00	495.50	503.78	499.62	504.21	0.001979	5.24	658.31	332.94	0.33
Reach 1	8659	0.2% AC EX	3990.00	495.50	506.14	500.01	506.33	0.000741	3.80	1638.27	441.87	0.21
Reach 1	8659	50% AC ULT	1470.00	495.50	500.07	497.98	500.34	0.002956	4.20	349.84	99.23	0.36
Reach 1	8659	20% AC ULT	2200.00	495.50	501.42	498.65	501.77	0.002617	4.76	462.16	107.81	0.36
Reach 1	8659	1% AC ULT	3500.00	495.50	504.10	499.66	504.51	0.001785	5.11	684.85	375.25	0.31
Reach 1	8610		Culvert									
Reach 1	8562	10% AC EX	2590.00	491.18	498.28	495.97	498.82	0.007302	5.88	440.47	104.88	0.45
Reach 1	8562	4% AC EX	2950.00	491.18	499.34	496.29	499.83	0.005155	5.58	528.68	109.20	0.39
Reach 1	8562	2% AC EX	3230.00	491.18	500.41	496.51	500.83	0.003687	5.23	617.25	113.55	0.34
Reach 1	8562	1% AC EX	3450.00	491.18	501.83	496.69	502.17	0.002352	4.69	734.89	119.32	0.28
Reach 1	8562	0.2% AC EX	3990.00	491.18	504.02	497.11	504.32	0.001504	4.35	917.00	323.46	0.23
Reach 1	8562	50% AC ULT	1470.00	491.18	497.23	494.90	497.50	0.004821	4.16	353.56	100.61	0.35
Reach 1	8562	20% AC ULT	2200.00	491.18	498.12	495.62	498.53	0.005824	5.15	427.42	104.24	0.40
Reach 1	8562	1% AC ULT	3500.00	491.18	502.06	496.74	502.39	0.002223	4.64	753.92	120.55	0.27
Reach 1	8487	10% AC EX	2500.00	491.50	498.24	494.86	498.35	0.001526	3.12	1000.76	196.12	0.21
Reach 1	8487	4% AC EX	3380.00	491.50	499.29	495.32	499.43	0.001568	3.49	1210.31	201.70	0.22

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	8487	2% AC EX	3730.00	491.50	500.40	495.49	500.52	0.001137	3.25	1437.17	207.85	0.19
Reach 1	8487	1% AC EX	4040.00	491.50	501.84	495.62	501.94	0.000768	2.96	1747.60	224.27	0.16
Reach 1	8487	0.2% AC EX	4770.00	491.50	504.06	495.93	504.14	0.000488	2.69	2246.66	226.41	0.13
Reach 1	8487	50% AC ULT	1570.00	491.50	497.14	493.99	497.22	0.001233	2.49	789.66	190.45	0.19
Reach 1	8487	20% AC ULT	2330.00	491.50	498.05	494.77	498.16	0.001484	3.02	964.02	195.06	0.21
Reach 1	8487	1% AC ULT	4110.00	491.50	502.07	495.67	502.17	0.000725	2.92	1799.81	224.40	0.16
Reach 1	7948	10% AC EX	2500.00	486.91	497.24	495.21	497.41	0.002296	4.27	913.12	254.78	0.26
Reach 1	7948	4% AC EX	3380.00	486.91	498.43	495.69	498.58	0.001827	4.15	1223.07	267.89	0.23
Reach 1	7948	2% AC EX	3730.00	486.91	499.89	495.88	499.99	0.000965	3.30	1626.16	282.90	0.17
Reach 1	7948	1% AC EX	4040.00	486.91	501.55	496.02	501.61	0.000523	2.67	2109.19	299.80	0.13
Reach 1	7948	0.2% AC EX	4770.00	486.91	503.89	496.33	503.94	0.000299	2.25	2831.56	314.57	0.10
Reach 1	7948	50% AC ULT	1570.00	486.91	496.28	493.45	496.42	0.002034	3.71	674.60	240.88	0.24
Reach 1	7948	20% AC ULT	2330.00	486.91	497.06	495.13	497.22	0.002302	4.21	867.37	252.93	0.26
Reach 1	7948	1% AC ULT	4110.00	486.91	501.80	496.07	501.86	0.000489	2.61	2185.21	303.41	0.13
Reach 1	7510	10% AC EX	2500.00	488.00	496.22	493.99	496.42	0.002443	4.15	744.02	194.66	0.27
Reach 1	7510	4% AC EX	3380.00	488.00	497.68	494.57	497.86	0.001642	3.85	1038.09	206.05	0.23
Reach 1	7510	2% AC EX	3730.00	488.00	499.52	494.77	499.64	0.000763	2.98	1430.10	223.57	0.16
Reach 1	7510	1% AC EX	4040.00	488.00	501.35	494.92	501.42	0.000409	2.43	1936.14	332.48	0.12
Reach 1	7510	0.2% AC EX	4770.00	488.00	503.79	495.26	503.84	0.000208	1.95	2803.37	369.70	0.09
Reach 1	7510	50% AC ULT	1570.00	488.00	492.66	492.66	494.01	0.031686	9.49	179.84	79.69	0.88
Reach 1	7510	20% AC ULT	2330.00	488.00	493.85	493.85	494.92	0.019545	9.00	321.55	151.69	0.72
Reach 1	7510	1% AC ULT	4110.00	488.00	501.62	494.95	501.69	0.000380	2.38	2025.45	339.10	0.12
Reach 1	7444	10% AC EX	2500.00	485.00	496.17	488.57	496.35	0.000436	3.44	725.80	296.16	0.18
Reach 1	7444	4% AC EX	3380.00	485.00	497.51	489.38	497.77	0.000546	4.16	812.86	349.41	0.21
Reach 1	7444	2% AC EX	3730.00	485.00	499.31	489.68	499.56	0.000425	4.01	929.87	451.85	0.19
Reach 1	7444	1% AC EX	4040.00	485.00	501.12	489.92	501.35	0.000335	3.86	1047.87	516.04	0.17
Reach 1	7444	0.2% AC EX	4770.00	485.00	503.68	490.49	503.80	0.000275	3.07	2237.10	628.70	0.14
Reach 1	7444	50% AC ULT	1570.00	485.00	491.11	487.62	491.35	0.001282	3.95	397.23	81.07	0.28
Reach 1	7444	20% AC ULT	2330.00	485.00	493.96	488.41	494.21	0.000788	4.00	582.55	145.67	0.24
Reach 1	7444	1% AC ULT	4110.00	485.00	501.38	489.97	501.61	0.000328	3.86	1064.88	525.72	0.17
Reach 1	7400		Culvert									
Reach 1	7348	10% AC EX	2500.00	483.40	495.97	486.97	496.12	0.000613	3.06	817.05	274.10	0.15
Reach 1	7348	4% AC EX	3380.00	483.40	497.08	487.78	497.30	0.000845	3.80	889.13	344.89	0.18
Reach 1	7348	2% AC EX	3730.00	483.40	498.71	488.08	498.93	0.000707	3.75	995.00	422.18	0.17
Reach 1	7348	1% AC EX	4040.00	483.40	500.36	488.32	500.57	0.000590	3.67	1102.17	544.59	0.16
Reach 1	7348	0.2% AC EX	4770.00	483.40	503.65	488.89	503.75	0.000382	2.74	2393.97	641.73	0.11
Reach 1	7348	50% AC ULT	1570.00	483.40	491.07	486.02	491.22	0.001256	3.15	498.36	72.32	0.20
Reach 1	7348	20% AC ULT	2330.00	483.40	493.87	486.81	494.05	0.000980	3.42	680.35	80.46	0.19
Reach 1	7348	1% AC ULT	4110.00	483.40	500.58	488.37	500.79	0.000584	3.68	1116.94	555.14	0.16
Reach 1	7164	10% AC EX	2090.00	482.44	495.95	489.88	496.00	0.000256	2.29	1328.00	290.37	0.12
Reach 1	7164	4% AC EX	2210.00	482.44	497.10	490.01	497.14	0.000168	1.98	1603.66	391.48	0.10
Reach 1	7164	2% AC EX	2370.00	482.44	498.76	490.15	498.78	0.000099	1.65	2015.35	432.98	0.08
Reach 1	7164	1% AC EX	2520.00	482.44	500.42	490.29	500.44	0.000063	1.42	2446.31	459.87	0.06
Reach 1	7164	0.2% AC EX	2790.00	482.44	503.67	490.50	503.69	0.000030	1.11	3343.21	554.13	0.04
Reach 1	7164	50% AC ULT	1380.00	482.44	490.52	488.25	490.84	0.002951	5.05	362.74	128.12	0.36
Reach 1	7164	20% AC ULT	1850.00	482.44	493.77	489.59	493.87	0.000578	2.99	857.78	180.24	0.17
Reach 1	7164	1% AC ULT	2540.00	482.44	500.65	490.31	500.67	0.000060	1.40	2507.56	463.26	0.06
Reach 1	6841	10% AC EX	2090.00	480.87	495.92	487.38	495.94	0.000125	1.56	2018.37	316.87	0.08
Reach 1	6841	4% AC EX	2210.00	480.87	497.08	487.39	497.10	0.000087	1.38	2359.35	326.44	0.06
Reach 1	6841	2% AC EX	2370.00	480.87	498.74	487.84	498.76	0.000055	1.19	2854.22	348.12	0.05
Reach 1	6841	1% AC EX	2520.00	480.87	500.41	488.26	500.42	0.000038	1.05	3365.84	427.41	0.04
Reach 1	6841	0.2% AC EX	2790.00	480.87	503.67	488.60	503.68	0.000020	0.85	4517.87	530.79	0.03
Reach 1	6841	50% AC ULT	1380.00	480.87	489.81	486.13	490.04	0.002109	4.17	462.05	190.73	0.28
Reach 1	6841	20% AC ULT	1850.00	480.87	493.69	487.02	493.73	0.000285	2.08	1388.15	291.62	0.11
Reach 1	6841	1% AC ULT	2540.00	480.87	500.64	488.26	500.65	0.000036	1.03	3437.08	428.34	0.04
Reach 1	6479	10% AC EX	2090.00	479.00	495.86	484.66	495.90	0.000096	1.67	1591.79	377.91	0.08
Reach 1	6479	4% AC EX	2210.00	479.00	497.04	484.82	497.07	0.000077	1.58	1783.90	399.41	0.07
Reach 1	6479	2% AC EX	2370.00	479.00	498.71	485.02	498.74	0.000058	1.46	2068.83	426.44	0.06
Reach 1	6479	1% AC EX	2520.00	479.00	500.38	485.21	500.40	0.000045	1.37	2369.21	449.39	0.06
Reach 1	6479	0.2% AC EX	2790.00	479.00	503.65	485.53	503.67	0.000028	1.20	3017.76	491.90	0.04
Reach 1	6479	50% AC ULT	1380.00	479.00	489.61	483.62	489.69	0.000451	2.47	687.47	237.13	0.15
Reach 1	6479	20% AC ULT	1850.00	479.00	493.62	484.34	493.66	0.000151	1.87	1244.36	327.46	0.09
Reach 1	6479	1% AC ULT	2540.00	479.00	500.61	485.24	500.63	0.000043	1.35	2412.61	454.78	0.05
Reach 1	6360	10% AC EX	2090.00	478.88	495.48	485.10	495.74	0.000537	4.07	513.81	357.12	0.18
Reach 1	6360	4% AC EX	2210.00	478.88	496.67	485.28	496.92	0.000468	3.99	553.65	372.34	0.17
Reach 1	6360	2% AC EX	2370.00	478.88	498.36	485.53	498.60	0.000389	3.88	610.21	396.06	0.16
Reach 1	6360	1% AC EX	2520.00	478.88	500.05	485.75	500.27	0.000328	3.78	666.79	423.00	0.15

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	6360	0.2% AC EX	2790.00	478.88	503.35	486.15	503.55	0.000241	3.59	777.31	517.02	0.13
Reach 1	6360	50% AC ULT	1380.00	478.88	489.13	483.90	489.46	0.001392	4.58	301.00	172.46	0.27
Reach 1	6360	20% AC ULT	1850.00	478.88	493.21	484.71	493.49	0.000719	4.23	437.63	316.56	0.21
Reach 1	6360	1% AC ULT	2540.00	478.88	500.28	485.78	500.50	0.000320	3.77	674.60	433.74	0.15
Reach 1	6200		Culvert									
Reach 1	5980	10% AC EX	2090.00	477.76	484.40	483.37	485.96	0.005684	10.03	208.30	91.50	0.74
Reach 1	5980	4% AC EX	2210.00	477.76	484.68	483.54	486.27	0.005419	10.11	218.51	94.73	0.73
Reach 1	5980	2% AC EX	2370.00	477.76	484.83	483.78	486.57	0.005729	10.58	224.10	96.50	0.75
Reach 1	5980	1% AC EX	2520.00	477.76	484.97	483.98	486.85	0.006020	11.00	229.07	98.07	0.77
Reach 1	5980	0.2% AC EX	2790.00	477.76	485.32	484.36	487.39	0.006159	11.54	241.84	101.92	0.79
Reach 1	5980	50% AC ULT	1380.00	477.76	483.52	482.23	484.47	0.004334	7.83	176.15	60.04	0.63
Reach 1	5980	20% AC ULT	1850.00	477.76	484.16	482.99	485.49	0.005154	9.28	199.38	88.68	0.70
Reach 1	5980	1% AC ULT	2540.00	477.76	485.00	484.01	486.89	0.006021	11.04	230.15	98.41	0.77
Reach 1	5908	10% AC EX	2220.00	477.74	484.44	482.87	484.77	0.001913	4.85	498.14	171.76	0.41
Reach 1	5908	4% AC EX	2470.00	477.74	484.73	483.07	485.08	0.001839	4.97	541.47	181.64	0.41
Reach 1	5908	2% AC EX	2630.00	477.74	484.91	483.19	485.27	0.001801	5.04	568.26	188.67	0.41
Reach 1	5908	1% AC EX	2780.00	477.74	485.07	483.28	485.44	0.001773	5.12	592.51	211.80	0.41
Reach 1	5908	0.2% AC EX	3150.00	477.74	485.46	483.49	485.85	0.001708	5.28	651.39	216.84	0.41
Reach 1	5908	50% AC ULT	1470.00	477.74	483.43	481.99	483.73	0.002334	4.47	354.66	145.98	0.44
Reach 1	5908	20% AC ULT	1990.00	477.74	484.15	482.57	484.47	0.002002	4.73	456.51	162.51	0.42
Reach 1	5908	1% AC ULT	2810.00	477.74	485.10	483.31	485.48	0.001767	5.13	597.35	212.22	0.41
Reach 1	5826	10% AC EX	2220.00	475.06	484.27	481.89	484.55	0.003297	4.27	519.67	125.50	0.37
Reach 1	5826	4% AC EX	2470.00	475.06	484.56	482.10	484.87	0.003340	4.44	556.80	128.38	0.38
Reach 1	5826	2% AC EX	2630.00	475.06	484.74	482.22	485.06	0.003365	4.53	579.95	130.14	0.38
Reach 1	5826	1% AC EX	2780.00	475.06	484.90	482.33	485.23	0.003392	4.63	600.99	131.72	0.38
Reach 1	5826	0.2% AC EX	3150.00	475.06	485.29	482.58	485.65	0.003432	4.83	652.78	135.55	0.39
Reach 1	5826	50% AC ULT	1470.00	475.06	483.27	481.25	483.48	0.003130	3.68	399.28	115.69	0.35
Reach 1	5826	20% AC ULT	1990.00	475.06	483.98	481.72	484.25	0.003253	4.11	484.35	122.70	0.36
Reach 1	5826	1% AC ULT	2810.00	475.06	484.93	482.34	485.27	0.003396	4.64	605.22	132.04	0.38
Reach 1	5597	10% AC EX	2220.00	475.63	482.90	481.67	483.49	0.006524	6.64	370.15	105.07	0.53
Reach 1	5597	4% AC EX	2470.00	475.63	483.16	481.87	483.79	0.006506	6.87	398.39	107.47	0.54
Reach 1	5597	2% AC EX	2630.00	475.63	483.32	482.00	483.98	0.006501	7.01	415.91	108.94	0.54
Reach 1	5597	1% AC EX	2780.00	475.63	483.47	482.12	484.15	0.006503	7.14	431.93	110.27	0.54
Reach 1	5597	0.2% AC EX	3150.00	475.63	483.82	482.40	484.55	0.006526	7.46	470.74	114.63	0.55
Reach 1	5597	50% AC ULT	1470.00	475.63	482.00	480.97	482.45	0.006589	5.82	279.26	96.91	0.52
Reach 1	5597	20% AC ULT	1990.00	475.63	482.64	481.47	483.19	0.006552	6.42	343.20	102.71	0.53
Reach 1	5597	1% AC ULT	2810.00	475.63	483.50	482.15	484.18	0.006504	7.17	435.10	110.53	0.54
Reach 1	5407	10% AC EX	2220.00	475.84	481.72	480.20	482.22	0.006377	5.66	392.15	105.50	0.52
Reach 1	5407	4% AC EX	2470.00	475.84	481.98	480.40	482.52	0.006467	5.88	419.77	107.65	0.53
Reach 1	5407	2% AC EX	2630.00	475.84	482.14	480.53	482.70	0.006472	6.01	437.42	108.62	0.53
Reach 1	5407	1% AC EX	2780.00	475.84	482.29	480.65	482.87	0.006497	6.14	453.12	109.41	0.53
Reach 1	5407	0.2% AC EX	3150.00	475.84	482.63	480.92	483.27	0.006557	6.42	490.60	111.30	0.54
Reach 1	5407	50% AC ULT	1470.00	475.84	480.87	479.49	481.23	0.005849	4.81	305.49	98.43	0.48
Reach 1	5407	20% AC ULT	1990.00	475.84	481.46	480.00	481.93	0.006308	5.45	365.39	103.37	0.51
Reach 1	5407	1% AC ULT	2810.00	475.84	482.32	480.67	482.90	0.006502	6.16	456.22	109.57	0.53
Reach 1	5230	10% AC EX	2220.00	475.36	481.18	479.30	481.56	0.002212	4.94	449.01	114.33	0.44
Reach 1	5230	4% AC EX	2470.00	475.36	481.43	479.50	481.85	0.002277	5.17	477.52	116.04	0.45
Reach 1	5230	2% AC EX	2630.00	475.36	481.59	479.63	482.03	0.002300	5.30	496.30	117.15	0.45
Reach 1	5230	1% AC EX	2780.00	475.36	481.73	479.74	482.19	0.002332	5.42	512.70	118.11	0.46
Reach 1	5230	0.2% AC EX	3150.00	475.36	482.06	479.99	482.57	0.002402	5.71	552.04	120.39	0.47
Reach 1	5230	50% AC ULT	1470.00	475.36	480.41	478.59	480.66	0.001858	4.06	362.18	108.97	0.39
Reach 1	5230	20% AC ULT	1990.00	475.36	480.94	479.10	481.28	0.002160	4.73	420.89	112.62	0.43
Reach 1	5230	1% AC ULT	2810.00	475.36	481.76	479.75	482.22	0.002338	5.45	515.94	118.30	0.46
Reach 1	5199	10% AC EX	2220.00	475.28	481.17	479.05	481.51	0.000617	4.71	471.23	114.44	0.41
Reach 1	5199	4% AC EX	2470.00	475.28	481.42	479.25	481.80	0.000641	4.94	499.70	116.15	0.42
Reach 1	5199	2% AC EX	2630.00	475.28	481.58	479.37	481.98	0.000651	5.07	518.47	117.23	0.43
Reach 1	5199	1% AC EX	2780.00	475.28	481.72	479.49	482.14	0.000663	5.20	534.84	118.17	0.43
Reach 1	5199	0.2% AC EX	3150.00	475.28	482.04	479.75	482.51	0.000690	5.49	574.11	120.48	0.44
Reach 1	5199	50% AC ULT	1470.00	475.28	480.39	478.42	480.62	0.000498	3.82	384.65	109.00	0.36
Reach 1	5199	20% AC ULT	1990.00	475.28	480.92	478.88	481.23	0.000596	4.49	443.15	112.72	0.40
Reach 1	5199	1% AC ULT	2810.00	475.28	481.74	479.51	482.17	0.000665	5.22	538.07	118.36	0.43
Reach 1	5184		Inl Struct									
Reach 1	5155	10% AC EX	2220.00	471.50	476.29	474.18	476.64	0.000603	4.72	470.52	111.46	0.40
Reach 1	5155	4% AC EX	2470.00	471.50	476.77	474.37	477.11	0.000538	4.71	524.21	114.09	0.39
Reach 1	5155	2% AC EX	2630.00	471.50	477.06	474.48	477.41	0.000504	4.71	558.43	115.74	0.38
Reach 1	5155	1% AC EX	2780.00	471.50	477.34	474.59	477.68	0.000476	4.71	590.51	117.26	0.37

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	5155	0.2% AC EX	3150.00	471.50	478.01	474.85	478.35	0.000418	4.70	670.36	120.96	0.35
Reach 1	5155	50% AC ULT	1470.00	471.50	474.77	473.55	475.12	0.000983	4.79	307.06	103.04	0.49
Reach 1	5155	20% AC ULT	1990.00	471.50	475.84	473.99	476.19	0.000681	4.73	420.95	108.98	0.42
Reach 1	5155	1% AC ULT	2810.00	471.50	477.39	474.61	477.74	0.000471	4.71	596.94	117.56	0.37
Reach 1	5106	10% AC EX	2220.00	468.00	476.37	471.48	476.53	0.000167	3.22	690.48	110.35	0.23
Reach 1	5106	4% AC EX	2470.00	468.00	476.84	471.71	477.01	0.000168	3.32	743.05	113.33	0.23
Reach 1	5106	2% AC EX	2630.00	468.00	477.13	471.86	477.31	0.000168	3.39	776.76	115.21	0.23
Reach 1	5106	1% AC EX	2780.00	468.00	477.41	471.99	477.59	0.000168	3.44	808.44	116.94	0.23
Reach 1	5106	0.2% AC EX	3150.00	468.00	478.07	472.30	478.27	0.000166	3.55	887.60	121.17	0.23
Reach 1	5106	50% AC ULT	1470.00	468.00	474.87	470.69	474.99	0.000154	2.76	532.06	100.81	0.21
Reach 1	5106	20% AC ULT	1990.00	468.00	475.92	471.25	476.07	0.000165	3.10	642.12	107.52	0.22
Reach 1	5106	1% AC ULT	2810.00	468.00	477.46	472.01	477.65	0.000168	3.45	814.80	117.29	0.23
Reach 1	5053	10% AC EX	2220.00	469.60	476.05	473.07	476.45	0.000427	5.04	440.60	104.33	0.36
Reach 1	5053	4% AC EX	2470.00	469.60	476.50	473.30	476.92	0.000417	5.22	473.13	107.61	0.36
Reach 1	5053	2% AC EX	2630.00	469.60	476.78	473.44	477.22	0.000410	5.33	493.54	109.66	0.36
Reach 1	5053	1% AC EX	2780.00	469.60	477.04	473.57	477.49	0.000404	5.43	512.42	111.57	0.36
Reach 1	5053	0.2% AC EX	3150.00	469.60	477.67	473.88	478.16	0.000390	5.64	558.48	116.23	0.36
Reach 1	5053	50% AC ULT	1470.00	469.60	474.62	472.20	474.92	0.000458	4.37	336.71	93.80	0.36
Reach 1	5053	20% AC ULT	1990.00	469.60	475.63	472.82	476.00	0.000436	4.86	409.87	101.23	0.36
Reach 1	5053	1% AC ULT	2810.00	469.60	477.09	473.59	477.55	0.000403	5.44	516.18	111.95	0.36
Reach 1	5035		Culvert									
Reach 1	5007	10% AC EX	2220.00	469.50	474.58	472.84	475.20	0.000908	6.35	349.62	99.51	0.51
Reach 1	5007	4% AC EX	2470.00	469.50	474.83	473.07	475.53	0.000951	6.72	367.64	101.35	0.53
Reach 1	5007	2% AC EX	2630.00	469.50	474.98	473.21	475.73	0.000977	6.95	378.63	102.49	0.54
Reach 1	5007	1% AC EX	2780.00	469.50	475.11	473.34	475.91	0.001001	7.15	388.63	103.60	0.55
Reach 1	5007	0.2% AC EX	3150.00	469.50	475.48	473.65	476.37	0.001031	7.59	415.14	106.54	0.56
Reach 1	5007	50% AC ULT	1470.00	469.50	473.72	472.10	474.13	0.000765	5.11	287.40	93.08	0.45
Reach 1	5007	20% AC ULT	1990.00	469.50	474.34	472.62	474.89	0.000867	5.99	331.97	97.69	0.49
Reach 1	5007	1% AC ULT	2810.00	469.50	475.14	473.36	475.94	0.001006	7.19	390.61	103.82	0.55
Reach 1	4847	10% AC EX	2220.00	468.24	474.45	472.57	474.79	0.004197	4.69	473.41	122.93	0.42
Reach 1	4847	4% AC EX	2470.00	468.24	474.71	472.74	475.08	0.004246	4.88	505.67	124.52	0.43
Reach 1	4847	2% AC EX	2630.00	468.24	474.87	472.85	475.26	0.004276	5.00	525.68	125.49	0.43
Reach 1	4847	1% AC EX	2780.00	468.24	475.02	472.97	475.42	0.004301	5.11	544.12	126.39	0.43
Reach 1	4847	0.2% AC EX	3150.00	468.24	475.41	473.23	475.85	0.004221	5.30	594.42	128.79	0.43
Reach 1	4847	50% AC ULT	1470.00	468.24	473.56	471.95	473.81	0.004024	4.00	367.05	117.23	0.40
Reach 1	4847	20% AC ULT	1990.00	468.24	474.19	472.40	474.51	0.004152	4.50	442.44	121.39	0.42
Reach 1	4847	1% AC ULT	2810.00	468.24	475.04	473.00	475.45	0.004305	5.13	547.80	126.56	0.43
Reach 1	4699	10% AC EX	2220.00	467.47	473.87	471.82	474.19	0.003795	4.55	487.97	122.34	0.40
Reach 1	4699	4% AC EX	2470.00	467.47	474.12	472.00	474.47	0.003928	4.77	518.20	124.31	0.41
Reach 1	4699	2% AC EX	2630.00	467.47	474.27	472.10	474.64	0.004005	4.90	537.06	125.51	0.42
Reach 1	4699	1% AC EX	2780.00	467.47	474.41	472.22	474.80	0.004074	5.01	554.52	126.70	0.42
Reach 1	4699	0.2% AC EX	3150.00	467.47	474.81	472.48	475.23	0.004069	5.20	606.31	131.21	0.43
Reach 1	4699	50% AC ULT	1470.00	467.47	473.05	471.20	473.27	0.003270	3.77	389.79	115.90	0.36
Reach 1	4699	20% AC ULT	1990.00	467.47	473.63	471.64	473.93	0.003658	4.33	459.10	120.44	0.39
Reach 1	4699	1% AC ULT	2810.00	467.47	474.43	472.23	474.83	0.004090	5.04	558.00	127.01	0.42
Reach 1	4647	10% AC EX	2220.00	467.70	473.56	472.00	473.95	0.005404	5.02	442.38	123.91	0.47
Reach 1	4647	4% AC EX	2470.00	467.70	473.80	472.17	474.22	0.005499	5.24	471.72	125.59	0.48
Reach 1	4647	2% AC EX	2630.00	467.70	473.94	472.28	474.39	0.005552	5.37	490.03	126.62	0.48
Reach 1	4647	1% AC EX	2780.00	467.70	474.08	472.38	474.54	0.005594	5.48	507.02	127.57	0.48
Reach 1	4647	0.2% AC EX	3150.00	467.70	474.49	472.62	474.98	0.005308	5.62	560.32	130.51	0.48
Reach 1	4647	50% AC ULT	1470.00	467.70	472.78	471.40	473.06	0.004934	4.23	347.71	117.68	0.43
Reach 1	4647	20% AC ULT	1990.00	467.70	473.34	471.82	473.69	0.005296	4.80	414.37	122.14	0.46
Reach 1	4647	1% AC ULT	2810.00	467.70	474.10	472.40	474.57	0.005602	5.51	510.39	127.76	0.49
Reach 1	4628	10% AC EX	2220.00	468.20	473.65	470.61	473.84	0.001739	3.53	629.77	129.18	0.28
Reach 1	4628	4% AC EX	2470.00	468.20	473.89	470.77	474.11	0.001857	3.74	660.94	130.38	0.29
Reach 1	4628	2% AC EX	2630.00	468.20	474.04	470.88	474.27	0.001927	3.87	680.30	131.07	0.30
Reach 1	4628	1% AC EX	2780.00	468.20	474.17	470.98	474.42	0.001986	3.98	698.18	131.60	0.30
Reach 1	4628	0.2% AC EX	3150.00	468.20	474.59	471.22	474.86	0.002019	4.18	752.78	133.18	0.31
Reach 1	4628	50% AC ULT	1470.00	468.20	472.85	470.03	472.97	0.001314	2.79	527.78	125.18	0.24
Reach 1	4628	20% AC ULT	1990.00	468.20	473.42	470.44	473.59	0.001623	3.32	599.88	128.02	0.27
Reach 1	4628	1% AC ULT	2810.00	468.20	474.20	471.00	474.45	0.001998	4.00	701.72	131.70	0.31
Reach 1	4608		Inl Struct									
Reach 1	4600	10% AC EX	2220.00	465.50	472.34	468.95	472.54	0.000283	3.64	609.70	120.69	0.29
Reach 1	4600	4% AC EX	2470.00	465.50	472.59	469.13	472.82	0.000303	3.86	640.31	122.41	0.30
Reach 1	4600	2% AC EX	2630.00	465.50	472.74	469.27	472.99	0.000315	3.99	659.33	123.47	0.30
Reach 1	4600	1% AC EX	2780.00	465.50	472.88	469.37	473.14	0.000328	4.11	675.91	124.40	0.31

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	4600	0.2% AC EX	3150.00	465.50	473.19	469.64	473.49	0.000354	4.40	715.53	127.84	0.33
Reach 1	4600	50% AC ULT	1470.00	465.50	471.48	468.30	471.61	0.000208	2.89	508.87	113.22	0.24
Reach 1	4600	20% AC ULT	1990.00	465.50	472.09	468.76	472.28	0.000263	3.43	580.28	119.01	0.27
Reach 1	4600	1% AC ULT	2810.00	465.50	472.91	469.40	473.17	0.000330	4.14	679.19	124.58	0.31
Reach 1	4529	10% AC EX	2220.00	464.80	472.35	467.92	472.50	0.000173	3.17	704.33	127.14	0.23
Reach 1	4529	4% AC EX	2470.00	464.80	472.60	468.13	472.78	0.000188	3.38	736.90	130.93	0.24
Reach 1	4529	2% AC EX	2630.00	464.80	472.76	468.28	472.95	0.000197	3.51	757.61	136.41	0.25
Reach 1	4529	1% AC EX	2780.00	464.80	472.89	468.39	473.09	0.000206	3.63	776.23	141.33	0.25
Reach 1	4529	0.2% AC EX	3150.00	464.80	473.21	468.68	473.44	0.000227	3.92	823.03	156.65	0.27
Reach 1	4529	50% AC ULT	1470.00	464.80	471.49	467.24	471.58	0.000123	2.45	599.89	115.81	0.19
Reach 1	4529	20% AC ULT	1990.00	464.80	472.10	467.73	472.24	0.000158	2.96	673.49	123.41	0.22
Reach 1	4529	1% AC ULT	2810.00	464.80	472.92	468.42	473.12	0.000207	3.66	779.98	142.30	0.25
Reach 1	4524		Inl Struct									
Reach 1	4519	10% AC EX	2220.00	464.68	468.87	468.23	469.74	0.002182	7.46	297.55	93.31	0.74
Reach 1	4519	4% AC EX	2470.00	464.68	469.69	468.45	470.36	0.001326	6.57	376.16	98.09	0.59
Reach 1	4519	2% AC EX	2630.00	464.68	470.35	468.57	470.90	0.000935	5.96	441.48	102.35	0.51
Reach 1	4519	1% AC EX	2780.00	464.68	470.62	468.69	471.16	0.000874	5.92	469.30	104.27	0.49
Reach 1	4519	0.2% AC EX	3150.00	464.68	471.28	468.97	471.81	0.000743	5.84	539.69	109.61	0.46
Reach 1	4519	50% AC ULT	1470.00	464.68	467.55	467.55	468.60	0.004616	8.20	179.17	85.85	1.00
Reach 1	4519	20% AC ULT	1990.00	464.68	468.19	468.03	469.30	0.003620	8.46	235.12	89.41	0.92
Reach 1	4519	1% AC ULT	2810.00	464.68	470.67	468.71	471.21	0.000862	5.92	474.88	104.65	0.49
Reach 1	4490	10% AC EX	2220.00	461.31	468.82	467.81	469.60	0.005174	7.04	315.15	88.04	0.66
Reach 1	4490	4% AC EX	2470.00	461.31	469.66	468.05	470.28	0.003400	6.31	391.46	94.04	0.54
Reach 1	4490	2% AC EX	2630.00	461.31	470.32	468.20	470.84	0.002558	5.76	456.84	101.70	0.48
Reach 1	4490	1% AC EX	2780.00	461.31	470.59	468.33	471.10	0.002402	5.74	484.64	103.43	0.47
Reach 1	4490	0.2% AC EX	3150.00	461.31	471.26	468.64	471.76	0.002087	5.68	554.60	108.02	0.44
Reach 1	4490	50% AC ULT	1470.00	461.31	467.38	467.03	468.25	0.009051	7.48	196.42	76.33	0.82
Reach 1	4490	20% AC ULT	1990.00	461.31	468.13	467.59	469.07	0.007635	7.78	255.68	82.39	0.78
Reach 1	4490	1% AC ULT	2810.00	461.31	470.65	468.35	471.16	0.002373	5.73	490.20	103.77	0.46
Reach 1	4286	10% AC EX	2220.00	460.32	468.32	465.77	468.68	0.003030	5.89	547.66	113.24	0.39
Reach 1	4286	4% AC EX	2470.00	460.32	469.34	465.99	469.64	0.002162	5.44	666.04	119.11	0.34
Reach 1	4286	2% AC EX	2630.00	460.32	470.06	466.13	470.34	0.001753	5.19	754.83	151.36	0.31
Reach 1	4286	1% AC EX	2780.00	460.32	470.34	466.26	470.62	0.001752	5.30	790.43	165.02	0.31
Reach 1	4286	0.2% AC EX	3150.00	460.32	471.01	466.55	471.31	0.001745	5.54	927.44	216.07	0.31
Reach 1	4286	50% AC ULT	1470.00	460.32	466.31	465.01	466.74	0.005255	6.21	333.71	99.38	0.49
Reach 1	4286	20% AC ULT	1990.00	460.32	467.23	465.55	467.71	0.004812	6.65	428.54	105.75	0.48
Reach 1	4286	1% AC ULT	2810.00	460.32	470.39	466.28	470.68	0.001750	5.32	797.70	169.15	0.31
Reach 1	3977	10% AC EX	2220.00	457.90	467.98	464.32	468.10	0.001092	3.81	1065.28	263.87	0.24
Reach 1	3977	4% AC EX	2470.00	457.90	469.16	464.52	469.24	0.000681	3.29	1335.48	318.63	0.19
Reach 1	3977	2% AC EX	2630.00	457.90	469.95	464.62	470.02	0.000520	3.04	1517.02	359.12	0.17
Reach 1	3977	1% AC EX	2780.00	457.90	470.23	464.74	470.30	0.000509	3.07	1582.23	371.88	0.17
Reach 1	3977	0.2% AC EX	3150.00	457.90	470.91	464.97	470.99	0.000486	3.13	1739.23	400.96	0.17
Reach 1	3977	50% AC ULT	1470.00	457.90	465.12	463.66	465.38	0.003711	5.19	477.68	172.77	0.41
Reach 1	3977	20% AC ULT	1990.00	457.90	466.47	464.14	466.67	0.002283	4.78	731.15	201.64	0.33
Reach 1	3977	1% AC ULT	2810.00	457.90	470.29	464.75	470.36	0.000507	3.08	1595.18	374.28	0.17
Reach 1	3908	10% AC EX	2220.00	458.90	467.69	462.47	467.98	0.000957	4.31	514.59	189.73	0.26
Reach 1	3908	4% AC EX	2470.00	458.90	468.86	462.74	469.14	0.000781	4.24	583.13	240.60	0.24
Reach 1	3908	2% AC EX	2630.00	458.90	469.65	462.91	469.92	0.000686	4.18	629.63	280.83	0.22
Reach 1	3908	1% AC EX	2780.00	458.90	469.91	463.05	470.20	0.000707	4.31	645.03	294.15	0.23
Reach 1	3908	0.2% AC EX	3150.00	458.90	470.54	463.41	470.87	0.000753	4.62	682.07	325.08	0.24
Reach 1	3908	50% AC ULT	1470.00	458.90	464.96	461.63	465.23	0.001463	4.15	353.80	120.50	0.30
Reach 1	3908	20% AC ULT	1990.00	458.90	466.17	462.24	466.51	0.001454	4.68	425.08	153.95	0.31
Reach 1	3908	1% AC ULT	2810.00	458.90	469.96	463.08	470.25	0.000711	4.34	648.09	296.80	0.23
Reach 1	3875		Culvert									
Reach 1	3828	10% AC EX	2220.00	456.55	467.27	461.29	467.54	0.000492	4.19	530.73	139.78	0.25
Reach 1	3828	4% AC EX	2470.00	456.55	468.25	461.56	468.52	0.000421	4.17	593.46	159.27	0.24
Reach 1	3828	2% AC EX	2630.00	456.55	468.92	461.75	469.18	0.000380	4.15	635.80	169.90	0.23
Reach 1	3828	1% AC EX	2780.00	456.55	469.08	461.91	469.37	0.000403	4.31	646.11	172.32	0.24
Reach 1	3828	0.2% AC EX	3150.00	456.55	469.43	462.28	469.78	0.000462	4.72	668.69	177.64	0.26
Reach 1	3828	50% AC ULT	1470.00	456.55	464.80	460.36	465.03	0.000426	3.85	381.42	67.26	0.25
Reach 1	3828	20% AC ULT	1990.00	456.55	465.89	461.01	466.20	0.000709	4.49	443.42	87.22	0.30
Reach 1	3828	1% AC ULT	2810.00	456.55	469.11	461.92	469.40	0.000408	4.35	648.09	172.79	0.24
Reach 1	3795	10% AC EX	2500.00	456.44	466.95	461.50	467.45	0.000970	5.66	445.61	51.79	0.32
Reach 1	3795	4% AC EX	2990.00	456.44	467.80	462.11	468.40	0.001051	6.22	491.26	56.26	0.33
Reach 1	3795	2% AC EX	3330.00	456.44	468.38	462.51	469.04	0.001091	6.56	525.07	61.14	0.34
Reach 1	3795	1% AC EX	3430.00	456.44	468.54	462.62	469.23	0.001101	6.66	535.29	62.22	0.34

