Drainage Report

City of West University Place

City-Wide Drainage Study

Harris County, Texas
April 11, 2019

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

Contents

Glossary of Terms 1
Executive Summary 3
Background Information 6
Drainage Infrastructure: Past and Present 7
Brays Bayou and its Effect on West University Place 13
Introduction 13
Project Brays 13
Other Factors to Consider 14
Stream Gages and Historical Data 14
Major West U Drainage Systems 18
Academy Street Drainage Area 19
Prior Study 19
Results from City-Wide Drainage Study 19
Poor Farm Ditch Drainage Area 21
HCFCD Studies: 2004, 2009, 2017 21
Results from City-Wide Drainage Study 23
College Avenue / Shared System Drainage Area 24
Buffalo Speedway Drainage Area 25
Kirby Drive Drainage Area 26
Planning Area Projects 27
Identification of Planning Areas 27
Planning Area 1 29
Planning Area 2 30
Planning Area 3 31
Planning Area 4 32
Planning Area 5 33
Planning Area 6 34
Planning Area 7 35
Planning Area 8 36
Planning Area 9 37
Planning Area 10 38
Planning Area 11 39
Planning Area 12 40
Opinions of Probable Construction Cost for Planning Areas 41
Trunk Line Projects 42
Academy Street 42
College Avenue / Shared System 45
Buffalo Speedway 46
Detention Requirements 49
NOAA Atlas 14 51
Conclusion 52

List of Figures

Figure 1: General Vicinity Map 6
Figure 2: Topographic Map 7
Figure 3: West Side of Brays Bayou at Stella Link Road (South of the City)..... 8
Figure 4: East Side of Brays Bayou at Buffalo Speedway (South of the City)..... 8
Figure 5: Original Street and Drainage Layout Developed in 1943 9
Figure 6: West University Place in 1944 11
Figure 7: Roadway Rehabilitation Status Map Developed in 2017 12
Figure 8: FEMA Effective Brays Bayou Floodplain (Approved June 18, 2007) 13
Figure 9: Harris County Flood Warning System Web Page with Gage Locations near West U .14
Figure 10: West University Place Major Drainage Areas & Major Trunk Lines / Channels.....18
Figure 11: Academy Street Drainage Area 19
Figure 12: Kilmarnock Ditch Outfall into Brays Bayou 20
Figure 13: Kilmarnock Ditch at N. Braeswood Blvd. (Looking North) 20
Figure 14: Poor Farm Ditch Drainage Area 21
Figure 15: Damage along Poor Farm Ditch – Looking North (Freese & Nichols 2017) 22
Figure 16: Typical PER Cross-Section for Recommended Poor Farm Ditch Improvement.....23
Figure 17: College Avenue / Shared System Drainage Area 24
Figure 18: Buffalo Speedway Drainage Area 25
Figure 19: Kirby Drive Drainage Area.....26
Figure 20: Drainage Planning Area Boundaries 28
Figure 21: Planning Area #1.....29
Figure 22: Planning Area #2.....30
Figure 23: Planning Area #3.....31
Figure 24: Planning Area #4.....32
Figure 25: Planning Area #5.....33
Figure 26: Planning Area #6.....34
Figure 27: Planning Area #7.....35
Figure 28: Planning Area #8.....36
Figure 29: Planning Area #9.....37
Figure 30: Planning Area #10.....38
Figure 31: Planning Area #11.....39
Figure 32: Planning Area #12.....40
Figure 33: Planning Area Locations & Extents 41
Figure 34: Existing Academy Street Storm Sewer 42
Figure 35: Alternative #1 - Pipeline Route 43
Figure 36: Alternative #2 - Community Drive Route.....45
Figure 37: Proposed Auden St. Trunk Line Project 45
Figure 38: Buffalo Speedway Trunk Line Project.....47
Figure 39: Proposed Placement of New Buffalo Speedway Storm Sewers 48
Figure 40: Potential Long-Term Detention Requirement for Each Major Watershed 49

List of Tables

Table 1: Brays Bayou Gage Data 15
Table 2: Probable Costs of for Planning Areas 1 - 12 41

List of Attachments

Attachment A: Roadway Rehabilitation Status
Attachment B: Fact Sheet – Poor Farm Ditch/Kilmarnock Ditch, HCFCD, August 2014
Attachment C: Drainage Planning Area Map
Attachment D: Opinions of Probable Cost for Planning Areas
Attachment E: Opinions of Probable Cost for Trunk Line Projects

List of Appendices

Appendix A: "Buffalo Speedway Improvements – Drainage Preliminary Engineering Report (Draft - October 19, 2018)

Appendix B: "Preliminary Storm Sewer Drainage Analysis for Six Ponding Locations in the Academy Street Drainage System in West University Place" (April 21, 2016)

Appendix C: "Poor Farm Ditch Conveyance Preliminary Engineering Report" (Freese & Nichols, Inc. - September 2017)

Appendix D: "Drainage Evaluation for Dead-End Streets" (July 6, 2017)

Appendix E: Preliminary Storm Sewer Drainage Analysis for Four Ponding Locations along Wakeforest Avenue in West University Place" (April 21, 2016)

This page is intentionally left blank

Glossary of Terms

Following are definitions of a number of technical terms used in this report. These are provided in order to allow the reader to gain a better understanding of the methods, data, and assumptions used in the city-wide drainage study, as well as the results obtained.

- **Acre-Foot** – This measure of storage is defined as one acre of land inundated at a depth of one foot. Because one acre of land covers 43,560 square feet, an acre-foot therefore totals 43,560 square feet x 1 foot = 43,560 cubic feet. In common usage by engineers, an acre-foot of storage represents any product of area and depth that yields a value of 43,560 cubic feet (e.g., 4,356 feet x 10 feet = 43,560 cubic feet = 1 acre-foot).
- **Capacity** – The capacity of a drainage system refers to the ability of that drainage system to carry the peak (maximum) runoff rate from a designated design storm event. For example, a storm sewer with 2-year storm capacity has the ability to collect and convey the peak runoff rate generated by that rainfall event within the pipe system without overflow or flooding along streets drained by the system.
- **Capital Improvements** – This term refers to significant public infrastructure projects for which a city or county has establish a priority and set aside funding. Capital improvement planning typically involves proposed improvements over a 5-year to 10-year period of time, and possibly longer.
- **Detention** – The term “detention” refers to the temporary storage of storm water for the purpose of mitigating a potential downstream impact. The impact typically results from an increase in runoff due to the placement of impervious materials or to increases in peak runoff rates due to increased efficiencies in drainage systems, as happens when natural overland drainage is replaced with storm sewer systems. Detention may take the form of “on-site” storage, which is located on or immediately adjacent to a project site, or “off-site” storage, which is provided at a location some distance from the project site.
- **Earthen Channel** – An “earthen” channel is one that is not lined with concrete or other material. The slopes and bottom of an earthen channel are typically covered with grass.
- **Opinion of Probable Cost** – This term refers to an estimate of design and construction costs for a given project. This estimate is based on the best available information, including construction quantities based on engineering studies, reasonable and up-to-date unit costs based on recent actual bids, and engineering design costs based on generally accepted percentages of construction cost. Opinions of probable costs are subject to change as unit prices often fluctuate over time, and data and assumptions may change as more detailed design information is developed. A contingency is typically included in an opinion of probable cost to cover potential costs associated with ancillary items not identified in detail for planning studies. The contingency is reduced as more detailed designs and estimates are prepared. In this report, opinions of probable cost do not include costs (land acquisition, design, or construction) for detention.

- **Planning Area** – A "planning area" is defined for this report as a geographic region for which requirements for drainage infrastructure upgrades have been defined. The number of planning areas is based on a desire to maintain an average cost of around $5,000,000 per planning area. Note that planning area numbering sequences do not identify priority of improvement or future implementation.
- **Recurrence Interval** – This is the average, long-term interval between storm events that produce a given rainfall depth within a given duration. For example, a 2-year event might be expected to occur, on average, about once every two years. The storm probability (change or occurring within any given year) is estimated using the following equation.

  Probability = [1 / Recurrence Interval] x 100%

  For example, the probability of occurrence of a 100-year event is [1/100] x 100% = 1%.
- **Trunk Line** – A main storm sewer line that collects runoff from smaller, tributary storm sewer lines and carries the combined flow to an outfall at the drainage channel.
- **Two-Year Storm** – A rainfall event that has approximately a 50% chance of occurring in any given year. The event is typically categorized as a given amount of rainfall in a specified period of time. This data is based on statistical studies of historical rainfall events in the Houston metropolitan area.
- **One Hundred-Year Storm** – A rainfall event that has approximately a 1% chance of occurring in any given year. The event is typically categorized as a given amount of rainfall in a specified period of time. This data is based on statistical studies of historical rainfall events in the Houston metropolitan area.
- **NOAA Atlas 14** – This term refers to National Oceanic and Atmospheric Administration (NOAA) publication titled "Atlas 14, Volume 11 Precipitation-Frequency Atlas of the United States, Texas" and issued in October 2018 to provide updated rainfall data for storm events ranging from the 2-year through 1000-year recurrence interval and from 5-minute to 60-day duration. Rainfall depths published in Atlas 14 are generally higher than those used previously in the Houston area. The following table provides a comparison of pre-Atlas 14 and Atlas 14 rainfall values for 2-year and 100-year events with durations ranging from 5 minutes to 1 day.

Summary of Rainfall Totals Pre-NOAA Atlas 14 and NOAA Atlas 14									
Duration	***5-min***	***15-min***	***30-min***	***1-hour***	***2-hour***	***3-hour***	***6-hour***	***12-hour***	***1-day***
Pre-NOAA Atlas 14 Data									
2-Year	0.7	1.1	1.5	2.0	2.3	2.6	3.1	3.7	4.4
100-Year	1.2	2.1	3.0	4.3	5.7	6.7	8.9	10.8	13.2
NOAA Atlas 14 Data									
2-Year	0.58	1.17	1.67	2.22	2.79	3.13	3.75	4.40	5.11
100-Year	1.26	2.49	3.48	4.78	6.89	8.48	11.30	14.00	14.90

Executive Summary

HDR Engineering, Inc. (HDR) has completed drainage planning studies and assessments for the City of West University Place (City) per the approved proposal dated July 12, 2017. These efforts were performed in phases, and the scope of work for different portions of the city varied according to the type of work requested by the City and the level of detail required from one area to the other. The combined effort reflects a general city-wide drainage capacity evaluation, with more detailed assessments and studies of specific areas within the City. The methodology, results, and recommendations related to each portion of the work are discussed in this report. Previous drainage capacity evaluations that were completed for the City are also discussed. The overall work effort is divided into five (5) phases as described below.

- **Phase 1: City-Wide Drainage Evaluation.** The first phase of the effort involved a general, city-wide evaluation of existing storm sewer systems within the City of West University Place. This evaluation was aimed at identifying those portions of the City where drainage improvements may be needed to convey the City's basic requirement of a 2-year storm event as defined by the City of Houston. This standard storm event is widely used and accepted by many cities throughout the Greater Houston Area.

  The Phase 1 effort included capacity evaluations, identification of storm sewers with insufficient capacity to satisfy basic requirements, and the development of recommendations for storm sewer sizing in areas where capacity deficiencies were identified. Existing storm sewer alignments were also evaluated to determine whether changes would lead to cost efficiencies. The city-wide drainage evaluation is further discussed in later sections of this report.

- **Phase 2: Buffalo Speedway Drainage Analysis.** This phase of the effort involved a detailed analysis of existing Buffalo Speedway drainage capacity and the development of recommendations for increasing capacity to limit roadway flooding during periods of heavy rainfall. This effort is connected with proposed Buffalo Speedway paving improvements using funds provided by the Houston-Galveston Area Council (HGAC) via the Transportation Improvement Program (TIP). The Buffalo Speedway drainage analysis, results, and conclusions are presented in a draft October 19, 2018 report titled "*Buffalo Speedway Improvements – Drainage Preliminary Engineering Report*" (Appendix A).

- **Phase 3: Identification of Potential Near-Term Drainage CIP Projects.** This phase of the work effort involved the identification of potential Capital Improvement Projects (CIP) in Planning Areas 1 through 3, which are located in the eastern and southwestern portions of the City. Later sections of the report describe additional planning areas established around the City. Planning Areas 1 through 3 were defined via review of the drainage assessments completed in Phase 1 and the City's Roadway Rehabilitation Status Map dated 2017 (Attachment A) . Planning area boundaries for Areas 1 through 3 were developed by identifying areas where both drainage and roadway upgrades are needed. Preliminary storm sewer sizing calculations and a preliminary opinion of costs for each planning area were prepared in connection with the Phase 3 work effort.

- **Phase 4: Drainage Improvements for Cul-de-Sac Streets.** This phase of the work effort involved an evaluation of drainage along nine (9) City streets which terminate at cul-de-sacs and drain to an existing "shared" storm sewer system located along the shared corporate boundary between West University Place and Southside Place. These streets were originally evaluated in 2017 and then re-evaluated as part of Phase 1 as described above. Because the existing shared system receives storm runoff from both cities, and it is located in a limited easement with significant encroachments and obstacles to access that may impede construction, a plan was developed for utilizing a new storm sewer alignment along Auden Street in Southside Place. Our analysis indicated that drainage improvements constructed along Auden would significantly improve drainage along the nine referenced streets within West University Place.
- **Phase 5: City-Wide Drainage Improvements.** This phase of the work effort involves the development of a city-wide drainage strategy, incorporating previous work completed in Phases 1 through 4 plus the development of recommendations for additional Planning Areas located around the City. Subsequent sections of this report describe the plan and summarize the probable costs of all improvements identified in connection with the overall study effort.

The results of these investigations indicate that about one-half of the City's existing storm sewer pipes satisfy the 2-year capacity requirement. Trunk lines along Academy Street and Buffalo Speedway, in addition to the shared system along the boundary between West University Place and Southside Place, are undersized and in need of improvement. In order to facilitate the planning and funding of drainage projects within the City, twelve (12) Planning Areas have been established around the city, and a number of trunk line improvement projects have been identified.

Opinions of probable costs associated with the general Planning Area upgrades to all storm sewer collection systems and drainage trunk line upgrades total approximately $85,200,000 without accounting for detention. Detention estimates developed in connection with this study are summarized in the table at right by major drainage area. Detention evaluations completed in 2016-17 indicate that properties of the size necessary to provide regional detention are not available within the City or within the immediate vicinity. Coordination with the City of Houston and Harris County Flood Control District may allow the City of West University Place to negotiate terms regarding a regional detention arrangement that would prove beneficial and cost effective solutions. The information on the following page represents individual trunk line and priority area projects.

Drainage Area	West U Area (acres)	Required Detention (acre-feet)
Academy	272	32.6
College/Shared	157	18.8
Poor Farm	339	40.7
Buffalo Spdwy.	360	43.2
Kirby Drive	190	22.8
Totals	**1,318**	**158.1**

The National Oceanic and Atmospheric Administration (NOAA) published "Atlas 14, Volume 11 Precipitation-Frequency Atlas of the United States, Texas" in October 2018, after the studies referenced in this report had been completed. The pre-Atlas 14 data were used for the studies described in this report. In order to account for the potential adoption of Atlas 14 and use of increased rainfall values in the future, an "Atlas 14" adjustment of 5% has been developed opinions of probable cost generated for Planning Areas 1 through 12. The Atlas 14

adjustment is not applied to Trunk Line projects, as the methods used for those projects to establish drainage requirements and costs were more stringent and somewhat more conservative than those applied to the local planning area systems.

Trunk Line Project Costs	
Academy Street (Base Option) ……...	$ 14,700,000
Shared System / Auden ……...	$ 3,100,000
Buffalo Speedway …….….	$ 15,200,000
**Sub-Total for Trunk Line Projects ..……..……	$ 33,000,000**
Planning Area Project Costs	
Planning Area #1 ……..……..	$ 6,900,000
Planning Area #2 ……..……..	$ 8,400,000
Planning Area #3 ……..……..	$ 9,400,000
Planning Area #4 ……..……..	$ 3,300,000
Planning Area #5 ……..……..	$ 4,500,000
Planning Area #6 ……..……..	$ 2,600,000
Planning Area #7 ……..……..	$ 2,700,000
Planning Area #8 ……..……..	$ 2,000,000
Planning Area #9 ……..……..	$ 2,800,000
Planning Area #10 ……..……..	$ 2,800,000
Planning Area #11 ……..……..	$ 3,100,000
Planning Area #12 ……..……..	$ 3,700,000
**Sub-Total for Planning Areas ..…….	$ 52,200,000**
Contingency for Update to NOAA Atlas 14 Rainfall	**$ 2,600,000**
Total for Trunk Lines & Planning Areas ……	**$ 87,800,000**
Future Detention Cost …….. $ TBD	
Total Project Cost ……..... $ TBD	

Opportunities for grant funding and other funding assistance are being pursued by the City as appropriate to satisfy the financial requirements associated with future drainage improvements and related roadway rehabilitation work. Additionally, sharing of funding with the City of Southside Place is being investigated in connection with the Shared System/ Auden project.

Background Information

The City of West University Place is located in southwestern Harris County at 29°42′57″N 95°25′59″W (29.715929, −95.432992). **Figure 1** illustrates the City limits and its boundaries. The City's drainage infrastructure was originally developed in the 1940s and consists of reinforced concrete pipe storm sewers with curb-and-gutter streets that convey storm water along the surface during heavy rainfall events.

Figure 1: General Vicinity Map

Drainage typically follows topography, and in the City of West University Place, ground elevations are highest in the northwestern portion of the City and lowest in the southeastern portion. **Figure**

2 illustrates the general topography of the City, with red areas indicating relatively high elevations and blue areas indicating areas of relatively low elevations.

Significant areas within the City of Houston drain through West University Place in existing drainage systems running from north to south, including Academy Street, Buffalo Speedway, and Kirby Drive storm sewers, as well as Poor Farm Ditch. The City of Bellaire, on the other hand, is separated from West University Place by a railroad embankment, and only a very limited amount of storm water crosses the shared corporate boundary between those cities.

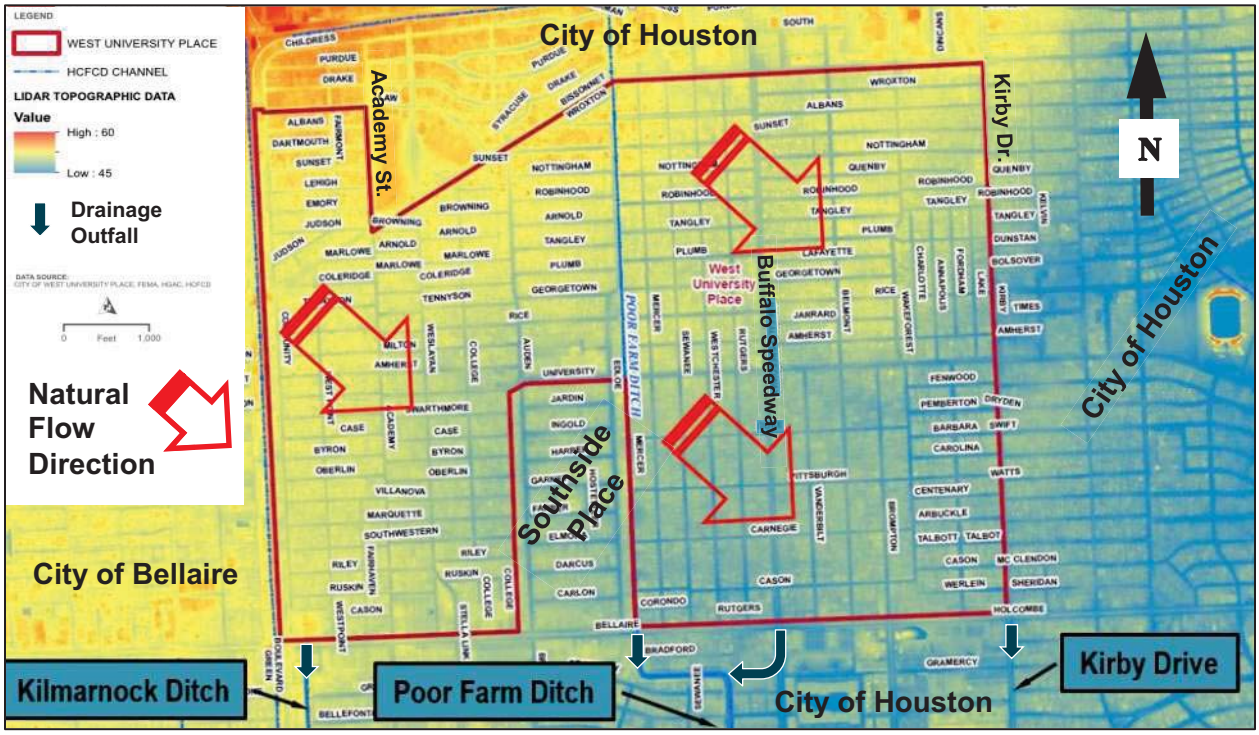


Figure 2: Topographic Map

Drainage Infrastructure: Past and Present

The City of West University Place is located within the Brays Bayou watershed. An array of waterways and drainage systems collect the City's storm water runoff and carry it southward to Brays Bayou. The channel of Brays Bayou passes a short distance to the south of the City, flowing generally from west to east (See **Figure 1**). Storm runoff from the City is drained southward to Brays Bayou via a number of waterways and drainage systems, including Kilmarnock Ditch, Poor Farm Ditch, and the Kirby Drive storm sewer system (see **Figure 2** for locations of City outfalls).

Figure 3 and **Figure 4** illustrate sections of the Brays Bayou channel. As indicated in these photographs, the channel is very large and well-defined, with concrete lining in the lower section to increase conveyance capacity and protect the channel from erosion.

Figure 3: West Side of Brays Bayou at Stella Link Road (South of the City)

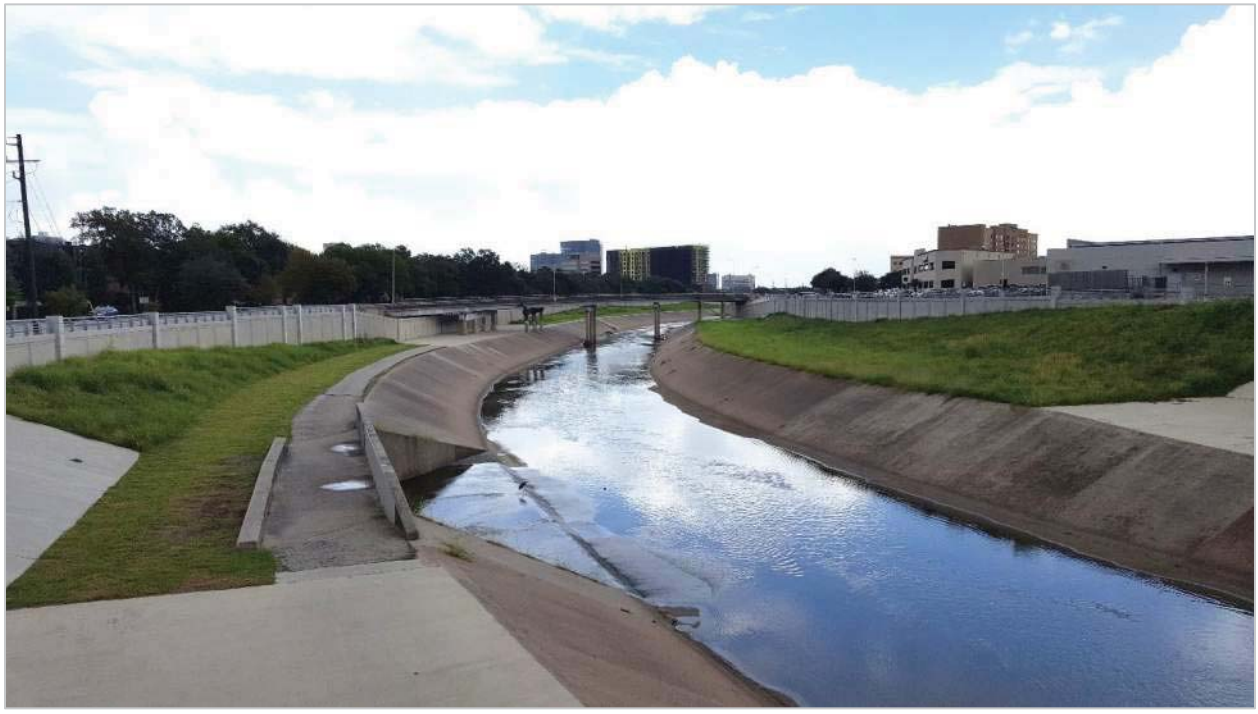


Figure 4: East Side of Brays Bayou at Buffalo Speedway (South of the City)

The original street and drainage layout developed for West University Place in 1943 is illustrated in **Figure 5**. That original drainage system included storm sewer systems that drained to Kilmarnock Ditch, Poor Farm Ditch, and Kirby Drive and then on to Brays Bayou in much the same way as they do today. The general alignments and locations of the major drainage systems outlined in **Figure 5** have not significantly changed in most areas of the city, with the exception of the Kirby Drive system, which drained to the east in 1943 but now continues to the south along Kirby Drive to Brays Bayou.

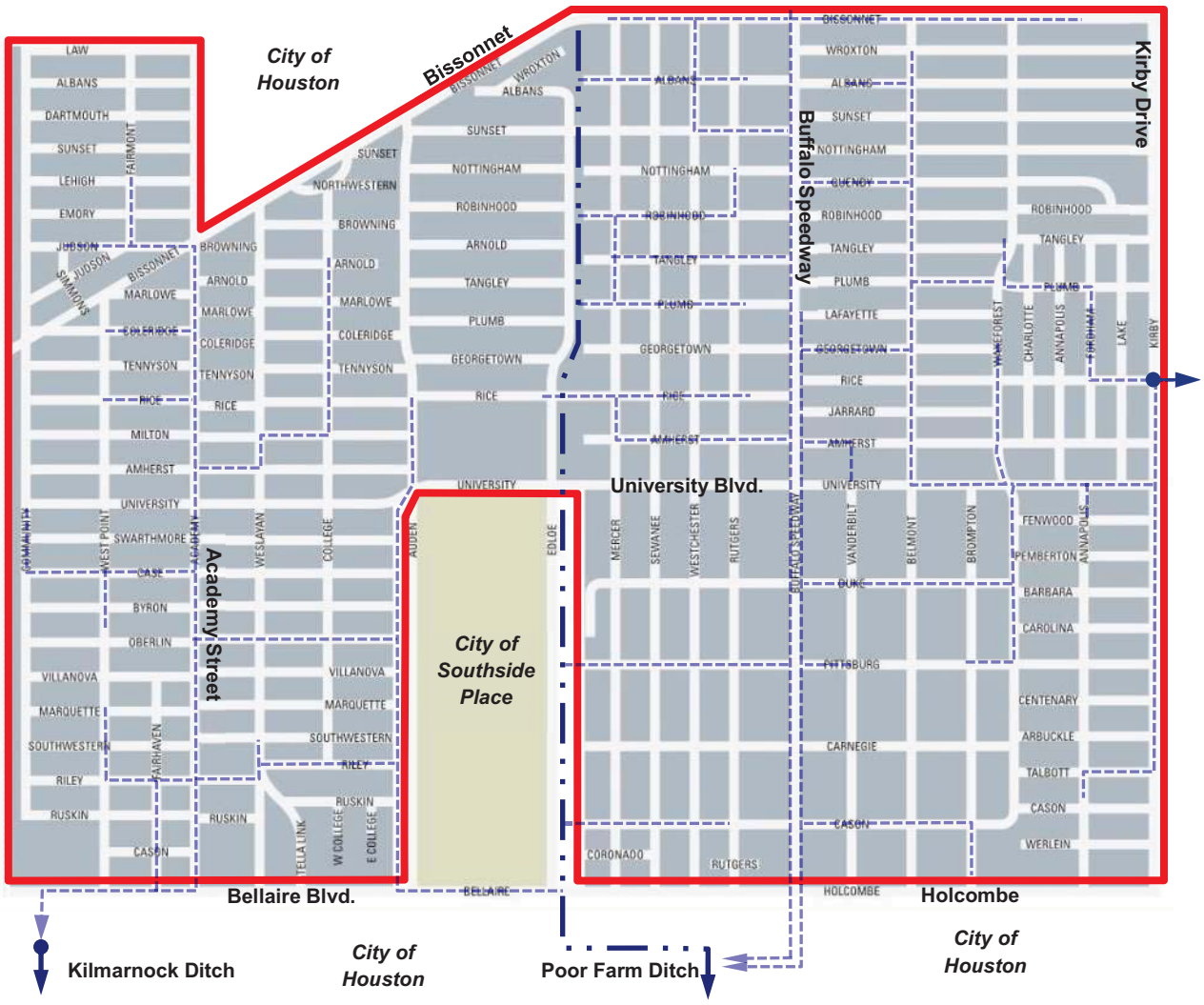
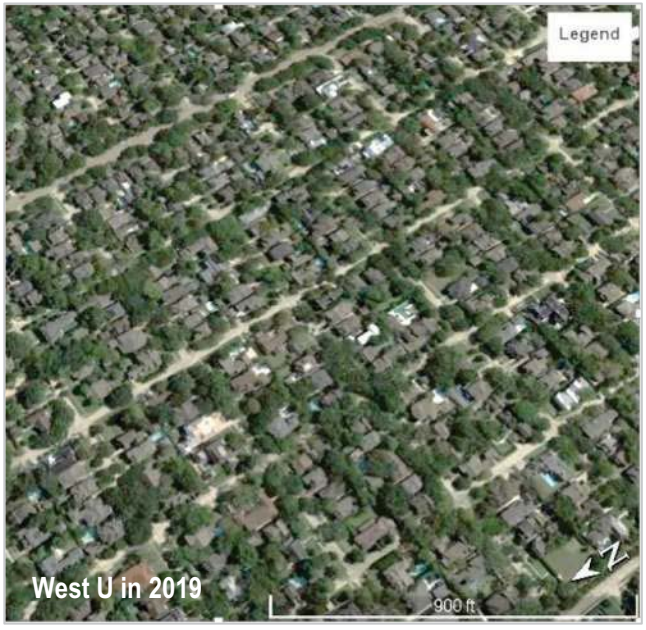


Figure 5: Original Street and Drainage Layout Developed in 1943

The photographs below illustrate a portion of West University Place as it appeared in 1946, along with a view of the same area in 2019. These photographs are provided to demonstrate that drainage conditions have changed significantly since the City's original storm sewer drainage system was designed in 1943. As may be noted from an examination of the photos, the amount of impervious cover has increased significantly as homes have become larger and more closely spaced.

Figure 6 is a December 1944 map that shows the area originally developed as West University Place. Brays Bayou, Kilmarnock Ditch, and Poor Farm Ditch are clearly visible in the figure. It should be noted that the areas north and south of West University Place were undeveloped in 1944. These areas were subsequently developed as single-family, multi-family, and commercial areas within the city of Houston.

These photographs are provided for the purpose of illustrating the changes that have occurred in terms of urbanization in and around the City of West University Place over the years. As a result of the increase area and density of development in the area, storm runoff rates and runoff volumes have increased significantly over the years.



In addition to illustrating urbanization patterns, **Figure 6** also illustrates the fact that a number of major drainage infrastructure components in the West U area have been in place for many years. Kilmarnock Ditch may be seen extending southward from Bellaire Boulevard to Brays Bayou, and Poor Farm Ditch still follows the same basic course to Buffalo Bayou that it did in 1944. Brays Bayou is also clearly visible, but was much smaller and had not been concrete lined as it is today.

Another difference between prior and current conditions involves the Kirby Drive outfall to Brays Bayou, which did not exist in 1943. As indicated in **Figure 5**, the original Kirby Drive system drained to the east. Later improvements by the City of Houston resulted in construction of the existing outfall to Brays Bayou.

The information provided in this section illustrates the changes that have occurred over a period 75 years within and around the City of West University Place. Those changes include increased development north and south of the City, coupled with increased impervious cover within the City itself. These changes have increased storm runoff and runoff rates, increasing the load on the drainage system within West University Place.

Figure 6: West University Place in 1944

In 1993 Langford Engineering, Inc. and the City of West University Place kicked off an infrastructure planning program. Engineering work on the program was subsequently taken over by Claunch & Miller, Inc. Significant infrastructure rehabilitation projects were completed within the City between 1993 and 2006, including reconstruction and replacement of roadways, water lines, and sanitary sewers. Work has been completed in all areas of the city, but improvements to drainage systems has in most parts of West University Place were limited to inlet upgrades and replacement of existing pipes that were in poor condition or past their life expectancy. All upgraded storm sewer elements were designed for a 2-year storm event per standard practice in the Houston area.

Figure 7 illustrates the status of street rehabilitation work in the City of West University Place. The streets categorized as "asphalt overlay" and "point repair" have been repaired as needed to address condition issues but not fully rehabilitated since the 1993 priority area map and overall City infrastructure plan were developed. All other West U streets have been fully rehabilitated. The work completed within the City represents a significant commitment to updating infrastructure within West University Place.

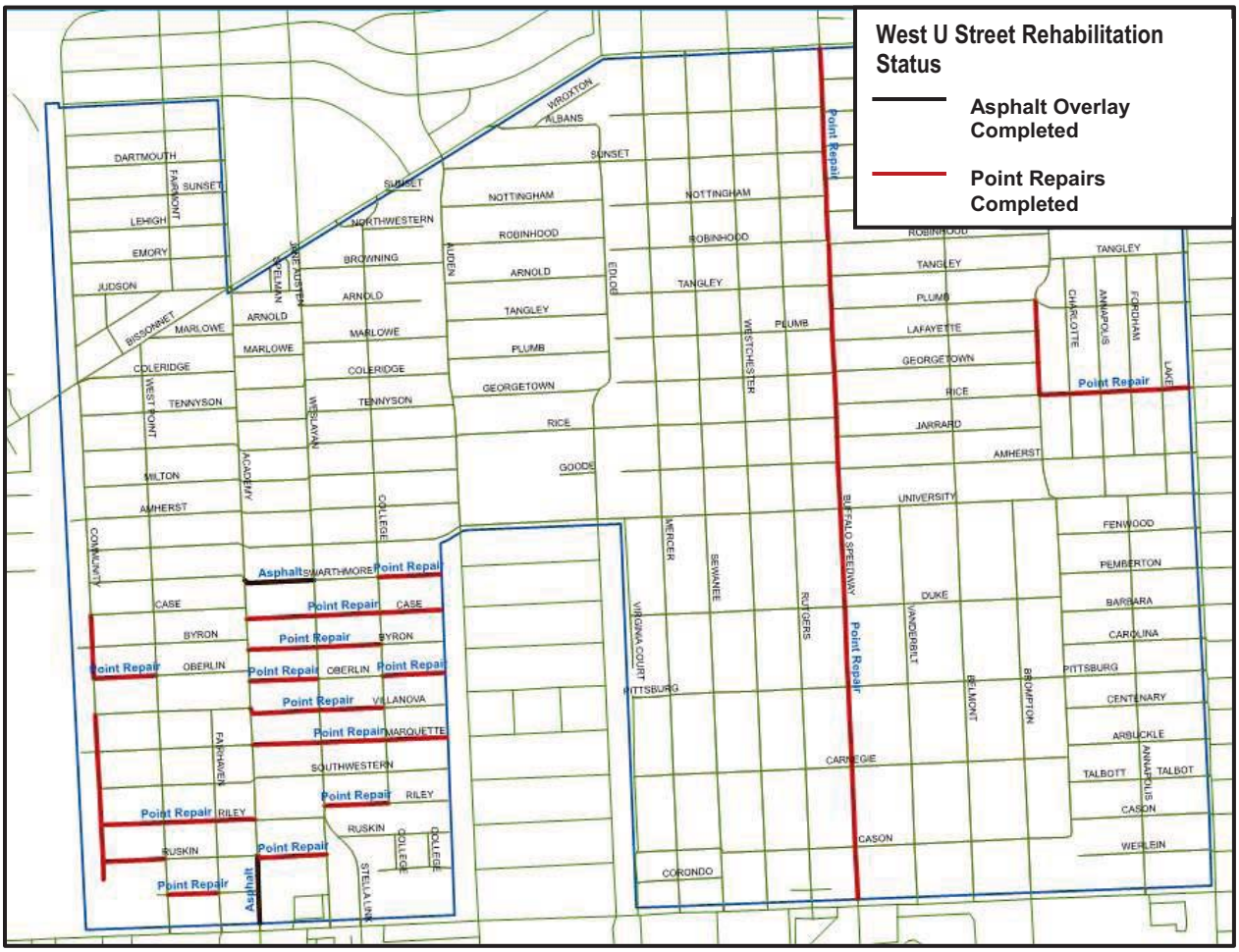


Figure 7: Roadway Rehabilitation Status Map Developed in 2017

Brays Bayou and its Effect on West University Place

Introduction

Brays Bayou has a significant effect on drainage and flooding potential within the City of West University Place. With a drainage area of 127 square miles, Brays Bayou is one of the major drainage arteries in Harris and Fort Bend Counties. The channel of Brays Bayou and most of its tributaries have been deepened, widened, and straightened over the years to improve flow capacity, and the channel of Brays Bayou itself is concrete lined for much of its length.

Project Brays

The Harris County Flood Control District (HCFCD) has worked for a number of years on a series of major drainage improvements known as Project Brays, a cooperative program funded via federal/local cooperation and administered locally by the HCFCD. Project Brays has added large regional detention facilities, channel improvements, and bridge replacements in an extensive effort to reduce flooding potential along the main stem of Brays Bayou.

Notwithstanding all of these efforts, severe rainfall may still cause the flood level in Brays Bayou to reach a point where either flood flows overtop the banks of the bayou and directly flood streets and homes within West University Place or the backwater effect from the Bayou reduces the efficiency of the storm sewers and channels that drain the city, causing secondary flooding of streets and homes when local rainfall is heavy. **Figure 8** illustrates the effective floodplain boundaries published in 2007 and currently recognized by the Federal Emergency Management Agency (FEMA) in the vicinity of the City of West University Place. Note that these boundaries do not reflect the benefits of Project Brays, which are projected to reduce, but not eliminate, the potential for flooding along the Bayou.

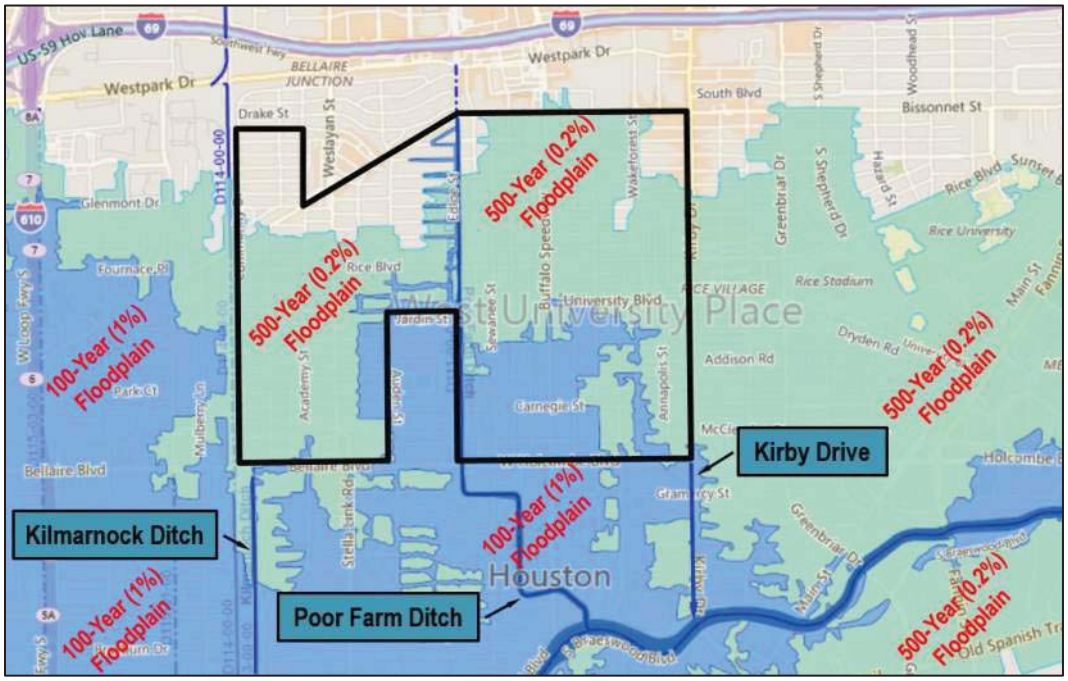


Figure 8: FEMA Effective Brays Bayou Floodplain (Approved June 18, 2007)

Other Factors to Consider

It is important to note that flooding may occur in West University Place even if flood elevations in Brays Bayou do not exceed the top of bank elevation or the 100-year flood elevation. Ground elevations in the City are lower than Brays Bayou 100-year flood levels in a significant portion of the city, and even a 10-year flood elevation in Brays Bayou may cause enough backwater effect to reduce storm sewer efficiency or create street flooding as water travels up the storm sewer systems and flows out of inlets.

Stream Gages and Historical Data

Stream gages operated by the HCFCD are located along the entire length of Brays Bayou. Two of those gages (South Main and Stella Link) are located in the immediate vicinity of the City of West University Place. **Figure 9** illustrates the locations of those gages relative to the corporate boundaries of the City.

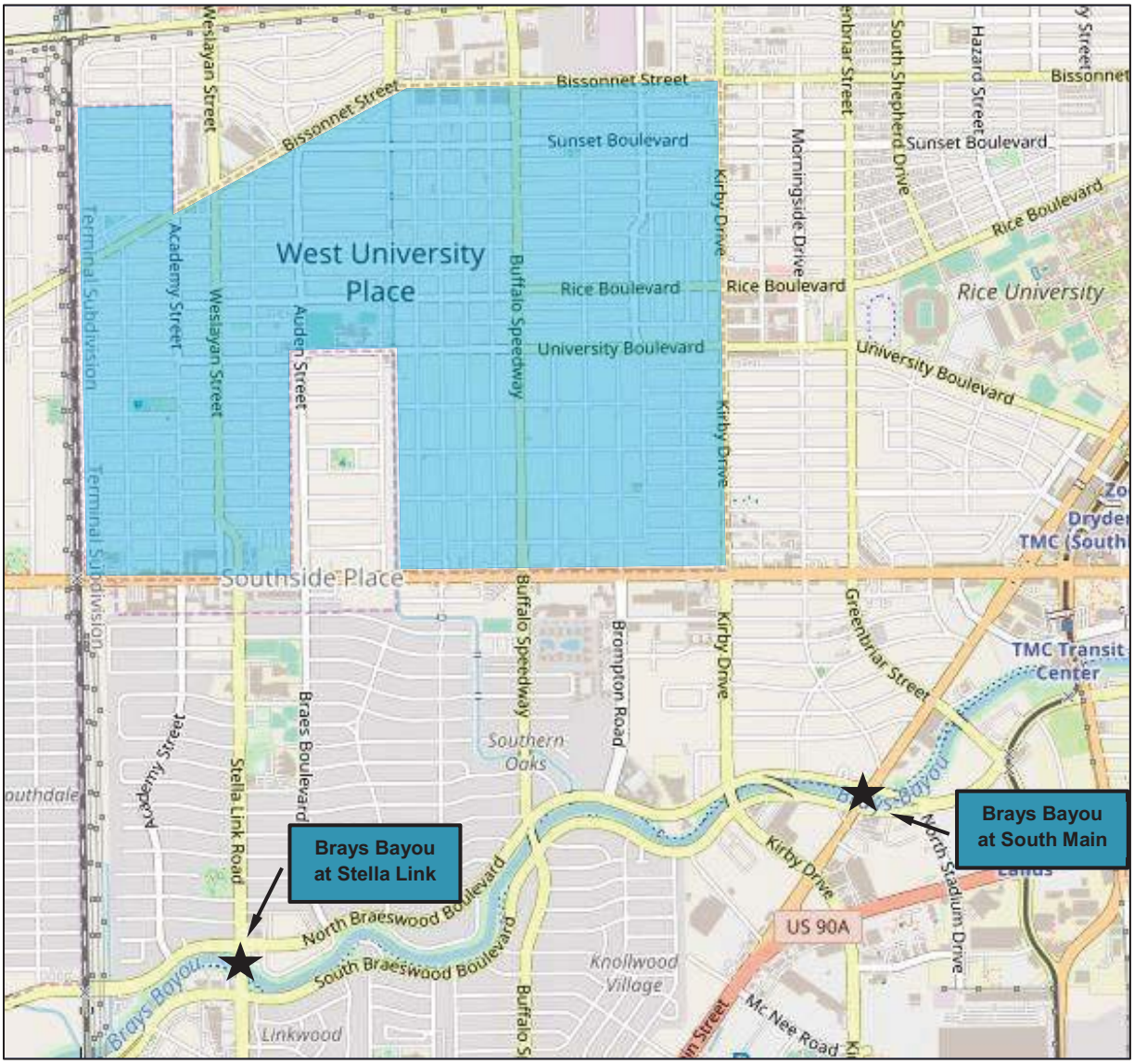


Figure 9: Harris County Flood Warning System Web Page with Gage Locations near West U

Significant flood events along Brays Bayou have been recorded since 1973. **Table 1** presents a summary of some of the more significant events with high water mark (HWM) elevations at the South Main and Stella Link crossings of Brays Bayou. The first few rows of Table 1 provide top of bank and flood frequency elevation data for each gage. The bottom portion provides high water mark elevations for various storm events.

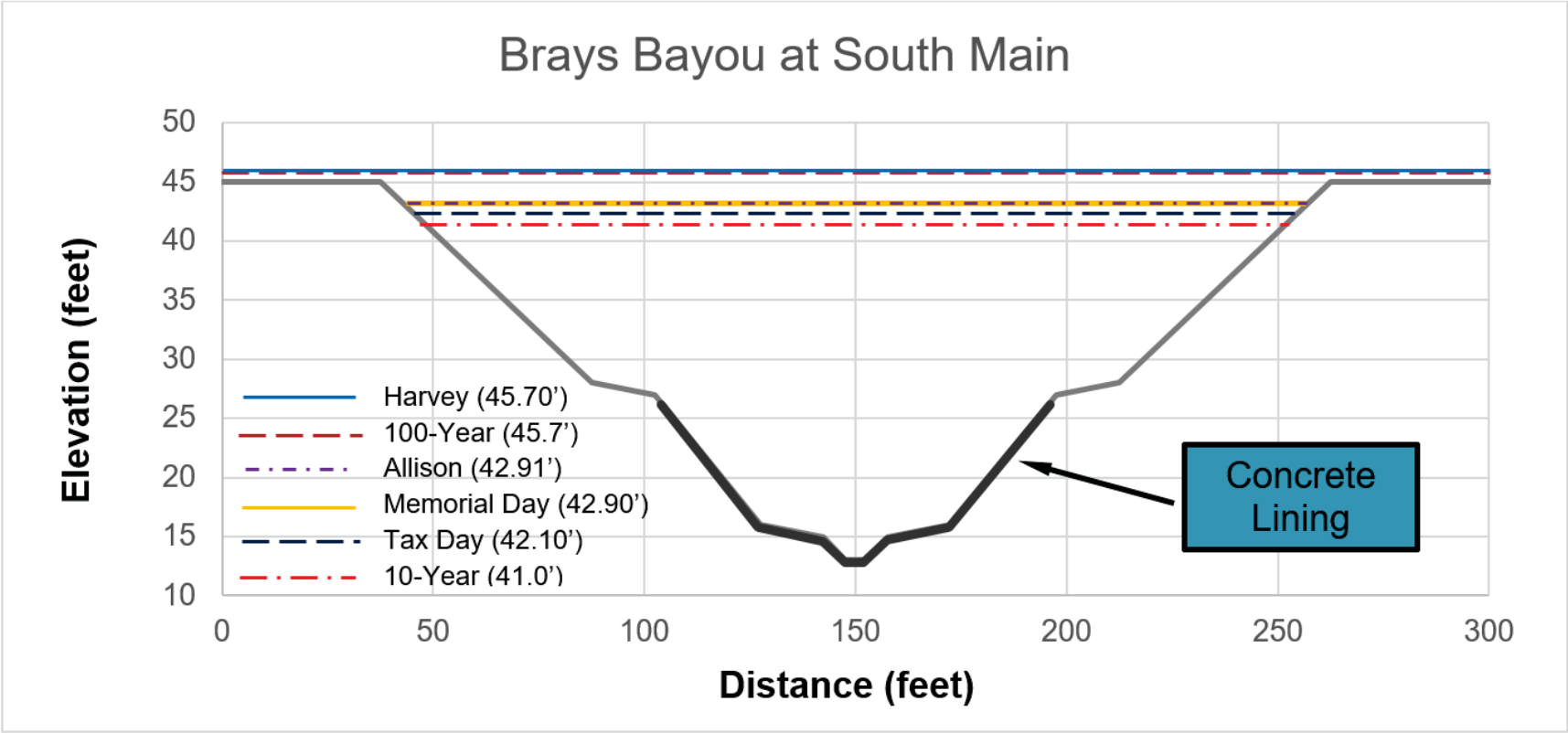
Table 1: Brays Bayou Gage Data

Data for South Main Gage			Data for Stella Link Gage		
Condition/Event		**Elevation**	**Condition/Event**		**Elevation**
Top of Bank		45.0	Top of Bank		48.4
10-Year [1]		41.0	10-Year [1]		45.5
50-Year [1]		43.1	50-Year [1]		47.5
100-Year [1]		45.7	100-Year [1]		49.6
500-Year [1]		50.0	500-Year [1]		51.8
Date	**Event**	**HWM Elev.**	**Date**	**Event**	**HWM Elev.**
6/18/1973	-----	41.21	6/18/1973	-----	45.08
8/31/1981	-----	41.51	8/31/1981	-----	46.08
8/18/1983	Alicia	37.41	8/18/1983	Alicia	42.68
9/19/1983	-----	42.41	No Data [2]	-----	-----
8/1/1989	Chantal	38.81	No Data [2]	-----	-----
No Data [2]	-----	-----	3/4/1992	-----	44.98
10/18/1994	-----	42.21	10/18/1994	-----	45.98
9/11/1998	Frances	39.61	9/11/1998	Frances	44.28
6/9/2001	Allison	42.91	6/9/2001	Allison	48.38
11/17/2003	-----	40.61	11/17/2003	-----	46.38
9/13/2008	Ike	41.30	9/13/2008	Ike	45.90
4/28/2009	-----	36.50	4/28/2009	-----	43.00
1/9/2012	-----	40.50	1/9/2012	-----	45.70
5/26/2015	Memorial Day	42.90	5/26/2015	Memorial Day	48.30
4/18/2016	Tax Day	42.10	4/18/2016	Tax Day	46.50
No Data [2]	-----	-----	1/18/2017	-----	45.70
8/27/2017	Harvey	**45.70**	8/27/2017	Harvey	**49.70**
7/4/2018	-----	37.33	7/4/2018	-----	41.28

[1] *Flood elevations for 10-year, 50-year, 100-year, & 500-year events reflect pre-Project Brays conditions.*

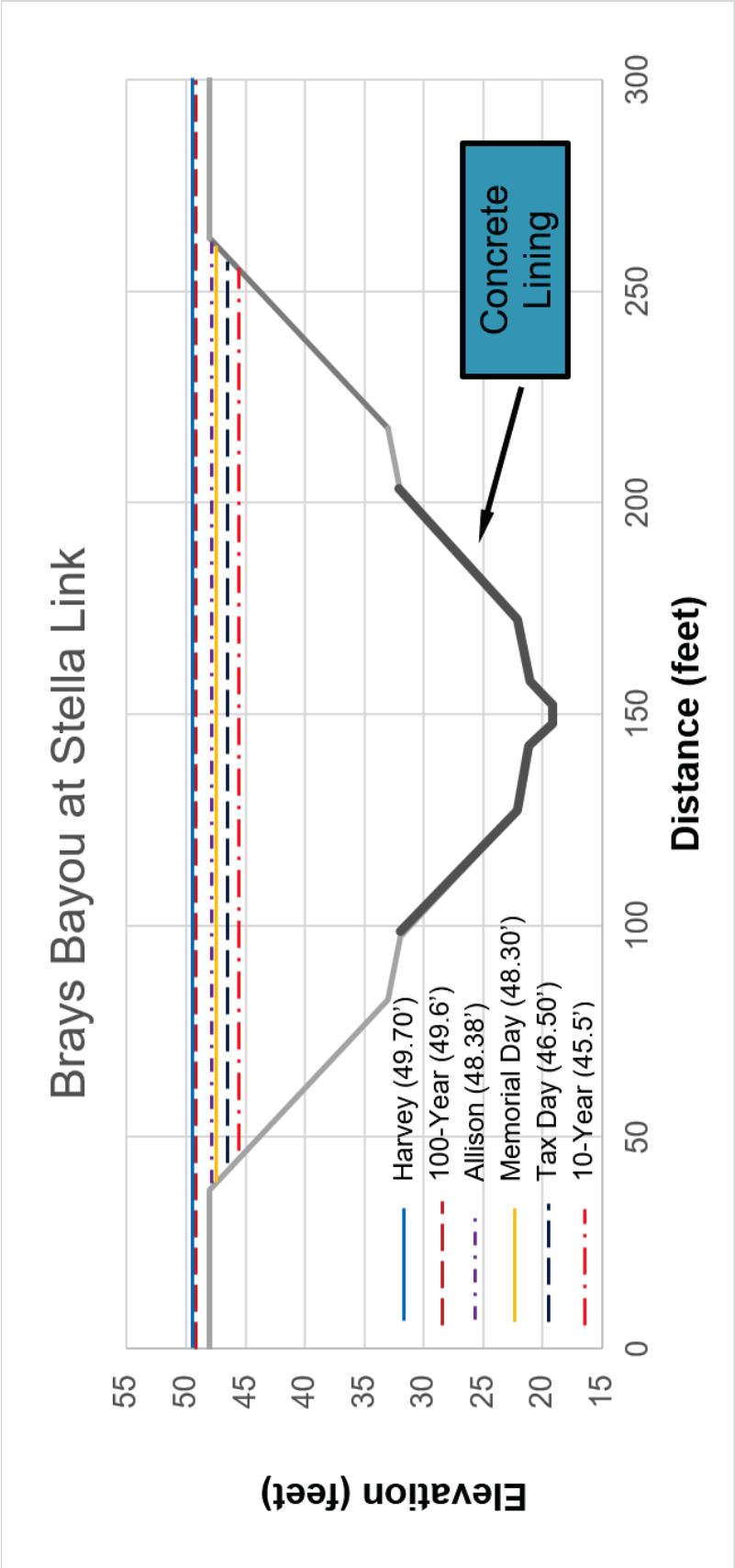
[2] *"No Data" indicates that elevation data for this event not available from the HCFCD Flood Warning System website. Data reflects pre-Project Brays conditions.*

Blue shading of cells in the table indicate occasions when the 10-year (10% annual chance) flood elevation was exceeded. A bold red elevation indicates a high water mark that is above the 100-year (1% annual chance) flood elevation. The following graphs illustrate the typical Brays Bayou cross-section at the South Main and Stella Link crossings of the channel. These graphs can be used to determine the general depth of flow at each location for a given historical event and the relationship of the high water elevations tabulated above to the top of bank of Brays Bayou.



Note: Flooding may occur in areas on either side of Brays Bayou even if the banks of the channel are not overtopped by a given flood level. This is due to the fact that many areas on either side of the Bayou are at elevations lower than the channel top of bank elevation.

hdrinc.com
4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264



Note: Flooding may occur in areas on either side of Brays Bayou even if the banks of the channel are not overtopped by a given flood level. This is due to the fact that many areas on either side of the Bayou are at elevations lower than the channel top of bank elevation.

Major West U Drainage Systems

The City's drainage system is divided into five (5) following major drainage areas are illustrated in **Figure 10** below.

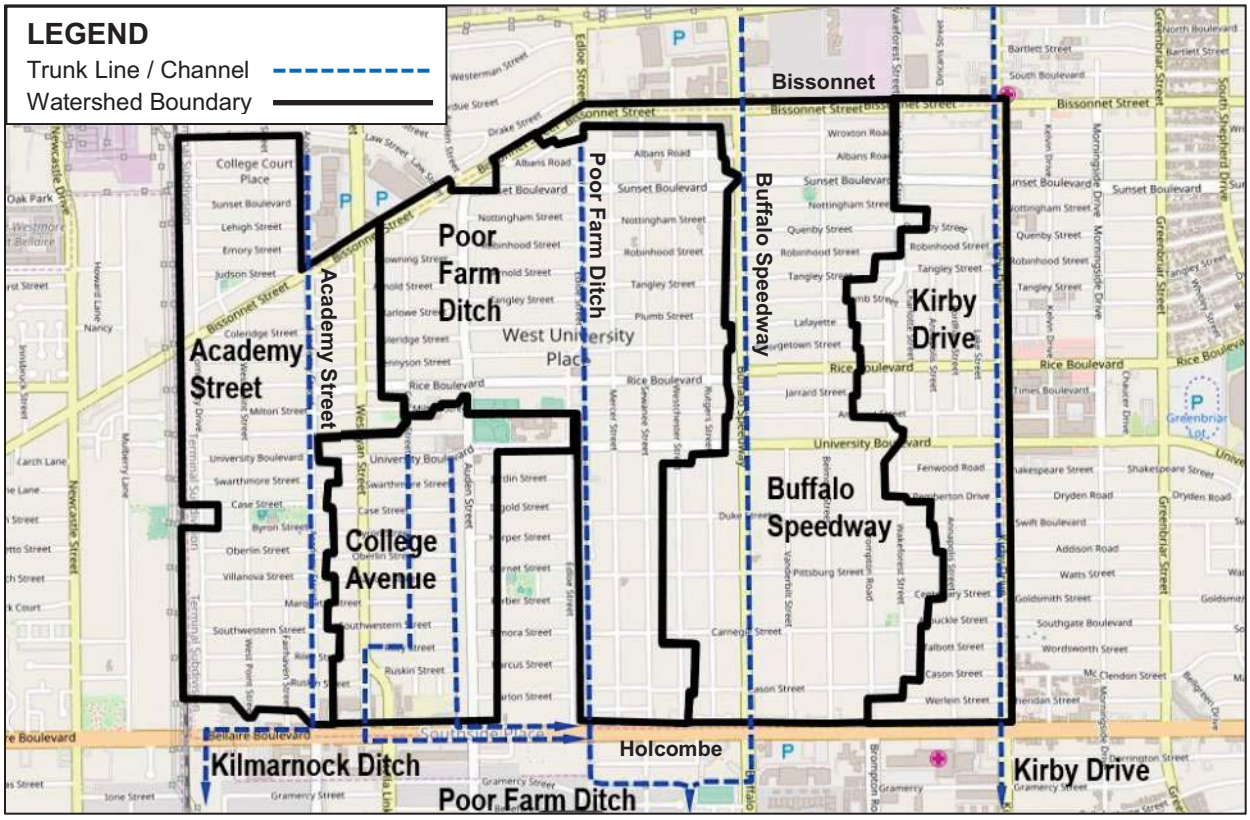


Figure 10: West University Place Major Drainage Areas & Major Trunk Lines / Channels

The watershed areas within West University Place that are indicated above, the type of drainage system, and their acreage are provided in the following list.

1. Academy Street (272 Acres - Storm Sewer)
2. College Avenue / Shared System (157 Acres - Storm Sewer)
3. Poor Farm Ditch (339 Acres – Concrete-Lined Open Channel)
4. Buffalo Speedway (360 Acres - Storm Sewer)
5. Kirby Drive (190 Acres - Storm Sewer)

Flood waters from these major drainage areas are ultimately conveyed away from the City via five corresponding main channels and storm sewer trunk lines.

- Academy Street Trunk Line (Kilmarnock Ditch)
- College Avenue / Shared System Trunk Lines (Poor Farm Ditch)
- Poor Farm Ditch Channel (Brays Bayou)
- Buffalo Speedway Trunk Line (Poor Farm Ditch),
- Kirby Street Trunk Line (Brays Bayou)

Storm runoff collected in each of these major storm water conveyances ultimately makes its way into Brays Bayou. Of the five major systems four (Academy Street, Poor Farm Ditch, Buffalo Speedway, and Kirby Drive) receive significant storm runoff from the City of Houston. Two (College Avenue / Shared System and Poor Farm Ditch) receive storm runoff from the City of Southside Place. Each of these major drainage systems is further discussed in subsequent sections of this report.

Academy Street Drainage Area

The Academy Street storm sewer system outfalls into Kilmarnock Ditch (HCFCD Unit D113-00-00). Kilmarnock Ditch is an earthen channel which extends southward from Holcombe Boulevard to Brays Bayou. Portions of the City of Bellaire and the City of Houston also drain to Kilmarnock Ditch.

Figure 11: Academy Street Drainage Area

Prior Study

Six (6) specific intersections within the Academy Street drainage service area were evaluated between February and April, 2016. Preliminary storm sewer sizes were calculated for Academy Street trunk line and a rough cost estimate for improvements and detention was developed. This effort was documented in an April 21, 2016 report titled "*Preliminary Storm Sewer Drainage Analysis for Six Ponding Locations in the Academy Street Drainage System in West University Place*" (Appendix B).

Results from City-Wide Drainage Study

The results of more recent evaluations completed in 2017-18 indicate that existing storm sewer infrastructure within the Academy Street drainage area generally does not satisfy current 2-year capacity requirements as recognized by the City. A few pipes do satisfy the 2-year requirement (some small branch systems with limited drainage areas, plus a small system just north of Bissonnet and a small system south of Bissonnet that ties to the City of Houston trunk line west of the railroad). However, the collector lines and the main trunk line along Academy Street do not provide the minimum design capacity. These results are consistent with the findings of the April 21, 2016

report. The main trunk line along Academy is further discussed in the **Trunk Line Projects** section of this report.

Kilmarnock Ditch

Kilmarnock ditch receives storm water from the Academy Street trunk line and conveys it to Brays Bayou. In response to flooding concerns, HCFCD initiated a regional drainage study of Poor Farm Ditch and Kilmarnock Ditch in 2002. The study findings were published in 2004 in a report entitled "*Poor Farm & Kilmarnock Regional Study*" (2004 Study). Findings from the study showed that Kilmarnock Ditch has adequate capacity to convey runoff from a 100-year storm event. However, the channel crossing at the Beechnut Street/North Braeswood Boulevard bridge, and the culverts at the Brays Bayou outfall, were found to be inadequate and in need of enlargement. These structures are south of the City of West University Place. The Harris County Flood Control District has not identified a project or time frame for upgrading these structures.

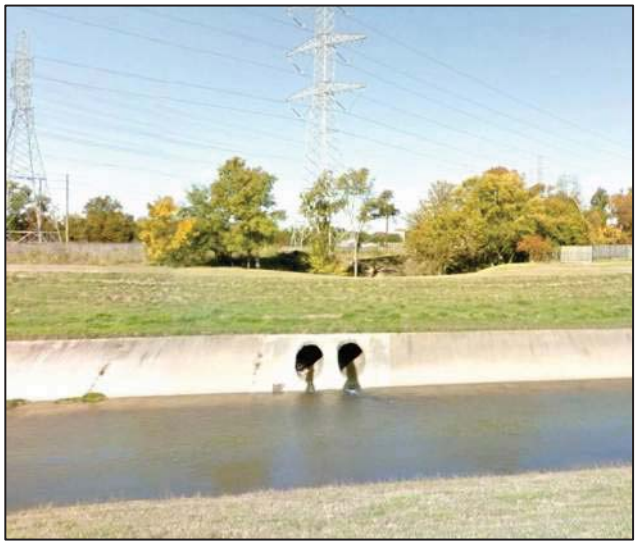


Figure 12: Kilmarnock Ditch Outfall into Brays Bayou

Figure 13: Kilmarnock Ditch at N. Braeswood Blvd. (Looking North)

The 2004 study also concluded it would be necessary to mitigate the impacts of the proposed Kilmarnock Ditch improvements on Brays Bayou by providing storm water detention along Brays Bayou. It was estimated that 21 acre-feet of mitigation was necessary to mitigate impacts of the proposed Kilmarnock Ditch improvements.

In 2010, HCFCD participated with the City of Houston in the construction of the Meyer Stormwater Detention Basin (HCFCD Unit D500-08-00), which created a total of 191 acre-feet of storm water storage (152 acre-feet for the City of Houston and 39 acre-feet for the HCFCD). This storage was eligible to be used for storm drainage mitigation projects between Fondren Road and State Highway 288, which included proposed improvements on Poor Farm Ditch and Kilmarnock Ditch.

The 2004 study was subsequently re-evaluated in 2013, at which time the HCFCD determined that the 21 acre-feet of detention storage identified in the 2004 study was not needed and could

be re-purposed for other uses. The District subsequently sold 9.1 acre-feet of Meyer Tract detention storage to the City of West University Place to fully address detention requirements associated with drainage improvements along College Avenue, which were completed in 2009. An August 2014 Fact Sheet published by the Harris County Flood Control District summarizing the various Kilmarnock Ditch studies, evaluations, and updates can be found in Attachment B to this report.

Poor Farm Ditch Drainage Area

Poor Farm Ditch drains southward from Bissonnet Avenue to Brays Bayou, passing completely through the City from north to south. Poor Farm Ditch also collects storm runoff from the areas that drain to the College Street and Shared System storm sewers as described in the College Avenue Drainage Area. **Figure 14** illustrates the boundaries of the area within West University Place that drains to Poor Farm Ditch.

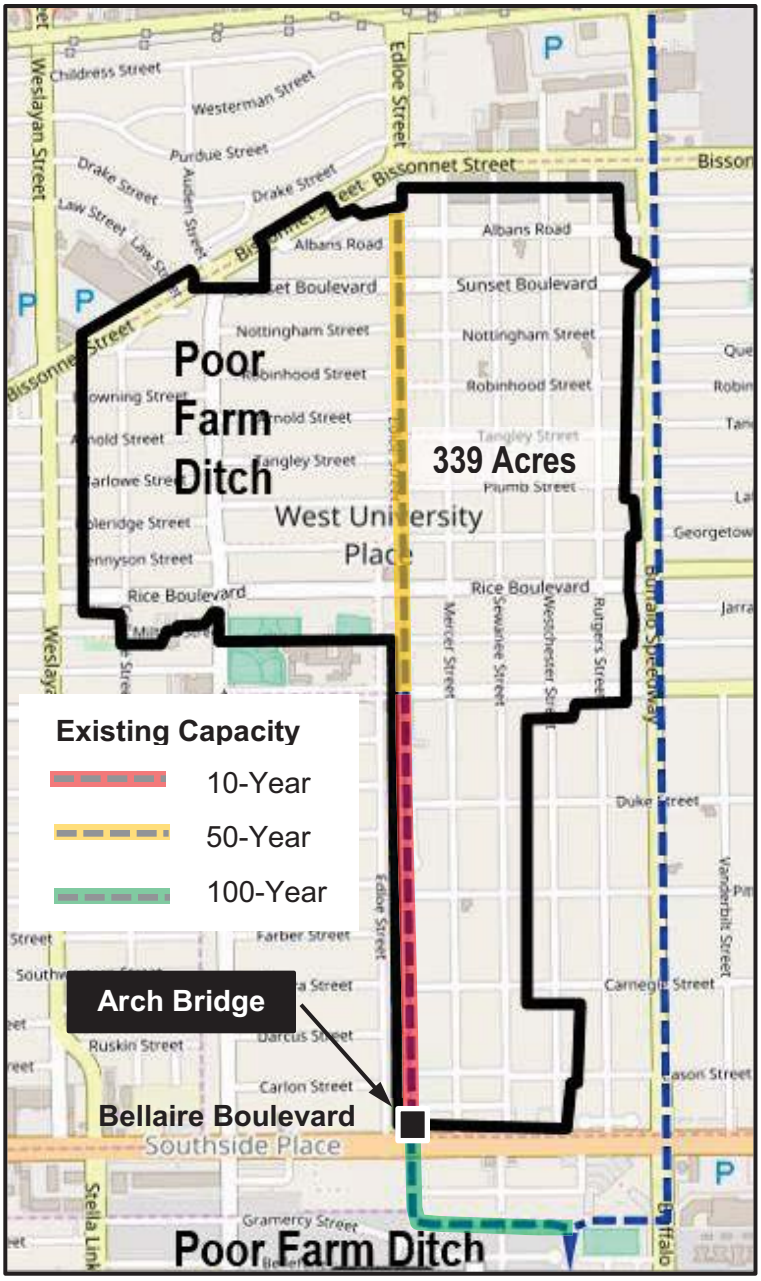


Figure 14: Poor Farm Ditch Drainage Area

HCFCD Studies: 2004, 2009, 2017

In response to flooding concerns and failing infrastructure along Poor Farm Ditch, the HCFCD initiated a regional drainage study to investigate improvements that might be considered to resolve the identified problems. The study findings were published in 2004 in a report entitled the "Poor Farm & Kilmarnock Regional Study" (2004 Study).

Findings from the 2004 study showed that Poor Farm Ditch upstream of University Boulevard had adequate capacity to convey runoff from a 50-year storm event. From Bellaire Boulevard downstream to the confluence with Brays Bayou there was capacity to convey runoff from a 100-year storm event. However, the reach of Poor Farm Ditch between University and Bellaire Boulevards was found to have only approximately 10-year capacity and would have to be significantly enlarged to convey

runoff from a 100-year storm event. Furthermore, it was determined that the Bellaire Boulevard bridge across Poor Farm Ditch needed to be widened because it was a constraint to storm water conveyance. That bridge was subsequently improved via the construction of a concrete arch span.

Further study by the HCFCD in 2009 revealed that proposed improvements to the channel between University Boulevard and Bellaire Boulevard would be limited by right-of-way (ROW) constraints, and a 100-year channel design would not be feasible without obtaining additional ROW. The study concluded that if proposed bridge and channel improvements were limited to fit within the existing ROW on Poor Farm Ditch, the required mitigation storage requirement could be reduced to 13.5 acre-feet.

As referenced in the previous section of this report, the HCFCD participated with the City of Houston in the construction of the Meyer Storm water Detention Basin to provide storage for application to storm drainage mitigation projects between Fondren Road and State Highway 288. Proposed improvements to Poor Farm Ditch were included in the projects to which Meyer Tract detention could be applied.

Figure 15: Damage along Poor Farm Ditch – Looking North (Freese & Nichols 2017)

In 2017, the HCFCD performed further evaluations on Poor Farm Ditch. This evaluation is documented in a September 2017 report titled “Poor Farm Ditch Conveyance Preliminary Engineering Report” (Appendix C). The report confirmed that the existing channel has 50-year capacity between Bissonnet Street and University Boulevard, 10-year capacity between University Boulevard and Bellaire Boulevard, and 100-year capacity downstream of Bellaire Boulevard. The report described a number of alternatives for improving the channel in the mid-reach area between University Boulevard and Bellaire Boulevard. **Figure 16** illustrates a typical cross-section as presented in the Preliminary Engineering Report (PER) for the recommended improvement alternative.

Figure 16: Typical PER Cross-Section for Recommended Poor Farm Ditch Improvement

This recommended alternative would provide approximately 50-year capacity within this segment and consisted of a concrete-lined channel from University to Bellaire Boulevard. This would put the Poor Farm Ditch capacity at the 50-year level for the entire channel upstream (north) of Bellaire Boulevard and at the 100-year level downstream of Bellaire Boulevard.

Results from City-Wide Drainage Study

In the spring of 2018, storm sewer capacities were evaluated in the Poor Farm Ditch watershed. A recent capacity evaluation revealed that storm sewers west of Poor Farm Ditch were typically found to lack the current 2-year design capacity requirement. On the other hand, the systems east of Poor Farm Ditch were generally found to have adequate capacity to satisfy the 2-year capacity requirement. Approximately 34% of the tributary storm sewer lines draining to the Poor Farm Ditch channel were found to have less than the current 2-year design capacity. **Attachment C** provides a graphical summary of the results of the city-wide capacity assessment.

College Avenue / Shared System Drainage Area

This drainage area has two drainage systems, both of which run down Bellaire Boulevard and outfall into Poor Farm Ditch. The College Avenue Drainage system was designed in 2007 and constructed in 2009 and was a shared project between West University Place and Southside Place. The remaining area in this drainage area drains to a shared storm sewer system that flows along the boundary between the Cities of West University Place and Southside Place. The shared system drains significant areas in both cities.

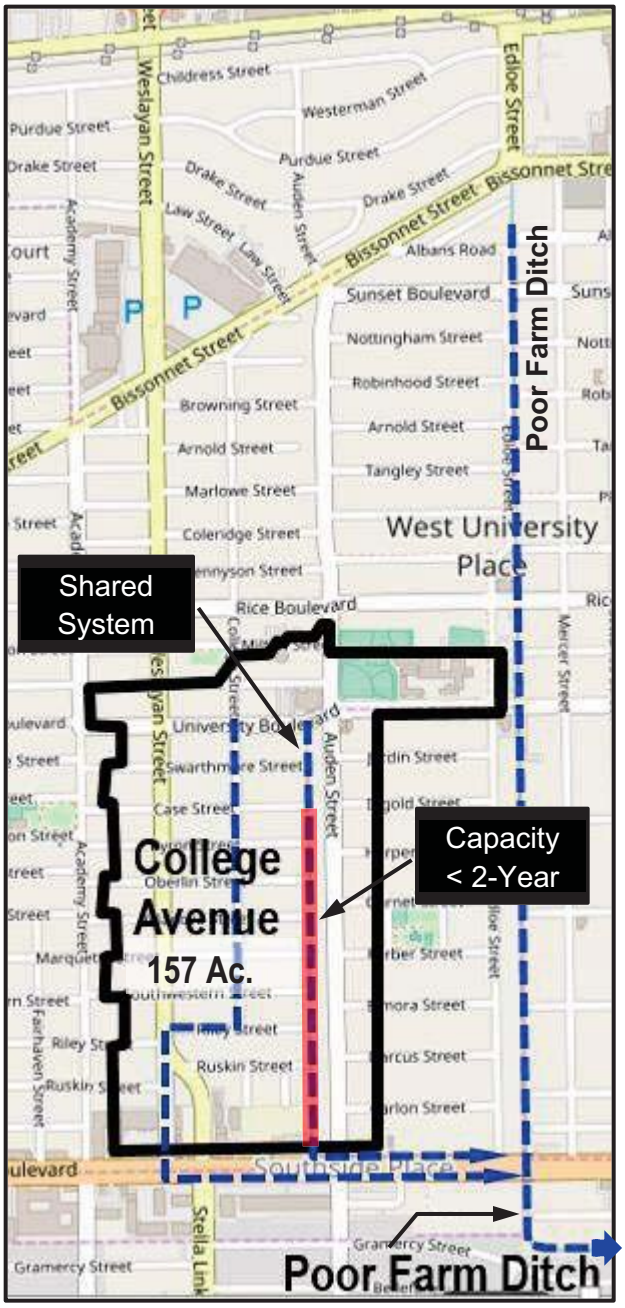


Figure 17: College Avenue / Shared System Drainage Area

2017 Drainage Study

The new storm sewer constructed along College Avenue in 2009 significantly reduced the area draining to the shared system west of Auden Street, while related improvements completed along Bellaire Boulevard provide better outfall capacity to Poor Farm Ditch. However, the results of a 2017 study indicated that portions of the existing shared drainage system still do not provide a standard 2-year design capacity downstream of Case Street. The study effort included the development of alternatives that utilize the existing alignment of the shared storm sewer between the City and Southside Place, as well as an alternative alignment along Auden Street within Southside Place. This effort was documented in a July 6, 2017 report titled "*Drainage Evaluation for Dead-End Streets*" (Appendix D).

Results of 2018 City-Wide Drainage Study

In 2018, supplemental storm sewer evaluations confirmed that the College Avenue trunk line satisfies the 2-year capacity requirement, and that the shared system downstream of Case Street does not satisfy that same capacity requirement. In total, approximately 34% of the storm sewer pipes within the College Avenue / Shared System drainage area, including tributary storm sewer systems along Swarthmore Street and Oberlin Street, were found to have less than 2-year design capacity. All of these findings confirmed the general results of the 2017 drainage study.

Buffalo Speedway Drainage Area

The Buffalo Speedway trunk line passes completely through the City from north to south and ultimately empties into Poor Farm Ditch a short distance south of Bellaire Boulevard and immediately west through an easement across the sports field of St. Vincent de Paul Catholic Church. The outfall lies within the City of Houston. The Buffalo Speedway trunk line drains significant areas within the City of Houston north of Bissonnet and south of Bellaire Boulevard.

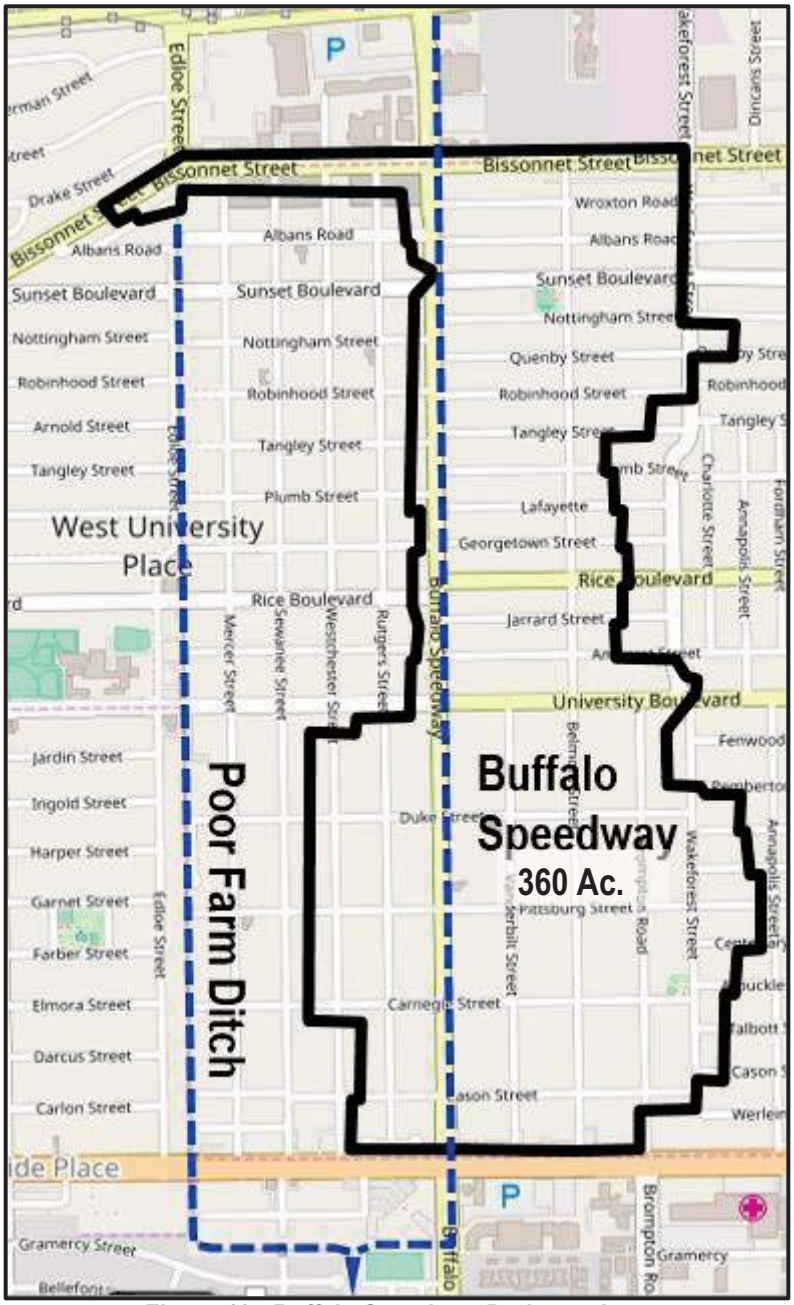


Figure 18: Buffalo Speedway Drainage Area

Results from City-Wide Study

In the spring of 2018, capacity evaluations of storm sewers within the Buffalo Speedway drainage area were completed. The results indicated that the capacity of the trunk line is less than the 2-year capacity requirement. Storm sewer systems draining to the Buffalo Speedway trunk line from the east and west were generally found to have sufficient capacity to satisfy the 2-year design requirement, although some systems (along George-town Street, Duke Street, Pitts-burg Street, Carnegie Street, and Cason Street) do not provide 2-year capacity. In total, about 37% of the tributary storm sewers are under capacity.

Results from PER

A more detailed analysis of the Buffalo Speedway system was completed in the summer of 2018. That analysis included detailed 2D modeling of the existing trunk line storm sewer and proposed improvements to the trunk line from Bissonnet to Poor Farm Ditch. The Buffalo Speedway drainage analysis, results, and conclusions are presented in a draft report dated October 19, 2018 and titled "*Buffalo Speedway Improvements – Drainage Preliminary Engineering Report*" (Appendix A), which was completed in connection with the proposed Buffalo Speedway Road Reconstruction project.

Kirby Drive Drainage Area

The Kirby Drive storm sewer systems extends southward from Bissonnet Avenue to Brays Bayou. This system drains the eastern portion of the City of West University Place, in addition to significant areas within the City of Houston. Kirby Drive lies within the City of Houston, but tributary storm sewers west of Kirby are within the City of West University Place.

Figure 19: Kirby Drive Drainage Area

2016 Study

HDR completed a drainage study in 2016 for four intersections along Wakeforest Avenue and found that existing storm sewer pipe and inlets at those intersections lack 2-year capacity. Results from the study were summarized in a report titled "*Preliminary Storm Sewer Drainage Analysis for Four Ponding Locations along Wakeforest Avenue in West University Place*" and dated April 21, 2016 (Appendix E).

Results from City-Wide Study

The results of a 2018 evaluation of existing drainage infrastructure in the Kirby Drive drainage area were mixed; about half of the systems appear to provide 2-year capacity, while the remaining systems do not. Existing systems that do not appear to have 2-year capacity include storm sewers along Arbuckle, Wakeforest, Rice, Amherst, Fordham, Plumb, Tangley, Robinhood, Nottingham, and Wroxton. These results were generally consistent with those obtained in connection with the 2016 study described above.

Planning Area Projects

Identification of Planning Areas

Between 1993 and 2006, the City of West University Place completed a number of significant street rehabilitation projects for various priority areas through its infrastructure rehabilitation program. Since 2007, the following additional projects have been completed:

- College Avenue Improvements;
- Cason Street Extension;
- Ruskin & West College Rehabilitation; and
- Inlets at Intersection of College Avenue & Southwestern Street.

Early rehabilitation projects generally did not involve storm sewer upgrades, but later projects did include replacement of some storm sewers due to condition issues. All replacement elements were designed to accommodate a 2-year design storm event. Drainage improvements were incorporated into some specific street projects (as they were for the College Avenue project completed in 2007), but in many areas only inlets and drainage leads (the pipes that connect the inlets to the storm sewers) were upgraded while existing trunk line storm sewers remained in place. In addition, while all of the storm sewer systems within the City were designed for a 2-year storm event at the time of construction, the definition of a 2-year storm has changed over the years, with drainage capacity requirements generally increasing. This change has occurred as the period of record for historical rainfall records has increased and the reliability of statistical analyses has improved. As a result, some of the storm sewer systems within the City of West University Place do not meet current 2-year capacity requirements as recognized by the City of West University Place. Those current capacity requirements have been applied to West University Place drainage systems for the purposes of completing drainage evaluations for various portions of the City as described in prior sections of this report.

Based on the results of the initial Phase I investigation previously described, Planning Areas 1, 2, and 3 were prioritized for early consideration because:

- storm sewers generally lack 2-year capacity; and
- street rehabilitation work was not fully carried out in those areas in the city-wide infrastructure rehab program of 1993 - 2006.

The storm drainage pipes in these areas will be upsized to provide adequate capacity for the current 2-year storm event requirement, with a minimum pipe size of 24 inches. The opinion of probable cost of construction for these areas is discussed in the next subsection. Major street rehabilitation work, along with incidental work such as the reconstruction of private driveways and accessible ramps, is included in the opinions of probable cost developed for Planning Areas 1 - 3. The boundaries of Planning Areas 1, 2, and 3 are illustrated in **Figure 20** below, along with the boundaries of nine (9) other areas where storm sewer upgrades are required, but streets have been fully rehabilitated since 1993. Attachment C to this report is a full-sized version of this map.

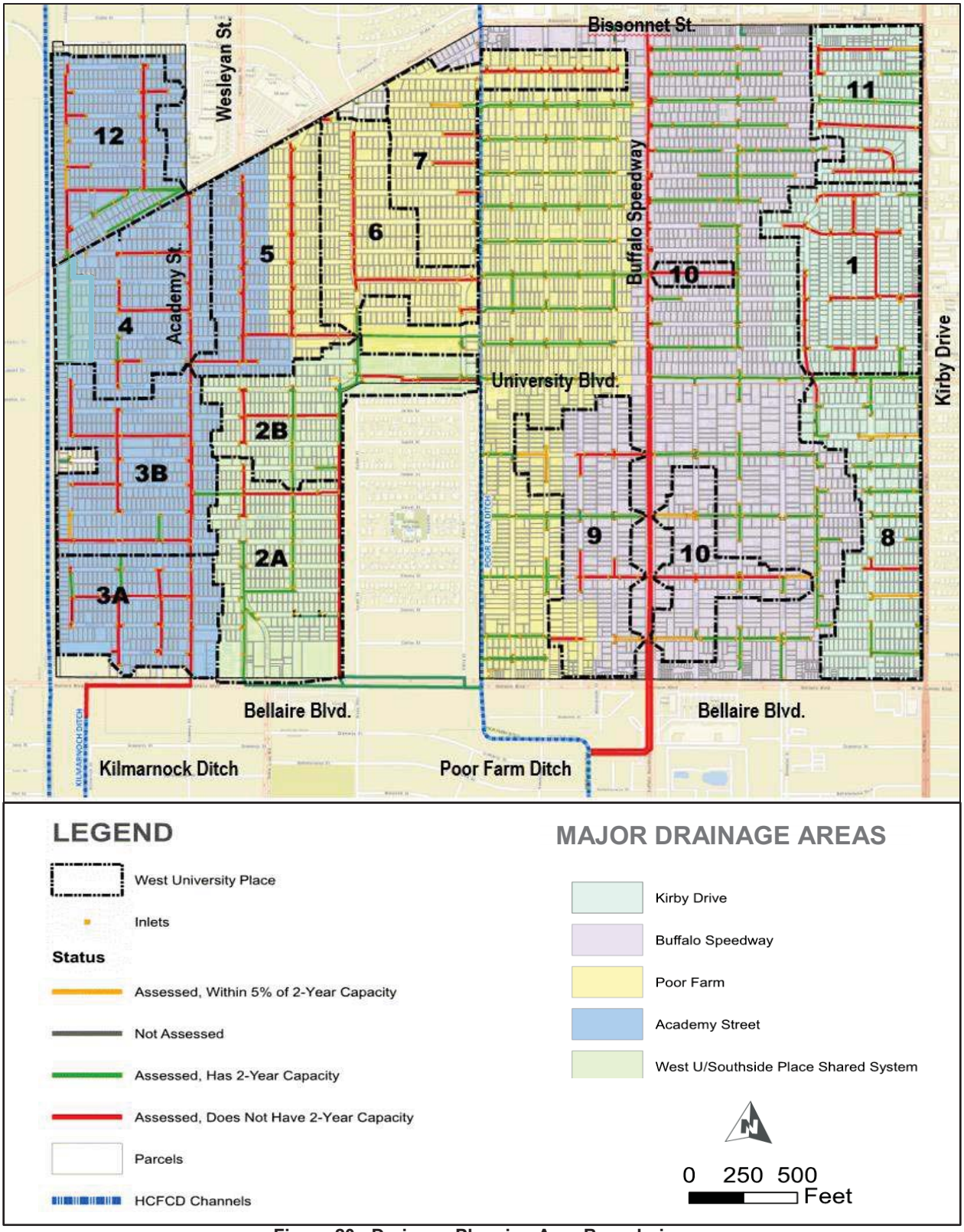


Figure 20: Drainage Planning Area Boundaries

Planning Area 1

This planning area covers an area of approximately 63 acres. General street rehabilitation work is required along Wakeforest and Rice Streets, as only concrete point repairs have been completed along those streets in the past. Drainage improvements are required along a number of other streets. Approximately 84% of the existing storm sewer pipe within Planning Area 1 does not meet the 2-year capacity requirement. For those other streets not identified as streets with drainage issues or paving issues, the removal and replacement of existing pavement will be limited to quantities required in connection with the proposed storm sewer upgrades.

The opinion of probable cost developed for Planning Area 1 indicates a total cost of $6,900,000 excluding any detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

Figure 21: Planning Area #1

Planning Area 2

This has is approximately 116 acres. For cost management, this area may be further divided into Planning Areas 2A (South – 65 acres) and 2B (North – 51 acres). General street rehabilitation work is required along Swarthmore, Case, Byron, Oberlin, Riley, Villanova, Marquette, and Ruskin Streets, as only concrete point repairs or asphalt overlays have been completed along those streets in the past. For those other streets not identified as streets with drainage issues or paving issues, the removal and replacement of existing pavement will be limited to quantities required in connection with the proposed storm sewer upgrades.

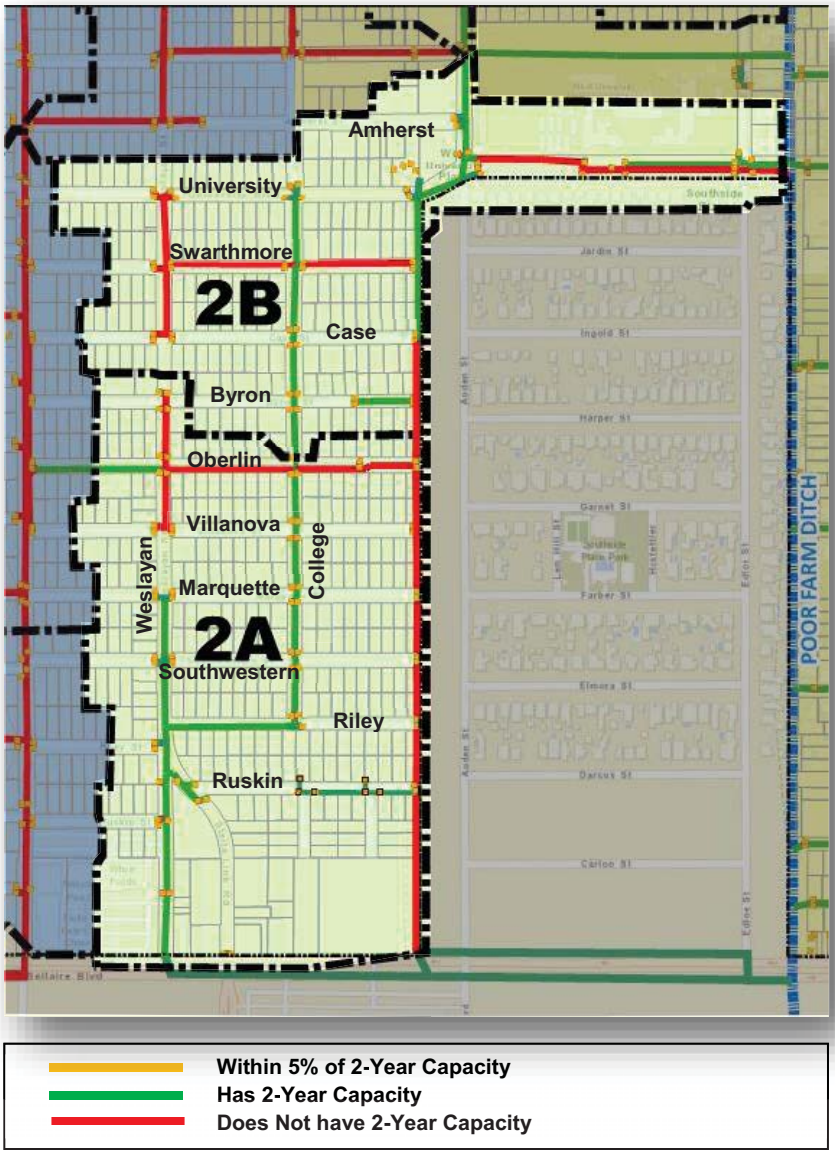


Figure 22: Planning Area #2

Approximately 36% of the existing storm sewer pipe within Planning Area 2 does not meet the 2-year capacity requirement. Note that improvements to the existing Shared System trunk line are not included in the proposed Planning Area 2 improvements. Those trunk line improvements are treated as a separate project.

The opinion of probable cost developed for Planning Area 2 indicates a total cost of $8,400,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

Planning Area 3

This area covers a total of 114 acres. For cost management, this area may be further divided into Planning Areas 3A (South – 46 acres) and 3B (North – 68 acres). General street rehabilitation work is required along Swarthmore, Case, Byron, Oberlin, Villanova, Marquette, Riley, Ruskin, Cason, and Community Streets, as only concrete point repairs or asphalt overlays have been completed along those streets in the past. For those streets not identified as streets with drainage issues or paving issues, the removal and replacement of existing pavement will be limited to quantities required in connection with the proposed storm sewer upgrades.

Approximately 84% of the existing storm sewer pipe within Planning Area 3 does not meet the 2-year capacity requirement. Note that improvements to the existing Academy Street trunk line are not included in the proposed Planning Area 3 improvements. Those trunk line improvements are treated as a separate project.

The opinion of probable cost developed for Planning Area 3 indicates a total cost of $9,400,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

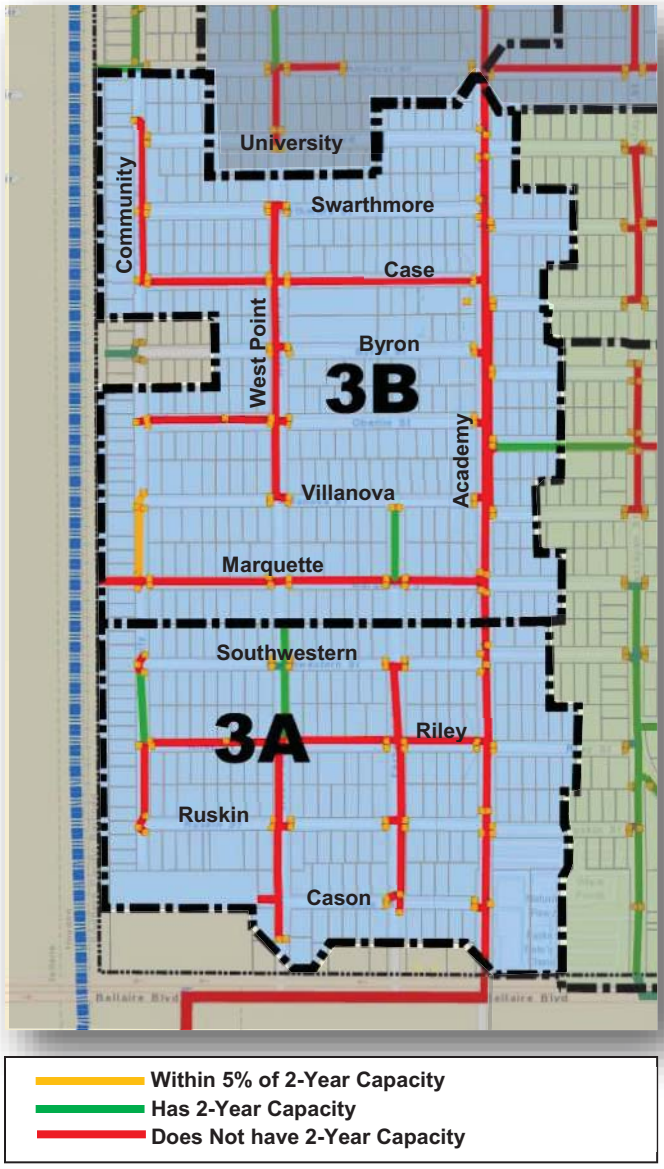


Figure 23: Planning Area #3

Planning Area 4

This planning area covers a total area of approximately 62 acres. Approximately 88% of the existing storm sewer pipe within Planning Area 4 does not satisfy the 2-year capacity criterion. No roadway rehabilitation work is required in this planning area. Only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed. Note that improvements to the existing Academy Street trunk line are not included in the proposed Planning Area 4 improvements. Those trunk line improvements are treated as a separate project. Information on trunk line projects may be found in the Trunk Line Projects section of this report and in Attachment E.

The opinion of probable cost developed for Planning Area 4 indicates a total cost of $3,300,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

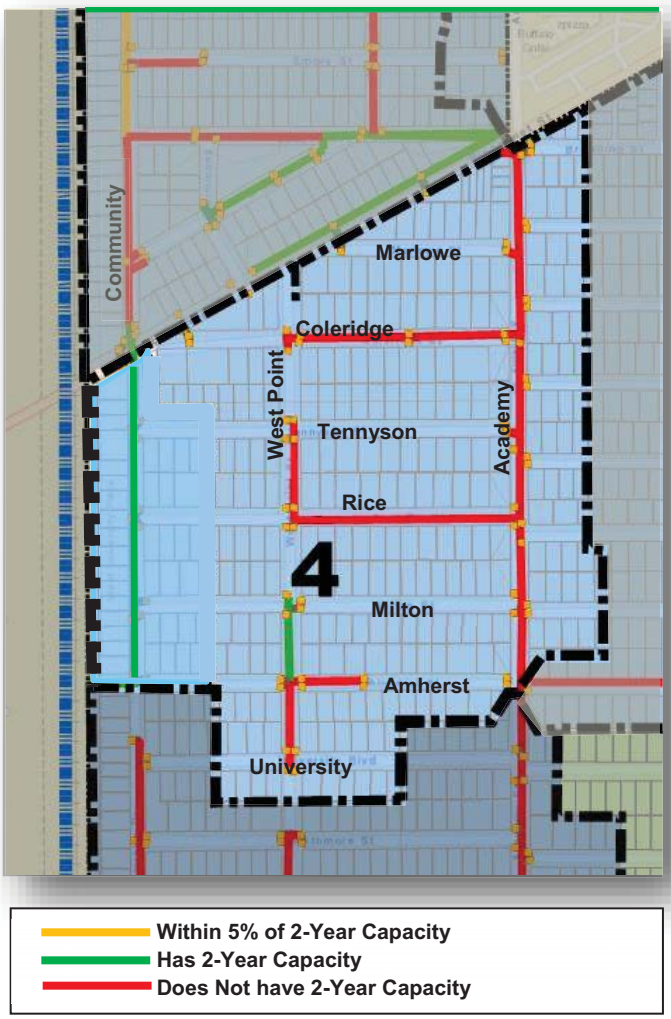


Figure 24: Planning Area #4

Planning Area 5

This planning area covers a total area of approximately 64 acres. Drainage from this planning area is split between the Academy Drive storm sewer system and Poor Farm Ditch.

Approximately 100% of the existing storm sewer pipe within Planning Area 6 does not meet the 2-year capacity criterion. Roadway rehabilitation work was previously completed for this planning area. Therefore, only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed.

The opinion of probable cost developed for Planning Area 5 indicates a total cost of $4,500,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

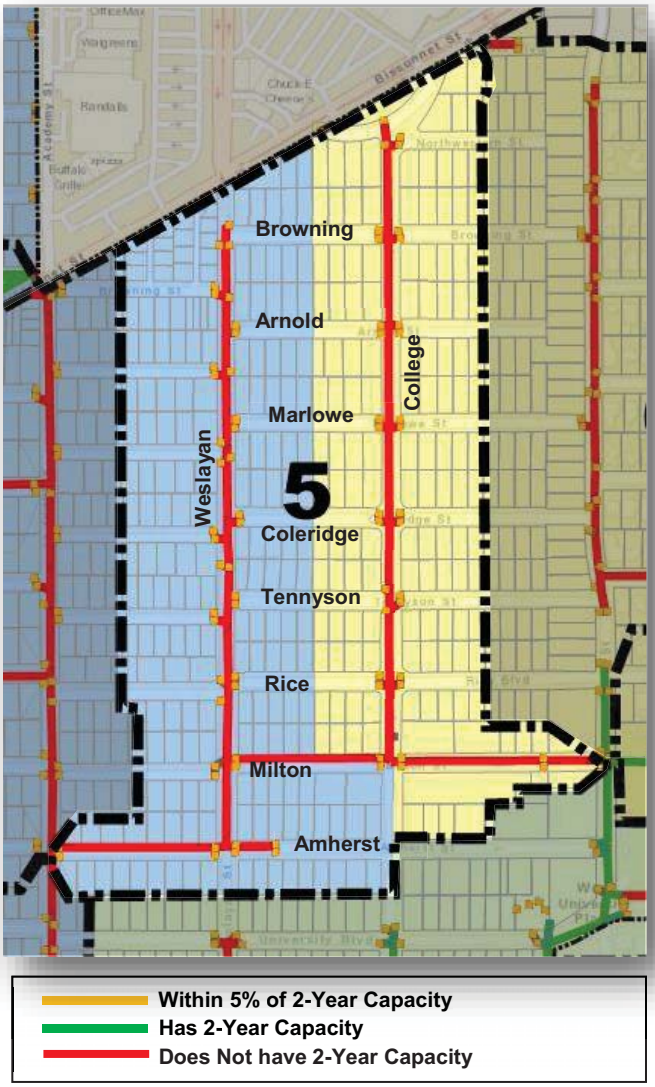


Figure 25: Planning Area #5

Planning Area 6

This planning area covers a total area of approximately 51 acres. Approximately 85% of the existing storm sewer pipe within Planning Area 6 does not meet the 2-year capacity criterion. Roadway rehabilitation work was previously completed for this planning area, and thus only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed.

The opinion of probable cost developed for Planning Area 6 indicates a total cost of $2,600,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

Figure 26: Planning Area #6

Planning Area 7

This planning area covers a total area of approximately 57 acres. Approximately 88% of the existing storm sewer pipe within Planning Area 7 does not meet the 2-year capacity requirement. Roadway rehabilitation work was previously completed for this planning area, and thus only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed.

The opinion of probable cost developed for Planning Area 7 indicates a total cost of $2,700,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

Figure 27: Planning Area #7

Planning Area 8

This planning area covers a total area of approximately 70 acres. Approximately 20% of the existing storm sewer pipe within Planning Area 7 does not satisfy the 2-year capacity criterion. Roadway rehabilitation work was previously completed for this planning area, and thus only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed.

The opinion of probable cost developed for Planning Area 8 indicates a total cost of $2,000,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

Figure 28: Planning Area #8

Planning Area 9

This planning area covers a total area of approximately 60 acres. Approximately 70% of the existing storm sewer pipe within Planning Area 9 does not meet the 2-year capacity requirement. Roadway rehabilitation work was previously completed for this planning area, and thus only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed. Note that improvements to the existing Buffalo Speedway trunk line are not included in the proposed Planning Area 9 improvements. Those trunk line improvements are treated as a separate project. Information on trunk line projects may be found in the Trunk Line Projects section of this report and in Attachment E.

The opinion of probable cost developed for Planning Area 9 indicates a total cost of $2,800,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

Figure 29: Planning Area #9

Planning Area 10

Planning Area 10 covers a total area of approximately 39 acres. Approximately 71% of the existing storm sewer pipe within Planning Area 10 does not satisfy the 2-year capacity requirement. Roadway rehabilitation work was previously completed for this planning area, and thus only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed. Note that improvements to the existing Buffalo Speedway trunk line are not included in the proposed Planning Area 10 improvements. Those trunk line improvements are treated as a separate project. Information on trunk line projects may be found in the Trunk Line Projects section of this report and in Attachment E.

The opinion of probable cost developed for Planning Area 10 indicates a total cost of $2,800,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

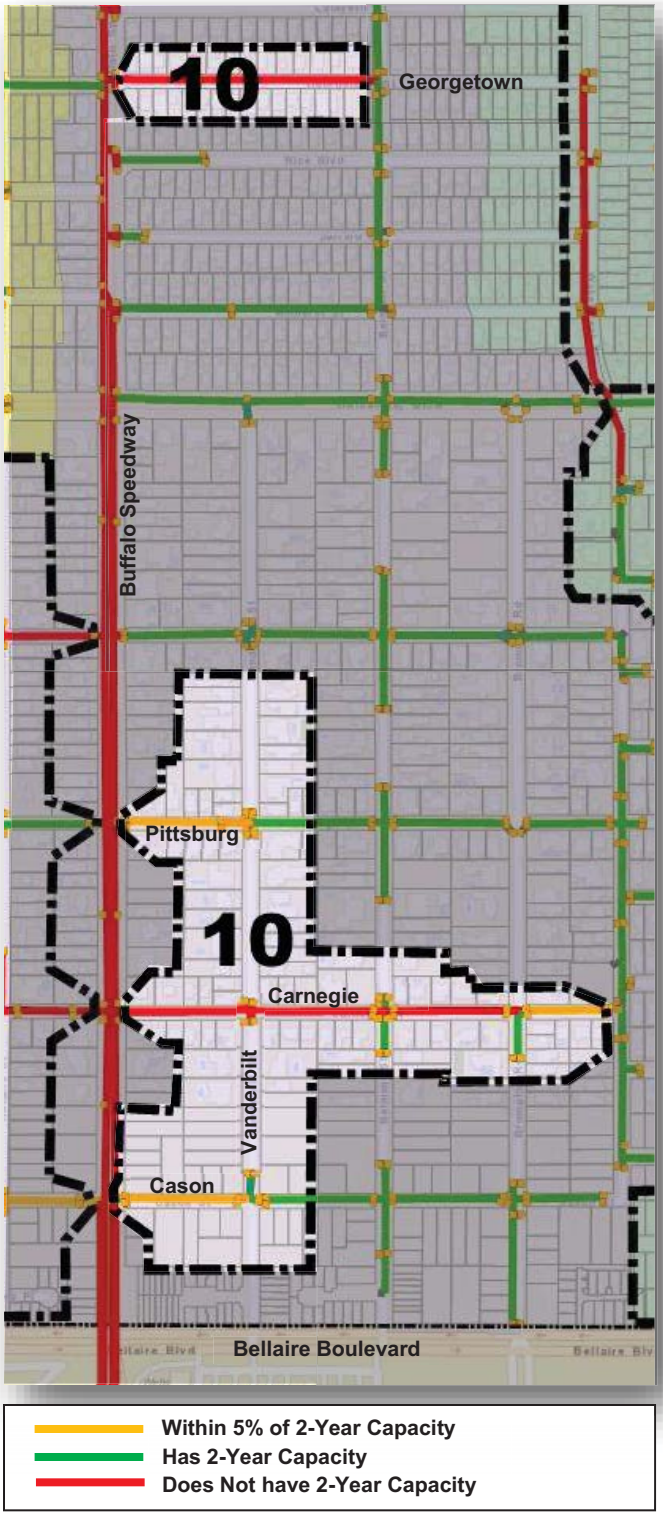


Figure 30: Planning Area #10

Planning Area 11

This planning area covers a total area of approximately 43 acres. Approximately 59% of the existing storm sewer pipe within Planning Area 11 does not satisfy the 2-year capacity requirement. Roadway rehabilitation work was previously completed for this planning area, and thus only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed.

The opinion of probable cost developed for Planning Area 11 indicates a total cost of $3,100,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

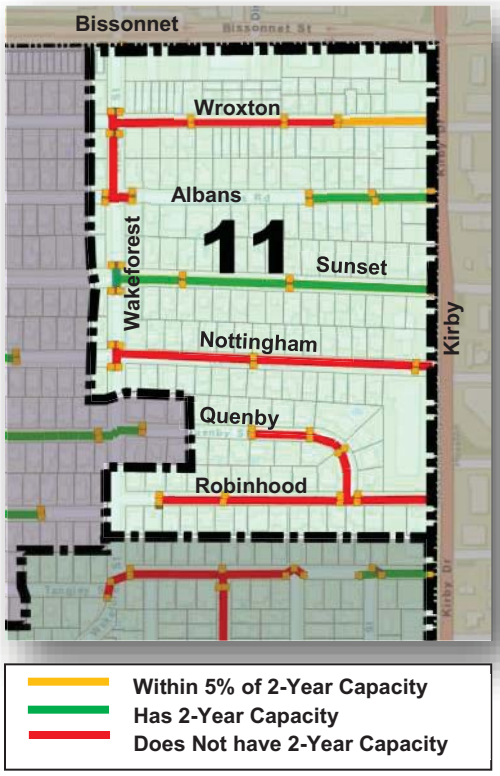


Figure 31: Planning Area #11

Planning Area 12

This planning area covers a total area of approximately 54 acres. Approximately 70% of the existing storm sewer pipe within Planning Area 12 does not satisfy the 2-year capacity requirement. Roadway rehabilitation work was previously completed for this planning area, and thus only the removal and replacement of existing pavement required in connection with the proposed storm sewer upgrades will be completed.

The opinion of probable cost developed for Planning Area 12 indicates a total cost of $3,700,000 excluding detention. Attachment D provides details on the development of an opinion of probable cost for each planning area.

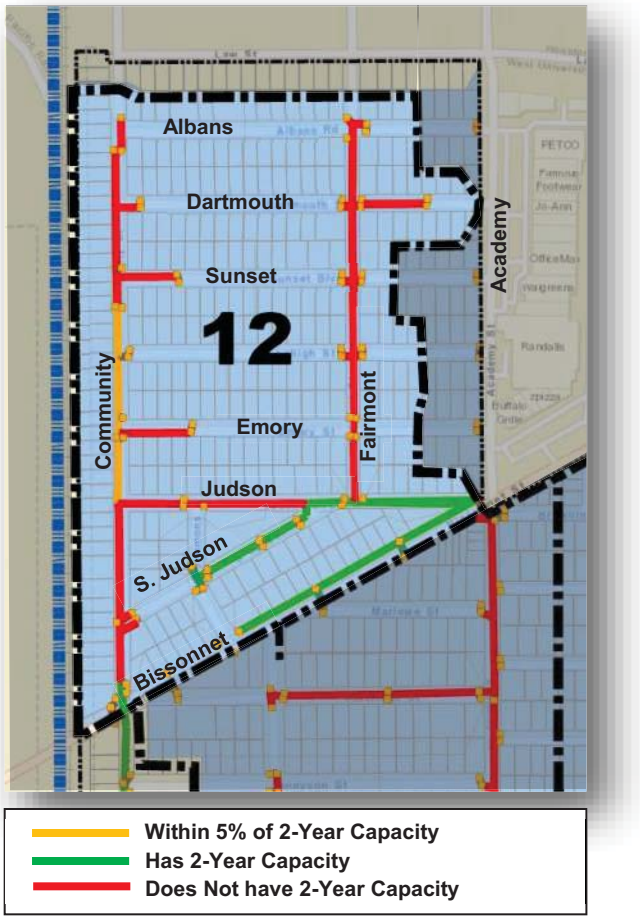


Figure 32: Planning Area #12

Opinions of Probable Construction Cost for Planning Areas

The probable costs of construction for Planning Areas 1 through 12 are summarized in the table at right. The figure below illustrates the locations and extents of the various planning areas identified in connection with the city-wide study.

The costs presented here account for drainage improvements, ancillary pavement removal and replacement, and roadway rehabilitation work in Planning Areas 1, 2, and 3. Note that these costs do not account for detention. Additionally, these costs do not account for improvements to the trunk lines along Academy Street, Buffalo Speedway, or the shared system within the College Avenue drainage area.

