Texas Water Development Board

VOLUME 2

2023 REGIONAL FLOOD PLAN

REGION 6

SAN JACINTO

July 2023

PREPARED FOR THE **SAN JACINTO REGIONAL FLOOD PLANNING GROUP**

TABLE OF CONTENTS

Appendix 5-4:
Supplemental Source Documentation

Appendix 5-4AG:
Carpenters Bayou – Mainstem Channel Modifications and Detention

Michael Baker INTERNATIONAL

We Make a Difference

TECHNICAL MEMORANDUM

To: Gary Bezemek, PE
Harris County Flood Control District – Planning Department

From: Mujahid Chandoo, PE

Date: February 24, 2023

Subject: The Carpenters Bayou Watershed Planning Project (N100-00-00-P004)
Benefit Cost Analysis (BCA)

The Carpenters Bayou watershed is a developed and flood prone watershed (population 57,249 [2010 U.S. Census Bureau]) that is vulnerable to (i.e., extreme rainfall, nuisance flooding, and some storm surge from a tidally influenced outfall). Carpenters Bayou watershed is located in east Harris County, bounded to the west by the Greens Bayou watershed (HCFCD Unit No: P100-00-00), and to the east by the San Jacinto River watershed (HCFCD Unit No: G100-00-00).

Project Description

The Carpenters Bayou Watershed Planning Project proposes to implement

- Approximately two miles of N100-00-00 channel improvements from Woodforest Boulevard at the upstream end to below Interstate Highway 10 at the downstream end with a natural stable channel design grass-lined cross-section at an average longitudinal slope of 0.05%;
- A short segment of N109-00-00 channel improvements comprising a 20 feet maximum bottom width and concrete-lined cross-sections at 2:1 side slopes with an average channel longitudinal slope of 0.2%; and
- 182 acre-feet stormwater detention facility for mitigating downstream impacts with a proposed basin encompassing vacant parcels already owned by Harris County

Carpenter's Bayou watershed is 25 square miles in area with approximately 44 linear miles of channel network within HCFCD jurisdiction. This watershed has been impacted by 32 of the previous 46 historical flood events in Harris County since 1979.

The Carpenter's Bayou Watershed Planning Project is based on a recommendation from the Torres & Associates, LLC Final Engineering Report, dated March 2021. The overall intent of this planning project was to develop a strategy of projects that best mitigates the watershed's inherent flood risk. The recommended N100-00-00 Channel Improvements project (Recommended Project #2) corroborated that the mid portion of the N100-00-00 mainstem and lower portions of tributary N109-00-00 experience out-of-bank riverine flooding. A suite of alternatives for channel improvements were modeled and analyzed to identify the alternative with low cost, high community uplift and high feasibility.

The proposed construction project is estimated to remove approximately 119 structures from flooding under 100-year storm conditions. The centralized location of these natural stable design channel improvements has potential for integrating with existing trail corridors to the north.

Structure Inventory

Two (2) datasets were used to obtain the information for Finished Floor Elevation (FFE), building footprint and building category.

- **Structure Inventory Dataset**: This information was obtained from Harris County Flood Control District (HCFCD). The Finished Floor Elevation (FFE) was obtained from this dataset.
- **National Structure Inventory (NSI):** The building (structure type) category (i.e., residential commercial and industrial) and building footprint (sq. ft) was obtained with this dataset.
- **Texas Water Development Board (TWDB):** This dataset was used as a supplement for building footprints for any missing portions

Using ArcGIS these datasets were joined together using the parcel information.

Project Schedule

The schedule is based on optimal delivery and includes anticipated activity durations with the following assumptions:

- Proposed Phase #1 (N100 Channel Improvements and Detention):
    - Recommended phase 1 is ROW acquisition and construction of the detention facility and N100-00-00 channel improvements starting south of IH-10 to east of Beltway 8.
    - ROW acquisition consists of residential and commercial parcels.
    - While phase 1 is in progress, it is recommended that ROW acquisition for the remaining channel improvements take place so that project implementation can progress efficiently
    - Phase 1 improvements are expected to take 5-10 years and is characterized as a mid-term to long-term project.
- Proposed Phase #2
    - Phase 2 consists of the remaining N100-00-00 channel improvements and N109-00-00 channel improvements.
    - The N100-00-00 channel improvements start just upstream of Beltway 8 Frontage Road (RS 28244.0) and end at the confluence of N100-00-00 and N109-00-00 (RS 31729.0).
    - The N109-00-00 channel improvements start downstream of the existing Colonial pipeline (RS 511) and tie in to the N100-00-00 channel improvements.
    - Phase 2 is expected to begin after phase 1 and overall, the project is expected to take beyond 10 years (long-term project)
- The proposed detention provides approximately 182 acre-feet of potential storage for mitigating conveyance impacts from N100 channel improvements. The detention basin entails acquisition of already vacant lots (based on aerial imagery and site visits), owned by Harris County with an appraisal value of $1.0M (Harris County Appraisal District 2019).

BCA Assumptions

Project costs estimated in March 2021 were adjusted to September 2020 dollars using a factor 0.98. The adjusted project costs were input to the TWDB BCA Input Workbook v1.2 to calculate the project's cost discounted by 7 percent over an assumed total project (Phase 1 and 2) construction period of 20 years. The discounted cost is $16.43 million. Non-discounted costs are itemized as follows:

Project Costs

Construction (including Excavation & Removal)	$10.65 million
Engineering and Contingencies*	$6.60 million
ROW Acquisition	$13.11 million
Total Project Cost	**$30.36 million**

* - Adjusted from March 2021 cost estimate (Torres & Associates, LLC, Appendix A: Preliminary Cost Estimate pdf page 426 of 759)

* - 35% contingency on construction costs.

Excavation costs for N100-00-00 channel improvements were determined using the cut and fill volume from HEC-RAS 1D/2D model. The utility adjustment and construction costs were determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects with a 2.5 multiplier. Partial and non-voluntary buyouts were considered for ROW acquisition with N100-00-00 channel improvements. Costs for the mitigation for the 10-year and 100-year storm events is included at a high planning-level.

For purposes of the BCA, project benefits are elimination of flooding damages to residential, commercial, and industrial structures. Benefits were quantified by inputting structure FFE's and flood depths to the BCA_Pilot_v5, provided by FNI. The output compares the baseline structure damages without the project to the project conditions in the 10-, 50- and 100-year storm scenarios:

Benefits Summary (non-discounted)

	100 - year storm		50 - year storm		10 - year storm	
	Baseline	w/Project	Baseline	w/Project	Baseline	w/Project
Residential Flood Damage	$33,474,070	$14,251,528	$13,021,401	$7,377,811	$2,679,597	$1,222,436
Commercial Flood Damage	$1,366,287	$129,765	$82,978	$82,978	$0	$0
Industrial Damages	$4,866,811	$3,985,413	$1,718,820	$1,998,157	$462,887	$173,741
Total Damages	$39,707,168	$18,366,707	$14,823,199	$9,458,946	$3,142,484	$1,396,177
Net Benefit by Storm		**$21,340,462**		**$5,364,253**		**$1,746,307**

Total Benefit: $28,451,022 (non-discounted)

Discounted Benefits

Total benefits discounted at 7 percent over the project's 30-year duration are $7,561,559 including $370,693 in residual value from right-of-way acquisition. These benefits only include the mitigated damages to residential, commercial. and industrial structures identified and no other additional mitigation.

Benefit Cost Ratio

Discounted Project Benefits (damages calculated in FEMA BCA toolkit)	$7,190,866
Discounted Residual Value (ROW)	$370,693
Total Benefits	$7,561,559
Discounted Project Cost	$16,431,877
Final BCR	**0.46**

The Carpenters Bayou Watershed Planning Project (N100-00-00-P004):

FINAL ENGINEERING REPORT

March 12, 2021

Prepared by:

Torres & Associates, LLC

STATE OF TEXAS
JACOB M. TORRES
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LICENSED
PROFESSIONAL ENGINEER

Firm: Torres & Associates, LLC
Firm ID: 20741
Date: 3/12/21

Executive Summary

Planning Project Purpose. The purpose of this Carpenters Bayou Planning Project is to clearly formulate a high-level watershed flood risk reduction strategy to 1) mitigate inherent flood risks and improve floodplain resiliency and 2) propose viable projects with potential for yielding near-term benefits to communities in the watershed. This watershed planning effort is intended to be multi-objective in scope, inclusive of the following study goals:

- *Identify Persistent Problems*. Define existing baseline conditions for the drainage infrastructure and identify existing and potential future flooding problems in the watershed.
- *Develop Strategies for Improvements*. Evaluate the severity and complexity of the problems and the potential future improvement alternatives using the criteria provided by HCFCD.
- *Develop Watershed Strategy*. Identify opportunities and constraints for the proposed solutions and develop a strategy for the watershed that provides appropriate improvement projects for the future drainage infrastructure.
- *Compile Watershed Planning Document*. Create a comprehensive watershed plan to document recommendations for the required improvement projects.
- *Develop Additional Details for Immediate Projects*. Develop more detailed cost and implementation information for identifiable near-term improvement projects.

This final engineering report documents the technical details for which the recommendations are based (i.e., modeled analyses, performance assessments, project screening and prioritization, cost estimation, constraints evaluation, preliminary impacts analyses, and implementation strategies). *The overall intent of this planning project is to develop a strategy of projects that best mitigates the watershed's inherent flood risk*. This report developed project recommendations with a potential for practical implementation; considering timing, partnership opportunities, mitigation needs, and projects that are multi-purpose and multi-benefit.

Watershed Description. The Carpenters Bayou watershed is a developed and flood prone watershed (population 57,249 [2010 U.S. Census Bureau]) that is vulnerable to (i.e., extreme rainfall, nuisance flooding, and some storm surge from a tidally influenced outfall). Carpenters

Bayou watershed is located in east Harris County, bounded to the west by the Greens Bayou watershed (HCFCD Unit No: P100-00-00), and to the east by the San Jacinto River watershed (HCFCD Unit No: G100-00-00) (**Exhibit 1**). The watershed's headwaters begin above Lake Sheldon and its primary outfall discharges into the Houston Ship Channel. Carpenters Bayou watershed is 25 square miles in area with approximately 44 linear miles of channel network within HCFCD jurisdiction. The watershed includes unincorporated Harris County (96%) Precincts 1 and 2 (62% and 38% by area, respectively), Community of Channelview (26%), Community of Cloverleaf (8%), City of Houston (4%), and Community of Sheldon (2%). The watershed is particularly well populated in its mid to downstream portion between Wallisville Road and Interstate Highway 10 and is highly industrialized in its southernmost portion with extensive petrochemical facilities and barge shipping terminals.

Existing Flood Conditions. This watershed has been impacted by 32 of the previous 46 historical flood events in Harris County since 1979. More recently, the watershed has experienced neighborhood-wide flooding from Tropical Storm Imelda (2019), Hurricane Harvey (2017), and the October "Halloween" Event (2015). Various structures experience flooding from different causes (e.g., overland sheet flow, overbank flooding, insufficient drainage capacity, deteriorating drainage infrastructure). Modeled results for baseline ("existing") conditions (coupled 1D/2D analysis with Atlas 14 Rainfall Update) reveal that flooded structures stem largely from sheet flow driven conditions, with flood risks compounded by insufficient drainage capacity and aging infrastructure (**Exhibits 2 and 3**). Comparison of modeled results, flood claim history, and reconnaissance level assessments confirm these observations. One modeled overflow condition was identified during significant storms with flows exiting Carpenters Bayou tributary N110-00-00 and entering Greens Bayou tributary P103-00-00.

Problem Area Classification. HCFCD provided guidance for delineating and classifying problem areas (PA) based on structural flooding (predicted and actual), quantifiable miles of flooded roadways, area potential for project viability, social vulnerability index (SVI), and costs; among other metrics. A calibrated 1D/2D baseline condition watershed-wide model, related site visits, and evaluation of prior engineering reports led to an identification of eleven (11) PAs (**Exhibit 4**). When used in conjunction with supporting data on repetitive loss, flood claims, existing level-of-service (LOS), and flood damage vulnerability, PAs were grouped into three tier classifications (**Table E.1**). PAs with the most severe flooding issues are classified as Tier 1. PAs classified as Tier 1 and Tier 2 are considered for detailed analyses with potential for preliminary engineering reports (PERs) and design. PAs with Tier 3 classification have only moderate flooding conditions and were designated for less detailed analysis.

Table E.1. Problem Area Summary (Baseline Conditions)

Problem Area Name	Primary Jurisdiction	Flooding Source	Historical Flooding Data	Total Predicted Structural Flooding (1% AEP)*	Predicted Structural Flooding (PSF50)	Predicted Roadway Flooding (Total Length >1-foot during 1% AEP)	Classification
			(number of homes)	(number of structures)	(structures per year)	(miles)	
PA01	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	64	427	853.9	13.6	Tier 1
PA02	Unincorporated Harris County/ Cloverleaf	Sheet flow from adjoining area and Local stormwater drainage limitation	12	785	1680.5	24.1	Tier 1
PA03	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	21	526	867.2	11.4	Tier 2
PA04	Unincorporated Harris County/ Cloverleaf	Local stormwater drainage limitation and sheet flow from adjoining area	32	206	661.9	3.0	Tier 2
PA05	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	25	218	569.8	1.5	Tier 2
PA06	Unincorporated Harris County	Sheet flow from adjoining area and Local stormwater drainage limitation	12	46	198.1	0.1	Tier 3
PA07	Unincorporated Harris County	Overbank flow and local stormwater drainage limitation	4	18	30.7	5.9	Tier 3
PA08	Unincorporated Harris County/ Channelview	Local stormwater drainage limitation and sheet flow from adjoining area	3	36	78.3	0.5	Tier 3
PA09	Unincorporated Harris County	Overbank flow	1	60	111.1	0.4	Tier 3
PA10	Unincorporated Harris County/ Channelview	Overbank flow	2	10	20.5	0.1	Tier 3
PA11	Unincorporated Harris County/ Channelview	Sheet flow from adjoining area and Local stormwater drainage limitation	0	16	71.7	0.1	Tier 3

Project Recommendations. Use of a prioritization framework – developed by HCFCD for 2018 Bond Projects – created project scoring and contributed to the final recommendations for the Watershed Plan. Project criterion such as flood risk reduction, existing LOS, SVIs, potential for multi-agency partnerships, maintenance cost considerations, and susceptibility for environmental impacts are among the key tenets used in weighting, scoring, and ranking candidate projects. A systematic application of these classification factors led to the identification of the following top performing candidate projects shown in **Table E.2** and described as follows:

Table E.2. Modeled Project Performance Summary

Project No:	Project Description[a,b]	Est. Flooded Structures (100-year)			Existing LOS	Proposed LOS	Project Cost Estimate ($Million)
		Existing Conditions	Proposed Conditions	Structures Removed			
1	Cloverleaf Food Risk Reduction (Interior Drainage Improv.plus Detention)[c]	206	99	107	<10yr	<50yr	$16.89
2	N100-00-00 Channel Improvements plus Detention (from Woodforest Blvd to IH-10)	122	3	119	<10yr	<100yr	$30.98
3	N104-00-00 Channel Improvements (from E.Bentwood Rd to IH-10)	79	31	48	<10yr	<100yr	$8.37
4	N110-00-00 Diversion (N110-00 Diversion to P103-00/P103-03)[d]	785	627	158	<10yr	<100yr	$1.19

[a] Modeled project performances were also evaluated against other factors not shown in this table (e.g., miles of inundated roadway, SVI/LMI, mobility, repetitive loss, critical facilities, partnership opportunities, etc.)

[b] These projects consider current land use conditions only.

[c] This project was among the top performing projects and an application was subsequently submitted for a GLO CDBG-MIT grant (Phase 1 Conditions) for this project

[d] The N110-00 diversion was not modeled extensively and is currently under evaluation as a part of the ongoing Lower Greens Bayou Study

(Recommended Project #1) Cloverleaf Community Flood Risk Reduction Project. The project combines a proposed 9 feet by 7 feet reinforced concrete box (RCB) trunk line, spanning approximately 3,000 feet, and a 109 acre-feet volume stormwater detention facility north of the San Jacinto Funeral Home and Memorial Park, for an approximate proposed 50-year LOS (**Exhibit 5**). This project will provide much needed drainage relief for this portion of the Cloverleaf Community with the storm sewer trunk line serving as a centralized drainage "artery" for conveying sheet flow runoff, before safely outfalling into the proposed detention. This includes laterally connected roadside ditch improvements. The proposed construction project is estimated to remove approximately 107 structures from prior flooding under the 100-year storm event and is estimated at approximately $ 17 M in total construction cost.

(Recommended Project #2) N100-00-00 Channel Improvements. The dynamic 1D/2D baseline conditions model – in conjunction with available flood claim data – corroborated that the mid portion of the N100-00-00 mainstem and lower portions of tributary N109-00-00 experience out-of-bank riverine flooding. A suite of alternatives for channel improvements were analyzed to identify an alternative channel configuration that yielded the most appropriate and cost-efficient option, while also providing multipurpose benefits, maintaining, environmentally friendly conditions, and providing a high potential for recreational uplift. The project consists of: 1) approximately two miles of N100-00-00 channel improvements from Woodforest Boulevard at the upstream end to below Interstate Highway 10 at the downstream end with a natural stable channel design grass-lined cross-section at an average longitudinal slope of 0.05% 2) a short segment of N109-00-00 channel improvements comprising a 20 feet maximum bottom width and concrete-lined cross-sections at 2:1 side slopes with an average channel longitudinal slope of 0.2%; and (3) 182 acre-feet stormwater detention facility for mitigating downstream impacts with a proposed

basin encompassing vacant parcels already owned by Harris County (**Exhibit 6**). The proposed construction project is estimated to remove approximately 119 structures from flooding under 100-year storm conditions, yielding a proposed LOS of 100-year, and is estimated at $31 M in total construction cost. The centralized location of these natural stable design channel improvements has potential for integrating with existing trail corridors to the north.

(Recommended Project #3) N104-00-00 Channel Improvements. Similarly, the dynamic 1D/2D baseline conditions model and flood claim data verified out-of-bank riverine flooding near the mid portion of N104-00-00. The channel improvements for this area span from East Brentwood Road to Interstate Highway 10 from upstream to downstream, respectively, with a 20 feet bottom width and a 4:1 side slope with an average longitudinal slope of 0.08% (**Exhibit 7**). The proposed construction project is estimated to remove approximately 48 structures from flooding under 100-year storm conditions, yielding a proposed LOS of 100-year, with an estimated total construction cost of over $8 M.

(Recommended Project #4) N110-00-00 Diversion to P103-00/P103-03. Early analysis of the Carpenters Bayou 2D rain-on-grid model revealed the potential for a substantial overflow exiting the N100-00-00 tributary system and entering lower Greens Bayou tributaries P103-00-00 and P103-03-00. This overflow is estimated at approximately 715 cfs for the 100-year event. Exploratory coordination is underway with an ongoing study in Lower Greens Bayou to ascertain available channel capacity that can allow for a N110-00 tie-in and/or available ROW along P103-00 and P103-03 if additional channel improvements are warranted (**Exhibit 8**). Performance metrics are considered preliminary until a more detailed feasibility study can be conducted but current planning-level results indicate a potential to remove 158 flood structures (100-year) from inundation with a proposed 100-year LOS for that portion of N110-00-00 experiencing overflow.

Project Implementation. The implementation strategy is meant to provide a critical path for each recommended project. The timeline for a project can be long term but a component within that project can be characterized as a near term goal. For example, the N100-00-00 channel improvement project comprises of several components, including ROW acquisition, bridge modifications, detention basins and channel improvements spanning approximately 2 miles. The different components within a project cannot be implemented at the same time and require phasing. It is important to define a critical path for the smooth and efficient implementation of the project. In general, near-term projects/phases represent a one to five-year timeline, mid-term represent a five to ten-year timeline and long-term represent a timeline beyond ten-years. Please refer to section 6 of this report for the implementation strategy for each recommended project.

Towards a Carpenters Bayou "Vision Plan." A Carpenters Bayou Vision Plan is proposed as a conceptual and preliminary effort to evaluate project recommendations that – when evaluated together under one combined watershed model – provide a long-term strategy that best mitigates the watershed's inherent flood risks (**Attachment #4**). The plan identifies a comprehensive regional solution for providing a 100-year LOS flood under existing hydrologic and land use conditions. Considerations for a Carpenters Bayou "Frontier-" like program that considers future development for undeveloped portions of the watershed are also cited. Early results reveal that proposed flood risk mitigation strategies (i.e., the combination of channel modifications and drainage improvements) are hydraulically feasible. The resultant Vision Plan helps to identify ROW needs, detention facilities, channel modifications, locations for potential bridge/culvert modifications, and interior drainage improvements, among other features (**Exhibit 9**).

Closing. For planning-level studies such as this, final constructed elements for each project may vary considerably from what is described in this report, exhibits, and attachments. Many factors and constraints can alter the project components during the project life cycle from planning to construction (e.g., development pace/location, ROW acquisition, geotechnical and environmental constraints, etc.). ROW acquisition is not a static process but requires significant coordination with relevant stakeholders such as communities and neighborhoods, landowners, potential land developers, HCFCD, and other agencies such as Harris County Engineering Department (HCED) and Texas Department of Transportation (TxDOT). Thus, project recommendations – as described and suggested in this report, including maps and results suggesting potential ROW acquisitions and potential buyouts – are considered planning-level until detailed feasibility assessments can advance these concepts into preliminary engineering analysis and detailed design.

Acknowledgments

The culmination of this Carpenters Bayou Watershed Planning Project (N100-00-P004) Final Engineering Report represents a key milestone towards the greater floodplain management of the watershed itself. Torres & Associates, LLC ("Torres") is extremely grateful to HCFCD for their consistent time and dedication throughout this study. These efforts included providing initial base data, development of guidance documents for project formulation and conducting a myriad of interim deliverable reviews, and weekly and monthly coordination meetings from which Torres was able to draw upon HCFCD's broader watershed insights for added study refinements. Other activities for which Torres is grateful include the invite and participation in public virtual meetings, such as those aimed at communicating project specific benefits (stemming from this study) that were used to determine grant eligibility for Community Development Block Grant (CDBG) funding. Taken together, this multidisciplinary effort – and supporting technical analysis – facilitated the identification of effective and feasible flood risk management strategies, from which a suite of practical projects (short-term and long-term) have been proposed (as described in this report) for further advancement and design considerations.

Table of Contents

List of Figures

List of Tables

List of Attachments

List of Exhibits

Acronyms

1D	1-Dimensional
2D	2-Dimensional
BDF	Basin Development Factor
CBW	Carpenters Bayou Watershed
CDBG	Community Development Block Grant
DEM	Digital Elevation Model
FER	Final Engineering Report
HAZMAT	Hazardous Materials
HCED	Harris County Engineering Department
HEC-RAS	Hydrologic Engineering Center River Analysis System
H&H	Hydrology & Hydraulics
HMS	Hydrologic Modeling System
HSC	Houston Ship Channel
IH	Interstate Highway
LOS	Level-Of-Service
NOAA	National Oceanic and Atmospheric Administration
NLCD	National Landover Cover Dataset
O&G	Oil & Gas
PA	Problem Area
PER	Preliminary Engineering Report
PSF(50)	Total cumulative probable structural flooding over the 50-year period.
RCB	Reinforced Concrete Box
ROW	Right-of-Way
SVI	Social Vulnerability Index
TM#1	Technical Memorandum #1
TM#2	Technical Memorandum #2
TM#3	Technical Memorandum #3
TM#4	Technical Memorandum #4
TxDOT	Texas Department of Transportation
VP	Carpenters Bayou "Vision Plan"
WSEL	Water Surface Elevation
WPP	Watershed Planning Project

1. Introduction

The purpose of this Carpenters Bayou ("Carpenters") Watershed (CBW) (HCFCD Unit No: N100-00-00) Planning Project (WPP) Final Engineering Report (FER) is to identify a plan and set of projects for reducing flood risk within the Carpenters Bayou watershed (CBW). The study includes:

- Identification and quantification of existing flood risk and channel level-of-service (LOS);
- Identification of planning objectives, constraints, and opportunities;
- Formulation of flood risk reduction alternatives;
- Evaluation and refinement of flood risk reduction alternatives and selection of a recommended flood damage reduction plan for the watershed; and
- Identification of initial projects from that plan.

This Carpenters Bayou WPP identifies a suite of recommended projects capable of advancing towards preliminary engineering reports (PER) and design as well as to formulate a broader watershed-wide regional strategy that can help mitigate inherent flood risks. Methods employed in this WPP include hydrologic and hydraulic (H&H) analyses, related to 1D/2D modeling, environmental assessments, cost estimates, right-of-way (ROW) assessments, and communications.

The project had three main goals. *Goal #1* focused on identification and evaluation of problem areas (PAs) within the watershed with the aid of 1D/2D modeling and computed flood metrics. The analysis was summarized in Technical Memorandum #1 (TM#1) (**Attachment #1**). *Goal #2* focused on further evaluation of PAs and development of potential solutions that best mitigate flood risk. Technical Memorandum #2 (TM#2) (**Attachment #2**) summarized the work accomplished for Goal #2. Goal #3 focused on the prioritization of projects identified in goal #2 based on damage reduction, feasibility of the project, environmental constraints, and overall cost estimates. Technical Memorandum #3 (TM#3) (**Attachment #3**) describes the improvement alternatives considered and summarizes the analysis conducted for goal #3.

The efforts of the WPP resulted in the recommendation of two projects: The Cloverleaf Flood Risk Reduction Project and N100-00-00 Channel Improvements. The Preliminary Project Plan (**Attachment #5**) provides an organized and detailed description of the recommended flood reduction projects. The purpose of this document was to clearly define the recommended projects and allow Harris County Flood Control District (HCFCD) staff and consultants to easily understand the important project details as necessary to progress the projects toward implementation.

One of the final deliverables for the WPP was the Watershed Plan Summary Report (**Attachment #6**). The purpose of this report was to provide a general summary of the watershed planning effort and the resulting strategies to implement specific improvement projects. This report was created for the public and engaged stakeholders.

Lastly, the final task conducted for the WPP was the inclusion of a planning-level formulation of a Carpenters Bayou 100-year LOS "Vision Plan" (**Attachment #4**). This plan aims to identify a regional watershed wide flood risk mitigation strategy for addressing widespread flooding issues known to Carpenters and its communities. This strategy considers the inherent flooding issues under a broader watershed perspective that has potential for providing a "100-year LOS" based on a combination of channel improvements, detention facilities, interior drainage improvements, and voluntary buyouts.

This following report is a summary of the work conducted through the WPP lifecycle. The memoranda and supporting reports have been attached as attachments to this report for a better understanding of the engineering planning activities that were behind this effort.

1.1. Report Organization

This FER represents a culmination of the overall effort conducted for the WPP. This main report provides a synthesis of key takeaways following a recursive analysis of multiple PA identification, project formulation, analyses, and performance metrics. **Figure 1** illustrates a general "road map" or flow chart of the WPP, with references to corresponding attachments. The attachments provide an expanded description of project recommendation and serve as a resource for understanding the technical underpinnings.

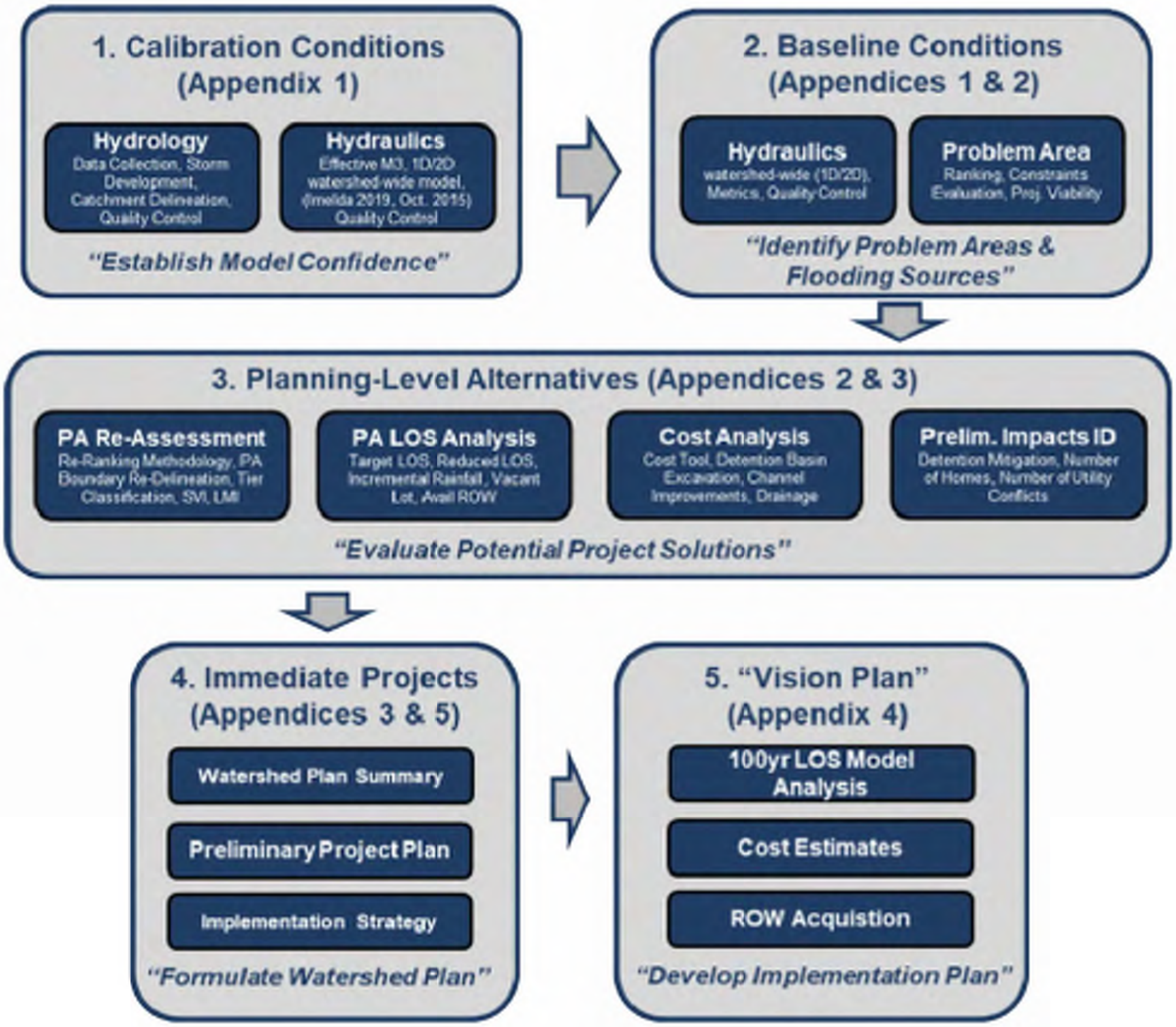


Figure 1. Carpenters Bayou WPP "Road Map"

Attachment #1 (TM#1) represents the model development of baseline conditions (1D/2D coupled) which entailed calibration and validation techniques. It also describes the methods used in the identification of the eleven (11) PAs.

Attachment #2 (TM#2) focuses on further evaluation of PAs and development of potential solutions that best mitigate flood risk. For this effort, drainage alternatives were identified and hydrologically evaluated. These alternatives were derived based on modeled output from baseline conditions, available ROW, constructability considerations, HCFCD input, understanding of prior studies, and general knowledge of the watershed.

Attachment #3 (TM#3) entails refined strategies that more efficiently balance flood risk mitigation measures defined in Attachment 2 in a more holistic manner of constructability and environmental concerns. For this effort, identified projects were hydrologically and hydraulically evaluated with the aid of 1D/2D modeling.

Attachment #4 (TM#4) describes the efforts conducted to provide a 100-year LOS i.e., the Vison Plan for the mainstem N100-00-00 of Carpenters Bayou watershed.

Attachment #5 (Preliminary Project Plan) describes the two identified immediate improvement projects i.e., Cloverleaf Flood Risk Reduction Project and N100-00-00 Channel Improvement Project in detail.

Attachment #6 (Watershed Plan Summary Report) encapsulates the overall effort of the WPP. This document describes the activities and analyses conducted for the WPP and summarizes PAs identified, the likely source of the flooding problems, the resulting flood damage metrics, the potential projects recommended for damage reduction, their estimated costs and benefits, and the scoring of those projects using the HCFCD criteria.

Attachment #7 entails all the presentation slides used in workshops and coordination meetings throughout the course of the WPP.

1.2. WPP Goals and Objectives

The goal of the WPP is to create a high-level Watershed Plan that identifies strategies for mitigation of existing flooding problems and to address improved drainage infrastructure required for future development (HCFCD 2019). This involves:

- Defining existing baseline conditions for Carpenters Bayou and identifying existing and potential future flooding problems in the watershed.
- Evaluating the severity and complexity of the problems and the potential solutions using computed flood metrics, historical flood information and previous engineering studies.
- Identifying opportunities and constraints for the proposed solutions and developing a strategy for the watershed that provides appropriate improvements for future drainage infrastructure.
- Creating a comprehensive Watershed Plan to document recommendations for required improvement projects.

- Developing more detailed cost and implementation information for identified immediate improvement projects.

1.3. Project Area

The Carpenters Bayou watershed (HCFCD Unit No: N100-00-00) is a developed and flood prone watershed (population 57,249 [2010 U.S. Census Bureau]); vulnerable to (1) extreme rainfall, (2) nuisance flooding, and (3) storm surge from a tidally influenced outfall. This watershed is located in east Harris County, bounded to the west by Greens Bayou watershed (HCFCD Unit No: P100-00-00), and to the east by San Jacinto River watershed (HCFCD Unit No: G100-00-00) (**Figure 2, Exhibit 1**). The watershed's headwaters begin near Lake Sheldon with its primary outfall at Houston Ship Channel (HSC). This watershed is 25 square miles in area with approximately 44 linear miles of channel network within Harris County Flood Control District (HCFCD) jurisdiction. The watershed includes Harris County Precincts 1 and 2 (62% and 38% by area, respectively). Other census entities include unincorporated Harris County (96%), Community of Channelview (26%), Community of Cloverleaf (8%), City of Houston (4%), and Community of Sheldon (2%). Carpenters Bayou watershed is particularly well populated between Wallisville Road and Interstate Highway (IH) 10 and is highly industrialized in its southern portion with extensive petrochemical facilities and HSC shipping terminals.

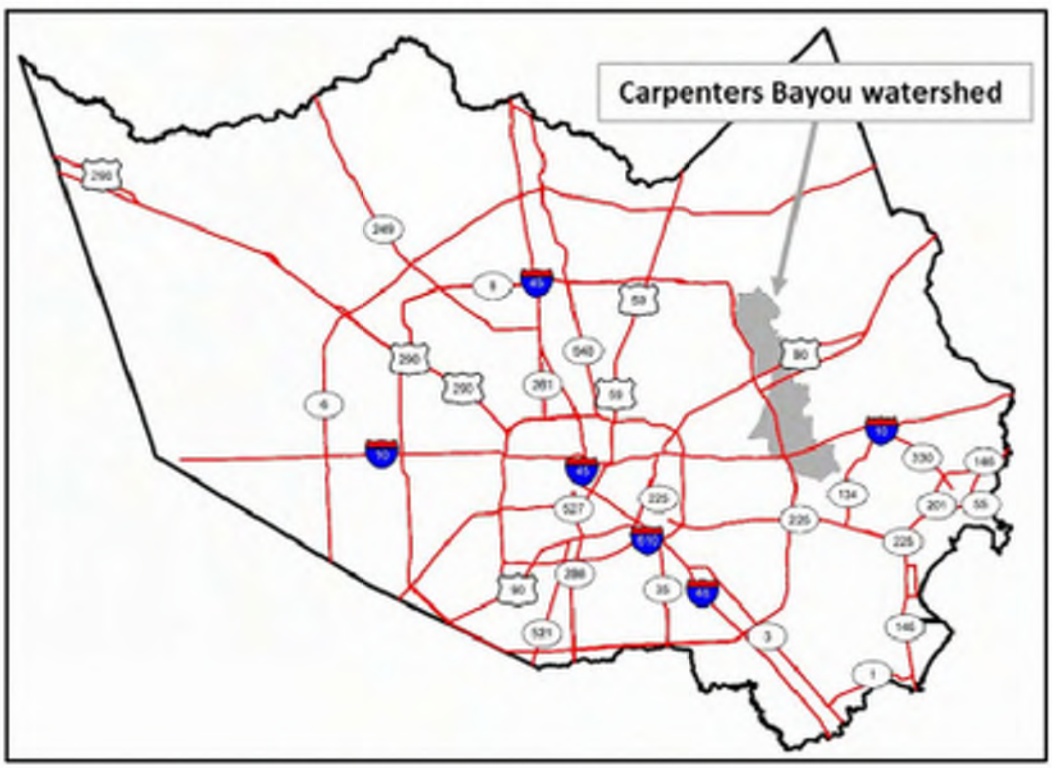


Figure 2. Carpenters Bayou watershed location

The effective M3 steady state Hydrologic Engineering Center River Analysis System (HEC-RAS) models were downloaded for each of the studied streams from the previous effective Federal Emergency Management Agency (FEMA) study for Carpenters Bayou watershed. These studied streams included HCFCD Project No. N100-00-00 (Carpenters Bayou), N104-00-00, and N117-00-00. Six additional unstudied streams N109-00-00, N109-01-00, N110-00-00, N110-02-00, N111-00-00 and N111-01-00 were combined with the effective M3 models into a single 1D/2D master model for baseline conditions analysis using HEC-RAS version 5.0.7 (USACE 2016). The characteristics of the studied and unstudied streams as well as channel bathymetry were updated from site visits. **Figure 3** shows some channel characteristics captured during site visits.

Figure 3. Channel characteristics

1.4. Flood Sources

Carpenters Bayou watershed has been impacted by 32 of the previous 46 historical flood events since 1979. More recently, the watershed has experienced neighborhood-wide flooding from Tropical Storm Imelda (2019), Hurricane Harvey (2017), and the October Halloween Event (2015) (**Figure 4**). Flooding of the structures in this watershed resulted from various reasons such as overland sheet flow, overbank flooding, insufficient drainage capacity, or deteriorating drainage infrastructure. Model results for baseline ("existing") conditions (coupled 1D/2D analysis and sheet flow analysis with Atlas 14 rainfall update) revealed flooded structures stem largely from sheet flow driven conditions, with flood risks compounded by insufficient drainage capacity and aging infrastructure. Comparison of modeled results, flood claim history, and reconnaissance level assessments confirm these observations. Please refer to **Attachment #1** (TM#1) for details of the modeled results.

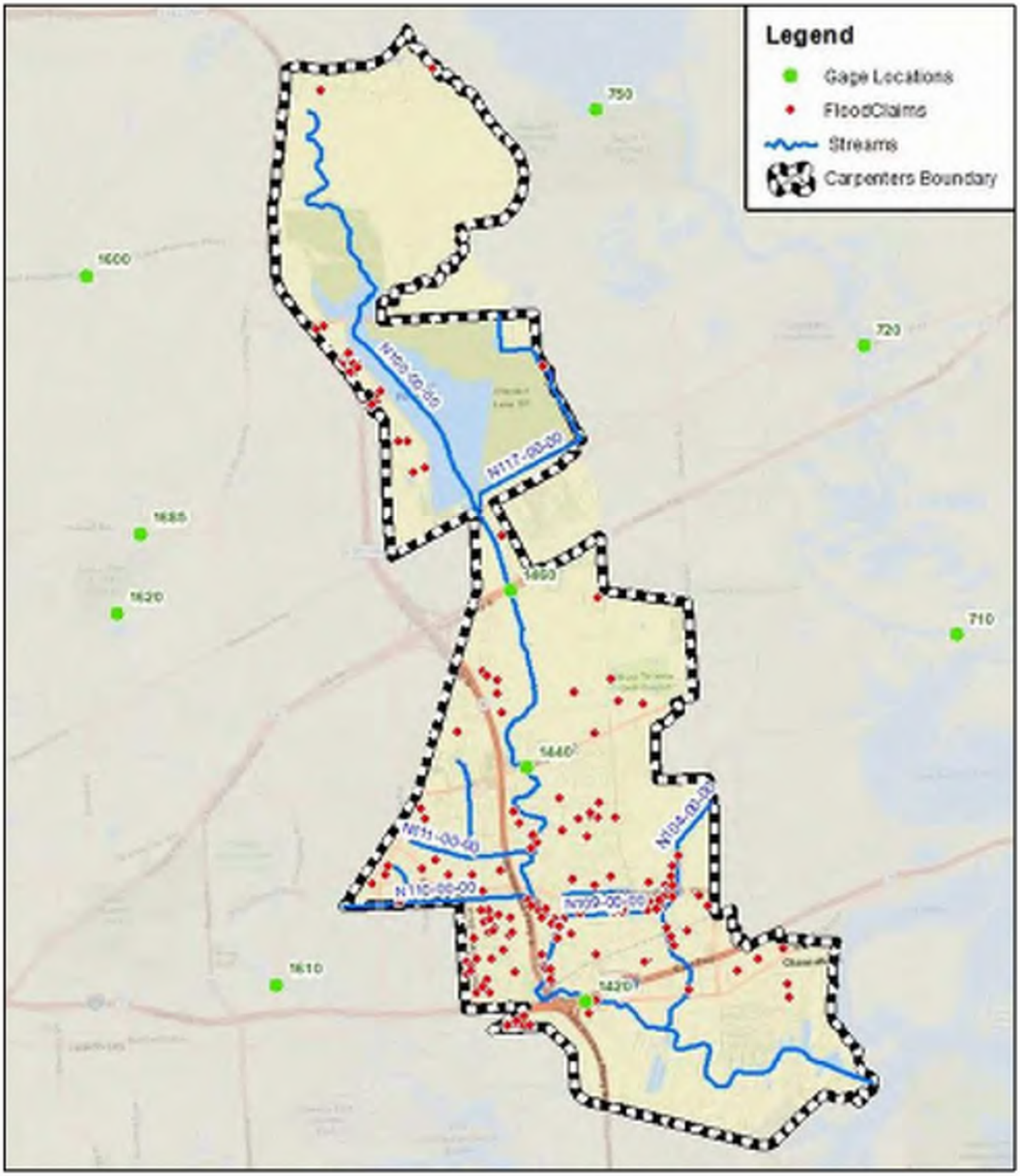


Figure 4. Recent Flood Claims (source: fsi.gdb)

2. Model Development

The purpose of this task was to identify a plan and projects to reduce flood risk within Carpenters Bayou watershed by defining baseline conditions of the Carpenters Bayou WPP (HCFCD Project No: N100-00-00-P004) and identifying and evaluating classifications of PAs. This entailed:

- Updating the modeled land use and terrain data
- Performing a 2D sheet flow analysis to update watershed sub-area boundaries
- Combining effective M3 hydraulic models from Carpenters Bayou watershed studied streams
- Converting steady to unsteady hydraulics and model stabilization
- Calibrating the Carpenters Bayou watershed hydraulic model to the 2019 September Tropical Storm Imelda
- Developing standalone models for the six tributaries that were previously unstudied
- Combining all models for baseline conditions
- Stabilizing and confirming accuracy of the baseline model and
- Identification and analysis of PAs

The models for the entire Carpenters Bayou watershed were analyzed according to the HCFCD H&H Criteria (HCFCD 2009). The following sections highlight the effort for the identification and classification of PAs for Carpenters Bayou watershed. Refer to **Attachment #1** for details of the engineering planning activities for TM#1.

2.1. Model Calibration and Validation

The HEC-RAS model was calibrated to the 2019 September Tropical Storm Imelda. Tropical Storm Imelda was one of the more recent storms that had impacted Carpenters Bayou watershed and thus was chosen for calibration purposes. During this storm, rainfall depths ranged from 3.36 to 10.4 inches, with the larger depths measured in the northern reaches of this watershed. These depths correspond to a 2-year to 50-year rainfall event for this region of Harris County. As such, Carpenters Bayou watershed has three Harris County stream gages that provide historical stage hydrographs for the full duration of the 2019 September Tropical Storm Imelda. These gages include Harris County Gage 1460 at Crosby Freeway, Gage 1440 at Wallisville Road, and Gage 1420 at IH-10. After calibration, differences in modeled versus observed water surface elevations (WSELs) were computed to be -0.03 feet at Crosby Freeway, 1.02 feet at Wallisville Road, and -0.65 feet at IH-10. The timing differences to peak WSELs between modeled and observed range from 0.45 to 0.82 hours across gage locations. **Table 1** provides a direct comparison of peak WSELs between the modeled and observed rainfall event along Carpenters Bayou watershed at the three gage locations.

Table 1. 2019 September Tropical Storm Imelda Calibration Summary

2019 September Tropical Storm Imelda					
Gage ID	**Road Name**	**River Station**	**Observed Max WSEL (ft)**	**Modeled Max WSEL (ft)**	**Delta (ft)**
1460	Crosby Freeway	56945.8	33.69	33.66	-0.03
1440	Wallisville Road	45189.7	26.25	27.27	1.02
1420	IH-10	23653.7	13.1	12.45	-0.65
				Average (ft) =	**0.11**
				Standard Deviation (ft) =	**0.84**

For detailed documentation on calibration and validation, please refer to **Attachment #1**.

2.2. Baseline Conditions

The baseline conditions model along with its full suite of runs was built on the calibration conditions model. Unstudied streams N109-00-00, N109-01-00, N110-00-00, N110-02-00, N111-00-00 and N111-01-00 were combined with studied streams into a single 1D/2D "master" model for baseline conditions analysis (**Table 2**). The National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall updates (HCFCD MAAPnext 2019) for 10-year, 50-year, 100-year and 500-year frequency storms were used as an input to Hydrologic Modeling System (HMS). 2018 LiDAR was used to create a high-resolution Digital Elevation Model (DEM) and 2016 National Landover Cover Dataset (NLCD) was used for land use and land cover. Junctions were placed to connect the tributaries to the main stem. Mainstem cross-sections were trimmed to accommodate the tributaries, and 2D flow areas were placed to capture overflow and sheet flow from the tributary models. The 2D flow areas were generated with computation point spacing of 150 feet on average. Break lines were imported from GIS roads data. Lateral structures were used to connect 2D areas with reaches to capture overflow.

Table 2: Unstudied Tributary Characteristics

Tributary	Length (miles)	Average Slope (ft/ft)	XS Count	Bridge/Culvert Crossings
N109-00-00	0.98	0.003	18	1
N109-01-00	0.76	0.001	0	1
N110-00-00	2.08	0.001	61	7
N110-02-00	0.47	0.001	6	1
N111-00-00	1.33	0.002	44	5
N111-01-00	1.06	0.002	32	3

2.3. Proposed Conditions

A suite of different alternative improvements was evaluated based on proposed conditions modeling results, cost estimates, ROW assessments and engineering judgement. Please refer to sections 4 and 5 of this report for modeling details and recommendations developed through the proposed conditions analysis. **Table 3** highlights the HEC-RAS plans constructed and used throughout the course of the WPP.