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	3795	0.2% AC EX	3670.00	456.44	468.91	462.89	469.64	0.001131	6.89	558.57	65.61	0.35
Reach 1	3795	50% AC ULT	1430.00	456.44	464.73	460.03	465.00	0.000683	4.17	342.95	44.17	0.26
Reach 1	3795	20% AC ULT	1900.00	456.44	465.79	460.71	466.16	0.000824	4.87	389.88	44.22	0.29
Reach 1	3795	1% AC ULT	3450.00	456.44	468.57	462.65	469.26	0.001103	6.67	537.28	62.43	0.35
Reach 1	3767	10% AC EX	2500.00	456.36	465.99	463.26	467.19	0.005212	8.77	286.51	39.13	0.54
Reach 1	3767	4% AC EX	2990.00	456.36	466.61	463.92	468.08	0.005808	9.73	311.43	42.17	0.58
Reach 1	3767	2% AC EX	3330.00	456.36	467.04	464.38	468.69	0.006126	10.31	330.34	48.01	0.60
Reach 1	3767	1% AC EX	3430.00	456.36	467.15	464.51	468.86	0.006235	10.49	336.38	55.83	0.61
Reach 1	3767	0.2% AC EX	3670.00	456.36	467.41	464.82	469.24	0.006480	10.89	351.97	65.07	0.62
Reach 1	3767	50% AC ULT	1430.00	456.36	464.21	461.40	464.85	0.003720	6.44	222.19	34.93	0.45
Reach 1	3767	20% AC ULT	1900.00	456.36	465.09	462.21	465.96	0.004418	7.51	253.03	35.12	0.49
Reach 1	3767	1% AC ULT	3450.00	456.36	467.18	464.54	468.89	0.006254	10.52	337.67	56.65	0.61
Reach 1	3729	10% AC EX	2500.00	456.33	465.91	462.33	466.69	0.003905	7.32	368.18	53.26	0.43
Reach 1	3729	4% AC EX	2990.00	456.33	466.53	463.03	467.48	0.004456	8.10	402.25	56.72	0.46
Reach 1	3729	2% AC EX	3330.00	456.33	466.96	463.49	468.01	0.004753	8.56	427.17	59.24	0.47
Reach 1	3729	1% AC EX	3430.00	456.33	467.08	463.63	468.16	0.004845	8.69	434.08	59.92	0.48
Reach 1	3729	0.2% AC EX	3670.00	456.33	467.33	463.97	468.50	0.005084	9.02	449.82	61.75	0.49
Reach 1	3729	50% AC ULT	1430.00	456.33	464.13	460.50	464.57	0.002698	5.40	278.64	47.46	0.35
Reach 1	3729	20% AC ULT	1900.00	456.33	465.01	461.35	465.59	0.003241	6.30	321.41	50.35	0.39
Reach 1	3729	1% AC ULT	3450.00	456.33	467.10	463.66	468.19	0.004862	8.72	435.47	60.05	0.48
Reach 1	3695	10% AC EX	2500.00	455.91	465.44	463.79	466.51	0.006020	9.30	362.65	68.50	0.56
Reach 1	3695	4% AC EX	2990.00	455.91	466.06	464.39	467.29	0.006416	10.05	405.83	70.90	0.58
Reach 1	3695	2% AC EX	3330.00	455.91	466.43	464.77	467.81	0.006864	10.68	433.18	75.51	0.61
Reach 1	3695	1% AC EX	3430.00	455.91	466.54	464.89	467.95	0.006977	10.84	441.14	76.58	0.61
Reach 1	3695	0.2% AC EX	3670.00	455.91	466.79	465.14	468.28	0.007187	11.19	460.55	78.44	0.63
Reach 1	3695	50% AC ULT	1430.00	455.91	463.69	462.00	464.42	0.005202	7.42	248.23	61.96	0.50
Reach 1	3695	20% AC ULT	1900.00	455.91	464.55	462.97	465.43	0.005531	8.28	303.18	65.13	0.53
Reach 1	3695	1% AC ULT	3450.00	455.91	466.56	464.91	467.98	0.006991	10.87	442.89	76.75	0.61
Reach 1	3610	10% AC EX	2500.00	454.82	465.41	462.97	466.01	0.003401	6.94	487.08	107.40	0.42
Reach 1	3610	4% AC EX	2990.00	454.82	466.09	463.58	466.74	0.003442	7.36	562.83	117.57	0.43
Reach 1	3610	2% AC EX	3330.00	454.82	466.52	463.95	467.21	0.003521	7.67	615.78	131.11	0.44
Reach 1	3610	1% AC EX	3430.00	454.82	466.64	464.04	467.34	0.003537	7.75	631.66	134.90	0.44
Reach 1	3610	0.2% AC EX	3670.00	454.82	466.92	464.28	467.65	0.003545	7.91	671.53	143.63	0.44
Reach 1	3610	50% AC ULT	1430.00	454.82	463.53	461.14	464.00	0.003418	5.88	305.65	85.33	0.41
Reach 1	3610	20% AC ULT	1900.00	454.82	464.45	461.99	464.97	0.003385	6.39	389.25	95.96	0.41
Reach 1	3610	1% AC ULT	3450.00	454.82	466.66	464.06	467.37	0.003537	7.77	635.11	135.71	0.44
Reach 1	3556	10% AC EX	2500.00	453.76	465.23	462.81	465.80	0.003667	6.96	472.19	103.36	0.41
Reach 1	3556	4% AC EX	2990.00	453.76	465.91	463.33	466.53	0.003695	7.34	545.35	112.44	0.42
Reach 1	3556	2% AC EX	3330.00	453.76	466.33	463.65	466.99	0.003763	7.62	594.87	124.87	0.43
Reach 1	3556	1% AC EX	3430.00	453.76	466.45	463.75	467.13	0.003785	7.70	610.00	129.95	0.43
Reach 1	3556	0.2% AC EX	3670.00	453.76	466.73	463.99	467.43	0.003813	7.88	648.36	142.03	0.43
Reach 1	3556	50% AC ULT	1430.00	453.76	463.35	461.33	463.79	0.003650	5.92	300.90	78.93	0.40
Reach 1	3556	20% AC ULT	1900.00	453.76	464.27	462.07	464.77	0.003634	6.42	378.87	90.80	0.40
Reach 1	3556	1% AC ULT	3450.00	453.76	466.47	463.77	467.15	0.003789	7.72	613.09	130.97	0.43
Reach 1	3278	10% AC EX	2500.00	452.18	464.24	461.51	464.83	0.003503	6.90	452.33	91.36	0.40
Reach 1	3278	4% AC EX	2990.00	452.18	464.87	462.16	465.53	0.003656	7.36	512.48	97.31	0.41
Reach 1	3278	2% AC EX	3330.00	452.18	465.27	462.57	465.98	0.003750	7.65	552.32	101.05	0.42
Reach 1	3278	1% AC EX	3430.00	452.18	465.39	462.70	466.10	0.003776	7.73	563.82	102.11	0.42
Reach 1	3278	0.2% AC EX	3670.00	452.18	465.66	462.96	466.40	0.003831	7.92	591.60	104.86	0.42
Reach 1	3278	50% AC ULT	1430.00	452.18	462.45	458.98	462.87	0.003074	5.61	303.98	73.98	0.36
Reach 1	3278	20% AC ULT	1900.00	452.18	463.33	460.51	463.83	0.003269	6.23	373.55	82.93	0.38
Reach 1	3278	1% AC ULT	3450.00	452.18	465.41	462.73	466.13	0.003780	7.75	566.15	102.32	0.42
Reach 1	3056	10% AC EX	2500.00	452.02	463.43	461.29	464.02	0.003898	7.10	535.54	133.83	0.43
Reach 1	3056	4% AC EX	2990.00	452.02	464.07	461.74	464.70	0.003914	7.47	624.05	142.48	0.44
Reach 1	3056	2% AC EX	3330.00	452.02	464.48	461.96	465.13	0.003891	7.67	683.48	145.57	0.44
Reach 1	3056	1% AC EX	3430.00	452.02	464.60	461.98	465.25	0.003882	7.72	700.58	146.17	0.44
Reach 1	3056	0.2% AC EX	3670.00	452.02	464.88	461.96	465.54	0.003852	7.84	741.65	147.64	0.44
Reach 1	3056	50% AC ULT	1430.00	452.02	461.73	459.69	462.15	0.003499	5.79	338.50	95.20	0.39
Reach 1	3056	20% AC ULT	1900.00	452.02	462.54	460.56	463.06	0.003818	6.52	422.01	116.80	0.42
Reach 1	3056	1% AC ULT	3450.00	452.02	464.63	462.00	465.27	0.003879	7.73	704.05	146.29	0.44
Reach 1	2845	10% AC EX	2500.00	452.49	462.07	460.64	462.98	0.006019	8.28	380.87	94.00	0.52
Reach 1	2845	4% AC EX	2990.00	452.49	462.58	461.19	463.61	0.006453	8.94	429.82	98.11	0.54
Reach 1	2845	2% AC EX	3330.00	452.49	462.90	461.55	464.02	0.006724	9.36	462.02	100.78	0.56
Reach 1	2845	1% AC EX	3430.00	452.49	462.99	461.62	464.14	0.006800	9.48	471.30	101.59	0.56
Reach 1	2845	0.2% AC EX	3670.00	452.49	463.21	461.86	464.42	0.006999	9.78	493.25	105.02	0.57
Reach 1	2845	50% AC ULT	1430.00	452.49	460.70	458.24	461.29	0.004661	6.42	262.68	78.93	0.44
Reach 1	2845	20% AC ULT	1900.00	452.49	461.34	459.40	462.09	0.005397	7.35	315.56	86.00	0.49
Reach 1	2845	1% AC ULT	3450.00	452.49	463.01	461.64	464.16	0.006815	9.51	473.18	101.85	0.56

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	2659	10% AC EX	2500.00	450.48	460.91	460.06	461.74	0.007131	8.43	434.76	139.60	0.56
Reach 1	2659	4% AC EX	2990.00	450.48	461.50	460.36	462.33	0.006715	8.62	519.41	148.47	0.55
Reach 1	2659	2% AC EX	3330.00	450.48	461.88	460.74	462.72	0.006473	8.74	576.33	153.08	0.54
Reach 1	2659	1% AC EX	3430.00	450.48	461.98	460.81	462.83	0.006412	8.77	592.69	154.37	0.54
Reach 1	2659	0.2% AC EX	3670.00	450.48	462.25	461.03	463.09	0.006183	8.80	634.07	155.64	0.53
Reach 1	2659	50% AC ULT	1430.00	450.48	459.61	458.47	460.26	0.006623	7.10	273.63	112.65	0.52
Reach 1	2659	20% AC ULT	1900.00	450.48	460.24	459.38	460.96	0.006822	7.71	346.36	118.90	0.53
Reach 1	2659	1% AC ULT	3450.00	450.48	462.01	460.83	462.85	0.006392	8.78	596.25	154.60	0.54
Reach 1	2477	10% AC EX	2500.00	449.21	459.75	458.89	460.52	0.006239	8.34	494.93	144.50	0.52
Reach 1	2477	4% AC EX	2990.00	449.21	460.49	459.27	461.21	0.005505	8.31	603.35	149.59	0.50
Reach 1	2477	2% AC EX	3330.00	449.21	460.91	459.50	461.63	0.005290	8.41	667.79	152.74	0.49
Reach 1	2477	1% AC EX	3430.00	449.21	461.03	459.59	461.74	0.005251	8.45	685.57	153.65	0.49
Reach 1	2477	0.2% AC EX	3670.00	449.21	461.33	459.77	462.04	0.005093	8.50	732.11	156.41	0.48
Reach 1	2477	50% AC ULT	1430.00	449.21	457.67	456.80	458.75	0.010129	8.69	218.19	102.80	0.63
Reach 1	2477	20% AC ULT	1900.00	449.21	458.71	458.17	459.62	0.007810	8.51	349.09	136.41	0.57
Reach 1	2477	1% AC ULT	3450.00	449.21	461.06	459.61	461.77	0.005233	8.45	689.70	153.90	0.49
Reach 1	2383	10% AC EX	2500.00	448.92	459.60	456.68	459.99	0.003926	5.67	605.25	157.49	0.34
Reach 1	2383	4% AC EX	2990.00	448.92	460.37	457.42	460.74	0.003469	5.65	727.79	161.57	0.33
Reach 1	2383	2% AC EX	3330.00	448.92	460.81	457.66	461.18	0.003347	5.72	798.86	163.90	0.32
Reach 1	2383	1% AC EX	3430.00	448.92	460.92	458.35	461.30	0.003326	5.75	818.30	164.53	0.32
Reach 1	2383	0.2% AC EX	3670.00	448.92	461.23	458.57	461.61	0.003224	5.78	869.29	166.07	0.32
Reach 1	2383	50% AC ULT	1430.00	448.92	457.42	454.63	457.88	0.005715	5.62	300.16	95.72	0.39
Reach 1	2383	20% AC ULT	1900.00	448.92	458.49	455.54	458.94	0.004928	5.79	435.24	146.97	0.37
Reach 1	2383	1% AC ULT	3450.00	448.92	460.95	458.37	461.32	0.003314	5.75	822.86	164.68	0.32
Reach 1	2162	10% AC EX	2500.00	447.39	456.72	455.94	458.50	0.010843	10.93	258.39	70.82	0.75
Reach 1	2162	4% AC EX	2990.00	447.39	457.07	457.07	459.24	0.012750	12.17	283.95	73.77	0.82
Reach 1	2162	2% AC EX	3330.00	447.39	457.47	457.47	459.72	0.012689	12.50	313.54	74.67	0.82
Reach 1	2162	1% AC EX	3430.00	447.39	457.60	457.60	459.85	0.012553	12.54	323.26	74.96	0.82
Reach 1	2162	0.2% AC EX	3670.00	447.39	457.78	457.78	460.16	0.013031	12.94	337.15	75.38	0.84
Reach 1	2162	50% AC ULT	1430.00	447.39	455.18	453.71	456.28	0.008515	8.44	173.14	43.16	0.65
Reach 1	2162	20% AC ULT	1900.00	447.39	455.97	454.69	457.37	0.009470	9.59	211.75	54.97	0.69
Reach 1	2162	1% AC ULT	3450.00	447.39	457.61	457.61	459.87	0.012634	12.59	323.99	74.99	0.82
Reach 1	2140	10% AC EX	2500.00	448.62	456.01	456.01	458.20	0.013421	11.98	222.71	62.90	0.94
Reach 1	2140	4% AC EX	2990.00	448.62	456.84	456.84	458.97	0.011479	11.96	280.35	74.38	0.89
Reach 1	2140	2% AC EX	3330.00	448.62	457.22	457.22	459.43	0.011336	12.27	309.05	76.24	0.89
Reach 1	2140	1% AC EX	3430.00	448.62	457.30	457.30	459.56	0.011423	12.41	315.84	76.67	0.89
Reach 1	2140	0.2% AC EX	3670.00	448.62	457.49	457.49	459.87	0.011742	12.77	330.36	77.59	0.91
Reach 1	2140	50% AC ULT	1430.00	448.62	454.11	454.11	455.96	0.017024	10.91	131.05	36.04	1.01
Reach 1	2140	20% AC ULT	1900.00	448.62	455.03	455.03	457.06	0.015250	11.44	168.30	47.39	0.98
Reach 1	2140	1% AC ULT	3450.00	448.62	457.33	457.33	459.59	0.011421	12.42	317.41	76.77	0.89
Reach 1	2109	10% AC EX	2500.00	445.77	454.28	449.20	454.46	0.000610	3.45	724.09	112.23	0.22
Reach 1	2109	4% AC EX	2990.00	445.77	455.43	449.57	455.63	0.000550	3.57	836.41	131.22	0.22
Reach 1	2109	2% AC EX	3330.00	445.77	456.23	449.82	456.43	0.000506	3.64	914.96	137.21	0.21
Reach 1	2109	1% AC EX	3430.00	445.77	456.46	449.90	456.67	0.000495	3.66	937.90	138.23	0.21
Reach 1	2109	0.2% AC EX	3670.00	445.77	457.03	450.06	457.24	0.000467	3.69	993.63	140.68	0.20
Reach 1	2109	50% AC ULT	1430.00	445.77	451.85	448.28	451.98	0.000652	2.88	496.51	99.15	0.22
Reach 1	2109	20% AC ULT	1900.00	445.77	453.00	448.70	453.15	0.000621	3.15	602.71	104.51	0.22
Reach 1	2109	1% AC ULT	3450.00	445.77	456.51	449.91	456.72	0.000492	3.66	942.54	138.43	0.21
Reach 1	2000		Culvert									
Reach 1	1952	10% AC EX	2500.00	445.17	453.52	449.38	453.93	0.000864	5.16	484.31	78.14	0.33
Reach 1	1952	4% AC EX	2990.00	445.17	454.31	449.87	454.79	0.000888	5.57	536.52	81.44	0.34
Reach 1	1952	2% AC EX	3330.00	445.17	454.80	450.18	455.33	0.000906	5.85	568.96	83.56	0.35
Reach 1	1952	1% AC EX	3430.00	445.17	454.94	450.27	455.48	0.000912	5.93	577.96	84.15	0.35
Reach 1	1952	0.2% AC EX	3670.00	445.17	455.26	450.49	455.84	0.000926	6.13	599.16	90.90	0.36
Reach 1	1952	50% AC ULT	1430.00	445.17	451.39	448.15	451.65	0.000754	4.09	349.58	68.04	0.30
Reach 1	1952	20% AC ULT	1900.00	445.17	452.40	448.74	452.73	0.000824	4.61	412.29	73.63	0.32
Reach 1	1952	1% AC ULT	3450.00	445.17	454.96	450.28	455.51	0.000914	5.95	579.76	85.99	0.35
Reach 1	1942	10% AC EX	2500.00	445.21	453.54	449.49	453.89	0.000839	4.76	525.73	82.29	0.33
Reach 1	1942	4% AC EX	2990.00	445.21	454.34	449.99	454.74	0.000853	5.04	593.52	86.15	0.34
Reach 1	1942	2% AC EX	3330.00	445.21	454.85	450.32	455.27	0.000857	5.23	637.96	92.29	0.34
Reach 1	1942	1% AC EX	3430.00	445.21	454.98	450.41	455.42	0.000857	5.28	650.97	94.31	0.34
Reach 1	1942	0.2% AC EX	3670.00	445.21	455.31	450.62	455.77	0.000856	5.41	682.74	99.05	0.34
Reach 1	1942	50% AC ULT	1430.00	445.21	451.39	448.24	451.63	0.000815	3.98	359.36	72.17	0.31
Reach 1	1942	20% AC ULT	1900.00	445.21	452.41	448.84	452.71	0.000827	4.36	435.97	77.08	0.32
Reach 1	1942	1% AC ULT	3450.00	445.21	455.01	450.43	455.45	0.000857	5.29	653.60	94.71	0.34
Reach 1	1938		Bridge									

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	1934	10% AC EX	2500.00	445.24	453.49	449.53	453.83	0.000825	4.67	534.96	85.73	0.33
Reach 1	1934	4% AC EX	2990.00	445.24	454.27	450.01	454.66	0.000838	4.95	603.90	91.67	0.34
Reach 1	1934	2% AC EX	3330.00	445.24	454.76	450.33	455.17	0.000835	5.14	650.47	98.88	0.34
Reach 1	1934	1% AC EX	3430.00	445.24	454.90	450.42	455.32	0.000836	5.19	664.01	100.81	0.34
Reach 1	1934	0.2% AC EX	3670.00	445.24	455.22	450.63	455.66	0.000836	5.32	696.96	105.36	0.34
Reach 1	1934	50% AC ULT	1430.00	445.24	451.38	448.30	451.62	0.000802	3.91	365.45	75.20	0.31
Reach 1	1934	20% AC ULT	1900.00	445.24	452.39	448.86	452.68	0.000809	4.28	443.98	80.23	0.32
Reach 1	1934	1% AC ULT	3450.00	445.24	454.93	450.44	455.35	0.000836	5.20	666.75	101.20	0.34
Reach 1	1882	10% AC EX	2500.00	444.91	453.01	450.48	453.67	0.001813	6.54	384.80	72.47	0.48
Reach 1	1882	4% AC EX	2990.00	444.91	453.75	451.03	454.49	0.001761	6.89	440.83	77.91	0.48
Reach 1	1882	2% AC EX	3330.00	444.91	454.20	451.37	455.00	0.001761	7.15	479.71	98.73	0.49
Reach 1	1882	1% AC EX	3430.00	444.91	454.33	451.50	455.14	0.001760	7.22	492.65	104.24	0.49
Reach 1	1882	0.2% AC EX	3670.00	444.91	454.64	451.74	455.48	0.001750	7.37	526.46	117.42	0.49
Reach 1	1882	50% AC ULT	1430.00	444.91	450.98	449.04	451.48	0.002026	5.68	251.71	59.65	0.49
Reach 1	1882	20% AC ULT	1900.00	444.91	451.95	449.72	452.53	0.001950	6.08	312.57	64.88	0.49
Reach 1	1882	1% AC ULT	3450.00	444.91	454.36	451.52	455.17	0.001760	7.24	495.34	105.35	0.49
Reach 1	1868	10% AC EX	2500.00	444.80	452.89	450.66	453.62	0.002259	6.86	364.42	70.56	0.53
Reach 1	1868	4% AC EX	2990.00	444.80	453.66	451.21	454.44	0.002103	7.12	427.61	97.54	0.52
Reach 1	1868	2% AC EX	3330.00	444.80	454.15	451.57	454.96	0.002010	7.27	479.90	115.14	0.52
Reach 1	1868	1% AC EX	3430.00	444.80	454.28	451.69	455.11	0.001987	7.31	495.83	118.78	0.51
Reach 1	1868	0.2% AC EX	3670.00	444.80	454.61	451.91	455.45	0.001926	7.40	536.01	127.50	0.51
Reach 1	1868	50% AC ULT	1430.00	444.80	450.83	449.18	451.42	0.002575	6.17	231.85	58.32	0.55
Reach 1	1868	20% AC ULT	1900.00	444.80	451.82	449.88	452.48	0.002370	6.49	292.56	63.85	0.53
Reach 1	1868	1% AC ULT	3450.00	444.80	454.31	451.71	455.14	0.001981	7.32	499.11	119.52	0.51
Reach 1	1865		Bridge									
Reach 1	1862	10% AC EX	2500.00	444.74	452.30	450.59	453.21	0.003014	7.65	326.59	66.58	0.61
Reach 1	1862	4% AC EX	2990.00	444.74	453.05	451.16	454.02	0.002901	7.91	378.34	80.25	0.61
Reach 1	1862	2% AC EX	3330.00	444.74	453.51	451.51	454.52	0.002755	8.07	422.79	104.34	0.60
Reach 1	1862	1% AC EX	3430.00	444.74	453.65	451.63	454.67	0.002716	8.12	436.77	107.43	0.59
Reach 1	1862	0.2% AC EX	3670.00	444.74	453.96	451.85	455.00	0.002626	8.21	471.30	114.69	0.59
Reach 1	1862	50% AC ULT	1430.00	444.74	450.29	449.11	451.05	0.003615	7.00	204.26	54.81	0.64
Reach 1	1862	20% AC ULT	1900.00	444.74	451.27	449.82	452.09	0.003246	7.29	260.73	60.64	0.62
Reach 1	1862	1% AC ULT	3450.00	444.74	453.67	451.65	454.69	0.002708	8.12	439.63	108.05	0.59
Reach 1	1815	10% AC EX	2500.00	444.18	452.22	450.21	453.03	0.002580	7.23	345.97	68.24	0.57
Reach 1	1815	4% AC EX	2990.00	444.18	452.97	450.78	453.84	0.002484	7.50	399.59	78.96	0.56
Reach 1	1815	2% AC EX	3330.00	444.18	453.44	451.13	454.36	0.002383	7.68	440.41	96.20	0.56
Reach 1	1815	1% AC EX	3430.00	444.18	453.57	451.23	454.50	0.002358	7.73	453.50	100.78	0.56
Reach 1	1815	0.2% AC EX	3670.00	444.18	453.89	451.48	454.84	0.002297	7.84	486.42	110.17	0.55
Reach 1	1815	50% AC ULT	1430.00	444.18	450.19	448.66	450.84	0.002883	6.49	220.26	55.56	0.57
Reach 1	1815	20% AC ULT	1900.00	444.18	451.18	449.38	451.90	0.002693	6.83	278.10	61.68	0.57
Reach 1	1815	1% AC ULT	3450.00	444.18	453.60	451.26	454.53	0.002352	7.74	456.20	101.59	0.56
Reach 1	1767	10% AC EX	2500.00	443.48	452.19	449.57	452.85	0.001951	6.56	381.34	70.11	0.50
Reach 1	1767	4% AC EX	2990.00	443.48	452.94	450.16	453.67	0.001912	6.86	437.76	86.42	0.50
Reach 1	1767	2% AC EX	3330.00	443.48	453.41	450.53	454.19	0.001860	7.06	483.14	103.68	0.50
Reach 1	1767	1% AC EX	3430.00	443.48	453.55	450.64	454.33	0.001846	7.11	497.36	109.10	0.49
Reach 1	1767	0.2% AC EX	3670.00	443.48	453.86	450.90	454.67	0.001813	7.23	533.49	120.41	0.49
Reach 1	1767	50% AC ULT	1430.00	443.48	450.15	448.00	450.66	0.001965	5.69	251.54	57.67	0.48
Reach 1	1767	20% AC ULT	1900.00	443.48	451.14	448.74	451.72	0.001945	6.10	311.42	63.68	0.49
Reach 1	1767	1% AC ULT	3450.00	443.48	453.57	450.66	454.36	0.001843	7.12	500.31	110.19	0.49
Reach 1	1764		Bridge									
Reach 1	1761	10% AC EX	2500.00	443.53	450.94	449.62	452.06	0.003931	8.50	294.00	61.71	0.69
Reach 1	1761	4% AC EX	2990.00	443.53	451.61	450.20	452.83	0.003891	8.88	336.87	65.78	0.69
Reach 1	1761	2% AC EX	3330.00	443.53	452.06	450.58	453.34	0.003831	9.07	367.03	68.54	0.69
Reach 1	1761	1% AC EX	3430.00	443.53	452.19	450.69	453.48	0.003811	9.12	376.11	69.41	0.69
Reach 1	1761	0.2% AC EX	3670.00	443.53	452.51	450.95	453.83	0.003739	9.20	398.70	71.54	0.69
Reach 1	1761	50% AC ULT	1430.00	443.53	449.09	448.09	449.97	0.004268	7.53	189.92	50.99	0.69
Reach 1	1761	20% AC ULT	1900.00	443.53	449.94	448.82	450.95	0.004151	8.07	235.41	55.70	0.69
Reach 1	1761	1% AC ULT	3450.00	443.53	452.22	450.71	453.51	0.003806	9.13	377.95	69.59	0.69
Reach 1	1712	10% AC EX	2500.00	443.54	450.88	449.09	451.79	0.002944	7.67	325.80	63.85	0.60
Reach 1	1712	4% AC EX	2990.00	443.54	451.55	449.66	452.56	0.002961	8.08	369.92	67.29	0.61
Reach 1	1712	2% AC EX	3330.00	443.54	452.00	450.03	453.07	0.002946	8.31	400.67	69.58	0.61
Reach 1	1712	1% AC EX	3430.00	443.54	452.13	450.14	453.22	0.002936	8.37	409.86	70.25	0.61
Reach 1	1712	0.2% AC EX	3670.00	443.54	452.45	450.38	453.57	0.002896	8.48	432.63	71.89	0.61
Reach 1	1712	50% AC ULT	1430.00	443.54	449.01	447.60	449.69	0.003067	6.64	215.47	54.33	0.59
Reach 1	1712	20% AC ULT	1900.00	443.54	449.87	448.31	450.67	0.003052	7.19	264.15	58.71	0.60
Reach 1	1712	1% AC ULT	3450.00	443.54	452.16	450.16	453.25	0.002933	8.38	411.72	70.39	0.61

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	1669	10% AC EX	2500.00	443.29	450.89	448.50	451.57	0.002035	6.60	379.04	71.02	0.50
Reach 1	1669	4% AC EX	2990.00	443.29	451.57	449.04	452.33	0.002063	6.98	428.67	74.55	0.51
Reach 1	1669	2% AC EX	3330.00	443.29	452.03	449.39	452.83	0.002063	7.19	463.12	76.90	0.52
Reach 1	1669	1% AC EX	3430.00	443.29	452.16	449.49	452.98	0.002059	7.25	473.39	77.59	0.52
Reach 1	1669	0.2% AC EX	3670.00	443.29	452.49	449.72	453.33	0.002039	7.36	498.78	79.26	0.52
Reach 1	1669	50% AC ULT	1430.00	443.29	449.00	447.11	449.49	0.002071	5.63	253.80	61.22	0.49
Reach 1	1669	20% AC ULT	1900.00	443.29	449.87	447.77	450.46	0.002084	6.14	309.30	65.74	0.50
Reach 1	1669	1% AC ULT	3450.00	443.29	452.19	449.51	453.01	0.002058	7.26	475.46	77.72	0.52
Reach 1	1665		Bridge									
Reach 1	1663	10% AC EX	2500.00	443.25	449.66	448.43	450.72	0.003868	8.28	301.84	65.54	0.68
Reach 1	1663	4% AC EX	2990.00	443.25	450.37	448.97	451.51	0.003642	8.54	350.12	69.32	0.67
Reach 1	1663	2% AC EX	3330.00	443.25	450.86	449.32	452.03	0.003474	8.66	384.51	71.89	0.66
Reach 1	1663	1% AC EX	3430.00	443.25	451.02	449.42	452.18	0.003396	8.66	395.95	72.72	0.65
Reach 1	1663	0.2% AC EX	3670.00	443.25	451.40	449.65	452.56	0.003217	8.66	423.73	74.71	0.64
Reach 1	1663	50% AC ULT	1430.00	443.25	448.09	447.04	448.84	0.003796	6.96	205.35	57.22	0.65
Reach 1	1663	20% AC ULT	1900.00	443.25	449.05	447.70	449.86	0.003311	7.23	262.76	62.31	0.62
Reach 1	1663	1% AC ULT	3450.00	443.25	451.05	449.44	452.22	0.003380	8.66	398.26	72.89	0.65
Reach 1	1596	10% AC EX	2500.00	442.81	449.59	447.77	450.36	0.002651	7.06	354.21	73.50	0.57
Reach 1	1596	4% AC EX	2990.00	442.81	450.32	448.29	451.15	0.002523	7.30	409.77	77.92	0.56
Reach 1	1596	2% AC EX	3330.00	442.81	450.82	448.62	451.67	0.002423	7.41	449.42	81.01	0.55
Reach 1	1596	1% AC EX	3430.00	442.81	450.98	448.72	451.84	0.002373	7.41	462.65	82.01	0.55
Reach 1	1596	0.2% AC EX	3670.00	442.81	451.37	448.94	452.22	0.002257	7.42	494.75	84.40	0.54
Reach 1	1596	50% AC ULT	1430.00	442.81	447.99	446.44	448.52	0.002498	5.86	244.14	64.18	0.53
Reach 1	1596	20% AC ULT	1900.00	442.81	448.98	447.05	449.56	0.002221	6.12	310.54	69.96	0.51
Reach 1	1596	1% AC ULT	3450.00	442.81	451.02	448.74	451.87	0.002363	7.41	465.32	82.21	0.55
Reach 1	1526	10% AC EX	2500.00	442.57	449.65	446.51	450.07	0.001142	5.23	478.05	81.37	0.38
Reach 1	1526	4% AC EX	2990.00	442.57	450.38	446.95	450.86	0.001144	5.55	538.97	87.91	0.39
Reach 1	1526	2% AC EX	3330.00	442.57	450.88	447.26	451.39	0.001114	5.73	588.89	113.97	0.38
Reach 1	1526	1% AC EX	3430.00	442.57	451.05	447.34	451.56	0.001091	5.76	608.16	122.93	0.38
Reach 1	1526	0.2% AC EX	3670.00	442.57	451.43	447.54	451.96	0.001040	5.82	663.16	164.04	0.38
Reach 1	1526	50% AC ULT	1430.00	442.57	448.03	445.36	448.28	0.000950	4.08	350.50	75.95	0.33
Reach 1	1526	20% AC ULT	1900.00	442.57	449.02	445.89	449.33	0.000919	4.44	427.88	79.28	0.34
Reach 1	1526	1% AC ULT	3450.00	442.57	451.08	447.36	451.59	0.001087	5.76	612.19	124.63	0.38
Reach 1	1523		Bridge									
Reach 1	1520	10% AC EX	2500.00	442.61	449.20	446.37	449.68	0.001387	5.54	451.00	80.30	0.41
Reach 1	1520	4% AC EX	2990.00	442.61	449.89	446.87	450.43	0.001394	5.90	506.99	82.29	0.42
Reach 1	1520	2% AC EX	3330.00	442.61	450.36	447.15	450.94	0.001370	6.09	547.57	94.35	0.42
Reach 1	1520	1% AC EX	3430.00	442.61	450.53	447.24	451.11	0.001343	6.12	563.67	105.73	0.42
Reach 1	1520	0.2% AC EX	3670.00	442.61	450.91	447.45	451.51	0.001271	6.18	615.16	156.71	0.41
Reach 1	1520	50% AC ULT	1430.00	442.61	447.78	445.25	448.05	0.001073	4.21	339.77	75.87	0.35
Reach 1	1520	20% AC ULT	1900.00	442.61	448.74	445.77	449.07	0.001033	4.58	414.63	78.89	0.35
Reach 1	1520	1% AC ULT	3450.00	442.61	450.56	447.25	451.14	0.001337	6.13	567.14	108.63	0.42
Reach 1	1511	10% AC EX	2500.00	442.57	449.21	446.20	449.65	0.001210	5.31	471.00	80.67	0.39
Reach 1	1511	4% AC EX	2990.00	442.57	449.90	446.68	450.40	0.001222	5.67	526.88	81.54	0.39
Reach 1	1511	2% AC EX	3330.00	442.57	450.37	446.97	450.91	0.001198	5.88	574.06	110.29	0.39
Reach 1	1511	1% AC EX	3430.00	442.57	450.53	447.05	451.08	0.001175	5.91	593.46	126.17	0.39
Reach 1	1511	0.2% AC EX	3670.00	442.57	450.92	447.25	451.47	0.001118	5.98	647.65	152.25	0.39
Reach 1	1511	50% AC ULT	1430.00	442.57	447.78	445.12	448.03	0.000924	4.00	357.75	77.53	0.33
Reach 1	1511	20% AC ULT	1900.00	442.57	448.75	445.62	449.05	0.000899	4.38	434.12	79.92	0.33
Reach 1	1511	1% AC ULT	3450.00	442.57	450.57	447.07	451.11	0.001170	5.92	597.61	128.43	0.39
Reach 1	1450		Culvert									
Reach 1	1353	10% AC EX	2500.00	441.43	448.83	444.50	449.05	0.000489	3.72	671.46	97.92	0.25
Reach 1	1353	4% AC EX	2990.00	441.43	449.27	444.87	449.55	0.000573	4.18	714.99	98.03	0.27
Reach 1	1353	2% AC EX	3330.00	441.43	449.53	445.12	449.85	0.000637	4.50	740.22	98.10	0.29
Reach 1	1353	1% AC EX	3430.00	441.43	449.62	445.18	449.94	0.000653	4.58	748.49	98.13	0.29
Reach 1	1353	0.2% AC EX	3670.00	441.43	449.81	445.34	450.16	0.000692	4.78	767.27	98.18	0.30
Reach 1	1353	50% AC ULT	1430.00	441.43	447.66	443.59	447.76	0.000289	2.57	557.18	97.64	0.19
Reach 1	1353	20% AC ULT	1900.00	441.43	448.56	444.01	448.69	0.000321	2.95	644.81	97.84	0.20
Reach 1	1353	1% AC ULT	3450.00	441.43	449.63	445.20	449.96	0.000656	4.60	750.10	98.13	0.29
Reach 1	1335	10% AC EX	2500.00	441.17	448.80	444.63	449.03	0.000529	3.84	651.41	102.05	0.27
Reach 1	1335	4% AC EX	2990.00	441.17	449.25	445.01	449.53	0.000618	4.29	696.81	103.62	0.29
Reach 1	1335	2% AC EX	3330.00	441.17	449.50	445.27	449.83	0.000686	4.60	723.40	104.59	0.31
Reach 1	1335	1% AC EX	3430.00	441.17	449.58	445.35	449.93	0.000703	4.68	732.22	104.97	0.31
Reach 1	1335	0.2% AC EX	3670.00	441.17	449.78	445.52	450.15	0.000743	4.88	752.36	105.82	0.32
Reach 1	1335	50% AC ULT	1430.00	441.17	447.65	443.63	447.76	0.000312	2.67	535.59	97.91	0.20

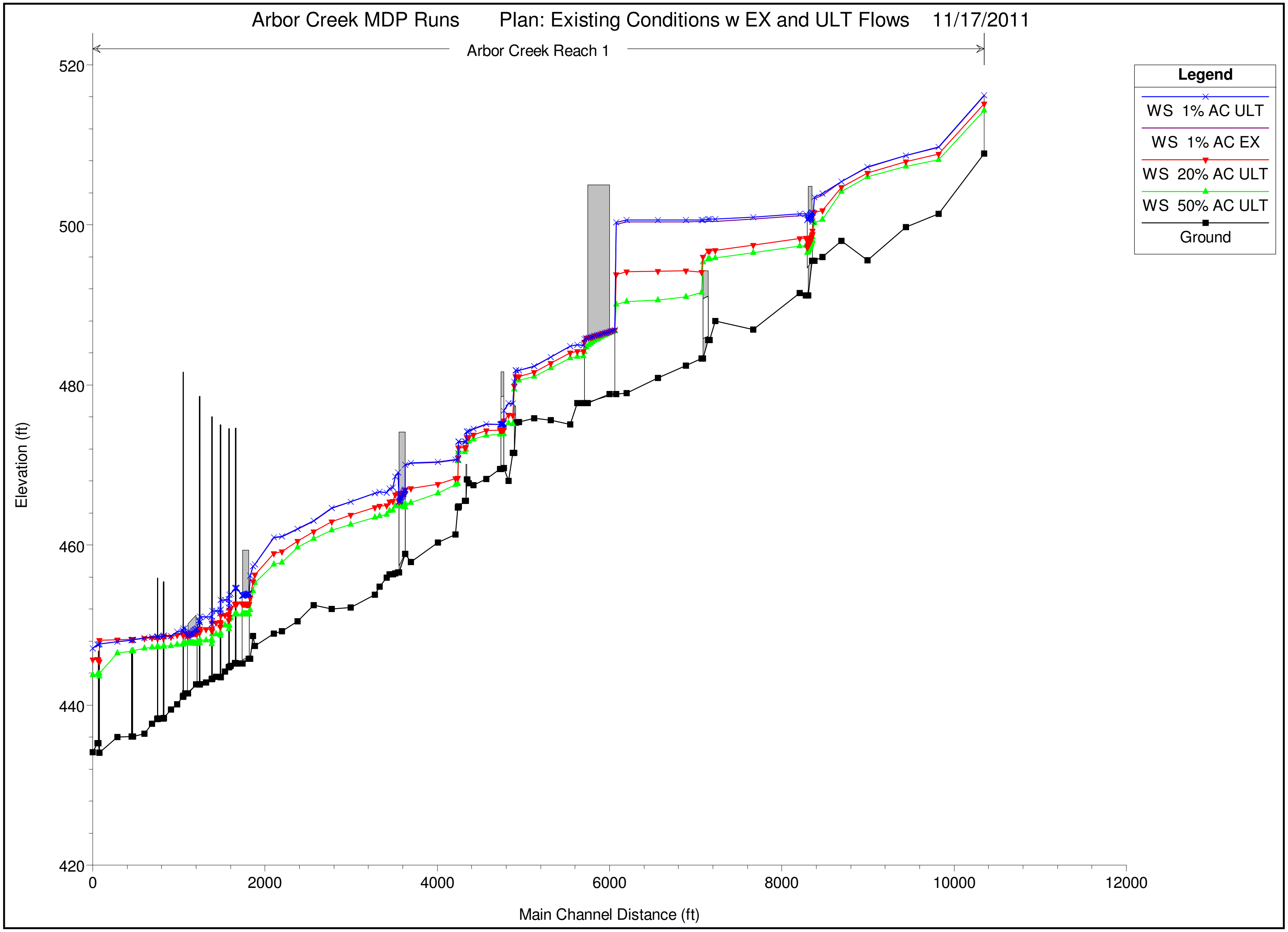
HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	1335	20% AC ULT	1900.00	441.17	448.54	444.10	448.68	0.000346	3.04	624.69	101.11	0.22
Reach 1	1335	1% AC ULT	3450.00	441.17	449.60	445.35	449.94	0.000706	4.70	733.94	105.04	0.31
Reach 1	1332		Bridge									
Reach 1	1328	10% AC EX	2500.00	441.07	448.63	444.54	448.88	0.000583	3.98	628.23	100.35	0.28
Reach 1	1328	4% AC EX	2990.00	441.07	449.02	444.95	449.33	0.000698	4.48	667.44	102.05	0.31
Reach 1	1328	2% AC EX	3330.00	441.07	449.23	445.21	449.60	0.000789	4.83	689.04	102.97	0.33
Reach 1	1328	1% AC EX	3430.00	441.07	449.30	445.29	449.68	0.000811	4.93	696.41	103.29	0.33
Reach 1	1328	0.2% AC EX	3670.00	441.07	449.46	445.46	449.87	0.000868	5.15	712.83	103.98	0.35
Reach 1	1328	50% AC ULT	1430.00	441.07	447.53	443.52	447.65	0.000334	2.75	519.87	95.49	0.21
Reach 1	1328	20% AC ULT	1900.00	441.07	448.41	443.99	448.56	0.000375	3.14	605.88	99.37	0.22
Reach 1	1328	1% AC ULT	3450.00	441.07	449.32	445.30	449.70	0.000816	4.94	697.83	103.35	0.34
Reach 1	1262	10% AC EX	2500.00	440.09	448.54	444.45	448.83	0.000726	4.26	586.54	100.48	0.31
Reach 1	1262	4% AC EX	2990.00	440.09	448.91	444.94	449.27	0.000877	4.79	624.50	108.71	0.34
Reach 1	1262	2% AC EX	3330.00	440.09	449.11	445.26	449.52	0.000995	5.17	647.60	127.19	0.37
Reach 1	1262	1% AC EX	3430.00	440.09	449.17	445.35	449.60	0.001023	5.26	656.27	128.24	0.37
Reach 1	1262	0.2% AC EX	3670.00	440.09	449.32	445.56	449.79	0.001093	5.50	675.60	130.56	0.39
Reach 1	1262	50% AC ULT	1430.00	440.09	447.48	443.26	447.62	0.000404	2.96	483.81	92.60	0.23
Reach 1	1262	20% AC ULT	1900.00	440.09	448.36	443.82	448.53	0.000459	3.35	567.74	99.08	0.25
Reach 1	1262	1% AC ULT	3450.00	440.09	449.19	445.37	449.62	0.001029	5.28	657.94	128.45	0.37
Reach 1	1188	10% AC EX	2500.00	439.42	448.17	445.32	448.72	0.001663	5.97	418.76	132.24	0.46
Reach 1	1188	4% AC EX	2990.00	439.42	448.41	445.88	449.14	0.002115	6.81	438.77	143.43	0.52
Reach 1	1188	2% AC EX	3330.00	439.42	448.61	446.25	449.38	0.002281	7.14	524.23	151.61	0.54
Reach 1	1188	1% AC EX	3430.00	439.42	448.65	446.34	449.46	0.002367	7.28	531.52	155.78	0.55
Reach 1	1188	0.2% AC EX	3670.00	439.42	448.75	446.58	449.63	0.002579	7.64	546.93	163.90	0.58
Reach 1	1188	50% AC ULT	1430.00	439.42	447.31	443.83	447.56	0.000831	4.04	353.58	96.59	0.32
Reach 1	1188	20% AC ULT	1900.00	439.42	448.14	444.53	448.47	0.000971	4.56	416.90	131.10	0.35
Reach 1	1188	1% AC ULT	3450.00	439.42	448.66	446.36	449.47	0.002386	7.31	532.83	156.89	0.55
Reach 1	1105	10% AC EX	2500.00	438.35	448.19	444.13	448.50	0.000812	4.67	689.20	460.96	0.33
Reach 1	1105	4% AC EX	2990.00	438.35	448.47	444.70	448.85	0.000963	5.21	770.50	525.49	0.36
Reach 1	1105	2% AC EX	3330.00	438.35	448.65	445.07	449.07	0.001051	5.53	834.29	575.01	0.38
Reach 1	1105	1% AC EX	3430.00	438.35	448.71	445.18	449.14	0.001079	5.61	853.92	586.89	0.38
Reach 1	1105	0.2% AC EX	3670.00	438.35	448.82	445.42	449.27	0.001157	5.81	895.97	611.48	0.39
Reach 1	1105	50% AC ULT	1430.00	438.35	447.30	442.67	447.47	0.000456	3.30	477.99	193.98	0.24
Reach 1	1105	20% AC ULT	1900.00	438.35	448.16	443.35	448.34	0.000480	3.58	679.81	457.23	0.25
Reach 1	1105	1% AC ULT	3450.00	438.35	448.72	445.19	449.15	0.001086	5.63	857.49	589.03	0.38
Reach 1	1103		Bridge									
Reach 1	1100	10% AC EX	2500.00	438.34	448.09	444.12	448.38	0.000801	4.56	729.77	470.80	0.32
Reach 1	1100	4% AC EX	2990.00	438.34	448.35	444.69	448.70	0.000951	5.09	811.02	517.13	0.35
Reach 1	1100	2% AC EX	3330.00	438.34	448.52	445.06	448.92	0.001050	5.41	868.31	534.06	0.37
Reach 1	1100	1% AC EX	3430.00	438.34	448.57	445.17	448.97	0.001081	5.49	884.29	538.58	0.38
Reach 1	1100	0.2% AC EX	3670.00	438.34	448.68	445.40	449.11	0.001148	5.71	920.62	548.97	0.39
Reach 1	1100	50% AC ULT	1430.00	438.34	447.25	442.63	447.40	0.000443	3.25	515.72	212.19	0.24
Reach 1	1100	20% AC ULT	1900.00	438.34	448.05	443.36	448.23	0.000473	3.50	720.31	463.88	0.25
Reach 1	1100	1% AC ULT	3450.00	438.34	448.58	445.18	448.99	0.001087	5.51	887.44	539.47	0.38
Reach 1	1037	10% AC EX	2500.00	438.33	448.08	443.89	448.30	0.000565	4.08	871.55	521.65	0.28
Reach 1	1037	4% AC EX	2990.00	438.33	448.34	444.46	448.61	0.000689	4.62	959.85	576.21	0.31
Reach 1	1037	2% AC EX	3330.00	438.33	448.51	444.82	448.82	0.000769	4.96	1023.76	614.72	0.33
Reach 1	1037	1% AC EX	3430.00	438.33	448.56	444.93	448.88	0.000792	5.05	1042.07	625.27	0.33
Reach 1	1037	0.2% AC EX	3670.00	438.33	448.66	445.17	449.01	0.000848	5.28	1084.77	649.18	0.34
Reach 1	1037	50% AC ULT	1430.00	438.33	447.24	442.39	447.36	0.000342	2.90	626.42	292.58	0.21
Reach 1	1037	20% AC ULT	1900.00	438.33	448.05	443.09	448.18	0.000333	3.12	861.43	516.84	0.21
Reach 1	1037	1% AC ULT	3450.00	438.33	448.57	444.94	448.89	0.000797	5.07	1045.69	627.34	0.33
Reach 1	1034		Bridge									
Reach 1	1032	10% AC EX	2500.00	438.28	448.05	443.87	448.26	0.000559	4.06	871.83	519.79	0.28
Reach 1	1032	4% AC EX	2990.00	438.28	448.31	444.44	448.57	0.000671	4.56	957.24	559.82	0.30
Reach 1	1032	2% AC EX	3330.00	438.28	448.48	444.81	448.77	0.000741	4.88	1017.77	586.87	0.32
Reach 1	1032	1% AC EX	3430.00	438.28	448.53	444.91	448.83	0.000762	4.96	1034.83	594.23	0.33
Reach 1	1032	0.2% AC EX	3670.00	438.28	448.63	445.17	448.96	0.000812	5.18	1074.14	611.15	0.34
Reach 1	1032	50% AC ULT	1430.00	438.28	447.21	442.38	447.32	0.000339	2.89	631.88	286.94	0.21
Reach 1	1032	20% AC ULT	1900.00	438.28	448.01	443.08	448.14	0.000331	3.11	860.30	514.25	0.21
Reach 1	1032	1% AC ULT	3450.00	438.28	448.53	444.92	448.84	0.000766	4.98	1038.20	595.67	0.33
Reach 1	971	10% AC EX	2500.00	437.67	447.99	444.87	448.21	0.002760	4.40	754.64	528.93	0.26
Reach 1	971	4% AC EX	2990.00	437.67	448.26	446.91	448.51	0.003050	4.72	858.01	609.61	0.28
Reach 1	971	2% AC EX	3330.00	437.67	448.44	447.08	448.70	0.003179	4.88	933.99	651.63	0.29
Reach 1	971	1% AC EX	3430.00	437.67	448.49	447.13	448.76	0.003211	4.92	956.05	659.89	0.29