Planning Area	Probable Cost
1	$6,900,000
2	$8,400,000
3	$9,400,000
4	$3,300,000
5	$4,500,000
6	$2,600,000
7	$2,700,000
8	$2,000,000
9	$2,800,000
10	$2,800,000
11	$3,100,000
12	$3,700,000
Sub-Total	**$52,200,000**
Off-Site Detention	**TBD**

Table 2: Probable Costs for Planning Areas 1 – 12

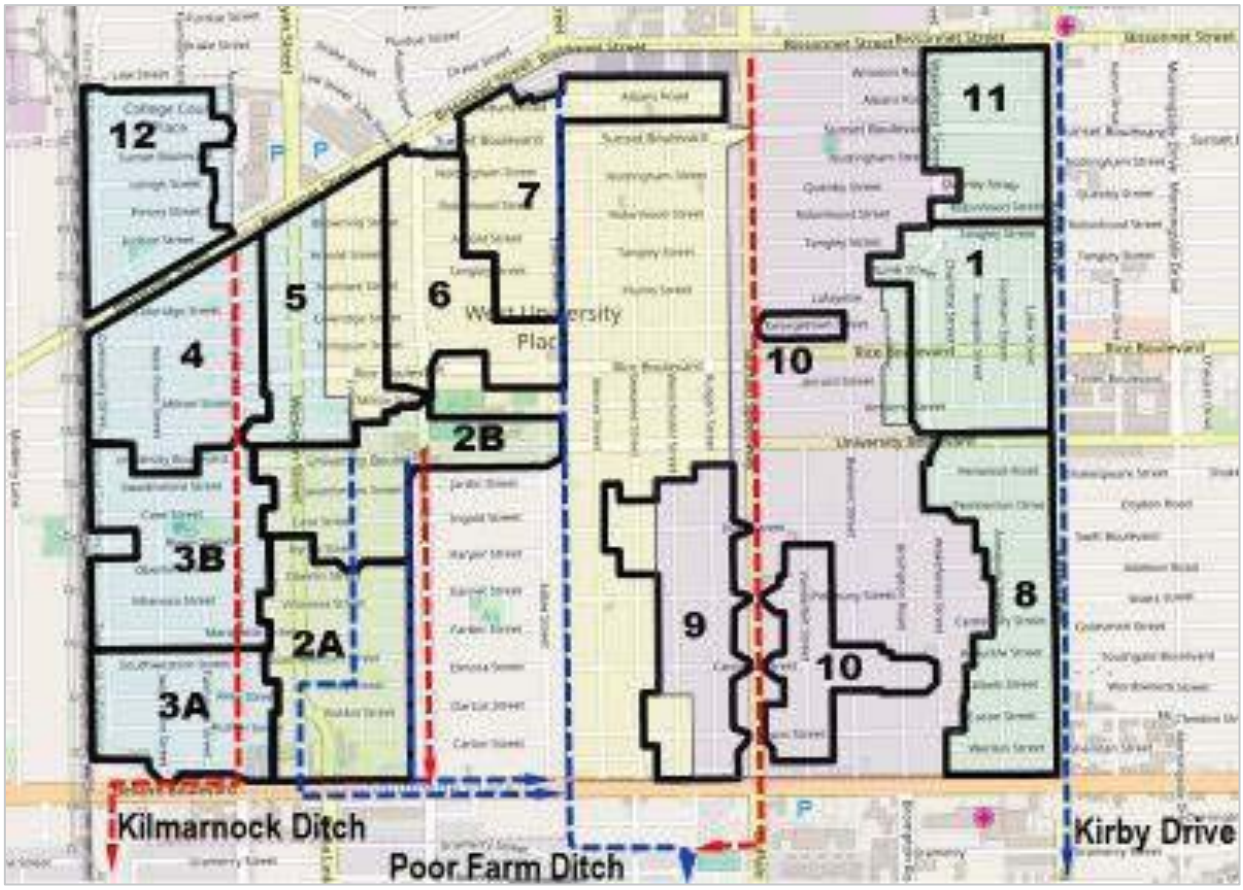


Figure 33: Planning Area Locations & Extents

Trunk Line Projects

The storm sewer capacity upgrades proposed for tributary systems in Planning Areas 1 through 12 will be fully utilized only when the receiving trunk lines in the Academy Street, Buffalo Speedway, College Avenue/Shared System areas are also improved to satisfy the 2-year design criteria. This section of the report describes the storm sewer trunk line improvements that are required to achieve this goal. Details regarding the opinions of probable cost referenced in this section of the report may be found in Attachment E to this report.

Academy Street

Academy Street has an average width of 27 feet and houses the main trunk line for the Academy Street drainage area. That trunk line drains areas within the City of Houston as well as a significant portion of West University Place. As discussed in the Major Drainage Areas section of this report, a recent analysis indicates that the main trunk line along Academy Street does not provide the minimum 2-year design capacity as currently defined.

Three options were identified for satisfying the infrastructure improvement requirements for the Academy Street storm sewer trunk line. The **Base Option** calls for the existing trunk line to be removed and replaced along the existing alignment, which follows Academy Street to Bellaire Boulevard, and then Bellaire Boulevard to Kilmarnock Ditch. **Alternative #1** to the Base Option calls for a new, supplemental storm sewer system to be constructed along the western boundary of West University Place, while **Alternative #2** to the Base Option calls for a supplemental system to be constructed along Community Drive.

The **Base Option**, which would involve an upgrade of the existing Academy street trunk line along the existing alignment to satisfy 2-year capacity requirements, has a probable cost of approximately $14,700,000. Error! Reference source not found. shows the base alignment along Academy Street. Following is

Figure 34: Existing Academy Street Storm Sewer

a list of pros and cons associated with the base option.

- Base Option Advantages
  - Preserves Existing Drainage Patterns
  - Takes Advantage of General West to East Slope in Existing Topography
  - Potential for a Phased Approach to Coincide with Planning Areas 3A, 3B, & 4
- Base Option Disadvantages
  - An Existing Duct Bank is Present Within the Easement
  - Additional Detention Requirements for Trunk Line Improvement
  - Disruption to Traffic on a "Through" Street with Significant Traffic
  - Maximizes Work Along Bellaire Boulevard in City of Houston

Alternative #1 to the base option involves the installation of new storm sewers along an existing pipeline easement located just west of the western boundary of the City. For this alternative, some of the runoff from the Academy Street drainage area would be redirected from the existing trunk line, which would remain in place along Academy Street, into the new supplemental relief trunk line along the pipeline easement, reducing or eliminating hydraulic overloading of the existing trunk line for the 2-year design storm event. This approach would allow the combined Academy Street system to provide the required 2-year capacity.

Alternative #1 has a probable cost of approximately $6,700,000 and is the City's preferred alignment based on the benefits cited below. However, it should be noted that this cost does not account for acquisition of the pipeline property or an easement. Real estate requirements, including property acquisition, are difficult to predict and can significantly alter the estimated probable cost of construction. Additional complications may arise in connection with co-locating a large trunk line storm sewer in close proximity to existing pipelines. Following is a list of pros and cons associated with this alternative.

- Alternative #1 Advantages
  - Apparent Lower Probable Cost of Construction

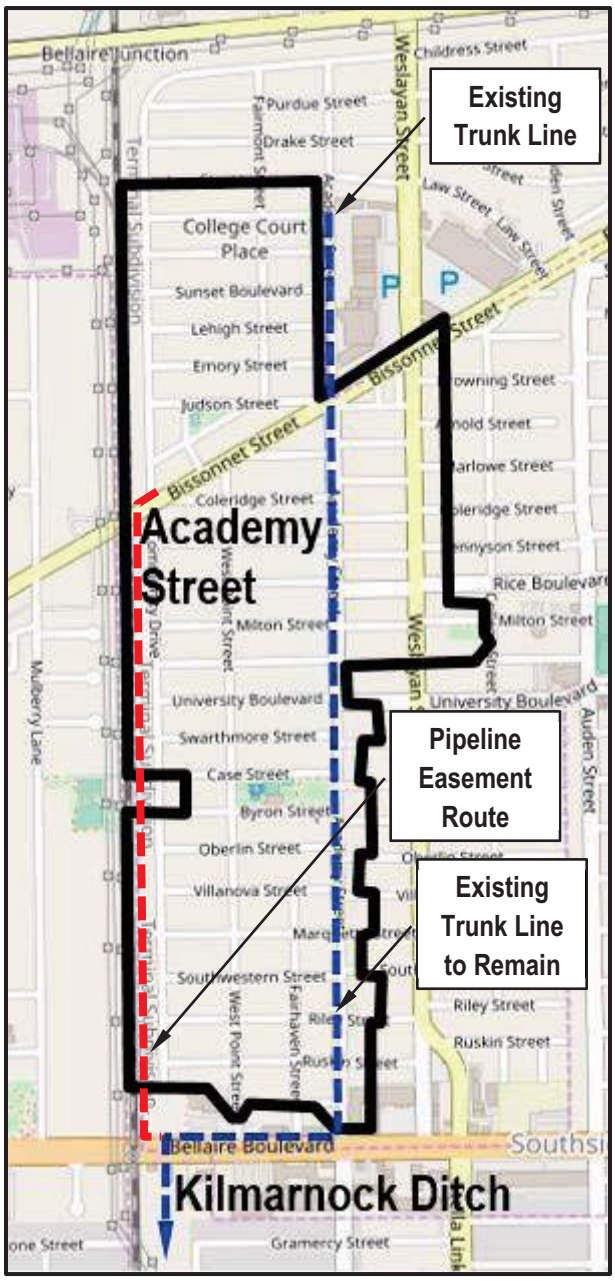
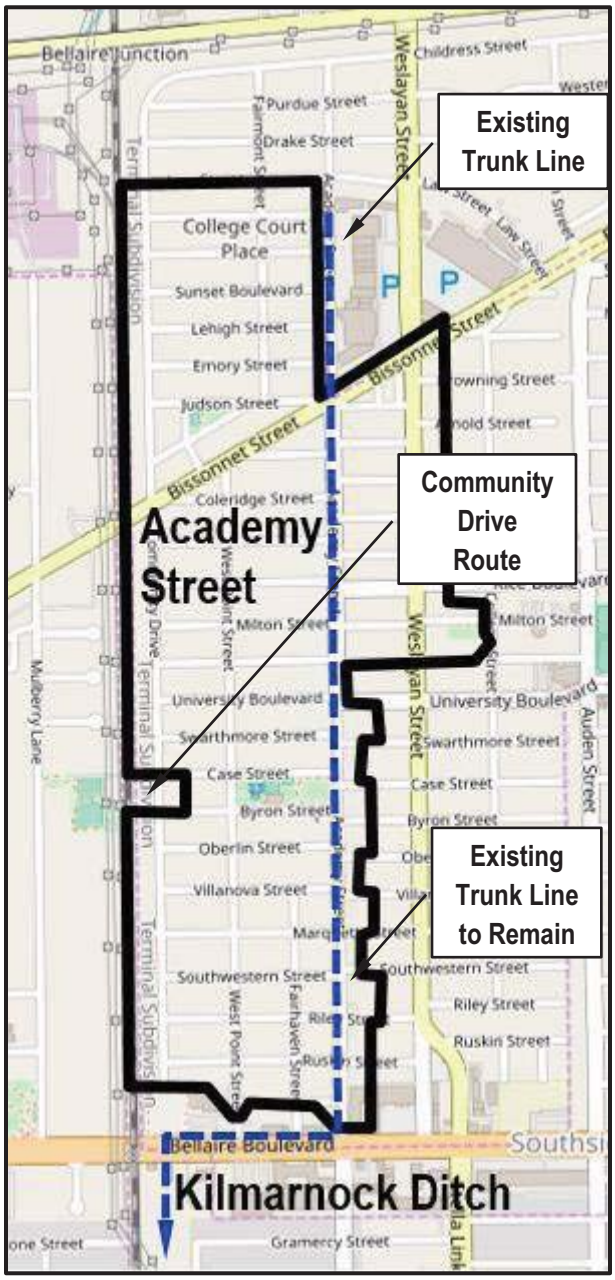


Figure 35: Alternative #1 - Pipeline Route

- Minimal Disruption for Residents along Academy Street
- Reduces Work along Bellaire Boulevard
- Potential for Linear Detention
- Potential for Open Recreational Space
- Potential for a Phased Approach to Coincide with Planning Areas 3A, 3B, & 4

- Alternative #1 Disadvantages
  - One or More Crude Oil Lines are Present Within the Easement
  - Close Proximity to Railroad Tracks and Trains
  - Existing Residential Encroachments on Easement must be Resolved
  - Additional Detention Requirements for Trunk Line Improvement
  - May Require Property Acquisition, Drainage Easements, Construction Easements, and Other Permits

Alternative #2 would involve the construction of a "relief trunk line" along Community Drive near the western boundary of the City of West University Place, utilizing portions of existing infrastructure. Similar to Alternative #1, some of the runoff from the Academy Street drainage area would be redirected from the existing trunk line into the new supplemental trunk along Community Drive to provide adequate combined capacity for the expanded system to accommodate the 2-year design storm event.



The opinion of probable construction cost for Alternative #2 is approximately $10,500,000, higher than the cost of Alternative #1, primarily due to removal and replacement of street paving, which is avoided for Alternative #1. Following is a list of pros and cons associated with this alternative.

- Alternative #2 Advantages
  - Lower Probable Cost of Construction than the Base Option
  - Minimal Disruption for Residents along Academy Street
  - Minimizes Work along Bellaire Boulevard
  - Potential for a Phased Approach to Coincide with Planning Areas 3A, 3B, & 4

- Alternative #2 Disadvantages
  - Additional Detention Requirements for Trunk Line Improvement
  - Significant Disruption to Residents Along Community Drive

- Work Space is More Limited / Restricted

Figure 36: Alternative #2 - Community Drive Route

Following is a summary of opinion of probable cost values for the various alternatives. Again, it should be noted that the probable cost for **Alternative #1** does not include property acquisition costs or costs associated with removing any obstructions or encroachments from the pipeline easement. It is recommended that alternatives for grant funding be evaluated and pursued as appropriate. Also note that off-site detention costs are not included in the estimated probable costs for either the **Base Option**, **Alternative #1**, or **Alternative #2**.

- **Base Option** (Construction Along Academy Street): $14,700,000
- **Alternative #1** (Construction Along Pipeline Easement): $ 6,700,000
- **Alternative #2** (Construction Along Community Drive): $10,500,000

College Avenue / Shared System

The content of this section is related to previous drainage planning and feasibility investigations performed in the initial stages of Phase I for the nine (9) dead-end streets that drain to an existing storm sewer system located along the shared corporate boundary between West University Place and Southside Place. The aforementioned effort is documented in a July 6, 2017 report titled "*Drainage Evaluation for Dead-End Streets*" (Appendix D). The report concludes that the "existing shared storm sewer system along the corporate boundary between the cities of West University Place and Southside Place lacks capacity to accommodate a standard 2-year storm event." Specifically, the existing shared system is under capacity between Case Street and Bellaire Boulevard.

The recommended improvement alternative involves the construction of a new parallel system along Auden Street within the City of Southside Place, with the existing shared system left in place. Auden Street is located just to the east of, and parallel to, the shared boundary between West University Place and Southside Place. It runs in the north-south direction and is approximately 27 feet wide and 3,150 feet long between University and Bellaire Boulevards. The addition of the Auden Street system provides additional capacity needed to accommodate the 2-year storm. The connection of inlets along Auden Street to the shared system would be eliminated under this plan.

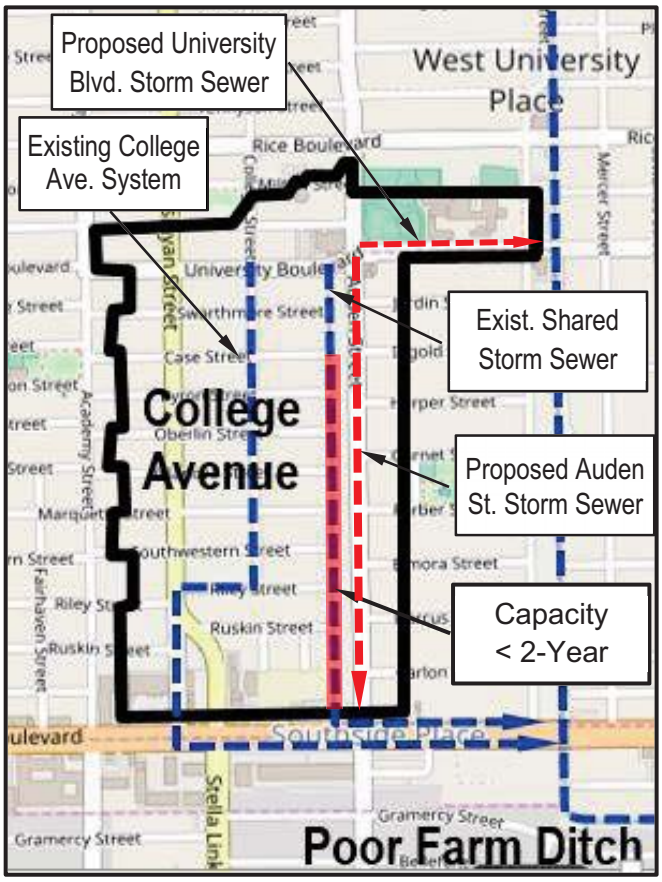


Figure 37: Proposed Auden St. Trunk Line Project

A variant to this recommendation involves the construction of a new storm sewer along University Boulevard in addition to the proposed new storm sewer along Auden Street. The

opinion of probable cost is approximately $3,100,000 with the additional West University storm sewer included. **Figure 37** illustrates the proposed Auden Street storm sewer alignment.

Buffalo Speedway

The results of the city-wide drainage assessment (Phase 1 study as previously described) indicated that the existing Buffalo Speedway drainage system does not have sufficient capacity to accommodate a 2-year design storm event. Improvements are required to bring the system up to 2-year design capacity. In the Phase 2 study, an improvement plan was developed using detailed 2D modeling techniques to analyze the existing trunk line system and proposed improvements to that system. The approach taken with regard to the Buffalo Speedway improvements was to leave existing 66-inch to 72-inch storm sewers in place and to incorporate flow regulators into a proposed new box culvert storm sewer system to provide in-line detention storage. The existing single 66-inch storm sewer pipe crossing Bissonnet Street was assumed to be left in place to regulate flows into West University Place from the City of Houston.

Similarly, the existing dual 66-inch storm sewers that pass through the Saint Vincent de Paul Catholic Church property and connect Buffalo Speedway storm sewer to Poor Farm Ditch were assumed for the purposes of analysis to be replaced with new, dual 66-inch pipes or hydraulically equivalent storm sewers to regulate discharges into Poor Farm Ditch. For the purposes of cost estimating, however, the existing dual 66-inch pipes were assumed to be replaced with dual 8’ x 8’ box culverts that provide full 2-year design capacity at a flow velocity of 3 feet per second, consistent with the rest of the Buffalo Bayou trunk line system. This covers a possible future condition in which the provision of off-site detention would Buffalo Speedway flow regulators to be removed. **Figure 38** illustrates the alignment of the Buffalo Speedway storm sewer.

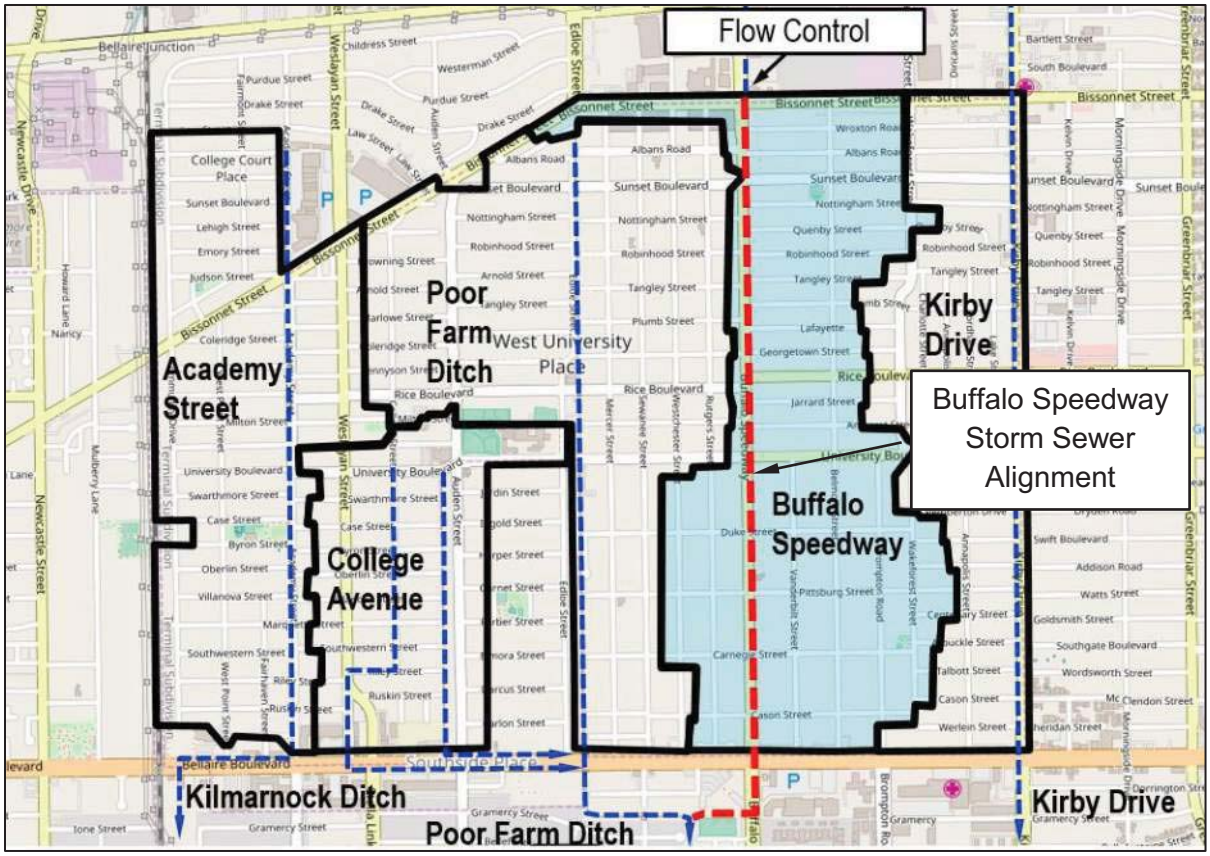


Figure 38: Buffalo Speedway Trunk Line Project

Figure 39 illustrates the basic approach developed with regard to the placement of new storm sewers between the existing storm sewer systems located on either side of Buffalo Speedway.

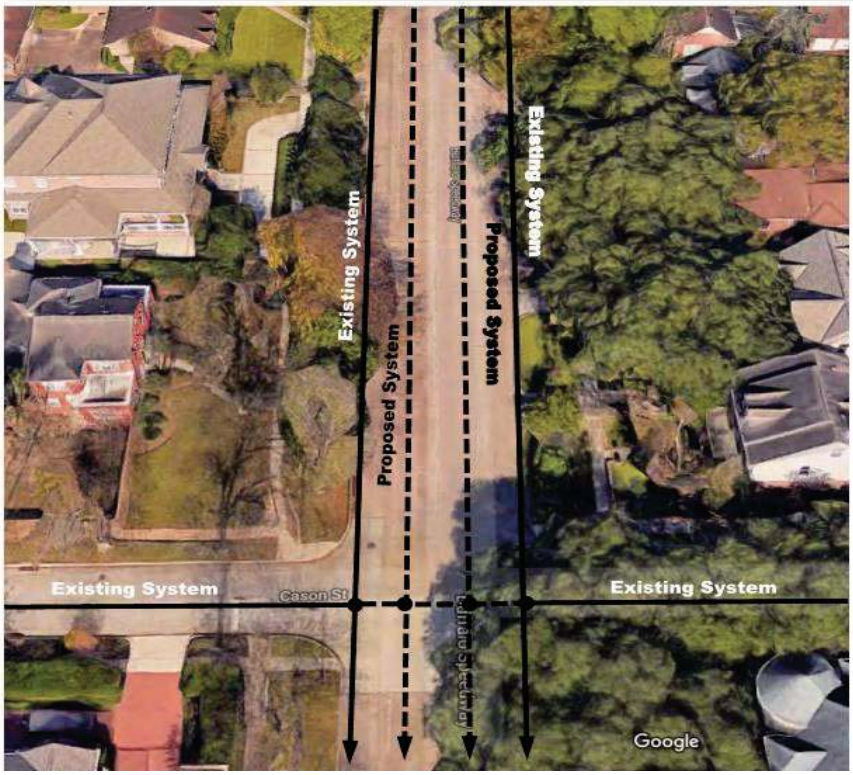


Figure 39: Proposed Placement of New Buffalo Speedway Storm Sewers

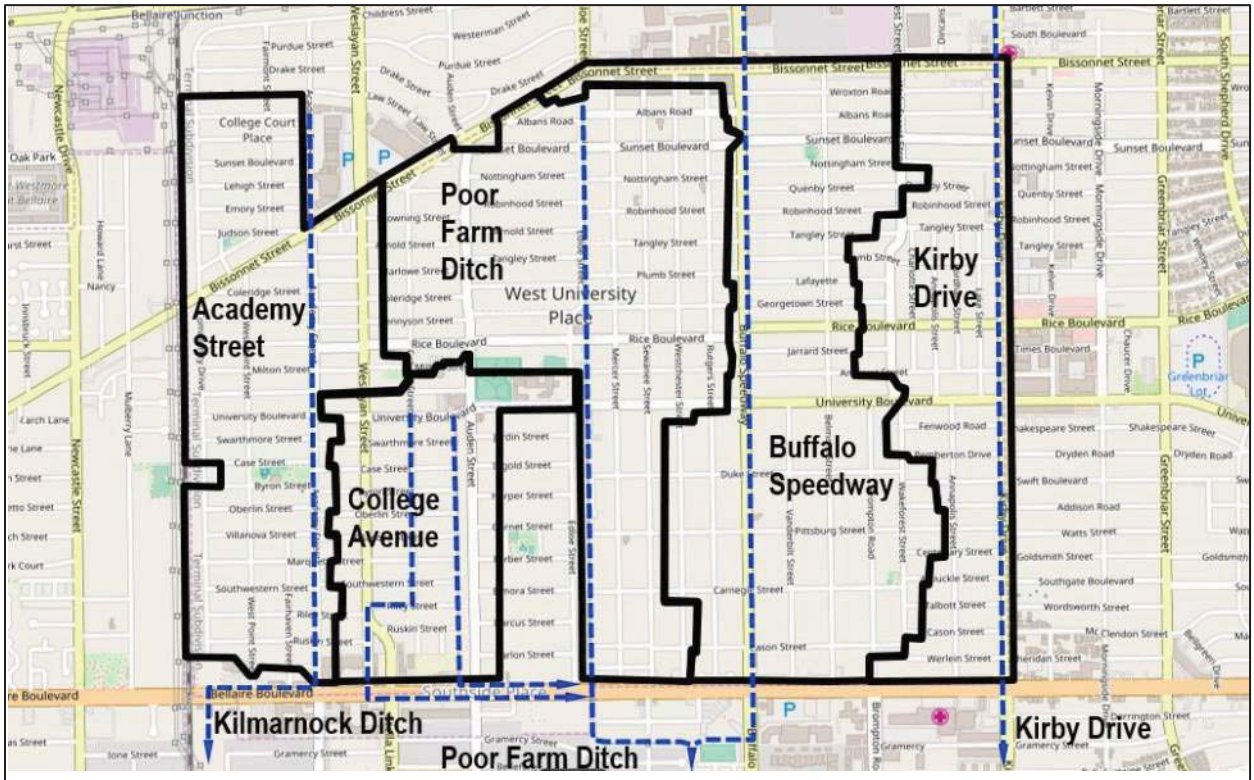
The Buffalo Speedway drainage analysis, results, and conclusions are presented in a draft October 19, 2018 report titled "*Buffalo Speedway Improvements – Drainage Preliminary Engineering Report*" (Appendix A). The preliminary opinion of probable cost for drainage improvements is approximately $15,200,000, for the full project from Bissonnet to Poor Farm Ditch. The City of West University Place has secured Transportation Improvement Program (TIP) funding for this project through the Houston-Galveston Area Council (H-GAC), and design work for the project is scheduled to begin in 2018. The TIP funding covers roadway work, including all paving, curbs, inlets, and appurtenant structures directly related to roadway construction, but does not cover the construction of the underground storm sewer trunk line. The initial estimate of probable cost for roadway construction is $12,500,000. Combining the drainage and roadway costs yields the following estimate of total probable cost. The City plans to pursue additional grant funding for the drainage portion of the project.

- **Drainage Cost ……... $15,200,000**
- **Pavement Cost …… $12,500,000**
- **Total Cost …….. $27,700,000**

Note that the probable cost includes in-line storage, but does not include detention storage that may be required should the City decide in the future to modify the Buffalo Speedway system in such a manner as to eliminate the provided in-line storage.

Detention Requirements

Detention is required when new development or drainage improvements increase the efficiency of existing drainage systems, reducing the time required for an area to drain and increasing the rate of runoff from that area. When downstream drainage systems cannot accommodate runoff from a 100-year storm event, any increase in downstream flow rates must typically be mitigated through the provision of detention storage. The 100-year storm is utilized in these situations as the generally accepted standard of care in the Greater Houston area. Most of the storm sewer system improvements previously described in this report will not operate at full capacity until trunk line improvements are completed. When those trunk line improvements are completed (or in the case of Buffalo Speedway, when flow regulators are removed), storm water detention will generally be required to compensate for the increased efficiency of the West University Place drainage systems and the resulting increases in downstream flow rates. **Figure 40** provides an estimate of estimated detention requirements based on proposed drainage improvements throughout the City and the assumption that detention will eventually be required for all areas within the City.



Drainage Area	West U Area (acres)	Required Detention (acre-feet)
Academy	272	32.6
College/Shared	157	18.8
Poor Farm	339	40.7
Buffalo Spdwy.	360	43.2
Kirby Drive	190	22.8
Totals	**1,318**	**158.1**

Note: Detention requirements are estimated using a standardized rate of 0.12 acre-foot of storage per acre of area where existing storm sewers are brought up to the 2-year design standard and flow constraints and restrictions between the affected area and outfall channel are effectively eliminated.

Figure 40: Potential Long-Term Detention Requirement for Each Major Watershed

As noted in **Figure 40**, the total estimated long-term detention storage requirement for the City is approximately 158 acre-feet.

Detention storage is typically provided in three ways:

1. as in-line detention created by oversizing storm sewers;
2. as on-site detention provided on a development site in the form of a small pond; or
3. as off-site detention provided on a remote property in the form of a large regional detention pond.

In-line detention is typically expensive, but in some cases (such as the Buffalo Speedway project), it can be cost-effective due to the scarcity of land suitable for creating detention facilities. Because West University Place is basically fully developed, there is little room for on-site detention facilities within the corporate limits of the City. This leaves off-site regional or sub-regional detention, which must be coordinated with the Harris County Flood Control District, the City of Houston, and other entities within the Brays Bayou watershed. HDR has completed preliminary investigations into the use of the Ruffino Hills property co-owned by the City of West University Place and the City of Bellaire and the Willow Waterhole Bayou regional detention facility operated by the Harris County Flood Control District. However, no specific plans or recommendations have been identified to date with regard to the establishment of off-site, regional detention facilities for use by the City of West University Place.

Storage may be provided via the creation of a new regional facility or the expansion of an existing regional facility. Detention costs have not been estimated for this report, but it should be noted that detention costs may be substantially reduced if land acquisition requirements can be reduced, or if land can be acquired at a relatively low cost. The general recommendation developed with regard to detention is for the City of West University Place to continue to coordinate with the Harris County Flood Control District and City of Houston regarding the possible use of the Ruffino Hills property, the Willow Waterhole regional detention site, or other existing or proposed regional facility to accommodate West University's detention requirements. Regional detention can typically be implemented at a substantially lower cost than linear detention or multiple project-based detention facilities.

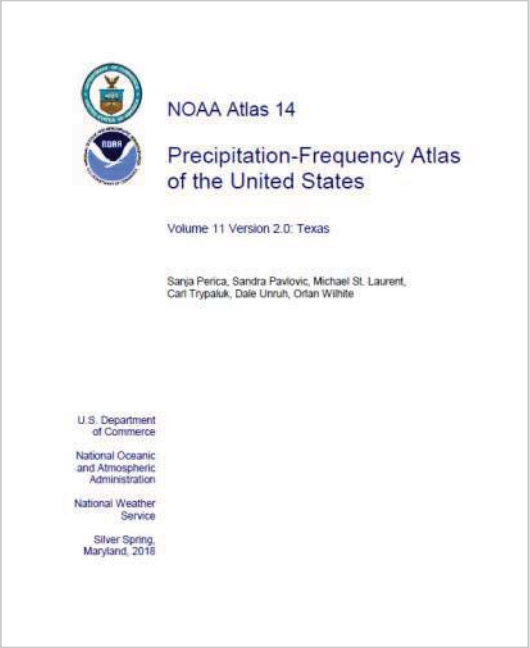
NOAA Atlas 14

The National Oceanic and Atmospheric Administration (NOAA) published "Atlas 14, Volume 11 Precipitation-Frequency Atlas of the United States, Texas" in October 2018, after the studies referenced in this report had been completed. This publication provides updated rainfall data for storm events ranging from the 2-year through 1000-year recurrence interval and from 5-minute to 60-day duration. NOAA Atlas 14 rainfall depths are generally higher than values previously published by the National Weather Service and U.S. Geological Survey, as indicated in the following table.

Summary of Rainfall Totals Pre-NOAA Atlas 14 and NOAA Atlas 14									
Duration	***5-min***	***15-min***	***30-min***	***1-hour***	***2-hour***	***3-hour***	***6-hour***	***12-hour***	***1-day***
Pre-NOAA Atlas 14 Data									
2-Year	0.7	1.1	1.5	2.0	2.3	2.6	3.1	3.7	4.4
100-Year	1.2	2.1	3.0	4.3	5.7	6.7	8.9	10.8	13.2
NOAA Atlas 14 Data									
2-Year	0.58	1.17	1.67	2.22	2.79	3.13	3.75	4.40	5.11
100-Year	1.26	2.49	3.48	4.78	6.89	8.48	11.30	14.00	14.90

The latter sources and "pre-Atlas 14" rainfall have been used in the Houston area for many years for drainage infrastructure design. The pre-Atlas 14 data were used for the studies described in this report. Local agencies, including the Harris County Flood Control District (HCFCD), the Harris County Engineering Department, and the City of Houston, are reviewing Atlas 14 rainfall data for possible use in County and City projects. While no definitive decision has been made as of the date of this report as to exactly how the Atlas 14 data will be applied to drainage infrastructure design, recent communications with persons familiar with the ongoing review process indicate that Atlas 14 data will be used without modification.

In order to account for the potential adoption of Atlas 14 and use of increased rainfall values in the future, an "Atlas 14" adjustment of 5% has been developed opinions of probable cost generated for Planning Areas 1 through 12. This value was computed by evaluating the percent increase in rainfall depth for storm durations of 15 minutes to 60 minutes (durations for which most local storm sewer systems are designed), which averages approximately 10%. This factor was applied to all drainage items in each opinion of probable cost (street repairs were assumed not to be affected by the change in rainfall values), which average about 50% of the total cost. The Atlas 14 adjustment is not applied to Trunk Line projects, as the methods used for those projects to establish drainage requirements and costs were more stringent and somewhat more conservative than those applied to the local planning area systems.


NOAA Atlas 14

Precipitation-Frequency Atlas of the United States

Volume 11 Version 2.0: Texas

Sanja Perica, Sandra Pavlovic, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Orlan Wilhite

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

National Weather Service

Silver Spring, Maryland, 2018

Conclusion

The results of the city-wide drainage study indicate that about one-half of the total length of storm sewer pipe within the City of West University Place does not satisfy the current 2-year capacity standard. Trunk lines along Academy Street and Buffalo Speedway, in addition to the shared system along the boundary between West University Place and Southside Place, are undersized and in need of improvement. In order to facilitate the planning, funding, and implementation of drainage projects within the City in manageable stages or phases, twelve (12) Planning Areas have been established around the city, and a number of separate trunk line improvement projects have been identified. Estimated probable costs associated with the general Planning Area upgrades to tributary storm sewer systems and trunk line upgrades are summarized below.

Trunk Line Project Costs	
Academy Street (Base Option) ……...	$ 14,700,000
Shared System / Auden ……...	$ 3,100,000
Buffalo Speedway …….….	$ 15,200,000
**Sub-Total for Trunk Line Projects ..……..……	$ 33,000,000**
Planning Area Project Costs	
Planning Area #1 ……..……..	$ 6,900,000
Planning Area #2 ……..……..	$ 8,400,000
Planning Area #3 ……..……..	$ 9,400,000
Planning Area #4 ……..……..	$ 3,300,000
Planning Area #5 ……..……..	$ 4,500,000
Planning Area #6 ……..……..	$ 2,600,000
Planning Area #7 ……..……..	$ 2,700,000
Planning Area #8 ……..……..	$ 2,000,000
Planning Area #9 ……..……..	$ 2,800,000
Planning Area #10 ……..……..	$ 2,800,000
Planning Area #11 ……..……..	$ 3,100,000
Planning Area #12 ……..……..	$ 3,700,000
**Sub-Total for Planning Areas ..…….	$ 52,200,000**
Contingency for Update to NOAA Atlas 14 Rainfall	**$ 2,600,000**
Total for Trunk Lines & Planning Areas ……	**$ 87,800,000**
Future Detention Cost …….. $ TBD	
Total Project Cost ……..... $ TBD	

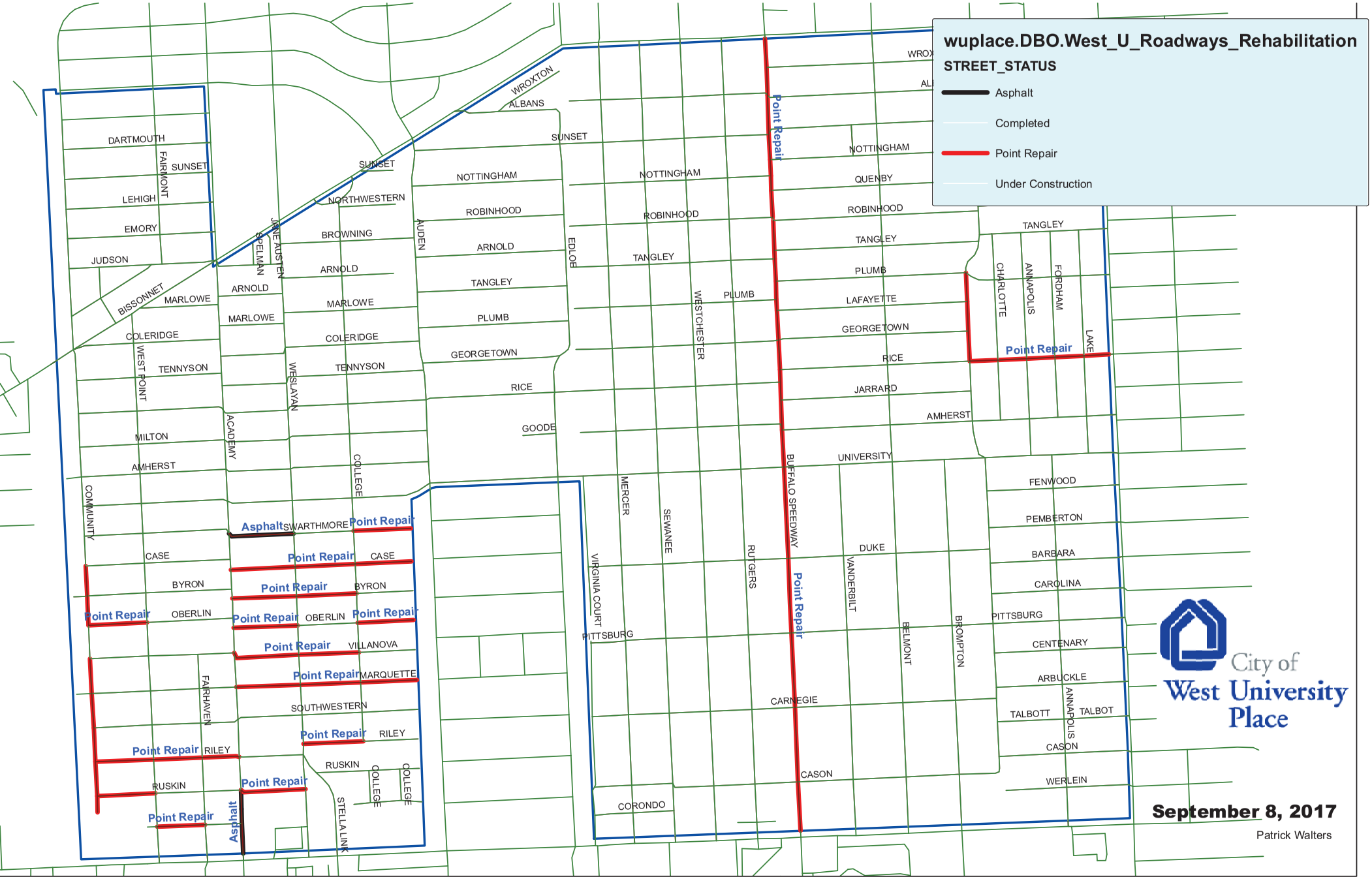
Note that these values do not include detention costs or property acquisition costs. Detention evaluations completed in 2016-17 indicate that properties of the size necessary to provide regional detention are not available within the City or within the immediate vicinity. Coordination with the City of Houston and Harris County Flood Control District may allow West University Place to negotiate terms regarding a regional detention arrangement that would prove beneficial and cost effective to West University.

Attachment

A

Roadway Rehabilitation Status

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264


wuplace.DBO.West_U_Roadways_Rehabilitation
STREET_STATUS
Asphalt
Completed
Point Repair
Under Construction
City of West University Place
September 8, 2017
Patrick Walters
DARTMOUTH
FAIRMONT
SUNSET
LEHIGH
EMORY
JUDSON
BISSONNET
MARLOWE
COLERIDGE
WEST POINT
TENNYSON
MILTON
AMHERST
COMMUNITY
CASE
BYRON
OBERLIN
FAIRHAVEN
RILEY
RUSKIN
ARNOLD
SELMAN
JANE AUSTEN
WESLAYAN
ACADEMY
BROWNING
NORTHWESTERN
SWARTHMORE
COLLEGE
VILLANOVA
MARQUETTE
SOUTHWESTERN
STELLA LINK
WROXTON
ALBANS
AUDEN
ROBINHOOD
TANGLEY
PLUMB
GEORGETOWN
RICE
GOODE
EDLOE
VIRGINIA COURT
PITTSBURG
CORONDO
MERCER
SEWANEE
WESTCHESTER
RUTGERS
BUFFALO SPEEDWAY
CARNEGIE
CASON
NOTTINGHAM
QUENBY
LAFAYETTE
JARRARD
UNIVERSITY
DUKE
VANDERBILT
BELMONT
BROMPTON
CHARLOTTE
ANNAPOLIS
FORDHAM
LAKE
FENWOOD
PEMBERTON
BARBARA
CAROLINA
CENTENARY
ARBUCKLE
TALBOTT
WERLEIN
Point Repair
Asphalt

Attachment

B

Fact Sheet - Poor Farm Ditch/Kilmarnock Ditch

Harris County Flood Control District

August 2014

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

HARRIS COUNTY FLOOD CONTROL DISTRICT

Fact Sheet

August 2014

Poor Farm Ditch/ Kilmarnock Ditch

BACKGROUND

Poor Farm Ditch (HCFCD Unit D111-00-00) and Kilmarnock Ditch (HCFCD Unit D113-00-00) are man-made drainage channels that carry stormwater from surrounding neighborhoods in southwest Harris County to Brays Bayou. Collectively, the channels provide drainage to portions of the cities of West University Place, Southside Place, Houston and Bellaire. Prompted by concerns of frequent street and house flooding, as well as failing infrastructure in Poor Farm Ditch, the Harris County Flood Control District, in 2002, initiated a regional drainage study for the two channels to investigate alternative improvements that might be considered. During the execution of the study, a stakeholders group comprised of representatives from the cities of West University Place, Southside Place, Houston and Bellaire, as well as representatives from the Braeswood Place Homeowners Association, was organized to help the Flood Control District formulate alternatives and assess community preferences regarding possible solutions. The study findings were published in 2004 in a report entitled the "Poor Farm & Kilmarnock Regional Study" (2004 Study).

FEASIBILITY STUDY

The study was directed by Flood Control District staff and supported by Claunch & Miller Inc., engineering consultants, and focused on the hydraulic capacity of Poor Farm Ditch and Kilmarnock Ditch and the constraints associated with these two channels. Poor Farm Ditch provides drainage to approximately 1,330 acres of highly developed watershed, and Kilmarnock Ditch provides drainage to 884 acres of highly developed watershed. The analysis considered stormwater flow that would be generated by both 10 percent (10-year) and 1 percent (100-year) rainfall events. Because of the two channels' close interface with Brays Bayou, and the ongoing federal flood damage reduction project ("Project Brays") sponsored by the US Army Corps of Engineers and the Flood Control District, the study had to consider stormwater detention volume needed to mitigate the potential impacts on Brays Bayou resulting from identified improvements on these two tributary channels.

Key findings from the 2004 Study included the following:

- Kilmarnock Ditch has adequate capacity to convey runoff from a 1 percent (100-year) storm event. However, the channel crossings at the Beechnut Street/North Braeswood Boulevard bridge, and at the Brays Bayou outfall, are inadequate and need to be enlarged.
- Poor Farm Ditch upstream of University Boulevard has adequate capacity to convey runoff from a 1 percent (100-year) storm event.
- Poor Farm Ditch downstream of Bellaire Boulevard to the confluence with Brays Bayou has more than 50 percent excess capacity to convey runoff from a 1 percent (100-year) storm event.
- The reach of Poor Farm Ditch between University and Bellaire boulevards is not adequate and would need to be enlarged by as much as 75 percent to convey runoff from a 1 percent (100-year) storm event.
- The Bellaire Boulevard bridge on Poor Farm Ditch needed to be widened because it was a constraint to stormwater conveyance.

The study concluded that, despite making the improvements to the reach of Poor Farm Ditch between University and Bellaire boulevards, the channel downstream of Bellaire Boulevard had more than adequate capacity to contain the increased flow within banks. No additional stormwater mitigation was necessary on Poor Farm Ditch.

However, the 2004 Study also concluded it would be necessary to mitigate the impacts of the proposed Poor Farm Ditch and Kilmarnock Ditch improvements on Brays Bayou by providing stormwater detention along Brays Bayou. It was estimated that 43 acre-feet of mitigation was necessary to mitigate impacts of the proposed Poor Farm Ditch improvements, and another 21 acre-feet for proposed Kilmarnock Ditch improvements.

SUBSEQUENT STUDIES

Following the 2004 Study, the Flood Control District undertook additional, more detailed studies of Poor Farm Ditch. It was determined that proposed improvements on the channel reach between University and Bellaire boulevards would be limited by right-of-way (ROW), and a 1 percent (100-year) channel design would not be possible without obtaining additional ROW. A 2009 study concluded that, if the proposed bridge and channel improvements were limited to fit within the existing ROW on Poor Farm Ditch, the mitigation could be reduced to 13.5 acre-feet. Combined with the 21 acre-feet needed to mitigate proposed Kilmarnock Ditch improvements, the revised volume for both Kilmarnock and Poor Farm Ditch is 34.5 acre-feet to mitigate impacts on Brays Bayou.

In 2010, the Flood Control District participated with the City of Houston in the construction of the Meyer Stormwater Detention Basin (HCFCD Unit D500-08-00), which created a total of 191 acre-feet of stormwater storage: 152 acre-feet for the City of Houston and 39 acre-feet for the District. This storage was eligible to be used for storm drainage mitigation projects between Fondren Road and State Highway 288, which included the proposed improvements on Poor Farm Ditch and Kilmarnock Ditch.

COLLEGE STREET STORM SEWER PROJECT/BELLAIRE BRIDGE AND RESTRICTOR REMOVAL

In 2007, the City of West University Place initiated construction of the College Street storm sewer project to improve local storm drainage. The storm sewer project did increase stormwater flow into Poor Farm Ditch; however, a hydraulic analysis proved that Poor Farm Ditch downstream of Bellaire Boulevard could accommodate the increased flows within the channel banks and without adverse impacts to Poor Farm Ditch. There was, however, an impact on Brays Bayou that required 13.5 acre-feet of storage to mitigate. For that reason, the Flood Control District required the City of West University Place to either restrict its outfall or provide 13.5 acre-feet of detention storage to offset the impacts on Brays Bayou. At that time, the District only had 4.4 acre-feet of storage in the Meyer Basin that was not already programmed and agreed to sell that to the City of West University Place in 2012 to mitigate a portion of the storm sewer project. As a result, a restrictor was installed on the College Street storm sewer outfall to Poor Farm Ditch until additional mitigation storage could be found.

In early 2008, the City of Southside Place launched the Bellaire Boulevard bridge replacement project. This project was identified in the 2004 study and determined to need 10.3 acre-feet of storage to mitigate impacts to Brays Bayou. This storage was secured in the Meyer Detention Basin in 2010.

KILMARNOCK DITCH STUDY

In 2013, the District further evaluated the stormwater detention requirements associated with Kilmarnock Ditch that were identified in the 2004 study. By conducting more detailed analyses that included field survey data and computer modeling, it was determined that under existing conditions the 1 percent (100-year) flows go over and through the existing dual culverts at the Brays Bayou outfall. The 2004 study did not consider the weir flow over the dual culverts which helps convey the existing 1% flows into Brays Bayou. For this reason, it was determined the 21 acre-feet stormwater mitigation requirement identified in the 2004 Study was not needed and could be used for other purposes. As a result of this finding, the District elected to sell an additional 9.1 acre-feet of capacity in the Meyer Basin to the City of West University Place, which along with the previously acquired 4.4 acre-feet, totaled 13.5 acre-feet or the amount needed to mitigate the College Street storm sewer project. In early 2014, the City of West University Place purchased the mitigation and subsequently removed the restrictor located at Bellaire Boulevard and Poor Farm Ditch.

MOVING FORWARD

After securing capacity in the Meyer Basin to mitigate the Bellaire Boulevard bridge replacement, the College Street storm sewer project, and determining that the previously reserved mitigation for Kilmarnock Ditch is no longer needed, the Flood Control District has just over 15 acre-feet of mitigation available at the Meyer Basin to offset future project impacts. Alternatives for improving Poor Farm Ditch from Bellaire Boulevard to University Boulevard have priority and are in the process of being further developed. This District will establish dates for future meetings to keep the stakeholder group informed and engaged as the alternatives are narrowed and the final design is initiated.

ABOUT THE HARRIS COUNTY FLOOD CONTROL DISTRICT

The Harris County Flood Control District provides projects that reduce flooding risks and damages, with appropriate regard for community and natural values. With more than 1,500 bayous and creeks totaling approximately 2,500 miles in length, the Flood Control District accomplishes its mission by devising flood damage reduction plans, implementing the plans and maintaining the infrastructure. To learn more about the Flood Control District, visit www.hcfcd.org

CONTACT US

To ask a question or to comment on the project, please contact the Harris County Flood Control District's Project and Study Information Line at 713-684-4040.

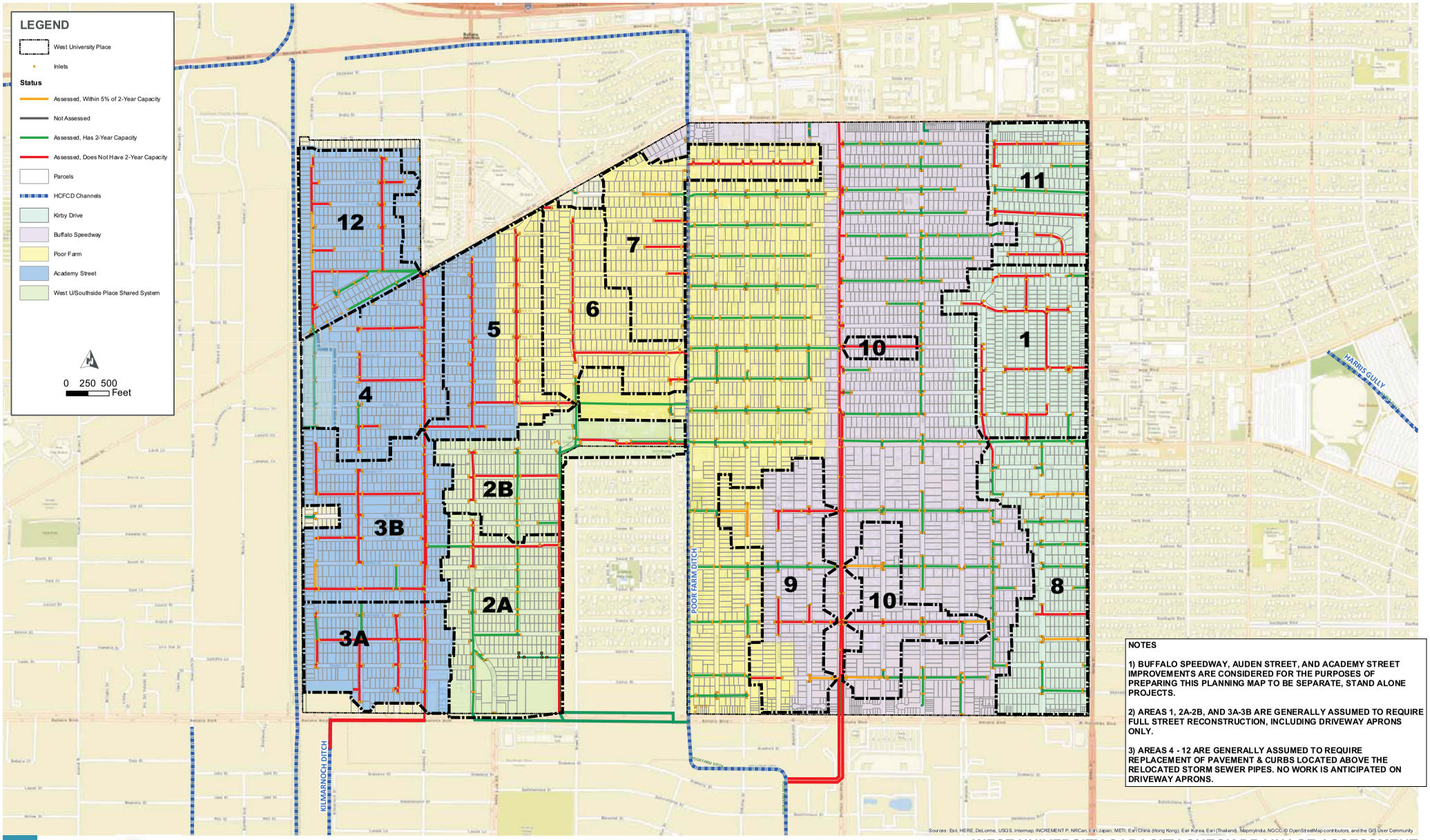
Attachment

C

Drainage Planning Area Map

City of West University Place

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264



NOTES

1) BUFFALO SPEEDWAY, AUDEN STREET, AND ACADEMY STREET IMPROVEMENTS ARE CONSIDERED FOR THE PURPOSES OF PREPARING THIS PLANNING MAP TO BE SEPARATE, STAND ALONE PROJECTS.

2) AREAS 1, 2A-2B, AND 3A-3B ARE GENERALLY ASSUMED TO REQUIRE FULL STREET RECONSTRUCTION, INCLUDING DRIVEWAY APRONS ONLY.

3) AREAS 4 - 12 ARE GENERALLY ASSUMED TO REQUIRE REPLACEMENT OF PAVEMENT & CURBS LOCATED ABOVE THE RELOCATED STORM SEWER PIPES. NO WORK IS ANTICIPATED ON DRIVEWAY APRONS.

HDR

City of West University Place

WEST UNIVERSITY CAPACITY CHECK DRAINAGE ASSESSMENT

CITY OF WEST UNIVERSITY

PATH: V:\WEST U\DRAINAGE AREA MAP 22X34.MXD - USER: JBLEVINS - DATE: 6/7/2018

Attachment

D

Opinions of Probable Cost for Planning Areas

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

Preliminary Opinion of Probable Constuction Cost (VE) for West University Place: Planning Area 1

PLANNING AREA 1					
LENGTH (FT)	9785		9	= No of Streets	
			193	= No. of Driveways	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 186,000.00	$ 186,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 74,500.00	$ 74,500.00
				SUB-TOTAL GENERAL ITEMS:	**$ 260,500.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	19,980.56	$ 13.00	$ 259,747.22
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	19,980.56	$ 70.00	$ 1,398,638.89
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	24,329.44	$ 12.00	$ 291,953.33
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	618.00	$ 165.00	$ 101,970.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	19,570.00	$ 8.00	$ 156,560.00
8	sum of:	S.Y.	6,437.00	$ 75.00	$ 482,775.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	9,650.00	$ 13.00	$ 125,450.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	124.00	$ 2,000.00	$ 248,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 3,065,094.44**
DRAINAGE ITEMS					
11	Remove existing storm sewer, all sizes and all depths, complete in place the sum of:	L.F.	6820	$ 30.00	$ 204,600.00
12	Remove existing storm sewer inlet/manhole, complete in place the sum of:	EA.	98	$ 600.00	$ 58,800.00
13	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	3575	$ 115.00	$ 411,125.00
14	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	950	$ 150.00	$ 142,500.00
15	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1420	$ 180.00	$ 255,600.00
16	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	585	$ 215.00	$ 125,775.00
17	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	250	$ 250.00	$ 62,500.00
18	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	700	$ 270.00	$ 189,000.00
19	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	250	$ 350.00	$ 87,500.00
20	66" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	260	$ 360.00	$ 93,600.00
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	76	$ 4,000.00	$ 304,000.00
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	0	$ 3,500.00	$ -
23	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	22	$ 4,500.00	$ 99,000.00
24	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	5945	$ 2.00	$ 11,890.00
25	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	2143	$ 2.50	$ 5,357.50
				SUB-TOTAL DRAINAGE ITEMS:	**$ 2,051,247.50**
	ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 5,376,841.94**
	15% CONTINGENCY:				**$ 806,526.29**
	TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 6,183,368.24**
	Design Engineering Services				**$ 494,669.46**
	Bid Phase Services				**$ 61,833.68**
	Construction Administration Services				**$ 61,833.68**
	Surveying Services				**$ 42,300.00**
	Geotechnical Services				**$ 36,100.00**
	Urban Forester				**$ 16,600.00**

OPCC INCLUDING PROFESSIONAL SERVICES:	**$ 6,896,705.06**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assume every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Construction Cost (VE) for West University Place: Planning Area 2

PLANNING AREA 2					
LENGTH (FT)	9628		11	*= No of Streets*	
			372	*= No. of Driveways*	
ITEM NO.	**ITEM DESCRIPTION**	**UNIT**	**QUAN.**	**UNIT PRICE**	**TOTAL AMOUNT**
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 203,500.00	$ 203,500.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 81,500.00	$ 81,500.00
				SUB-TOTAL GENERAL ITEMS:	**$ 285,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	29,313.94	$ 13.00	381,081.21
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	29,313.94	$ 70.00	2,051,975.72
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	34,194.32	$ 12.00	410,331.80
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	866.00	$ 165.00	142,890.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	21,961.70	$ 8.00	175,693.60
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	12,395.00	$ 75.00	929,625.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	18,583.33	$ 13.00	241,583.33
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	112.00	$ 2,000.00	224,000.00
				SUB-TOTAL PAVING ITEMS:	**4,557,180.66**
DRAINAGE ITEMS					
11	Remove existing storm sewer, all sizes and all depths, complete in place the sum of:	L.F.	5720	$ 300.00	$ 171,600.00
12	Remove existing storm sewer inlet/manhole, complete in place the sum of:	EA.	105	$ 600.00	$ 63,000.00
13	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	5110	$ 115.00	$ 587,650.00
14	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1545	$ 150.00	$ 231,750.00
15	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1050	$ 180.00	$ 189,000.00
16	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 215.00	$ -
17	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 250.00	$ -
18	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 270.00	$ -
19	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 350.00	$ -
20	66" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 360.00	$ -
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	84	$ 4,000.00	$ 336,000.00
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	0	$ 3,500.00	$ -
23	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	25	$ 4,500.00	$ 112,500.00
24	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	7830	$ 2.00	$ 15,410.00
25	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	0	$ 2.50	$ 272.50
				SUB-TOTAL DRAINAGE ITEMS:	**$ 1,707,182.50**
	ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 6,549,363.16**
	15% CONTINGENCY:				**$ 982,404.47**
	TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 7,531,767.64**
	Design Engineering Services				**$ 602,541.41**
	Bid Phase Services				**$ 75,317.68**
	Construction Administration Services				**$ 75,317.68**
	Surveying Services				**$ 32,800.00**
	Geotechnical Services				**$ 40,400.00**
	Urban Forester				**$ 18,900.00**
	OPCC INCLUDING PROFESSIONAL SERVICES:				**$ 8,377,044.40**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assume every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost (VE) for West University Place: Planning Area 3

PLANNING AREA 3				
LENGTH (FT)	14830		12	= *No of Streets*
			281	= *No. of Driveways*

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 250,000.00	$ 250,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 102,000.00	$ 102,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 352,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	29,230.00	$ 13.00	$ 379,990.00
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	29,230.00	$ 70.00	$ 2,046,100.00
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	35,821.11	$ 12.00	$ 429,853.33
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	910.00	$ 165.00	$ 150,150.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	29,660.00	$ 8.00	$ 237,280.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	9,358.00	$ 75.00	$ 701,850.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	14,033.33	$ 13.00	$ 182,433.33
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	148.00	$ 2,000.00	$ 296,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 4,423,656.67**
DRAINAGE ITEMS					
11	Remove existing storm sewer, all sizes and all depths, complete in place the sum of:	L.F.	9895	$ 30.00	$ 296,850.00
12	Remove existing storm sewer inlet/manhole, complete in place the sum of:	EA.	130	$ 600.00	$ 78,000.00
13	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	5620	$ 115.00	$ 646,300.00
14	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1025	$ 150.00	$ 153,750.00
15	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	917	$ 180.00	$ 165,060.00
16	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1007	$ 215.00	$ 216,505.00
17	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	260	$ 250.00	$ 65,000.00
18	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1167	$ 270.00	$ 315,090.00
19	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 350.00	$ -
20	66" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 360.00	$ -
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	105	$ 4,000.00	$ 420,000.00
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	0	$ 3,500.00	$ -
23	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	31	$ 4,500.00	$ 139,500.00
24	Trench safety for all storm sewers greater than 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	7562	$ 2.00	$ 15,124.00
25	Trench safety for all storm sewers greater than 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	2570	$ 2.50	$ 6,425.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 2,517,604.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 7,293,260.67**
15% CONTINGENCY:	**$ 1,093,989.10**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 8,387,249.77**
Design Engineering Services	**$ 670,979.98**
Bid Phase Services	**$ 83,872.50**
Construction Administration Services	**$ 83,872.50**
Surveying Services	**$ 49,600.00**
Geotechnical Services	**$ 54,400.00**
Urban Forester	**$ 24,900.00**
OPCC INCLUDING PROFESSIONAL SERVICES:	**$ 9,354,874.74**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section

[2] Sidewalk is assumed both sides of the street, but limited to 5 linear feet on either side of driveways

[3] All inlets are assumed to be Type BB

[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)

[5] Inlets at intersections were generally included in the E-W street

[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions

[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.

[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 4

STREET NAME	**Planning Area #4**			
LENGTH (FT)	4170	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	46	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	4	$ 25,000.00	$ 100,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	4	$ 10,000.00	$ 40,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 140,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	6,487	$ 13.00	$ 84,326.67
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	6,487	$ 70.00	$ 454,066.67
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	8,340	$ 12.00	$ 100,080.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	211	$ 165.00	$ 34,815.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	8,340	$ 8.00	$ 66,720.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,534	$ 75.00	$ 115,050.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	2300	$ 13.00	$ 29,900.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	48	$ 2,000.00	$ 96,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 980,958.33**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	4,170	$ 20.00	$ 83,400.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	44	$ 370.00	$ 16,280.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	20	$ 390.00	$ 7,800.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	4,170	$ 180.00	$ 750,600.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	44	$ 4,000.00	$ 176,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	10	$ 3,470.00	$ 34,700.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	10	$ 6,340.00	$ 63,400.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	4170	$ 2.00	$ 8,340.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	64	$ 2.50	$ 160.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 1,140,680.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,261,638.33**
25% CONTINGENCY:		**$ 565,409.58**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,827,047.92**
Design Engineering Services	**10.00%**	**$ 282,704.79**
Bid Phase Services	**1.00%**	**$ 28,270.48**
Construction Administration Services	**1.00%**	**$ 28,270.48**
Surveying Services		**$ 12,600.00**
Geotechnical Services		**$ 15,200.00**
Urban Forester		**$ 6,900.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 3,200,993.67**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 5

STREET NAME	**Planning Area #5**			
LENGTH (FT)	5910	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	54	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	4	$ 25,000.00	$ 100,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	4	$ 10,000.00	$ 40,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 140,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	9,193	$ 13.00	$ 119,513.33
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	9,193	$ 70.00	$ 643,533.33
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	11,820	$ 12.00	$ 141,840.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	298	$ 165.00	$ 49,170.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	11,820	$ 8.00	$ 94,560.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,800	$ 75.00	$ 135,000.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	2700	$ 13.00	$ 35,100.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	72	$ 2,000.00	$ 144,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 1,362,716.67**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	5,910	$ 20.00	$ 118,200.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	76	$ 370.00	$ 28,120.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	28	$ 390.00	$ 10,920.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	5,910	$ 180.00	$ 1,063,800.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	76	$ 4,000.00	$ 304,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	14	$ 3,470.00	$ 48,580.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	14	$ 6,340.00	$ 88,760.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	5910	$ 2.00	$ 11,820.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	104	$ 2.50	$ 260.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 1,674,460.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 3,177,176.67**
25% CONTINGENCY:		**$ 794,294.17**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 3,971,470.83**
Design Engineering Services	**10.00%**	**$ 397,147.08**
Bid Phase Services	**1.00%**	**$ 39,714.71**
Construction Administration Services	**1.00%**	**$ 39,714.71**
Surveying Services		**$ 18,900.00**
Geotechnical Services		**$ 21,500.00**
Urban Forester		**$ 9,800.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 4,498,247.33**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 6

STREET NAME	**Planning Area #6**			
LENGTH (FT)	3340	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	51	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	2	$ 25,000.00	$ 50,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	2	$ 10,000.00	$ 20,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 70,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	5,196	$ 13.00	$ 67,542.22
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	5,196	$ 70.00	$ 363,688.89
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	6,680	$ 12.00	$ 80,160.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	169	$ 165.00	$ 27,885.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	6,680	$ 8.00	$ 53,440.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,700	$ 75.00	$ 127,500.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	2550	$ 13.00	$ 33,150.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	32	$ 2,000.00	$ 64,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 817,366.11**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	3,340	$ 20.00	$ 66,800.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	40	$ 370.00	$ 14,800.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	16	$ 390.00	$ 6,240.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	3,340	$ 180.00	$ 601,200.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	40	$ 4,000.00	$ 160,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	8	$ 3,470.00	$ 27,760.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	8	$ 6,340.00	$ 50,720.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	3340	$ 2.00	$ 6,680.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	56	$ 2.50	$ 140.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 934,340.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 1,821,706.11**
25% CONTINGENCY:		**$ 455,426.53**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,277,132.64**
Design Engineering Services	**10.00%**	**$ 227,713.26**
Bid Phase Services	**1.00%**	**$ 22,771.33**
Construction Administration Services	**1.00%**	**$ 22,771.33**
Surveying Services		**$ 8,400.00**
Geotechnical Services		**$ 12,200.00**
Urban Forester		**$ 5,600.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 2,576,588.56**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 7

STREET NAME	**Planning Area #7**			
LENGTH (FT)	3350	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	43	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	5	$ 25,000.00	$ 125,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	5	$ 10,000.00	$ 50,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 175,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	5,211	$ 13.00	$ 67,744.44
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	5,211	$ 70.00	$ 364,777.78
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	6,700	$ 12.00	$ 80,400.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	169	$ 165.00	$ 27,885.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	6,700	$ 8.00	$ 53,600.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,434	$ 75.00	$ 107,550.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	2150	$ 13.00	$ 27,950.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	18	$ 2,000.00	$ 36,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 765,907.22**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	3,350	$ 20.00	$ 67,000.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	37	$ 370.00	$ 13,690.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	19	$ 390.00	$ 7,410.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	3,350	$ 180.00	$ 603,000.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	37	$ 4,000.00	$ 148,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	10	$ 3,470.00	$ 34,700.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	9	$ 6,340.00	$ 57,060.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	3350	$ 2.00	$ 6,700.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	56	$ 2.50	$ 140.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 937,700.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 1,878,607.22**
25% CONTINGENCY:		**$ 469,651.81**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,348,259.03**
Design Engineering Services	**10.00%**	**$ 234,825.90**
Bid Phase Services	**1.00%**	**$ 23,482.59**
Construction Administration Services	**1.00%**	**$ 23,482.59**
Surveying Services		**$ 4,800.00**
Geotechnical Services		**$ 12,200.00**
Urban Forester		**$ 5,600.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 2,652,650.11**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 8

STREET NAME	**Planning Area #8**			
LENGTH (FT)	2340		1	*= 2 if Boulevard Street*
WIDTH (FT)	14		30	*= No. of Driveways*

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	4	$ 25,000.00	$ 100,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	4	$ 10,000.00	$ 40,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 140,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	3,640	$ 13.00	$ 47,320.00
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	3,640	$ 70.00	$ 254,800.00
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	4,680	$ 12.00	$ 56,160.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	118	$ 165.00	$ 19,470.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	4,680	$ 8.00	$ 37,440.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,000	$ 75.00	$ 75,000.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	1500	$ 13.00	$ 19,500.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	32	$ 2,000.00	$ 64,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 573,690.00**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	2,340	$ 20.00	$ 46,800.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	28	$ 370.00	$ 10,360.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	11	$ 390.00	$ 4,290.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	2,340	$ 180.00	$ 421,200.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	28	$ 4,000.00	$ 112,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	6	$ 3,470.00	$ 20,820.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	5	$ 6,340.00	$ 31,700.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	2340	$ 2.00	$ 4,680.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	39	$ 2.50	$ 97.50
				SUB-TOTAL DRAINAGE ITEMS:	**$ 651,947.50**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 1,365,637.50**
25% CONTINGENCY:		**$ 341,409.38**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 1,707,046.88**
Design Engineering Services	**10.00%**	**$ 170,704.69**
Bid Phase Services	**1.00%**	**$ 17,070.47**
Construction Administration Services	**1.00%**	**$ 17,070.47**
Surveying Services		**$ 8,400.00**
Geotechnical Services		**$ 8,500.00**
Urban Forester		**$ 3,900.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 1,932,692.50**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 9

STREET NAME	**Planning Area #9**			
LENGTH (FT)	3470	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	34	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	4	$ 25,000.00	$ 100,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	4	$ 10,000.00	$ 40,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 140,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	5,398	$ 13.00	$ 70,171.11
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	5,398	$ 70.00	$ 377,844.44
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	6,940	$ 12.00	$ 83,280.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	175	$ 165.00	$ 28,875.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	6,940	$ 8.00	$ 55,520.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,134	$ 75.00	$ 85,050.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	1700	$ 13.00	$ 22,100.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	44	$ 2,000.00	$ 88,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 810,840.56**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	3,470	$ 20.00	$ 69,400.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	50	$ 370.00	$ 18,500.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	20	$ 390.00	$ 7,800.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	3,470	$ 180.00	$ 624,600.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	50	$ 4,000.00	$ 200,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	10	$ 3,470.00	$ 34,700.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	10	$ 6,340.00	$ 63,400.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	3470	$ 2.00	$ 6,940.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	70	$ 2.50	$ 175.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 1,025,515.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 1,976,355.56**
25% CONTINGENCY:		**$ 494,088.89**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,470,444.44**
Design Engineering Services	**10.00%**	**$ 247,044.44**
Bid Phase Services	**1.00%**	**$ 24,704.44**
Construction Administration Services	**1.00%**	**$ 24,704.44**
Surveying Services		**$ 11,500.00**
Geotechnical Services		**$ 12,600.00**
Urban Forester		**$ 5,800.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 2,796,797.78**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 10

STREET NAME	**Planning Area #10**			
LENGTH (FT)	3580	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	45	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	4	$ 25,000.00	$ 100,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	4	$ 10,000.00	$ 40,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 140,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	5,569	$ 13.00	$ 72,395.56
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	5,569	$ 70.00	$ 389,822.22
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	7,160	$ 12.00	$ 85,920.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	181	$ 165.00	$ 29,865.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	7,160	$ 8.00	$ 57,280.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,500	$ 75.00	$ 112,500.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	2250	$ 13.00	$ 29,250.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	44	$ 2,000.00	$ 88,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 865,032.78**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	3,580	$ 20.00	$ 71,600.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	36	$ 370.00	$ 13,320.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	12	$ 390.00	$ 4,680.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	3,580	$ 180.00	$ 644,400.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	36	$ 4,000.00	$ 144,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	6	$ 3,470.00	$ 20,820.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	6	$ 6,340.00	$ 38,040.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	3580	$ 2.00	$ 7,160.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	48	$ 2.50	$ 120.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 944,140.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 1,949,172.78**
25% CONTINGENCY:		**$ 487,293.19**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,436,465.97**
Design Engineering Services	**10.00%**	**$ 243,646.60**
Bid Phase Services	**1.00%**	**$ 24,364.66**
Construction Administration Services	**1.00%**	**$ 24,364.66**
Surveying Services		**$ 11,500.00**
Geotechnical Services		**$ 13,000.00**
Urban Forester		**$ 6,000.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 2,759,341.89**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 11

STREET NAME	**Planning Area #11**			
LENGTH (FT)	3980	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	54	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	4	$ 25,000.00	$ 100,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	4	$ 10,000.00	$ 40,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 140,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	6,191	$ 13.00	$ 80,484.44
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	6,191	$ 70.00	$ 433,377.78
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	7,960	$ 12.00	$ 95,520.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	201	$ 165.00	$ 33,165.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	7,960	$ 8.00	$ 63,680.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	1,800	$ 75.00	$ 135,000.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	2700	$ 13.00	$ 35,100.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	28	$ 2,000.00	$ 56,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 932,327.22**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	3,980	$ 20.00	$ 79,600.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	40	$ 370.00	$ 14,800.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	16	$ 390.00	$ 6,240.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	3,980	$ 180.00	$ 716,400.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	40	$ 4,000.00	$ 160,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	8	$ 3,470.00	$ 27,760.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	8	$ 6,340.00	$ 50,720.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	3980	$ 2.00	$ 7,960.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	56	$ 2.50	$ 140.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 1,063,620.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,135,947.22**
25% CONTINGENCY:		**$ 533,986.81**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,669,934.03**
Design Engineering Services	**10.00%**	**$ 266,993.40**
Bid Phase Services	**1.00%**	**$ 26,699.34**
Construction Administration Services	**1.00%**	**$ 26,699.34**
Surveying Services		**$ 7,400.00**
Geotechnical Services		**$ 14,500.00**
Urban Forester		**$ 6,600.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 3,018,826.11**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Planning Area 12

STREET NAME	**Planning Area #12**			
LENGTH (FT)	4940	1	*= 2 if Boulevard Street*	
WIDTH (FT)	14	66	*= No. of Driveways*	

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	3	$ 25,000.00	$ 75,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	3	$ 10,000.00	$ 30,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 105,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	7,684	$ 13.00	$ 99,897.78
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	7,684	$ 70.00	$ 537,911.11
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	9,880	$ 12.00	$ 118,560.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	249	$ 165.00	$ 41,085.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	9,880	$ 8.00	$ 79,040.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	2,200	$ 75.00	$ 165,000.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	3300	$ 13.00	$ 42,900.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	36	$ 2,000.00	$ 72,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 1,156,393.89**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	4,940	$ 20.00	$ 98,800.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	45	$ 370.00	$ 16,650.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	25	$ 390.00	$ 9,750.00
15	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 115.00	$ -
16	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 150.00	$ -
17	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	4,940	$ 180.00	$ 889,200.00
18	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 215.00	$ -
19	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 250.00	$ -
20	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 270.00	$ -
21	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	-	$ 350.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	45	$ 4,000.00	$ 180,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
24	Manholes (For 42" Dia. Pipe and Smaller) (All Types)	EA.	13	$ 3,470.00	$ 45,110.00
25	Manholes (For 48" to 72" Dia. Pipe) (All Types)	EA.	12	$ 6,340.00	$ 76,080.00
26	Manholes (For 78" Dia. Pipe and Larger) (All Types)	EA.	-	$ 16,500.00	$ -
27	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	-	$ 4,500.00	$ -
28	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	4940	$ 2.00	$ 9,880.00
29	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	70	$ 2.50	$ 175.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 1,325,645.00**

ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 2,587,038.89**
25% CONTINGENCY:		**$ 646,759.72**
TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:		**$ 3,233,798.61**
Design Engineering Services	**10.00%**	**$ 323,379.86**
Bid Phase Services	**1.00%**	**$ 32,337.99**
Construction Administration Services	**1.00%**	**$ 32,337.99**
Surveying Services		**$ 9,500.00**
Geotechnical Services		**$ 18,000.00**
Urban Forester		**$ 8,200.00**
OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):		**$ 3,657,554.44**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for one side of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Attachment

E

Opinions of Probable Cost for Trunk Line Projects

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

Preliminary Opinion of Probable Constuction Cost for West University Place: Academy Street Trunkline

STREET NAME	**Academy (Trunkline)**				
LENGTH (FT)	6750		1	*= 2 if Boulevard Street*	
WIDTH (FT)	27		120	*= No. of Driveways*	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 25,000.00	$ 25,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 10,000.00	$ 10,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 35,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	20,250	$ 13.00	$ 263,250.00
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	20,250	$ 70.00	$ 1,417,500.00
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	23,250	$ 12.00	$ 279,000.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	586	$ 165.00	$ 96,690.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	13,500	$ 8.00	$ 108,000.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	4,000	$ 75.00	$ 300,000.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	6000	$ 13.00	$ 78,000.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	88	$ 2,000.00	$ 176,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 2,718,440.00**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	6,750	$ 20.00	$ 135,000.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	20	$ 370.00	$ 7,400.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	12	$ 390.00	$ 4,680.00
15	9 x 8 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	675	$ 940.00	$ 634,500.00
16	9 x 9 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	590	$ 960.00	$ 566,400.00
17	10 x 9 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	560	$ 1,130.00	$ 632,800.00
18	10 x 10 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	780	$ 1,300.00	$ 1,014,000.00
19	11 x 10 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	1,000	$ 1,320.00	$ 1,320,000.00
20	11 x 11 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	3,145	$ 1,335.00	$ 4,198,575.00
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	20	$ 4,000.00	$ 80,000.00
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
23	Manholes, all depths, including foundation and backfill, complete in place the sum of:	EA.	12	$ 3,470.00	$ 41,640.00
24	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	12	$ 4,500.00	$ 54,000.00
25	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	3375	$ 2.00	$ 6,750.00
26	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	3375	$ 2.50	$ 8,437.50
				SUB-TOTAL DRAINAGE ITEMS:	**$ 8,704,182.50**
	ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 11,457,622.50**
	15% CONTINGENCY:				**$ 1,718,643.38**
	TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 13,176,265.88**
	Design Engineering Services				**$ 1,054,101.27**
	Bid Phase Services (1%)				**$ 131,762.66**
	Construction Administration Services (1%)				**$ 131,762.66**
	Surveying Services (1%)				**$ 131,762.66**
	Geotechnical Services				**$ 24,600.00**
	Urban Forester				**$ 11,200.00**
	OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):				**$ 14,661,455.12**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for both sides of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Academy Street Pipeline Easement Option

STREET NAME	**Academy (Pipeline Easement Option)**				
LENGTH (FT)	0		1	*= 2 if Boulevard Street*	
WIDTH (FT)	0		0	*= No. of Driveways*	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 10,000.00	$ 10,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 15,000.00	$ 15,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 25,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	0	$ 13.00	$ -
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	0	$ 70.00	$ -
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	0	$ 12.00	$ -
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	0	$ 165.00	$ -
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	0	$ 8.00	$ -
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	0	$ 75.00	$ -
9	5' concrete sidewalk, complete in place the sum of:	S.F.	26200	$ 13.00	$ 340,600.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	10	$ 2,000.00	$ 20,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 360,600.00**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 20.00	$ -
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	-	$ 370.00	$ -
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	-	$ 390.00	$ -
15	8' x 6' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1,680	$ 770.00	$ 1,293,600.00
16	9' x 6' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	580	$ 780.00	$ 452,400.00
17	9' x 7' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	570	$ 850.00	$ 484,500.00
18	10' x 7' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	770	$ 920.00	$ 708,400.00
19	10' x 8' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	990	$ 960.00	$ 950,400.00
20	10' x 9' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	650	$ 1,130.00	$ 734,500.00
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	20	$ 4,000.00	$ 80,000.00
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
23	Manholes, all depths, including foundation and backfill, complete in place the sum of:	EA.	12	$ 3,470.00	$ 41,640.00
24	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	12	$ 4,500.00	$ 54,000.00
25	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	2620	$ 2.00	$ 5,240.00
26	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	2620	$ 2.50	$ 6,550.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 4,811,230.00**
				ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 5,196,830.00**
				15% CONTINGENCY:	**$ 779,524.50**
				TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 5,976,354.50**
	Design Engineering Services (8%)				**$ 478,108.36**
	Bid Phase Services (1%)				**$ 59,763.55**
	Construction Administration Services (1%)				**$ 59,763.55**
	Surveying Services (1%)				**$ 59,763.55**
	Geotechnical Services				**$ 19,100.00**
	Urban Forester				**$ 8,700.00**
	OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):				**$ 6,661,553.50**

Engineering Fee Assumptions:

[1] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.

[2] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Academy Street (Community/Ruskin/W Point)

STREET NAME	**Academy (Community / Ruskin / West Point)**				
LENGTH (FT)	5700		1	*= 2 if Boulevard Street*	
WIDTH (FT)	27		120	*= No. of Driveways*	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 35,000.00	$ 35,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 15,000.00	$ 15,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 50,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	17,100	$ 13.00	$ 222,300.00
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	17,100	$ 70.00	$ 1,197,000.00
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	19,633	$ 12.00	$ 235,600.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	495	$ 165.00	$ 81,675.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	11,400	$ 8.00	$ 91,200.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	4,000	$ 75.00	$ 300,000.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	6000	$ 13.00	$ 78,000.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	88	$ 2,000.00	$ 176,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 2,381,775.00**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	5,700	$ 20.00	$ 114,000.00
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	20	$ 370.00	$ 7,400.00
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	12	$ 390.00	$ 4,680.00
15	8' x 6' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	880	$ 770.00	$ 677,600.00
16	9' x 6' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	584	$ 780.00	$ 455,520.00
17	9' x 7' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	570	$ 850.00	$ 484,500.00
18	10' x 7' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	768	$ 920.00	$ 706,560.00
19	10' x 8' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	991	$ 960.00	$ 951,360.00
20	10' x 9' RCB, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1,907	$ 1,130.00	$ 2,154,910.00
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	20	$ 4,000.00	$ 80,000.00
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
23	Manholes, all depths, including foundation and backfill, complete in place the sum of:	EA.	12	$ 3,470.00	$ 41,640.00
24	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	12	$ 4,500.00	$ 54,000.00
25	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	2850	$ 2.00	$ 5,700.00
26	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	2850	$ 2.50	$ 7,125.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 5,744,995.00**
	ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 8,176,770.00**
	15% CONTINGENCY:				**$ 1,226,515.50**
	TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:				**$ 9,403,285.50**
	Detention Pond (Dry), 32.4 acre-feet @ $20,000/acre-foot				**$ 648,000.00**
	Detention Pond Land Acquisition, 8.2 acres @ $1,960,200/acre				**$ 16,073,640.00**
	Design Engineering Services				**$ 752,262.84**
	Bid Phase Services (1%)				**$ 94,032.86**
	Construction Administration Services (1%)				**$ 94,032.86**
	Surveying Services (1%)				**$ 94,032.86**
	Geotechnical Services				**$ 20,700.00**
	Urban Forester				**$ 9,500.00**
	OPCC INCLUDING PROFESSIONAL SERVICES (NO DETENTION):				**$ 10,467,846.91**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section
[2] Sidewalk is assumed for both sides of the street, but limited to 5 linear feet on either side of driveways
[3] All inlets are assumed to be Type BB
[4] At intersections, all sidewalks are assumed to have accessible ramps leading to adjacent sidewalk(s)
[5] Inlets at intersections were generally included in the E-W street
[6] One standard driveway per lot
[7] The cost of drainage improvement and roadway replacement included in this spreadsheet for Community Dr, Ruskin Dr, and W Point Dr is limited to sections of the Academy Street relief pipe route.
[8] Should this option be preferred, the opinion of cost for Planning Area III (Community Dr, Ruskin Dr, and W Point Dr) would need to be revised.
[9] the drainage conditions along Academy Street.

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF, extending only 100 feet from intersections in all directions
[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.
[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Construction Cost for West University Place: Auden Street University Blvd.

STREET NAME	**Auden Street & University Boulevard**			
LENGTH (FT)	4500		1	*= 2 if Boulevard Street*
WIDTH (FT)	12		70	*= No. of Driveways*

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 20,000.00	$ 20,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 10,000.00	$ 10,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 30,000.00**
PAVING ITEMS					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	6,000	$ 13.00	$ 78,000.00
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	6,000	$ 70.00	$ 420,000.00
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	8,000	$ 12.00	$ 96,000.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	202	$ 165.00	$ 33,330.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	4,500	$ 8.00	$ 36,000.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	2,334	$ 75.00	$ 175,050.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	22500	$ 13.00	$ 292,500.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	4	$ 2,000.00	$ 8,000.00
				SUB-TOTAL PAVING ITEMS:	**$ 1,138,880.00**
DRAINAGE ITEMS					
11	Remove existing storm sewer, all sizes and all depths, complete in place the sum of:	L.F.	4700	$ 30.00	$ 141,000.00
12	Remove existing storm sewer inlet/manhole, complete in place the sum of:	EA.	28	$ 600.00	$ 16,800.00
13	24" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	350	$ 115.00	$ 40,250.00
14	30" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	350	$ 150.00	$ 52,500.00
15	36" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	900	$ 180.00	$ 162,000.00
16	42" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	350	$ 215.00	$ 75,250.00
17	48" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	1100	$ 250.00	$ 275,000.00
18	54" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	350	$ 270.00	$ 94,500.00
19	60" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	750	$ 350.00	$ 262,500.00
20	66" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 360.00	$ -
21	72" RCP, ASTM C76, Class III storm sewer, rubber gasket joints, all depths, cement stabilized sand bedding and backfill, complete in place the sum of:	L.F.	0	$ 485.00	$ -
22	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	18	$ 4,000.00	$ 72,000.00
23	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	0	$ 3,500.00	$ -
24	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	14	$ 4,500.00	$ 63,000.00
25	Trench safety for all storm sewers greater than 5' deep, including installation, operation and removal, complete in place the sum of:	L.F.	4186.8	$ 1.00	$ 4,186.80
				SUB-TOTAL DRAINAGE ITEMS:	**$ 1,258,986.80**
				ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 2,427,866.80**
				15% CONTINGENCY:	**$ 364,180.02**
				TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 2,792,046.82**

Design Engineering Services	8.00%	**$223,363.75**
Bid Phase Services	1.00%	**$27,920.47**
Construction Administration Services	1.00%	**$27,920.47**
Surveying Services		**$ 23,600.00**
Geotechnical Services		**$ 23,600.00**
Urban Forester		**$ 7,500.00**
Total Engineering Services		**$ 333,904.68**

Overall Total Estimated Probable Cost	**$3,125,951.50**

Quantity Calculation Assumptions:

[1] Removal and replacement of concrete is based on existing paving section

[2] Sidewalk is assumed for one side of the street only.

Engineering Fee Assumptions:

[1] Surveying services fee is estimated based on $4.75/LF.

[2] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes every 500 LF.

[3] Urban Forester service fee is estimated based on $1.50/LF.

Preliminary Opinion of Probable Constuction Cost for West University Place: Buffalo Speedway

STREET NAME	**Buffalo Speedway**				
LENGTH (FT)	8240		1	*= 2 if Boulevard Street*	
WIDTH (FT)	25		4	*= No. of Driveways*	
ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT
GENERAL ITEMS					
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 50,000.00	$ 50,000.00
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 25,000.00	$ 25,000.00
				SUB-TOTAL GENERAL ITEMS:	**$ 75,000.00**
PAVING ITEMS (CITY OF HOUSTON SOUTH OF BELLAIRE BOULEVARD)					
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	6,000	$ 13.00	$ 78,000.00
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	6,000	$ 70.00	$ 420,000.00
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	6,000	$ 12.00	$ 72,000.00
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	152	$ 165.00	$ 25,080.00
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	3,000	$ 8.00	$ 24,000.00
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	134	$ 75.00	$ 10,050.00
9	5' concrete sidewalk, complete in place the sum of:	S.F.	100	$ 13.00	$ 1,300.00
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	0	$ 2,000.00	$ -
				SUB-TOTAL PAVING ITEMS:	**$ 630,430.00**
DRAINAGE ITEMS					
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 20.00	$ -
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	-	$ 370.00	$ -
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	-	$ 390.00	$ -
15	72" RCP, all depths, including foundation and backfill, complete in place the sum of:	L.F.	520	$ 485.00	$ 252,200.00
16	8 x 5 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	3,000	$ 660.00	$ 1,980,000.00
17	8 x 6 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	2,050	$ 770.00	$ 1,578,500.00
18	8 x 8 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	4,130	$ 920.00	$ 3,799,600.00
19	9 x 8 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	750	$ 940.00	$ 705,000.00
20	8 x 7 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	2,600	$ 840.00	$ 2,184,000.00
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 4,000.00	$ -
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -
23	Manholes, all depths, including foundation and backfill, complete in place the sum of:	EA.	20	$ 3,470.00	$ 69,400.00
24	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	35	$ 4,500.00	$ 157,500.00
25	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	4120	$ 2.00	$ 8,240.00
26	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	4120	$ 2.50	$ 10,300.00
				SUB-TOTAL DRAINAGE ITEMS:	**$ 10,744,740.00**
				ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 11,450,170.00**
				15% CONTINGENCY:	**$ 1,717,525.50**
				TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 13,167,695.50**
	Design Engineering Services (12%)				**$ 1,580,123.46**
	Bid Phase Services (1%)				**$ 131,676.96**
	Construction Administration Services (1%)				**$ 131,676.96**
	Surveying Services (1%)				**$ 131,676.96**
	Geotechnical Services				**$ 30,000.00**
	Urban Forester				**$ 13,600.00**
	OPCC INCLUDING PROFESSIONAL SERVICES:				**$ 15,186,449.83**

Engineering Fee
Assumptions:

[1] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Boreholes assumed every 500 LF.

[2] Urban Forester service fee is estimated based on $1.50/LF.

Appendix

A

Buffalo Speedway Drainage Preliminary Engineering Report

Draft – October 19, 2018

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

2nd DRAFT REPORT

Buffalo Speedway Improvements

Drainage Preliminary Engineering Report

City of West University Place, TX

October 19, 2018

Contents

1 Project Introduction 1
2 Hydrologic Methodology 4
3 Proposed Drainage Plan 6
3.1 Proposed Storm Sewer Sizing & Layout 6
3.2 Crossing the St. Vincent de Paul Church Property 9
3.3 Tying Into Existing Monolithic Concrete Storm Sewers 11
3.4 Flow Regulation at Bissonnet Street 12
3.5 Flow Regulation along Buffalo Speedway 13
3.6 Utility Concerns 14
4 Hydraulic Analysis 15
4.1 Existing Conditions 15
4.2 Proposed Conditions 17
4.3 Comparison of Ponding Depths along Buffalo Speedway 19
5 Pre-Design Activities 20
6 Conclusion 21

Tables

Table 1 - Summary of Peak Discharge Rates 5
Table 2 – Summary of Proposed Storm Sewer Improvements 6
Table 3: Evaluation of Potential Flow Regulation Methods 13
Table 4 - Comparison of Ponding Depths along Buffalo Speedway 19

Figures

Figure 1: Typical Configuration of the Existing Buffalo Speedway in West University Place 1
Figure 2: Route of Existing Dual 66" Storm Sewer Across the St. Vincent de Paul Campus 2
Figure 3: General Extents of Buffalo Speedway Drainage Improvements 3
Figure 4: Sample 100-Year Hydrograph 4
Figure 5: Proposed Storm Sewer Arrangement North of Amherst 7
Figure 6: Proposed Storm Sewer Arrangement South of Amherst 8
Figure 7: Possible Traffic Control Approach for Buffalo Speedway 9
Figure 8: Possible Pipe Combinations Across the St. Vincent de Paul Campus 10
Figure 9: Typical Section, Monolithic Concrete Storm Sewer 11
Figure 10: Detail for Connecting to Monolithic Concrete Storm Sewers 11
Figure 11: Flow Regulation at Bissonnet Street 12
Figure 12: General Form of Masonry Flow Regulator 14
Figure 13: Typical Water Line Arrangement along Buffalo Speedway 14
Figure 14 - Existing Conditions 2-Year Runoff Hydrographs 15
Figure 15 - Existing Conditions 10-year Runoff Hydrographs 16
Figure 16 - Existing Conditions 100-Year Runoff Hydrographs 16
Figure 17 –Existing Conditions vs. Proposed Conditions 2-Year Runoff Hydrographs 17
Figure 18 - Existing Conditions vs. Proposed Conditions 10-Year Runoff Hydrographs 18
Figure 19 – Existing Conditions vs. Proposed Conditions 100-Year Runoff Hydrographs 18

Exhibits

1. Drainage Area Map
2. Storm Sewer Sizing Layout
3. Flooding Map, Existing Conditions, 2-Year Storm Event
4. Flooding Map, Existing Conditions, 10-Year Storm Event
5. Flooding Map, Existing Conditions, 100-Year Storm Event
6. Profile Plot, Existing System, 2-Year Storm Event
7. Profile Plot, Existing System, 100-Year Storm Event
8. Flooding Map, Proposed Conditions, 2-Year Storm Event
9. Flooding Map, Proposed Conditions, 10-Year Storm Event
10. Flooding Map, Proposed Conditions, 100-Year Storm Event
11. Profile Plot, Existing System, 2-Year Storm Event
12. Profile Plot, Existing System, 100-Year Storm Event
13. Geotechnical Boring Plan
14. Buffalo Speedway Water Line Layout from Recent Infrastructure Upgrades

Appendices

A. “Virtual Tour” Photos for the Buffalo Speedway Project
B. Construction Plans for Rehabilitation of Buffalo Speedway Outfall to Poor Farm Ditch
C. Construction Plans for Original West University Place Storm Sewer System
D. Construction Details for Connections to Existing Buffalo Speedway Monolithic Concrete Pipe
E. Field Survey Data and Field Notes from West Belt Surveying, Inc.
F. Geotechnical Investigations Report from Aviles Engineering Corporation
G. Preliminary Construction Quantity Take-off and Cost Estimate from HDR Engineering, Inc.

This page is intentionally left blank.

1 Project Introduction

This preliminary engineering report describes the drainage system upgrades associated with proposed roadway improvements to Buffalo Speedway within the City of West University Place, Texas. The following sections provide descriptions of the hydrologic methodology for computing peak discharges and runoff hydrographs for the existing drainage system, discuss the proposed plan for roadway and drainage improvements to Buffalo Speedway, and provide the results of the hydraulic analysis of the existing and proposed drainage system.

Buffalo Speedway is a four-lane, curb-and-gutter roadway with storm sewer drainage. It passes through the east-central portion of West University Place from north to south, entering West U from the City of Houston to the north and exiting into the City of Houston to the south. Storm sewers along Buffalo Speedway drain storm runoff from a total drainage area of approximately 541 acres, including approximately 131 acres north of West U and 46 acres to the south. The Buffalo Speedway drainage system empties into Poor Farm Ditch a short distance south of Bellaire Boulevard. **Exhibit 1** is a drainage area map for the Buffalo Speedway storm sewer system.

Figure 1: Typical Configuration of the Existing Buffalo Speedway in West University Place

The existing drainage system of Buffalo Speedway consists of a single 66-inch RCP storm sewer between Bissonnet and Georgetown, a single 72-inch RCP between Georgetown and Amherst, and dual 66-inch RCPs between Amherst and the system outfall to Poor Farm Ditch. The existing storm sewer passes through the St. Vincent De Paul Catholic Church property prior to reaching the Poor Farm Ditch outfall. The alignments and extents of the existing trunk line storm sewers are illustrated on **Exhibit 1**.

Various lateral pipes empty into the Buffalo Speedway system from the east and west, and connectors are provided between the dual 66-inch RCPs to allow water to flow from one pipe to the other. The existing system does not have sufficient capacity to convey the 2-year storm event, and the lack of storm sewer capacity causes significant street ponding within the project area during periods of heavy rainfall.

The City of West University Place proposes to complete improvements to Buffalo Speedway from Bissonnet Street southward Bellaire Boulevard and has secured Transportation Improvement Program (TIP) funding for re-paving the roadway within the proposed project limits. In addition to paving improvements, West U proposes to upgrade the existing storm sewer drainage system, with improvements extending all the way to the Poor Farm Ditch outfall. The following figure illustrates the general extents of the Buffalo Speedway project and the size

of the proposed new storm sewer pipes and culverts along the roadway. Storm sewer sizing for the preliminary drainage design is based on the assumption that the existing single 66-inch storm sewer at Bissonnet Street remains in place, serving as a flow regulator and maintaining existing flow rates into West U from the 131-acre City of Houston drainage area to the north.

Proposed storm sewer sizes range from a single 66-inch RCP at Bissonnet Street to dual 8' x 8' RCB culverts at the point where the Buffalo Speedway storm sewer exits the road right-of-way to cross the St. Vincent de Paul campus and outfall to Poor Farm Ditch. **Exhibit 2** illustrates the proposed storm sewer sizes along Buffalo Speedway required to pass the 2-year storm design storm event with average velocity of 3 feet per second.

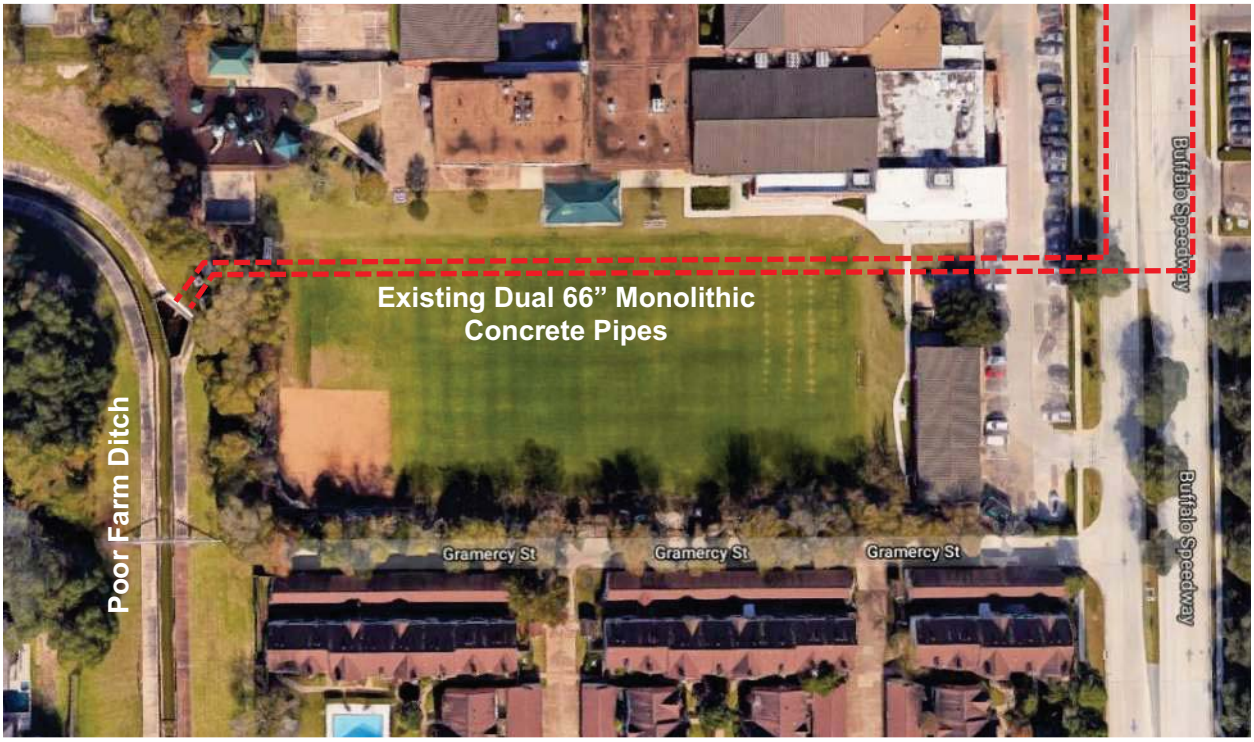


Figure 2: Route of Existing Dual 66" Storm Sewer Across the St. Vincent de Paul Campus

Existing storm sewers along Buffalo Speedway, consisting mainly of single 66-inch to 72-inch pipes or dual 66-inch pipes, are assumed to remain in place to provide in-line detention storage. The existing dual 66-inch storm sewer pipes between Buffalo Speedway and Poor Farm Ditch (i.e., the pipes that pass through the St. Vincent de Paul campus) are assumed to be replaced with either dual 8' x 8' box culverts plus flow regulators or replaced in kind (i.e., as new dual 66-inch pipes) to regulate flows to the outfall. Regulating structures are provided at intervals along the Buffalo Speedway system to make full use of system storage. No increases in downstream are proposed for storm events ranging from the 10-year (10% annual chance) event to the 100-year (1% annual chance) storm event. Flow rates are increased somewhat for the 2-year (50%

annual chance event), but both Poor Farm Ditch and Brays Bayou provide sufficient capacity to accommodate peak runoff rates for the 2-year event.

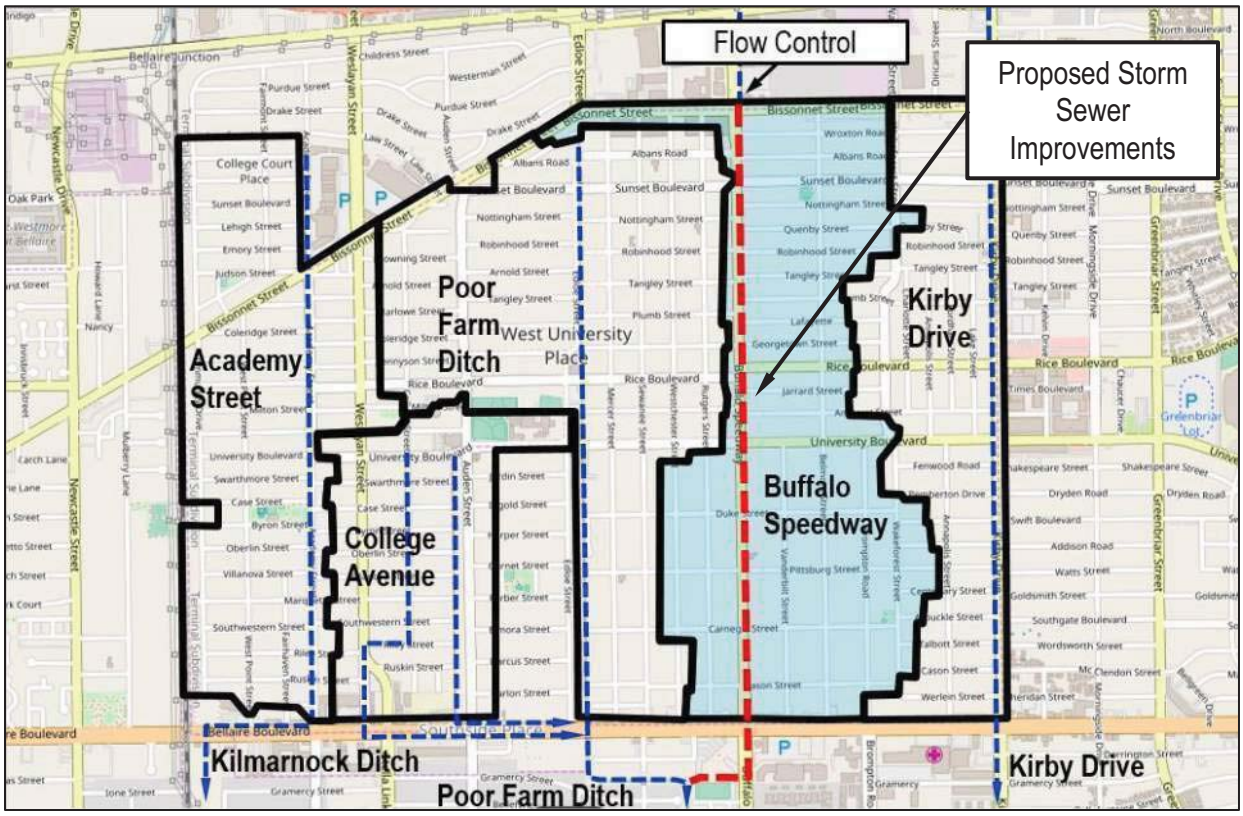


Figure 3: General Extents of Buffalo Speedway Drainage Improvements

A set of images provided in Appendix A to this report offer a “virtual tour” of the Buffalo Speedway project area, with a separate image at each intersection starting at Bissonnet and extending southward to Bellaire Boulevard, with supplemental information on the outfall to Poor Farm Ditch. These images provide background information on the existing roadway, cross-streets, signals, sidewalks, and other infrastructure, as well as trees and other features.

2 Hydrologic Methodology

Peak discharge rates for the areas draining toward Buffalo Speedway were computed using the Rational Method. The time of concentration was computed using the method described in the TXDOT Hydraulic Design Manual using the equation shown below. This equation is based on an average storm sewer flow velocity of 3 feet per second, which is very standard for the Houston area.

$$T_c = 10\ minutes + \frac{Length\ of\ Flow\ Path}{3\ {}^{ft}/_{s} \times 60\ \frac{s}{min}}$$

The rainfall intensity for each drainage area was computed using the equation shown below.

$$i = \frac{b}{(T_c + d)^e}$$

The e, d and b values required to compute rainfall intensities were taken from the latest version of the TXDOT "*EBD Look-Up Table*." The peak discharge rates were computed for the 2-year (50% annual chance) and 100-year (1% annual chance) storm events using the Rational Method and the equation below:

$$Q = CiA$$

Where Q = peak discharge rate in cubic feet per second, i = rainfall intensity in inches per hour, C = runoff coefficient based on land use, and A = drainage area of the sub-watershed.

Runoff hydrographs for each sub-basin were created using the HEC-HMS software program. The Green-Ampt loss function was used to simulate the runoff losses within the drainage area, and the Clark Unit Hydrograph method was used to develop the hydrographs. The runoff coefficient used in the Clark Unit Hydrograph method was iterated such that the peak discharge rate of the hydrograph was equal to the peak discharge rate computed with the Rational Method. Those runoff hydrographs were then applied to the XP-SWMM 1D/2D model of the Buffalo Speedway drainage system. All hydrographs were developed for rainfall events with 24-hour duration.

Table 1 below provides a summary of the drainage areas, their times of concentration, and the peak discharge rates computed with HEC-HMS for the 2-year, 10-year, and 100-year storm events. **Exhibit 1** provides a drainage area map of the Buffalo Speedway drainage system. The boundaries of each of the drainage area listed in **Table 1** are illustrated on the exhibit. The figure at right illustrates a sample computed hydrographs for the 100-year storm event.

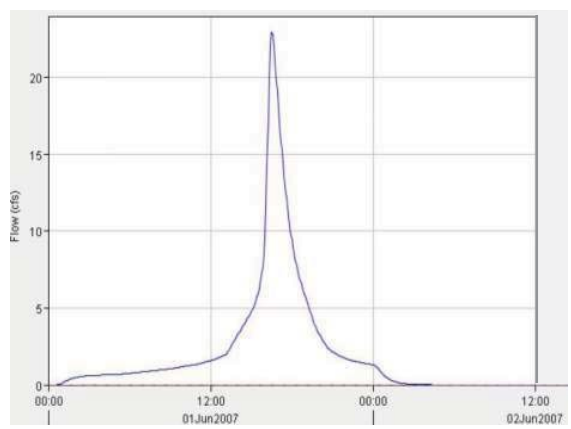


Figure 4: Sample 100-Year Hydrograph

Table 1 - Summary of Peak Discharge Rates

Area ID	Area (acres)	Time of Concentration (hours)	Storage Coefficient (hours)	Peak Discharge (cfs)		
				2-Year	10-Year	100-Year
COH N	131.21	0.64	0.40	251	411	608
COH S	45.57	0.58	0.55	77	128	191
BSW 09	32.57	0.56	0.87	42	72	111
BSWT 1A	21.27	0.54	0.85	28	48	74
BSW 01	10.00	0.50	0.80	14	23	36
BSW 11	28.62	0.55	0.87	37	64	98
BSW 08	27.51	0.55	0.86	36	62	94
BSW 05 S	25.64	0.55	0.86	34	58	88
BSW 10	24.71	0.54	0.86	32	56	85
BSW 12	15.00	0.52	0.82	20	35	53
BSWT 5A	8.80	0.49	0.79	12	21	32
BSW 07	19.58	0.53	0.84	26	45	68
BSW 06 N	19.23	0.53	0.84	26	44	67
BSWT 3A	18.47	0.53	0.84	25	42	64
BSW 14	11.71	0.51	0.81	16	27	42
BSWT 7A	5.26	0.47	0.77	7	13	19
BSW 04	10.21	0.50	0.80	14	24	36
BSWT 2A	6.32	0.48	0.78	9	15	23
BSW 15	8.69	0.49	0.79	12	21	31
BSWT 8A	7.30	0.49	0.78	10	17	26
BSW13	10.06	0.50	0.80	14	24	36
BSWT 6A	5.48	0.48	0.77	8	13	20
BSW06 S	13.23	0.51	0.82	18	31	47
BSWT 4A	10.52	0.50	0.80	14	25	38
BSW 03	10.25	0.50	0.80	14	24	37
BSW 02	9.98	0.50	0.80	14	23	36
BSW 05N	4.72	0.47	0.77	7	11	17

Computed hydrographs are inserted into hydraulic models (described in Section 4 of this report) at nodes where tributary storm sewer systems tie into the Buffalo Speedway system, typically from the east or west.

3 Proposed Drainage Plan

A preliminary design was developed for the proposed storm sewer based on the peak discharge rates for the 2-year (50% annual chance) storm event. A Microsoft Excel® spreadsheet was used to establish preliminary storm sewer sizes based on a nominal full flow velocity of 3 feet per second, a value which initial assessments would minimize the potential for downstream impacts on peak flow rates. Detailed modeling of the existing and proposed storm sewers is described in the next section of this report.

3.1 Proposed Storm Sewer Sizing & Layout

The proposed storm sewer ranges in size from a single 66-inch RCP at Bissonnet Street (increasing to a 72-inch RCP just downstream of Bissonnet) to dual 8'x8' box culverts near the outfall. The outfall pipes which cross the St. Vincent De Paul Catholic Church property are proposed to remain as 66-inch RCPs in order to maintain the same existing drainage easement through that property. Connectors between existing and proposed storm sewers will be provided in order to allow storm water to transfer between the existing and proposed storm sewers. In order to meter the discharge into Poor Farm Ditch, short segments of 48-inch RCP are proposed at various locations throughout the proposed drainage system. These short segments of pipe serve as restrictors to allow the velocity of flow through the proposed system to mimic the velocity of flow in the existing system. Note that these 48-inch pipes are proposed for ease of modeling, but actual restrictors should be designed using steel plates or other means that allow restrictors to be adjusted or removed as downstream channel capacity is increased or detention becomes available. The existing pipes along Buffalo Speedway are proposed to be left in place and connected to the proposed storm sewer to provide storage within the drainage system. **Table 2** provides a summary of the existing storm sewer and the proposed storm sewer improvements.

Table 2 – Summary of Proposed Storm Sewer Improvements

Cross-Street	Existing Storm Sewer		Proposed Storm Sewer		
	Number	Diameter (inches)	Number	Span/Dia (ft)	Rise (ft)
Bissonnet	1	66	1	6	-
Albans	1	66	1	8	5
Nottingham	1	66	1	8	6
Tangley	1	66	1	8	8
Georgetown	1	72	1	9	8
Amherst	2	66	2	8	5
University	2	66	2	8	5
Duke	2	66	2	8	6
Pittsburgh	2	66	2	8	7
Carnegie	2	66	2	8	7
Cason	2	66	2	8	8
Bellaire	2	66	2	8	8
Outfall	2	66	2	5.5	-

Exhibit 2 provides a layout of the existing and proposed storm sewer systems with sizing. The total length of the Buffalo Speedway storm sewer system from Bissonnet Street to Poor Farm Ditch is approximately 8,450 feet.

The following figures illustrates the general approach recommended for constructing the storm sewers within the existing Buffalo Speedway right-of-way. In both figures, solid black lines represent existing storm sewers, while dashed black lines represent proposed storm sewers. North of Amherst, the existing 66-inch to 72-inch storm sewers consists of a single line on the west side of the road. Therefore, from Bissonnet southward to Amherst, the new storm sewer is proposed to be constructed on the east side of the road as indicated on **Figure 5**.

Figure 5: Proposed Storm Sewer Arrangement North of Amherst

South of Amherst, an existing 66-inch storm sewer pipe lies along each side of the road, so it is recommended that the proposed storm sewers be constructed “inside” of the existing pipes, as indicated on **Figure 6**.