Table 3: HEC-RAS Plans modeled to evaluate improvement alternatives

HEC RAS Plan	Model Type	Scale	Historical	500yr	100yr	50yr	25yr	10yr
Sheet Flow	2D Sheet Flow	Watershed-Wide		X	X	X		X
Calibration_Imelda2019	Coupled 1D/2D	Watershed-Wide	X					
Validation_Halloween2015	Coupled 1D/2D	Watershed-Wide	X					
Baseline Conditions	Coupled 1D/2D	Watershed-Wide		X	X	X		X
Proposed Conditions ("No_MIT")	Coupled 1D/2D	Watershed-Wide		X	X	X		X
Proposed Conditions ("wMIT")	Coupled 1D/2D	Watershed-Wide		X	X	X		X
PA01_25yrTargetLOS	2D Sheet Flow	Problem Area-Level					X	
PA01_10yrReducedLOS	2D Sheet Flow	Problem Area-Level						X
PA02_50yrTargetLOS	2D Sheet Flow	Problem Area-Level				X		
PA02_25yrReducedLOS	2D Sheet Flow	Problem Area-Level					X	
PA03_25yrTargetLOS	2D Sheet Flow	Problem Area-Level					X	
PA03_10yrReducedLOS	2D Sheet Flow	Problem Area-Level						X
PA04_50yrTargetLOS	2D Sheet Flow	Problem Area-Level				X		
PA04_25yrReducedLOS	2D Sheet Flow	Problem Area-Level					X	
PA05_50yrTargetLOS	2D Sheet Flow	Problem Area-Level				X		
PA05_25yrReducedLOS	2D Sheet Flow	Problem Area-Level					X	
Regional #1-Lake Sheldon Storage	Coupled 1D/2D	Watershed-Wide			X			
Regional #2-N100 Channel Improvements	Coupled 1D/2D	Watershed-Wide			X			
Regional #3-P103-00 Diversion	2D Sheet Flow	Watershed-Wide			X			
Project based-BaselineConditionsCloverleaf	2D Sheet Flow	Project Area			X			
Project Based-Phase1CloverleafCloverleafBaseline_50yr	Coupled 1D/2D	Project Area				X		
Project Based-Phase1CloverleafCloverleafBaseline_50yr	Coupled 1D/2D	Watershed-Wide				X		
Project Based-N100N109ChannelImprov	Coupled 1D/2D	Watershed-Wide		X	X	X		X
Project Based-N104 Channel Improv	Coupled 1D/2D	Watershed-Wide		X	X	X		X
Vision Plan	Coupled 1D/2D	Watershed-Wide			X			

2.4. Model Results

Model results for baseline ("existing") conditions (coupled 1D/2D analysis with Atlas 14 rainfall update) revealed flooded structures stemmed largely from sheet flow driven conditions, with flood risks compounded by insufficient drainage infrastructure across several neighborhoods. Comparison of modeled results, flood claim history, and reconnaissance level assessments confirmed these observations. Flood claims data provided by HCFCD was superimposed on the 100-year floodplain maps for sheet flow and baseline conditions (**Exhibit 2**) as shown in **Figure 5**.

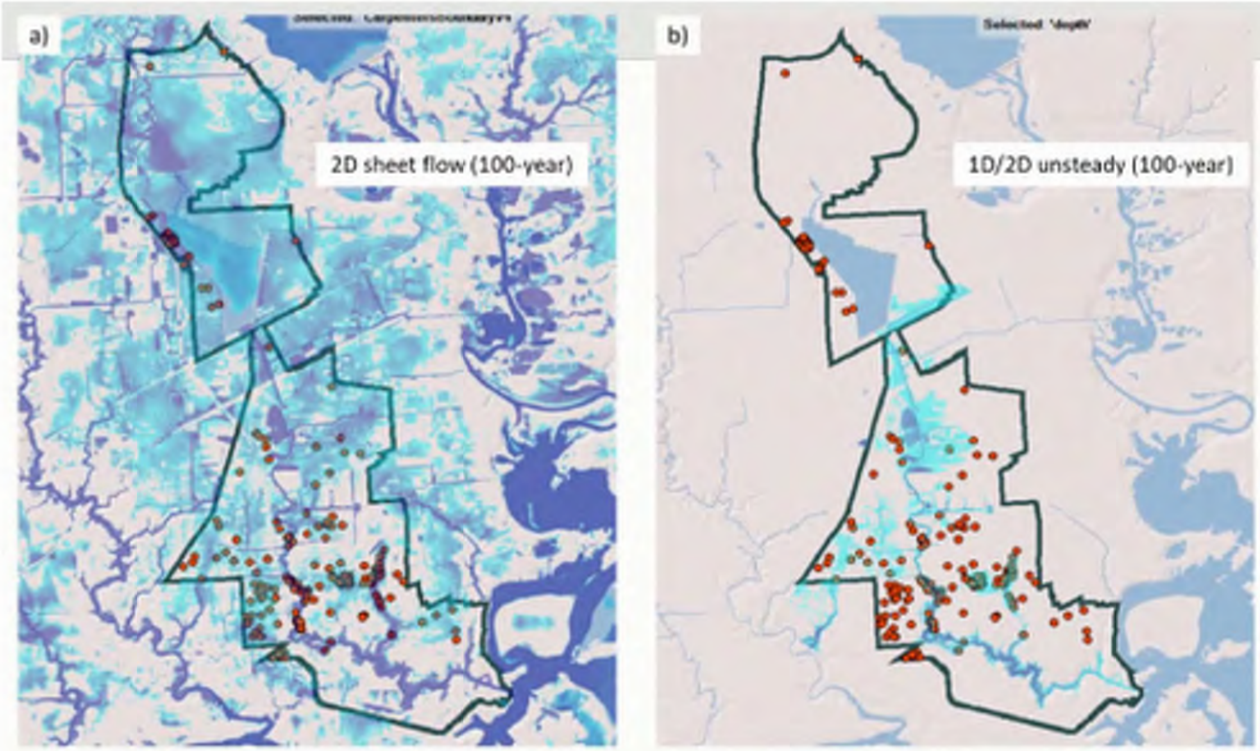


Figure 5. Baseline condition model comparison with flood claim data (red dots)

Distribution of flooded structures by depth was calculated for the 10-year, 50-year, 100-year, and 500-year storms using sheet flow and baseline results for the respective storm events. **Figure 6** shows a histogram for flooded structures by depth resulting from a 100-year storm event under sheet flow conditions (**Exhibit 3**).

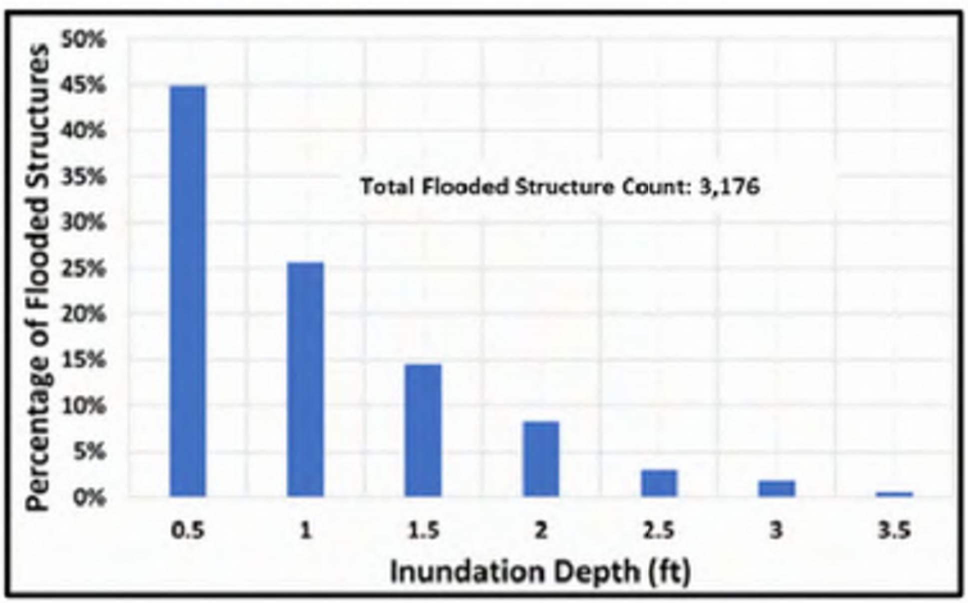


Figure 6. Distribution of Flooded Structures by Depth (100-year)

3. Flood Problem Area Identification

The 1D/2D baseline and sheet flow condition model results, site visits, and evaluation of prior engineering reports led to an identification of eleven (11) PAs (**Exhibit 4**). PAs were grouped into three tiers using supporting data on repetitive loss, flood claims, existing LOS, flood damage potential, and perceived project viability. PAs with the most severe flooding issues were classified as "Tier 1". PAs classified as "Tier 1" and "Tier 2" are considered strong candidates for detailed analyses and potential consideration for realizing near-term flood mitigation benefits for surrounding communities. PAs of "Tier 3" have only moderate flooding conditions and were designated for less detailed analysis.

A methodology was provided by HCFCD using three primary flooding criteria (number of flooded structures, length of inundated roadways, and overall flood claims) for grouping the PAs into the three tiers as shown in **Table 4**. Refer to **Attachment #1** for details of these attributes, which are also listed below.

- Inundated Structures (count)
- Inundated Roadway (miles)
- Flood Claims (count)

Table 4. PA Summary

Problem Area Name	Primary Jurisdiction	Flooding Source	Historical Flooding Data	Total Predicted Structural Flooding (1% AEP) *	Predicted Structural Flooding (PSF50)	Predicted Roadway Flooding (Total Length >1-foot during 1% AEP)	Classification
			(number of homes)	(number of structures)	(flooded structures over 50 years)	(miles)	
PA01	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	64	427	853.9	13.6	Tier 1
PA02	Unincorporated Harris County/ Cloverleaf	Sheet flow from adjoining area and Local stormwater drainage limitation	12	785	1680.5	24.1	Tier 1
PA03	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	21	526	867.2	11.4	Tier 2
PA04	Unincorporated Harris County/ Cloverleaf	Local stormwater drainage limitation and sheet flow from adjoining area	32	206	661.9	3.0	Tier 2
PA05	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	25	218	569.8	1.5	Tier 2
PA06	Unincorporated Harris County	Sheet flow from adjoining area and Local stormwater drainage limitation	12	46	198.1	0.1	Tier 3
PA07	Unincorporated Harris County	Overbank flow and local stormwater drainage limitation	4	18	30.7	5.9	Tier 3
PA08	Unincorporated Harris County/ Channelview	Local stormwater drainage limitation and sheet flow from adjoining area	3	36	78.3	0.5	Tier 3
PA09	Unincorporated Harris County	Overbank flow	1	60	111.1	0.4	Tier 3
PA10	Unincorporated Harris County/ Channelview	Overbank flow	2	10	20.5	0.1	Tier 3
PA11	Unincorporated Harris County/ Channelview	Sheet flow from adjoining area and Local stormwater drainage limitation	0	16	71.7	0.1	Tier 3

Table 4 Notes and Abbreviations:

- **Historical Flooding (data value)** = Total historical flooding from the multiple events recorded in the HCFCD database – (Events include Imelda 2019, Harvey 2017, Memorial Day 2015, Tax Day 2016, Halloween 2015, Ike 2008, and others). They do not include storm events prior to 2015 such as Tropical Storm Allison (2001), Carpenters Bayou watershed flooded extensively during this storm event.
- **Total Predicted Structural Flooding (1% AEP)**- Number of homes predicted to flood during storm event with a 1% annual exceedance probability.
- **Predicted Structural Flooding (PSF50)** -Total cumulative probable structural flooding over the 50-year period
- This statistic based on four predicted frequency events, i.e [(N10year x 5) + ((N50year-N10year) x 1) + ((N100year-N50year) x 0.5) + ((N500year-N100year) x 0.1)] = theoretical probable structural flooding of homes over a 50-year period within each problem area.
- **Predicted Roadway Flooding (Total Length >1-foot in 1% AEP)** =Total Length of all roadways flooded by more than 1 foot during 1% AEP storm event for each problem area. The total length is the cumulative sum of linear feet inundation for all classifications of roadways within the problem area.

3.1. Problem Area #1 (PA01)

PA01 is part of unincorporated Harris County and lies within the community of Channelview. It includes Sterling Green South and Sterling Forest neighborhoods. HCFCD Tributaries Unit No: N109-00-00, N109-01-00, and a small portion of the mainstem N100-00-00 lie within this PA (**Figure 7**).

Figure 7. Location of PA01

The primary sources of flooding for PA01 are related to insufficient capacity of tributaries within PA01, overland sheet flow and deteriorating drainage infrastructure. The Sterling Forest Subdivision Drainage Assessment (2019) states that the flooding in the Sterling Forest subdivision occurs due to inadequate flow paths to accommodate extreme storm event runoff. The analysis in the report supports the idea that flooding in PA01 primarily occurs because of overland sheet flow through complex but inadequate ditch networks.

3.2. Problem Area #2 (PA02)

PA02 primarily lies in the community of Cloverleaf and is a part of the unincorporated Harris County. Tributaries Unit No: N110-00-00, N110-02-00, N111-00-00 and N111-01-00 lie within this PA (**Figure 8**).

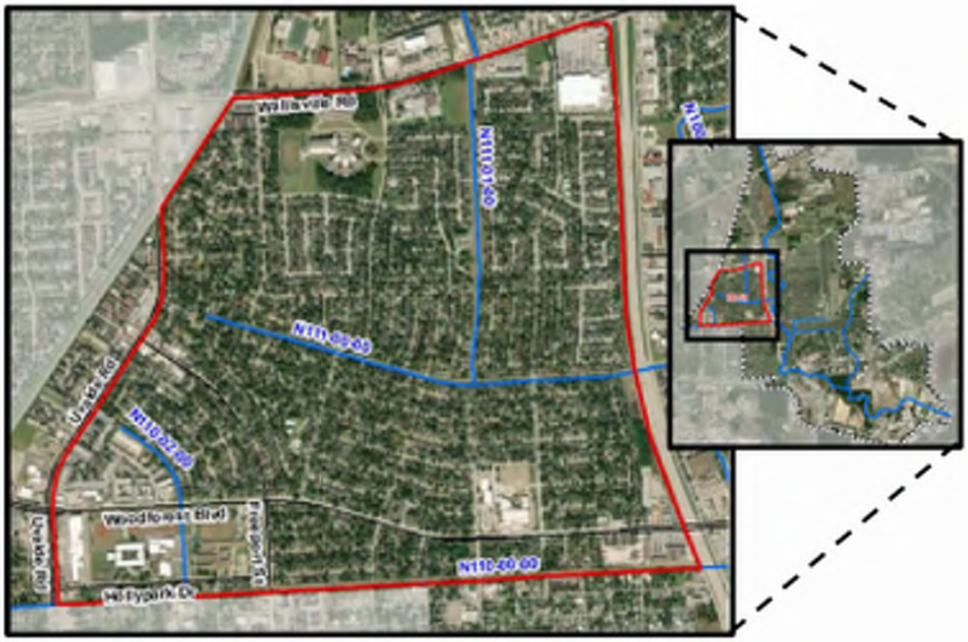


Figure 8: Location of PA02

Modeled baseline conditions show that N110-02-00 and N111-00-00 have less than a 100-year LOS and N110-00-00 and N111-01-00 have less than a 500-year LOS. The individual homes in this area were mainly built between years 1940 and1980 with newer structures built between years 1980 and 2020 located north of N111-00-00. The historical flood claims in this area are widespread. There are five critical facilities (elementary and middle schools), and a few hazardous materials (HAZMAT) sites present in this area. The primary source of flooding for PA02 is related to potential overland sheet flow and an insufficient drainage network.

3.3. Problem Area #3 (PA03)

PA03 is a part of the unincorporated Harris County and the community of Channelview. It includes the Sterling Green neighborhood. A small portion of the mainstem N100-00-00 lies within this PA (**Figure 9**).

Figure 9. Location of PA03

Modeled baseline conditions show that the mainstem (N100-00-00) in PA03 has less than a 50-year LOS. Most structures were mainly built between years 1980 and 2020, with older structures built between years 1940 and 1980 located west of N100-00-00 and along the banks of the mainstem. The historical flood claims in this area are widespread in the Sterling Green neighborhood and along the banks of N100-00-00. There was a cultural resource survey conducted in this area. There is an Oil & Gas (O&G) well and an O&G pipeline present in this area. The primary source of flooding is related to overbank flooding and overland sheet flow.

3.4. Problem Area #4 (PA04)

PA04 primarily lies in the community of Cloverleaf and is a part of the unincorporated Harris County (**Figure 10**). None of the Carpenters Bayou watershed tributaries or mainstem pass through this area. The PA is characterized by roadside ditches and old residential structures.

Figure 10. Location of PA04

Modeled baseline conditions show that the mainstem N100-00-00 that PA04 outfalls to, has less than a 50-year LOS. The structures were mainly built between years 1940 and 1980 with a few older structures built between years 1900 and 1940 in this area and a few newer structures built between years 1980 and 2020 scattered throughout the PA. The historical flood claims in this area are widespread. There is one critical facility (elementary school), a cemetery, and a wetland area in the vicinity of the PA. A cultural resource survey has also been conducted in this area. The primary source of flooding is related to overland sheet flow and deteriorating drainage infrastructure.

3.5. Problem Area #5 (PA05)

PA05 is a part of the unincorporated Harris County and the Channelview community. Tributary Unit No. N104-00-00 lies within this PA (**Figure 11**). This PA is comprised of the neighborhoods West Acres, Shadowglen and Old River Terrace.

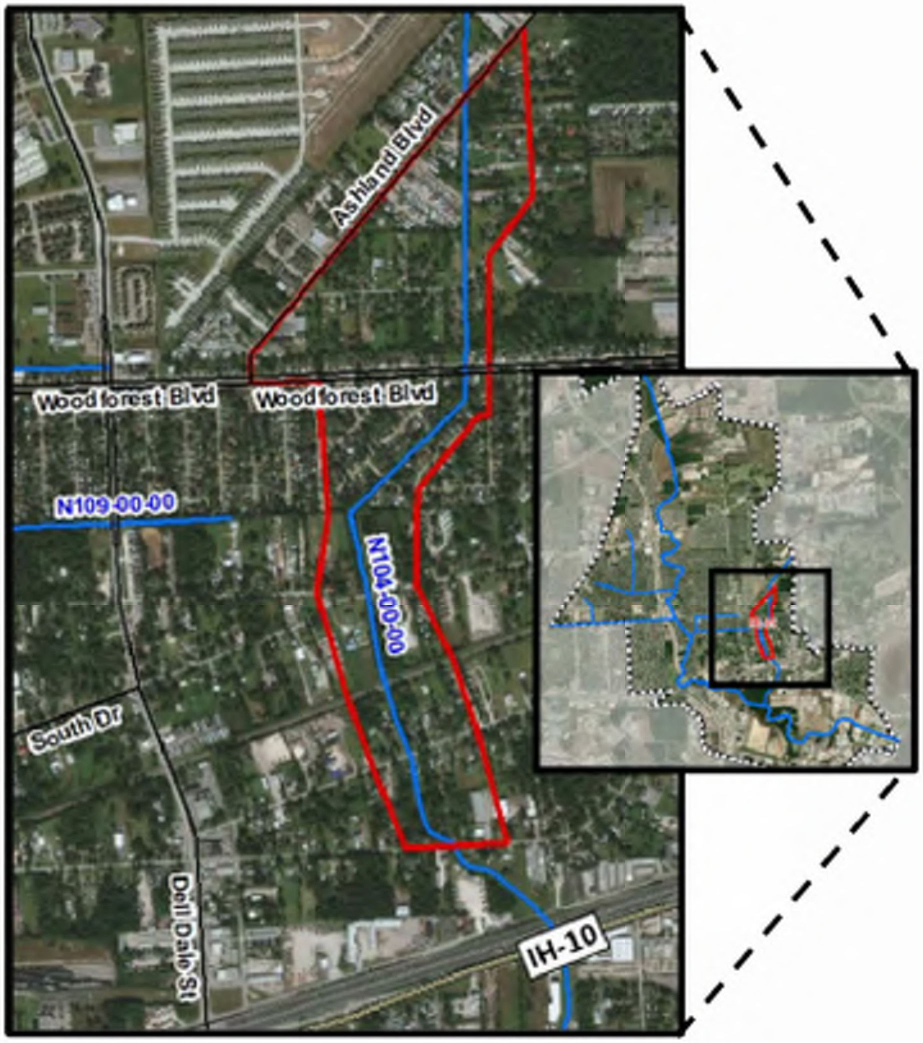


Figure 11. Location of PA05

Modeled baseline conditions show that the stream N104-00-00 in PA05 has less than a 10-year LOS. Most structures were mainly built between years 1940 and 1980. The historical flood claims in this area are along the banks of N104-00-00 and in the 100-year FEMA effective floodplain. There are a few HAZMAT sites and an O&G pipeline present in this area. PA05 is unique because it floods mostly because of overbank topping of tributary N104-00-00.

4. Modeling Approach for Improvement Strategies

The purpose of this task was to efficiently screen a suite of drainage improvements for screening initial feasibility. For this effort, drainage alternatives were identified and hydrologically evaluated. These alternatives were derived based on modeled output from baseline conditions, available ROW, constructability considerations, HCFCD input, understanding of prior studies, and general knowledge of the watershed. Alternatives served well for filtering candidate projects for detailed modeling under proposed conditions and PER consideration and incorporated the following factors:

- Identification of alternative improvements for the Tier 1 and Tier 2 PAs to best mitigate existing flood risks.
- Preliminary impacts identification
- Regional-level strategies that provide watershed wide benefits; and
- Analysis of the potential for future drainage problems associated with new development or re-development within the watershed

The following sections highlight the proposed methodology and identified alternatives at the planning-level effort for each of the identified Tier 1 and Tier 2 PAs. Please refer to **Attachment #2** for details on the strategies for improvements.

4.1. Local Strategies

The approach for identifying local strategies relied on identifying a Target LOS for Tier 1 and Tier 2 PAs experiencing sheet flow driven flooding. This section describes the methodology used to identify the Target LOS.

PAs 1 through 4 in Carpenters Bayou watershed experienced neighborhood-level flooding (sheet flow driven), hence a flexible hydrologic approach for evaluating potential recommendations (at the neighborhood-level) was warranted. In other words, some PAs or neighborhoods located sufficiently away from jurisdictional waterways may not – in some circumstances – directly benefit from traditional channel improvements or inline detention along studied streams or tributaries. The Basin Development Factor (BDF) (Sauer et al. 1983; Asquith et al. 2011) – when used in conjunction with Clark Unit Hydrograph – provides for a flexible and robust approach for characterizing small catchment and urbanized watersheds under baseline and proposed condition scenarios. For a given neighborhood, or PA, the BDF-based hydrologic approach allows for proposed conditions (planning-level) that include improvement considerations to (1) curb and gutter, (2) storm sewers, (3) channel improvements, and (4) channel lining (**Figure 12**). Refer to **Attachment #2** (TM#2) for details of the BDF based methodology.

PRE BDF PA01 (Existing Conditions)	10-year storm		
	Upper	Middle	Lower
Channel Improvements	0	1	1
Channel Linings	0	1	0
Storm Sewers	1	0.5	0.5
Curb and Gutter Streets	1	1	1
Sub-Totals	2	3.5	2.5
Overall Total BDF			8

Figure 12. Example of BDF improvement indices and scoring

PA01 through PA04 were analyzed using the BDF based methodology and the Target LOS alternative to help identify potential solutions for the neighborhood level flooding issues. Based on the analysis, a mitigation volume for the Target LOS alternative was proposed. **Figure 13** illustrates the methodology used for the BDF based analysis.

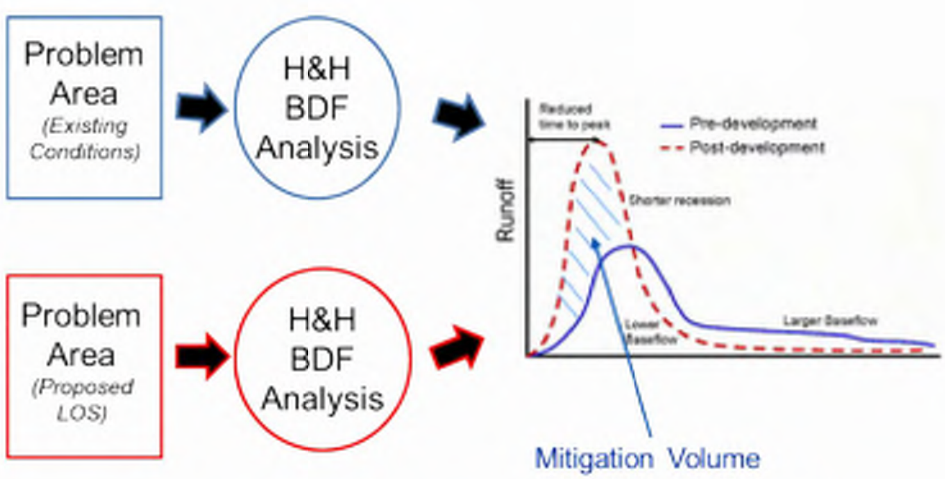


Figure 13. Methodology used for planning-level alternatives analysis

A Target LOS alternative is defined as the smallest storm event that the drainage system must handle to achieve the most significant reduction in damages. If the proposed drainage system is even larger, very few additional damages are removed. Identification of the Target LOS for each PA required the incremental subtraction of hyetographs of smaller storm events (e.g., 2-year, 10-year, 25-year, 50-year) from a benchmark storm (100-year) until the Target LOS was obtained (**Figure 14**).

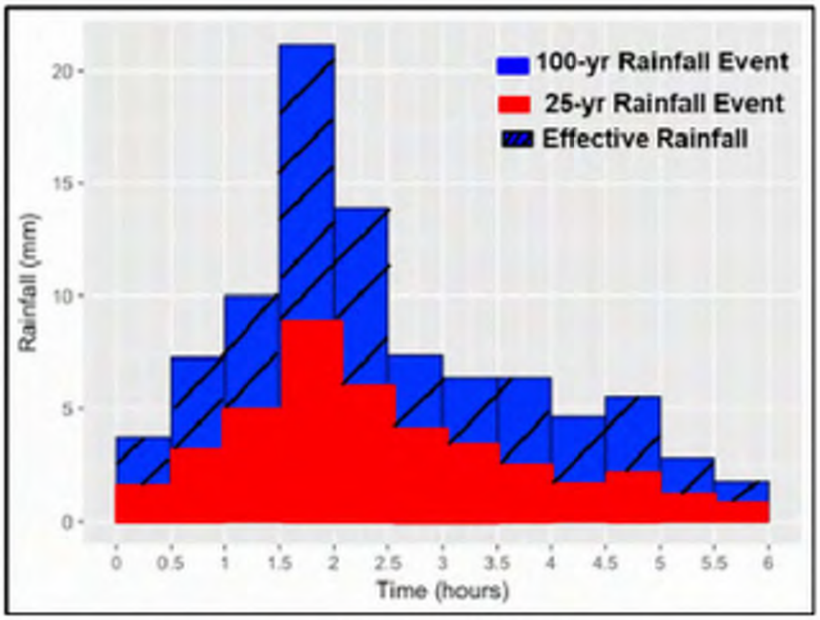


Figure 14. Explanation of "Target LOS alternative"

The subtracted storm events represent the required LOS functioning of the associated drainage system. Refer to **Attachment #2** for details on the Target LOS alternative. **Table 5** shows the Target LOS identified for PAs 1 through 4 since they mainly experience sheet flow driven flooding (PA05 mainly experiences out-of-bank flooding thus channel improvement alternatives were explored to reduce flood risk in PA05). Please refer to section 4.3 of this report for the proposed channel improvements in PA05.

Table 5. Target LOS alternative for PAs 1 through 4

Problem Area	"Target" LOS	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Total HCAD market value of Residual Properties ($)	Proposed Detention Volume (ac-ft)
PA01	25	417	10	$598,000	22 ac-ft
PA02	50	782	3	$319,000	77 ac-ft
PA03	25	525	1	$69,000	23 ac-ft
PA04	50	188	18	$844,000	135 ac-ft

This methodology was applied to PAs 1 through 4 and a mitigation volume was determined to offset the conveyance impacts from the neighborhood wide improvements (**Table 5**). This was one of the alternatives that was presented for sheet flow driven problems at the neighborhood-level.

4.2. Regional Strategies

The improvements evaluated in this section were geared towards providing watershed wide benefits. Channel improvements to N100-00-00, a diversion towards lower Greens Bayou, and the use of Lake Sheldon as a storage facility were all explored as potential solutions to watershed wide flooding issues.

4.2.1. Channel Improvements (Unit N100-00-00)

Channel improvements along the segments of the mainstem Unit N100-00-00 would provide a regional solution to several identified PAs including PA01 and PA03. For this analysis, stream segments were examined by reviewing aerial imagery and the terrain topography. Stream segments that could be widened and deepened without impacting the adjacent developed parcels and segments that cause the least geomorphic impacts in the form of steep or flat longitudinal and cross-sectional channel slopes were selected for improvements. Several runs with varying bottom widths and channel slopes were conducted on stream segments to determine the combination that would yield the most benefit (**Figure 15**). Please refer to section 4.2 for the proposed N100-00-00 channel improvements.

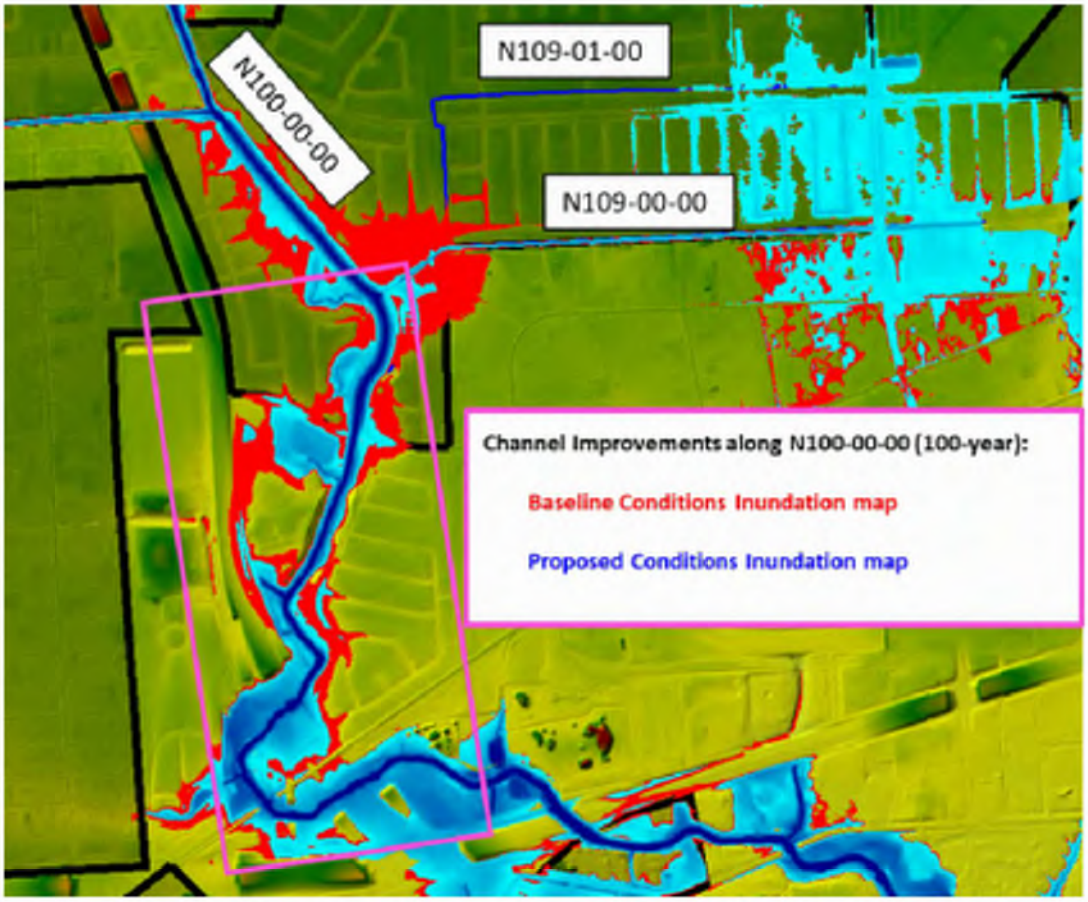


Figure 15. Channel improvements along N100-00-00

4.2.2. Diversion to Lower Greens Bayou

The baseline conditions model revealed an overflow into Greens Bayou from Carpenters Bayou along tributary N110-00-00. A diversion to the P103-00-00 and P103-03-00 tributary located in lower Greens Bayou was evaluated. Existing conditions sheet flow model was used to determine the capacity of P103. Refer to **Attachment #2** for the computed water surface elevation of the 10-year, 50-year, 100-year and 500-year storm events. It was determined that P103-00/P103-03 lacks capacity in the upstream reaches but has enough capacity downstream as it connects with the mainstem. Channel improvements could be conducted in the upper reaches of P103-00/P103-03 to facilitate overflow from Carpenters Bayou into Greens Bayou. Further analysis is required to evaluate this project and has been handed off to the lower Greens Bayou study team which is currently evaluating that adjacent watershed at the time of this report.

4.2.3. Lake Sheldon Reservoir

The presence of Lake Sheldon in the Carpenters Bayou watershed provides for a unique opportunity in multi-purpose use. As development continues to move northward, the use of Lake Sheldon as a flood mitigation resource can be explored. A preliminary analysis was conducted to determine the benefits that Lake Sheldon would provide as a storage facility. The flows from N100A, N100B, N100C and N117 were removed from the H&H models to demonstrate the maximum benefit possible from use of the reservoir as a detention basin. **Figure 16** shows the resulting Inundation map for the 100-year storm event. As expected under this maximum benefit condition, the storage facility does provide benefit to the northern region of the watershed where there is a potential for development. This alternative could be evaluated in more detail and might be considered as a long-term improvement project as future development takes place.

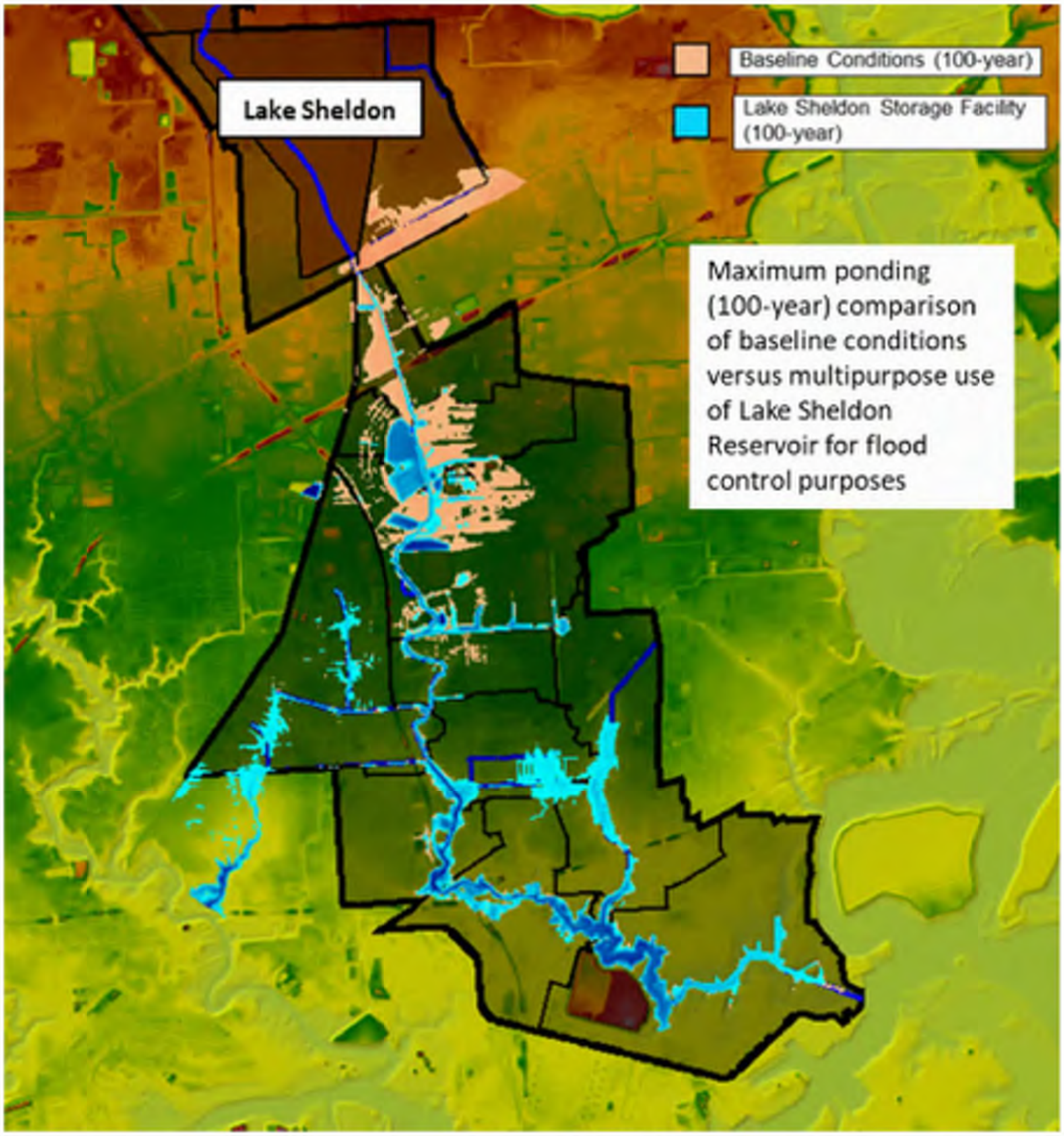


Figure 16. Multipurpose use of Lake Sheldon Reservoir

5. Project Recommendations

To effectively consider projects for future implementation, an array of alternatives was modeled, and the analysis revealed four projects that showed significant benefits in flood damage reductions. After computing flood metrics, identifying constraints, assessing feasibility, and estimating costs, these projects are recommended as the highest priority for future implementation. These projects range from being PA focused to providing watershed wide benefits. The Cloverleaf Flood Risk Reduction Project (WP01), N100-00-00 Channel Improvements (WP02), N104-00-00 Channel Improvements (WP03) and the P103-00/P103-03 Diversion (WP04) were prioritized using the project prioritization sheet provided by HCFCD. The following section describes the recommended projects and cost estimates of the Carpenters Bayou WPP. Details of the Cloverleaf Flood Risk Reduction Project and N100-00-00 Channel Improvements can be found in **Attachment #5**. Refer to **Attachment #3** for details of N104-00-00 Channel Improvements and N110-00-00 Diversion to P103/P103-03.

5.1. Cloverleaf Flood Risk Reduction Project (WP01)

The sheet flow model, flood claims data, and site visits revealed that the lower Cloverleaf community specifically PA04 is highly affected by sheet flow driven flooding. Cloverleaf lies in the southern portion of the Carpenters Bayou and comprises of older residential structures built between the 1940's and 1980's, with roadside ditches generally lacking in sufficient drainage capacity. The preliminary project for this area consists of a proposed combination of a (1) dual trunk line system (trunk line #1 and trunk line #2) and a (2) 109 acre-feet stormwater detention facility north of the San Jacinto Funeral Home & Memorial Park, for an approximate combined 50-year LOS (**Figure 17, Exhibit 5**).

Figure 17. Cloverleaf Flood Risk Reduction Project

The stormwater trunk lines serve as centralized drainage “arteries” and allow for lateral tie-ins from roadside ditch connections (**purple** and **blue** dash lines in **Figure 17**), before safely out falling into proposed detention or tying into existing drainage systems (**Figure 18**). Please refer to **Attachment #5** for a detailed description of the Cloverleaf Flood Risk Reduction Project

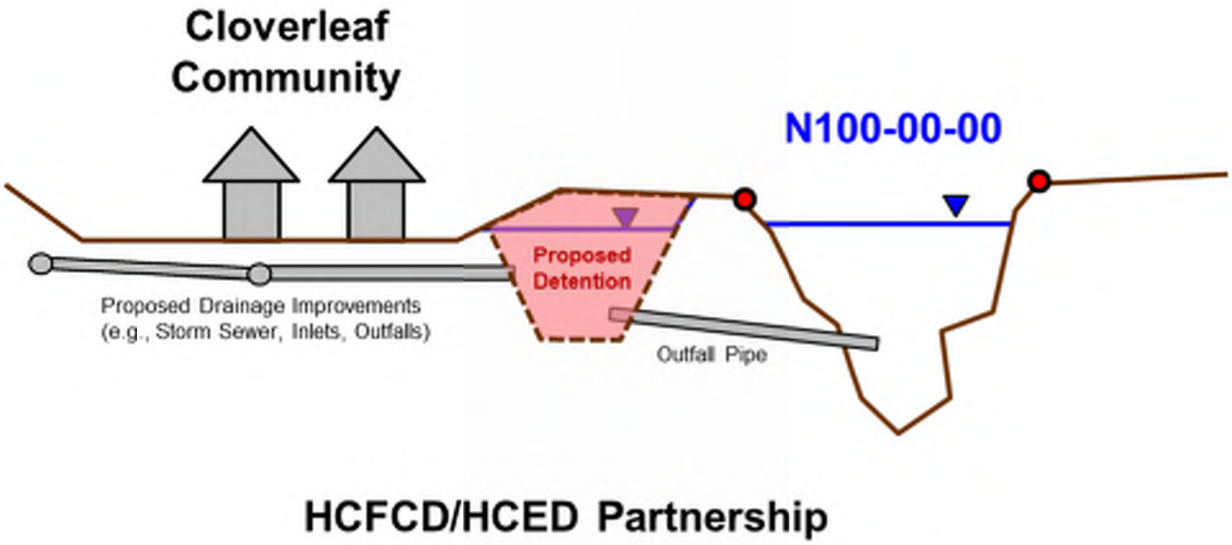


Figure 18. Cloverleaf Flood Risk Reduction Project concept

The project provides a flexible means for phasing trunk lines based on need and funding sources; as well as growing in drainage capacity with the community. Phase 1 of the Cloverleaf Flood Risk Reduction Project was modeled in HEC-RAS using coupled 1D/2D unsteady modeling techniques (**Figure 19**). The trunk line was modeled using enclosed conduits and the detention basin was added into the terrain.

Figure 19. Max Depth for the 50-year storm event

Based on 2D sheet flow modeling assessments, and the project's estimated 50-year LOS, project benefits (trunk lines #1 and #2 [with assumed roadside ditch improvements for lateral tie-ins] and detention) have the potential for substantial flood damage reductions based on quantities of flooded structure removals for the 100-year storm; with the removal of approximately 107 structures for phase 1 improvements (100-year) (**Table 6**) and the removal of 187 structures for phase 1 and phase 2 improvements.

Table 6. Reduction in Flooded Structures for WP01

Phase	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
Phase 1	206	99	661.9	373.1
Phase 1 & 2	206	19	661.9	19.4

*PSF(50): Total cumulative probable structural flooding over the 50-year period

Construction cost for the Cloverleaf Flood Risk Reduction Project Recommendation was determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects. A multiplier of 2.5 was used for property acquisition estimates. Altogether, the total opinion of probable construction costs is estimated to be $16.9M for Phase 1 and $27.2M for Phase 1 and Phase 2. Refer to **Attachment #5** for detailed cost estimates.

5.2. N100-00-00 Channel Improvements (WP02)

The baseline conditions model reveals that the main stem N100-00-00 and tributary N109-00-00 experience out-of-bank flooding. A suite of alternatives for channel improvements were modeled and analyzed to identify the alternative with low cost, high community uplift and high feasibility. The preliminary project for this area consists of a proposed combination of (1) a segment of N100-00-00 channel improvements with a natural stable channel design grass-lined cross-section with, an average channel longitudinal slope of 0.05%, (2) channel improvements at the bridge cross-sections, concrete lined with 60 feet bottom width and 1:1 side slope with an average channel longitudinal slope of 0.05%, (3) a short segment of N109-00-00 channel improvements with a 20 feet maximum bottom width and concrete-lined cross-sections at 2:1 side slopes with an average channel longitudinal slope of 0.2% and (4) 182 acre-feet stormwater detention facility to mitigate impacts downstream caused by the channel improvements (**Figure 20**). Please refer to **Attachment #5** for a detailed description of N100-00-00 Channel Improvement Project.

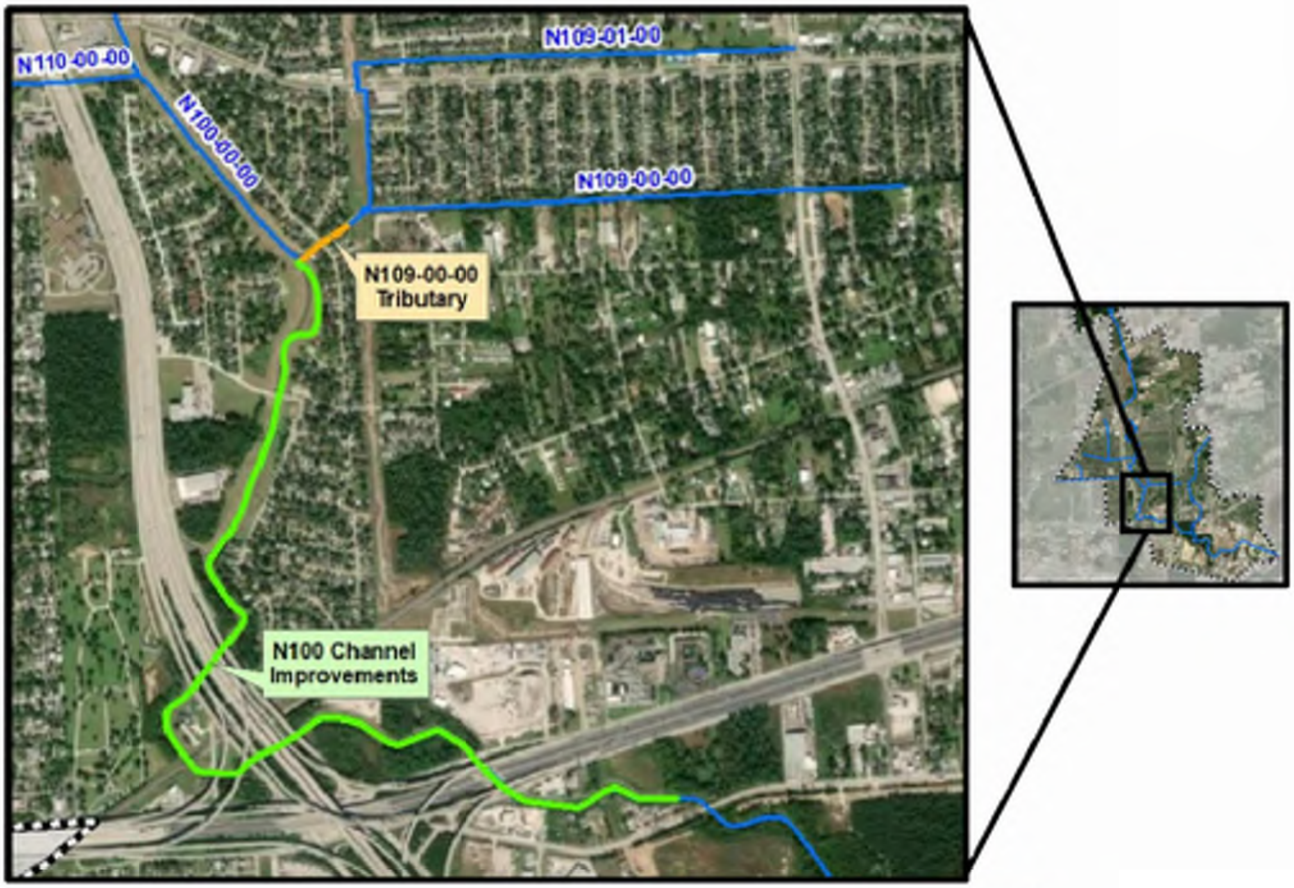


Figure 20. Segment of Channel Improvements at N109-00-00 and N100-00-00

ROW acquisition for this project consisted of partial and full buyouts, some are owned by HCFCD and some are privately owned. The parcels considered for detention purposes are owned by the county (**Figure 21**, **Exhibit 6**).