HEC-RAS Plan: Tarrant Impr. River: Arbor Creek Reach: Reach 1 (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Reach 1	971	0.2% AC EX	3670.00	437.67	448.61	447.25	448.88	0.003292	5.03	1006.86	685.86	0.29
Reach 1	971	50% AC ULT	1430.00	437.67	447.11	442.92	447.28	0.002310	3.74	489.04	297.22	0.24
Reach 1	971	20% AC ULT	1900.00	437.67	447.98	443.92	448.11	0.001615	3.36	750.00	523.55	0.20
Reach 1	971	1% AC ULT	3450.00	437.67	448.50	447.14	448.77	0.003217	4.93	960.41	661.54	0.29
Reach 1	884	10% AC EX	2500.00	436.44	447.88	444.17	448.03	0.001792	3.59	897.32	572.39	0.24
Reach 1	884	4% AC EX	2990.00	436.44	448.13	444.83	448.31	0.002007	3.88	1013.50	656.38	0.25
Reach 1	884	2% AC EX	3330.00	436.44	448.31	446.67	448.50	0.002121	4.04	1097.35	688.95	0.26
Reach 1	884	1% AC EX	3430.00	436.44	448.36	446.71	448.55	0.002169	4.10	1120.54	723.74	0.26
Reach 1	884	0.2% AC EX	3670.00	436.44	448.46	446.81	448.67	0.002270	4.24	1177.42	751.09	0.27
Reach 1	884	50% AC ULT	1430.00	436.44	447.01	442.50	447.12	0.001452	3.04	586.07	303.33	0.21
Reach 1	884	20% AC ULT	1900.00	436.44	447.92	443.30	448.00	0.000993	2.68	915.20	584.58	0.18
Reach 1	884	1% AC ULT	3450.00	436.44	448.37	446.72	448.56	0.002176	4.11	1125.48	727.29	0.26
Reach 1	750	10% AC EX	2500.00	436.06	447.68	446.66	447.82	0.002153	3.80	974.31	580.77	0.25
Reach 1	750	4% AC EX	2990.00	436.06	447.92	446.83	448.09	0.002290	4.01	1092.91	618.12	0.25
Reach 1	750	2% AC EX	3330.00	436.06	448.10	446.94	448.27	0.002349	4.12	1181.11	724.16	0.26
Reach 1	750	1% AC EX	3430.00	436.06	448.14	446.97	448.31	0.002365	4.15	1206.70	746.66	0.26
Reach 1	750	0.2% AC EX	3670.00	436.06	448.25	447.05	448.42	0.002406	4.22	1268.52	799.39	0.26
Reach 1	750	50% AC ULT	1430.00	436.06	446.69	442.73	446.87	0.002832	3.97	537.16	437.40	0.28
Reach 1	750	20% AC ULT	1900.00	436.06	447.82	443.71	447.89	0.001045	2.68	1042.44	602.38	0.17
Reach 1	750	1% AC ULT	3450.00	436.06	448.15	446.98	448.32	0.002367	4.15	1212.12	751.33	0.26
Reach 1	740		Bridge									
Reach 1	730	10% AC EX	2500.00	436.06	447.63	446.53	447.75	0.001860	3.40	1034.10	571.88	0.22
Reach 1	730	4% AC EX	2990.00	436.06	447.88	446.68	448.01	0.001971	3.58	1156.98	625.35	0.23
Reach 1	730	2% AC EX	3330.00	436.06	448.05	446.78	448.19	0.002004	3.67	1252.91	835.55	0.24
Reach 1	730	1% AC EX	3430.00	436.06	448.10	446.81	448.24	0.002017	3.69	1283.42	841.91	0.24
Reach 1	730	0.2% AC EX	3670.00	436.06	448.20	446.87	448.35	0.002050	3.76	1353.42	856.42	0.24
Reach 1	730	50% AC ULT	1430.00	436.06	446.61	443.18	446.76	0.002753	3.81	573.12	453.34	0.27
Reach 1	730	20% AC ULT	1900.00	436.06	447.80	446.23	447.86	0.000872	2.37	1118.17	616.65	0.15
Reach 1	730	1% AC ULT	3450.00	436.06	448.11	446.82	448.25	0.002018	3.70	1289.77	843.23	0.24
Reach 1	570	10% AC EX	2500.00	436.00	447.47	445.39	447.52	0.000817	2.47	1543.50	750.21	0.16
Reach 1	570	4% AC EX	2990.00	436.00	447.71	445.65	447.77	0.000858	2.59	1723.02	780.19	0.16
Reach 1	570	2% AC EX	3330.00	436.00	447.88	445.81	447.94	0.000863	2.63	1853.93	801.20	0.17
Reach 1	570	1% AC EX	3430.00	436.00	447.93	445.84	447.99	0.000869	2.65	1887.94	806.64	0.17
Reach 1	570	0.2% AC EX	3670.00	436.00	448.03	445.94	448.09	0.000891	2.71	1964.80	977.57	0.17
Reach 1	570	50% AC ULT	1430.00	436.00	446.35	442.79	446.43	0.001228	2.72	772.94	587.53	0.19
Reach 1	570	20% AC ULT	1900.00	436.00	447.73	444.95	447.76	0.000336	1.62	1742.08	783.26	0.10
Reach 1	570	1% AC ULT	3450.00	436.00	447.93	445.85	448.00	0.000869	2.65	1895.10	807.78	0.17
Reach 1	359	10% AC EX	2500.00	434.06	446.85	446.76	447.13	0.005988	5.43	765.01	761.38	0.39
Reach 1	359	4% AC EX	2990.00	434.06	447.35	446.87	447.48	0.002992	3.89	1160.34	831.10	0.28
Reach 1	359	2% AC EX	3330.00	434.06	447.57	446.94	447.68	0.002479	3.56	1340.70	857.60	0.25
Reach 1	359	1% AC EX	3430.00	434.06	447.62	446.95	447.73	0.002412	3.50	1383.07	862.47	0.25
Reach 1	359	0.2% AC EX	3670.00	434.06	447.73	446.98	447.84	0.002313	3.41	1474.17	874.88	0.25
Reach 1	359	50% AC ULT	1430.00	434.06	443.74	442.41	445.32	0.023807	10.10	141.60	24.24	0.74
Reach 1	359	20% AC ULT	1900.00	434.06	445.52	443.62	447.08	0.021366	10.05	189.14	30.97	0.72
Reach 1	359	1% AC ULT	3450.00	434.06	447.63	446.95	447.74	0.002395	3.49	1392.22	863.52	0.25
Reach 1	349		Bridge									
Reach 1	338	10% AC EX	2500.00	435.23	446.62	443.36	447.11	0.005962	6.31	612.80	606.15	0.42
Reach 1	338	4% AC EX	2990.00	435.23	447.25	444.13	447.45	0.003022	4.59	1051.34	743.36	0.30
Reach 1	338	2% AC EX	3330.00	435.23	447.49	446.93	447.66	0.002531	4.24	1236.19	801.07	0.27
Reach 1	338	1% AC EX	3430.00	435.23	447.55	446.95	447.70	0.002476	4.20	1277.43	809.13	0.27
Reach 1	338	0.2% AC EX	3670.00	435.23	447.66	447.02	447.81	0.002400	4.15	1364.78	824.32	0.27
Reach 1	338	50% AC ULT	1430.00	435.23	443.63	441.43	444.46	0.010433	7.32	195.42	33.65	0.54
Reach 1	338	20% AC ULT	1900.00	435.23	445.06	442.33	445.99	0.010031	7.75	245.24	37.05	0.53
Reach 1	338	1% AC ULT	3450.00	435.23	447.56	446.96	447.71	0.002468	4.19	1284.99	810.45	0.27
Reach 1	281	10% AC EX	2500.00	434.12	446.38	441.09	446.80	0.003506	5.36	566.23	434.26	0.33
Reach 1	281	4% AC EX	2990.00	434.12	446.79	441.79	447.17	0.003506	5.38	769.38	553.90	0.33
Reach 1	281	2% AC EX	3330.00	434.12	447.03	442.24	447.38	0.003506	5.34	913.16	660.58	0.33
Reach 1	281	1% AC EX	3430.00	434.12	447.09	442.37	447.43	0.003505	5.32	953.26	682.62	0.33
Reach 1	281	0.2% AC EX	3670.00	434.12	447.21	442.67	447.54	0.003506	5.30	1039.65	718.99	0.33
Reach 1	281	50% AC ULT	1430.00	434.12	443.55	439.31	443.90	0.003501	4.73	302.38	45.72	0.32
Reach 1	281	20% AC ULT	1900.00	434.12	445.00	440.15	445.41	0.003500	5.12	371.37	49.36	0.33
Reach 1	281	1% AC ULT	3450.00	434.12	447.10	442.39	447.44	0.003506	5.32	960.49	685.86	0.33

Flood Profile



Arbor Creek MDP Runs Plan: Existing Conditions w EX and ULT Flows 11/17/2011
Arbor Creek Reach 1
Legend
WS 1% AC ULT
WS 1% AC EX
WS 20% AC ULT
WS 50% AC ULT
Ground
Elevation (ft)
520
500
480
460
440
420
0
2000
4000
6000
8000
10000
12000
Main Channel Distance (ft)

Response to QC Comments

O'Brien Engineering, Inc.
Hydraulics · Hydrology · Civil Engineering

November 22, 2011

Mr. Gabe G. Johnson, PE, PH, CFM
Floodplain Administrator
City of Grand Prairie
206 West Church Street
Grand Prairie, Texas 75053-4045

RE: City-Wide Drainage Master Plan for Arbor Creek, Y#0879
Response to QA/QC Comments for DRAFT Arbor Creek CWDMP Received October 10, 2011
OEI Job # 196.006

Dear Mr. Johnson:

O'Brien Engineering, Inc. (OEI) has reviewed the comments provided by Halff Associates, Inc. (Halff) in their letter titled *QA/QC – Draft Arbor Creek CWDMP – Updated,* dated October 10, 2011. Several revisions have been made to the hydrologic and hydraulic modeling and the CWDMP report. Your annotated items are noted below in bold, while our responses are noted in blue text.

1. **Arbor Creek CWDMP needs to be in 3-Ring Binder, for potential future Addendums and other possible inserts into the document**

   The Final Report is submitted in a 3-ring binder.

2. **Please include a CD-ROM with supporting technical data, hydrologic & hydraulic models, and GIS shapefiles for Arbor Creek**

   A CD-ROM with supporting data is included in the Final Report.

3. **Need Resolution for City Council – needs to be included in front of report**

   The City Council Resolution is included in the Final Report.

4. **Need cover letter, signed and sealed by professional engineer**

   A cover letter, signed and sealed by a professional engineer, is included.

5. **Include CIP Map and Preliminary Short-Term & Long-Term Implementation Plan (table) with the Executive Summary (will go into the document right after the Executive Summary, like the Joe Pool CWDMP)**

   The CIP Map is included in front of the report after the Executive Summary and the preliminary Short-Term & Long-Term Implementation Plan table is also included in the front of the report.

6. **Section I - Add "Acknowledgments" section in the Introduction (similar to Joe Pool CWDMP)**

   An "Acknowledgments" section has been added to the Introduction section.

7. **Section I - Add "City Ordinances and Development Requirements" section in the Introduction (similar to Joe Pool CWDMP)**

City Ordinances and Development Requirements section has been added to Section I.

8. **Section I - Watershed Description states that watershed is 82% urbanized, but Executive Summary says it is 90% urbanized. Be consistent.**

   The description listed in Section I is correct and therefore the executive summary has been updated to reflect the correct description.

9. **Section I - Add "Unique Attributes of Watershed" under Watershed Description. Can include quick summary of unique attributes – I-30 crossing, small dams, SH 161 crossings, Egyptian Way bend, also goes upstream into Arlington, state that it is called JC-1 on FEMA maps, but GP calls it Arbor Creek, etc.**

   A description about the unique attributes of the watershed has been added to the Watershed Description section of Section I.

10. **Section I - Add section after "Channel Stability Assessment" in Introduction – "Pertinent Study and Technical Data Related to Watershed Prior to Arbor Creek CWDMP Preparation" – describe previous studies and models available. Include LOMRs, previous analyses (i.e. Halff's study of Tarrant Road improvements in 2005), etc. Describe any on-going studies as well, such as future work in City of Arlington. This is shown later on in the document, but also needs to be included in this section.**

    A section regarding Pertinent Study and Technical Data has been added to Section I.

11. **Section II – Impervious Coverage – Include a table listing the % impervious values used for various land use classifications**

    Table II-4 Land Use Percent Impervious has been added to Section II.

12. **Section IV - Remember to complete QA/QC section with dates**

    A QAQC response noting dates is included in Appendix A.

13. **Section V – Include BFEs on Floodplain Maps and reduce thickness of cross-section lines (red lines)**

    Maps have been updated to include BFEs.

14. **Section VI.B – Did not see Figure VI-1 in the report, although it is mentioned in the text. Please include.**

    Figure VI-1 is included in the Final Report.

15. **Section IX – A map of Potential Sedimentation Areas is included, but did not see a map of Potential Erosion Areas. Please combine into one set of maps that show both the potential sedimentation areas and potential erosion areas. Also include sanitary sewer line locations and locations of sanitary sewer crossings along Arbor Creek.**

    Figure IX-3 was added showing all of the noted problem areas. Figure IX-7 was modified to show areas of potential downcutting as well as sedimentation.

16. **Figure IX-16 (1) – Can you limit drop structures to 1 each in Reach G, Reach F, and/or Reach E?**

    One drop-structure in Reach E was removed and the quantities and costs adjusted accordingly. The same was done for Reach F, although there was little impact to costs because the entire reach must be restored and the drop structures are only a portion of such an effort. All proposed drop structures for Reach F are necessary to protect existing facilities; therefore, the number of proposed drop structures has been kept the same.

17. **Figure IX-16 (2) – Why do you need 3 drop structures in an area of potential sedimentation (upstream of IH-30)? Can you limit drop structures to 1 in Reach B?**

    As the text discusses, this area shows low velocities in higher flow scenarios due to the constrictions at IH-30. Lower flows continue to cause scour and the area is expected to downcut over time. No sedimentation has been observed in this area and no accumulation of sediment is expected in the future, as discussed in Chapter IX.

18. **Figure IX-16 – What is the different proposed improvement methodologies for scour protection, bank armoring, and drop structure?**

    Chapter IX discusses the proposed methods for each location.

19. **For Table XIII-1, please make sure that rankings shown on left side of table match those on right side. For # structures benefited, this only applies to those being removed from the 100-year floodplain. Please confirm that this applies or does not apply to erosion control improvement projects. Make sure everything is being calculated correctly per the Road Map. Appears that there are some miscalculations in Step #5. Please confirm.**

    The 4% AC flood alternative for Tarrant Road was removed based on City comments. Consideration of whether a house or other structures would be saved by an improvement was removed; therefore, no houses or other structures are considered to be benefited by any of the proposed improvements. Step 5 was adjusted from the Road Map methodology because the methodology was not designed to handle stream improvements not associated with flooding or roadway overtopping. This is discussed in Section XIII. The projects were sorted in order of priority and the left and right columns were revised to match.

20. **Proposed Tarrant Road Improvements**
    a. **Need to explain and/or confirm that 100-year WSEL upstream of IH-30 (501.37) should match or be close to matching 100-year WSEL for STO1 in HEC-HMS model. Existing conditions HEC-HMS model shows 499.8 for 100-year WSEL.**

       Our original discharge rating curve in the HMS model was based on spreadsheet calculations of the culvert discharge where the RAS model uses a different method for the discharge through the culverts at I-30. We have updated the HMS discharge curve with one from the RAS model and now our two models (RAS and HMS) have peak stages within 0.2'. The peak stage as shown in the HEC-HMS model also dropped from about 501.5 to 500.5.

       Mutiplte parameters were compared between the previous Halff existing conditions model and the current model in this study. Some differences between parameters were observed, however, the only parameter which caused a significant difference in the flow or peak stage upstream of I-30 was the storage volume rating curve. This study determined the volume based on 2009 topography and the previous model's storage curve was based on 1999 topography. The storage curves for each set of topography was rechecked to determine any differences and it was that there is approximately 15 ac-ft of difference in flood storage between the two sets of topography. Also the previous model storage curve was plugged into the current model and executed which resulted in a similar peak stage upstream of I-30 to the previous Halff model.

In summary, the HEC-HMS discharge rating has been updated to reflect HEC-RAS computations and the storage curve is based on 2009 topography.

b. **Currently, the 300 cfs difference between the Halff and O'Brien models at IH-30 is causing a 2.5' difference in WSEL. This also is creating a much different tailwater at Tarrant Road, in which the two designs are ultimately based on. Please confirm the discharge at IH-30 is correct.**

Please reference response to Item # 20b above.

21. **(NEW) Please provide GIS shapefiles for the deposition, erosion, and set back areas from the Channel Stability Assessment with the final submittal.**

GIS shapefiles are included with final version of report.

We trust that the above details provided address your comments.

We appreciate your time and assistance in the matter. If you have further questions, please feel free to contact us. We may be reached at (972) 233-2288.

Sincerely,

O'BRIEN ENGINEERING, INC.

Jacob S. Lesué, PE, CFM
Project Manager

attachments

xc: Mr. Stephen Crawford, PE, CFM, Halff Associates, Inc.

November 22, 2011

Mr. Gabe G. Johnson, PE, PH, CFM
Floodplain Administrator
City of Grand Prairie
206 West Church Street
Grand Prairie, Texas 75053-4045

RE: City-Wide Drainage Master Plan for Arbor Creek, Y#0879
Response to Questions and Comments from November 3, 2011 City Progress Meeting
OEI Job # 196.006

Dear Mr. Johnson:

O'Brien Engineering, Inc. (OEI) has addressed the questions, comments, and items discussed during the November 3, 2011 progress meeting held at the City of Grand Prairie for the City-Wide Drainage Master Plan for Arbor creek. Meeting discussion items are noted below in bold, while our responses are noted in blue text.

1. **Submit 2-3 final reports in a 3-ring binder.**

   Final report has been submitted in a 3-ring binder.

2. **How many property owners would be affected by the Tarrant Road Culvert Improvement Concept?**

   An updated discussion of the improvements related to this topic has been included in Chapter 7, Alternatives for Streams and Open Channels

3. **Were Arbor Creek flood profiles included in the report?**

   Appendix A, Hydrologic and Hydraulic Data has a HEC-RAS style flood profile for Arbor Creek, while Figure VII-1 contains a more detailed flood profile of Arbor Creek between I-30 and Duncan Perry Road.

4. **Would additional storage excavated between Tarrant Road and I-30 help reduce the flood profile at Tarrant Road and reduce the overall construction costs for replacing the Tarranht Road culverts and elevating the road deck above the 1% annual chance flood profile?**

   The amount of fill required to raise Tarrant Road above the 1% annual chance flood profile is estimated to be approximately 4 ac-ft. However, if 4 ac-ft of materials were to be excavated in the area between I-30 and Tarrant Road for additional flood storage and placed as fill on Tarrant Road, no net increase in flood storage would be available. The excavated material may still provide reduced costs due to the close proximity of the fill material and eliminate costs for transporting fill material over a considerable distance. Also, it may be possible to excavate additional material for additional flood storage. Location and grading of excavated material can be completed at the design phase of the improvements. The peak 1% annual chance flood stage could be reduced up to 0.7' with an additional 15 ac-ft of flood storage excavated between I-30 and Tarrant Road.

5. **What would be the cost difference between 2 lanes and 6 lanes on the Tarrant Road culvert improvements?**

   After reviewing the City Thoroughfare Plan and further discussion with City Staff, OEI was directed to only provide costs for keeping the current 4 lanes and sidewalks on both sides.

6. **Show storm, sewer, and other utility crossings on exhibits.**

   Data has been included on exhibits.

7. **Provide in report description about how rankings were determined.**

   Report has been updated to include discussion on ranking procedures.

We trust that the above details provided address the questions and comments.

We appreciate your time and assistance in the matter. If you have further questions, please feel free to contact us. We may be reached at (972) 233-2288.

Sincerely,

O'BRIEN ENGINEERING, INC.

Jacob S. Lesué, PE, CFM
Project Manager

attachments

xc: Mr. Stephen Crawford, PE, CFM, Halff Associates, Inc.

Appendix B
Elevation Certificates

U.S. DEPARTMENT OF HOMELAND SECURITY
Federal Emergency Management Agency
National Flood Insurance Program

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

	For Insurance Company Use:
A1. Building Owner's Name HALL JAY JONATHAN	Policy Number
A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 2002 DOGWOOD CT.	Company NAIC Number

City Grand Prairie State TX ZIP Code 75050

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)
WEDGEWOOD ESTATES REP, BLK 1 LT 43R ACS 0.5892

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) Residential
A5. Latitude/Longitude: Lat. N32°45'57.2" Long. W97°01'50.4" Horizontal Datum: ☐ NAD 1927 ☒ NAD 1983
A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.
A7. Building Diagram Number 1A
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) _____ sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A8.b _____ sq in
d) Engineered flood openings? ☐ Yes ☒ No

A9. For a building with an attached garage:
a) Square footage of attached garage 480 sq ft
b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade 0
c) Total net area of flood openings in A9.b 0 sq in
d) Engineered flood openings? ☐ Yes ☒ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State
Grand Prairie 485472	Dallas	TX

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
0295	J	August 23, 2001	August 23, 2001	AE	467.2

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.
☒ FIS Profile ☐ FIRM ☐ Community Determined ☐ Other (Describe) _____
B11. Indicate elevation datum used for BFE in Item B9: ☒ NGVD 1929 ☐ NAVD 1988 ☐ Other (Describe) _____
B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ☐ Yes ☒ No
Designation Date _____ ☐ CBRS ☐ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.
C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.
Benchmark Utilized RM255 Vertical Datum NGVD 1929
Conversion/Comments _____

Check the measurement used.

a) Top of bottom floor (including basement, crawlspace, or enclosure floor) 468.3 ☒ feet ☐ meters (Puerto Rico only)
b) Top of the next higher floor 477.6 ☒ feet ☐ meters (Puerto Rico only)
c) Bottom of the lowest horizontal structural member (V Zones only) N/A._____ ☐ feet ☐ meters (Puerto Rico only)
d) Attached garage (top of slab) 468.2 ☒ feet ☐ meters (Puerto Rico only)
e) Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments) 467.5 ☒ feet ☐ meters (Puerto Rico only)
f) Lowest adjacent (finished) grade next to building (LAG) 465.9 ☒ feet ☐ meters (Puerto Rico only)
g) Highest adjacent (finished) grade next to building (HAG) 472.0 ☒ feet ☐ meters (Puerto Rico only)
h) Lowest adjacent grade at lowest elevation of deck or stairs, including structural support N/A._____ ☐ feet ☐ meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.* ☒ Check here if comments are provided on back of form. Were latitude and longitude in Section A provided by a licensed land surveyor? ☒ Yes ☐ No

Certifier's Name Marshall Lancaster License Number 4873
Title Vice President Company Name Marshall Lancaster & Associates, Inc.
Address 1864 N. Norwood Dr. City Hurst State TX ZIP Code 76054
Signature Date 11-21-2011 Telephone 817-268-8000

IMPORTANT: In these spaces, copy the corresponding information from Section A.	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 2002 DOGWOOD CT.	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION (CONTINUED)

Copy both sides of this Elevation Certificate for (1) community official, (2) insurance agent/company, and (3) building owner.

Comments Elevation provided in C2e is the lowest elevation of the 2 AC units on concrete pads.

Signature Date 11-21-2011

☐ Check here if attachments

SECTION E - BUILDING ELEVATION INFORMATION (SURVEY NOT REQUIRED) FOR ZONE AO AND ZONE A (WITHOUT BFE)

For Zones AO and A (without BFE), complete Items E1-E5. If the Certificate is intended to support a LOMA or LOMR-F request, complete Sections A, B, and C. For Items E1-E4, use natural grade, if available. Check the measurement used. In Puerto Rico only, enter meters.

E1. Provide elevation information for the following and check the appropriate boxes to show whether the elevation is above or below the highest adjacent grade (HAG) and the lowest adjacent grade (LAG).
a) Top of bottom floor (including basement, crawlspace, or enclosure) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.
b) Top of bottom floor (including basement, crawlspace, or enclosure) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the LAG.

E2. For Building Diagrams 6-9 with permanent flood openings provided in Section A Items 8 and/or 9 (see pages 8-9 of Instructions), the next higher floor (elevation C2.b in the diagrams) of the building is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E3. Attached garage (top of slab) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E4. Top of platform of machinery and/or equipment servicing the building is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E5. Zone AO only: If no flood depth number is available, is the top of the bottom floor elevated in accordance with the community's floodplain management ordinance? ☐ Yes ☐ No ☐ Unknown. The local official must certify this information in Section G.

SECTION F - PROPERTY OWNER (OR OWNER'S REPRESENTATIVE) CERTIFICATION

The property owner or owner's authorized representative who completes Sections A, B, and E for Zone A (without a FEMA-issued or community-issued BFE) or Zone AO must sign here. *The statements in Sections A, B, and E are correct to the best of my knowledge.*

Property Owner's or Owner's Authorized Representative's Name

Address City State ZIP Code

Signature Date Telephone

Comments

☐ Check here if attachments

SECTION G - COMMUNITY INFORMATION (OPTIONAL)

The local official who is authorized by law or ordinance to administer the community's floodplain management ordinance can complete Sections A, B, C (or E), and G of this Elevation Certificate. Complete the applicable item(s) and sign below. Check the measurement used in Items G8 and G9.

G1. ☐ The information in Section C was taken from other documentation that has been signed and sealed by a licensed surveyor, engineer, or architect who is authorized by law to certify elevation information. (Indicate the source and date of the elevation data in the Comments area below.)

G2. ☐ A community official completed Section E for a building located in Zone A (without a FEMA-issued or community-issued BFE) or Zone AO.

G3. ☐ The following information (Items G4-G9) is provided for community floodplain management purposes.

G4. Permit Number	G5. Date Permit Issued	G6. Date Certificate Of Compliance/Occupancy Issued

G7. This permit has been issued for: ☐ New Construction ☐ Substantial Improvement

G8. Elevation of as-built lowest floor (including basement) of the building: _____._____ ☐ feet ☐ meters (PR) Datum _____

G9. BFE or (in Zone AO) depth of flooding at the building site: _____._____ ☐ feet ☐ meters (PR) Datum _____

G10. Community's design flood elevation _____._____ ☐ feet ☐ meters (PR) Datum _____

Local Official's Name Title

Community Name Telephone

Signature Date

Comments

☐ Check here if attachments

Building Photographs

See Instructions for Item A6.

	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 2002 DOGWOOD CT.	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

If using the Elevation Certificate to obtain NFIP flood insurance, affix at least two building photographs below according to the instructions for Item A6. Identify all photographs with: date taken; “Front View” and “Rear View”; and, if required, “Right Side View” and “Left Side View.” If submitting more photographs than will fit on this page, use the Continuation Page, following.

Front View – Photo Taken 10/07/11

Back View – Photo Taken 10/07/11

Building Photographs

Continuation Page

	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 2002 DOGWOOD CT.	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

If submitting more photographs than will fit on the preceding page, affix the additional photographs below. Identify all photographs with: date taken; “Front View” and “Rear View”; and, if required, “Right Side View” and “Left Side View.”

U.S. DEPARTMENT OF HOMELAND SECURITY
Federal Emergency Management Agency
National Flood Insurance Program

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

For Insurance Company Use:
Policy Number
Company NAIC Number

A1. Building Owner's Name AZURE BELMONT, LLC

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.
1920 WEST TARRANT ROAD, BLDG. #4
City Grand Prairie State TX ZIP Code 75050

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)
TARRANT 30, BLOCK A LOT 1, ACRES 14.5414

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) Residential
A5. Latitude/Longitude: Lat. N32°45'30.4" Long. W97°01'57.8" Horizontal Datum: ☐ NAD 1927 ☒ NAD 1983
A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.
A7. Building Diagram Number 3
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) _____ sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A8.b _____ sq in
d) Engineered flood openings? ☐ Yes ☒ No

A9. For a building with an attached garage:
a) Square footage of attached garage _____ sq ft
b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A9.b _____ sq in
d) Engineered flood openings? ☐ Yes ☒ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State
Grand Prairie 485472	Dallas	TX

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
0295	J	August 23, 2001	August 23, 2001	AE	499.4

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.
☒ FIS Profile ☐ FIRM ☐ Community Determined ☐ Other (Describe) _____
B11. Indicate elevation datum used for BFE in Item B9: ☒ NGVD 1929 ☐ NAVD 1988 ☐ Other (Describe) _____
B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ☐ Yes ☒ No
Designation Date _____ ☐ CBRS ☐ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.
C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.
Benchmark Utilized RM255 Vertical Datum NGVD 1929
Conversion/Comments _____

Check the measurement used.

a)	Top of bottom floor (including basement, crawlspace, or enclosure floor)	500.7	☒ feet	☐ meters (Puerto Rico only)
b)	Top of the next higher floor	502.8	☒ feet	☐ meters (Puerto Rico only)
c)	Bottom of the lowest horizontal structural member (V Zones only)	N/A._____	☐ feet	☐ meters (Puerto Rico only)
d)	Attached garage (top of slab)	N/A._____	☐ feet	☐ meters (Puerto Rico only)
e)	Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments)	499.9	☒ feet	☐ meters (Puerto Rico only)
f)	Lowest adjacent (finished) grade next to building (LAG)	499.2	☒ feet	☐ meters (Puerto Rico only)
g)	Highest adjacent (finished) grade next to building (HAG)	501.7	☒ feet	☐ meters (Puerto Rico only)
h)	Lowest adjacent grade at lowest elevation of deck or stairs, including structural support	N/A._____	☐ feet	☐ meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.* ☒
Check here if comments are provided on back of form.
Were latitude and longitude in Section A provided by a licensed land surveyor? ☒ Yes ☐ No

Certifier's Name Marshall Lancaster License Number 4873
Title Vice President Company Name Marshall Lancaster & Associates, Inc.
Address 1864 N. Norwood Dr. City Hurst State TX ZIP Code 76054
Signature Date 11-21-2011 Telephone 817-268-8000

STATE OF TEXAS
REGISTERED
MARSHALL LANCASTER
4873
PROFESSIONAL LAND SURVEYOR

IMPORTANT: In these spaces, copy the corresponding information from Section A.	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 1920 WEST TARRANT ROAD, BLDG. #4	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION (CONTINUED)

Copy both sides of this Elevation Certificate for (1) community official, (2) insurance agent/company, and (3) building owner.

Comments Elevation provided in C2e is the lowest elevation of the AC units setting on concrete pads.

Signature Date 11-21-2011

☐ Check here if attachments

SECTION E - BUILDING ELEVATION INFORMATION (SURVEY NOT REQUIRED) FOR ZONE AO AND ZONE A (WITHOUT BFE)

For Zones AO and A (without BFE), complete Items E1-E5. If the Certificate is intended to support a LOMA or LOMR-F request, complete Sections A, B, and C. For Items E1-E4, use natural grade, if available. Check the measurement used. In Puerto Rico only, enter meters.

E1. Provide elevation information for the following and check the appropriate boxes to show whether the elevation is above or below the highest adjacent grade (HAG) and the lowest adjacent grade (LAG).
a) Top of bottom floor (including basement, crawlspace, or enclosure) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.
b) Top of bottom floor (including basement, crawlspace, or enclosure) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the LAG.

E2. For Building Diagrams 6-9 with permanent flood openings provided in Section A Items 8 and/or 9 (see pages 8-9 of Instructions), the next higher floor (elevation C2.b in the diagrams) of the building is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E3. Attached garage (top of slab) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E4. Top of platform of machinery and/or equipment servicing the building is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E5. Zone AO only: If no flood depth number is available, is the top of the bottom floor elevated in accordance with the community's floodplain management ordinance? ☐ Yes ☐ No ☐ Unknown. The local official must certify this information in Section G.

SECTION F - PROPERTY OWNER (OR OWNER'S REPRESENTATIVE) CERTIFICATION

The property owner or owner's authorized representative who completes Sections A, B, and E for Zone A (without a FEMA-issued or community-issued BFE) or Zone AO must sign here. *The statements in Sections A, B, and E are correct to the best of my knowledge.*

Property Owner's or Owner's Authorized Representative's Name

Address City State ZIP Code

Signature Date Telephone

Comments

☐ Check here if attachments

SECTION G - COMMUNITY INFORMATION (OPTIONAL)

The local official who is authorized by law or ordinance to administer the community's floodplain management ordinance can complete Sections A, B, C (or E), and G of this Elevation Certificate. Complete the applicable item(s) and sign below. Check the measurement used in Items G8 and G9.

G1. ☐ The information in Section C was taken from other documentation that has been signed and sealed by a licensed surveyor, engineer, or architect who is authorized by law to certify elevation information. (Indicate the source and date of the elevation data in the Comments area below.)

G2. ☐ A community official completed Section E for a building located in Zone A (without a FEMA-issued or community-issued BFE) or Zone AO.

G3. ☐ The following information (Items G4-G9) is provided for community floodplain management purposes.

G4. Permit Number	G5. Date Permit Issued	G6. Date Certificate Of Compliance/Occupancy Issued

G7. This permit has been issued for: ☐ New Construction ☐ Substantial Improvement

G8. Elevation of as-built lowest floor (including basement) of the building: _____._____ ☐ feet ☐ meters (PR) Datum _____

G9. BFE or (in Zone AO) depth of flooding at the building site: _____._____ ☐ feet ☐ meters (PR) Datum _____

G10. Community's design flood elevation _____._____ ☐ feet ☐ meters (PR) Datum _____

Local Official's Name Title

Community Name Telephone

Signature Date

Comments

☐ Check here if attachments

Building Photographs

See Instructions for Item A6.

	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 1920 WEST TARRANT ROAD, BLDG. #4	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

If using the Elevation Certificate to obtain NFIP flood insurance, affix at least two building photographs below according to the instructions for Item A6. Identify all photographs with: date taken; "Front View" and "Rear View"; and, if required, "Right Side View" and "Left Side View." If submitting more photographs than will fit on this page, use the Continuation Page, following.

Front View – Photo Taken 10/07/11

Back View – Photo Taken 10/07/11

Building Photographs

Continuation Page

	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 1920 WEST TARRANT ROAD, BLDG. #4	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

If submitting more photographs than will fit on the preceding page, affix the additional photographs below. Identify all photographs with: date taken; “Front View” and “Rear View”; and, if required, “Right Side View” and “Left Side View.”

U.S. DEPARTMENT OF HOMELAND SECURITY
Federal Emergency Management Agency
National Flood Insurance Program

ELEVATION CERTIFICATE

Important: Read the instructions on pages 1-9.

OMB No. 1660-0008
Expires March 31, 2012

SECTION A - PROPERTY INFORMATION

For Insurance Company Use:
Policy Number
Company NAIC Number

A1. Building Owner's Name FIFTEEN SAC SELF STORAGE CORP

A2. Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No.
2455 WEST TARRANT ROAD
City Grand Prairie State TX ZIP Code 75050

A3. Property Description (Lot and Block Numbers, Tax Parcel Number, Legal Description, etc.)
HOUSEMAN/NCS ADDITION, BLK A, LOT 2

A4. Building Use (e.g., Residential, Non-Residential, Addition, Accessory, etc.) Non-Residential
A5. Latitude/Longitude: Lat. N32°45'24.5" Long. W97°02'06.9" Horizontal Datum: ☐ NAD 1927 ☒ NAD 1983
A6. Attach at least 2 photographs of the building if the Certificate is being used to obtain flood insurance.
A7. Building Diagram Number 1A
A8. For a building with a crawlspace or enclosure(s):
a) Square footage of crawlspace or enclosure(s) _____ sq ft
b) No. of permanent flood openings in the crawlspace or enclosure(s) within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A8.b _____ sq in
d) Engineered flood openings? ☐ Yes ☒ No

A9. For a building with an attached garage:
a) Square footage of attached garage _____ sq ft
b) No. of permanent flood openings in the attached garage within 1.0 foot above adjacent grade _____
c) Total net area of flood openings in A9.b _____ sq in
d) Engineered flood openings? ☐ Yes ☒ No

SECTION B - FLOOD INSURANCE RATE MAP (FIRM) INFORMATION

B1. NFIP Community Name & Community Number	B2. County Name	B3. State
Grand Prairie 485472	Dallas	TX

B4. Map/Panel Number	B5. Suffix	B6. FIRM Index Date	B7. FIRM Panel Effective/Revised Date	B8. Flood Zone(s)	B9. Base Flood Elevation(s) (Zone AO, use base flood depth)
0295	K	August 23, 2001	August 23, 2001	AE	502.00

B10. Indicate the source of the Base Flood Elevation (BFE) data or base flood depth entered in Item B9.
☒ FIS Profile ☐ FIRM ☐ Community Determined ☐ Other (Describe) _____

B11. Indicate elevation datum used for BFE in Item B9: ☐ NGVD 1929 ☒ NAVD 1988 ☐ Other (Describe) _____

B12. Is the building located in a Coastal Barrier Resources System (CBRS) area or Otherwise Protected Area (OPA)? ☐ Yes ☒ No
Designation Date _____ ☐ CBRS ☐ OPA

SECTION C - BUILDING ELEVATION INFORMATION (SURVEY REQUIRED)

C1. Building elevations are based on: ☐ Construction Drawings* ☐ Building Under Construction* ☒ Finished Construction
*A new Elevation Certificate will be required when construction of the building is complete.

C2. Elevations – Zones A1-A30, AE, AH, A (with BFE), VE, V1-V30, V (with BFE), AR, AR/A, AR/AE, AR/A1-A30, AR/AH, AR/AO. Complete Items C2.a-h below according to the building diagram specified in Item A7. Use the same datum as the BFE.
Benchmark Utilized RM255 Vertical Datum NGVD 1929
Conversion/Comments Datum shift (NAVD 1988 minus NGVD 1929) is 0.003'

Check the measurement used.

a) Top of bottom floor (including basement, crawlspace, or enclosure floor) 502.5 ☒ feet ☐ meters (Puerto Rico only)
b) Top of the next higher floor N/A._____ ☐ feet ☐ meters (Puerto Rico only)
c) Bottom of the lowest horizontal structural member (V Zones only) N/A._____ ☐ feet ☐ meters (Puerto Rico only)
d) Attached garage (top of slab) N/A._____ ☐ feet ☐ meters (Puerto Rico only)
e) Lowest elevation of machinery or equipment servicing the building (Describe type of equipment and location in Comments) 502.4 ☒ feet ☐ meters (Puerto Rico only)
f) Lowest adjacent (finished) grade next to building (LAG) 501.4 ☒ feet ☐ meters (Puerto Rico only)
g) Highest adjacent (finished) grade next to building (HAG) 502.2 ☒ feet ☐ meters (Puerto Rico only)
h) Lowest adjacent grade at lowest elevation of deck or stairs, including structural support 501.7 ☒ feet ☐ meters (Puerto Rico only)

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION

This certification is to be signed and sealed by a land surveyor, engineer, or architect authorized by law to certify elevation information. *I certify that the information on this Certificate represents my best efforts to interpret the data available. I understand that any false statement may be punishable by fine or imprisonment under 18 U.S. Code, Section 1001.* ☒

Check here if comments are provided on back of form. Were latitude and longitude in Section A provided by a licensed land surveyor? ☒ Yes ☐ No

Certifier's Name Marshall Lancaster License Number 4873
Title Vice President Company Name Marshall Lancaster & Associates, Inc.
Address 1864 N. Norwood Dr. City Hurst State TX ZIP Code 76054
Signature Date 11-21-2011 Telephone 817-268-8000

IMPORTANT: In these spaces, copy the corresponding information from Section A.	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 2455 WEST TARRANT ROAD	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

SECTION D - SURVEYOR, ENGINEER, OR ARCHITECT CERTIFICATION (CONTINUED)

Copy both sides of this Elevation Certificate for (1) community official, (2) insurance agent/company, and (3) building owner.