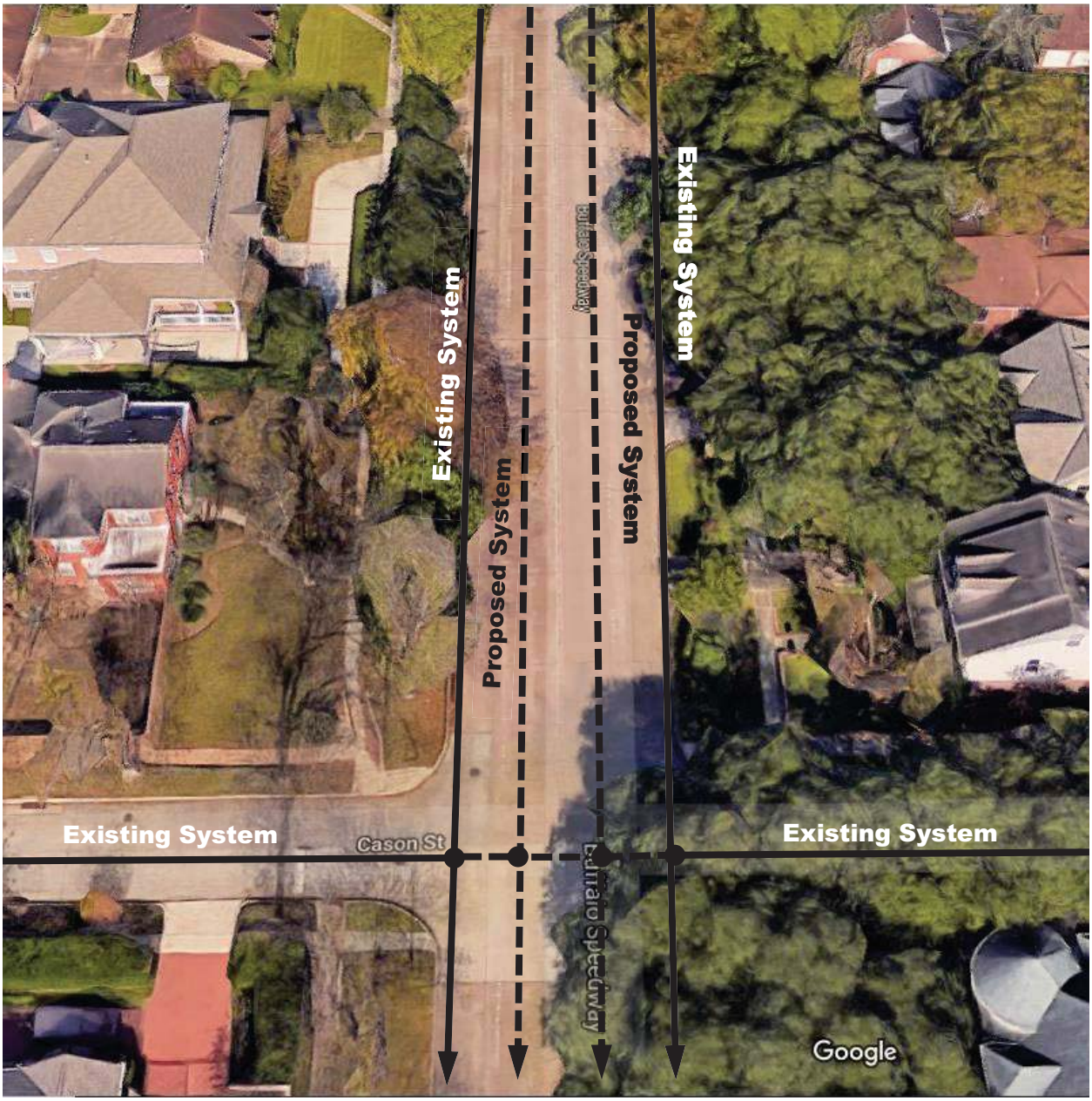


Figure 6: Proposed Storm Sewer Arrangement South of Amherst

This approach allows for improved traffic control, as in addition to two traffic lanes on one side of the road, an outside lane can be made available on the other side of the road for access to existing driveways. The following figure illustrates this approach to traffic control, which has been successfully utilized by HDR on recent construction projects.

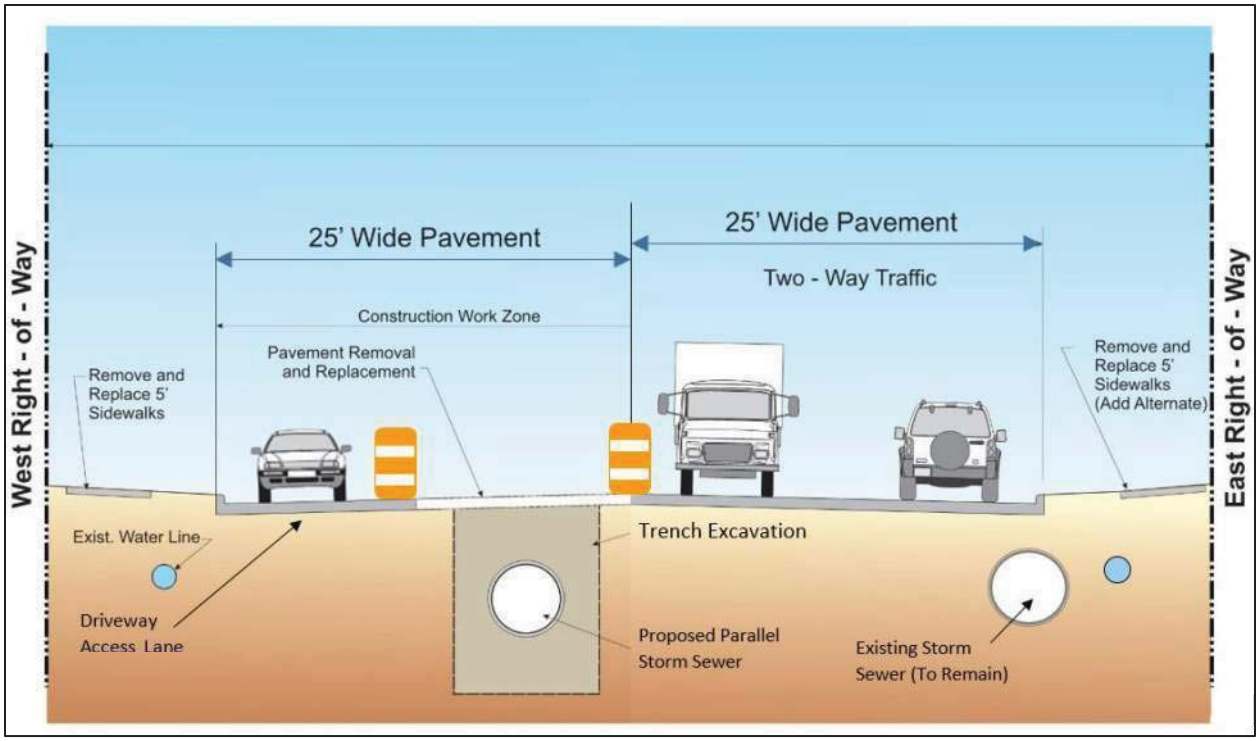


Figure 7: Possible Traffic Control Approach for Buffalo Speedway

3.2 Crossing the St. Vincent de Paul Church Property

Hydraulic modeling results indicate that the existing dual 66-inch storm sewer crossing the St. Vincent de Paul Catholic Church campus could, in terms of capacity, be left in place to regulate flows to Poor Farm Ditch. However, information provided by the City of West University Place indicates that the existing pipes are in less than satisfactory condition and must be replaced. The replacement storm sewer may take the form of dual 8' x 8' box culvert storm sewers per the design summary presented on **Exhibit 2**. Alternatively, the existing dual 66-inch storm sewers may be replaced in kind, with the new dual 66-inch pipes regulating flow to Poor Farm Ditch. The latter approach would likely result in significant cost savings, but should conditions change sufficiently in the future to allow the flow regulators in the proposed system to be removed, replacing the dual 66-inch storm sewers in kind would not provide full capacity for the non-regulated condition. Additionally, entering the church property a second time in the future to re-construct or add to the dual 66-inch storm sewers may prove to be problematic. Following is a list of possible design issues and approaches that must be considered for these two options.

Option #1: Construct New Dual 8' x 8' Box Culvert Storm Sewer

- Accounted for in the project cost estimate.
- Provides capacity for possible future condition where detention is provided downstream.
- Must negotiate an alignment and easement with the church.
- Can remove the existing dual 66-inch pipes or grout fill in place.
- Easement will be wider if existing 66-inch pipes are left in place.
- If existing 66-inch pipes are left in place, will have to construct a new outfall at Poor Farm Ditch.

- If existing 66-inch pipes are left in place, the new storm sewer will intersect the existing.
- Leaving existing 66-inch pipes in place will reduce disturbance related to required pipe demo.
- If 66-inch pipes are removed, can replace with 2 – 8' x 8' and preserve the existing outfall.
- The cost estimate developed for the project does not account for a new outfall.

Option #2: Construct Dual 66-inch Storm Sewer

- Cost would be reduced, as 2 – 8' x 8' are accounted for in the project cost estimate.
- Would lack capacity for possible future condition where detention is provided downstream.
- Permutation would involve new dual 66" & cure-in-place of existing 66" for future capacity.
- Must negotiate an alignment and easement with the church.
- Can remove the existing dual 66-inch pipes or grout fill in place.
- Easement will be wider if existing 66-inch pipes are left in place.
- If existing 66-inch pipes are left in place, will have to construct a new outfall at Poor Farm Ditch.
- Leaving existing 66-inch pipes in place will reduce disturbance related to required pipe demo.
- If existing 66-inch pipes are cured in place, can use the existing outfall for those existing pipes.
- If 66-inch pipes are removed, can replace with dual 66-inch and preserve the existing outfall.
- The cost estimate developed for the project does not account for a new outfall.

The following figure illustrates some of the possible combinations described above.

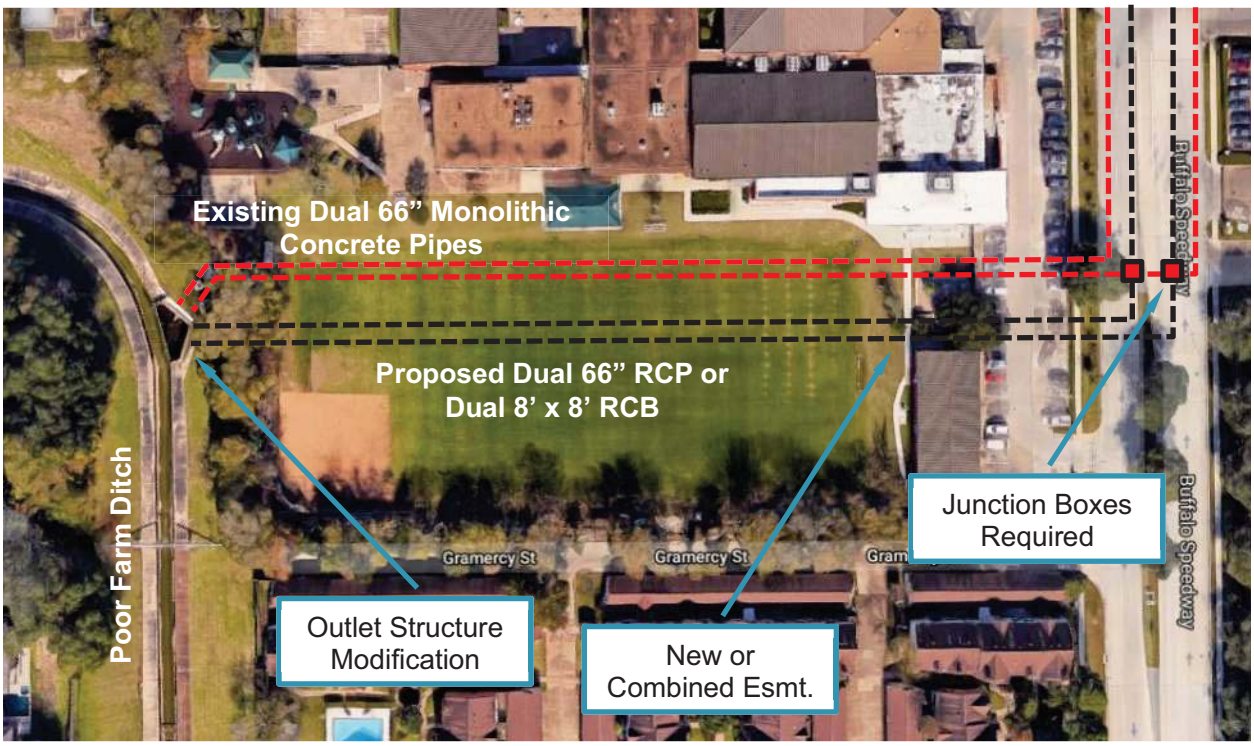


Figure 8: Possible Pipe Combinations Across the St. Vincent de Paul Campus

As indicated, leaving the existing monolithic pipes in place creates the need for an added easement or a wider easement, and may require that the existing outfall structure be replaced or significantly

modified. That structure was repaired in 2014. Construction documents prepared for that project by HDR Engineering, Inc. in 2014 are attached to this report as **Appendix B**.

3.3 Tying Into Existing Monolithic Concrete Storm Sewers

The existing storm sewers along Buffalo Speedway were constructed during World War II, and due to rationing of steel during the war, the storm sewers were constructed as monolithic concrete pipes. The figure at right illustrates a typical section of the existing storm sewers. The prescribed wall thickness for the 66-inch and 72-inch pipes along Buffalo Speedway was 8 inches to $8^{1/2}$ inches. A copy of the construction plans for the original West U storm sewer system is attached to this report as **Appendix C**. The plans, which were completed in 1942, include storm sewer layouts, details, and the design of the original outfall structure at the Buffalo Speedway outfall to Poor Farm Ditch.

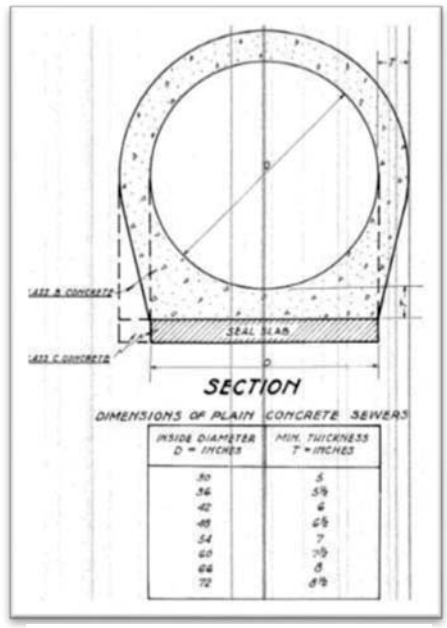


Figure 9: Typical Section, Monolithic Concrete Storm Sewer

The construction of new box culvert storm sewers under the inner lanes of Buffalo Speedway will require that flow be transferred from the existing 66-inch and 72-inch storm sewers on the outside of the roadway to the new box culverts. In order to achieve the required transfer of storm water, physical connections between the existing monolithic concrete storm sewers and the proposed box culvert storm sewers will be required. The figure below provides a possible means of making the required connections. This detail was detailed in connection with past roadway rehabilitation projects involving drainage improvements at intersections of Buffalo Speedway with various cross-streets.

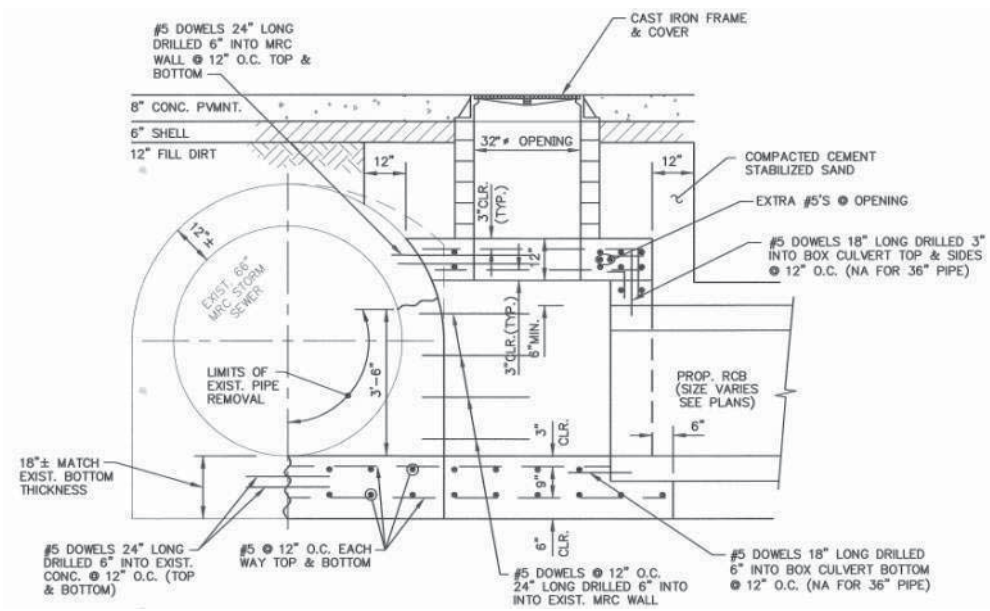


Figure 10: Detail for Connecting to Monolithic Concrete Storm Sewers

Appendix D contains excerpts from construction plans developed by Claunch & Miller, Inc. in 2002 for Priority Area 10 improvements, which involved side streets south of University Boulevard, and for Priority Area 11B, which involved side streets north of University Boulevard.

3.4 Flow Regulation at Bissonnet Street

As indicated previously in this report, it is proposed that the existing single 66-inch storm sewer pipe that enters West University Place from the Bissonnet Street right-of-way be left in place to serve as a flow regulator. The following figure provides a basic approach to the manner in which this is proposed to be accomplished.

Figure 11: Flow Regulation at Bissonnet Street

As indicated in the figure, the existing City of Houston storm sewer is left in place between Bissonnet Street and Wroxton Road. The Buffalo Speedway design calculations call for a new 66-inch storm sewer on the east side of Buffalo Speedway. In the interim, however, that 66-inch storm sewer may be omitted from West U's Buffalo Speedway improvement plan. Under this scenario, proposed storm sewer improvements would begin at the intersection of Buffalo Speedway and Wroxton Road and extend southward from that location. This would leave only the existing single 66-inch storm sewer in place between Bissonnet and Wroxton Road, with the possibility of adding the second 66-inch storm sewer along the east side of Buffalo Speedway in the future. This plan achieves the goal of regulating flows from the north while preserving the ability to make future improvements.

3.5 Flow Regulation along Buffalo Speedway

Due to the lack of available detention, the existing 66-inch and 72-inch storm sewers along Buffalo Speedway are proposed to be left in place to provide in-line detention storage. Proposed new box culvert storm sewers are designed to accommodate the existing conditions 2-year flow from the area north of Bissonnet Street (set equal for design purposes to the capacity of the existing 66-inch storm sewer that enters West University Place from the north) as well as 2-year flows from areas within the City of West University Place and contributing areas in the City of Houston south of Bellaire Boulevard. However, the proposed new storm sewers are significantly larger than the existing storm sewers, they have a much greater flow capacity than the existing storm sewers, and the detention storage made available by leaving existing storm sewer pipes in place along Buffalo Speedway is not sufficient to fully mitigate potential increases in 10-year and 100-year flow rates. In order to regulate the flow from the proposed storm sewer system, the proposed storm sewers are proposed to be regulated to provide additional in-line storage until such time as downstream capacity along Brays Bayou is sufficient to accept the full-capacity flow from the proposed storm sewers or detention is provided at some downstream location.

In the proposed conditions XPSWMM models of the Buffalo Speedway drainage system, a total of six (6) flow regulators are represented at intervals along the new storm sewer. These regulators are modeled as 48-inch pipes, but the actual physical configuration of the regulators may take a number of forms. Possible alternatives for constructing the required regulators include the following.

- Construct masonry walls in manholes or junction boxes to limit flow openings at regulator locations to roughly to the equivalent of a 48-inch pipe.
- Install steel plates at manholes or junction boxes to limit flow openings at regulator locations to roughly to the equivalent of a 48-inch pipe.
- Concrete or grout short segments of 48-inch pipe into the proposed box culverts at the prescribed locations.
- Use a stop-log system at each of the prescribed locations to limit flow openings at regulator locations to roughly to the equivalent of a 48-inch pipe.

The selected means of achieving the required degree of flow regulation should be simple, cost-effective, long-lasting, require little maintenance, and allow for modification or removal of regulators. The following matrix is used to evaluate the various regulation alternatives for overall suitability.

Table 3: Evaluation of Potential Flow Regulation Methods

Approach/ Method	Simple	Cost-Effective	Long Lasting	Easily Maintained	Easily Modified
Masonry Walls	✓	✓	✓	✓	
Steel Plates	✓	✓			✓
Pipe Segments	✓		✓	✓	
Stop-Logs	✓		✓		✓

As indicated in the table, none of the evaluated approaches satisfies all of the criteria, but a simple masonry wall satisfies most of the criteria, failing only the ease of modification criterion. The

following figure represents the basic approach to the construction of a masonry wall that is strong enough to withstand hydraulic pressure but also represents a modular system that can be removed without undue difficulty.

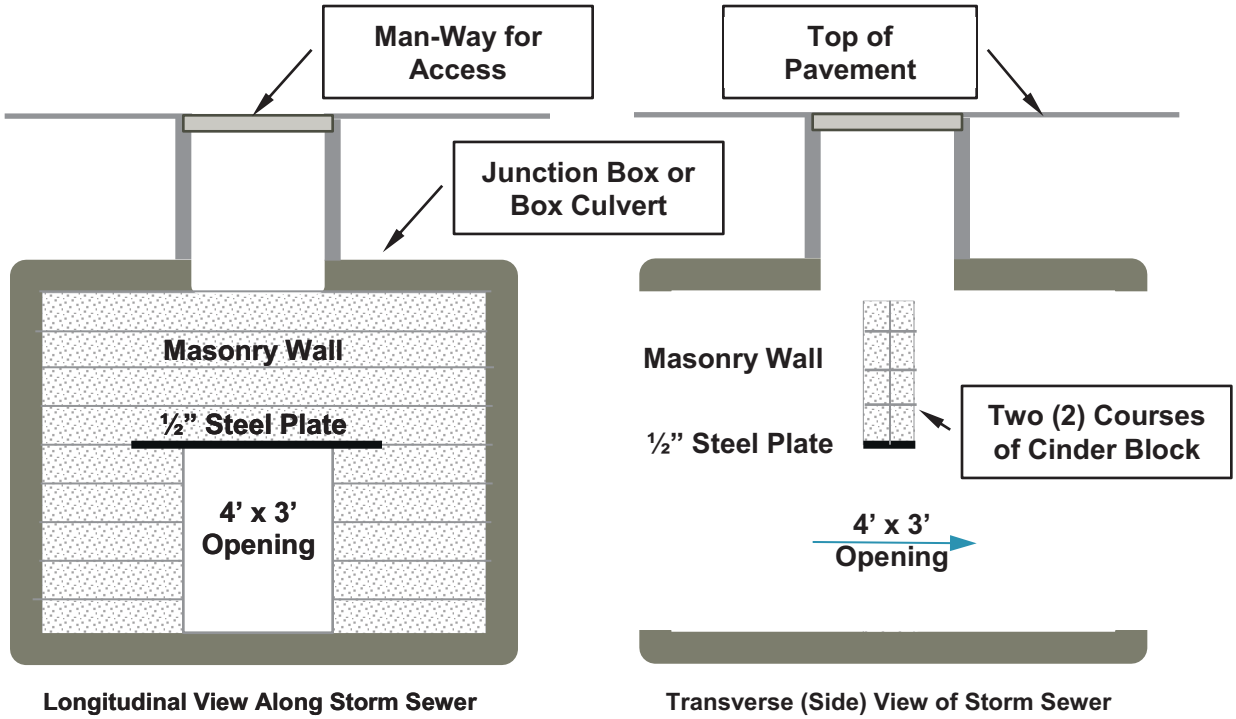


Figure 12: General Form of Masonry Flow Regulator

3.6 Utility Concerns

In constructing the proposed new storm sewers, care must be exercised to avoid existing utilities along Buffalo Speedway. The figure at right is representative of the water line layout for the entire length of the proposed roadway and drainage improvement project. The traffic control plan described in the foregoing section of this report minimizes potential conflicts with existing utilities, including sanitary sewers and existing water lines, the latter of which are located on both sides of the roadway, by constructing the storm sewers in the middle portion of the roadway, away from the curb lines and the area immediately behind the curbs where utilities are located.

Figure 13: Typical Water Line Arrangement along Buffalo Speedway

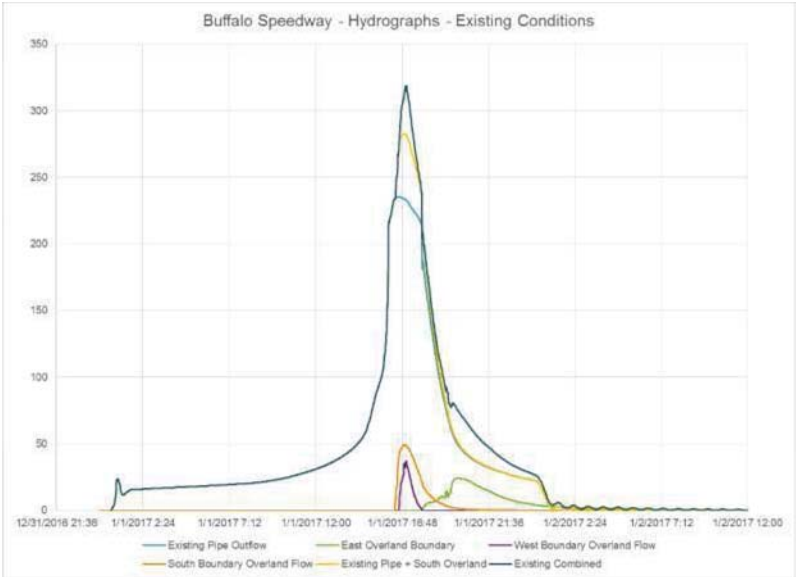
4 Hydraulic Analysis

4.1 Existing Conditions

The existing conditions hydraulic model is a 1D/2D coupled XP-SWMM model created by HDR. The storm sewer elevation data was obtained from field survey provided by West Belt Surveying, Inc. **Appendix E** contains a map of the Buffalo Speedway project area with tabulated field survey data for the existing storm sewer system between Bissonnet Street and Poor Farm Ditch. The 2D domain of the model was created using the 2008 LiDAR data obtained by the Houston-Galveston Area Council. The runoff hydrographs described in Section 2 of this report were inserted using the "User Inflow" setting at computation points along the system. The model only includes the storm sewer trunk line(s) and does not include the inlet level calculations, as under the TIP funding program the roadway design engineer is responsible for designing storm sewer inlets and providing sufficient inlet capacity, while the storm sewer design engineer is responsible for the sizing and arrangement of storm sewer pipes. The model includes the 2-year, 10-year, and 100-year storm events. The tailwater condition was set at the top of the outfall pipe at Poor Farm Ditch.

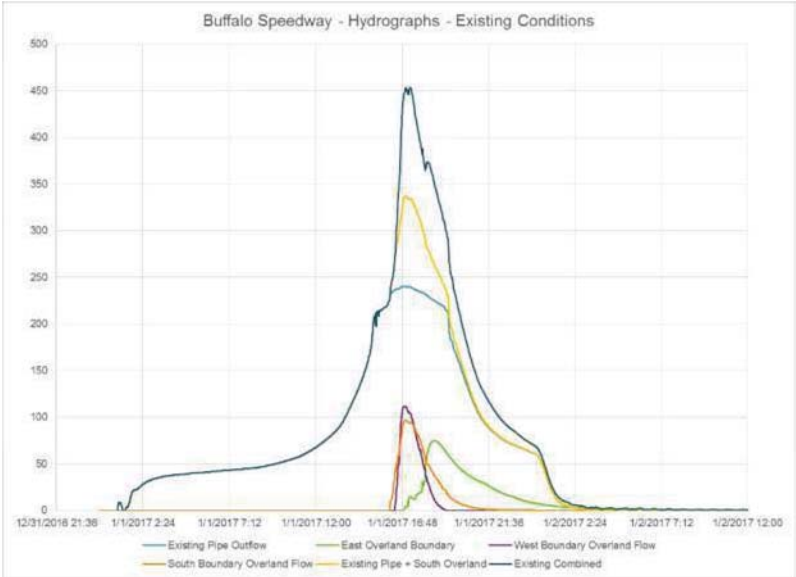
The results of the existing conditions hydraulic analysis indicate that the storm sewer trunk line does not have sufficient capacity to convey the 2-year peak discharge. Storm water ponding is expected along the entire corridor of Buffalo Speedway, and storm water flows eastward toward Belmont Street and then outside the extents of the 2D domain on the east, west and south boundaries of the 2D domain. The runoff which exits the 2D domain is calculated via a 2D flow line along the boundary within the hydraulic model. The runoff hydrographs from the storm sewers and 2D flow lines are shown below in **Figure 14**. As shown, the combined peak discharge from the system via all routes (including overland routes as well as the Poor Farm Ditch outfall) is approximately 325 cfs. The combined peak discharge at the outlet to Poor Farm Ditch is approximately 280 cfs.

Figure 14 - Existing Conditions 2-Year Runoff Hydrographs



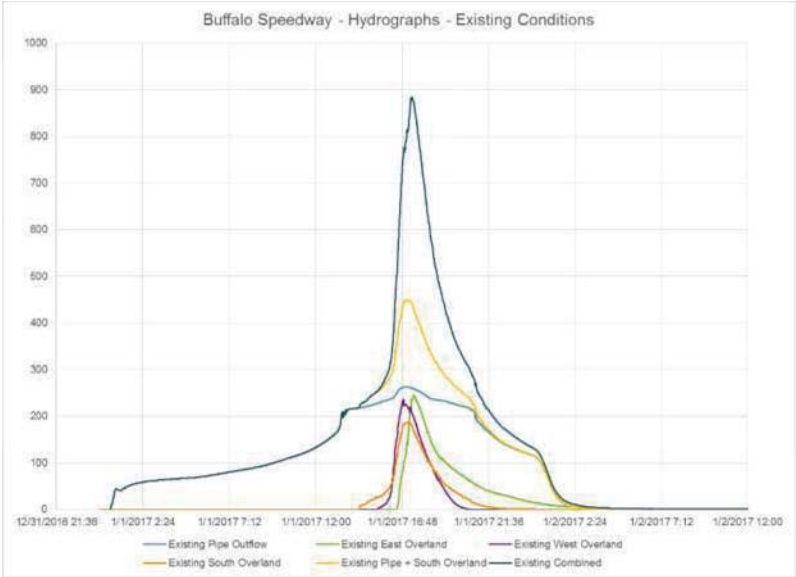
The 10-year runoff hydrographs for the existing conditions are shown below in **Figure 15**. As shown, the combined peak discharge from the system (via all routes) is approximately 450 cfs. The 10-year peak discharge at the storm sewer outfall to Poor Farm Ditch is approximately 340 cfs.

Figure 15 - Existing Conditions 10-year Runoff Hydrographs



The 100-year runoff hydrographs for the existing conditions are provided below in **Figure 16**. As shown, the combined peak discharge (via all routes) is approximately 880 cfs. The 100-year peak discharge at the Poor Farm Ditch outfall is approximately 450 cfs.

Figure 16 - Existing Conditions 100-Year Runoff Hydrographs



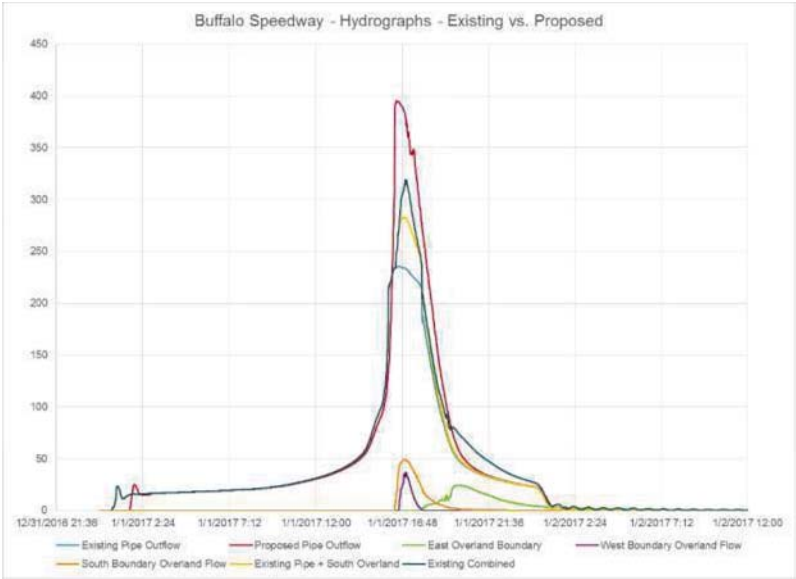
Flooding depth grids of the 2-year, 10-year, and 100-year storm events are provided in **Exhibits 3, 4, and 5**, respectively. Hydraulic grade line plots of the 2-year and 100-year storm events (generated directly from XPSWMM) are provided in **Exhibits 6 and 7**, respectively.

4.2 Proposed Conditions

The existing conditions hydraulic model was modified to include the proposed storm sewer. The proposed storm sewer sizes range from a single 66-inch RCP at Bissonnet Street to dual 8'x8' box culverts near the outfall. The proposed conditions model results indicate significant reductions in street ponding along Buffalo Speedway for the 2-year storm event. There is still significant ponding in the upper portions of the system, and storm water flows eastward toward Belmont Street during the 2-year storm event. For the 100-year storm event, street ponding is significantly reduced in the proposed conditions.

The runoff hydrographs from the storm sewers and 2D flow lines are shown below in **Figure 17**. As shown, the proposed combined peak discharge from the system is approximately 390 cfs, which is an increase of approximately 110 cfs above the existing peak discharge rate at Poor Farm Ditch outfall. Based on that increase and evaluation of existing and proposed conditions 2-year discharge hydrographs, approximately 9 acre-feet of detention storage would be required to mitigate impacts for the 2-year storm event. However, due to the fact that Poor Farm Ditch has sufficient capacity to convey the 2-year storm, it will not be necessary to provide detention to mitigate potential increases in peak discharge from the Buffalo Speedway system if no impacts are computed for 10-year and 100-year events.

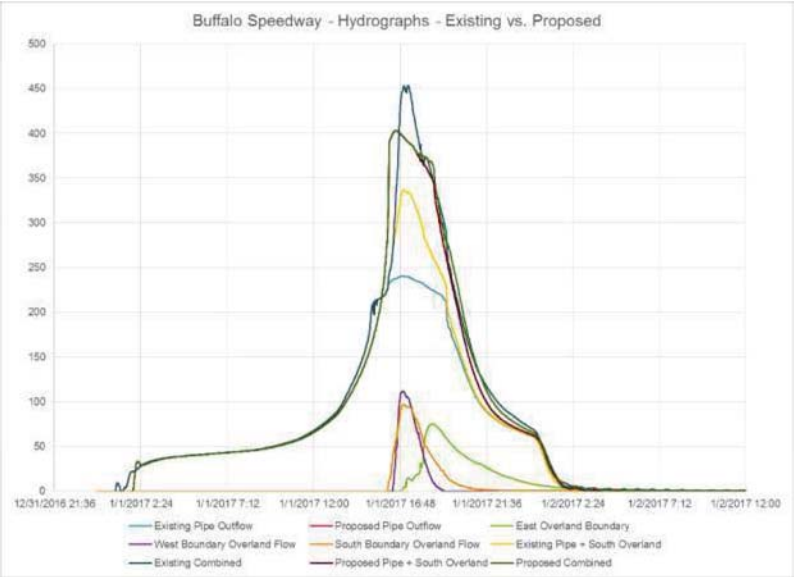
Figure 17 –Existing Conditions vs. Proposed Conditions 2-Year Runoff Hydrographs



The 10-year runoff hydrographs for the existing conditions are provided below in **Figure 18**. As shown, the combined peak discharge is approximately 400 cfs, which is less than the combined existing conditions peak discharge to Poor Farm Ditch. XPSWMM results indicate that overland sheet flow to locations outside of the 2D domain was eliminated for the 10-year storm event, leaving only the storm sewer and overland route to Poor Farm Ditch. Storage within the streets and the storm sewer system, including storage provided in the existing sewer pipes left in place, meters flow out of the system to broaden the hydrograph to reduce the combined peak discharge rate to Poor Farm Ditch to a value less than the existing conditions combined value for all discharge routes. Thus, while the 10-year peak discharge to Poor Farm Ditch increases

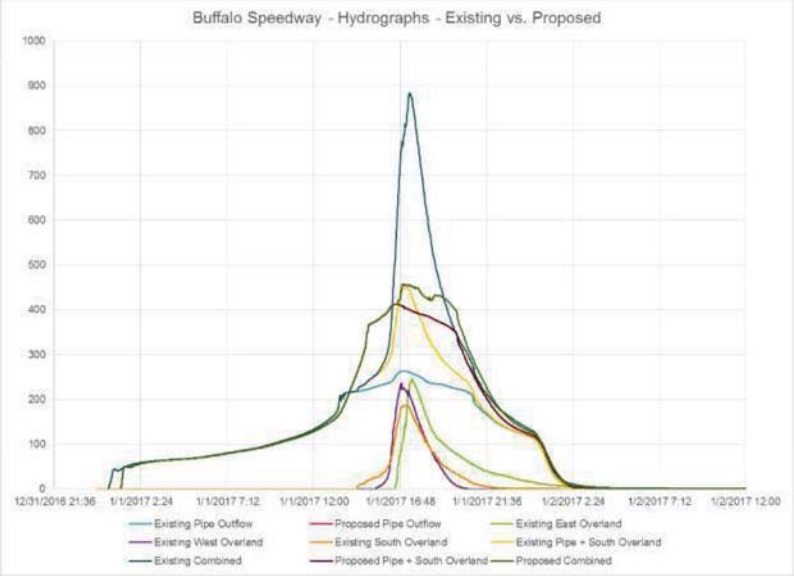
from approximately 340 cfs to approximately 400 cfs, the combined peak discharge to Brays Bayou via all routes is reduced from 450 cfs to 400 cfs, and the HCFCD has indicated that the channel of Poor Farm Ditch downstream of Bellaire Boulevard has 100-year flow capacity.

Figure 18 - Existing Conditions vs. Proposed Conditions 10-Year Runoff Hydrographs



The 100-year runoff hydrographs for the existing conditions are provided below in **Figure 19**. As shown, the combined peak discharge is approximately 450 cfs, which is very comparable to the existing conditions combined peak discharge to Poor Farm Ditch. XPSWMM results indicate that overland sheet flow to locations outside of the 2D domain was eliminated for the 10-year storm event, leaving only the storm sewer and overland route to Poor Farm Ditch. Storage within the streets and storm sewer system meters flow out the system to broaden the hydrograph to reduce the peak discharge rates to Poor Farm Ditch.

Figure 19 – Existing Conditions vs. Proposed Conditions 100-Year Runoff Hydrographs



These results demonstrate no increase in peak discharge to Poor Farm Ditch, although the volume of water flowing to the channel is increased due to the elimination of overland flow to Brays Bayou via alternate routes. Flooding depth grids of the 2-year, 10-year, and 100-year storm events are provided on **Exhibits 8, 9, and 10**, respectively. Hydraulic grade line plots of the 2-year and 100-year storm events are provided on **Exhibits 11 and 12**, respectively.

4.3 Comparison of Ponding Depths along Buffalo Speedway

Table 3 below provides a summary of maximum flood depths at street intersections for each storm frequency based on the results of the XP-SWMM model. During a 2-year storm, street flooding is expected along Buffalo Speedway between Rice Blvd. and Bissonnet St. and between University Blvd. and Bellaire Blvd. During a 10-year and 100-year storm event, street flooding is expected along the entire stretch of Buffalo Speedway between Bissonnet St. and Bellaire Blvd.

Storm sewer improvements associated with the proposed improvements to Buffalo Speedway reduce ponding depths along Buffalo Speedway in the southern portions of the project limits. During a 100-year storm event, the proposed improvements provide a reduction in ponding depths as much as 1.5 feet along Buffalo Speedway.

Table 4 - Comparison of Ponding Depths along Buffalo Speedway

Location	2-Year			10-Year			100-Year		
	Existing	Proposed	Difference	Existing	Proposed	Difference	Existing	Proposed	Difference
Buffalo Speedway @ Bissonet	1.5	1.4	-0.1	1.7	1.7	0.0	2.0	2.0	0.0
Buffalo Speedway @ Wroxton	1.3	1.0	-0.3	1.7	1.7	0.0	2.2	2.1	-0.1
Buffalo Speedway @ Albans	1.6	1.2	-0.4	2.0	1.9	0.0	2.5	2.4	-0.1
Buffalo Speedway @ Sunset	1.1	0.6	-0.5	1.2	1.2	0.0	1.8	1.7	-0.1
Buffalo Speedway @ Nottingham	0.5	0.2	-0.3	0.8	0.6	-0.2	1.1	1.0	-0.1
Buffalo Speedway @ Quenby	0.2	0.2	0.0	1.1	0.7	-0.4	1.4	1.2	-0.2
Buffalo Speedway @ Robinhood	0.3	0.0	-0.3	0.5	0.4	-0.1	0.7	0.6	-0.1
Buffalo Speedway @ Tangley	0.8	0.5	-0.3	0.9	0.8	-0.1	1.0	0.8	-0.2
Buffalo Speedway @ Plumb	1.0	0.4	-0.5	1.0	0.9	-0.1	1.2	1.2	0.0
Buffalo Speedway @ Lafayette	1.2	1.0	-0.2	1.2	1.1	-0.1	1.4	1.3	-0.1
Buffalo Speedway @ Georgetown	1.3	0.7	-0.6	1.4	0.9	-0.5	1.4	1.3	-0.1
Buffalo Speedway @ Rice	0.5	0.1	-0.4	0.7	0.4	-0.3	0.9	0.8	-0.1
Buffalo Speedway @ Jarrard	0.0	0.0	0.0	0.6	0.4	-0.2	0.8	0.5	-0.3
Buffalo Speedway @ Amherst	0.0	0.0	0.0	0.0	0.3	0.3	0.6	0.6	-0.1
Buffalo Speedway @ University	0.9	0.8	-0.1	1.0	0.9	-0.2	1.2	0.6	-0.5
Buffalo Speedway @ Duke	1.8	0.9	-0.9	1.8	1.2	-0.7	2.0	1.2	-0.8
Buffalo Speedway @ Pittsburgh	1.6	0.0	-1.6	1.9	0.6	-1.3	2.2	0.6	-1.6
Buffalo Speedway @ Carnegie	0.8	0.0	-0.8	1.1	0.0	-1.1	1.3	0.0	-1.3
Buffalo Speedway @ Cason	1.3	0.2	-1.1	1.7	0.2	-1.5	2.1	0.6	-1.5
Buffalo Speedway @ Bellaire	1.5	0.5	-1.1	1.8	0.6	-1.2	2.0	0.5	-1.5

5 Pre-Design Activities

Limited pre-design activities have been completed as needed to develop the recommended drainage improvement plan. Those activities include the following.

- Limited field survey was completed by West Belt Surveying, Inc. Information collected was limited to top of manhole and invert elevations of existing storm sewers, and digital work products were provided to HDR. **Appendix E** includes work products prepared by West Belt Surveying, Inc.
- Limited geotechnical testing was completed by Aviles Engineering Corporation was completed. Work was limited to three (3) borings located at approximately intervals along Buffalo Speedway within the project segment. **Appendix F** includes a geotechnical investigations report prepared by Aviles Engineering Corporation. **Exhibit 13** illustrates the locations of three (3) borings completed along Buffalo Speedway. The geotechnical investigations revealed a number of concerns, including water at depths of approximately 6 feet 24 hours after drilling, as well as fat clays with Plasticity Index (PI) values as high as 56.
- An estimate of the costs associated with construction of the proposed storm drainage system was prepared by HDR Engineering, Inc. The estimated total construction cost is $15.2 million. **Appendix G** includes a copy of the cost estimate with additional calculations and details. As noted previously in this report, the estimated cost covers the installation of full-sized, dual box culvert replacements of the existing dual 66-inch storm sewer pipes that cross the St. Vincent de Paul Catholic Church campus. Depending upon the outcome of negotiations between the City of West University and the Church, it is possible that a lower-cost alternative may be implemented, but for purposes of preparing the cost estimate, the full cost for the full-capacity replacement option was included. Similarly, the cost estimate includes a proposed 66-inch storm sewer between Bissonnet Street and Wroxton Road that, as noted previously, will likely not be constructed in the near-term so that flows entering West University Place from the north are regulated to existing conditions levels. Again, for purposes of preparing the cost estimate, the full cost for the proposed Buffalo Speedway drainage infrastructure was included.
- Plans from prior roadway rehabilitation and infrastructure repair/upgrade projects were located and assemble for possible future consultation in the design phase. These plans are available for use by the City and its design consultants on the Buffalo Speedway project for purposes of locating utilities, identifying past construction, and evaluating new designs for space requirements and constructability. Following is a partial list of available construction documents.
    - West U Storm Sewer System (Garrett Engineering - 1942)
    - Priority Area 10 Drawings (Claunch & Miller, Inc. - 2001)
    - Priority Area 11 Drawings (Claunch & Miller, Inc. - 2001)
    - Poor Farm Ditch Outfall Rehabilitation (HDR Engineering, Inc. - 2013)
- Other information is available via GIS data. The type of GIS-based information available may be seen on **Exhibit 14**, which illustrates water line locations and sizes along Buffalo Speedway from Bissonnet Street southward to Bellaire Boulevard.

6 Conclusion

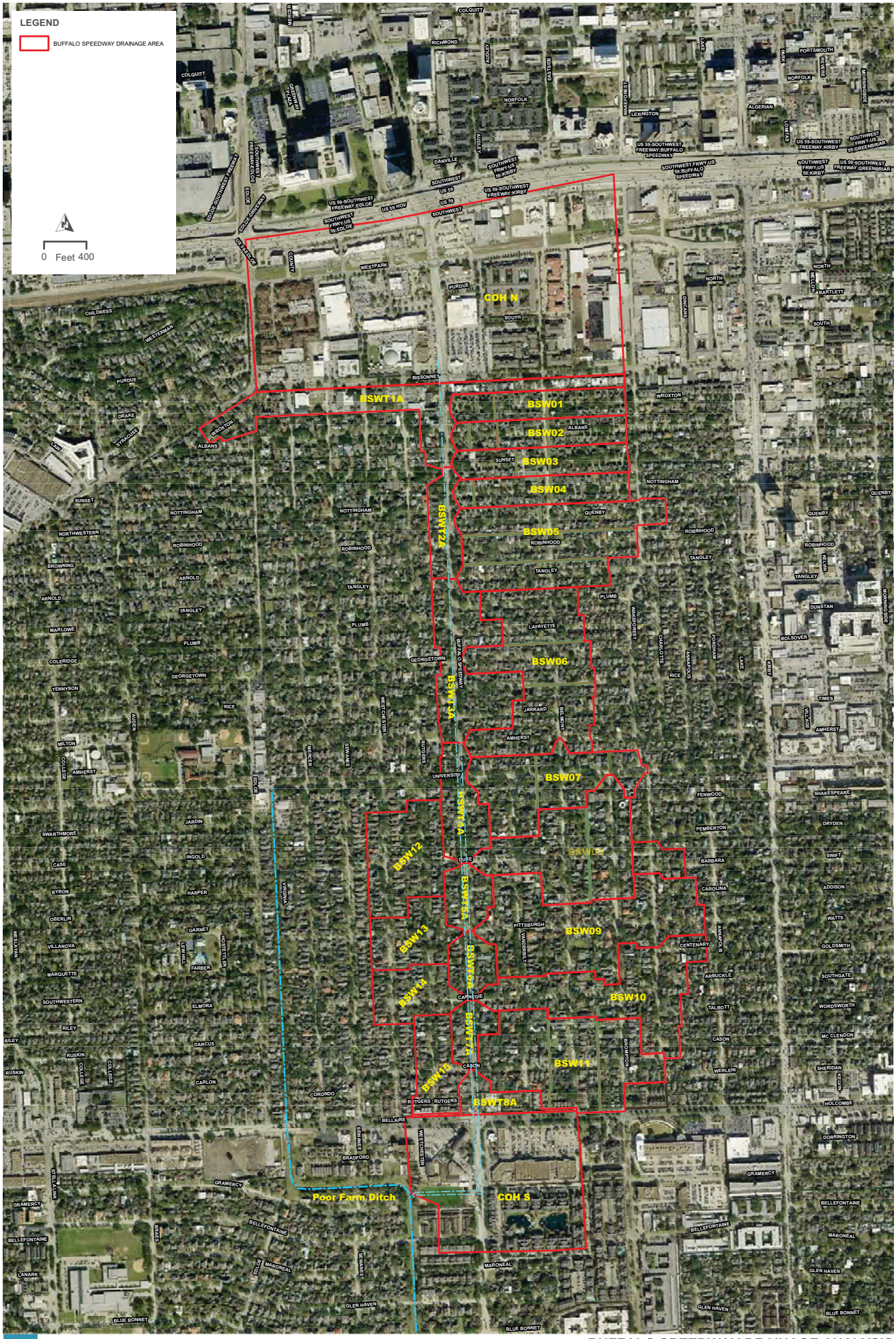
Based on the results of this analysis, the proposed improvements will not cause any adverse impacts on downstream peak flow rates along Poor Farm Ditch. The following recommendations are included as a part of the drainage plan associated with the improvements to Buffalo Speedway.

- Construct storm sewers along Buffalo Speedway between Bissonnet Street to the existing outfall to Poor Farm Ditch ranging in size from one 66-inch RCP to dual 8' x 8' RCBs.
- Construct the new storm sewers within the "inner" lanes along Buffalo Speedway in order to minimize impact to existing utilities and to allow the development of traffic control plans that provide access to driveways along both sides of the road.
- Install flow control devices along the proposed storm sewer to maintain existing conditions velocities within the storm sewer. The flow control devices should allow for a cross-sectional flow area equivalent to a 48-inch RCP.
- Design flow control devices using masonry walls or other means that are properly design to allow the flow controls to be adjusted or removed in the future without undue effort. Flow controls may be removed as downstream channel capacity improves or detention is provided.
- Do not construct the proposed single 66-inch RCP between Bissonnet Street and Wroxton Road in the interim, but include that pipe in the design plans so that it may be constructed in the future should the need to restrict flows from the north be eliminated.
- Consider alternatives for leaving the existing dual 66" storm sewers in place across the St. Vincent De Paul Catholic Church property, replacing the existing 66" storm sewers in kind, or upsizing to dual 8' x 8' box culverts to provide future capacity. Coordinate with the church with regard to any desired changes in the pipe alignment, and make sure there is a well-defined easement across the church property.
- In the design phase, account for possible shallow groundwater and the presence of fat clays. Provide for adequate trench safety and traffic safety at all times, in accordance with all applicable regulatory guidelines.

Based on the results of this analysis, the proposed improvements to Buffalo Speedway presented in this report will not cause any adverse impacts on downstream peak flow rates or upstream flood levels for storm events up to and including the 1% annual chance (100-year) storm event.

CHESTER
MERCER
SEWANEE
RUTGERS
UNIVERSITY
DUKE
PITTSBURGH
CARNEGIE
CASON
CORONDO
RUTGERS
RUTGERS
BELLAIRE
AMHERST
BELMONT
VANDERBILT
BROMPTON

EXHIBITS

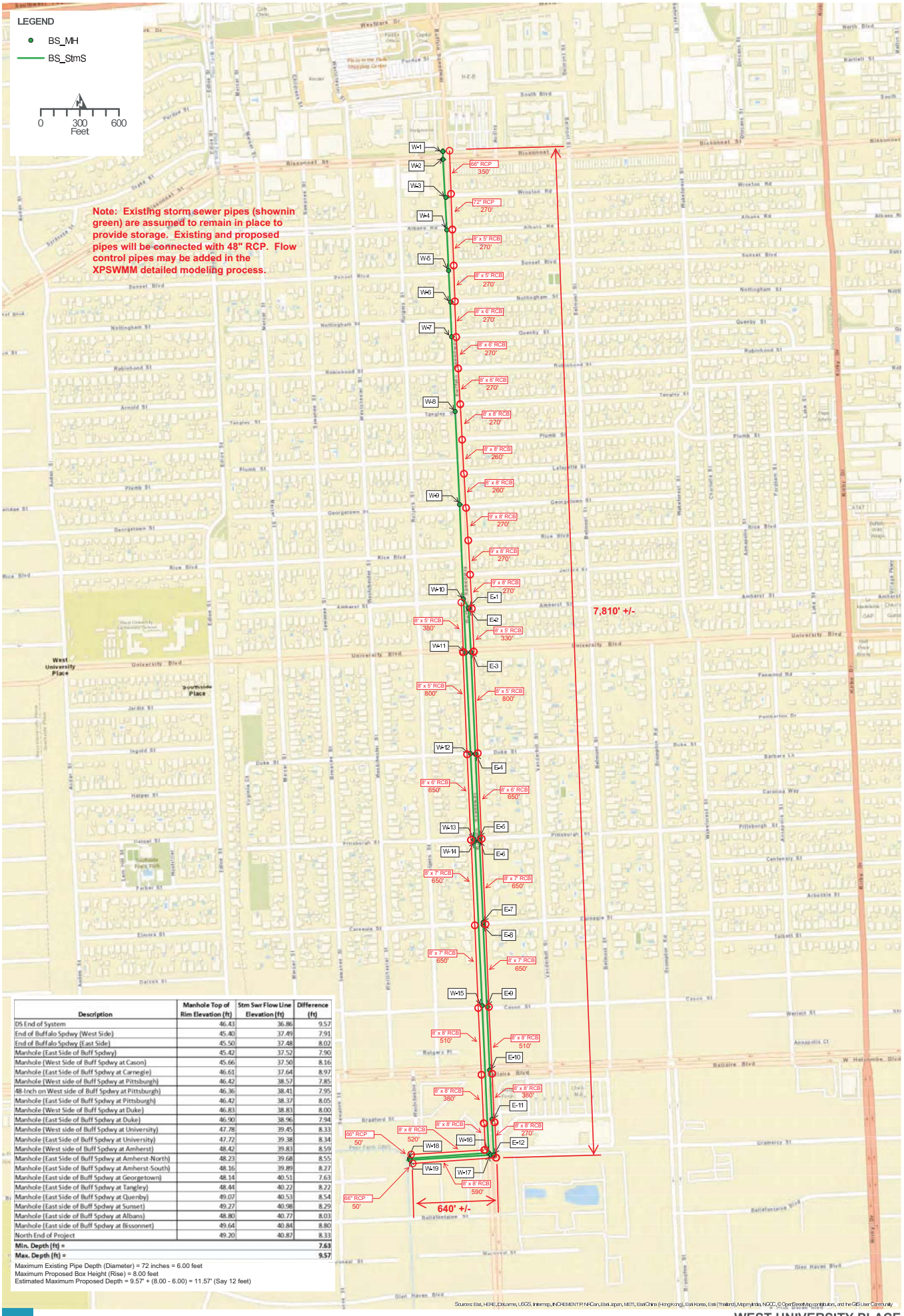


BUFFALO SPEEDWAY DRAINAGE ANALYSIS

DRAINAGE AREA MAP

EXHIBIT 1

PATH: C:\WORKSPACE\WEST U BUFFALO SPEEDWAY\SWMMLAYOUT.MXD - USER: JBLEVINS - DATE: 4/11/2018



Description	Manhole Top of Rim Elevation (ft)	Stm Swr Flow Line Elevation (ft)	Difference (ft)
DS End of System	46.43	36.86	9.57
End of Buffalo Spdwy (West Side)	45.40	37.49	7.91
End of Buffalo Spdwy (East Side)	45.50	37.48	8.02
Manhole (East Side of Buff Spdwy)	45.42	37.52	7.90
Manhole (West Side of Buff Spdwy at Cason)	45.66	37.50	8.16
Manhole (East Side of Buff Spdwy at Carnegie)	46.61	37.64	8.97
Manhole (West side of Buff Spdwy at Pittsburgh)	46.42	38.57	7.85
48-Inch on West side of Buff Spdwy at Pittsburgh)	46.36	38.41	7.95
Manhole (East Side of Buff Spdwy at Pittsburgh)	46.42	38.37	8.05
Manhole (West Side of Buff Spdwy at Duke)	46.83	38.83	8.00
Manhole (East Side of Buff Spdwy at Duke)	46.90	38.96	7.94
Manhole (West side of Buff Spdwy at University)	47.78	39.45	8.33
Manhole (East Side of Buff Spdwy at University)	47.72	39.38	8.34
Manhole (West side of Buff Spdwy at Amherst)	48.42	39.83	8.59
Manhole (East Side of Buff Spdwy at Amherst-North)	48.23	39.68	8.55
Manhole (East Side of Buff Spdwy at Amherst-South)	48.16	39.89	8.27
Manhole (East side of Buff Spdwy at Georgetown)	48.14	40.51	7.63
Manhole (East Side of Buff Spdwy at Tangley)	48.44	40.22	8.22
Manhole (East Side of Buff Spdwy at Quenby)	49.07	40.53	8.54
Manhole (East side of Buff Spdwy at Sunset)	49.27	40.98	8.29
Manhole (East side of Buff Spdwy at Albans)	48.80	40.77	8.03
Manhole (East side of Buff Spdwy at Bissonnet)	49.64	40.84	8.80
North End of Project	49.20	40.87	8.33
Min. Depth (ft) =			**7.63**
Max. Depth (ft) =			**9.57**

Maximum Existing Pipe Depth (Diameter) = 72 inches = 6.00 feet
Maximum Proposed Box Height (Rise) = 8.00 feet
Estimated Maximum Proposed Depth = 9.57' + (8.00 - 6.00) = 11.57' (Say 12 feet)

Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Note: Proposed storm sewer pipes are shown in red. This exhibit illustrates a preliminary design based on 2-year flow rates and gravity flow pipe capacity calculations.

HDR

WEST UNIVERSITY PLACE

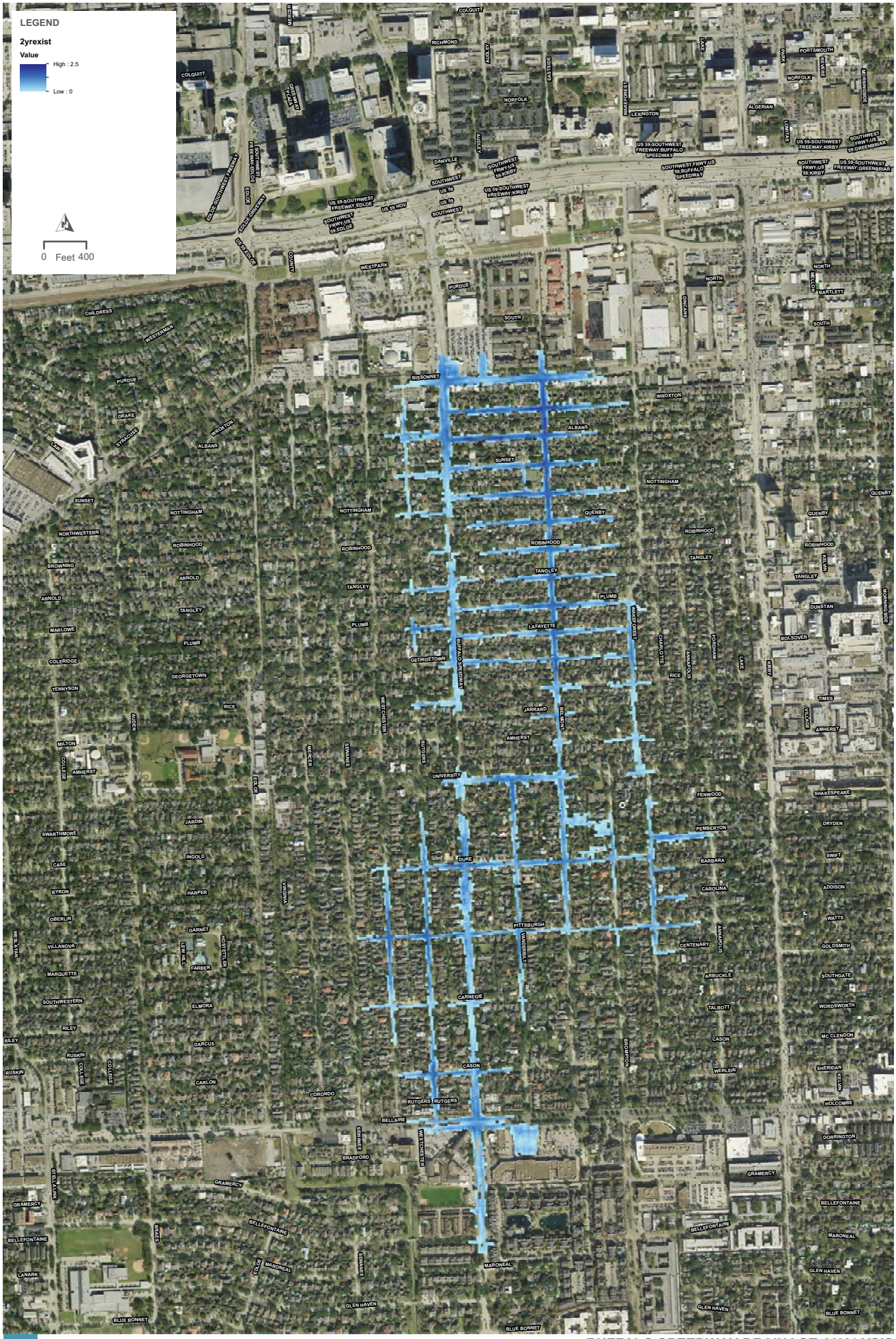
BUFFALO SPEEDWAY

EXISTING DRAINAGE LAYOUT

PATH: C:\USERS\ROSIBAJO\DOCUMENTS\ARCGIS\WEST_U_BS\BUFFALO_SPDWY.MXD - USER: ROSIBAJO - DATE: 2/6/2018

WEST U BUFFALO SPEEDWAY PER

EXHIBIT 2

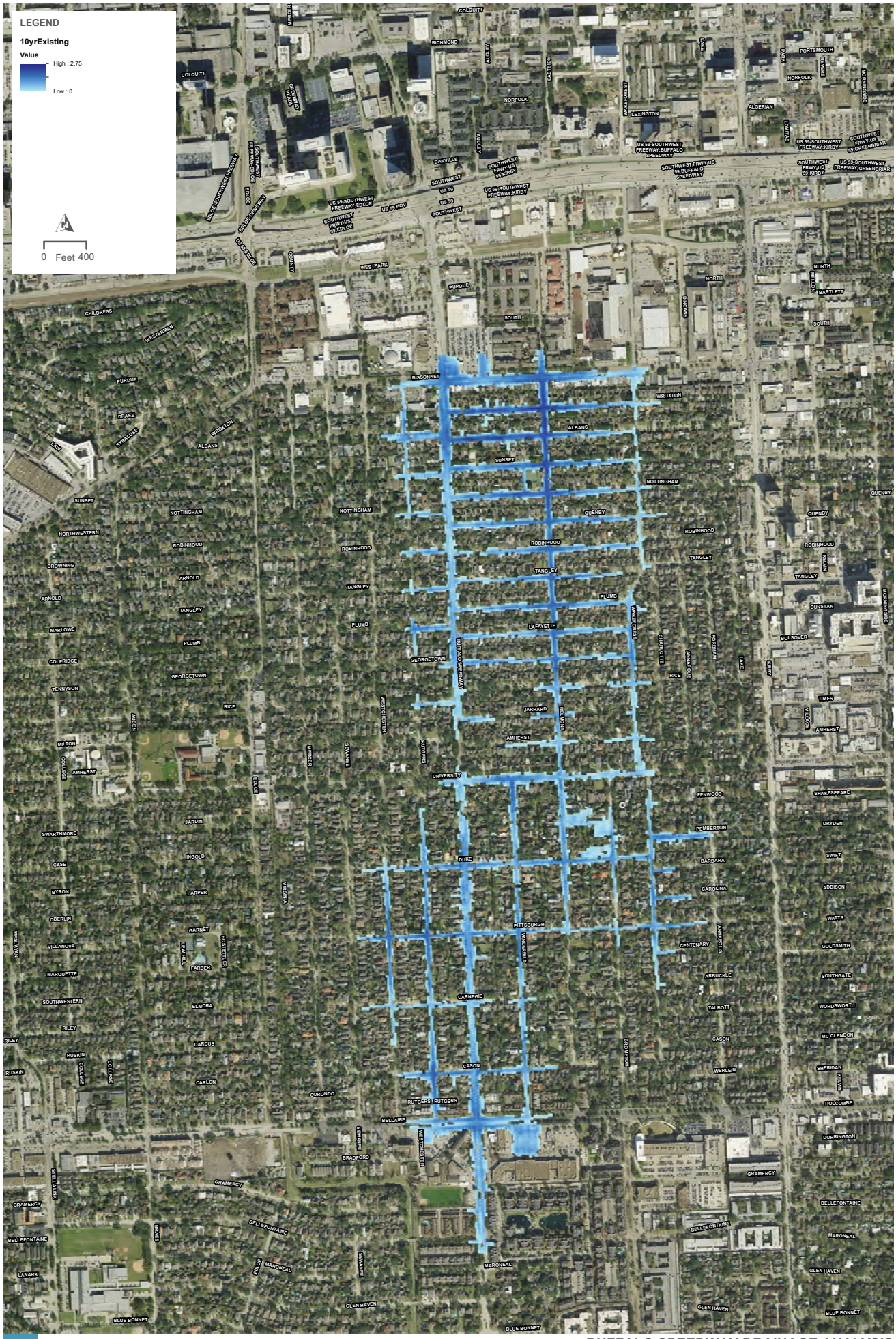


BUFFALO SPEEDWAY DRAINAGE ANALYSIS

EXISTING PONDING MAP - 2-YEAR

EXHIBIT 3

PATH: C:\WORKSPACE\WEST U BUFFALO SPEEDWAY\SWMMLAYOUT.MXD - USER: JBLEVINS - DATE: 4/13/2018

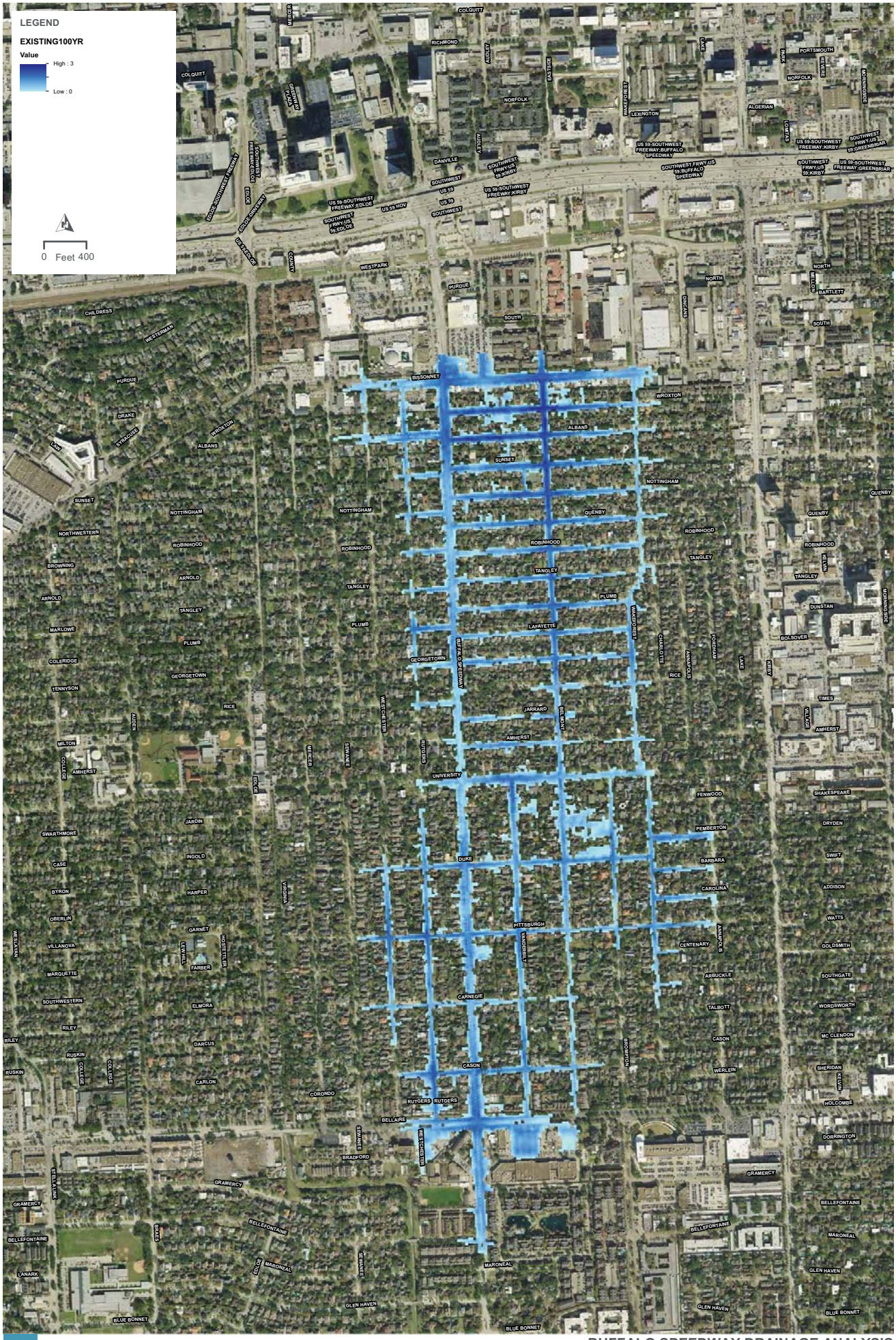


BUFFALO SPEEDWAY DRAINAGE ANALYSIS

EXISTING PONDING MAP - 10-YEAR

EXHIBIT 4

PATH: C:\WORKSPACE\WEST U BUFFALO SPEEDWAY\SWMMLAYOUT.MXD - USER: JBLEVINS - DATE: 4/13/2018

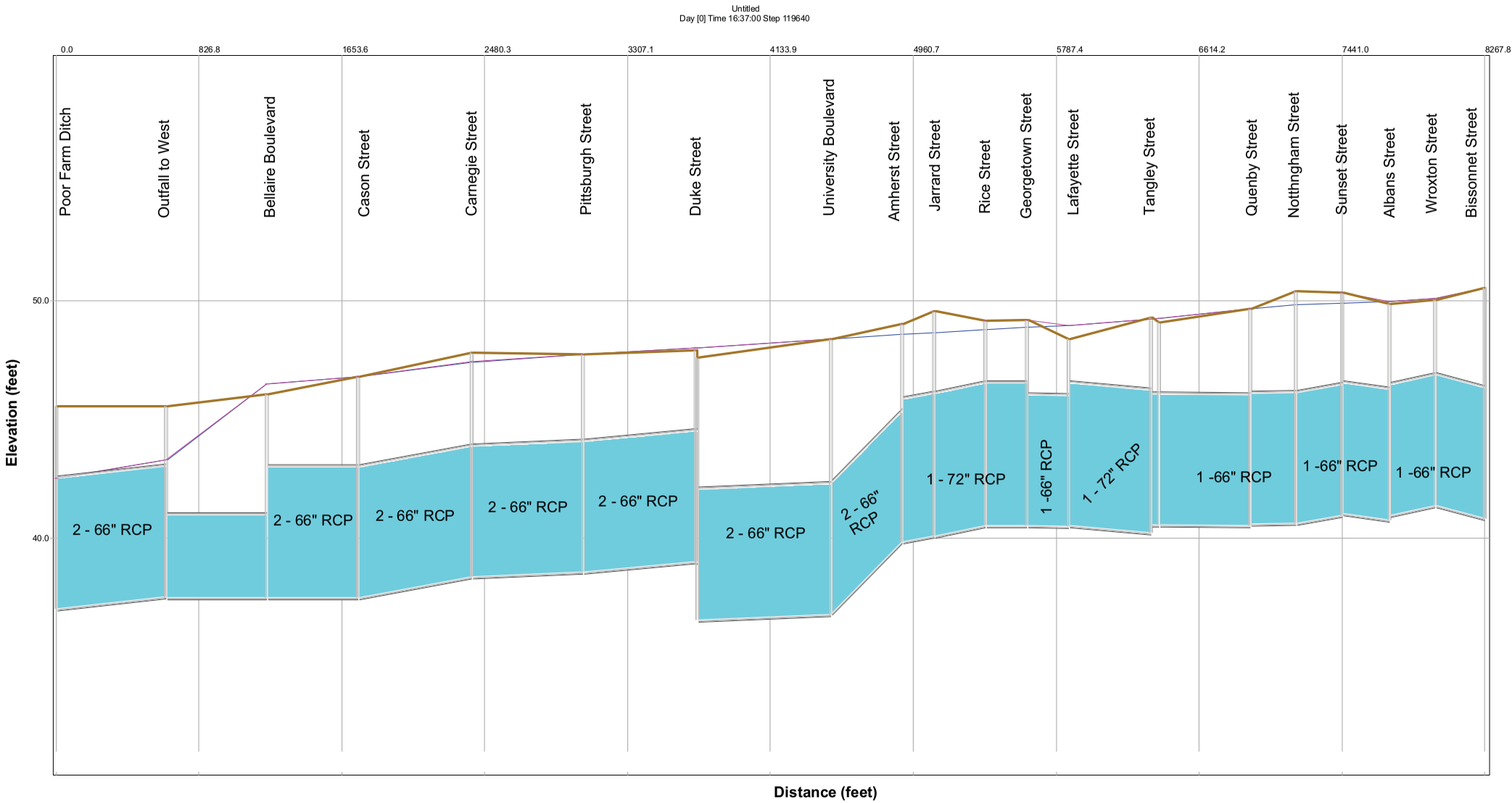


BUFFALO SPEEDWAY DRAINAGE ANALYSIS

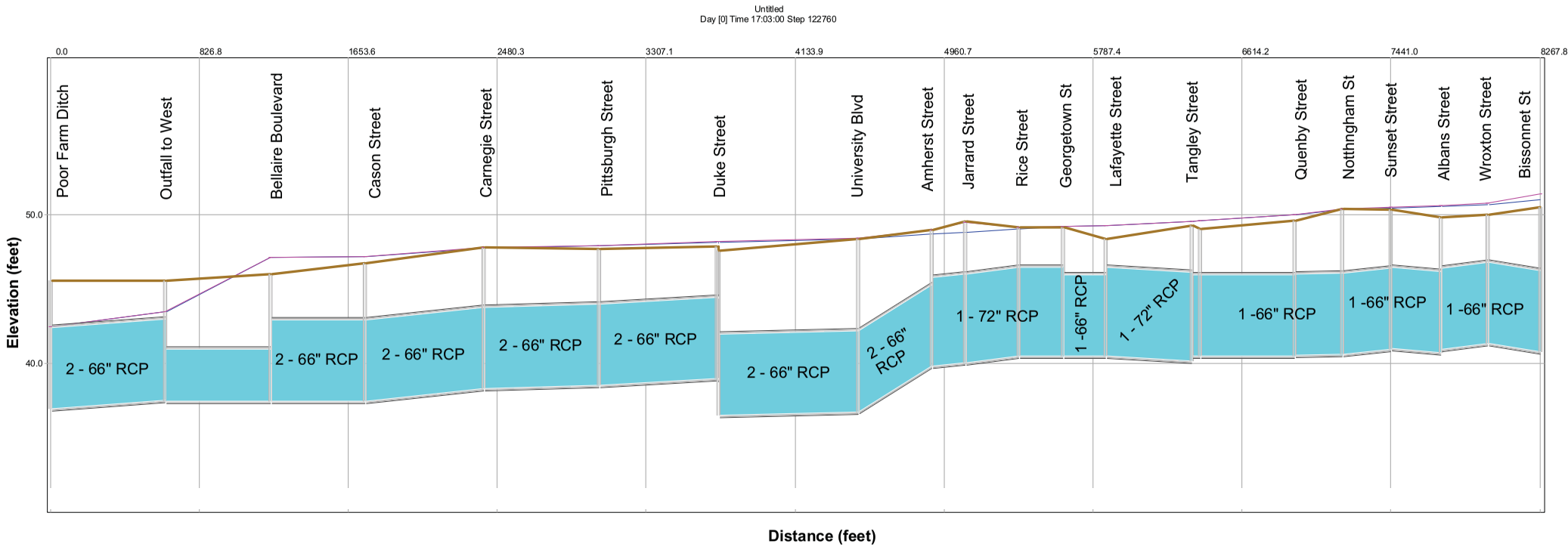
EXISTING PONDING MAP - 100-YEAR

EXHIBIT 5

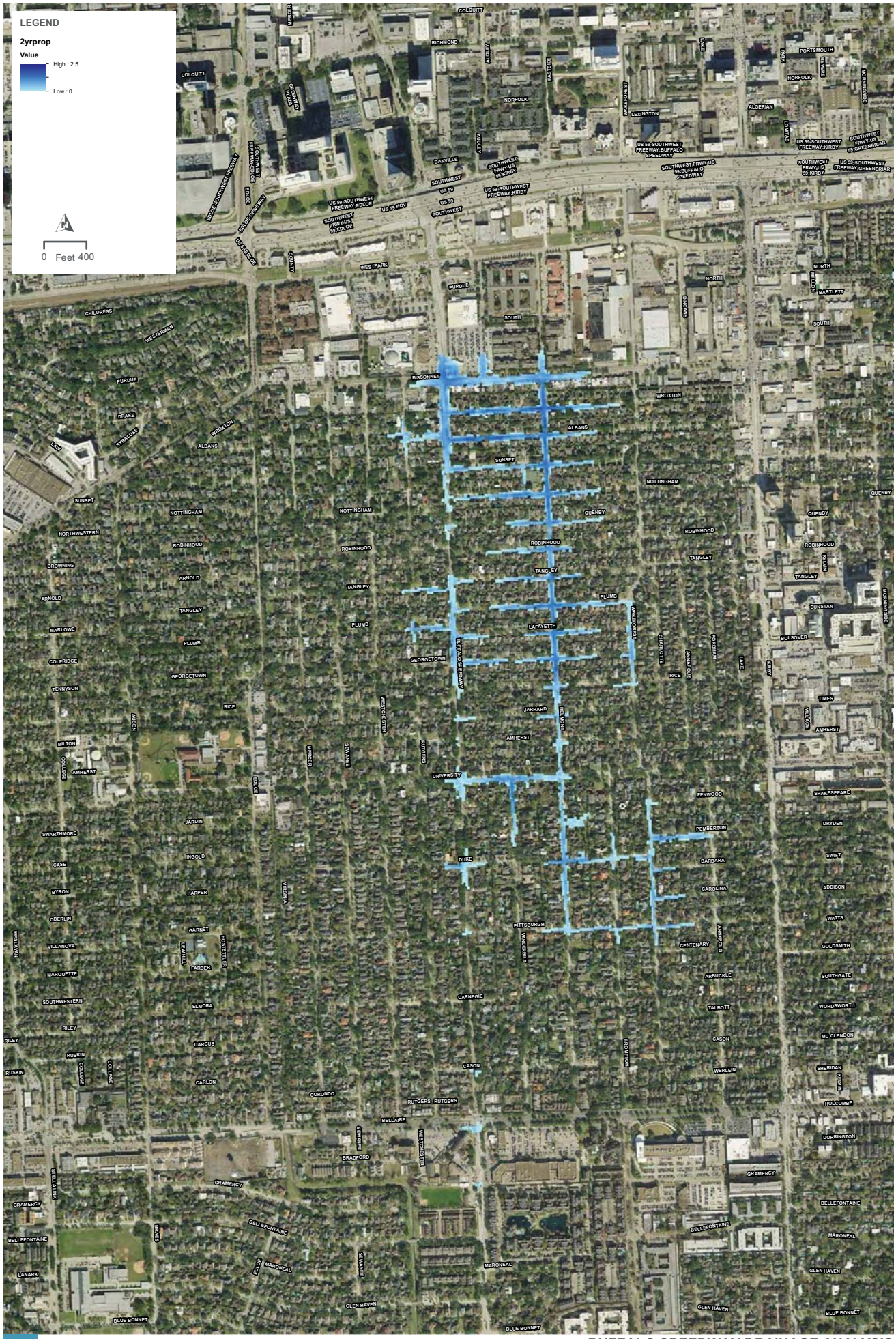
PATH: C:\WORKSPACE\WEST U BUFFALO SPEEDWAY\SWMMLAYOUT.MXD - USER: JBLEVINS - DATE: 4/13/2018



BUFFALO SPEEDWAY DRAINAGE PRELIMINARY ENGINEERING REPORT
EXHIBIT 6 - 2-YEAR HGL PLOT - EXISTING CONDITIONS



BUFFALO SPEEDWAY DRAINAGE PRELIMINARY ENGINEERING REPORT
EXHIBIT 7 - 100-YEAR HGL PLOT - EXISTING CONDITIONS



BUFFALO SPEEDWAY DRAINAGE ANALYSIS

PROPOSED PONDING MAP - 2-YEAR

EXHIBIT 8

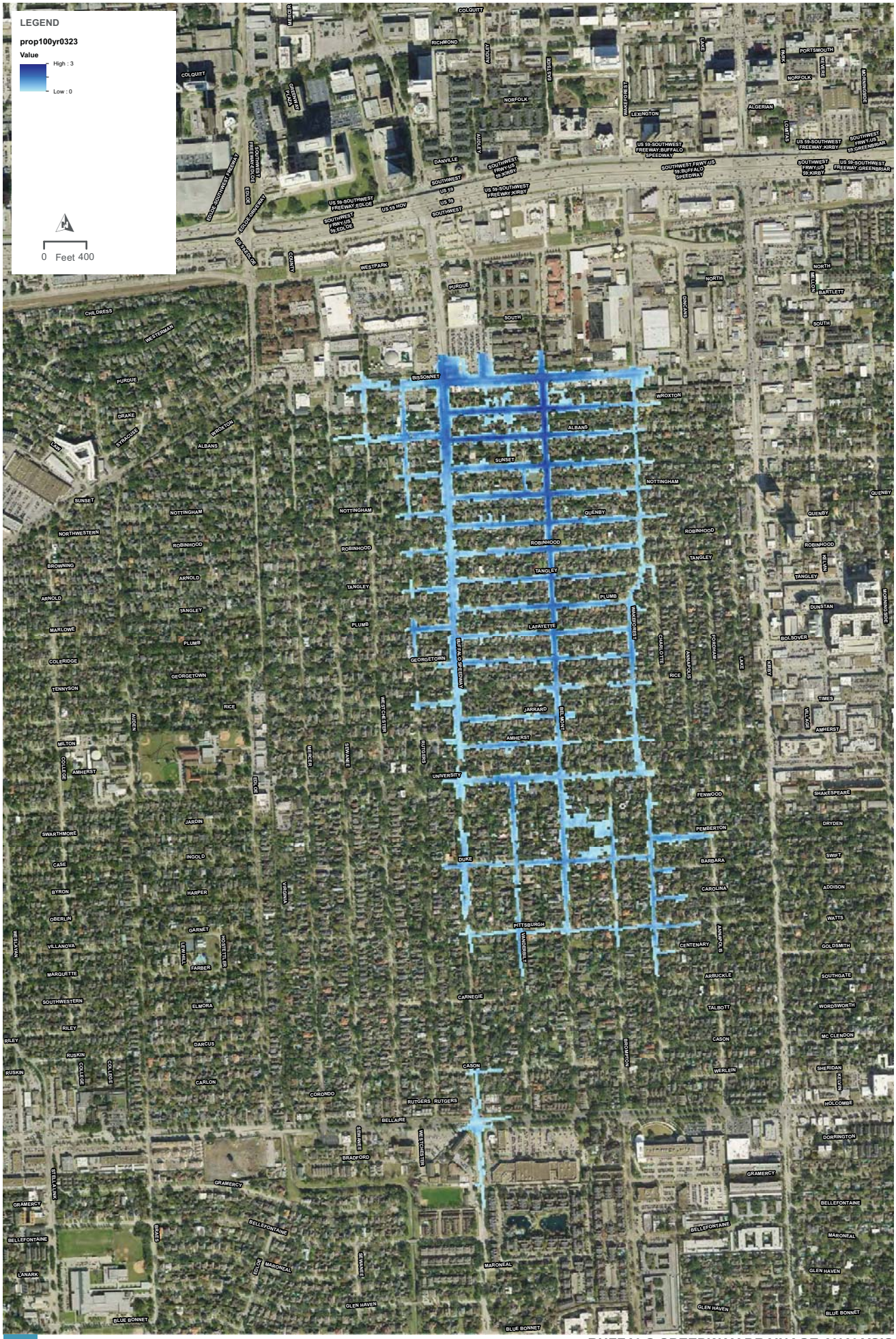
PATH: C:\WORKSPACE\WEST U BUFFALO SPEEDWAY\SWMMLAYOUT.MXD - USER: JBLEVINS - DATE: 4/13/2018

BUFFALO SPEEDWAY DRAINAGE ANALYSIS

PROPOSED PONDING MAP - 10-YEAR

EXHIBIT 9

PATH: C:\WORKSPACE\WEST U BUFFALO SPEEDWAY\SWMMLAYOUT.MXD - USER: JBLEVINS - DATE: 4/13/2018

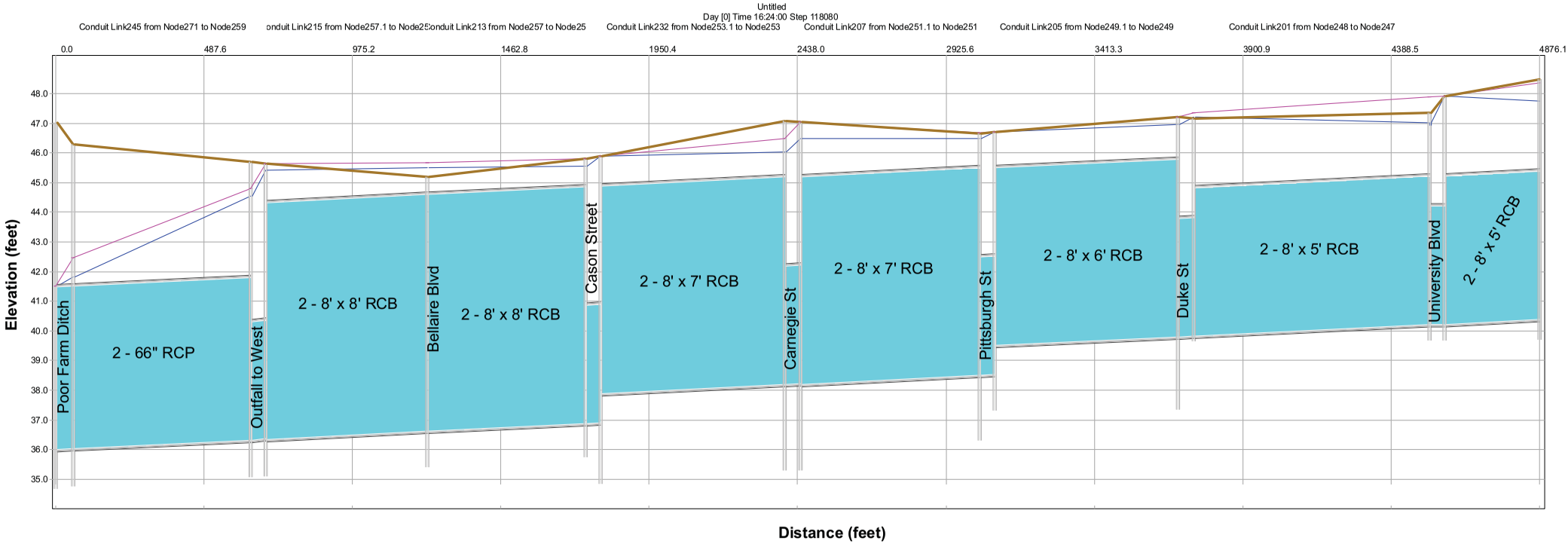


BUFFALO SPEEDWAY DRAINAGE ANALYSIS

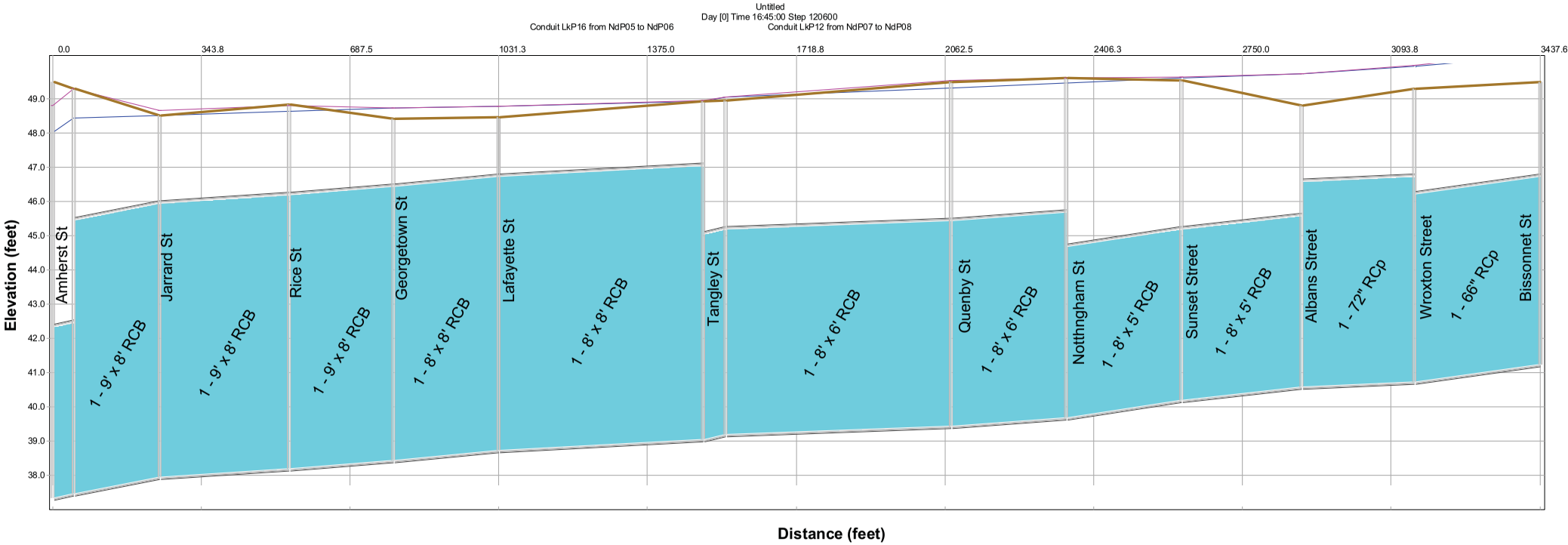
PROPOSED PONDING MAP - 100-YEAR

EXHIBIT 10

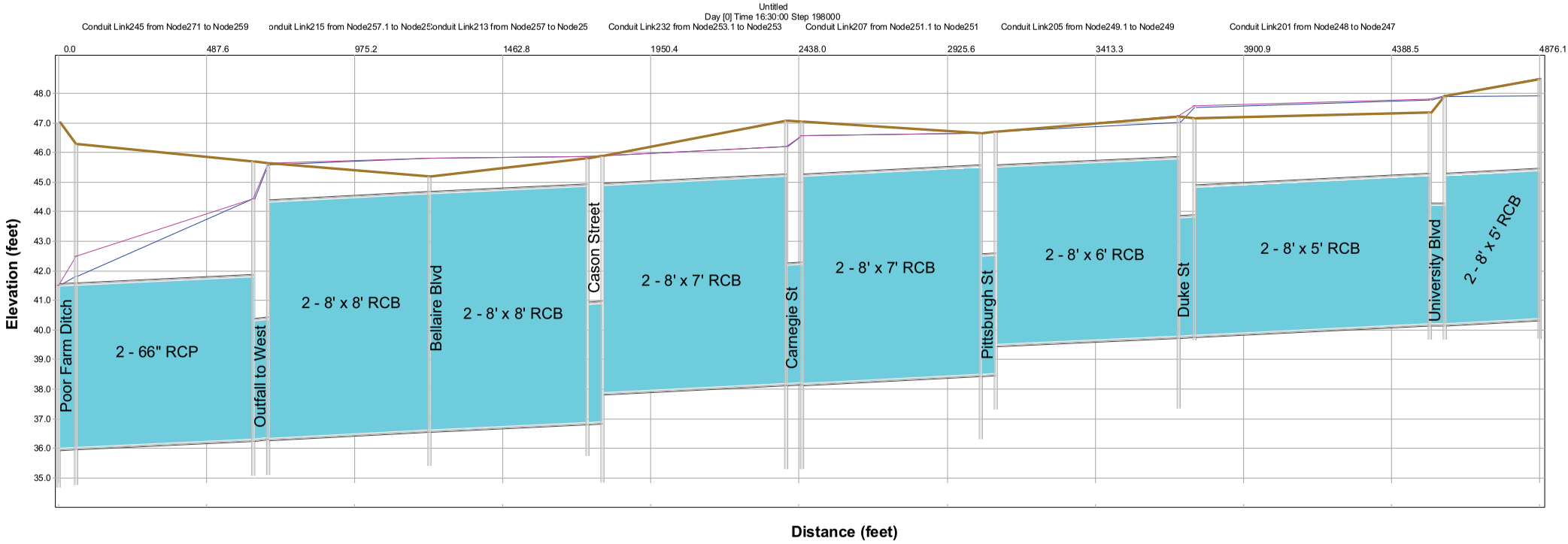
PATH: C:\WORKSPACE\WEST U BUFFALO SPEEDWAY\SWMMLAYOUT.MXD - USER: JBLEVINS - DATE: 4/13/2018



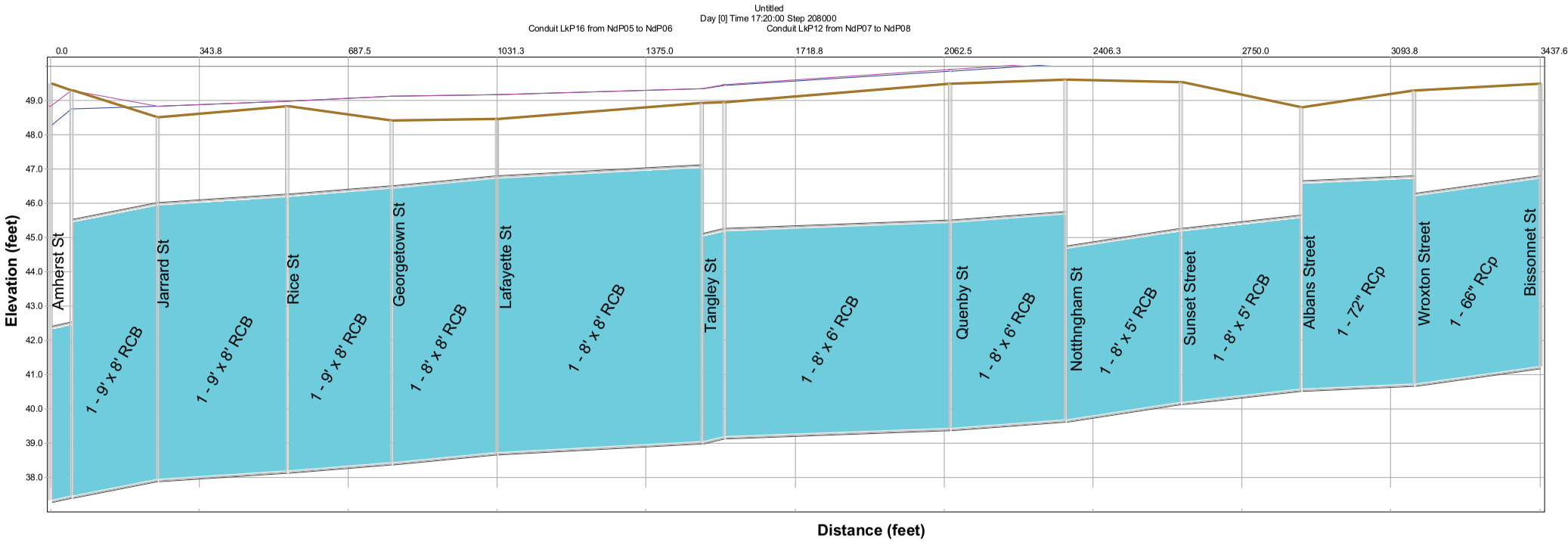
BUFFALO SPEEDWAY DRAINAGE PRELIMINARY ENGINEERING REPORT
EXHIBIT 11A - 2-YEAR HGL PLOT - PROPOSED CONDITIONS
DOWNSTREAM END OF SYSTEM



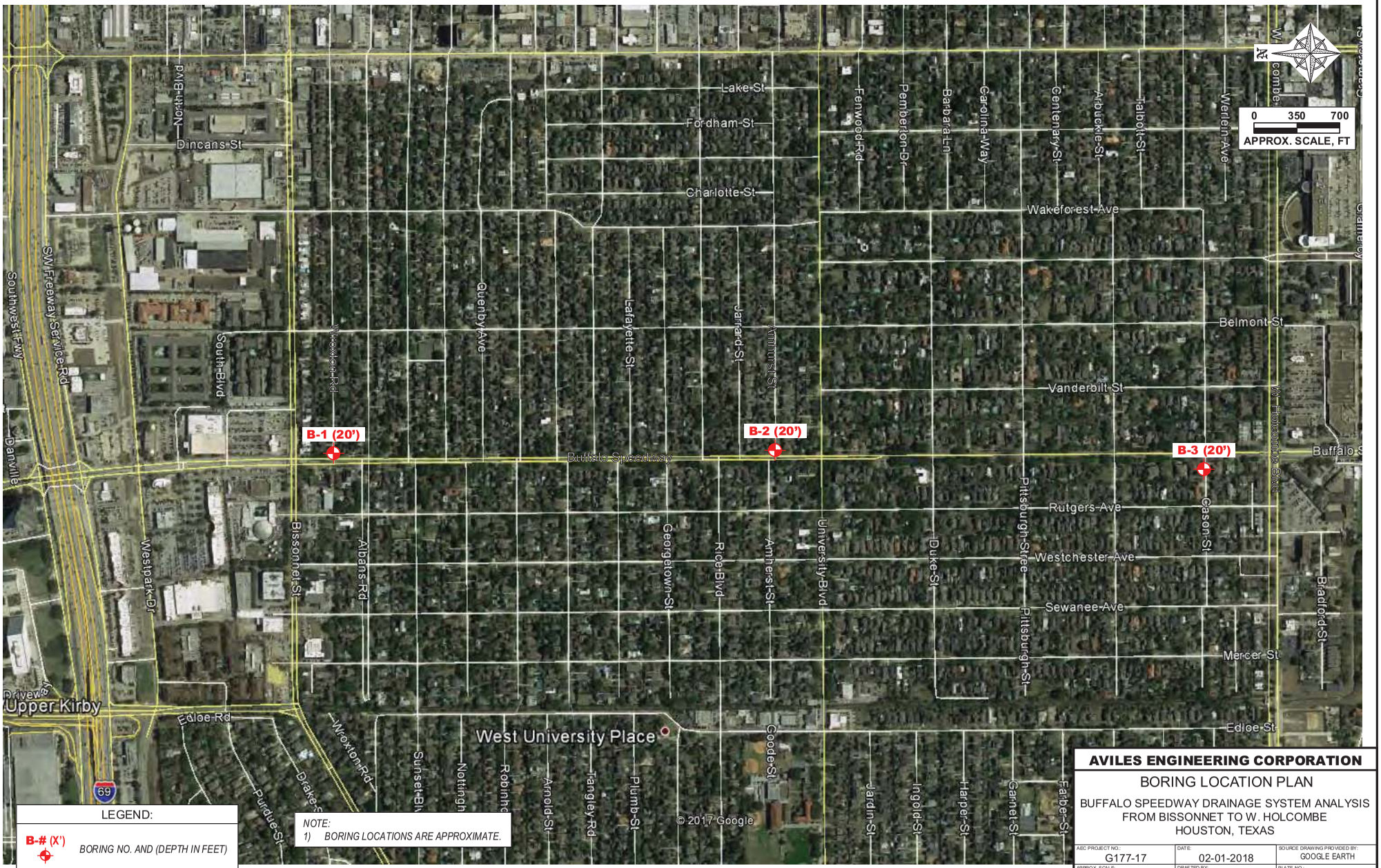
BUFFALO SPEEDWAY DRAINAGE PRELIMINARY ENGINEERING REPORT
EXHIBIT 11B - 2-YEAR HGL PLOT - PROPOSED CONDITIONS
UPSTREAM END OF SYSTEM



BUFFALO SPEEDWAY DRAINAGE PRELIMINARY ENGINEERING REPORT
EXHIBIT 12A - 100-YEAR HGL PLOT - PROPOSED CONDITIONS
DOWNSTREAM END OF SYSTEM



BUFFALO SPEEDWAY DRAINAGE PRELIMINARY ENGINEERING REPORT
EXHIBIT 12B - 100-YEAR HGL PLOT - PROPOSED CONDITIONS
UPSTREAM END OF SYSTEM



LEGEND:

B-# (X') — BORING NO. AND (DEPTH IN FEET)

NOTE:
1) BORING LOCATIONS ARE APPROXIMATE.

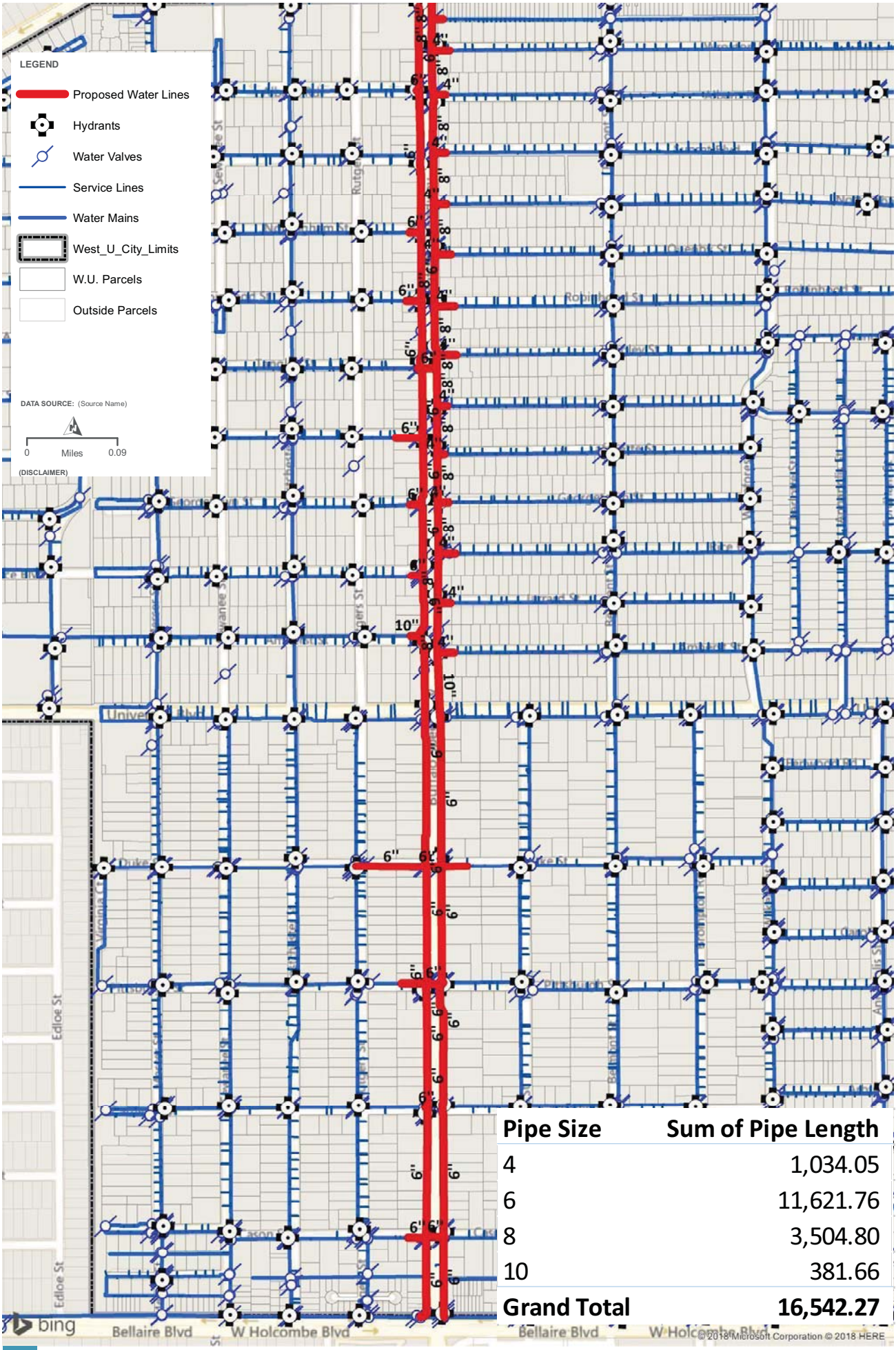
AVILES ENGINEERING CORPORATION

BORING LOCATION PLAN

BUFFALO SPEEDWAY DRAINAGE SYSTEM ANALYSIS
FROM BISSONNET TO W. HOLCOMBE
HOUSTON, TEXAS

AEC PROJECT NO.:	DATE:	SOURCE DRAWING PROVIDED BY:
G177-17	02-01-2018	GOOGLE EARTH
APPROX. SCALE: 1" = 700'	DRAFTED BY: WLW/JG	PLATE NO.: PLATE 1

EXHIBIT 13



Pipe Size	Sum of Pipe Length
4	1,034.05
6	11,621.76
8	3,504.80
10	381.66
Grand Total	**16,542.27**

PROPOSED WATER LINE REPLACEMENT ALONG BUFFALO SPEEDWAY

BISSONNET TO AMHERST

(FIGURE #)

PATH: Z:\CLIENTS\ANGLETON\MASTER PLAN\WATER MODEL\WEST UNIVERSITY PLACE BUFFALO SPEEDWAY WATER LINES ALL.MXD - USER: LTEFFT - DATE: 8/16/2018

EXHIBIT 14

APPENDIX A

"Virtual Tour" Photographs

Buffalo Speedway Improvements

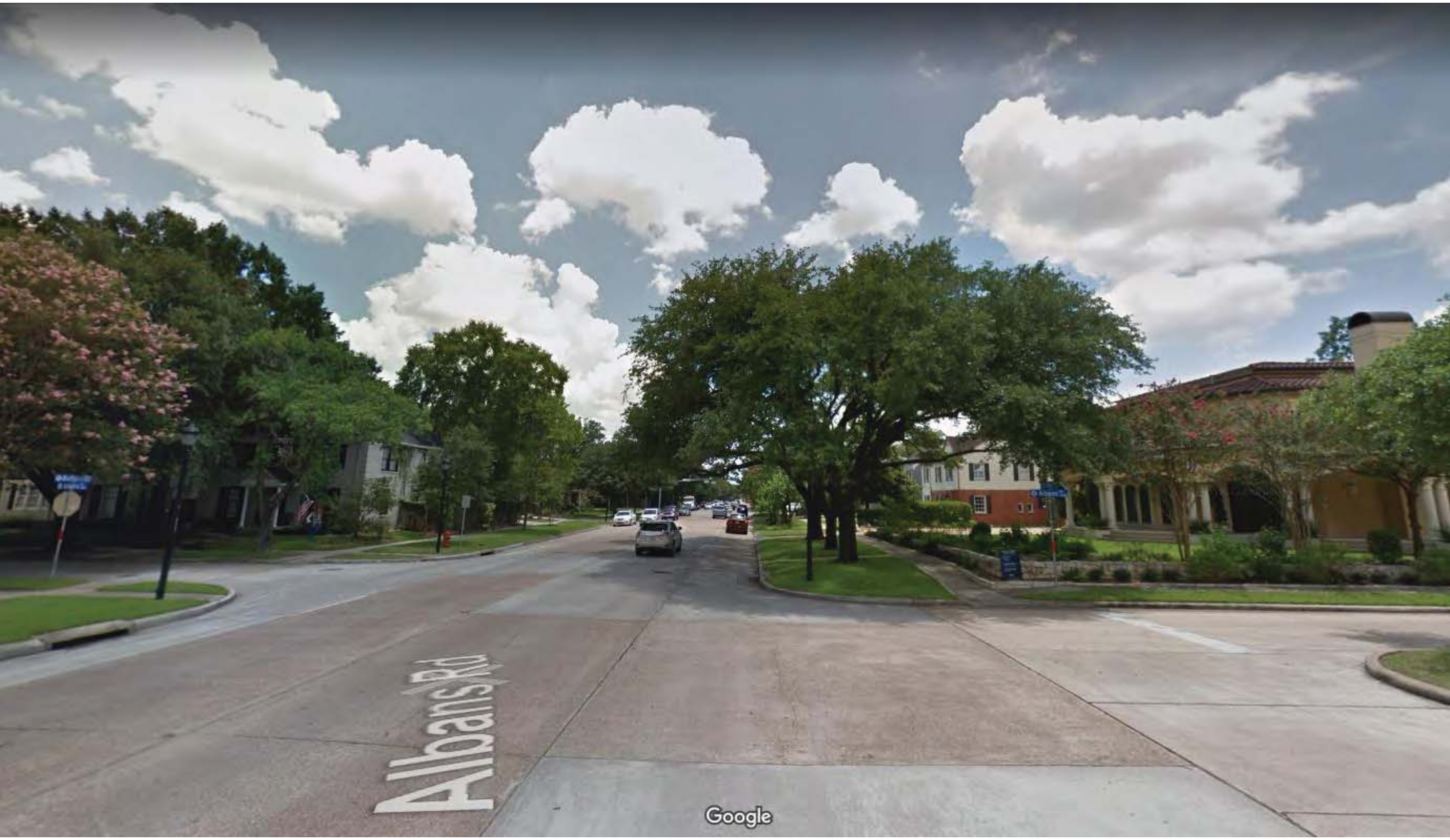
Virtual Tour of Project Area

City of West University Place, TX

August 10, 2018

Buffalo Speedway at Bissonnet

Buffalo Speedway at Wroxton



Buffalo Speedway at Albans

Buffalo Speedway at Sunset

Buffalo Speedway at Nottingham

Buffalo Speedway at Quenby

Buffalo Speedway at Robin Hood

Buffalo Speedway at Tangley

Buffalo Speedway at Plumb

Buffalo Speedway at Lafayette

Buffalo Speedway at Georgetown

Buffalo Speedway at Rice

Buffalo Speedway at Jarrard

Buffalo Speedway at Amherst

Buffalo Speedway at University

Buffalo Speedway at Duke

Buffalo Speedway at Pittsburgh

Buffalo Speedway at Carnegie

Buffalo Speedway at Cason

Buffalo Speedway at Bellaire Blvd.

Outfall to Poor Farm Ditch (From Bellefontaine)

Existing Storm Sewer Outfall Route

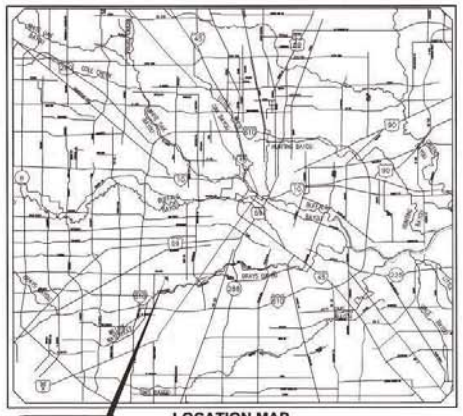
APPENDIX B

Construction Plans for Rehabilitation of Buffalo Speedway Outfall to Poor Farm Ditch

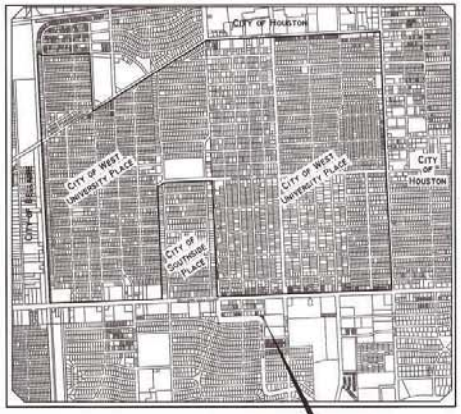
City of West University Place, Texas

Repair of St. Vincent's Storm Sewer Outfall
at
Poor Farm Ditch Stilling Basin

April, 2014



LOCATION MAP



VICINITY MAP

NOT TO SCALE
KEY MAP NO. - 532 L
GIMS MAP NO. - 5255D
ZIP CODE - 77025

SUBMITTED BY: _____ DATE: _____

Stephen Ratcliffe, P.E.
HDR Engineering, Inc.

MAYOR

Bob Fry

COUNCIL

Susan Sample (Mayor Pro-Tem) **Joan Johnson**
Ed Heathcoat **Dick Yehle**

CITY MANAGER

Michael G. Ross

Assistant City Manager/Public Works Director

Chris Peifer

HDR
HDR Engineering Inc. Texas Reg. No. 754
4635 Southwest Freeway, Suite 1000 • Houston, Texas 77027
(713) 622-9264 •Fax (713) 623-9265 • www.hdrinc.com

HDR JOB NO. 13-053

SHEET NO.	SHEET TITLE
1.	Cover Sheet/Location Map
2.	Access and Storm Water Pollution Prevention Plan
3.	Structural Repair Details
4.	H.C.F.C.D. Notes & Reinforcing Details
5.	H.C.F.C.D. Concrete Channel Lining Details
6.	H.C.F.C.D. Stormwater Pollution Prevention Details

THIS PROJECT INCLUDES WORK TO BE PERFORMED IN THE CITY OF HOUSTON'S RIGHT OF WAY AND EASEMENTS. DRAWINGS MUST BE APPROVED AND PERMITTED PRIOR TO BEGIN CONSTRUCTION

CONTACT REQUIRED SECTIONS BELOW AS INDICATED

DRAWINGS APPROVAL
☐ 1002 Washington (2nd Floor) 832-394-9146

PERMITS 1002 Washington (2nd Floor)
☐ PAVING 832-394-8851
☒ STORM 832-394-8851
☐ ALLEY 832-394-8851
☐ STREET CUT 832-394-9101
☐ EXCAVATION 832-394-9101

PERMITS 1002 Washington (2nd Floor)
☐ SANITARY 832-394-8971
☐ WATER 832-394-8971

Log No. 14-0274
ILMS No. 14027779

FOR PLAN REVIEW WALK THRU ONLY
APPROVED
FLOODPLAIN GROUP
4/3/14 By: Vmo

ONE-CALL NOTIFICATION SYSTEM
CALL BEFORE YOU DIG!!!
(713) 223-4567 (in Houston)
(New Statewide Number Outside Houston)
1-800-545-6005

* NO PROPOSED WASTEWATER WORK IS SHOWN ON THIS PLAN SET NOR INCLUDED IN THIS WORK SCOPE.