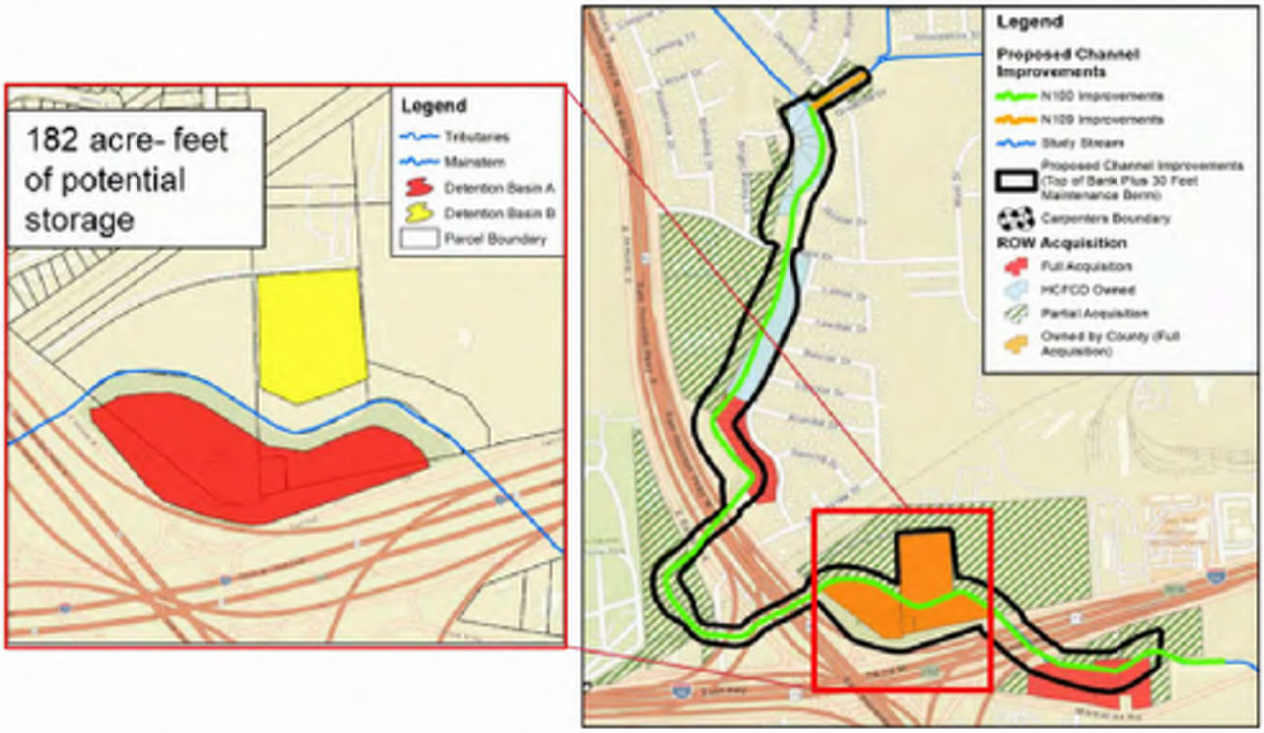


Figure 21. ROW acquisition for proposed Full and Partial Buyouts. (Note: Actual acreage of partial buyouts are subject to change and require further feasibility. This study assumes a representative partial acquisition needed to achieve proposed channel cross-section improvements with partial acquisitions reflected in cost estimates).

Damage reduction was estimated using the reduction in flooded structures (100-year) and the reduction in PSF(50) between baseline conditions and proposed conditions (**Table 7**). The proposed channel improvements show large benefits along the main stem (N100-00-00) and at the confluence of N100-00-00 and N109-00-00.

Table 7. Reduction in Flooded Structures for WP02

Location	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
N100-00-00	122	3	149.1	18.8
Watershed-wide	354	182	460	235.8

*PSF(50): Total cumulative probable structural flooding over the 50-year period

Excavation costs for N100-00-00 channel improvements were determined using the cut and fill volume from HEC-RAS 1D/2D model. The utility adjustment and construction costs were determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects. Partial and non-voluntary buyouts were considered for ROW acquisition with N100-00-00 channel improvements. Altogether, the total opinion of probable construction costs is estimated to be $31M. Please refer to **Attachment #5** for an extended cost table and a detailed description of this project.

5.3. N104-00-00 Channel Improvements (WP03)

The baseline conditions model revealed that N104-00-00 experiences out-of-bank flooding. A suite of alternatives for channel improvements were modeled and analyzed to identify the alternative with low costs, high community uplift and high feasibility. The preliminary project for this area consists of a segment of N104-00-00 channel improvements with a 20 feet bottom width and 4:1 side slope (**green** line in **Figure 22, Exhibit 7**) with an average longitudinal slope of 0.08%. This improvement is considered to have PA focused benefits since it provides benefit to structures along the N104-00-00 tributary located in PA05 (**Table 8**).

Figure 22. Segment of Channel Improvements at N104-00-00.

Table 8. Reduction in Flooded Structures for WP03

Location	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
N104-00-00	79	31	114.4	59.3

*PSF(50): Total cumulative probable structural flooding over the 50-year period

Excavation costs for N104-00-00 channel improvements were determined using the cut and fill volume from the HEC-RAS 1D/2D model. The utility adjustment and construction costs were determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects. Full and non-voluntary buyouts were considered with N104-00-00 channel improvements for a conservative approach (It is important to note that partial non-voluntary buyouts would reduce ROW acquisition costs significantly [from $6.1M to $2.3M]). Altogether, the total opinion of probable construction costs is estimated to be $8.4M. Please refer to **Attachment #3** for an extended cost table and a detailed description of this project.

5.4. N110-00-00 Diversion to P103-00/P103-03 (WP04)

The rain-on-grid model revealed an overflow into Greens Bayou from Carpenters Bayou along tributary N110-00-00 (**Figure 23, Exhibit 8**). A diversion from N110-00-00 to the P103-00-00 and P103-03-00 tributary located in lower Greens Bayou was explored. Channel improvements are proposed in the upper reaches of P103-03-00 to facilitate overflow from Carpenters Bayou into Greens Bayou. Further coordination with HCFCD and the Greens Bayou study team is recommended to determine the project feasibility. Existing conditions sheet flow model was used to determine the capacity of P103.

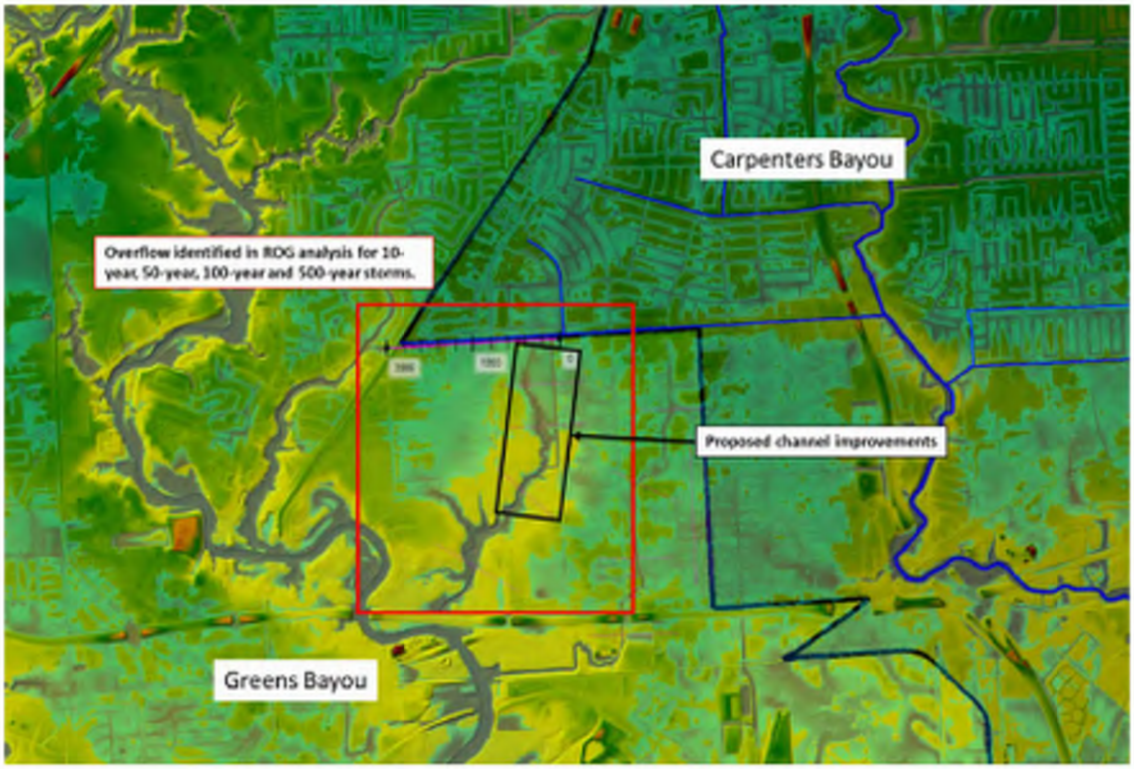


Figure 23. Identified overflow into Greens Bayou watershed

Damage reduction was estimated using the reduction in flooded structures (100-year) and the reduction in PSF(50) between baseline conditions and proposed conditions (**Table 9**). The proposed diversion is assumed to save structures upstream of the diversion in PA02 (**yellow** line **Figure 24**). Almost 20% of the PA is predicted to have a reduction in flooded structures. The damage reduction was based on this assumption.

Table 9. Reduction in Flooded Structures for WP04

Location	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
PA02	785	627	1680.5	1158.5

*PSF(50): Total cumulative probable structural flooding over the 50-year period

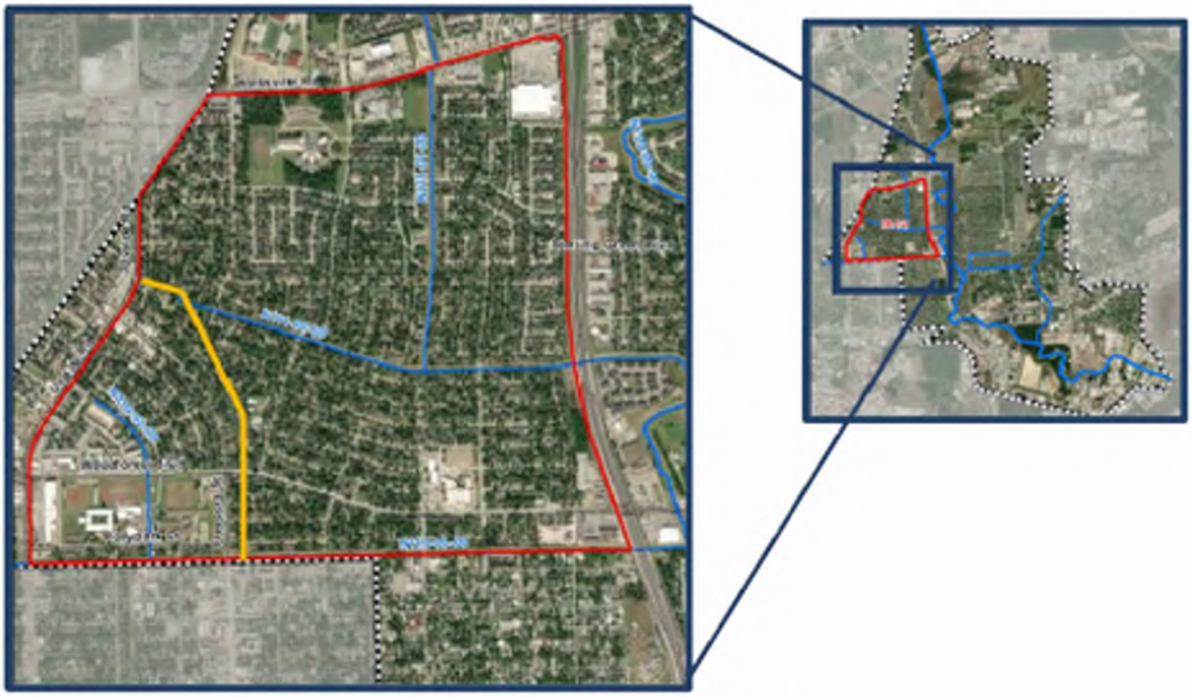


Figure 24. Assumed benefited area of PA02

The cost estimates for this project are based on a planning level analysis, thus the contingency for this project is higher (55%). The tributaries P103-03 and P103-00 have not been modeled so far because of scoping limitations and thus the effects of channel widening/deepening have not been analyzed. The proposed improvements are assumed to provide enough capacity for the flow to be diverted from PA02 to P103. It is important to note that ROW acquisition costs are not included for this project. Altogether, the total opinion of probable construction costs is estimated to be $1.2M (ROW acquisition costs not included). Please refer to **Attachment #3** for an extended cost table. This project was not scored because further analysis is required to assess the benefits associated with this recommendation.

5.5. Project Scoring

HCFCD provided a procedure for the prioritization of projects based on the following criteria:

- Flood Risk Reduction
- Existing Conditions Drainage LOS
- Social Vulnerability Index (SVI)
- Project Efficiency
- Partnership Funding
- Environmental Impacts and
- Potential for Multiple Benefits

Table 10 provides a summary of the project scoring sheets. The Cloverleaf Flood Risk Reduction Project (WP01) scored the highest under the criteria described. It is important to note that WP04 was not scored because further analysis is required to assess the project efficiency and flood risk reductions for this project. Refer to **Attachment #3** for the individual Project Scoring Summary sheet.

Table 10. Project prioritization summary table

Project ID	Description	Total Score Scenario #1 (100-year)
N100-WP01	Cloverleaf Flood Risk Reduction Project- Phase 1	7.70
N100-WP01	Cloverleaf Flood Risk Reduction Project- Phase 1 and 2	8.20
N100-WP02	N100-00-00 Channel Improvements	5.88
N104-WP03	N104-00-00 Channel Improvements	6.33
N110-WP04	N110-00-00 Diversion to P103	0.0

6. Implementation Strategy

The implementation strategy is meant to provide a critical path for each recommended project. The timeline for a project can be long term but a component within that project can be characterized as a near term goal. For example, the N100-00-00 Channel Improvement Project comprises of several components, including ROW acquisition, bridge modifications, detention basins and channel improvements spanning approximately 2 miles. The different components within a project cannot be implemented at the same time and require phasing. It is important to define a critical path for the smooth and efficient implementation of the project. Near-term projects/phases represent a one to five-year timeline, mid-term represent a five to ten-year timeline and long-term represent a timeline beyond ten-years. **Figure 25** represents the timeline identified for each recommended project.

6.1. Near-Term (1 to 5 years)

Cloverleaf Flood Risk Reduction Project (Phase 1 – Trunk line #1) Phase 1 might include the ROW acquisition and permitting for the detention basin and simultaneous construction of trunk line #1, while a feasibility analysis on the IH-10 frontage road drainage system is underway. Phase 1 will potentially reduce flood risk north of Hershe Street. The performance of phase 1 will help inform phase 2 of the project (i.e., mitigation requirements for phase 2, outfall location and trunk line placement).

N104-00-00 Channel Improvements (ROW Acquisition) Recommended phase 1 of N104-00-00 channel improvements is ROW acquisition of the parcels needed for these improvements. This is because acquisition of parcels can take up to two years and for any improvements to take place, ROW is a primary requirement.

6.2. Mid-Term (5 to 10 years)

Cloverleaf Flood Risk Reduction Project (Phase 2 –Trunk line #2). After the conveyance capacity of the drainage system of IH-10 is determined, it will reveal the optimal placement of trunk line #2. This will take a longer time to determine and finalize and thus is a mid-term plan that falls under phase 2 of the Cloverleaf Flood Risk Reduction Project.

N100-00-00 Channel Improvements (Phase 1 – Detention Basin, ROW acquisition, and IH-10 to Beltway 8 Channel Improvements) Recommended phase 1 of N100-00-00 Channel Improvements is ROW acquisition for detention and the channel improvements extending from IH-10 to Beltway 8. Actual acreage of partial buyouts is subject to change and requires a feasibility study. Channel improvements from IH-10 to Beltway 8 can begin soon after. While Phase 1 of the project is in progress, it is recommended that ROW acquisition for the remaining channel improvements (Beltway 8 to N109-00 confluence) takes place so that the project can move forward at a steady pace. Phase 1 of N100 Channel Improvements has several components thus is categorized as a mid-term project.

N104-00-00 Channel Improvements (Phase 2) Phase 2 of this project are the recommended channel improvements along tributary N104-00-00.

N110-00-00 Diversion to P103 A preliminary analysis is recommended for this project before any improvements can take place. WP04 is a mid-term project, team meetings and preliminary analysis are required before a plan for the project is determined.

6.3. Long-Term (beyond 10 years)

N100-00-00 Channel Improvements (Phase 2 – Beltway 8 to N109-00-00 confluence) Since N100-00-00 channel improvements will have to occur in phases, the overall project is expected to take more than ten years to complete and thus N100-00-00 Channel Improvement Project is characterized as a long-term project.

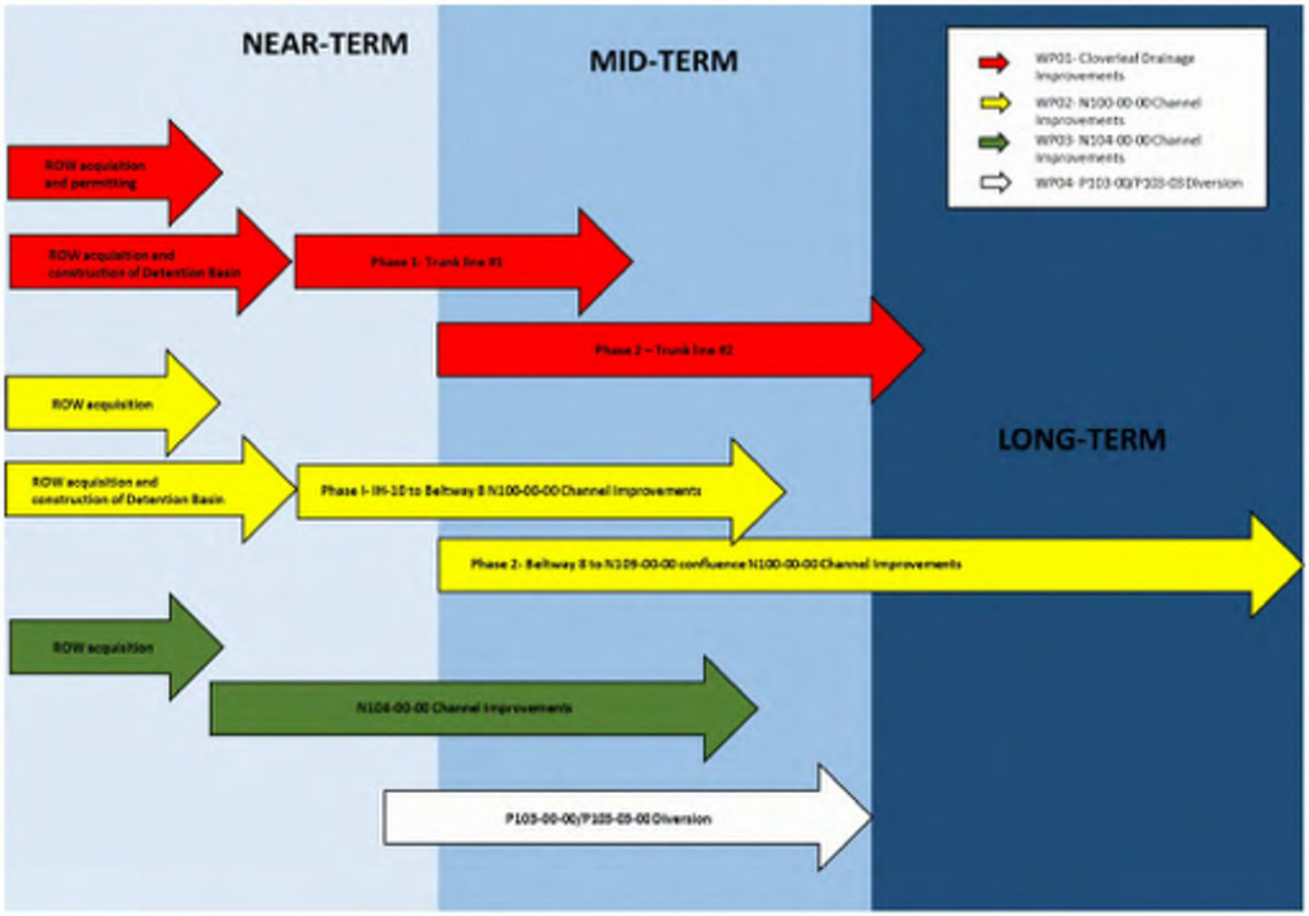


Figure 25. Project Timeline

7. Towards a Carpenters Bayou "Vision Plan"

Carpenters Bayou Vision Plan is part of a strategic effort to help identify the projects that best mitigate the entire watershed's inherent flood risk for the 100-year frequency storm. This plan aims at identifying a comprehensive master plan that mitigates flood risk under existing hydrologic conditions, as well as provide a strategy for improvements as future development occurs. The plan consists of two major components, (1) a master model that combines recommended improvements and is used to evaluate damage reduction for the entire watershed and (2) TM#4 (**Attachment #4**) to provide the technical framework that describes the efforts conducted for the Vision Plan.

The development of the Vision Plan included the following tasks:

- Combing all HEC-RAS 1D/2D models developed in the proposed conditions modeling phase of the WPP and making one combined master model.
- Analyzing and developing a watershed wide plan that uses the recommended projects from TM#3.
- Strategy Development- developing a strategy that will provide a 100-year LOS for the mainstem N100-00-00. Identification of the "100-year LOS" was based on a combination of channel capacity and number of inundated structures.
- Cost Estimates - developing cost estimates for the proposed recommendations using insights developed from sight visits, engineering judgement, proposed conditions modeling, and a uniform cost estimation tool provided by HCFCD.

Overall, the Vision Plan has the potential for substantial flood damage reductions based on number of flooded structures removal for the 100-year storm, acres of inundation and miles of inundated roadway with the removal of approximately 474 structures (**Table 11**). **Exhibit 9** displays the proposed ROW acquisition for the Vision Plan. Additional details such as costs, benefits, and uncertainties associated with the Vision Plan can be found in TM#4 (**Attachment #4**). Please refer to **Attachment #4** for the engineering details and analyses related to the Carpenters Bayou Vision Plan.

Table 11. Flood Metrics for the Vision Plan (100-year)

Metrics	Existing Conditions	Proposed Conditions
Flooded Structures (count)	549	75
Miles of Inundated Roadway (above road)	85	51
Acres of Land Flooded (acres)	3028	2117

8. Conclusions

The overall intent of the Carpenters Bayou Watershed Plan was to develop a comprehensive package of flood reduction projects that best mitigate the watershed's inherent flood risk and improve its floodplain resiliency. This was achieved by developing a clearly defined strategy and outlining achievable and practical project implementation pathways that facilitate the flood damage reduction project lifecycle. The FER for Carpenters Bayou serves as a guide to the efforts conducted for the planning project.

To facilitate the greater vision of the WPP, Torres & Associates – in partnership and collaboration with HCFCD – developed the WPP in summary through (1) PA Identification aimed at identifying and analyzing PAs within Carpenters Bayou with the most severe flooding issues using flood metrics and historical data, (2) the Planning-Level Alternatives Analysis aimed at identifying improvement projects that could help reduce flood risk and be further studied at the PER level and (3) a 100-year LOS Plan that identified a plan which would solve most flooding issues in the watershed pertaining to the 100-year storm event. The work for this study has been documented in the form of four Technical Memorandums which cover the different phases of the WPP development (**Attachment #1, Attachment #2, Attachment #3, and Attachment #4**), the Preliminary Project Plan Report (**Attachment #5**) which specifically describes the recommended projects identified in this study and the Watershed Plan Summary Report (**Attachment #6**) which is meant for the public and describes the overall effort conducted for the WPP.

The modeling methodology consisted of combining the HCFCD's M3 System Effective steady-state models for all CBW watershed studied streams and six additional unstudied streams into one unified hydraulic model, converting steady state models to an unsteady 1D/2D hydraulic framework. Bring the effective M3 model up to baseline conditions, calibrating to the 2019 Tropical Storm Imelda and validating against the 2015 "Halloween" Rainfall Event. Four design storms (10-year, 50-year, 100-year and 500-year) were modeled using the updated NOAA Atlas 14 rainfall data.

Overall, approximately 20 plans were modeled to evaluate improvement alternatives and two recommendations were identified that best served the watershed flooding issues: The Cloverleaf Flood Risk Reduction Project and the N100-00-00 Channel Improvement Project. These two projects help reduce flood risk significantly removing approximately 306 flooded structures in the 100-year storm event under proposed conditions valued at approximately $58M.

Moving forward recommendations include the following:

- Perform PERs for each recommendation to determine feasibility, recreation and environmental features, ROW, outlet structure configurations, etc.
- Use the MAAPnext models to re-evaluate performance metrics of the proposed projects.
- The proposed detention basins to mitigate impacts for N100-00-00 channel improvements were modeled as 1D storage areas in the N100 channel improvements model, these basins require further detailed modeling to evaluate their performance more accurately.
- Consider drop structures where necessary at tributary confluences with N100-00-00 to dissipate energy due to higher velocities from steeper tributaries relative to the mild-sloped mainstem.

It should be noted that for planning-level studies such as this, final constructed elements for project recommendations may vary considerably from what is described in this report, exhibits, and attachments. A multitude of factors and constraints influence the project life cycle; from planning to construction (e.g., development pace/location, ROW acquisition, geotechnical and environmental constraints, etc.). ROW acquisition is not a static process but requires continued coordination with relevant stakeholders such as communities and neighborhoods, landowners, potential land developers, HCFCD, and other agencies such as Harris County Engineering Department (HCED) and Texas Department of Transportation (TxDOT). Thus, project recommendations – as described and suggested in this report, including maps and results suggesting potential ROW acquisitions and potential buyouts – are considered planning-level until detailed feasibility assessments can advance these concepts into preliminary engineering analysis and detailed design. Moreover, Carpenters MAAPnext efforts are ongoing at the time of this report. A re-analysis of key project recommendations may be warranted at a later date.

9. References

Federal Emergency Management Agency (FEMA) (2018). “Flood Insurance Study,” revised August 18, 2018.

Harris County Flood Control District. (2009). “Hydrology & Hydraulics Guidance Manual,” December 2009.

Harris County Flood Control District. (2019). “Workbook for Carpenters Bayou Watershed,” September 2019.

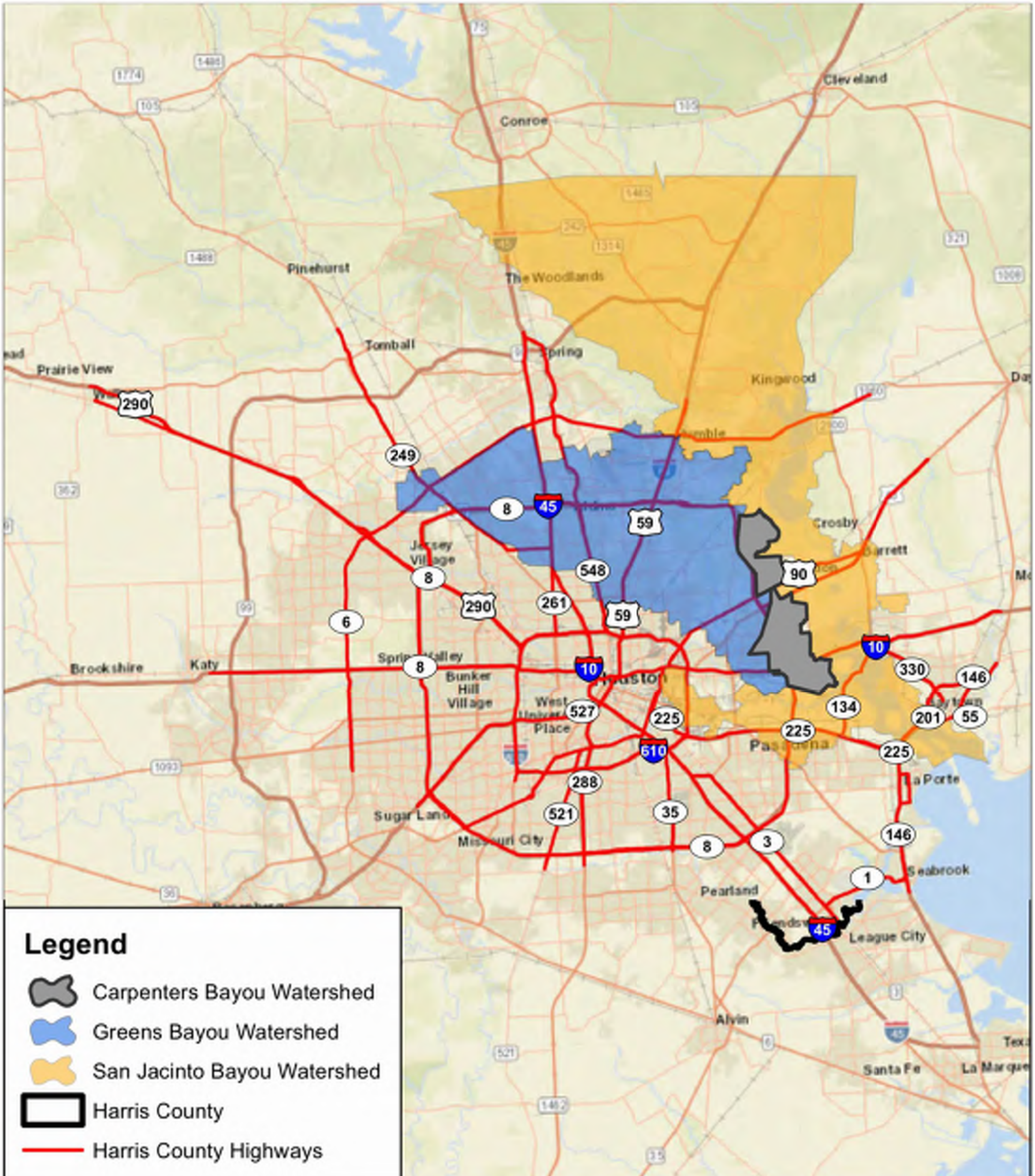
Harris County Flood Control District MAAPnext. (2018). “HEC-RAS Unsteady Modeling Guidelines,” July 2018.

Harris County Flood Control District MAAPnext. (2018). “Two-Dimensional Modeling Guidelines,” July 2018.

Harris County Flood Control District MAAPnext. (2019). “White Paper #01, Recommendation for: Rainfall Depths and Intensities in Harris County,” May 2019.

United States Army Corps of Engineers (USACE). (2000). “HEC-HMS Hydrologic Model System Technical Reference Manual,” Institute for Water Resources, Hydrologic Engineering Center, Davis, CA.

United States Army Corps of Engineers (USACE). (2016). “HEC-RAS River Analysis System Hydraulic Reference Manual Version 5.0,” Institute for Water Resources, Hydrologic Engineering Center, Davis, CA.



Final Engineering Report

Exhibit 1
Carpenters Bayou Location

Miles
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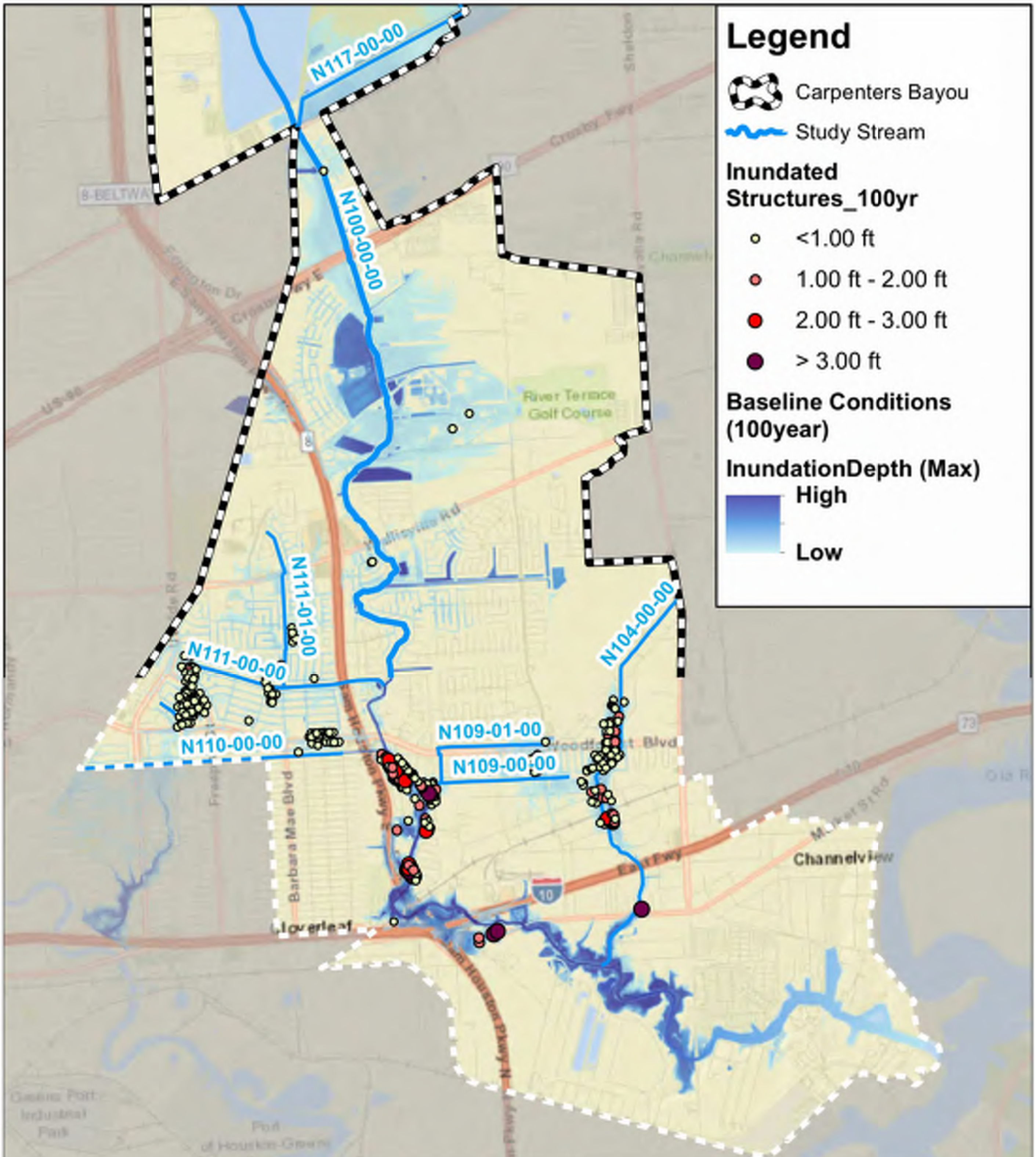
Created: 1/22/2021

Carpenters Bayou
Watershed Plan



Final Engineering Report

Exhibit 2
Baseline Conditions (100year)
Coupled 1D/2D model
Computed Flooded Structures

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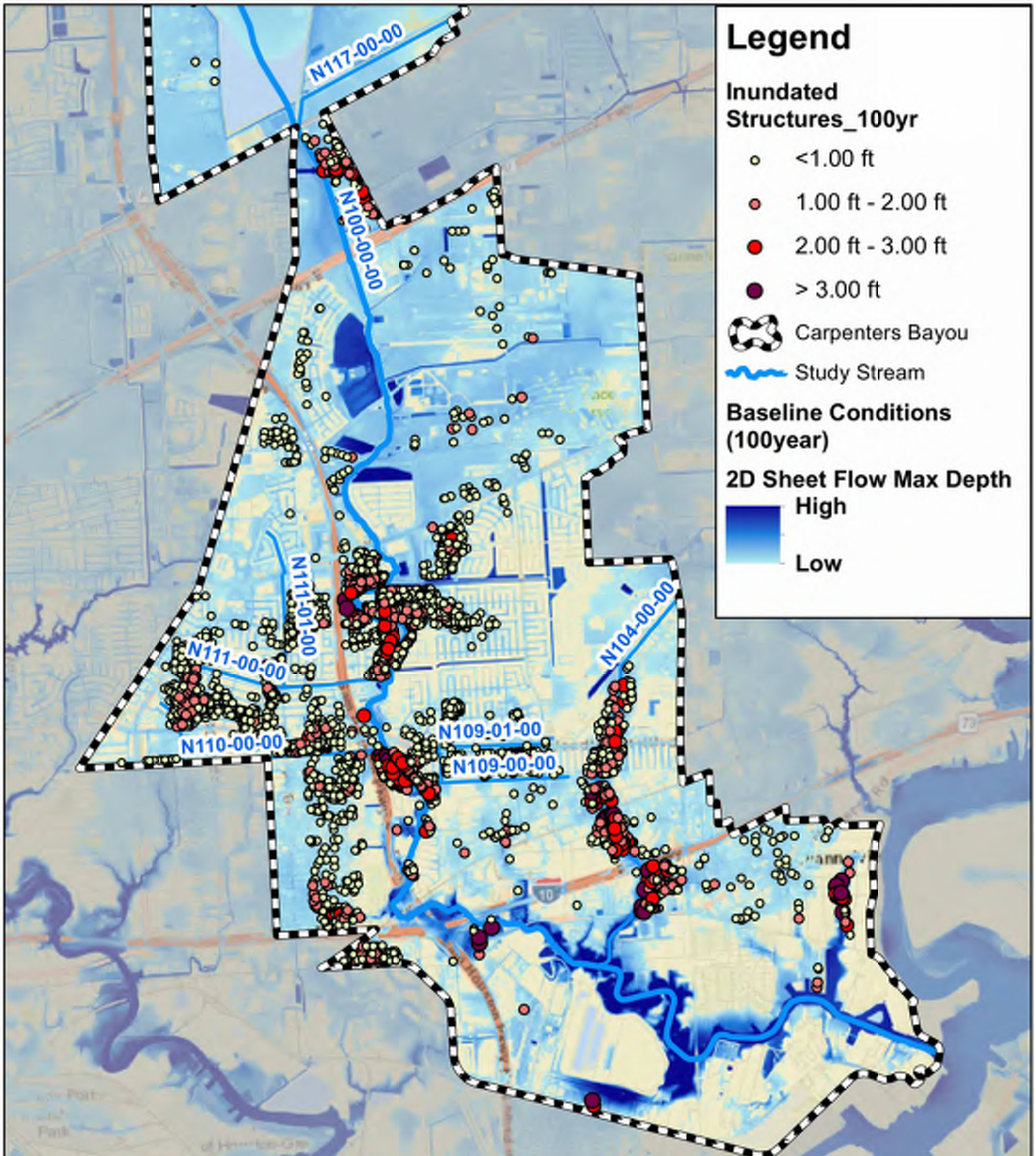
Created: 1/22/2021

Carpenters Bayou

Watershed Plan



Final Engineering Report

Exhibit 3
Baseline Conditions (100year)
2D Sheet Flow Model
Computed Flooded Structures

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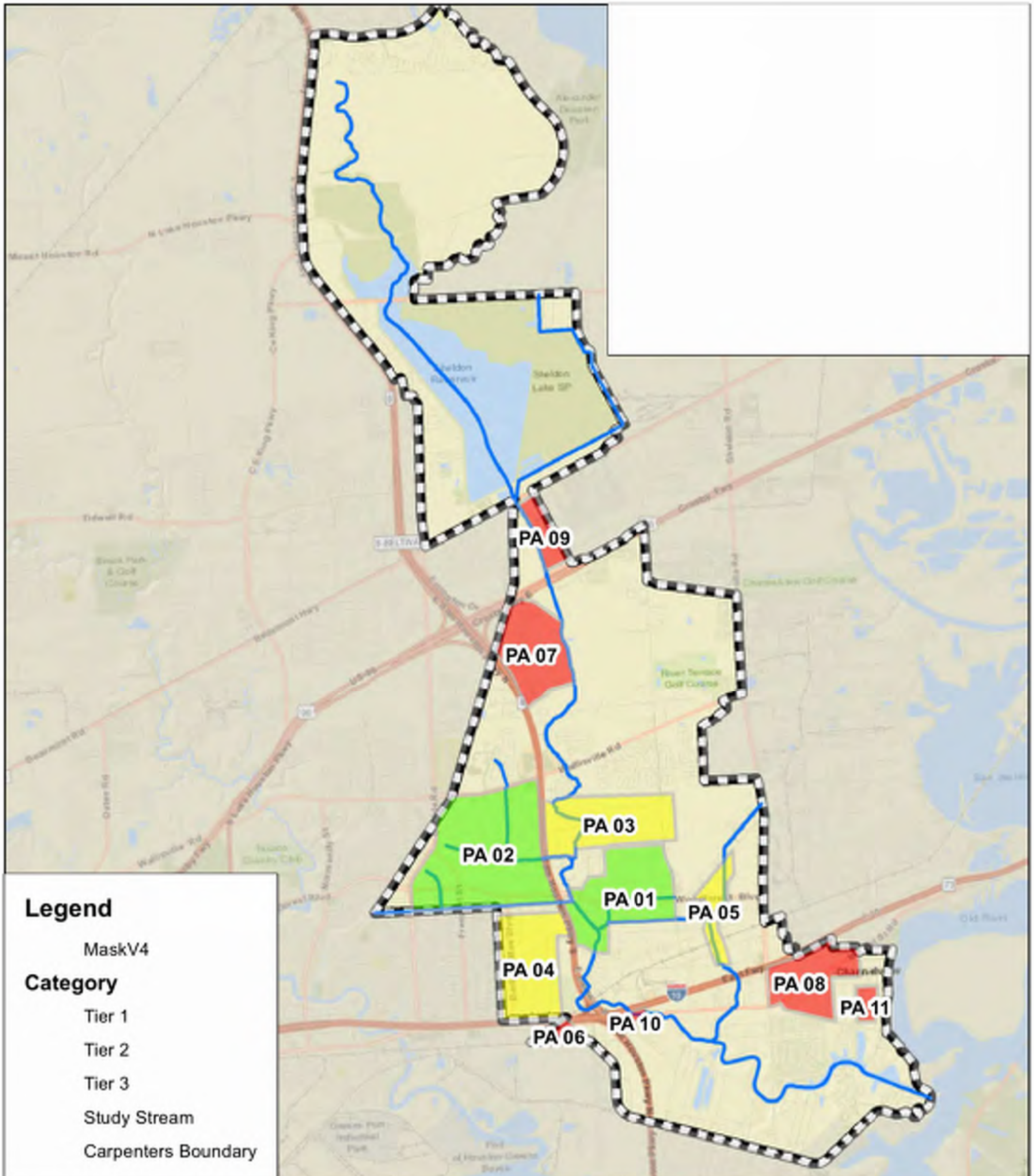
Created: 1/1/2021

Carpenters Bayou

Watershed Plan



FInal Engineering Report

Exhibit 4
Problem Area Classification

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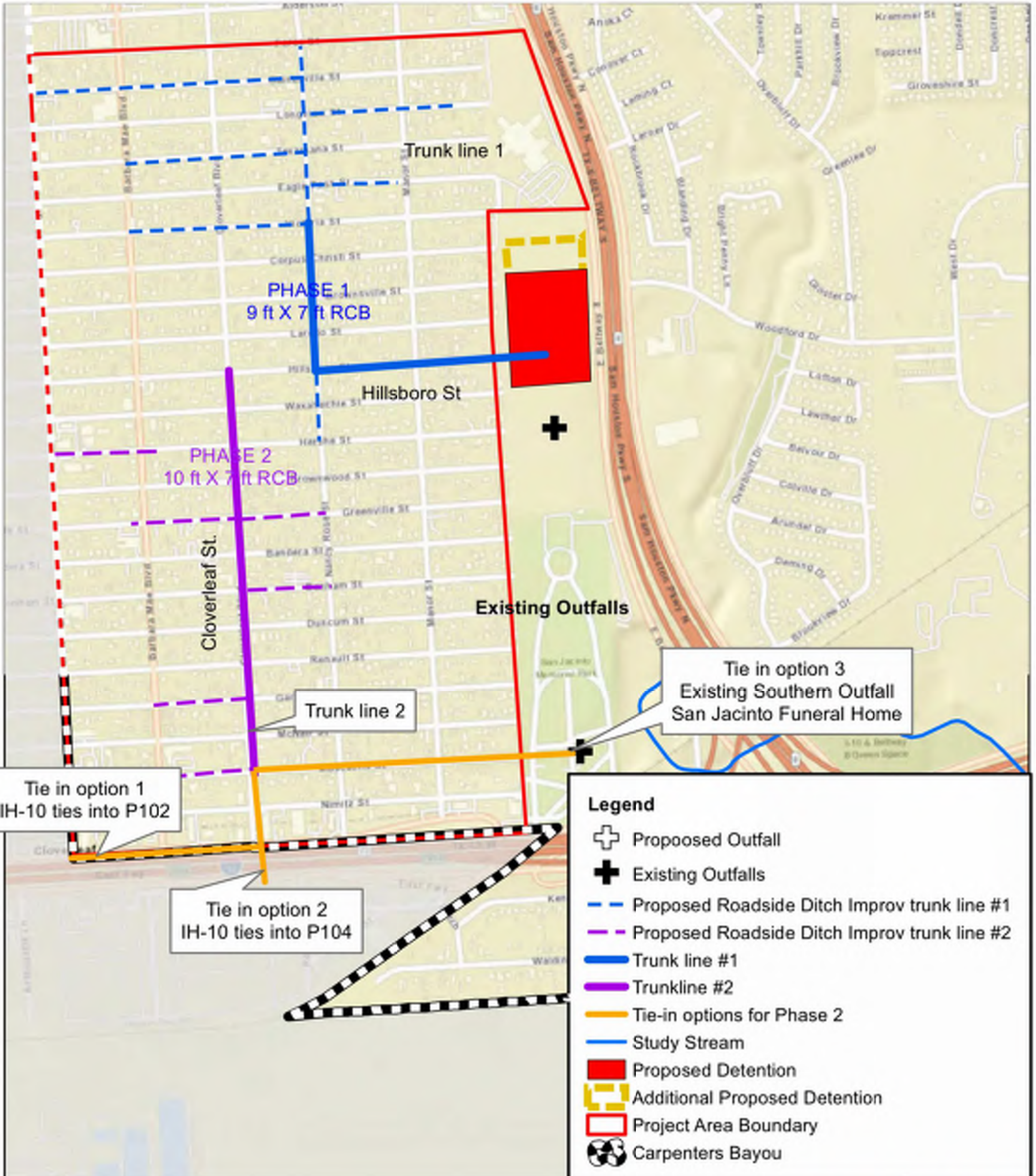
Created: 1/1/2021

Carpenters Bayou

Watershed Plan



Final Engineering Report

Exhibit 5
Cloverleaf Flood Risk Reduction Project

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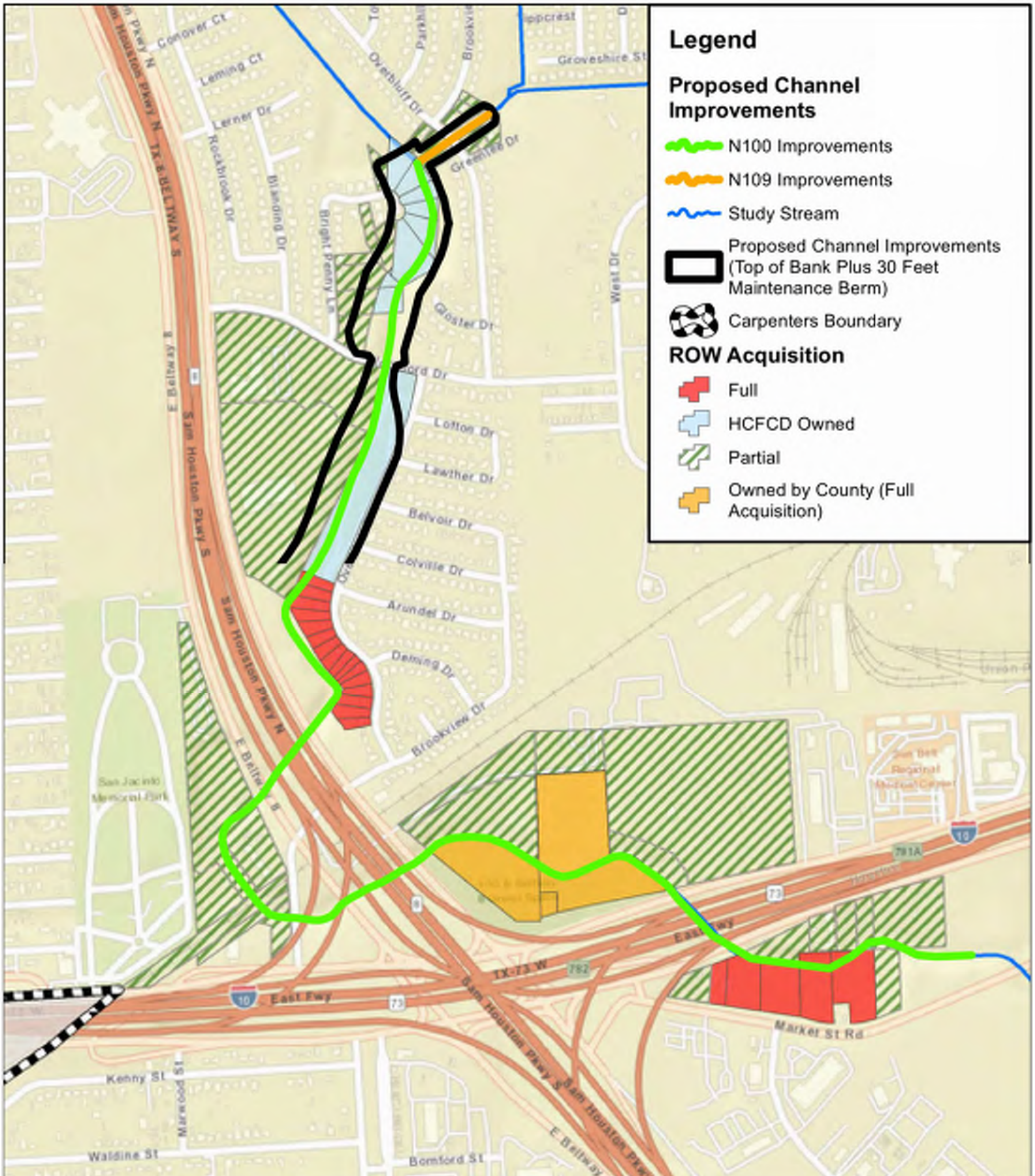
Carpenters Bayou

Watershed Plan



Final Engineering Report

Exhibit 6
N100-00-00
Channel Improvements
Project Description and ROW Acquisition

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Created: 1/22/2021

Carpenters Bayou

Watershed Plan

Final Engineering Report

Exhibit 7
N104-00-00
Channel Improvements
Project Description

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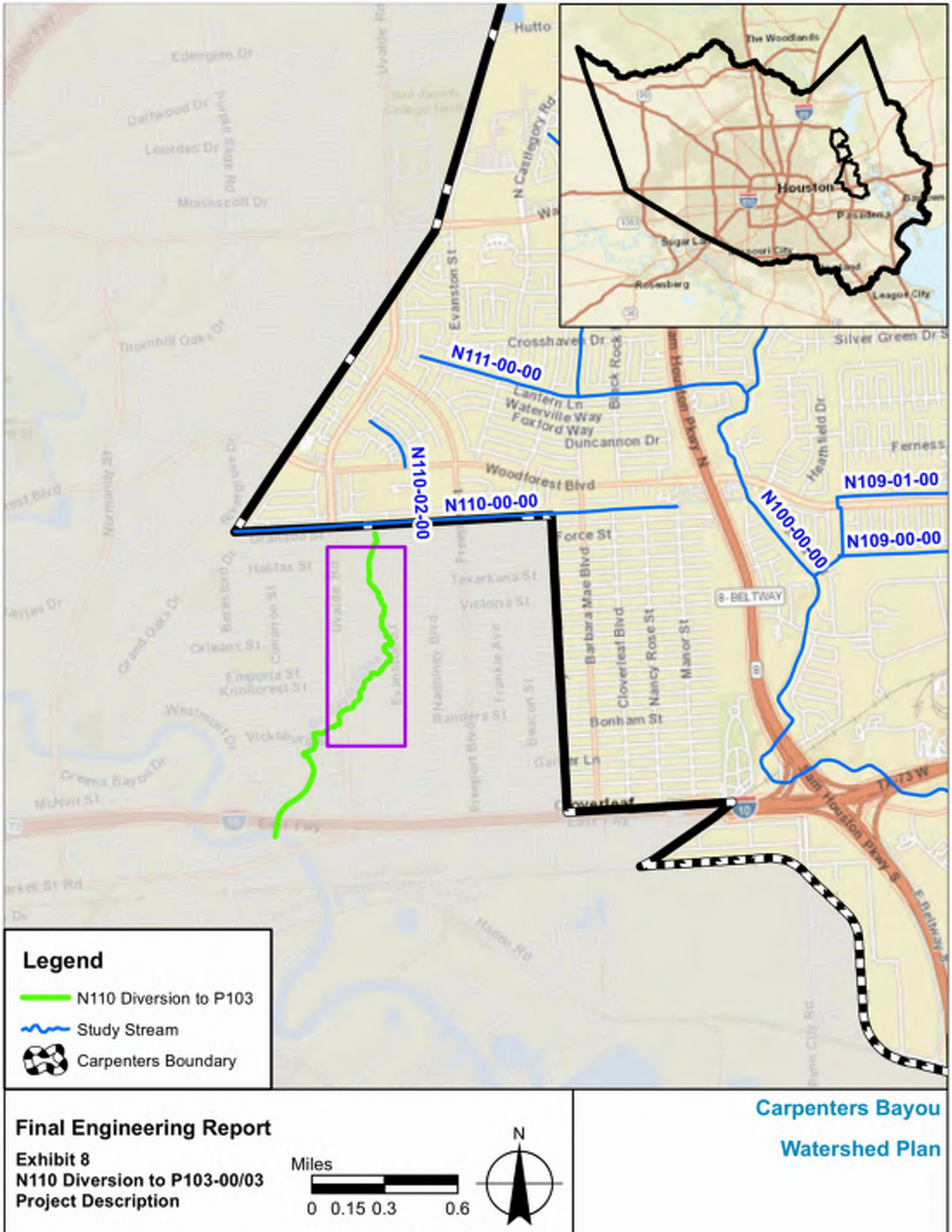
Created: 1/22/2021

Carpenters Bayou

Watershed Plan



Final Engineering Report

Exhibit 8
N110 Diversion to P103-00/03
Project Description

Created: 1/22/2021

Carpenters Bayou

Watershed Plan

Final Engineering Report

Exhibit 9
Proposed ROW Acquisition for Vision Plan

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Created: 1/1/2021

Carpenters Bayou

Watershed Plan

Attachment #1

Technical Memorandum #1

INTERIM REVIEW ONLY
This document was submitted for interim review only and is not intended for construction, bidding, permit, or final submittal purposes.