Comments Elevation provided in C2e is the lowest elevation of the AC unit setting on concrete slab.

Signature Date 11-21-2011

☐ Check here if attachments

SECTION E - BUILDING ELEVATION INFORMATION (SURVEY NOT REQUIRED) FOR ZONE AO AND ZONE A (WITHOUT BFE)

For Zones AO and A (without BFE), complete Items E1-E5. If the Certificate is intended to support a LOMA or LOMR-F request, complete Sections A, B, and C. For Items E1-E4, use natural grade, if available. Check the measurement used. In Puerto Rico only, enter meters.

E1. Provide elevation information for the following and check the appropriate boxes to show whether the elevation is above or below the highest adjacent grade (HAG) and the lowest adjacent grade (LAG).

a) Top of bottom floor (including basement, crawlspace, or enclosure) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

b) Top of bottom floor (including basement, crawlspace, or enclosure) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the LAG.

E2. For Building Diagrams 6-9 with permanent flood openings provided in Section A Items 8 and/or 9 (see pages 8-9 of Instructions), the next higher floor (elevation C2.b in the diagrams) of the building is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E3. Attached garage (top of slab) is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E4. Top of platform of machinery and/or equipment servicing the building is _____._____ ☐ feet ☐ meters ☐ above or ☐ below the HAG.

E5. Zone AO only: If no flood depth number is available, is the top of the bottom floor elevated in accordance with the community's floodplain management ordinance? ☐ Yes ☐ No ☐ Unknown. The local official must certify this information in Section G.

SECTION F - PROPERTY OWNER (OR OWNER'S REPRESENTATIVE) CERTIFICATION

The property owner or owner's authorized representative who completes Sections A, B, and E for Zone A (without a FEMA-issued or community-issued BFE) or Zone AO must sign here. *The statements in Sections A, B, and E are correct to the best of my knowledge.*

Property Owner's or Owner's Authorized Representative's Name

Address City State ZIP Code

Signature Date Telephone

Comments

☐ Check here if attachments

SECTION G - COMMUNITY INFORMATION (OPTIONAL)

The local official who is authorized by law or ordinance to administer the community's floodplain management ordinance can complete Sections A, B, C (or E), and G of this Elevation Certificate. Complete the applicable item(s) and sign below. Check the measurement used in Items G8 and G9.

G1. ☐ The information in Section C was taken from other documentation that has been signed and sealed by a licensed surveyor, engineer, or architect who is authorized by law to certify elevation information. (Indicate the source and date of the elevation data in the Comments area below.)

G2. ☐ A community official completed Section E for a building located in Zone A (without a FEMA-issued or community-issued BFE) or Zone AO.

G3. ☐ The following information (Items G4-G9) is provided for community floodplain management purposes.

G4. Permit Number	G5. Date Permit Issued	G6. Date Certificate Of Compliance/Occupancy Issued

G7. This permit has been issued for: ☐ New Construction ☐ Substantial Improvement

G8. Elevation of as-built lowest floor (including basement) of the building: _____._____ ☐ feet ☐ meters (PR) Datum _____

G9. BFE or (in Zone AO) depth of flooding at the building site: _____._____ ☐ feet ☐ meters (PR) Datum _____

G10. Community's design flood elevation _____._____ ☐ feet ☐ meters (PR) Datum _____

Local Official's Name Title

Community Name Telephone

Signature Date

Comments

☐ Check here if attachments

Building Photographs

See Instructions for Item A6.

	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 2455 WEST TARRANT ROAD	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

If using the Elevation Certificate to obtain NFIP flood insurance, affix at least two building photographs below according to the instructions for Item A6. Identify all photographs with: date taken; “Front View” and “Rear View”; and, if required, “Right Side View” and “Left Side View.” If submitting more photographs than will fit on this page, use the Continuation Page, following.

Front View – Photo Taken 10/05/11

Back View – Photo Taken 10/05/11

Building Photographs

Continuation Page

	For Insurance Company Use:
Building Street Address (including Apt., Unit, Suite, and/or Bldg. No.) or P.O. Route and Box No. 2455 WEST TARRANT ROAD	Policy Number
City Grand Prairie State TX ZIP Code 75050	Company NAIC Number

If submitting more photographs than will fit on the preceding page, affix the additional photographs below. Identify all photographs with: date taken; "Front View" and "Rear View"; and, if required, "Right Side View" and "Left Side View."

Back Left Side View – Photo Taken 10/05/11

Appendix C
Storm Drain Outfalls

Photo of Storm Drain Outfall 01

Photo of Storm Drain Outfall 02

Photo of Storm Drain Outfall 03

Photo of Storm Drain Outfall 05

Photo of Storm Drain Outfall 06

Photo of Storm Drain Outfall 07

Photo of Storm Drain Outfall 09

Photo of Storm Drain Outfall 10

Photo of Storm Drain Outfalls 11 and 12

Photo of Storm Drain Outfall 11

Photo of Storm Drain Outfall 12

Photo of Storm Drain Outfall 13

Photo of Storm Drain Outfall 14

Photo of Storm Drain Outfall 16

Photo of Storm Drain Outfall 17

Photo of Storm Drain Outfall 18

Photo of Storm Drain Outfall 19

Photo of Storm Drain Outfall 20

Photo of Storm Drain Outfall 21

Photo of Storm Drain Outfall 22

Photo of Storm Drain Outfall 23

Photo of Storm Drain Outfall 24

Photo of Storm Drain Outfall 25

Photo of Combined Storm Drain Outfalls 26 and 27

Photo of Storm Drain Outfall 28

Photo of Storm Drain Outfall 28b

Photo of Storm Drain Outfall 28c

Photo of Storm Drain Outfall 29

Photo of Storm Drain Outfall 30

Photo of Storm Drain Outfall 31

Photo of Storm Drain Outfall 32

Photo of Storm Drain Outfall 33

Photo of Storm Drain Outfall 34

Photo of Storm Drain Outfall 35

Appendix D
Arbor Creek Channel Assessment by
Dr. Peter M. Allen

Arbor Creek Channel Assessment for The City of Grand Prairie

Submitted to O'Brien Engineering By:

Peter M. Allen, PhD., PG
Jeff Arnold, PhD.
Gary Stinchcomb, M.S.

Arbor Cr.: *Executive Summary: Fluvial Geomorphology for Channel Design*

Bed	Clay alluvium; limestone sand and gravel; D_{50} 4 mm; minor Eagle Ford shale exposed in stream. Bed material is highly variable. Much of the bed was pooled due to backwater effects from drop structures and hardpoints.
Bed Stability	All bed material mobile 2 year; most in 0.5 year recurrence interval; clay/shale will slake upon wetting and drying; roads and associated structures are acting as hardpoints, separating channels into 6 distinct reaches; City limits to Duncan Perry; Duncan Perry to W. Tarrant; W Tarrant to I-30; I-30 to Egyptian Way; Egyptian Way to Hwy 161; and Hwy 161 to Johnson Creek. There are also numerous drop structures in each reach which also control bed stability.
Banks	Alluvial clay-silty clay banks in Frio series soil. The majority of the channel is classified as slight erosion with major erosion noted associated with man made structures (local scour). The major channel erosion is between Egyptian Way and Hwy 161.
Bank Stability	Presently bank scour; future degradation will cause increased wedge and slump failures and tree loss; tree dams. Critical height around 8 feet for vertical slopes. No major slumps were noticed in the survey. Wedge failures were noticed in the lower reaches below Egyptian Way where the east side bank is being undercut; and below Hwy 161 in the Park.
Potential Widening	The bankfull channel should widen to about 30 feet and attain a bankfull depth of about 4-5 feet. Future degradation will be controlled by location of future hardpoints.
Potential	Most of the stream degradation is controlled by existing hardpoints

Degradation	(bridges, drop structures); with the exception of one area (4519-3908) which could downcut up to 5 + feet. Without hardpoints in the reach, the channel could have downcut over 25 feet from its confluence with Johnson Creek to the City limits.
Number of Drops@ <3ft.	Up to 7 drops/hard points to stabilize potential down cutting in selected areas of the stream should be considered.
Meander Migration ft/yr	1-2 feet/year outside if not protected possible; up to 8.7ft. maximum water depth in bend (bend scour)
Bank Protection	Bank protection should be considered in areas where the survey has shown severe erosion and structures are involved (see Survey notes for details) Care should be made in design to consider the combined effects of degradation and local scour for foundations of bank protection.

Table Contents

1.0 *Introduction: Stream Assessment Arbor Creek* 6

1.1 Methods of Assessment: ***Alluvial and Threshold Channels*** 7

1.2 Field Channel Survey Approach 12

2.0 *Watershed Characteristics* 15

3.0 *Watershed Flow Regime and Flood Discharges* 30

4.0 *Hydraulic Conditions (O'BRIEN)* 33

5.0 *Bed and Bank Material Erosion and Armoring Potential* 34

5.1 Erosion Rates and Movement of Bed Material 34

5.2 Erosion Rates: Alluvial Material 41

5.3 Erosion Rates: Shale 47

6.0 *Vertical Stability* 49

6.1 Equilibrium Slope 49

6.2 Field Survey Results 54

6.3 Predicted Rate of Degradation: SWAT-DEG Model 77

6.4 Stream Power and Instability of Arbor Creek 79

6.5 Predicted Channel Dimensions 80

7.0 *Planform Stability* 84

7.1 Meanders 84

7.2 Bank Stability 87

7.3 Future Channel Evolution 92

8.0 *Local Scour* 95

9.0 *Conclusions* 95

Bibliography 99

Appendix Stable Slope 104

Appendix: Stable Channel Dimension Calculations: Extremal Hypothesis 107

1.0 *Introduction*: *Stream Assessment Arbor Creek*

A stream channel assessment of Arbor Creek Watershed was authorized by O'BRIEN Engineering for the City of Grand Prairie, Texas. Arbor Creek is a tributary of Johnson Creek. This study involves the 1.78 square mile Arbor Creek watershed within the City of Grand Prairie. This survey concentrated on channel stability assessment from the City Limits at approximately (32 45.238N and 97 2.413W) or a length of approximately 10,100 feet of stream channel.

The assessment of the stability of stream channels is driven by the frequency and magnitude of channel discharges, the slope and depth of the water, the amount of sediment being moved, and the size of the sediment . This relationship is the keystone of stream assessment and was given by Lane (1955) amongst others in evaluating rivers of all sizes. The boundary conditions limiting the channel adjustment are the bed and bank materials, the channel vegetation, and the slope and size of the valley in which the stream is positioned. The stream reacts to these variables by adjusting its channel through changes in channel planform, channel depth, and cross section Figure 1. The creek is in effect continuously adjusting so that it will most efficiently carry the sediment downstream given the spectrum of discharges over time. The key in assessing the stability of the channel is to try and quantify the driving variables and then using analytical and empirical techniques, to try and assess what changes the stream will undergo, and what will the stream ultimately look like over a specified period of time.

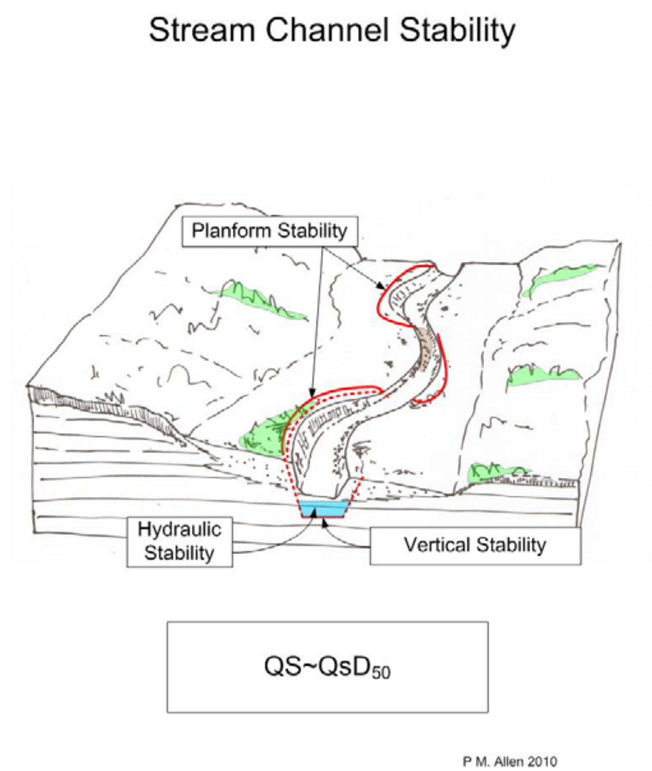


Figure 1. Changes in the fluvial system.

Owing to general increases in magnitude and frequency of floods in urbanized watersheds across the country, work has shown a similarity in the reaction of the stream to increased discharge. The magnitude and speed of changes to the stream are dictated by the local climate, relief and soils, and the history of impacts to the stream over time brought on by changes in land use.

1.1 Methods of Assessment: *Alluvial and Threshold Channels*

Shields et. al. (2003) details the protocol for assessment of channels in which the bed material inflow is negligible and the channel boundary is immobile even at high flows. Much of the theory in channel restoration has evolved in channels in which the channel bed material is mobile and the channel will down cut or aggrade depending on the flow regime and upstream sediment delivery. In the case of the channels in the study area, the channels fall somewhere between alluvial or mobile bed channels and threshold channels. Basically, one must use both types of assessment to adequately design these channels.

The channels in the study area have the following characteristics:

- the bed material is supply limited; it is not present throughout the channel system
- bed material has a wide range in sizes owing to widely varying sources of bed material (local terrace deposits, bedrock, and more recent alluvium)
- the bottom of the channels range from clay to shale; the shale upon weathering/slaking is removed in cases as fast as the soil material

Channels in the study are fall into the areas of allowable shear stress and tractive power approaches.

Technique	Significant sediment load and movable channel boundaries	Boundary material smaller than sand size	Boundary material larger than sand size	Boundary material does not act as discrete particles	No base flow in channel. Climate cannot support permanent vegetation
Allowable Velocity		X			
Allowable Shear Stress			X		
Tractive Power				X	
Grass Lined Channel					X
Alluvial Channel Design	X				

From NRCS 2005. Stream Restoration Design Handbook.

Table 1. Design Methods for Threshold Channels

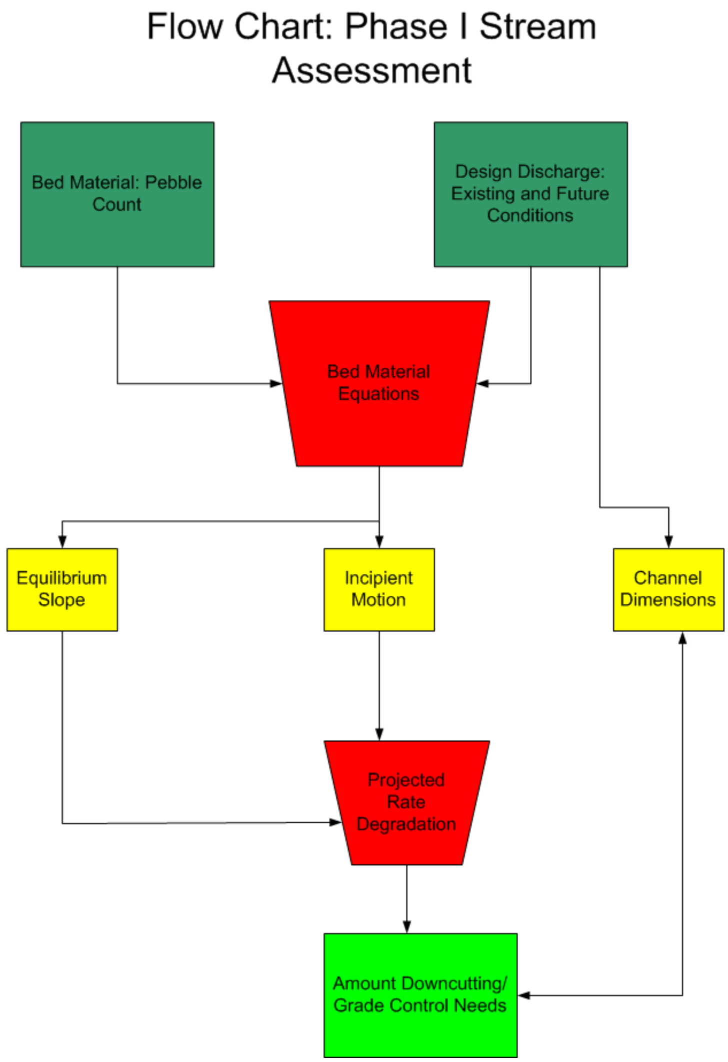


Figure 2. Flow chart of stream assessment for channel stability.

The geomorphic engineering approach used in this study consists of four phases; the general sequence used in analysis is presented in Figure 2. This requires information to be collected to ascertain each of the above so that qualitative and quantitative decisions can be made for the stream detailed below:

1. Involves investigation of the restoration reach using detailed stream reconnaissance techniques. This involves characterizing the channel geometry (bars, pools, riffles, cross sectional characteristics), channel stability status (erosion, slumps, earthflows) , bed and bank materials and riparian vegetation, the

2. Involves establishing the design or effective discharge for the restoration reach. This is based on the conditions in the approach reach upstream that furnishes the water and sediment and previous studies in the area on the magnitude and frequency of sediment and bed material transport. This discharge is the flow that is responsible for most of the sediment movement over the long term under the proposed land use in the basin.

3. Uses the bed material and design discharge to determine the equilibrium slope for the reach. This is done by substituting the design discharge into bed material formulas and back solving for the slope at which the bed material just begins to move or using two design programs (SAMWIN and GBR) to assess equilibrium channel dimensions and channel slope based on the concept of minimization of stream power. This slope is assumed to represent the slope of the stream that will be stable under the new flow conditions. This former approach assumes that the design discharge which is input is adequate to predict changes in the channel system over time. Actually, a series of flows are necessary to maintain the channel; the design discharge is a simplified surrogate for this range of channel forming flows. To test the viability of this assumption, we also run a continuous simulation model. The model also gives us an indication of the timing of potential channel change.

4. Involves looking at the results of the stable slope analysis and the field derived geomorphic assessment. The stable slope details how far the stream will down cut from its existing condition. In general, channels have been shown to go through a series of steps as they adjust to newly imposed conditions (such as increased impervious surfaces). This series of changes has been documented as the Channel Evolution Model (CEM) by Schumm and Simons.

1.2 Field Channel Survey Approach

Methods utilized in surveying the channels consisted of assessment of channel hydrology and hydraulics, walking the channel, recording channel dimensions, determining channel processes, and identifying potential structural problems.

Channel hydrology and hydraulics were analyzed (O'BRIEN) using detailed topographic control (2 ft. CI) maps, and HEC-1 and HEC-RAS or HEC-HMS, (U.S. Army Corps Engineers, HEC, 1990a,1990b) hydrology and hydraulics models for assessment of flood heights and channel velocities. General engineering properties of bed and bank materials such as grain size, Atterberg limits, and shear strength were obtained from the literature; and bed load gradation from limited pebble counts or sieve analysis.

The channel survey was conducted on 200 foot reaches; this distance was a compromise between survey speed and the accuracy needed for assessment of rapidly changing channel conditions. Distances were measured using a string-line, which was accurate to one foot. For each reach, data for the channel bottom, side slopes, and structural channel dimensions were compiled on survey sheets. Information of use on the field sheets depends to some extent on the purpose of the survey. Thorne (1998) gives an excellent checklist of information to consider. For purposes of this survey, the following variables were routinely recorded for each 200 foot reach:

- top width, bottom width, active channel width and depth were measured
- bed material, bedload size (field estimate and photograph), bar location
- knickpoints, gullys
- pool and riffle areas
- height of rock in channel bank, rock types, alluvium description
- degree and extent of bank erosion (low, moderate, high) The ratings used in this study were slight, moderate and high. High erosion was noted when greater than 75 percent of the active channel was scoured, the bank was near vertical and greater than 4 feet in height, and the roots of any plants were completely exposed. Moderate erosion was cited when the scour was from 50 to 75 percent of the bank and the bank was over 4 feet in height. Minimum scour was noted when the scour was less than 50 percent of the bank height or the bank was less than 4 feet high.
- mass movement, type, dimensions

Photographs were taken of the channel with a digital camera format. The survey information was compiled by stream and results tabulated for comparison of stream reaches within the study area. Based on the results of the channel survey, as well as previous work in the area (Allen and Narramore, 1985), specific erosion mechanisms were identified based on the type of channel boundary material and its position in the channel cross section.

In urbanizing watersheds, it is very hard to establish reference reaches or stable reaches owing to the fact that the watersheds are in a constant state of flux and in fact are still in adjustment to agricultural practices which occurred long before urbanization. Therefore, the approach used in this report seems to allow the best overall assessment of channels in this area.

In order to assess the channels, various levels of data must be analyzed. Simons and Li (1984) and others have demonstrated that information is best presented and analyzed using the STEPS shown in Figure 3. In general, the flow chart show the information required for channel assessment as well as who is responsible for major inputs. This procedure of presenting information is followed in this report.

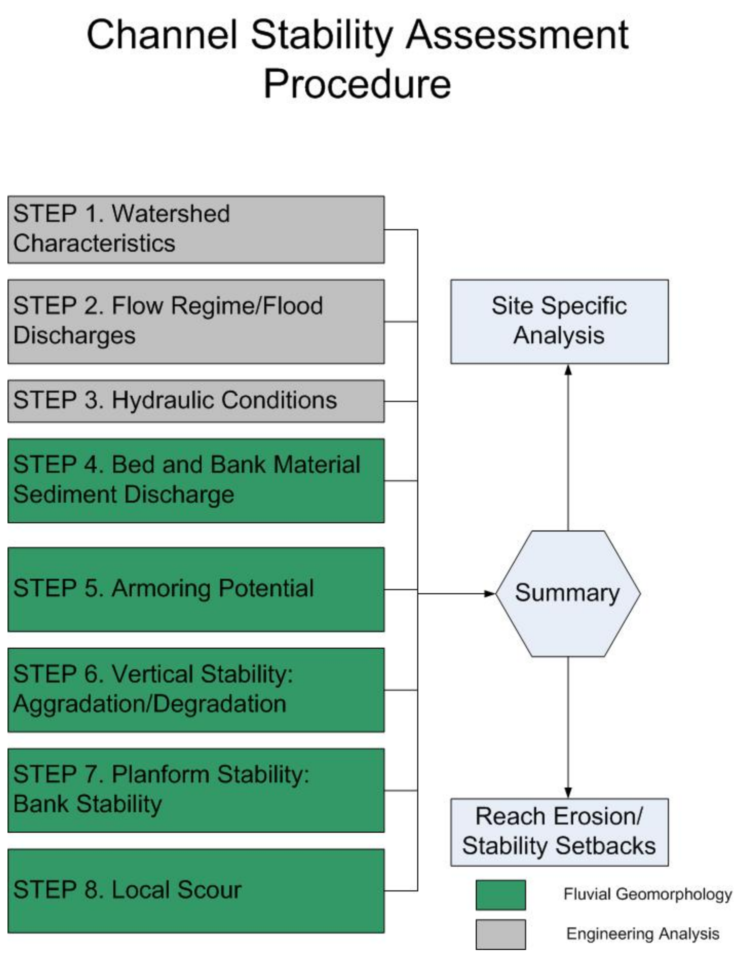


Figure 3. STEPS for Stream Channel Assessment for Engineering after Simons and Li (1984)

2.0 *Watershed Characteristics*

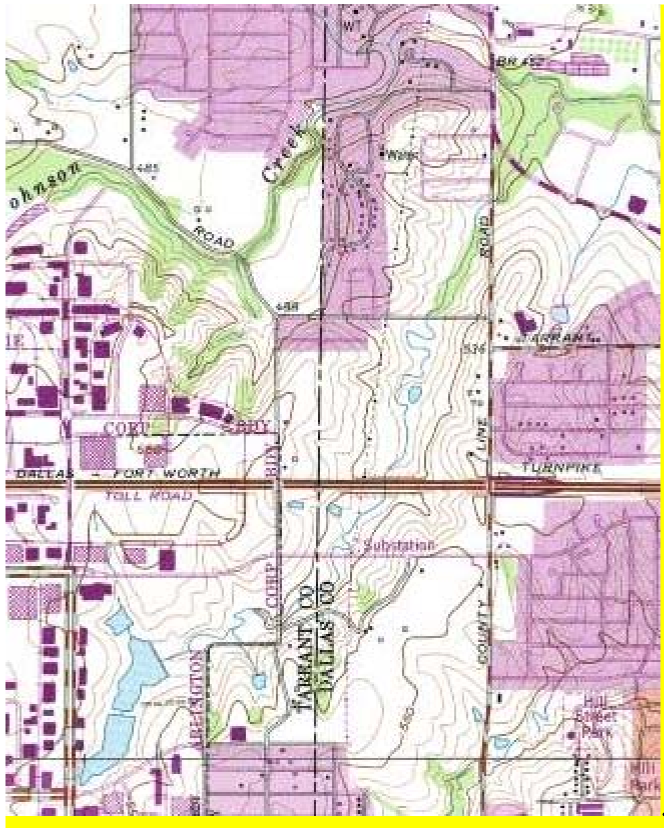
The study area occupies the extreme northern part of the humid subtropical belt which extends inland from the Gulf of Mexico. Average seasonal temperatures range from 46-85 degrees Fahrenheit. Annual precipitation averages 34 inches. Rainfall in the fall and winter is triggered by southward moving continental polar fronts. These fronts produce low intensity long duration storms. The most common storms in April to September are thunderstorms which are responsible for most of the serious flooding (100 year R.I.) in the smaller urban watersheds (1-10 square miles).

A natural basin is defined as a basin with less than 10 percent impervious cover; less than 10 percent of its drainage controlled by reservoirs, and no other human-related factors that would effect peak stream flow (Asquith and Slade, 1999). The two year discharge for natural basins range in this region of Texas ranges from 293 cfs (1 sq. mile) to 1155 cfs (10 sq. miles). Analysis indicates that in a fully developed residential area, flood peaks will be 1.2 to 1.4 times larger than those of a comparable natural area; the annual direct runoff will be about double that of a natural area (Dempster, 1974).

The watershed in this study is classified as a sinuous (sinuosity of 1.2), mixed load, slightly entrenched stream with a low width depth ratio and moderately steep channel slope, (Figure 4.) Arbor Creek would be classified as a E3 to E4 depending upon the bed material using the Rosgen Classification. Major bed material for the stream is furnished from erosion of limestone seams found in the stream bed and banks. The upstream "supply reach" of the stream is a urbanized segment of stream outside of the city limits. Minor sediment is assumed to make it downstream into the study area from upstream owing to the gabion structure and the small length of upstream channel.

The Blackland Prairie study area is underlain by Cretaceous age shales which dip gently to the southeast at 0.54 degrees, (Allen and Flannigan, 1985), Figure 5. Channel beds vary from clay (Quaternary Alluvium) to shale (Eagle Ford Shale). The shale is the lowermost portion of the Britton Formation, of the Eagle Ford Group. It consists of calcareous shale interbedded with numerous bentonite seams and some limestone seams. The alluvial soils, which form the channel banks, consist of silty clay soils mapped as Frio silty clay by the NRCS. The banks contain over 75 percent silt-clay in the banks and are classified as CH-CL soils with moderate high plasticity, Figures 6,7. The stream slope is approximately 37 feet per mile. Slopes fall within the coarse bed alluvial region of Sklar and Dietrich (1998). This is consistent with the highly variable amount of bed load found in the channel bottom. Bed load material consists of sand to cobble size platy limestone, and shale clasts. Dark gray colored shale in the bed material indicates the channel is actively mining the shale bedrock in the bed of the channel.

The watershed has remained in agricultural land use from the late 1800's to about 1979. The upstream portion of the watershed was built up into commercial /industrial land use sometime between 1972 and 1979 while the lower watershed developed into residential land use. The watershed has progressively followed this trend over the pursuing decades. Figures 8-11.



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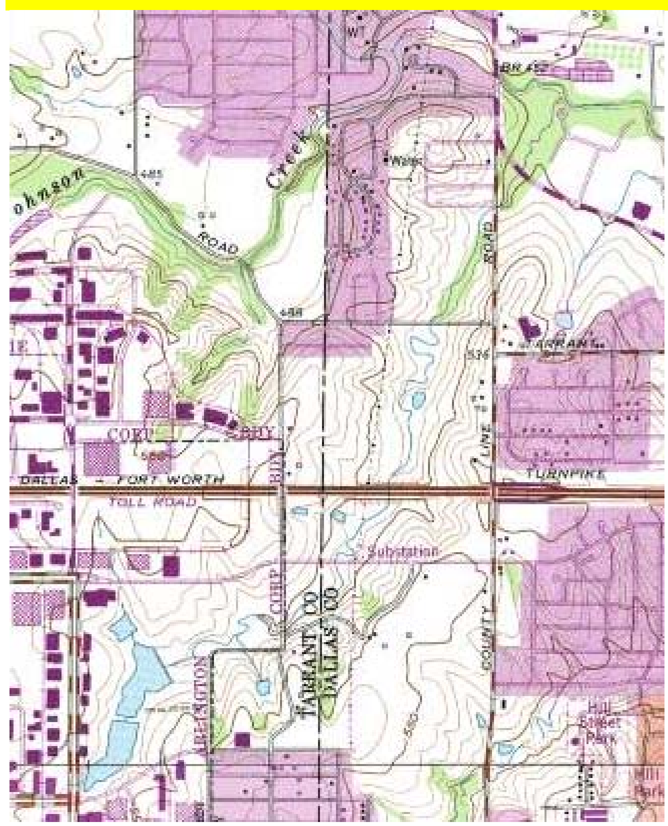
TOLL ROAD
TURNPIKE
Substation
TARRANT CO
DALLAS CO
COUNTY
LINE
ROAD
TARRANT
Hill Street Park



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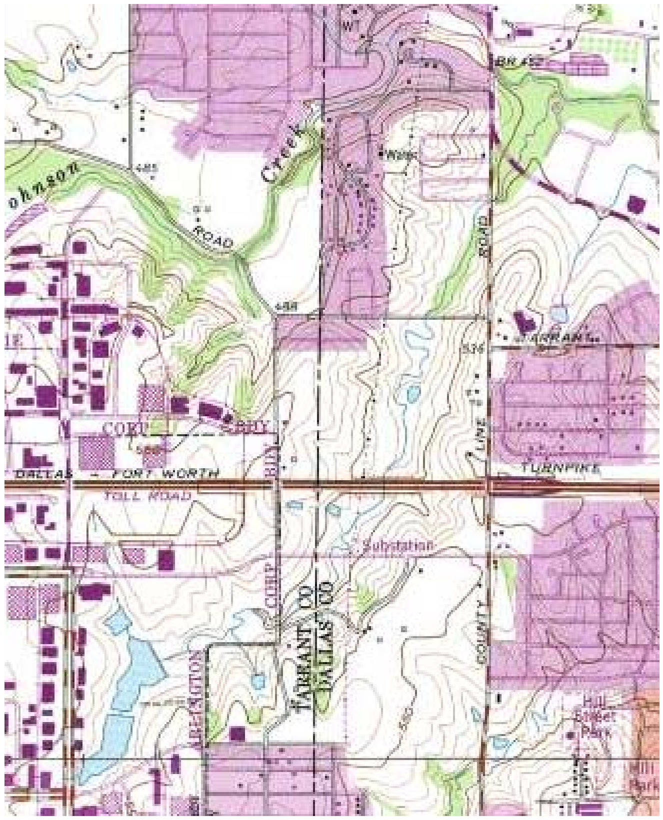


Figure 4. Topography of Arbor Cr. (Source USGS). Note Study reach begins at at the City limits and ends at the confluence with Johnson Creek. The map illustrates the general landscape prior to extensive urbanization.

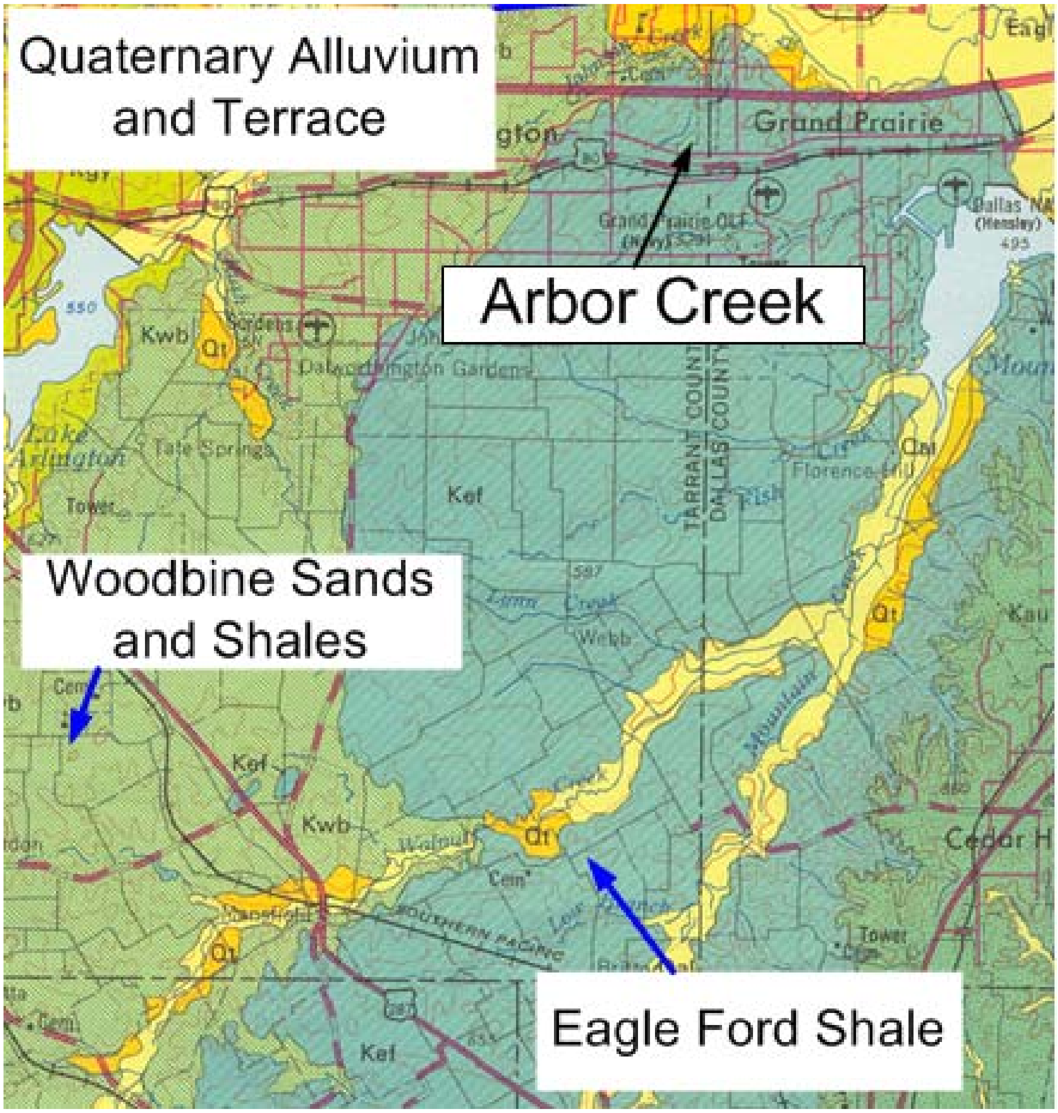


Figure 5. Regional Geology of Arbor Creek. Shown in outcropping area of Eagle Ford Shale. (Bureau of Economic Geology, Dallas Sheet). The stream flows in a north east direction. Dip of the formation is to the southeast at around 50 feet per mile. Arbor Creek flows approximately along the strike of the formation and therefore stays within about the same stratigraphic interval of the lower Eagle Ford Group.