Contractor shall notify the City of Houston, Department of Public Works and Engineering, Office of the City Engineer, 48 hours before starting work on this project. Telephone No. 832-394-9098.

ACCORDING TO MAP (NO. 48201C0860L) OF THE FEDERAL EMERGENCY MANAGEMENT AGENCY'S FLOOD INSURANCE RATE MAPS FOR HARRIS COUNTY AND INCORPORATED AREAS, DATED JUNE 18, 2007, THE SUBJECT TRACT IS SITUATED WITHIN (ZONE AE).

4635 SW Fwy., Suite 1000
Houston, TX. 77027
(713) 622-9264

STATE OF TEXAS
STEPHEN RATCLIFFE
66251
4/2/14

SURVEYED BY:
FB NO.:

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

WATER
WASTEWATER *
STORM
FACILITIES
WATER AND WASTEWATER QUALITY
STORM WATER QUALITY

CITY ENGINEER
DIRECTOR OF PUBLIC WORKS AND ENGINEERING

FOR CITY OF HOUSTON USE ONLY
51973

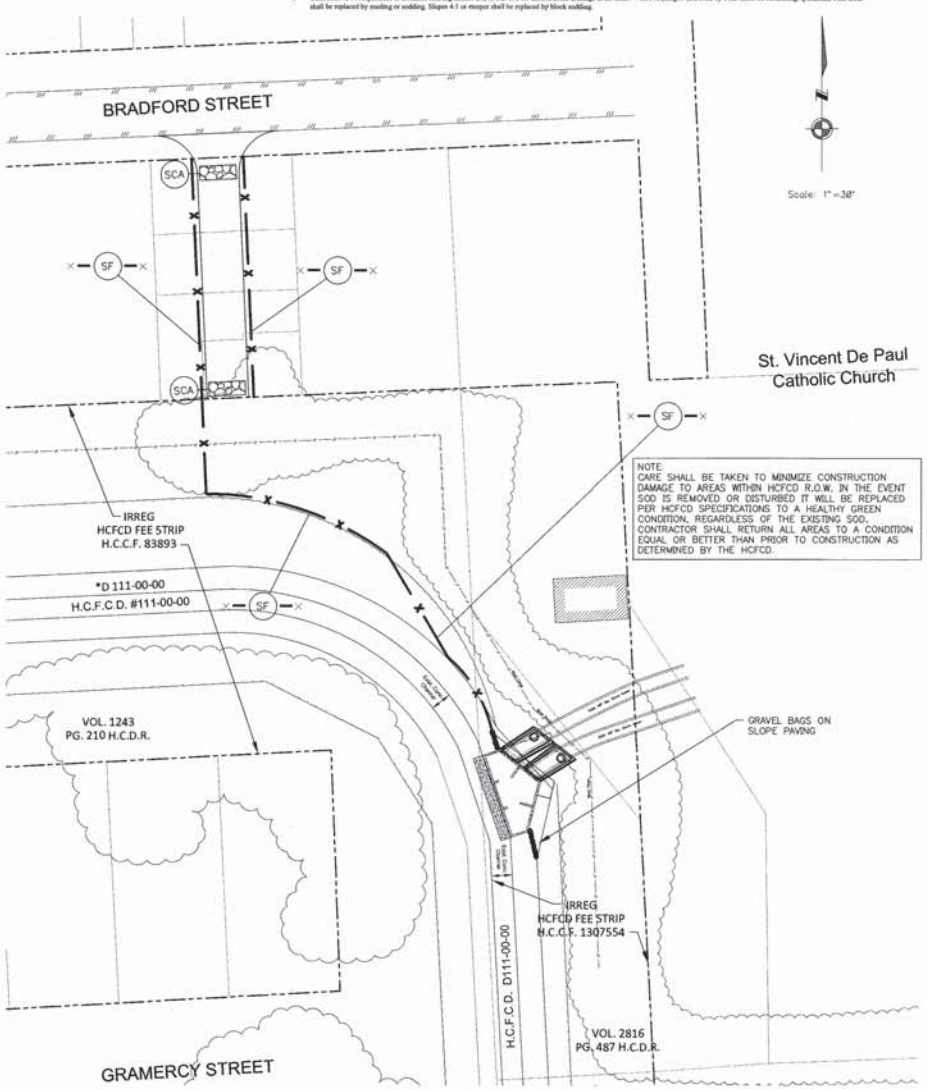
SHEET No: 1 OF 6

SWPP CONSTRUCTION NOTES

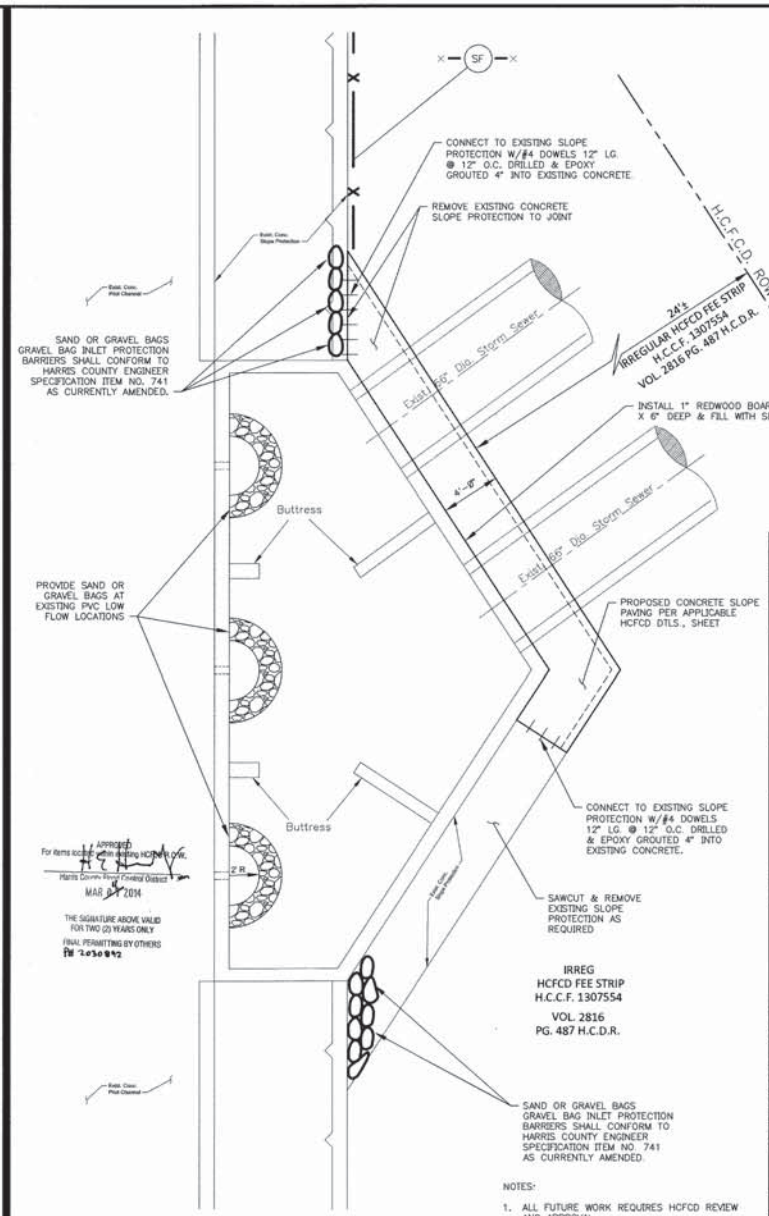
× — (SF) — × SILT FENCE

(SCA) STABILIZED CONSTRUCTION ACCESS

1. Contractor shall implement inlet protection devices and Reinforced Filter Fabric barrier along road side ditches at locations shown on the typical Storm Water Pollution Prevention (SWPP) plans to keep silt and or excavation materials from entering into the storm water inlets and ditches eventually polluting the receiving streets.
2. During the excavation phase of the project, Contractor shall schedule the work in short segments so that excavation material can be quickly hauled away from the site and to prevent it from staying uncollected on the existing pavement. Any loose excavated material which falls on pavement or driveways shall be swept back into the excavated area.
3. Contractor shall clean up the existing street intersections and driveways daily, as necessary, to remove any excess mud, silt or rock tracked from the excavated area.
4. Contractor shall follow good housekeeping practices during the construction of the project, always cleaning up dirt and loose material as construction progresses.
5. Contractor to inspect and maintain the areas listed below at least once every fourteen(14) calendar days and within 24 hours of the end of a storm event of 0.5 inches or greater.
   - Disturbed areas of the construction site that have not been finally stabilized.
   - Areas used for storage of materials that are exposed to precipitation.
   - Structural control measures.
   - Location where vehicles enter or exit the site.
6. Contractor to be responsible to maintain existing ditches and or culverts for unobstructed drainage at all times. Where sodding is disrupted by excavation on backfilling operations, such areas shall be replaced by sodding or sodding. Slopes 4:1 or steeper shall be replaced by block sodding.



NOTE:
CARE SHALL BE TAKEN TO MINIMIZE CONSTRUCTION DAMAGE TO AREAS WITHIN HCFCD R.O.W. IN THE EVENT SOD IS REMOVED OR DISTURBED IT WILL BE REPLACED PER HCFCD SPECIFICATIONS TO A HEALTHY GREEN CONDITION, REGARDLESS OF THE EXISTING SOD. CONTRACTOR SHALL RETURN ALL AREAS TO A CONDITION EQUAL OR BETTER THAN PRIOR TO CONSTRUCTION AS DETERMINED BY THE HCFCD.



APPROVED
For items located within existing HCFCD ROW.
Harris County Flood Control District
MAR 27 2014
THE SIGNATURE ABOVE VALID FOR TWO (2) YEARS ONLY
FINAL PERMITTING BY OTHERS
PM 2030892

NOTES:

1. ALL FUTURE WORK REQUIRES HCFCD REVIEW AND APPROVAL.
2. ALL WORK PER HCFCD SPECS. WITHIN HCFCD ROW.

No.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS
STEPHEN RATCLIFFE
LICENSED
4/2/14

HDR
HDR Engineering Inc. Texas Reg. No. 754
4635 Southwest Freeway, Suite 1000 • Houston, Texas 77027
(713) 622-9264 • Fax (713) 622-9265 • www.hdrinc.com

Job No.: 13-0153 | Dwn By: G.S. Fuller
Date: April, 2014 | Chkd By: D. Jorgensen

City of West University Place
Repair of St. Vincent's Outfall

Access and Storm Water
Pollution Prevention Plan

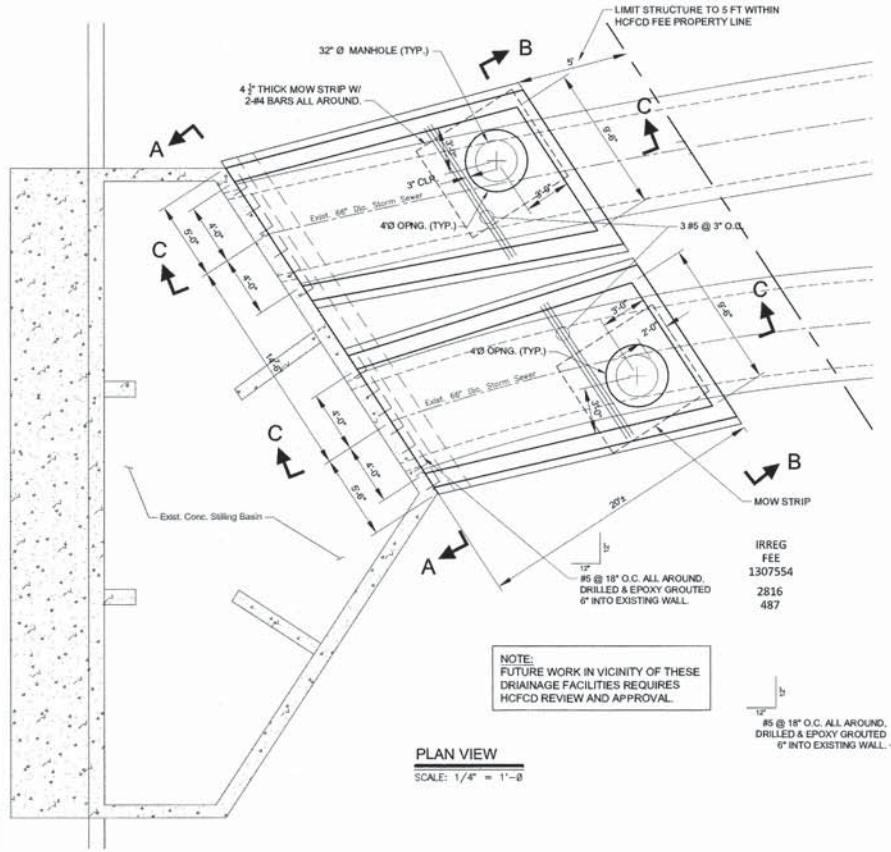
NOTE: CITY SIGNATURES VALID FOR ONE YEAR ONLY AFTER DATE OF SIGNATURES

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING
WATER
WASTEWATER
DRAINAGE
PAVING
DATE
FOR CITY OF HOUSTON USE ONLY

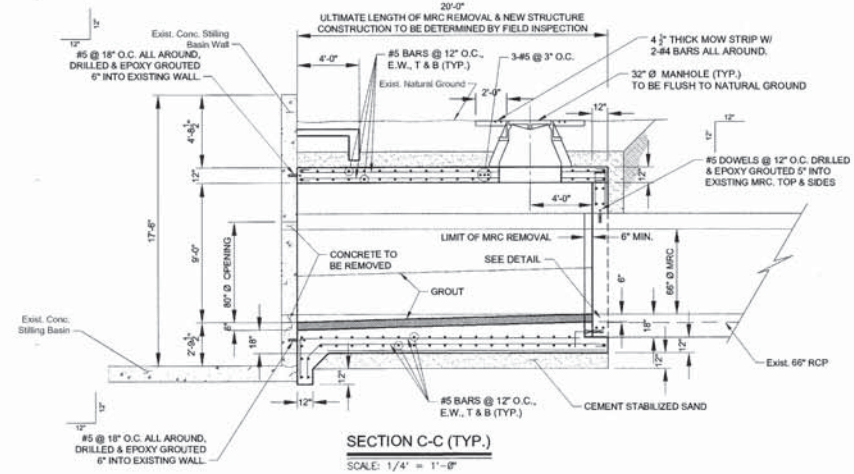
FILE NO:
DRAWING SCALE
HORZ :
VERT :

51973

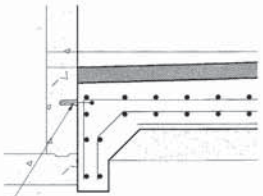
SHEET No. 2 OF 6



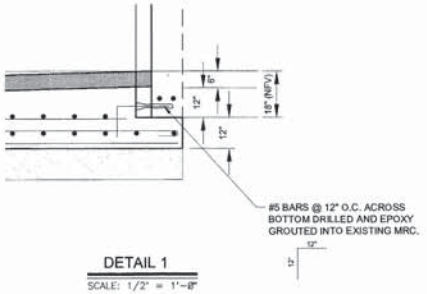
PLAN VIEW
SCALE: 1/4" = 1'-0



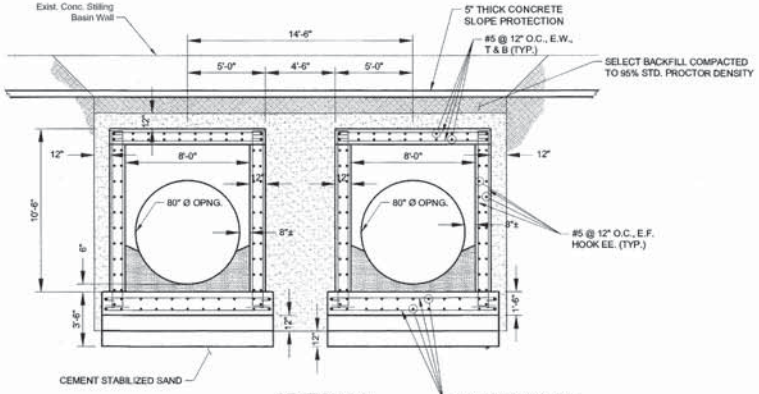
SECTION C-C (TYP.)
SCALE: 1/4" = 1'-0"



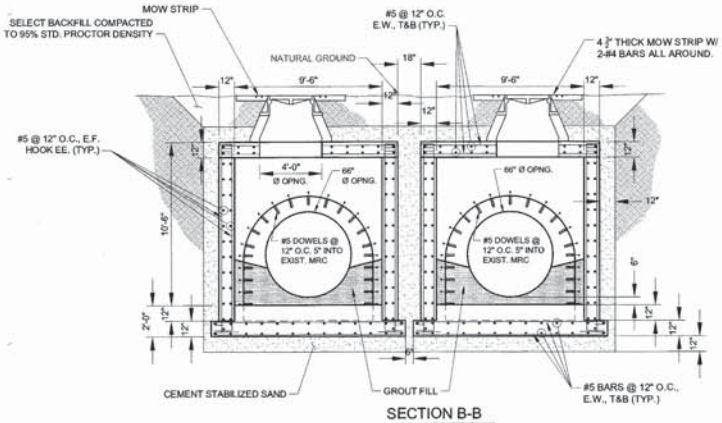
DETAIL 2
SCALE: 1/2" = 1'-0"



DETAIL 1
SCALE: 1/2" = 1'-0"



SECTION A-A
SCALE: 1/4" = 1'-0"



SECTION B-B
SCALE: 1/4" = 1'-0"

PK.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS — STEPHEN RATCLIFFE — LICENSED — PROFESSIONAL ENGINEER

4/2/14

HDR

HDR Engineering Inc. Texas Reg. No. 754
4615 Southwest Freeway, Suite 1000 • Houston, Texas 77027
(713) 622-9264 • Fax (713) 622-9265 • www.hdrinc.com

Job No.: 13 053	Dwn By: G.S. Fuller
Date: April, 2014	Chkd By: G. Jorgensen

City of West University Place
Repair of St. Vincent's Outfall

Structural Repair
Details

NOTE: CITY SIGNATURES VALID FOR ONE YEAR ONLY AFTER DATE OF SIGNATURES

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

MAYOR 4-3-14
CITY ENGINEER 4/3/14
DIRECTOR 4.3.14
PROJECT MANAGER 4/3/14

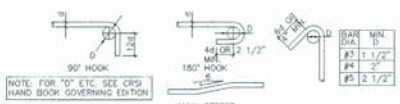
FILE NO:

DRAWING SCALE
HORZ :
VERT :

SHEET No: 3 OF 6

FOR CITY OF HOUSTON USE ONLY

51973



PRINCIPAL REINFORCING

TIE OR STIRRUP

NOTES:
1. ALL BENDS SHALL BE MADE COLD.
2. #14 AND #18 BARS SHALL BE BEND-TESTED AND APPROVED PRIOR TO BENDING.

1 Bar Bending Details

SCALE: N.T.S.

CONCRETE:

MATERIAL:
1. CONCRETE SHALL BE NORMAL WEIGHT CONCRETE WITH MINIMUM f'c AS INDICATED BELOW.

   A. PIERS, FOOTINGS ..... f'c=3000 PSI AT 28 DAYS.

2. REINFORCING STEEL SHALL CONFORM TO FOLLOWING GRADE.
   REINFORCING BARS ASTM A-615 GRADE 60 EXCEPT NOTED
   WELDED WIRE FABRIC ASTM A-185
   REINFORCING BARS WELDED TO STEEL SHALL BE WELDABLE GRADE 40
3. DETAILING OF REINFORCING BARS AND ACCESSORIES SHALL BE IN ACCORDANCE WITH ACI PUBLICATION 315, LATEST EDITION.
4. ALL MIXING TRANSPORTING, PLACING, CURING OF CONCRETE SHALL BE ACCORDANCE WITH RECOMMENDATION OF AMERICAN CONCRETE INSTITUTE.
5. ALL MIX DESIGN SHALL BE SUBJECT TO ENGINEER'S APPROVAL.
6. ALL REINFORCING BARS SHALL HAVE CLASS B LAP SPLICE PER ACI-318-02 SECTION 12.15 UNO ON DRAWINGS.
7. ALL REINFORCING SHALL BE SUPPORTED IN PLACE BY STANDARD CHAIRS. PROVIDE 3"x6"x 20 GAGE SHEET METAL BAR CHAIR AT 4'-0" O.C. EACH WAY FOR ALL TOP REINFORCING FOR SLAB ON GRADE.
8. ALL CONSTRUCTION JOINTS SHALL BE SUBJECT TO ENGINEERS APPROVAL.
9. FORMS SHALL NOT BE REMOVED UNTIL FOLLOWING STRENGTH IS REACHED. THE STRENGTH SHOWN BELOW IS THE PERCENTAGE OF 28 DAY COMPRESSIVE STRENGTH f'c.

   WALL, COLUMN, BEAM SIDE 40 PERCENT

10. ALL POURED IN PLACE CONCRETE MEMBERS SHALL HAVE FOLLOWING CLEAR COVER TO REINFORCING.

FOOTING AND PIERS	3 INCH
GRADE BEAMS BOTTOM	3 INCH
SIDE POURED AGAINST SOIL	3 INCH
SIDE FORMED	2 INCH
TOP	1 1/2 INCH WALLS
SIDE EXPOSED TO EARTH	2 INCH
ALL OTHER	3/4 INCH
SLAB ON GRADE	1 INCH(TOP)

11. PROVIDE GRANULAR FILL BEHIND WALLS AS REQUIRED BY WEEP HOLE DETAILS ON SHEET 115.

LAP & DEVELOPMENT LENGTH INCH
NORMAL WEIGHT CONCRETE-REFER NOTES BELOW

BAR SIZE	LAP CLASS	f'c=3000 psi TOP	f'c=3000 psi OTHER	f'c=4000 psi TOP	f'c=4000 psi OTHER	f'c=5000 psi TOP	f'c=5000 psi OTHER
#3	A	22	17	19	15	17	13
	B	28	22	24	19	22	17
#4	A	29	22	25	19	22	17
	B	37	29	32	25	29	22
#5	A	36	28	31	24	28	22
	B	47	36	40	31	36	28
#6	A	43	33	37	29	33	26
	B	56	43	48	37	43	33
#7	A	63	48	54	42	49	37
	B	81	63	70	54	63	49
#8	A	72	55	62	48	55	43
	B	93	72	80	62	72	55
#9	A	81	62	70	54	63	48
	B	105	81	91	70	81	63
#10	A	91	70	79	61	70	54
	B	118	91	102	79	91	70
#11	A	101	78	87	67	78	60
	B	131	101	113	87	101	78

1. DEVELOPMENT LENGTH 'ld' OF A BARS IS EQUAL TO LENGTH OF CLASS A LAP LENGTH.

2 Reinforcing Development And Lap Lengths

SCALE: N.T.S.

MINIMUM TENSION EMBEDMENT LENGTHS 'ldh' FOR STANDARD HOOKS – GRADE 60(FY-60,000PSI) REINFORCING BARS

'ldh'

BAR SIZE	NORMAL WEIGHT CONCRETE f'c=3000 psi	f'c=4000 psi	f'c=5000 psi
#3	6	8	6
#4	8	7	6
#5	10	9	8
#6	12	10	9
#7	14	12	11
#8	16	14	12
#9	18	15	14
#10	20	17	15
#11	22	19	17

3 Reinforcing 'ldh' Lengths

SCALE: N.T.S.

STORM SEWER CONSTRUCTION NOTES

1. STORM SEWERS SHALL BE REINFORCED CONCRETE PIPE (C-76, CLASS III), AND SHALL BE INSTALLED, BEDDED, AND BACKFILLED IN ACCORDANCE WITH THE CITY OF HOUSTON DRAWING NOS. 02317-02, 02317-03, 02317-06, AND 02317-07 (OCT. 2002) AS APPLICABLE UNLESS OTHERWISE SHOWN ON THE DRAWINGS.
2. ALL STORM SEWER CONSTRUCTED IN SIDE LOT EASEMENT SHALL BE R.C.P. (C-76, CLASS III) AND SHALL BE BEDDED IN ACCORDANCE WITH THE CITY DRAWING NOS. 02317-02, 02317-03, 02317-05, 02317-06, AND 02317-07 AS APPLICABLE.
3. ALL SEWER UNDER PROPOSED OR FUTURE PAVEMENT AND TO A POINT ONE (1) FOOT BACK OF ALL PROPOSED OR FUTURE CURBS SHALL BE BACKFILLED WITH 1-1/2 SACK CEMENT/C.Y. STABILIZED SAND TO WITH IN ONE (1) FOOT OF SUBGRADE. THE REMAINING DEPTH OF TRENCH SHALL BE BACKFILLED WITH SUITABLE EARTH MATERIAL.
4. ALL TRENCH BACKFILLS SHALL BE IN 8" LIFTS, WITH TESTS TAKEN AT 100 FOOT INTERVALS ON EACH LIFT, AND MECHANICALLY COMPACTED TO A DENSITY OF NOT LESS THAN 95% OF THE MAXIMUM DRY DENSITY AS DETERMINED BY THE STANDARD PROCTOR COMPACTION TEST (ASTM D-698/AASHTO T99).
5. CIRCULAR AND ELLIPTICAL REINFORCED CONCRETE PIPE SHALL BE INSTALLED USING RUBBER GASKET JOINTS CONFORMING TO ASTM ASTM C443 AND C877 RESPECTIVELY.
6. ALL STORM SEWER PIPES AND INLET LEADS SHALL BE 24-INCH AND LARGER R.C.P. (C-76, CLASS III).
7. ALL PROPOSED PIPE STUB-OUTS EROM MANHOLES AND INLETS ARE TO BE PLUGGED WITH 8" BRICK WALLS UNLESS OTHERWISE NOTED.
8. CONTRACTOR SHALL PROVIDE 12" MINIMUM CLEARANCE AT STORM SEWER AND WATER LINE CROSSINGS.
9. ADJUST MANHOLE COVERS TO GRADE CONFORMING TO REQUIREMENTS OF SECTION 02086-ADJUSTING MANHOLES, INLETS AND VALVE BOXES TO GRADE.
10. THE CONTRACTOR SHALL BE RESPONSIBLE FOR PROTECTING, MAINTAINING, AND RESTORING ANY BACK SLOPE DRAINAGE SYSTEM DISTURBED AS A RESULT OF HIS WORK.
11. ALL DITCHES SHALL BE REGRADED TO PROPOSED ELEVATIONS TO INSURE PROPER DRAINAGE. ALL OUTFALLS SHALL BE PROPERLY BACKFILLED AND COMPACTED. ALL DISTURBED AREA SHALL BE GRADED, SEEDED, AND FERTILIZED.
12. ALL DRIVEWAYS WILL BE LOCATED TO AVOID EXISTING CURB INLET STRUCTURES.

12/21/10 Update

STANDARD HCFCD NOTES FOR CONSTRUCTION DRAWINGS

1. Obtain and comply with all applicable City, County, State, and Federal permits and approvals, with assistance from Engineer, if necessary. Obtain permit (certification) from Harris County Engineer to enter Harris County Flood Control District right-of-way.
2. Notify the Harris County Flood Control District's Property Management Department in writing at least 48 hours prior to construction. Submit the HCFCD 48 Hour Pre-Construction Notification form, a copy of the approved construction drawings, and a copy of the Corps of Engineers individual Section 404 permit, if applicable, to HCFCD, 9900 Northwest Freeway, Houston, Texas 77092, Attn: Property Management Dept. by hand delivery, or fax to 713-684-4129 (fax number).
3. Engineer shall submit certification letter and record drawings to the Harris County Flood Control District's Property Management Department requesting inspection of items constructed in Harris County Flood Control District right-of-way. Prior to requesting inspection, the drainage right-of-way and/or easements shall be staked and flagged.
4. Protect, maintain, and restore existing backslope drainage systems.
5. Backslope swale and interceptor structure elevations and locations shown on plans are approximate. Final elevations and locations shall be field verified by the Engineer prior to installation.
6. Establish turf grass on all disturbed areas within the channel or detention right-of-way, except the channel bottom and where structural erosion measures are used. Minimum acceptance criteria are 75% coverage of live Bermuda grass and no erosion or rills deeper than 4".
7. Backfill in accordance with the Harris County Flood Control District Standard Specification, Section 02315 - Excavating and Backfilling, or equivalent.
8. Excavate channel flowline to design elevation as shown on plans and downstream, as necessary, to ensure no water remains in the facility (storm sewer, lateral channel, or dry bottom detention basin) during normal water surface conditions in the channel, so the facility will function as intended. For wet bottom detention basins, ensure no water is above the design level in the wet bottom during normal water surface conditions in the channel.
9. Maintain flow in channel during construction and restore channel to original condition.
10. Remove all excavated material from the Harris County Flood Control District or drainage right-of-way. No fill is to be placed within a designated flood plain area without first obtaining a fill permit from the appropriate jurisdictional authority.

NOTE:
CONTRACTOR TO OBTAIN HCFCD PERMIT.

NOTE:
THE CONTRACTOR SHALL BE RESPONSIBLE FOR PROTECTING, MAINTAINING, AND RESTORING ANY BACK SLOPE DRAINAGE SYSTEM DISTURBED AS A RESULT OF HIS WORK.

MK.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS
STEPHEN RATCLIFFE
51973
LICENSED
PROFESSIONAL ENGINEER

4/2/14

HDR

HDR Engineering Inc. Texas Reg. No. 754
4635 Southwest Freeway, Suite 1000 • Houston, Texas 77027
(713) 622-9264 • Fax (713) 622-9265 • www.hdrinc.com

Job No.: 15 053 | Dwn By: G.S. Fuller
Date: April, 2014 | Chkd By: D. Jorgensen

City of West University Place
Repair of St. Vincent's Outfall

H.C.F.C.D. Notes & Reinforcing Details

NOTE: CITY SIGNATURES VALID FOR ONE YEAR ONLY AFTER DATE OF SIGNATURES

CITY OF HOUSTON
DEPARTMENT OF PUBLIC WORKS AND ENGINEERING

MAYOR
DIRECTOR 4/3/14
CITY ENGINEER 4.3.14
DEPUTY DIRECTOR
FACILITIES

FILE NO:

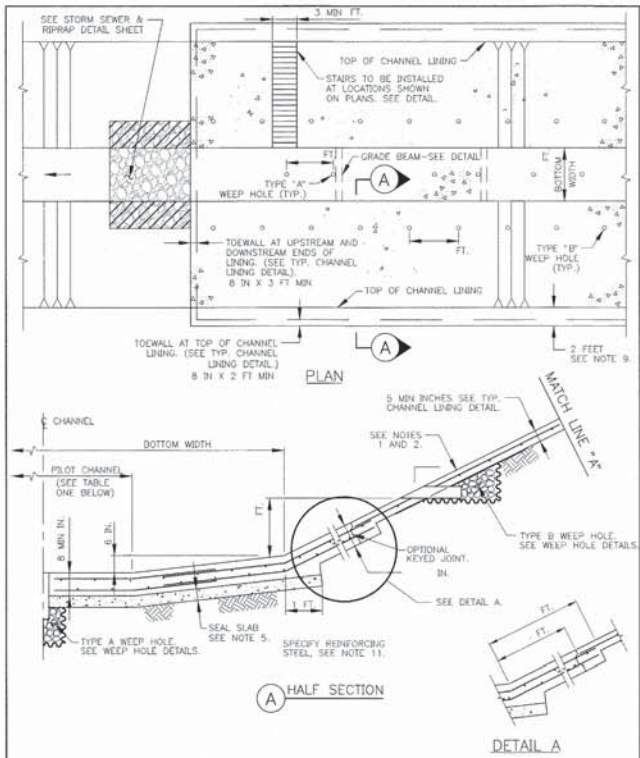
FOR CITY OF HOUSTON USE ONLY

DRAWING SCALE

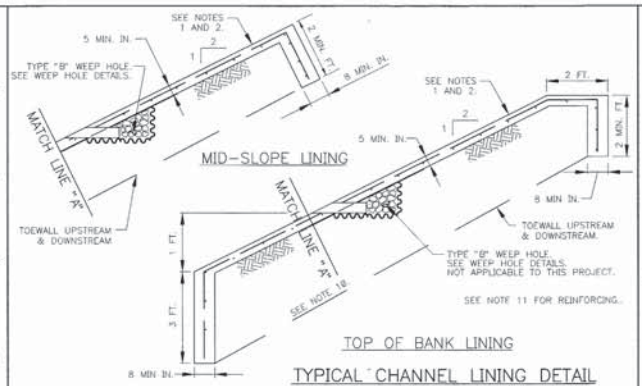
HORZ :
VERT :

STATE OF TEXAS
51973
LICENSED PROFESSIONAL ENGINEER

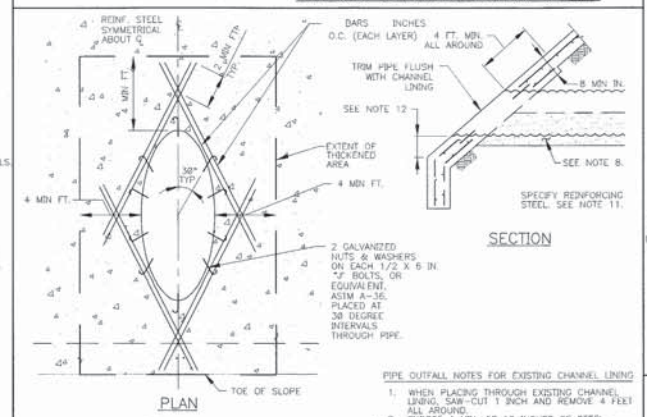
SHEET No: 4 OF 6



TYPICAL TRAPEZOIDAL CHANNEL LINING (NA)



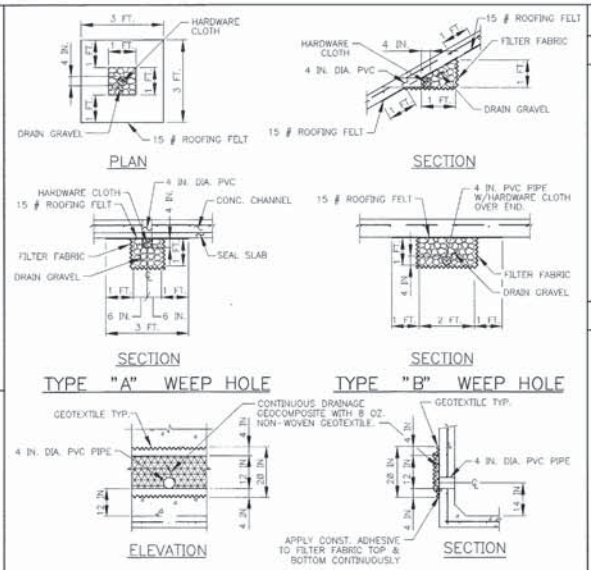
TYPICAL CHANNEL LINING DETAIL



PIPE OUTFALL DETAILS (NA)
(FOR CMP OUTFALLS 24-42 INCH DIA. ONLY)

PIPE OUTFALL NOTES FOR EXISTING CHANNEL LINING

1. WHEN PLACING THROUGH EXISTING CHANNEL LINING, SAW-CUT 1 INCH AND REMOVE 4 FEET ALL AROUND.
2. EXPOSE A MIN. OF 18 INCHES OF STEEL.



WEEP HOLE NOTES:

1. MATERIALS:
   a. PIPE: 4 INCH DIA. SCH. 40 PVC
   b. DRAIN GRAVEL:

SIEVE SIZE	% FINER
1 IN	100
3/4 IN	70 – 100
3/8 IN	20 – 90
NO. 4	0 – 60
NO. 8	0

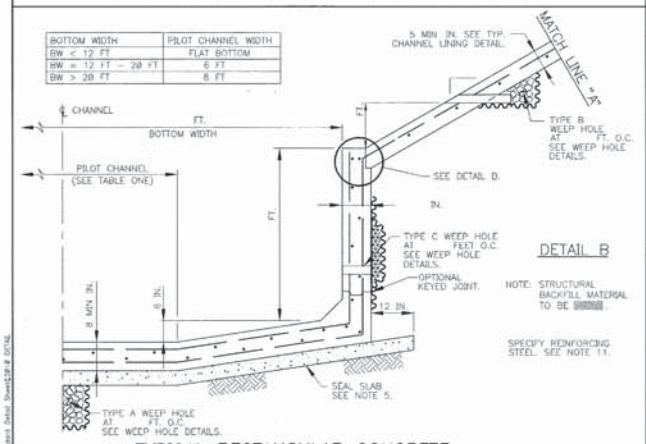
   c. HARDWARE CLOTH: MIN. OPEN 1/8 IN, MAX. OPEN 1/4 IN
   d. FILTER FABRIC: NON-WOVEN GEOTEXTILE

MIN. AOS	SIEVE NO.	100 MIN
MAX. AOS	SIEVE NO.	70 MAX
WEIGHT	OZ/SY	6 OZ. MIN

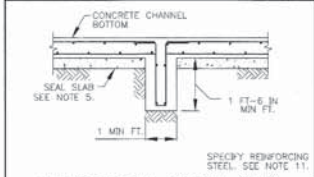
2. CUT WEEP HOLE PIPE FLUSH WITH CONCRETE SURFACE.
3. TYPE "A" AND "C" WEEP HOLES FOR TYPICAL RECTANGULAR CONCRETE CHANNEL LINING, TO BE STAGGERED.

WEEP HOLE DETAILS (NA)

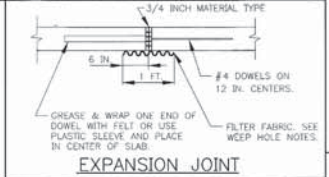
BOTTOM WIDTH	PILOT CHANNEL WIDTH
BW < 12 FT	FLAT BOTTOM
BW = 12 FT – 20 FT	6 FT
BW > 20 FT	8 FT



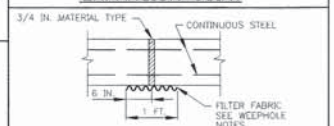
TYPICAL RECTANGULAR CONCRETE CHANNEL LINING HALF SECTION (NA)



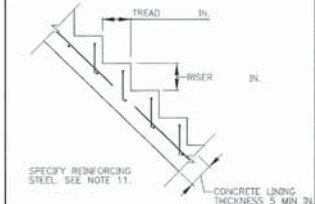
GRADE BEAM DETAIL (NA)
(SEE NOTE 6)



EXPANSION JOINT



CONSTRUCTION JOINT



STAIR DETAIL (NA)

HALF JOINT
(SLOPES ONLY)

CONTROL JOINT

CONCRETE CHANNEL LINING DETAILS NOTES:

1. STRUCTURAL CONCRETE FOR CONCRETE CHANNEL LINING AND NONSTRUCTURAL CONCRETE FOR SEAL SLAB SHALL BE IN ACCORDANCE WITH SPECIFICATION SECTION NO. 02310-CONCRETE.
2. REINFORCING STEEL SHALL BE IN ACCORDANCE WITH SPECIFICATION SECTION NO. 03310-CONCRETE.
3. EXCAVATION AND BACKFILL FOR CONCRETE CHANNEL LINING SHALL BE IN ACCORDANCE WITH SPECIFICATION SECTION NO. 02316-STRUCTURAL EXCAVATING AND BACKFILLING.
4. RIPRAP SHALL BE IN ACCORDANCE WITH SPECIFICATION SECTION NO. 02378-RIPRAP AND GRANULAR FILL.
5. A NON-REINFORCED 4 INCH MINIMUM NONSTRUCTURAL CONCRETE SEAL SLAB WILL BE REQUIRED BENEATH THE BOTTOM OF CONCRETE CHANNELS.
6. STRUCTURAL CONCRETE GRADE BEAMS SHALL BE INSTALLED TRANSVERSLEY AT 20 FOOT MAX. CENTERS ON CONCRETE LINED CHANNELS WITH BOTTOM WIDTHS EQUAL TO OR GREATER THAN 20 FEET.
7. JOINTS:
   A. PLACE CONSTRUCTION AND/OR EXPANSION JOINT IN CONCRETE LOW-FLOW AND TRAPEZOIDAL BOTTOM SECTIONS AT 20 FOOT MIN., 60 FOOT MAX. SPACING CONTINUOUSLY THROUGH CHANNEL LINING.
   B. PLACE CONTROL JOINT ON SLOPES AT 20 FOOT SPACING.
8. CEMENT STABILIZED SAND SHALL BE PROVIDED AND PLACED IN ACCORDANCE WITH SPECIFICATION SECTION NO. 02321-CEMENT STABILIZED SAND.
9. DELETE 2 FT FLAT EDGE WHEN LINING IS BELOW TOP OF BANK. SEE MID-SLOPE LINING DETAIL.
10. UPSTREAM AND DOWNSTREAM TOE WALL 3 FOOT MIN. DEPTH AT BOTTOM OF SLOPE AND 8 INCHES THICK.
11. #4 AT 12 INCH O.C. MINIMUM OR EQUIVALENT WELDED WIRE FABRIC.
12. VARIES BASED ON SIDE SLOPE. MINIMUM 1 FOOT VERTICAL AT TOE OF SLOPE.

THIS DETAIL SHEET HAS BEEN PREPARED FOR USE ON HCFCD PROJECTS OR PROJECTS TO BE MAINTAINED BY THE HCFCD WHEN COMPLETED BY OTHERS. AN ENGINEER WHO INCORPORATES THE DETAILS ON THIS SHEET BECOMES RESPONSIBLE FOR ITS USE IN THE END PRODUCT IN ACCORDANCE WITH RULE 137.33 (b) AND (c) OF THE TEXAS STATE BOARD OF REGISTRATION FOR PROFESSIONAL ENGINEERS.

STATE OF TEXAS
STEPHEN RATCLIFFE
51973
LICENSED
4/2/14

P.E. SEAL AND SIGNATURE

51973

REV	DESCRIPTION	DATE	APPR

PROJECT ID#

REPAIR OF ST. VINCENT'S STORM SEWER OUTFALL

CONCRETE CHANNEL LINING DETAILS

PREPARED: CHECKED: APPROVED:

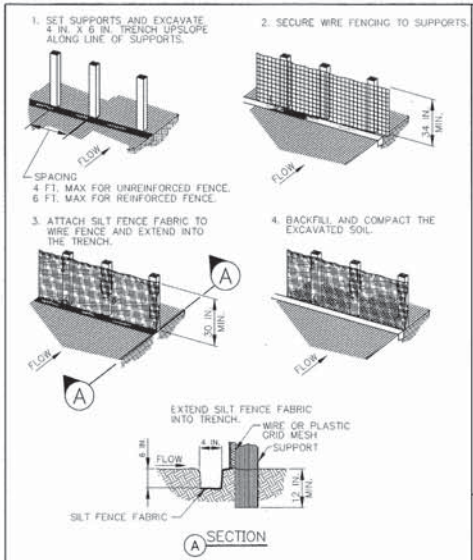
HDR
HDR Engineering, Inc. Texas Reg. No. 754
4615 Southwest Freeway, Suite 1000 • Houston, Texas 77027
(713) 622-9264 • Fax (713) 622-9265 • www.hdrinc.com

Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092

DATE: 12-21-2010
SCALE: NTS

SHEET NUMBER
5 OF 6

STD\CONCRETE CHANNEL LINING DETAIL



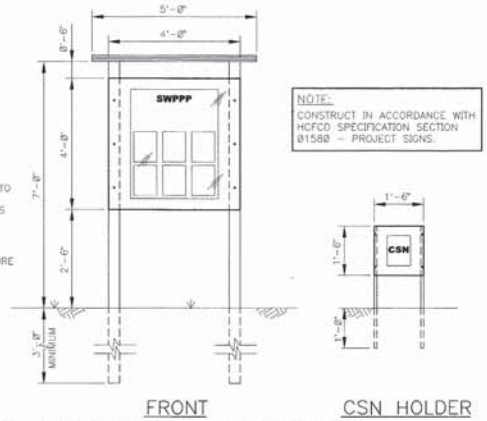
CONSTRUCTION NOTES:

1. SEE SPECIFICATION SECTION NO. 02361-SILT FENCES.

RSF — REINFORCED SILT FENCE
SYMBOL

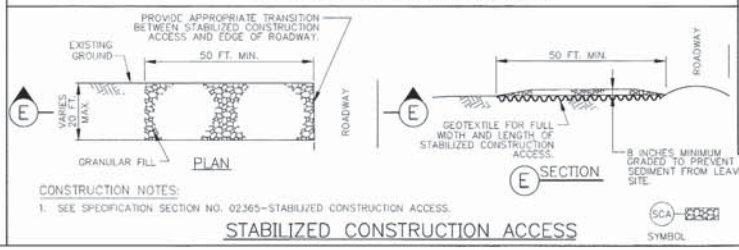
SF — SILT FENCE
SYMBOL

SILT FENCE



NOTE:
CONSTRUCT IN ACCORDANCE WITH HCFCD SPECIFICATION SECTION 01580 - PROJECT SIGNS.

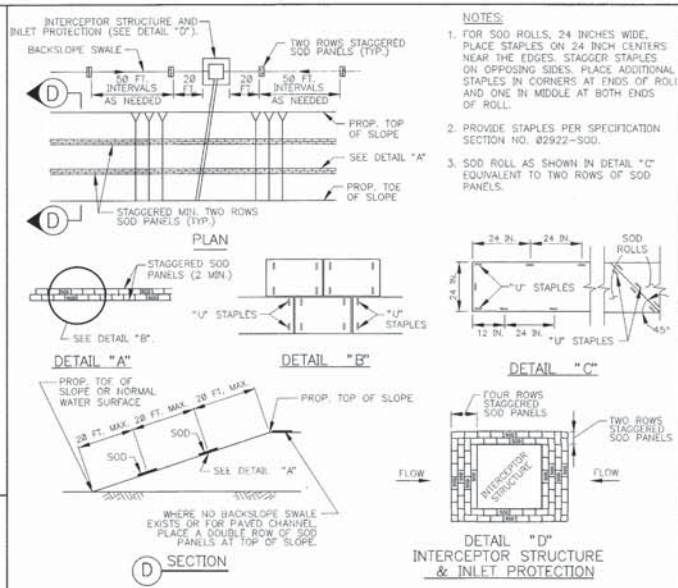
SWPPP / BMP SIGN AND CONSTRUCTION SITE NOTICE HOLDER DETAILS



CONSTRUCTION NOTES:

1. SEE SPECIFICATION SECTION NO. 02365-STABILIZED CONSTRUCTION ACCESS.

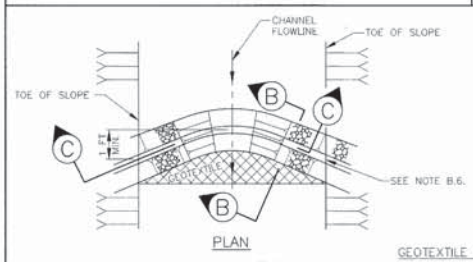
STABILIZED CONSTRUCTION ACCESS



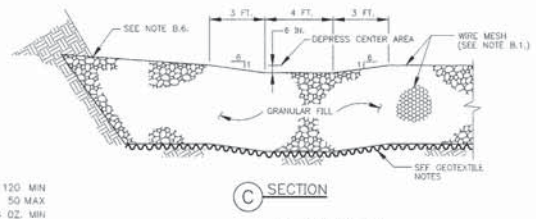
NOTES:

1. FOR SOD ROLLS, 24 INCHES WIDE, PLACE STAPLES ON 24 INCH CENTERS NEAR THE EDGES. STAGGER STAPLES ON OPPOSING SIDES. PLACE ADDITIONAL STAPLES IN CORNERS AT ENDS OF ROLL AND ONE IN MIDDLE AT BOTH ENDS OF ROLL.
2. PROVIDE STAPLES PER SPECIFICATION SECTION NO. 02922-SOD.
3. SOD ROLL AS SHOWN IN DETAIL "C" EQUIVALENT TO TWO ROWS OF SOD PANELS.

SODDING

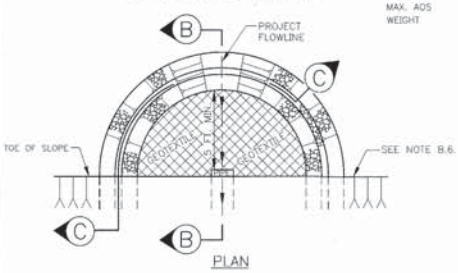


IN-CHANNEL FILTER DAM

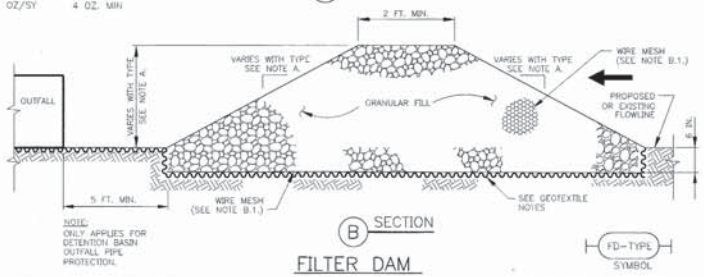


GEOTEXTILE NOTES:

MIN. AOS	SIEVE NO.	120 MIN
MAX. AOS	SIEVE NO.	50 MAX
WEIGHT	OZ/SY	4 OZ. MIN



FILTER DAM AT DETENTION BASIN OUTFALL PIPE



NOTE:
ONLY APPLIES FOR DETENTION BASIN OUTFALL PIPE PROTECTION.

FILTER DAM

FILTER DAM NOTES:

A. TYPES OF FILTER DAMS
1. TYPE 1 (NON-REINFORCED)
   a. HEIGHT - 18-24 INCHES. MEASURE VERTICALLY FROM EXISTING GROUND TO TOP OF FILTER DAM.
   b. TOP WIDTH - 2 FEET (MINIMUM)
   c. SLOPES - 2:1 (MAXIMUM).
2. TYPE 2 (REINFORCED)
   a. HEIGHT - 18-36 INCHES. MEASURE VERTICALLY FROM EXISTING GROUND TO TOP OF FILTER DAM.
   b. TOP WIDTH - 2 FEET (MINIMUM).
   c. SLOPES - 2:1 (MAXIMUM).
3. TYPE 3 (REINFORCED)
   a. HEIGHT - 36-48 INCHES. MEASURE VERTICALLY FROM EXISTING GROUND TO TOP OF FILTER DAM.
   b. TOP WIDTH - 2 FEET (MINIMUM).
   c. SLOPES - 3:1 (MAXIMUM).
4. TYPE 4 (GABION)
   a. HEIGHT - 30 INCHES (MINIMUM). MEASURE VERTICALLY FROM EXISTING GROUND TO TOP OF FILTER DAM.
   b. TOP WIDTH - 2 FEET (MINIMUM).
5. TYPE 5. AS SHOWN ON THE PLANS.

B. CONSTRUCT FILTER DAMS ACCORDING TO THE FOLLOWING CRITERIA UNLESS SHOWN OTHERWISE ON THE PLANS.
1. TYPE 2 AND 3 FILTER DAMS: SECURE WITH 20 GAUGE GALVANIZED WOVEN WIRE MESH WITH 1 INCH DIAMETER HEXAGONAL OPENINGS.
2. GRANULAR FILL:
   a. PLACE ON MESH TO HEIGHT AND SLOPES SHOWN ON PLANS OR AS SPECIFIED BY THE ENGINEER.
   b. 3-5 INCHES FOR ROCK FILTER DAM TYPES 1,2, AND 4 AND 4-8 INCHES FOR ROCK FILTER DAM TYPE 3. REFER TO GRANULAR FILL IN SPECIFICATION SECTION NO. 02378-RIPRAP AND GRANULAR FILL.
3. WIRE MESH: FOLD AT UPSTREAM SIDE OVER GRANULAR FILL AND TIGHTLY SECURE TO ITSELF ON THE DOWNSTREAM SIDE USING WIRE TIES OR HOG RINGS.
4. IN STREAMS: SECURE OR STAKE MESH TO STREAM BED PRIOR TO AGGREGATE PLACEMENT.
5. SEE SPECIFICATION SECTION NO. 02364-FILTER DAMS.
6. EMBED ONE FOOT MINIMUM INTO SLOPE AND AT SLOPE RAISE ONE FOOT HIGHER THAN CENTER OF DEPRESSED AREA.

THIS DETAIL SHEET HAS BEEN PREPARED FOR USE ON HCFCD PROJECTS OR PROJECTS TO BE MAINTAINED BY THE HCFCD WHEN COMPLETED BY OTHERS. AN ENGINEER WHO INCORPORATES THE DETAILS ON THIS SHEET BECOMES RESPONSIBLE FOR ITS USE IN THE END PRODUCT IN ACCORDANCE WITH RULE §137.33 (b) AND (c) OF THE TEXAS STATE BOARD OF REGISTRATION FOR PROFESSIONAL ENGINEERS.

P.E. SEAL AND SIGNATURE

REV	DESCRIPTION	DATE	APPR

PROJECT ID#

REPAIR OF ST. VINCENT'S STORM SEWER OUTFALL

STORMWATER POLLUTION PREVENTION DETAILS

PREPARED:

CHECKED:

APPROVED:

HDR
HDR Engineering, Inc. Texas Reg. No. 754
4835 Southwest Freeway, Suite 1200, Houston, Texas 77027
(713) 62-2000 • FAX (713) 962-3201 • www.hdrinc.com

Harris County Flood Control District
9900 Northwest Freeway
Houston, Texas 77092

DATE: 08-31-05
SCALE: NTS

SHEET NUMBER
6 OF 6

STD\SWPPP02.DWG

APPENDIX C

Construction Plans for Original West University Place Storm Sewer System

STORM SEWER SYSTEM

FOR

CITY OF WEST UNIVERSITY PLACE

MAYOR
F.M.MAINOUS

CITY SECRETARY
R.B.ALLEN

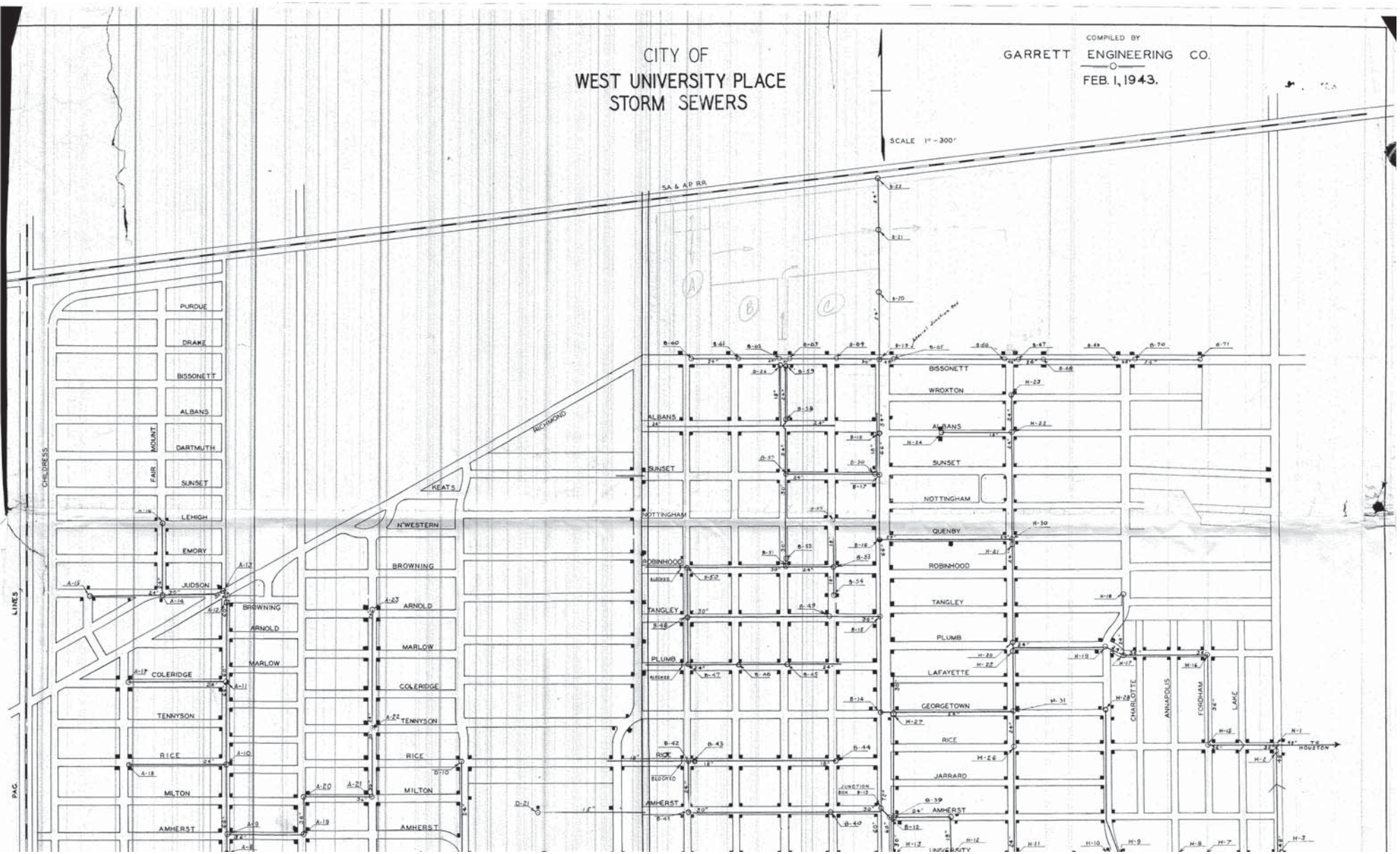
COMMISSIONERS
DR. A.L.KERBOW
DR. J.A.HERSCHEL
T.WESLEY WOODARD
J.M.DUNNINGTON

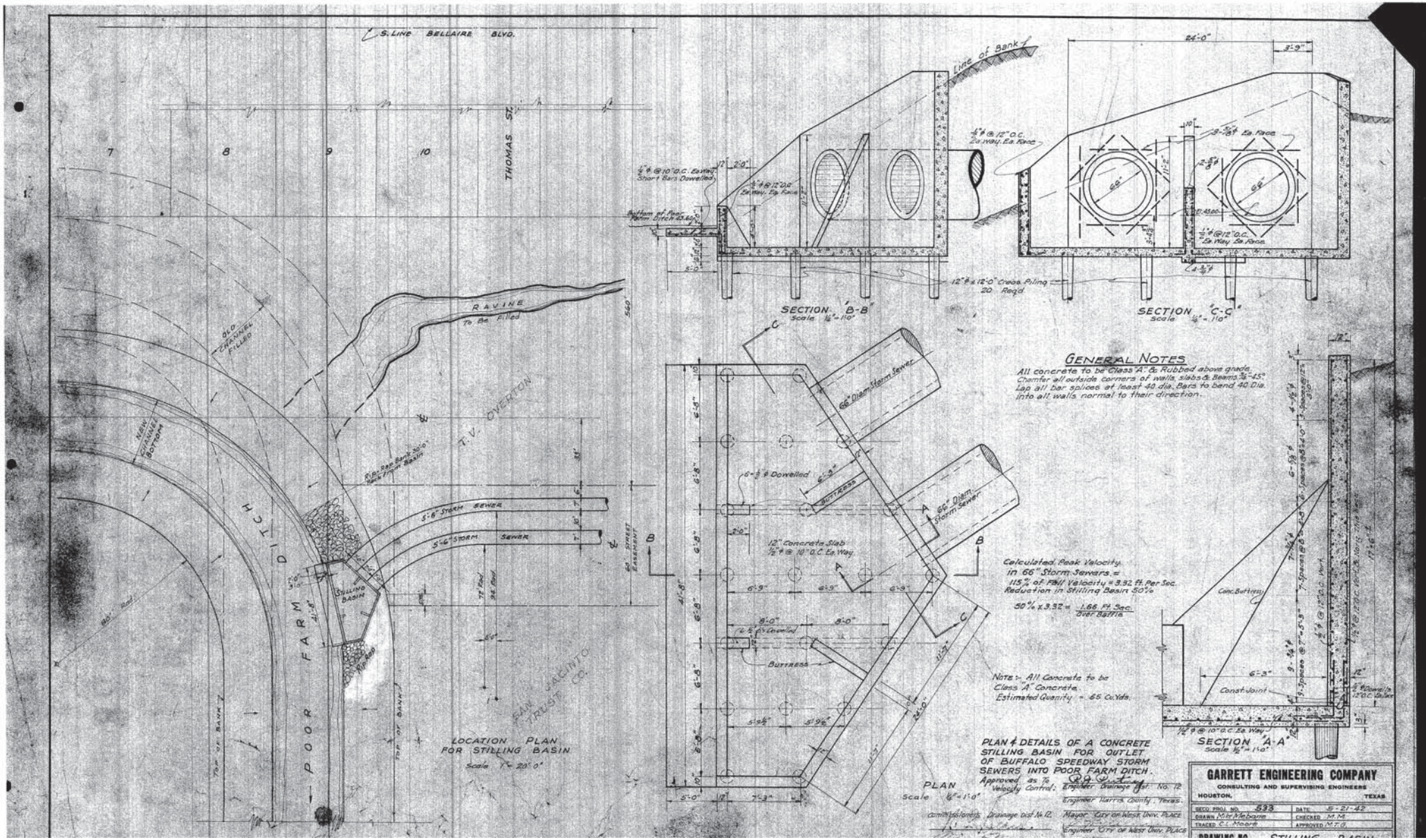
BY

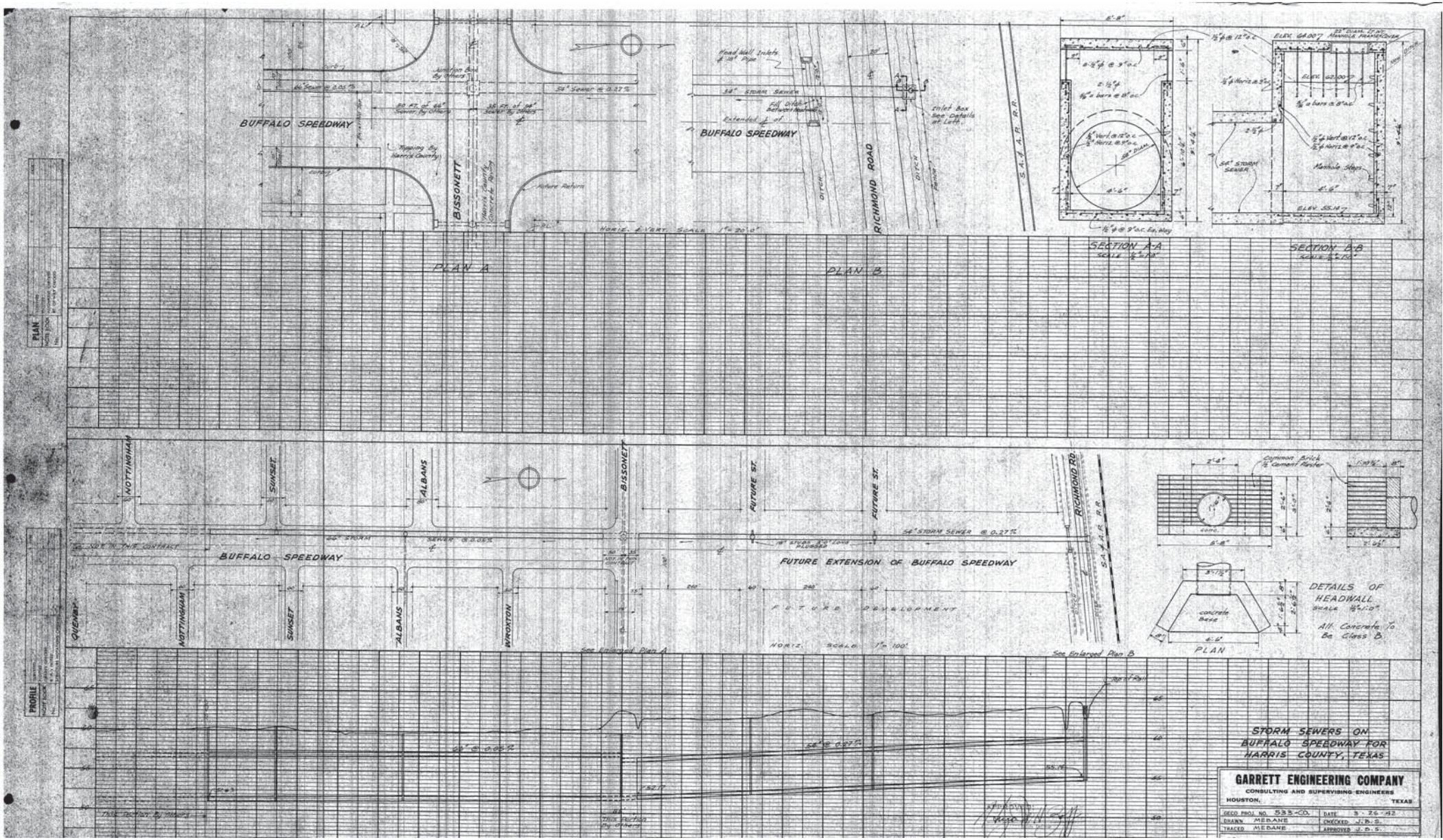
GARRETT ENGINEERING CO.

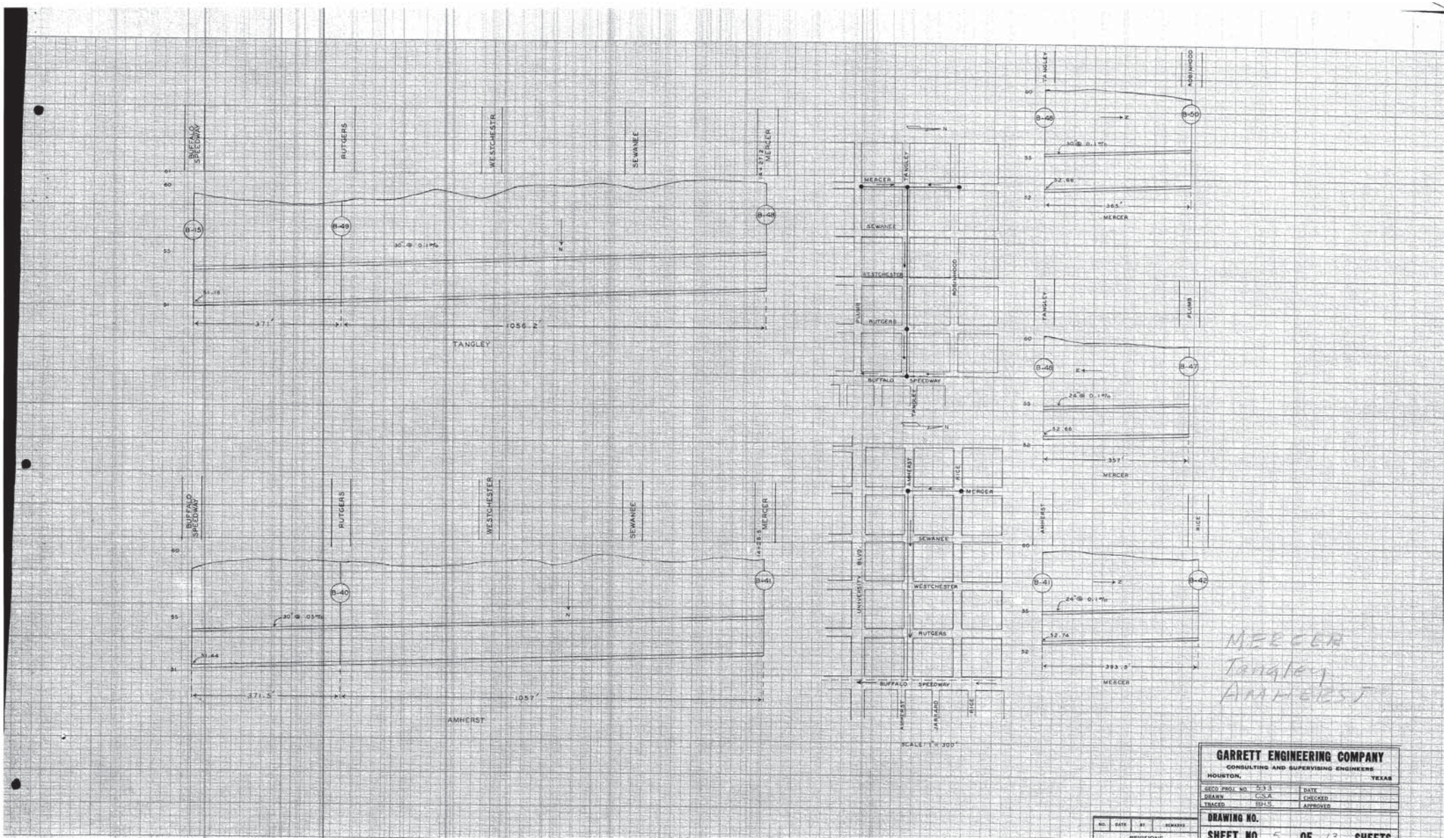
HOUSTON, TEXAS

GECO.PROJ.NO. 533


CITY OF
WEST UNIVERSITY PLACE
STORM SEWERS
COMPILED BY
GARRETT ENGINEERING CO.
FEB. 1, 1943.
SCALE 1" = 300'
SA & AP RR
PURDUE
DRAKE
BISSONETT
ALBANS
DARTMUTH
SUNSET
LEHIGH
EMORY
JUDSON
BROWNING
ARNOLD
MARLOW
COLERIDGE
TENNYSON
RICE
MILTON
AMHERST
MOUNT
FAIR
CHILDRESS
KEATS
N'WESTERN
ARCHMOND
WROXTON
NOTTINGHAM
QUENBY
ROBINHOOD
TANGLEY
PLUMB
LAFAYETTE
GEORGETOWN
JARRARD
CHARLOTTE
ANNAPOLIS
FORDHAM
LAKE
TO HOUSTON
BLOCKED
JUNCTION BOX
UNIVERSITY
LINES
PAG.


S. LINE BELLAIRE BLVD.
THOMAS ST.
7
8
9
10
RAVINE
To Be Filled
OLD CHANNEL FILLED
NEW CHANNEL BOTTOM
T.V. OVERTON
POOR FARM DITCH
STILLING BASIN
RIP RAP
5'-6" STORM SEWER
5'-6" STORM SEWER
80' STREET EASEMENT
TOP OF BANK
SAN JACINTO TRUST CO.
LOCATION PLAN
FOR STILLING BASIN
Scale 1" = 20'-0"
Line of Bank
24'-0"
3'-9"
SECTION "B-B"
Scale 1/4" = 1'-0"
SECTION "C-C"
Scale 1/4" = 1'-0"
12" x 12'-0" Creos. Piling
20 Reqd.
66" Diam. Storm Sewer
12" Concrete Slab
1/2" ϕ @ 10" O.C. Ea. Way
Buttress
PLAN
Scale 1/8" = 1'-0"
GENERAL NOTES
All concrete to be Class "A" & Rubbed above grade.
Chamfer all outside corners of walls, slabs & Beams 3/4" - 45°.
Lap all bar splices at least 40 dia. Bars to bend 40 Dia. into all walls normal to their direction.
Calculated Peak Velocity in 66" Storm Sewers =
115% of Full Velocity = 3.32 Ft. Per Sec.
Reduction in Stilling Basin 50%
50% x 3.32 = 1.66 Ft. Sec. over Baffle
Note:- All Concrete to be Class "A" Concrete.
Estimated Quantity = 65 Cu. Yds.
Conc. Buttress
Const. Joint
SECTION "A-A"
Scale 1/2" = 1'-0"
PLAN & DETAILS OF A CONCRETE STILLING BASIN FOR OUTLET OF BUFFALO SPEEDWAY STORM SEWERS INTO POOR FARM DITCH.
Approved as to Velocity Control: R. A. Dunlap Engineer Drainage Dist. No. 12
Engineer Harris County, Texas.
Commissioners Drainage Dist. No. 12.
Mayor City of West Univ. Place
Engineer City of West Univ. Place
GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS
RECD. PROJ. NO. 533
DATE 5-21-42
DRAWN Mike Mebane
CHECKED M.M.
TRACED C.L. Moore
APPROVED M.T.G.
DRAWING NO.
STILLING BASIN


BUFFALO SPEEDWAY
BISSONETT
Junction Box By Others
66" Sewer @ 0.05%
54" Sewer @ 0.27%
80 Ft. of 66" Sewer By Others
35 Ft. of 54" Sewer By Others
Mapping By Harris County
Future Return
Harris County Curve Marking
Head Wall Inlets & 18" Pipe
54" STORM SEWER
Fill Ditch Between Headwalls
Extended ℄ of
Inlet Box See Details at Left
DITCH
RICHMOND ROAD
S.A. & A.P. R.R.
HORIZ. & VERT. SCALE 1"=20'-0"
PLAN A
PLAN B
SECTION A-A
SCALE 1/4"=1'0"
SECTION B-B
SCALE 1/4"=1'0"
ELEV. 64.00
ELEV. 62.00
ELEV. 55.14
Manhole Steps
NOTTINGHAM
SUNSET
ALBANS
FUTURE ST.
RICHMOND RD.
66" STORM SEWER @ 0.05%
54" STORM SEWER @ 0.27%
18" STORM SEWER PROPOSED
SEE IN THE CONTRACT
FUTURE EXTENSION OF BUFFALO SPEEDWAY
QUEWAY
WROXTON
FUTURE DEVELOPMENT
HORIZ. SCALE 1"=100'
See Enlarged Plan A
See Enlarged Plan B
Common Brick
½ Cement Mortar
concrete Base
PLAN
DETAILS OF HEADWALL
SCALE 1/4"=1'0"
All Concrete To Be Class B
Top of Pavt.
66" @ 0.05%
54" @ 0.27%
55.16
52.17
THIS SECTION BY OTHERS
THIS SECTION By Others
PROFILE
PLAN
STORM SEWERS ON BUFFALO SPEEDWAY FOR HARRIS COUNTY, TEXAS
GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS
GECO PROJ. NO. 535-CO.
DATE 3-26-42
DRAWN MEDANE
CHECKED J.B.S.
TRACED MEDANE
APPROVED J.B.S.



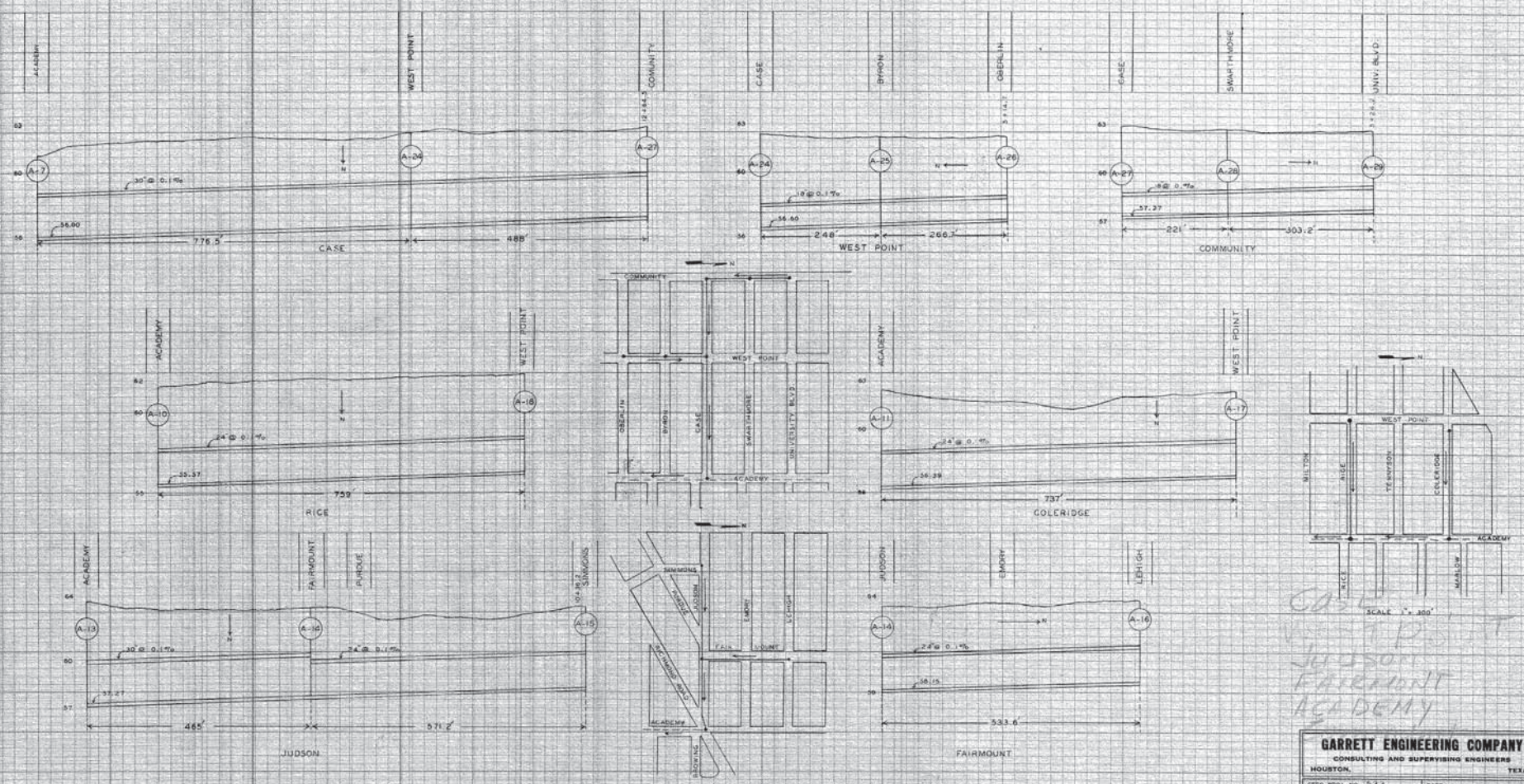
GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS

GECO PROJ. NO.	533	DATE	
DRAWN	C.S.A.	CHECKED	
TRACED	E.H.S.	APPROVED	

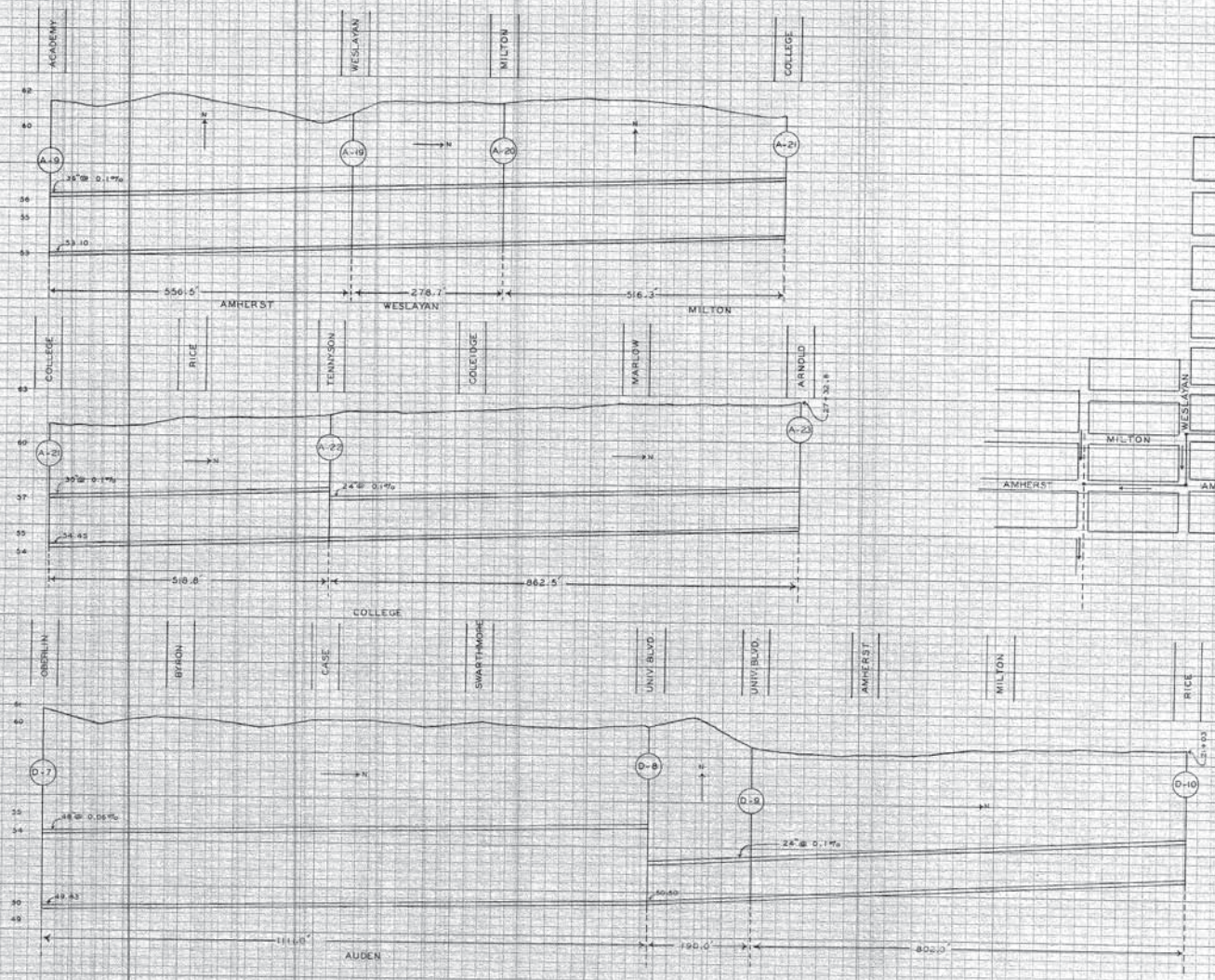
DRAWING NO.

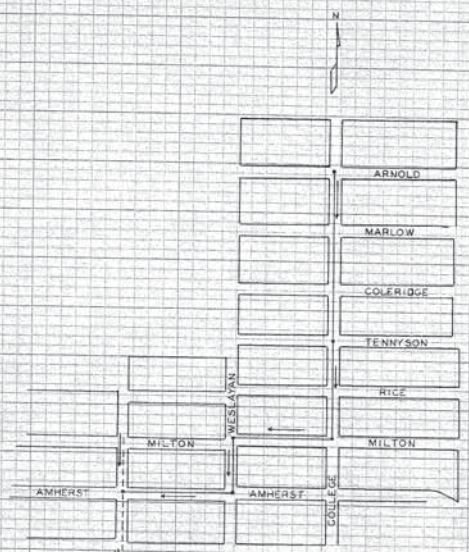
SHEET NO. 5 OF 13 SHEETS

NO.	DATE	BY	REMARKS
			REVISIONS



Jefferson
Fairmont
Academy





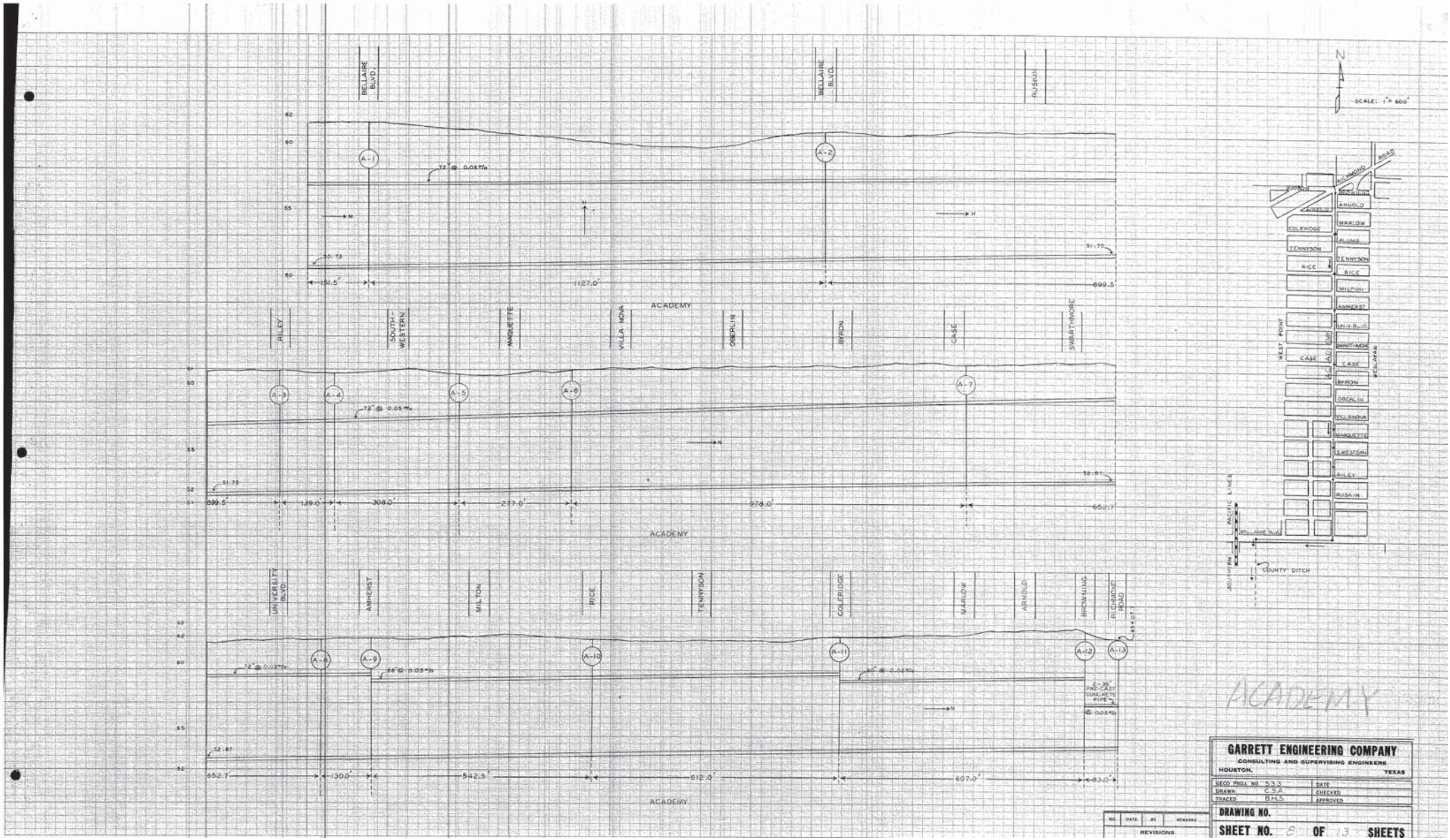
GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS

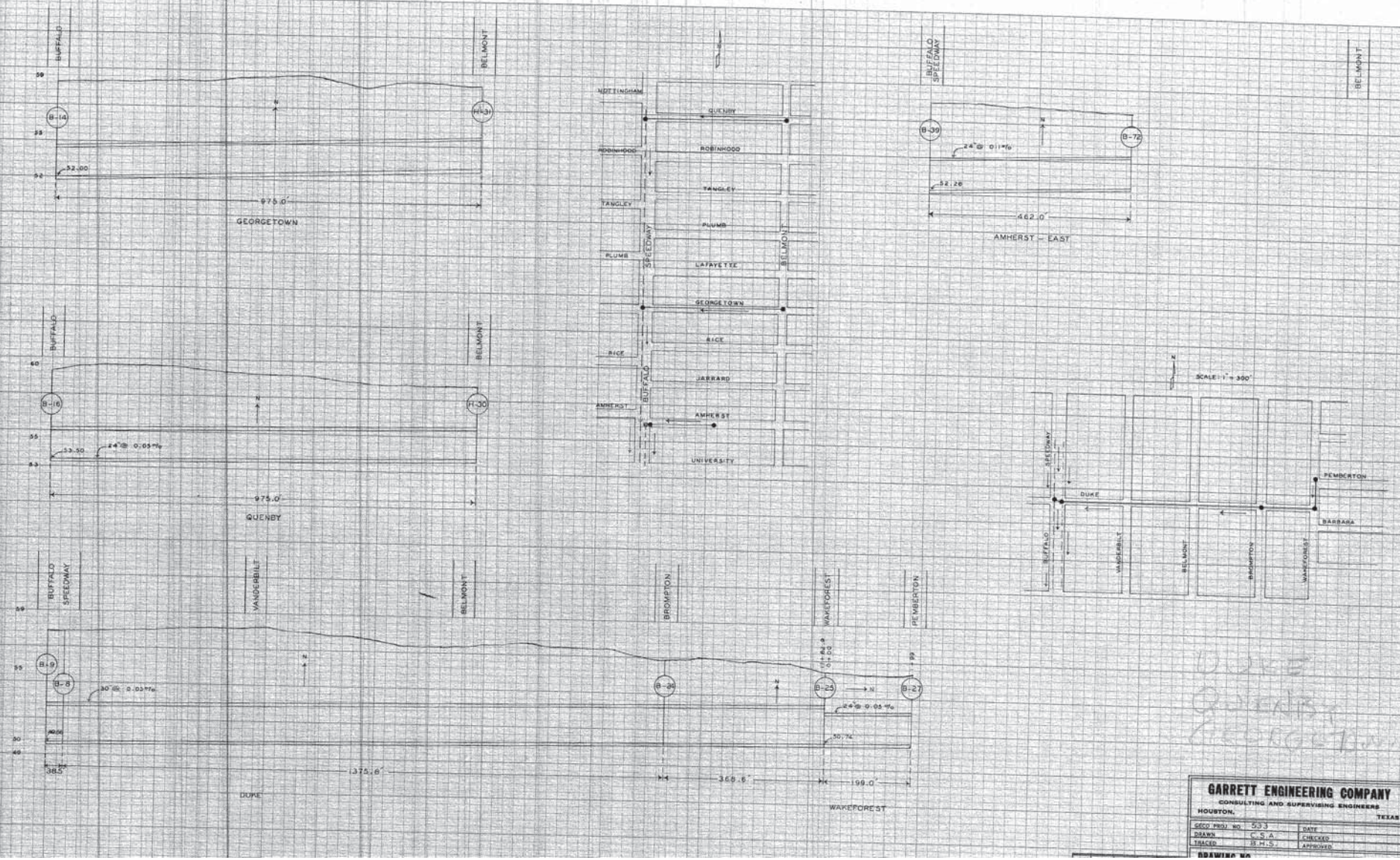
GECO PROJ. NO.	533	DATE	
DRAWN	C.S.A.	CHECKED	
TRACED	B.H.S.	APPROVED	

DRAWING NO.

NO.	DATE	BY	REMARKS

SHEET NO. OF SHEETS


BELLAIRE BLVD.
RUSKIN
A-1
A-2
72" @ 0.05%
50.75
51.75
151.5'
1127.0'
899.5'
ACADEMY
RILEY
SOUTH-WESTERN
MARQUETTE
VILLA NOVA
OBERLIN
BYRON
CASE
SMARTHMORE
A-3
A-4
A-5
A-6
A-7
52.87
139.0'
308.0'
277.0'
978.0'
652.7'
UNIVERSITY BLVD.
AMHERST
MILTON
RICE
TENNYSON
COLERIDGE
MARLOW
ARNOLD
BROWNING
RICHMOND ROAD
A-8
A-9
A-10
A-11
A-12
A-13
66" @ 0.05%
80" @ 0.05%
2-36" PRE-CAST CONCRETE PIPE @ 0.05%
130.0'
542.5'
612.0'
607.0'
83.0'
N
SCALE: 1" = 600'
RICHMOND ROAD
RUSKIN
ARNOLD
MARLOW
BROWNING
COLERIDGE
TENNYSON
RICE
MILTON
AMHERST
UNIV. BLVD.
SMARTMORE
CASE
BYRON
OBERLIN
VILLANOVA
MARQUETTE
S. WESTERN
RILEY
RUSKIN
WEST POINT
BELLAIRE
SOUTHERN PACIFIC LINES
COUNTY DITCH
ACADEMY
GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS
GECO PROJ. NO. 533
DRAWN: G.S.A.
TRACED: B.H.S.
DATE
CHECKED
APPROVED
DRAWING NO.
SHEET NO. 8 OF 13 SHEETS
NO. DATE BY REMARKS
REVISIONS

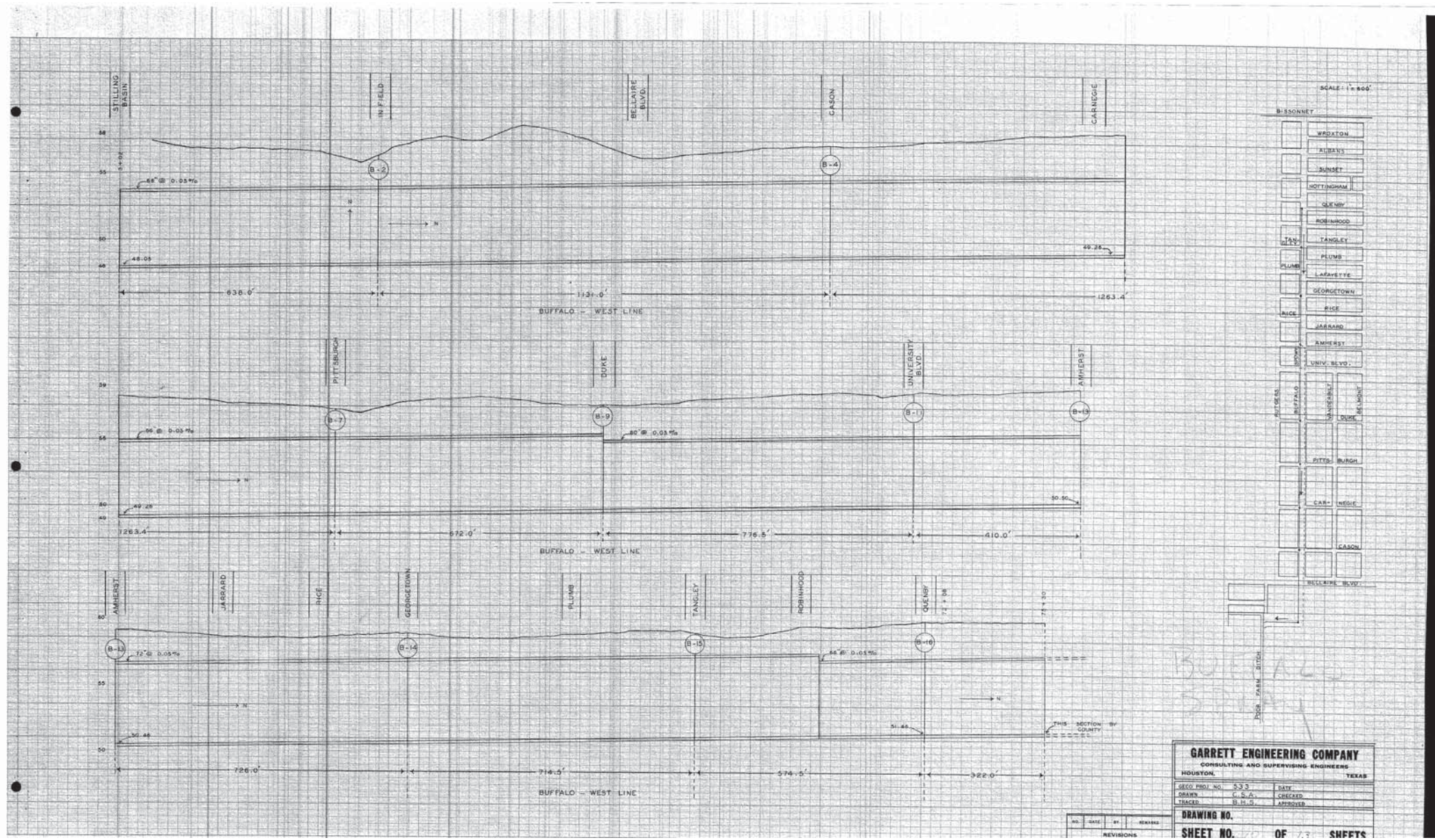


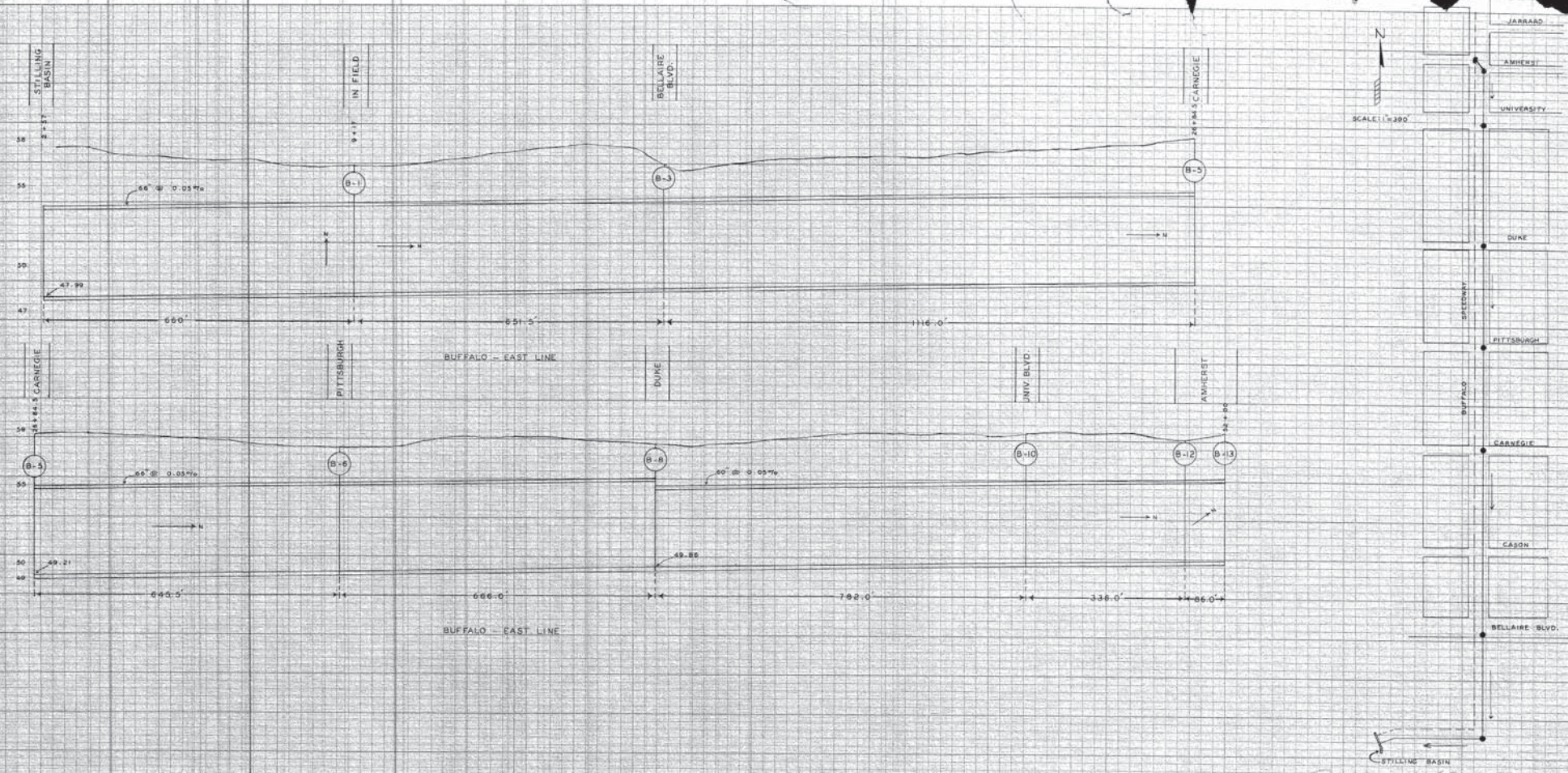
DUKE
BARBARA
PEMBERTON

GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS

GECO PROJ. NO.	533	DATE	
DRAWN	C.S.A.	CHECKED	
TRACED	B.M.S.	APPROVED	

DRAWING NO.


STILLING BASIN
INFIELD
BELLAIRE BLVD.
CASON
CARNEGIE
B-2
B-4
68' @ 0.05%
46.05
49.28
638.0'
1131.0'
1263.4'
BUFFALO - WEST LINE
PITTSBURGH
DUKE
UNIVERSITY BLVD.
AMHERST
B-7
B-9
B-11
B-13
66' @ 0.05%
80' @ 0.05%
49.28
50.50
1263.4'
672.0'
776.5'
410.0'
BUFFALO - WEST LINE
AMHERST
JARRARD
RICE
GEORGETOWN
PLUMB
TANGLEY
ROBINHOOD
QUENBY
B-13
B-14
B-15
B-16
72' @ 0.05%
66' @ 0.05%
50.46
51.46
THIS SECTION BY COUNTY
726.0'
714.5'
574.5'
322.0'
BUFFALO - WEST LINE
SCALE: 1" = 800'
BISSONNET
WROXTON
ALBANS
SUNSET
NOTTINGHAM
QUENBY
ROBINHOOD
TANGLEY
PLUMB
LAFAYETTE
GEORGETOWN
RICE
JARRARD
AMHERST
UNIV. BLVD.
BUFFALO
VANDERBILT
BELMONT
DUKE
PITTS-BURGH
CARNEGIE
CASON
BELLAIRE BLVD.
POOR FARM DITCH
GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS
GECO PROJ. NO. 533
DRAWN C.S.A.
TRACED B.H.S.
DATE
CHECKED
APPROVED
DRAWING NO.
SHEET NO. OF SHEETS
NO. DATE BY REMARKS
REVISIONS



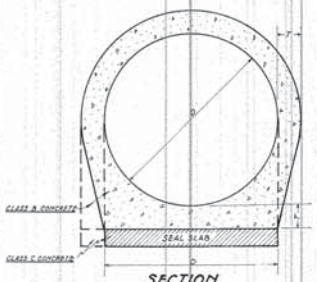
GARRETT ENGINEERING COMPANY
CONSULTING AND SUPERVISING ENGINEERS
HOUSTON, TEXAS

GECO PROJ. NO.	533	DATE	
DRAWN	C.S.A.	CHECKED	
TRACED	B.H.S.	APPROVED	

DRAWING NO.

NO.	DATE	BY	REMARKS

TYPICAL PLAIN CONCRETE SEWER



SECTION

DIMENSIONS OF PLAIN CONCRETE SEWERS

INSIDE DIAMETER D = INCHES	MIN. THICKNESS T = INCHES
30	5
36	5½
42	6
48	6½
54	7
60	7½
66	8
72	8½

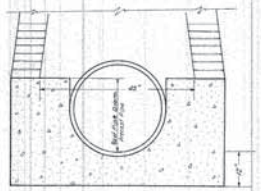
NOTE

1. Seal slab to be constructed only upon written order of the Engineer.
2. Seal slab concrete shall set 24 hours before setting forms.
3. Excavation for Seal Slab will be paid for at the Unit Price bid for hand excavation.
4. When contractor uses a sheeting method requiring vertical sides below center line of sewer, extra concrete used shall be placed at contractor's expense.
5. When soil conditions require vertical sides below center line of sewer the Engineer shall order extra concrete to be placed and the contractor shall be paid for the extra concrete used at Unit price bid for concrete in place.
6. Forms shall be securely held in place with precast concrete blocks and timber shoring.

TYPICAL MANHOLE TYPE "A"

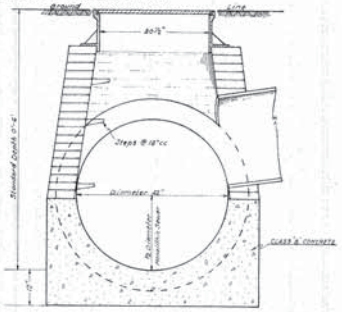
for

SEWERS WITH DIAMETERS 42" & SMALLER



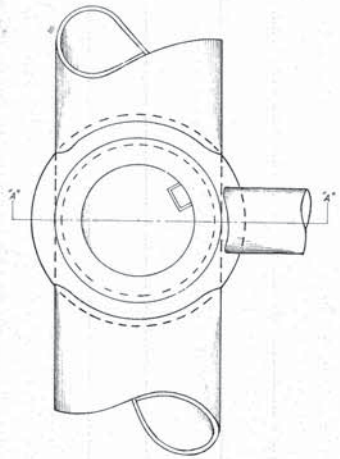
SECTION "A-A"

Diameter of Sewer Less than 42"



SECTION "A-A"

Diameter of Sewer 42"

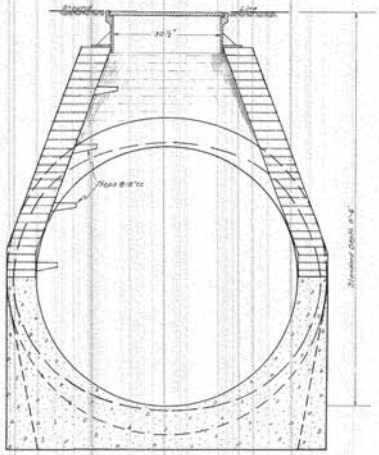


PLAN

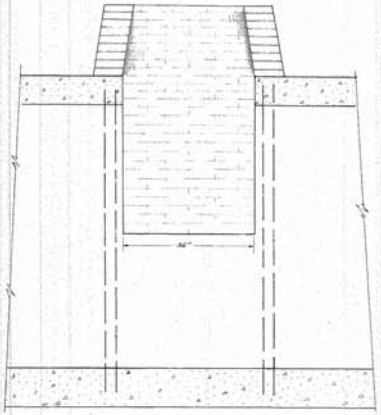
TYPICAL MANHOLE TYPE "B"

for

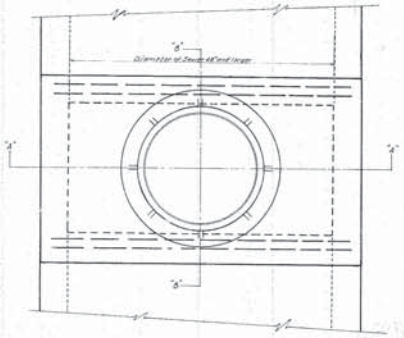
SEWERS WITH DIAMETERS 48" & LARGER



SECTION "A-A"



SECTION "B-B"



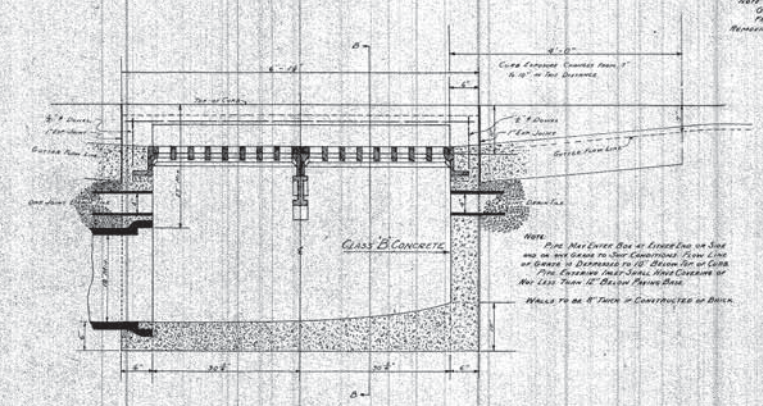
PLAN

STORM SEWERS ON BUFFALO SPEEDWAY FOR HARRIS COUNTY, TEXAS

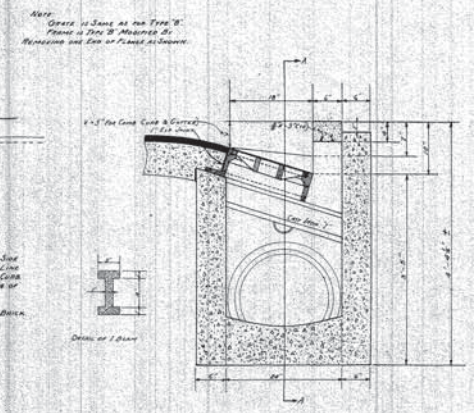
GARRETT ENGINEERING CO.
HOUSTON PROJECT NO. 533 TEXAS

CIRCULAR STORM SEWER AND MANHOLES

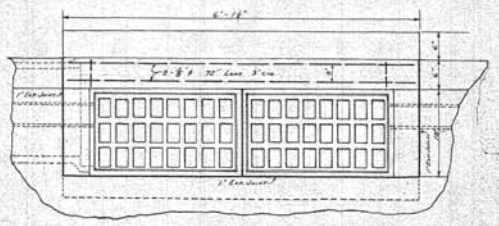
REVISED	DATE	DRAWN BY	M.L.G.
J.P.C.	11-5-41	CHECKED	J.A.S.



Section "A-A"

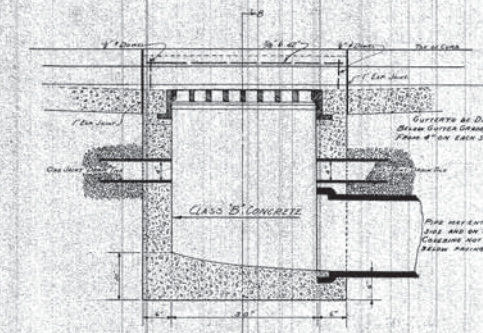


Section "B-B"

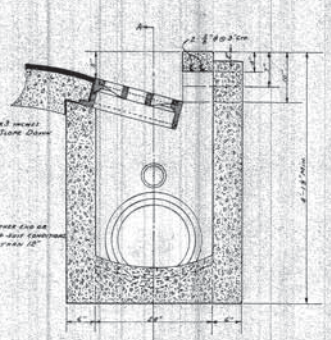


Plan

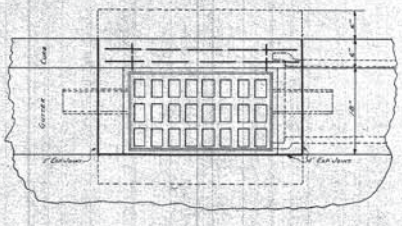
Type "B-B" Inlet



Section A-A



Section B-B



Plan

Type "B" Inlet

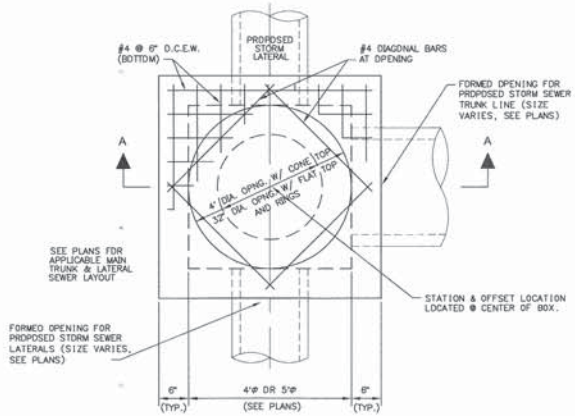
GARRETT ENGINEERING CO.
HOUSTON PROJECT NO. 533 TEXAS

STORM SEWER INLETS
CITY OF
WEST UNIVERSITY PLACE

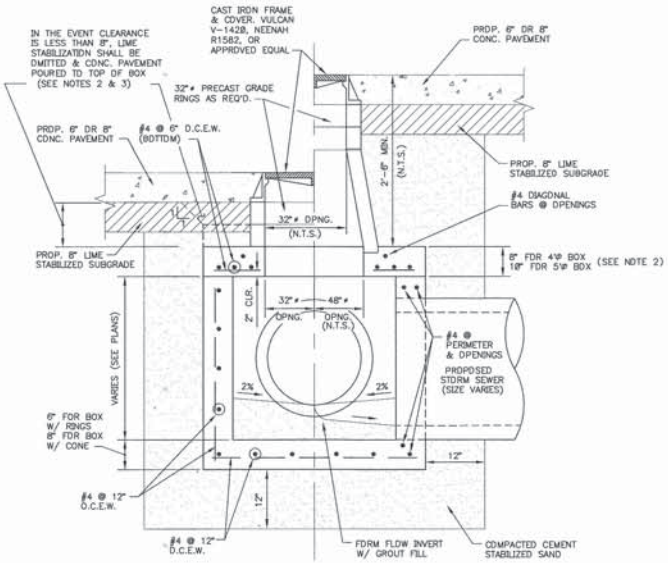
REVISED	DATE		
		DRAWN BY	H.L.G.
		CHECKED	J.B.S.
		TRACED	D.A.
		APPROVED	M.T.G.
		SHEET NO.	13 OF 13

APPENDIX D

Construction Details for Connections to Existing Monolithic Concrete Pipe



PLAN

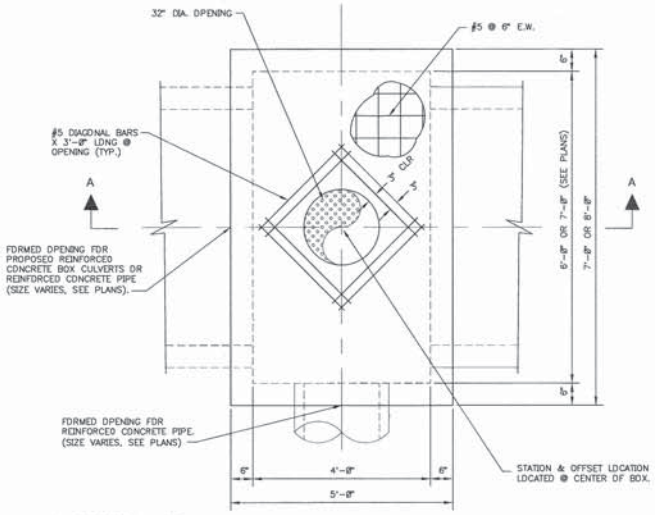


SECTION A-A

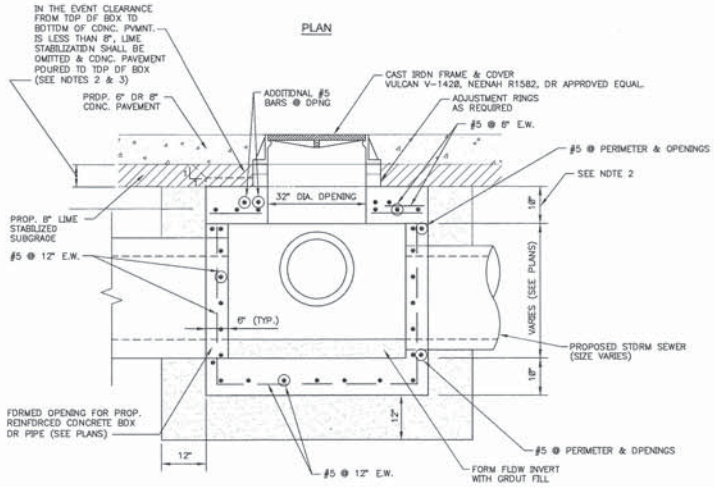
PRECAST STORM BOX MANHOLE DETAIL (SQUARE)

SCALE: NTS

BOX MANHOLES: 5-14, 18-30, 34-45, 48-63, 66, 67, & 69-85.