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PE Registration Number: 111737
Firm: Torres & Associates, LLC
Firm ID: 20741

Carpenters Bayou Watershed Plan

Technical Memorandum #1:

Problem Identification

March 3, 2021

Prepared by:

Torres & Associates, LLC

Table of Contents

Acknowledgements

This planning project represents a key milestone towards the greater management and success of the Harris County 2018 Bond Projects for Flood Mitigation and is the product of interdisciplinary coordination between HCFCD, engineering consultants, key stakeholders, and the general public. Torres & Associates is particularly grateful to HCFCD staff for their invested time, effort, and commitment towards providing Torres & Associates with necessary data, background, interim deliverable reviews, logistical guidance, and general insights on day-to-day, watershed-wide operations ranging from permitting reviews to ROW acquisition. This coordination was instrumental for evaluating effective and feasible flood risk management solutions with Carpenters Bayou watershed, as well as the successful management of the broader Harris County 2018 Bond Projects for Flood Mitigation.

List of Figures

List of Tables

Acronyms

1D	1-Dimensional
2D	2-Dimensional
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FWS	Flood Warning System
H&H	Hydrology & Hydraulics
HCFCD	Harris County Flood Control District
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
LiDAR	Light Detection and Ranging
NLCD	National Landover Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
TxDOT	Texas Department of Transportation
USGS	United States Geological Survey
CBW	Carpenters Bayou Watershed
WSEL	Water Surface Elevation
WSP	Water Surface Profile
HAZMAT	Hazardous Materials

1. Introduction

1.1. Purpose

The purpose of this report is to identify a plan and projects to reduce flood risk within Carpenters Bayou watershed by defining baseline conditions of the Carpenters Bayou watershed Planning Project (HCFCD Project No: N100-00-00-P004) and identifying and evaluating classifications of problem areas. This entailed:

- Updating the modeled land use and terrain data
- Performing a 2D sheet flow analysis to update watershed sub-area boundaries
- Combining Effective M3 hydraulic models from Carpenters Bayou watershed studied streams
- Converting steady to unsteady hydraulics and model stabilization
- Calibrating the Carpenters Bayou watershed hydraulic model to the 2019 September Tropical Storm Imelda
- Developing standalone models for the six tributaries that were scoped
- Combining all models for baseline conditions
- Stabilizing and confirming accuracy of the baseline model and
- Identification and analysis of problem areas (PA)

The models for the entire Carpenters Bayou watershed were analyzed according to the Harris County Flood Control District (HCFCD) H&H Criteria (HCFCD 2009).

1.2. Study Area

The Carpenters Bayou (HCFCD Project No: N100-00-00) watershed is in the east portion of Harris County, Texas (**Exhibit 1**), with an area of approximately 25 square miles and a mainstem length of about 44 miles. The land use consists primarily of agricultural land with a few commercial lots and a residential neighborhood north of US 90. It also includes the Sheldon Lake State Park and Environmental Learning Center. Downstream of Lake Sheldon the land use consists of mixed commercial and residential land cover. Carpenters Bayou watershed has been impacted by 32 of the previous 46 historical flood events since 1979. More recently, it has experienced neighborhood-wide flooding from Tropical Storm Imelda (2019), Hurricane Harvey (2017), and the October Halloween Event (2015). Moreover, tidal influence controls the lower Carpenters Bayou channel which makes it susceptible to inundation from hurricane storm surges.

1.3. Data Collection

Data collection began with collecting and reviewing "Workbook for Carpenters Bayou watershed"- funded by Harris County 2018 Bond Projects for flood mitigation. The starting H&H models for Carpenters Bayou watershed were obtained from HCFCD. Percent impervious data from 2006 to 2016 was downloaded from the United States Geological Survey's (USGS) National Land Cover Database to verify changes in development within Carpenters Bayou watershed. H-GAC 2018 Light Detection and Ranging (LiDAR) data was used to compare and update cross-section geometry to reflect terrain changes due to excavation and fill patterns from new developments since Tropical Storm Allison Recovery Project (TSARP). Other geospatial datasets such as stream network, lakes, and gage locations were provided by HCFCD. Roads and highway geospatial datasets were collected from Texas Department of Transportation (TXDOT) to update and refine the H&H models. **Table 1** provides a summary of the data sources collected and used throughout this analysis.

Table 1. Data Collection Summary

Data	Source	Purpose
2018 LiDAR	HCFCD/H-GAC	Exhibit development, creating terrain model in RAS to help mapping sheet flow, and updating cross-section geometry of the existing ditches/waterbodies in the study area
2006 & 2016 Raster Data/Land Use Land Cover	USDA-NRCS	To analyze if significant development occurred from the last time Carpenters Bayou watershed was studied.
2007-2017 Aerial imagery	HCFCD	To update cross-sections, model ineffective flows, study significant changes in land use, study storm systems.
FEMA Effective M3 Models HEC-RAS/HMS Models	Harris County Flood Control District (HCFCD)	Starting models used for building Carpenters Bayou watershed updates. Model calibration and validation.
Historical Storm/Gage Data	Harris County Flood Warning System (FWS)	Compare Harris County FWS hydrographs for each storm event. Thiessen Polygon Analysis, developing meteorological model in HEC-HMS and for model calibration
Road Network Data	TXDOT	Exhibit development, creating break lines in 2D sheet flow model
FEMA Flood Maps	FEMA	Exhibit development, comparing simulated inundation flood maps with FEMA flood maps
NOAA Atlas 14 500-yr, 100-yr ,50-yr, 10-yr 24-hour precipitation	NOAA Atlas 14	H&H analysis: 2D sheet flow analysis
FEMA all Claims	HCFCD	Identification of problem areas

1.4. Prior Studies

Prior studies within the Carpenters Bayou watershed, including relevant H&H models, analyses, and reports were reviewed in order to account for either 1) necessary changes needed for developing a calibration conditions model or 2) additional hydraulic insights that may serve to benefit the phasing study modeling efforts.

- FEMA Effective H&H models (2007). After Tropical Storm Allison in 2001, FEMA and the HCFCD together developed a countywide study, Tropical Storm Allison Recovery Project (TSARP), to assess the flood risks associated with the major flooding sources. This resulted in a Flood Insurance Study (FIS) and effective model. As part of the project FEMA revised the H&H models and remapped the floodplains. This effective M3 model is used as a go-by model for the 2020 Carpenter Bayou watershed plan
- Carpenters Bayou watershed Planning Study – Workbook for Carpenters Bayou watershed (September 2019). The purpose of this watershed planning study was to identify plans and projects to reduce riverine flood risk within the Carpenters Bayou watershed. The study was

substantially funded under the Harris County 2018 Bond Program for flood mitigation. This study provided guidelines into identification of problem areas.

- The Sterling Forest Subdivision Drainage Assessment helped identify the flooding that occurs due to inadequate flow paths to accommodate extreme storm event runoff. The analysis supports the modeled results for Baseline ("Existing") Conditions, that flooded structures stem largely from sheet flow driven conditions, with flood risks compounded by insufficient drainage capacity and aging infrastructure.

2. Flood Mitigation Facilities

2.1. HCFCD Channels and ROW

The watershed contains eight modeled streams and the main stem (N100-00-00), primarily located within public ROW, mostly HCFCD (**Exhibit 2**). The headwaters lie north of Sheldon Lake State Park and the watershed drains approximately 7.5 miles to the Houston Ship Channel. The lower Carpenters Bayou channel is controlled by tidal influences which make it prone to flooding from hurricane storm surges. The upstream end of N109-01-00 is not located within the public ROW thus improvements along this stream segment may require ROW acquisition.

2.2. HCFCD regional detention facilities and major on-site detention facilities

Sheldon reservoir located north of the watershed was constructed in 1942 by the federal government to provide water for war industries along the Houston Ship Channel. In 1952 Texas Parks and Wildlife acquired the reservoir and in 1984 Lake Sheldon was designated a state park. The Sheldon reservoir is 1240 acres and supports native plant and animal species. The reservoir has experienced many changes since 1943 including progressive land development, westward extension of a drainage ditch outfalling to Lake Houston and the redirection of drainage to Greens Bayou associated with the construction of Beltway 8. The West Canal forms the east levee of Sheldon reservoir. The regrading and construction of barrier islands and the gradual accumulation of sediments within the reservoir have also had an impact on the reservoir. Some of these changes have significantly reduced runoff volumes entering the reservoir and may have affected the storage capacity of the reservoir according to the Sheldon Reservoir Study (December 1998).

Based on HCFCD geodatabase records provided to Torres & Associates for this study and aerial imagery, a regional detention facility (Gene Green Beltway 8 Park) is located south of Lake Sheldon. The detention facility is located next to Liberty Lakes, a relatively new neighborhood. Gene Green Beltway 8 Park uplifts the neighborhood and provides detention.

2.3. Other local flood mitigation facilities

The community of Cloverleaf and the community of Channelview lack sufficient secondary drainage systems. Cloverleaf is located west of Beltway 8 and south of Wallisville Road. South of Woodforest Blvd, the community of Cloverleaf is marked by an old neighborhood with roadside ditches. The northern part is newer with a curb-and-gutter system and roadways acting as secondary drainage systems. The community of Channelview consists of the area east of Beltway 8 and south of Wallisville Road. It consists of the Sterling Green, Sterling Green South and Sterling Forest neighborhoods which are newer neighborhoods where the roads act as secondary drainage systems. Channelview also contains older neighborhoods such as Old River Terrace and Shadowglen which do not have secondary drainage systems and are characterized by roadside ditches and old structures. No other special flood mitigation facilities exist in the watershed besides the detention pond at Gene Green Beltway 8 park which was constructed to provide detention to the surrounding areas.

3. Hydrology

3.1. Storm Development

The effective HEC-HMS model was downloaded and utilized from the HCFCD Model and Map Management (M3) system. HEC-HMS version 4.3 (USACE 2009) was used throughout this analysis. The meteorological model was developed to include two storm events – the 2019 September Tropical Storm Imelda and the October 2015 Halloween Event. Tropical Storm Imelda recorded rainfall depths (3.36 to 6.4 inches over a 7-hour period on average) that ranged between a 2-year to a 50-year rainfall event. The 2015 October Halloween Event recorded rainfall depths (0.56 to 10.68 inches over 12 hours on average) that ranged between a 2-year to a 25-year rainfall event. Historical storm data for rainfall events was obtained from Harris County's Flood Warning System rain gage network. Rainfall data was collected from gages, both within Carpenters Bayou watershed and seven gages outside of the boundary, which included gages 710, 720, 750 located in San Jacinto River and 1600, 1610, 1620, 1685 located in Greens Bayou watershed. Refer to **Figure 1**.

3.2. Thiessen Polygon Analysis

Thiessen polygons were used for spatial interpolation of rain gage data and for determining the relative weights from each gage based on its area of influence within the Thiessen Polygon network. **Figure 1** shows the generated Thiessen Polygon network, along with the rainfall gage locations and HEC-HMS sub-basin boundaries. **Figure 1** and **Exhibit 3** show the gages used in the storm development.

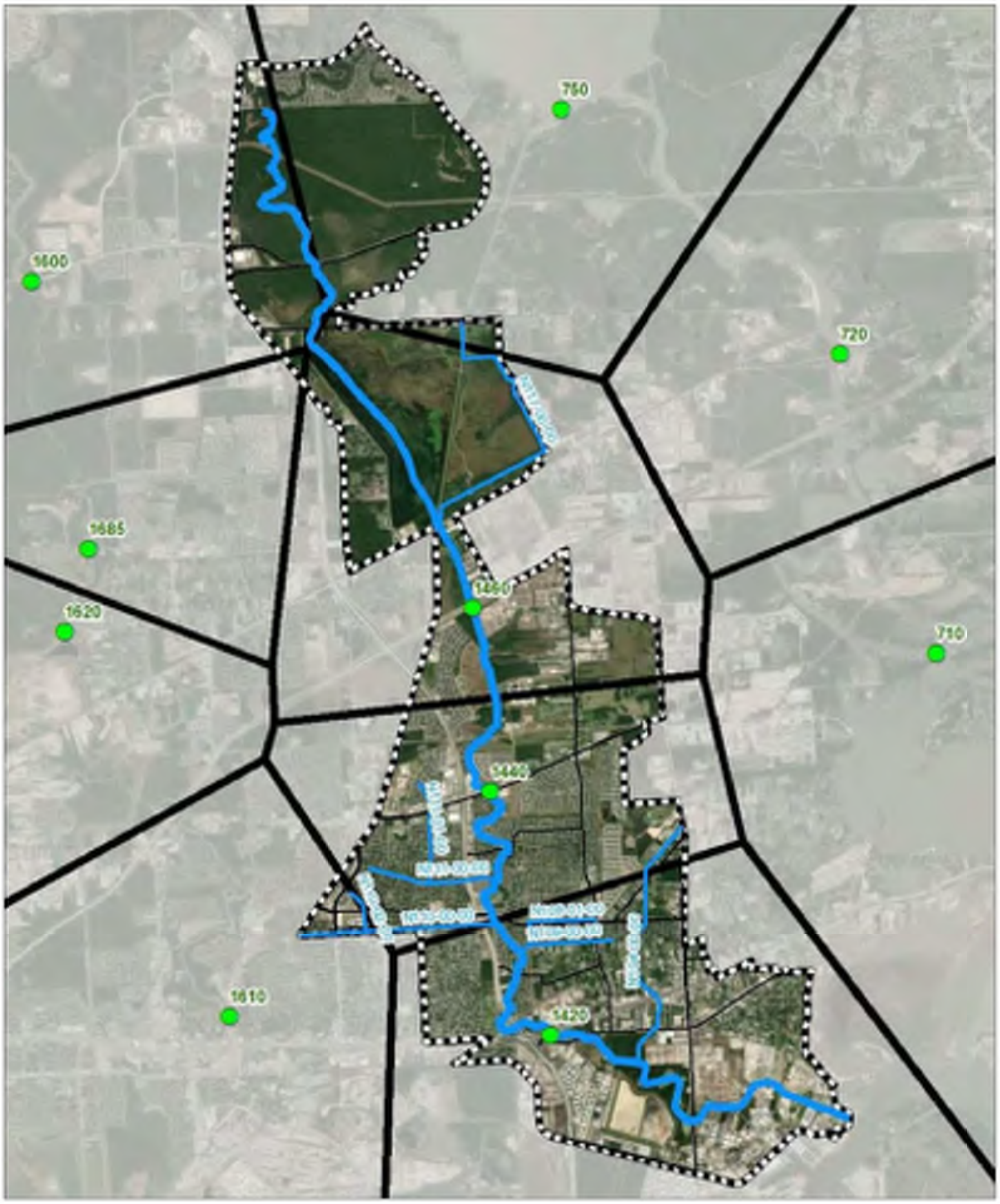


Figure 1. Thiessen Polygons

3.3. HEC-HMS Sub-basin Development

Carpenters Bayou watershed sub-area boundaries for N100E, N100F, N100G, N100J, N100L, N104 and N117 were adjusted using the 2D sheet flow model to provide appropriate hydrologic boundary conditions for the hydraulic model. These changes were conducted out of necessity for achieving appropriate storage and attenuation effects for calibrating the HEC-RAS model. The original sub-areas of Carpenters Bayou watershed are displayed in **Exhibit 4** and the revised sub-areas are displayed in **Exhibit 5** to demonstrate the changes made clearly. Green and Ampt infiltration loss parameters remained consistent with the M3 effective model. The NLCD land use land cover data and aerial imagery from 2006 to 2016 comparisons showed that there has not been significant development. This resulted in the impervious percent values and the DLU values to remain consistent with the M3 effective model. Time of Concentration (Tc) & Storage Coefficient (R) parameters were developed using the HCFCD hydrologic methodology (HCFCD 2009). Length of watershed and Length to Centroid values were updated based on the updated sub-areas and engineering judgment using GIS. The full TC&R calculations are provided in **Appendix A**. No storage-discharge cycling was necessary since dynamic routing was conducted using unsteady HEC-RAS. Relationships between HEC-HMS and HEC-RAS were defined such that proper lateral inflow connections could be established.

3.3.1. HEC-RAS 2D Sheet Flow Model

The model was based on a surface terrain (2018 LiDAR) and 2D mesh (gridded cells) of the study area. A flow chart of the model development process is provided below in **Figure 2**.

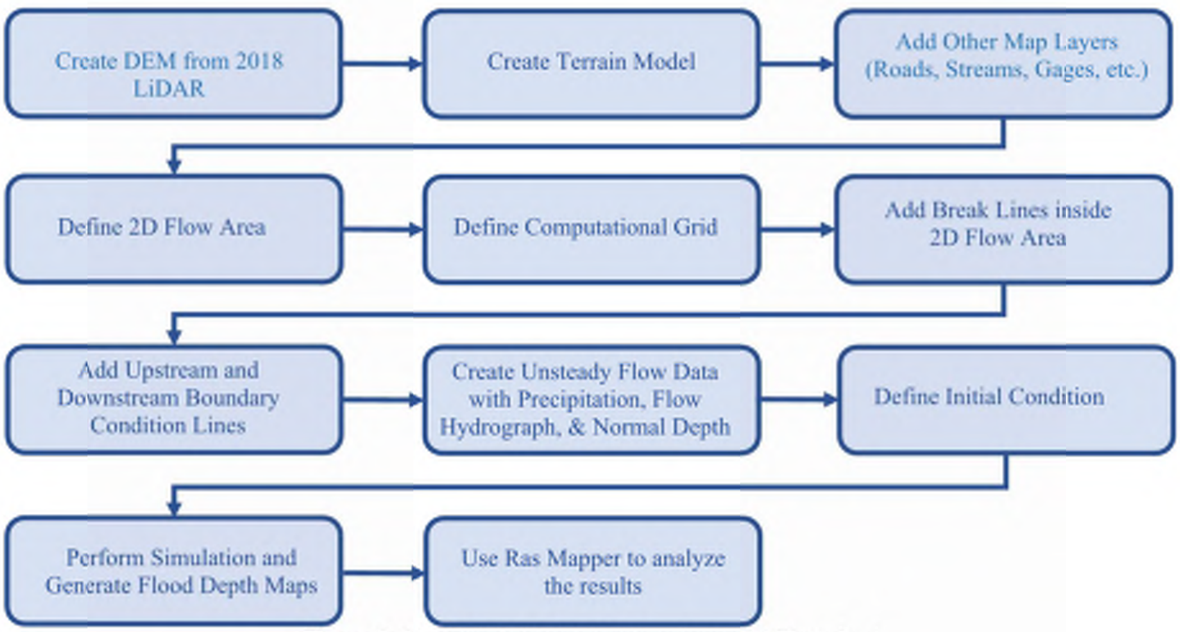


Figure 2. HEC-RAS 2D Model Development Flowchart

The NOAA Atlas 14 rainfall updates for 10-year, 50-year, 100-year and 500-year frequency storms were used as an input to HMS. The 2018 LiDAR was used to create a high-resolution DEM. Other layers such as spatially varied streams, and roadways were added to the terrain model. Roadways were used to enforce break lines and 2016 NLCD data was used for land cover. **Figure 3** shows the mesh developed to perform the 2D analysis, the pink lines represent the roads used to reinforce break lines.

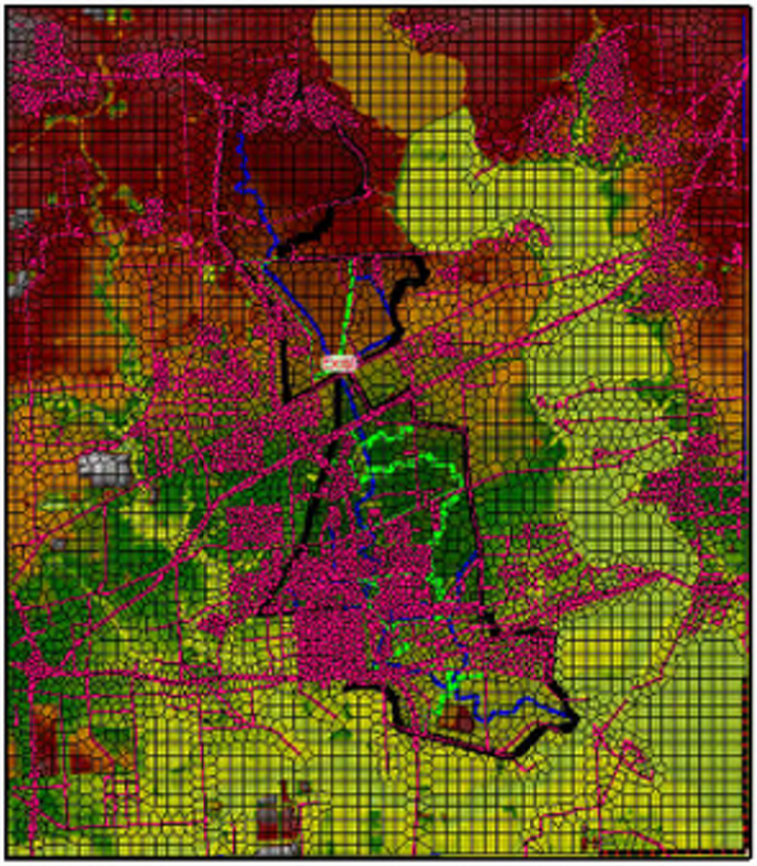


Figure 3. HEC-RAS 2D Sheet Flow Computational Mesh and incorporation of Break lines

The particle tracing function on RAS mapper helped visualize the flow of water. **Figure 4** shows a still image of the particle tracing and some updates made. The green represents the updated boundary and the red represents the original boundary. Three overflows were also identified through the sheet flow analysis. **Exhibit 6** shows an enhanced version of the boundary updates made using the results of 2D sheet flow analysis.

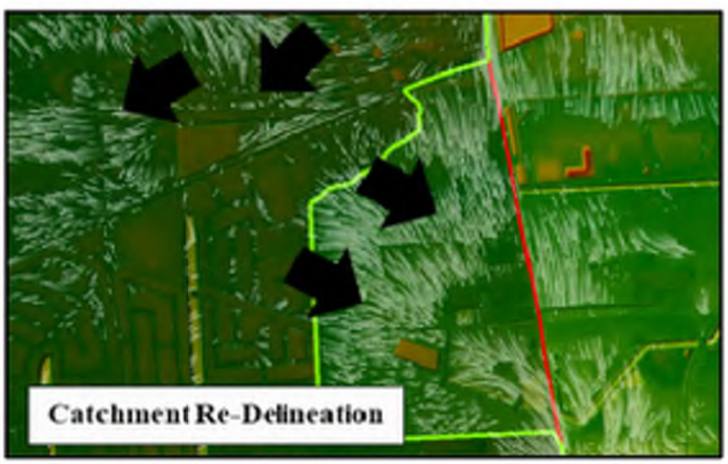


Figure 4. Boundary re-delineation and overflow identification

4. Hydraulics (1D and 2D)

Both 1D and 2D hydraulic models were developed using HEC-RAS 5.0.7 (USACE 2016). The model development methodologies are described in detail in the following sections.

4.1. HEC-RAS Model Development

The effective M3 steady state HEC-RAS models were downloaded for each of the studied streams in the previous Effective FEMA Study for Carpenters Bayou watershed. These studied streams included HCFCD Project No. N100-00-00 (Carpenters Bayou), N104-00-00, and N117-00-00. For this current study, the models were upgraded to HEC-RAS version 5.0.7 (USACE 2016). N100-00-00, N104-00-00 and N117-00-00 were converted to unsteady hydraulic models, and then combined into a single model for use in calibration/validation. The HEC-RAS schematic is illustrated in **Figure 5**

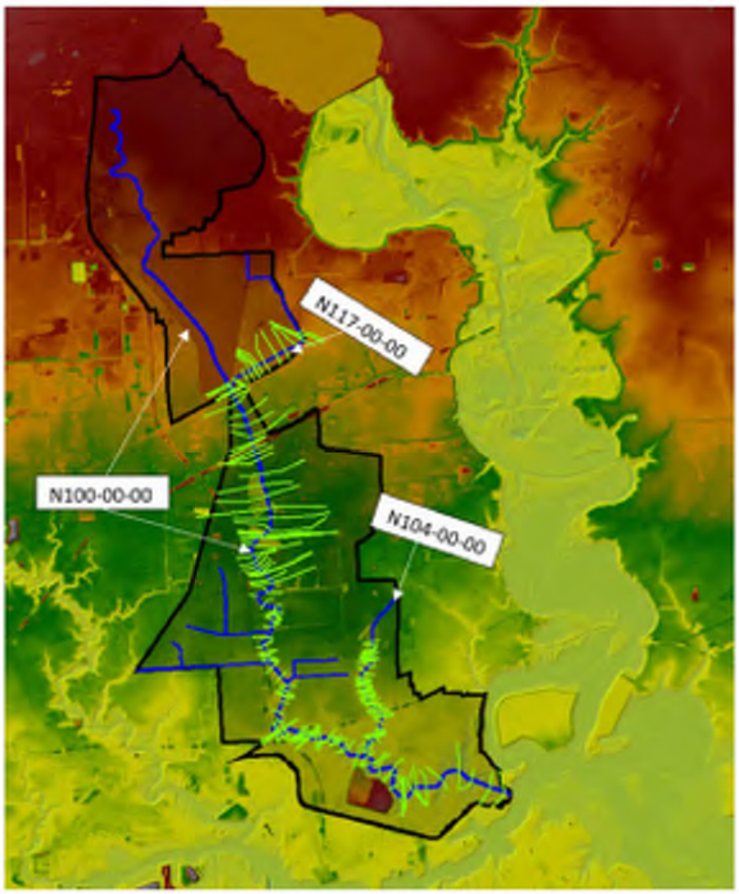


Figure 5. Calibration/Validation Model

The following section describe steps taken towards bringing the HEC-RAS model up to current day conditions.

4.1.1. Terrain Updates

The starting plan terrains are primarily based on the effective M3 model which was built using 2001 LiDAR data. In general, the effective M3 model cross sections location remained unchanged in the current study. However, for each of the 1D cross-sections in need of revision, effective M3 main channel bathymetry was incorporated with 2018 LiDAR. Ineffective flows were added to model wet ponds in cross-sections which passed through such areas. A comparison of cross-sections cut from the 2018 LiDAR versus the 2001 LiDAR data from the hydraulic model is illustrated in **Figure 6**. The 2001 and

2018 LiDAR were developed with 15 feet and 3 feet pixel resolution, respectively. So as not to discount the quality and accuracies of the 2001 LiDAR-based cross-sections provided in the effective M3 models, only cross-sections showing obvious discrepancies between 2001 LiDAR and 2018 LiDAR were updated.

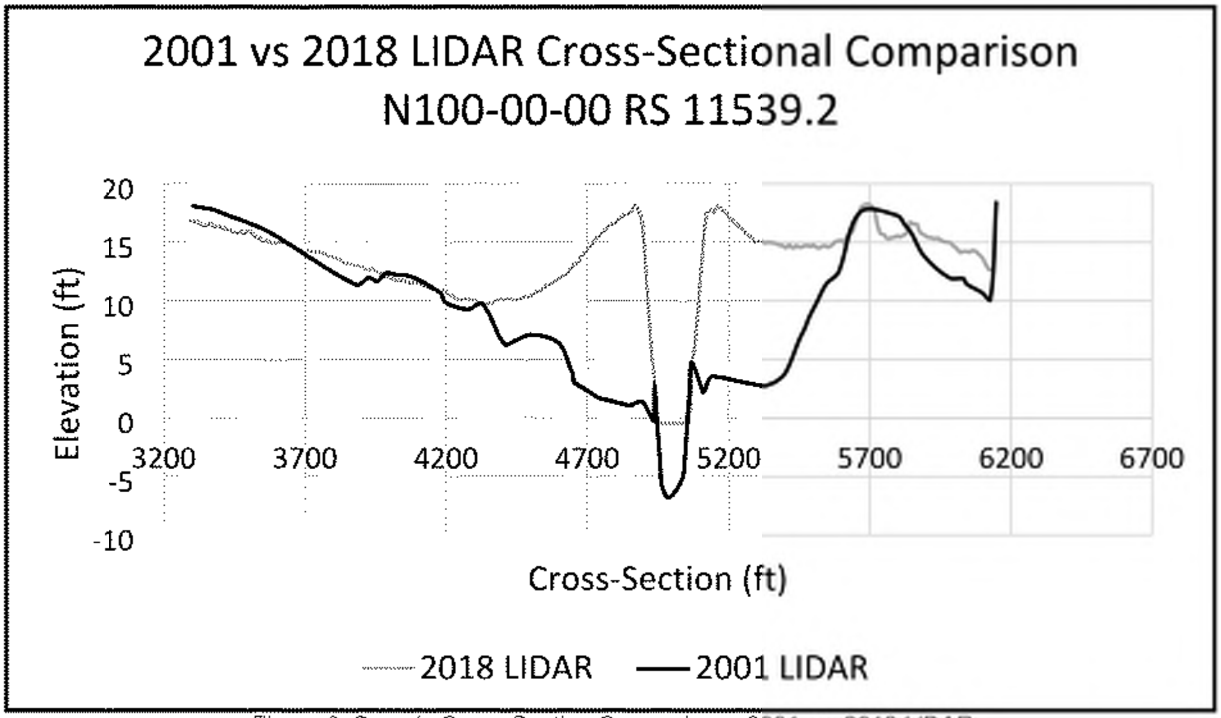


Figure 6. Sample Cross-Section Comparisons 2001 vs. 2018 LiDAR

5. Calibration and Validation

5.1. Model Calibration

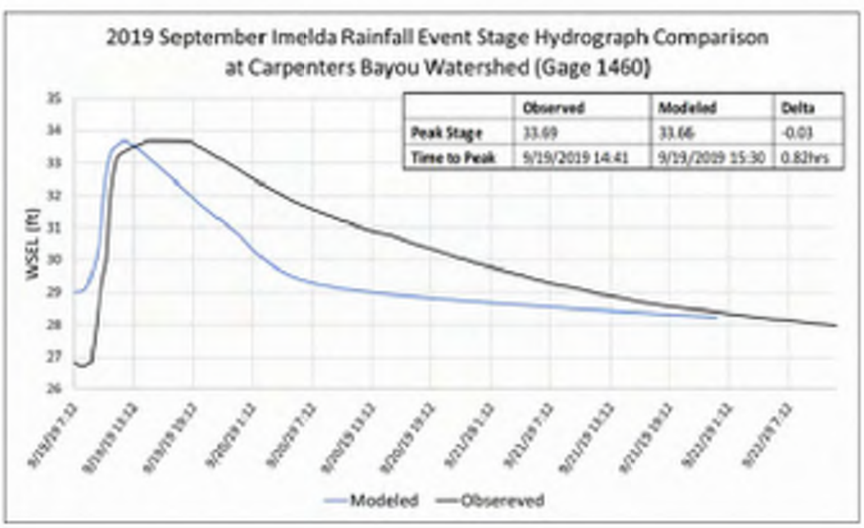
The HEC-RAS model was calibrated to the 2019 September Tropical Storm Imelda. During this storm, rainfall depths ranged from 3.36 to 10.4 inches, with the larger depths measured in the northern reaches of Carpenters Bayou watershed. These depths correspond with a 2-yr to 50-year rainfall event for this region of Harris County. When calibrating an unsteady model, it is important to consider the modeled magnitude, size, and shape of the full hydrograph for the location under consideration. As such, Carpenters Bayou watershed has three Harris County stream gages that provide historical stage hydrographs for the full duration of the 2019 September Tropical Storm Imelda. These gages include Harris County Gage 1460 at Crosby Freeway, Gage 1440 at Wallisville Road, and Gage 1420 at IH-10.

DLU's, channel slopes, and channel n-values, remained consistent since there has not been significant change in land use since 2007. The boundary condition was set to normal depth at the most downstream cross-section in the watershed.

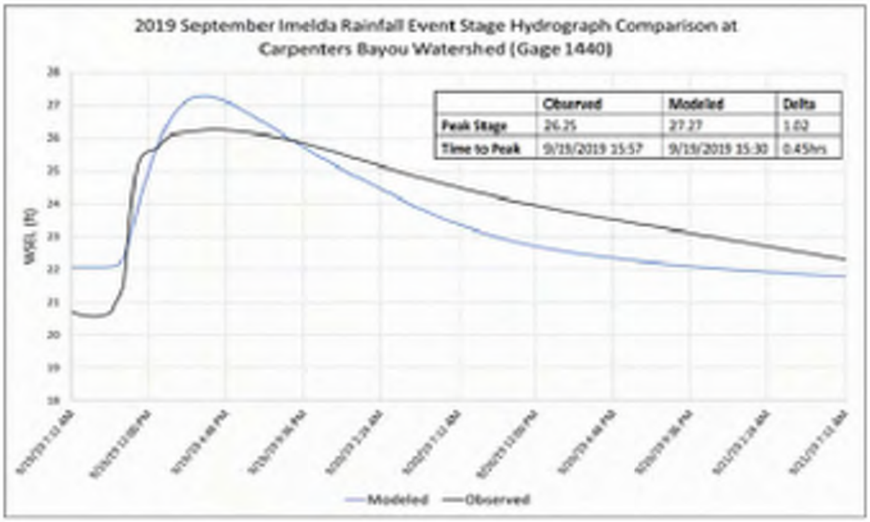
Another factor of consideration was the location and ratios of the flow hydrographs obtained from HEC-HMS to be input into the HEC-RAS model. The 2D sheet flow model was used to inform the location and ratios of the inflow hydrographs. This change significantly improved the shape and timing of all three modeled stage hydrographs to more closely resemble the observed event in the main reach of Carpenters Bayou watershed.

After calibration, differences in modeled versus observed WSELs were computed to be -0.03 feet at Crosby Freeway, 1.02 feet at Wallisville Road, and -0.65 feet at IH-10. The timing differences to peak WSELs between modeled and observed range from 0.45 to 0.82 hours across gage locations. Figure 7 illustrates the observed versus modeled comparisons at these gage locations.

(a)



(b)



(c)

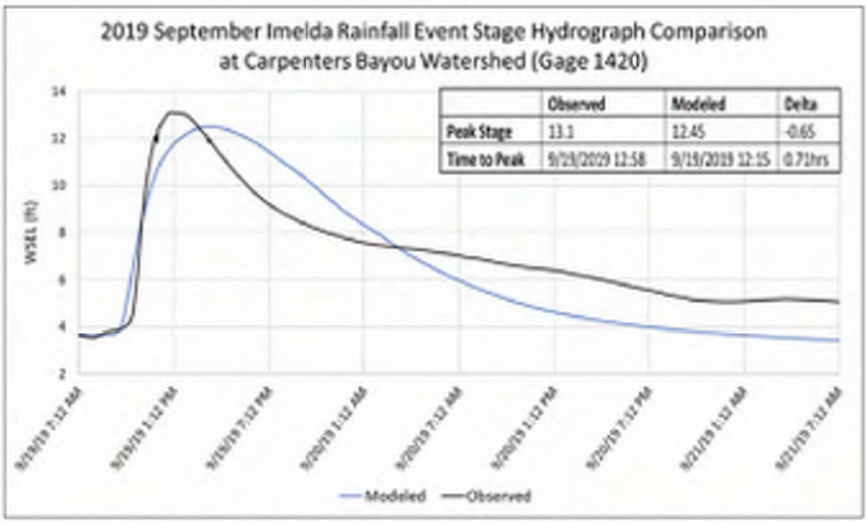


Figure 7. 2019 September Tropical Storm Imelda Stage Hydrograph of Observed vs Modeled Comparisons at (a) Crosby Freeway, (b) Wallisville Road, and (c) IH-10

Hydrograph shapes are reasonable between modeled and observed, but it is worth noting that the starting WSEL for the modeled graphs in (a) and (b) is higher than the observed. This is owed to the inability of HEC-RAS to account for relatively dry channels. In unsteady HEC-RAS, channels require initial flow conditions to initiate the numerical solver for computing solutions to the 1-dimensional (1D) Saint-Venant equations (continuity and momentum equations). The modeled receding limb of graph (c) also deviates from the observed receding limb. This is because normal depth was used as a boundary condition at the most downstream cross-section of Carpenters Bayou watershed and does not account for tidal influences. **Appendix B** shows higher resolution hydrograph comparisons. **Table 2** provides a direct comparison of peak WSELs between the modeled and observed rainfall event along Carpenters Bayou watershed at the three gage locations.

Table 2. 2019 September Tropical Storm Imelda Calibration Summary of Observed vs Modeled WSELs.

2019 September Tropical Storm Imelda					
Gage ID	Road Name	HEC-RAS River Station	Observed Max WSEL (ft)	Modeled Max WSEL (ft)	Delta (ft)
1460	Crosby Freeway	56945.8	33.69	33.66	-0.03
1440	Wallisville Road	45189.7	26.25	27.27	1.02
1420	IH-10	23653.7	13.1	12.45	-0.65
			Average (ft) =	0.57	
			Standard Deviation (ft) =	0.84	

Exhibit 7 illustrates the modeled maximum floodplain extents for this storm event. **Figure 8** illustrates the modeled peak WSEL profile for Carpenters Bayou (N100-00-00), along with the NOAA Atlas 14 updated rainfall WSEL for the 500-year, 100-year, 50-year and 10-year storm for benchmarking purposes. **Appendix B** provides a higher resolution illustration of the 2019 September Tropical Storm Imelda WSPs.

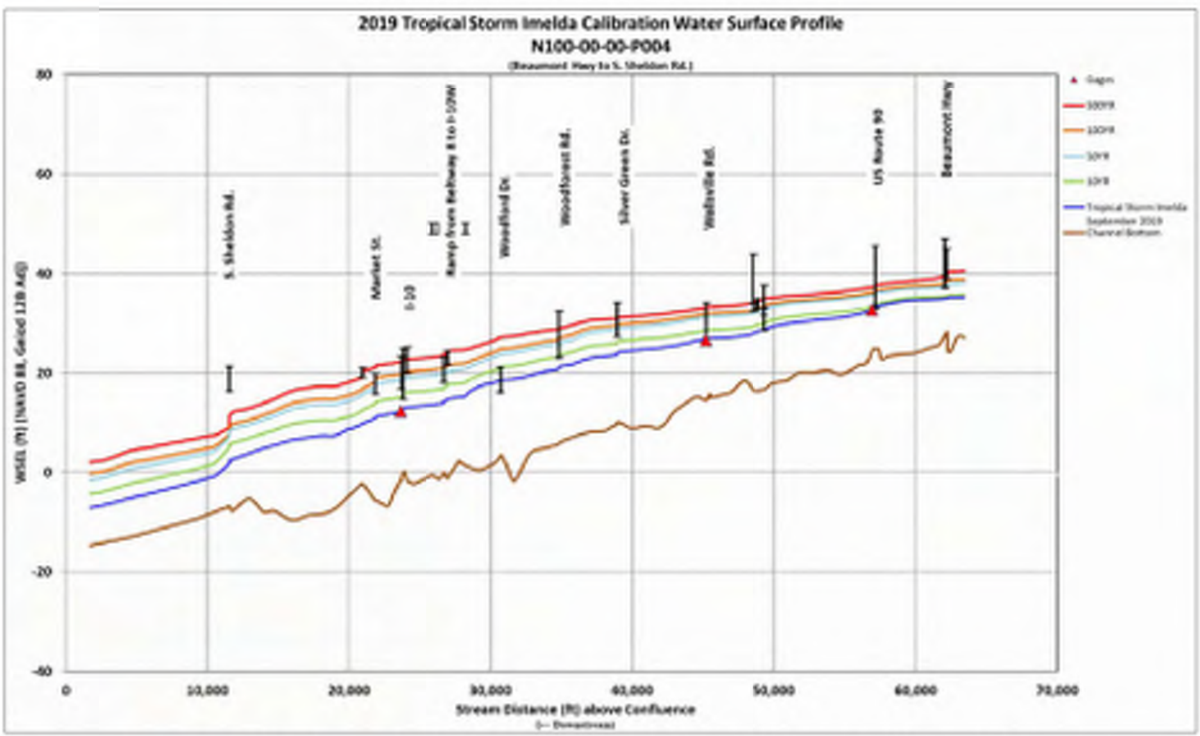


Figure 8. 2019 September Tropical Storm Imelda Modeled Maximum Water Surface Profile

5.2. Model Validation

5.2.1. October Halloween Event (2015)

The HEC-RAS model was validated to the October 2015 Halloween Event. During this storm, rainfall depths ranged from 0.56 to 10.68 inches, with the larger depths measured in the southern reaches of

Carpenters Bayou watershed. **Figure 10** illustrates the observed versus modeled comparisons at gages 1460, 1440 and 1420. The difference in modeled versus observed peak WSELs are -5.7 feet at Crosby Freeway, -2.75 feet at Wallisville Road, and -0.64 feet at IH-10. The timing differences to peak WSELs between modeled and observed range from 0.47 to 13.3 hours across gage locations. The modeled peak stage for gage 1460 is significantly lower than the observed peak stage and does not follow a similar trend to the observed stage hydrograph. A site visit was conducted for inspection of gage 1460. It was discovered that gage 1460 had been replaced (**Figure 9**), indicating that the results from the 2015 Halloween Event were computed using the old gage. This is because 2019 Tropical Storm Imelda was a more recent event and the modeled and observed hydrographs at gage 1460 matched up well. Furthermore, little rainfall was collected during the October 2015 Halloween Event in the upstream gage of Carpenters Bayou watershed which caused the lower water surface elevation modeled in gages 1460 and 1440.