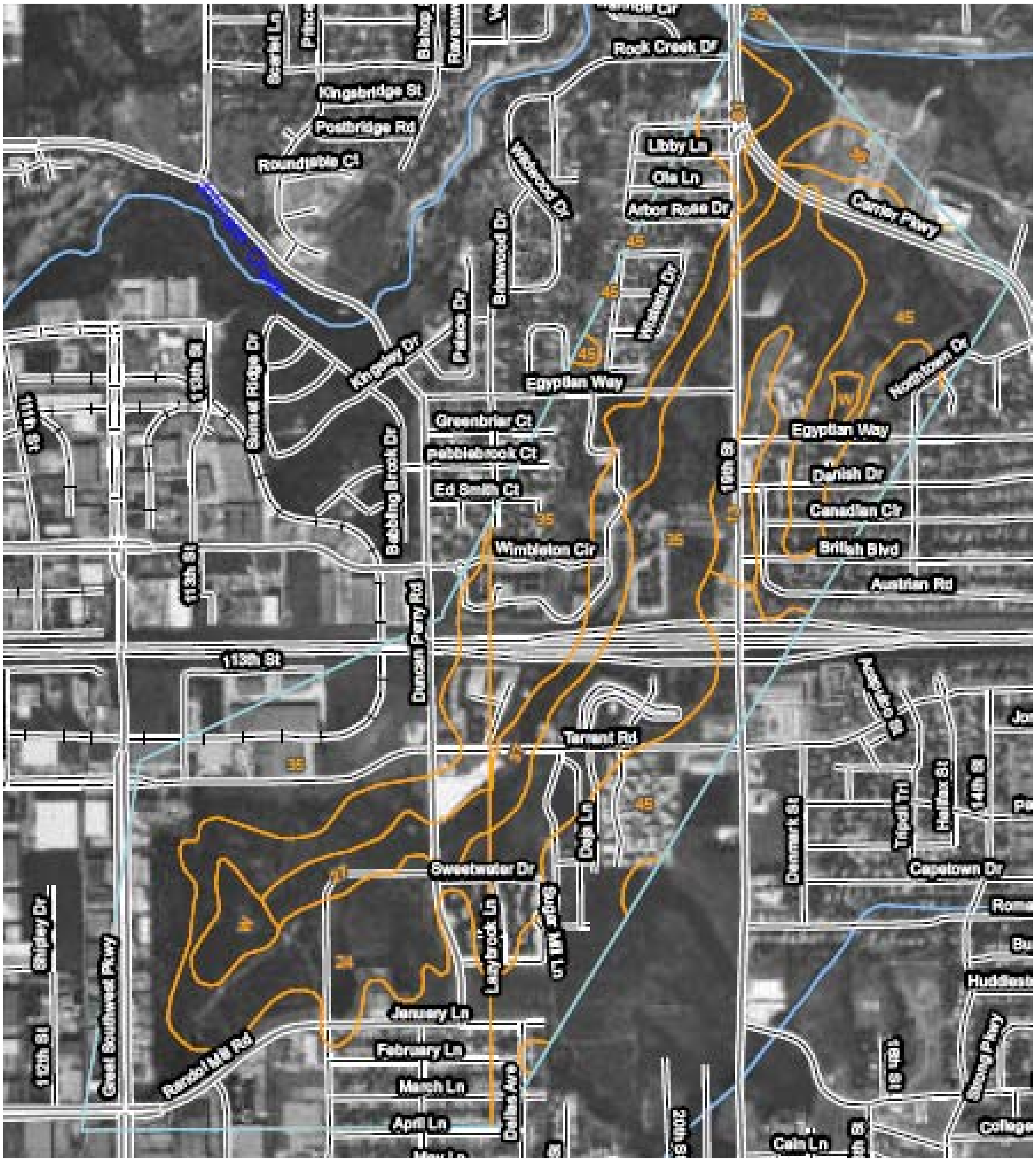

Rock Creek Dr
Kingsbridge St
Postbridge Rd
Roundtable Ct
Libby Ln
Ola Ln
Arbor Rose Dr
Carrier Pkwy
Wildwood Dr
Briarwood Dr
Palace Dr
Kingsley Dr
Sunset Ridge Dr
113th St
Egyptian Way
Northtown Dr
Greenbriar Ct
pebblebrook Ct
Ed Smith Ct
Babbling Brook Dr
Danish Dr
Canadian Cir
British Blvd
Austrian Rd
19th St
Wimbleton Cir
Duncan Perry Rd
Tarrant Rd
Dalja Ln
Sweetwater Dr
Capetown Dr
Denmark St
Tripoli Trl
Halifax St
14th St
Leybrook Ln
Sugar Mill Ln
Shipley Dr
Great Southwest Pkwy
112th St
Randol Mill Rd
January Ln
February Ln
March Ln
April Ln
Dallas Ave
20th St
Cain Ln
Huddleston
College
45
35
24

Figure 6. Detailed soil map of study area. Arbor Cr. is within the mapped area. The channel is mapped as 27/37 (Frio silty clay frequently flooded). (Source: NRCS Web Soil Survey)

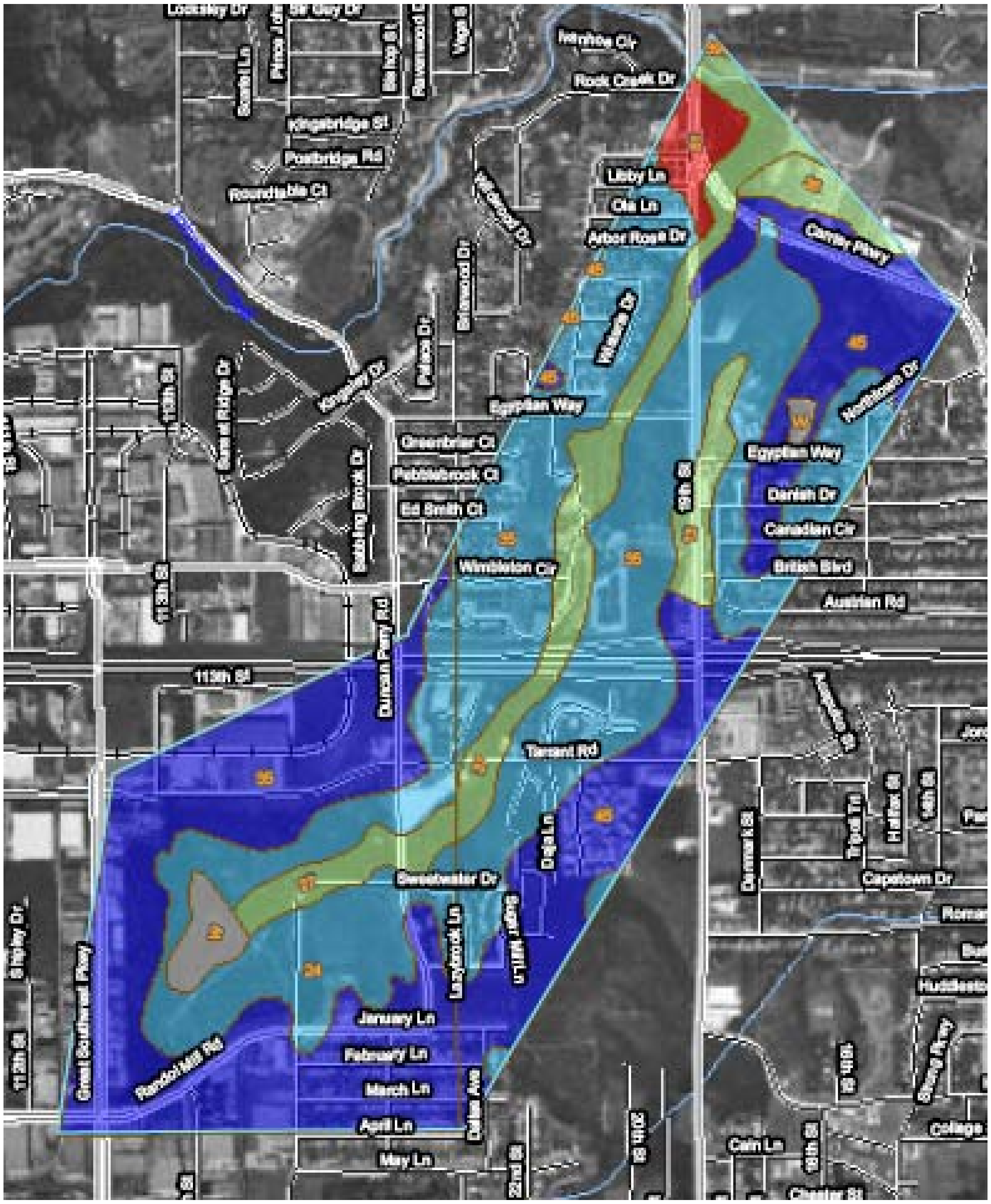
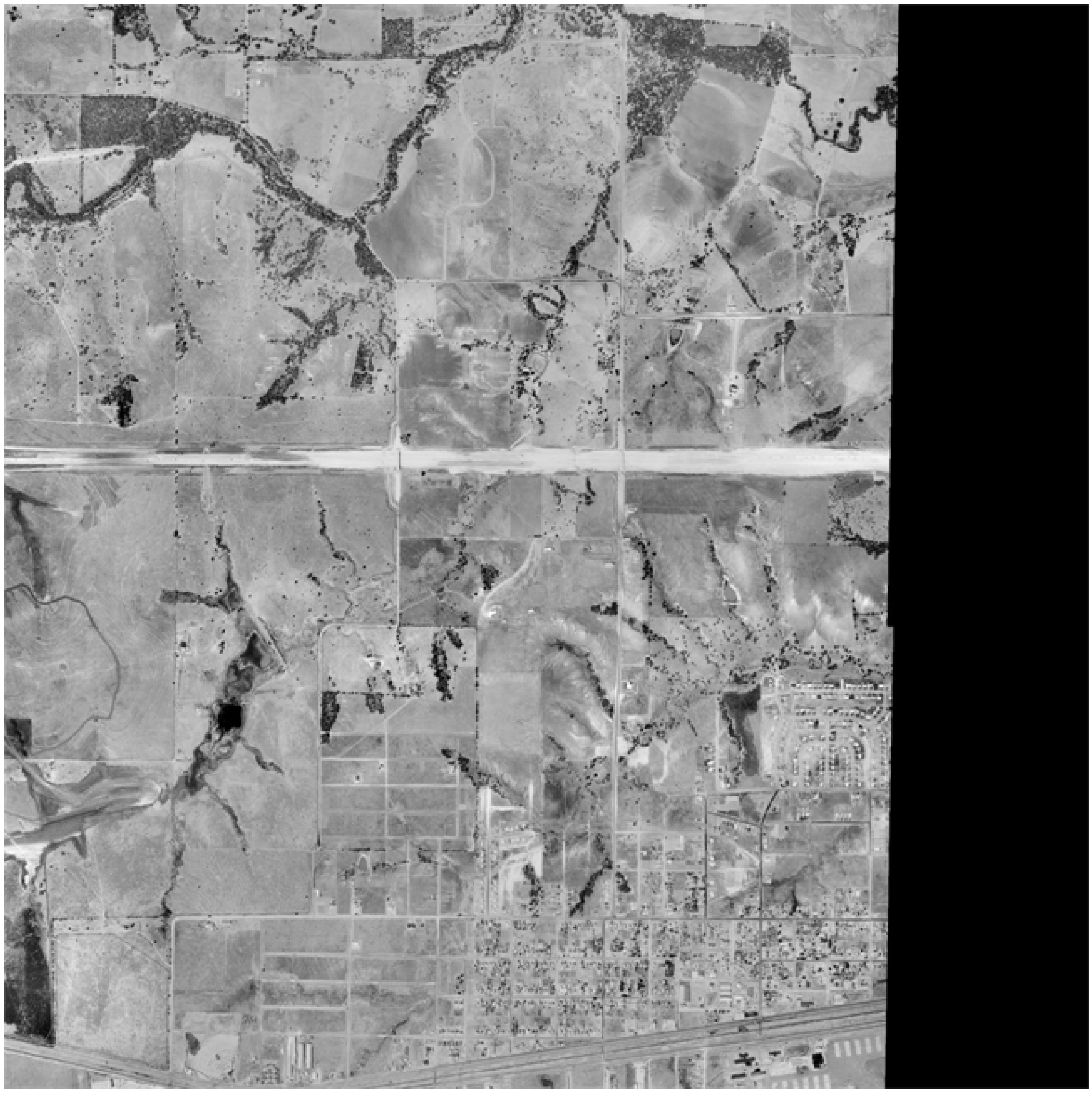


Figure 7. Soil Plasticity Index for Arbor Br. PI for the Frio silty clay, shown in green is 25.5. The uplands mapped as Ferris or Heiden clays have very high PI's of over 50. (Source NRCS Web Soil Survey)

Watershed Development History



Arbor Creek 1956

Figure 8. Land use in Arbor Creek Basin. At this time the watershed was principally agricultural land use. A small dam was built in the upper watershed. The channel is sinuous and lacks riparian vegetation.

Arbor Creek 1958

Figure 9. Land use in 1958. This followed the large rains after the drought "broke" in 1957. Of note is the floodwater structure in the upper watershed, the abundant gullies in the lower watershed, and the land alteration in the western portions of the watershed.

Arbor Creek 1972

Figure 10. Land use in 1972. Continued industrial and commercial infilling to the west of the watershed and apparent “curing” of the gully erosion in the lower watershed.

Arbor Creek 1979

Figure 11. Major changes in land use in the watershed; infilling of residential in the lower watershed and industrial and commercial in the upper watershed.

Arbor Creek 1990

Figure. 12. Land use in 1990.

Arbor Creek 2001

Figure 13. Arbor Creek watershed almost totally urbanized.

Arbor Creek 2004

Figure 14. Land use in 2004.

3.0 *Watershed Flow Regime and Flood Discharges*

Figure 15. Watershed Sub-basins (Source: O'BRIEN).

The Arbor Creek watershed has been subdivided into subasins based on soil landuse and hydrological conditions. This watershed close to being 100 percent urban with mixed industrial, commercial and residential land uses and resulting high curve numbers indicating high levels of runoff.

Area #	Area (mi ^{2})	CN	Lag (min.)	Tc (min.)	Reach	Length (miles)	Elev. (US)	Elev. (DS)	Slope (ft./ft.)
1	0.75	93.6	15.08	22.13	1	.82	524	496	0.0065
2	0.39	87.9	24.48	40.8	2	.44	496	480	0.00696
3	0.18	89.5	16.49	27.48	3	.47	478	460	0.00726
4	0.21	89.6	20.88	34.8	4	.73	460	438	0.00569
5	0.25	88.5	25.22	42.03					

Table 2. Watershed Characteristics (Source: O'BRIEN); illustrating routing structure and hydrologic properties of the watershed.

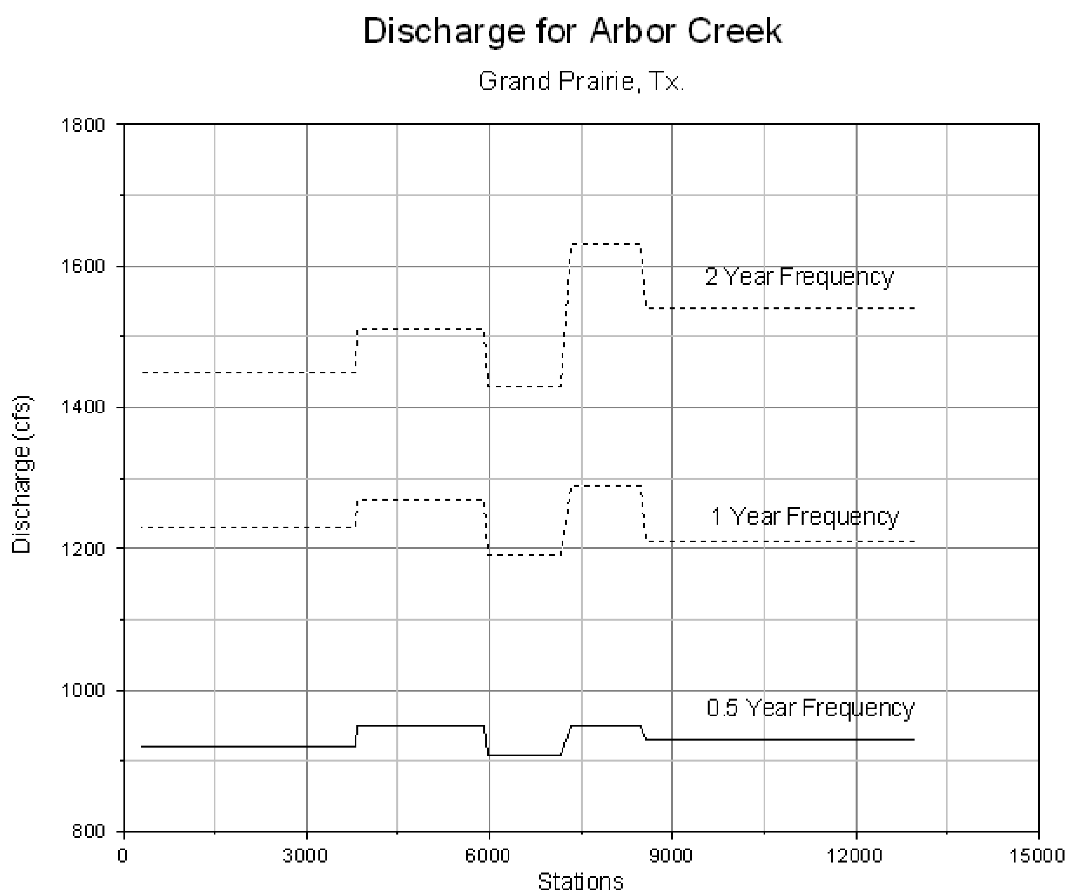


Figure 13. High frequency channel forming flow regime in the watershed. The existing channel still exhibits characteristics (cross sectional area, width, depth) of flow regimes less than the existing 0.5 year flow. There is a lag time between urbanization and channel and geomorphic change. This can be from 5 to 50 years.

Flow Regime	Arbor Creek
USGS 2 yr. Natural	874
O'BRIEN 0.5yr. Existing	950
O'BRIEN 1yr Existing	1290
O'BRIEN 2 yr Existing	1630
Ratio 0.5yr./2yr.Natural	1.1
Ratio 1year Existing/2yr.Natural	1.47
Ratio 2year Existing/2yr. Natural	1.86

Table 3. Characteristics of Arbor Creek Flood Discharge and Frequency

In the Metroplex, the geomorphically effective discharge of urbanized watersheds seems to correspond to a recurrence interval slightly less than the 1.25 year frequency flood (Allen, Arnold, and Skipwith, 2002). Dempster's (1974) equations, which include the percent of impervious surfaces in the drainage basin, allow prediction of future discharge under fully urbanized watersheds and are therefore useful in predicting current as well as ultimate active channel dimensions. Dempster's equation is based on extended flood records and has been found to more accurately reflect the flow regime of smaller floods than the HEC modeled events. While the Dempster equation has been shown to be helpful in predicting the effective discharge in local urban basins (Allen, Arnold, and Skipwith, 2003), it is a simple regression model and cannot be used in assessing reach hydrology and hydraulics and the effects of complex channel routing structure. Therefore, analysis of the results indicate that multiplication of the HEC-HMS 1 year flood discharges by 0.6 results in an adequate preliminary design discharge for study watersheds or 0.8 times the 6 month flow, Table 3. The air photographs and results (using the 2 year flow for example) indicate that the major changes in the watershed occurred during the last decade. The agricultural discharge was doubled as land use changed: agricultural to urban. (Note ratios). The ultimate 2 year discharge ranges from 20-30 percent greater than the existing urbanized flows but far less than the past changes in hydrology as the basin was converted from agricultural land uses to urban which doubled discharge. The ratios for both the 2 year and 100 year flows indicate a similar response to future urbanization of the watershed or about 1.1 times greater discharge. Also of note is that the existing 0.5 year flow is comparable to the 2 year "natural " floods in the watershed. The 0.5 year existing flow is expected to change about 20 to 30 percent from current values as the basin reaches ultimate land use conditions. Since the 0.5 year flow is approximately the "bankfull flow" in the channel, it is used to examine channel reach hydraulics.

4.0 *Hydraulic Conditions (O'BRIEN)*

Frequency	Velocity (fps)	Hi	Low	Shear (lbs/sq.ft.)	Hi	Low	Power (lbs/fts)	Hi	Low
0.5 yr.	4.46	11.37	1.07	.97	10.4	.02	6.29	118.2	.04
1 Year	4.81	10.52	1.12	1.0	6.05	.03	6.3	58.9	.07
2 Year	5.08	10.9	1.18	1.07	6.42	.04	7.2	65.0	.1
100Year	5.89	12.58	.98	1.2	11.16	.03	10.13	140.4	.03

Table 4. Mean, maximum and minimum hydraulic factors by reach for Arbor Cr for 0.5 year frequency.

Average values for the 0.5 year flow indicate velocities of 4.37 fps, moderately high shear, Froude numbers, and stream power. These values are used in subsequent sections for analysis of bed/bank stability. The NRCS Stream Corridor Manual cites work by Brooks who, for limited channels, postulated that stream power can be used as an indicator of channel stability. Channels with stream power over 3.4 are prone to erosion and instability; channels below 1 are prone to deposition and aggradation, and channels are stable in the 2.5 range. Units are in lbs/ft-sec. As can be seen, reaches 2 and three exceed these limits. Simons and Albertson (1963) indicate Froude numbers in excess of .3 to .35 indicate unstable conditions.

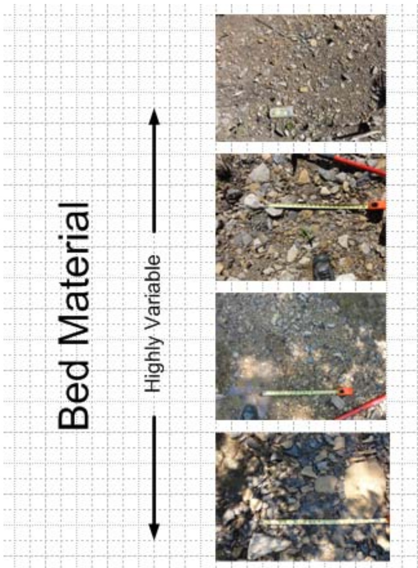
5.0 *Bed and Bank Material Erosion and Armoring Potential*

5.1 Erosion Rates and Movement of Bed Material

Bed material mobility analysis is essential for assessing stream stability. If the bedload is not moved, the stream will not degrade. If there is more bed material supplied to a reach than it can transport, the stream can aggrade. If the stream has excess capacity to move bed material and/or the supply is limited, the stream can degade. Bed material transport has also been linked to abrasion and wearing away of the underlying bedrock.

There was a lot of variability in the bed material in the channel bottom. The bed material was discontinuous along the channel and sources of bed material were from mined alluvial deposits along the channel and minor sourcing from discontinuous limestone flags in the shale. Bed material was sampled in the field and sieved (ASTM methods). Results are given in Figure 14. Bed material consisted of limestone gravel and some pieces of shale bedrock. Studies have shown that the gravel and cobbles made of shale will break down in days of exposure and essentially disintegrate into clay size particles.

In the channel bottom, the potential for movement of the loose bed material was determined from incipient motion assessment. The critical tractive force using Shields relationship is 0.1 (D50) to .41 lbs/ft^2 (D95).



Grain Size	D16	D35	D50	D84	D95
Composite	0.9	2	3.96	14.73	25

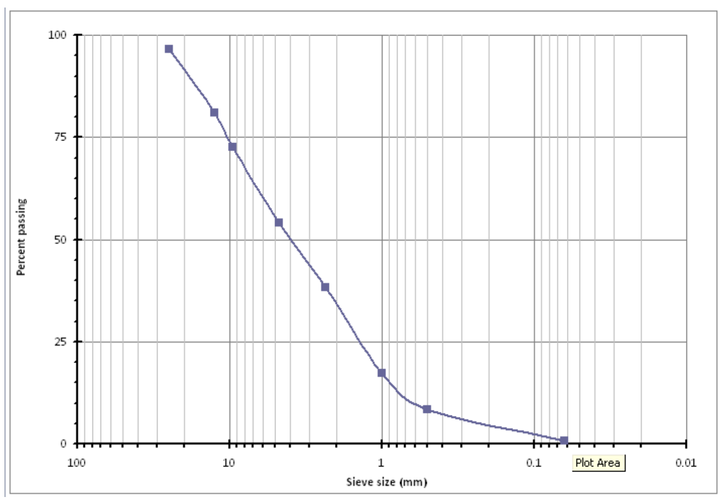


Figure 14. Representative Sieve Gradation of Bed Material in Arbor Creek.

Several methods were used to assess bed load movement as analysis of movement under the discharge regime of the stream is needed to see if this material can be moved and thus determine if the channel is prone to degradation or aggradation. Figure 15, and thresholds given in Table 5. indicate the critical velocity or shear needed to move the bed material and erode the rock. It is shown that the dominant discharge or approximately the 0.5 year storm will move the bed material. To calculate potential for armoring the following formula is used:

$$Yd = Ya *(1/p - 1)$$

Where: Yd= depth from original streambed to top of armoring layer
Ya= thickness of armor layer (3*Dc)
P= decimal percentage of original bed material larger than armor size (Dc)
Dc= (.00659*Velocity2)*304.8 after Yang (1973)

Results of this assessment indicate that the 0.5 year event would have Dc = 44mm or need an armor layer of about 132mm. This would require degradation of the bed material about 1.05 feet. based on the analysis of the bed material. The 2 year storm, assuming an average velocity of about 6.72 would move all the material with no potential for armoring the channel. Similarly, analysis of the 0.5 year flood in Figure 16 illustrates the shear generated by the 0.5 year flood compared to the mobility of 3 sizes of bed material. Essentially it illustrates the same results as Figure 15 ; the majority of bed material is mobile in very small floods.

This assessment indicates the following when the amount or supply of bed material is taken into account. (1) the channel will coarsen and establish an armor for the smaller flood events (less 0.5 year) which may cause local diversion of the bed and bank scour. (2) the large flood events (2 year or greater) will move the bed material down channel with no potential for armoring (3) the supply of bed material alone from the channel banks and upstream appears low as there are many portions of the channel with little or no gravel making continuous armor of the channel bottom, and (4) this means that the channel can downcut without armoring to its equilibrium slope.

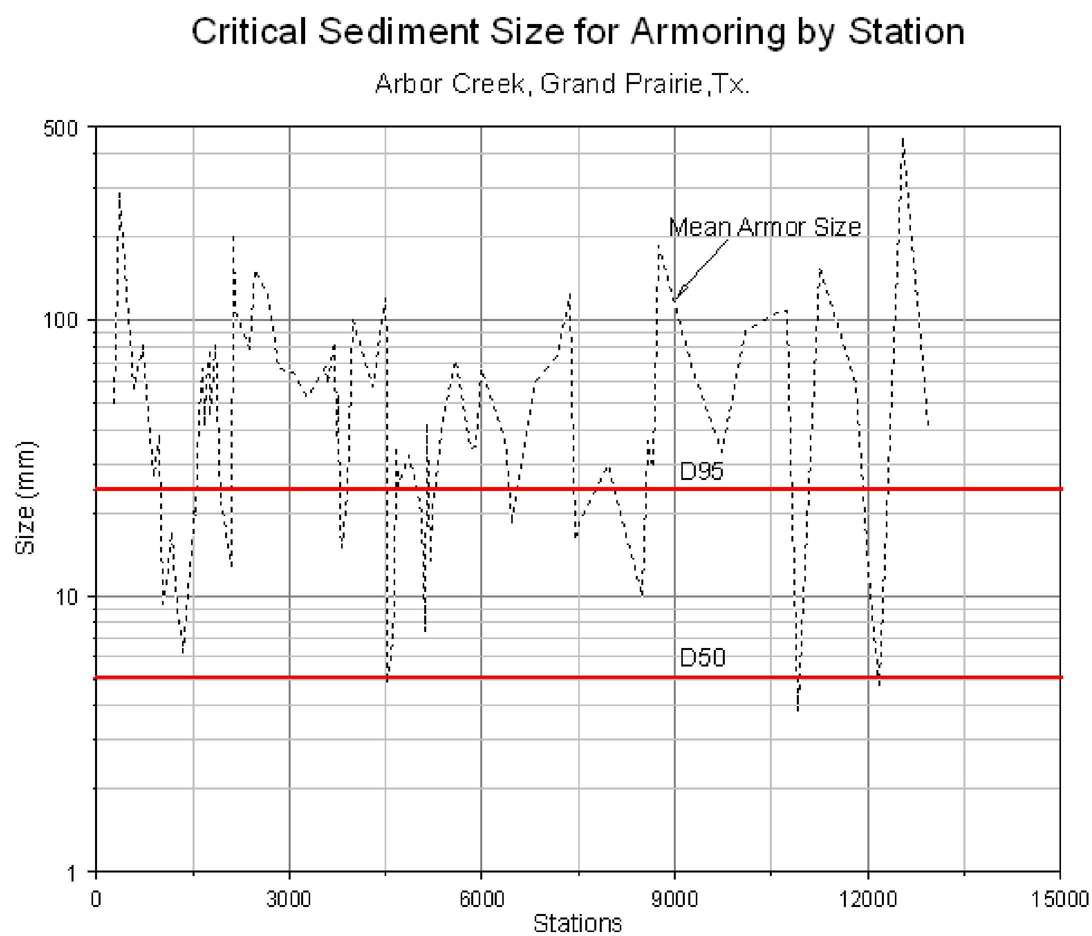


Figure 15. Plot of the Armor size to contain the 0.5 year frequency event indicates that the sampled bed material for the most part will be in motion and armoring will probably be an insignificant factor influencing degradation.

Class name	d_s (in)	ϕ (deg)	τ_{*c}	τ_{cr} (lb/sf)	V_{*c} (ft/s)
Boulder					
Very large	>80	42	0.054	37.4	4.36
Large	>40	42	0.054	18.7	3.08
Medium	>20	42	0.054	9.3	2.20
Small	>10	42	0.054	4.7	1.54
Cobble					
Large	>5	42	0.054	2.3	1.08
Small	>2.5	41	0.052	1.1	0.75
Gravel					
Very coarse	>1.3	40	0.050	0.54	0.52
Coarse	>0.6	38	0.047	0.25	0.36
Medium	>0.3	36	0.044	0.12	0.24
Fine	>0.16	35	0.042	0.06	0.17
Very fine	>0.08	33	0.039	0.03	0.12
Sands					
Very coarse	>0.04	32	0.029	0.01	0.070
Coarse	>0.02	31	0.033	0.006	0.055
Medium	>0.01	30	0.048	0.004	0.045
Fine	>0.005	30	0.072	0.003	0.040
Very fine	>0.003	30	0.109	0.002	0.035
Silts					
Coarse	>0.002	30	0.165	0.001	0.030
Medium	>0.001	30	0.25	0.001	0.025

Table 5. Critical shear table from USACE. This indicates the critical tractive force and critical velocities for moving bed material.

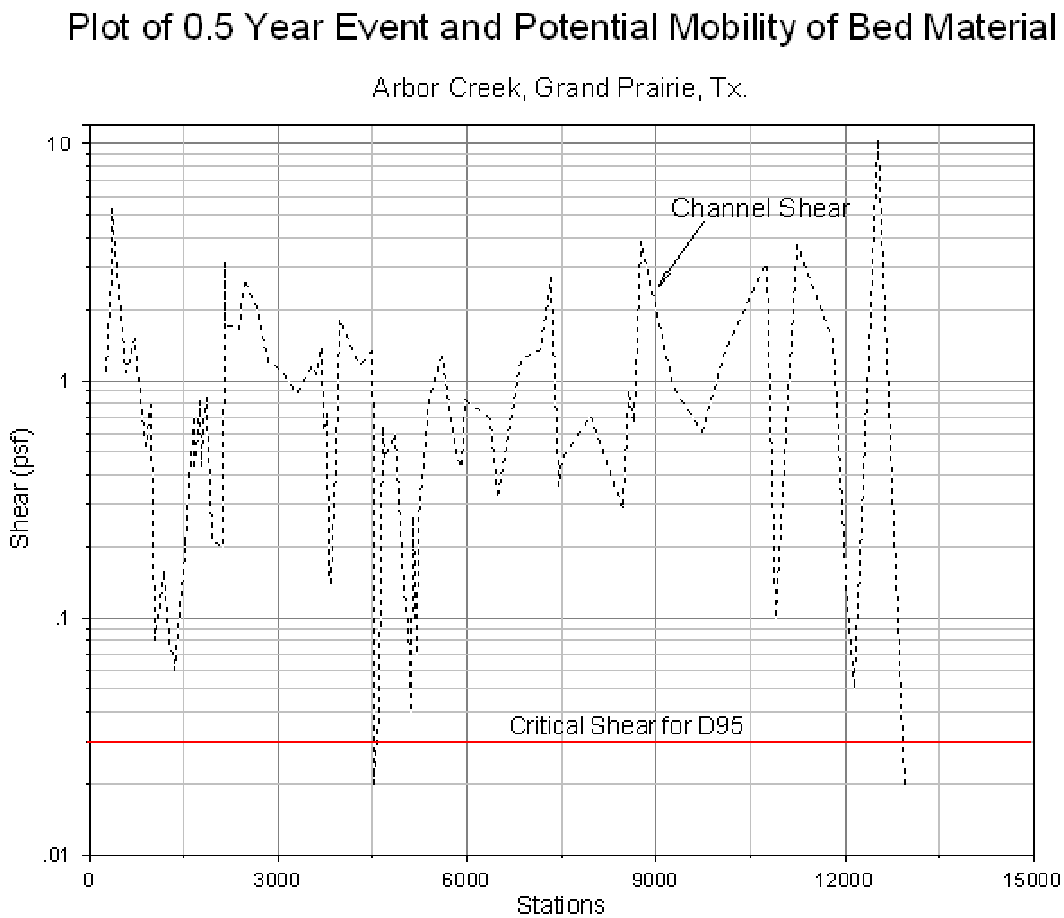


Figure 16. Illustrates the shear for the 0.5 year event compared to the critical shear for various sizes of bed material. It illustrates that most of the bed material will be mobile in the 0.5 year event. The 7.62mm material will be mobile for example, for most of the channel except in the area between stations 14000 and 16000. The largest clasts >5inches will be mobile only in about 3 locations during the 0.5 year event.

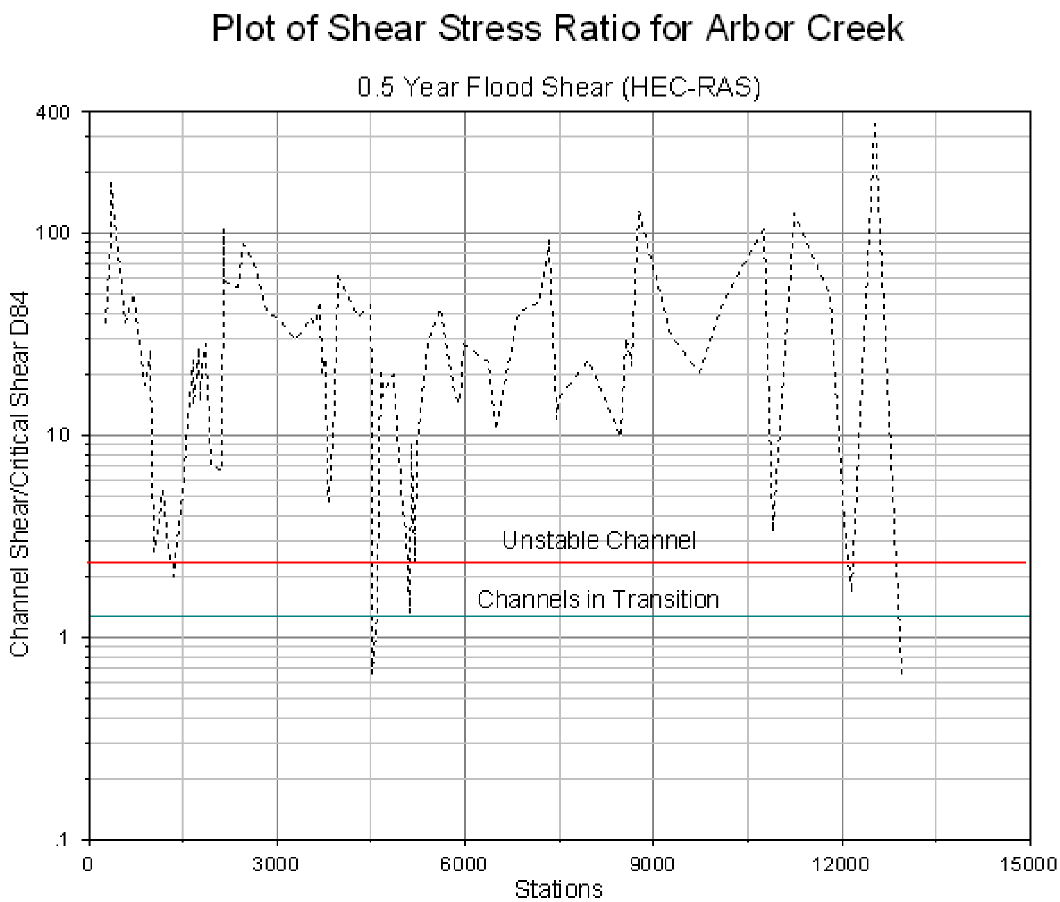


Figure 17. Illustrates Arbor Creek and the Shear Stress Ratio. The SSSR is the ratio of the average boundary shear stress divided by the critical shear stress at which grains move.

Figure 17. is a plot of the shear strength ratio of the stream under various frequency flows. This is constructed by dividing the average boundary shear stress provided by HEC-RAS by the critical shear stress required to move the bed load. The shear stress ratio is used as an indicator of channel stability. A channel is considered stable in form when the shear stress is approximately 20% greater than that required to initiate motion in the center of the channel. This would provide a shear stress ratio of less than 1.2, indicating that stable banks can coexist with low but non zero rates of gravel transport.

This would maintain the channel banks while still transporting sediment. When the SSR exceeds 2.5, most of the bed is in motion and this is considered unsuitable or unstable channel conditions. Ratios from 1.2-2.5 indicate transitional channels. Arbor Creek appears to be a channel in transition with trends during most flows plotting in the unstable or transition zones.

5.2 Erosion Rates: Alluvial Material

Erosion rates in the soil/alluvial zone (channel banks or channel bottom) were tested using submerged jet testing (Allen and others,1997,1999, and Hanson, 1990;1991). Tests were made on a representative silty clay/ clay alluvial soils just upstream of section 11000. A sample was collected and laboratory tests were done to determine the engineering properties of the material such as Atterberg limits, and bulk density (Allen and others, 1999). Briaud et. al. (1999) has developed the scour rate in cohesive soils method (SRICOS) to predict scour depth versus time at bridges. His method includes testing samples obtained with shelby tubes in the field in an erosion function apparatus (EFA) as a means to establish erosion rates of materials under given shear stresses. Rates established by this method are comparable in magnitude to those obtained for similar cohesive soils by Allen and others (1999). For cohesive soils with moderate to high plasticity (CH-CL Unified Classification) such as are found in the Dallas/Ft. Worth area, Briaud and others (1999) reports a mean rate of scour of 5.2 in/hr/lbs./ft^2 and a range of scour from 0.94 to 14.1 in/hr/lbs./ft^2 While either method appears suitable for use in the alluvial soil zone, the submerged jet test was done for this study.

Submerged Jet Test Dry Conditions (Clay) (Wilting Point)	Moderately erodible: 0.825 ft./hr./lbs/ft^2
Submerged Jet Test (Plastic Limit) (Clay)	Moderately Resistant: 0.0075 ft./hr./lbs/ft^2
Submerged Jet Test Arbor Creek	Very Erodible: 1-10 ft/hr./ ft^2 Critical Tractive Force: 0.022psf

Table 6. Estimated Erosion rates in Arbor Creek.

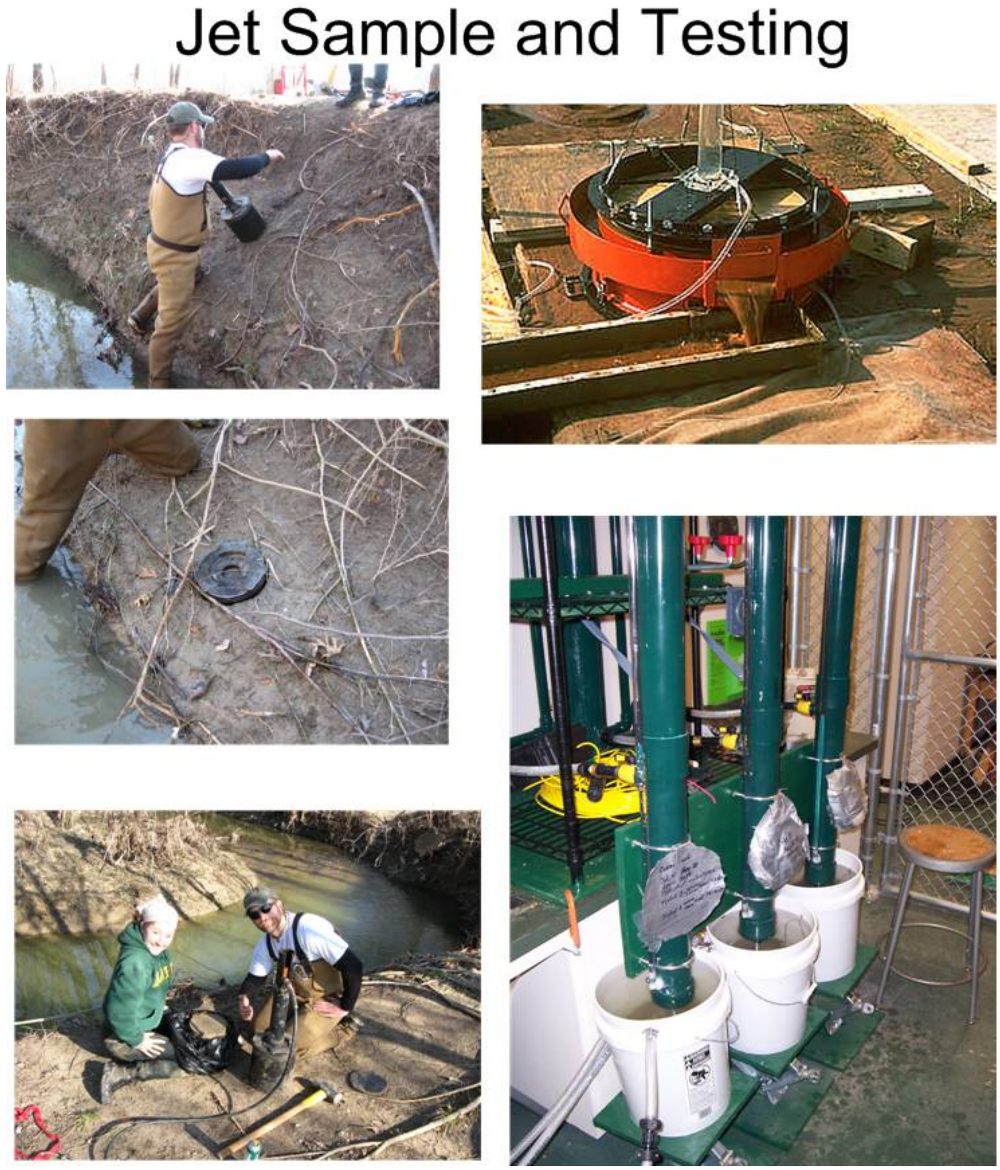


Figure 18. Examples of field sampling procedure, (left) and examples of test equipment for the jet test , (right).

From the simple assessment of the hydraulics, the following relationships are established for shear and velocity in the channel for the 0.5 year flood.

Where: $$\text{Shear} = a\,V^{\,b}$$

The average values for estimates of channel shear for the 0.5 year frequency are:

$$\text{Shear (lbs./ft.}^2) = 0.18\ \text{Velocity(fps)}^{2.33}$$

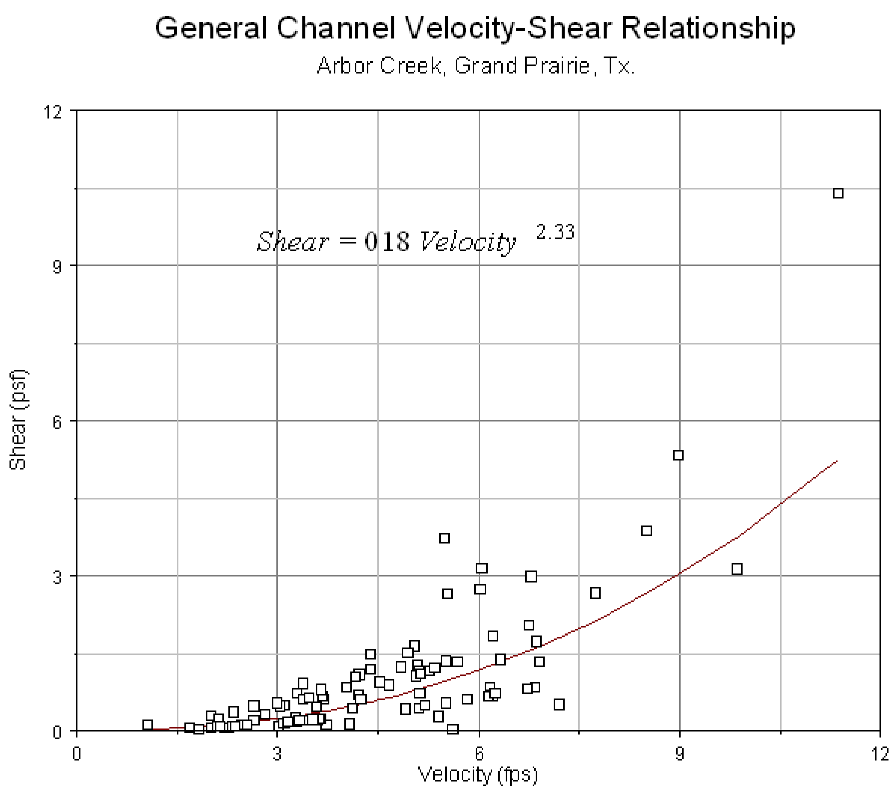


Figure 19. Relationship of channel velocity to channel shear.

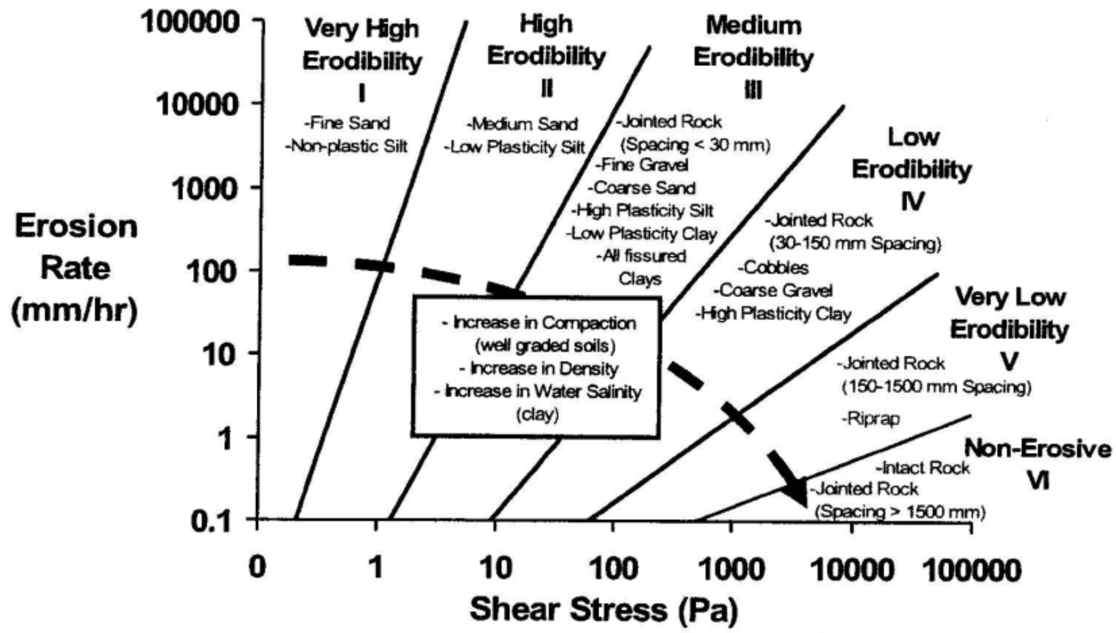


Figure 20. Shows the relationship established by Briaud (2008; J. Geotech. And Geoenvironmental Eng. Vol 134, No. 10)) for the rate of erosion to shear stress. Soil in the watershed would be in Categories III-IV. Note 47.88Pa = 1psf

Figure 19. indicates that the channel during the frequent 0.5 year event will have shear with a mean of 33.5 Pa and a maximum shear of 156 Pa would erode at a rate from around 0.1 to 10 mm/hr. This is consistent with rates indicated below due to submerged jet testing.