PLAN



SECTION A-A

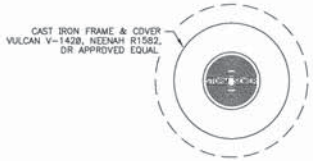
PRECAST STORM BOX MANHOLE DETAIL (RECTANGULAR)

SCALE: NTS

BOX MANHOLES: 3, 4, & 17

PRECAST STORM BOX MANHOLE NOTES:

1. ALL PRECAST STORM BOX MANHOLES SHALL BE CONSTRUCTED OF 4000 PSI CONCRETE, REINFORCED 60000 PSI HS 20 LOADING PER MOOR-TEX CONCRETE PRODUCTS, INC. OR APPROVED EQUAL. THE DETAILS ON THIS SHEET REFLECT DESIGN REQUIRMENTS PROVIDED BY MOOR-TEX ENGINEERS. ANY VARIATION TO THESE DESIGNS OTHER THAN THOSE SHOWN IN THE DETAILS SHALL REQUIRE THE CONTRACTOR TO SUBMIT FOR APPROVAL SAID REVISIONS SIGNED & SEALED BY AN ENGINEER LICENSED IN THE STATE OF TEXAS.
2. CWI REVIEW INDICATES NO PRECAST STORM BOX MANHOLE TOP SLABS SHOULD ENCROACH INTO PROPOSED PAVEMENT; HOWEVER, IF ACTUAL CONSTRUCTION RESULTS IN THIS BEING UNAVOIDABLE, THE TOP SLAB THICKNESS SHALL BE MADE 14" AND REINFORCED PER TOP SLAB DETAILS FOR THE TYPE 2 STORM JUNCTION BOX ON SHEET 83.
3. CWI REVIEW DOES INDICATE THAT SOME PRECAST STORM BOX MANHOLE TOP SLABS MAY ENCROACH INTO PROPOSED PAVEMENT SUBGRADE. IN THESE CASES, THE SUBGRADE OVER THE BOX SHALL BE ELIMINATED AND THE PROPOSED CONCRETE PAVEMENT SHALL BE POURED TO THE TOP OF THE BOX AS DETAILED ON THIS SHEET.



STORM SEWER MANHOLE COVER

NOT TO SCALE

NO.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS
C. DIETER UFER
53617
REGISTERED PROFESSIONAL ENGINEER

C Dieter Ufer
9/16/02

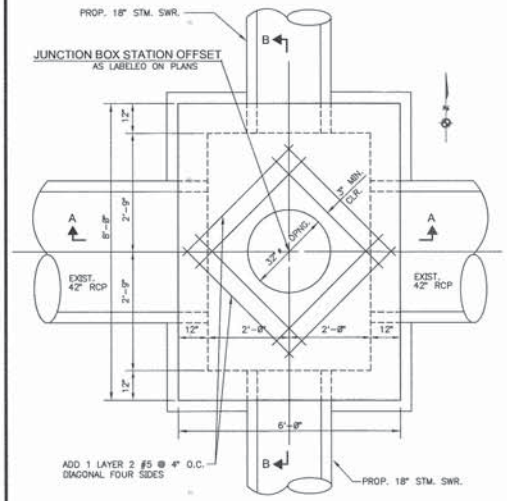
CLAUNCH & MILLER, INC.
Engineering Consultants
1701 Kirby Drive, Suite 1604 • Houston, Texas 77098-3969
(713) 524-7133 • Fax (713) 524-7770 • www.claunchmiller.com

City of West University Place

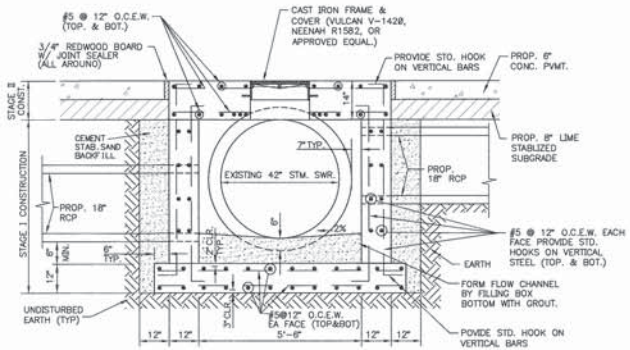
Priority Area 11B

Storm Sewer
Construction Details

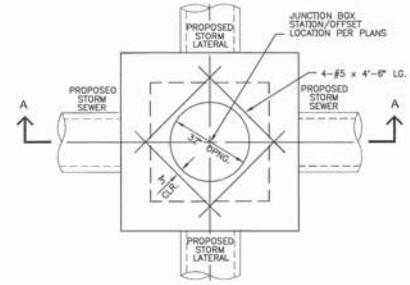
Job No.: 01-041	SCALE: HORZ: NTS VERT: NTS	SHEET 81 OF 92
Date: July, 2002		
Dwn By: P.B. Hopsh		
Chkd By: C.D. Ufer		



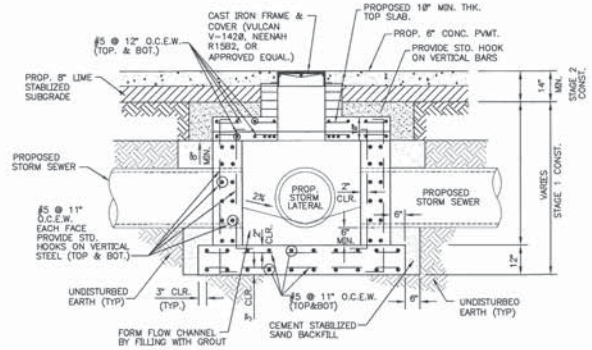
PLAN 1



SECTION B-B



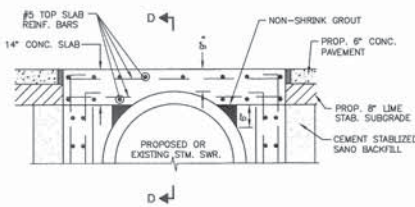
PLAN



SECTION A-A

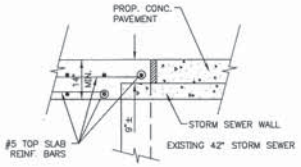
STORM SEWER JUNCTION BOX DETAIL
(FOR 30"Ø OR LESS PIPE, MANHOLE No.'s 64 & 65)

SCALE: 1/2" = 1'-0"



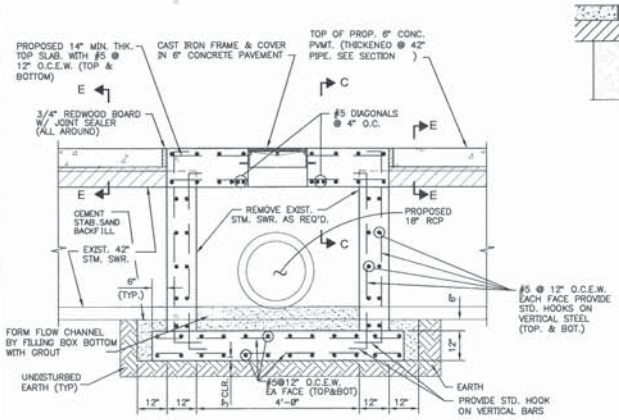
SECTION C-C

SCALE: 1/2" = 1'-0"

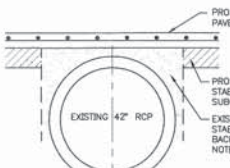


SECTION D-D

SCALE: 1/2" = 1'-0"

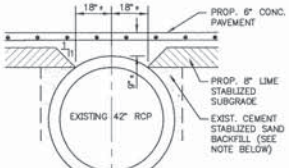


SECTION A-A

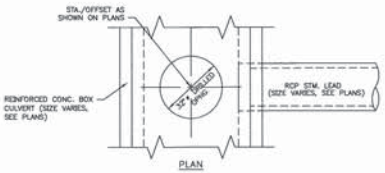


SECTION E-E
ALTERNATE 1

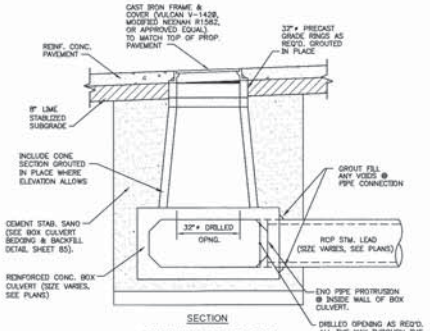
SECTION E-E NOTE:
IF CEMENT STAB. SAND BACKFILL EXISTS WITHIN LIMITS OF PROPOSED 8" SUBGRADE, GRIND C. SAND TO ELEVATION OF BOTTOM OF PROPOSED CONC. & CONSTRUCT AS SHOWN IN ALTERNATE 1. IF CEMENT STAB. SAND BACKFILL DOES NOT EXIST OR IS DAMAGED WITH EXCAVATION ACTIVITIES, CONSTRUCT PAVEMENT OVER 42" RCP AS SHOWN ALTERNATE 2.



SECTION E-E
ALTERNATE 2



PLAN



SECTION

MANWAY DETAIL

SCALE: 1/2" = 1'-0"

1.) ALL CONCRETE SHALL HAVE SAND AND GRAVEL AGGREGATE TYPE I PORTLAND CEMENT WITH 28 DAY COMPRESSIVE STRENGTH (f'c) OF 3000 PSI.

2.) ALL REINFORCING BARS SHALL CONFORM TO ASTM A615-GRADE 60.

TYPE 1 STORM SEWER JUNCTION BOX DETAIL

SCALE: 1/2" = 1'-0"
JUNCTION BOX NO. 68

NO.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS — C. DIETER UFER — 65617 — REGISTERED PROFESSIONAL ENGINEER

9/14/02

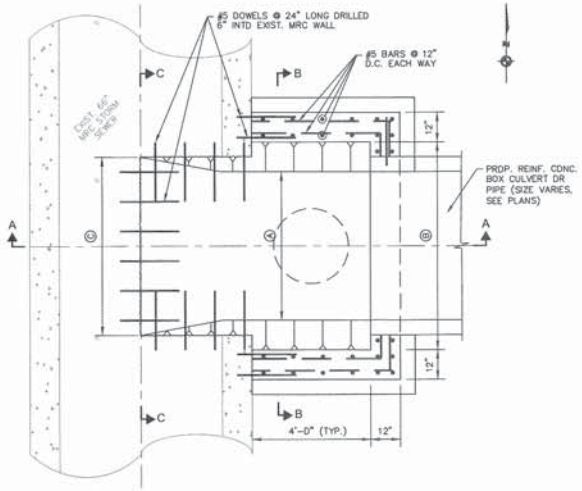
CLAUNCH & MILLER, INC.
Engineering Consultants
3701 Kirby Drive, Suite 860a Houston, Texas 77098-3969
(713) 524-7113 • Fax (713) 524-1716 • www.claunchmiller.com

City of West University Place

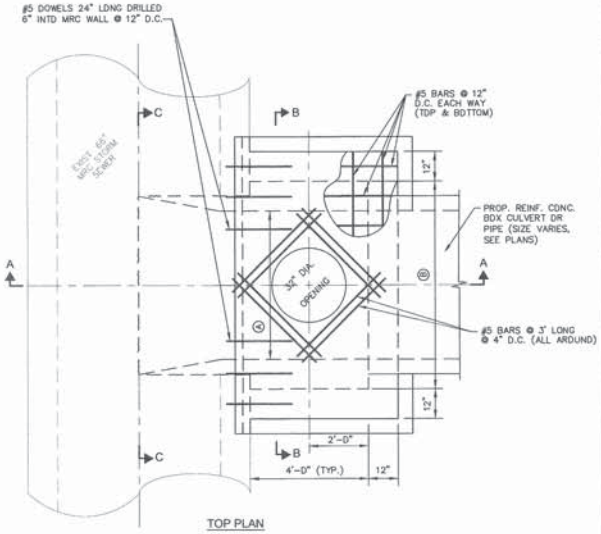
Priority Area 11B

Storm Sewer
Construction Details

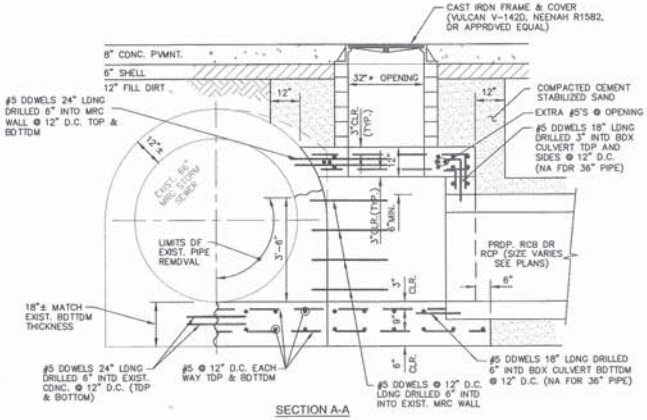
Job No.: 00-041	Scale: HORZ - NTS VERT - NTS	SHEET 82 OF 92
Date: July, 2002		
Dwn By: P.B. Horsh		
Chkd By: C.D. Ufer		



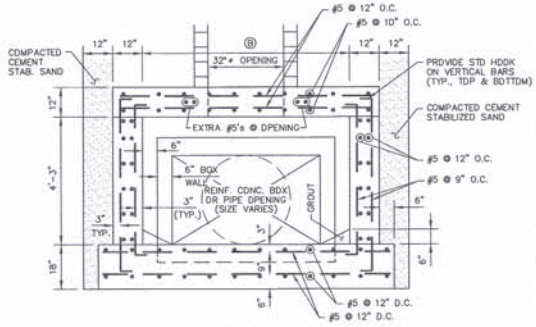
BOTTOM PLAN



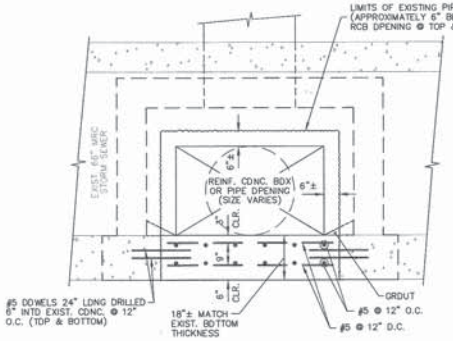
TOP PLAN



SECTION A-A



SECTION B-B



SECTION C-C

TYPE 2 STORM SEWER JUNCTION BOX TABLE			
No.	Ⓐ	Ⓑ	Ⓒ
1 (4' x 2' RCB)	4'-0"	6'-0"	5'-0"
15 (4' x 2' RCB)	4'-0"	6'-0"	5'-0"
31 (4' x 2' RCB)	4'-0"	6'-0"	5'-0"
47 (36" RCP)	3'-0"	5'-0"	4'-0"

1.) ALL CONCRETE SHALL HAVE SAND AND GRAVEL AGGREGATE TYPE I PORTLAND CEMENT WITH 28 DAY COMPRESSIVE STRENGTH (f'c) OF 3000 PSI.

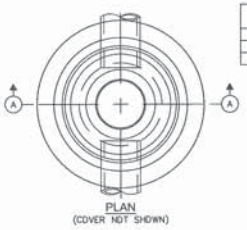
2.) ALL REINFORCING BARS SHALL CONFORM TO ASTM A615-GRADE 60.

TYPE 2 STORM SEWER JUNCTION BOXES AT 66" STORM SEWER

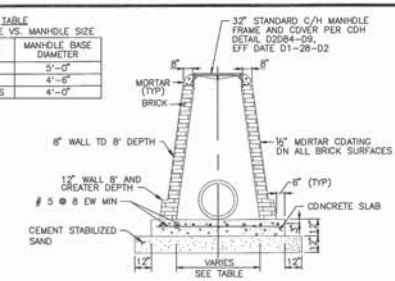
SCALE: 1/2" = 1'-0"

TABLE
SEWER SIZE VS. MANHOLE SIZE

SEWER SIZE	MANHOLE BASE DIAMETER
42"	5'-0"
36"	4'-6"
30" AND LESS	4'-0"



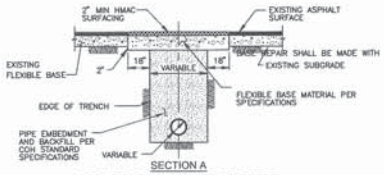
PLAN
(COVER NOT SHOWN)



SECTION A

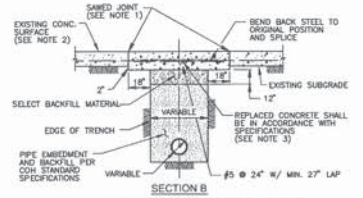
STANDARD CITY OF HOUSTON TYPE "C" STORM MANHOLE

NOT TO SCALE DTL. NO. D2081-D3 EFF. DATE: JUL-01-97



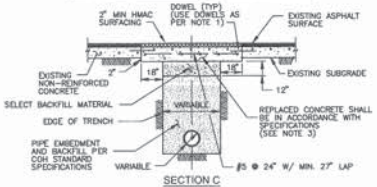
SECTION A

REPAIR OF FLEXIBLE BASE PAVEMENT



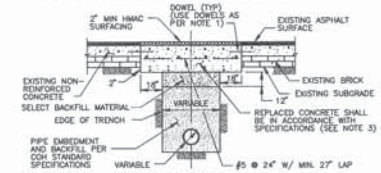
SECTION B

REPAIR OF REINFORCED CONCRETE PAVEMENT



SECTION C

REPAIR OF NON-REINFORCED CONCRETE PAVEMENT



SECTION D

REPAIR OF NON-REINFORCED CONCRETE PAVEMENT WITH BRICK

NOTE:
1. EXPOSE 15" OF REINFORCING STEEL AT PROPOSED SAWED JOINT. IF NO REINFORCING STEEL EXISTS, USE HORIZONTAL DOWELS. HORIZONTAL DOWELS SHALL BE # 6 BARS, 24" LONG, 24" C-C, DRILLED AND EMBEDDED 8" INTO THE CENTER OF THE EXISTING SLAB. WITH "PO ROC" OR EQUAL.
2. IF REINFORCED CONCRETE IS OVERLAYED WITH ASPHALT, REPLACE WITH 2" MIN HMAC SURFACING.
3. CENTER REINFORCING IN SLAB THICKNESS.

PAVEMENT REPAIR DETAILS

(FOR PAVEMENT REPAIR WITHIN CITY OF HOUSTON RIGHT-OF-WAYS ONLY)
NOT TO SCALE DTL. NO. 02902-01 EFF. DATE: JUL-01-97

CITY OF HOUSTON
DEPT. OF PUBLIC WORKS & ENGINEERING

PRIVATELY FUNDED PUBLIC WORKS | CITY FUNDED PUBLIC WORKS
WATER — 9-5-02
WASTEWATER — PROJECT MANAGER
STORM WATER — 9.5.02 — CONSTRUCTION
STREET & BRIDGE — 9.5.02 — CHIEF ENGINEER
OTHER DEPARTMENTS
TRAFFIC AND TRANSPORTATION — 9-5-02 — SPONSOR DEPARTMENT
CITY ENGINEER — DATE
DIRECTOR OF PUBLIC WORKS AND ENGINEERING — DATE 9-5-2002

NO.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS — C. DIETER UFER — 39001 — REGISTERED PROFESSIONAL ENGINEER
8/20/02

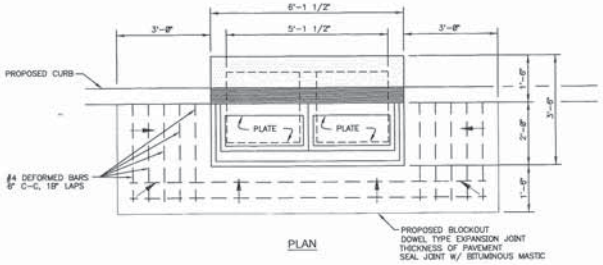
CLAUNCH & MILLER, INC.
Engineering Consultants
3701 Kirby Drive, Suite 860 • Houston, Texas 77098-3969
(713) 524-7113 • Fax (713) 524-1718 • www.claunchmiller.com

City of West University Place

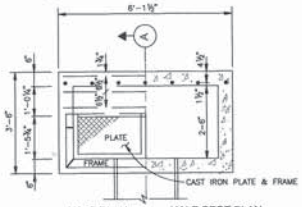
Priority Area 11B

Storm Sewer Construction Details

JOB NO: 01-041	SCALE: HORZ: NTS VERT: NTS	SHEET 83 OF 92
DATE: July, 2002		
DWN BY: P.B. Harsh		
CHK BY: C.D. Ufer		



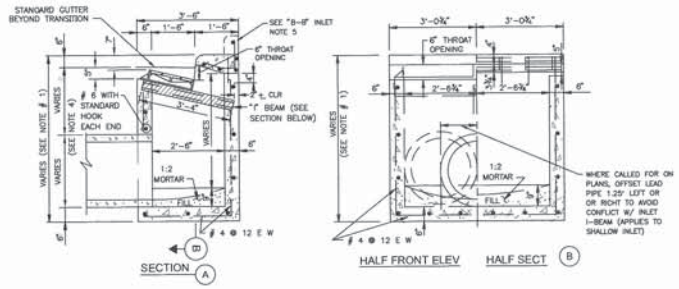
PLAN



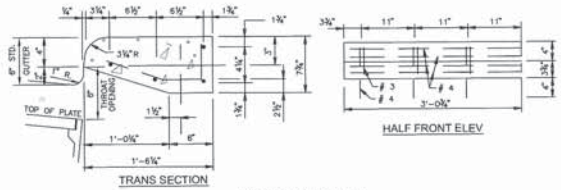
HALF PLAN HALF SECT PLAN

"B-B" INLET NOTES:

1. DIMENSION VARIES BASED ON PIPE DIAMETER AND WALL THICKNESS.
2. CENTER REINFORCING IN SLAB AND WALLS.
3. CENTER STEEL BEAM ON INLET AND CAST INTO WALLS AS SHOWN.
4. SEE PLANS FOR TOP-OF-CURB ELEVATION, PIPE SIZE & FLOWLINE ELEVATION.
5. WHEN INLET FALLS WITHIN LIMITS OF EXACCERATED HEIGHT CURB CALLED FOR IN PLANS, DOWEL PROPOSED 6" CURB TO INLET TOP, (BACK AND SIDES) WITH #4 BARS, 9" LONG @ 12" C-C. RUN CONTINUOUS #4 BAR AS PER TYPICAL CONCRETE CURB DETAIL SHEET B6.
6. USE STD CAST IRON FRAME & PLATES. LEAD SHALL LEAVE INLET AT LOCATION AND GRADE REQUIRED.



SECTION (A) HALF FRONT ELEV HALF SECT (B)



TRANS SECTION HALF FRONT ELEV

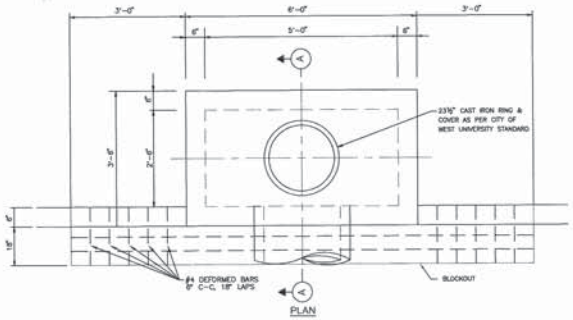
PRECAST CURB BEAM

ACCEPTABLE ALTERNATE STEEL BEAM SIZES: S8x17.5 W8x16 (GALVANIZED)

SECTION THRU BEAM

CURB BEAM BAR LIST				
NO	SIZE	LENGTH	SHAPE	LOC
4	# 4	5'-10"	ST	HOR
7	# 4	0'-10"	ST	VERT
7	# 3	1'-6"	BT	

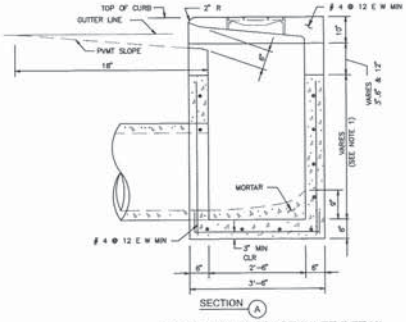
TYPE "BB" INLET DETAIL
NOT TO SCALE



PLAN

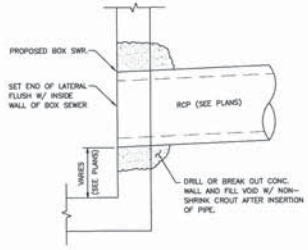
"H-2" INLET NOTES:

1. DIMENSION VARIES BASED ON PIPE DIAMETER AND WALL THICKNESS.
2. CENTER REINFORCING IN SLAB AND WALLS
3. SEE PLANS FOR TOP-OF-CURB ELEVATION, PIPE SIZE, & FLOWLINE ELEVATION.
4. WHEN INLET FALLS WITHIN LIMITS OF EXACERATED HEIGHT CURB (WHERE CALLED FOR ON PLANS) DOWEL PROPOSED 6" CURB TO TOP, BACK & SIDES OF INLET TOP WITH # 4 BARS, 9" LONG @ 12" OC. RUN CONTINUOUS #4 BAR AS PER TYPICAL CONCRETE CURB DETAIL, SHEET B6.

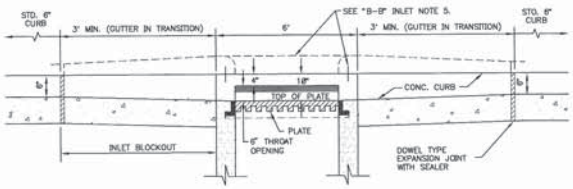


SECTION (A)

TYPE "H-2" PRECAST INLET DETAIL
NOT TO SCALE



PIPE-TO-BOX CONNECTION DETAIL
NOT TO SCALE



GUTTER DEPRESSIONS FOR
TYPE "BB" & "H-2" INLET

NO.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS
C. DIETER UFER
REGISTERED PROFESSIONAL ENGINEER
9/16/02

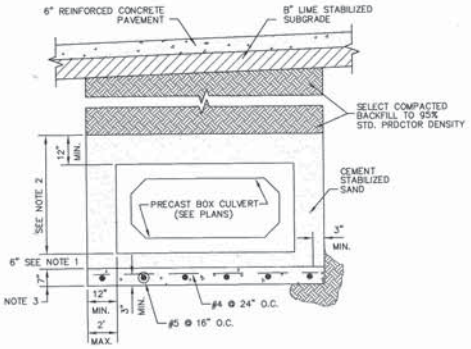
CLAUNCH & MILLER, INC.
Engineering Consultants
3701 Kirby Drive, Suite 860• Houston, Texas 77098-3969
(713) 524-7115 • Fax (713) 524-1719• www.clauncheller.com

City of West University Place

Priority Area 11B

Storm Sewer
Construction Details

Job No. 01-041	SCALE: HORZ NTS VERT NTS	SHEET 84 OF 92
DATE July, 2002		
Dwn By: P.B. Harsh		
Chkd By: C.D. Ufer		



BOX CULVERT BEDDING & BACKFILL DETAIL

SCALE: 1/2" = 1'-0"

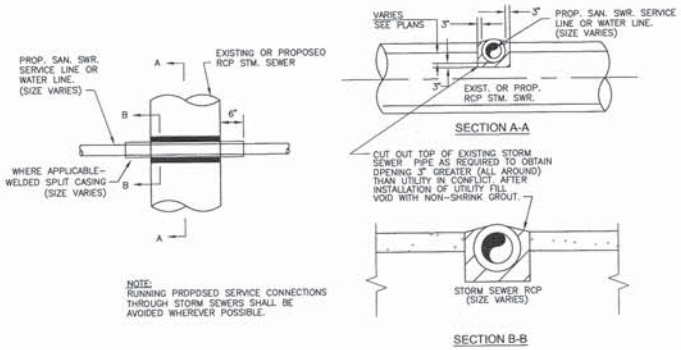
NOTES:

1. CEMENT STABILIZED SAND TO BE LAID PRIOR TO BOX PLACEMENT.
2. CEMENT STABILIZED SAND TO BE LAID AFTER BOX PLACEMENT.
3. IN DRY TRENCH CONDITION, THE 7" REINFORCED CONCRETE SLAB SHALL BE OMITTED. (NOTE: 12" THICK CRUSHED ROCK MAY BE INSTALLED IN PLACE OF 7" REINF. CONC. SLAB. ADD DEPTH AS NEEDED FOR SEEPAGE DRAINAGE.)

DRY TRENCH CONDITIONS ARE DEFINED AS FOLLOWS:

A. STRATA FROM THE SPRINGLINE (CENTER) TO 3' BELOW THE FLOWLINE OF THE BOX CONSIST OF NON-WATERBEARING COHESIVE SOILS HAVING A SHEAR STRENGTH OF 1000 PSF OR GREATER.

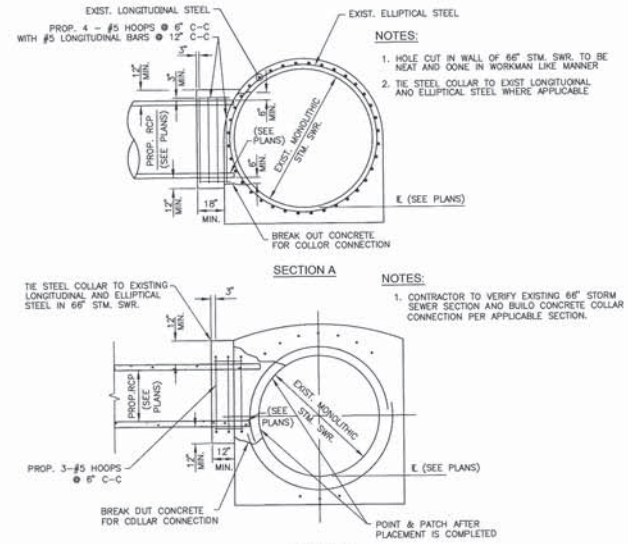
B. NO WET SAND STRATA EXIST IN THE AREA FROM 1' ABOVE THE TOP OF THE BOX TO 3' BELOW THE FLOWLINE.



NOTE:
RUNNING PROPOSED SERVICE CONNECTIONS THROUGH STORM SEWERS SHALL BE AVOIDED WHEREVER POSSIBLE.

STORM SEWER/UTILITY CONFLICT DETAIL

NOTE:
SEE SHEET 79 FOR SPLIT CASING DETAIL.



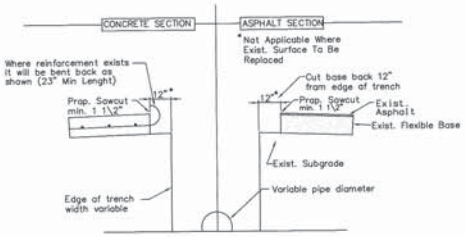
NOTES:

1. HOLE CUT IN WALL OF 66" STM. SWR. TO BE NEAT AND DONE IN WORKMAN LIKE MANNER
2. TIE STEEL COLLAR TO EXIST LONGITUDINAL AND ELLIPTICAL STEEL WHERE APPLICABLE

NOTES:

1. CONTRACTOR TO VERIFY EXISTING 66" STORM SEWER SECTION AND BUILD CONCRETE COLLAR CONNECTION PER APPLICABLE SECTION.

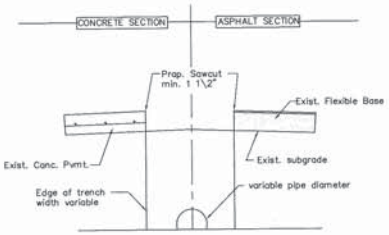
CONCRETE COLLAR CONNECTION DETAIL



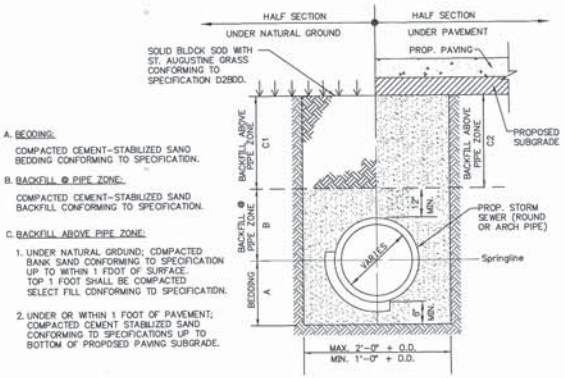
SECTION SHOWING METHOD OF CUTTING

Table of Slab Depths & Reinf.

Min. Depth of Slab	Width of Trench	Size of Bar	Spacing	Length of Bar
8"	18"	4	9"	40"
8"	24"	4	8"	48"
8"	30"	4	7"	52"
8"	36"	4	6"	58"
10"	42"	4	8½"	64"
10"	48"	4	7½"	70"
10"	54"	4	7"	76"
10"	60"	4	6½"	82"
10"	66"	5	9"	88"
10"	72"	6	8½"	94"
10"	78"	6	8"	100"
10"	84"	6	7½"	106"



SECTION SHOWING METHOD OF CUTTING



A. BEDDING:

COMPACTED CEMENT-STABILIZED SAND BEDDING CONFORMING TO SPECIFICATION.

B. BACKFILL @ PIPE ZONE:

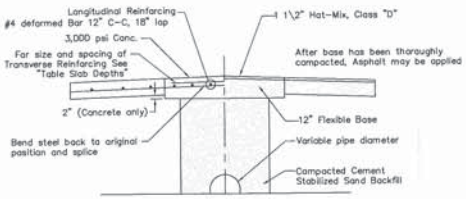
COMPACTED CEMENT-STABILIZED SAND BACKFILL CONFORMING TO SPECIFICATION.

C. BACKFILL ABOVE PIPE ZONE:

1. UNDER NATURAL GROUND; COMPACTED BANK SAND CONFORMING TO SPECIFICATION UP TO WITHIN 1 FOOT OF SURFACE. TOP 1 FOOT SHALL BE COMPACTED SELECT FILL CONFORMING TO SPECIFICATION.
2. UNDER OR WITHIN 1 FOOT OF PAVEMENT; COMPACTED CEMENT STABILIZED SAND CONFORMING TO SPECIFICATIONS UP TO BOTTOM OF PROPOSED PAVING SUBGRADE.

STORM SEWER BEDDING & BACKFILL DETAILS

NOT TO SCALE

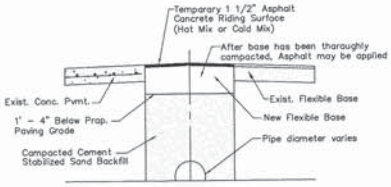


SECTION SHOWING METHOD OF REPAIR

CUTTING AND REPAIRING CONCRETE AND ASPHALT PAVEMENT DETAIL

NOTE: THIS DETAIL SHALL ONLY BE USED IN THE PROJECT WHERE THE EXISTING STREET PAVEMENT IS NOT TO BE REPLACED. TYPICAL FOR ALL PROPOSED UTILITY CONSTRUCTION.

SEE DETAILS, SHEET 83 FOR PAVEMENT REPAIR REQUIREMENTS WITHIN CITY OF HOUSTON RIGHT-OF-WAY.



SECTION SHOWING METHOD OF REPAIR

CUTTING AND REPAIRING CONCRETE AND ASPHALT PAVEMENT DETAIL

NOTE: THIS DETAIL SHALL ONLY BE USED IN THE PROJECT WHERE THE EXISTING STREET PAVEMENT IS TO BE REPLACED. TYPICAL FOR ALL PROPOSED UTILITY CONSTRUCTION.

No.	DESCRIPTION	DATE	DWN.	CHK.

REVISIONS

STATE OF TEXAS — C. DIETER UFER — 23017 — REGISTERED PROFESSIONAL ENGINEER

9/16/02

CLAUNCH & MILLER, INC.
Engineering Consultants
3701 Kirby Drive, Suite 1086 Houston, Texas 77098-3969
(713) 524-1111 • Fax (713) 524-2710 • www.claunchmiller.com

City of West University Place

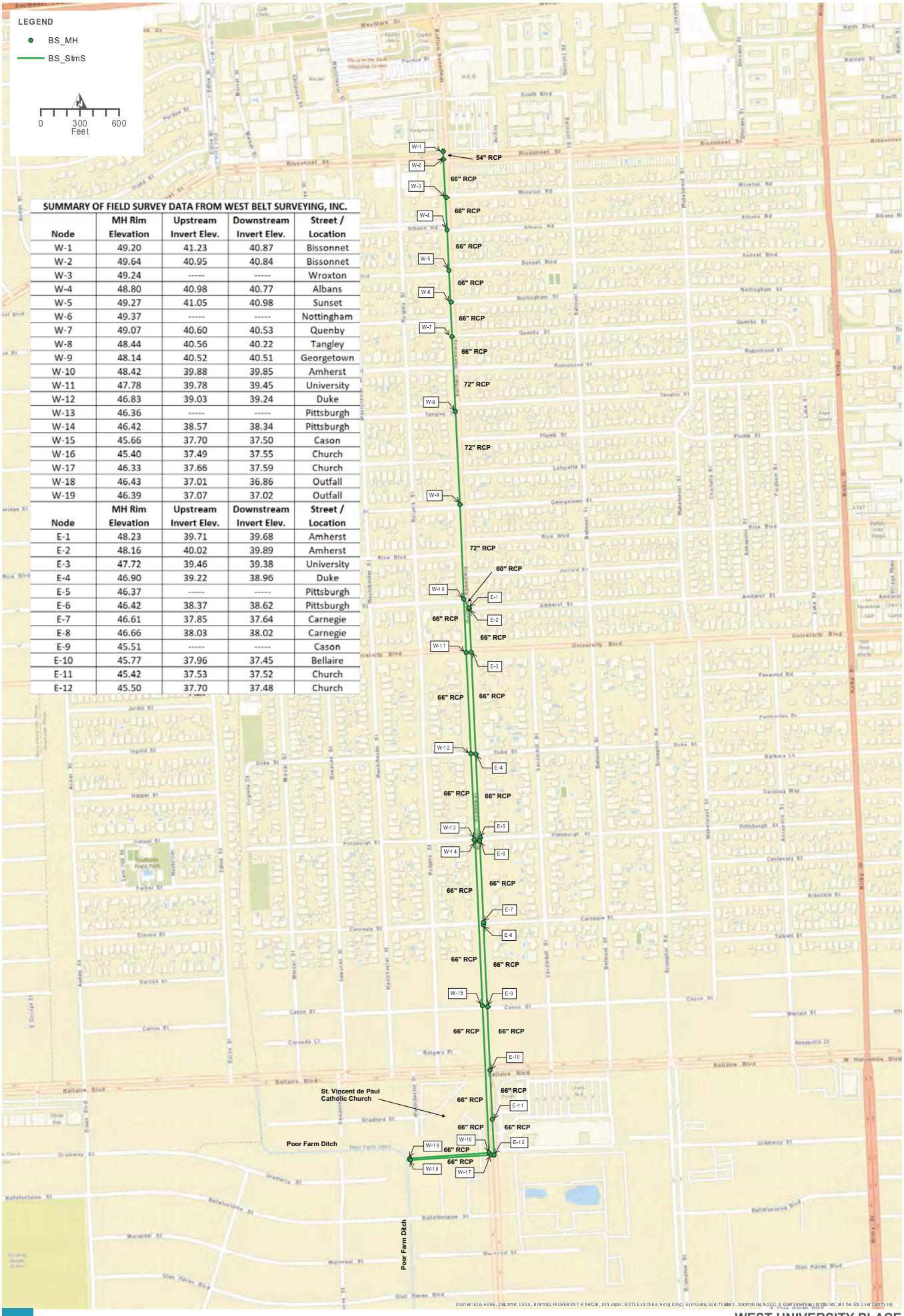
Priority Area 11B

Storm Sewer Construction Details

JOB No.: 01-041	SCALE: HORZ: NTS VERT: NTS	SHEET 85 OF 92
DATE: July, 2002		
DWN BY: P.B. Marsh		
CHKD BY: C.D. Ufer		

APPENDIX E

Field Notes and Survey Data



SUMMARY OF FIELD SURVEY DATA FROM WEST BELT SURVEYING, INC.				
Node	MH Rim Elevation	Upstream Invert Elev.	Downstream Invert Elev.	Street / Location
W-1	49.20	41.23	40.87	Bissonnet
W-2	49.64	40.95	40.84	Bissonnet
W-3	49.24	-----	-----	Wroxton
W-4	48.80	40.98	40.77	Albans
W-5	49.27	41.05	40.98	Sunset
W-6	49.37	-----	-----	Nottingham
W-7	49.07	40.60	40.53	Quenby
W-8	48.44	40.56	40.22	Tangley
W-9	48.14	40.52	40.51	Georgetown
W-10	48.42	39.88	39.85	Amherst
W-11	47.78	39.78	39.45	University
W-12	46.83	39.03	39.24	Duke
W-13	46.36	-----	-----	Pittsburgh
W-14	46.42	38.57	38.34	Pittsburgh
W-15	45.66	37.70	37.50	Cason
W-16	45.40	37.49	37.55	Church
W-17	46.33	37.66	37.59	Church
W-18	46.43	37.01	36.86	Outfall
W-19	46.39	37.07	37.02	Outfall
Node	MH Rim Elevation	Upstream Invert Elev.	Downstream Invert Elev.	Street / Location
E-1	48.23	39.71	39.68	Amherst
E-2	48.16	40.02	39.89	Amherst
E-3	47.72	39.46	39.38	University
E-4	46.90	39.22	38.96	Duke
E-5	46.37	-----	-----	Pittsburgh
E-6	46.42	38.37	38.62	Pittsburgh
E-7	46.61	37.85	37.64	Carnegie
E-8	46.66	38.03	38.02	Carnegie
E-9	45.51	-----	-----	Cason
E-10	45.77	37.96	37.45	Bellaire
E-11	45.42	37.53	37.52	Church
E-12	45.50	37.70	37.48	Church

HDR

WEST UNIVERSITY PLACE

BUFFALO SPEEDWAY

EXISTING DRAINAGE LAYOUT

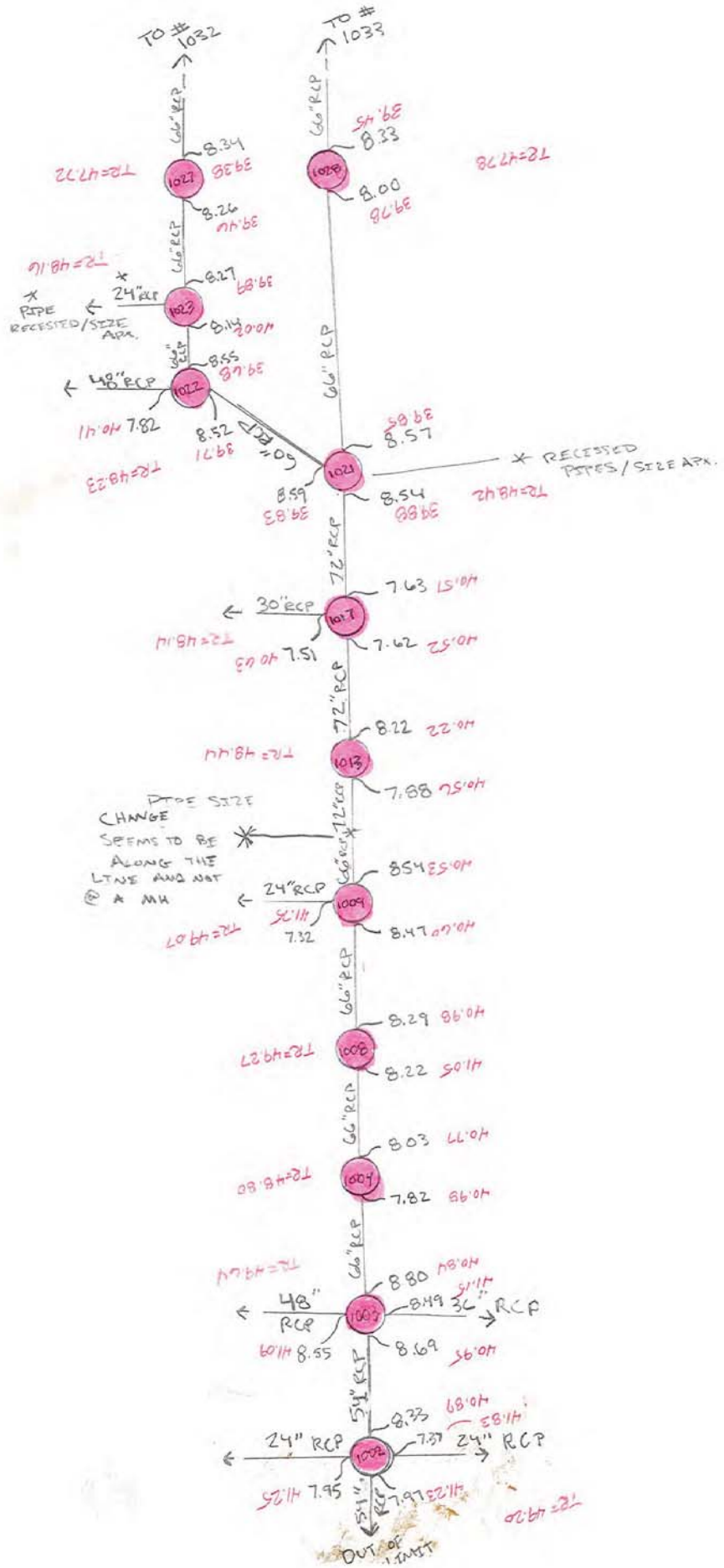
PATH: C:\USERS\ROBIBAJO\DOCUMENTS\ARCGIS\WEST_U_BSBUFFALO_SPDWY.MXD - USER: ROBIBAJO - DATE: 2/6/2018

WEST U BUFFALO SPEEDWAY PER

AM 12 15 17

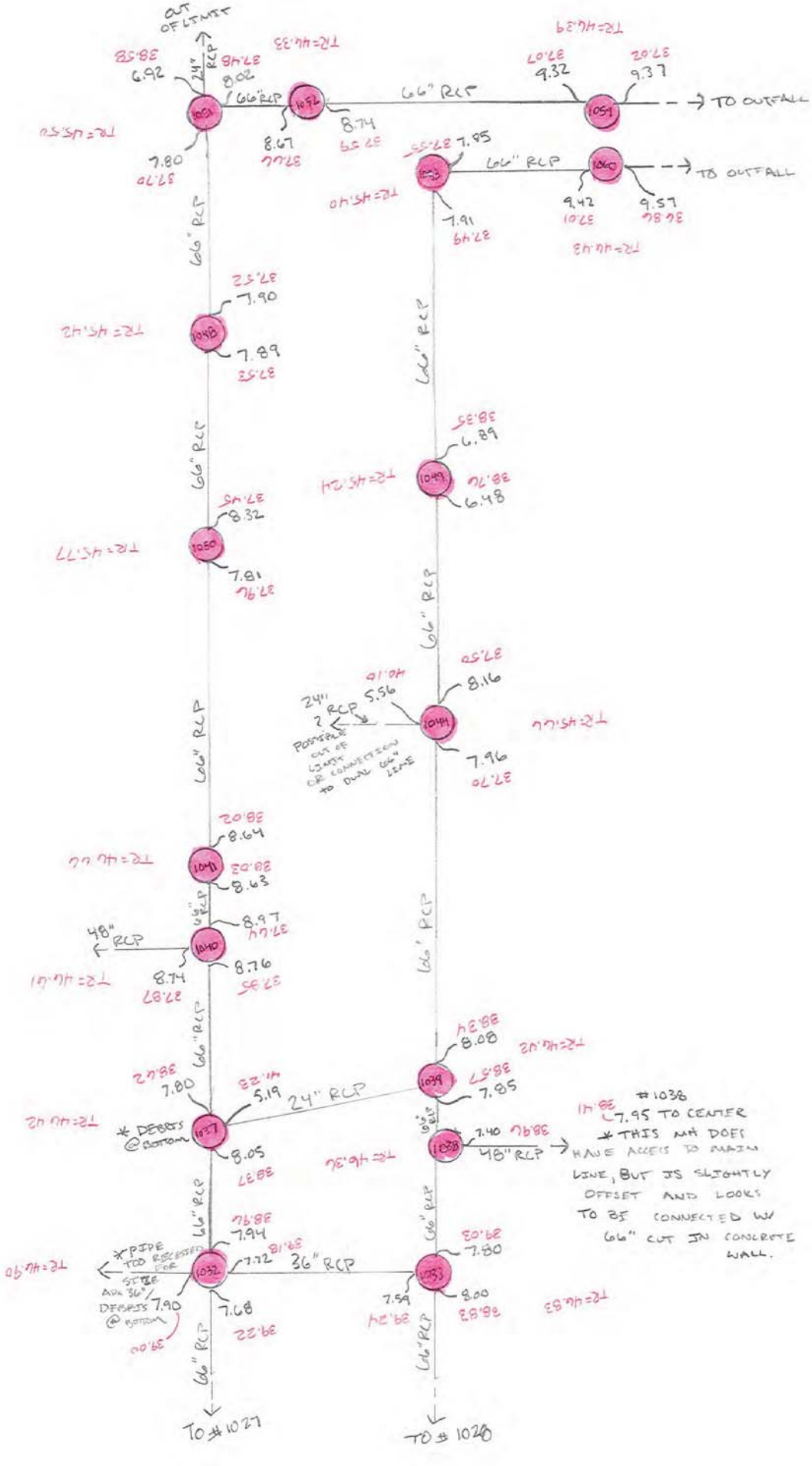
BUFFALO SPEEDWAY
STORM

N



AM 12.15.17

BUFFALO SPEEDWAY STORM



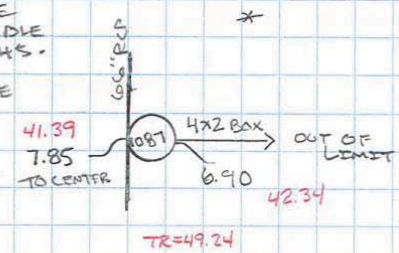
1N

BUFFALO SPEEDWAY STORM

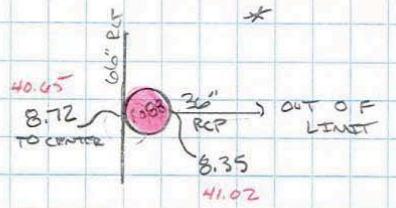
* MAIN LINE NOT VISIBLE ON THESE MH'S.

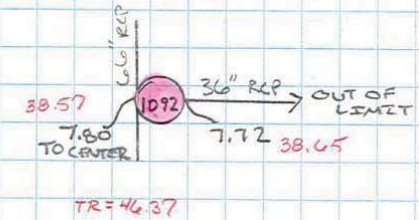
· MH'S DO HAVE ACCESS TO MAIN LINE BUT SEEM OFFSET FROM THE LINE

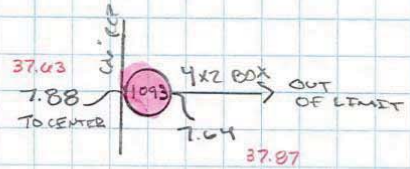
#1049 IS NOT PART OF MAIN SYSTEM



* ALL PIPES RECESSED / SIZES ARE APX.







APPENDIX F

Geotechnical Investigations Report

This document is released for the purpose of interim review under the authority of Wilber L. Wang, P.E. 99226 on March 30, 2018. It is not to be used for bidding or construction purposes.

DRAFT

GEOTECHNICAL INVESTIGATION

BUFFALO SPEEDWAY DRAINAGE SYSTEM EVALUATION FROM BISSONNET TO HOLCOMBE WEST UNIVERSITY PLACE, TEXAS

Prepared for:
HDR Engineering, Inc.
Houston, Texas

by

Aviles Engineering Corporation
5790 Windfern Road
Houston, Texas 77041
713-895-7645

REPORT NO. G177-17

MARCH 2018

5790 Windfern Road
Houston, Texas 77041
Tel: (713)-895-7645
Fax: (713)-895-7943

March 30, 2018

Mr. Jeremy Blevins, P.E.
HDR Engineering, Inc.
4828 Loop Central Drive, Suite 800
Houston, Texas 77081

Reference: Geotechnical Investigation
Buffalo Speedway Drainage System Evaluation from Bissonnet to Holcombe
West University Place, Texas
AEC Report No. G177-17

Dear Mr. Blevins,

Aviles Engineering Corporation (AEC) is pleased to present this report of the results of our geotechnical investigation for the above referenced project. Project terms and conditions were in accordance with the Geotech Subconsultant Agreement between HDR Engineering, Inc. (HDR) and AEC, dated December 20, 2017. The project scope of services was performed in general accordance with AEC Proposal G2017-07-04, dated July 10, 2017.

AEC appreciates the opportunity to be of service to you. Please call us if you have any questions or comments concerning this report or when we can be of further assistance.

Respectfully submitted,
Aviles Engineering Corporation
(TBPE Firm Registration No. F-42)

DRAFT

Wilber L. Wang, P.E.
Senior Engineer

Jacob Garza, E.I.T.
Staff Engineer

Reports Submitted: 2 HDR Engineering, Inc.
1 File (electronic)

Z:\ENGINEERING\REPORTS\2017\177-17 BUFFALO SPEEDWAY DRAINAGE PER - HDR (WILBER)\G177-17 DRAFT.DOCX

AVILES ENGINEERING CORP.

TABLE OF CONTENTS

1.0 INTRODUCTION 1
- **1.1 General** 1
- **1.2 Project Description and Scope of Work** 1

2.0 SUBSURFACE INVESTIGATION PROGRAM 2
3.0 LABORATORY TESTING PROGRAM 2
4.0 SITE CONDITIONS 3
- **4.1 Subsurface Conditions** 3
- **4.2 Subsurface Variations** 5

5.0 GEOTECHNICAL ENGINEERING RECOMMENDATIONS 5
- **5.1 Storm Sewer** 5
  - 5.1.1 Geotechnical Parameters for Storm Sewers 5
  - 5.1.2 Loadings on Pipes 6
  - 5.1.3 Trench Stability 7
  - 5.1.4 Bedding and Backfill 10

6.0 CONSTRUCTION CONSIDERATIONS 10
- **6.1 Site Preparation and Grading** 10
- **6.2 Dewatering** 10
- **6.3 Construction Monitoring** 12

7.0 LIMITATIONS 12

DRAFT

APPENDICES

APPENDIX A

Plate A-1	Vicinity Map
Plate A-2	Boring Location Plan
Plates A-3 to A-5	Boring Logs
Plate A-6	Boring Log Key to Symbols
Plate A-7	Classification of Soils for Engineering Purposes
Plate A-8	Terms Used on Boring Logs
Plate A-9	ASTM & TXDOT Designation for Soil Laboratory Tests
Plate A-10	Sieve Test Result

APPENDIX B

Plate B-1	Recommended Geotechnical Design Parameters for Underground Utilities
Plate B-2	Load Coefficients for Pipe Loading
Plate B-3	Live Loads on Pipe Crossing Under Roadway

APPENDIX C

Plate C-1	Critical Heights of Cut Slopes in Nonfissured Clays
Plate C-2	Maximum Allowable Slopes
Plate C-3	A Combination of Bracing and Open Cuts
Plate C-4	Lateral Pressure Diagrams for Open Cuts in Cohesive Soil-Long Term Conditions
Plate C-5	Lateral Pressure Diagrams for Open Cuts in Cohesive Soil-Short Term Conditions
Plate C-6	Lateral Pressure Diagrams for Open Cuts in Sand
Plate C-7	Bottom Stability for Braced Excavation in Clay

GEOTECHNICAL INVESTIGATION

BUFFALO SPEEDWAY DRAINAGE SYSTEM EVALUATION
FROM BISSONNET TO HOLCOMBE
WEST UNIVERSITY PLACE, TEXAS

1.0 INTRODUCTION

1.1 General

Aviles Engineering Corporation (AEC) performed a geotechnical investigation for the proposed evaluation of existing 66 inch diameter storm sewers along Buffalo Speedway from Bissonnet Street to Holcombe Boulevard, in West University Place, Texas (Harris County Key Map No. 532B and F). A vicinity map of the project alignment is presented on Plate A-1, in Appendix A.

1.2 Project Description and Scope of Work

AEC understands that the Preliminary Engineering Report (PER) is to evaluate the condition of the existing 66 inch diameter storm sewer located along Buffalo Speedway, at the intersections of Bissonnet Street, University Boulevard, and W. Holcombe Boulevard. As-built drawings for the intersection of Buffalo Speedway and Wroxton Road, Amherst Street, and Cason Street were provided to AEC prior to drilling. The as-built drawings indicate that the existing 66 inch storm sewer is approximately 8 to 10 feet deep at these intersections.

To avoid disrupting traffic on Buffalo Speedway during drilling, AEC performed Borings B-1 through B-3 on residential cross streets that were in the vicinity of the project intersections, approximately 280 to 460 feet away. However, at the time of AEC's field investigation, Boring B-3 was moved to a distance of approximately 550 feet from the intersection of Buffalo Speedway and W. Holcombe Boulevard because of potential utility conflicts and trees along Cason Street. AEC recommends that the soil and groundwater conditions encountered in the borings be used for general PER evaluation purposes only. AEC notes that changed soil or groundwater conditions could potentially be encountered at the specific project intersections because the soil borings are located on adjacent residential cross streets. AEC recommends that additional borings be performed at or near the project intersections if the PER recommends that the existing storm sewer be replaced in the future.

DRAFT

As directed by HDR, the purpose of this geotechnical investigation is to determine the soil and groundwater conditions encountered in the borings and provide geotechnical engineering recommendations as if new storm sewers will be installed by open cut method. The scope of this geotechnical investigation is summarized below:

1. Drilling and sampling three geotechnical borings 20 feet below existing grade;
2. Soil laboratory testing on selected soil samples;
3. Engineering analyses and recommendations for the installation of storm sewers by open cut method, including loadings on pipes, trench excavation, shoring, bedding and backfill;
4. Construction recommendations for the storm sewer.

2.0 SUBSURFACE INVESTIGATION PROGRAM

The subsurface exploration consisted of drilling and sampling a total of three borings each to 20 feet below existing grade. The boring locations are shown on the Boring Location Plan on Plate A-2, in Appendix A. The total drilling footage is 60 feet. Boring locations were marked in the field by AEC personnel. Boring survey data was not available at the time this report was prepared.

Prior to drilling, existing pavement was first cut with a core barrel. Borings were performed with a truck-mounted drill rig and advanced using dry auger method. Undisturbed samples of cohesive soils were obtained from the borings by pushing 3-inch diameter thin-wall, seamless steel Shelby tube samplers in general accordance with ASTM D-1587. Granular soils were sampled with a 2-inch split-barrel sampler in accordance with ASTM D-1586. Standard Penetration Test resistance (N) values were recorded for the granular soils as "Blows per Foot" and are shown on the boring logs. Strength of the cohesive soils was estimated in the field using a hand penetrometer. The undisturbed samples of cohesive soils were extruded mechanically from the core barrels in the field and wrapped in aluminum foil; all samples were sealed in plastic bags to reduce moisture loss. Reasonable care was taken to minimize disturbance to the samples during transport to AEC's laboratory. After completion of drilling, the borings were left open so that 24 hour groundwater readings could be obtained. After the final water readings were obtained, the borings were backfilled using bentonite chips. Existing pavement was then patched using non-shrink grout.

3.0 LABORATORY TESTING PROGRAM

Samples from the borings were examined and classified in the laboratory by a geotechnical technician under supervision of a geotechnical engineer. Laboratory tests were performed on selected soil samples to evaluate

DRAFT

the engineering properties of the foundation soils in accordance with applicable ASTM/TxDOT Standards. Soil classification and index property tests included Atterberg limits, moisture content, percent passing No. 200 sieve, sieve analysis, and dry unit weight. Torvane (TV), unconfined compression (UC), and unconsolidated-unconfined (UU) triaxial tests were performed on selected undisturbed samples to estimate the shear strength of cohesive soils. The laboratory test results are summarized on their respective boring logs. The key to symbols, classification of soils for engineering purposes, terms used on boring logs, and ASTM/TxDOT designation for soil laboratory testing are presented on Plates A-6 through A-9, respectively, in Appendix A. The sieve analysis result is presented on Plate A-10, in Appendix A.

4.0 SITE CONDITIONS

A summary of existing pavement encountered the borings is presented in Table 1.

Table 1. Pavement Cores

Boring No.	Street	Pavement Section
B-1	Wroxton Road	7.25" concrete, 5.125" cement stabilized crushed shell
B-2	Amherst Street	6.25" concrete, 7" cement stabilized crushed stone
B-3	Cason Street	6.625" concrete, 7.375" cement stabilized crushed shell

4.1 Subsurface Conditions

Details of the soils encountered during drilling are presented in the boring logs. Soil strata encountered in our borings are summarized below.

Boring	Depth (ft)	Description of Stratum
B-1	0 - 1	Pavement and Base: see Table 1 in Section 4.0 of this report
	1 - 8	Firm to very stiff, Lean Clay with Sand (CL)
	8 - 16	Stiff to very stiff, Sandy Lean Clay (CL)
	16 - 20	Medium dense, Silty Sand (SM), with clayey sand pockets
B-2	0 - 1.1	Pavement and Base: see Table 1 in Section 4.0 of this report
	1.1 - 2	Fill: stiff, Sandy Lean Clay (CL), with gravel and silty sand seams
	2 - 12	Stiff to very stiff, Sandy Fat Clay (CH), with ferrous nodules and sandy lean clay pockets
	12 - 17	Medium dense, Poorly Graded Sand (SP)
	17 - 20	Very stiff, Fat Clay (CH), with chalk pockets and siltstones

DRAFT

Boring	Depth (ft)	Description of Stratum
B-3	0 - 1.2	Pavement and Base: see Table 1 in Section 4.0 of this report
	1.2 - 17	Stiff to very stiff, Fat Clay (CH), with slickensides
	17 - 20	Very stiff, Sandy Lean Clay (CL), with vertical silt partings, ferrous nodules, and calcareous nodules

Details of the soils encountered during drilling are presented on the boring logs. The cohesive soils encountered in our borings have Liquid Limits (LL) ranging from 37 to 74 and Plasticity Indices (PI) ranging from 21 to 56. In general, the cohesive soils encountered in the borings have high to very high expansive potential. The cohesive soils encountered at the site are classified as "CL" and "CH" type soils and granular soils are classified as "SM" and "SP" type soils in accordance with ASTM D 2487. "CH" soils can undergo significant volume changes due to seasonal changes in moisture contents. "CL" soils with lower LL (less than 40) and PI (less than 20) generally do not undergo significant volume changes with changes in moisture content. However, "CL" soils with LL approaching 50 and PI greater than 20 essentially behave as "CH" soils and could undergo significant volume changes.

Groundwater Conditions: Groundwater levels and boring cave-in depths encountered during drilling are presented in Table 2. Based on Table 2, groundwater along the project alignment is likely to be pressurized.

Table 2. Water Levels in Borings

Boring/PZ No.	Date Drilled	Boring Depth (ft)	Groundwater Depth (ft)	Boring Cave in Depth (ft)
B-1	02/08/18	20	16 (Drilling) 9 (Completion) 5 (02/09/18)	5.6 (02/09/18)
B-2	02/08/18	20	12 (Drilling) 10 (Completion) 6 (02/09/18)	6.4 (02/09/18)
B-3	02/08/18	20	17 (Drilling) 15 (Completion) 6.5 (02/09/18)	8.5 (02/09/18)

The information in this report summarizes conditions found on the dates the borings were drilled. It should be noted that our groundwater observations are short-term; groundwater depths and subsurface soil moisture contents will vary with environmental variations such as frequency and magnitude of rainfall, the time of year when construction is in progress, and the water level in nearby bodies of water such as channels or ponds.

DRAFT

4.2 Subsurface Variations

The information contained in this report summarizes the conditions encountered on the dates the borings were drilled. The ground water depths and subsurface soil moisture contents will vary with seasonal and environmental variations, frequency, and magnitude of rainfall and the time of year when construction is in progress.

Clay soils in the Greater Houston area typically have secondary features such as slickensides and contain sand/silt seams/lenses/layers/pockets. It should be noted that the information in the boring logs is based on 3-inch diameter soil samples which were generally continuously obtained at intervals of 2 feet in the top 10 feet of the borings and then at intervals of 5 feet thereafter to the boring termination depths. A detailed description of the soil secondary features may not have been obtained due to the small sample size and sampling interval between the samples. Therefore, while some of AEC's logs show the soil secondary features, it should not be assumed that the features are absent where not indicated on the logs. Fill soils could also vary considerably in regards to soil/material type, thickness, depth, and consistency.

DRAFT

5.0 GEOTECHNICAL ENGINEERING RECOMMENDATIONS

5.1 Storm Sewer

Storm sewers installed by open-cut methods should be designed and installed in accordance with Item 430 of the 2016 Harris County Engineering Department (HCED) Standard Engineering Design Specifications for Construction and Maintenance of Roads and Bridges (SEDS), or equivalent local standard.

5.1.1 Geotechnical Parameters for Storm Sewers

Geotechnical Parameters: Recommended geotechnical parameters for the subsurface soils along the alignment to be used for design of the storm sewers are presented on Plate B-1, in Appendix B. The design values are based on the results of field and laboratory test data on individual boring logs as well as our experience. It should be noted that because of the variable nature of soil stratigraphy, soil types and properties along the alignment or at locations away from a particular boring may vary substantially.

5.1.2 Loadings on Pipes

Underground conduits support the weight of the soil and water above the crown, as well as roadway traffic and any structures that exist above the conduits.

Earth Loads: For underground conduits to be installed using the trench method, the vertical soil load W_e can be calculated as the larger of the two values from Equations (1) and (3):

$$W_e = C_d \gamma B_d^2 \quad \text{.....Equation (1)}$$

$$C_d = [1 - e^{-2K\mu'(H/B_d)}]/(2K\mu') \quad \text{.....Equation (2)}$$

$$W_e = \gamma B_c H \quad \text{.....Equation (3)}$$

where:
- W_e = trench fill load, in pounds per linear foot (lb/ft);
- C_d = trench load coefficient, see Plate B-2, in Appendix B;
- γ = effective unit weight of soil over the conduit, in pounds per cubic foot (pcf);
- B_d = trench width at top of the conduit < 1.5 B_c (ft);
- B_c = outside diameter of the conduit (ft);
- H = variable height of fill (ft); when the height of fill above the top of the conduit $H_c > 2\ B_d$, $H = H_h$ (height of fill above the middle of the conduit). When $H_c < 2\ B_d$, H varies over the height of the conduit; and
- $K\mu'$ = 0.1650 maximum for sand and gravel, 0.1500 maximum for saturated top soil, 0.1300 maximum for ordinary clay, 0.1100 maximum for saturated clay.

When underground conduits are located below ground water, the total vertical dead loads should include the weight of the projected volume of water above the conduits.

Traffic Loads: The vertical stress p_L (psf) resulting from traffic loads (from a HS-20 truck) can be obtained from Plate B-3, in Appendix B. The live load on the top of the underground conduit can be calculated from Equation (4):

$$W_L = p_L B_c \quad \text{.....Equation (4)}$$

where:
- W_L = live load on the top of the conduit (lb/ft);
- p_L = vertical stress (on the top of the conduit) resulting from traffic loads (psf);
- B_c = outside diameter of the conduit, (ft);

DRAFT

Lateral Loads: The lateral soil pressure p_l can be calculated from Equation (5); hydrostatic pressure should be added, if applicable.

$$p_l = 0.5\,(\gamma H_h + p_s) \qquad \text{.....Equation (5)}$$

where: H_h = height of fill above the center of the conduit (ft);
γ = effective unit weight of soil over the conduit (pcf);
p_s = vertical pressure on conduit resulting from traffic and/or construction equipment (psf).

5.1.3 Trench Stability

Cohesive soils in the Greater Houston area contain many secondary features which affect trench stability, including sand seams, slickensides, and siltstones. Slickensides are shiny weak failure planes which are commonly present in fat clays; such clays often fail along these weak planes when they are not laterally supported, such as in an open excavation. The Contractor should not assume that slickensides and sand seams/layers/pockets are absent where not indicated on the logs.

The Contractor should be responsible for designing, constructing and maintaining safe excavations. The excavations should not cause any distress to existing structures.

Trenches 20 feet and Deeper: The Occupational Safety and Health Administration (OSHA) requires that shoring or bracing for trenches 20 feet and deeper be specifically designed by a licensed professional engineer.

Trenches Less than 20 Feet Deep: Trench excavations that are less than 20 feet deep may be shored, sheeted and braced, or laid back to a stable slope for the safety of workers, the general public, and adjacent structures, except for excavations which are less than 5 feet deep and verified by a competent person to have no cave-in potential. The excavation and trenching should be in accordance with OSHA Safety and Health Regulations, 29 CFR, Part 1926. Recommended OSHA Soil Types for trench design for existing soils can be found on Plate B-1, in Appendix B. Granular soils and fill soils should be considered OSHA Class "C" soils. Submerged soils should also be considered OSHA Class "C" soils, unless dewatering is conducted to lower the ground water level below the excavation.

DRAFT

Critical Height is defined as the height a slope will stand unsupported for a short time; in cohesive soils, it is used to estimate the maximum depth of open-cuts at given side slopes. Critical Height may be calculated based on the soil cohesion. Values for various slopes and cohesion are shown on Plate C-1, in Appendix C. Cautions listed below should be exercised in use of Critical Height applications:

1. No more than 50 percent of the Critical Height computed should be used for vertical slopes. Unsupported vertical slopes are not recommended where granular soils or soils that will slough when not laterally supported are encountered within the excavation depth.

2. If the soil at the surface is dry to the point where tension cracks occur, any water in the crack will increase the lateral pressure considerably. In addition, if tension cracks occur, no cohesion should be assumed for the soils within the depth of the crack. The depth of the first waler should not exceed the depth of the potential tension crack. Struts should be installed before lateral displacement occurs.

3. Shoring should be provided for excavations where limited space precludes adequate side slopes, e.g., where granular soils will not stand on stable slopes and/or for deep open cuts.

4. All excavation, trenching and shoring should be designed and constructed by qualified professionals in accordance with OSHA requirements.

Plate C-2, in Appendix C presents the maximum (steepest) allowable slopes for OSHA Soil Types for excavations less than 20 feet.

If limited space is available for the required open trench side slopes, the space required for the slope can be reduced by using a combination of bracing and open cut as illustrated on Plate C-3, in Appendix C. Guidelines for bracing and calculating bracing stress are presented below.

Stockpile and Equipment Surcharge: To avoid surcharging the excavation walls, stockpile of excavated materials immediately adjacent to the excavation face should be prohibited. We recommend stockpiled materials be placed at least 6 feet away from the edge of an excavation face, and no higher than 3 feet. Construction equipment working near the trench may also induce excessive surcharge loads; AEC recommends appropriate shoring or shield system be provided considering these impacts in addition to the lateral earth and hydrostatic pressures.

Computation of Bracing Pressures: The following method can be used for calculating earth pressure against bracing for open cuts. Lateral pressure resulting from construction equipment, traffic loads, or other surcharge

DRAFT

should be taken into account by adding the equivalent uniformly distributed surcharge to the design lateral pressure. Hydrostatic pressure, if any, should also be considered. The active earth pressure at depth z can be determined by Equation (6), the design soil parameters are presented on Plate B-1, in Appendix B.

$$p_a = (q_s + \gamma h_1 + \gamma' h_2)K_a - 2c\sqrt{K_a} + \gamma_w h_2 \qquad \text{.....Equation (6)}$$

where:
- p_a = active earth pressure (psf);
- q_s = uniform surcharge pressure (psf);
- γ, γ' = wet unit weight and buoyant unit weight of soil (pcf);
- h_1 = depth from ground surface to ground water table (ft);
- h_2 = $z-h_1$, depth from ground water table to the point under consideration (ft);
- z = depth below ground surface for the point under consideration (ft);
- K_a = coefficient of active earth pressure;
- c = cohesion of clayey soils (psf);
- γ_w = unit weight of water, 62.4 pcf.

Pressure distribution for the practical design of struts in open cuts for clays and sands are illustrated on Plates C-4 through C-6, in Appendix C.

<u>Bottom Stability:</u> In open-cuts, it is necessary to consider the possibility of the bottom failing by heaving, due to the removal of the weight of excavated soil. Heaving typically occurs in soft plastic clays when the excavation depth is sufficiently deep enough to cause the surrounding soil to displace vertically due to bearing capacity failure of the soil beneath the excavation bottom, with a corresponding upward movement of the soils in the bottom of the excavation. In fat and lean clays, heave normally does not occur unless the ratio of Critical Height to Depth of Cut approaches one. In very sandy and silty lean clays and granular soils, heave can occur if an artificially large head of water is created due to installation of impervious sheeting while bracing the cut. This can be mitigated if ground water is lowered below the excavation by dewatering the area. Guidelines for evaluating bottom stability in clay soils are presented on Plate C-7, in Appendix C.

If the excavation extends below ground water, and the soils at or near the bottom of the excavation are mainly sands or silts, the bottom can fail by blow-out (boiling) when a sufficient hydraulic head exists. The potential for boiling or in-flow of granular soils increases where the ground water is pressurized. To reduce the potential for boiling of excavations terminating in granular soils below pressurized ground water, the ground water table should be lowered at least 3 feet below the excavation.

DRAFT

Calcareous nodules and silt partings were encountered within the cohesive soil strata in the borings. These secondary structures may become sources of localized instability when they are exposed during excavation, especially when they become saturated. Such soils have a tendency to slough or cave in when not laterally confined, such as in trench excavations. The Contractor should be aware of the potential for cave-in of the soils. Low plasticity soils (silts and clayey silts) will lose strength and may behave like granular soils when saturated.

5.1.4 Bedding and Backfill

Trench excavation, bedding, and backfill for storm sewers should be in accordance with Item 430 of the 2016 HCED SEDS, or equivalent local standard.

6.0 CONSTRUCTION CONSIDERATIONS

6.1 Site Preparation and Grading

To mitigate site problems that may develop following prolonged periods of rainfall, it is essential to have adequate drainage to maintain a relatively dry and firm surface prior to starting any work at the site. Adequate drainage should be maintained throughout the construction period. Methods for controlling surface runoff and ponding include proper site grading, berm construction around exposed areas, and installation of sump pits with pumps.

6.2 Dewatering

The need for groundwater control will depend on the depth of excavation relative to the groundwater depth at the time of construction. In the event that there is heavy rain prior to or during construction, the groundwater table may be higher than indicated in this report; higher seepage is also likely and may require a more extensive groundwater control program. In addition, groundwater may be pressurized in certain areas of the alignment, requiring further evaluation and consideration of the excess hydrostatic pressures. Groundwater control should be in general accordance with Item 436 of the 2016 HCED SEDS, or equivalent local standard.

The Contractor should be responsible for selecting, designing, constructing, maintaining, and monitoring a groundwater control system and adapt his operations to ensure the stability of the excavations. Groundwater information presented in Section 4.1 and elsewhere in this report, along with consideration for potential

DRAFT

environmental and site variation between the time of our field exploration and construction, should be incorporated in evaluating groundwater depths. The following recommendations are intended to guide the Contractor during design and construction of the dewatering system.

In cohesive soils seepage rates are lower than in granular soils and groundwater is usually collected in sumps and channeled by gravity flow to storm sewers. If cohesive soils contain significant secondary features, seepage rates will be higher. This may require larger sumps and drainage channels, or if significant granular layers are interbedded within the cohesive soils, methods used for granular soils may be required. Where it is present, pressurized groundwater will also yield higher seepage rates.

Groundwater for excavations within saturated sands can be controlled by the installation of wellpoints. The practical maximum dewatering depth for well points is about 15 feet. When groundwater control is required in sands or silts below 15 feet, possible ground water control measures include: (i) deep wells with turbine or submersible pumps (for sands); (ii) multi-staged well points (for sands); (iii) eductor or ejector type systems (for silts); or (iv) water-tight sheet pile cut-off walls. Generally, the groundwater depth should be lowered at least 3 feet below the excavation bottom to be able to work on a firm surface when water-bearing granular soils are encountered.

Extended and/or excessive dewatering can result in settlement of existing structures in the vicinity of the dewatering; the Contractor should take the necessary precautions to minimize the effect on existing structures in the vicinity of the dewatering operation. We recommend that the Contractor verify the groundwater depths and seepage rates prior to and during construction and retain the services of a dewatering expert (if necessary) to assist him in identifying, implementing, and monitoring the most suitable and cost-effective method of controlling groundwater.

For open cut construction in cohesive soils, the possibility of bottom heave must be considered due to the removal of the weight of excavated soil. In lean and fat clays, heave normally does not occur unless the ratio of Critical Height to Depth of Cut approaches one. In silty clays, heave does not typically occur unless an artificially large head of water is created through the use of impervious sheeting in bracing the cut. Guidelines for evaluating bottom stability are presented in Section 5.1.3 of this report.

DRAFT

6.3 Construction Monitoring

Site preparation (including clearing and proof rolling), earthwork operations, soil stabilization, and foundation construction should be monitored by qualified geotechnical professionals to check for compliance with project documents and changed conditions, if encountered. AEC should be allowed to review the design and construction plans and specifications prior to release to check that the geotechnical recommendations and design criteria presented herein are properly interpreted.

7.0 LIMITATIONS

The information contained in this report summarizes conditions found on the dates the borings were drilled. The attached boring logs are true representations of the soils encountered at the specific boring locations on the date of drilling. Reasonable variations from the subsurface information presented in this report should be anticipated. AEC should be notified immediately if conditions encountered during construction are significantly different from those presented in this report.

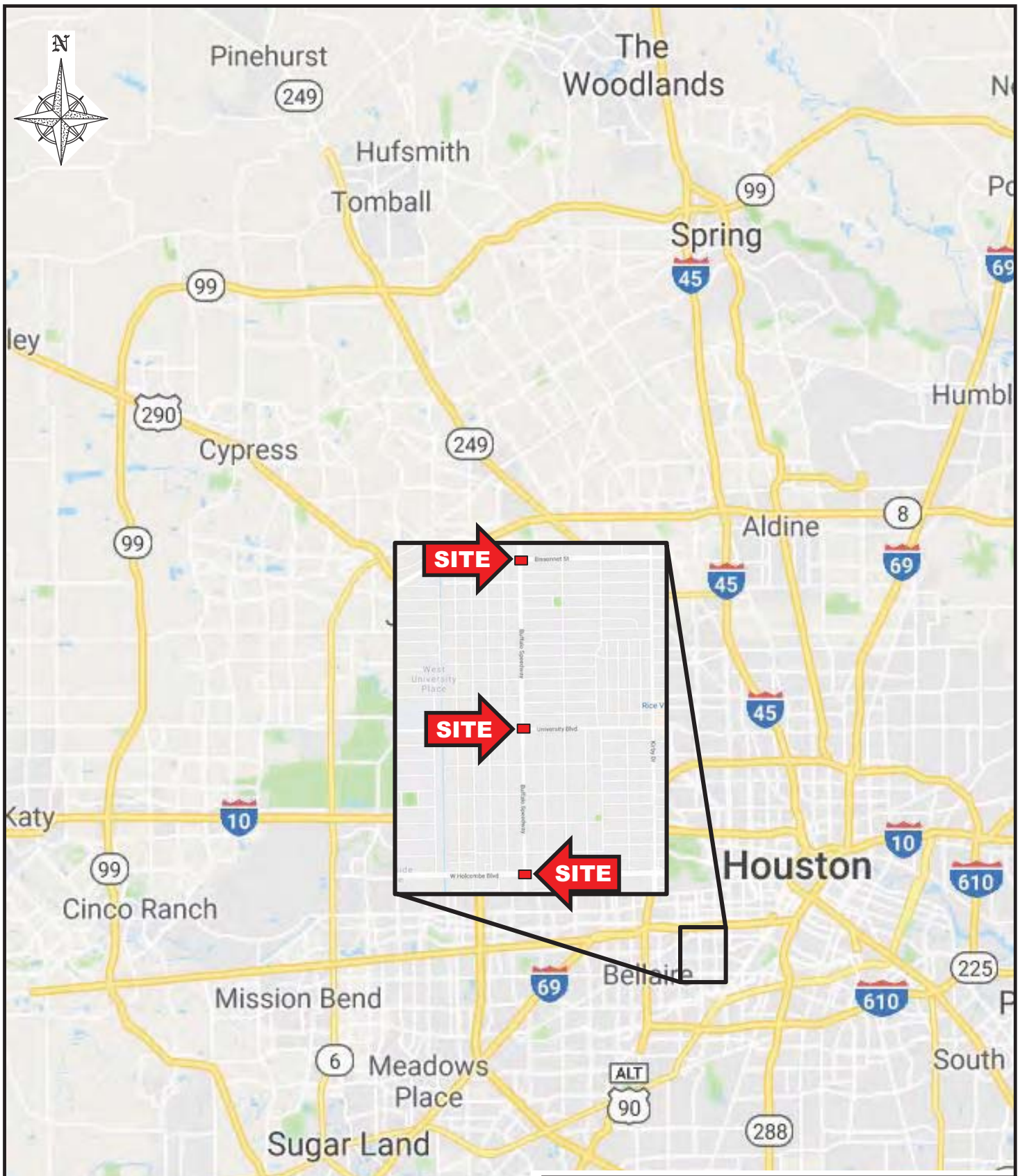
This investigation was performed using the standard level of care and diligence normally practiced by recognized geotechnical engineering firms in this area, presently performing similar services under similar circumstances. This report is intended to be used in its entirety. The report has been prepared exclusively for the project and location described in this report. If pertinent project details change or otherwise differ from those described herein, AEC should be notified immediately and retained to evaluate the effect of the changes on the recommendations presented in this report, and revise the recommendations if necessary. The recommendations presented in this report should not be used for other structures located along these alignments or similar structures located elsewhere, without additional evaluation and/or investigation.

DRAFT

APPENDIX A

APPENDIX A

Plate A-1	Vicinity Map
Plate A-2	Boring Location Plan
Plates A-3 to A-5	Boring Logs
Plate A-6	Boring Log Key to Symbols
Plate A-7	Classification of Soils for Engineering Purposes
Plate A-8	Terms Used on Boring Logs
Plate A-9	ASTM & TXDOT Designation for Soil Laboratory Tests
Plate A-10	Sieve Test Result

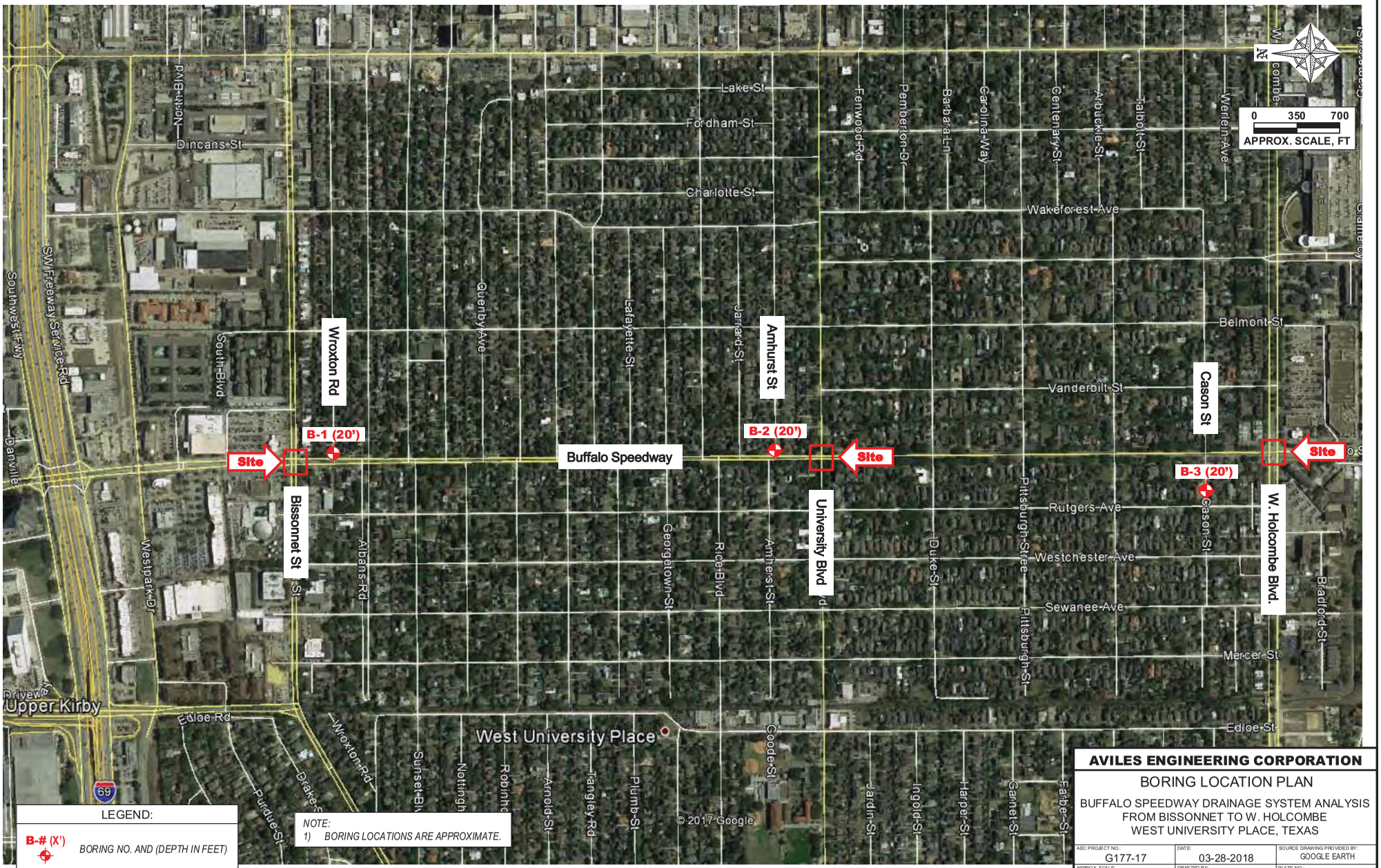


AVILES ENGINEERING CORPORATION

VICINITY MAP

BUFFALO SPEEDWAY DRAINAGE SYSTEM ANALYSIS
FROM BISSONNET TO W. HOLCOMBE
WEST UNIVERSITY PLACE, TEXAS

AEC PROJECT NO.:	DATE:	SOURCE DRAWING PROVIDED BY:
G177-17	03-28-2018	GOOGLE MAPS
APPROX. SCALE:	DRAFTED BY:	PLATE NO.:
N.T.S.	JG	PLATE A-1



LEGEND:

B-# (X') — BORING NO. AND (DEPTH IN FEET)

NOTE:
1) BORING LOCATIONS ARE APPROXIMATE.

AVILES ENGINEERING CORPORATION

BORING LOCATION PLAN

BUFFALO SPEEDWAY DRAINAGE SYSTEM ANALYSIS
FROM BISSONNET TO W. HOLCOMBE
WEST UNIVERSITY PLACE, TEXAS

AEC PROJECT NO.:	DATE:	SOURCE DRAWING PROVIDED BY:
G177-17	03-28-2018	GOOGLE EARTH
APPROX. SCALE: 1" = 700'	DRAFTED BY: WLW/JG	PLATE NO.: PLATE A-2

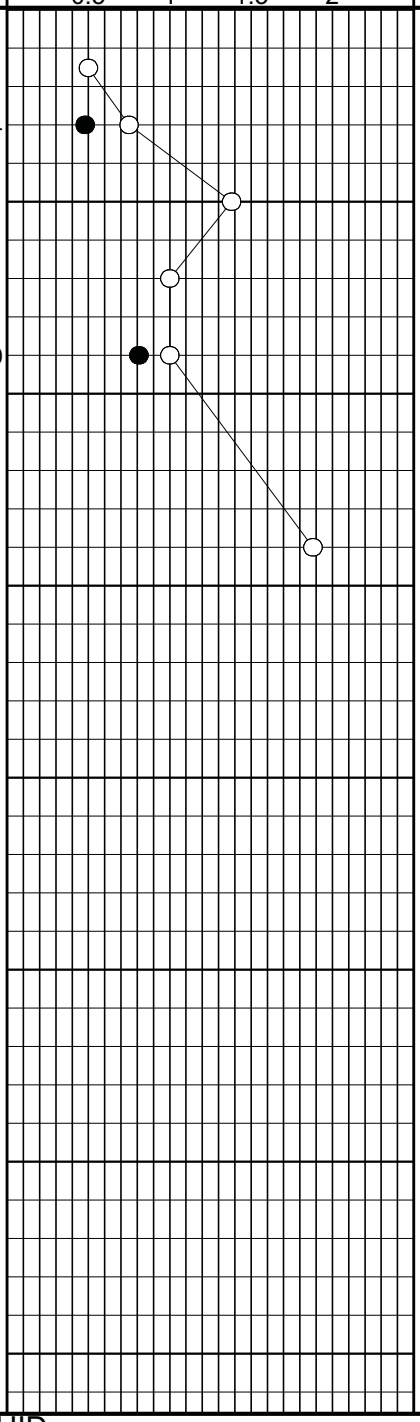
AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **Buffalo Speedway Drainage System PER** BORING **B-1**

DATE **02/08/18** TYPE **4" Auger** LOCATION **See Boring Location Plan**

DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	MOISTURE CONTENT, %	DRY DENSITY, PCF	-200 MESH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0			Pavement: 7.25" concrete							
			Base: 5.125" cement stabilized crushed shell		24					
			Firm to very stiff, gray and tan Lean Clay with Sand (CL)		20	106.4				
			-with fat clay 1'-2' and ferrous nodules 1'-8'							
5			-with silty clay partings 2'-4' and calcareous nodules 2'-8'		17		70	48	15	33
			-boring cave-in at 5.6' on 02/09/18							
			-with fat clay pockets and seams 6'-8'		22					
			Stiff to very stiff, gray and tan Sandy Lean Clay (CL)		21	109.0				
10			-groundwater measured at 9' after completion of drilling							
			-light gray and tan 13'-15'		16			37	16	21
15										
			Medium dense, light gray Silty Sand (SM), with clayey sand pockets							
				17	27		18			
20			Termination Depth = 20 feet							
25										
30										
35										

SHEAR STRENGTH, TSF



△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane

BORING DRILLED TO **20** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **16** FEET WHILE DRILLING

WATER LEVEL AT **5** FEET AFTER **02/09/18**

DRILLED BY **JH** DRAFTED BY **JG** LOGGED BY **JH**

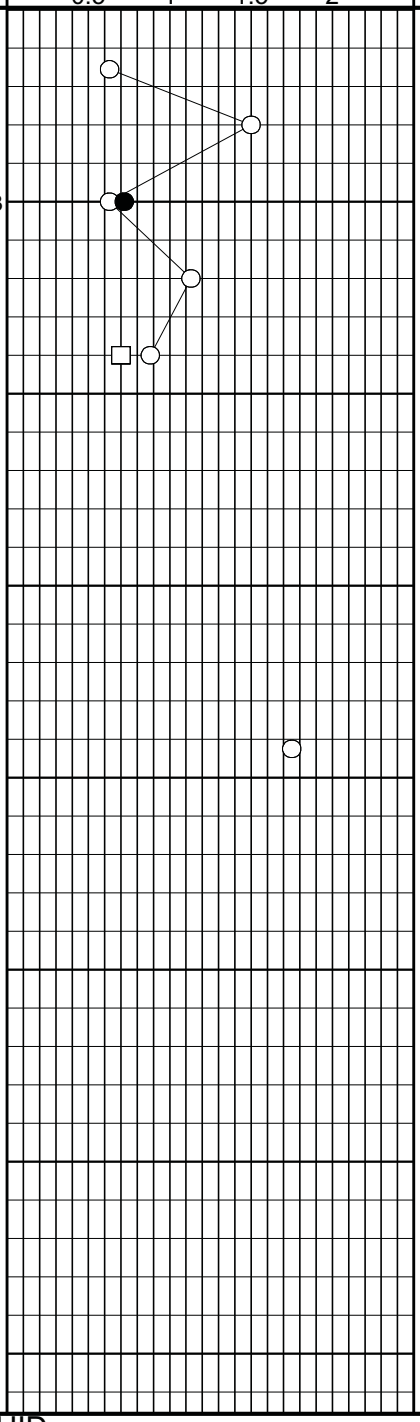
AVILES ENGINEERING CORP. GEOTECHNICAL ENGINEERS

PROJECT: **Buffalo Speedway Drainage System PER** BORING **B-2**

DATE **02/08/18** TYPE **4" Auger** LOCATION **See Boring Location Plan**

DEPTH IN FEET	SYMBOL	SAMPLE INTERVAL	DESCRIPTION	S.P.T. BLOWS / FT.	MOISTURE CONTENT, %	DRY DENSITY, PCF	-200 MESH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0			Pavement: 6.25" concrete							
			Base: 7" cement stabilized crushed stone		25					
			Fill: stiff, gray and dark gray Sandy Lean Clay (CL), with gravel and silty sand seams		19		63	50	16	34
			Stiff to very stiff, gray and tan Sandy Fat Clay (CH), with ferrous nodules and sandy lean clay pockets							
5			-with calcareous nodules 2'-6'		19	110.3				
			-boring cave-in at 6.4' on 02/09/18		21					
					20					
10			-groundwater measured at 10' after completion of drilling							
			Medium dense, tan Poorly Graded Sand (SP)							
				16	22		4			
15										
			Very stiff, tan and light gray Fat Clay (CH), with chalk pockets and siltstones							
				31	17		93			
20			Termination Depth = 20 feet							
25										
30										
35										

SHEAR STRENGTH, TSF



BORING DRILLED TO **20** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **12** FEET WHILE DRILLING

WATER LEVEL AT **6** FEET AFTER **02/09/18**

DRILLED BY **JH** DRAFTED BY **JG** LOGGED BY **JH**

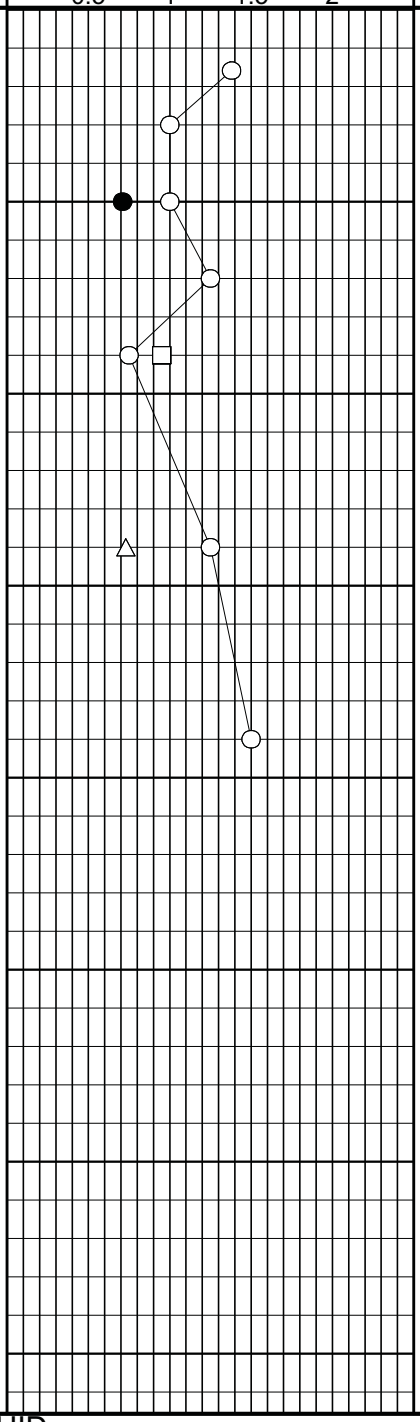
PROJECT: **Buffalo Speedway Drainage System PER** BORING **B-3**

DATE **02/08/18** TYPE **4" Auger** LOCATION **See Boring Location Plan**

DEPTH IN FEET	DESCRIPTION	MOISTURE CONTENT, %	DRY DENSITY, PCF	-200 MESH	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX
0	Pavement: 6.625" concrete						
	Base: 7.375" cement stabilized crushed shell						
	Stiff to very stiff, dark gray and olive gray Fat Clay (CH), with slickensides	25					
	-with lean clay pockets 1'-2' and ferrous nodules 1'-6'	25			74	18	56
5	-dark gray and tan 2'-4'	26	99.1				
	-gray and tan, with calcareous nodules 4'-10'						
	-with lean clay pockets 6'-8'	28					
	-boring cave-in at 8.5' on 02/09/18	29		86	68	19	49
10							
	-reddish tan and light gray 13'-15'	30	94.6				
15	-groundwater measured at 15' after completion of drilling						
	Very stiff, tan and gray Sandy Lean Clay (CL), with vertical silt partings, ferrous nodules, and calcareous nodules	16					
20	Termination Depth = 20 feet						
25							
30							
35							

SHEAR STRENGTH, TSF

△ Confined Compression
● Unconfined Compression
○ Pocket Penetrometer
□ Torvane



BORING DRILLED TO **20** FEET WITHOUT DRILLING FLUID

WATER ENCOUNTERED AT **17** FEET WHILE DRILLING

WATER LEVEL AT **6.5** FEET AFTER **02/09/18**

DRILLED BY **JH** DRAFTED BY **JG** LOGGED BY **JH**

KEY TO SYMBOLS

Symbol	Description
Strata symbols	
	Paving
	Low plasticity clay
	Silty sand
	Fill
	High plasticity clay
Misc. Symbols	
	Water table depth during drilling
	Subsequent water table depth
○	Pocket Penetrometer
●	Unconfined Compression
□	Torvane
△	Confined Compression
Soil Samplers	
	Rock core
	Undisturbed thin wall Shelby tube
	Standard penetration test

AYLES ENGINEERING CORP.

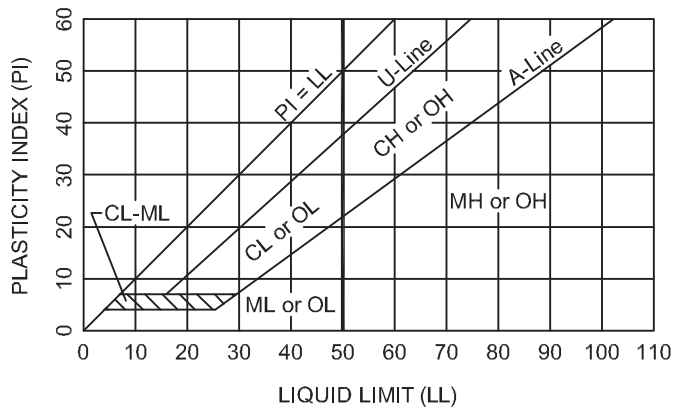
CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES

ASTM Designation D-2487

MAJOR DIVISIONS				GROUP SYMBOL	TYPICAL NAMES
COARSE-GRAINED SOILS (Less than 50% passes No. 200 sieve)	GRAVELS (Less than 50% of coarse fraction passes No. 4 sieve)	CLEAN GRAVELS (Less than 5% passes No. 200 sieve)		GW	Well-graded gravel, well-graded gravel with sand
				GP	Poorly-graded gravel, poorly-graded gravel with sand
		GRAVELS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	GM	Silty gravel, silty gravel with sand
			Limits plot above "A" line & hatched zone on plasticity chart	GC	Clayey gravel, clayey gravel with sand
	SANDS (50% or more of coarse fraction passes No. 4 sieve)	CLEAN SANDS (Less than 5% passes No. 200 sieve)		SW	Well-graded sand, well-graded sand with gravel
				SP	Poorly-graded sand, poorly-graded sand with gravel
		SANDS WITH FINES (More than 12% passes No. 200 sieve)	Limits plot below "A" line & hatched zone on plasticity chart	SM	Silty sand, silty sand with gravel
			Limits plot above "A" line & hatched zone on plasticity chart	SC	Clayey sand, clayey sand with gravel
FINE-GRAINED SOILS (50% or more passes No. 200 sieve)		SILTS AND CLAYS (Liquid Limit Less Than 50%)		ML	Silt, silt with sand, silt with gravel, sandy silt, gravelly silt
				CL	Lean clay, lean clay with sand, lean clay with gravel, sandy lean clay, gravelly lean clay
				OL	Organic clay, organic clay with sand, sandy organic clay, organic silt, sandy organic silt
		SILTS AND CLAYS (Liquid Limit 50% or More)		MH	Elastic silt, elastic silt with sand, sandy elastic silt, gravelly elastic silt
				CH	Fat clay, fat clay with sand, fat clay with gravel, sandy fat clay, gravelly fat clay
				OH	Organic clay, organic clay with sand, sandy organic clay, organic silt, sandy organic silt

NOTE: Coarse soils between 5% and 12% passing the No. 200 sieve and fine-grained soils with limits plotting in the hatched zone of the plasticity chart are to have dual symbols.

PLASTICITY CHART



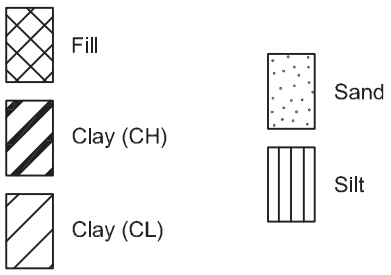
Equation of A-Line: Horizontal at PI=4 to LL=25.5, then PI=0.73(LL-20)

Equation of U-Line: Vertical at LL=16 to PI=7, then PI=0.9(LL-8)

DEGREE OF PLASTICITY OF COHESIVE SOILS

Degree of Plasticity	Plasticity Index
None	0 - 4
Slight	5 - 10
Medium	11 - 20
High	21 - 40
Very High	>40

SOIL SYMBOLS



AYLES ENGINEERING CORP.

TERMS USED ON BORING LOGS

SOIL GRAIN SIZE

U.S. STANDARD SIEVE

6"	3"	3/4"	#4	#10	#40	#200	
BOULDERS	COBBLES	GRAVEL		SAND		SILT	CLAY
		COARSE	FINE	COARSE	MEDIUM	FINE	
152	76.2	19.1	4.76	2.00	0.420	0.074	0.002

SOIL GRAIN SIZE IN MILLIMETERS

STRENGTH OF COHESIVE SOILS

Consistency	Undrained Shear Strength, Kips per Sq. ft.	SPT Blowcount
Very Soft	less than 0.25	< 2 bpf
Soft	0.25 to 0.50	2-4 bpf
Firm	0.50 to 1.00	4-8 bpf
Stiff	1.00 to 2.00	8-16 bpf
Very Stiff	2.00 to 4.00	16-32 bpf
Hard	greater than 4.00	>32 bpf

RELATIVE DENSITY OF COHESIONLESS SOILS FROM STANDARD PENETRATION TEST

Very Loose	<4 bpf
Loose	5-10 bpf
Medium Dense	11-30 bpf
Dense	31-50 bpf
Very Dense	>50 bpf

SPLIT-BARREL SAMPLER DRIVING RECORD

Blows per Foot	Description
25	25 blows driving sampler 12 inches, after initial 6 inches of seating.
50/7"	50 blows driving sampler 7 inches, after initial 6 inches of seating.
Ref/3"	50 blows driving sampler 3 inches, during initial 6-inches seating interval.

NOTE: To avoid change to sampling tools, driving is limited to 50 blows during or after seating interval.

DRY STRENGTH ASTM D2488

None	Dry specimen crumbles into powder with mere pressure of handling
Low	Dry specimen crumbles into powder with some finger pressure
Medium	Dry specimen breaks into pieces or crumbles with considerable pressure
High	Dry specimen cannot be broken with finger pressure, it can be broken between thumb and hard surface
Very High	Dry specimen cannot be broken between thumb and hard surface

MOISTURE CONDITION ASTM D2488

Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water

SOIL STRUCTURE

Slickensided	Having planes of weakness that appear slick and glossy. The degree of slickensidedness depends upon the spacing of slickensides and the easiness of breaking along these planes.
Fissured	Containing shrinkage or relief cracks, often filled with fine sand or silt; usually more or less vertical.
Pocket	Inclusion of material of different texture that is smaller than the diameter of the sample.
Parting	Inclusion less than 1/8 inch thick extending through the sample.
Seam	Inclusion 1/8 inch to 3 inches thick extending through the sample.
Layer	Inclusion greater than 3 inches thick extending through the sample.
Laminated	Soil sample composed of alternating partings or seams of different soil types.
Interlayered	Soil sample composed of alternating layers of different soil types.
Intermixed	Soil sample composed of pockets of different soil types and layered or laminated structure is not evident.
Calcareous	Having appreciable quantities of calcium material.

AVILES ENGINEERING CORP.

ASTM & TXDOT DESIGNATION FOR SOIL LABORATORY TESTS

SOIL TEST	ASTM TEST DESIGNATION	TXDOT TEST DESIGNATION
Unified Soil Classification System	D 2487	Tex-142-E
Moisture Content	D 2216	Tex-103-E
Specific Gravity	D 854	Tex-108-E
Sieve Analysis	D 6913	Tex-110-E (Part 1)
Hydrometer Analysis	D 7928	Tex-110-E (Part 2)
Minus No. 200 Sieve	D 1140	Tex-111-E
Liquid Limit	D 4318	Tex-104-E
Plastic Limit	D 4318	Tex-105-E
Standard Proctor Compaction	D 698	Tex-114-E
Modified Proctor Compaction	D 1557	Tex-113-E
California Bearing Ratio	D 1883	-
Swell	D 4546	-
Consolidation	D 2435	-
Unconfined Compression	D 2166	-
Unconsolidated-Undrained Triaxial	D 2850	Tex-118-E
Consolidated-Undrained Triaxial	D 4767	Tex-131-E
Permeability (constant head)	D 5084	-
Pinhole	D 4647	-
Crumb	D 6572	-
Double Hydrometer	D 4221	-
pH of Soil	D 4972	Tex-128-E
Soil Suction	D 5298	-
Soil Sulfate	C 1580	Tex-145-E
Organics	D 2974	Tex-148-E

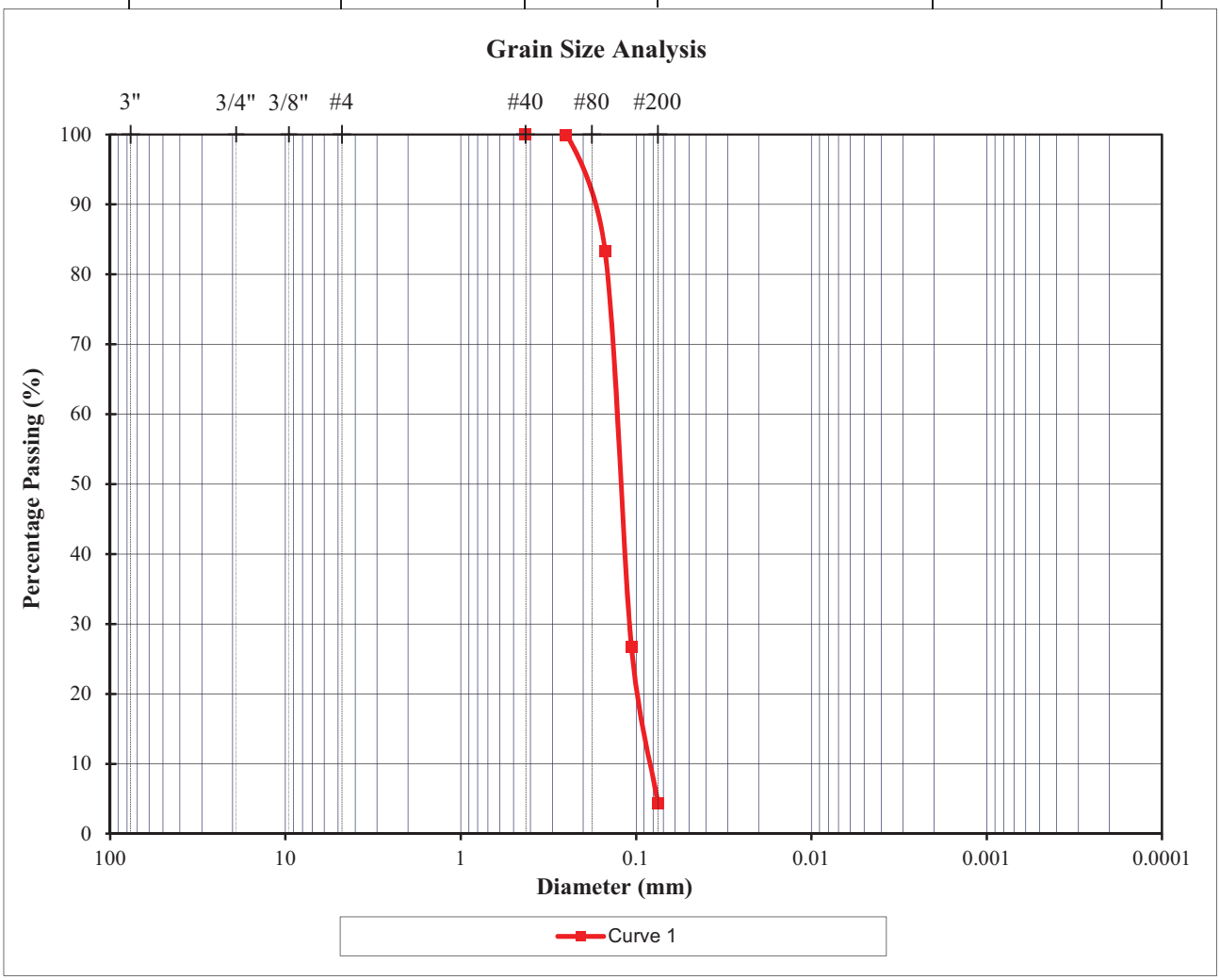
AVILES ENGINEERING CORPORATION

Consulting Engineers - Geotechnical, Construction Materials Testing, Environmental

GRAIN SIZE ANALYSIS - SIEVE

Project : Buffalo Speedway Drainage System PER **Job No.:** G177-17
Location of Project: West University Place, Texas **Date of Testing:** 2/19/2018

Gravel	Sand		Silt	Clay
	Coarse to Medium	Fine		



Curve	Boring	Depth (ft)	Soil Description	Cu	Cc
1	B-2	13-15	Poorly Graded Sand (SP)	1.59	1.10

APPENDIX B

APPENDIX B

Plate B-1	Recommended Geotechnical Design Parameters for Underground Utilities
Plate B-2	Load Coefficients for Pipe Loading
Plate B-3	Live Loads on Pipe Crossing Under Roadway

G177-17 BUFFALO SPEEDWAY DRAINAGE SYSTEM PER, WEST UNIVERSITY PLACE, TEXAS
SOIL PARAMETERS FOR UNDERGROUND UTILITIES

Boring	Depth (ft)	Soil Type	γ (pcf)	γ' (pcf)	OSHA Type	Short-Term					Long-Term				
						C (psf)	φ (deg)	K_a	K_0	K_p	C' (psf)	φ' (deg)	K_a	K_0	K_p
B-1	0-4	Firm to very stiff CL	128	66	C	900	0	1.00	1.00	1.00	75	18	0.53	0.69	1.89
	4-16	Stiff to very stiff CL	132	70	C*	1600	0	1.00	1.00	1.00	150	18	0.53	0.69	1.89
	16-20	Medium dense SM	120	58	C	0	30	0.33	0.50	3.00	0	30	0.33	0.50	3.00
B-2	0-2	Fill: stiff CL	120	58	C	800	0	1.00	1.00	1.00	75	18	0.53	0.69	1.89
	2-12	Stiff to very stiff CH	131	69	B (C*, 6-12)	1400	0	1.00	1.00	1.00	125	16	0.57	0.72	1.76
	12-17	Medium dense SP	120	58	C	0	30	0.33	0.50	3.00	0	30	0.33	0.50	3.00
	17-20	Very stiff CH	120	58	C*	2500	0	1.00	1.00	1.00	250	16	0.57	0.72	1.76
B-3	0-20	Stiff to very stiff CH/CL	123	61	B (C*, 6.5-20)	1450	0	1.00	1.00	1.00	125	16	0.57	0.72	1.76

(1) γ = Unit weight for soil above water level, γ' = Buoyant unit weight for soil below water level;

(2) C = Soil ultimate cohesion for short term (upper limit of 3,000 psf for design purposes), φ = Soil friction angle for short term;

(3) C' = Soil ultimate cohesion for long term (upper limit of 300 psf for design purposes), φ' = Soil friction angle for long term;

(4) K_a = Coefficient of active earth pressure, K_0 = Coefficient of at-rest earth pressure, K_p = Coefficient of passive earth pressure;

(5) CL = Lean Clay, CH = Fat Clay, SM = Silty Sand, SP = Poorly Graded Sand;

(6) OSHA Soil Types for soils in the top 20 feet below grade:

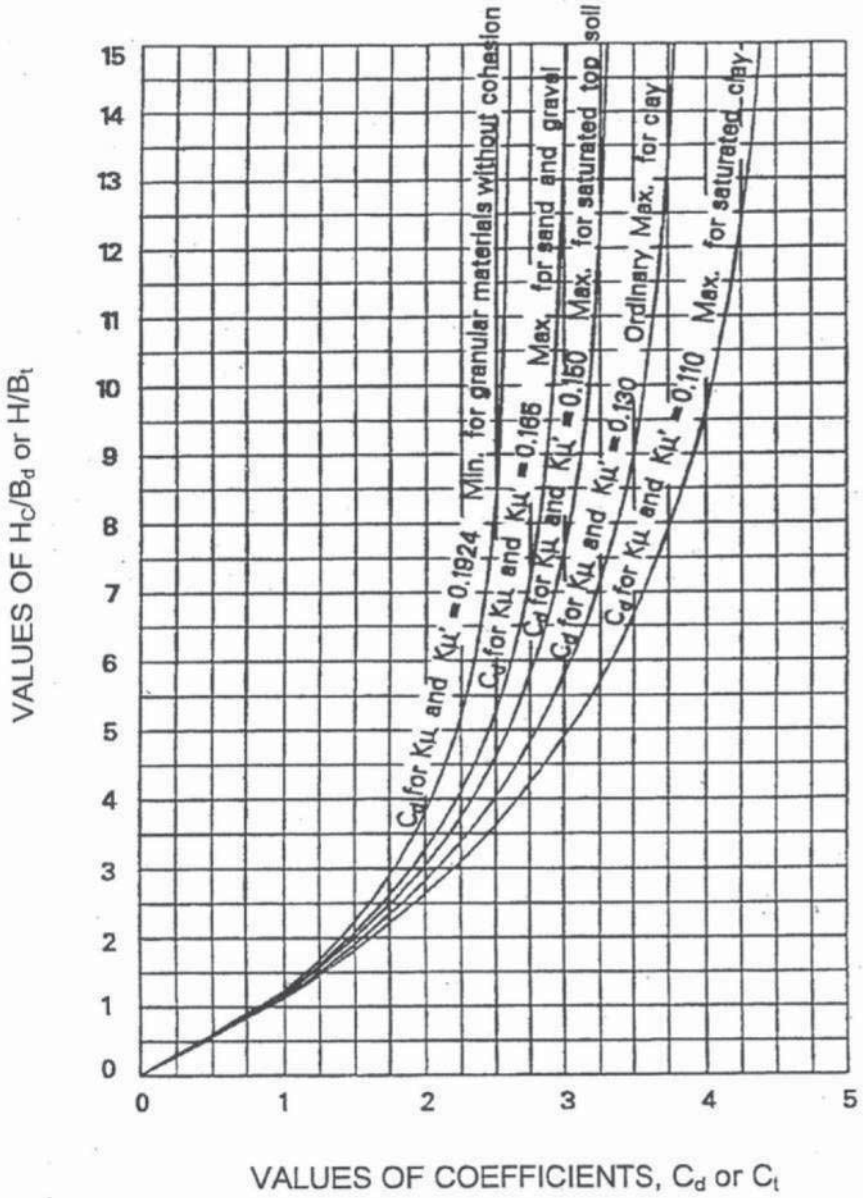
A: cohesive soils with qu = 1.5 tsf or greater (qu = Unconfined Compressive Strength of the Soil)

B: cohesive soils with qu = 0.5 tsf or greater

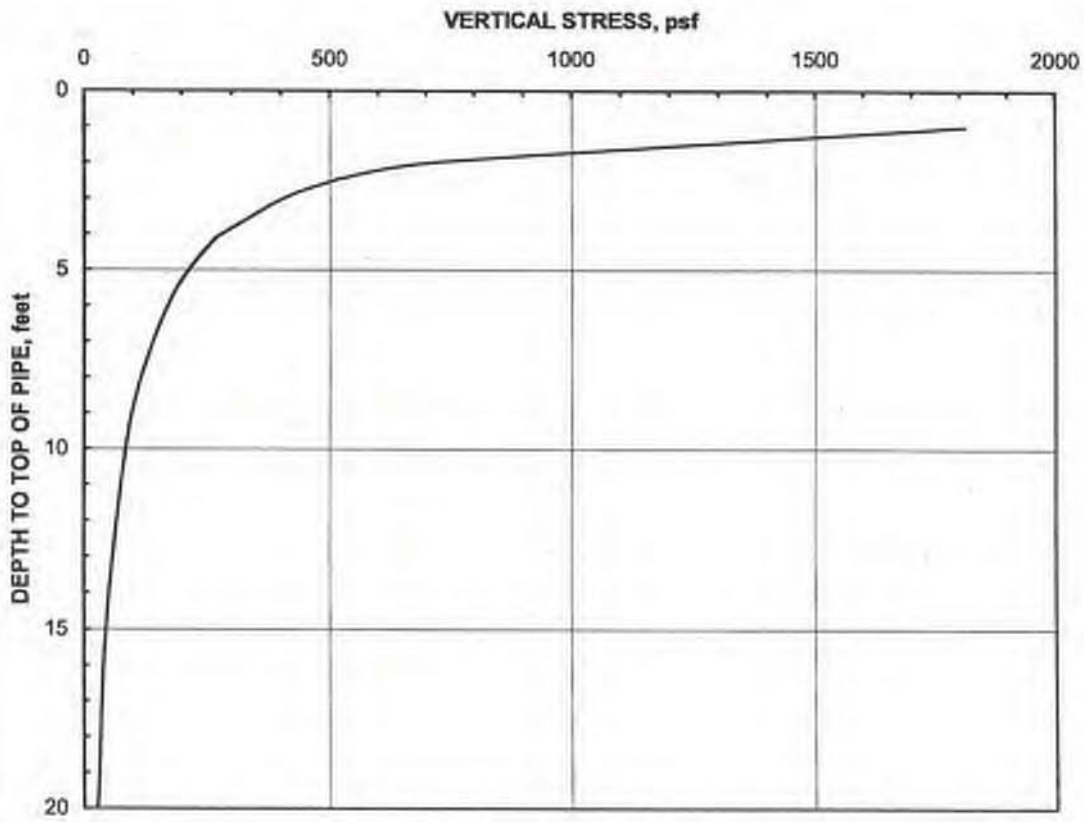
C: cohesive soils with qu = less than 0.5 tsf, fill materials, or granular soil

C*: submerged cohesive soils; dewatered cohesive soils can be considered OSHA Type B.