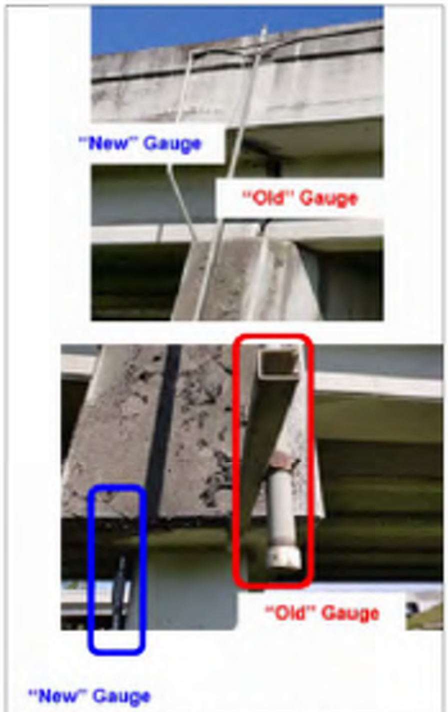
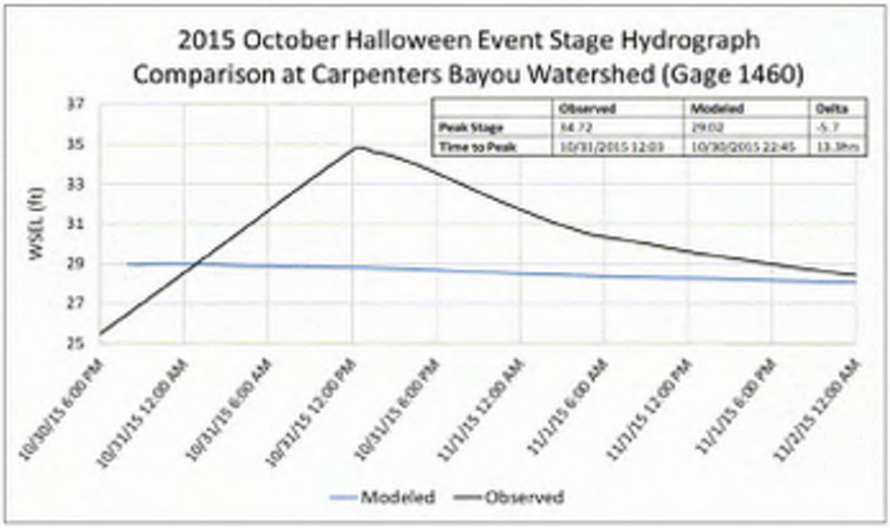
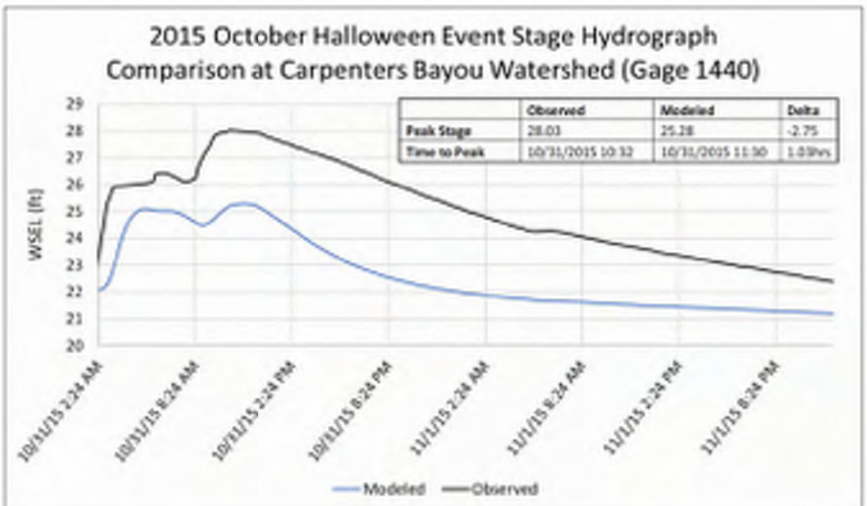


Figure 9. Gage 1460

(a)



(b)



(c)

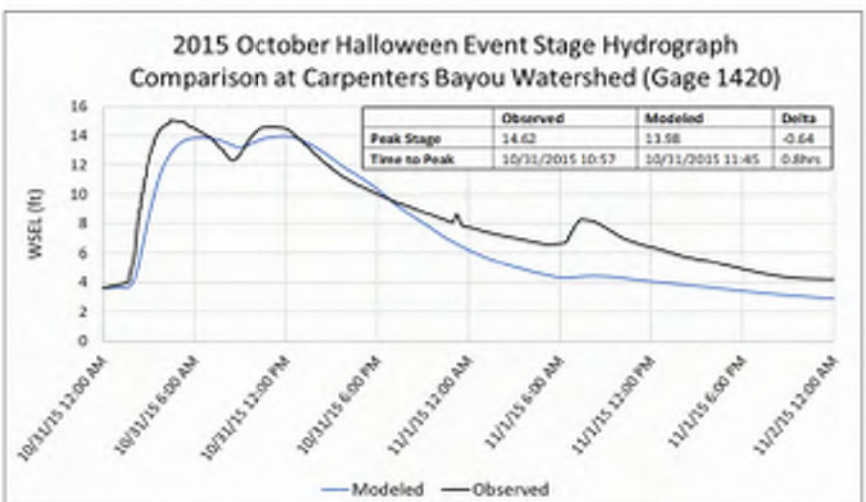


Figure 10. Halloween Event Stage Hydrograph Comparisons of Observed vs Modeled at (a) Crosby Freeway, and (b) Wallisville Road (c) IH-10

Appendix B show higher resolution hydrograph comparisons during the 2015 Halloween Event. **Table 3** provides a direct comparison of peak WSELs between the modeled and observed rainfall event along Carpenters Bayou watershed at three gage locations. Based on **Table 3**, the average difference between modeled and observed peak WSELs is 1.6 feet, with a standard deviation of 1.34 feet *(using gage 1440 and 1420).*

Table 3. 2015 Halloween Event Validation
Summary of Observed vs Modeled WSELs.

2016 April Rainfall Event					
Gage ID	Road Name	HEC-RAS River Station	Observed Max WSEL (ft)	Modeled Max WSEL (ft)	Delta (ft)
1460	Crosby Freeway	56945.8	34.72	29.02	-5.7
1440	Wallisville Road	45189.7	28.03	25.48	-2.55
1420	IH-10	23653.7	14.62	13.96	-0.66
			Average (ft) =	1.5	
			Standard Deviation (ft) =	1.7	

Exhibit 8 shows the maximum floodplain extents for the 2015 October Halloween Event. **Figure 11** provides computed peak WSEL profiles for Carpenters Bayou (N100-00-00), along with NOAA Atlas 14 updated rainfall WSEL for the 500-year, 100-year, 50-year and 10-year storm event for benchmarking purposes. **Appendix B** provides a higher resolution illustration of the 2015 October Halloween Event WSPs.

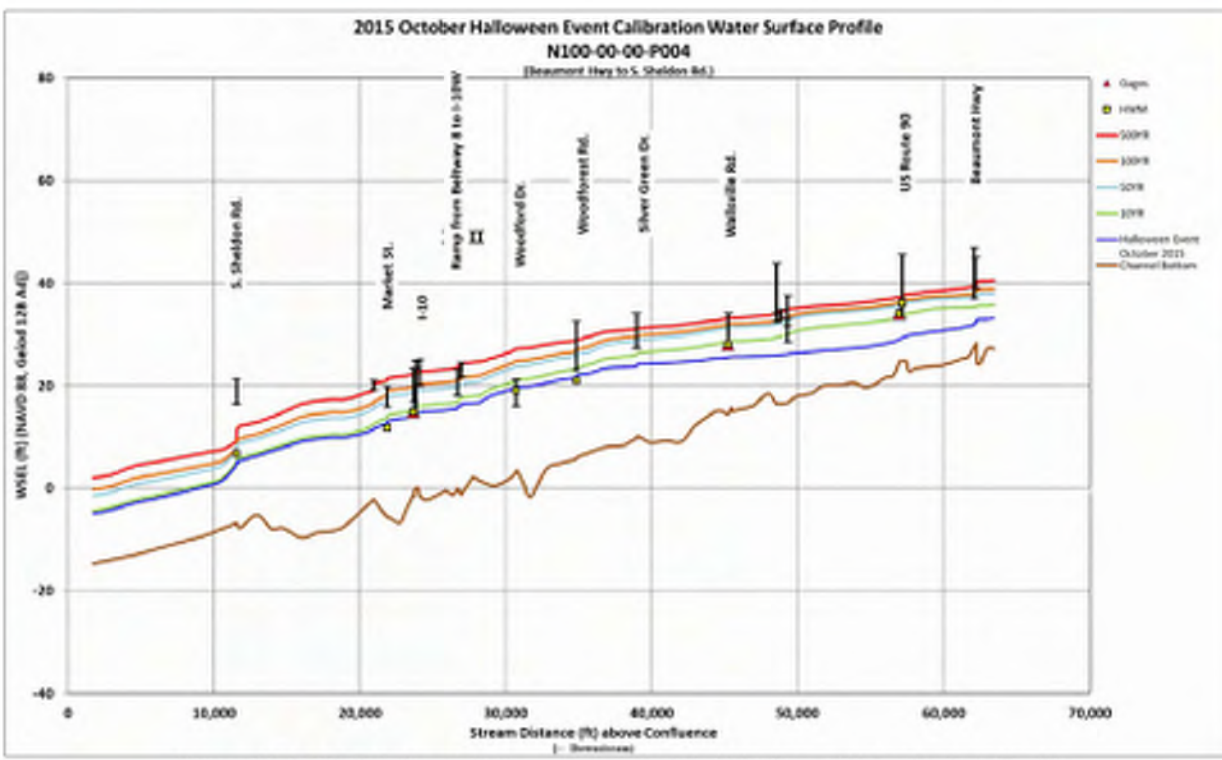


Figure 11. 2015 October Halloween Event Modeled Maximum Water Surface Profile

6. Baseline Conditions Development

The baseline conditions model was built on the calibration conditions model and was retrofitted with six additional tributaries. Unstudied streams N109-00-00, N109-01-00, N110-00-00, N110-02-00, N111-00-00 and N111-01-00 were combined with the calibration conditions model into a single 1D/2D master model for baseline conditions analysis.

The NOAA Atlas 14 rainfall updates for 10-year, 50-year, 100-year and 500-year frequency storms were used as an input to HMS. 2018 LiDAR was used to create a high-resolution DEM and 2016 NLCD data was used for land use and land cover. Junctions were placed to connect the tributaries to the main stem. Mainstem cross-sections were trimmed to accommodate the tributaries, and 2D flow areas were placed to capture overflow and sheet flow from the tributary models. The 2D flow areas were generated with computation point spacing of 150 feet on average. Break lines were imported from GIS roads data. Lateral structures were used to connect 2D areas with reaches to capture overflow.

Baseline flow file was built on the calibration conditions flow file. Flow file updates for the baseline conditions model were limited to the drainage areas containing tributaries, new inflows for the tributaries themselves, and flow location adjustments because of the reaches being split. The calibration conditions model had 17 boundary conditions, while the baseline conditions model had 26. Calibration was re-evaluated once the baseline conditions model was stabilized.

6.1. Unstudied Tributary HEC-RAS Model Development

Unstudied tributary models were developed as standalone models, and then incorporated into the baseline conditions master model. Necessary cross-sections were laid out using RAS mapper to accurately capture the channels geometry and cut from the 2018 LiDAR. Overbank areas were modeled using 2D flow areas, with an average resolution of 150 feet by 150 feet. Survey data for bridges and culverts was not provided, however bridges and culverts were added based on 2018 LiDAR and aerial imagery. Cross-sections, bridges and culverts were centered on cross-section horizontal station 5000, bank stations were assigned, and ineffective flow areas were determined. For each cross-section, the number of points was filtered down, while maintaining the detail in the channel. See **Figure 12** for a flow chart of the model development process.

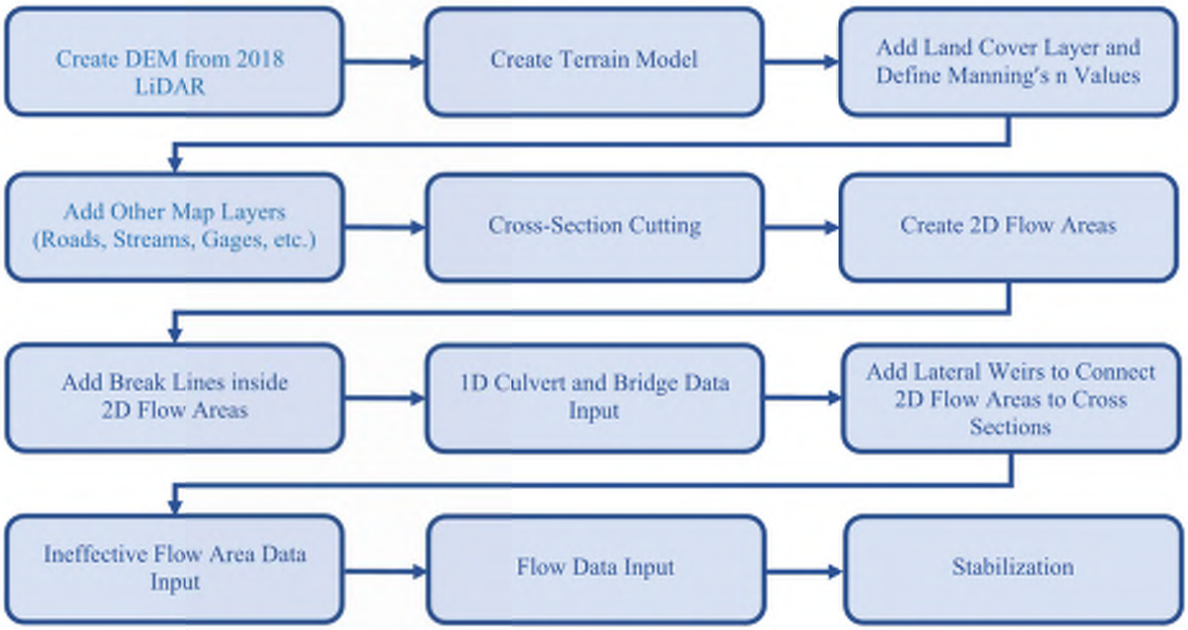


Figure 12. Flow Chart for Unstudied Tributary Model Development

Each unstudied tributary brought unique characteristics that had to be addressed during stabilization. The primary influences on stabilization for standalone tributary models were steep drops, connections to 2D areas through lateral structures, bridge and culvert crossings, and boundary conditions type and location. Refer to **Table 4** for a summary of unstudied tributary characteristics.

Table 4. Unstudied Tributary characteristics

Tributary	Length (miles)	Average Slope (ft/ft)	XS Count	Bridge/Culvert Crossings
N109-00-00	0.98	0.003	18	1
N109-01-00	0.76	0.001	0	1
N110-00-00	2.08	0.001	61	7
N110-02-00	0.47	0.001	6	1
N111-00-00	1.33	0.002	44	5
N111-01-00	1.06	0.002	32	3

6.1.1. N109-00-00 & N109-01-00 Model Development

The main source of instability was a steep drop at the end of the channel where flow enters N100-00-00. There is a 14-foot drop in elevation over 500 feet which makes this area particularly problematic. **Figure 13** shows the drop structure downstream of N109-00-00. The use of multiple cross sections and the division of uniform lateral inflow across several cross-sections helped with stability.

Figure 13. Drop structure at N109-00-00

Another source of instability was N109-01-00 which drains to N109-00-00. The two tributaries meet at the drop structure which causes further instability. N109-01-00 is an enclosed ditch (3ft diameter), a pipe was used to model this tributary. The headwaters of N109-01-00 fall next to a small pond and the tailwater is attached to a lateral structure which connects 2D flow area E to N109-00-00. An internal boundary condition assigns the flow to the enclosed pipe. Since most of the flooding in this area is sheet flow driven, the 2D mesh extends to capture the complete effect.

6.1.2. N110-00-00 & N110-02-00 Model Development

North Shore Ninth Grade campus crosses the end of N110-02-00 near the confluence with N110-00-00. Survey data was not provided for the culvert that passes under the school. A site visit was conducted for inspection of this culvert. A three barrel, 6-foot by 4-foot concrete box culvert passes under the campus. This was modeled as a concrete culvert lateral structure.

Greens Bayou watershed is located south of N110-00-00. There is an overflow of Qp= 620 cfs entering Greens Bayou at this location. The 2D flow area A extends south of N110-00-00 into Greens Bayou to capture this overflow accurately. Dummy storage (SA2) area was used at the confluence of N110-00 and N110-02 for added stability. **Figure 14** shows the overflow location and magnitude.

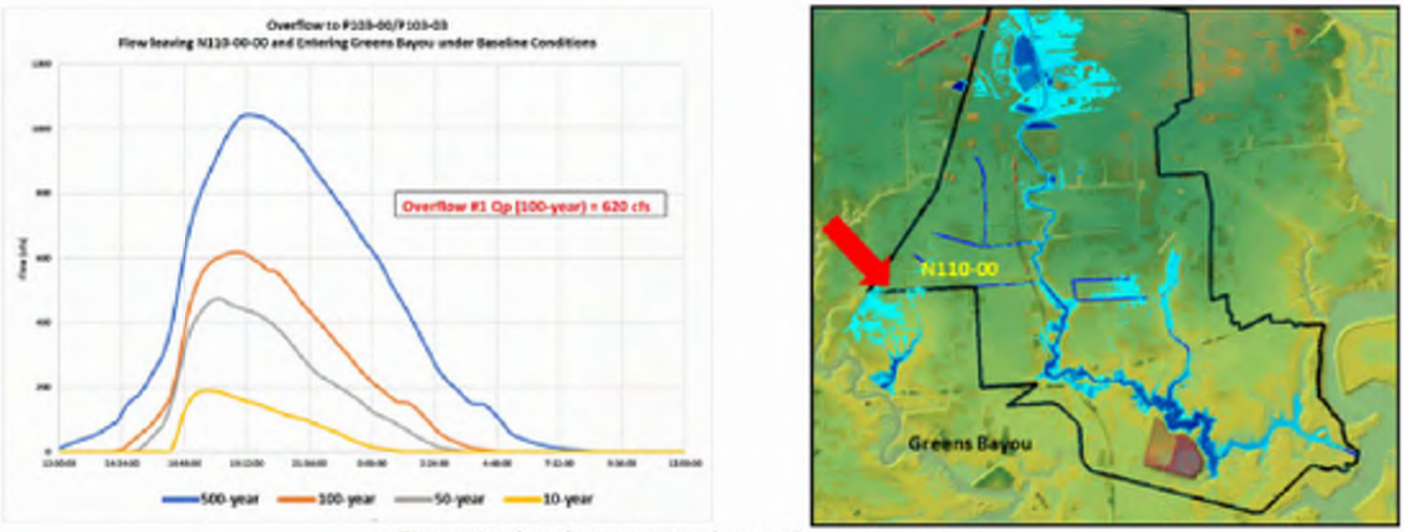


Figure 14. Overflow entering Greens Bayou Watershed

6.1.3. N111-00-00 & N111-01-00 Model Development

Both N111-00-00 and N111-01-00 have 2D flow areas connected to them. These two tributaries pass through neighborhoods which experience flooding. Dummy storage (SA1) area was used at the confluence of N111-00-00 and N111-01-00 for added stability. The 2D flow area D was extended to the north of N111-00-00 to capture the flow from the main channel towards the neighborhoods around N111-00-00 and N111-01-00. See **Figure 15** for details.

Figure 15. 2D flow area D connecting N100-00 to N111-00 & N111-01

6.2. H&H modeling results

Modeled results for baseline ("existing") conditions (coupled 1D/2D analysis with Atlas 14 rainfall update) reveal flooded structures stem largely from sheet flow driven conditions, with flood risks compounded by insufficient drainage infrastructure across several neighborhoods. Comparison of modeled results, flood claim history, and reconnaissance level assessments confirm these observations. Flood claims data provided by HCFCD was superimposed on the 100-year floodplain maps for sheet flow and baseline conditions as shown in **Figure 16.**

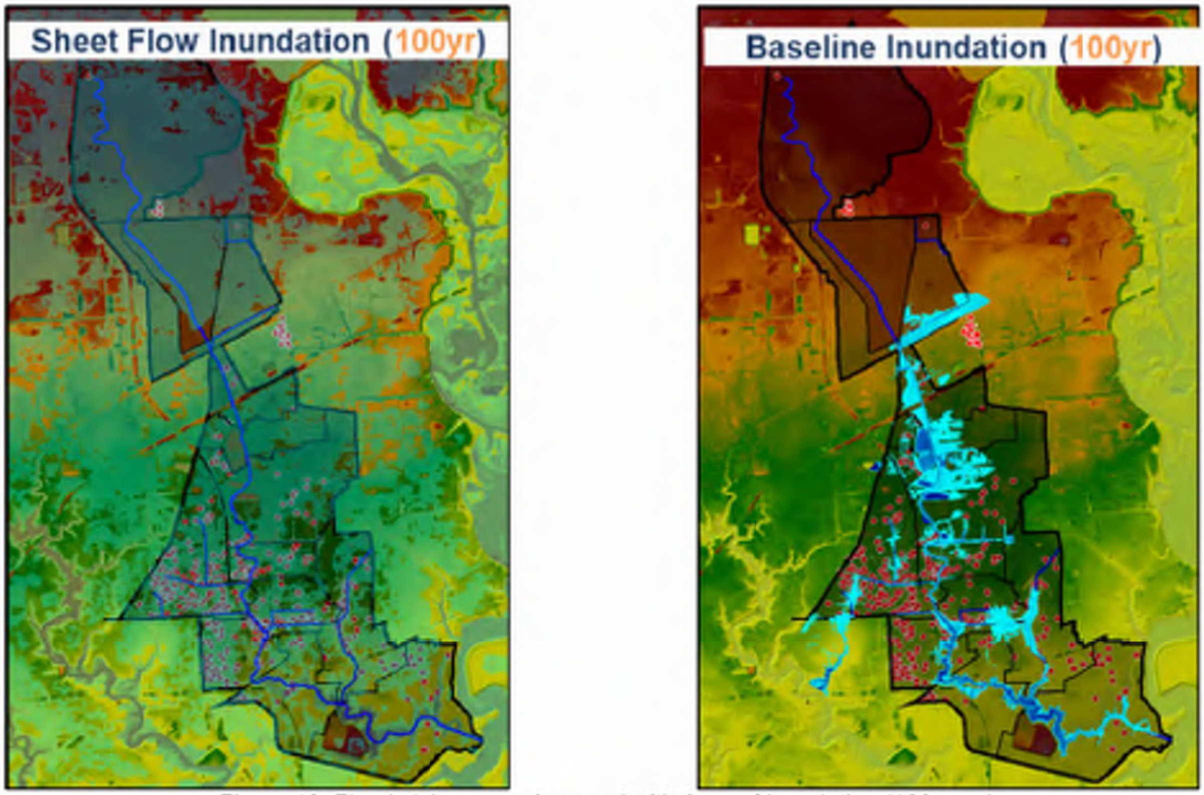


Figure 16. Flood claims superimposed with Area of Inundation (100-year)

Distribution of flooded structures by depth was calculated for the 10-year, 50-year, 100-year, and 500-year storms using sheet flow and baseline results for the respective storm events. **Figure 17** shows a histogram for flooded structures by depth for the sheet flow 100-year storm. Histograms for all frequency storm events can be found in **Appendix A**. See **Exhibits 9-12** for sheet flow flooded structures by depth for all storm events.

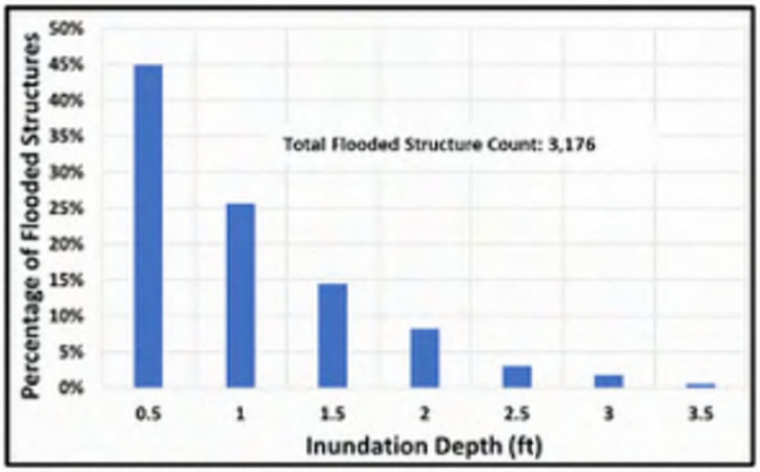


Figure 17. Distribution of Flooded Structures by Depth (100-year)

Torres & Associates was able to use model builder to evaluate sheet flow metrics: miles of inundated roadways by depth, area of inundation and count of flooded structures by depth. These metrics along with other attributes were then used to classify and identify problem areas. Based on the results of the baseline conditions model, level of service (LOS) classifications were assigned to the tributaries as illustrated in **Exhibit 13**. Floodplain maps for the 10-year, 50-year, 100-year, and 500-year storms were developed from HEC-RAS results for baseline conditions. Refer to **Exhibits 14-17.** The figure below shows the comparison between the WSEL of the Atlas 14 100-year baseline conditions model and the effective M3 model. This is to show the degree of change caused by the baseline model as compared to the previous regulatory model. The H&H models will be further revised in the future with MAAPnext updates. Refer to **Appendix A** for a graph with better resolution.

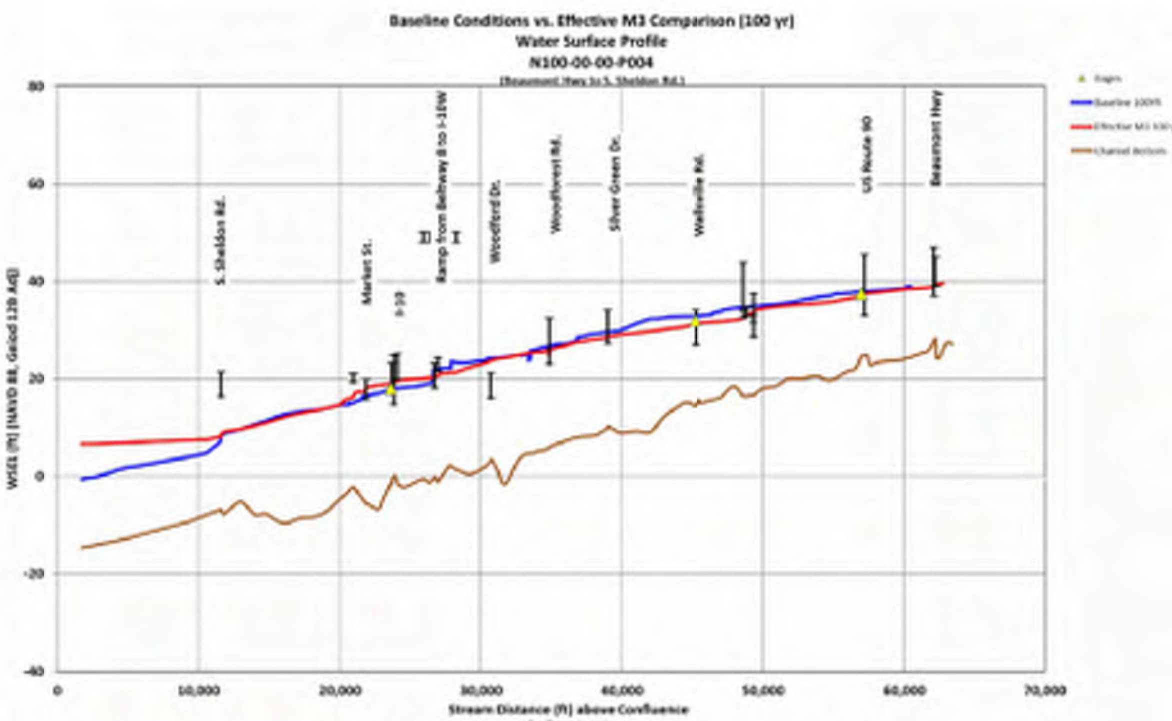


Figure 18. Baseline Conditions vs. Effective M3 Comparison (100 year)

6.3. Recommended future improvements

Torres & Associates recommends that after official implementation of MAAPnext methodology to Carpenters Bayou watershed, the hydrology be updated using current watershed conditions. Most of the 1D/2D hydraulic elements will still be applicable and should be updated using the latest available LiDAR at that time, including roughness coefficients and ineffective areas.

7. Problem Areas

7.1. Characterization of history and source of major problems

Carpenters Bayou watershed has been impacted by 32 of the previous 46 historical flood events since 1979. More recently, the watershed has experienced neighborhood-wide flooding from Tropical Storm Imelda (2019), Hurricane Harvey (2017), and the October Halloween Event (2015). Carpenters Bayou watershed structures flood for various reasons (e.g. overland sheet flow, overbank flooding, insufficient drainage capacity, deteriorating drainage infrastructure). Modeled results for baseline ("existing") conditions (coupled 1D/2D analysis with Atlas 14 rainfall update) reveal flooded structures stem largely from sheet flow driven conditions, with flood risks compounded by insufficient drainage capacity and aging infrastructure. Comparison of modeled results, flood claim history, and reconnaissance level assessments confirm these observations. It is important to note that since most of the problems associated with Carpenters Bayou watershed are sheet flow driven, the County Precinct's role is essential in providing for the maintenance of the roadside ditches and major detention facilities in some areas.

7.2. Discussion of selection process for problem areas

Calibrated 1D/2D baseline condition model results, site visits, and evaluation of prior engineering reports led to an identification of eleven (11) problem areas (PA) (**Exhibit 18**). When used in conjunction with supporting data on repetitive loss, flood claims, existing level-of-service (LOS), flood damage potential, and perceived project viability; a grouping methodology was formulated for identifying PAs of "1," "2," and "3" tier classifications. PAs with the most severe flooding issues are classified as "Tier 1". PAs classified as "Tier 1" And "Tier 2" are considered strong candidates for detailed analyses and potential consideration into preliminary engineering reports (PERs) for realizing near-term flood mitigation benefits for surrounding communities. PAs of "Tier 3" classification can be studied in forthcoming analyses with efforts geared towards identifying regional solutions, right-of-way needs, preemptive stakeholder engagement, and sponsorship mechanisms to facilitate phasing towards project implementation.

A grouping methodology was formulated across three (3) attributes for identifying PAs of "1," "2," and "3" tier classifications. Refer to **Appendix C** for details of these attributes.

- Inundated Structures (count)
- Inundated Roadway (miles)
- Flood Claims (count)

Tier 1 and 2 PAs are discussed in further detail in this report.

7.2.1. Problem Area 1 (PA01) - Tier 1

Tributaries N109-00-00/N109-01-00 and N100-00-00 in PA01 have less than 10-year and less than 50-yr level of service, respectively. The primary source of flooding for Problem Area 1 (PA01) is related to insufficient capacity of tributaries within PA01, overland sheet flow and deteriorating drainage infrastructure. PA01 includes Sterling Forest Subdivision. The Sterling Forest Subdivision Drainage Assessment helped identify the flooding that occurs due to inadequate flow paths to accommodate extreme storm event runoff. The analysis supports the idea that most of the flooding in PA01 occurs as a result of overland sheet flow through complex ditch networks. **Exhibit 19** shows flooded structures, inundated roadway and area of inundation for a 100-year storm event. Refer to **Table 5** for the summary of existing conditions for PA01.

Table 5. Existing Conditions for PA01

Existing Conditions (100 yr):	
Flood Type:	SF;OB
Existing LOS	< 10yr
Pot. Flood Dam. ($) (100yr):	$27.4M
Perf. Metrics	
Flooded Structures (counts):	427
Inundated Roads (miles):	43.0
Area of Inundation (acres):	293
TPSF 50	853.9
Impact of Roadway Closure (100 yr)?	Yes
Critical Facilities?	Yes
Environmental Constraints?	Yes
Repetitive Loss?	Yes
SVI/LMI:	0.72/57%
Flood Claims (counts):	64
Tier Classification:	1

The proposed mitigation strategies for PA01 are local drainage improvements (addition of inlets, increasing pipe capacity), channel widening (N100-00-00) and voluntary buyouts (**Figure 19**). This will result in substantially lower levels of structural flooding along N100-00-00 during high and low frequency events as well as lower levels of inundated roadways around N109-01-00.

Figure 19. Proposed Projects for PA01

7.2.2. Problem Area 2 (PA02) - Tier 1

Tributaries N110-02-00 and N111-00-00 in PA02 both have less than 100-year level of service indicating sufficient capacity. The primary source of flooding for Problem Area 2 (PA02) is related to overland sheet flow and insufficient storm sewer network. **Exhibit 20** shows flooded structures, inundated roadway, and area of inundation for a 100-year storm event. Refer to **Table 6** for the summary of existing conditions for PA02.

Table 6. Existing Conditions for PA02

Existing Conditions (100 yr):	
Flood Type:	SF; OB
Existing LOS	< 100yr
Pot. Flood Dam. ($) (100yr):	$85.5M
Perf. Metrics	
Flooded Structures (counts):	785
Inundated Roads (miles):	46.7
Area of Inundation (acres):	267
TPSF 50	1680.5
Impact of Roadway Closure?	Yes
Critical Facilities?	Yes
Environmental Constraints?	Yes
Repetitive Loss?	Yes
SVI/LMI:	0.54/43%
Flood Claims (counts):	125
Tier Classification:	1

The proposed mitigation strategies for PA02 are local drainage improvements (optimal inlet placement, enhancing storm sewer system) and channel maintenance (removal of debris and obstructions at the upstream end of culvert located at North Shore School) as observed in Figure 20. This will result in lower levels of nuisance yard flooding and structural flooding around N110-02-00 and N110-00-00 during high and low frequency events.

Figure 20. Proposed Projects for PA02

7.2.3. Problem Area 3 (PA03) - Tier 2

The segment of N100-00-00 in PA03 has less than 50-year level of service. The primary source of flooding for Problem Area 3 (PA03) is related to the low LOS of N100-00-00, overland sheet flow and deteriorating drainage infrastructure. **Exhibit 21** shows flooded structures, inundated roadway and area of inundation for a 100-year storm event. Refer to **Table 7** for the summary of existing conditions for PA03.

Table 7. Existing Conditions for PA03

Existing Conditions (100 yr):	
Flood Type:	SF; OB
Existing LOS	< 50yr
Pot. Flood Dam. ($) (100yr):	$49M
Perf. Metrics	
Flooded Structures (counts):	526
Inundated Roads (miles):	41.9
Area of Inundation (acres):	296
TPSF 50	867.2
Impact of Roadway Closure (100 yr)?	Yes
Critical Facilities?	No
Environmental Constraints?	Yes
Repetitive Loss?	Yes
SVI/LMI:	0.68/34%
Flood Claims (counts):	12
Tier Classification:	2

The proposed mitigation strategies for PA03 are channel widening and local drainage improvements (optimal inlet placement, enhancing storm sewer system) (**Figure 21**). This will result in substantially lower levels of structural flooding along the banks of N100-00-00 and neighborhood-level nuisance yard flooding during higher frequency events.

Figure 21. Proposed Projects for PA03

7.2.4. Problem Area 4 (PA04) - Tier 2

Stream N100-00-00 near PA04 has less than 50-year level of service. The primary source of flooding for Problem Area 4 (PA04) is related to overland sheet flow and deteriorating drainage infrastructure. **Exhibit 22** shows flooded structures, inundated roadway and area of inundation for a 100-year storm event. Refer to **Table 8** for the summary of existing conditions for PA04.

Table 8. Existing Conditions for PA04

Existing Conditions (100 yr):	
Flood Type:	SF
Existing LOS	< 50yr
Pot. Flood Dam. ($) (100yr):	$13.6
Perf. Metrics	
Flooded Structures (counts):	206
Inundated Roads (miles):	26.2
Area of Inundation (acres):	390
TPSF 50	661.9
Impact of Roadway Closure (100 yr)?	No
Critical Facilities?	Yes
Environmental Constraints?	Yes
Repetitive Loss?	Yes
SVI/LMI:	0.94/77%
Flood Claims (counts):	32
Tier Classification:	1

The proposed mitigation strategies for PA04 are local drainage improvements (key trunk lines, roadside ditches, driveway culverts), outfall improvements and voluntary buyouts (**Figure 22**). This will result in substantially lower levels of nuisance yard flooding and ponding in older neighborhoods during high and low frequency events. Outfall improvements will cause lower levels of structural flooding near the outfall.

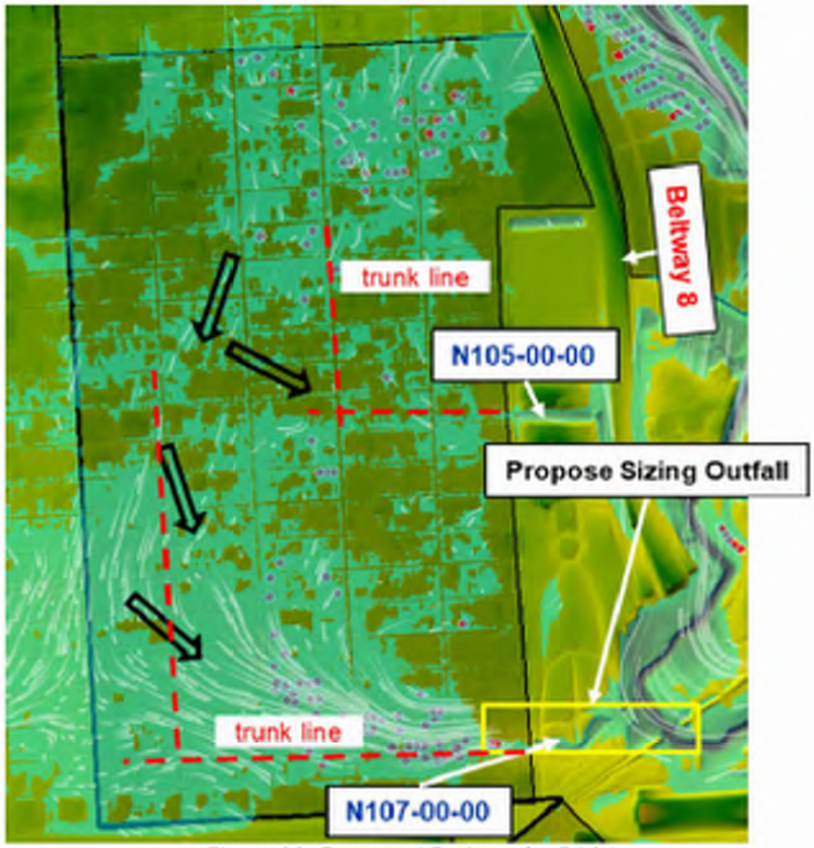


Figure 22. Proposed Projects for PA04

7.2.5. Problem Area 5 (PA05) - Tier 2

The segment of N104-00-00 in PA05 has less than 10-year level of service, indicating insufficient capacity. Most flood claims and flooded structures are along the banks of N104-00-00. PA05 is unique because it is the only PA which floods mostly because of overbank topping. The primary source of flooding for Problem Area 5 (PA05) is related to the low LOS of N104-00-00. **Exhibit 23** shows flooded structures, inundated roadway and area of inundation for a 100-year storm event. Refer to **Table 9** for the summary of existing conditions for PA05.

Table 9. Existing Conditions for PA05

Existing Conditions (100 yr):	
Flood Type:	OB
Existing LOS	< 10yr
Pot. Flood Dam. ($) (100yr):	$20M
Perf. Metrics	
Flooded Structures (counts):	218
Inundated Roads (miles):	9.9
Area of Inundation (acres):	134
TPSF 50	569.8
Impact of Roadway Closure (100 yr)?	No
Critical Facilities?	No
Environmental Constraints?	Yes
Repetitive Loss?	Yes
SVI/LMI:	0.74/81%
Flood Claims (counts):	25
Tier Classification:	2

The proposed mitigation strategies for PA05 are channel widening and inline/offline detention shown in Figure 23. This will result in a substantial decrease in the count of flooded structures along the banks of N104-00-00 for all storm events.

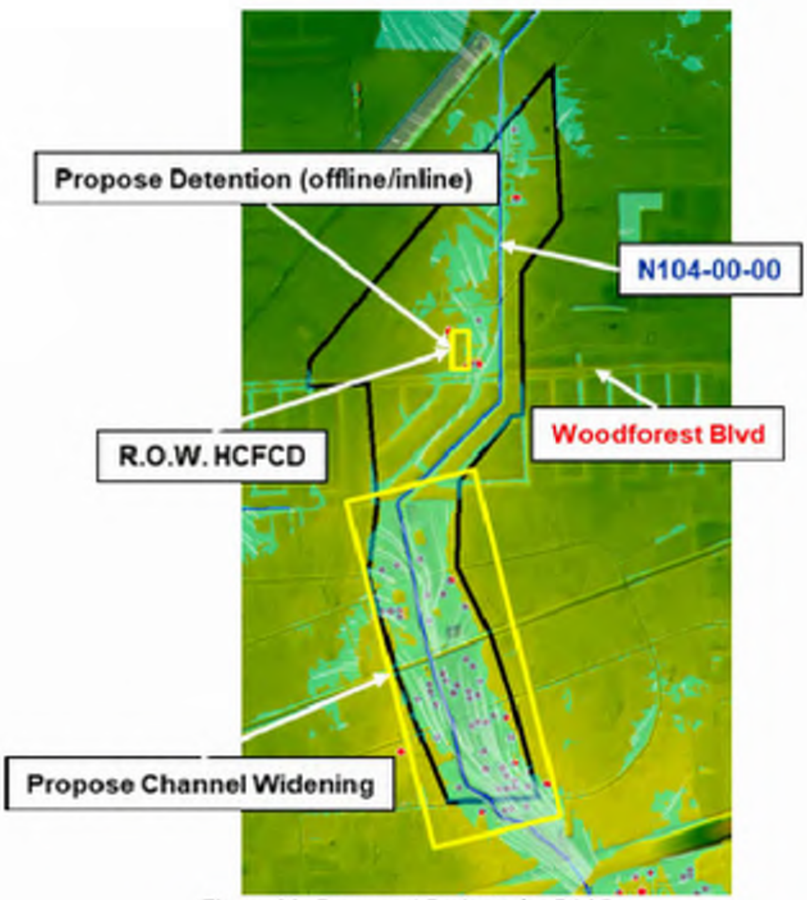


Figure 23. Proposed Projects for PA05

7.3. Summary of grouping methodology and results

PAs were grouped according to the list of attributes described under Notes and Abbreviations for **Table 10**. Potential partnerships for each PA were also identified.

Table 10. Problem Area Summary

Problem Area Name	Primary Jurisdiction	Flooding Source	Historical Flooding Data	Total Predicted Structural Flooding (1% AEP)'	Predicted Structural Flooding (PSF50)	Predicted Roadway Flooding (Total Length >1-foot during 1% AEP)	Classification
			(number of homes)	(number of structures)	(structures per year)	(miles)	
PA01	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	64	427	853.9	13.6	Tier 1
PA02	Unincorporated Harris County/ Cloverleaf	Sheet flow from adjoining area and Local stormwater drainage limitation	12	785	1680.5	24.1	Tier 1
PA03	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	21	526	867.2	11.4	Tier 2
PA04	Unincorporated Harris County/ Cloverleaf	Local stormwater drainage limitation and sheet flow from adjoining area	32	206	661.9	3.0	Tier 2
PA05	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	25	218	569.8	1.5	Tier 2
PA06	Unincorporated Harris County	Sheet flow from adjoining area and Local stormwater drainage limitation	12	46	198.1	0.1	Tier 3
PA07	Unincorporated Harris County	Overbank flow and local stormwater drainage limitation	4	18	30.7	5.9	Tier 3
PA08	Unincorporated Harris County/ Channelview	Local stormwater drainage limitation and sheet flow from adjoining area	3	36	78.3	0.5	Tier 3
PA09	Unincorporated Harris County	Overbank flow	1	60	111.1	0.4	Tier 3
PA10	Unincorporated Harris County/ Channelview	Overbank flow	2	10	20.5	0.1	Tier 3
PA11	Unincorporated Harris County/ Channelview	Sheet flow from adjoining area and Local stormwater drainage limitation	0	16	71.7	0.1	Tier 3

Table 10 Notes and Abbreviations:

- **Historical Flooding (data value)**= Total historical flooding from the multiple events recorded in the HCFCD database – (Events include Imelda 2019, Harvey 2017, Memorial Day 2015, Tax Day 2016, Halloween 2015, Ike 2008, and others). They do not include storm events prior to 2015 such as Tropical Storm Allison (2001), Carpenters Bayou watershed flooded extensively during this storm event.
- **Predicted Structural Flooding (1% AEP)**- Number of homes predicted to flood during storm event with a 1% annual exceedance probability.
- **Predicted Structural Flooding (total TPASF50)** = Total Probable Annual Structural Flooding (all structures) predicted to occur in the problem area over a 50-year period. This statistic based on four predicted frequency events, i.e. [(N10yr x 5) + (N50yr x 1) + (N100yr x 0.5) + (N500yr x 0.1)] = theoretical annual flooding of homes over a 50-year period within each problem area.
- **Predicted Roadway Flooding (Total Length >1-foot in 1% AEP)** =Total Length of all roadways flooded by more than 1 foot during 1% AEP storm event for each problem area. The total length is the cumulative sum of linear feet inundation for all classifications of roadways within the problem area.

8. Constraints Evaluation

8.1. Desktop Environmental Assessment

Detailed knowledge of sensitive environmental conditions and constraints is useful for the watershed planning phases. An environmental assessment was conducted to evaluate and map existing environmental conditions to aid in the planning and prioritization of future projects. A review of the GIS files provided by HCFCD was conducted. This included compilation of (**Exhibit 24**):

- Hazardous materials
    - 1420 identified sites within the watershed, types of materials present not specified
- Landfills
    - 1 identified landfill: Eastbelt landfill, currently closed.
- Pipelines: oil and gas
    - Approximately 50 miles of oil and gas pipelines within the watershed
        - Operators include: Centerpoint energy, Colonial pipeline company, Enterprise crude pipeline, Equistar chemicals, Explorer pipeline company, ExxonMobil pipeline company, HFOTCO LLC, Kinder Morgan Texas pipeline LLC, Ocelot energy management LLC, Petroleum fuels company inc, Shell pipeline company, Targa NGL Pipeline company
- Wells
    - 95 identified wells within the watershed
        - Operators include: Amerada Hess corporation, Atlantic Richfield Co, Ballard exploration company, Bock & Bacon inc, Etoco inc, Gordy Oil Company, Hedge, R.H., Inexco oil company, J-W Operating co, KP Exploration inc, Kelly-Brock, New Century Exploration inc and Zero corporation of Texas
- Parks
    - 7 identified parks: occupy approximately 3212 acres of land in the watershed.
- Archeological and cultural resources
    - 2306 acres of cultural resources within the watershed
- Cemeteries
    - 1 identified cemetery within the watershed: San Jacinto cemetery
- Potential wetlands
    - 3144 acres of wetlands within the watershed
- Threatened and endangered species (N/A)

8.2. Desktop Baseline Fluvial Geomorphic Assessment

Stream Condition Assessment (SCA), the guidance document, aerial imagery, Google Earth, HEC-RAS cross-sections, site visits and engineering judgement was used to analyze the streams. Level 1 Stream Condition Assessment (SCA) procedures by U.S. Army Corps of Engineers and the guidance document on Environmental and Geomorphological Analysis provided by HCFCD entailed a detailed description of the methodology for calculating the Reach Condition Index. The geomorphological assessment was conducted using three parameters: Channel Condition Parameter, Riparian Buffer Parameter and Desktop Aquatic Use Parameter. These parameters were scored on a scale of 1-5, 5 representing optimal conditions.