Basically, depending on weathering, bare surficial soils (no vegetative cover) will erode at velocities around 2.7 fps (critical shear based on void ratio and Plasticity Index) at a rate of about .09 in/hr/lbs/sq.ft. (based on Submerged jet testing at Arbor Creek). Vegetation or cover has a large effect on erosion rates

The weathered shale will erode at velocities in the range of 12.9 fps. Shale loss may be related to slake durability noted in the next section. Intact, unweathered shale bedrock will erode based on assessment of Tractive Power. Tractive power to erode shale may also be estimated with the following equation:

$$\text{Threshold Power} = 2.93\text{EE-7 } UCC^{2.52}$$

Where: TP = lbs/ft-sec

UCC = unconfined compressive strength lbs./sq. ft.

(Arizona Dept. of Water Resources; State Standards, 5-96)

Without local engineering tests, the depth to shale is not known except in areas where it is observed along the channel (as noted in the channel surveys). Unweathered Eagle Ford Shale has an average unconfined compressive strength of 310 psi. with values ranging from 14 to 670. This indicates that the intact shale is non erodible according to the above equation. However, based on field observations, the shale does erode. This is evidenced by the shale clasts found on the channel bars and shale knickzones where the shale is being mined.

Another method used to assess rock erosion thresholds has been put forth by Annandale (1995). Basically, the channel stream power is assessed in kW/m and compared to an erosion threshold based on evaluation of unlined spillways. The erosion factor (Kh) is based on analysis of the following:

$$Kh = Ms^* Kb^* Kd^* Js$$

Where: Ms = material strength number

Kb= Block or particle size number

Kd= Interparticle bond shear strength

Js = Ground structure number

Based on the lowest possible ranges for the Eagle Ford Shale, and assuming no structural control, the values range from about .084 to 2.49 for Kh. These are plotted on the threshold chart below along with the stream power of the 100 year ultimate flow. The lesser flows did not have the necessary stream power to plot. Based on the results, it appears that the 100 year flow can erode the shale when the shale is highly weathered as is discussed in the next section.

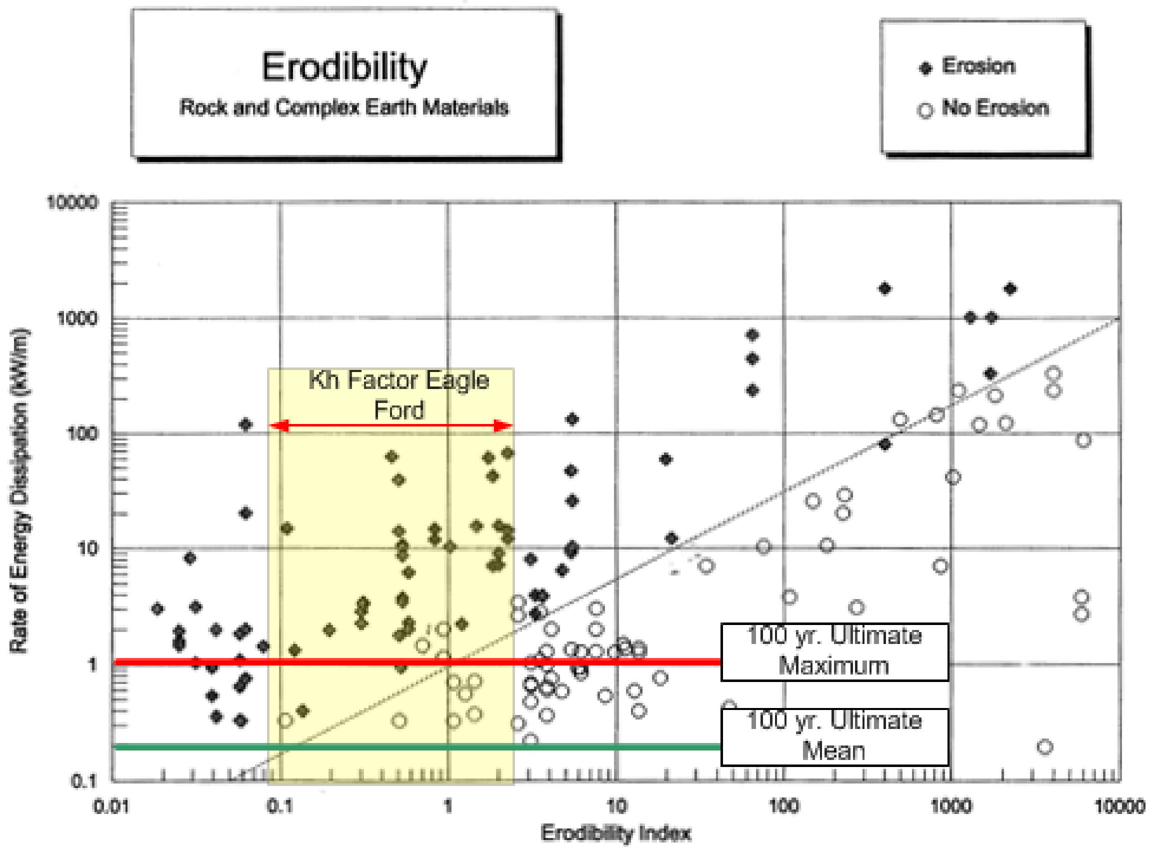


Figure 21. Potential Scour of Bedrock in Arbor Creek.

The zone above the threshold line in yellow, bounded by the red and green lines represents the conditions under which bedrock can be eroded in the channel based on Annandale's criterion.

5.3 Erosion Rates: Shale

The erosion rate in the bedrock slake zone (active channel zone) has been assessed in previous studies in both the field and laboratory. The field tests consisted of repeated measurements of stream bank profiles in a shale dominated bedrock channel after flood events (greater than 1 year Return Interval) based on procedures and equipment used by Zonge, Swanson, and Myers (1996). The laboratory tests consisted of performing slake durability tests on the shale bedrock utilizing methods modified from Richardson and Long (1987). The procedure consisted of oven drying the bulk rock samples from the bank (2 x 4 inches) in the oven at 105 C for 12 hours. The samples were then weighed and put in a #12 sieve and immersed in and out of a water bath 200 times in a period of ten minutes. The sample was then oven dried, reweighed and the process repeated for five more cycles. The slake durability index was found by dividing each final dry weight retained on the sieve by the original weight and multiplying the result by 100%. The slope of the plotted relationship between percent loss due to slaking and the number of slake cycles was determined by regression analysis. The average slake rate for the Eagle Ford Shale are given below.

Dry Density	Total Density	2^{nd} Cycle Slake
119 pcf	138 pcf	21 %

Table 6. Slake Durability for Shale

In areas where the channels have down cut into the underlying rock, widening of the channel is accomplished through scour of the alluvial material and weathering (slaking) and removal of the exposed rock material. This zone of exposed rock which extends from the mean flow line of the channel taken as the riffle height to the soil/rock interface is termed the slake zone. In the Dallas/Fort Worth area, the slake zone along the urban channel banks ranges in height from 0-5 feet.

Channel loss rates in this zone range from less than 0.4 to over 2 inches a year depending on the number of wet dry cycles per year and flood frequency. This is based on the following assumptions: (1) This lower portion of the bank is subject to high shear stress and numerous wet and dry cycles (Lawler, 1992;1993, Thorne and others, 1982;1998), and (2) the shale and limestone rock in this zone are subject to repeated cycles of slaking and subsequent removal by flooding.

The slake rate equation derived for this zone is based on repeated site surveys on a shale bedrock channel in North Texas and slake testing done on the bedrock samples. The bank scour process in this zone appears related to both the location of the erosion site on the meander and to the exhaustion of slaked material after numerous flood events. Greater erosion is associated with the downstream portion of the meander. Slake durability test data for the site represents the slake loss for each laboratory slake cycle. The equation derived in this study for predicting ultimate bed and bank loss rates due to slaking and subsequent entrainment is based on: (1) assessment of the number of flood flows in this zone per year, (2) slake rates established by the work of Shakoor and Rodgers (1996), and (3) previous suggestions by Howard and Kerby (1983).

$$SLR = \text{Sum}\,(LR^*(e^{at}))$$

where:

SLR = annual slake loss (inches) in the <u>stream channel</u>

LR = maximum annual loss rate (inches) of <u>shale material</u>

a = slake rate (slope of slake durability loss per slake cycle range or -0.4 to -0.65)

t = number of floods in slake zone

With an average second cycle slake durability value one can compute the maximum slake loss rate in inches per year based on Shakoor and Rodgers (1996), where:

LR= 3.91 - .0792*SR (For SR less than 30)

LR = 2.10 – 0.0119*SR (For SR greater than 30)
LR = Maximum rate of loss in in/yr.
SR = 2nd Cycle Slake Durability

For example, for a channel with a second cycle slake durability of 21 percent, up to 3.64 inches could be lost if four floods occurred during that year under worst case conditions. (1.506+1.009+.676+.45) Generally about 3 to 5 inches per year is the observed rate of loss for totally exposed shale channels in the area subject to wetting and drying cycles. Work by Prosser, and others (2000) reinforces these assumptions. They show that erosion can be controlled by subaerial processes such as dessication of clays.

6.0 *Vertical Stability*

6.1 Equilibrium Slope

The bed material gradation combined with the channel forming discharge is used to estimate the equilibrium or "ultimate" stable channel slope. Five methods are used to assess stable slope under boundary conditions imposed within the design reach. The rationale for using this number of methods is due to the fact that the bedload equations on which they are based are not very accurate. Equilibrium slope is given for the stream in Table 8. Most methods of solving for the equilibrium slopes utilize bed load equations and back solve for slopes at incipient motion. These methods assume that there is insufficient coarse material to form an armored layer, the gradation of the bed material is the same down to the depth of degradation, and the bed material depth is greater than the expected degradation limit. While all these assumptions are not met (shale bedrock lies below the bed material at depths of less than the depth of degradation) this analysis gives a reasonable point to which the stream would down cut if new bed material is supplied through erosion of terrace material. In addition, since the critical tractive force of the weathered bed shale is in the range of the tractive force of the bed material, this assumption seems appropriate. Six methods were used to calculate the equilibrium slope; USACE, Meyer Peter Muller, Schoklitsch, Shields, SAMWin, Blackland Regression, and Bledsoe (GBR) . These methods are given in the appendix.

Station	Equilibrium Slope	Actual Slope	Maximum Number Drops @ 3 ft.
10104-9584	.00075	.0071	3.3ft or 1 drops
9584-8659	.00075	.0023	1.48ft. or no drops
8562-7798	.00075	.0048	3.1.ft. or 1 drops
7798-7443	.00075	.00534	1.63ft. no drops
7348-6790	.00075	.00606	2.96ft. or 1 drop
6790-6360	.00075	.00246	.74ft. no drop
4519-3908	.00075	.00946	5.32ft. or 2 drops
3828-3353	.00075	.0075	3.22ft. or 1 drop
3353-2140	.00075	.0035	3.44ft. or 1 drop

Table 8. Computation of equilibrium channel slope and projected maximum degradation by study reach. The number of drop structures is determined by:
Number =((Actual S –Eq. S)*Length))/3. This assumes a maximum engineered drop height of 3 feet.

Table 8. indicates that in each cited reach of the stream, based on the existing slope of the channel, the bed material, as well as the effective discharge, the channel will try and downcut to achieve quasi equilibrium over time. The conservative estimate indicates that the slope will degrade to 0.0009 feet per foot. This assumes no armoring and sediment supply is continuous. SAM Win gives a higher slope which is less conservative as does the GBR model (appendix). While these models optimize for the equilibrium slope, they assume abundant bed material supply and have no way to control bank vegetative effects. Therefore for design, the lower slope was chosen. SWAT-DEG runs (next section)

indicate the amount of time this degradation should take. The 3 foot drop is used as an upper limit of usually accepted drop structure heights. The particle size used to predict equilibrium slope is 3.6 mm. This is approximately D_{50} and is considered a representative particle size in the stream where the bed material changed from one reach to the next. This is conservative as entering a large particle size will steepen the equilibrium slope.

The Channel Evolution Model (CEM) has been formulated by Schumm et. al. (1984) and later by Simon and Hupp (1986). In this model the fluvial geomorphologists noted that alluvial channels in different environments, when destabilized by human and natural disturbances, pass through a sequence of channel forms through time. These systematic channel adjustments through time have been called the CEM and permit interpretation of past, present and future channel conditions. Figure 21 indicates the simple stages identified in previous work in the Metroplex with references to the original work by Schumm and Simon. When doing field work in the area, the various attributes of the channel are noted. The major disturbances causing changes in channel morphology in this area are related to increased impervious surfaces and runoff, increased storm sewers, modified channel sections (channelization) and hydraulic changes near bridges. The combination of these parameters results in channel disequilibrium and bed and bank erosion. The impact was first summarized by Lane (1955) where:

$$QS \sim Q_s D_{50}$$

Where: Q= discharge

S = slope

Q_s = bed material transport

D50 = size of bed material

In general if the other variables are held constant and one increases discharge, the channel will tend to reduce its slope. As it degrades, it will go through a sequence of

Stages shown in Figure 21. The channel will downcut in Stage 2; as it reaches the critical slope height based on the engineering characteristics of the bank (cohesion, internal angle of friction, weathering, and water table) it will fail and the channel will begin to widen. As it widens and deepens in Stage III, it will reduce the tractive force and velocity of the water and at a certain point, it will begin to cease downcutting and begin to stabilize through deposition, and restabilized banks with a new lower floodplain and new channel or Stage IV. While channels can also adjust to the greater urban discharge by increasing their length (larger meanders), in this particular terrain, owing to either rock or cohesive soils, the channels are more prone to downcut to reduce the slope, Figure 21..

Channel Evolution Model (CEM)

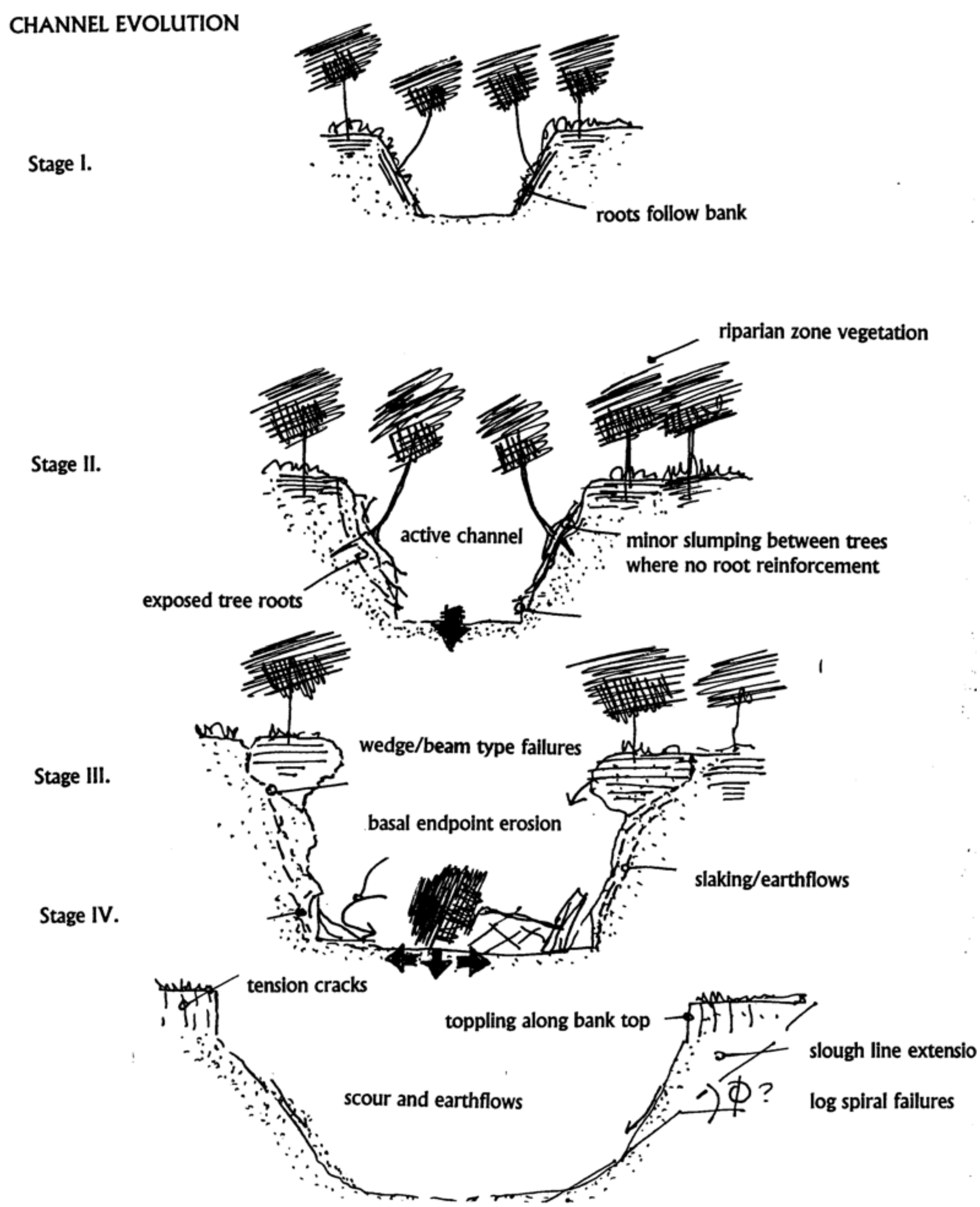


Figure 21. Channel Evolution Model adapted from previous work by Schumm , Simon and others adapted for Metroplex streams.

6.2 Field Survey Results

Survey results are given in Figures 22-59 which illustrate the bed and bank processes and also document each 200 foot survey reach of the channel. Field notes along with GPS locations of all photographs are in the appendix. Figure 22 illustrates the field data collected by survey segment; Figure 23 is a plot of the general trends in field surveyed data, and Figures 24-25 are a summary of the field data in the context of the channel evolution model (CEM). Specific areas of change in the channel and key erosion or sites where changes are taking place in the stream are noted diagrammatically and in photographs in Figures 26-60.

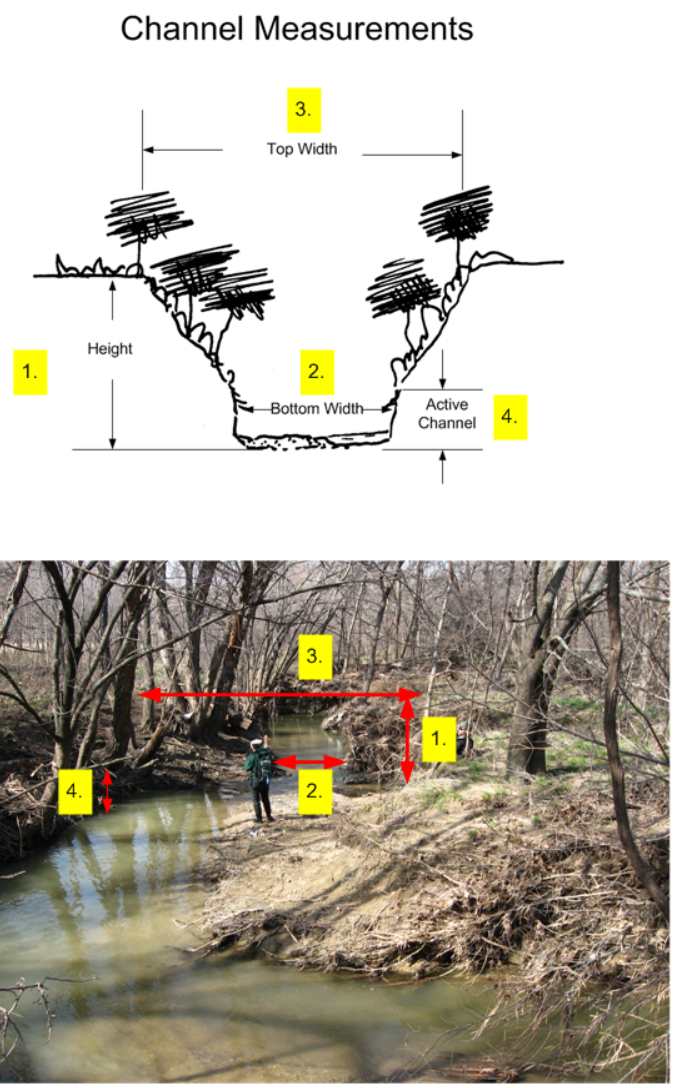


Figure 22. Illustration of typical channel measurements on stream in field survey.

The channel characteristics are shown in three ways; (1) by plots of the general existing active channel dimensions, (2) by a plot of the channel thalweg and general divisions of morphological types, and (3) reach summaries with associated photographs.

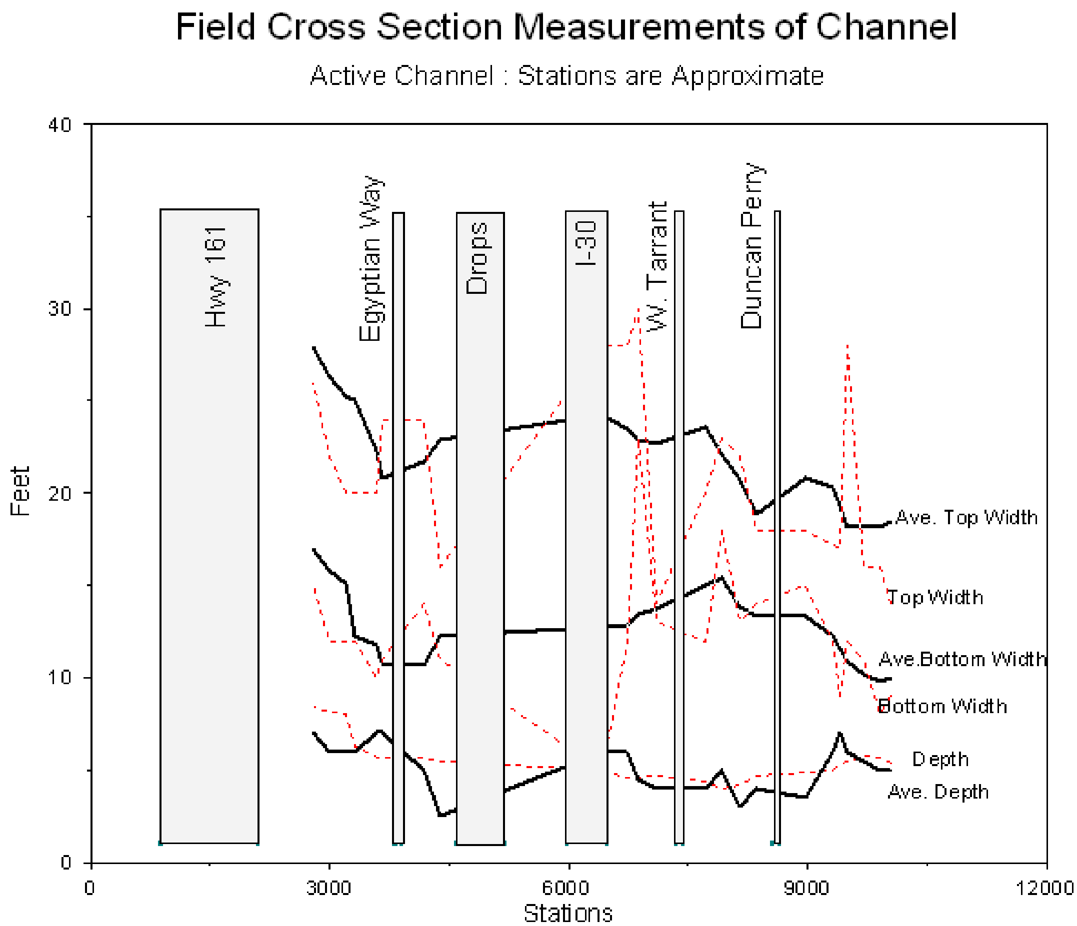


Figure 23. Channel Geometry: Active Channel Width and Depth Arbor Cr.

Field measured dimensions are meant to detail trends in channel dynamics. Moving average values have been found to most accurately reflect general progression of in channel processes in stream evaluation. The following observations can be made from the plots:

- Top Width ranges from 14 - 30 feet with a mean of around 21 feet; the channel increases in width slightly as one progresses downstream. The channel is narrower in areas where the banks are heavily vegetated.

- Average Channel Side Slope ranges from 20 to 85 degrees with a mean of 50 degrees. Maximum slope angles are associated with side slope erosion which increases below Egyptian Way and is greatest below Hwy 161.
- Bottom Active Channel Width ranged from 5 to 23 feet with a mean of 12 feet; width increases as side slope vegetation changes from trees to grass to areas that are eroding.
- Active Channel Depth ranges from 2.5 to 7.5 feet with a mean of about 5.2 feet. Active channel width mirrors top width. Overall channel depth is greatest downstream of Hwy 161 where the stream enters the park. Here total channel depth can reach over 12 -14 feet.

Based on the field survey, the channel has been classified into six basic reaches separated by hardpoints at the bridges. These hardpoints will control the channel degradation at the lower end of each reach.

As can be seen in Figures 24 and 25, Arbor Cr. is predominantly in Stage I and II from upstream of Duncan Perry to below Egyptian Way; the channel is adjusting to the increased discharge and increased number of overbank flows. The lack of degradation and widening as seen in the model is believed to be due to the additional hardpoints installed within the reaches as noted by the yellow circles in the following field notes. Below Hwy 161, the channel is in the final Stage II and beginning to enter Stage III where slope stability will decrease, and slopes will fail by wedge and slump failure modes. At Stage III, it is very costly to control the stream as the channel has already down cut enough to begin to cause massive bank failures. Drop structures are typically advocated for streams entering Stage II to prevent potential degradation.

The following diagrams summarize the field survey results. Note that all photographs with GPS locations and site notes are in the appendix. The yellow pins indicate problem locations, the red dots with "x" represent field cross sections for active channel dimensions. The field notes are shown diagrammatically in plan view. Channel erosion locations are denoted by purple (moderate) and red (severe) erosion. Each hardpoint (bridge or drop structure) is shown with a yellow circle. These areas are critical for assessing channel degradation potential.

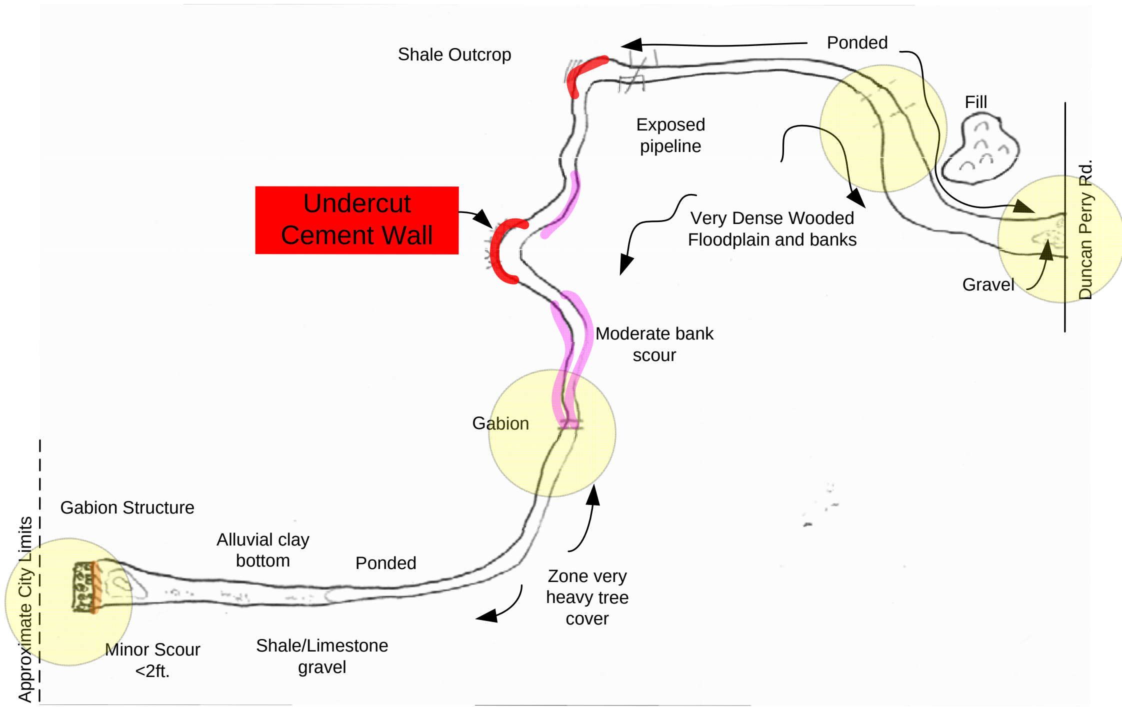
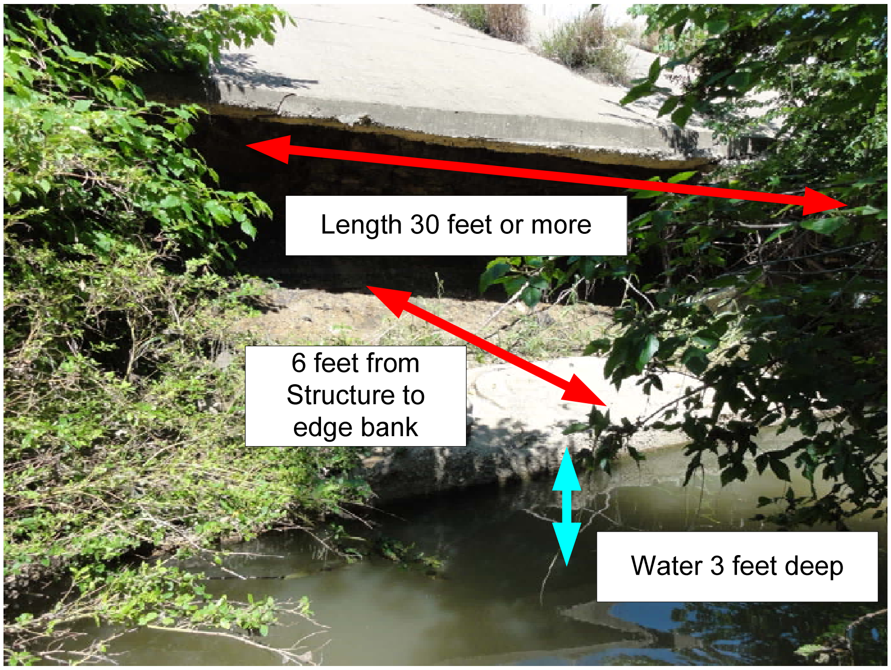
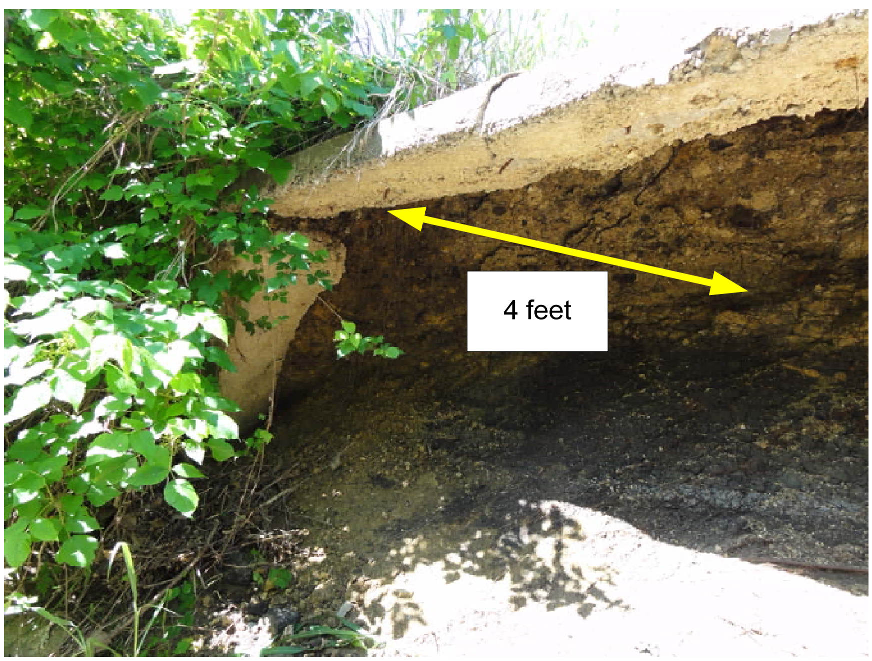


Figure 26. Reach I from City Limits to Duncan Perry Road.

Undercut Cement Side slope

32 45.279N 97 02.334W





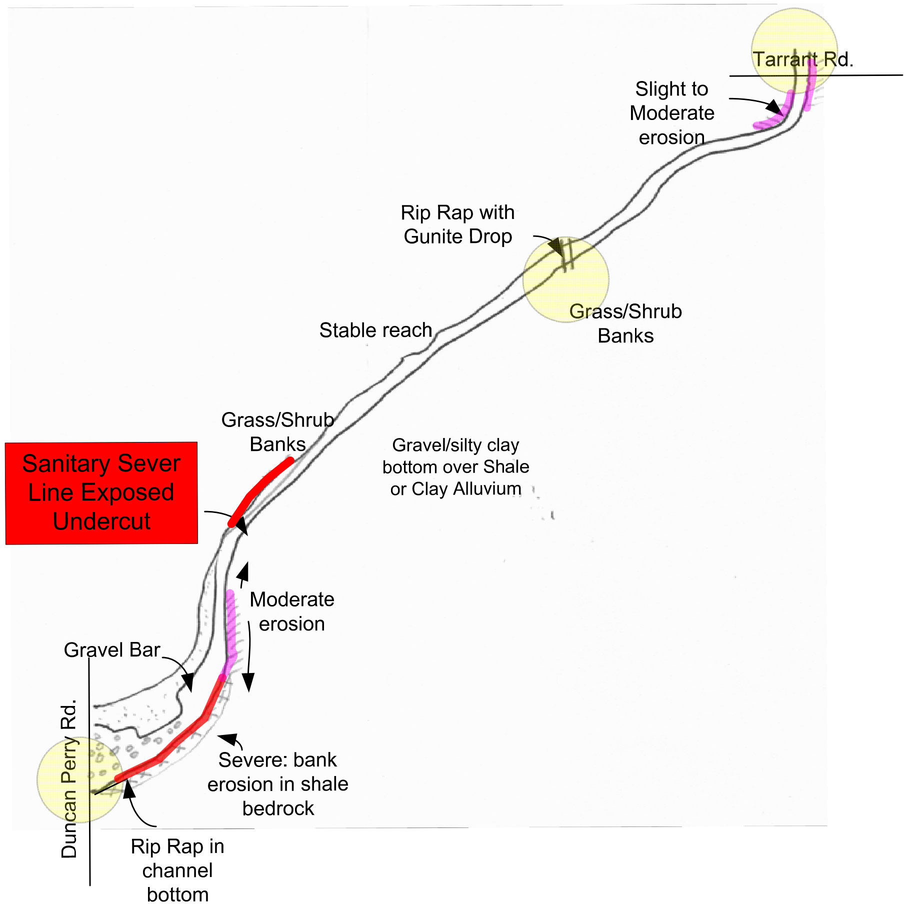
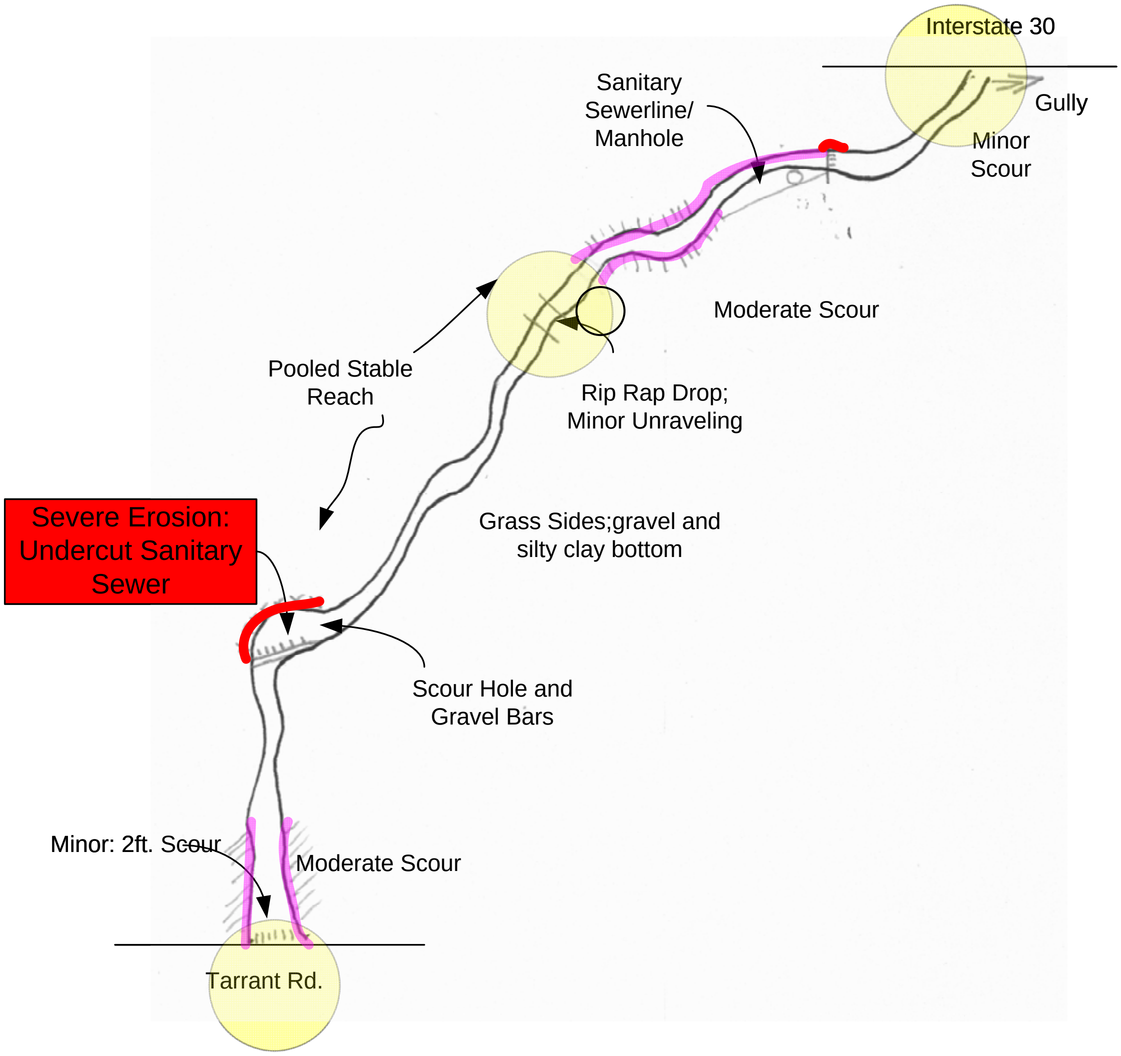


Figure 27. Scour below rip rap at end of channelized section.

Exposed and Undercut Sanitary Sewer

32 45.338N 97 02.185W

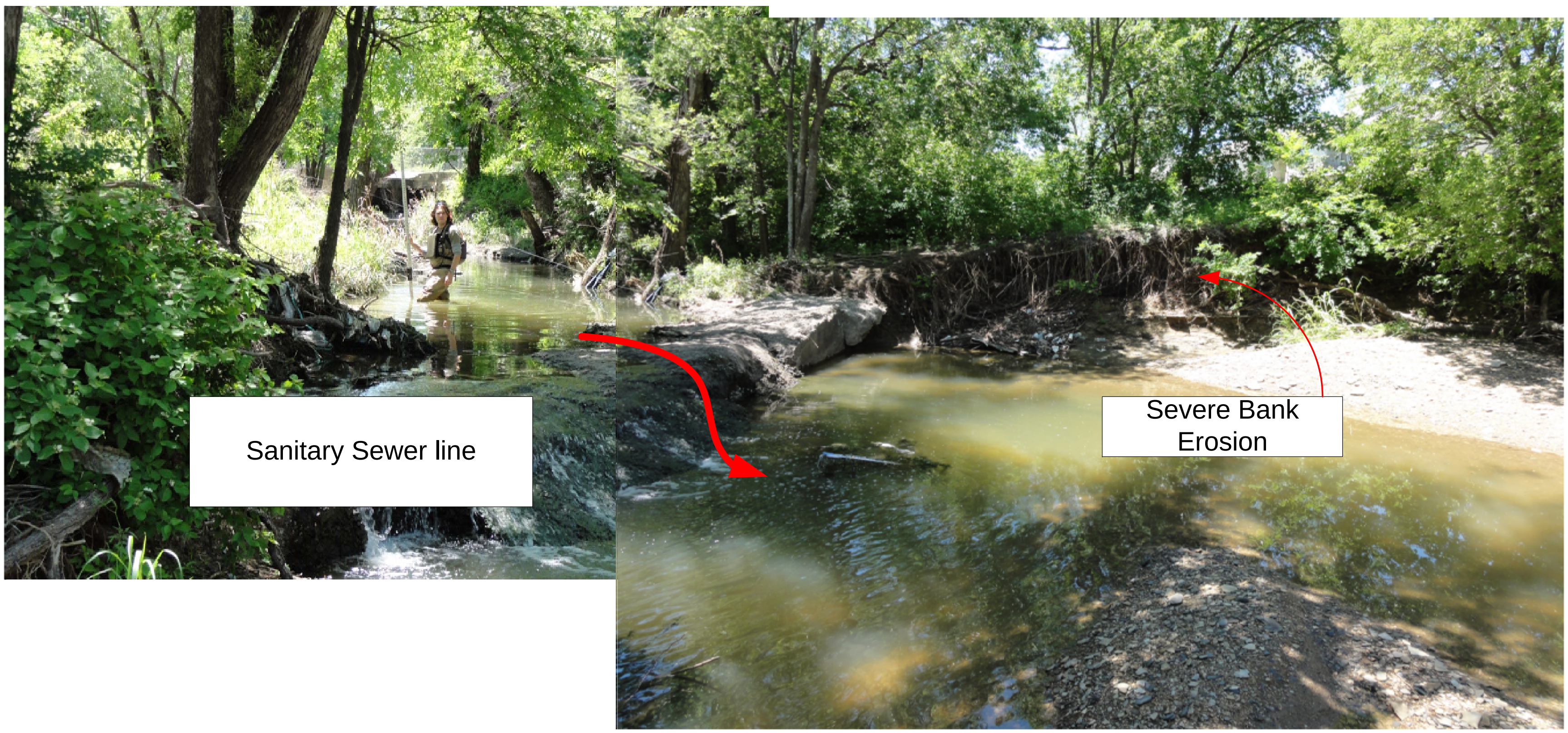
Figure 28. Minor bank scour caused by diversion due to willow growth.