TRENCH LOAD COEFFICIENTS



Reference: US Army Corps of Engineers Engineering Manual, EM 1110-2-2902, Oct. 31, 1997, Figure 2-5.



LIVE LOADS ON PIPE CROSSING UNDER ROADWAY

Note: 1. The vertical stress was estimated using AASHTO HS20 truck axle loadings on paved surfaces (Reference: ASCE 15-98, "Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standandard Installations").
2. Single truck passing.

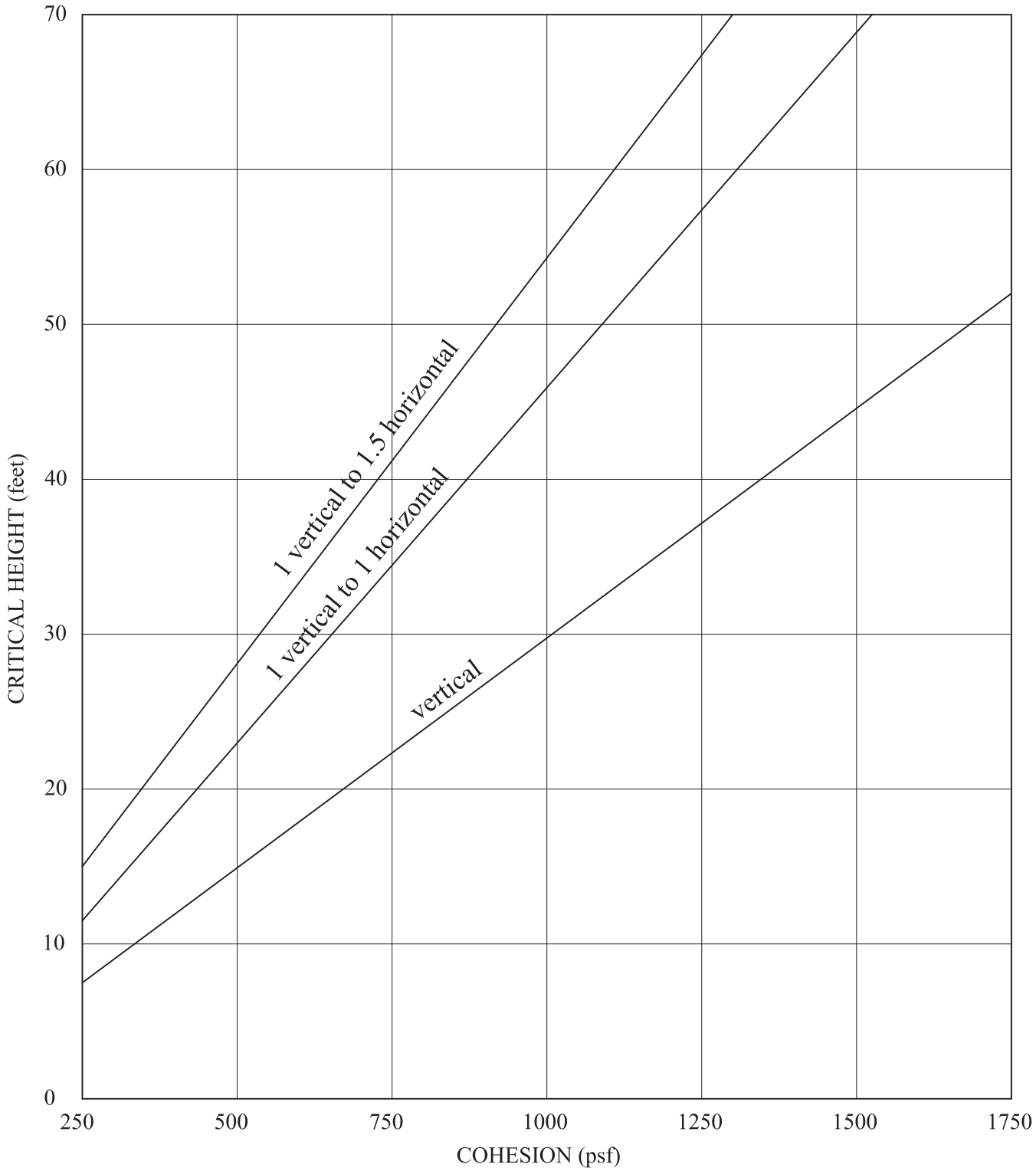
APPENDIX C

APPENDIX C

Plate C-1	Critical Heights of Cut Slopes in Nonfissured Clays
Plate C-2	Maximum Allowable Slopes
Plate C-3	A Combination of Bracing and Open Cuts
Plate C-4	Lateral Pressure Diagrams for Open Cuts in Cohesive Soil-Long Term Conditions
Plate C-5	Lateral Pressure Diagrams for Open Cuts in Cohesive Soil-Short Term Conditions
Plate C-6	Lateral Pressure Diagrams for Open Cuts in Sand
Plate C-7	Bottom Stability for Braced Excavation in Clay

AYLES ENGINEERING CORP.

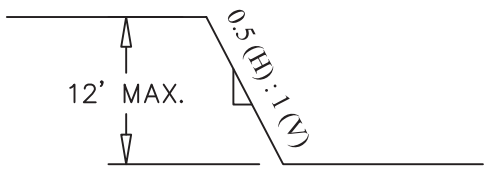
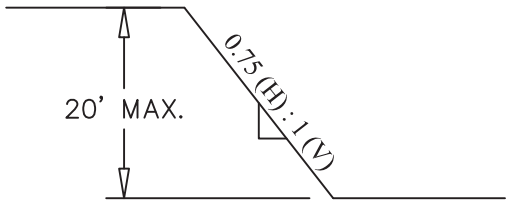
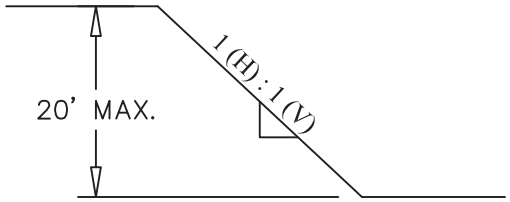
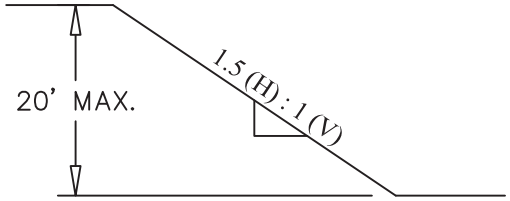
Critical Heights of Cut Slopes in Nonfissured Clays



Note: The charts are calculated based on NAVFAC DM7.1, Page 7.1-319, assuming the critical circles are toe circles, and wet unit weight of soils = 125pcf.

AYLES ENGINEERING CORP.

MAXIMUM ALLOWABLE SLOPES

	SHORT TERM	LONG TERM
TYPE A SOILS		
TYPE B SOILS	N/A	
TYPE C SOILS	N/A	

NOTES:

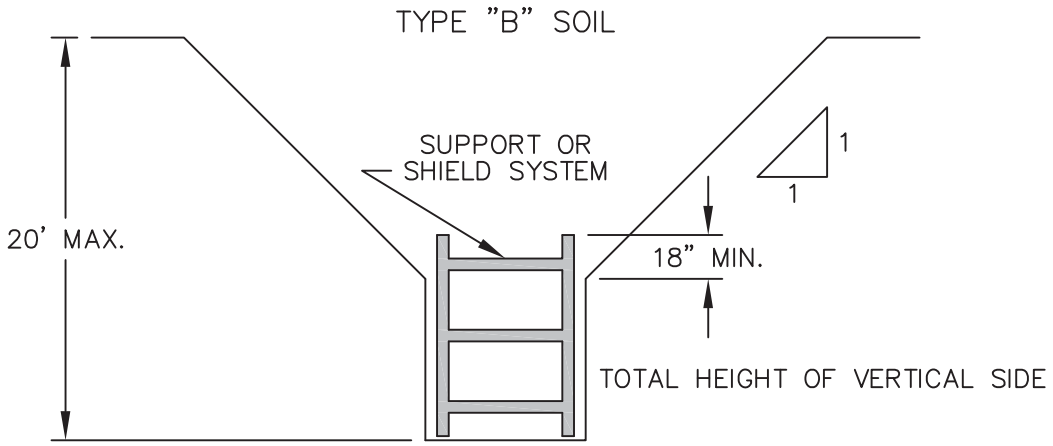
(1) For Type A soils, a short term maximum allowable slope of 0.5 (H) : 1 (V) is allowed in excavations that are 12 feet or less in depth; short term (24 hours or less) maximum allowable slopes for excavations greater than 12 feet in depth shall be 0.75 (H) : 1 (V).

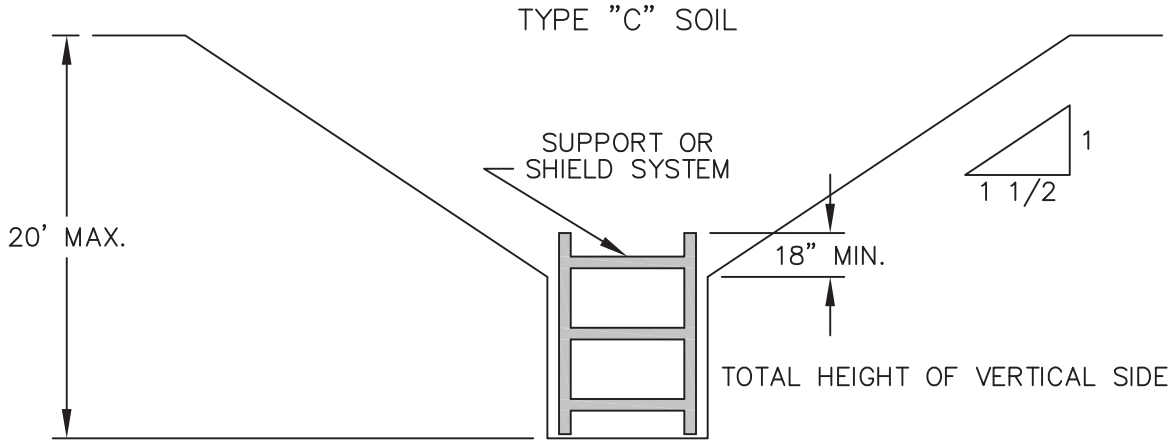
(2) Maximum depth for above slopes is 20 feet. For slopes deeper than 20 feet, trench protection should be designed by the Contractor's professional engineer.

Reference: OSHA, Safety and Health Regulations for Construction, 1926 Subpart P.

AYLES ENGINEERING CORP.

A COMBINATION OF BRACING AND OPEN CUTS

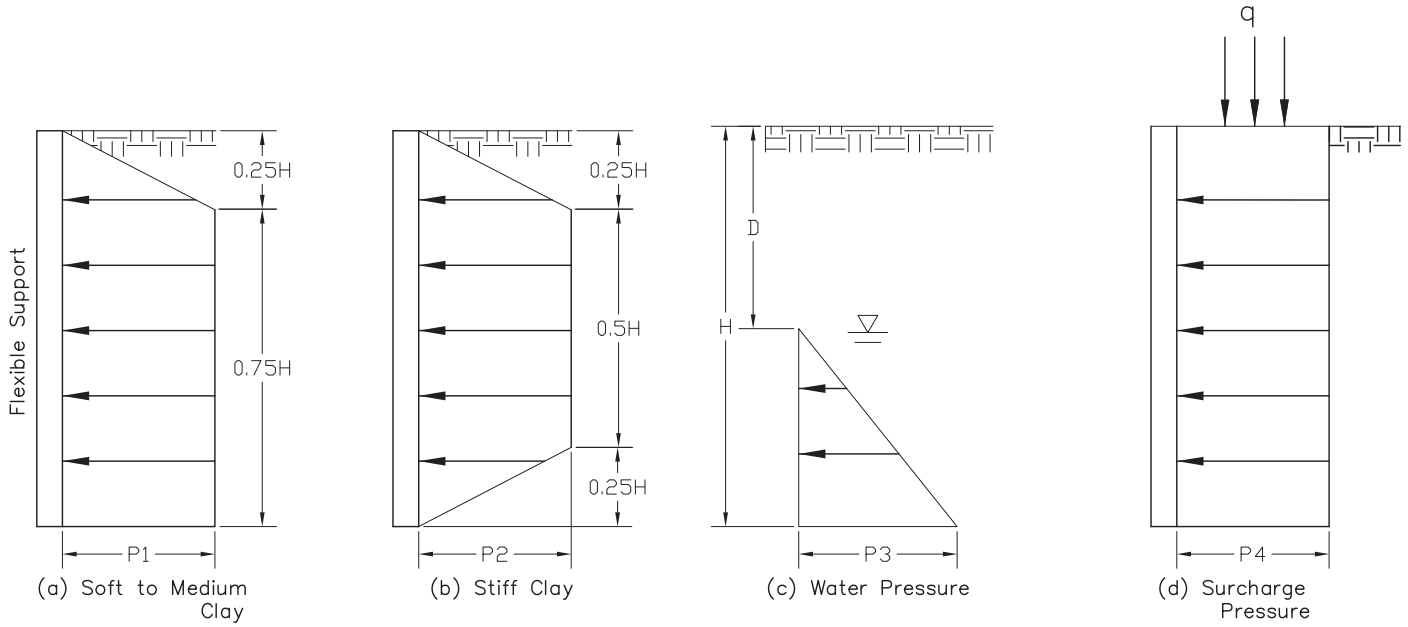




Reference: OSHA, Safety and Health Regulations for Construction, 1926 Subpart P.

AVILES ENGINEERING CORP.

LATERAL PRESSURE DIAGRAMS
FOR OPEN CUTS IN COHESIVE SOIL - LONG TERM CONDITIONS



Empirical Pressure Distributions

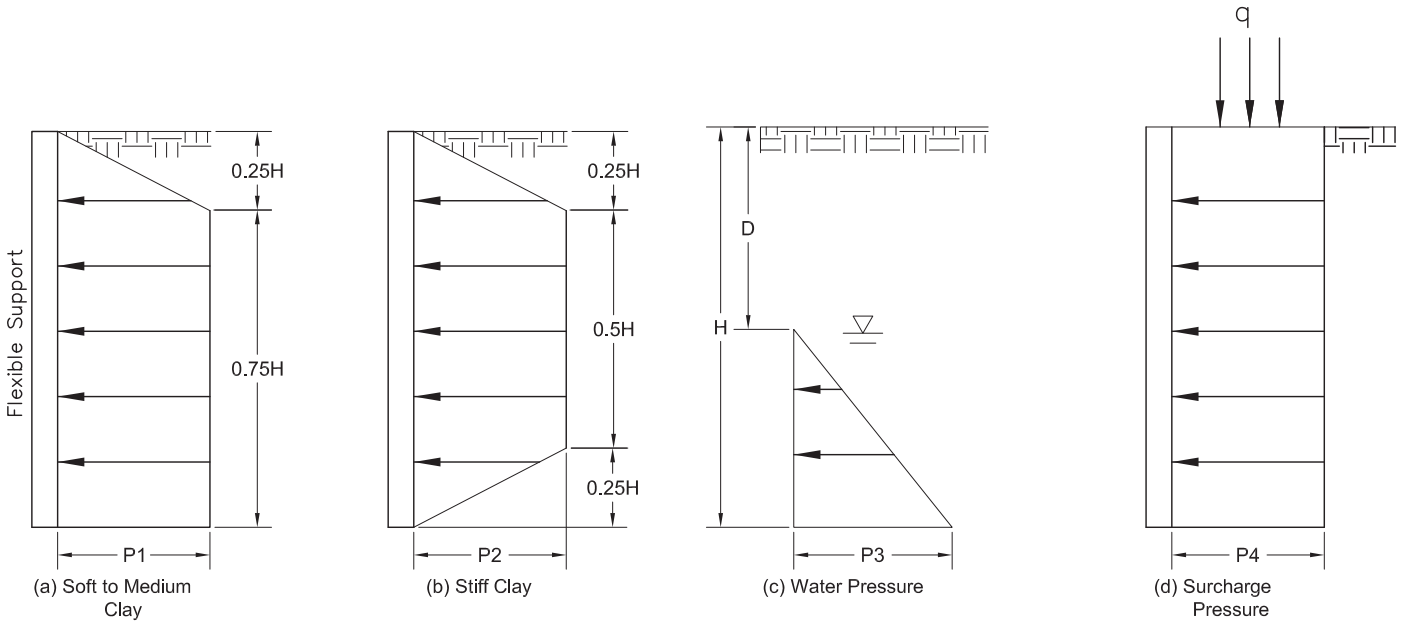
Where:
H = Total excavation depth, feet
D = Depth to water table, feet
P1 = Lateral earth pressure = γH-4C, psf
P2 = Lateral earth pressure = 0.4γH, psf
P3 = Water pressure = γ_w (H-D), psf
P4 = Lateral earth pressure caused by surcharge = qK_a, psf
γ = Effective unit weight of soil, pcf
γ_w = Unit weight of water, pcf
C = Drained shear strength or cohesion, psf
K_a = Coefficient of active earth pressure

Notes:
1. All pressures are additive.
2. No safety factors are included.
3. For use only during long term construction.
4. If γH/C < 4, use section (b),
   If 4 < γH/C < 6, use larger of section (a) or (b),
   If γH/C > 6, use section (a).

Reference: Peck, R.B. (1969), "Deep Excavation and Tunneling in soft Ground", 7th ICSMFE, State of art volume, pp. 225-290.

AYLES ENGINEERING CORP.

LATERAL PRESSURE DIAGRAMS
FOR OPEN CUTS IN COHESIVE SOIL - SHORT TERM CONDITIONS



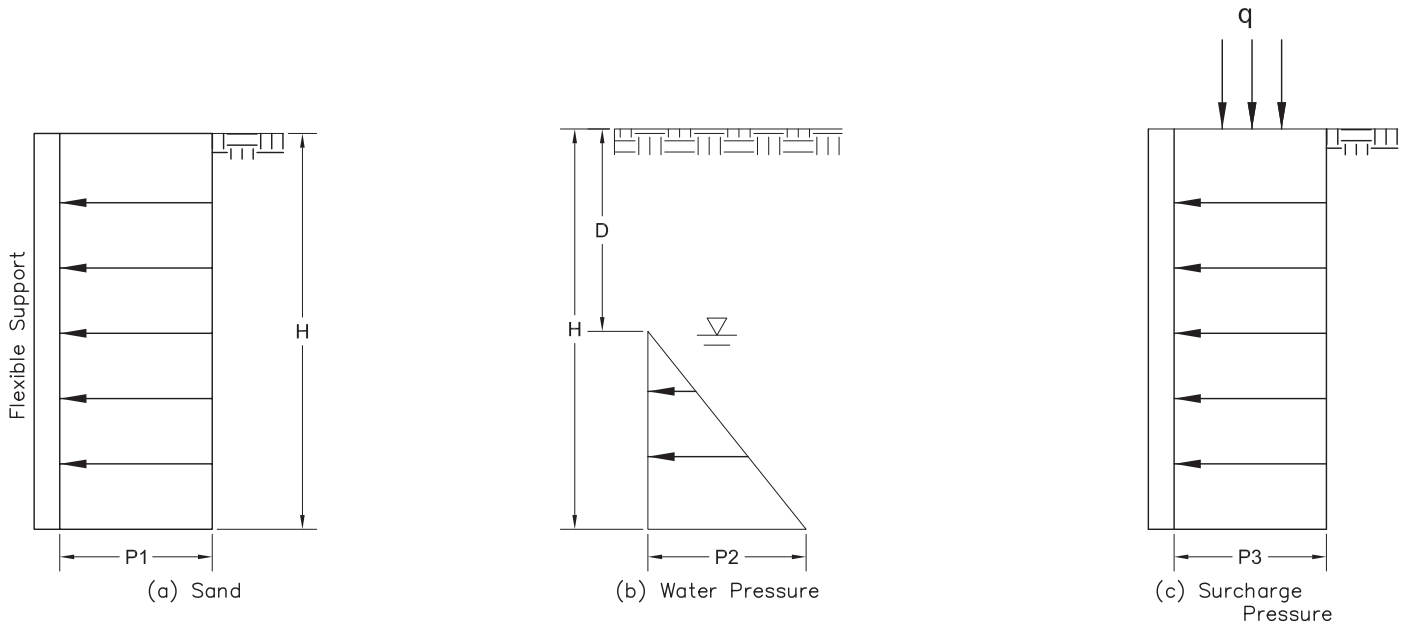
Empirical Pressure Distributions

Where:
H = Total excavation depth, feet
D = Depth to water table, feet
P1 = Lateral earth pressure = $\gamma H - 4S_u$, psf
P2 = Lateral earth pressure = $0.2\gamma H$, psf
P3 = Water pressure = γ_w (H-D), psf
P4 = Lateral earth pressure caused by surcharge = qK_a, psf
γ = Effective unit weight of soil, pcf
γ_w = Unit weight of water, pcf
S_u = Undrained shear strength = $q_u/2$, psf
q_u = Unconfined compressive strength, psf
K_a = Coefficient of active earth pressure

Notes:
1. All pressures are additive.
2. No safety factors are included.
3. For use only during short term construction.
4. If $\gamma H/S_u < 4$, use section (b),
   If $4 < \gamma H/S_u < 6$, use larger of section (a) or (b),
   If $\gamma H/S_u > 6$, use section (a).

Reference: Peck, R.B. (1969), "Deep Excavation and Tunneling in soft Ground", 7th ICSMFE, State of art volume, pp. 225-290.

LATERAL PRESSURE DIAGRAMS
FOR OPEN CUTS IN SAND



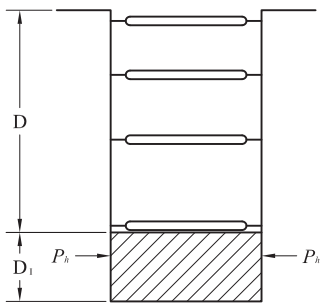
Empirical Pressure Distributions

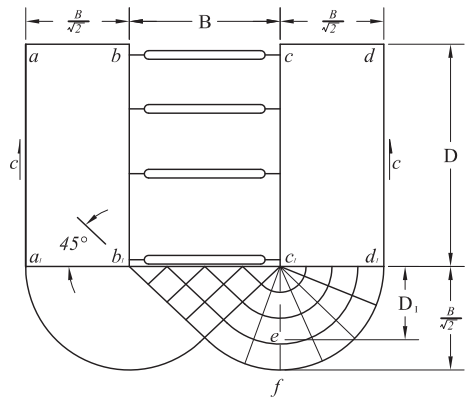
Where:
H = Total excavation depth, feet
D = Depth to water table, feet
P1 = Lateral earth pressure = $0.65*\gamma HK_a$, psf
P2 = Water pressure = γ_w (H-D), psf
P3 = Lateral earth pressure caused by surcharge = qK_a, psf
γ = Effective unit weight of soil, pcf
γ_w = Unit weight of water, pcf
K_a = Coefficient of active earth pressure = $(1-\sin\varphi)/(1+\sin\varphi)$
φ = Drained friction angle

Notes:
1. All pressures are additive.
2. No safety factors are included.

Reference: Peck, R.B. (1969), "Deep Excavation and Tunneling in soft Ground", 7th ICSMFE, State of art volume, pp. 225-290.

BOTTOM STABILITY FOR BRACED EXCAVATION IN CLAY





Factor of Safety against bottom of heave,

$$F.S = \frac{NcC}{(\gamma D+q)}$$

where, Nc = Coefficient depending on the dimension of the excavation (see Figure at the bottom)
C = Undrained shear strength of soil in zone immediately around the bottom of the excavation,
γ = Unit weight of soil,
D = Depth of excavation,
q = Surface surcharge.

If F.S < 1.5, sheeting should be extended further down to achieve stability

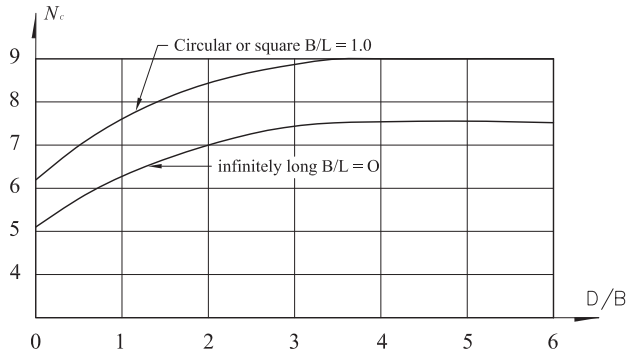
$$\textit{Depth of Buried Length, } (D_1) = \frac{1.5(\gamma D+q)-NcC}{(C/B)-0.5\gamma} \; ; D_1 \geq 5\ ft.$$

Pressure on buried length, P_h:

For $D_1 < 0.47B$; $P_h = 1.5\ D_1(\gamma D - 1.4\ CD/B - 3.14C)$

For $D_1 > 0.47B$; $P_h = 0.7\ (\gamma DB - 1.4\ CD - 3.14CB)$

where; B = width of excavation



N_c rectangular = $(0.84 + 0.16B/L)N_c$ square

Reference: Bjerrum, L. and Eide, O., Stability of Strutted Excavations in Clay, Geotechnique, 6, 32-47 (1956).

APPENDIX G

Preliminary Quantity Take-Off and Cost Estimate

Buffalo Speedway Preliminary Drainage Capacity Check
HDR Engineering, Inc.
8/9/2018

Note: The City of Houston drainage area upstream of Bissonnet covers an area of about 130 acres, but is represented in this spreadsheet as covering an area of only 47.35 acres, a value which yields a 2-year peak flow rate consistent with the capacity of the existing single 66-inch pipe that enters West U from the north. This simulates the flow restriction created by the 66-inch pipe, which lacks full 2-year capcity.

	Drainage Area & 2-Year Peak Flow Rate								Existing Storm Sewer						Proposed Storm Sewer						
Location	DDA	∑DA	Length	∑Length	Tc	I_2	C	Q_2	Number	Diameter	Area/Pipe	Total Area	Capacity	Diff.	Number	Span/Dia	Span	Area/Pipe	Total Area	Capacity	Diff.
Bissonnet	47.35	47.35	2720	2720	37.09	2.74	0.55	71.25	1	66	23.76	23.76	71.27	0.03	1	6	-	28.26	28.26	84.78	13.53
Albans	39.70	87.05	720	3440	41.09	2.56	0.55	122.69	1	66	23.76	23.76	71.27	-51.42	1	8	5	40.00	40.00	120.00	-2.69
Nottingham	23.31	110.36	730	4170	45.15	2.41	0.55	146.30	1	66	23.76	23.76	71.27	-75.03	1	8	6	48.00	48.00	144.00	-2.30
Tangley	35.44	145.80	710	4880	49.09	2.28	0.55	182.88	1	66	23.76	23.76	71.27	-111.60	1	8	8	64.00	64.00	192.00	9.12
Georgetown	24.69	170.49	750	5630	53.26	2.16	0.55	202.49	1	72	28.27	28.27	84.82	-117.67	1	9	8	72.00	72.00	216.00	13.51
Amherst	25.47	195.96	330	5960	55.09	2.11	0.55	227.48	2	66	23.76	47.52	142.55	-84.93	2	8	5	40.00	80.00	240.00	12.52
University	21.82	217.78	810	6770	59.59	2.00	0.55	239.65	2	66	23.76	47.52	142.55	-97.10	2	8	5	40.00	80.00	240.00	0.35
Duke	48.95	266.73	660	7430	63.26	1.92	0.55	281.70	2	66	23.76	47.52	142.55	-139.15	2	8	6	48.00	96.00	288.00	6.30
Pittsburgh	47.07	313.80	640	8070	66.81	1.85	0.55	319.09	2	66	23.76	47.52	142.55	-176.54	2	8	7	56.00	112.00	336.00	16.91
Carnegie	40.57	354.37	660	8730	70.48	1.78	0.55	347.16	2	66	23.76	47.52	142.55	-204.61	2	8	7	56.00	112.00	336.00	-11.16
Cason	41.80	396.17	520	9250	73.37	1.73	0.55	377.33	2	66	23.76	47.52	142.55	-234.78	2	8	8	64.00	128.00	384.00	6.67
Bellaire	4.99	401.16	390	9640	75.53	1.70	0.55	374.33	2	66	23.76	47.52	142.55	-231.78	2	8	8	64.00	128.00	384.00	9.67
Outfall	28.89	**430.05**	650	10290	79.15	1.64	0.55	**388.25**	2	66	23.76	47.52	142.55	-245.70	2	8	8	64.00	128.00	384.00	-4.25

NOTES

Preliminary Cost Estimate for Buffalo Speedway Storm Sewer Infrastructure

Number	Span/Dia	Span	Map Length	Total Length	Unit Price	Cost	West U Cost
1	6	-	520	520	$485	$252,200	$252,200
1	8	5	720	720	$660	$475,200	$475,200
1	8	6	730	730	$770	$562,100	$562,100
1	8	8	710	710	$920	$653,200	$653,200
1	9	8	750	750	$940	$705,000	$705,000
2	8	5	330	660	$660	$435,600	$435,600
2	8	5	810	1,620	$660	$1,069,200	$1,069,200
2	8	6	660	1,320	$770	$1,016,400	$1,016,400
2	8	7	640	1,280	$840	$1,075,200	$1,075,200
2	8	7	660	1,320	$840	$1,108,800	$1,108,800
2	8	8	520	1,040	$920	$956,800	$956,800
2	8	8	540	1,080	$920	$993,600	$993,600
2	8	8	650	1,300	$920	$1,196,000	$1,196,000
City of Houston Paving							$710,000
Sub-Total for Box Culverts			8240.00			**$10,499,300**	**$11,209,300**
Contingency for Inlets & Manholes					**7.00%**	**$734,951**	**$784,651**
Sub-Total						**$11,234,251**	**$11,993,951**
Contingency for Quantity					**10.00%**	**$1,123,425**	**$1,199,395**
Sub-Total						**$12,357,676**	**$13,193,346**
Engineering					**15.00%**	**$1,853,651**	**$1,979,002**
Estimated Total Cost						**$14,211,328**	**$15,172,348**

City of Houston 2018 Box Culvert Prices

263138	8x5 RCB	LF	$660
263139	8x6 RCB	LF	$770
263140	8X7 RCB	LF	$840
263141	8x8 RCB	LF	$920
263142	9X5 RCB	LF	$710
263143	9x6 RCB	LF	$780
263144	9X7 RCB	LF	$850
263145	9X8 RCB	LF	
263146	9X9 RCB	LF	$960
263147	10X5 RCB	LF	$850
263148	10X6 RCB	LF	$880
263149	10X7 RCB	LF	
263150	10X8 RCB	LF	$960
263151	10X9 RCB	LF	$1,130
263152	10X10 RCB	LF	$1,300
263153	11X4 RCB	LF	
263154	11X6 RCB	LF	
263155	11X8 RCB	LF	
263109	72-inch RCP	LF	$485

TxDOT Intensity Equation

$$I = \frac{b}{(t_c + d)^e}$$

COH Tc = 15 + 10($A^{0.1761}$)

Tc values are based on time of travel with Tc values are based on time of travel with storm sewer velocity of 3 feet per second. The Tc at the most upstream inlet at the upper end of the system is computed using the City of Houston eqn for 90 acres. Intensities are computed using the 2-year eqn from the TxDOT Hydraulic Manual.

The drainage area is set equal to the value that produces a 2-year flow rate equal to the capacity of the existing 66" RCP at the upstm end of the system with V = 3 ft/sec.

Preliminary Opinion of Probable Constuction Cost for West University Place: Buffalo Speedway

STREET NAME	**Buffalo Speedway**			
LENGTH (FT)	8240		1	*= 2 if Boulevard Street*
WIDTH (FT)	25		4	*= No. of Driveways*

ITEM NO.	ITEM DESCRIPTION	UNIT	QUAN.	UNIT PRICE	TOTAL AMOUNT	
GENERAL ITEMS						
1	Traffic Control and Regulation, including signs, barrels, barricades, and flagmen	L.S.	1	$ 50,000.00	$ 50,000.00	
2	Temporary Sediment Control including Inlet protection barrier, Stage I and II inlets and existing inlets, including filter fabric fence, gravel bags, repair and replacement, maintenance and removal of sediments, complete in place the sum of:	L.S.	1	$ 25,000.00	$ 25,000.00	
				SUB-TOTAL GENERAL ITEMS:	**$ 75,000.00**	
PAVING ITEMS (CITY OF HOUSTON SOUTH OF BELLAIRE BOULEVARD)						
3	Existing concrete pavement removal, complete in place the sum of:	S.Y.	6,000	$ 13.00	$ 78,000.00	
4	6" thick reinforced concrete pavement, including reinforcement, joints and grading, complete in place the sum of:	S.Y.	6,000	$ 70.00	$ 420,000.00	
5	8" lime stabilized subgrade, including grading, mixing, compacting and curing, complete in place the sum of:	S.Y.	6,000	$ 12.00	$ 72,000.00	
6	Lime for lime stabilized subgrade (7% minimum by dry weight), complete in place the sum of:	TON	152	$ 165.00	$ 25,080.00	
7	6" concrete curb, including reinforcement and joints, complete in place the sum of:	L.F.	3,000	$ 8.00	$ 24,000.00	
8	6" concrete driveway, including blockout, reinforcement and joints, complete in place the sum of:	S.Y.	134	$ 75.00	$ 10,050.00	
9	5' concrete sidewalk, complete in place the sum of:	S.F.	100	$ 13.00	$ 1,300.00	
10	Concrete curb ramp per ADA requirements, complete in place the sum of:	EA.	0	$ 2,000.00	$ -	# of Int., St. cont.
				SUB-TOTAL PAVING ITEMS:	**$ 630,430.00**	# of Int, St. ends
DRAINAGE ITEMS						
11	Remove existing storm sewer pipe, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 20.00	$ -	
12	Remove existing storm sewer box, all sizes and all depths, complete in place the sum of:	L.F.	-	$ 40.00	$ -	
13	Remove existing storm sewer inlets, complete in place the sum of:	EA.	-	$ 370.00	$ -	
14	Remove existing storm sewer manhole, complete in place the sum of:	EA.	-	$ 390.00	$ -	
15	72" RCP, all depths, including foundation and backfill, complete in place the sum of:	L.F.	520	$ 485.00	$ 252,200.00	
16	8 x 5 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	3,000	$ 660.00	$ 1,980,000.00	
17	8 x 6 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	2,050	$ 770.00	$ 1,578,500.00	
18	8 x 8 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	4,130	$ 920.00	$ 3,799,600.00	
19	9 x 8 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	750	$ 940.00	$ 705,000.00	
20	8 x 7 RCB, all depths, including foundation and backfill, complete in place the sum of:	L.F.	2,600	$ 840.00	$ 2,184,000.00	
21	Type "BB" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 4,000.00	$ -	
22	Type "D" Inlet, all depths, including foundation and backfill, complete in place the sum of:	EA.	-	$ 3,500.00	$ -	
23	Manholes, all depths, including foundation and backfill, complete in place the sum of:	EA.	20	$ 3,470.00	$ 69,400.00	
24	Reinforced precast junction box, including excavation, bedding and backfill, connection to existing system, complete in place, the sum of:	EA.	35	$ 4,500.00	$ 157,500.00	
25	Trench safety for all storm sewers 5' - 10' deep, including installation, operation and removal, complete in place the sum of:	L.F.	4120	$ 2.00	$ 8,240.00	
26	Trench safety for all storm sewers 10' - 15' deep, including installation, operation and removal, complete in place the sum of:	L.F.	4120	$ 2.50	$ 10,300.00	
				SUB-TOTAL DRAINAGE ITEMS:	**$ 10,744,740.00**	
				ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 11,450,170.00**	
				15% CONTINGENCY:	**$ 1,717,525.50**	
				TOTAL ESTIMATED PROBABLE COST OF CONSTRUCTION:	**$ 13,167,695.50**	
	Design Engineering Services (12%)				**$ 1,580,123.46**	
	Bid Phase Services (1%)				**$ 131,676.96**	
	Construction Administration Services (1%)				**$ 131,676.96**	
	Surveying Services (1%)				**$ 131,676.96**	
	Geotechnical Services				**$ 30,000.00**	16 No. of borings
	Urban Forester				**$ 13,600.00**	
	OPCC INCLUDING PROFESSIONAL SERVICES:				**$ 15,186,449.83**	

Engineering Fee Assumptions:

[1] Geotechnical services fee is estimated based on $110/VF. The average depth of borehole is assumed as 15 VF. Borehole is assume to be placed every 500 LF.

[2] Urban Forester service fee is estimated based on $1.50/LF.

Appendix

B

Preliminary Storm Sewer Drainage Analysis for Six Ponding Locations in the Academy Street Drainage System in West University Place

April 21, 2016

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

Preliminary Storm Sewer Drainage Analysis for Six Ponding Locations in the Academy Street Drainage System in West University Place

West University Place, Texas

April 2016

HDR

Preliminary Storm Sewer Drainage Analysis for Six Ponding Locations in the Academy Street Drainage System in West University Place

West University Place, Texas

Project Engineer

Min Xiao, PE
Name as Registered

96830
Texas Serial No.

STATE OF TEXAS
MIN XIAO
96830
LICENSED
PROFESSIONAL ENGINEER

4/21/16

Project Manager

Duane Barrett, PE
Name as Registered

63703
Texas Serial No.

STATE OF TEXAS
DUANE BARRETT
63703
LICENSED
PROFESSIONAL ENGINEER

4/21/16

April 2016

CONTENTS

1.0 EXECUTIVE SUMMARY 1

2.0 INTRODUCTION 2
2.1 Project Name and Purpose 2
2.2 Project Location 2
2.3 Project Objectives 2
2.4 FEMA Flood Zones 2
2.5 Data Sources 2

3.0 DRAINAGE ANALYSIS 4
3.1 Existing Condition 4
3.2 Brays Bayou Water Surface Elevation 4
3.3 Street Profiles 4
3.4 Inlets at Ponding Locations 9
3.5 Drainage Area 13
3.6 Hydrologic Methods 14
3.6.1 Land Use 14
3.6.2 Time of Concentration 14
3.6.3 Rational Method 15
3.7 Calculated 2-Year Peak Flow Rates 16
3.8 Storm Sewer Conveyance Capacity Required 17

4.0 CONCLUSION 22

List of Tables

Table 3-1. Brays Bayou Water Surface Elevation (feet) within City Limits 4
Table 3-2. Inlets at Locations of Interest 10
Table 3-3. Land-Use Categories 14
Table 3-4. Harris County 2-Year Intensity-Duration-Frequency Coefficients 16
Table 3-5. Accumulative Drainage Area and 2-Year Flow Rate for Storm Sewer Segments 17
Table 3-6. Existing and Required Storm Sewer Size to Convey 2-Year Flow Rates 18
Table 3-7. Summary of Inlet Capacity 19
Table 3-8. Cost Estimate of Storm Sewer System Improvement for Project Area 21

List of Figures

Figure 1. Academy Street Profile 5
Figure 2. Fairmont Street Profile 6
Figure 3. Albans Road Profile 6
Figure 4. Judson Avenue Profile 7
Figure 5. West Point Street Profile 7
Figure 6. Amherst Street Profile 8
Figure 7. Oberlin Street Profile 8
Figure 8. Villanova Street Profile 9
Figure 9. Inlets on Academy Street in Project Area (1) 10
Figure 10. Inlets on Academy Street and Fairmont Street in Project Area (2) 11
Figure 11. Inlets on West Point Street in Project Area (1) 11
Figure 12. Inlets on West Point Street in Project Area (2) 12
Figure 13. Commercial Area of Houston Draining to West University Place 13
Figure 14. Upland Method Correlation between Flow Velocity, Surface Type, and Slope 15

List of Exhibits

Exhibit 1. Areas of Interest and Vicinity Map
Exhibit 2. Floodplain Map of West University Place
Exhibit 3. Topographic Map of Project Area
Exhibit 4. Storm Sewer Layout in Project Area
Exhibit 5. Brays Bayou Water Surface Elevation Profiles
Exhibit 6. Overall Drainage Area Map
Exhibit 7. Project Drainage Area Map
Exhibit 8. Land Use Type Map

List of Acronyms

AEP	Annual Exceedance Probability
CFS	Cubic Feet Per Second
COH	City of Houston
CN	Curve Number
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FPS	Feet Per Second
FT	Feet
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
IN/HR	Inches Per Hour
LiDAR	Light Detection and Ranging
NAIP	National Aerial Imagery Program
NAVD	North American Vertical Datum
NRCS	Natural Resources Conservation Service
ROW	Right-Of-Way
TxDOT	Texas Department of Transportation
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WSE	Water Surface Elevation

1.0 Executive Summary

A preliminary storm sewer drainage analysis was performed for six (6) ponding locations in the City of West University Place. A significant portion of the city is within the 100-year floodplain of Brays Bayou. However, none of the six locations of interest are within the 100-year floodplain. The existing layouts and sizes of storm sewer lines were obtained from the report titled "Comprehensive Plan for Infrastructure Improvements" dated April 1993 and prepared for the City of West University Place by Langford Engineering, Inc., with supplemental information from construction documents prepared for paving and drainage projects completed in the City since 1993. Note that the report does not provide invert elevation information for storm sewer lines.

Elevation profiles were plotted for the streets where these intersections are located. It is found that most of the intersections are located at low points along street profiles. Any excess of runoff above the conveyance capacity of the storm sewer lines serving these locations will accumulate and pond in the intersections instead of sheet-flowing away along the streets.

The 2-year peak flow rate was computed at locations of interest using the Rational Method to estimate the required inlet and storm sewer capacities serving the areas of interest. The required capacities were then compared to the existing capacities to determine the deficiencies. A constant 3 fps storm sewer flow velocity was used in estimating the existing and required storm sewer capacities. This assumption reflects standard design procedure in the Greater Houston area and is considered adequate for this preliminary study. A detailed study involving hydrologic and hydraulic modeling tools is recommended to size the storm sewer lines in order to account for the slope of the storm sewer system. In order to complete that study, field survey data will be required to define the storm sewer elevation data.

The results of this preliminary study show that inlet capacity is insufficient at the intersections of Academy Street and Albans Road, and Academy Street and Bissonnet Street. In addition, inlet density is found to be inadequate along the street gutters around the commercial area located within the City of Houston and bounded by Law Street, Academy Street, and Bissonnet Street. It is likely that the insufficient inlet density on the bounding gutters of this commercial section will fail to capture all the runoff flow generated from the commercial section, which lies within the City of Houston. The excess of flow will travel to surrounding intersections and may contribute to ponding within West University Place.

The existing conveyance capacities of most storm sewer lines serving the locations of interest do not satisfy current 2-year storm capacity requirements. The existing storm sewer lines will have to be upsized in order to provide the 2-year storm capacity. The required storm sewer sizes are provided in ***Table 3-6*** in this report.

2.0 INTRODUCTION

2.1 Project Name and Purpose

This study includes a preliminary drainage analysis of the storm sewer systems of interest in the City of West University Place, Texas. The purpose of this study is to assess ponding issues that occur at six (6) street intersections during storm events. This report is prepared for the Public Works Department of the City of West University Place.

2.2 Project Location

The project area is within the city limits of West University Place in Harris County. The six ponding locations of interest are listed below. ***Exhibit 1*** shows the six ponding locations of interest and the city limits.

1. Academy Street at Albans Road
2. Fairmont Street at Judson Avenue
3. Academy Street at Bissonnet Street
4. West Point Street at Amherst Street
5. West Point Street at Oberlin Street
6. West Point Street at Villanova Street

2.3 Project Objectives

This drainage study includes drainage area delineation, peak flow estimation, and storm sewer evaluation. The storm frequency used in this analysis is the 2-year storm event. The objective of the analysis is to assess the capacities of the existing storm sewer systems at the locations of interest.

2.4 FEMA Flood Zones

The project area is located in the western portion of the City of West University Place. The area is located on Harris County FIRM Panel 48201C0855L. A significant portion of the City of West University Place is within the regulatory floodplain of Brays Bayou (HCFCD Channel D100-00-00) designated as Zone AE with defined flood elevations, as shown on ***Exhibit 2***. The City of West University Place is located approximately between FIRM panel Cross Section BF and Cross Section AX (see ***Exhibit 3***). Zone AE indicates that base flood elevation has been determined for this stream. The BFE value of Brays Bayou in the West University Place city limits ranges from 47 ft at Kirby Drive to 49 ft at College Avenue (NAVD 88 2001 adjustment). The portion of the city west of College Avenue lies mostly outside of the regulatory floodplain.

Although a significant portion of the city is within the regulatory floodplain, this report does not address the flooding issues caused by Brays Bayou. Instead, this report focuses on the capacity of the existing storm sewer system at each of the locations of interest and the storm sewer's ability to convey standard 2-year design runoff rates.

2.5 Data Sources

A list of data that were used for this project is provided below.

- The 2008 H-GAC LIDAR (NAVD 1988 2001 adjustment) was used for drainage area delineation and was also used to evaluate street elevation profiles to determine low points along streets where ponding may occur.

- The report titled “Comprehensive Plan for Infrastructure Improvements” dated April 1993 and prepared for the City of West University Place by Langford Engineering, Inc. (referred to as the Report in this document) was provided by the Public Works Department of the City of West University Place. This report presents the layouts and sizes of the existing storm sewer lines within the City of West University Place, but does not provide information on invert elevations of storm sewer lines.

- The GIS layer of storm sewer lines within the West University Place city limits was downloaded from the City of Houston (COH) GIMS database. It is noted that the storm sewer data within the project area in this database is limited. It is likely that COH does not collect and maintain the infrastructure data for the area within the city limits of West University Place. The data downloaded from GIMS was used as a supplement to the storm sewer information obtained from the Report.

- Construction documents for paving and drainage projects completed within the City of West University Place since 1993 were used to supplement and update information obtained from the Report and from the City of Houston GIMS database.

- Harris County FIRM maps were obtained from the FEMA web site.

- H-GAC aerial images dated 2014 were used in the study.

- Field visits were conducted by HDR staff in November 2015 to visually evaluate the general condition of the roadway and storm sewer systems, especially inlet density and size, within the project area. Photos were taken during field visits.

3.0 Drainage Analysis

A hydrologic analysis was performed to delineate drainage areas and to determine the 2-year peak flow rates for the storm sewer systems where the ponding occurs. This section describes the methodologies used in the peak flow calculations and presents the results.

3.1 Existing Condition

The six ponding locations of interest are shown on ***Exhibit 1***. The City of West University Place is primarily developed in single family residential areas with some light commercial areas scattered within the city limits. The ground elevation slopes south-eastward ranging from approximately 54.0 ft (NAVD 88 2001 Adjustment) at the northwest corner of the city to approximately 47.5 ft at the southeast corner. A topographic map is provided as ***Exhibit 3***. The ponding locations on Fairmont Street, West Point Street and Academy Street (a total of 6 locations) are served by storm sewers that drain to the main storm sewer line along Academy Street, which drains southward to Bellaire Blvd, then westward along Bellaire Blvd, and eventually outfalls to Kilmarnock Ditch (HCFCD Channel D113-00-00). ***Exhibit 4*** presents the storm sewer systems in the project area, including the storm sewer lines serving the six locations of interest, as well as storm sewers along Academy Street.

In some areas, storm sewer systems have been improved over a number of years. For example, a new storm sewer trunk line was installed on College Avenue (See ***Exhibit 4***) to improve drainage for that area. Other improvements have been completed in various portions of the City. However, available information indicates that no significant upgrades to the main trunk storm sewer along Academy Street have been completed since that system was originally constructed.

3.2 Brays Bayou Water Surface Elevation

The City of West University Place is located approximately between FIRM panel Cross Section BF and Cross Section AX (see ***Exhibit 3***). A significant portion of West University Place is within the 100-year floodplain of Brays Bayou. ***Exhibit 5*** illustrates the FEMA water surface elevation (WSE) profile for this portion of Brays Bayou. This profile is taken directly from the FEMA FIS study report for Harris County. ***Exhibit 3*** plots the FEMA cross sections of Brays Bayou with 10- and 100-year WSE indicated on a contour and color-shaded topographic map of West University Place. ***Table 3-1*** summarizes the 10-, 50, 100- and 500-year water surface elevations along Brays Bayou at FEMA Cross Sections BF, BE, BD, BC, BB, BA, AZ, AY and AX. The 10-year WSE from west to east within the city limits ranges from 46.4 ft at Cross Section BF to 41.9 ft at Cross Section AX; the 100-year WSE ranges from 50.8 ft to 46.9 ft.

Table 3-1. Brays Bayou Water Surface Elevation (feet) within City Limits

FEMA Cross Section	BF	BE	BD	BC	BB	BA	AZ	AY	AX
500-Year WSE	52.2	52.0	51.7	51.7	51.6	51.4	51.1	50.9	50.5
100-Year WSE	50.8	50.7	49.5	49.4	49.3	49.0	48.3	48.1	46.9
50-Year WSE	48.8	48.7	47.3	47.2	47.0	46.6	45.9	45.7	44.1
10-Year WSE	46.4	46.1	45.1	44.9	44.7	44.3	43.3	43.1	41.9

3.3 Street Profiles

Most of the locations of interest are on West Point Street and Academy Street. Street profiles were plotted along these streets and the streets that intersect with them. ***Exhibit 1*** shows the extents of these street profile plots. ***Figure 1*** to ***Figure 8*** illustrate the actual street profiles.

It is noted that the intersections where ponding occurs are usually located at low points along the street profile. In some cases, the centerline of the road (e.g., Bissonnet Street on Academy Street profile in ***Figure 1***) is elevated, but both edges of the roadway are depressed, and water ponds along the curb. If the runoff during a storm event exceeds the conveyance capacity of the storm sewer inlets and pipes serving these areas, water will accumulate and pond instead of sheet-flowing away along the streets.

Figure 1. Academy Street Profile

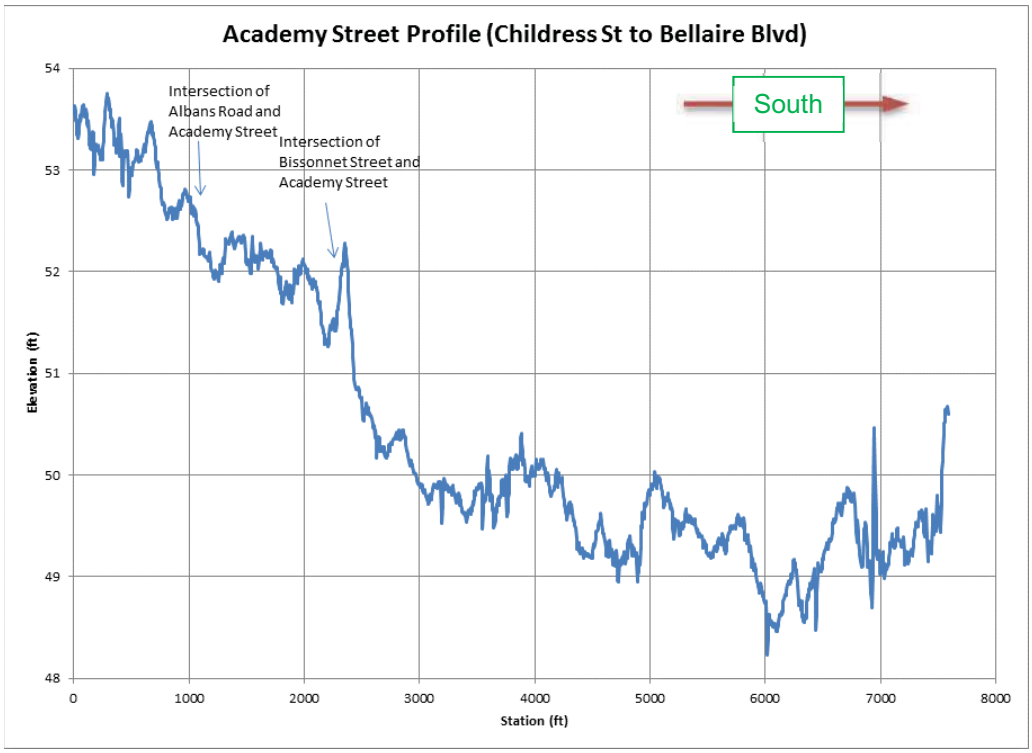


Figure 2. Fairmont Street Profile

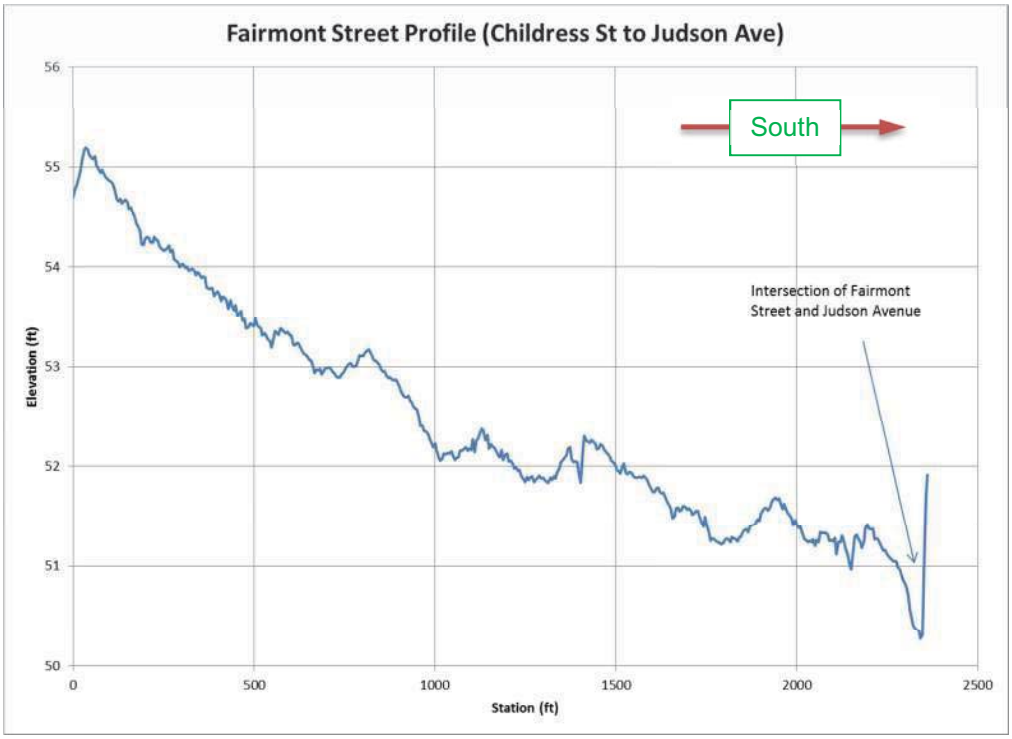


Figure 3. Albans Road Profile

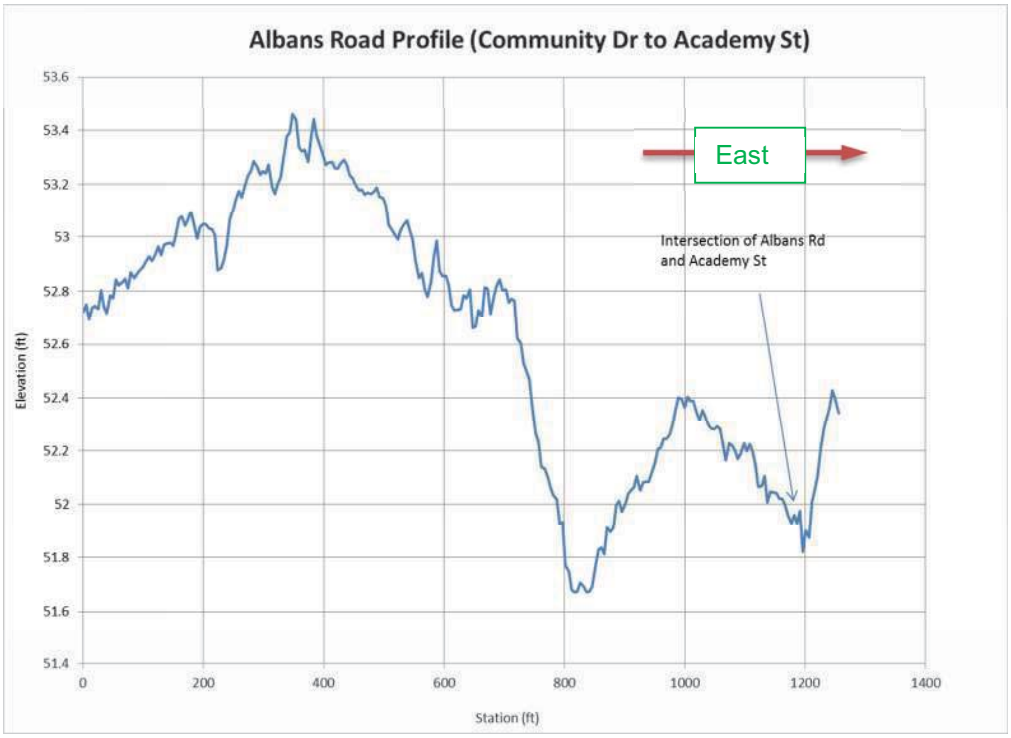


Figure 4. Judson Avenue Profile

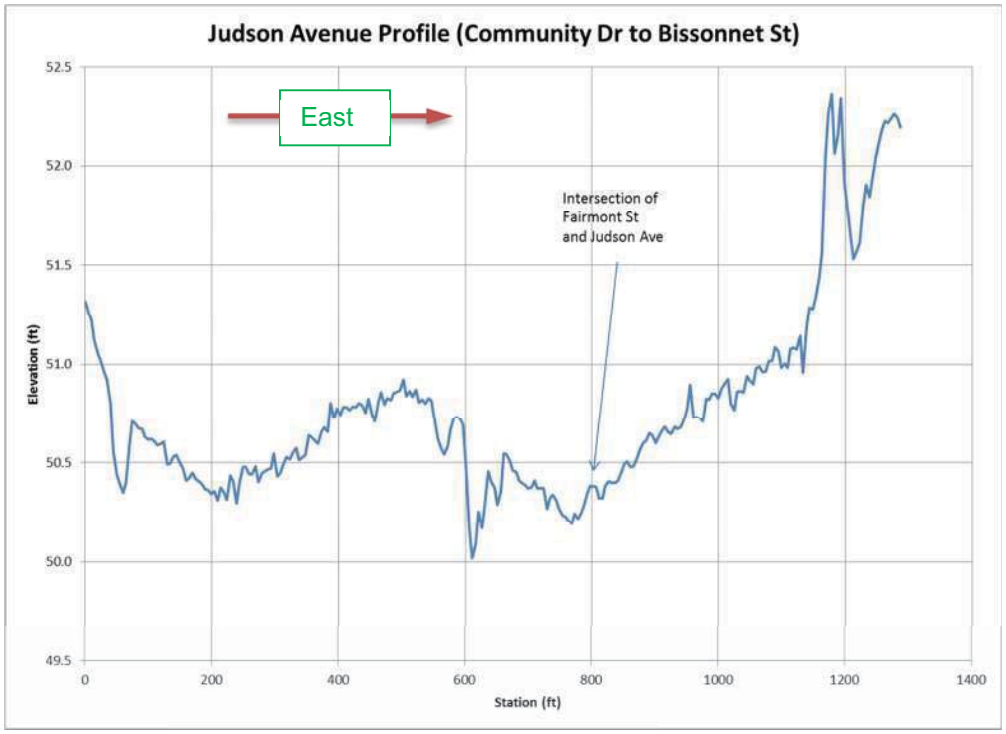


Figure 5. West Point Street Profile

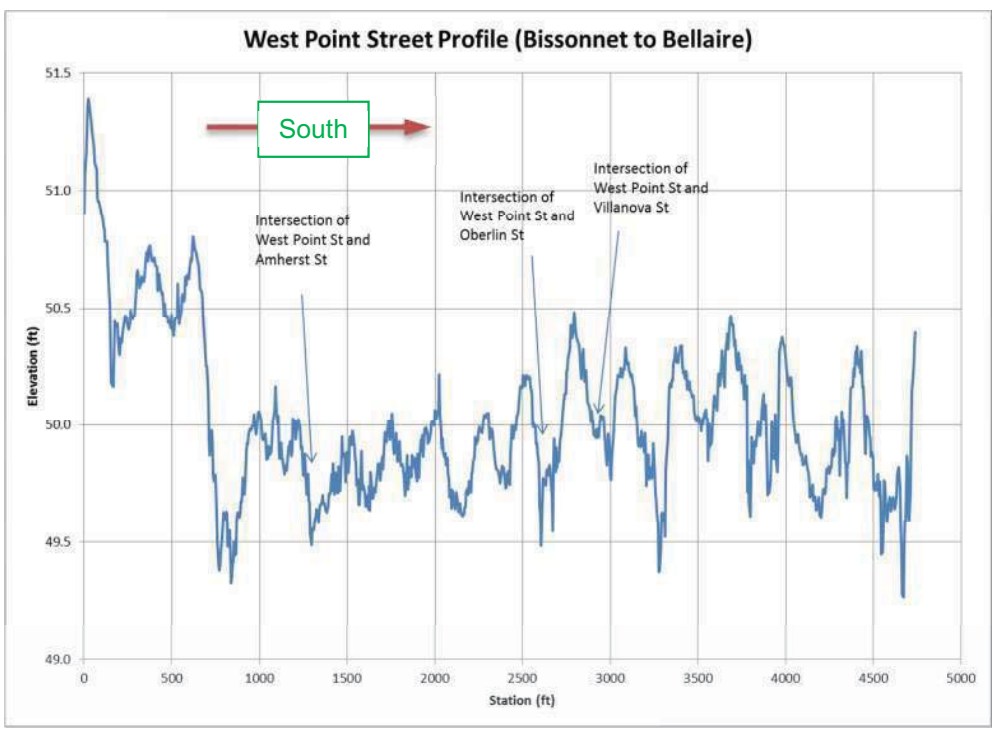


Figure 6. Amherst Street Profile

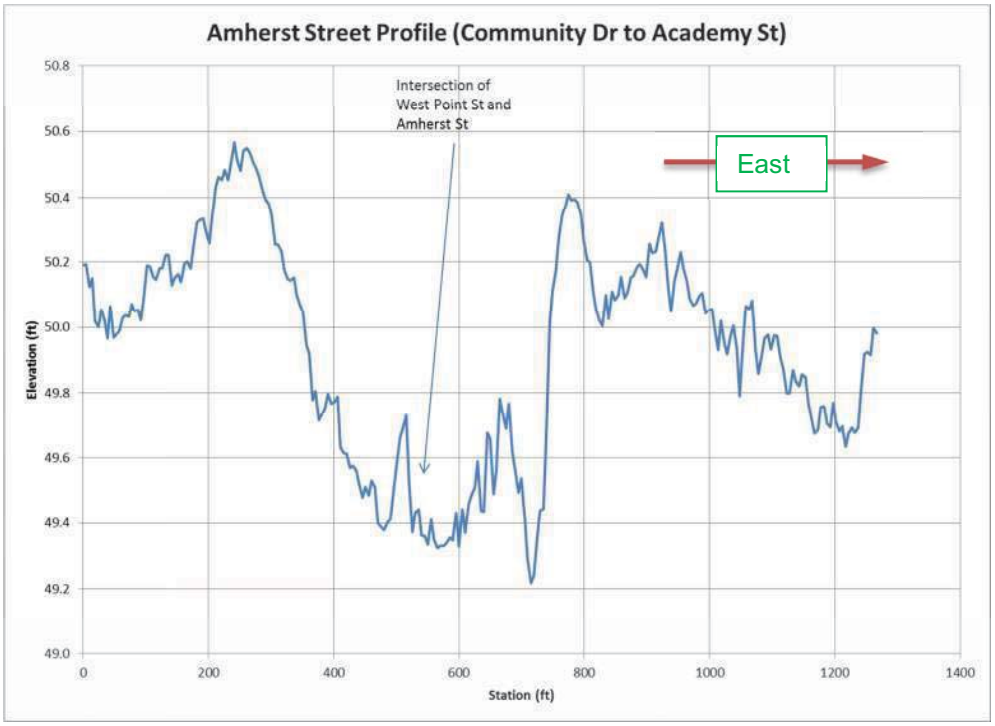


Figure 7. Oberlin Street Profile

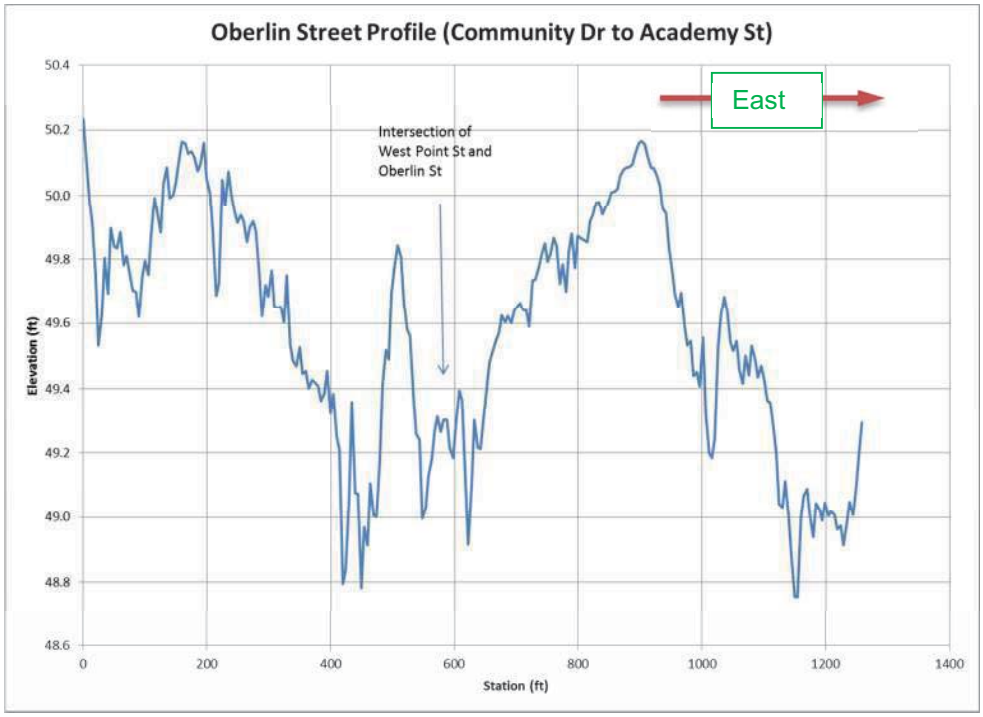
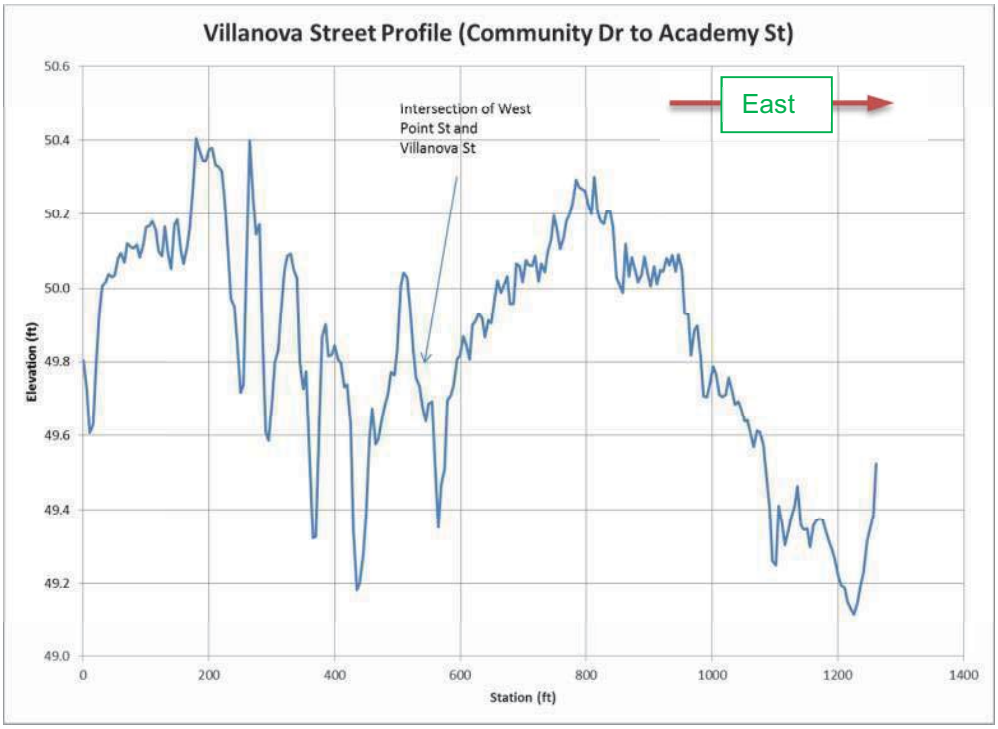


Figure 8. Villanova Street Profile



3.4 Inlets at Ponding Locations

Inlet type and density at the ponding locations were checked to see if sufficient inlet capacity is provided to satisfy the standard 2-year design storm requirement. ***Table 3-2*** summarizes the inlet type and number at these intersections. ***Figure 9*** to

Figure ***12*** are aerial photos showing inlet locations at these intersections and in the surrounding areas. Most of the inlets at these intersections are double B inlets. Occasionally singe B inlets are observed at some locations. Single B inlets are an old type of inlet, while double B inlets are popularly used currently; as the name implies, they double the inlet opening and capacity of single B inlets. Inlet capacity is a function of inlet type, size, location (on grade or in sag), ponding depth, gutter depression, longitudinal gutter slope, transverse gutter slope, transverse gutter width, etc. Typically, a single B inlet or grate inlet provides approximately 2 cfs capacity, whereas a double B inlet provides 2 x 2 = 4 cfs capacity.

Table 3-2. Inlets at Locations of Interest

Intersection	Number of Existing Inlets	Type of Inlet
Academy Street at Albans Road	2	Double B
Fairmont Street at Judson Avenue	3	Double B
Academy Street at Bissonnet Street	2	One single B; One double B
West Point Street at Amherst Street	4	Double B
West Point Street at Oberlin Street	4	Double B
West Point Street at Villanova Street	4	Double B

Two double B inlets are provided at the intersection of Academy Street and Albans Road. Also, two single B inlets are provided approximately 120 ft south of the intersection on Academy Street. The area between Albans Road and Bissonnet Street along Academy Street east of the road is a commercial area in the City of Houston with extensive parking areas and lots of impervious cover.

Only a single B inlet (on Bissonnet Street) and a double B inlet (on Academy Street) was observed at the intersection of Bissonnet Street and Academy Street. Two single inlets were observed approximately 110 ft north of the intersection on Academy Street. There are three double B inlets at the intersection of Fairmont Street and Judson Avenue.

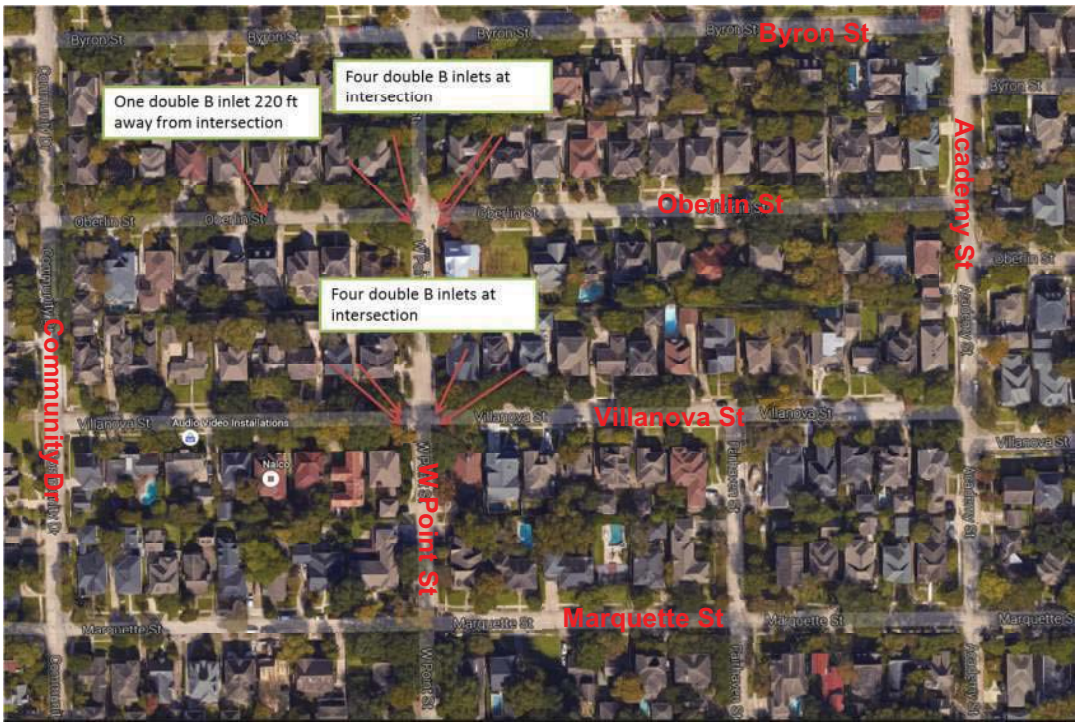
The intersection of West Point Street and Amherst Street also has four double B inlets. Additionally, there are two double B inlets approximately 300 ft east of this intersection on Amherst Street. Both the intersection of West Point Street and Oberlin Street and the intersection of West Point Street and Villanova Street have four double B inlets. There is a double B inlet on Oberlin Street located approximately 220 ft west of the intersection of West Point Street and Oberlin Street.

Figure 9. Inlets on Academy Street in Project Area (1)

Figure 10. Inlets on Academy Street and Fairmont Street in Project Area (2)

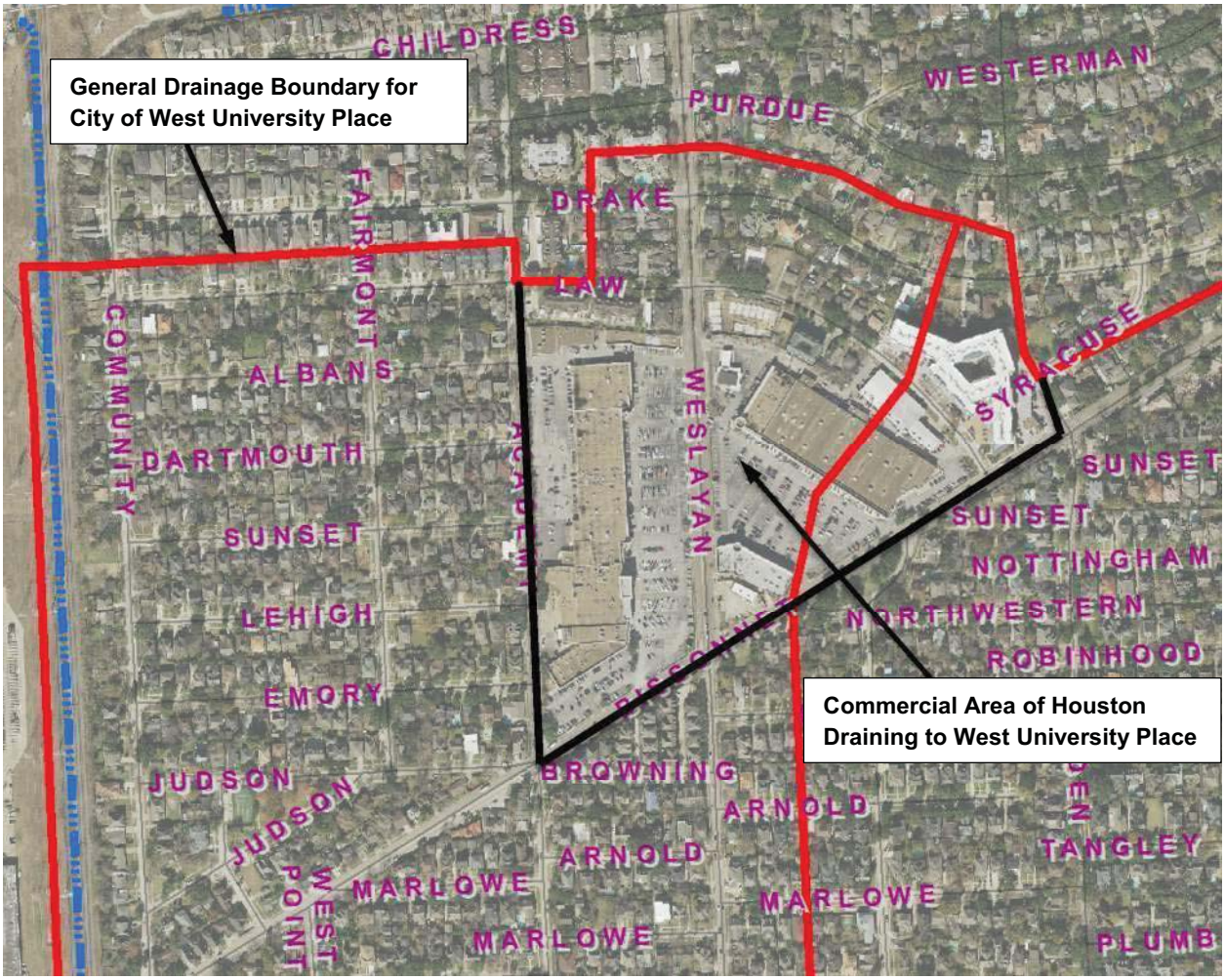
Figure 11. Inlets on West Point Street in Project Area (1)

Figure 12. Inlets on West Point Street in Project Area (2)



The commercial area (shown in ***Figure 13***) bounded by Academy Street, Law Street and Bissonnet Street consists of a Randall's supermarket, along with a number of restaurants and retail stores with large, impervious parking lots. This commercial area lies within the City of Houston. Weslayan Street passes through the commercial area from north to south and divides it into two parts. Four grate inlets were observed during field visits around the parking lot of the Wells Fargo Bank located at the northwest corner of the eastern portion of the commercial area. No other onsite inlets were found on the parking lots of the commercial area. Therefore, runoff generated from the commercial area, except for that on the Wells Fargo Parking lot, has to be captured by the street inlets along Weslayan Street. Some street inlets were observed at or near the driveway to the commercial area that appear to be intended to capture runoff leaving the commercial section. However, the street inlets do not appear to be adequate for this extensive impervious area. The 1,550 ft long east street gutter bounding the commercial area along Academy Street between Law Street and Bissonnet Street has three single B inlets and one grate inlet. The gutter bounding the commercial area along the south side of the 1,750 ft long segment of Law Street between Academy Street and Bissonnet Street has two double B inlets and one single B inlet. The street gutter along the west side of the 1,700 ft long segment of Bissonnet Street between Law Street and Academy Street has three single B inlets and one grate inlet. The 1,200 ft long segment of Weslayan Street that passes through the commercial area between Law Street and Bissonnet Street has only one double B inlet and 1 single B inlet on its west gutter and one double B inlet on its east gutter. It appears that the inlet capacity is not adequate on these street gutters bounding the commercial section to capture the runoff from the commercial section, especially for Weslayan Street. The excess of water above and beyond the inlet and storm sewer capacity may flow to surrounding intersections within the City of West University Place, potentially including the intersections of Academy Street and Bissonnet Street, Academy Street and Albans Road, and Fairmont Street and Judson Avenue, and may cause ponding problems at those locations. It is understood that the commercial section is outside of the West University Place City corporate boundary, and those bounding streets (except for Academy Street) that lack inlet capacity are also outside the city limits. The City of West University Place would have to discuss this issue with the City of Houston in order to formulate a plan for addressing the problem.

Figure 13. Commercial Area of Houston Draining to West University Place



3.5 Drainage Area

The City of Houston GIMS database and the storm sewer information obtained from the Report and construction plans were used to delineate the approximate drainage areas used for this study. ***Exhibit 6*** presents an overall drainage map for the City of West University Place. This overall drainage map includes the City of Houston areas that drain to the City of West University Place drainage systems. The western portion of the city, including the six locations of interest, discharges to Kilmarnock Ditch. The middle portion drains to Poor Farm Ditch. The eastern portion drains to storm sewer lines on Kirby Drive, which in turn drain to City of Houston storm sewer systems. The major areas that belong to the City of Houston but drain to the City of West University Place are indicated on the map. These areas include the triangular commercial area east of Academy Street and north of Bissonnet Street, and the areas north of the City of West University Place boundary along Bissonnet Street that drain southward into the City's storm sewer systems.

The project drainage areas for the storm sewer systems that serve the ponding locations of interest were further delineated using available maps and storm sewer data. The delineated drainage areas were used to calculate 2-year peak flow rates for the storm sewer lines under consideration in this study. ***Exhibit 7*** displays the project drainage areas delineated for analysis.

3.6 Hydrologic Methods

The Rational Method was utilized to compute 2-year peak flow rates in this study. The Rational Method requires the composite C value and time of concentration (t_c) for each drainage area. The e, d and b values developed by TxDOT for Harris County were used to compute rainfall intensities.

3.6.1 Land Use

Land-use data are required to estimate the composite C value for each drainage area. The land use classification was determined based on the aerial photography of the project area. The land-use types within the project drainage areas were defined into two classifications: single-family residential and commercial/multi-family. ***Exhibit 8*** depicts the land use types defined for the project area. Typical Rational Method runoff coefficients were assigned to each of the two land use classifications. ***Table 3-3*** presents the land-use types and the associated runoff coefficients used in the study.

Table 3-3. Land-Use Categories

General Land-Use Categories	C Value
Single Family Residential	0.40
Commercial or Multi-Family	0.65

The land-use data were combined with drainage areas to allow computation of the composite C value for each drainage area. The combined land-uses and associated areas for each drainage area were identified. Using the following equation, the composite land-use C value was calculated for each drainage area:

$$\bar{C} = \frac{\sum_{i=0}^{n} A_i RC_i}{\sum_{i=0}^{n} A_i}$$

where:

C_i = C value of each land-use type for a drainage area;

A_i = area associated with land-use type for a drainage area; and

$\bar{C}$= composite *C* value for a drainage area.

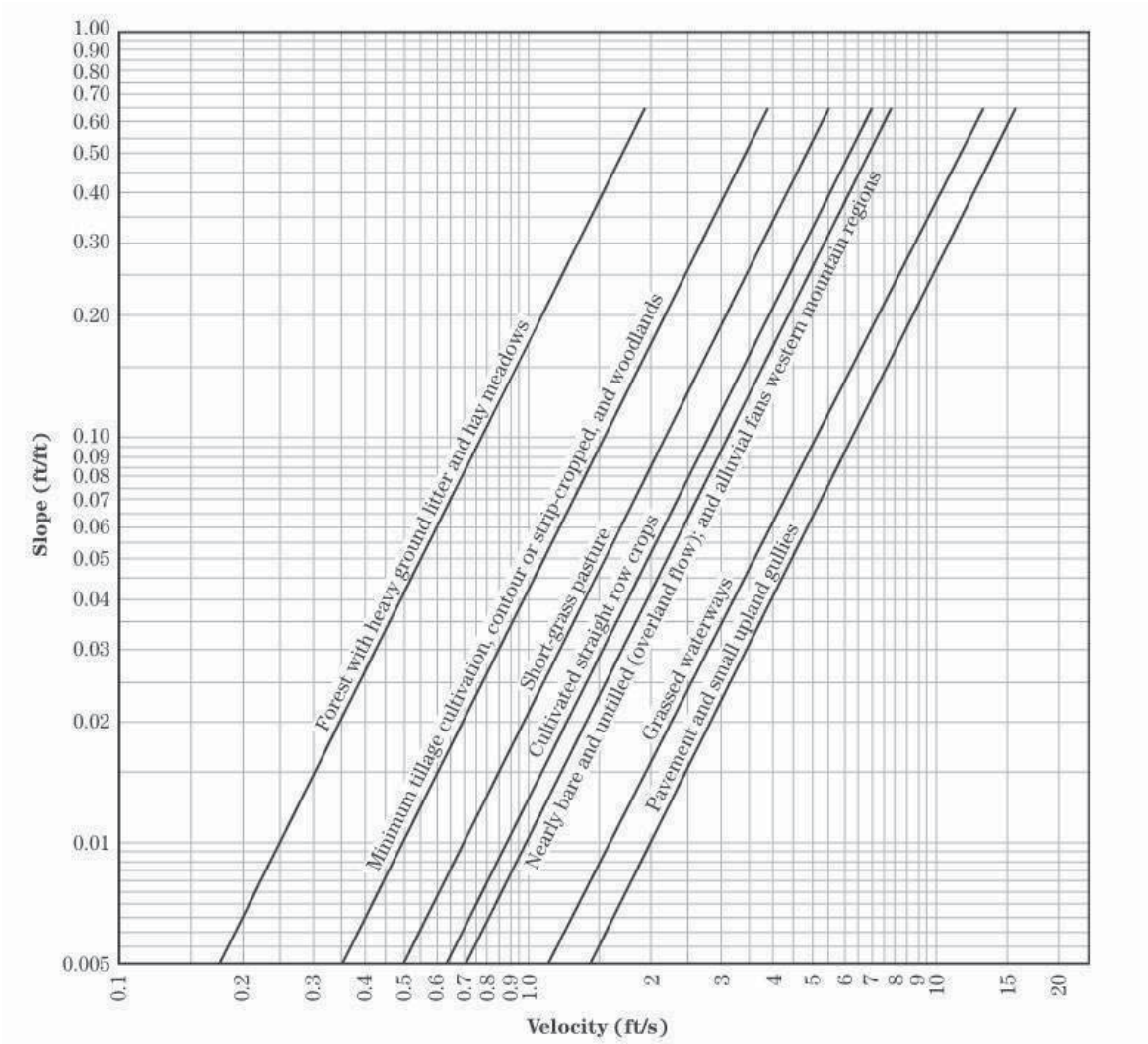
The area-weighted C value for each drainage area was then used in the Rational Method to compute the 2-year peak flow rate.

3.6.2 Time of Concentration

The NRCS Upland Method was used to estimate the time of concentration (t_c) for each of the drainage areas. Flow paths were divided into flow segments that were defined by various flow classifications, including short grass overland flow, paved area/shallow gutter flow, and storm sewer flow. Flow velocity for each flow segment was determined based on the flow classification and slope of flow path (except for storm sewer flow, which used a constant design flow velocity of 3 fps per standard design practice in the Greater Houston area). The travel time through each flow segment was summed for each drainage area

to obtain the time of concentration. ***Figure 14*** presents the NRCS Upland Method correlation between flow velocity, surface flow type and flow path slope.

Figure 14. Upland Method Correlation between Flow Velocity, Surface Type, and Slope



A ten-minute minimum time of concentration was utilized for all inlet drainage areas.

3.6.3 Rational Method

The Rational Method equation is expressed as:

$$Q = CIA$$

where:

Q = computed peak runoff discharge (cfs);
C = weighted runoff coefficient;
I = average rainfall intensity (in/hr); and
A = drainage area (ac).

The rainfall intensity was determined using the equation

$$I = \frac{b}{(t_c + d)^e}$$

where:

I = rainfall intensity (in/hr);
t_c = time of concentration (min); and
b, d, e = coefficients for each storm frequency.

The *b*, *d,* and *e* values for Harris County are presented in ***Table 3-4***.

Table 3-4. Harris County 2-Year Intensity-Duration-Frequency Coefficients

Coefficient	2-year
e	0.800
b	68
d	7.9

Once the runoff coefficient (*C*), average rainfall intensity (*I*), and drainage area acreage (*A*), were determined for each drainage area, these values were substituted into the Rational Method equation to calculate the 2-year peak flow rates. The Rational Method is usually used for drainage area less than 200 acres. The accumulative drainage area in this study draining to the Academy Street storm sewer and eventually to Kilmarnock Ditch (HCFCD Channel D113-00-00) is greater than 200 acres. This drainage area is divided into several sub-drainage areas that are less than 200 acres. The flow contributions to each node from these sub-drainage areas were calculated separately but summed at the nodes to comply with the criterion of a maximum drainage area of 200 acres for the Rational Method.

3.7 Calculated 2-Year Peak Flow Rates

The 2-year flow rates calculated using the Rational Method for the study storm sewer segments serving the areas of interest (see ***Exhibit 4***) are summarized in ***Table 3-5***. These 2-year flow rates were compared with the estimated capacities of existing storm sewer pipes to identify any capacity deficiencies in the existing systems. Note that the start node and end node of each storm sewer segment are shown on ***Exhibit 4***.

Table 3-5. Accumulative Drainage Area and 2-Year Flow Rate for Storm Sewer Segments

Storm Sewer Segment		Drainage Area (acres)	2-Year Flow Rate (cfs)	Existing Storm Sewer Capacity (cfs)	Deficiency (cfs)
From Node	To Node				
11-a	11	3.6	8.5	5.3	3.2
13	14	48	82.3	66.5	15.7
14-a	14	3.4	6.8	9.4	No Deficiency
11	15	17	32.7	21.2	11.5
14	15	52	89.1	28.8	60.2
12	15	32	50.4	47.7	2.7
15	16	121	211.3	58.9	152.5
16	17	136	225.1	71.2	153.9
18	20	3.3	8.7	5.3	3.4
19	20	3.5	9.6	5.3	4.3
20	21	11	27.8	14.7	13.1
17	21	179	258.7	71.2	187.5
21	28	200	279.2	84.8	194.4
23	25	3.0	8.1	5.3	2.8
24	25	4.8	8.6	5.3	3.3
25	26	12	21.0	5.3	15.7
26	27	17	27.2	5.3	21.9
27	28	33	48.5	14.7	33.8
28	29	240	303.5	84.8	218.7
29	30	284	351.0	84.8	266.2
30	31	298	353.1	84.8	268.3
31	32	308	360.4	84.8	275.6
32	33	318	360.4	84.8	275.6

3.8 Storm Sewer Conveyance Capacity Required

The street profiles show that each of the locations of interest where the ponding occurs are usually located at a low point along the street. In a storm event the runoff exceeds the storm sewer conveyance capacity serving these locations, and the excess of water cannot flow away via sheet (surface) flow, but accumulates and ponds at these locations.

The 2-year flow rates calculated by the Rational Method were used to evaluate the storm sewer systems serving these areas to check if the existing storm sewer has sufficient capacity to convey the 2-year flow, and if not, the required size of each storm sewer segment was estimated.

It is typically recommended that hydrologic and hydraulic modeling tools (e.g., SWMM or WinStorm) be used to evaluate storm sewer systems. However, modeling of storm sewer systems requires details of the systems, including the invert elevations of the storm sewer lines. This information was not available for this study. Because this study is a preliminary drainage analysis, instead of completing detailed storm sewer modeling, a rough storm sewer evaluation was performed using the required conveyance flow rates (i.e. the 2-year flow calculated above) and storm capacities based on an assumed constant average storm sewer flow velocity of 3 fps for all storm sewer lines to estimate the storm sewer size required. The

flow rate ($ft^{3/}sec$) in a storm sewer was divided by the flow velocity of 3 fps to determine the cross-sectional area required, and then to obtain the storm sewer dimensions that provide the required cross-sectional area. As stated above, this method only provides a rough estimate of the storm sewer size required, but it is adequate for this preliminary study. A detailed study involving storm sewer modeling is recommended for a more accurate evaluation.

Table 3-6 shows the approximate storm sewer sizes required to convey the 2-year flow in comparison with the existing storm sewer sizes. It can been seen that most of the existing storm sewer lines that serve the locations of interest do not have sufficient conveyance capacity, which explains at least in part why these locations frequently suffer ponding problems.

Table 3-6. Existing and Required Storm Sewer Size to Convey 2-Year Flow Rates

Storm Sewer Segment			Storm Sewer Size Required			
From Node	To Node	Existing Circular Pipe Diameter (ft)	Storm Sewer Shape	Diameter for Circular; or Width for Box (ft)	Height for Box (ft)	Barrel Quantity
11-a	11	1.5	Circular	2.0	-----	1
13	14	2.5 and 3.5	Circular	4.5	-----	2
14-a	14	2	Circular	2.0	-----	1
11	15	3	Circular	4.0	-----	1
14	15	3.5	Circular	6.5	-----	1
12	15	4.5	Circular	5.0	-----	1
15	16	5	Box	9	8	1
16	17	5.5	Box	9	9	1
18	20	1.5	Circular	2.0	-----	1
19	20	1.5	Circular	2.5	-----	1
20	21	2.5	Circular	3.5	-----	1
17	21	5.5	Box	10	9	1
21	28	6	Box	10	10	1
23	25	1.5	Circular	2.0	-----	1
24	25	1.5	Circular	2.0	-----	1
25	26	1.5	Circular	3.0	-----	1
26	27	1.5	Circular	3.5	-----	1
27	28	2.5	Circular	5.0	-----	1
28	29	6	Box	11	10	1
29	30	6	Box	11	11	1
30	31	6	Box	11	11	1
31	32	6	Box	11	11	1
32	33	6	Box	11	11	1

Table 3-7 summarizes the existing inlet capacity at each of the intersections of interest and the required capacity, which is the 2-year flow rate generated in the direct drainage area contributing to each intersection. The actual inlet capacity is affected by many factors. For this study, the evaluation of inlet capacity at each intersection is simplified by assuming an inlet capacity of 2 cfs for single B inlets or grate inlets and 4 cfs for double B inlets, which is typical capacity for these inlets. This assumption is considered adequate for the preliminary level study. Insufficient inlet capacity was found at the intersections of Academy Street and Albans Road and Academy Street and Bissonnet Street. In addition, inlet density is found to be inadequate on the bounding street gutters around the City of Houston commercial section bounded by Law Street, Academy Street and Bissonnet Street. The area is indicated

on both ***Exhibit 6*** and ***Exhibit 7***. The inlet density on Weslayan Street between Law Street and Bissonnet Street within the commercial section also appears to be insufficient. The excess of flow from the commercial section is likely to make its way to surrounding intersections and may cause ponding within the City of West University Place.

Note that the required capacity presented in ***Table 3-7*** is only the runoff generated within the direct drainage area contributing to the intersections of interest and does not account for any additional flows that exceed the capacity of nearby street inlets and travel along the street gutters to the intersections of interest. It is likely that some intersections will receive the excess of flow from surrounding areas, especially the intersections of Academy Street and Bissonnet Street, Academy Street and Albans Road, and Fairmont Street and Judson Avenue, because they are close to the commercial section bounded by Academy Street, Law Street and Bissonnet Street where the bounding street gutters appear to lack adequate inlet density. The quantification of the excess of runoff from other inlets requires a more detailed storm sewer modeling tool (e.g. WinStorm or SWMM) and is not reflected in this preliminary study.

Table 3-7. Summary of Inlet Capacity

Intersection	Number of Inlet	Type of Inlet	Available Capacity (cfs)	Required Capacity (cfs)	Additional Double B Inlets
Academy Street at Albans Road	2	Double B	8	8.5	1
Fairmont Street at Judson Avenue	3	Double B	12	7.3	0
Academy Street at Bissonnet Street	2	One single B; One double B	6	14.7	2
West Point Street at Amherst Street	4	Double B	16	12.2	0
West Point Street at Oberlin Street	4	Double B	16	8.6	0
West Point Street at Villanova Street	4	Double B	16	10.4	0

It should be noted that inlet capacity has been supplemented over the years as streets have been repaired or upgraded. Thus, inlet capacity appears to be adequate at many of the intersections evaluated in connection with this study and report. However, storm sewer systems have not been upgraded for the most part in the identified areas of interest, and they show deficiencies when compared with standard 2-year design flow rates.

A rough cost estimate for upgrading the existing storm sewer systems analyzed in this study to standard 2-year design storm sewer and inlet capacity was prepared for this report. The cost estimate includes the removal of existing undersized storm sewer systems (inlets, manholes and storm sewer lines), the removal of pavement, the replacement of inlets, manholes, storm sewer lines, and pavement, and provisions for a potential detention requirement. The estimate includes 15% for ancillary items and another 15% for contingencies. Since the detailed inlet and manhole database is not available, it was assumed for cost estimating that there are four inlets at each four-way intersection and three at each “T” intersection. It is also assumed that there is a manhole at each storm sewer junction to estimate the number of manholes.

The detention requirement was estimated using a Basin Development Factor (BDF) approach developed by HDR for the Harris County Flood Control District to estimate detention requirements in urban areas. The worksheet facilitates determination of the total BDF value, which is a function of channel, storm sewer, and street conditions, for both existing conditions and improved conditions with 2-year capacity. The difference between the existing and improved BDF values was then used to estimate the detention storage rate (ac-ft of required detention storage per acre of drainage area) based on a Detention Storage Rate versus Change in BDF Value chart. The detention storage rate to improve the project area was determined to be 0.12 ac-ft of detention per acre of drainage area. For a total drainage area of 270 acres for the area within West University Place analyzed in connection with this study and report, the total required detention volume was then determined to be 0.12 ac-ft/acre x 270 acres = 32.4 ac-ft. Note that the COH area that drains to West University Place was excluded in determining the storage requirement as it is assumed that West University Place does not need to improve the City of Houston storm sewer system and does not need to provide storage for the COH drainage area. A detention basin depth of 6.5 ft (including 1 ft unusable freeboard) was used to estimate the total acreage of the detention basin, which includes 30-ft maintenance berms around the basin. The total area of the detention basin site was determined to be approximately 8.2 acres.

The cost estimate is presented in ***Table 3-8***. The unit prices were taken from the City of Houston's *FY15 Pre-Engineering Bid Unit Prices*. The cost for land acquisition was estimated based on an approximate average HCAD value of $15 per square ft in the general project area. A multiplier of 3 was then applied to the average HCAD value to estimate the land acquisition cost.

Table 3-8. Cost Estimate of Storm Sewer System Improvement for Project Area

ITEM	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
1	Remove Storm Sewer Pipe (All Types)	LF	$15	14,175	$212,625
2	Remove Storm Sewer Box (All Types)	LF	$15	0	$0
3	Remove Inlets (All Types)	EA	$340	132	$44,880
4	Remove Manholes (All Types, All Depths)	EA	$350	24	$8,400
5	Inlets (All Types)	EA	$2,150	132	$283,800
6	Manholes (42" Dia Pipe and Smaller) (All Types)	EA	$2,800	10	$28,000
7	Manholes (48" to 72" Dia Pipe) (All Types)	EA	$6,000	4	$24,000
8	Manholes (78" Dia Pipe and Larger) (All Types)	EA	$10,000	9	$90,000
9	24" RCP	LF	$75	2,469	$185,175
10	30" RCP	LF	$105	521	$54,705
11	36" RCP	LF	$126	259	$32,634
12	42" RCP	LF	$142	1,011	$143,562
13	48" RCP	LF	$173	1,270	$219,710
14	54" RCP	LF	$221	840	$185,640
15	60" RCP	LF	$277	1,379	$381,983
16	66" RCP	LF	$311	0	$0
17	72" RCP	LF	$355	0	$0
18	78" RCP	LF	$425	83	$35,275
19	9'X8' RCB	LF	$600	702	$421,200
20	9'X9' RCB	LF	$600	584	$350,400
21	10'X9' RCB	LF	$600	570	$342,000
22	10'X10' RCB	LF	$600	768	$460,800
23	11'X10' RCB	LF	$600	991	$594,600
24	11'X11' RCB	LF	$600	1,657	$994,200
25	12'X11' RCB	LF	$1,200	0	$0
26	Trench Safety System	LF	$2	27,590	$55,180
27	Remove Pavement	SY	$6	36,680	$220,080
28	8" Reinforced Concrete Pavement	SY	$43	36,680	$1,577,240
29	Detention Pond (DRY)	AC-FT	$20,000	32.4	$648,000
30	Detention Pond Land Acquisition	AC	$1,960,200	8.2	$16,073,640
				COST	**$23,667,729**
				20% ANCILLARY ITEMS	**$4,733,546**
				20% GENERAL ITEMS	**$4,733,546**
				TOTAL COST	**$33,134,821**

4.0 Conclusion

Based on the results of the analysis described in this report, the following conclusions are reached.

1. A significant portion of the City of West University Place is within the regulatory floodplain of Brays Bayou (HCFCD Channel ID D100-00-00) designated as Zone AE with defined flood elevations. In an extreme storm event, the floodplain is affected by the water from Brays Bayou (via overtopping of the channel banks and backwater through channels and storm sewer lines). Improving storm sewer systems alone in areas located within the regulatory floodplain would not solve the flooding issue caused by Brays Bayou.

2. The ponding intersections studied are located at low points along the roadway profile. Runoff water that exceeds the conveyance capacity of the storm sewer lines serving these areas cannot sheet-flow away, but accumulates and ponds at these intersections.

3. Most of these ponding intersections have sufficient inlet capacity. However, the following intersections were found to have insufficient inlet capacity:

    - Academy Street at Albans Road;
    - Academy Street at Bissonnet Street.

4. The commercial area bounded by Law Street, Academy Street and Bissonnet Street does not have adequate onsite inlets. The inlet density does not appear to be adequate on the gutters of Law Street, Academy Street, Bissonnet Street and Weslayan Street, all of which bound or pass through the commercial area, which is located within the City of Houston.

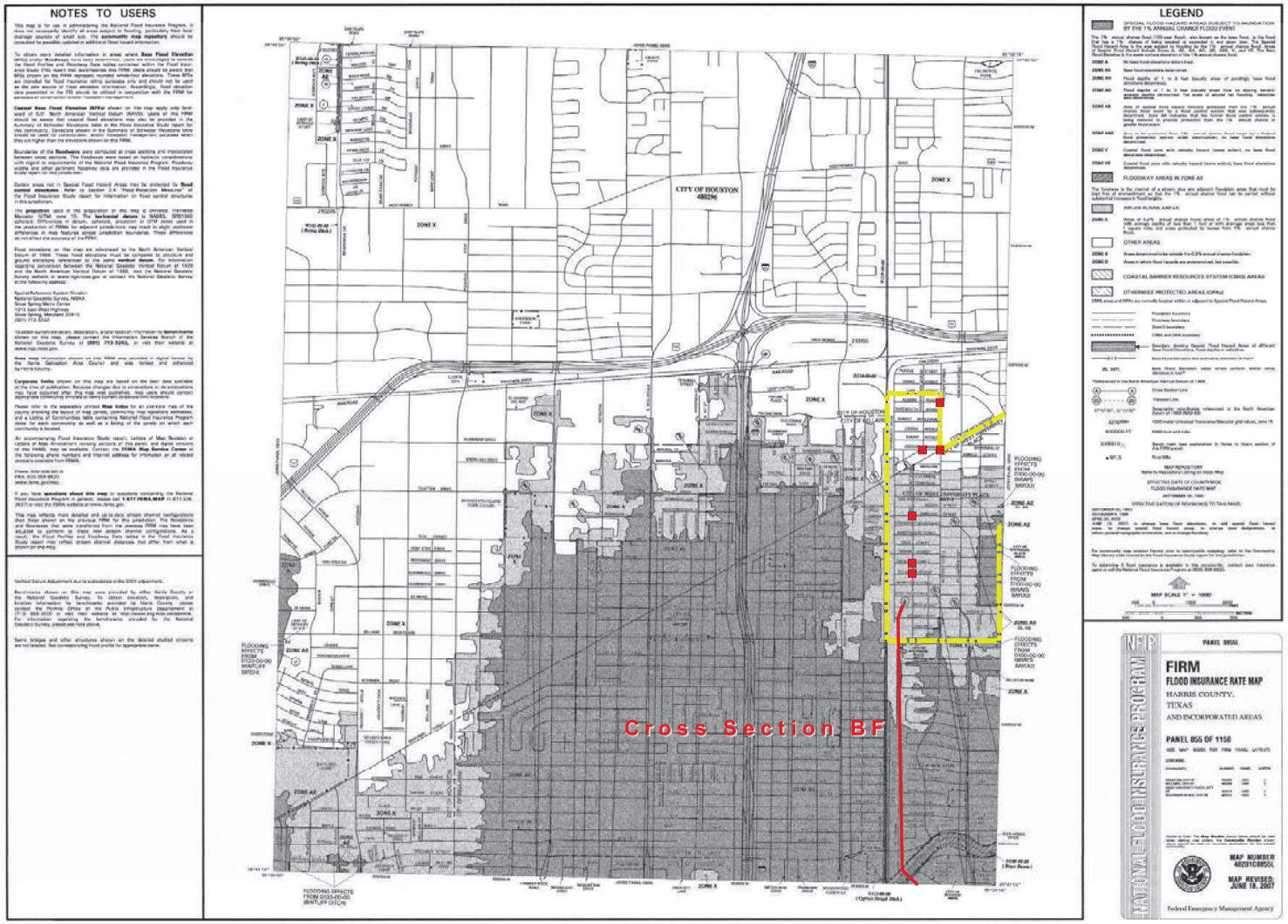
5. The existing conveyance capacities of most storm sewer lines serving these locations of interest are not sufficient for the current standard 2-year design storm. These existing storm sewer lines will have to be upsized in order to satisfy the 2-year flow rate capacity requirement. The approximate storm sewer sizes required to convey the 2-year flow rates are presented in ***Table 3-6***.

6. A further study using more detailed storm sewer system modeling tools is recommended to size the storm sewer lines in order to account for the slope of the storm sewer system with accurate storm sewer invert elevations, roadway and top of curb elevations, inlet throat elevations and measurements, and other important details. Such a detailed modeling study requires survey to obtain the existing storm sewer elevation data.