For the Channel Assessment Parameter, natural channels that appeared to have no or little historical modification were given an "Optimal" or "Suboptimal" (4-5) score. Channels that had been historically modified but had re-naturalized were given a "Marginal" (3) score. Channels that had been improved or modified were given a "Poor" score (1-2). For the Riparian Buffer Parameter, wooded buffers were given an "Optimal" or "Suboptimal" (4-5) score. Mixed buffers (some forests & maintained ROW) were given a "Marginal" (3) score. Grass-lined maintained ROW was given a "Poor" score (2) and impervious surfaces were given a "Severe" (1) score. For Desktop Aquatic Use Parameter, Texas Surface Water Quality Standards for Aquatic Life Use designations based on TCEQ assessed stream segments and an attached Excel spreadsheet of Aquatic Life Use Scores provided by HCFCD was used to score segments. There were only 3 segments along the main stem (N100-00-00) in the watershed that were assessed by TCEQ in these documents. The remaining tributaries and main stem were scored based on the guidance document. Channels with perennial flow were given a "High" (4) score. Channels with intermittent flow were given a "Limited" (2) score and channels with ephemeral flow were given a "Severe" (1) score. The three parameters were then averaged to develop the Reach Condition Index for each segment analyzed. **Table 11** shows the Reach Condition Index score with the corresponding color.

Table 11. Reach Condition Index (RCI) score for each assessment unit with color coding

Reach Condition Index Score	Color Code
Optimal-Score 5	Green
Suboptimal- Score4-4.9	Blue
Marginal - Score 3-3.9	Yellow
Poor - Score 2-2.9	Orange
Severe - Score 1-1.9	Red

Exhibit 25 shows the color-coded streams of the watershed. The mainstem is mainly orange which indicates poor stream conditions. N109-00-00, N109-01-00, N110-00-00 and N110-02-00 are red indicating severe stream conditions. **Appendix D** has an excel table with all the parameter scores. The Geomorphological Assessment was used as a parameter for project viability. Since a high RCI indicates good stream conditions and a low RCI indicates poor stream conditions, for proposed projects a low RCI stream has better project viability. Thus, a score of 1 to 5 was given based on high RCI and low RCI respectively. (1= High RCI, 5= Low RCI).

9. Potential Future Development

The age of structures (**Exhibit 26**) and site visits confirmed that future development will occur in the northern regions of Carpenters Bayou watershed, south and north of Lake Sheldon. Aerial imagery shows the availability of land in this area of the watershed. Liberty Lakes is a recently developed neighborhood in this area characterized by a huge detention facility (Gene Green Beltway 8 Park) with a storage capacity of approximately 1300 ac-ft. **Figure 25** shows images taken within the watershed which are indicative of potential future development.

HCFCD owns ROW (**Exhibit 2**) in this region which could be used for inline/offline detention facilities to accommodate higher levels of flow. These improvements could also benefit neighborhoods and roadways downstream of the watershed. Moreover, the analysis of the watershed reveals that flooding problems arise from poor drainage infrastructure. It is recommended that the storm sewer systems used for future development should be designed to have adequate capacity to safely facilitate neighborhoods and reduce flooding.

Figure 24. Potential Future Development

10. References

Federal Emergency Management Agency (FEMA). "Flood Insurance Study," revised August 18, 2018.

Harris County Flood Control District. (2018). "Two-dimensional Modeling Guidelines," July 2018.

United States Army Corps of Engineers (USACE). (2016). "HEC-RAS River Analysis System Hydraulic Reference Manual Version 5.0," Institute for Water Resources, Hydrologic Engineering Center, Davis, CA.

Harris County Flood Control District. "Workbook for Carpenters Bayou Watershed," September 2019.

Harris County Flood Control District (2018)

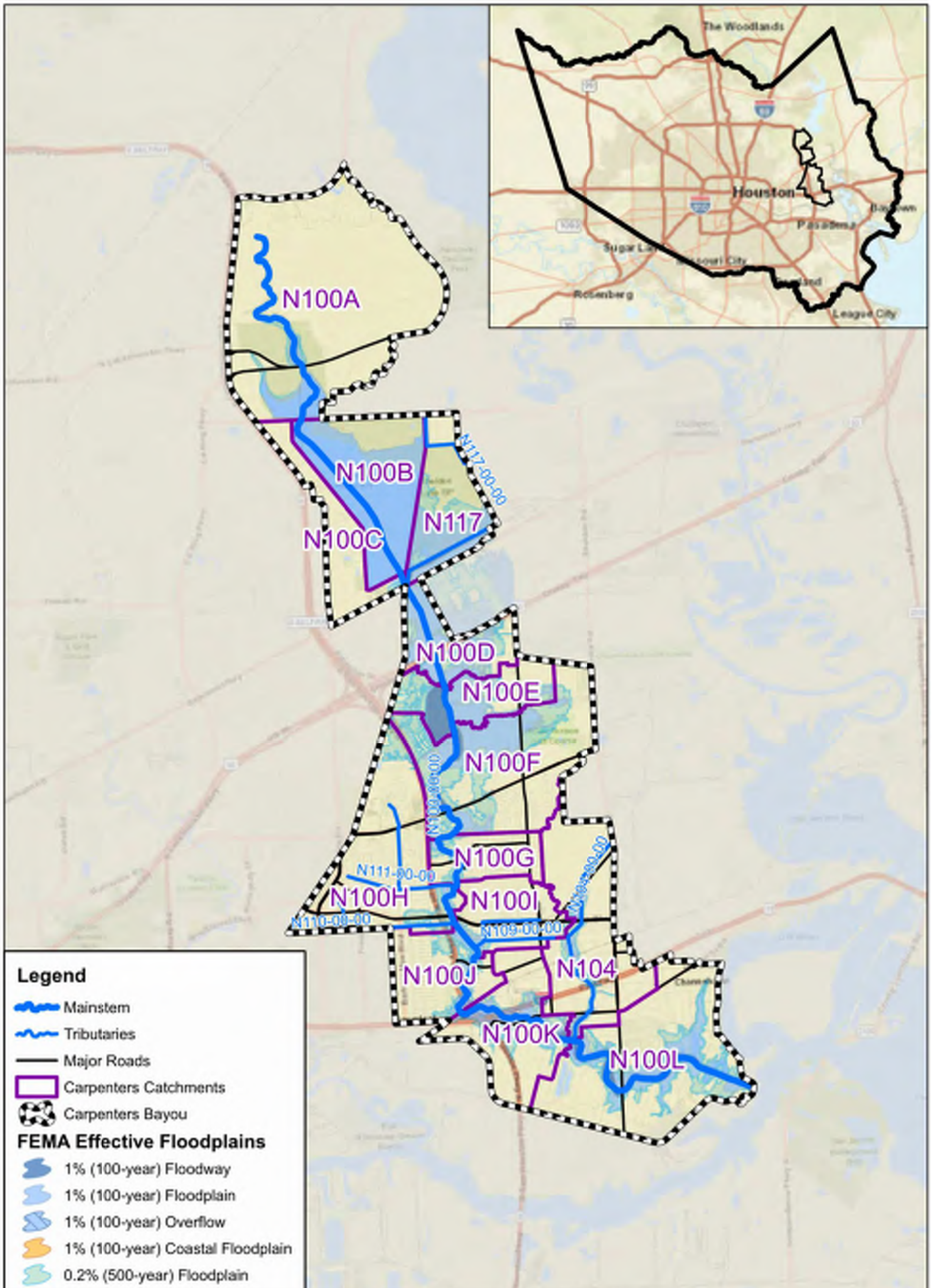
"Sterling Forest Subdivision Drainage Assessment" prepared for Harris County Engineering Department

"Sheldon Reservoir Study" prepared by HDR Engineering, Inc. December 1998

List of Exhibits

List of Appendices

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 01
Study Area Map

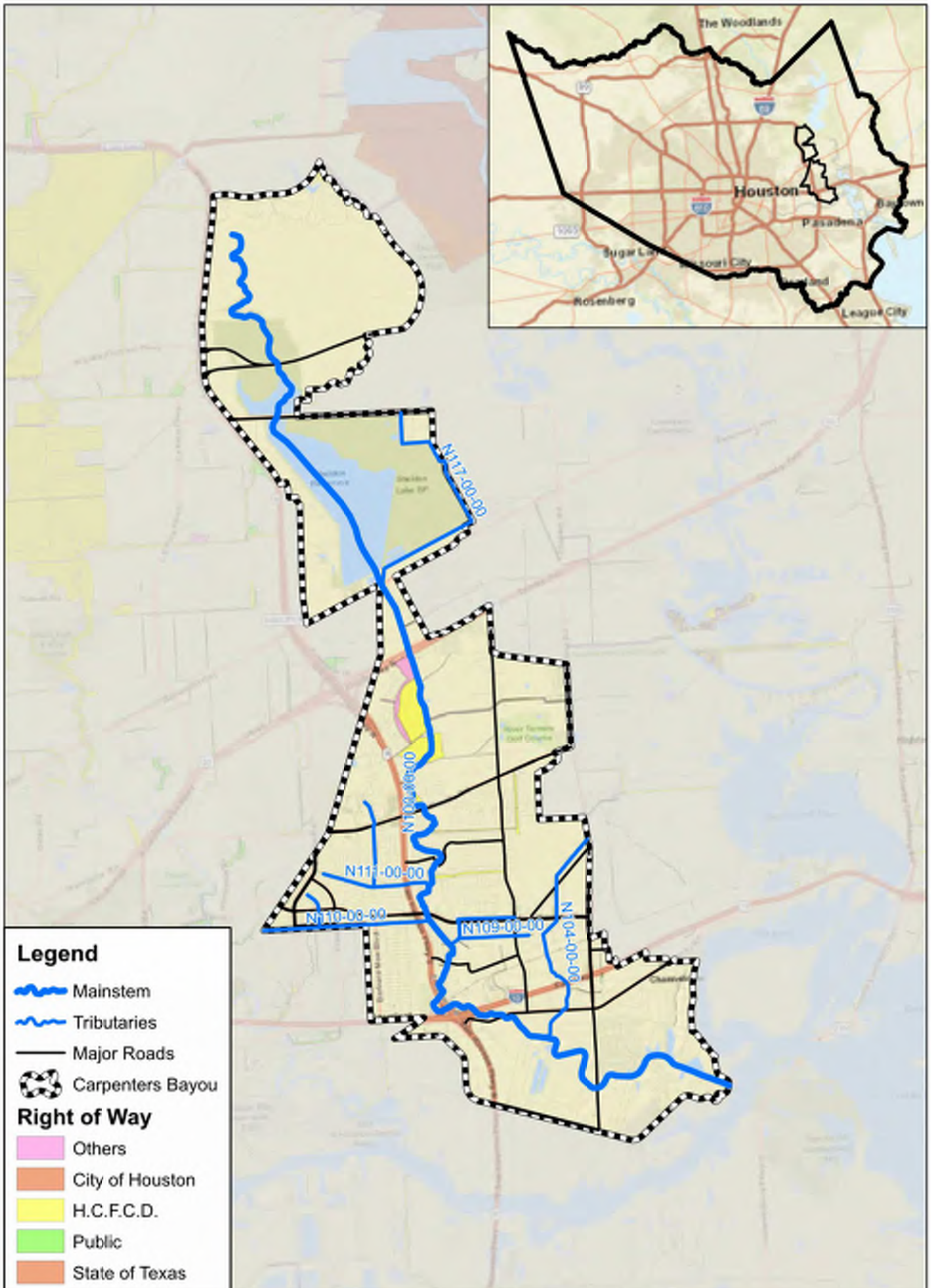
Miles
0 0.5 1 2

N

Created: 9/22/2020

Carpenters Bayou
Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

Exhibit 02
Right of Way

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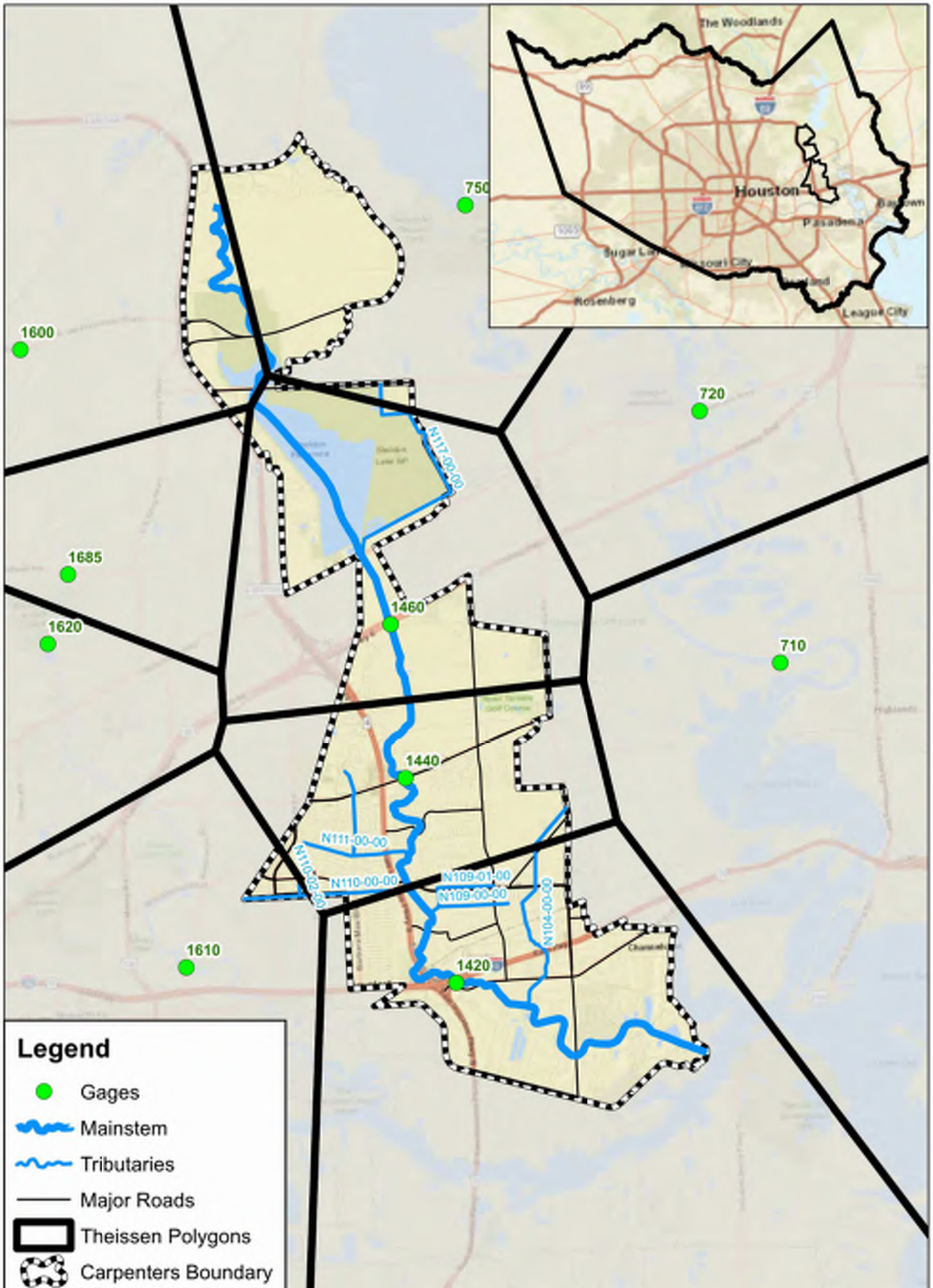
Created: 9/22/2020

Carpenters Bayou
Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

Exhibit 03
Thiessen Polygons

Miles
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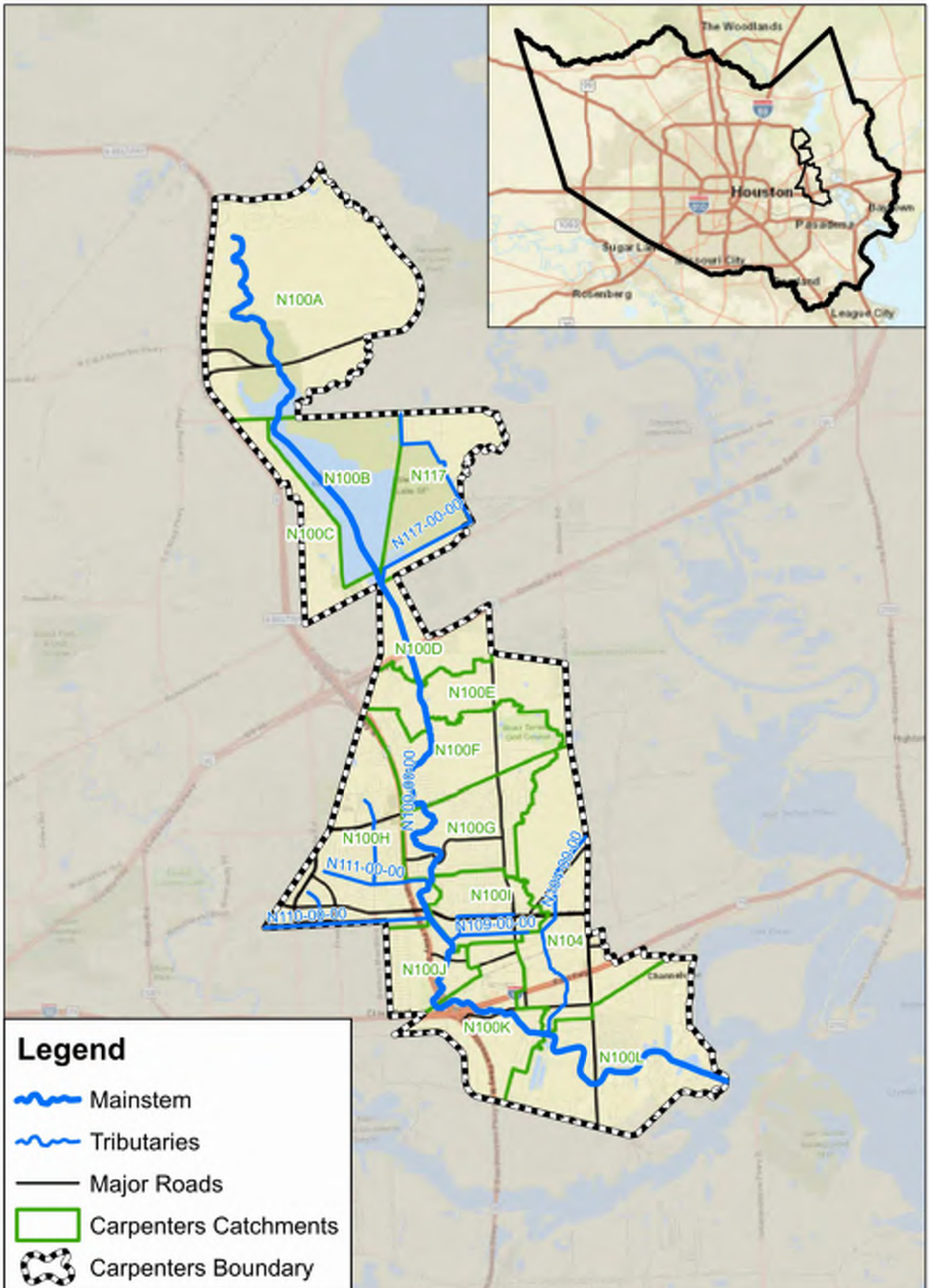
Created: 9/22/2020

Carpenters Bayou
Watershed Plan

FLOOD CONTROL DISTRICT



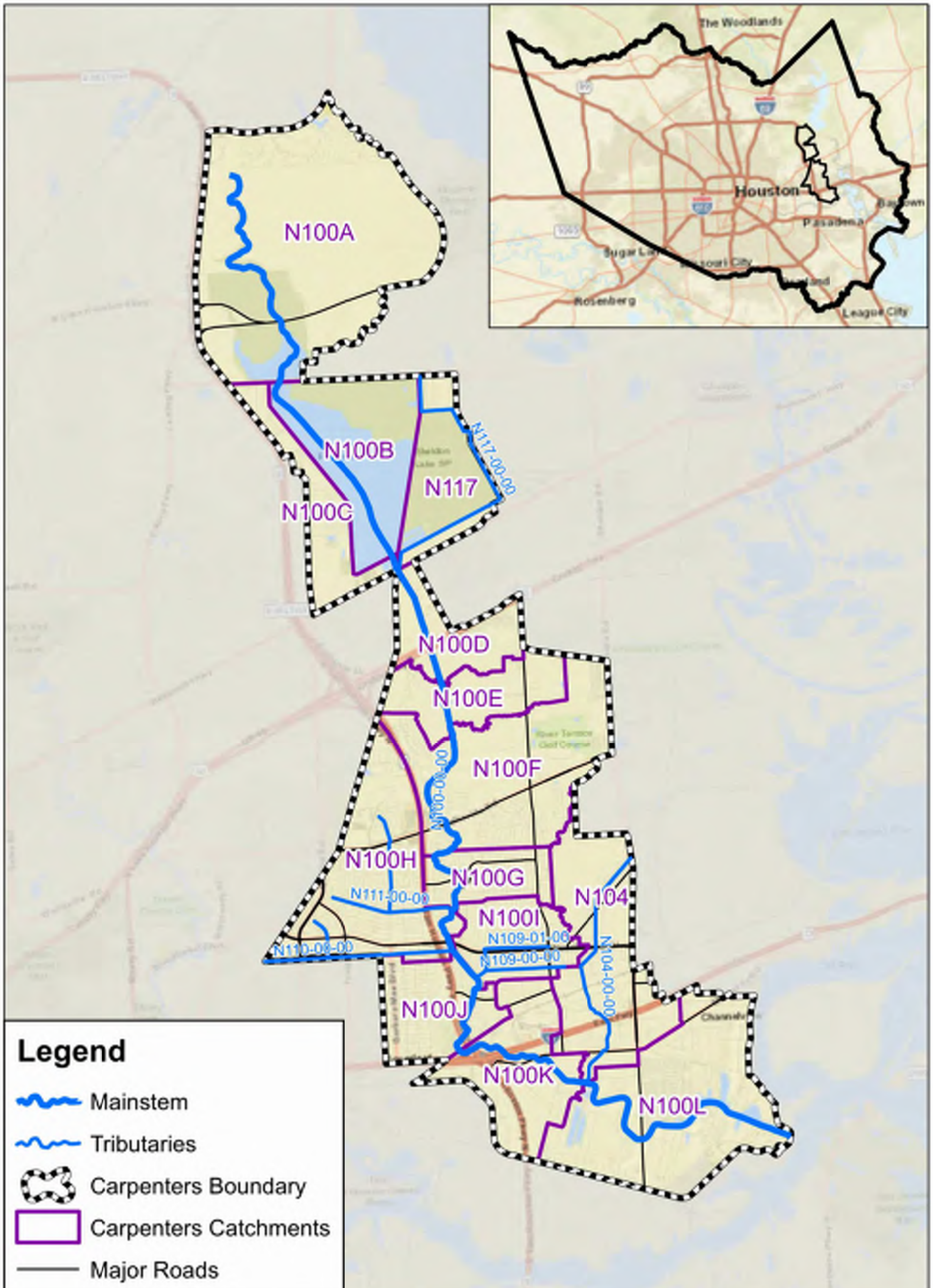
Technical Memorandum 1

Exhibit 04
Old Catchments

Created: 9/22/2020

Carpenters Bayou
Watershed Plan

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 05
New Catchments

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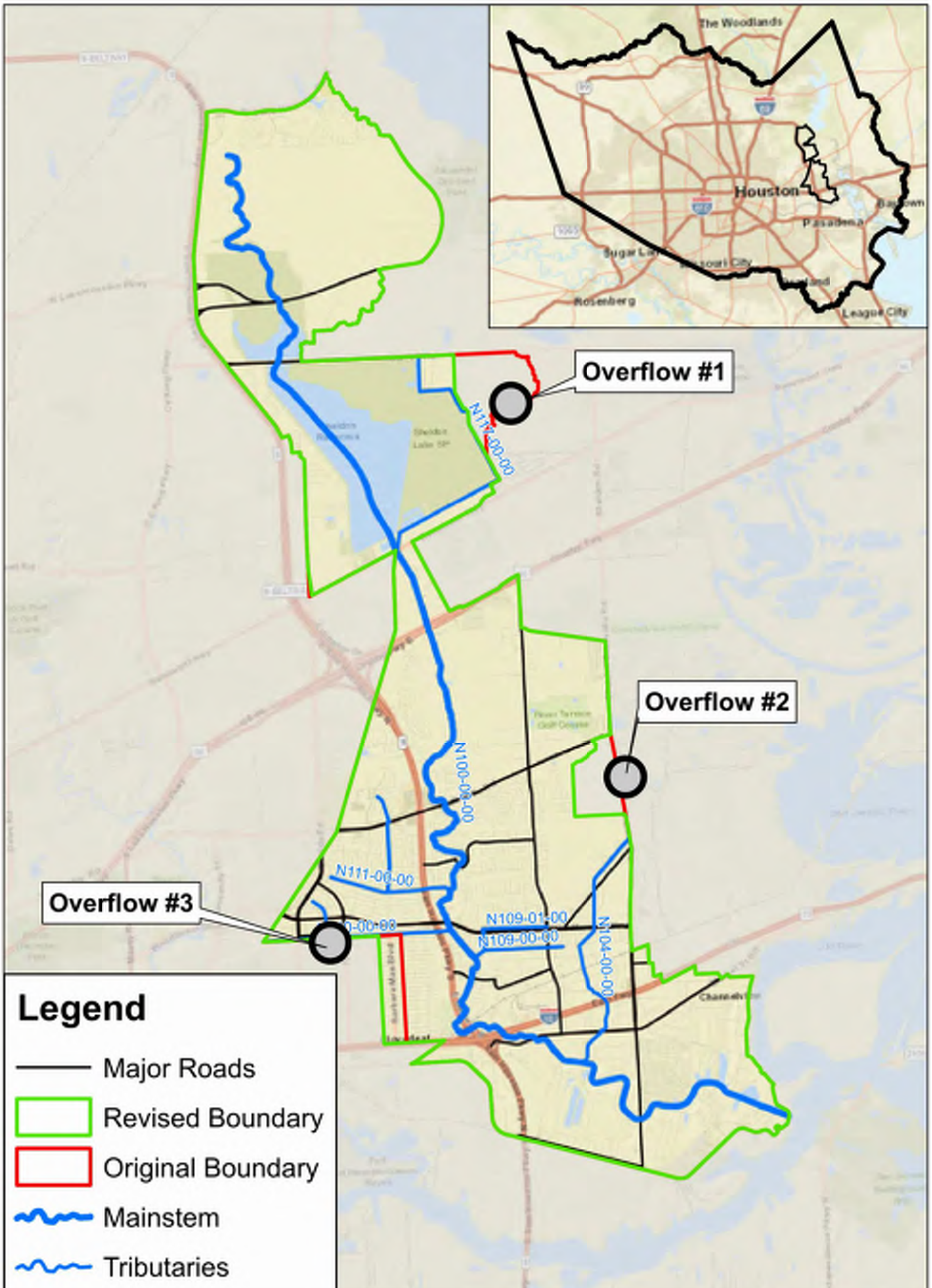
Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 06
Boundary Revisions

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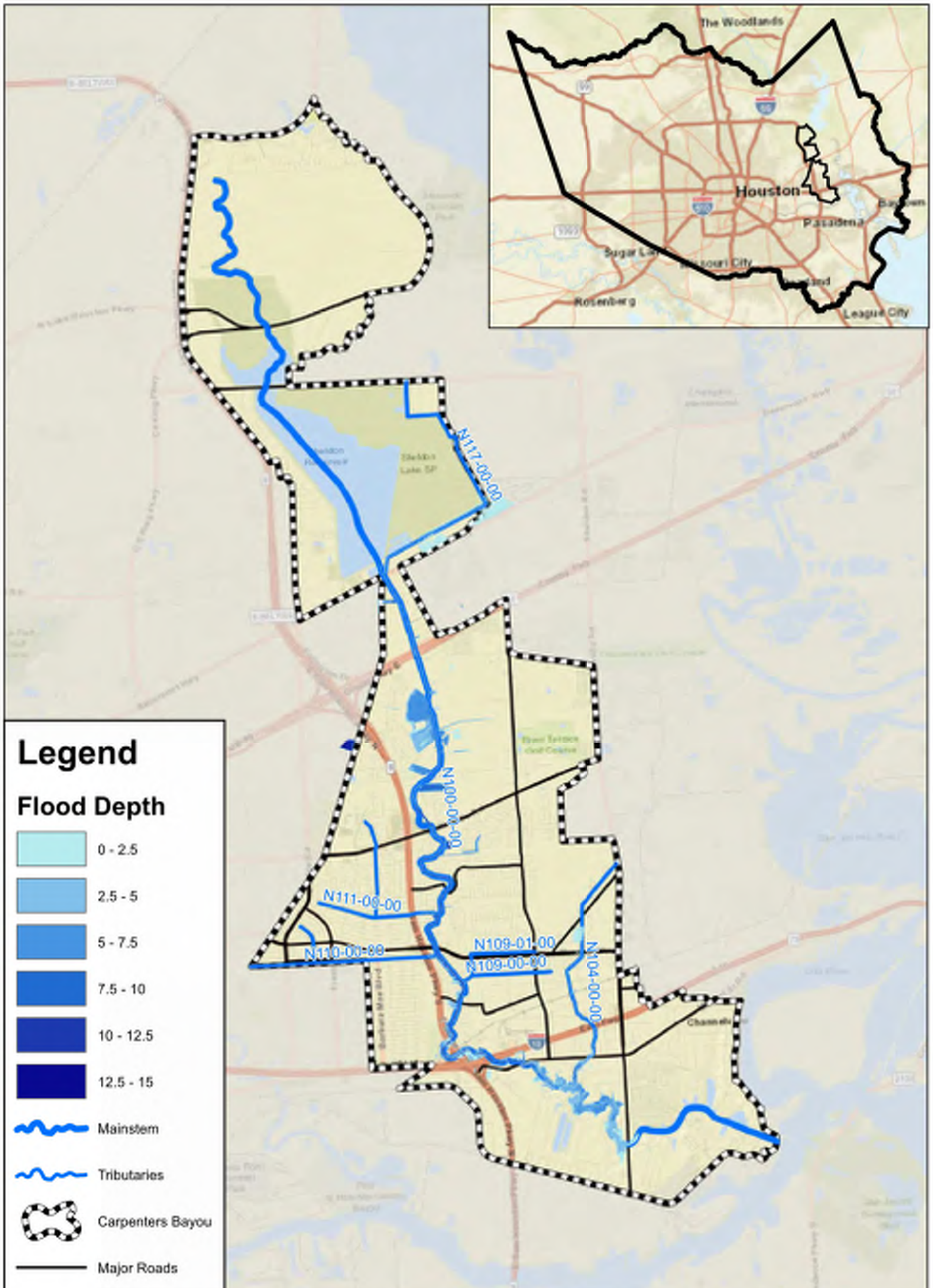
Created: 9/22/2020

Carpenters Bayou
Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 07
Imelda Calibration Floodplain

Miles
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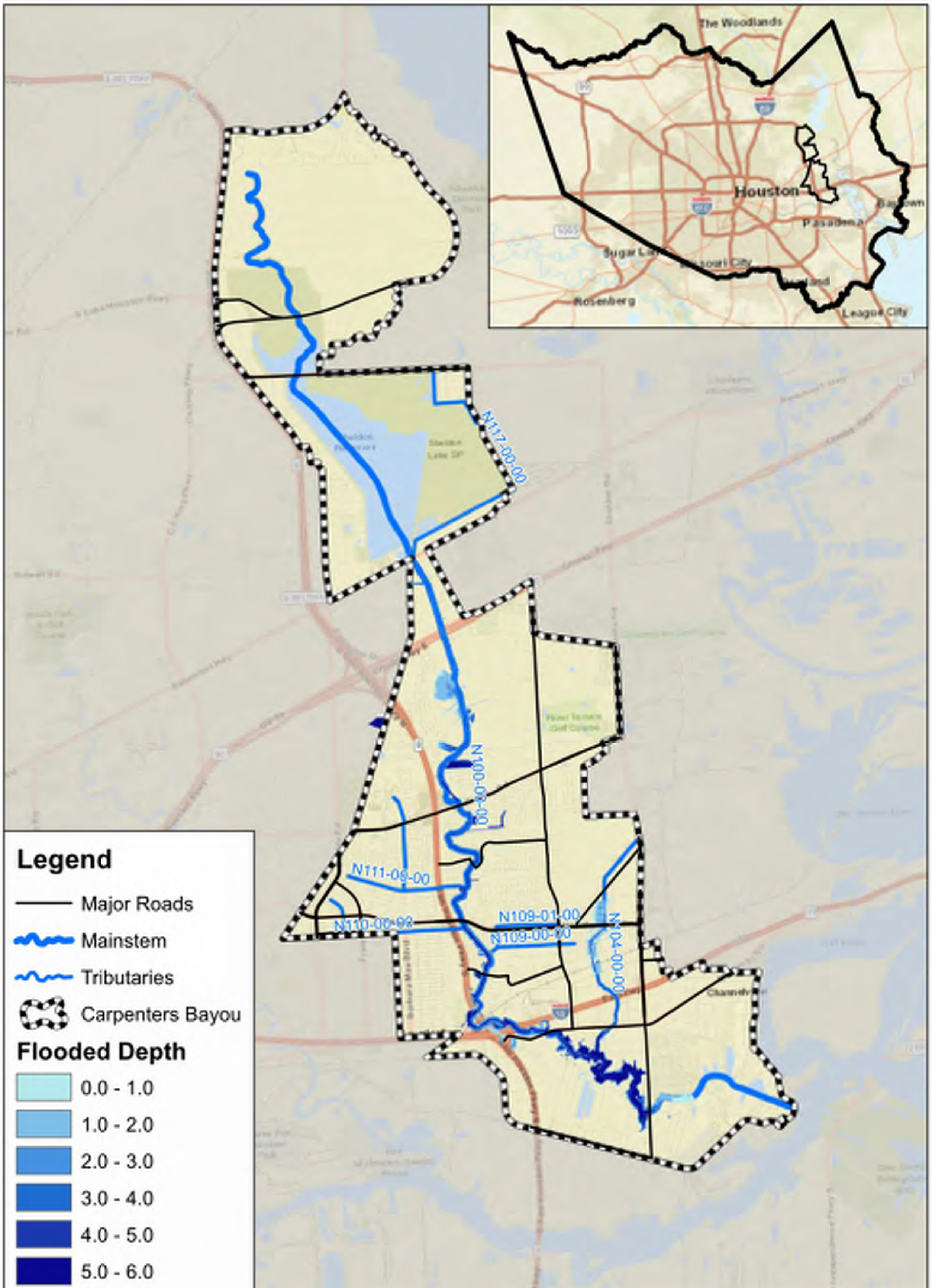
N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

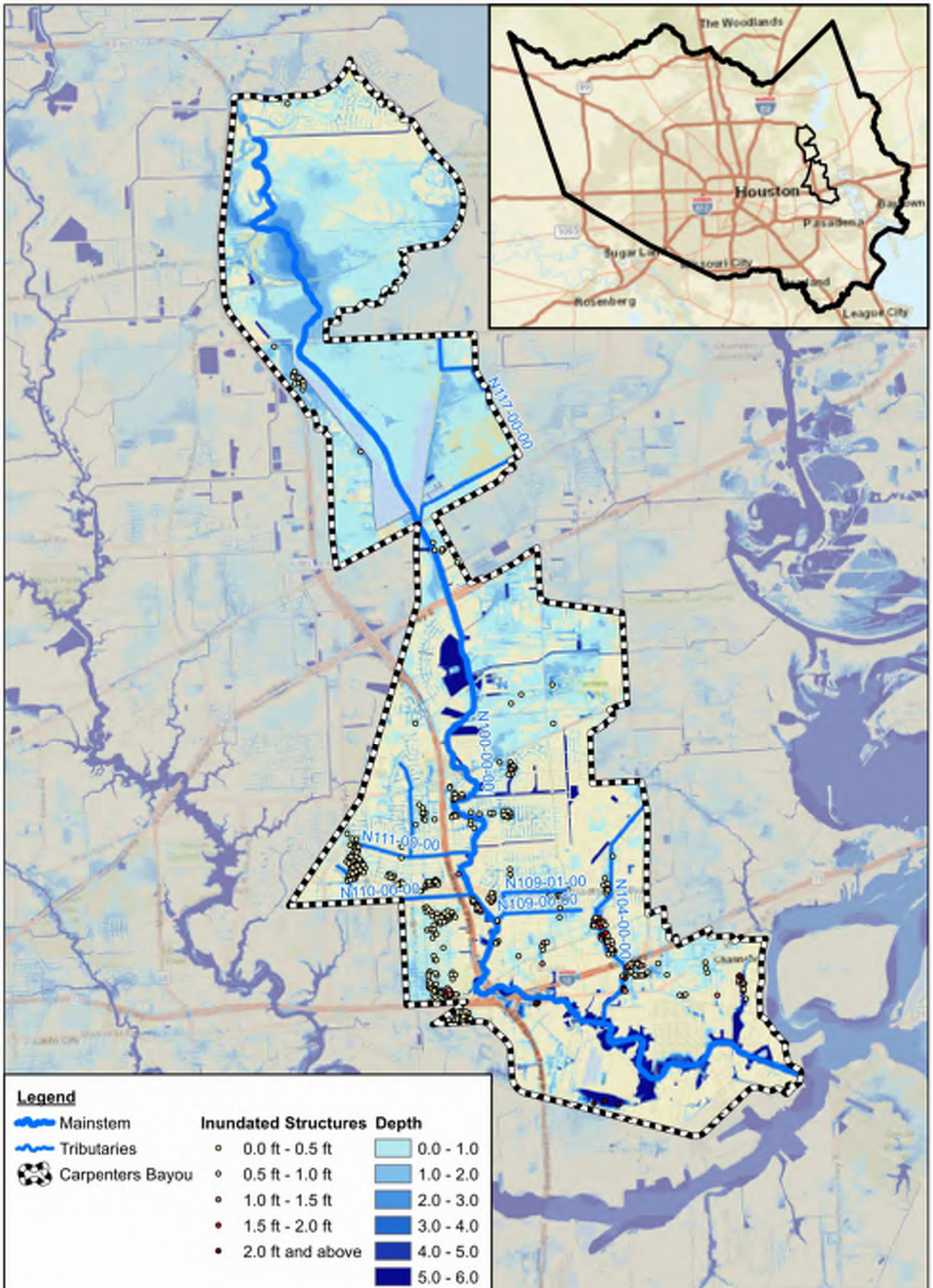
Exhibit 08
2015 Halloween Event
Validation Floodplain

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 09
10 Year Sheet Flow
Flooded Structures

Miles
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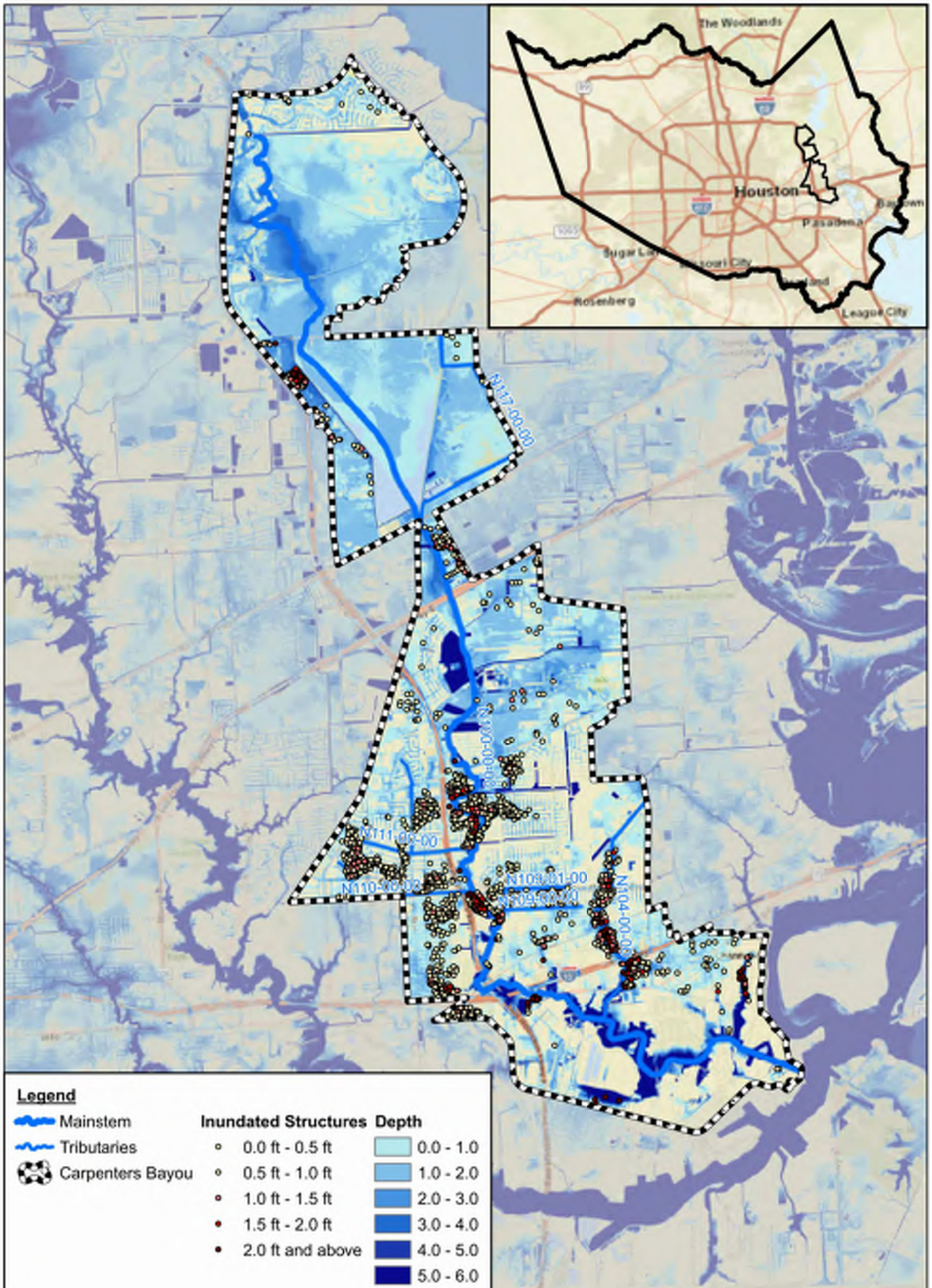
Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

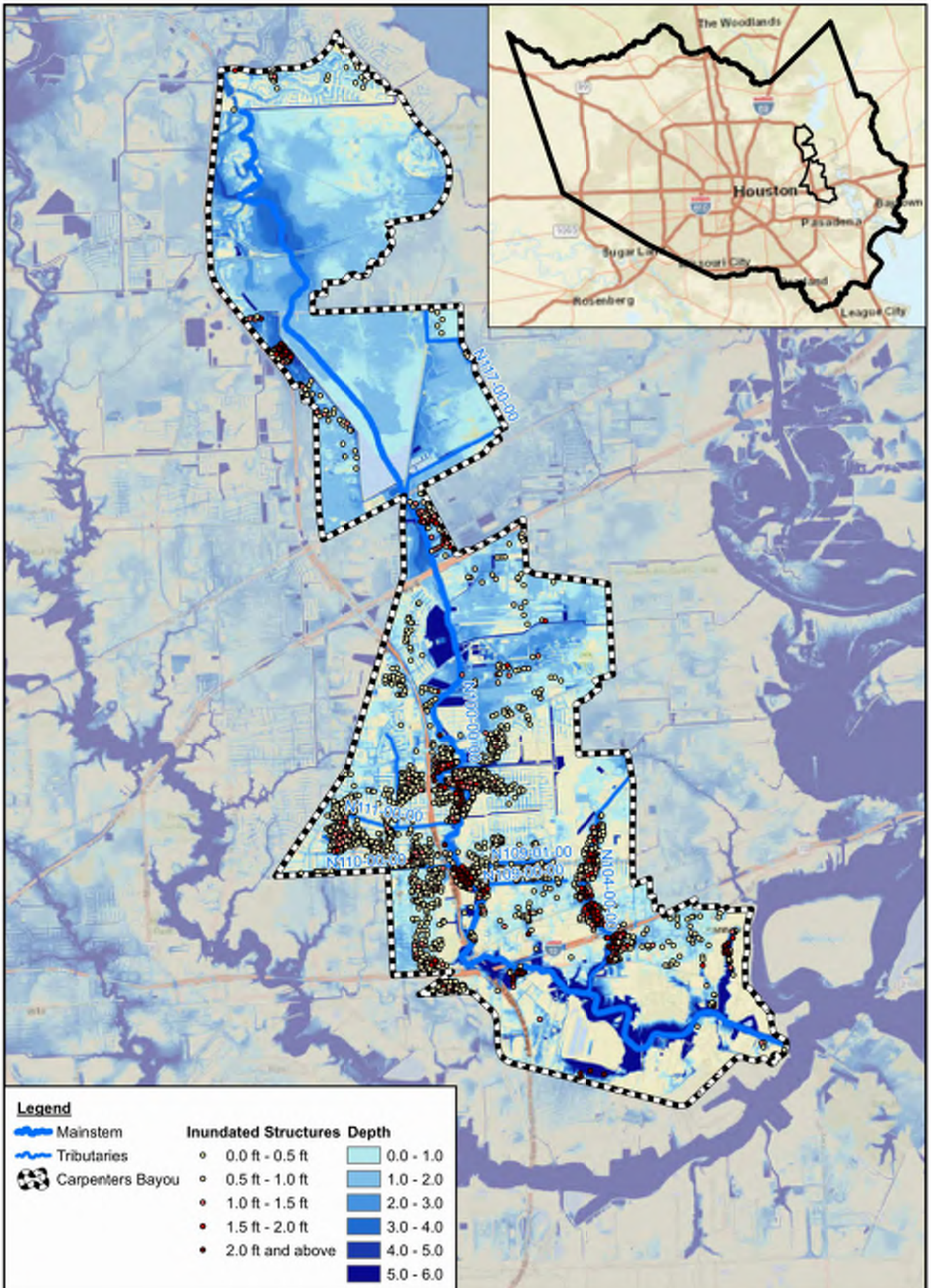
Exhibit 10
50 Year Sheet Flow
Flooded Structures

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 11
100 Year Sheet Flow
Flooded Structures