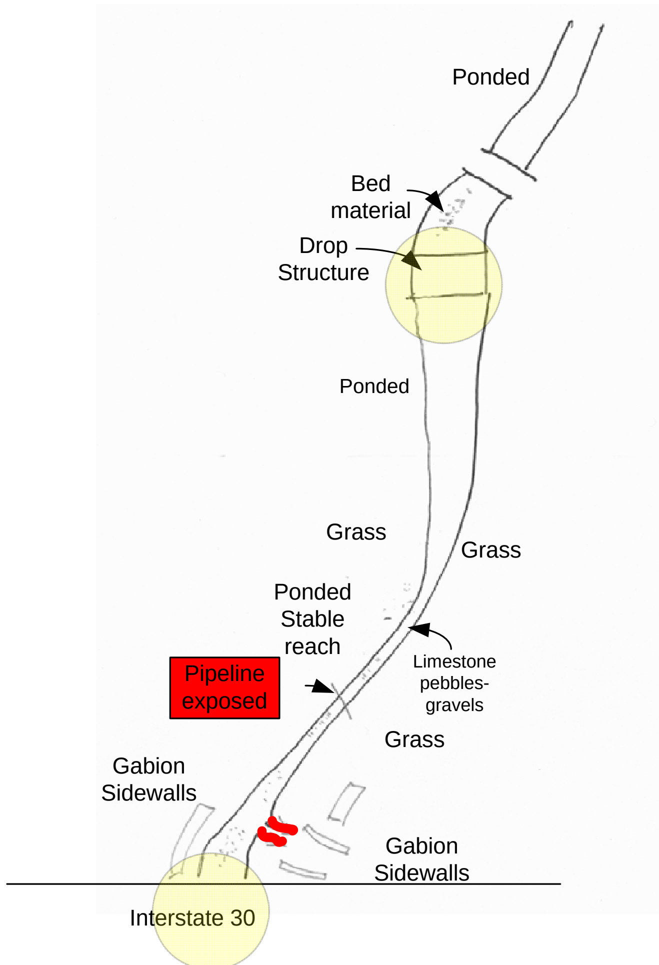

Interstate 30
Gully
Minor
Scour
Sanitary
Sewerline/
Manhole
Moderate Scour
Pooled Stable
Reach
Rip Rap Drop;
Minor Unraveling
Grass Sides;gravel and
silty clay bottom
Severe Erosion:
Undercut Sanitary
Sewer
Scour Hole and
Gravel Bars
Minor: 2ft. Scour
Moderate Scour
Tarrant Rd.

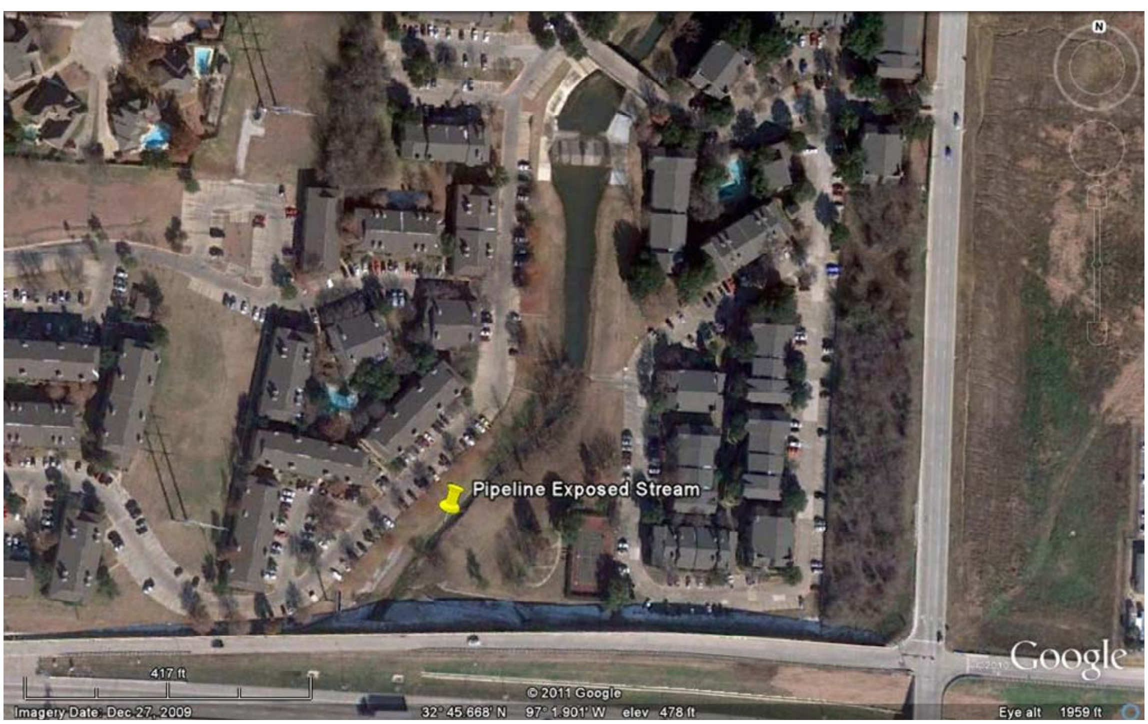

Gully Erosion
X15
X14
X13
Erosion Sanitary Sewer
X12
317 ft
©2011 Google
Google
Imagery Date: Dec 27, 2009
32° 45.485' N 97° 2.034' W elev 504 ft
Eye alt 1606 ft

Erosion of Sewer line and Bank Scour

32 45.471N 97 02.067W

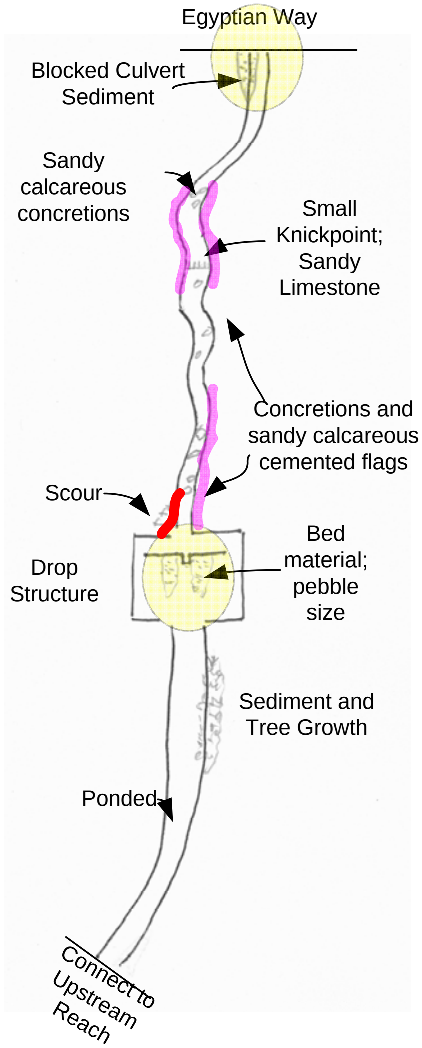



Ponded
Bed material
Drop Structure
Ponded
Grass
Grass
Ponded Stable reach
Limestone pebbles-gravels
Pipeline exposed
Grass
Gabion Sidewalls
Gabion Sidewalls
Interstate 30

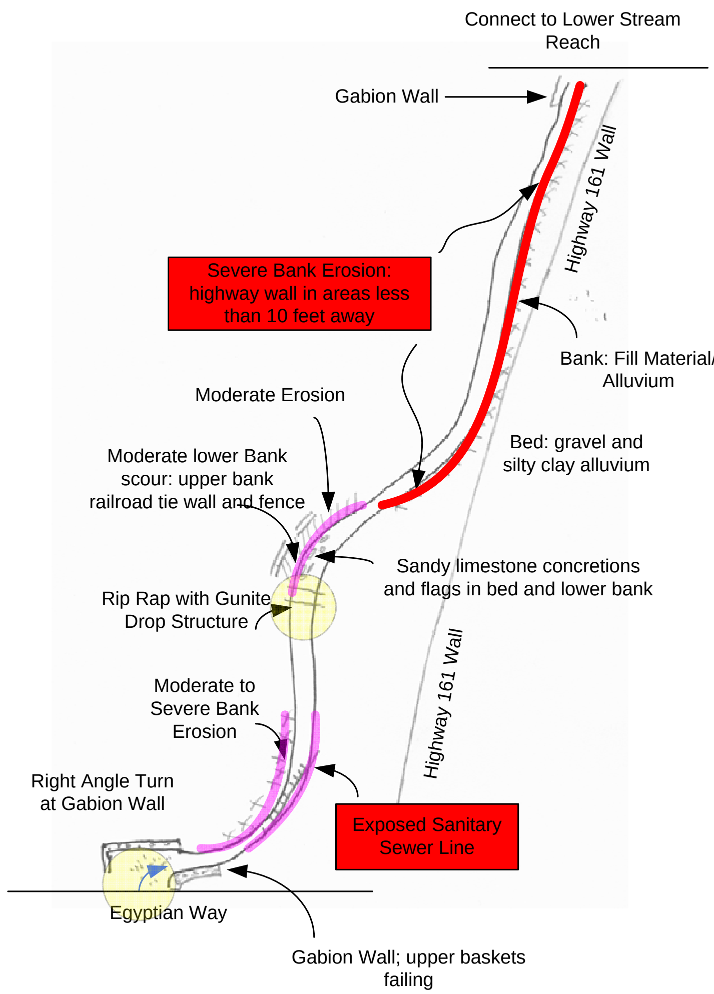

Pipeline Exposed Stream
417 ft
Imagery Date: Dec 27, 2009
© 2011 Google
32° 45.668' N 97° 1.901' W elev 478 ft
Eye alt 1959 ft
Google

Pipeline Exposed Potential Problem

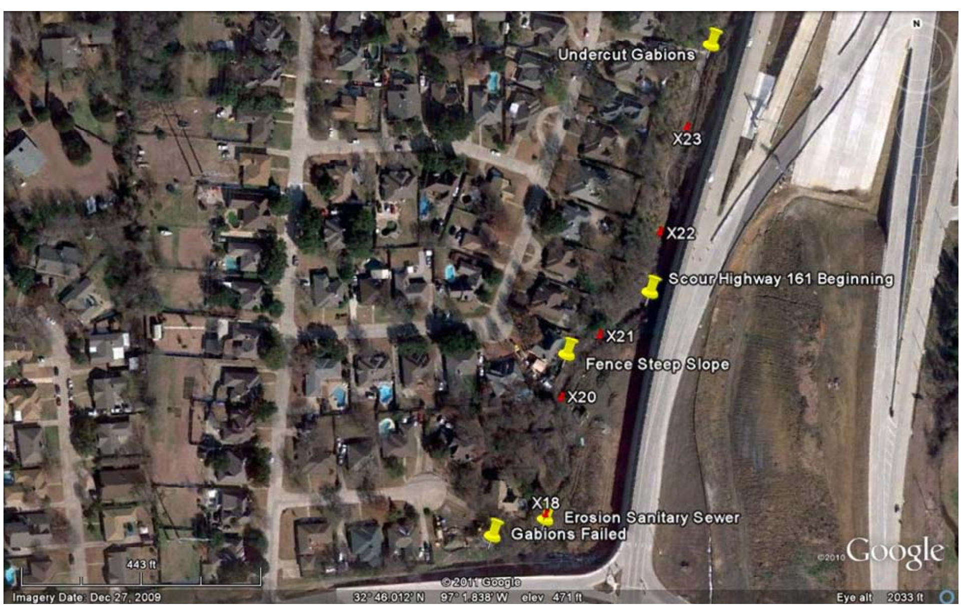
32 45.628N 97 01.937W


Egyptian Way
Blocked Culvert
Sediment
Sandy
calcareous
concretions
Small
Knickpoint;
Sandy
Limestone
Concretions and
sandy calcareous
cemented flags
Scour
Drop
Structure
Bed
material;
pebble
size
Sediment and
Tree Growth
Ponded
Connect to
Upstream
Reach


X17 Untitled Placemark
Concretions
X16
314 ft
Imagery Date: Dec 27, 2009
32° 45.852' N 97° 1.885' W elev 467 ft
© 2011 Google
Google
Eye alt 1606 ft



Connect to Lower Stream Reach
Gabion Wall
Highway 161 Wall
Severe Bank Erosion: highway wall in areas less than 10 feet away
Bank: Fill Material/ Alluvium
Moderate Erosion
Bed: gravel and silty clay alluvium
Moderate lower Bank scour: upper bank railroad tie wall and fence
Sandy limestone concretions and flags in bed and lower bank
Rip Rap with Gunite Drop Structure
Highway 161 Wall
Moderate to Severe Bank Erosion
Right Angle Turn at Gabion Wall
Exposed Sanitary Sewer Line
Egyptian Way
Gabion Wall; upper baskets failing



Undercut Gabions
X23
X22
Scour Highway 161 Beginning
X21
Fence Steep Slope
X20
X18
Erosion Sanitary Sewer
Gabions Failed
Google
443 ft
Imagery Date: Dec 27, 2009
©2011 Google
32°46'012" N 97°1'838" W elev 471 ft
Eye alt 2033 ft

Failed Gabions
32 45.936N 97 01.842W

Erosion of Sanitary Sewer line
32 45.940N 97 01.822W

Fence and Rail Road Ties Steep Bank

32 45.991N 97 01.810W

Severe Scour Along Highway 161

32 46.0009N 97 01.778W to 32 46.085N 97 01.749W

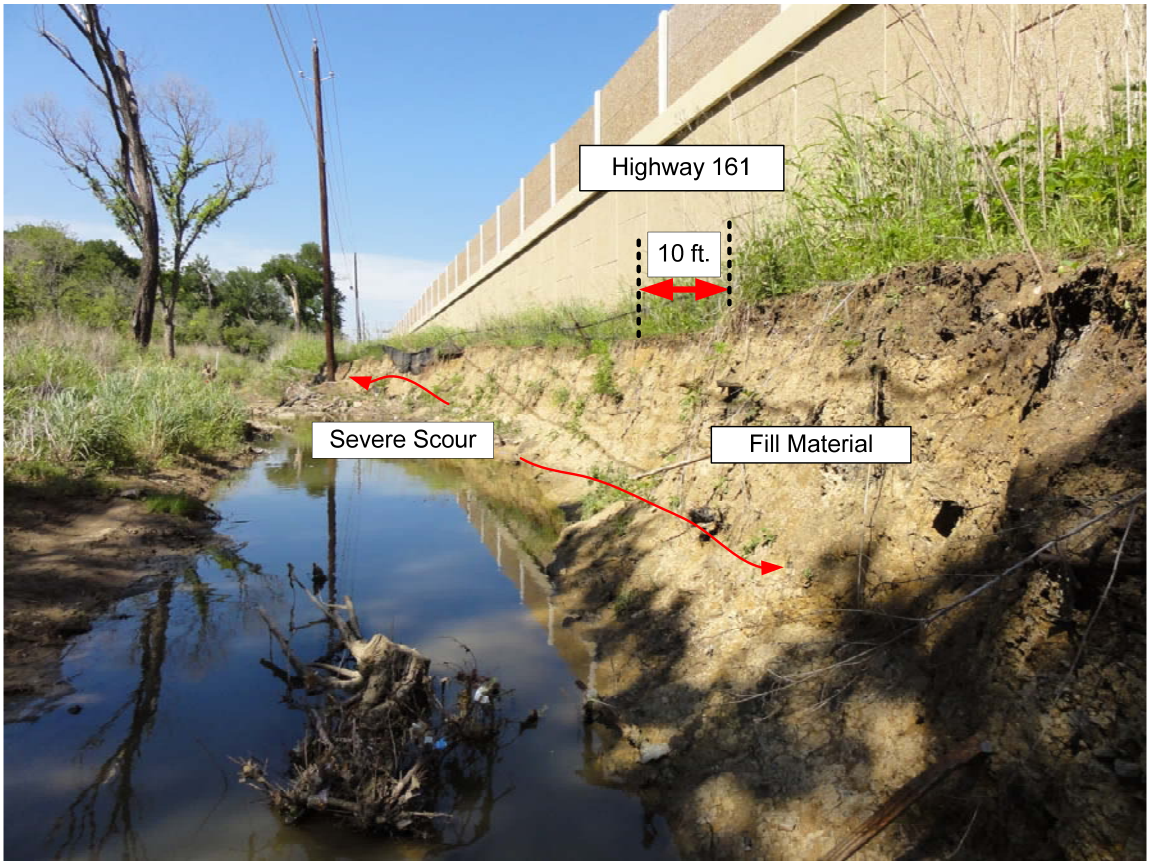
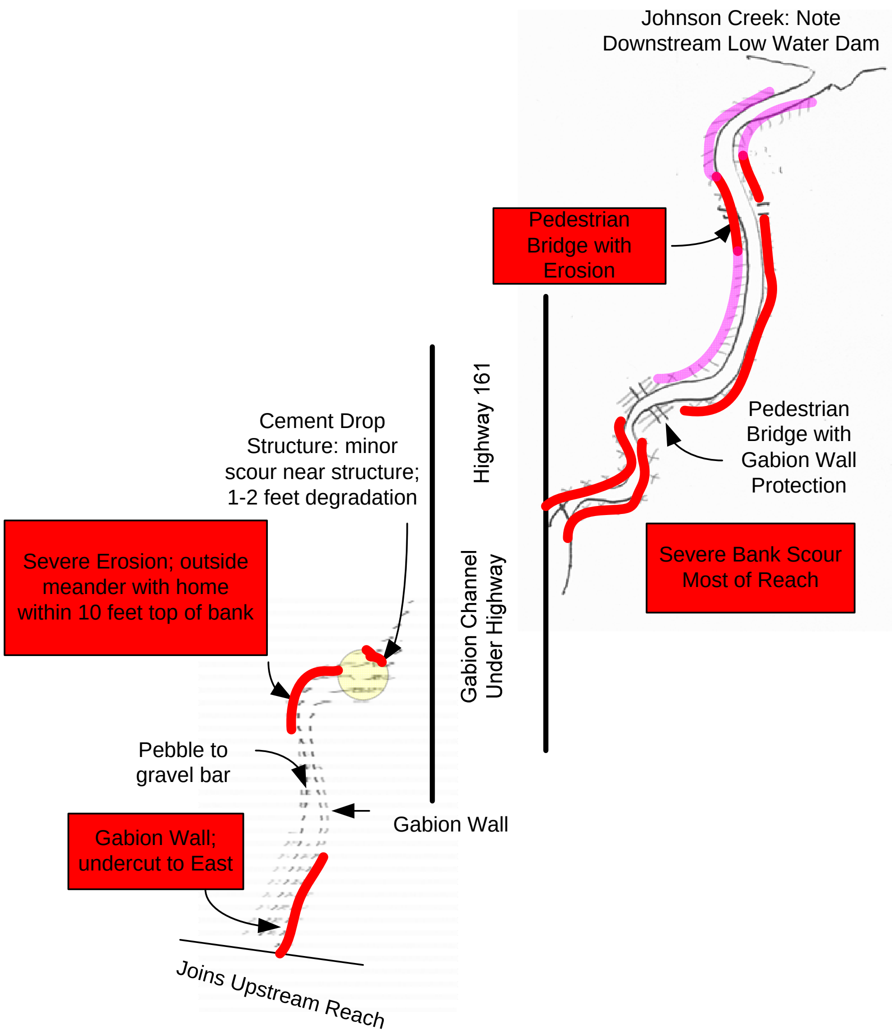


Figure 29.   Channel jumps concrete liner and is scouring bank.


Johnson Creek: Note
Downstream Low Water Dam
Pedestrian Bridge with Erosion
Highway 161
Pedestrian Bridge with Gabion Wall Protection
Severe Bank Scour Most of Reach
Gabion Channel Under Highway
Cement Drop Structure: minor scour near structure; 1-2 feet degradation
Severe Erosion; outside meander with home within 10 feet top of bank
Pebble to gravel bar
Gabion Wall
Gabion Wall; undercut to East
Joins Upstream Reach

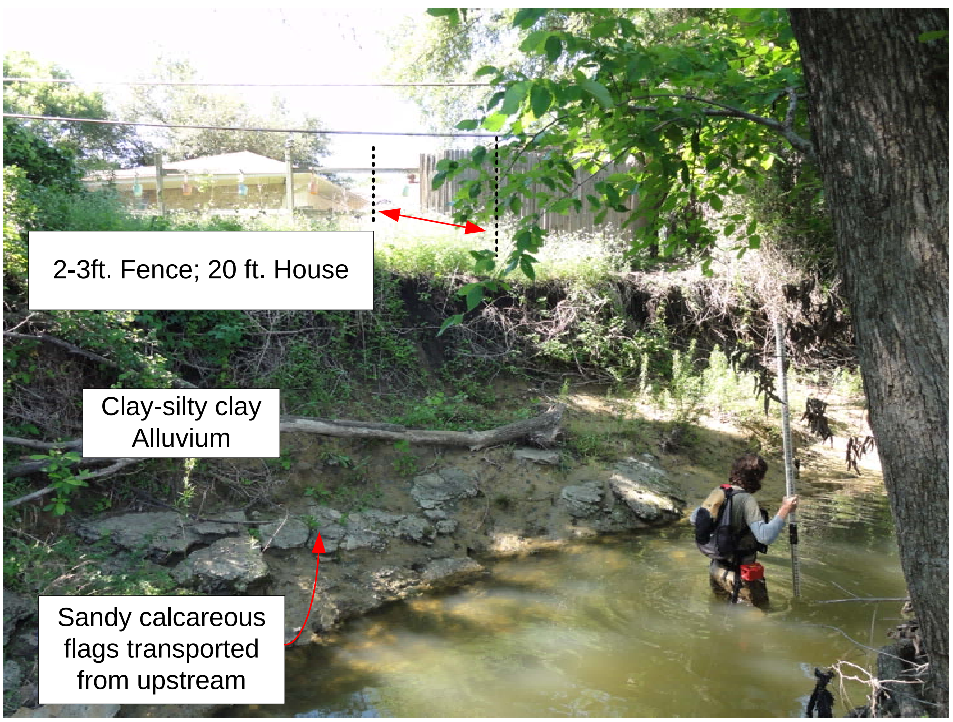

Confluence with Johnson Creek
Pedestrian Bridge Erosion
Begin Park Severe Erosion
161
Severe Bend Erosion
X24
Undercut Gabions
Imagery Date: Dec 27, 2009
© 2011 Google
Google

Undercut Gabions Along West Side Channel

32 46.085N 97 01.749W

Severe Bend Scour at Meander

32 46.143N 97 01.732W



Severe Scour in Park

32 46.229N 97 01.599W

6.3 Predicted Rate of Degradation: SWAT-DEG Model

The rate of bed degradation can be assessed with the Soil Water Assessment Tool (Arnold, et. al., 1993) and a simple degradation component SWAT- DEG, (Allen et. al., 1994;1999). SWAT-DEG is a continuous simulation model , which has been developed to predict time series channel erosion and degradation. Input to this model, besides basic watershed parameters (curve numbers or loss rates, time of concentration, routing structure), are channel dimensions, channel slopes, erodibility of the channel bottoms and width depth ratios of the channel. Erodibility is assessed utilizing the submerged jet technique (Hanson, 1990; Allen et. al., 1999). Bed load is assessed using the appropriate bed load equation after Stevens and Yang (1989). Width-depth ratios and general channel dimensions are based on channel surveys. A W/D of 4 and was used in the SWAT-DEG model for assessing channel degradation and dimensions over time.

This method has the advantage of giving the time rate of potential degradation and can be used to test the effects of varying land-use and climatic conditions on channel erosion. The modeled climate was the daily rainfall and temperature for Grand Prairie, Texas from 1950-1986 . Boundary conditions for design of degradation can utilize the SWAT-DEG results as a general planning tool for assessment of acceptable planning horizons for designing engineering works. Figure 61 illustrates the speed of knickpoint migration up the middle reach of Arbor Creek. This is based on sequential analysis of air photographs. This is the only area where, owing to vegetative cover, the channel could be seen. Average annual knickpoint migration from 2001 to 2009 appears to approach 52 feet.

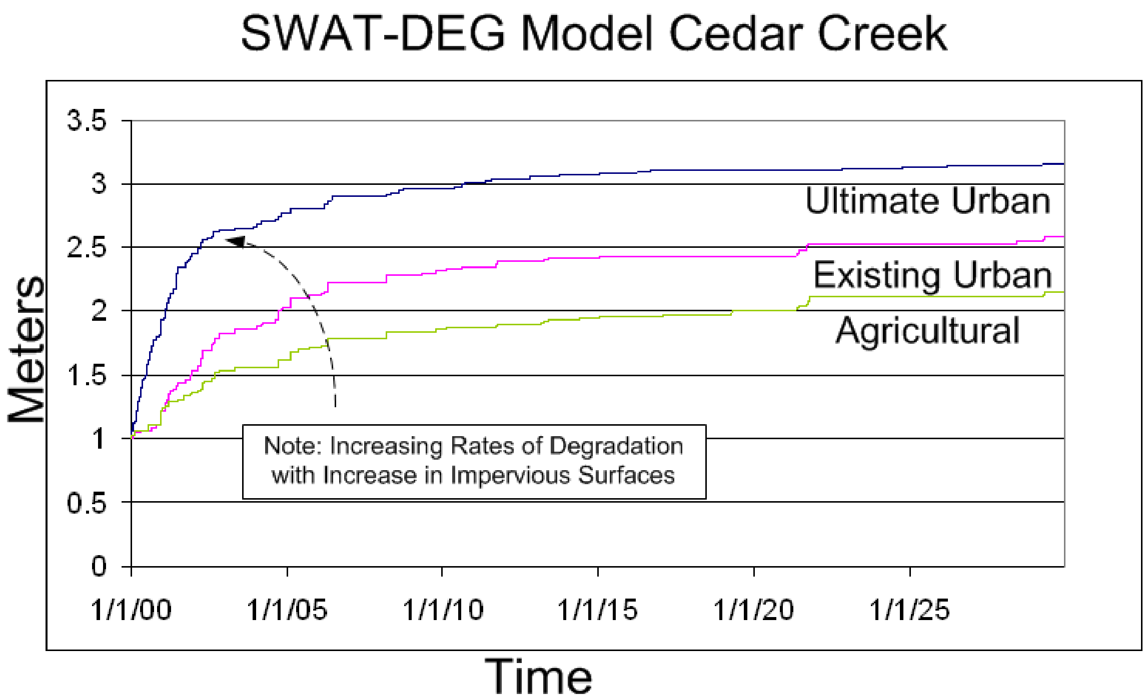


Figure 62. This diagram indicates the potential degradation, and changes possible in a straight reach of the channel over a 30 year time period in Arbor Creek with SWAT-DEG. under 3 different land use conditions.

Results shown in Figure 62 indicate the amount of degradation possible over time. Model results indicate that under *Agricultural Conditions* the channel is slow to change; it is still slowly degrading after 30 years and it never reaches the proposed equilibrium slope over this time. As the basin urbanizes, *Existing Conditions,* more pronounced changes occur in the in basin curve numbers and runoff, and the degradation process speeds up. If we assume that these changes took place over the past decade, then this implies that the basin has not yet adapted to those changes as the channel takes about 21 years to reach equilibrium or it has another decade or more to respond to these changes. Urbanization under the *Ultimate Conditions* infers that these added changes in impervious surfaces will occur more rapidly in perhaps as little as a decade. In summary, there is a lag in watershed response to land use changes. The greater the change in curve number and time of concentration, the more rapid the response of the watershed. This also infers that changes in the channel reflect the entire history of the watershed; that adjustments from one era overlap more recent changes. This infers that the watershed will reach the degradation from the first wave of urbanization in the next decade and continue to degrade in response to future land use changes over the next 20 years.

6.4 Stream Power and Instability of Arbor Creek

Booth (1990) for work in the Pacific Northwest found that improved correlation between flow parameters and observed erosion was found by using the unit stream power or energy expended by the flow per unit time per unit bed area. This author has found that the moving average approach gives a better indication of general trends in stream power and is shown in Figure 63. Comparing this figure with the field data indicates that while this plot illustrates the worst areas, it does fail to pick out the more subtle changes noted in the field in terms of the CEM model and the evolution of the channel. The ultimate 2 year and 100 year power reinforce the same trends. Note how the 2 year ultimate surpasses the threshold in the areas that are currently experiencing problems. This plot reinforces the field data shown in plots 23-25 and coupled with the time rates of degradation aids in prioritizing areas for stream repair and can probably be used as a first order tool in defining problem areas.

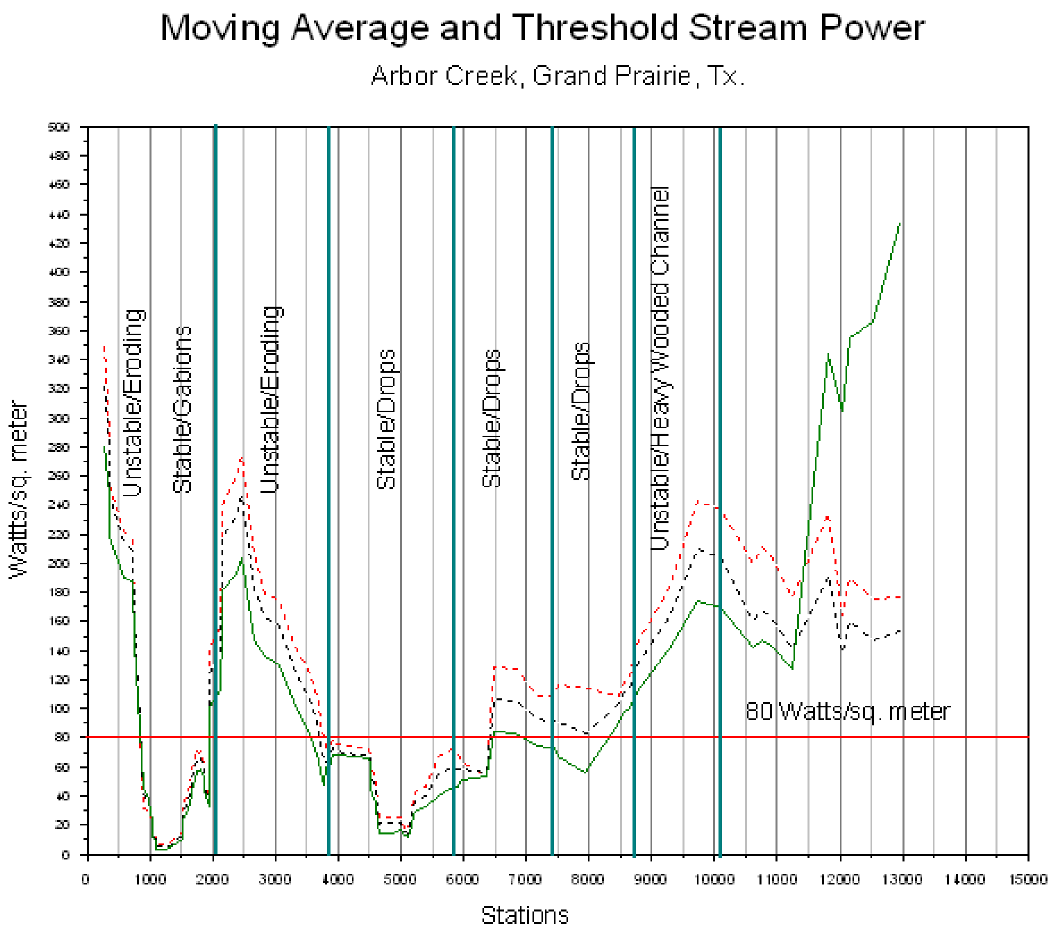


Figure 63. Illustrates the existing 0.5 year stream power in Watts/m-2 and the ultimate 2 and 100 year values for the channel. Note how the major area denoted by the moving average stream power coincides with the area of major channel incision and disturbance.

6.5 Predicted Channel Dimensions

From the effective discharge, work in the Metroplex has shown that the channel dimensions can be predicted within an acceptable error and are comparable to other methods of estimating equilibrium dimensions (Allen, Arnold, and Skipwith, 2002.). The results of SAM model runs (appendix) indicate the channel will be stable at a width of approximately 30 feet and a depth of 4.9 feet with an equilibrium slope of .0032; the

GBR (Bledsoe Colorado State Model) results (appendix) using a different transport equation give widths of 65 feet , depths around 2 feet and channel slopes around .001. Both these methods assume that there is an abundant supply of the bed material; this is not the case in this channel. Regional Regime Equations based on field surveys of gaging stations in the Metroplex are shown in Figures 64 and 65. The Simons and Albertson (1963) relationship is based on analysis of regime channels with cohesive beds and banks. The Hey (2006) relationship is given for gravel bed streams and does allow for vegetative factors and a width depth ratio for input. In this case, a ultimate width depth ratio of 6 was used and a cover factor of 0.6 or heavy side slope vegetation.

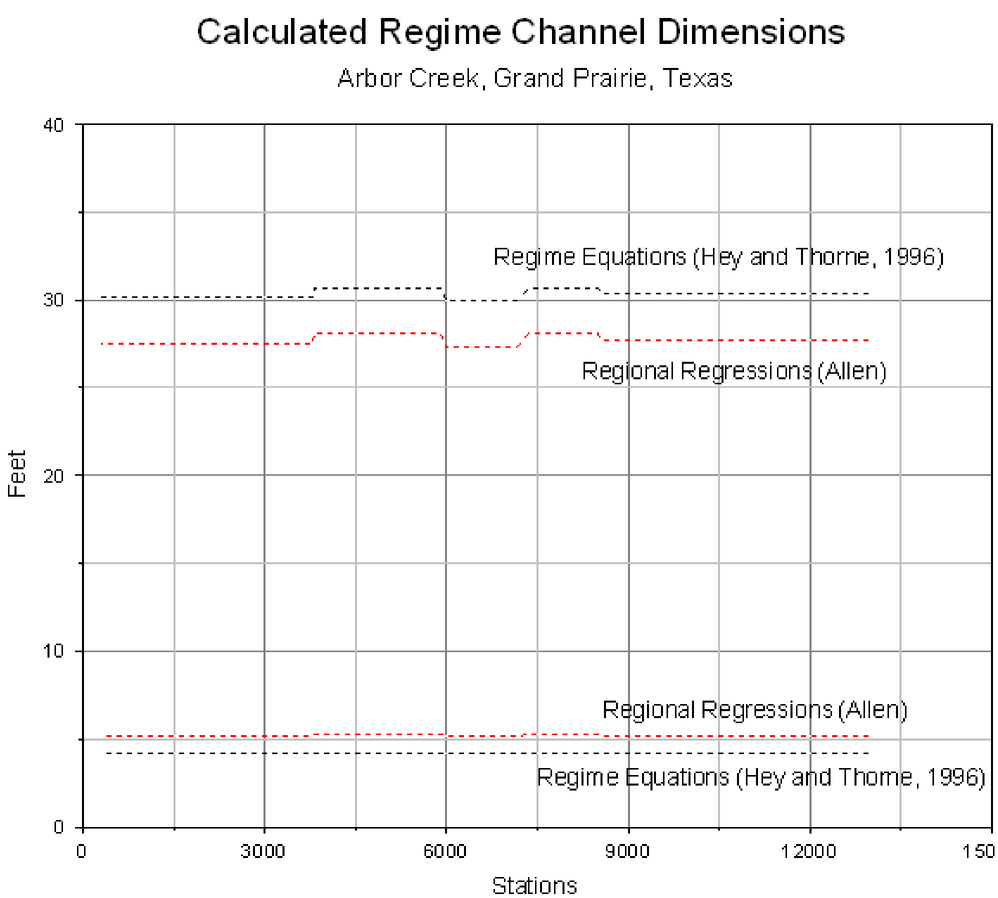


Table 7. Station, Effective Discharge and Channel Dimensions for Arbor Cr.

The above computations are based on the effective channel discharge and are guides to potential change in the active channel. The numbers in parenthesis are the 0.5 year existing x 1.12 urbanization effect x 0.8. The other is the Dempster 1.25 year based on ultimate levels of imperviousness. The higher value was used in this assessment.

Therefore, the existing active channel will widen about 11 feet and deepen about 1 foot. The channel thalweg , due to degradation in the reach can add another 4.6 feet of depth to the channel for each 1000 feet of channel length over the next 20 years. Increase in bank height (reach degradation plus local scour), will increase the channel width due to bank failures and slumping on meanders (@4:1 width depth could be 60 feet top width). Associated riparian tree loss will cause localized tree dams and scour as well as localized backwater conditions.

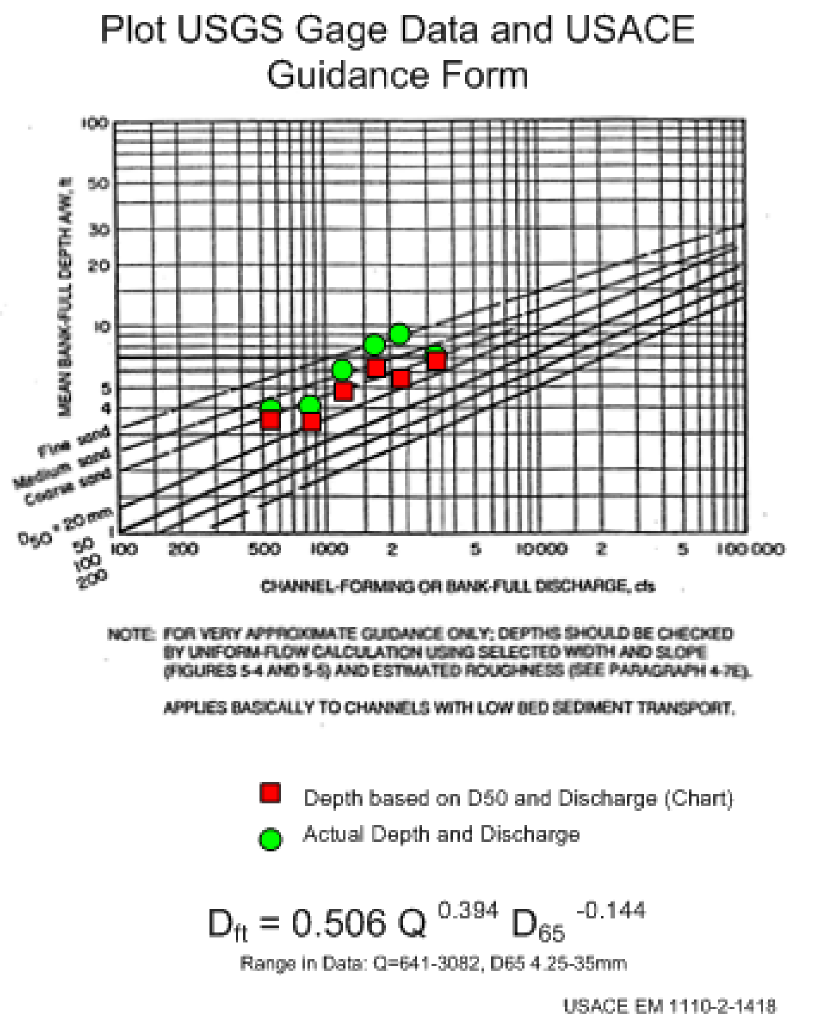


Figure 64. This diagram illustrates the general relationship between channel depth, effective discharge, and bed material size. The colored symbols are for gage site assessments previously done in the Metroplex. With a effective discharge around 500 and a bed material size of 4mm would have a design depth of about 4-5 feet.

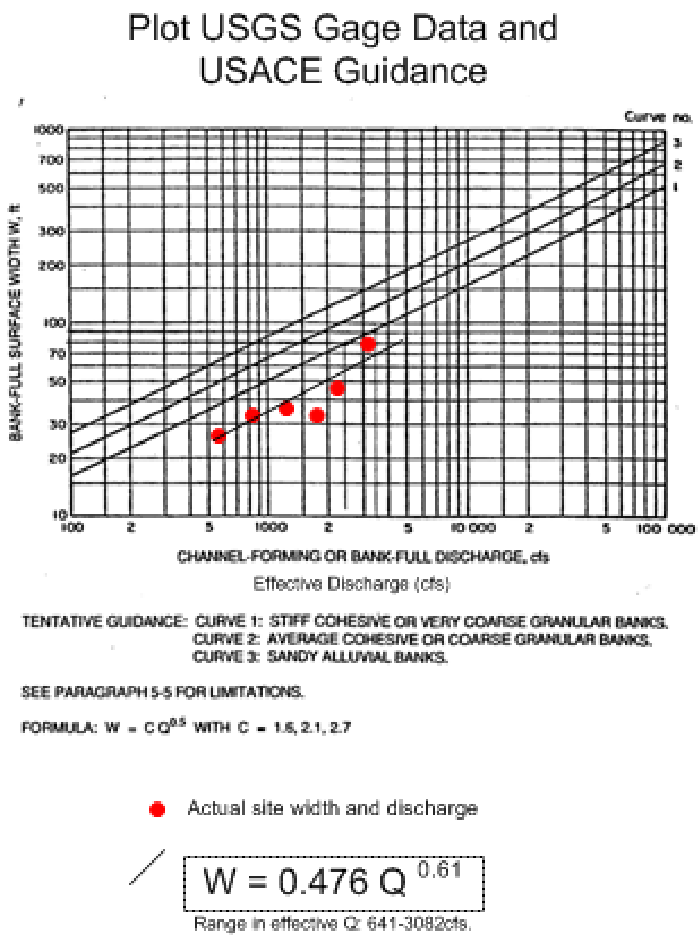


Figure 65. This is a similar chart showing previously surveyed channel widths at Metroplex gage sites and channel width. It can be seen that the USACE relationships indicates larger channel widths. This is because this does not take into account the effects of bank vegetation. In general, the 500 cfs effective discharge will give ultimate widths of around 30-34 feet. the channel could be wider depending on bank vegetation.