EXHIBIT 1. AREAS OF INTEREST AND VICINITY MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\KPS\WMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX01.MXD - USER: MXIAO - DATE: 2/11/2016



Ponding Locations of Interest

EXHIBIT 2. FLOODPLAIN MAP OF WEST UNIVERSITY PLACE (MAP NUMBER 48201C0855L)

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH : X:\KPS\WMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX02.MXD - USER: MXIAO - DATE: 2/11/2016

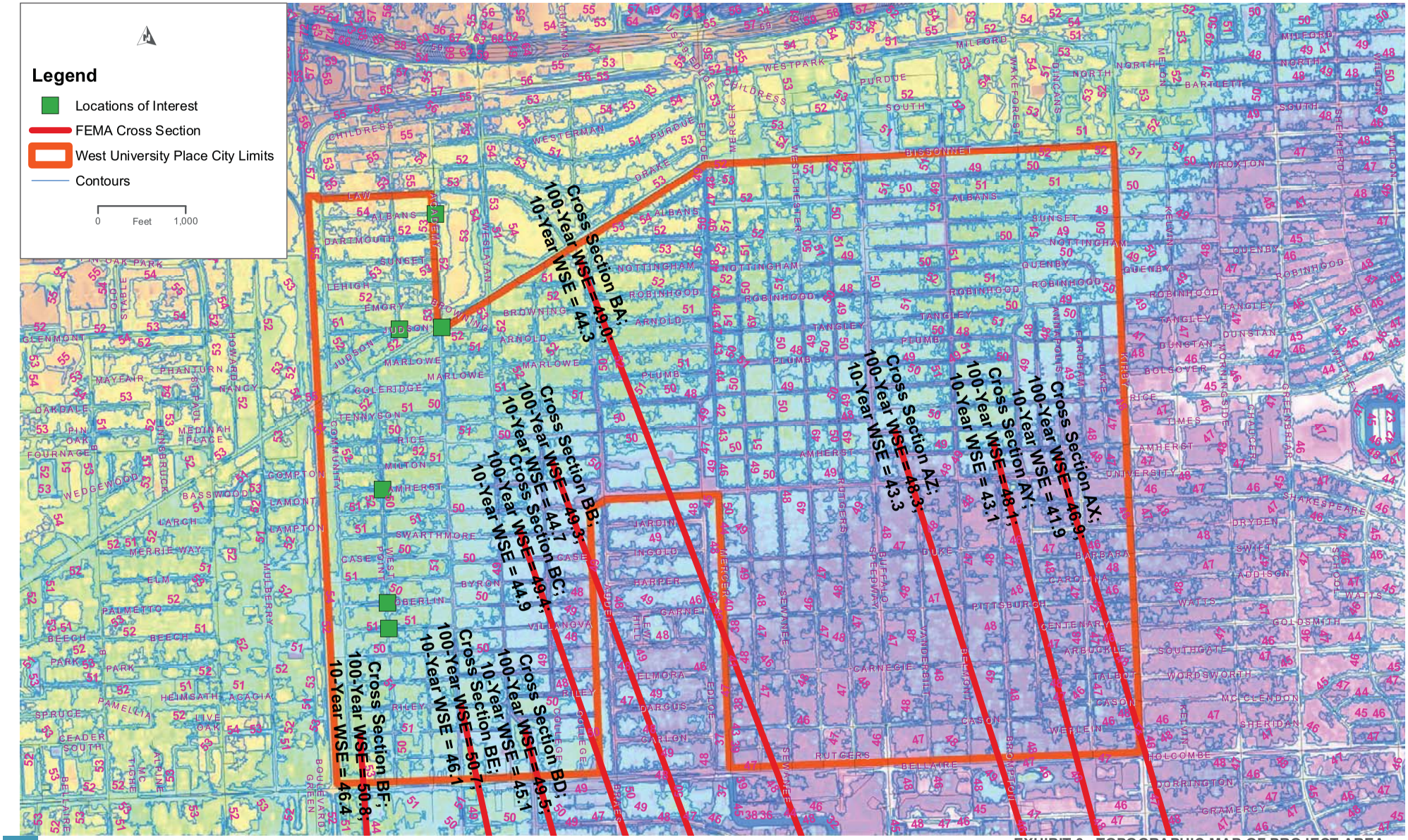


EXHIBIT 3. TOPOGRAPHIC MAP OF PROJECT AREA

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\KPS\WM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX03.MXD - USER: MXIAO - DATE: 2/11/2016

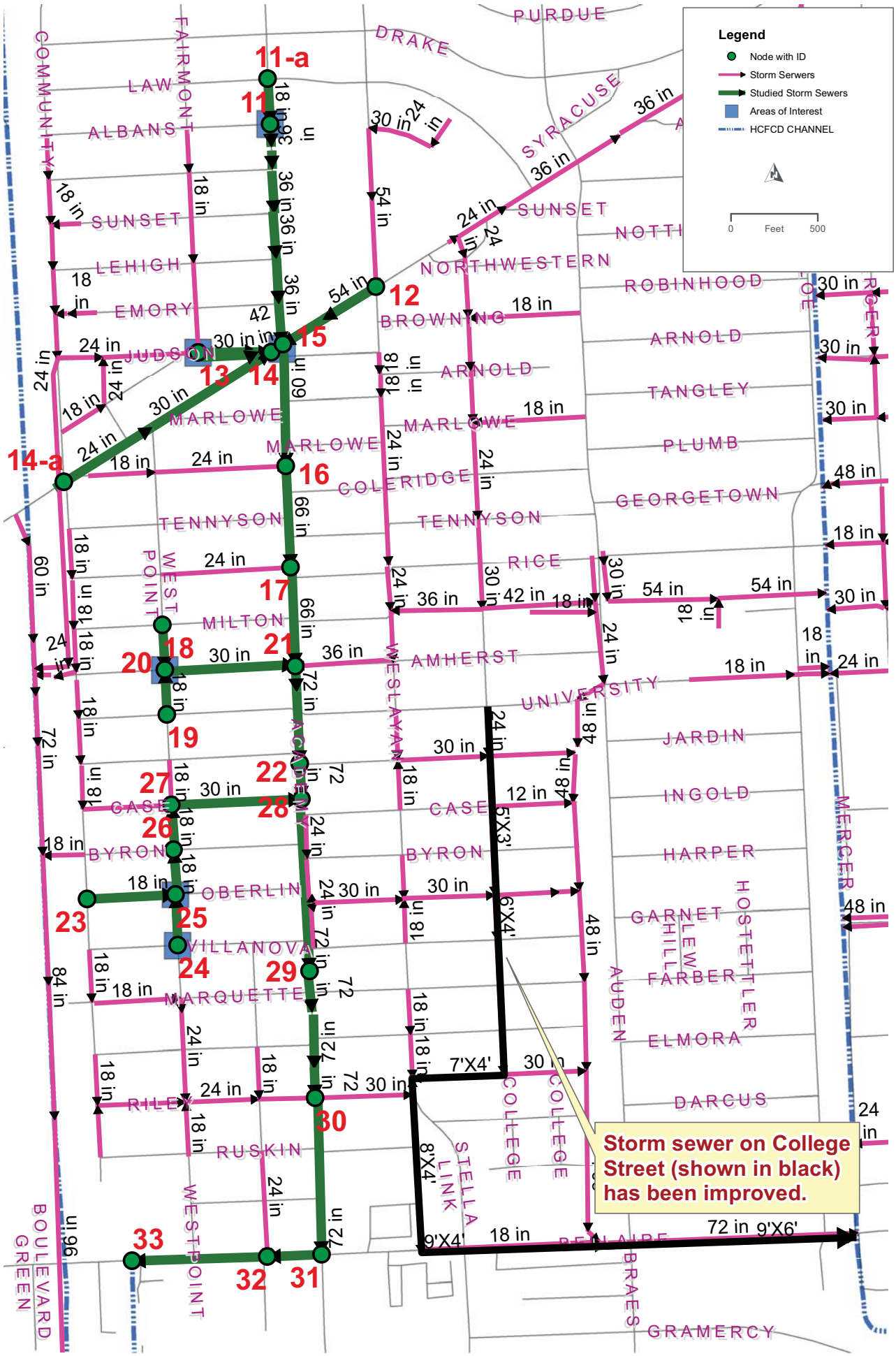


EXHIBIT 4. STORM SEWER LAYOUT IN PROJECT AREA

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATION IN WEST UNIVERSITY PLACE

PATH: X:\XP\SWMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX04.MXD - USER: MXIAO - DATE: 3/4/2016

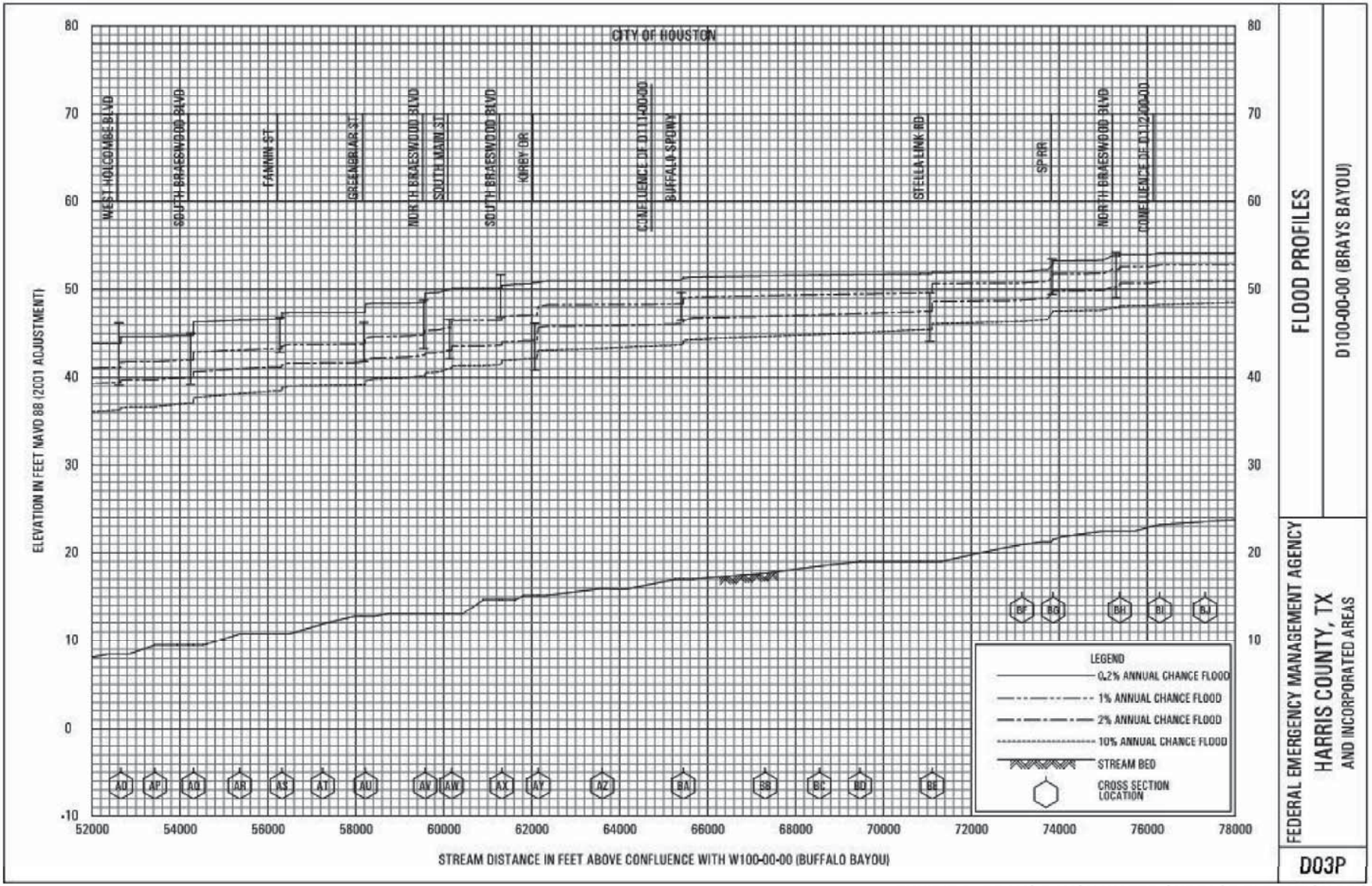


EXHIBIT 5. BRAYS BAYOU WATER SURFACE ELEVATION PROFILES

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\KPS\WMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX05.MXD - USER: MXIAO - DATE: 2/12/2016

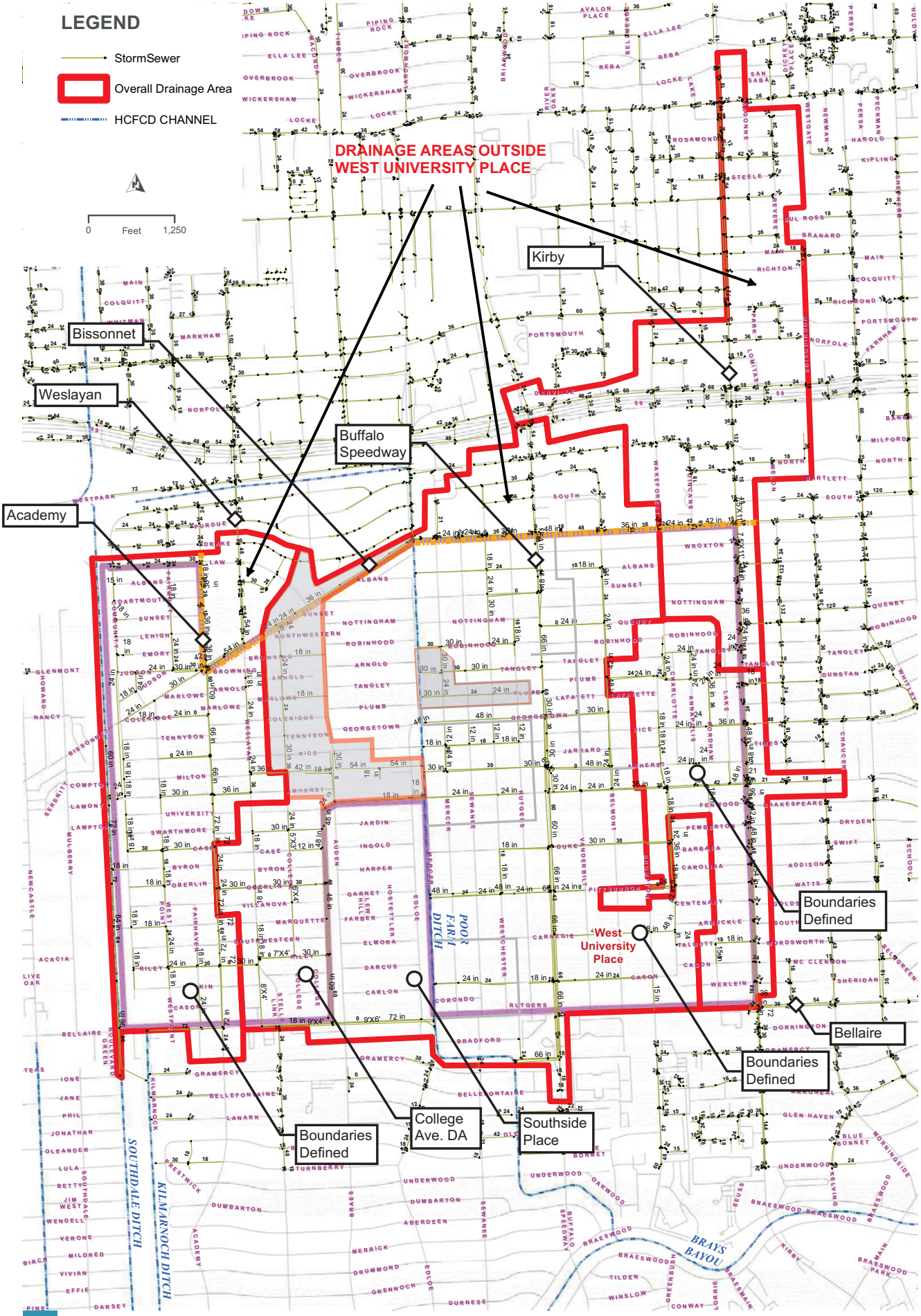


EXHIBIT 6. OVERALL DRAINAGE AREA MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\XPSWMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX06.MXD - USER: MXIAO - DATE: 2/16/2016

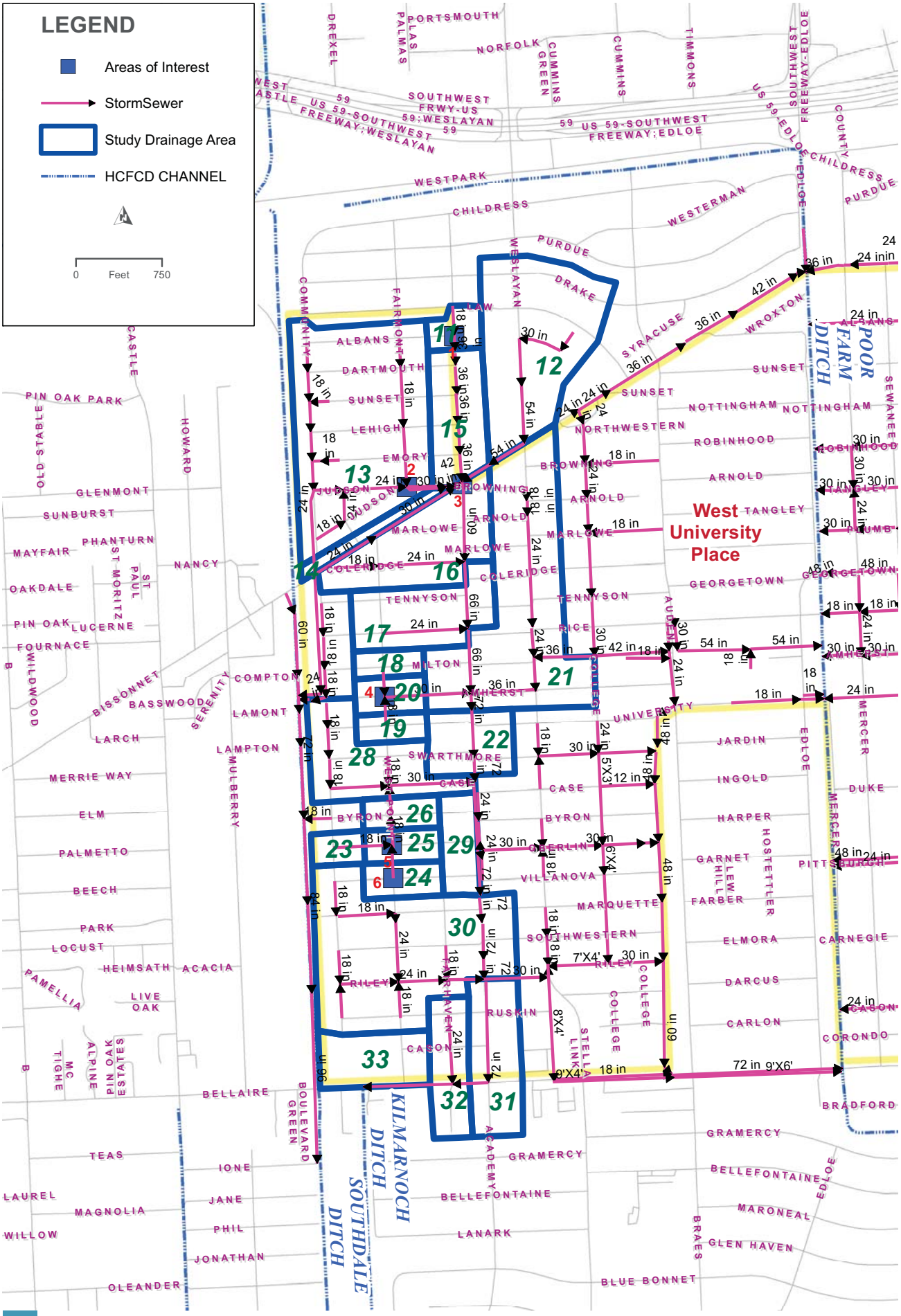


EXHIBIT 7. STUDY DRAINAGE AREA MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\XPSWMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX07.MXD - USER: MXIAO - DATE: 3/4/2016

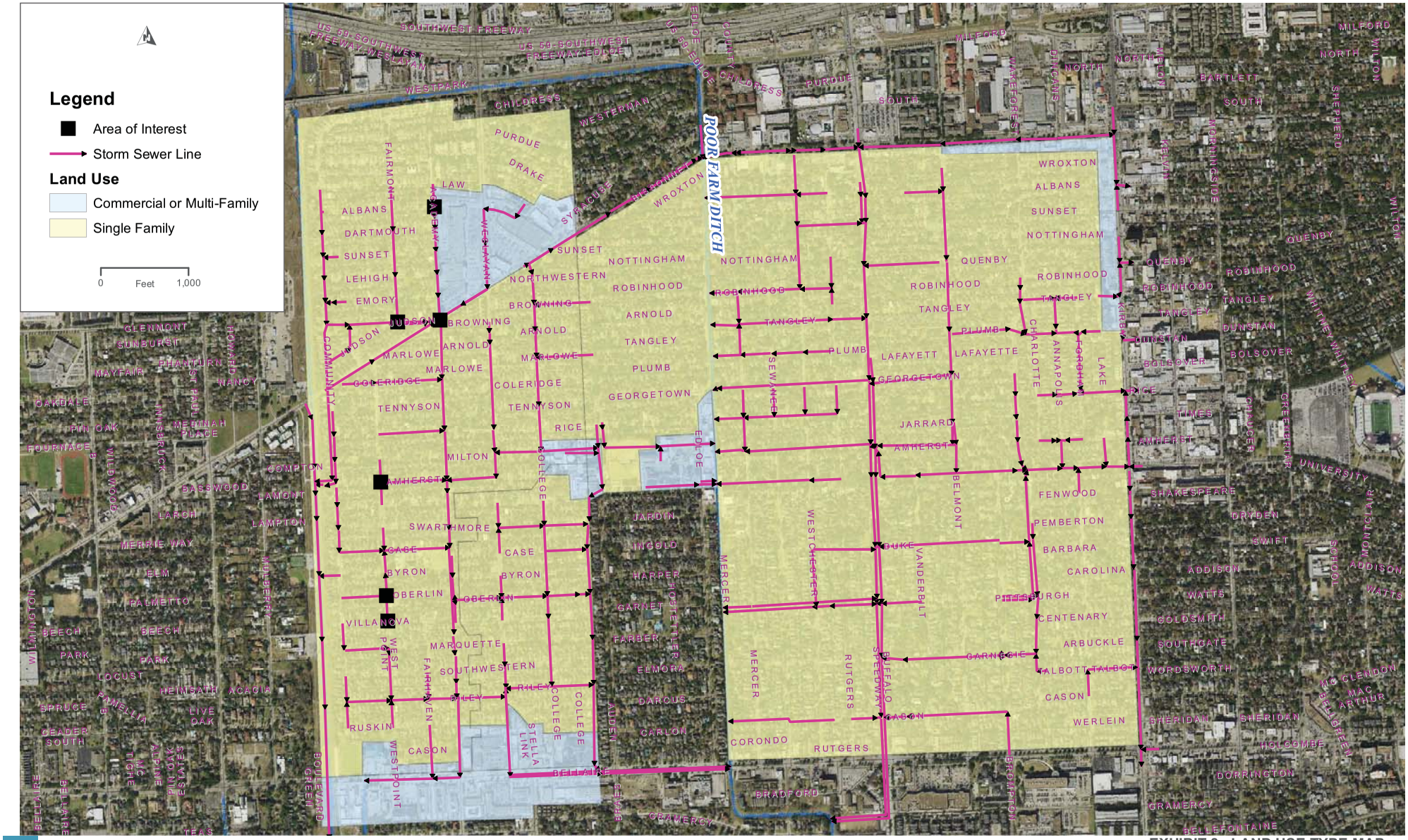


EXHIBIT 8. LAND USE TYPE MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR SIX PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH : X:\KPS\WM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT1_EX\WESTUNIVREPORT1_EX08.MXD - USER: MXIAO - DATE: 2/12/2016

Appendix

C

Poor Farm Ditch Conveyance Preliminary Engineering Report

Freese & Nichols, Inc.

September 2017

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

Innovative approaches
Practical results
Outstanding service

POOR FARM DITCH CONVEYANCE PRELIMINARY ENGINEERING REPORT

Prepared for:

Harris County Flood Control District

September 27, 2017

Prepared by:

FREESE AND NICHOLS, INC.
10497 Town and Country Way, Suite 600
Houston, Texas 77024
713-600-6800

FREESE AND NICHOLS

Innovative approaches
Practical results
Outstanding service

POOR FARM DITCH CONVEYANCE PRELIMINARY ENGINEERING REPORT

Prepared for:

Harris County Flood Control District

STATE OF TEXAS
KALLI CLARK-EGAN
122407
LICENSED
PROFESSIONAL ENGINEER
9-27-2017

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

STATE OF TEXAS
CORY J. STULL
113321
LICENSED
PROFESSIONAL ENGINEER
9/27/17

FREESE AND NICHOLS, INC.
TEXAS REGISTERED
ENGINEERING FIRM
F-2144

[For Hydrology and Hydraulics]

Prepared by:

FREESE AND NICHOLS, INC.
10497 Town and Country Way, Suite 600
Houston, Texas 77024
713-600-6800

HCF15148

TABLE OF CONTENTS

EXECUTIVE SUMMARY ES-1

1.0 INTRODUCTION 1
1.1 Background 1
1.2 Purpose 6

2.0 EXISTING CONDITIONS 8
2.1 Existing Configuration 8
2.1.1 Channel Reach Upstream of the University Boulevard Crossing 8
2.1.2 University Boulevard Crossing 9
2.1.3 Channel Reach Between University Boulevard and Bellaire Boulevard 10
2.1.4 Bellaire Boulevard Crossing 14
2.1.5 Channel Reach Downstream of Bellaire Boulevard Crossing 15
2.2 Existing Stormwater Conditions 16
2.2.1 Design Cross-Section 17
2.2.2 Existing Cross-Section 18

3.0 TEMPORARY EXCAVATIONS 20

4.0 CHANNEL DESIGN ALTERNATIVES 22
4.1 Box Culverts 22
4.1.1 Conceptual Design 22
4.1.2 Stormwater Analysis 23
4.2 Rectangular Channel 26
4.2.1 Conceptual Design 26
4.2.2 Stormwater Analysis 28
4.3 Permanently Nailed Soil Wall 31
4.3.1 Conceptual Design 31
4.3.2 Stormwater Analysis 33
4.4 Stormwater Analysis Summary 35
4.5 Construction Considerations 38
4.5.1 Mobilization 38
4.5.2 Demolition 39
4.5.3 Concrete Placements 39
4.5.4 Procurement of Construction 39
4.5.5 Care and Control of Water 40
4.5.6 Construction Duration 41
4.6 Longterm Maintenance Considerations 42
4.7 Comparison of Probable Construction Cost Items 43

5.0 EVALUATION OF ALTERNATIVES 45

5.1 Metrics for Evaluation Criteria 45
5.1.1 Hydraulic Capacity 45
5.1.2 Project Cost 46
5.1.3 Design Life 46
5.1.4 Maintenance 47
5.1.5 Construction Duration 47
5.1.6 Impact of Construction Activities 47
5.2 Weighted Factors Analysis 48
5.3 Pairwise Analysis 49

6.0 SUMMARY AND RECOMMENDATION 52

Table of Figures

Figure 1-1: Cross-Section Depicting Constrained Portions of Poor Farm Ditch 2
Figure 1-2: Parson Brinckerhoff's Recommended Channel Configuration 4
Figure 1-3: HCFCD New Design Concept 5
Figure 2-1: View of Channel Reach Upstream of University Boulevard Crossing 9
Figure 2-2: Downstream End of University Boulevard Crossing 10
Figure 2-3: View of Transition Zone Downstream of University Boulevard Crossing 11
Figure 2-4: View of Concrete Buckling Damage Along Project Reach 12
Figure 2-5: View of Concrete Pavement Damages Along Project Reach 12
Figure 2-6: View of Temporary Stabilization Measures Along Project Reach (2015) 13
Figure 2-7: View of Temporary Stabilization Measures Along Project Reach (2017) 13
Figure 2-8: Upstream End of Bellaire Boulevard Crossing 14
Figure 2-9: Downstream End of Bellaire Boulevard Crossing 15
Figure 2-10: View of Channel Reach Downstream of Bellaire Boulevard Crossing 16
Figure 2-11: Effective Model Cross-Section 6656.935 18
Figure 2-12: Corrected Effective Model Cross-Section 6656.935 19
Figure 3-1: Factor of Safety Chart for Temporary Excavations 21
Figure 4-1: Alternative 1A Design Configuration 22
Figure 4-2: Alternative 1B Design Configuration 23
Figure 4-3: Alternative 1A Typical Model Cross-Section 24
Figure 4-4: Alternative 1B Typical Model Cross-Section 25
Figure 4-5: Alternative 2A Design Configuration 26
Figure 4-6: Alternative 2B Design Configuration 26
Figure 4-7: Alternative 2C Design Configuration 27
Figure 4-8: Alternative 2A Typical Model Cross-Section 28
Figure 4-9: Alternative 2B Typical Model Cross-Section 29
Figure 4-10: Alternative 2C Typical Model Cross-Section 30
Figure 4-11: Alternative 3A Design Configuration 31
Figure 4-12: Alternative 3B Design Configuration 31
Figure 4-13: Factor of Safety Chart for Permanent Excavations 32
Figure 4-14: Alternative 3A Typical Model Cross-Section 34
Figure 4-15: Alternative 3B Typical Model Cross-Section 35
Figure 4-16: Estimated Construction Duration 42

Figure 6-1: 3D Rendering of Alternative 3B 54

Table of Tables

Table 4-1: Summary of Maximum WSEL Increases Within or Upstream of the Study Reach (feet) 36
Table 4-2: Summary of Maximum WSEL Decreases Within or Upstream of the Study Reach (feet) 36
Table 4-3: Summary of Average WSEL Changes in Study Reach (feet) 37
Table 4-4: Approximate Level of Service of Each Alternative 37
Table 4-5: Summary of Probable Construction Cost Items 44
Table 5-1: Hydraulic Capacity Scoring Criteria 46
Table 5-2: Project Cost Scoring Criteria 46
Table 5-3: Design Life Scoring Criteria 47
Table 5-4: Maintenance Scoring Criteria 47
Table 5-5: Construction Time Scoring Criteria 47
Table 5-6: Impact of Construction Activities Scoring Criteria 48
Table 5-7: Weighted Factor Ranking of Channel Cross-Section Alternatives 49
Table 5-8: Calculation of Pairwise Weighting Factors for Evaluation Criteria 50
Table 5-9: Pairwise Ranking of Channel Cross-Section Alternatives 50

APPENDICES

APPENDIX A: EXISTING CONDITIONS
APPENDIX B: REFERENCES
APPENDIX C: GEOTECHNICAL ANALYSIS
APPENDIX D: DESIGN EXHIBITS
APPENDIX E: STORMWATER ANALYSIS
APPENDIX F: ESTIMATES OF PROBABLE CONSTRUCTION COST ITEMS (CHANNEL ONLY)
APPENDIX G: TOTAL PROJECT COSTS (ALTERNATIVES 3A AND 3B)
APPENDIX H: ENGINEERING REVIEW BOARD SUMMARY DOCUMENT
APPENDIX I: PRELIMINARY MITIGATION RESULTS

EXECUTIVE SUMMARY

On July 23, 2015, the Harris County Flood Control District (HCFCD) issued a contract for Freese and Nichols, Inc. (FNI) to develop the construction documents for improvements to HCFCD Unit Number D111-00-00 (Poor Farm Ditch).

Poor Farm Ditch is a tributary to Brays Bayou (D100-00-00) and provides drainage to approximately 1,330 acres of developed watershed. The project reach is situated between the cities of Southside Place (SSP) on the west side of the channel and West University Place (WUP) on the east side of the channel between University Boulevard and Bellaire Boulevard. On July 16, 2014, an Approved Jurisdictional Determination (AJD) was issued for this reach of Poor Farm Ditch by the United States Army Corps of Engineers (USACE). This AJD (SWG-2009-00591), which expires on July 16, 2019, indicates that Poor Farm Ditch is non-jurisdictional by USACE.

The HCFCD right-of-way (ROW) within the project reach varies from 45 feet to 80 feet. For the first 420 feet of the most downstream reach, the HCFCD ROW width varies between 60 feet and 80 feet. For the next 615 feet upstream, the ROW width is 55 feet. The ROW then narrows to 50 feet for 2,030 feet further upstream, of which 20 feet is an easement within SSP and 30 feet is a joint-use agreement with the city of WUP. For the remaining 40 feet of the project reach, the HCFCD ROW is 45 feet wide.

This portion of Poor Farm Ditch is over 55 years old, and the reinforced concrete slope pavement has deteriorated significantly and buckled at many locations. HCFCD has historically performed spot repairs to prevent an overall failure of the channel, but these repairs are only short-term solutions. Some property owners within SSP have encroached into the easement by placing fill and various structures along the channel, which has exacerbated the issues. Existing conditions are further discussed in Section 2.0. Due to the continued deterioration of the channel, a full rehabilitation is required.

Multiple efforts were undertaken to evaluate options for this full rehabilitation as described further in Section 1.0. On October 9, 2014, HCFCD held an audit committee meeting to discuss the project. There were three options discussed along with a new concept developed internally within HCFCD, which was based on the information provided as part of previous evaluations. This new concept included two 7-feet wide by 9-feet tall reinforced concrete box culverts (RCBs) placed on the outside edges of a 40-feet wide corridor with a concrete lined open channel (approximately 15-feet wide) in between.

After performing a geotechnical investigation as well as a topographic survey of the project reach, FNI identified multiple concerns associated with the culvert design concept. Discussions were held with HCFCD to present the preliminary findings and determine a path forward. HCFCD issued a contract amendment on September 9, 2016, authorizing FNI to proceed with developing a Preliminary Engineering Report (PER) to identify and evaluate channel cross-section alternatives associated with improving Poor Farm Ditch. This work was authorized under Purchase Order P250265 of the Professional Service Agreement (PSA) Number 2016-07.

This PER presents conceptual level designs for the following seven alternatives associated with improving the identified project reach of Poor Farm Ditch:

- Alternative 1A: Installation of two 7x7 RCBs separated by a rectangular open channel configuration that includes a slab on grade constructed using an excavation stabilized with temporary soil nails;
- Alternative 1B: Installation of two 7x7 RCBs separated by a rectangular open channel configuration that includes a slab on grade constructed using a vertical excavation stabilized with shoring methods;
- Alternative 2A: Cast-in-place rectangular channel constructed using a sloped excavation stabilized with temporary soil nails;
- Alternative 2B: Cast-in-place rectangular channel constructed using a vertical excavation stabilized with vertical shoring methods;
- Alternative 2C: Cast-in-place rectangular channel constructed using both sloped and vertical excavation stabilized by a combination of temporary soil nails and vertical shoring methods;
- Alternative 3A: Trapezoidal channel with reinforced concrete slope pavement anchored by permanent soil nails extending to the existing 50-feet HCFCD ROW; and
- Alternative 3B: Trapezoidal channel with reinforced concrete slope pavement anchored by permanent soil nails extending to the proposed 40-feet HCFCD ROW.

A geotechnical analysis was performed for the temporary excavations required during construction and is further discussed in Section 3.0. The design concepts are presented with additional detail in Section 4.0. Each feasible channel cross-section alternative was evaluated regarding hydraulic capacity, project cost, design life, maintenance, construction duration, and impact of construction activities as further discussed in Section 5.0. Evaluations included analyzing the alternatives using both a weighted factors method and a Pairwise method.

Using the weighted factors method to evaluate the five alternatives, Alternatives 3A and 3B were both

ranked the highest. Using the Pairwise method, Alternative 3B was ranked the highest with Alternative 3A as the second highest.

Alternative 3B was ranked high based upon the following:

- Decrease in WSELs when compared to both the Effective Model and Corrected Effective Model for all storm events;
- Lowest cost for the items associated with the design configuration; and
- Least impact of construction activities to nearby residences.

The most significant tradeoffs associated with this alternative when compared to others is that the desired HCFCD maintenance access along the channel is not feasible, the time of construction is longer than all other alternatives, the hydraulic benefits are not as great when compared to Alternative 3A, and the design life is slightly less than other alternatives.

Alternative 3A is similar in geometry to Alternative 3B but has a wider cross section with permanent soil nails utilizing the full 50-feet HCFCD ROW. The only difference in scoring was that this alternative had more of a significant impact of construction activities to nearby residences due to the extended soil nails; however, this alternative provided greater hydraulic benefits when compared to Alternative 3B, as it lowered WSELs by an additional 0.2 feet on average within the study reach.

For HCFCD to evaluate the implementation of either of these alternatives and coordinate with each of the cities, total project costs were developed for Alternatives 3A and 3B. A breakout of each total project cost is included as Appendix G. The total project costs for Alternatives 3A and 3B are $23,740,768 and $20,350,561, respectively. The following assumptions are noted:

- The Opinion of Probable Construction Costs (OPCCs) for Alternative 3A and 3B were determined to be $20,904,585 and $17,644,770, respectively. The OPCCs include a 30% contingency factor to account for:
    - Uncertainties associated with the contractor's care of water plan, as well as dealing with limited site access and staging opportunities; and
    - Adjusting, or working around, existing and proposed structures and facilities adjacent to the channel. Specific items already identified include a proposed concrete-lined swale feature within SSP, and an existing sanitary sewer lift station as well as a group of

maintenance boxes associated with ATT underground cables within WUP.

- The total engineering design fee, inclusive of FNI's contract as well as previous studies, was set equal to $2,000,000.00; and
- The anticipated construction management fees were set equal to 4 percent of the respective OPCCs.

On April 20, 2017, a meeting was held with HCFCD's Engineering Review Board (ERB) to consider the findings, existing conditions, conveyance, and encroachment issues identified during the preliminary engineering phase of the project. An additional objective of this meeting was to solicit concurrence for moving forward with the final design of Alternative 3B. At the conclusion of this meeting, the recommendation to move forward with the final design of Alternative 3B was unanimously approved by the ERB.

After establishing Alternative 3B as the preferred alternative, FNI performed a preliminary analysis at the request of HCFCD to determine if additional volume would be required in the Meyer Basin to mitigate the proposed channel improvements. The memorandum documenting this analysis is provided in Appendix I. While there are several variables which will impact final design and, ultimately, the final mitigation volume required, it is expected that the volume previously allocated within the Meyer Basin is adequate in mitigating the proposed channel improvements associated with Alternative 3B.

Based on the feedback received at the ERB meeting, as well as per subsequent direction given by HCFCD, the following items reflect activities that will be incorporated into the final design of Alternative 3B:

- Based on the anticipated needs of HCFCD's Infrastructure Department, incorporate at least two permanent maintenance access points;
- Incorporate provisions for public safety and deterrence of trespassing along the project reach; and
- Perform an expanded Impact Analysis to include:
    - Development of a detailed steady state hydraulic model which incorporates topographic survey data to reflect the current channel condition;
    - An evaluation of Brays Bayou backwater conditions for the Current Effective and Brays

Bayou Conditional Letter of Map Revision (CLOMR) modeling;

- Development of an unsteady state hydraulic model to evaluate potential for increases in flows and WSE downstream of the project reach; and
- An evaluation of potential impacts to storm sewer outfalls downstream of the project reach.

At the request of HCFCD's stormwater quality department, FNI evaluated the feasibility of implementing water quality enhancements along the project reach. FNI specifically consulted the document entitled, "HCFCD Water Quality Enhancement Section for Preliminary Engineering Report (PER) or Project Design Report (PDR)" to determine its applicability to the content presented in this PER. It was determined by HCFCD and FNI project team members that the project reach does not have sufficient opportunities for water quality enhancements. It was further concluded that such enhancements would not be required along the project reach given:

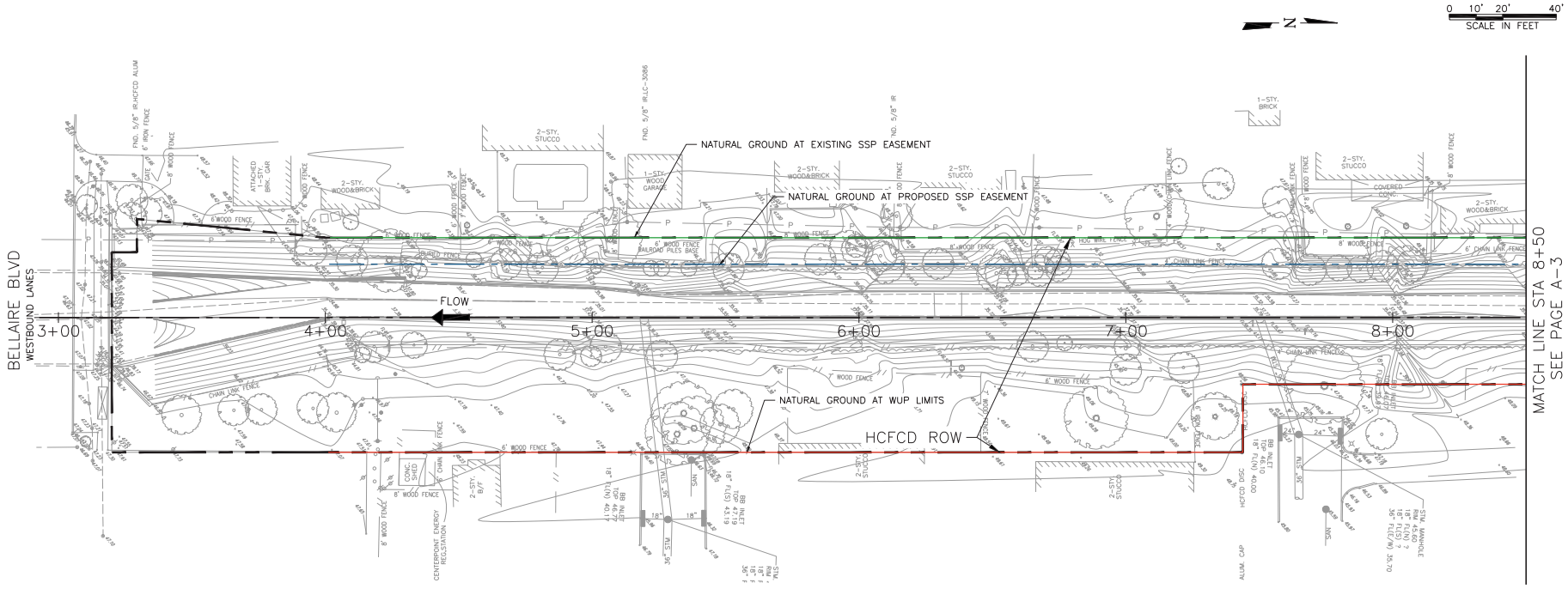
- The total footprint of impervious cover is not being increased by more than one acre from its current condition; and
- The project reach is not located within unincorporated Harris County or the City of Houston.

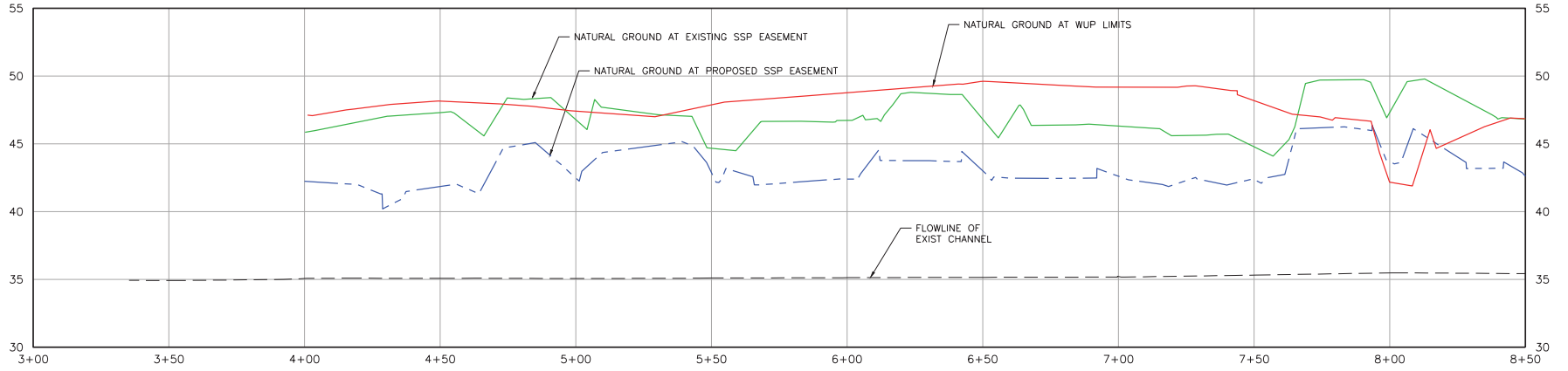
During final design, the project team will coordinate with SSP and WUP as appropriate to verify that the cities will not require specific provisions for water quality enhancements.

The outline of the PER is summarized as follows:

- Section 1.0 – Introduction
- Section 2.0 – Existing Conditions
- Section 3.0 – Temporary Excavations
- Section 4.0 – Channel Design Alternatives
- Section 5.0 – Evaluation of Alternatives
- Section 6.0 – Summary and Recommendation

Attachment 1





NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALU K. CLARK-EGAN P.E. TEXAS NO: 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX A

POOR FARM DITCH IMPROVEMENTS
HARRIS COUNTY FLOOD CONTROL

EXISTING PLAN AND PROFILE

PREPARED:
CHECKED:
APPROVED:

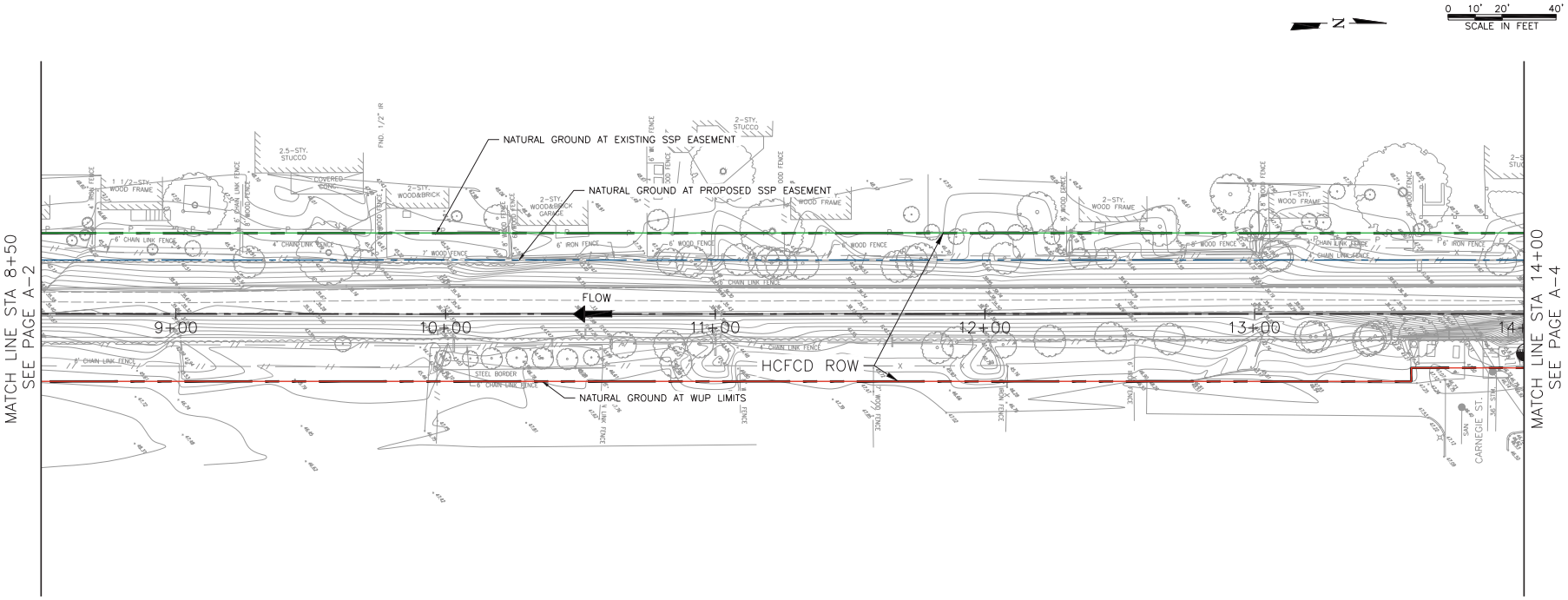
FREESE AND NICHOLS
10497 Town and Country Way,
Suite 600
Houston, Texas 77024
Phone – (713) 600-6800
Fax – (713) 600-6801

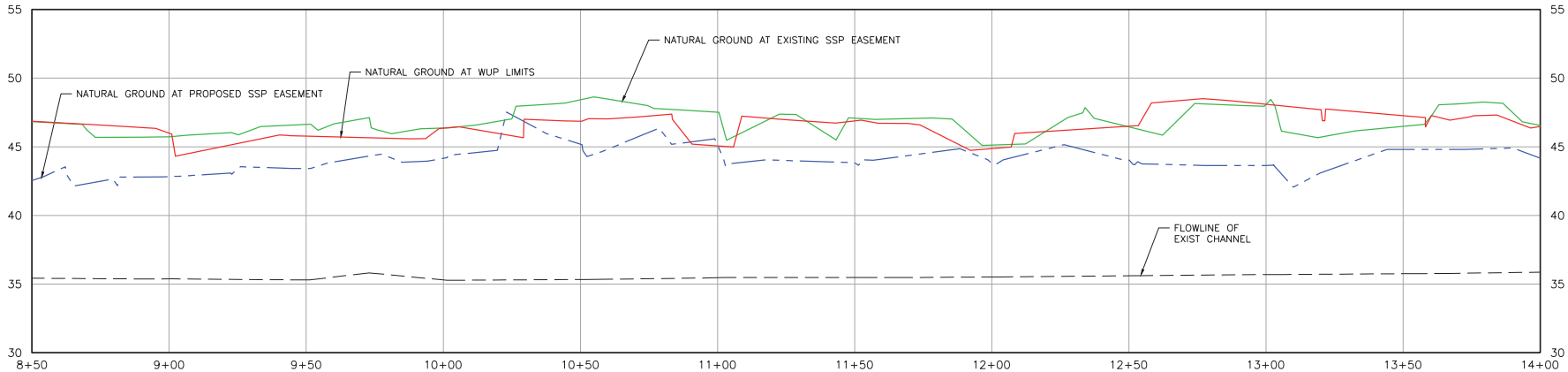
HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

DATE: DECEMBER 2016
SCALE: AS SHOWN

PAGE
A–2

ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148][N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97253
Date: Dec 13, 2016 – 9:17am User: 02462 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept.dwg





NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALLI K. CLARK-EGAN P.E. TEXAS NO: 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX A

POOR FARM DITCH IMPROVEMENTS
HARRIS COUNTY FLOOD CONTROL

EXISTING PLAN AND PROFILE

PREPARED:
CHECKED:
APPROVED:

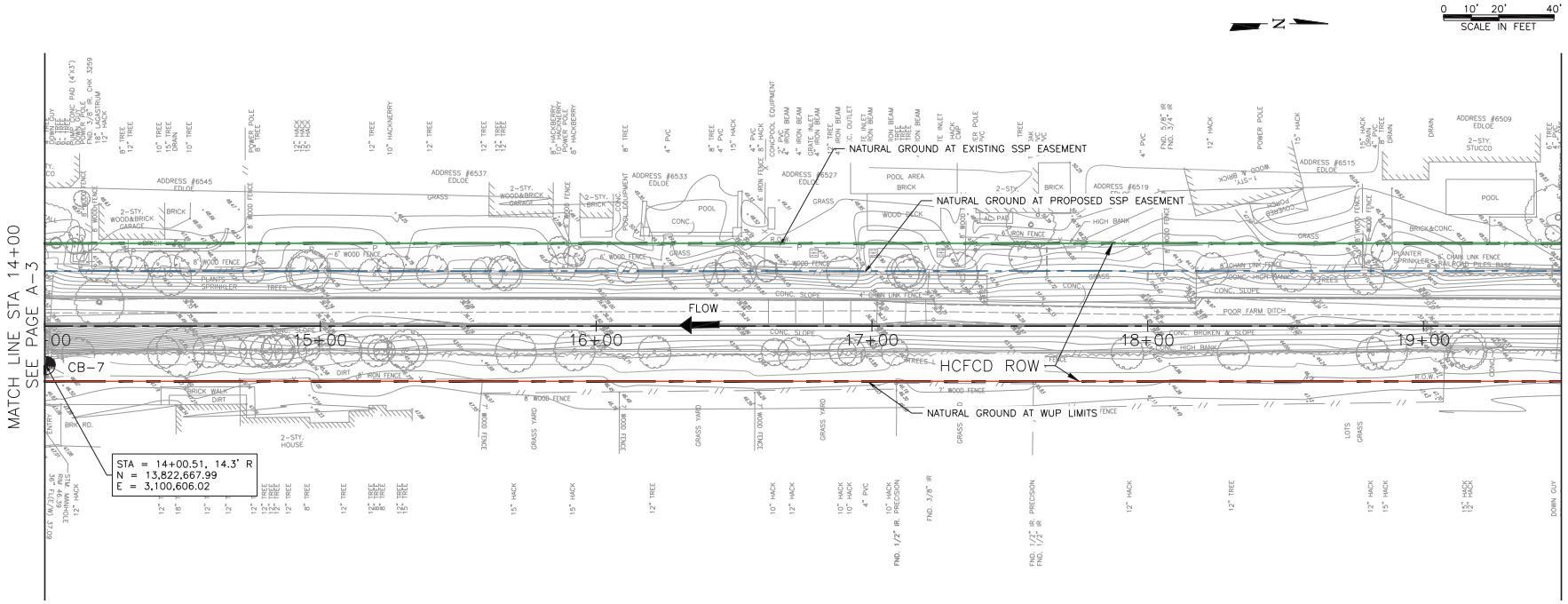
FREESE AND NICHOLS
10497 Town and Country Way,
Suite 600
Houston, Texas 77024
Phone – (713) 600-6800
Fax – (713) 600-6801

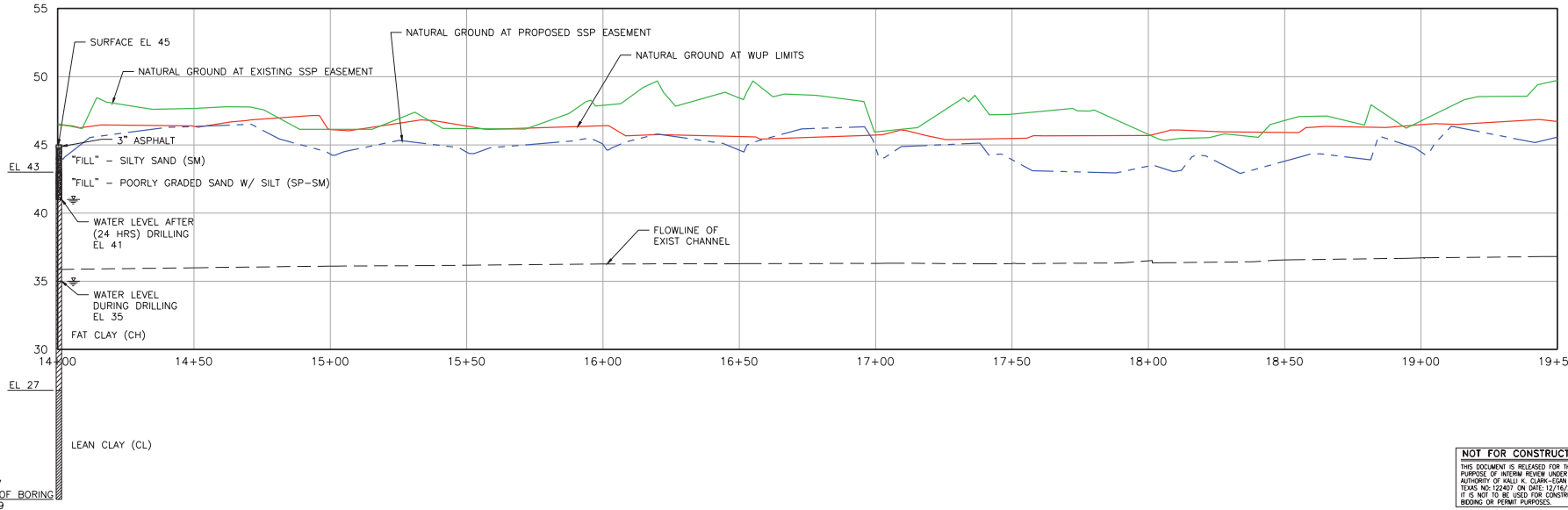
HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

DATE: DECEMBER 2016
SCALE: AS SHOWN

PAGE
A-3

ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148][N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97253
Date: Dec 13, 2016 – 9:17am User: 02462 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept.dwg





NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALLI K. CLARK-EGAN P.E. TEXAS NO: 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX A

POOR FARM DITCH IMPROVEMENTS
HARRIS COUNTY FLOOD CONTROL

EXISTING PLAN AND PROFILE

PREPARED:
CHECKED:
APPROVED:

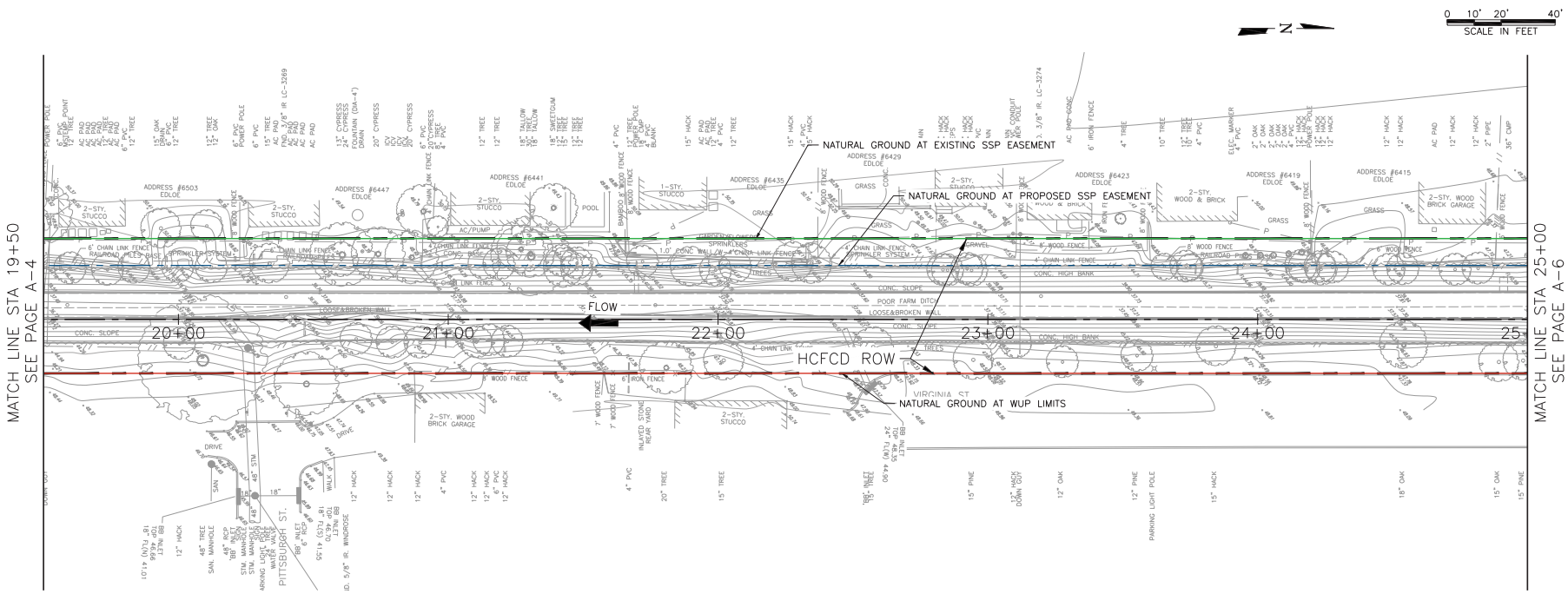
FREESE AND NICHOLS
10497 Town and Country Way,
Suite 600
Houston, Texas 77024
Phone - (713) 600-6800
Fax - (713) 600-8801

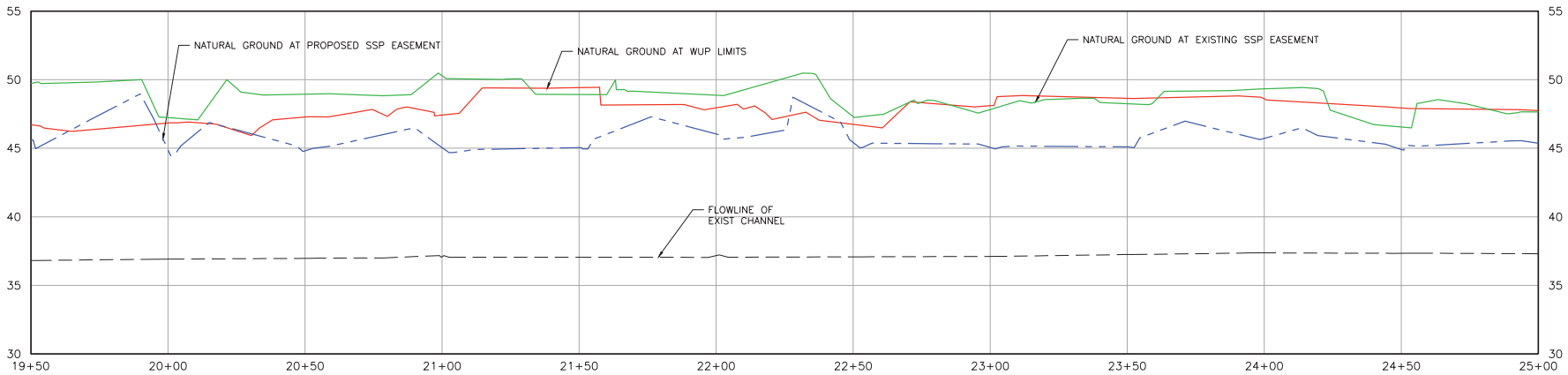
HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

DATE: DECEMBER 2016
SCALE: AS SHOWN

PAGE
A-4

ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148][N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97253
Date: Dec 13, 2016 - 9:17am User: 02462 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept.dwg





NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALU K. CLARK-EGAN P.E. TEXAS NO: 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX A

POOR FARM DITCH IMPROVEMENTS
HARRIS COUNTY FLOOD CONTROL

EXISTING PLAN AND PROFILE

PREPARED:
CHECKED:
APPROVED:

FREESE AND NICHOLS
10497 Town and Country Way,
Suite 600
Houston, Texas 77024
Phone – (713) 600-6800
Fax – (713) 600-6801

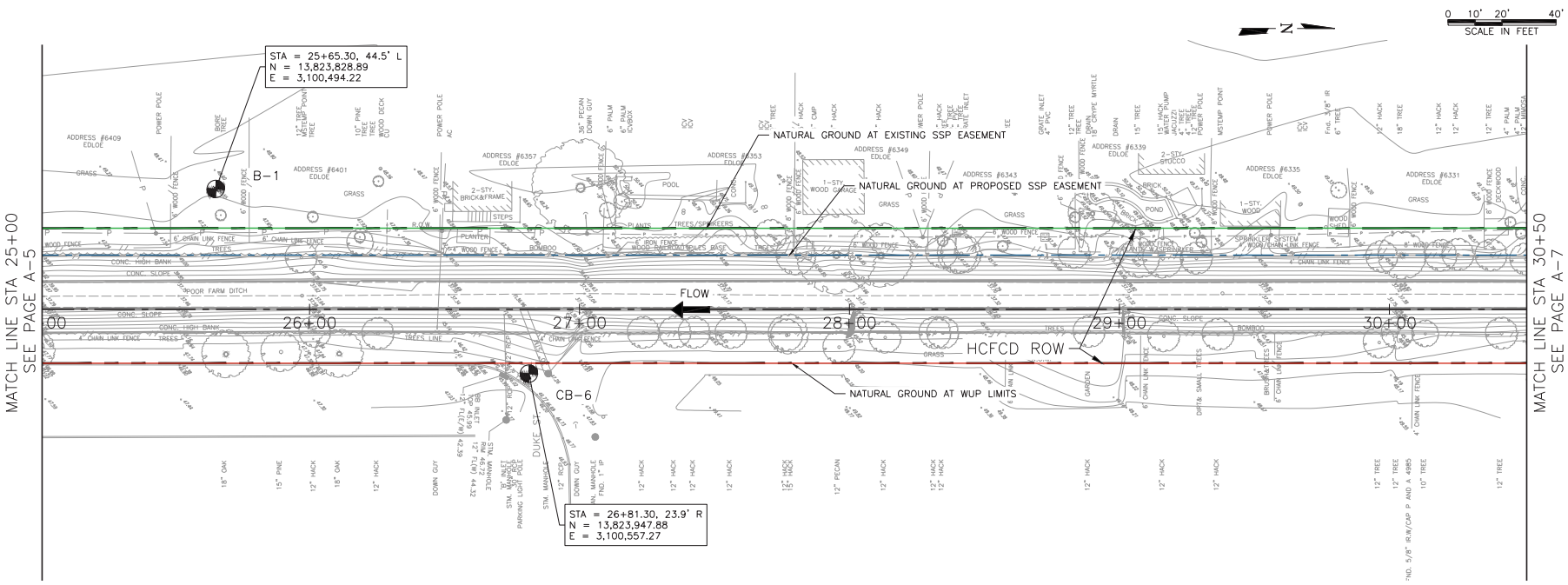
HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

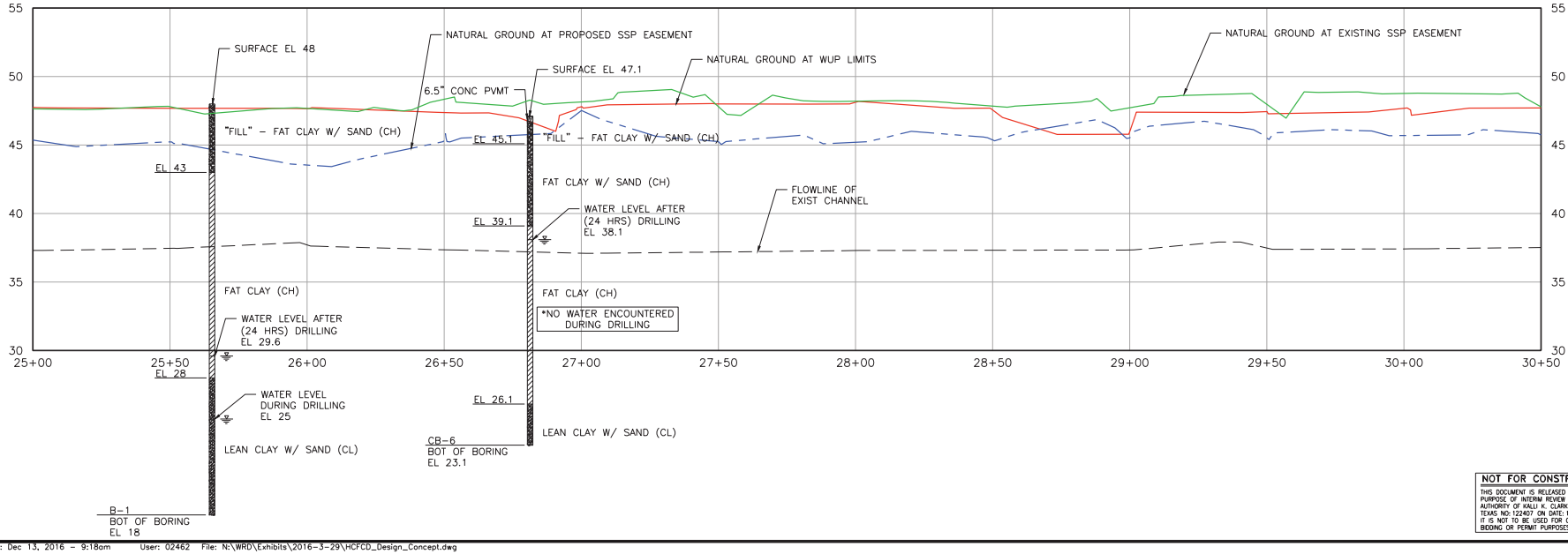
DATE: DECEMBER 2016
SCALE: AS SHOWN

PAGE
A–5

ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148][N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97253

Date: Dec 13, 2016 – 9:17am User: 02462 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept.dwg





NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALLI K. CLARK-EGAN P.E. TEXAS NO: 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX A

POOR FARM DITCH IMPROVEMENTS
HARRIS COUNTY FLOOD CONTROL

EXISTING PLAN AND PROFILE

PREPARED:
CHECKED:
APPROVED:

FREESE AND NICHOLS
10497 Town and Country Way,
Suite 600
Houston, Texas 77024
Phone - (713) 600-6800
Fax - (713) 600-6801

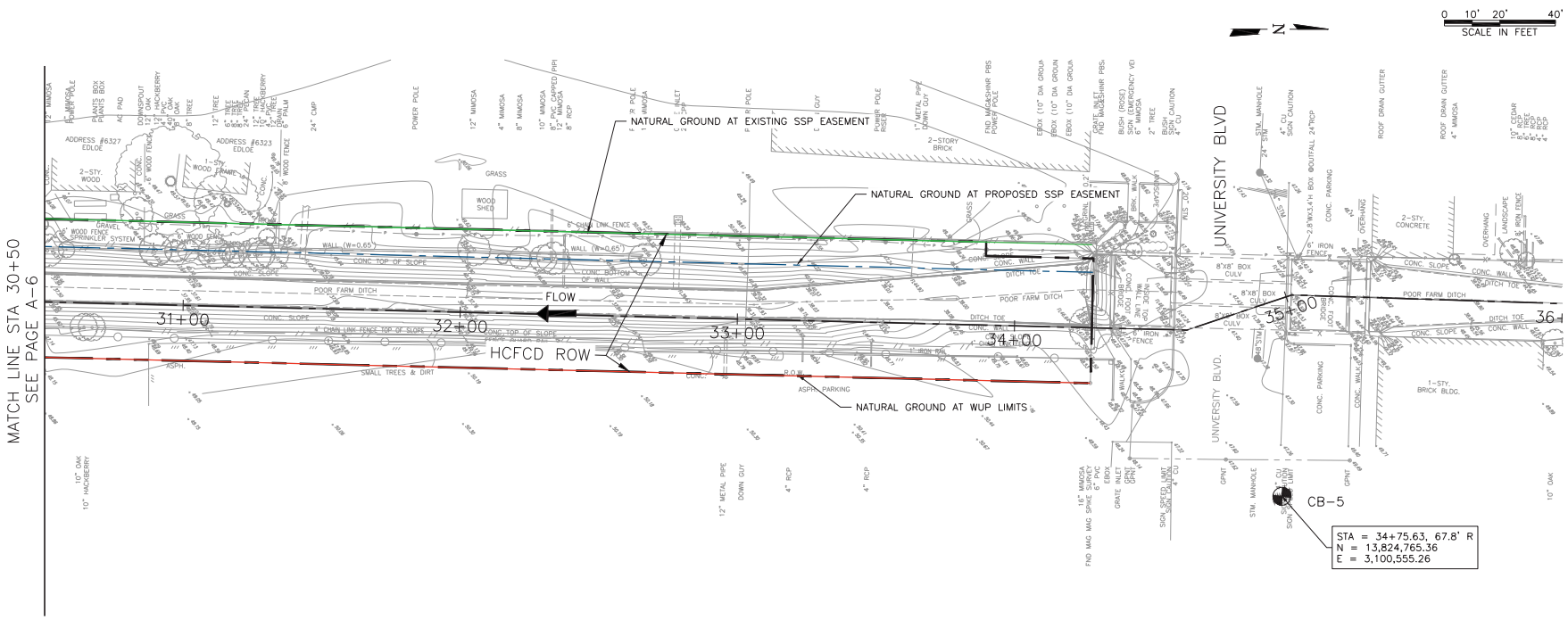
HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

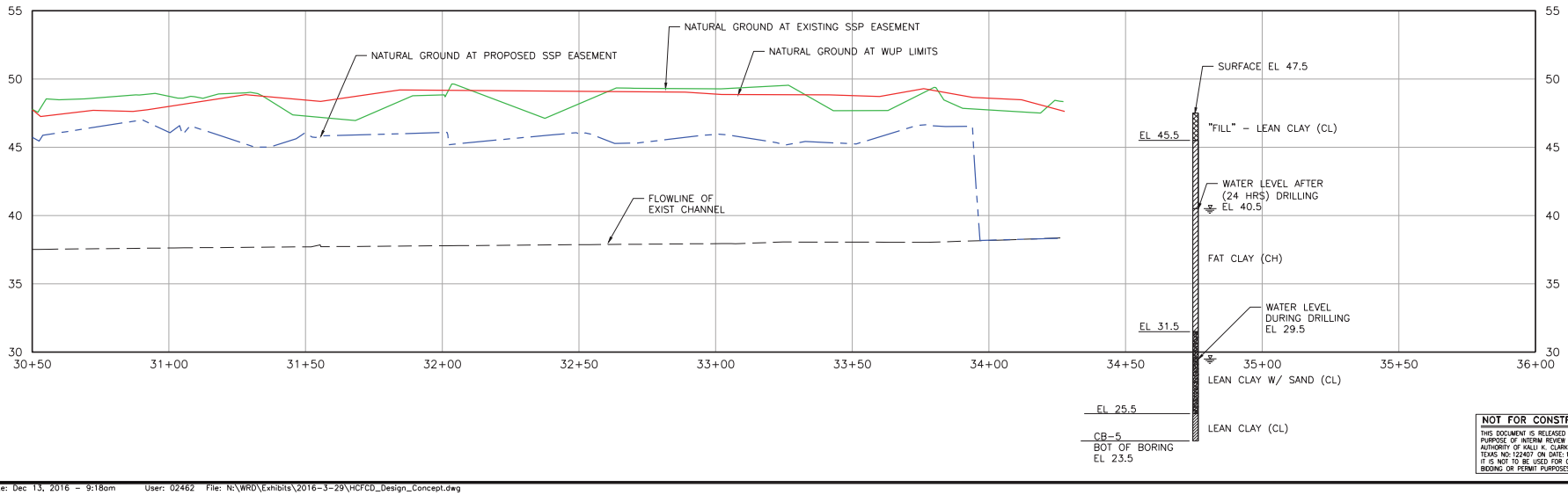
DATE: DECEMBER 2016
SCALE: AS SHOWN

PAGE
A-6

ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148][N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97253

Date: Dec 13, 2016 - 9:18am User: 02462 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept.dwg





NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALU K. CLARK-EGAN P.E. TEXAS NO: 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX A

POOR FARM DITCH IMPROVEMENTS
HARRIS COUNTY FLOOD CONTROL

EXISTING PLAN AND PROFILE

PREPARED:
CHECKED:
APPROVED:

FREESE AND NICHOLS
10497 Town and Country Way,
Suite 600
Houston, Texas 77024
Phone - (713) 600-6800
Fax - (713) 600-6801

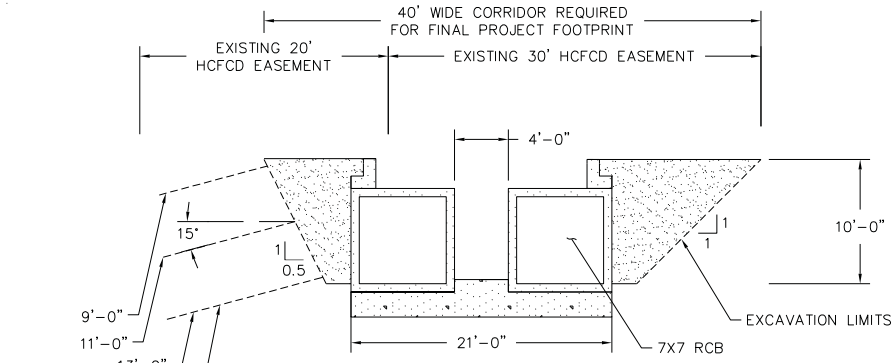
HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

DATE: DECEMBER 2016
SCALE: AS SHOWN

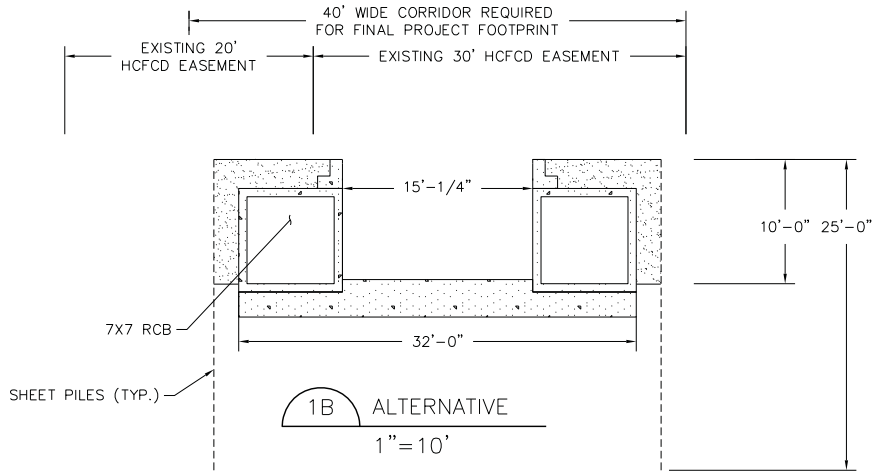
PAGE
A-7

ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148][N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97255
Date: Dec 13, 2016 - 9:18am User: 02462 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept.dwg

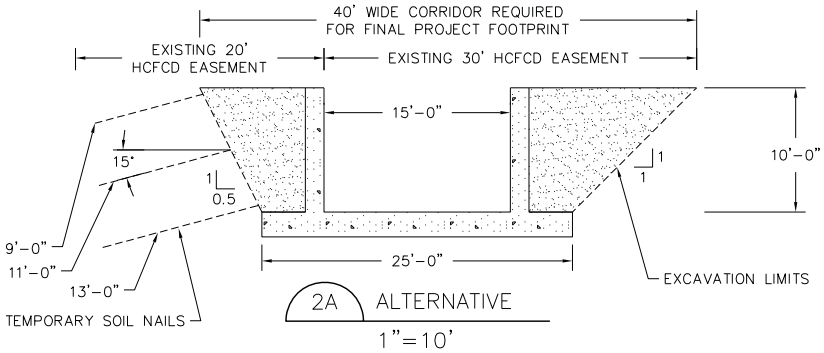
Attachment 2



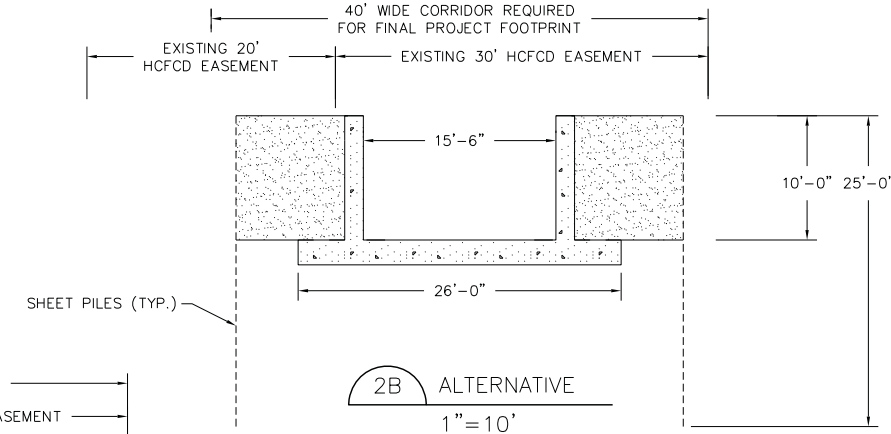
1A ALTERNATIVE
1"=10'



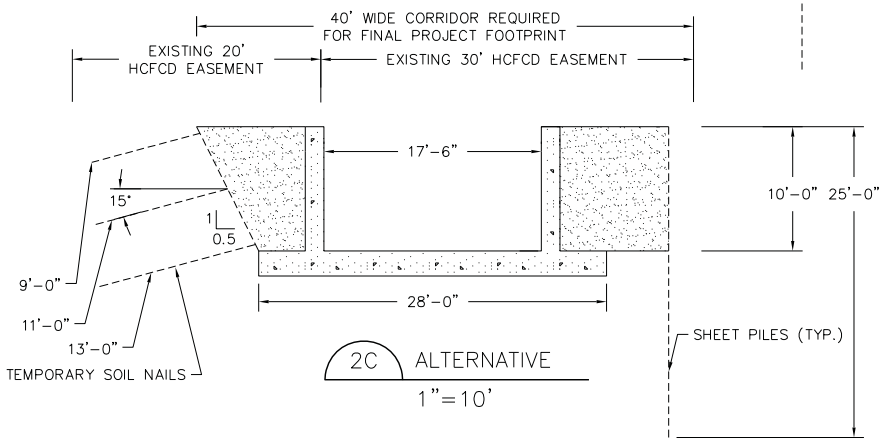
1B ALTERNATIVE
1"=10'



2A ALTERNATIVE
1"=10'



2B ALTERNATIVE
1"=10'



2C ALTERNATIVE
1"=10'

NOTE:

1. ALTHOUGH SOIL HEIGHTS VARY IN DEPTH, SOIL NAIL PLACEMENT EVALUATED ON A CUT DEPTH OF 11 FEET. REFERENCE ANALYSIS INCLUDED IN PER.
2. TEMPORARY SOIL NAILS SHOWN SPACED 4 FEET CENTER TO CENTER ALONG THE LENGTH OF CHANNEL.

NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALLI K. CLARK-EGAN P.E. TEXAS NO. 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX D

POOR FARM DITCH IMPROVEMENTS
HARRIS COUNTY FLOOD CONTROL

DESIGN ALTERNATIVES
TYPICAL SECTIONS

PREPARED:
CHECKED:
APPROVED:

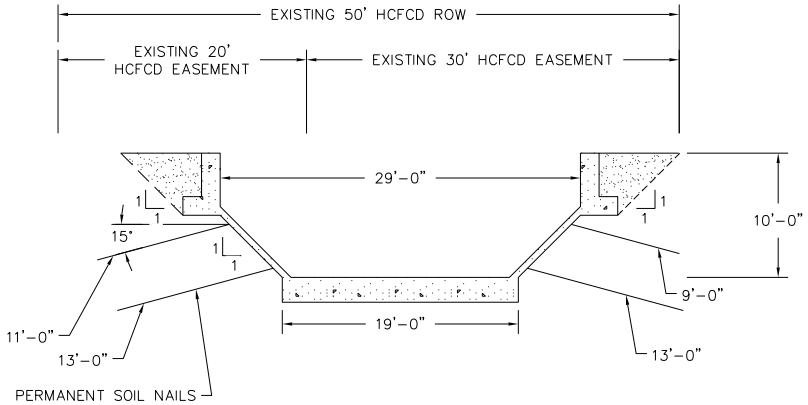
FREESE AND NICHOLS
10497 Town and Country Way,
Suite 600
Houston, Texas 77024
Phone – (713) 600-6800
Fax – (713) 600-6801

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

DATE: DECEMBER 2016
SCALE: AS SHOWN

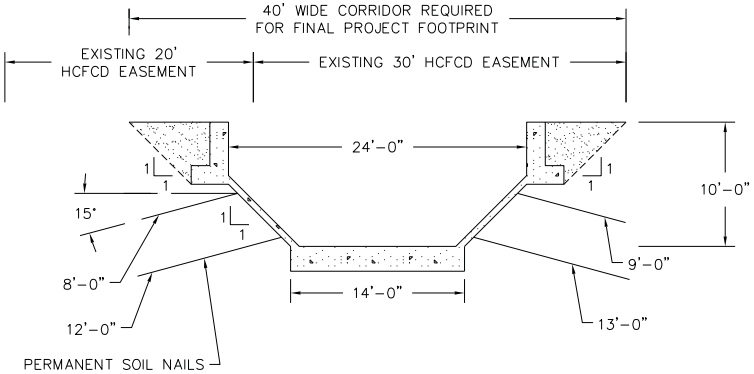
ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148]N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97235

Date: Apr 13, 2017 – 12:26pm User: 02163 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept-X SECTIONS.dwg



3A ALTERNATIVE

1"=10'



3B ALTERNATIVE

1"=10'

NOTE:

1. FOR PERMANENT SOIL NAIL PLACEMENT, REFERENCE ANALYSIS INCLUDED IN PER.
2. PERMANENT SOIL NAILS SHOWN SPACED 2 FEET CENTER TO CENTER ALONG THE LENGTH OF CHANNEL.

NOT FOR CONSTRUCTION

THIS DOCUMENT IS RELEASED FOR THE PURPOSE OF INTERIM REVIEW UNDER THE AUTHORITY OF KALU K. CLARK-EGAN P.E. TEXAS NO. 122407 ON DATE: 12/16/2016 IT IS NOT TO BE USED FOR CONSTRUCTION, BIDDING OR PERMIT PURPOSES.

REV	DESCRIPTION	DATE	APPR

APPENDIX D

POOR FARM DITCH IMPROVEMENTS

HARRIS COUNTY FLOOD CONTROL

DESIGN ALTERNATIVES
TYPICAL SECTIONS

PREPARED:

CHECKED:

APPROVED:

FREESE AND NICHOLS
10497 Town and Country Way, Suite 600
Houston, Texas 77024
Phone – (713) 600-6800
Fax – (713) 600-6801

HARRIS COUNTY FLOOD CONTROL DISTRICT
9900 Northwest Freeway
Houston, Texas 77092

DATE: DECEMBER 2016
SCALE: AS SHOWN

ACAD Rel 19.0s (LMS Tech) User: 02462
[HCF15148]N:\STANDARD\HCFCD BORDER GENERAL.DWG LAYOUT: Model
02/25/2016 8:39:51 A.M. LTS: 1.00 PSLTS: 1
REFERENCE FILE: 97235

Date: Apr 13, 2017 – 12:25pm User: 02163 File: N:\WRD\Exhibits\2016-3-29\HCFCD_Design_Concept-X SECTIONS.dwg

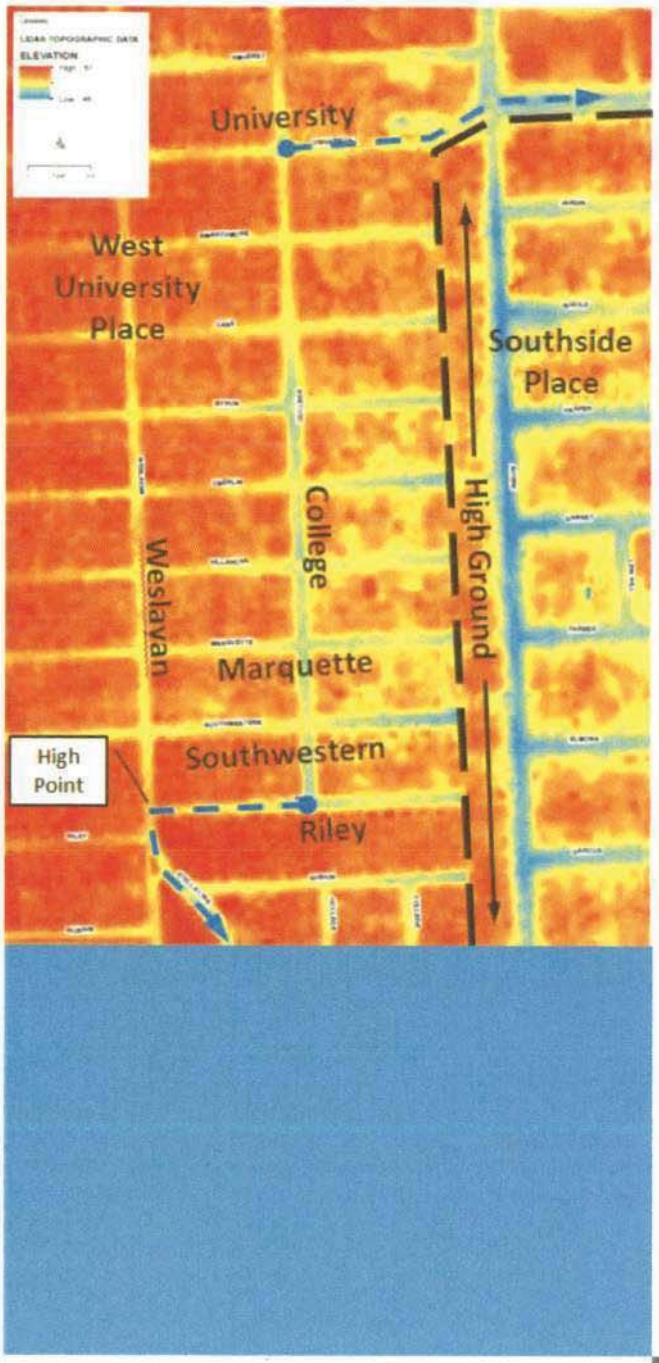
Appendix

D

Drainage Evaluation for Dead-End Streets

July 6, 2017

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264



Drainage Evaluation for Dead-End Streets

City of West University Place

Poor Farm Ditch Watershed

HCFCD Unit No. D111-00-00

Harris County, TX

July 6, 2017

STATE OF TEXAS
DUANE BARRETT
63703
LICENSED
PROFESSIONAL ENGINEER

7/6/2017

CONTENTS

EXECUTIVE SUMMARY 1
INTRODUCTION 2
ENGINEERING BASIS FOR CALCULATIONS PRESENTED IN THIS REPORT 4
FIELD CHECKS AND ADJUSTMENTS TO CITY-WIDE DRAINAGE AREA MAP 5
EVALUATION OF EXISTING SHARED STORM SEWER SYSTEM 6
EVALUATION OF POSSIBLE IMPROVEMENTS TO EXISTING SHARED SYSTEM 7
OTHER ALTERNATIVES FOR IMPROVING STORM SEWER CAPACITY 9
ALTERNATIVE INVOLVING A PARALLEL STORM SEWER ALONG AUDEN STREET 10
ALTERNATIVE INVOLVING A NEW STORM SEWER ALONG UNIVERSITY BOULEVARD 13
COMPARISON OF ALTERNATIVES 16
IMPACT & DETENTION CONSIDERATIONS 18
CONCLUSION 19

TABLES

Table 1: Equivalent Drainage Area Contributions from Southside Place Storm Sewer Connections 5
Table 2: Pipe Capacity Estimates for Shared System Along Corporate Boundary 7
Table 3: Calculations for 2-Year Event – Existing Shared Storm Sewer System 7
Table 4: Calculations for 2-Year Event – Improved Shared System Along Existing Alignment 8
Table 5: Estimated Cost for Upgrading the Existing Shared System to 2-Year Capacity 9
Table 6: Calculations for 2-Year Event – Existing Shared System with Reduced Drainage Area 10
Table 7: Calculations for 5-Year Event – Existing Shared System with Reduced Drainage Area 11
Table 8: Calculations for 5-Year Event - New Parallel Storm Sewer Along Auden Street 11
Table 9: Estimated Cost for New Storm Sewer Along Auden Street (5-Year Capacity) 13
Table 10: Calculations for 2-Year Event – New Storm Sewer Along University Boulevard 14
Table 11: Calculations for 2-Year Event - Existing Shared System with New Storm Sewer Along University Blvd. 14
Table 12: Calculations for 2-Year Event - New Storm Sewer Along Auden (Assumes New System Along University) 15
Table 13: Estimated Cost for New Storm Sewer System Along University Boulevard 15
Table 14: Estimated Cost for New Storm Sewer System Along Auden (Assumes New System Along University) 16
Table 15: Comparison of Estimates Costs for the Various Alternatives 17

FIGURES

Figure 1: Map of West U and Southside Place 3
Figure 2: Typical Street in the Project Area 5
Figure 3: Drainage Area Map 6
Figure 4: Urbanization in the Project Area 8
Figure 5: Drainage Area Map for Proposed Conditions 12
Figure 6: View Looking Southward Along Auden Street 14
Figure 7: Improvement Alternatives 17

This page is intentionally left blank.

EXECUTIVE SUMMARY

This report is associated with drainage planning and feasibility investigations requested by the City of West University Place for nine (9) dead-end streets that drain to an existing storm sewer system located along the shared corporate boundary between West University Place and Southside Place. Flooding of those streets has occurred to varying extents in recent years, and the City is considering options for reducing the depth, duration, and frequency of street flooding. Alternatives evaluated include improvements to the existing storm sewer system along its current alignment, construction of a new system along Auden Street within the City of Southside Place to complement the capacity of the existing shared system, and construction of a relief sewer along University Boulevard.

The analysis described in this report indicates that the existing shared storm sewer system does not have sufficient capacity to convey peak runoff rates from a 2-year storm event as computed using current City of Houston storm sewer design methods. Improvements to the existing shared system along its existing alignment would provide 2-year flow capacity to areas in West University Place and Southside Place that drain to the shared system. Construction of a new storm sewer along Auden Street (within Southside Place) would provide 5-year capacity for the existing shared system and the new Auden Street system for localized rainfall events, but for more widespread events and for events more severe than the 2-year design storm, capacity would be limited to a 2-year design event for both systems. The construction of a relief storm sewer along University Boulevard may be considered as a stand-alone project or could be constructed in conjunction with a new storm sewer along Auden Street to provide 2-year capacity for the existing shared system and an improved Auden Street system. The following table summarizes estimated costs associated with a) improvements to the existing shared system to increase the level of service of that system to a 2-year storm event, b) construction of a new parallel system along Auden Street to provide a 5-year local level of service for the shared and parallel systems, and c) construction of a new system along Auden plus a small system along University Boulevard to provide a 2-year level of service for the shared and parallel systems.

Description of Alternative	Level of Service	Estimated Cost
Improve Existing Shared Storm Sewer Along Existing Alignment	2-Year	$3,565,201.25
Construct Parallel System Along Auden Street Draining 11.23 Acres in West U	5-Year	$2,787,128.50
Construct Parallel System Along Auden Plus Separate System Along University	2-Year	$2,681,805.75

The storm improvements described above will provide improved drainage during smaller events (generally less than or equal to 2-year), but will not operate as efficiently during greater events. Thus, the potential for impacts on downstream flow rates and flood levels will be limited during larger storm events by high-water conditions along Brays Bayou and Poor Farm Ditch. Since the 10-year event is generally considered to represent the “threshold” for flooding along Brays Bayou, increases in drainage efficiency for lesser storm events do not represent a significant risk in terms of increased flooding. For these reasons, detention is not recommended in connection with the improvements described in this report.

Improvements to the existing system will be expensive and disruptive to local residents of both cities. Construction of a new parallel system along Auden Street within Southside Place offers a very reasonable and mutually beneficial option for reducing flow to the shared system and providing capacity ranging from 2-year to 5-year depending on whether drainage from West University Place flows to the Auden Street system. An alternative that includes a new system along Auden plus a new storm sewer along University Boulevard would provide 2-year capacity at a total cost consistent with that of a single 5-year-capacity system along Auden that accepts storm runoff from an area of approximately 11.17 acres within West University Place. Both of the alternatives involving a new system along Auden provide greater benefit at lower cost than replacing the existing shared system with larger storm sewers along the existing alignment. HDR recommends that an alternative involving a new system along Auden be evaluated very seriously by the City of West University Place in cooperation with the City of Southside Place.

INTRODUCTION

This report is associated with drainage planning and feasibility investigations requested by the City of West University Place. The effort described in this report covers analyses of the following specific tasks and questions as communicated to us by Mr. Patrick Walters. The following preparatory tasks involving various field investigations were completed by the City during the week of May 8th, 2017 with the assistance of one engineering staff member from HDR.

- Jet the lines at the intersection of Amherst and University to verify that they are clear.
- Get elevation shots of storm sewer inverts in the intersection of Amherst and University.
- Obtain measurements of inverts and pipe sizes of existing inlet(s) that should connect to the 54" storm sewer behind the elementary school, which was not completed across the ball field.

The following tasks have been be completed by HDR Engineering, Inc.

1. Determine the capacity of the shared storm sewer line that runs along the boundary between West U and Southside Place (SSP), just east of the cul-de-sacs at the east ends of Swarthmore, Case, Byron, Oberlin, Villanova, Marquette, Southwestern, Riley, and Ruskin Streets. Check pipe sizes and drainage boundaries established in previous studies. Determine whether this line meets the 2-yr design criteria established by West U, and if not, identify the location at which it becomes inadequate to convey the 2-yr storm flow.
2. If any portion of the existing storm sewer system along the West U / Southside boundary does not satisfy current 2-year design storm criteria, determine the storm sewer pipe size(s) necessary to provide 2-year capacity. Prepare a preliminary estimate of the cost necessary to replace the undersized pipes in their existing location and a separate estimate for one alternative alignment (e.g., along Auden Street in Southside Place).
3. Determine the location of the elevation/drainage break-point on Marquette St. Determine how much runoff flows to the west towards College Street and how much flows east to the common system line between West U and Southside Place.
4. It appears that a storm sewer pipe extends eastward along Riley towards the dead end at the West U / Southside boundary. Determine whether there is an elevation break point on Riley and what the drainage pattern is in this area (i.e., how much area drains to the east to the West U / Southside boundary and how much drains westward to the College Avenue storm sewer system).
5. Update the city-wide drainage area map for West U, adding drainage breaks from the Marquette St. and Riley St. evaluations on the current drainage area map as well as any prior drainage system modifications identified in completing the preceding tasks. Include updated drainage boundaries and pipe sizes and alignments from the Ruskin / College project.

The following sections of this report present HDR's findings regarding the various tasks described in the scope of work. Figure 1 on the following page of this report provides a general overview of the project area.

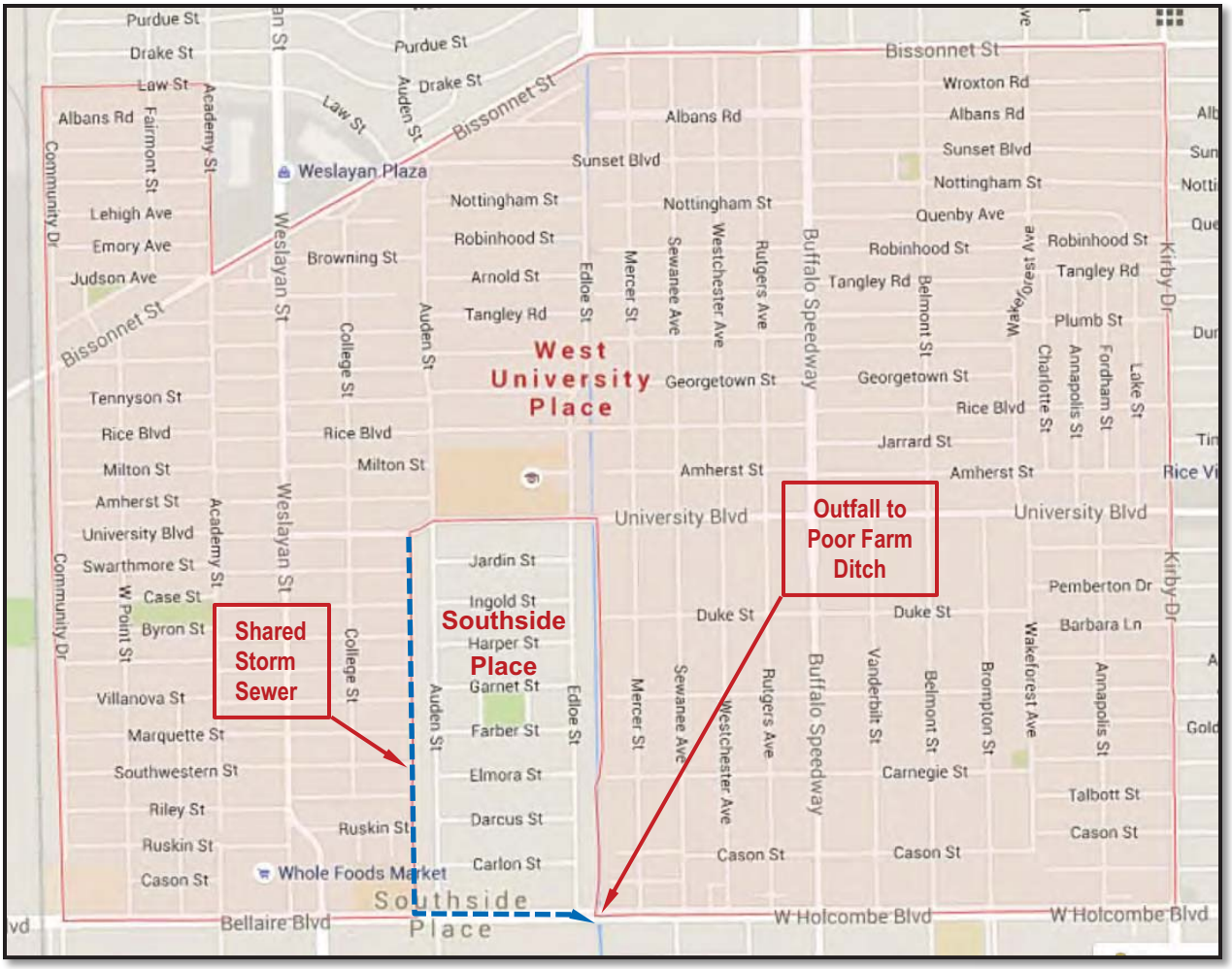


Figure 1: Map of West U and Southside Place

ENGINEERING BASIS FOR CALCULATIONS PRESENTED IN THIS REPORT

Capacities of storm sewer pipes are estimated using the Manning Equation, which utilizes the pipe cross-sectional area, rougness, and slope to produce a "full gravity flow" flow capacity in units of cubic feet per second. The standard Manning formula is as follows.

$$Q = (1.49/n)\ A\ R^{2/3}\ S^{1/2}$$

In the Manning formula, Q is the flow capacity in cubic feet per second (cfs), n is the roughness coefficient, A is the cross-sectional area of the pipe in square feet, R is the hydraulic radius of the pipe (computed as the area divided by the wetted perimeter, or the circumference, of the pipe) and S is the slope in units of feet of drop in elevation per foot of length of pipe. In the Houston area, standard engineering practice is to design storms sewers to flow at 3 feet per second under full flow conditions. Pipe slope is varied with size to provide the standard 3-foot-per-second velocity.

Runoff flow rates for given drainage areas are computed using the Rational Method, which associates peak runoff rates with a runoff coefficient that describes the relative level of development and impervious cover, the rainfall intensity in inches per hour, and the drainage area. The standard Rational Method formula is as follows.

$$Q = CIA$$

Where C is the runoff coefficient, I is the rainfall intensity, and A is the drainage area. Specific techniques and parameters developed by the City of Houston have been utilized in this analysis of storm sewers within the City of West University Place. The following excerpts from Chapter 9 of the City of Houston Design Manual define the approach utilized to apply the Rational Method to local watersheds.

Time of concentration can be calculated from the following formula:

$$TC = 10A^{0.1761} + 15$$

Where: TC = time of concentration (minutes)
A = subarea (acres)

Land Use Type	Runoff Coefficient (C)
Residential Districts	
Lots more than 1/2 acre	0.35
Lots 1/4 - 1/2 acre	0.45
Lots less than 1/4 acre	0.55

Calculate Intensity: The intensity calculation is based on duration equal to the time of concentration. The intensity is calculated as follows:

$$I = b/(d + T_C))^e$$

Where b, d, and e are coefficients dependent on the storm event, as provided in Table 9.1, below and are based on City of Houston depth-duration-frequency values.

Table 9.1
Rainfall Intensity Parameters

Rainfall Frequency	b	d	e
2-year	75.01	16.2	0.8315
3-year	77.27	17.1	0.8075
5-year	84.14	17.8	0.7881
10-year	93.53	18.9	0.7742
25-year	115.9	21.2	0.7808
100-year	125.4	21.8	0.7500

FIELD CHECKS AND ADJUSTMENTS TO CITY-WIDE DRAINAGE AREA MAP

Field measurements indicate that the drainage break on both Marquette and Riley Streets is approximately 290 feet east of the curb return on the east side of College Avenue. Those measurements, additional field observations, and other available information were used to update the City-wide drainage area map as requested. Attachment 1 to this report is a drainage area map for the shared system. The updated map shows a total area of 34.72 acres draining to the shared system from West University Place. Five (5) interconnections with the existing Southside Place drainage system along Auden Street are noted on available drainage areas maps dating back a number of years. The connector pipes range in size from 15 inches to 24 inches in diameter. In order to account for drainage to the shared storm sewer system at each connection, the capacity of each connector pipe was estimated using a standard design velocity of 3.0 feet per second. An equivalent drainage area was then determined using the Rational Method formula and solving for the drainage area as follows.

$$A = Q / CI$$

Table 1 provides equivalent drainage area values developed for the various connections. The computed total equivalent drainage area contributing flow to the shared storm sewer system via the SSP connectors is 18.83 acres.

Table 1: Equivalent Drainage Area Contributions from Southside Place Storm Sewer Connections

Connector Location	West U Street	Connector Pipe Diam. (inches)	Flow Area (sq. ft.)	Connector Capacity (cfs)	Equivalent DA (acres)	Tc (min.)	Intensity (in/hr)	2-Yr Flow (cfs)
Ingold	Case	24	3.14	9.4	5.37	28.44	3.19	9.4
Garnet	Villanova	15	1.23	3.7	2.02	26.32	3.32	3.7
Farber	Marquette	21	2.41	7.2	4.05	27.79	3.23	7.2
Elmora	Riley	24	3.14	9.4	5.37	28.44	3.19	9.4
Darcus	Ruskin	15	1.23	3.7	2.02	26.32	3.32	3.7

Figure 2 is a snapshot of a typical curb-and-gutter street in the project area. Significant ponding in local streets is not uncommon. Figure 3 represents a portion of the West University Place city-wide drainage area map, with focus on the areas draining to the shared storm sewer along the West University Place / Southside Place corporate boundary. Blue shading represents the area within the City of West University Place that drains to the shared West U / SSP storm sewer. Text in black denotes West U storm sewer sizes, drainage areas, times of concentration, and 2-year flow rates, while green lines and orange dots represent existing West U storm sewers and inlet locations. Red arrows and corresponding text (e.g., 24") represent locations where the existing Southside Place storm sewer along Auden Street connects to the shared storm sewer system along the corporate boundary. Red text denotes the equivalent drainage area corresponding to each connector pipe.

Figure 2: Typical Street in the Project Area

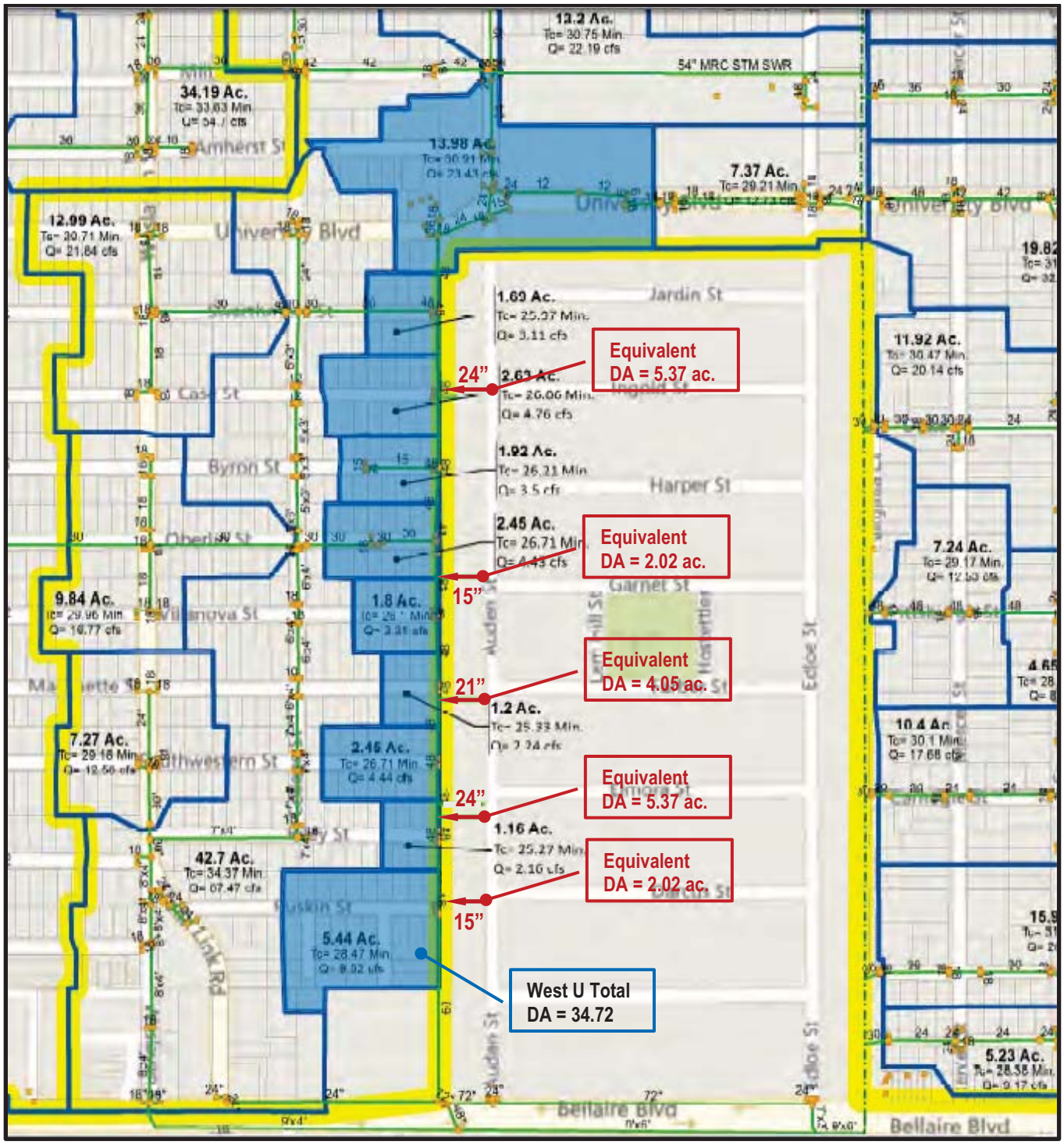


Figure 3: Drainage Area Map

EVALUATION OF EXISTING SHARED STORM SEWER SYSTEM

The existing shared storm sewer system along the corporate boundary between the Cities of West University Place and Southside Place consists of a single 48-inch reinforced concrete pipe (RCP) storm sewer from University Boulevard southward to Riley Street. From that point southward to Bellaire Boulevard, the shared sytem consists of a single 60-inch

RCP. The capacities of the 48-inch and 60-inch lines are estimated using the standard design velocity of 3 feet per second.. Table 2 presents pipe capacity estimates for 48-inch and 60-inch storm sewer pipes with slopes required to generate the typical design velocity of 3 feet per second using the Manning Equation.

Table 2: Pipe Capacity Estimates for Shared System along Corporate Boundary

Pipe Diameter (inches)	Roughness Coefficient	Section Area (sq. ft.)	Pipe Circumference (feet)	Hydraulic Radius (feet)	Pipe Slope (ft/ft)	Flow Velocity (ft/sec)	Pipe Capacity (cfs)
48	0.013	12.57	12.57	1.00	0.0007	3.00	37.7
60	0.013	19.63	15.71	1.25	0.0005	3.00	58.9

The peak runoff rate is computed at each of the streets that "dead end" at the corporate boundary between the Cities of West University Place and Southside Place. Table 3 summarizes the peak flow calculations completed in connection with the analysis. Flow contributions from West University Place and Southside Place are accounted for in the analysis. Computed 2-year flow rates are compared with the capacity of the shared storm sewer. Shaded cells indicate locations where the computed 2-year flow rate exceeds the estimated pipe capacity. As indicated, the estimated available pipe capacity is exceeded at Case Street and at all locations downstream of Case Street. Note that in the table, rainfall intensities decrease with increased drainage area and time of concentration, as in order for the probability of occurrence to remain constant (50% for a 2-year storm event) with increasing drainage areas and longer times of concentration, the rainfall and rainfall intensity are reduced. This is standard practice when using the Rational Method to complete peak runoff calculations.

Table 3: Calculations for 2-Year Event – Existing Shared Storm Sewer System

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	2-Year Intensity (in/hr)	2-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
University	13.98	0.00	13.98	30.91	0.55	3.05	23.4	48	37.7
Swarthmore	15.67	0.00	15.67	31.23	0.55	3.03	26.1	48	37.7
Case	18.30	5.37	23.67	32.46	0.55	2.97	**38.6**	48	**37.7**
Byron	20.22	5.37	25.59	32.70	0.55	2.95	**41.6**	48	**37.7**
Oberlin	22.67	5.37	28.04	32.99	0.55	2.94	**45.3**	48	**37.7**
Villanova	24.47	7.39	31.86	33.40	0.55	2.92	**51.2**	48	**37.7**
Marquette	25.67	11.44	37.11	33.90	0.55	2.90	**59.1**	48	**37.7**
Southwestern	28.12	11.44	39.56	34.11	0.55	2.89	**62.8**	48	**37.7**
Riley	29.28	16.81	46.09	34.63	0.55	2.86	**72.5**	60	**58.9**
Ruskin	34.72	18.83	53.55	35.16	0.55	2.84	**83.5**	60	**58.9**

EVALUATION OF POSSIBLE IMPROVEMENTS TO EXISTING SHARED SYSTEM

Adjustments were made to the existing storm sewer pipe sizes in order to determine what changes would be necessary to allow the shared system to convey the computed 2-year flow rates. Table 4 provides an updated analysis with existing pipe sizes replaced by pipes large enough to provide the required 2-year flow capacity at standard velocity of 3 feet per second. As shown, proposed pipe diameters range from 48 inches to 72 inches where existing values range from 48 inches to 60 inches. Proposed pipe capacities are adequate to convey computed 2-year flow rates under this improved scenario. Note

that one pipe capacity is slightly less than the computed peak flow rate, but the shortfall is small enough (0.3%) to be negligible. In design, a slight increase in pipe slope would suffice to increase the velocity and capacity to the required value.