Miles
0 0.5 1 2

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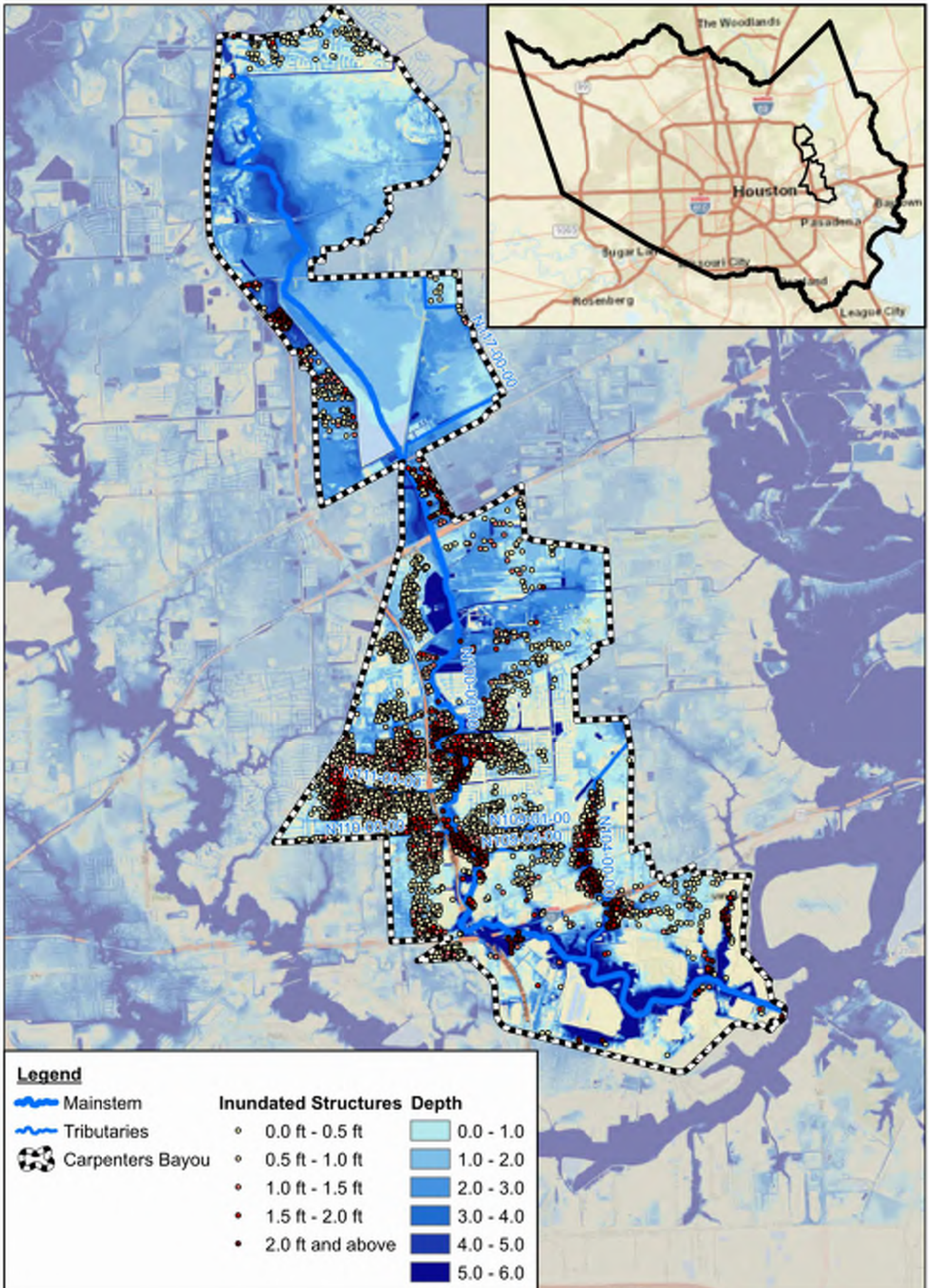
Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 12
500 Year Sheet Flow
Flooded Structures

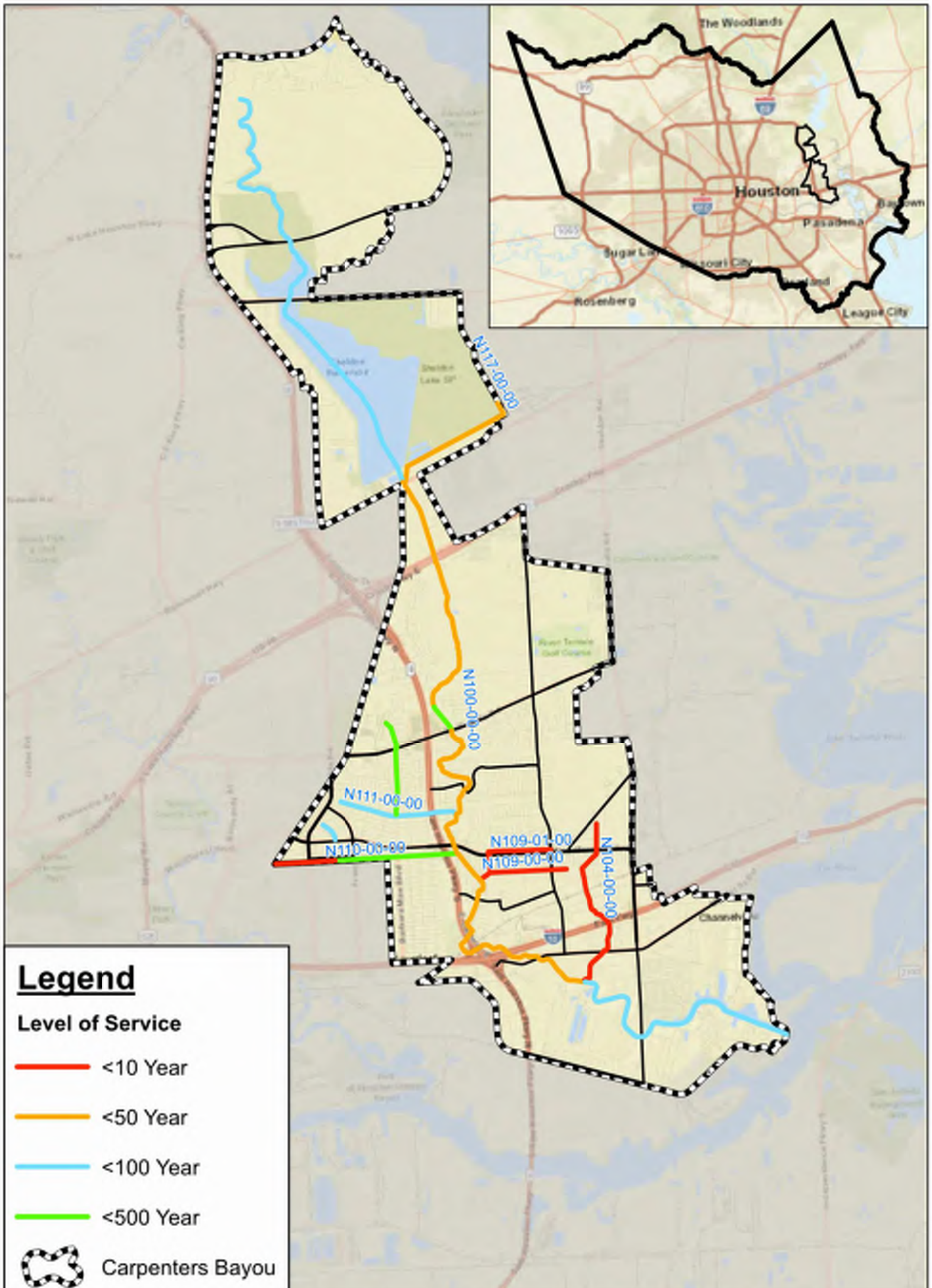
Miles
0 0.5 1 2

N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

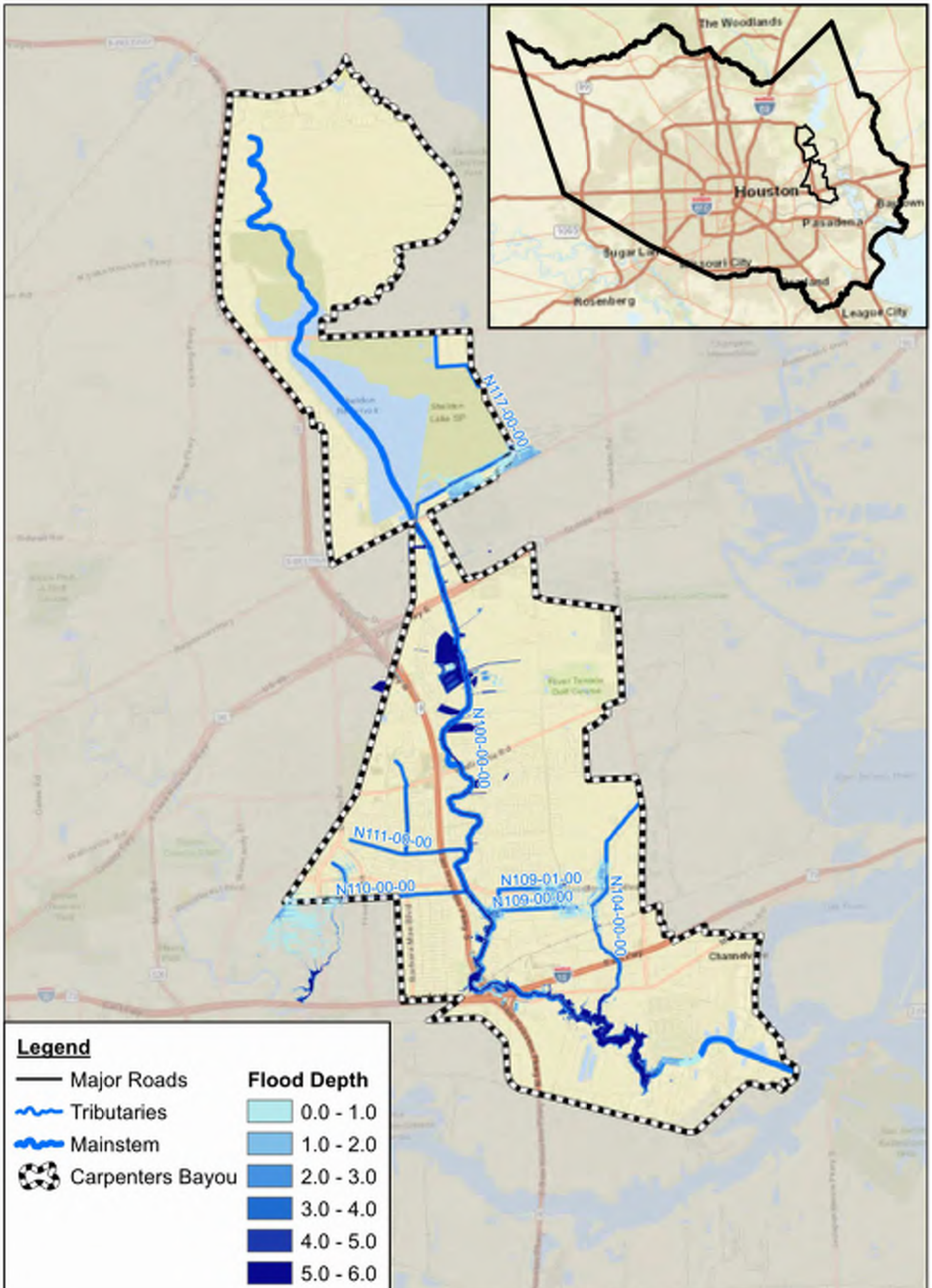
Exhibit 13
Level of Service

Miles
0 0.5 1 2

N

Created: 9/22/2020

Carpenters Bayou Watershed Plan



Technical Memorandum 1

Exhibit 14
10 Year Baseline Flooding

Miles
0 0.5 1 2

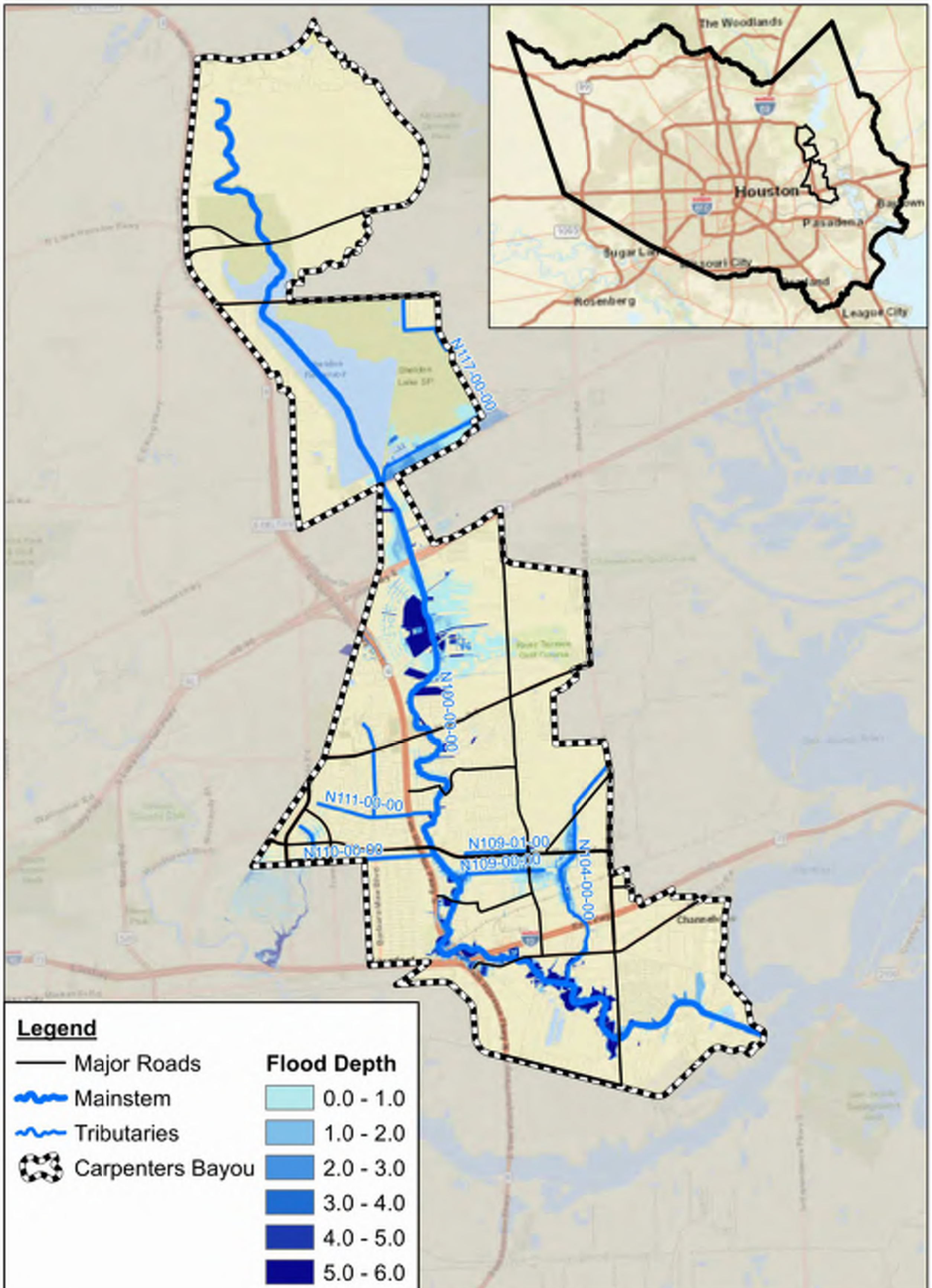
N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 15
50 Year Baseline Flooding

Miles
0 0.5 1 2

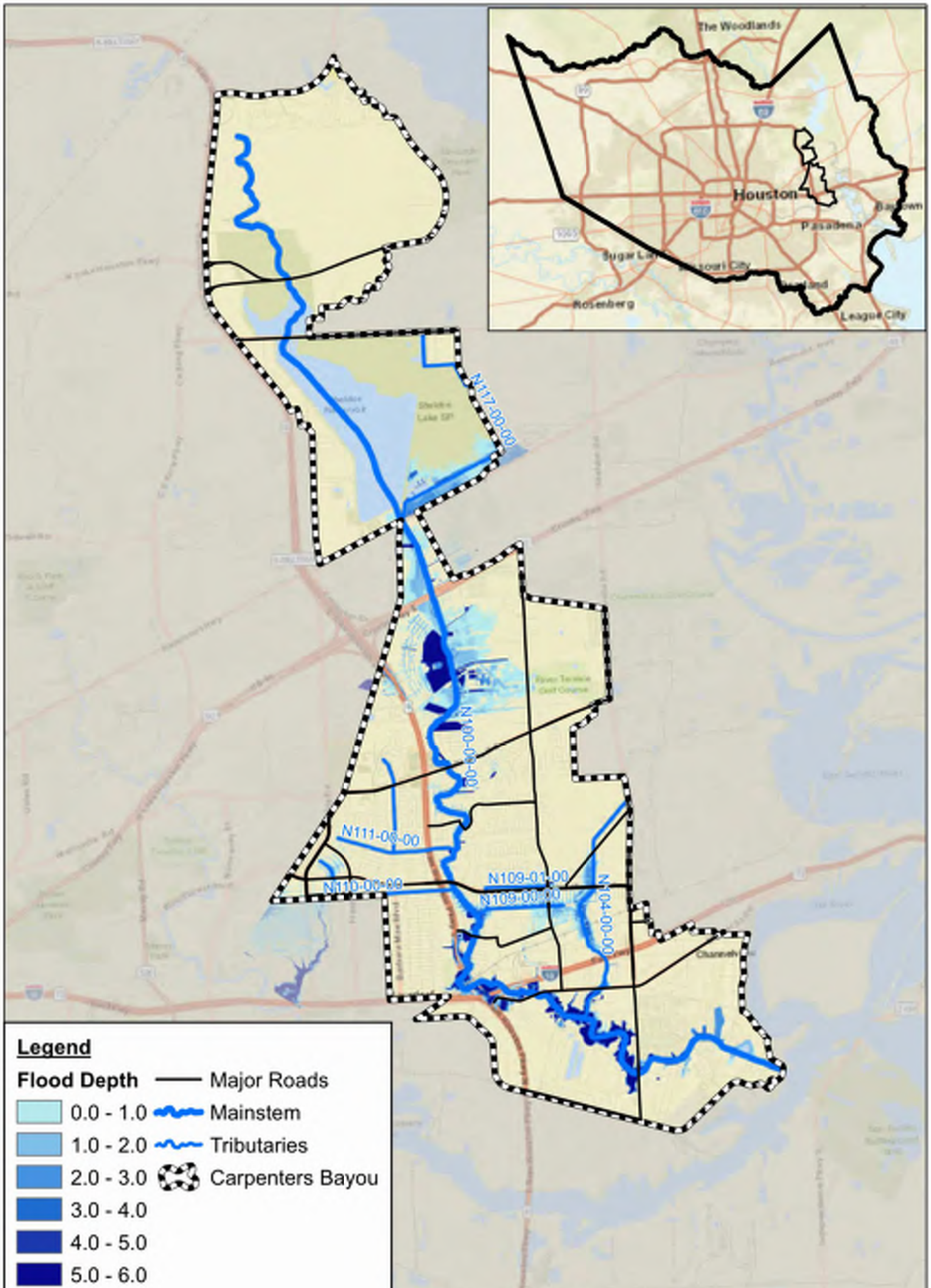
N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

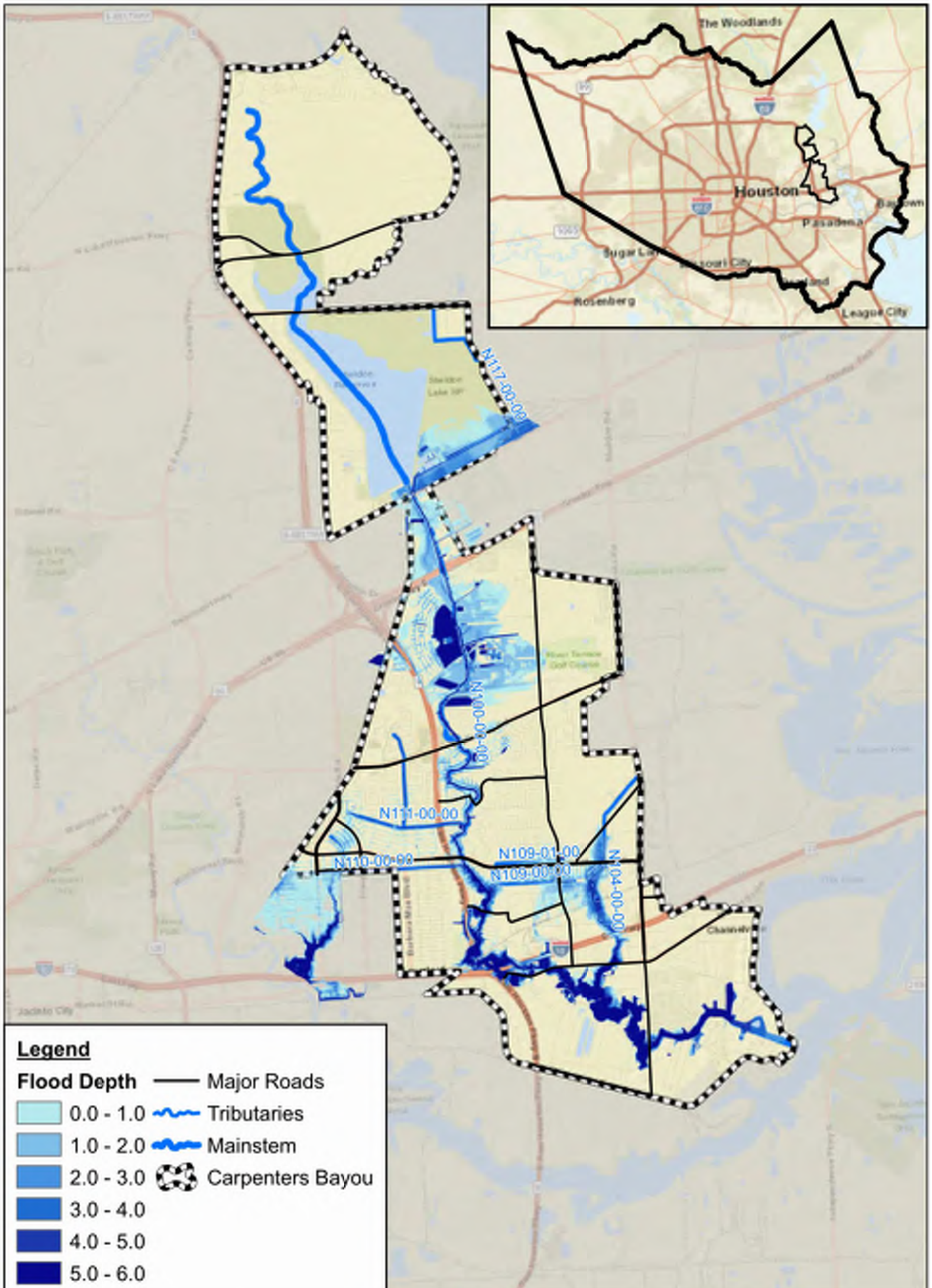
Exhibit 16
100 Year Baseline Flooding

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 17
500 Year Baseline Flooding

Miles
0 0.5 1 2

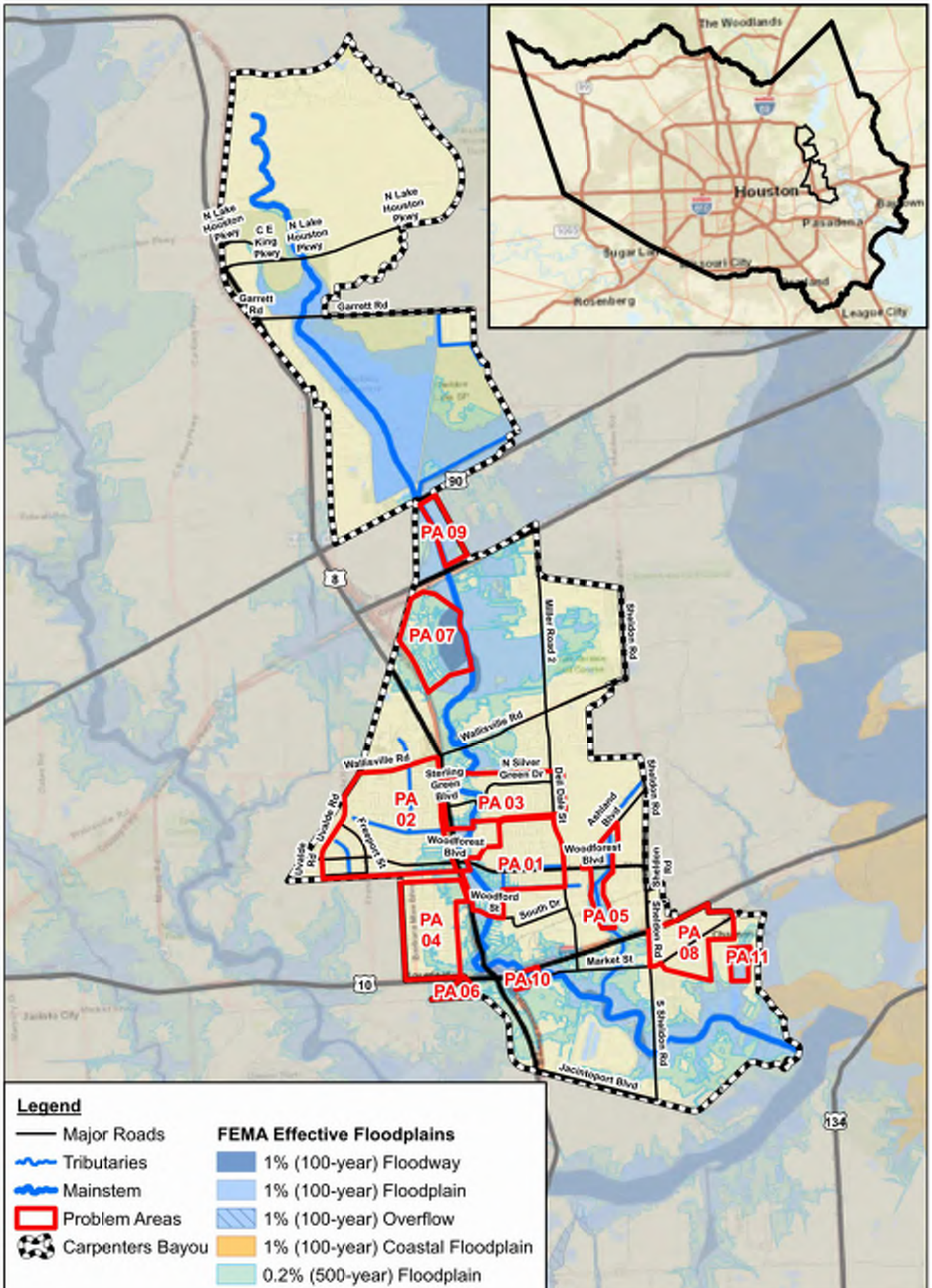
N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 18
Problem Area Overview

Miles
0 0.5 1 2

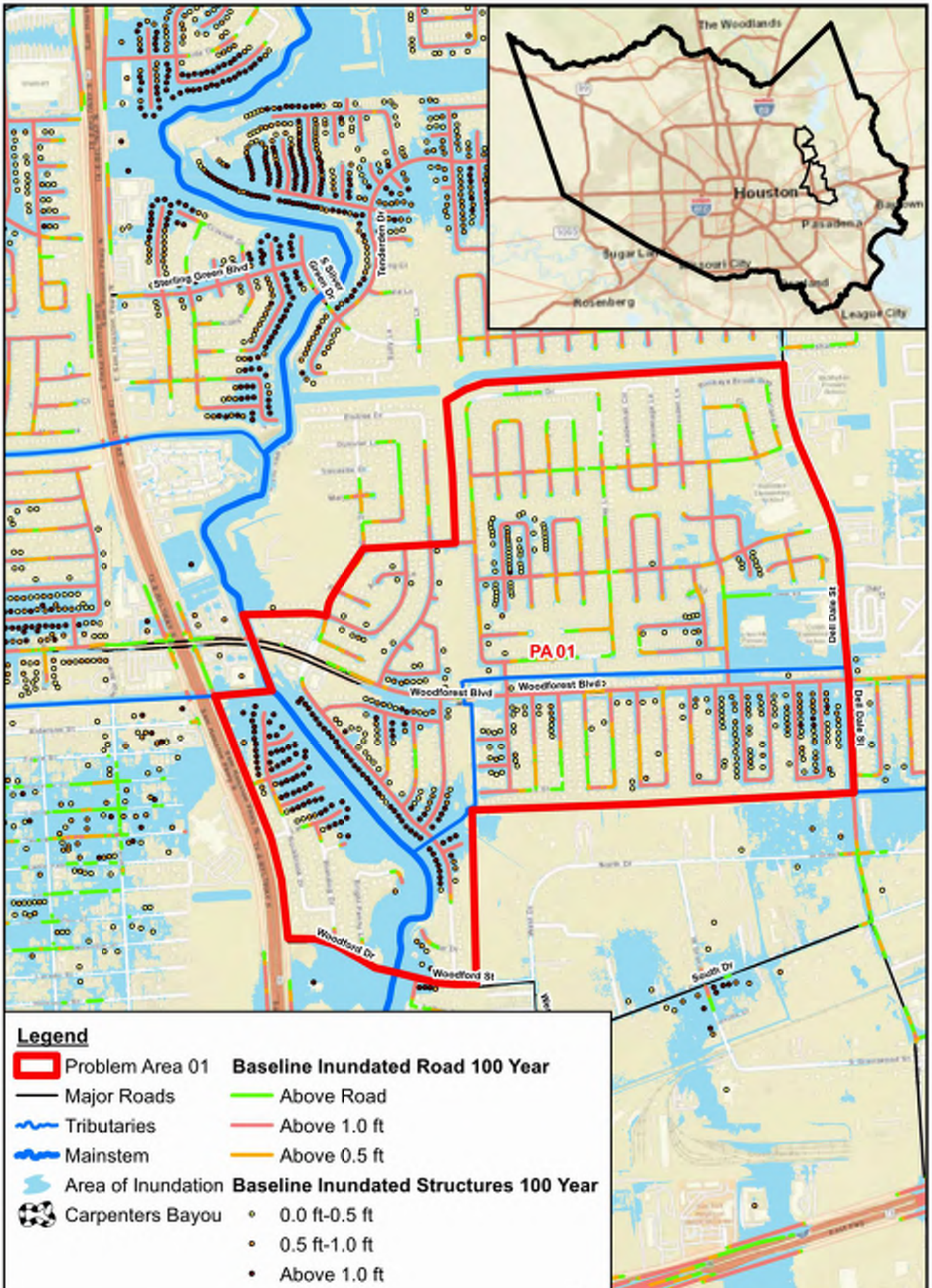
N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 19
Problem Area 1

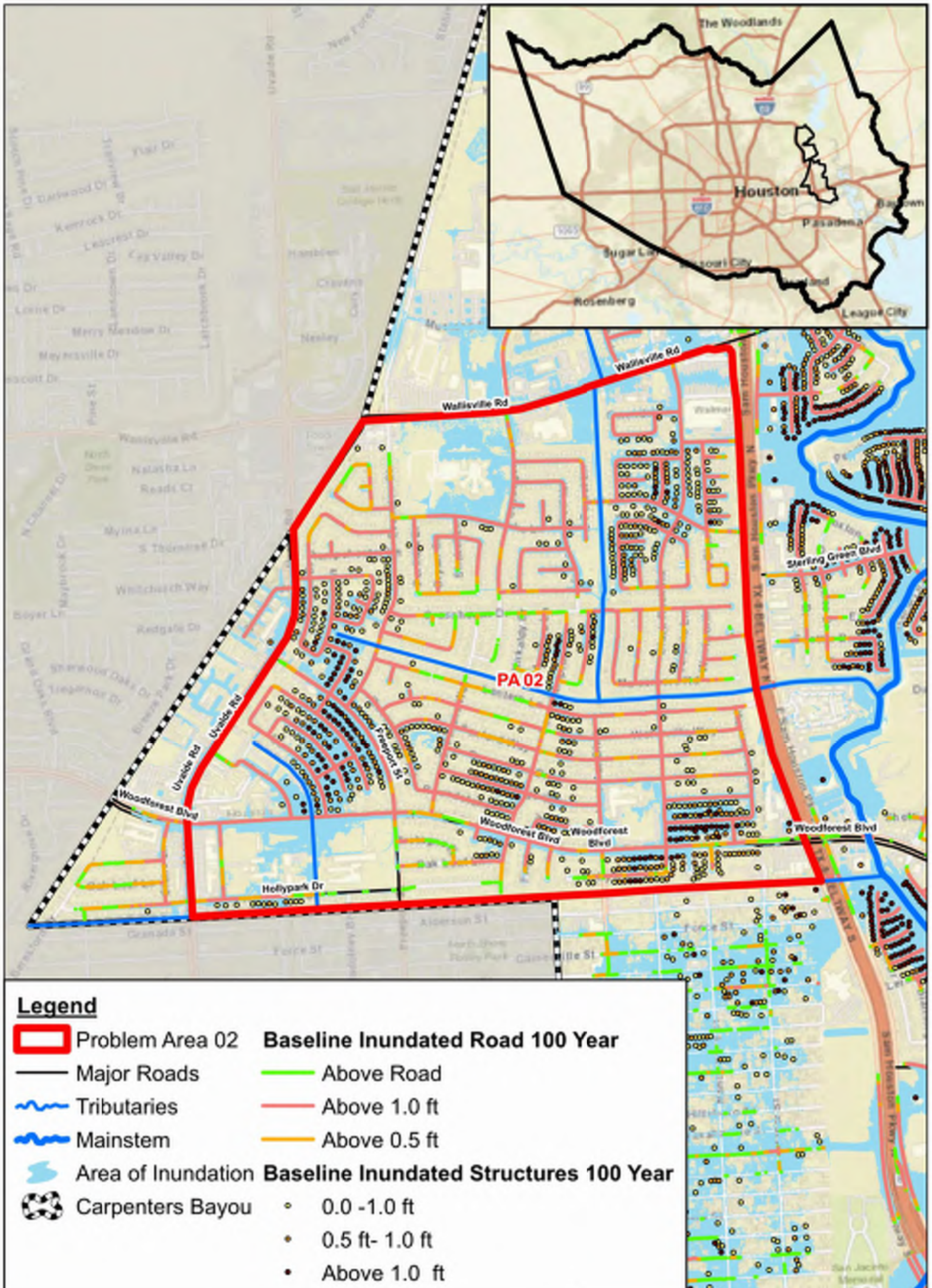
Miles
0 0.15 0.3

N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

Exhibit 20
Problem Area 2

Miles
0 0.1 0.2 0.4

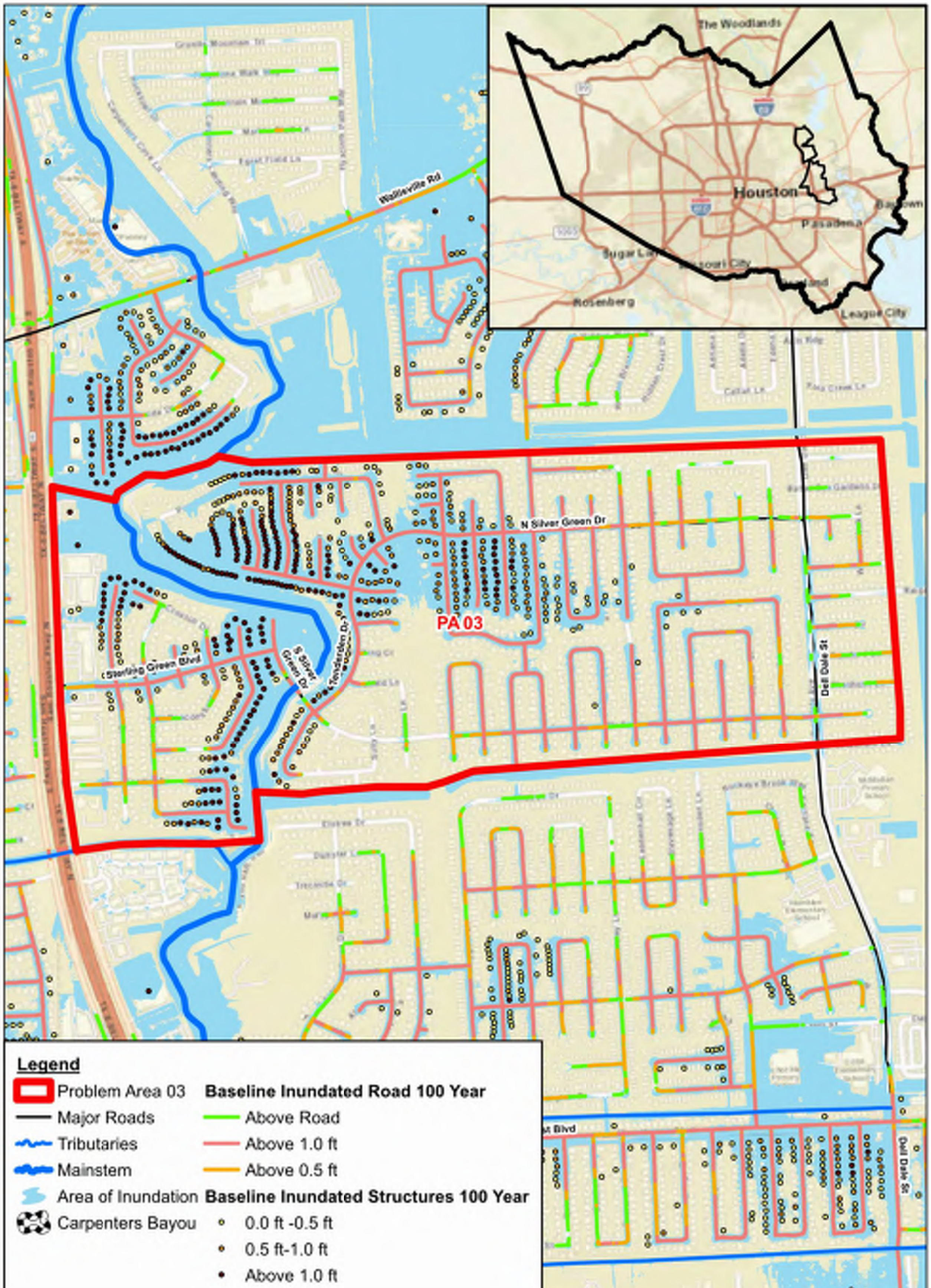
N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 21
Problem Area 3

N

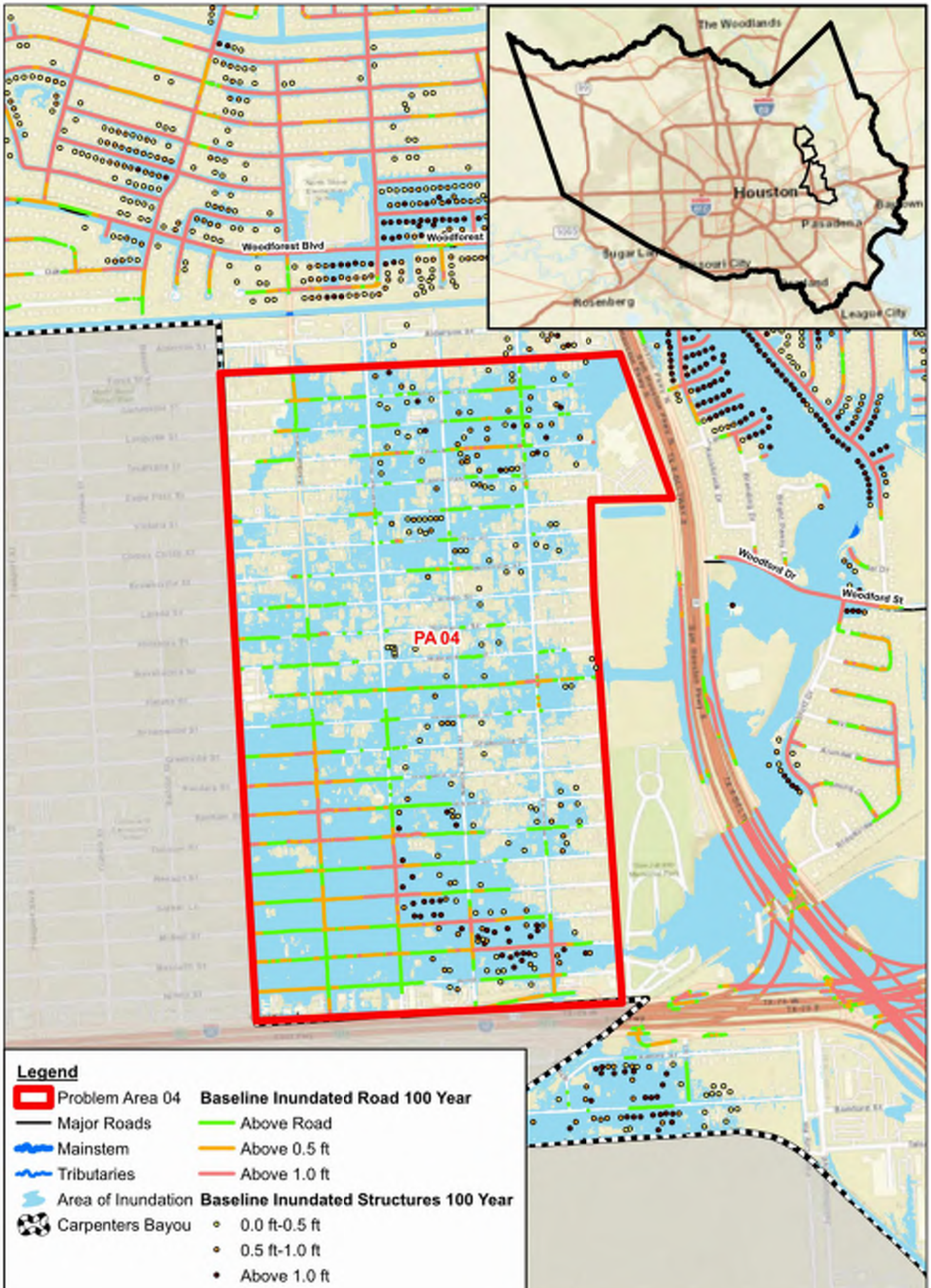
Miles
0 0.1 0.2

Created: 9/22/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 22
Problem Area 4