7.0 *Planform Stability*

7.1 Meanders

Work by Leopold and Wolman (1957) on rivers in the United States indicates that, based on channel slope, rivers will tend to go from meandering to braided when the channel slope exceeds the threshold slope of :

$$S_t = .06\ Q^{-.44}$$

Where: S_t is in ft/ft. dimensionless

Q is in cfs.

Using this relationship, and the predicted effective discharge of the stream, it appears that the stream is steep enough to trend toward braiding as the actual slope is greater than the predicted threshold for the stream between .0036-.004. This infers that the tendency of the stream will be to widen and straighten to effectively carry the load of the stream. This is a very simplistic representation of stream dynamics but does show the tendency of the stream, eg. for the predicted effective discharge, the slope is very high.

While the SWAT model infers maximum degradation in the channel, it assumes no meanders.

Based on a limited time series photographic assessment of channel migration in the Blackland Prairie and in the Metorplex, the following regression appears appropriate for a first order estimate of potential meander migration rates in small channels.

$$\text{Channel Widths/Year} = 0.1346 - 0.0128\ Rc/W - 0.00115\ Da$$

Where: Rc = radius of curvature in feet

W = channel width in feet

Da = drainage area in sq. miles

So, for a 1.7 square mile drainage area with a channel width of 10-20 feet and a projected mean radius of curvature of 60 feet, the channel bend loss rate could be .1092 widths a year or up to 2 feet/year. This indicates on meanders, some form of bank protection will be needed to arrest lateral migration if structures or other critical facilities are within this zone. The only visible meander in which some time series analysis could be done was in the Polo to Bardin Reach. Here, based on 5 years of photographic data, the channel appears to migrate from 0.8 to 1.2 feet per year or within the limits of the above equation.

For design, the maximum bank shear stress and shear stresses in bends should probably be adjusted as shown below after the USACE.

For straight channel segments: $T_{max} = 1.5\ T$

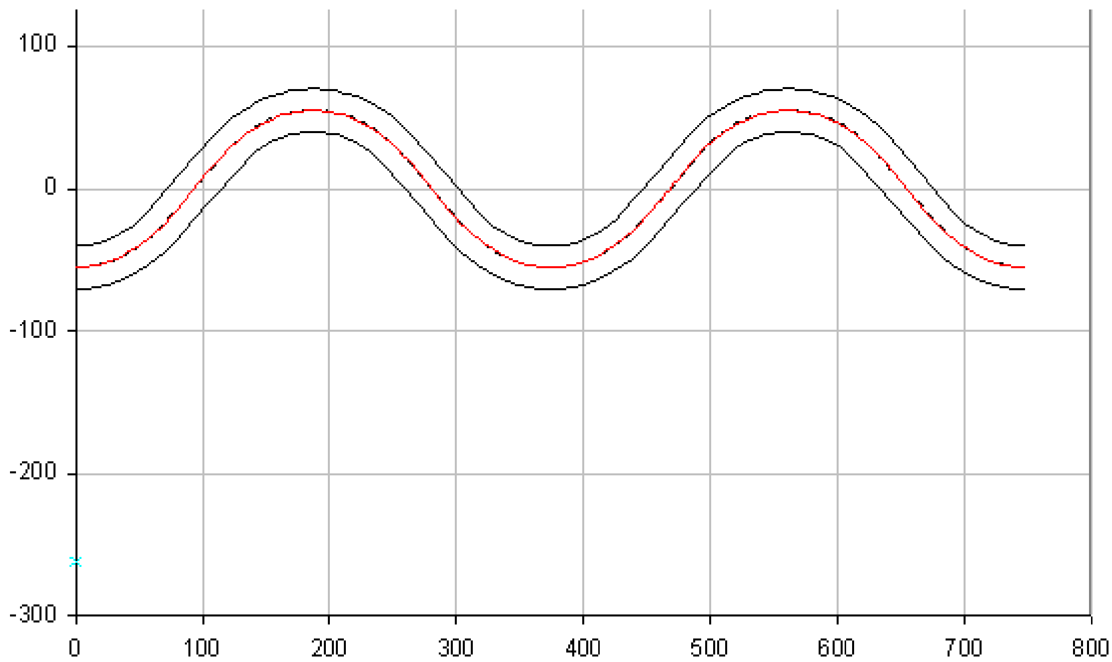
For Bends: $T_{max} = 2.64\ T(Rc/W)^{-.5}$

Where: T = maximum shear stress HEC-RAS

Rc= radius of curvature

W= channel bankfull width..

From ERDC TN-EMRRP-SR-29 Fischenich (2001)



30	channel width (ft)	93.4	radius of curvature, centerline (ft)
1.2	sinuosity	91	arc angle (degrees)
374.1	meander length (ft)	147.8	arc length (ft)
448.9	stream length per meander (ft)	45	angle of deflection (degrees)
110.3	amplitude (ft)	77.1	cross over line length (ft)

Table 10. Projected Meander Dimensions and bed material transport relationships for Arbor Cr. (after Mecklenberg, Ohio Department of Natural Resources).

Table 10 indicates that given the design discharge and channel width, the channel, should develop a meandering pattern with dimensions shown in the Table. These are for idealized meanders based on large data sets. These should be used only for a guide, more detailed assessment of the channel in any area of proposed channel alteration must be done to assess the proximity of the bend to hard points, incoming tributaries, depth of shale bedrock, and depth to sewer and water lines. The general dimensions of the radius of curvature will change in relation to the increased discharges and predicted downcutting. In general, it has been found that most channels in the Metroplex will tend to downcut rather than increase the meander dimensions in an effort to lower overall channel slope. As was shown in the tendency toward braiding given in the beginning of the section.

7.2 Bank Stability

Bank stability is complicated and based on slope geometry, material properties, ground water table and pore water conditions, vegetation, as well as climatic and stream flood cycles. Work in shale terrain has shown several types of failure which are shown in diagrams and pictures for failures found along Arbor Creek.

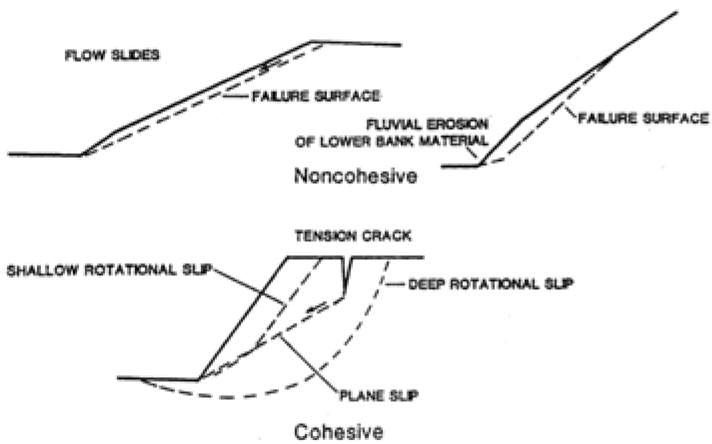


Figure 66. Wedge Failures are common along the outside of meanders or in Type II streams where the channel is incising.

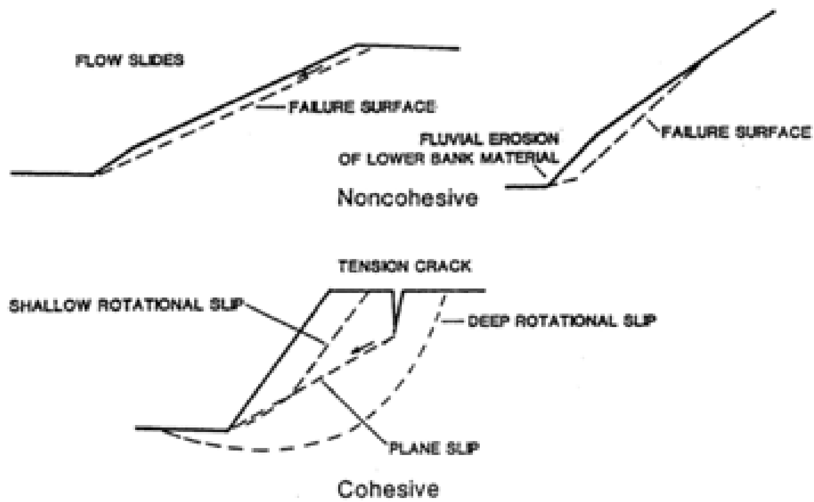


Figure 67. Slump type failure along Arbor Creek (Between Stations 11921 and 12 291). These failures are found where the slopes are typically less than 60 degrees and the stream cuts into an area where the shale is highly weathered or there is soil forming

the channel banks. In this case, the slump appears to occur in the upper bank soil material above the shale bedrock. In most cases the failures will "bottom out" on top of the shale at the base of the weathered material.

For wedge failure analysis, a simple method proposed by Thorne (1982) indicates that the maximum stable slope height assuming a tension crack which extends ½ the bank height is:

$$Hc = 2c/g * \text{Tan}\ (45+p/2)$$

Where: Hc = critical height

c = cohesion

g = saturated weight

p = internal angle of friction

If one assumes that the maximum height (Hc) of a stable vertical channel as seen in the field is in the range of 8 feet, and one assumes the internal angle of friction is the fully softened value of 20 degrees, and the saturated weight is 125 pounds per cubic foot, then the computed cohesion active in the field is around 350 psf. This relationship then assumes that if the slope exceeds this height, given these conditions, it will fail. For more rigorous design of wedge failures, one should consult work by Andrew Simon and BSTEM analysis ARS/USDA.http://www.ars.usda.gov/Research/docs.htm?docid=5044) This method allows one to assess progressive failures on streambanks with variable properties as well as vegetative effects, coupled with dominant discharge. This cohesion is well below that predicted by laboratory unconfined compression tests as were used in assessing rock erosion. However, with weathering and moisture, the author has found cohesion from post mortem analysis of slope failures in the area has been consistently in this range.

For slumps, work in the area has shown that the failures along stream channels are highly related to the depth of the top of the shale, weathering of the shale, and height of the shale in the stream bank. The higher the shale is positioned within the channel bank, the more the channel will tend to fail by wedge failures and by erosive scour rather than slumping. The wedge failures in the shale bedrock will tend to occur along fractures, tension cracks, and fault planes. If the soil material extends the whole height of the bank, and the shale is in the channel bottom, scouring of the channel toe can result in slumps. The depth of the bank failure arcs tend to be less than 10 feet and the failures are a result of high pore pressures and are related to floods or intense rain storms which can charge the surficial cracked soil resulting in high pore pressures and failure (Kuhn and Zornberg, 2006). *For any site, geotechnical engineers should be consulted for analysis of the failure when structures are involved.*

ambient soil unit weight	saturated soil unit weight	cohesion	friction angle	bank angle	bank height	design factor of safety	linearly interpolated factor of safety (ambient conditions)	estimated bank angle @ design FS	linearly interpolated factor of safety (saturated conditions)	estimated bank angle @ design FS
15.72	19.64	16.80	20.00	30.00	3.00	1.50	3.32	stable @ 90°	2.32	62.73
15.70	19.60	16.80	20.00	40.00	3.00	1.50	3.00	stable @ 90°	2.06	62.80
15.70	19.60	16.80	20.00	50.00	3.00	1.50	2.68	stable @ 90°	1.80	62.80
15.70	19.60	16.80	20.00	60.00	3.00	1.50	2.40	stable @ 90°	1.57	62.80
15.70	19.60	16.80	20.00	70.00	3.00	1.50	2.11	stable @ 90°	1.33	62.80
15.70	19.60	16.80	20.00	80.00	3.00	1.50	1.85	stable @ 90°	1.08	62.80
15.70	19.60	16.80	20.00	30.00	5.00	1.50	2.57	71.78	1.71	39.34
15.70	19.60	16.80	20.00	40.00	5.00	1.50	2.28	71.78	1.49	39.34
15.70	19.60	16.80	20.00	50.00	5.00	1.50	2.00	71.78	1.26	39.34
15.70	19.60	16.80	20.00	60.00	5.00	1.50	1.77	71.78	1.07	39.34
15.70	19.60	16.80	20.00	70.00	5.00	1.50	1.54	71.78	0.88	39.34
15.70	19.60	16.80	20.00	80.00	5.00	1.50	1.33	71.78	0.65	39.34

Using the REAME program (Soenksen, et. al. 2003), and assuming similar bank properties as in the vertical slope, it can be seen that under saturated bank conditions, the 10 foot tall bank is stable up to about 60 degrees and then falls below the 1.5 design factor of safety. In other words, as the bank is eroded, it would maintain stability until the bank is undercut to about 60 degrees. The 16 foot bank reaches the same level of stability at an angle of about 40 degrees. In other words, the taller the bank, the greater the driving forces and the more the banks will be subject to failure at smaller slope angles. This also indicates that as the channel degrades, and bank height increases, the streambank will readily fail as the channel degrades.

Infinite slope failures are typically seen along stream banks where there is abundant soil material above weathered shale (.5 to 3 feet). Slope angles can range from near vertical to less than 60 degrees. Here, as in the case of the slumps, the failures are shallow with Length to depth rations of greater than 20 with depths typically less than a meter. The failures parallel the ground surface and if moist can be considered earthflows or mudflows. The depth of infinite slope failures in this area is associated with the depth of surfical soil cracking due to dessication. The process is explained by Kuhn and Zornberg, (2006) and can be related to rainstorm properties of intensity and duration.

7.3 Future Channel Evolution

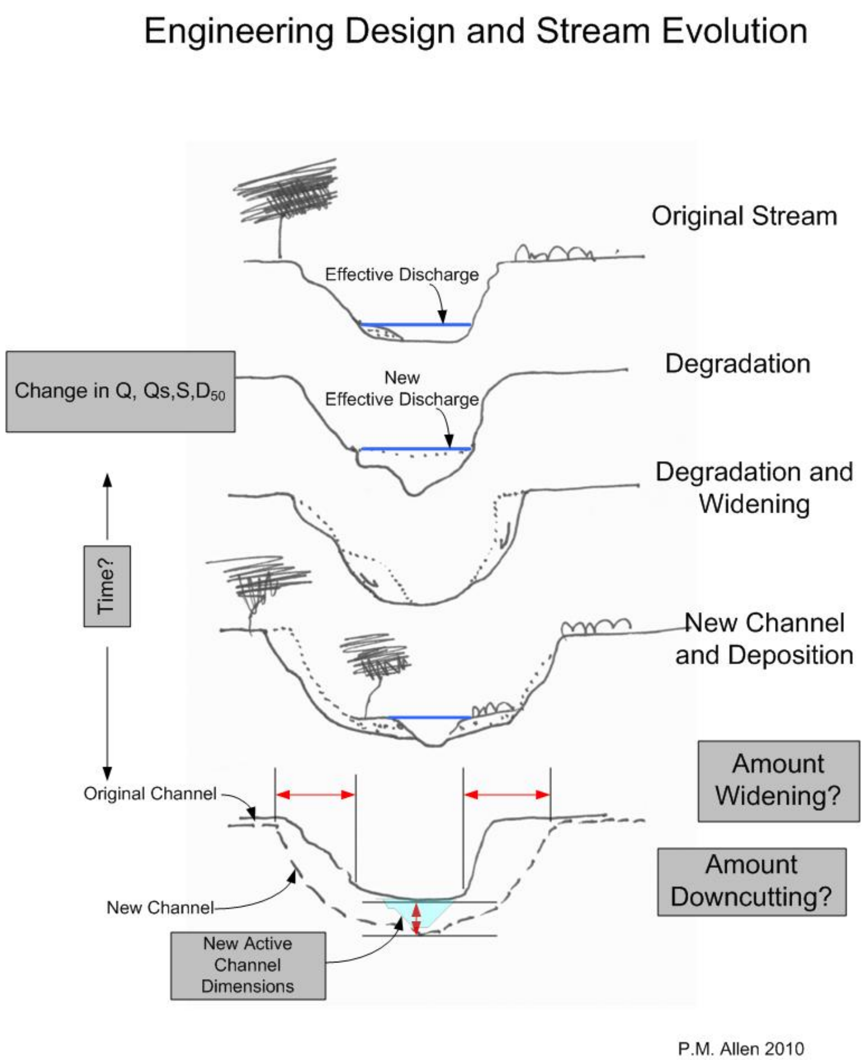
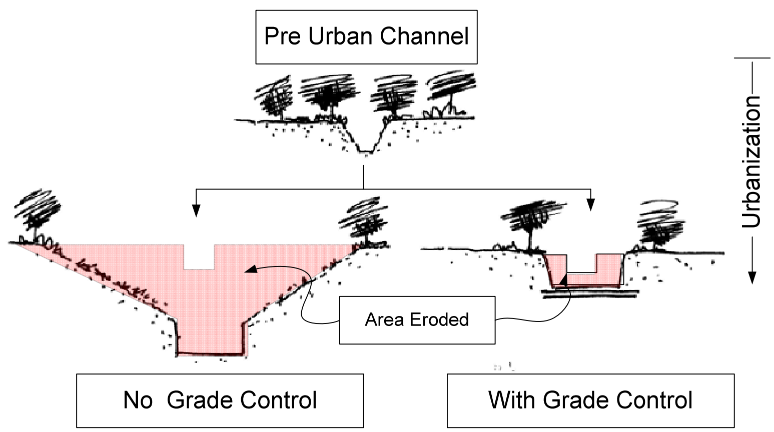


Figure 68. Major Design Questions for Channel Stability Analysis

The following comments and figure are shown to illustrate the potential changes predicted in the channel based on accumulated field evidence and past history of similar streams.

- the channel will continue to downcut and widen over time , perhaps doubling its size following the trends in the channel evolution model over the next 20 years (SWAT-DEG). Widening will not be rapid until the channel has cut down through the tree root zone; when the trees are undercut, the channel will continue to widen and downcut more rapidly. Estimates for channel width and depth are given in Table 7.

- Tree falls will be very active in CEM Stage III and form local low woody debri dams (LWD) which can cause local backwater and or scour problems if not removed.
- Flows less than the 0.5 year flood event will continue to go overbank until the channel degrades and widens to the newer bank full flow (estimated to be around 459-584 cfs); when this new width and depth is reached, the channel will not flow overbank as often, lessening the overbank scour and deposition.
- The channel will continue to downcut to lower the channel slope to reach its projected equilibrium slope (.0009) based on the effects of urbanization and great discharge. This will tend to release large amounts of sediment from the eroded channel. Sediment will pass downstream and deposit in any areas of current ponding or low velocity overbank flow. Downcutting without grade control will be about 4.6 feet/1000 feet of channel (Reach 2 could be 16 feet to thalweg and 60 foot top width).The channel can follow two paths depending on grade control shown below. In both cases the channel will widen; without grade control it will also deepen and ultimately cause a lot larger land loss with potential structural damage.



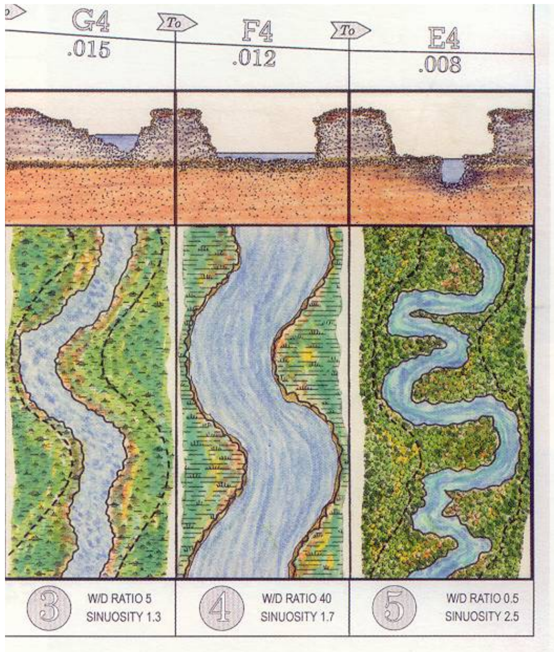


Figure 69 . Illustrates the potential evolution of the current stream according to Rosgen,1996. Basically it shows the current channel downcutting and widening and then aggrading and infilling to form a more sinuous channel in a newly developed lower floodplain.

- The evolutionary sequence (Figure 69) as explained will cause massive tree loss and sedimentation downstream if allowed to progress. The installation of hard points to halt downcutting is advocated.
- The hard points (grade control) spaced as stated will contain the channels downcutting but the channel will still tend to widen. In addition, the sediment caused by widening will be a factor during this period of stream adjustment and some maintenance will be required for localized sediment problems
- The wetland, upstream of Polo will continue to receive sediments as the channel widens and erodes. Plans should be made to assess what the ultimate status of the area will be; pond; wetland, or lowland with cattails and grasses. If left alone, this area will probably be filled with sediment and ultimately grow up in willows and then over time hardwoods.

8.0 *Local Scour*

- In general the major points of this report have dealt with changes in the stream due to changes in regional watershed scale variables of land use, and interpretation of watershed scale impacts. The design parameters indicated do not take into account local scour around culverts, bridge piers, local structures, weirs, trees wads, and scour lengths and depths at meanders. These local scour phenomena can often be of the same or greater magnitude that those associated with more regionally induced degradation or aggradation. For analysis of this type of scour, more detailed engineering is advocated and examples are given in the appendix by the NRCS for scour and grade control (NEH -654 National Engineering Handbook NRCS, Technical Supplement 14G on grade control and 14B on scour calculations. In addition, manuals prepared by the FHWA such as FHWA NHI 01-001 and 003 for evaluating scour at bridges and bridge scour and stream instability countermeasures are excellent.

9.0 Conclusions/Comments

- The channels flow in CH-CL soils and are underlain by Eagle Ford Shale Bedrock in some areas. The shale as well as soil is subject to slope instability owing to high plasticity and low shear strength. Post mortem of failures in the shale have shown strength values approaching residual values or fully softened values.
- The soils are prone to shrink and swell with varying moisture conditions which enhances erodibility of the materials upon drying. Use of allowable velocity approaches in such material are questionable as the dry material cracks and the material is far more erosive. Based on submerged jet testing, rates range from 1-10

mm/hour or from .09 in/hr. per psf tractive force for bare soil. Cover vegetation can reduce these effects dramatically.

- Drying and stress in vertical cut slopes can aid in creation of tension cracks and bank failure, cracks in side slopes can enhance shallow or infinite slope failures on steeper slopes and smaller cantilever failures on small cut-banks. The BSTEM model is applicable for evaluation of local vertical slopes. The toe areas of slopes adjacent to homes should be protected to prevent slumping. Once established slumps will tend to progress upslope toward the structure. Slumps will tend to be in the weathered soil and bottom out on the top of the shale bedrock. The critical slope height for vertical slopes approaches 8 feet.
- The channel bottoms are covered in places with a diverse size range of bed material owing to the location of outcropping limestone ledges and formerly deposited gravel in terraces. More extensive assessment of bed material is advocated prior to any design of channel restoration projects.
- Where the shale is exposed it will be subject to slaking. Slaking will result in easily entrainable particles and erosion. Rates are given in the text and average from 1-3 inches per year.
- The channel banks are predominantly covered with trees and brush except in areas where the channel is entrenched or on steep cut banks; while trees resist lateral erosion, bank vegetation is highly susceptible to degradation as trees can be lost with as little as 2 feet of degradation; once the trees are gone, the bank can erode faster resulting in definable widening and downcutting according to the CEM model and the equilibrium slope.
- Incipient motion assessment using an average bed material sample indicates in the one year event, all D50 material will be in motion, D90 material will be in motion in the 2 year event; armoring is not considered to be a factor in stream evolution.
- Stream Power assessment of future conditions indicates that the channel may exceed simple erosion thresholds set at 80 Watts m-2. This is also seen in the high Froude values(>0.35) and velocities in the reach. Such indicators help point to areas of instability in the channel and are shown in Figure 63.

- Increased runoff and related degradation caused by past land use changes will cause continued headward gully erosion, slumping on steeper shale side slopes, and bank and channel bed erosion with rates approaching 52 feet per year; Figure 61.
- Channels will widen Table 7. from around 10-20 feet to 30 feet.
- Channel degradation, if uncontrolled, could result in downcutting of up to 4.6 feet/1000 feet channel.
- SWAT-DEG runs done indicate the approximate rate of degradation. In this stream, degradation under future conditions can cause degradation over 20 years
- Most channel dimensions and processes are controlled by the frequency and magnitude of discharge, channel bed and bank lithologies, and bank vegetation. Urbanization is shown to increase the 2 year discharge by about 2 times over natural conditions for the study watershed but a little over 1.1 times for future conditions. Channel widths will increase, meander geometry will change, and related pool riffle spacing. It should be noted that the channel is still in transition from the past urbanization and according to the SWAT-DEG runs, the channel will continue to adjust over the next 20 years.
- Previous studies have indicated that a bimodal flow regime may occur as a result of storm sewer systems and surface runoff. This should be considered in future channel design. Often this creates a two stage channel with the smaller inner channel related to high frequency storm sewer discharge and the larger channel to the less frequent bankfull flows.
- Results are based on conditions at the time of the field survey and computed hydrology and hydraulics, changes in the watershed land use and sediment and erosion control practices can alter the rates and magnitude of indicated change in the watershed.
- Grade control is advocated for all three study reaches in order to halt predicted degradation and related bank instability (CEM model). Evaluation indicates (p.43) the approximate number of drop structures needed by reach. In practice, the number of drop structures is related to a number of factors including stream sinuosity, land ownership, access, sewer and water lines, and the state of the stream with regard to the CEM model. Typically, drops are not advocated for CEM Stage III-IV as the

stream is already widening and degrading and the cost is often prohibitive. Drops are indicated for Type II streams. Therefore, taking this into account, logical areas for assessment of drops would be around stations 14918 in Reach 1, around stations 13959, (13167-13071) and (12873-12477) in Reach 2, and around stations (9535 or 9839), station 9195 and station 8539 in Reach 3. (See Biedenharn and Hubbard, 2001; ERDC/CHL CHETN-VII-3 Design Considerations for Siting Grade Control Structures USACE). Location of existing sewer and water lines should be considered in placement of structures taking into account the existing depth of the lines and future degradation potential.

- Local scour around structures is not considered in this study but should be evaluated when planning engineering works.
- Meander migration can average about 1-2 feet per year. The only area which requires immediate planform attention is the meander near station 8982. At this point the previously placed rip rap is being undercut. Engineering placement of protection should consider reach degradation from the downstream hard point at 4.6ft./1000 feet, increased tractive force on the outside of the meander and potential scour depths near walls.

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Appendix Stable Slope

Example stable slope formulas.

1. **Meyer Peter Muller Formula**:

S = .19*((n/(d90**1/6))**1.5)dm/R

Where:

Dm = effective size of bed material expressed as a weighted mean diameter or d50 in mm
D90= particle size of bed material at 90 percent finer in mm
R = hydraulic radius, for width depth ratio greater than 40 use water depth in feet
N = manning n factor

2. **Schoklitsch Formula**

S = ((.00021*dm*B/Q)**0.75

Where:

B= Channel width
Q = dominant discharge

3. **Shields/DuBoys**

S = tau-cr /(gma*R)

Where:

Gma = specific weight of water in lbs./cuft.
Tau-cr = critical bed shear stress in lbs/sq. ft. using dm

4. **Regional Regression for North Texas**

S = 0.01576*Q**-.3534

Where:

Q = dominant discharge in cfs.

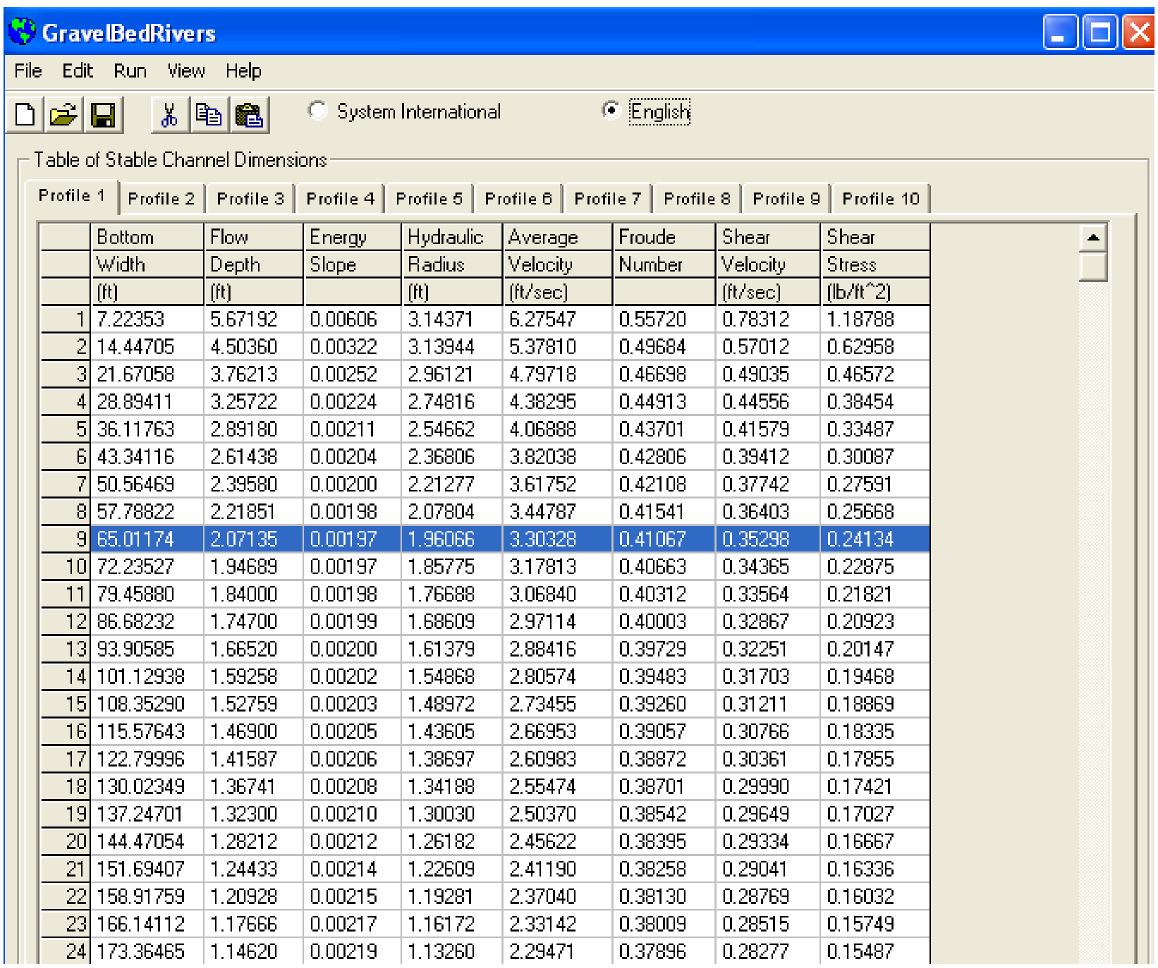
Represents lower prediction interval for USGS gage sites in Region 7 (North Texas) of channel slope versus discharge.

5. **Beldsoe et. al.**

S = 0.000246*Cs**.559*Q**-.336
Where:

Q = dominant discharge in cfs
Cs = ppm sediment

Appendix: Stable Channel Dimension Calculations: Extremal Hypothesis



	Bottom Width (ft)	Flow Depth (ft)	Energy Slope	Hydraulic Radius (ft)	Average Velocity (ft/sec)	Froude Number	Shear Velocity (ft/sec)	Shear Stress (lb/ft^2)
1	7.22353	5.67192	0.00606	3.14371	6.27547	0.55720	0.78312	1.18788
2	14.44705	4.50360	0.00322	3.13944	5.37810	0.49684	0.57012	0.62958
3	21.67058	3.76213	0.00252	2.96121	4.79718	0.46698	0.49035	0.46572
4	28.89411	3.25722	0.00224	2.74816	4.38295	0.44913	0.44556	0.38454
5	36.11763	2.89180	0.00211	2.54662	4.06888	0.43701	0.41579	0.33487
6	43.34116	2.61438	0.00204	2.36806	3.82038	0.42806	0.39412	0.30087
7	50.56469	2.39580	0.00200	2.21277	3.61752	0.42108	0.37742	0.27591
8	57.78822	2.21851	0.00198	2.07804	3.44787	0.41541	0.36403	0.25668
9	65.01174	2.07135	0.00197	1.96066	3.30328	0.41067	0.35298	0.24134
10	72.23527	1.94689	0.00197	1.85775	3.17813	0.40663	0.34365	0.22875
11	79.45880	1.84000	0.00198	1.76688	3.06840	0.40312	0.33564	0.21821
12	86.68232	1.74700	0.00199	1.68609	2.97114	0.40003	0.32867	0.20923
13	93.90585	1.66520	0.00200	1.61379	2.88416	0.39729	0.32251	0.20147
14	101.12938	1.59258	0.00202	1.54868	2.80574	0.39483	0.31703	0.19468
15	108.35290	1.52759	0.00203	1.48972	2.73455	0.39260	0.31211	0.18869
16	115.57643	1.46900	0.00205	1.43605	2.66953	0.39057	0.30766	0.18335
17	122.79996	1.41587	0.00206	1.38697	2.60983	0.38872	0.30361	0.17855
18	130.02349	1.36741	0.00208	1.34188	2.55474	0.38701	0.29990	0.17421
19	137.24701	1.32300	0.00210	1.30030	2.50370	0.38542	0.29649	0.17027
20	144.47054	1.28212	0.00212	1.26182	2.45622	0.38395	0.29334	0.16667
21	151.69407	1.24433	0.00214	1.22609	2.41190	0.38258	0.29041	0.16336
22	158.91759	1.20928	0.00215	1.19281	2.37040	0.38130	0.28769	0.16032
23	166.14112	1.17666	0.00217	1.16172	2.33142	0.38009	0.28515	0.15749
24	173.36465	1.14620	0.00219	1.13260	2.29471	0.37896	0.28277	0.15487

Equilibrium Dimensions from Meyer Peter Muller Equation for Above Carrier based on Bledsoe GBR model. *No Vegetation effects included.*

Equilibrium Channel Dimensions and Slope from SAM Program Copeland Method.

```
       USING  BROWNLIES RESISTANCE & TRANSPORT EQUATIONS

MEDIAN BED SIZE ON BED, MM            =    3.54664
GRADATION COEFFICIENT                 =      6.102
VALLEY SLOPE                          = 0.00800000

                                        LEFT BANK  RIGHT BANK
SIDE SLOPE                            =      1.000       1.000
Ks, FT                                =  2.560       2.560
n-VALUE                               =    0.04000     0.04000
```

TABLE 4-1. STABLE CHANNELS FOR Q= 584.0 C,mgl= 500.0 D50= 3.547

K:	BOTTOM WIDTH FT	DEPTH FT	ENERGY SLOPE FT/FT	CMPOSIT n-Value	HYD RADIUS FT	VEL FPS	FROUDE NUMBER	SHEAR STRESS #/SF	BED * B-REGIME
1	3.	8.2	0.005754	0.0408	3.50	6.37	0.39	2.94	TL
2	6.	7.6	0.004244	0.0412	3.75	5.67	0.36	2.01	LO
3	9.	6.9	0.003691	0.0415	3.84	5.33	0.36	1.59	LO
4	12.	6.3	0.003432	0.0418	3.84	5.12	0.36	1.34	LO
5	15.	5.7	0.003307	0.0419	3.79	4.96	0.37	1.17	LO
6	18.	5.2	0.003255	0.0420	3.70	4.83	0.37	1.06	LO
7	21.	4.8	0.003246	0.0420	3.58	4.71	0.38	0.97	LO
8	24.	4.4	0.003264	0.0420	3.46	4.62	0.39	0.90	LO
9	27.	4.1	0.003300	0.0420	3.33	4.53	0.39	0.85	LO
10	30.	3.9	0.003348	0.0420	3.20	4.45	0.40	0.81	LO
11	33.	3.6	0.003404	0.0419	3.08	4.38	0.40	0.77	LO
12	36.	3.4	0.003466	0.0419	2.96	4.31	0.41	0.74	LO
13	39.	3.3	0.003531	0.0418	2.85	4.25	0.42	0.72	LO
14	42.	3.1	0.003600	0.0417	2.75	4.19	0.42	0.69	LO
15	45.	2.9	0.003669	0.0416	2.65	4.14	0.43	0.67	LO
16	48.	2.8	0.003740	0.0416	2.55	4.09	0.43	0.66	LO
17	51.	2.7	0.003812	0.0415	2.47	4.04	0.43	0.64	LO
18	54.	2.6	0.003884	0.0414	2.39	3.99	0.44	0.63	LO
19	57.	2.5	0.003955	0.0413	2.31	3.95	0.44	0.61	LO
20	60.	2.4	0.004027	0.0412	2.24	3.91	0.45	0.60	LO
	RESULTS AT MINIMUM STREAM POWER								
21	20.	4.9	0.003245	0.0420	3.61	4.74	0.38	0.99	LO

* REGIMES: LO=LOWER, TL=TRANSITIONAL-LOWER, TU=TRANSITIONAL-UPPER, UP=UPPER.

Stop Notes:

GPS Stations	Photo Numbers	Comments
32 45.240 97 02.405	698-701	Gabion structure
32 45.240 97 02.390	702-705	Bed material/tan alluvial clay
32 45.235 97 02.390	706-707	
32 45.236 97 02.357	708-709	Bed material
32 45.242 97 02.338	710-711	
32 45.259 97 02.324	712	
32 45.265 97 02.325	713-714	Gabion
32 45.278 97 02.328	715-716	
32 45.279 97 02.334	717-722	Undercut cement wall
32 45.285 97 02.334	721-724	Wall/clay bottom/bed material
32 45.298 97 02.325	725-726	
32 45.303 97 02.327	727-729	

32 45.322 97 02.322	730-735	Bed material; shale outcrop with bentonite beds
32 45.320 97 02.305	736-739	Pipeline and gabions
32 45.298 97 02.226	740-741	Bridge
32 45.296 97 02.216	742-746	Rip rap/cut bank
32 45.299 97 02.204	747-750	Shale upper weathered (tan) lower unweathered (dark gray)
32 45.310 97 02.194	751-753	Shale bed material and limestone flags
32 45.314 97 02.194	754	Moderate scour
32 45.321 97 02.191	755-756	
32 45.38 97 02.185	757-758	Exposed sewer line
32 45.349 97 02.169	759-760	
32 45.365 97 02.155	761-762	
32 45.373 97 02.138	763-764	
32 45.383 97 02.119	765-767	Rip rap drop
32 45.388 97 02.108	768-770	Bed material
32 45.400 97 02.086	771	

32 45.408 97 02.072	772-773	Bridge
32 45.437 97 02.069	774-778	Bridge; downstream degradation
32 45.454 97 02.070	779	
32 45.471 97 02.067	780	Sewer line undercut
32 45.471 97 02.067	781-786	Meander/sewer line overfall; home
32 45.473 97 02.066	787	Bed material
32 45.496 97 02.042	788-789	
32 45.509 97 02.035	790	Rip-rap grade control
32 45.523 97 02.021	791-794	
32 45.521 97 02.011	795	
32 45.527 97 02.002	796-798	Sewer line
32 45.533 97 01.988	799-800	Cement drop structure
32 45.533 97 01.976	803-807	Bridge I-30; gully erosion
32 45.608 97 02.952	808-810	Downstream I-30; channelized
32 45.614 97 01.978	811-812	Gully erosion at end of outlet
32 45.628	813	Pipeline

97 01.937		
32 45.628 97 01.938	814-815	
32 45.669 97 01.911	818-819	
32 45.694 97 01.908	820-821	
32 45.726 97 01.917	822-824	Drop Structure I
32 45.744 97 01.898	825-826	
32 45.754 97 01.892	827-829	Bed material
32 45.744 97 01.878	830-831	Backwater
32 45.810 97 01.885	832-835	Drop Structure II
32 45.814 97 01.876	836-839	Minor erosion drop
32 45.847 97 01.869	840-842	Concretion Zone
32 45.851 97 01.870	843	Concretion Zone Knickpoint
32 45.872 97 01.873	844-846	
32 45.885 97 01.875	847	
32 45.890 97 01.871	848	Concretions
32 45.901 97 01.864	850-851	Bridge

32 45.908 97 01.857	852-856	Downstream Bridge; right angle turn gabion wall
32 45.943 97 01.837	857-859	Gabion wall; failed upper baskets
32 45.943 97 01.832	860-861	
32 45.946 97 01.829	862-864	Gabion drop
32 45.947 97 01.824	865-868	Fence; sewer line
32 45.956 97 01.817	869	Mod-severe erosion and fence
32 45.966 97 01.813	870-871	
32 45.980 97 01.812	872-878	Rip-rap drop; undercut storm sewer outfall
32 45.991 97 01.810	879-883	Concretion Zone; RR Tie Wall and Fence steep slope
32 46.003 97 01.801	884-888	Slight-moderate bank erosion
32 45.003 97 01.794	889	
32 46.009 97 01.782	890-892	Begin East side stream severe erosion; potential problems with 161 Wall
32 46.030 97 01.774	895-896	
32 46.040 97 01.772	897-899	
32 46.048 97 01.767	900-902	Gabion W side

32 46.063 97 01.764	903-904	
32 46.077 97 01.756	905-907	Gabions West undercut on East
32 46.085 97 01.754	908-909	
32 46.097 97 01.747	910-912	
32 46.107 97 01.740	913-916	
32 46.118 97 01.739	917	Gabions E side
32 46.130 97 01.740	918-919	
32 46.143 97 01.732	920-923	Severe Bend erosion and home; End of 161 erosion.
32 46.151 97 01.720	924-934	Begin Gabions 161
	935-950	
32 46.229 97 01.609	951-970	Park

Appendix E
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