Table 4: Calculations for 2-Year Event – Improved Shared System along Existing Alignment

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	2-Year Intensity (in/hr)	2-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
University	13.98	0.00	13.98	30.91	0.55	3.05	23.4	48	37.7
Swarthmore	15.67	0.00	15.67	31.23	0.55	3.03	26.1	48	37.7
Case	18.30	5.37	23.67	32.46	0.55	2.97	38.6	54	47.7
Byron	20.22	5.37	25.59	32.70	0.55	2.95	41.6	54	47.7
Oberlin	22.67	5.37	28.04	32.99	0.55	2.94	45.3	54	47.7
Villanova	24.47	7.39	31.86	33.40	0.55	2.92	51.2	60	58.9
Marquette	25.67	11.44	37.11	33.90	0.55	2.90	59.1	60	58.9
Southwestern	28.12	11.44	39.56	34.11	0.55	2.89	62.8	66	71.3
Riley	29.28	16.81	46.09	34.63	0.55	2.86	72.5	72	84.8
Ruskin	34.72	18.83	53.55	35.16	0.55	2.84	83.5	72	84.8

The estimated cost associated with upsizing existing storm sewer pipes from Case Street to Bellaire Boulevard is summarized in Table 5. It should be noted that replacement of pipe along the existing alignment will be very difficult due to the proximity of homes and appurtenant structures along both the West University Place and Southside Place sides of the corporate boundary. Figure 4 illustrates the heavily urbanized nature of the project area and the existing shared storm sewer alignment. The existing storm sewer lies within an existing easement, but that easement is heavily encumbered. Therefore, the pipe removal and installation prices used below reflect an assumed increase of 100% above typical values to cover anticipated difficulty accessing and working in the shared system easement. We have also included significant sums to cover site preparation and restoration in light of the limited available space and the need to remove and replace existing fencing.

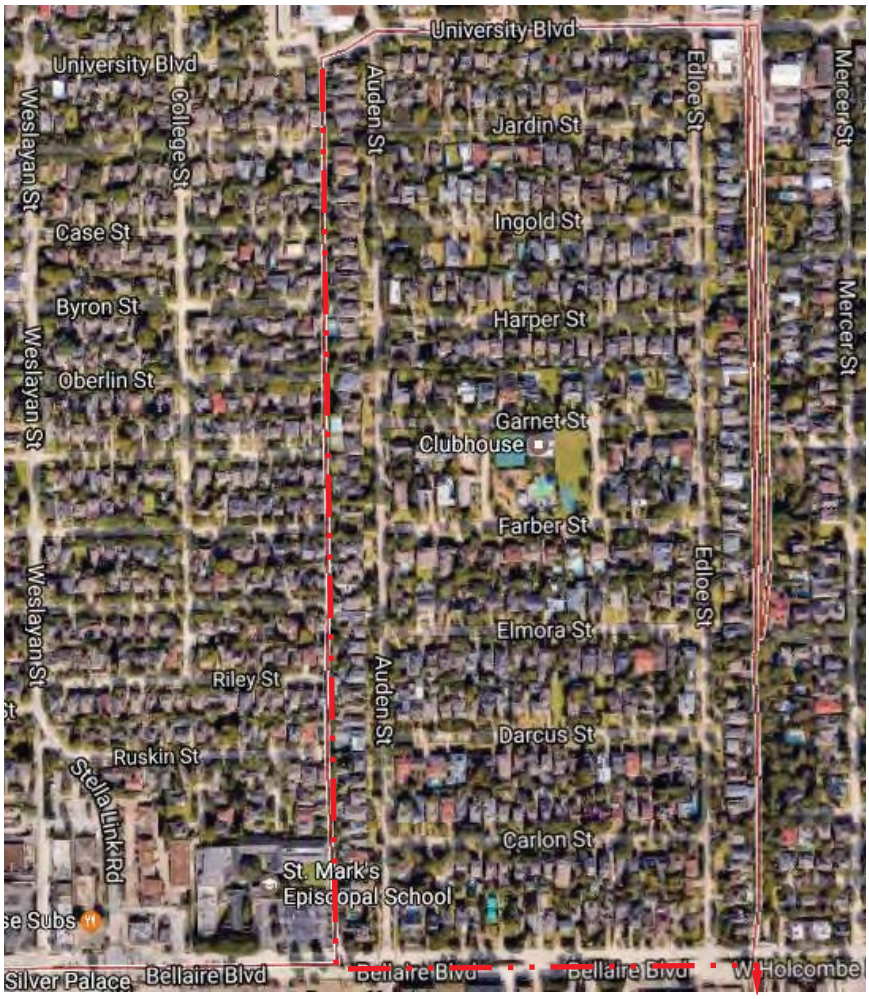


Figure 4: Urbanization in the Project Area

Table 5: Estimated Cost for Upgrading the Existing Shared System to 2-Year Capacity

Item Description	Quantity	Unit of Measurement	Unit Price	Cost
Mobilization	1	LS	$50,000.00	$50,000.00
Site Preparation	1	LS	$100,000.00	$100,000.00
Remove Pavement at Ends of All Streets (Curbs Incl.)	720	SY	$25.00	$18,000.00
Remove Existing Pipe, All Sizes	2480	LF	$25.00	$62,000.00
Install 54" Reinforced Concrete Pipe	760	LF	$540.00	$410,400.00
Install 60" Reinforced Concrete Pipe	520	LF	$590.00	$306,800.00
Install 66" Reinforced Concrete Pipe	240	LF	$720.00	$172,800.00
Install 72" Reinforced Concrete Pipe	960	LF	$810.00	$777,600.00
Remove & Replace Existing Curb Inlets	18	EA	$5,000.00	$90,000.00
Remove & Replace Existing Manholes	9	EA	$7,500.00	$67,500.00
Remove & Replace 24" Storm Sewer Laterals	270	LF	$95.00	$25,650.00
Replace Pavement at Ends of All Streets (Curbs Incl.)	720	SY	$75.00	$54,000.00
Site Restoration	1	LS	$200,000.00	$200,000.00
De-Mobilization	1	LS	$50,000.00	$50,000.00
Sub-Total	-----	-----	-----	$2,384,750.00
Contingency	30%	-----	-----	$715,425.00
Sub-Total	-----	-----	-----	$3,100,175.00
Engineering	15%	-----	-----	$465,026.25
Overall Total	**-----**	**-----**	**-----**	**$3,565,201.25**

CONSIDERATION OF OTHER ALTERNATIVES FOR IMPROVING STORM SEWER CAPACITY

Because the existing shared system is difficult to access and will be expensive to upgraded, a number of other alternatives to improving the existing storm sewer "in place" were evaluated by HDR, including the following.

1. Construct a new storm sewer along Auden Street in Southside Place to relieve the hydraulic loading on the existing shared system. This alternative has the advantage of using an existing public street right-of-way with adequate space to construct a new storm sewer system. The major disadvantage is the fact that the affected segment of Auden lies entirely within the City of Southside Place, and this will require development of an interlocal agreement.

2. Create additional storm sewer capacity and depth along College Avenue to allow the nine dead-end streets to drain to the west. This option would push the College Avenue system closer to the "extreme event" system previously considered but ultimately dismissed as too expensive. Another disadvantage is the possibility that water collected in the College Avenue system would back up into the nine streets during extreme events, inadvertently exacerbating flooding.

3. Use a pump(s) to evacuate storm water from the dead-end streets via a force main along the existing storm sewer alignment. The major advantage of this approach is that a force main would be significantly smaller than a gravity line, and a force main could potentially be installed adjacent to the existing shared system at a significantly lower cost than replacing the existing storm sewer with larger pipes. However, there is no room to locate a pump station(s) with the required back-up power.

ALTERNATIVE INVOLVING A PARALLEL STORM SEWER ALONG AUDEN STREET

Careful consideration of the available alternatives indicates that construction of a parallel system along Auden Street represents the most favorable option. Two approaches to the design and construction of that system are available. The first would involve construction of a parallel system with sufficient capacity to replace the existing shared system. The second is to construct a system along Auden Street with sufficient capacity that, when combined with the capacity of the existing system, provides enough capacity to convey the 2-year design flow. The first approach would involve abandonment of the existing system, which we understand to be in reasonable condition. The second offers the possibility of developing an effective solution at a lower cost. Therefore, we have investigated the option of creating a parallel system along Auden Street that, when combined with the existing shared storm sewer, provides adequate total capacity to accommodate at minimum a 2-year storm event. Table 6 reflects revised calculations for the existing system with all Southside Place drainage areas assumed to drain to a new storm sewer along Auden Street. In addition, approximately 11.23 acres of the 13.98-acre drainage area along and north of University Boulevard is assumed to drain to a new system along Auden, with the residual 2.75 acres (area that cannot be easily re-directed to a system along Auden) draining to the existing shared system. As indicated in Table 6, the proposed reduction in the area draining to the existing shared system brings 2-year design flows well below the estimated conveyance capacity of the existing 48-inch and 60-inch storm sewer pipes.

Table 6: Calculations for 2-Year Event – Existing Shared System with Reduced Drainage Area

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	2-Year Intensity (in/hr)	2-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
University	2.75	0.00	2.75	26.95	0.55	3.28	5.0	48	37.7
Swarthmore	4.44	0.00	4.44	28.00	0.55	3.21	7.8	48	37.7
Case	7.07	0.00	7.07	29.11	0.55	3.15	12.2	48	37.7
Byron	8.99	0.00	8.99	29.72	0.55	3.11	15.4	48	37.7
Oberlin	11.44	0.00	11.44	30.36	0.55	3.08	19.4	48	37.7
Villanova	13.24	0.00	13.24	30.76	0.55	3.06	22.2	48	37.7
Marquette	14.44	0.00	14.44	31.00	0.55	3.04	24.2	48	37.7
Southwestern	16.89	0.00	16.89	31.45	0.55	3.02	28.0	48	37.7
Riley	18.05	0.00	18.05	31.64	0.55	3.01	29.9	60	58.9
Ruskin	23.49	0.00	23.49	32.43	0.55	2.97	38.3	60	58.9

In order to determine the level of service that could be achieved along the existing shared system with the proposed drainage area reduction, flow rates for 3-year and 5-year storm events have been computed. Table 7 compares computed 5-year flow rates with estimated existing conditions pipe capacities. As indicated in the table, computed 5-year flow rates are less than existing pipe capacities at all points, indicating that the system would have sufficient capacity to accommodate runoff from a 5-year event. Please note, however, that downstream conditions, including high flood levels in Brays Bayou and limited capacity in the existing storm sewer systems along Bellaire Boulevard, may constrain the actual capacity of the shared system to something less than a 5-year event. Under those conditions, the unused storm sewer capacity would serve as in-line storage.

Table 7: Calculations for 5-Year Event – Existing Shared System with Reduced Drainage Area

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	5-Year Intensity (in/hr)	5-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
University	2.75	0.00	2.75	26.95	0.55	4.21	6.4	48	37.7
Swarthmore	4.44	0.00	4.44	28.00	0.55	4.13	10.1	48	37.7
Case	7.07	0.00	7.07	29.11	0.55	4.05	15.8	48	37.7
Byron	8.99	0.00	8.99	29.72	0.55	4.01	19.8	48	37.7
Oberlin	11.44	0.00	11.44	30.36	0.55	3.97	25.0	48	37.7
Villanova	13.24	0.00	13.24	30.76	0.55	3.94	28.7	48	37.7
Marquette	14.44	0.00	14.44	31.00	0.55	3.93	31.2	48	37.7
Southwestern	16.89	0.00	16.89	31.45	0.55	3.90	36.2	48	37.7
Riley	18.05	0.00	18.05	31.64	0.55	3.89	38.6	60	58.9
Ruskin	23.49	0.00	23.49	32.43	0.55	3.84	49.6	60	58.9

Table 8 provides preliminary storm sewer design capacity calculations for a parallel system along Auden Street. Figure 5 illustrates the drainage boundaries established for the purposes of analyzing a system along Auden. Red lines represent the area within Southside Place assumed to drain to the Auden Street system. The eastern boundary of that area coincides with the western edge of the Chilos Street right-of-way on the west side of Fire Truck Park. Dashed red lines represent approximate breaks between areas that flow to Auden along various east-west streets. Red boxes with leader lines and red text represent approximate areas that drain to the storm sewer interconnects along Auden Street. For the purposes of this conceptual design exercise, we have assumed that 11.23 acres of land within West University Place will drain to the system at University Boulevard, and that the eastern boundary of the area within the City of Southside Place draining to the system may be represented by a straight line approximately 1/3 of the way from Auden Street to Edloe Street. In order to provide the same level of service as the shared system, we have computed 5-year flow rates for the purposes of preparing a conceptual design for the Auden system. Pipe sizes required to convey 5-year flow rates along Auden range from 42 inches at University Boulevard to 78 inches at Bellaire Boulevard.

Table 8: Calculations for 5-Year Event - New Parallel Storm Sewer along Auden Street

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	5-Year Intensity (in/hr)	5-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
University	11.23	0.00	11.23	30.31	0.55	3.97	24.5	42	28.9
Jardin	11.23	3.82	15.05	31.12	0.55	3.92	32.5	48	37.7
Ingold	11.23	8.12	19.35	31.85	0.55	3.88	41.3	54	47.7
Harper	11.23	12.20	23.43	32.43	0.55	3.84	49.5	60	58.9
Garnet	11.23	16.86	28.09	32.99	0.55	3.81	58.8	60	58.9
Farber	11.23	21.27	32.50	33.46	0.55	3.78	67.6	66	71.3
Elmora	11.23	25.64	36.87	33.88	0.55	3.76	76.2	72	84.8
Darcus	11.23	30.23	41.46	34.27	0.55	3.73	85.1	72	84.8
Riley	11.23	33.46	44.69	34.53	0.55	3.72	91.4	78	99.5

Note that the construction of a new storm sewer along Auden will likely require the addition of a connector between the existing 72-inch storm sewer on the north side of Bellaire Boulevard and the existing box culvert storm sewer on the south side of Bellaire Boulevard, similar to the existing 48-inch connector between the two systems at the point where the existing shared storm sewer ties into the 72-inch system.

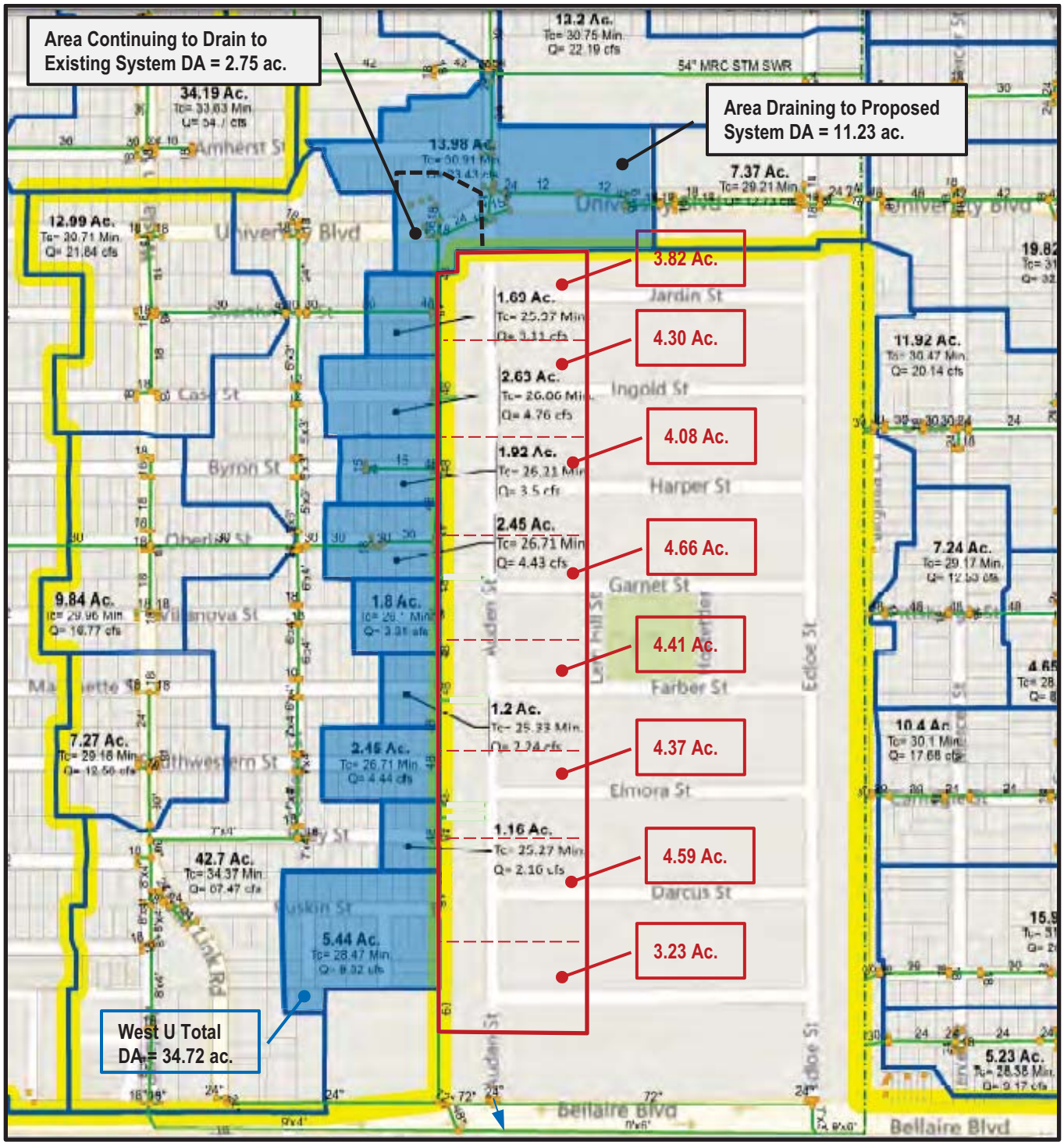


Figure 5: Drainage Area Map for Proposed Conditions

The cost associated with constructing a new storm sewer along Auden Street is estimated as shown in Table 9.

Table 9: Estimated Cost for New Storm Sewer along Auden Street (5-Year Capacity)

Item Description	Quantity	Unit of Measurement	Unit Price	Cost
Mobilization	1	LS	$25,000.00	$25,000.00
Site Preparation	1	LS	$25,000.00	$25,000.00
Remove Pavement (One 12' Lane x 3200')	4270	SY	$15.00	$64,050.00
Remove Existing Pipe, All Sizes	2600	LF	$10.00	$26,000.00
Install 42" Reinforced Concrete Pipe	350	LF	$180.00	$63,000.00
Install 48" Reinforced Concrete Pipe	350	LF	$210.00	$73,500.00
Install 54" Reinforced Concrete Pipe	350	LF	$270.00	$94,500.00
Install 60" Reinforced Concrete Pipe	350	LF	$295.00	$103,250.00
Install 66" Reinforced Concrete Pipe	350	LF	$360.00	$126,000.00
Install 72" Reinforced Concrete Pipe	700	LF	$405.00	$283,500.00
Install 78" Reinforced Concrete Pipe	750	LF	$550.00	$412,500.00
Remove & Replace Existing Curb Inlets	30	EA	$3,500.00	$105,000.00
Remove & Replace Existing Manholes	10	EA	$5,000.00	$50,000.00
Remove & Replace 24" Storm Sewer Laterals	450	LF	$95.00	$42,750.00
Replace Pavement (One 12' Lane x 3200')	4270	SY	$75.00	$320,250.00
Site Restoration	1	LS	$25,000.00	$25,000.00
De-Mobilization	1	LS	$25,000.00	$25,000.00
Sub-Total	-----	-----	-----	$1,864,300.00
Contingency	30%	-----	-----	$559,290.00
Sub-Total	-----	-----	-----	$2,423,590.00
Engineering	15%	-----	-----	$363,538.50
Overall Total	**-----**	**-----**	**-----**	**$2,787,128.50**

The cost of constructing a new storm sewer system along Auden Street, while costly, is significantly lower in cost than the alternative that calls for replacement of existing pipes along the existing shared system alignment. Based on the very preliminary cost numbers developed for this report, the cost of the Auden Street storm sewer is only about 3/4 of the cost associated with storm sewer replacement along the existing alignment. This fact, coupled with the difficulty of accessing the existing storm sewer and potential impacts to local residents in both West University Place and Southside Place, indicates that the Auden Street alternative warrants serious consideration.

ALTERNATIVE INVOLVING A NEW STORM SEWER ALONG UNIVERSITY BOULEVARD

We have also evaluated a possible project in which storm water from the 13.98-acre drainage area along University Boulevard is conveyed eastward along that roadway to Poor Farm Ditch. This improvement may be evaluated as a stand-alone project that could be implemented relatively quickly because it would involve work only in West University Place. It also represents an alternative to draining water from the 13.98-acre drainage area southward along Auden. Table 10 provides a summary of peak flow calculations and storm sewer pipe sizing for a storm sewer along University Boulevard. Note that the “DA Bndy.”

location refers to a point at the eastern boundary of the 13.98-acre drainage area. That point is approximately halfway between Auden Street and Edloe Street.

Table 10: Calculations for 2-Year Event – New Storm Sewer along University Boulevard

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	2-Year Intensity (in/hr)	2-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
Auden	11.23	0.00	11.23	30.31	0.55	3.08	19.0	36	21.2
DA Bndy.	18.60	0.00	18.60	31.73	0.55	3.00	30.7	48	37.7

Table 11 provides a summary of residual 2-year flow rates along the existing shared system with 11.17 acres of drainage area diverted to a proposed system along University Boulevard. As indicated, 2-year flow rates still exceed pipe capacities at several locations, but flow rates are significantly reduced as compared with the existing conditions values presented in Table3, which range from 23.4 cfs at University to 83.5 cfs at Ruskin.

Table 11: Calculations for 2-Year Event - Existing Shared System with New Storm Sewer along University Blvd.

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	2-Year Intensity (in/hr)	2-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
University	2.75	0.00	2.75	26.95	0.55	3.28	5.0	48	37.7
Swarthmore	4.44	0.00	4.44	28.00	0.55	3.21	7.8	48	37.7
Case	7.07	5.37	12.44	30.59	0.55	3.06	21.0	48	37.7
Byron	8.99	5.37	14.36	30.99	0.55	3.04	24.0	48	37.7
Oberlin	11.44	5.37	16.81	31.44	0.55	3.02	27.9	48	37.7
Villanova	13.24	7.39	20.63	32.04	0.55	2.99	33.9	48	37.7
Marquette	14.44	11.44	25.88	32.73	0.55	2.95	42.0	48	37.7
Southwestern	16.89	11.44	28.33	33.02	0.55	2.94	45.8	48	37.7
Riley	18.05	16.81	34.86	33.69	0.55	2.91	55.7	60	58.9
Ruskin	23.49	18.83	42.32	34.34	0.55	2.87	66.9	60	58.9

Table 12 summarizes 2-year flow rates and pipe sizes for a system along Auden that does not receive drainage from West University Place. With no inflow from West University Place, the required storm sewer sizes range from 24 inches at Jardin Street to 60 inches at Bellaire Boulevard. Figure 6 illustrates the existing condition of Auden Street, which as indicated is a curb-and-gutter street in a residential area.

Figure 6: View Looking Southward along Auden Street

Table 12: Calculations for 2-Year Event - New Storm Sewer along Auden (Assumes New System along University)

Location	West U DA (acres)	SSP DA (acres)	Total Area (acres)	Tc (minutes)	Runoff Coefficient	2-Year Intensity (in/hr)	2-Year Flow (cfs)	Pipe Size (inches)	Pipe Capacity (cfs)
University	0.00	0.00	0.00	15.00	0.55	4.29	0.0	---	---
Jardin	0.00	3.82	3.82	27.66	0.55	3.23	6.8	24	9.4
Ingold	0.00	8.12	8.12	29.46	0.55	3.13	14.0	30	14.7
Harper	0.00	12.20	12.20	30.53	0.55	3.07	20.6	36	21.2
Garnet	0.00	16.86	16.86	31.45	0.55	3.02	28.0	42	28.9
Farber	0.00	21.27	21.27	32.13	0.55	2.98	34.9	48	37.7
Elmora	0.00	25.64	25.64	32.71	0.55	2.95	41.7	54	47.7
Darcus	0.00	30.23	30.23	33.23	0.55	2.93	48.7	60	58.9
Riley	0.00	33.46	33.46	33.56	0.55	2.91	53.6	60	58.9

Table 13 provides an estimate of the total cost of a system along University Boulevard, while Table 14 provides an estimate of the cost of a system along Auden that does not receive runoff from West University Place. The total cost for the two projects is estimated to be $2,681,805.75. This total is consistent with the estimated cost of $2,787,128.50 for 5-year storm sewer along Auden as presented in Table 8.

Table 13: Estimated Cost for New Storm Sewer System along University Boulevard

Item Description	Quantity	Unit of Measurement	Unit Price	Cost
Mobilization	1	LS	$10,000.00	$10,000.00
Site Preparation	1	LS	$10,000.00	$10,000.00
Remove Pavement (One 12' Lane x 1300')	1740	SY	$15.00	$26,100.00
Remove Existing Pipe, All Sizes	2100	LF	$10.00	$21,000.00
Install 36" Reinforced Concrete Pipe	550	LF	$160.00	$88,000.00
Install 48" Reinforced Concrete Pipe	750	LF	$210.00	$157,500.00
Remove & Replace Existing Curb Inlets	12	EA	$3,500.00	$42,000.00
Remove & Replace Existing Manholes	6	EA	$5,000.00	$30,000.00
Remove & Replace 24" Storm Sewer Laterals	360	LF	$95.00	$34,200.00
Replace Pavement (One 12' Lane x 1300')	1740	SY	$75.00	$130,500.00
Site Restoration	1	LS	$10,000.00	$10,000.00
De-Mobilization	1	LS	$10,000.00	$10,000.00
Sub-Total	-----	-----	-----	$569,300.00
Contingency	30%	-----	-----	$170,790.00
Sub-Total	-----	-----	-----	$740,090.00
Engineering	15%	-----	-----	$111,013.50
Overall Total	**-----**	**-----**	**-----**	**$851,103.50**

Table 14: Estimated Cost for New Storm Sewer System along Auden (Assumes New System along University)

Item Description	Quantity	Unit of Measurement	Unit Price	Cost
Mobilization	1	LS	$25,000.00	$25,000.00
Site Preparation	1	LS	$25,000.00	$25,000.00
Remove Pavement (One 12' Lane x 2850')	3800	SY	$15.00	$57,000.00
Remove Existing Pipe, All Sizes	2600	LF	$10.00	$26,000.00
Install 24" Reinforced Concrete Pipe	350	LF	$95.00	$33,250.00
Install 30" Reinforced Concrete Pipe	350	LF	$120.00	$42,000.00
Install 36" Reinforced Concrete Pipe	350	LF	$160.00	$56,000.00
Install 42" Reinforced Concrete Pipe	350	LF	$180.00	$63,000.00
Install 48" Reinforced Concrete Pipe	350	LF	$210.00	$73,500.00
Install 54" Reinforced Concrete Pipe	350	LF	$270.00	$94,500.00
Install 60" Reinforced Concrete Pipe	750	LF	$295.00	$221,250.00
Remove & Replace Existing Curb Inlets	26	EA	$3,500.00	$91,000.00
Remove & Replace Existing Manholes	9	EA	$5,000.00	$45,000.00
Remove & Replace 24" Storm Sewer Laterals	390	LF	$95.00	$37,050.00
Replace Pavement (One 12' Lane x 3200')	3800	SY	$75.00	$285,000.00
Site Restoration	1	LS	$25,000.00	$25,000.00
De-Mobilization	1	LS	$25,000.00	$25,000.00
Sub-Total	-----	-----	-----	$1,224,550.00
Contingency	30%	-----	-----	$367,365.00
Sub-Total	-----	-----	-----	$1,591,915.00
Engineering	15%	-----	-----	$238,787.25
Overall Total	**-----**	**-----**	**-----**	**$1,830,702.25**

COMPARISON OF ALTERNATIVES

Table 15 provides a brief comparison of the alternatives evaluated in connection with the analysis described in this letter report, which include the following.

1. Improve the existing shared storm sewer system along the West U / Southside Place corporate boundary in place to provide 2-year capacity. This alternative assumes that a contractor will remove the existing storm sewer pipe and replace it along the existing pipe alignment.
2. Construct a new storm sewer along Auden Street with approximately 11.23 acres in West University Place included in the system drainage area. Design for 5-year capacity to match the level of service provided by the existing shared system with reduced drainage area.
3. Construct a new storm sewer along University Boulevard to convey flow from the 11.23-acre mentioned above plus an additional 7.37 acres along University to an outfall at Poor Farm Ditch. Construct a separate system along Auden Street to convey flow from Southside Place only.

The results briefly summarized in Table 15 indicate that the second alternative, involving a parallel system along Auden Street with inflow from 11.23 acres from West University Place, has the second-lowest cost but represents the most cost-effective option because it provides a greater level of service for the areas it would serve.

Table 15: Comparison of Estimates Costs for the Various Alternatives

Description of Alternative	Level of Service	Estimated Cost
Improve Existing Shared Storm Sewer Along Existing Alignment	2-Year	$3,565,201.25
Construct Parallel System Along Auden Street Draining 11.23 Acres in West U	5-Year	$2,787,128.50
Construct Parallel System Along Auden Plus Separate System Along University	2-Year	$2,681,805.75

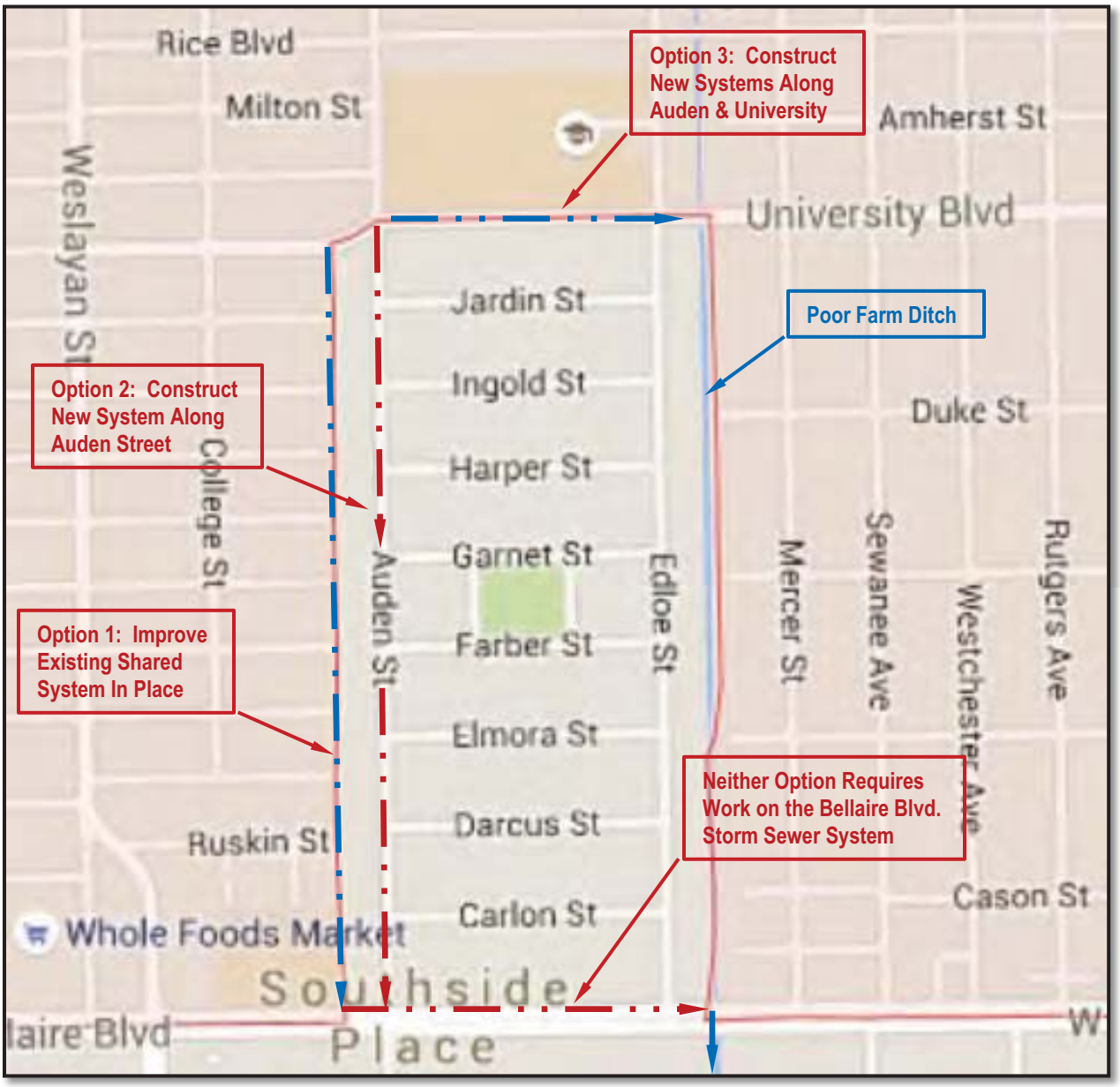


Figure 7: Improvement Alternatives

IMPACT & DETENTION CONSIDERATIONS

When planning development and drainage improvements in Harris County and the Greater Houston area, care must be taken to evaluate the potential for impacts on flood flow rates and flood elevations in downstream areas. The major reasons for requiring detention in connection with development, storm sewer improvements, and related roadway improvements is that impervious cover and runoff volume are increased, storm water is evacuated more efficiently via improved drainage systems, and streets are typically graded to provide more efficient surface flow to outfall channels. In the case of the improvements considered in this report, the following observations may be made.

1. The project area is already developed, and no increase in impervious cover is proposed. Therefore, runoff volumes will not be increased. Storm sewer systems are already in place, and thus the timing of flows to Poor Farm Ditch and Brays Bayou will not be significantly altered.

2. With the exception of the relatively small storm sewer that would be constructed along University Drive under Option 3, the storm sewer systems identified for possible improvement tie into existing storm sewers along Bellaire Boulevard with capacity to accommodate runoff from only a 2-year storm event. Those downstream systems will tend to regulate discharges from the improved systems and limit the potential for downstream impacts under more severe events. Out of bank flooding along Brays Bayou generally does not occur or is very limited within the project area during storms less severe than the 10-year event.

3. Re-grading of streets will be limited only to Auden (no re-grading of existing dead-end streets in West University Place is proposed), and top of pavement elevations along Auden are low enough that high water elevations in Brays Bayou and Poor Farm Ditch will limit the flow-carrying capacity of the street. In addition, opportunities for significant re-grading will be limited by existing development along the road. Therefore, no significant increase in flow-carrying capacity is anticipated.

4. Brays Bayou top of bank elevations at Buffalo Speedway and Stella Link Road (which bracket the project area to the east and west) range from about 48 feet to 49 feet. Top of bank elevations between those roadways range from about 45 feet to 48 feet. Information from the Flood Insurance Study for Harris County, Texas indicates that Brays Bayou flood elevations reach the following levels at various key points near the project area.

   - **Poor Farm Ditch**: 43.7', 46.0', and 48.3' for 10-year, 50-year, and 100-year events, respectively;
   - **Buffalo Speedway**: 44.3', 46.7', 49.0' for 10-year, 50-year, and 100-year events, respectively;
   - **Stella Link Road**: 45.5', 47.5', and 49.6' for 10-year, 50-year, and 100-year events, respectively.

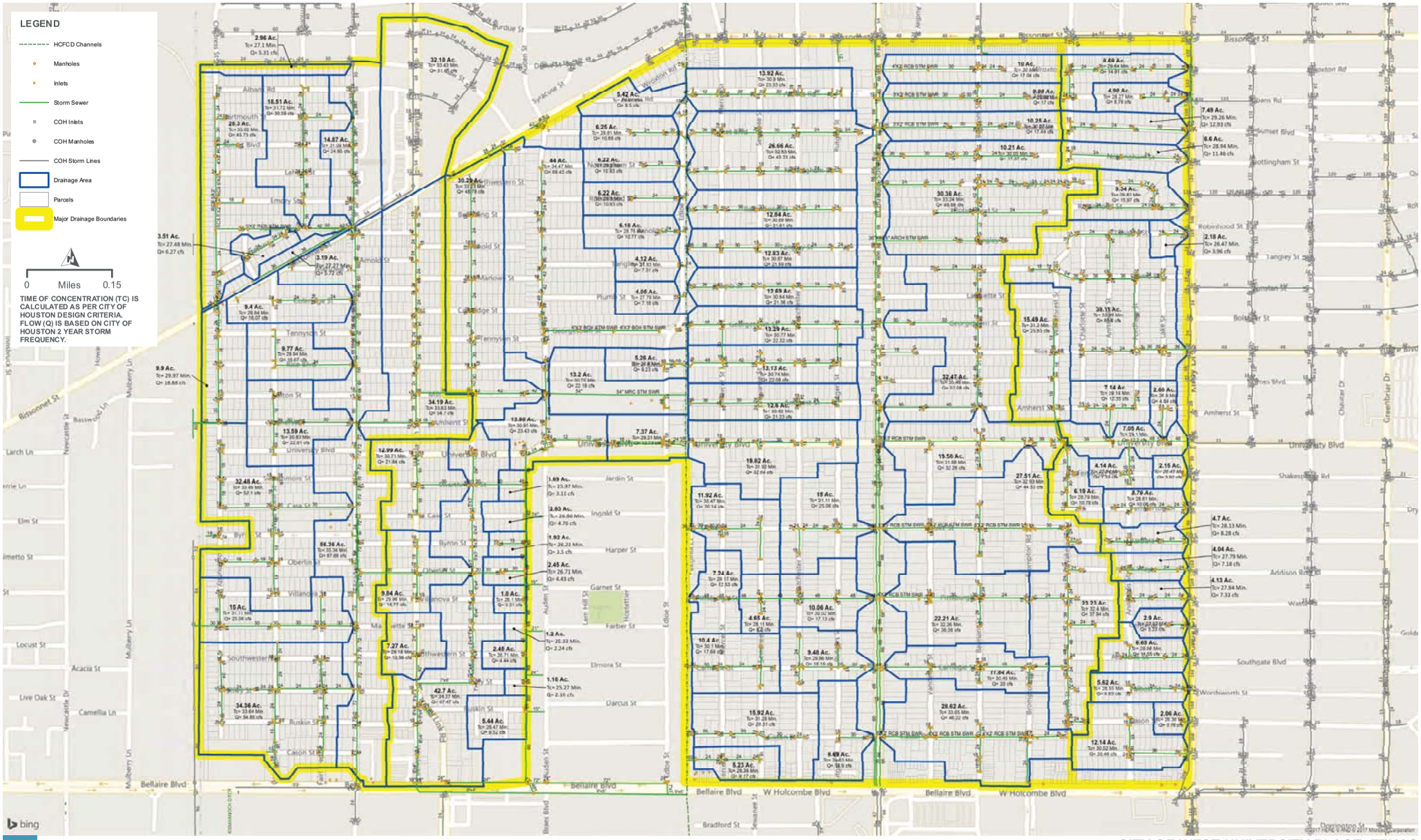
   The dead-end streets within West University Place experience substantial ponding at elevations of 48 feet and higher, and Auden Street experiences substantial ponding at elevations of 47 feet and higher. Even if the ongoing Project Brays improvements reduce flood elevations in the area, flooding will not be eliminated, and flood elevations will likely still be high during severe events. Under those conditions, tailwater in Brays Bayou and Poor Farm Ditch will still be high enough to affect drainage from the project area during events more severe than the 10-year. With backwater from Brays Bayou and Poor Farm Ditch, discharges from the storm sewer systems analyzed in connection with this report will be restricted.

Given these observations and considerations, it appears that the storm improvements described above will provide improved drainage during smaller events (generally less than the 10-year), but will not operate as efficiently during 10-year and greater events. Thus, the potential for impacts on downstream flow rates and flood levels will be limited during 10-year and greater events by conditions along Brays Bayou and Poor Farm Ditch. Since the 10-year event is generally considered to represent the "threshold" for flooding along Brays Bayou, increases in drainage efficiency for lesser storm events do not represent a significant risk in terms of increased flooding. For these reasons, detention is not recommended in connection with the

improvements described in this report. Note, however, that if any of the mitigating circumstances described above should change, the detention issue should be revisited.

CONCLUSION

The existing shared storm sewer system along the corporate boundary between the Cities of West University Place and Southside Place lacks capacity to accommodate a standard 2-year design storm event. Improvements to the existing system will be expensive and disruptive to local residents of both cities. Construction of a new parallel system along Auden Street within Southside Place offers a very reasonable alternative for reducing the flow to the existing shared system and providing capacity ranging from 2-year to 5-year depending on whether drainage from West University Place flows to the Auden Street system. An alternative that includes a new system along Auden plus a new storm sewer along University Boulevard would provide 2-year capacity at a total cost consistent with that of a single 5-year-capacity system along Auden that accepts storm runoff from an area of approximately 11.17 acres within West University Place. Both of the alternatives involving a new system along Auden provide greater benefit at lower cost than replacing the existing shared system with larger storm sewer along the existing alignment. HDR recommends that an alternative involving a new system along Auden be evaluated very seriously by the City of West University Place in cooperation with the City of Southside Place.



CITY OF WEST UNIVERSITY PLACE, TEXAS

DRAINAGE AREA MAP

PATH: Z:\CLIENTS\WEST UNIVERSITY PLACE\ASSORTED MAP FILES\DRAINAGE\DRAINAGE AREA MAP ANNO.MXD - USER: LTEFFT - DATE: 5/22/2017

Appendix

E

Preliminary Storm Sewer Drainage Analysis for Four Ponding Locations along Wakeforest Avenue in West University Place

April 21, 2016

hdrinc.com 4828 Loop Central Drive, Suite 800, Houston, TX US 77081-2220
(713) 622-9264

Preliminary Storm Sewer Drainage Analysis for Four Ponding Locations Along Wakeforest Avenue in West University Place

West University Place, Texas

April 2016

HDR

Preliminary Storm Sewer Drainage Analysis for Six Ponding Locations in the Academy Street Drainage System in West University Place

West University Place, Texas

Project Engineer

Min Xiao, PE
Name as Registered

96830
Texas Serial No.

STATE OF TEXAS
MIN XIAO
96830
LICENSED
PROFESSIONAL ENGINEER

4/21/16

Project Manager

Duane Barrett, PE
Name as Registered

63703
Texas Serial No.

STATE OF TEXAS
DUANE BARRETT
63703
LICENSED
PROFESSIONAL ENGINEER

4/21/16

April 2016

CONTENTS

1.0 EXECUTIVE SUMMARY 1

2.0 INTRODUCTION 2
- 2.1 Project Name and Purpose 2
- 2.2 Project Location 2
- 2.3 Project Objectives 2
- 2.4 FEMA Flood Zones 2
- 2.5 Data Sources 2

3.0 DRAINAGE ANALYSIS 4
- 3.1 Existing Condition 4
- 3.2 Brays Bayou Water Surface Elevation 4
- 3.3 Street Profiles 4
- 3.4 Inlets at Ponding Locations 7
- 3.5 Drainage Area 10
- 3.6 Hydrologic Methods 10
  - 3.6.1 Land Use 10
  - 3.6.2 Time of Concentration 11
  - 3.6.3 Rational Method 12
- 3.7 Calculated 2-Year Peak Flow Rates 12
- 3.8 Storm Sewer Conveyance Capacity Required 13

4.0 CONCLUSION 17

List of Tables

Table 3-1. Brays Bayou Water Surface Elevation within City Limits 4
Table 3-2. Inlets at Locations of Interest 7
Table 3-3. Land-Use Categories 10
Table 3-4. Harris County 2-Year Intensity-Duration-Frequency Coefficients 12
Table 3-5. Accumulative Drainage Area and 2-Year Flow Rate for Storm Sewer Segments 13
Table 3-6. Existing and Required Storm Sewer Size to Convey 2-Year Flow Rates 14
Table 3-7. Summary of Inlet Capacity 14
Table 3-8. Cost Estimate of Storm Sewer System Improvement for Project Area 16

List of Figures

Figure 1. Wakeforest Avenue Profile 5
Figure 2. Georgetown Street Profile 5
Figure 3. River Boulevard Profile 6
Figure 4. Carolina Way Profile 6
Figure 5. Pittsburgh Street Profile 7
Figure 6. Inlets on Wakeforest Avenue in Project Area (1) 9
Figure 7. Inlets on Wakeforest Avenue in Project Area (2) 9
Figure 8. Upland Method Correlation between Flow Velocity, Surface Type, and Slope 11

List of Exhibits

Exhibit 1. Areas of Interest and Vicinity Map
Exhibit 2. Floodplain Map of West University Place
Exhibit 3. Topographic Map of Project Area
Exhibit 4. Storm Sewer Layout in Project Area
Exhibit 5. Brays Bayou Water Surface Elevation Profiles
Exhibit 6. Overall Drainage Area Map
Exhibit 7. Project Drainage Area Map
Exhibit 8. Land Use Type Map

List of Acronyms

AEP	Annual Exceedance Probability
CFS	Cubic Feet Per Second
COH	City of Houston
CN	Curve Number
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FPS	Feet Per Second
FT	Feet
GIS	Geographic Information System
H-GAC	Houston-Galveston Area Council
IN/HR	Inches Per Hour
LiDAR	Light Detection and Ranging
NAIP	National Aerial Imagery Program
NAVD	North American Vertical Datum
NRCS	Natural Resources Conservation Service
ROW	Right-Of-Way
TxDOT	Texas Department of Transportation
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WSE	Water Surface Elevation

1.0 Executive Summary

A preliminary storm sewer drainage analysis was performed for four (4) ponding locations in the City of West University Place. A significant portion of the city is within the 100-year floodplain of Brays Bayou, including two of the four locations of interest. The existing layouts and sizes of storm sewer lines were obtained from the report titled "Comprehensive Plan for Infrastructure Improvements" dated April 1993 and prepared for the City of West University Place by Langford Engineering, Inc., with supplemental information from construction documents prepared for paving and drainage projects completed in the City since 1993. Note that the report does not provide invert elevation information for storm sewer lines.

Elevation profiles were plotted for the streets where these intersections are located. It is found that most of the intersections are located at low points along street profiles. Any excess of runoff above the conveyance capacity of the storm sewer lines serving these locations will accumulate and pond in the intersections instead of sheet-flowing away along the streets.

The 2-year peak flow rate was computed at locations of interest using the Rational Method to estimate the required inlet and storm sewer capacities serving the areas of interest. The required capacities were then compared to the existing capacities to determine deficiencies. A constant 3 fps storm sewer flow velocity was used in estimating the existing and required storm sewer capacities. This assumption reflects standard design procedure in the Greater Houston area and is considered adequate for this preliminary study. A detailed study involving hydrologic and hydraulic modeling tools is recommended to size the storm sewer lines in order to account for the slope of the storm sewer system. In order to complete that study, field survey data will be required to define the storm sewer elevation data.

The results of this preliminary study show that inlet capacity is insufficient at the intersection of Wakeforest Avenue and Pittsburgh Street.

The existing conveyance capacities of most storm sewer lines serving these locations of interest do not satisfy current 2-year storm capacity requirements. The existing storm sewer lines will have to be upsized in order to provide the 2-year storm capacity. The required storm sewer sizes are provided in ***Table 3-6*** in this report.

2.0 INTRODUCTION

2.1 Project Name and Purpose

This study includes a preliminary drainage analysis of the storm sewer systems of interest along Wakeforest Avenue in the City of West University Place, Texas. The purpose of this study is to assess ponding issues that occur at four (4) street intersections during storm events. This report is prepared for the Public Works Department of the City of West University Place.

2.2 Project Location

The project area is within the city limits of West University Place in Harris County. The four ponding locations of interest are listed below. ***Exhibit 1*** shows the four ponding locations of interest and the city limits.

1. Wakeforest Avenue at Georgetown Street
2. Wakeforest Avenue at Rice Boulevard
3. Wakeforest Avenue at Carolina Way
4. Wakeforest Avenue at Pittsburgh Street

2.3 Project Objectives

This drainage study includes drainage area delineation, peak flow estimation, and storm sewer evaluation. The storm frequency used in this analysis is the 2-year storm event. The objective of the analysis is to assess the capacity of the existing storm sewer systems at the locations of interest.

2.4 FEMA Flood Zones

The project area is located in the eastern portion of the City of West University Place. The area is located on Harris County FIRM Panel 48201C0860L. A significant portion of the City of West University Place is within the regulatory floodplain of Brays Bayou (HCFCD Channel D100-00-00) designated as Zone AE with defined flood elevations, as shown on ***Exhibit 2***. The City of West University Place is located approximately between FIRM panel Cross Section BF and Cross Section AX (see ***Exhibit 3***). Zone AE indicates that base flood elevation has been determined for this stream. The BFE value of Brays Bayou in West University Place city limits ranges from 47 ft at Kirby Drive to 49 ft at College Avenue (NAVD 88 2001 adjustment). The portion of the city west of College Avenue lies mostly outside of the regulatory floodplain. Two of the four locations of interest, Wakeforest Avenue at Carolina Way and Wakeforest at Pittsburgh Street, are within the regulatory floodplain with a BFE value of 48 ft.

Although a significant portion of the city is within the regulatory floodplain, this report does not address the flooding issues caused by Brays Bayou. Instead, this report focuses on the capacity of the existing storm sewer system at each of the locations of interest and the storm sewer's ability to convey standard 2-year design runoff rates.

2.5 Data Sources

A list of data that were used for this project is provided below.

- The 2008 H-GAC LIDAR (NAVD 1988, 2001 adjustment) was used for drainage area delineation and was also used to evaluate street elevation profiles to determine low points along streets where ponding may occur.

- The report titled “Comprehensive Plan for Infrastructure Improvements” dated April 1993 and prepared for the City of West University Place by Langford Engineering, Inc. (referred to as the Report in this document) was provided by the Public Works Department of the City of West University Place. This report presents the layouts and sizes of the existing storm sewer lines within the City of West University Place, but does not provide information on invert elevations of storm sewer lines.

- The GIS layer of storm sewer lines within the West University Place city limits was downloaded from the City of Houston (COH) GIMS database. It is noted that the storm sewer data within the project area in this database is limited. It is likely that COH does not collect and maintain the infrastructure data for the area within the city limits of West University Place. The data downloaded from GIMS was used as a supplement to the storm sewer information obtained from the Report.

- Construction documents for paving and drainage projects completed within the City of West University Place since 1993 were used to supplement and update information obtained from the Report and from the City of Houston GIMS database.

- Harris County FIRM maps were obtained from the FEMA web site.

- H-GAC aerial images dated 2014 were used in the study.

- Field visits were conducted by HDR staff in November 2015 to visually evaluate the general condition of the roadway and storm sewer systems, especially inlet density and size, within the project area. Photos were taken during field visits.

3.0 Drainage Analysis

A hydrologic analysis was performed to delineate drainage areas and to determine the 2-year peak flow rates for the storm sewer systems where the ponding occurs. This section describes the methodologies used in the peak flow calculations and presents the results.

3.1 Existing Condition

The four ponding locations of interest are shown on ***Exhibit 1***. The City of West University Place is primarily developed in single family residential areas with some light commercial areas scattered within the city limits. The ground elevation slopes south-eastward ranging from approximately 54.0 ft (NAVD 88, 2001 Adjustment) at the northwest corner of the city to approximately 47.5 ft at the southeast corner. A topographic map is provided on ***Exhibit 3***. ***Exhibit 4*** presents the storm sewer systems in the project area, including the four locations of interest on Wakeforest Avenue. Available information indicates that areas of interest north of University Boulevard (Wakeforest at Georgetown and Wakeforest at Rice) drain to the east via a storm located within the University Boulevard right-of-way and enter the Kirby Drive storm sewer system. The areas of interest south of University Boulevard (Wakeforest at Carolina Way and Pittsburg) drain to the west via a storm sewer located within the right-of-way of Carnegie Street and enter the Buffalo Speedway storm sewer system, which in turn empties into Poor Farm Ditch.

3.2 Brays Bayou Water Surface Elevation

The City of West University Place is located approximately between FIRM panel Cross Section BF and Cross Section AX (see ***Exhibit 3***). A significant portion of West University Place is within the 100-year floodplain of Brays Bayou. ***Exhibit 5*** illustrates the FEMA water surface elevation (WSE) profiles for this portion of Brays Bayou. This profile is taken directly from the FEMA FIS study report for Harris County. ***Exhibit 3*** plots the FEMA cross sections of Brays Bayou with 10- and 100-year WSE indicated on a contour and color-shaded topographic map of West University Place. ***Table 3-1*** summarizes the 10-, 50, 100- and 500-year water surface elevations along Brays Bayou at FEMA Cross Sections BF, BE, BD, BC, BB, BA, AZ, AY and AX. The 10-year WSE from west to east within the city limits ranges from 46.4 ft at Cross Section BF to 41.9 ft at Cross Section AX; the 100-year WSE ranges from 50.8 ft to 46.9 ft.

Table 3-1. Brays Bayou Water Surface Elevation within City Limits

FEMA Cross Section	BF	BE	BD	BC	BB	BA	AZ	AY	AX
500-Year WSE	52.2	52.0	51.7	51.7	51.6	51.4	51.1	50.9	50.5
100-Year WSE	50.8	50.7	49.5	49.4	49.3	49.0	48.3	48.1	46.9
50-Year WSE	48.8	48.7	47.3	47.2	47.0	46.6	45.9	45.7	44.1
10-Year WSE	46.4	46.1	45.1	44.9	44.7	44.3	43.3	43.1	41.9

3.3 Street Profiles

All of the locations of interest are on Wakeforest Avenue. Street profiles were plotted along Wakeforest and the streets of interest that intersect it. ***Exhibit 1*** shows the extents of these street profile plots. ***Figure 1*** to ***Figure 5*** illustrate the actual street profiles.

It is noted that the intersections where ponding occurs are usually located at low points along the street profile. If the runoff during a storm event exceeds the conveyance capacity of the storm sewer inlets and

pipes serving these areas, water will accumulate and pond instead of sheet-flowing away along the streets.

Figure 1. Wakeforest Avenue Profile

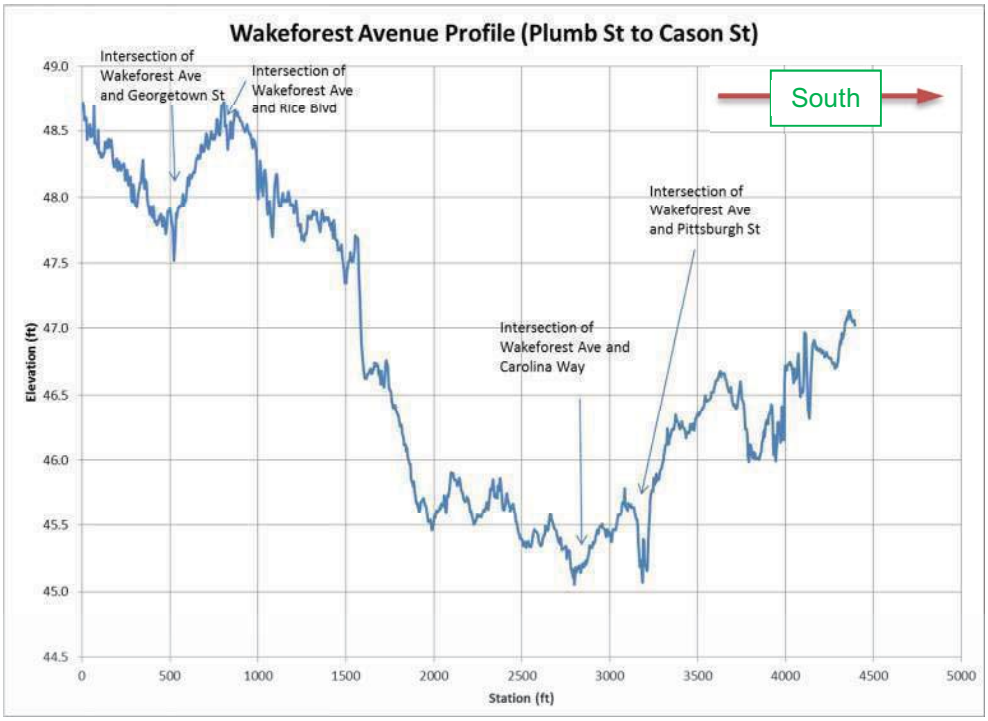


Figure 2. Georgetown Street Profile

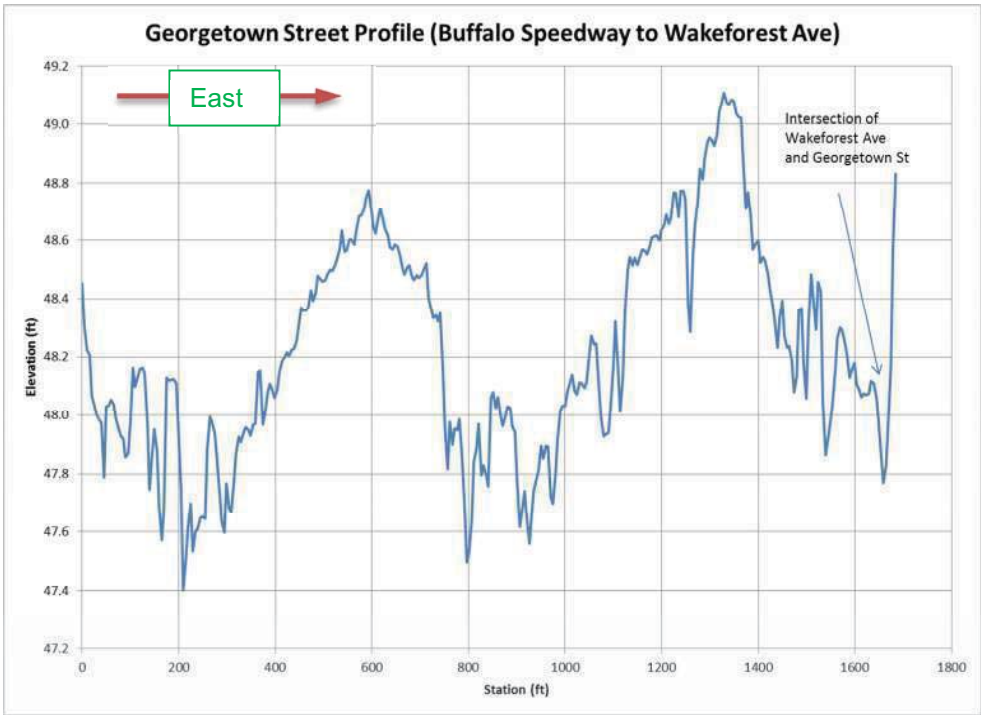


Figure 3. River Boulevard Profile

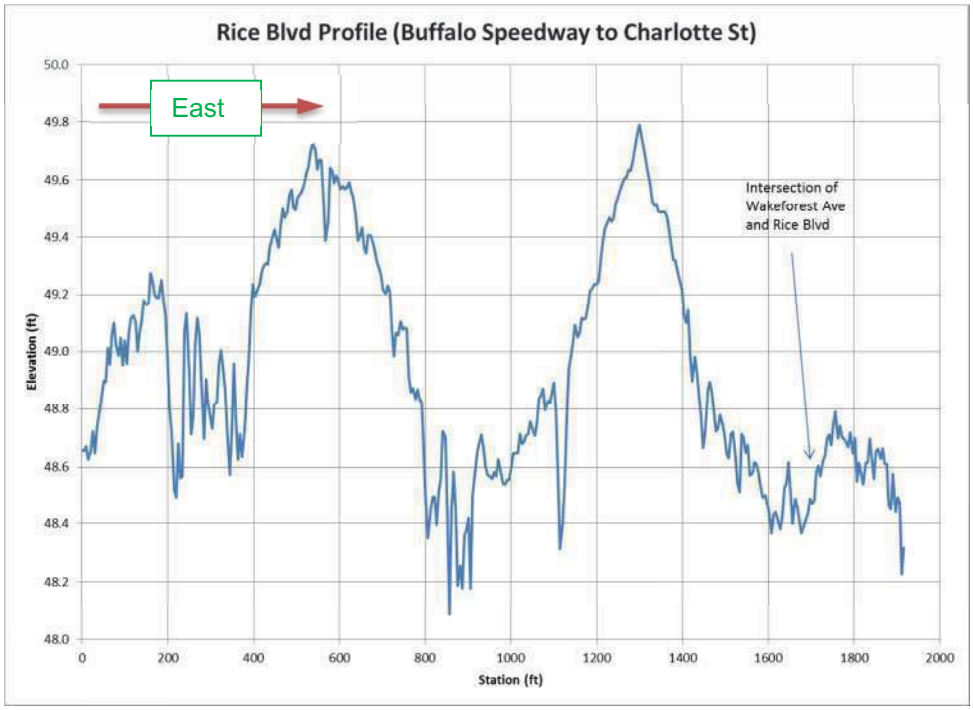


Figure 4. Carolina Way Profile

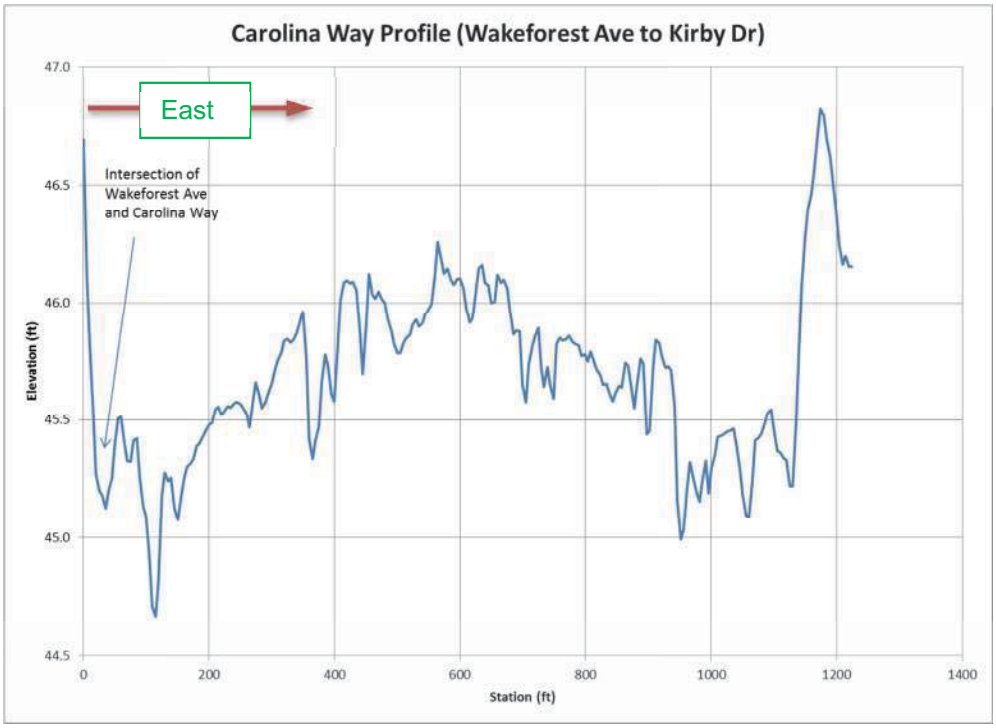
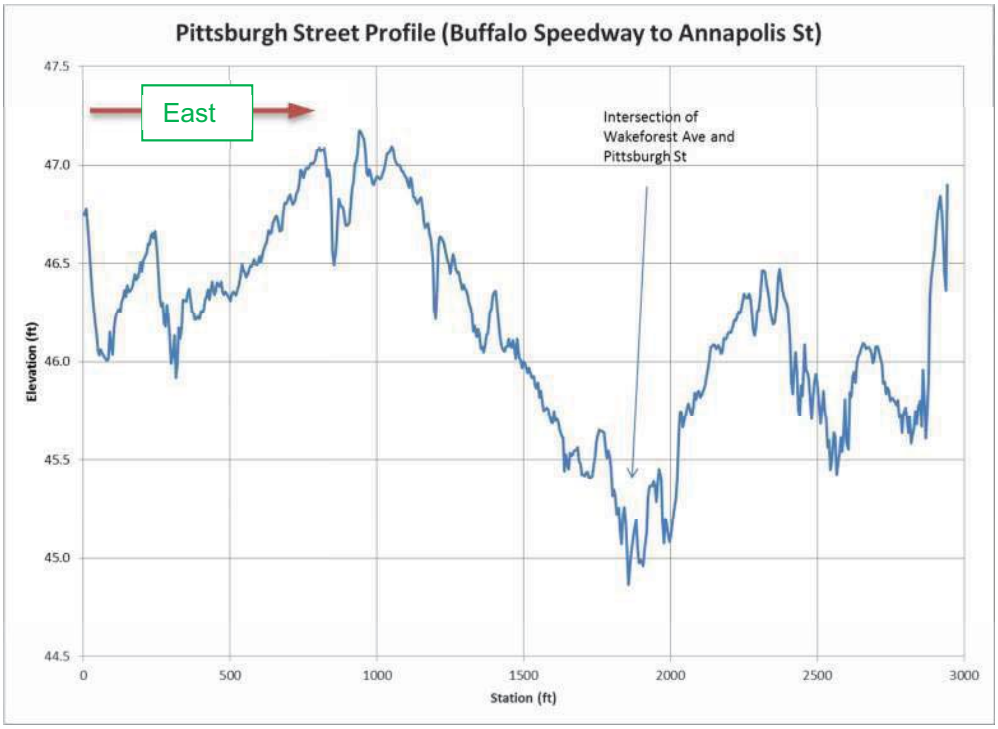


Figure 5. Pittsburgh Street Profile



3.4 Inlets at Ponding Locations

Inlet type and density at the ponding locations were checked to see if sufficient inlet capacity is provided to satisfy the standard 2-year design storm requirement. ***Table 3-2*** summarizes the inlet type and number at these intersections. ***Figure 6*** to ***Figure 7*** are aerial photos showing inlet locations at these intersections and in the surrounding areas. Most of the inlets at these intersections are double B inlets. Occasionally, grate inlets are observed at some locations, usually at driveways. Inlet capacity is a function of inlet type, size, location (on grade or in sag), ponding depth, gutter depression, longitudinal gutter slope, transverse gutter slope, transverse gutter width, etc. Typically, a double B inlet provides approximately 4 cfs capacity, whereas a single B inlet or a grate inlet provides about 2 cfs capacity.

Table 3-2. Inlets at Locations of Interest

Intersection	Number of Existing Inlets	Type of Inlet
Wakeforest Avenue at Georgetown Street	4	Three Double B, One grate
Wakeforest Avenue at Rice Boulevard	4	Double B
Wakeforest Avenue at Carolina Way	3	Double B
Wakeforest Avenue at Pittsburgh Street	2	Double B

There are four inlets (three double B and one grate inlet at a driveway) at the intersection of Wakeforest Avenue and Georgetown Street. Four double B inlets are observed at the intersection of Wakeforest Avenue and Rice Boulevard. Three double B inlets were observed at the intersection of Wakeforest Avenue and Carolina Way. Also, two double B inlets were observed approximately 105 ft east of the intersection on Carolina Way.

Two double B inlets are available at the intersection of Wakeforest Avenue and Pittsburgh Street. Two double B inlets are found approximately 100 ft north of the intersection on Wakeforest Avenue, and another two double B inlets are located approximately 100 ft south of the intersection on Wakeforest Avenue. In addition, two double B inlets were observed approximately 100 ft east of the intersection on Pittsburgh Street.

Figure 6. Inlets on Wakeforest Avenue in Project Area (1)

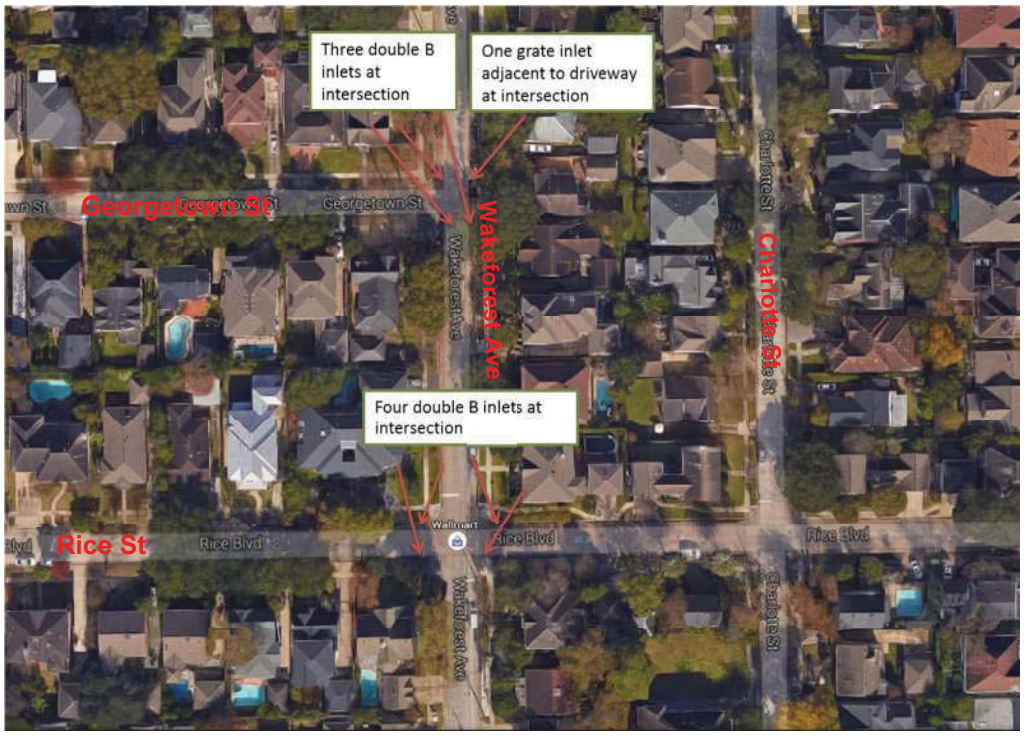


Figure 7. Inlets on Wakeforest Avenue in Project Area (2)

3.5 Drainage Area

The City of Houston GIMS database and the storm sewer information obtained from the Report and construction plans were used to delineate the approximate drainage areas used for this study. ***Exhibit 6*** presents an overall drainage map for the City of West University Place. This overall drainage map includes the City of Houston areas that drain to the City of West University Place drainage systems. The western portion of the city discharges to Kilmarnock Ditch. The middle portion of the City, including two of the four areas of interest, drains to Poor Farm Ditch. The eastern portion, including the remaining two of four areas of interest, drains to storm sewer lines on Kirby Drive, which in turn drain to City of Houston storm sewer systems. The major areas that lie within the City of Houston but drain to the City of West University Place are indicated on the overall drainage map. These areas include the triangular commercial area east of Academy Street and north of Bissonnet Street, and the areas that are located north of the City of West University Place boundary along Bissonnet Street but drain southward into the City's storm sewer systems.

The project drainage areas for the storm sewer systems that serve the ponding locations of interest were delineated using available maps and storm sewer data. The delineated drainage areas were used to calculate 2-year peak flow rates for the storm sewer lines under consideration in this study. ***Exhibit 7*** displays the project drainage areas delineated for analysis.

3.6 Hydrologic Methods

The Rational Method was utilized to compute 2-year peak flow rates in this study. The Rational Method requires the composite C value and time of concentration (t_c) for each drainage area. The e, d and b values developed by TxDOT for Harris County were used to compute rainfall intensities.

3.6.1 Land Use

Land-use data are required to estimate the composite C value for each drainage area. The land use classification was determined based on the aerial photography of the project area. The land-use types within the project drainage areas were defined into two classifications: single-family residential and commercial/multi-family. ***Exhibit 8*** depicts the land use types defined for the project area. Typical Rational Method runoff coefficients were assigned to each of the two land use classifications. ***Table 3-3*** presents the land-use types and the associated runoff coefficients used in the study.

Table 3-3. Land-Use Categories

General Land-Use Categories	C Value
Single Family Residential	0.40
Commercial or Multi-Family	0.65

The land-use data were combined with drainage areas to allow computation of the composite C value for each drainage area. The combined land uses and associated areas for each drainage area were identified. Using the following equation, the composite land-use C value was calculated for each drainage area:

$$\bar{C} = \frac{\sum_{i=0}^{n} A_i RC_i}{\sum_{i=0}^{n} A_i}$$

where:

C_i = C value of each land-use type for a drainage area;

A_i = area associated with land-use type for a drainage area; and

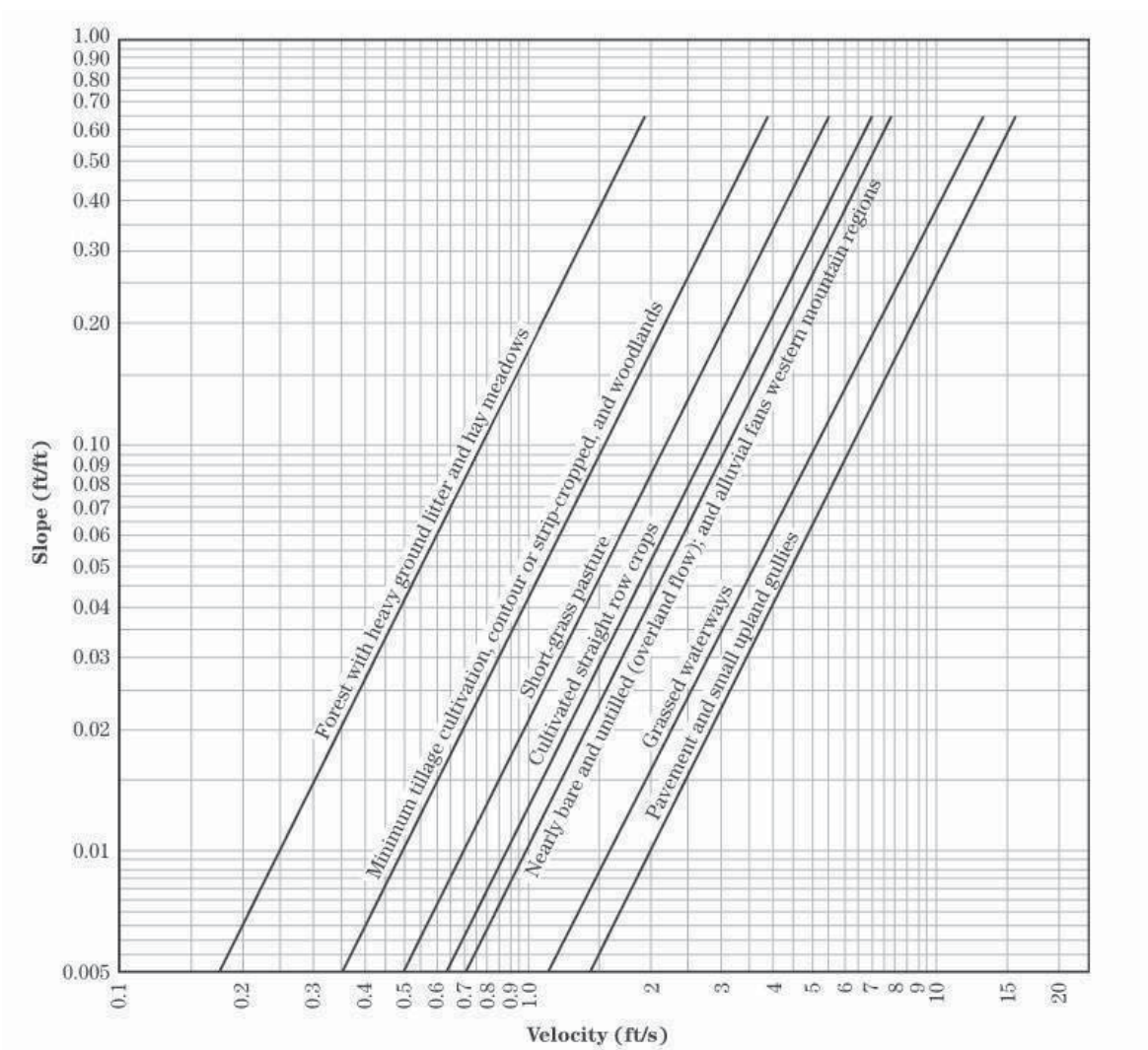
$\bar{C}$ = composite C value for a drainage area.

The area-weighted C value for each drainage area was then used in the Rational Method to compute the 2-year peak flow rate.

3.6.2 Time of Concentration

The NRCS Upland Method was used to estimate the time of concentration (t_c) for each of the drainage areas. Flow paths were divided into flow segments that were defined by various flow classifications, including short grass overland flow, paved area/shallow gutter flow, and storm sewer flow. Flow velocity for each flow segment was determined based on the flow classification and slope of flow path (except for storm sewer flow, which used a constant design flow velocity of 3 fps per standard design practice in the Greater Houston area). The travel time through each flow segment was summed for each drainage area to obtain the time of concentration. ***Exhibit 8*** presents the NRCS Upland Method correlation between flow velocity, surface flow type and flow path slope.

Figure 8. Upland Method Correlation between Flow Velocity, Surface Type, and Slope



A ten-minute minimum time of concentration was utilized for all inlet drainage areas.

3.6.3 Rational Method

The Rational Method equation is expressed as:

$$Q = CIA$$

where:

Q = computed peak runoff discharge (cfs);
C = weighted runoff coefficient;
I = average rainfall intensity (in/hr); and
A = drainage area (ac).

The rainfall intensity was determined using the following equation:

$$I = \frac{b}{(t_c+d)^e}$$

where:

I = rainfall intensity (in/hr);
t_c = time of concentration (min); and
b, d, e = coefficients for each storm frequency.

The *b*, *d,* and *e* values for Harris County are presented in ***Table 3-4***.

Table 3-4. Harris County 2-Year Intensity-Duration-Frequency Coefficients

Coefficient	2-year
e	0.800
b	68
d	7.9

Once the runoff coefficient (*C*), average rainfall intensity (*I*), and drainage area acreage (*A*), were determined for each drainage area, these values were substituted into the Rational Method equation to calculate the 2-year peak flow rates.

3.7 Calculated 2-Year Peak Flow Rates

The 2-year flow rates calculated using the Rational Method for the study storm sewer segments serving the areas of interest (see ***Exhibit 4***) are summarized in ***Table 3-5***. These 2-year flow rates were compared with the estimated capacities of existing storm sewer pipes to identify any capacity deficiencies in the existing systems. Note that the start node and end node of each storm sewer segment are shown on ***Exhibit 4***.

Table 3-5. Accumulative Drainage Area and 2-Year Flow Rate for Storm Sewer Segments

Storm Sewer Segment		Drainage Area (acres)	2-Year Flow Rate (cfs)	Existing Storm Sewer Capacity (cfs)	Deficiency (cfs)
From Node	To Node				
501	502	6.1	12.0	5.3	6.7
502	503	10	18.4	5.3	13.1
601	503	8.1	20.3	14.7	5.6
503	602	46	40.1	37.7	2.4
701-a	701	4.8	8.6	9.4	No Deficiency
701	702	11	18.3	9.4	8.9
702	703	16	26.7	14.7	12.0
703	704	27	42.1	37.7	4.4
704	705	49	63.5	37.7	25.8

3.8 Storm Sewer Conveyance Capacity Required

The street profiles show that each of the locations of interest where the ponding occurs are located at a low point along the street. In a storm event the runoff exceeds the storm sewer conveyance capacity serving these locations, and the excess of water cannot flow away via sheet (surface) flow, but accumulates and ponds at these locations.

The 2-year flow rates calculated by the Rational Method were used to evaluate the storm sewer systems serving these areas to check if the existing storm sewer has sufficient capacity to convey the 2-year flow, and if not, the required size of each storm sewer segment was estimated.

It is typically recommended that hydrologic and hydraulic modeling tools (e.g., SWMM or WinStorm) be used to evaluate storm sewer systems. However, modeling of storm sewer systems requires details of the systems, including the invert elevations of the storm sewer lines. This information was not available for this study. Because this study is a preliminary drainage analysis, instead of completing detailed storm sewer modeling, a rough storm sewer evaluation was performed using the required conveyance flow rates (i.e. the 2-year flow calculated above) and storm capacities based on an assumed constant average storm sewer flow velocity of 3 fps for all storm sewer lines to estimate the storm sewer size required. The flow rate ($ft^{3/}sec$) in a storm sewer was divided by the flow velocity of 3 fps to determine the cross-sectional area required, and then to obtain the storm sewer dimensions that provide the required cross-sectional area. As stated above, this method only provides a rough estimate of the storm sewer size required, but it is adequate for this preliminary study. A detailed study involving storm sewer modeling is recommended for a more accurate evaluation.

Table 3-6 shows the approximate storm sewer sizes required to convey the 2-year flow in comparison with the existing storm sewer sizes. It can been seen that most of the existing storm sewer lines that serve the locations of interest do not have sufficient conveyance capacity, which explains at least in part why these locations frequently suffer ponding problems.

Table 3-6. Existing and Required Storm Sewer Size to Convey 2-Year Flow Rates

Storm Sewer Segment		Existing Circular Pipe Diameter (ft)	Storm Sewer Size Required			
From Node	To Node		Storm Sewer Shape	Diameter for Circular; or Width for Box (ft)	Height for Box (ft)	No. of Barrels
501	502	1.5	Circular	2.5	-----	1
502	503	1.5	Circular	3.0	-----	1
601	503	2.5	Circular	3.0	-----	1
503	602	3.0 - 4.0	Circular	4.5	-----	1
701-a	701	2.0	Circular	2.0	-----	1
701	702	2.0	Circular	3.0	-----	1
702	703	2.5	Circular	3.5	-----	1
703	704	4.0	Circular	4.5	-----	1
704	705	4.0	Circular	5.5	-----	1

Table 3-7 summarizes the existing inlet capacity at each of the intersections of interest and the required capacity, which is the 2-year flow rate generated in the direct drainage area contributing to each intersection. The actual inlet capacity is affected by many factors. For this study, the evaluation of inlet capacity at each intersection is simplified by assuming an inlet capacity of 2 cfs for single B inlets or grate inlets and 4 cfs for double B inlets, which is typical capacity for these inlets. This assumption is considered adequate for the preliminary level study. The intersection of Wakeforest Avenue and Pittsburgh Street was found to be approximately 1.6 cfs deficient in inlet capacity. However, a number of inlets were observed in the street near the intersection (see ***Figure 7***). These street inlets serve as on-grade inlets to capture flow on the way to the intersection. Therefore, it is likely the inlet capacity at this intersection will satisfy the 2-year storm capacity requirement.

Note that the required capacity presented in ***Table 3-7*** is only the runoff generated within the direct drainage area contributing to the intersections of interest and does not account for any additional flows that exceed the capacity of nearby street inlets and travel along the street gutters to the intersections of interest. The quantification of the excess of runoff from other inlets requires a more detailed storm sewer modeling tool (e.g. WinStorm or SWMM) and is not reflected in this preliminary study.

Table 3-7. Summary of Inlet Capacity

Intersection	Number of Inlet	Type of Inlet	Available Capacity (cfs)	Required Capacity (cfs)	Additional Double B Inlets
Wakeforest Avenue at Georgetown Street	4	Three double B & One grate	14	12.0	0
Wakeforest Avenue at Rice Boulevard	4	Double B	16	9.9	0
Wakeforest Avenue at Carolina Way	3	Double B	12	8.6	0
Wakeforest Avenue at Pittsburgh Street*	2	Double B	8	9.6	1

***Street inlets near the intersection will help meet the capacity requirement.**

It should be noted that inlet capacity has been supplemented over the years as streets have been repaired or upgraded. Thus, inlet capacity appears to be adequate at many of the intersections evaluated

in connection with this study and report. However, storm sewer systems still show deficiencies when compared with standard 2-year design storm flow rates.

A rough cost estimate for upgrading the existing storm sewer systems analyzed in this study to standard 2-year design storm sewer and inlet capacity was prepared for this report. The cost estimate includes the removal of existing undersized storm sewer systems (inlets, manholes and storm sewer lines), the removal of pavement, the replacement of inlets, manholes, storm sewer lines, and pavement, and provisions for the potential detention requirement. The estimate includes 15% for ancillary items and another 15% for contingencies. Since the detailed inlet and manhole database is not available, it was assumed for cost estimating that there are four inlets at each four-way intersection and three at each "T" intersection. It is also assumed that there is a manhole at each storm sewer junction to estimate the number of manholes.

The detention requirement was estimated using a Basin Development Factor (BDF) approach developed by HDR for the Harris County Flood Control District to estimate detention requirements in urban areas. The worksheet facilitates determination of the total BDF value, which is a function of channel, storm sewer, and street conditions, for both existing conditions and improved conditions with 2-year capacity. The difference between the existing and improved BDF values was then used to estimate the detention storage rate (ac-ft of required detention storage per acre of drainage area) based on a Detention Storage Rate versus Change in BDF Value chart. The detention storage rate to improve the project area was estimated to be 0.12 ac-ft of detention per acre of drainage area. For a total drainage area of 46.0 + 49.0 = 95.0 acres for the two areas analyzed in connection with this study and report, the total required detention volume was then determined to be 0.12 ac-ft/acre x 95 acres = 11.4 ac-ft. A detention basin depth of 6.5 ft (including 1 ft unusable freeboard) was used to estimate the total acreage of the detention basin, which includes 30-ft maintenance berms around the basin. The total area of the detention basin site was determined to be approximately 3.5 acres.

The cost estimate is presented in ***Table 3-8***. The unit prices were taken from the City of Houston's *FY15 Pre-Engineering Bid Unit Prices*. The cost for land acquisition was estimated based on an approximate average HCAD value of $15 per square ft in the area. A multiplier of 3 was then applied to the average HCAD value to estimate the land acquisition cost.

Table 3-8. Cost Estimate of Storm Sewer System Improvement for Project Area

ITEM	DESCRIPTION	UNIT	UNIT PRICE	QUANTITY	COST
1	Remove Storm Sewer Pipe (All Types)	LF	$15	5,693	$85,395
2	Remove Storm Sewer Box (All Types)	LF	$15	0	$0
3	Remove Inlets (All Types)	EA	$340	58	$19,720
4	Remove Manholes (All Types, All Depths)	EA	$350	8	$2,800
5	Inlets (All Types)	EA	$2,150	58	$124,700
6	Manholes (42" Dia Pipe and Smaller) (All Types)	EA	$2,800	3	$8,400
7	Manholes (48" to 72" Dia Pipe) (All Types)	EA	$6,000	5	$30,000
8	Manholes (78" Dia Pipe and Larger) (All Types)	EA	$10,000	0	$0
9	24" RCP	LF	$75	0	$0
10	30" RCP	LF	$105	263	$27,615
11	36" RCP	LF	$126	1,746	$219,996
12	42" RCP	LF	$142	258	$36,636
13	48" RCP	LF	$173	0	$0
14	54" RCP	LF	$221	1,560	$344,760
15	60" RCP	LF	$277	0	$0
16	66" RCP	LF	$311	1,759	$547,049
17	72" RCP	LF	$355	0	$0
18	78" RCP	LF	$425	0	$0
19	84" RCP	LF	$500	0	$0
20	6'X6' RCB	LF	$442	0	$0
21	Trench Safety System	LF	$2	5,591	$11,182
22	Remove Pavement	SY	$6	15,181	$91,088
23	8" Reinforced Concrete Pavement	SY	$43	15,181	$652,797
24	Detention Pond (DRY)	AC-FT	$20,000	11.4	$228,000
25	Detention Pond Land Acquisition	AC	$1,960,200	3.5	$6,860,700
				COST	**$9,290,838**
				20% ANCILLARY ITEMS	**$1,858,168**
				20% GENERAL ITEMS	**$1,858,168**
				TOTAL COST	**$13,007,174**

4.0 Conclusion

Based on the results of the analysis described in this report, the following conclusions are reached.

1. A significant portion of the City of West University Place is within the regulatory floodplain of Brays Bayou (HCFCD Channel D100-00-00) designated as Zone AE with defined flood elevations. Two of the four locations of interest, including the intersection of Wakeforest Avenue and Carolina Way and the intersection of Wakeforest at Pittsburgh Street, are located within the regulatory floodplain. In an extreme storm event, the floodplain is affected by the water from Brays Bayou (via overtopping of the channel banks and backwater through channels and storm sewer lines). Improving storm sewer systems alone in areas located within the regulatory floodplain would not solve the flooding issue caused by Brays Bayou.

2. The ponding intersections studied are located at low points along the roadway profile. Runoff water that exceeds the conveyance capacity of the storm sewer lines serving these areas cannot sheet-flow away, but accumulates and ponds at these intersections.

3. Most of these ponding intersections have sufficient inlet capacity. However, the intersection of Wakeforest Avenue at Pittsburgh Street was found to have insufficient inlet capacity.

4. The existing conveyance capacities of most storm sewer lines serving these locations of interest are not sufficient for the current standard 2-year design storm. These existing storm sewer lines will have to be upsized in order to satisfy the 2-year flow rate capacity requirement. The approximate storm sewer sizes required to convey the 2-year flow rates are presented in ***Table 3-6***.

5. A further study using more detailed storm sewer system modeling tools is recommended to size the storm sewer lines in order to account for the slope of the storm sewer system with accurate storm sewer invert elevations, roadway and top of curb elevations, inlet throat elevations and measurements, and other important details. Such a detailed modeling study requires survey to obtain the existing storm sewer elevation data.

EXHIBIT 1. AREAS OF INTEREST AND VICINITY MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\KPSW\MM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EX\WESTUNIVREPORT2_EX01.MXD - USER: MXIAO - DATE: 2/11/2016

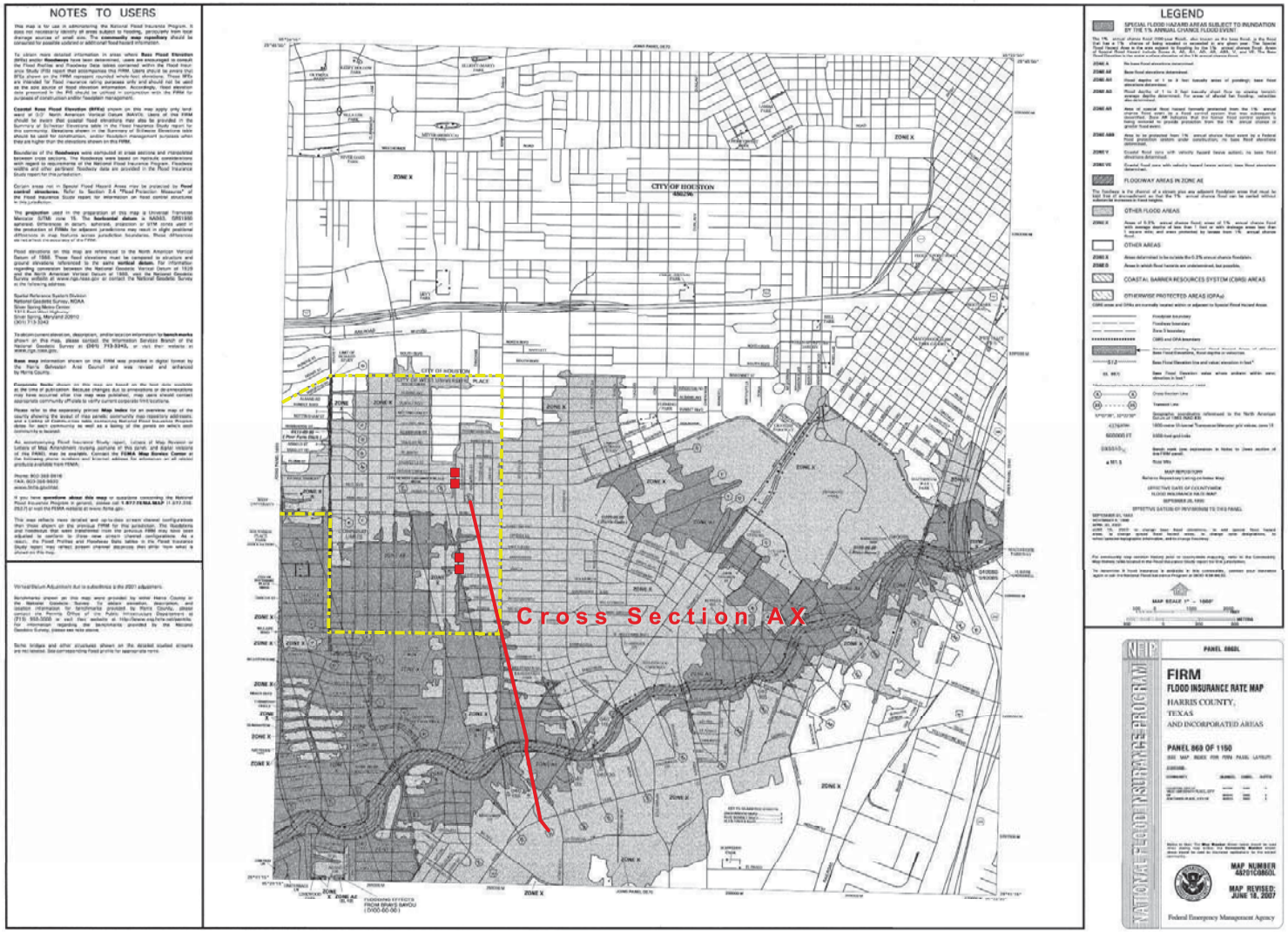


EXHIBIT 2. FLOODPLAIN MAP OF WEST UNIVERSITY PLACE (MAP NUMBER 48201C0860L)

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH : X:\KPS\WMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EXHIBITS\UNIVREPORT2_EX02.MXD - USER: MXIAO - DATE: 2/11/2016

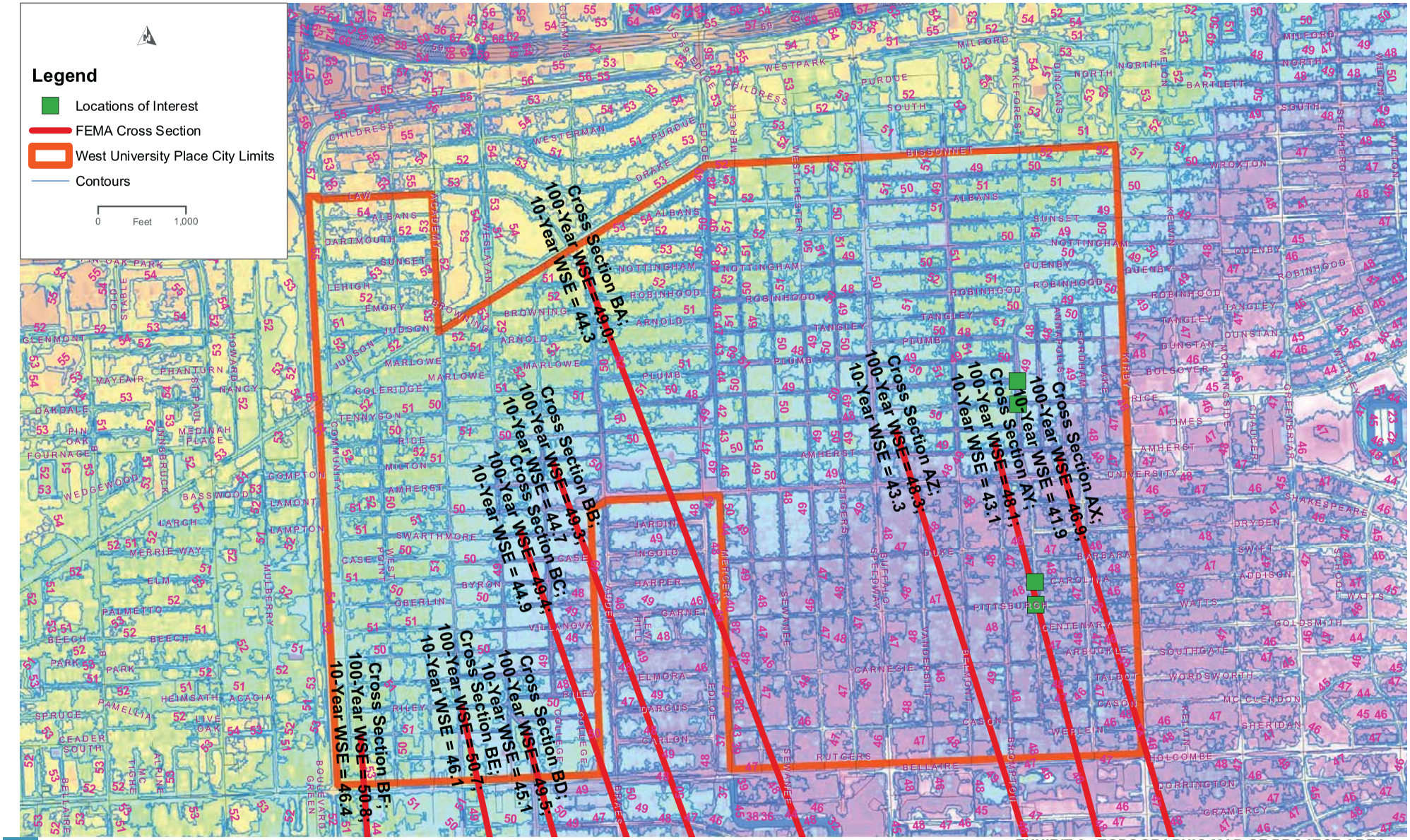


EXHIBIT 3. TOPOGRAPHIC MAP OF PROJECT AREA

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\KPS\WMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EX\WESTUNIVREPORT2_EX03.MXD - USER: MXIAO - DATE: 2/11/2016

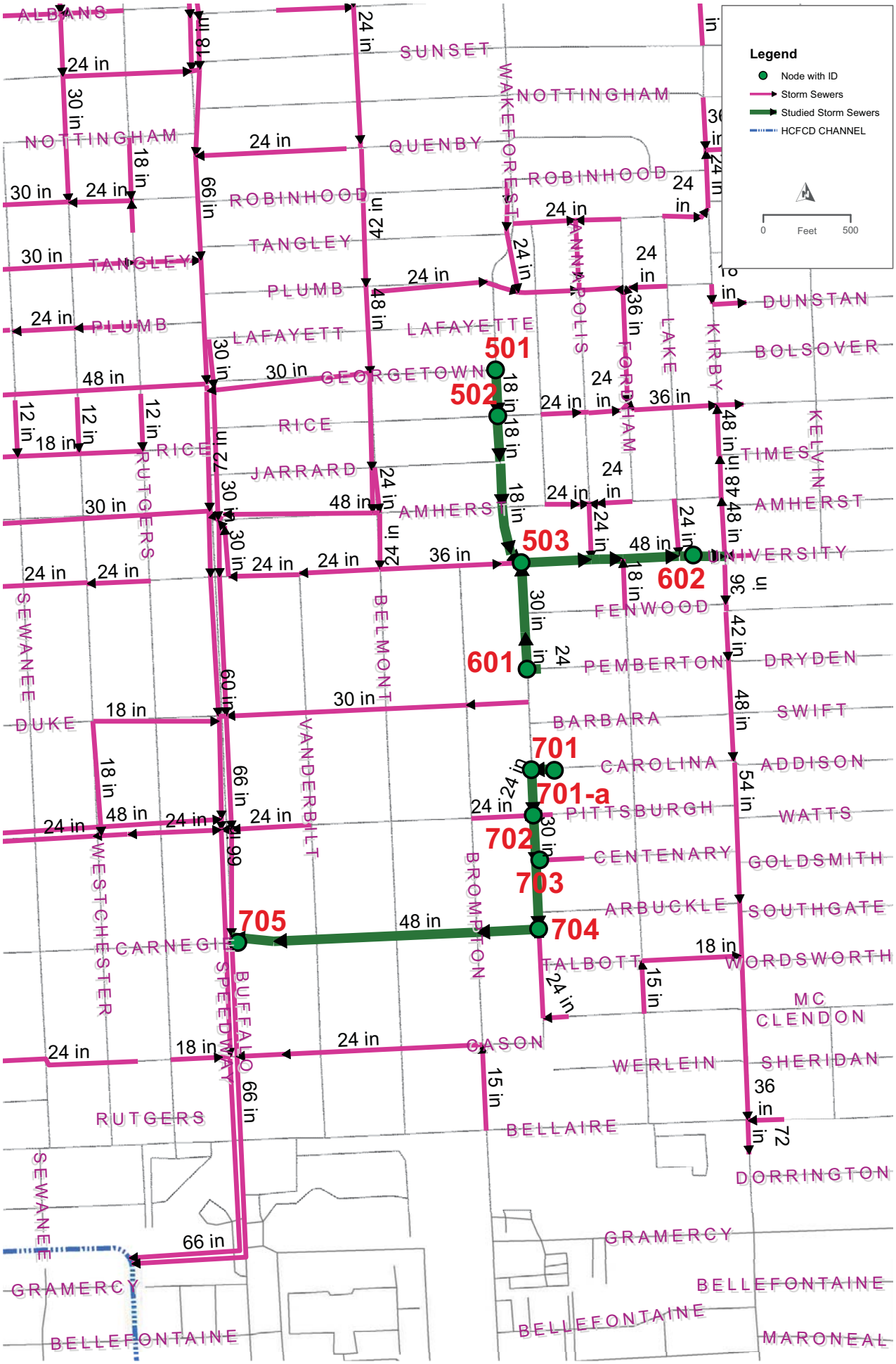


EXHIBIT 4. STORM SEWER LAYOUT IN PROJECT AREA

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATION IN WEST UNIVERSITY PLACE

PATH: X:\XPSWMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EX\WESTUNIVREPORT2_EX04.MXD - USER: MXIAO - DATE: 3/4/2016

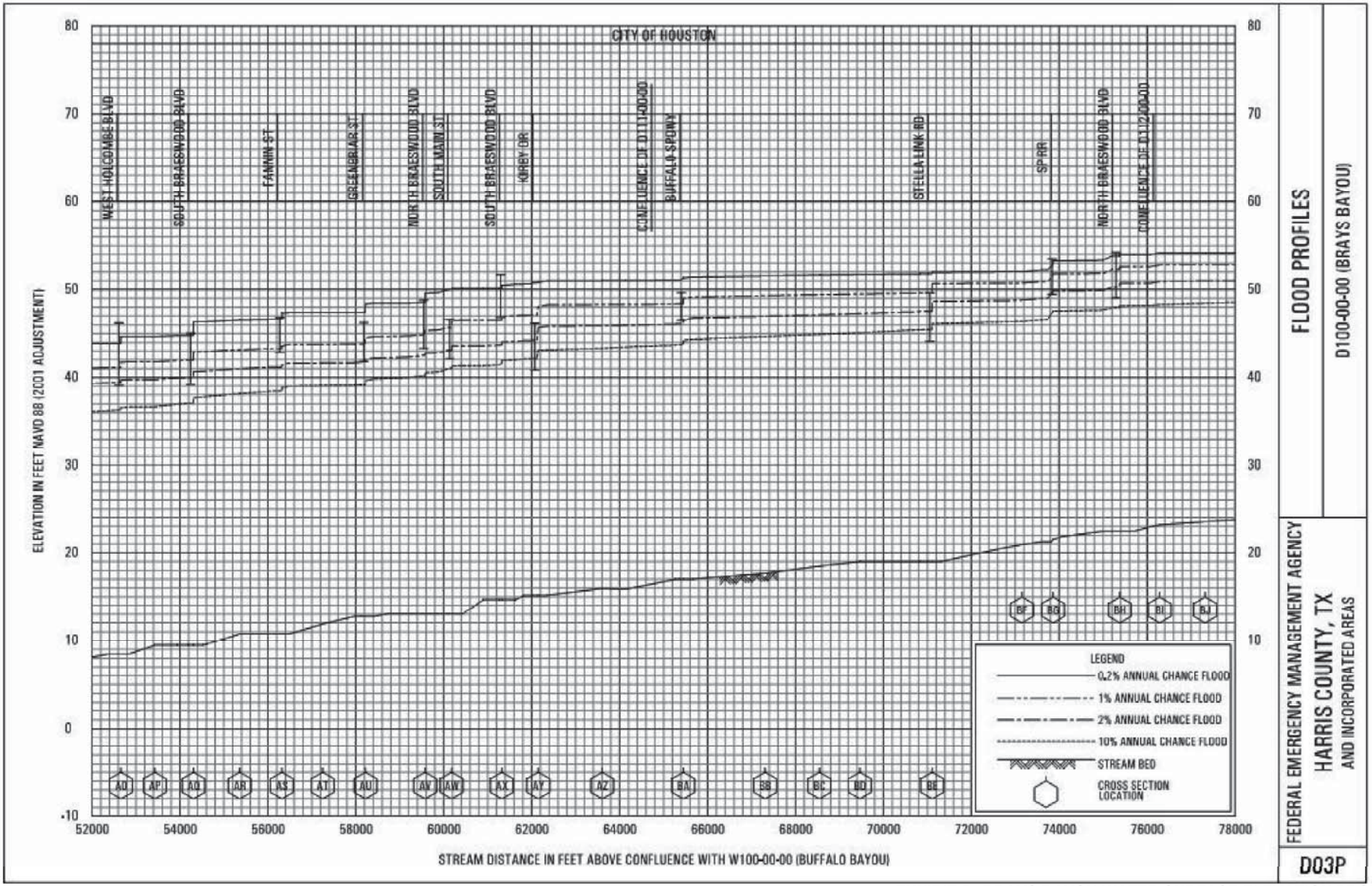


EXHIBIT 5. BRAYS BAYOU WATER SURFACE ELEVATION PROFILES

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\KPS\WMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EX\WESTUNIVREPORT2_EX05.MXD - USER: MXIAO - DATE: 2/12/2016

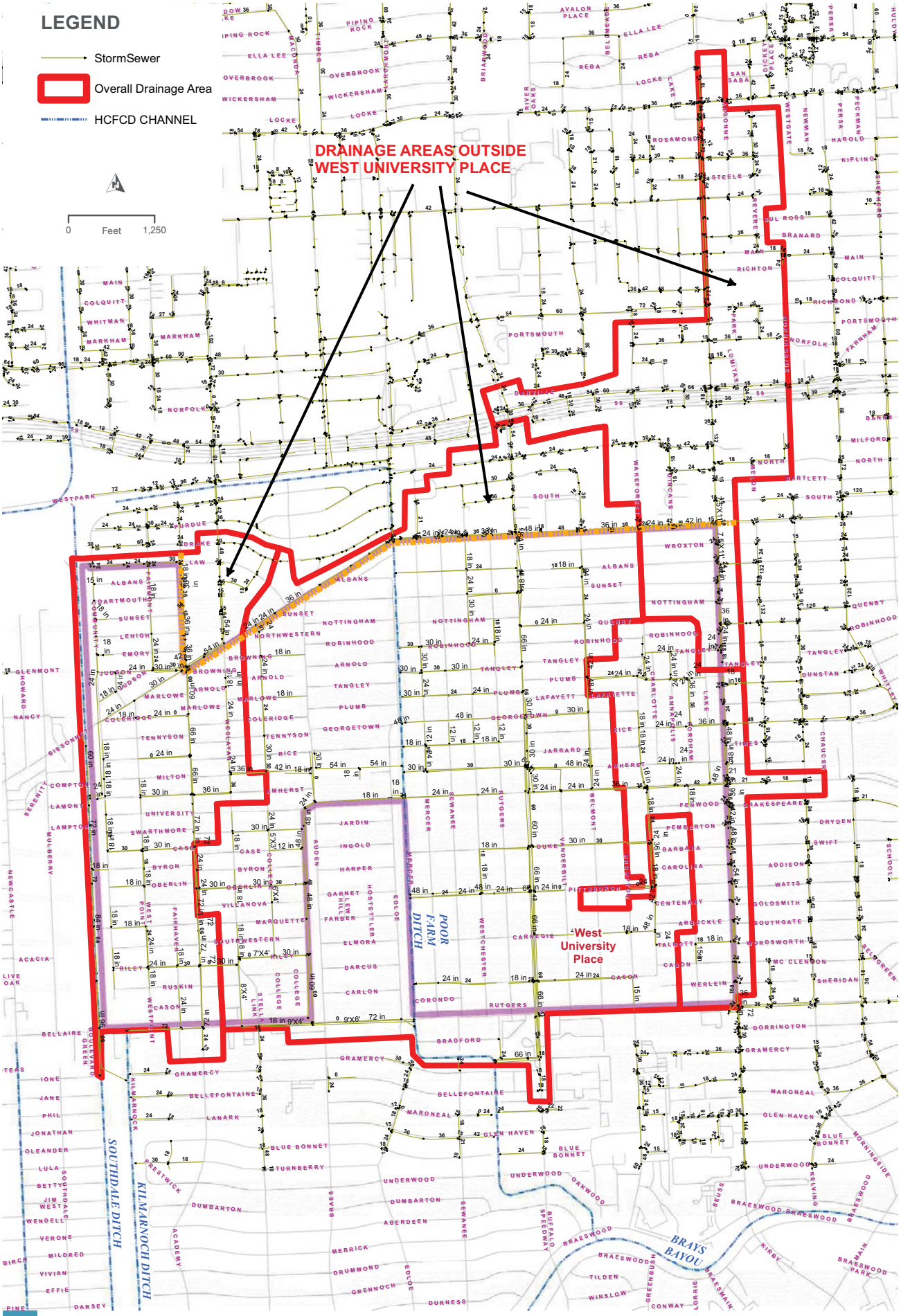


EXHIBIT 6. OVERALL DRAINAGE AREA MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\XPSWMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EX\WESTUNIVREPORT2_EX06.MXD - USER: MXIAO - DATE: 2/16/2016

EXHIBIT 7. STUDY DRAINAGE AREA MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH: X:\XPSWMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EX\WESTUNIVREPORT2_EX07.MXD - USER: MXIAO - DATE: 3/4/2016

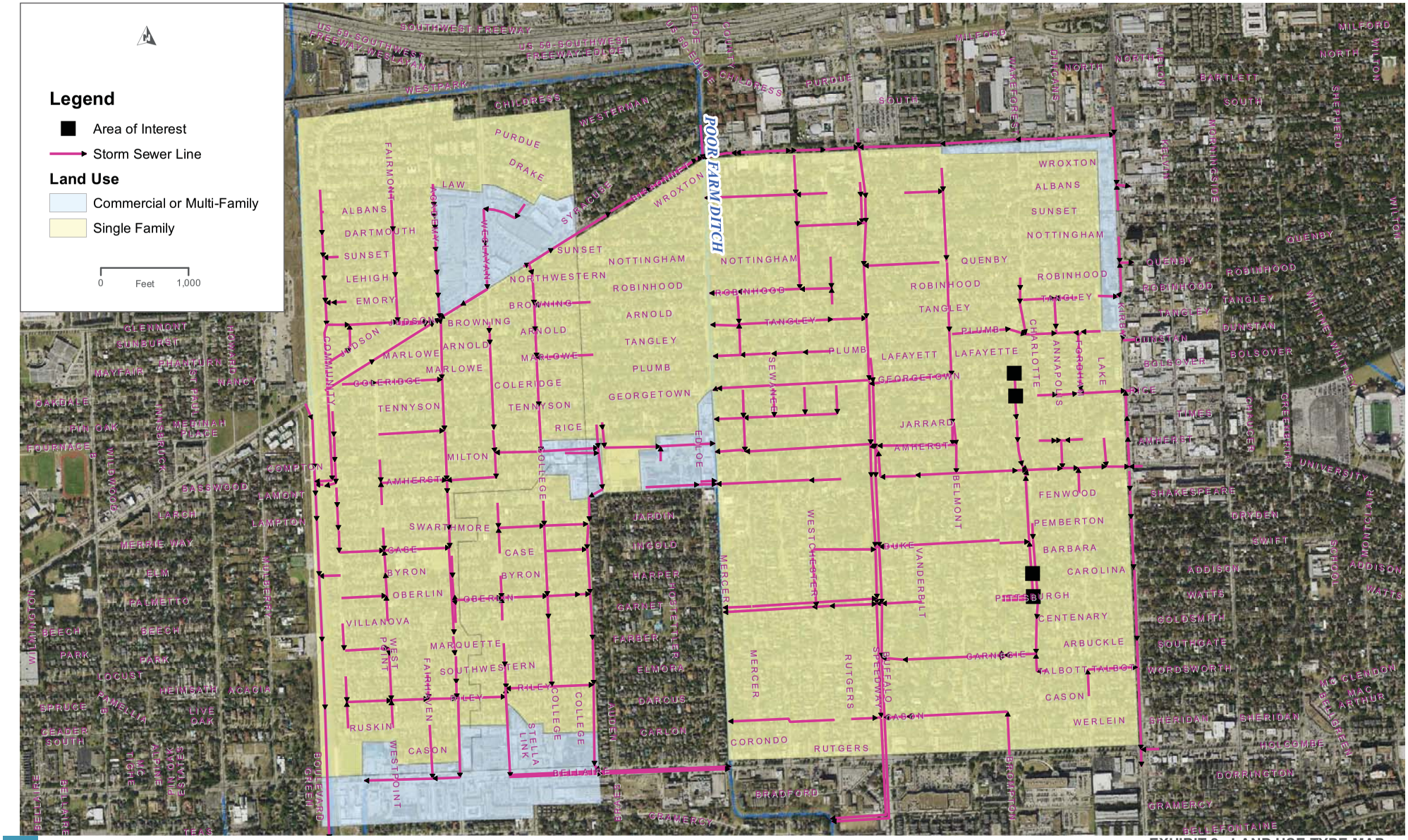


EXHIBIT 8. LAND USE TYPE MAP

PRELIMINARY STORM SEWER DRAINAGE ANALYSIS FOR FOUR PONDING LOCATIONS IN WEST UNIVERSITY PLACE

PATH : X:\KPS\WMM_MODELS\HOUSTON_PROJECTS\WEST_UNIVERSITY\UPDATES_2_REPORTS\REPORT2_EXHIBITS\WESTUNIVREPORT2_EX08.MXD - USER: MXIAO - DATE: 2/12/2016