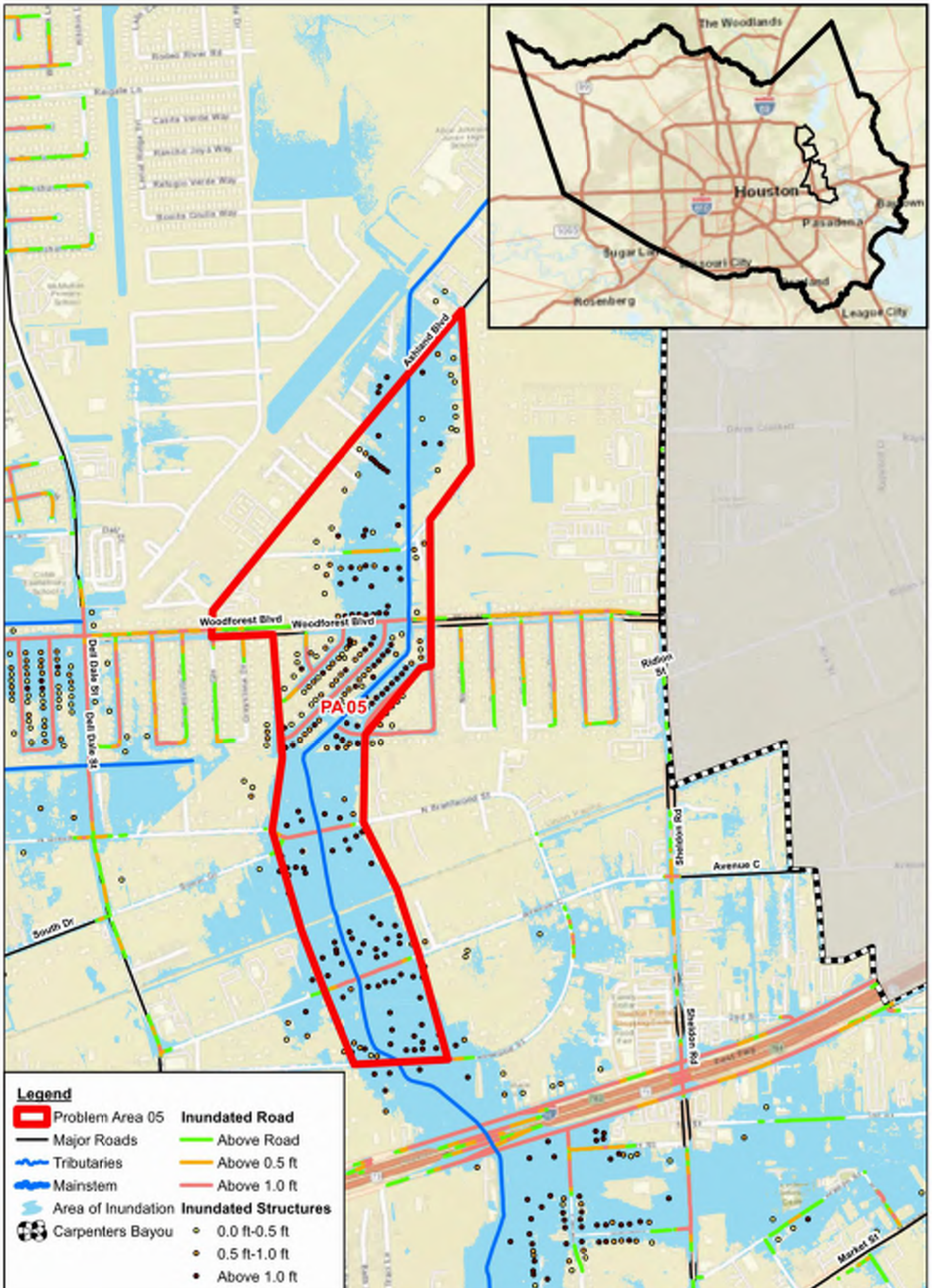
Miles
0 0.15 0.3

N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

Exhibit 23
Problem Area 5

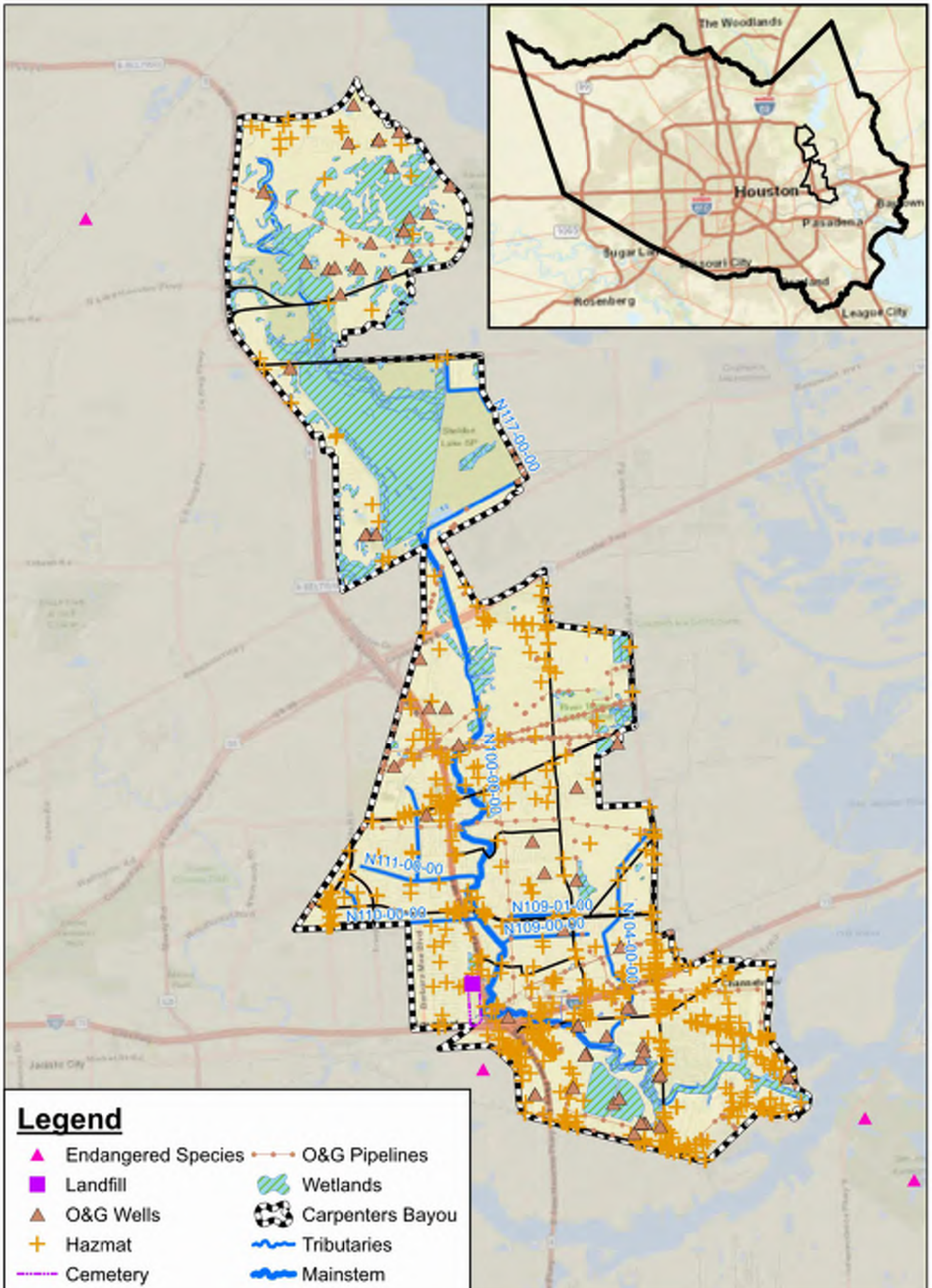
Miles
0 0.1 0.2

N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

Exhibit 24
Environmental Constraints

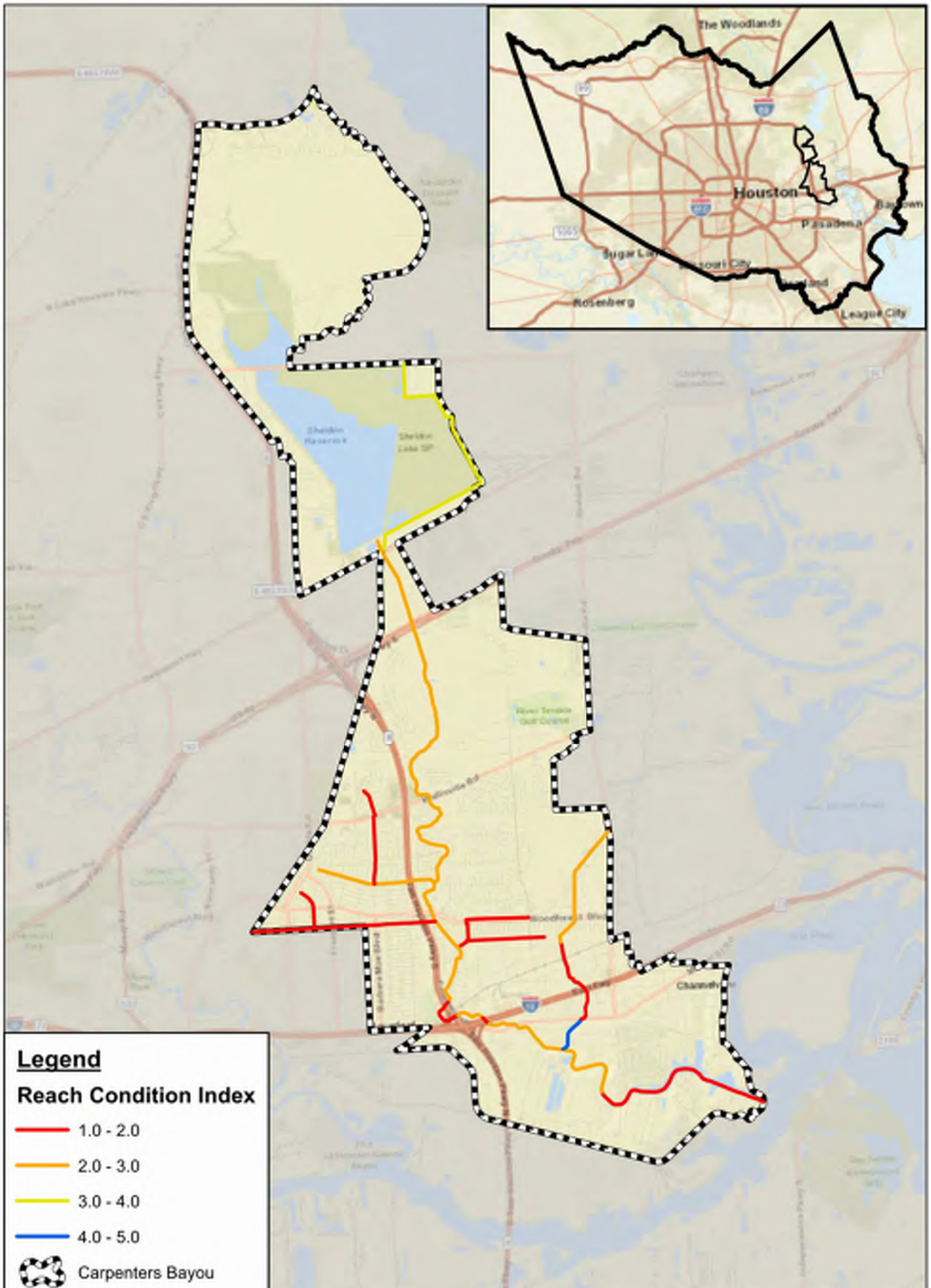
Miles
0 0.75 1.5

N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

Attachment #1 Interim Deliverable



Technical Memorandum 1

Exhibit 25
Geomorphological Assessment

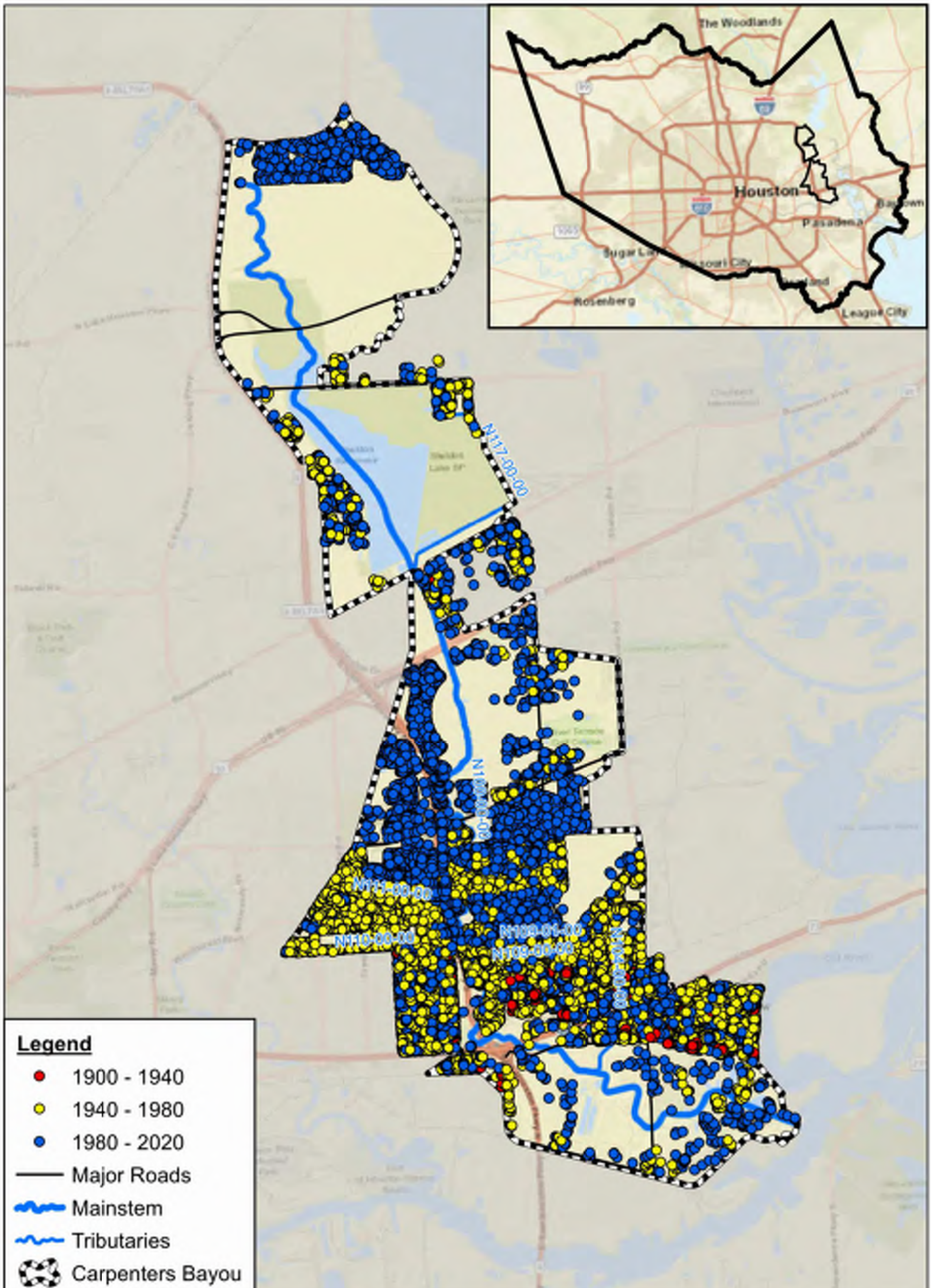
Miles
0 0.75 1.5

N

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT



Technical Memorandum 1

Exhibit 26
Age of Structures

Created: 9/22/2020

Carpenters Bayou Watershed Plan

FLOOD CONTROL DISTRICT

Appendix A

Supporting Tables and Graphs

Attachment #1 Interim Deliverable

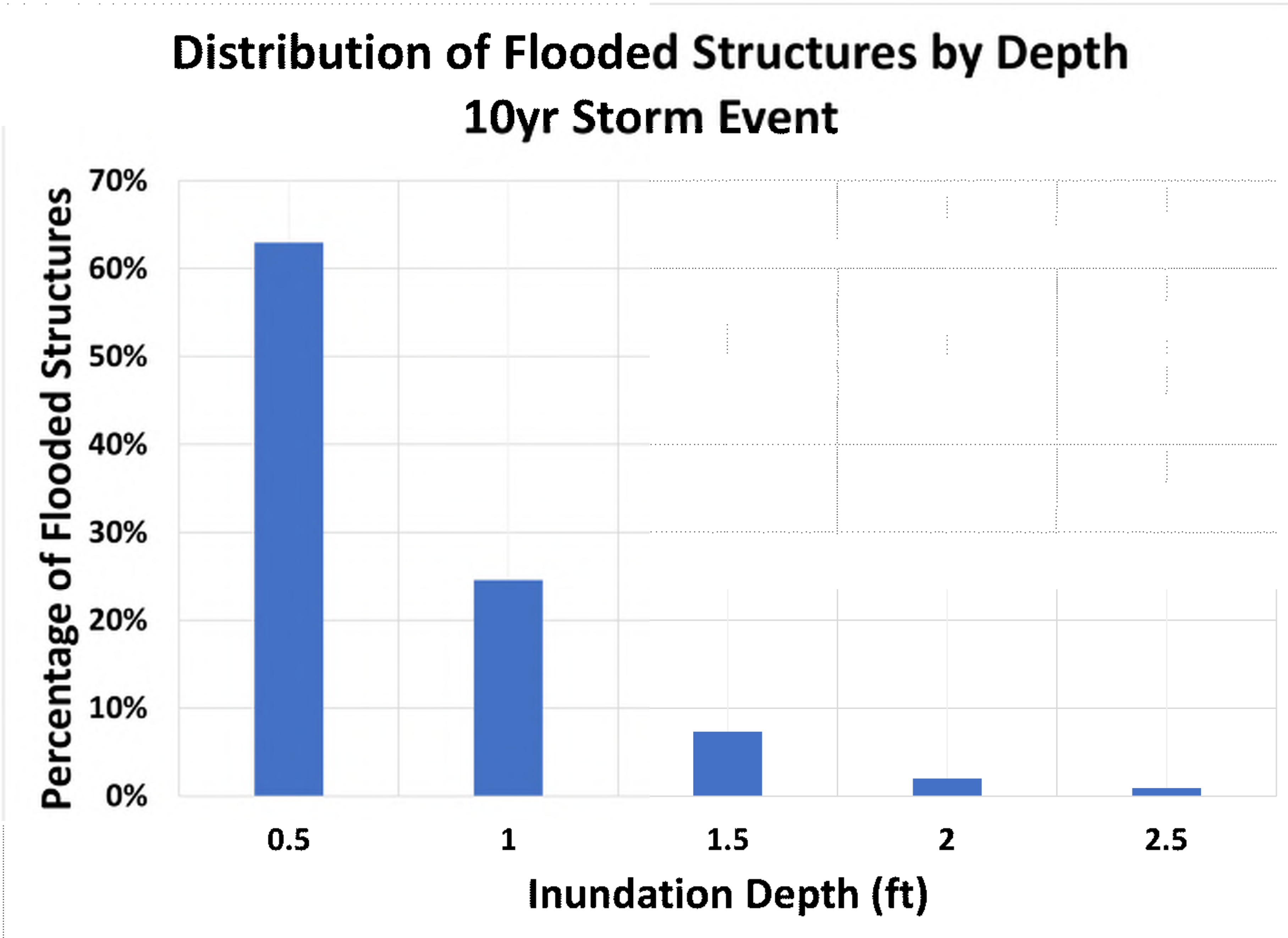
Tc and R Calculations

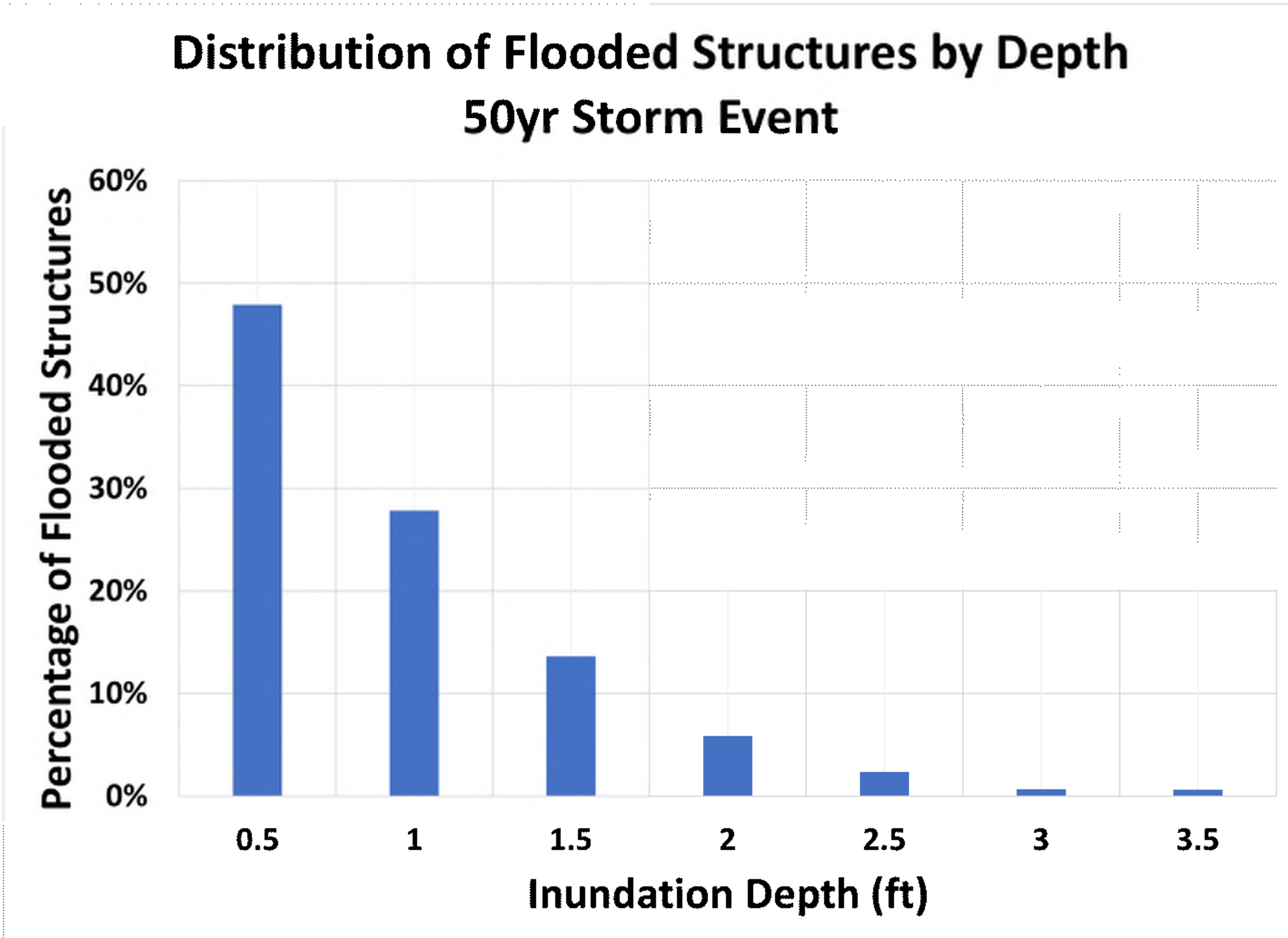
Updated by Torres & Associates 04/15/2020

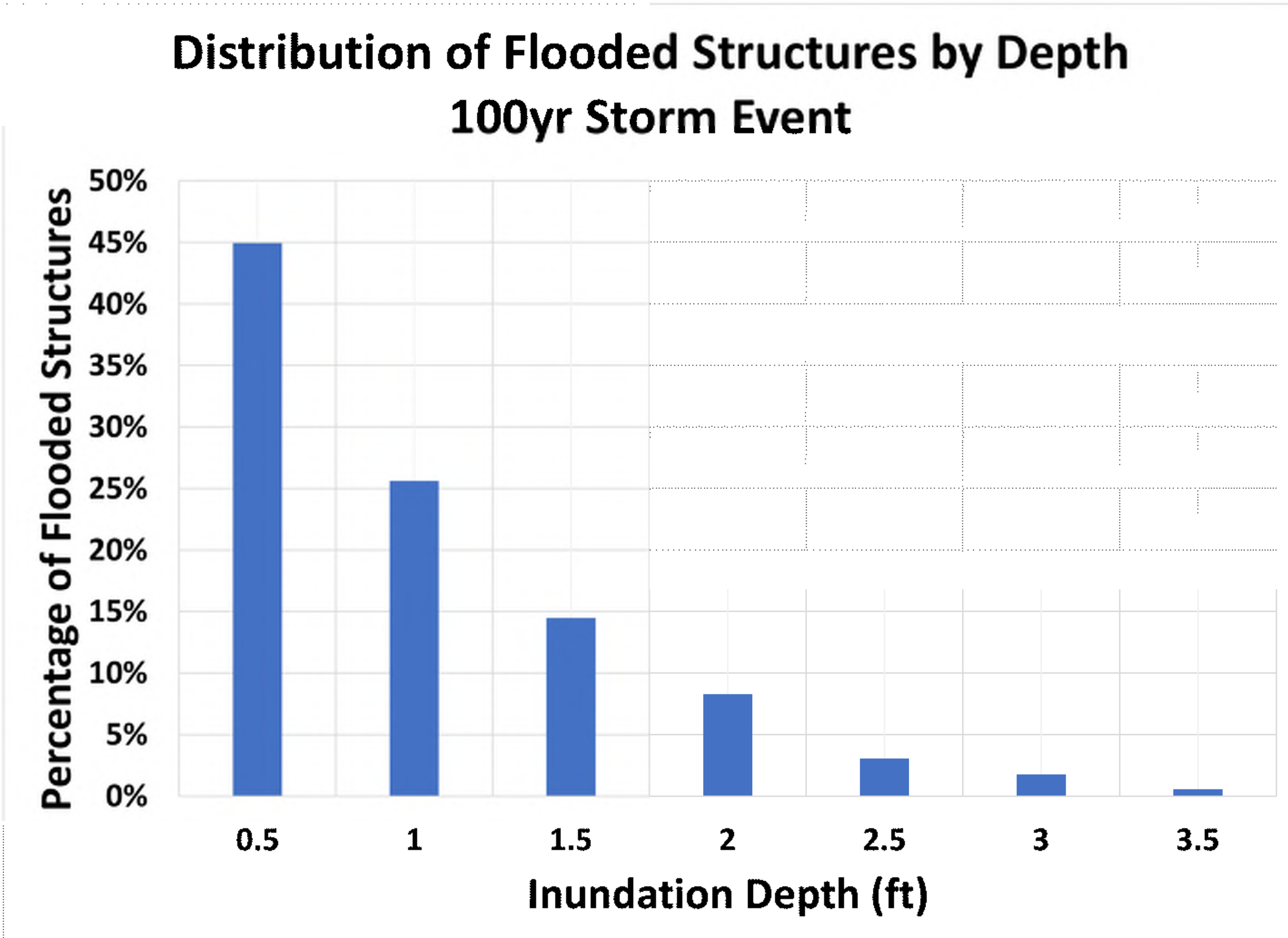
TC&R values for Baseline Conditions Model

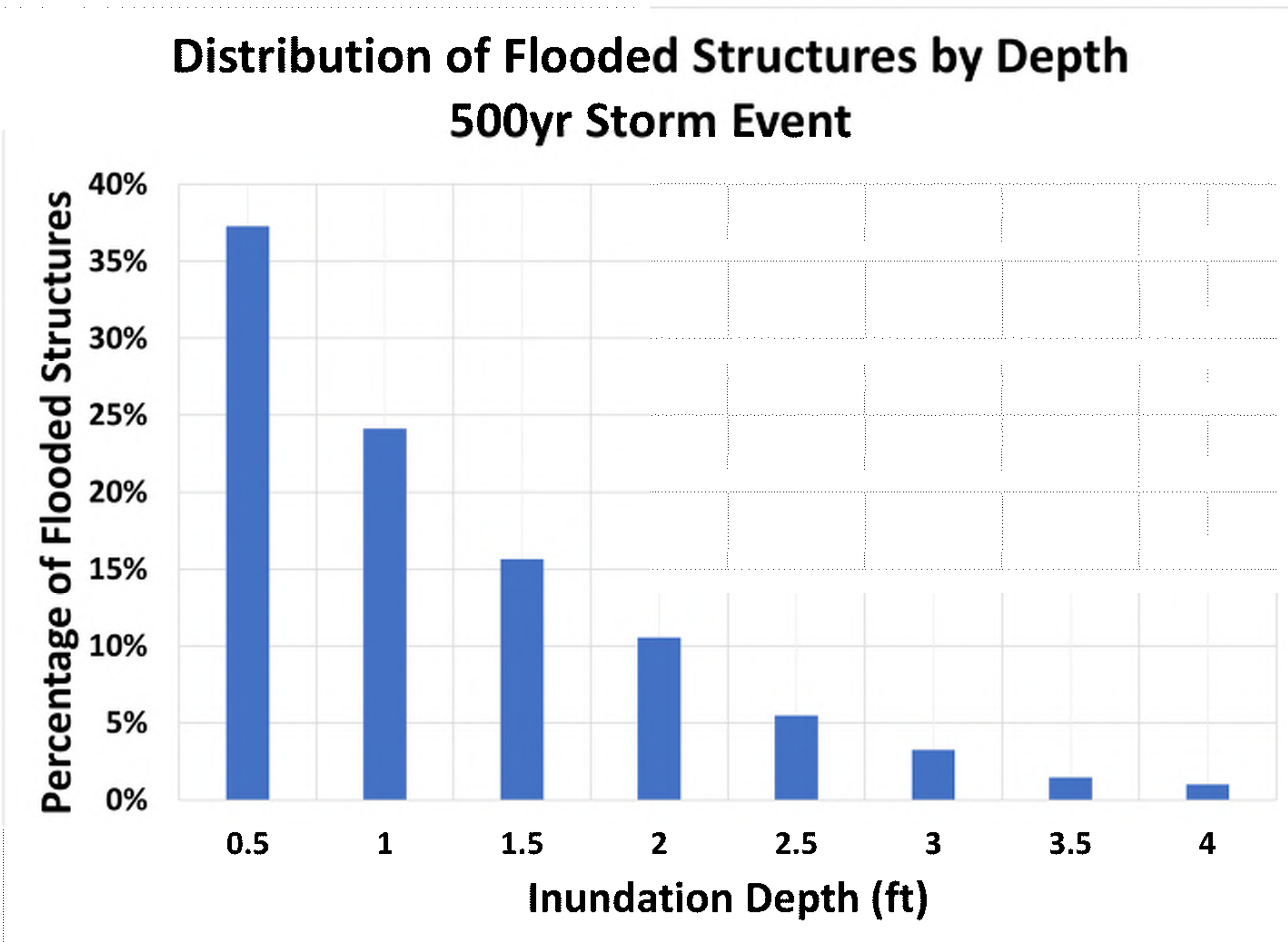
Carpenters Bayou Watershed

Subwatershed	Drainage Area (acres)	Drainage Area (sq.mi.)	Watershed Length (mi.) L	Length to Centroid(mi.) Lca	Channel Slope(ft./mi) S	Overland Slope(ft./mi.) So	D	Percent Urban Development 2002 DLU	Percent Channel Improvement DCI	Percent Channel Conveyance DCC	Percent Ponding DPP	DLU affected by Detention DET	Percent Impervious 2002	(TC+R)"	TC"	R"	DLU Minimum	DLU (Detention)
N100A	3962	6.19	4.93	2.07	1.90	10.00	2.46	**3.94**	0	100	0	0.04	11.46	17.83	**3.76**	**14.07**	17.59	3.94
N100B	1405	2.20	3.78	1.38	1.90	10.00	2.46	**0.51**	0	100	0	0.15	91.63	14.78	**2.46**	**12.32**	17.59	0.51
N100C	691	1.08	0.66	0.31	1.80	10.00	2.46	**33.10**	100	70	0	0.04	23.60	3.97	**0.26**	**3.71**	29.03	33.06
N100D	704	1.10	2.69	1.20	5.46	5.28	2.46	**50.17**	100	90	0	0.01	35.80	4.30	**0.57**	**3.73**	20.39	50.16
N100E	779	1.22	2.35	0.66	1.07	7.39	2.46	**14.36**	100	70	0	0.29	12.20	12.94	**0.82**	**12.12**	29.03	14.36
N100F	2086	3.26	2.76	1.89	5.18	6.34	2.46	**18.04**	100	80	0	0.25	15.68	8.31	**1.08**	**7.23**	24.06	18.04
N100G	543	0.85	2.27	0.68	4.16	5.28	2.46	**50.11**	100	100	0	0.27	31.00	3.81	**0.36**	**3.44**	17.59	49.84
N100H	1756	2.74	3.89	1.66	5.17	7.39	2.46	**61.56**	100	100	0	0.65	40.55	4.50	**0.80**	**3.71**	17.59	60.91
N100I	700	1.09	1.69	0.73	3.94	6.86	2.46	**75.35**	100	90	0	0.11	45.57	2.64	**0.36**	**2.28**	20.39	75.24
N100J	835	1.30	1.71	0.68	3.12	13.20	2.46	**69.66**	100	60	0	0.09	42.44	4.51	**0.39**	**4.12**	36.04	69.57
N100K	1153	1.80	2.26	0.88	2.73	8.98	2.46	**55.34**	60	40	0	0.00	42.85	9.04	**0.80**	**8.24**	63.71	55.34
N100L	2367	3.70	4.15	1.52	1.55	5.28	2.46	**55.46**	66	70	0	0.00	43.16	10.85	**1.86**	**9.00**	29.03	55.46
N104	1617	2.53	4.18	1.97	12.07	7.39	2.46	**44.49**	86	60	0	0.58	29.12	7.19	**0.73**	**6.45**	36.04	43.91
N117	901	1.41	3.51	1.63	4.54	1.06	2.46	**11.76**	26	90	0	2.77	7.50	10.31	**1.60**	**8.71**	20.39	11.76

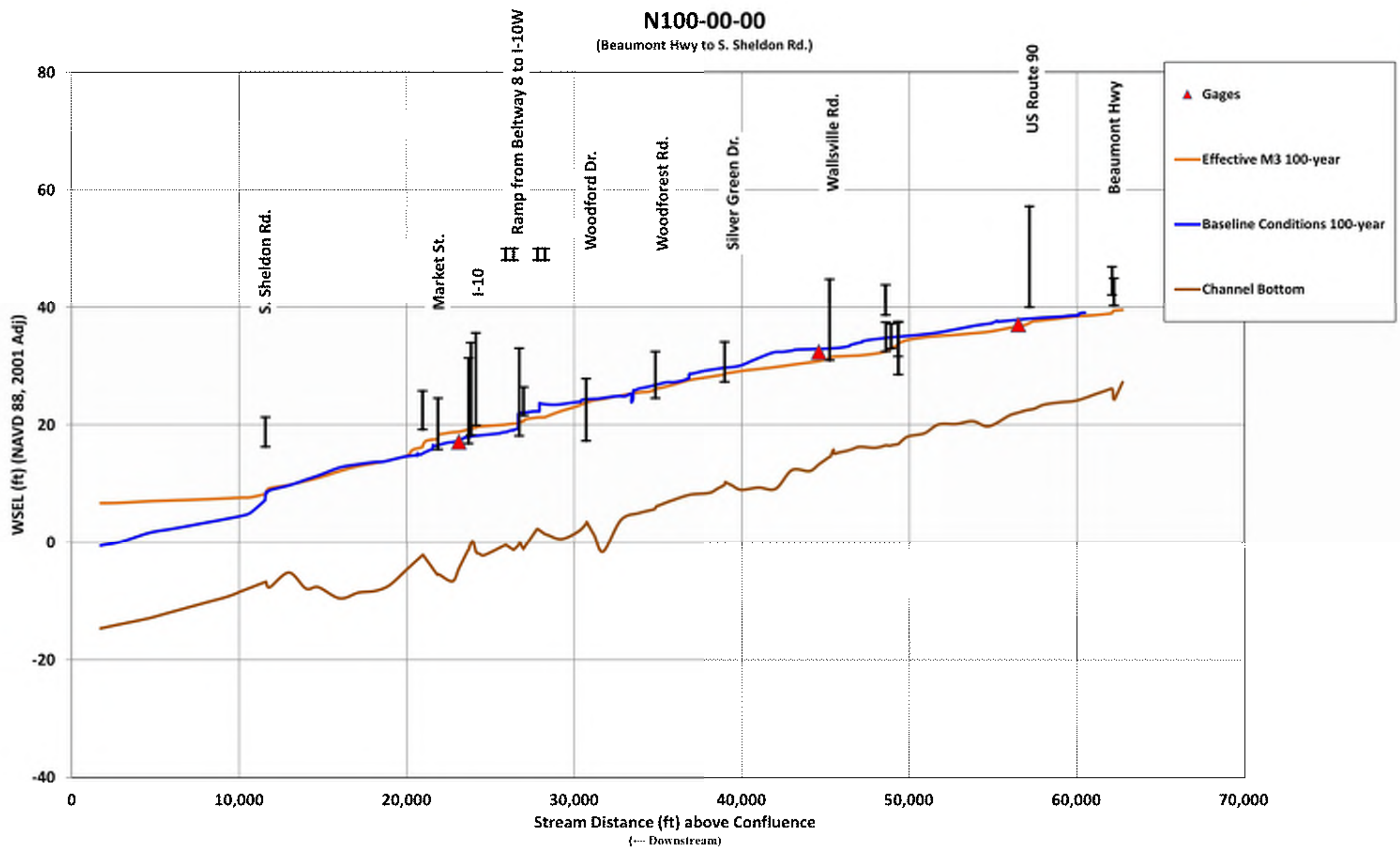

Distribution of Flooded Structures by Depth
10yr Storm Event
Percentage of Flooded Structures
70%
60%
50%
40%
30%
20%
10%
0%
0.5
1
1.5
2
2.5
Inundation Depth (ft)


Distribution of Flooded Structures by Depth
50yr Storm Event
Percentage of Flooded Structures
60%
50%
40%
30%
20%
10%
0%
0.5
1
1.5
2
2.5
3
3.5
Inundation Depth (ft)


Distribution of Flooded Structures by Depth
100yr Storm Event
Percentage of Flooded Structures
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1
1.5
2
2.5
3
3.5
Inundation Depth (ft)

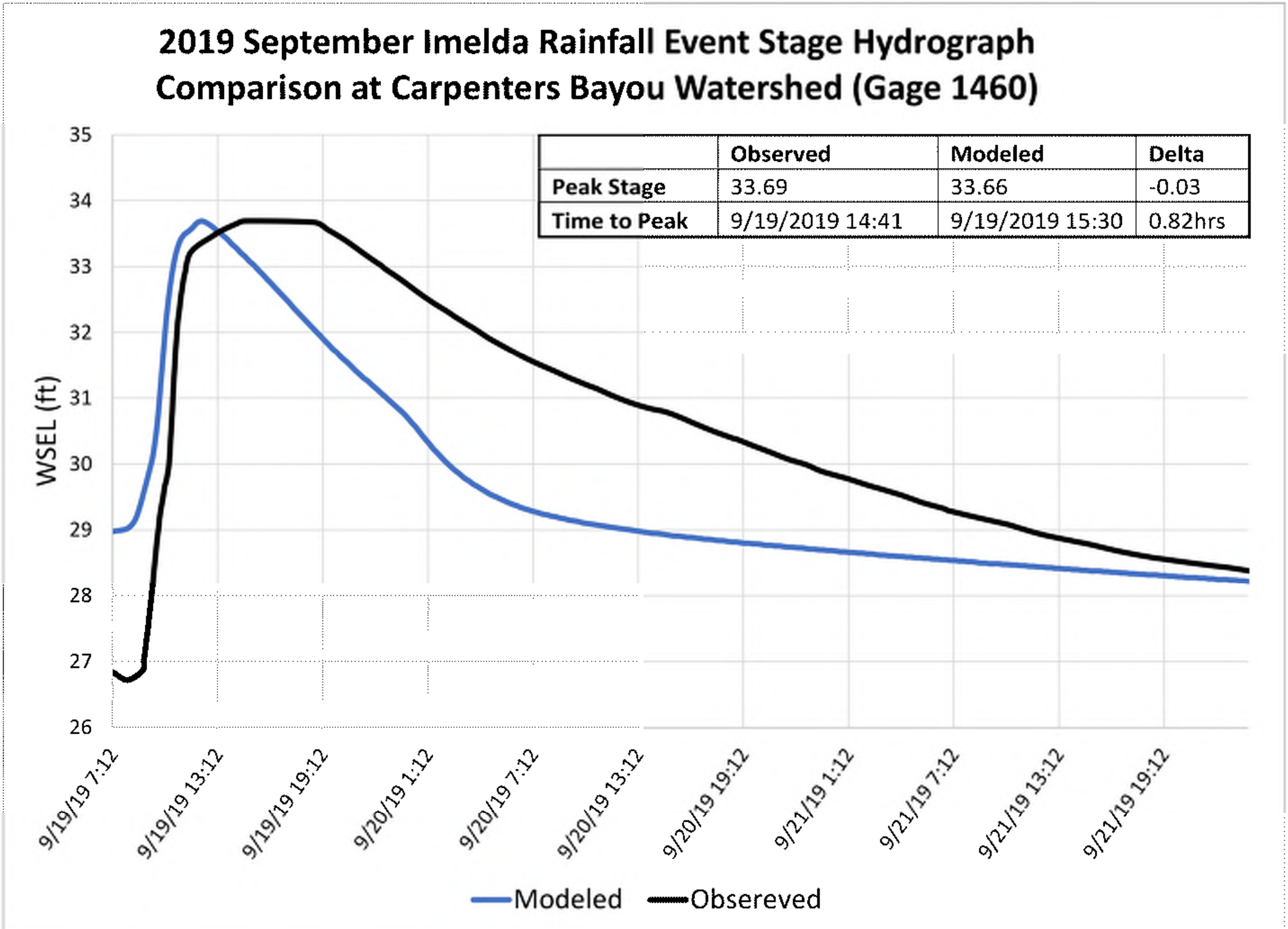

Distribution of Flooded Structures by Depth
500yr Storm Event
Percentage of Flooded Structures
40%
35%
30%
25%
20%
15%
10%
5%
0%
0.5
1
1.5
2
2.5
3
3.5
4
Inundation Depth (ft)

Attachment #1 Interim Deliverable



Appendix B

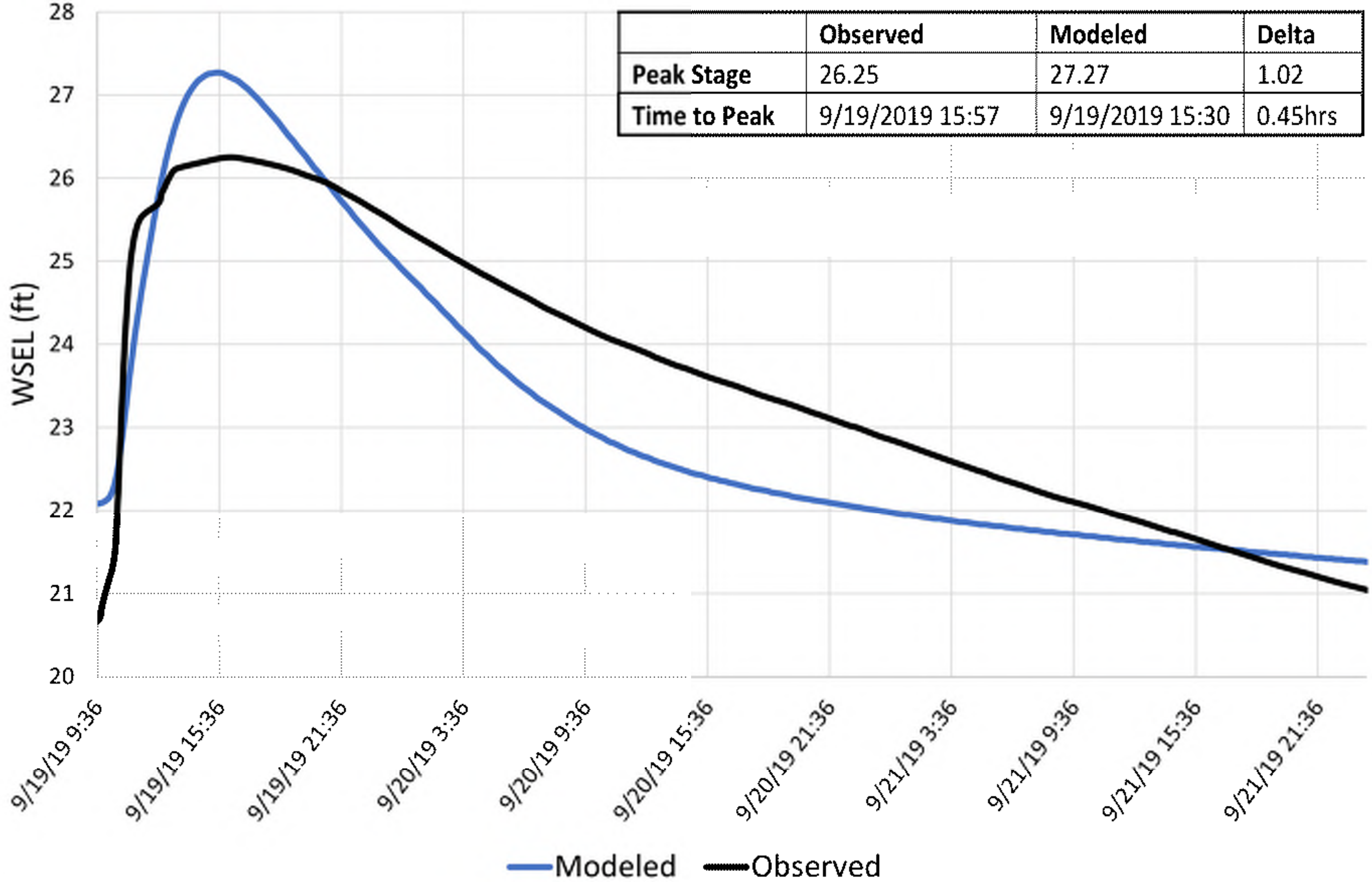
Hydrographs & Water Surface Profiles



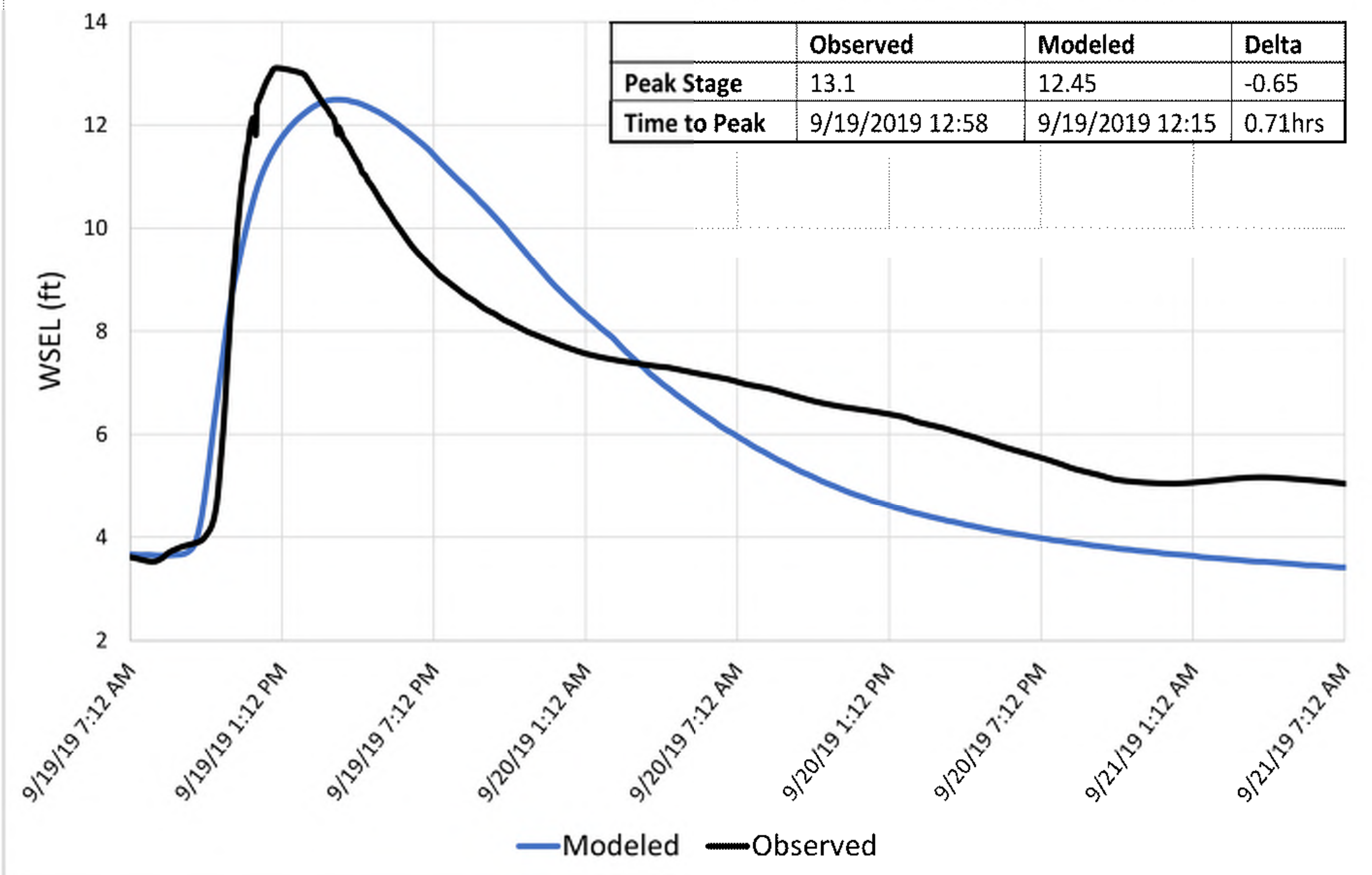
	Observed	Modeled	Delta
Peak Stage	33.69	33.66	-0.03
Time to Peak	9/19/2019 14:41	9/19/2019 15:30	0.82hrs

2019 September Imelda Rainfall Event Stage Hydrograph Comparison at Carpenters Bayou Watershed (Gage 1440)

	Observed	Modeled	Delta
Peak Stage	26.25	27.27	1.02
Time to Peak	9/19/2019 15:57	9/19/2019 15:30	0.45hrs

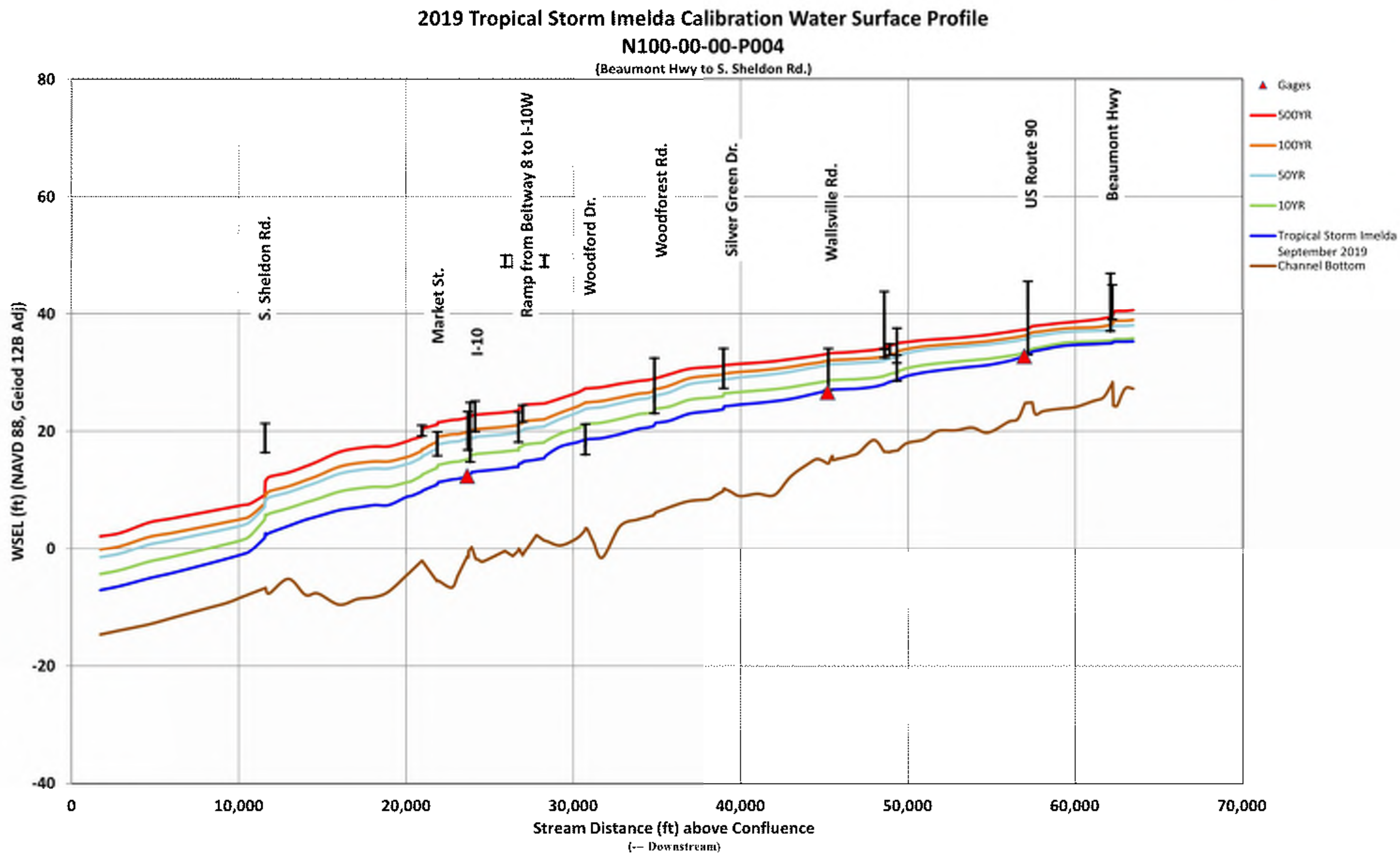


2019 September Imelda Rainfall Event Stage Hydrograph Comparison at Carpenters Bayou Watershed (Gage 1420)



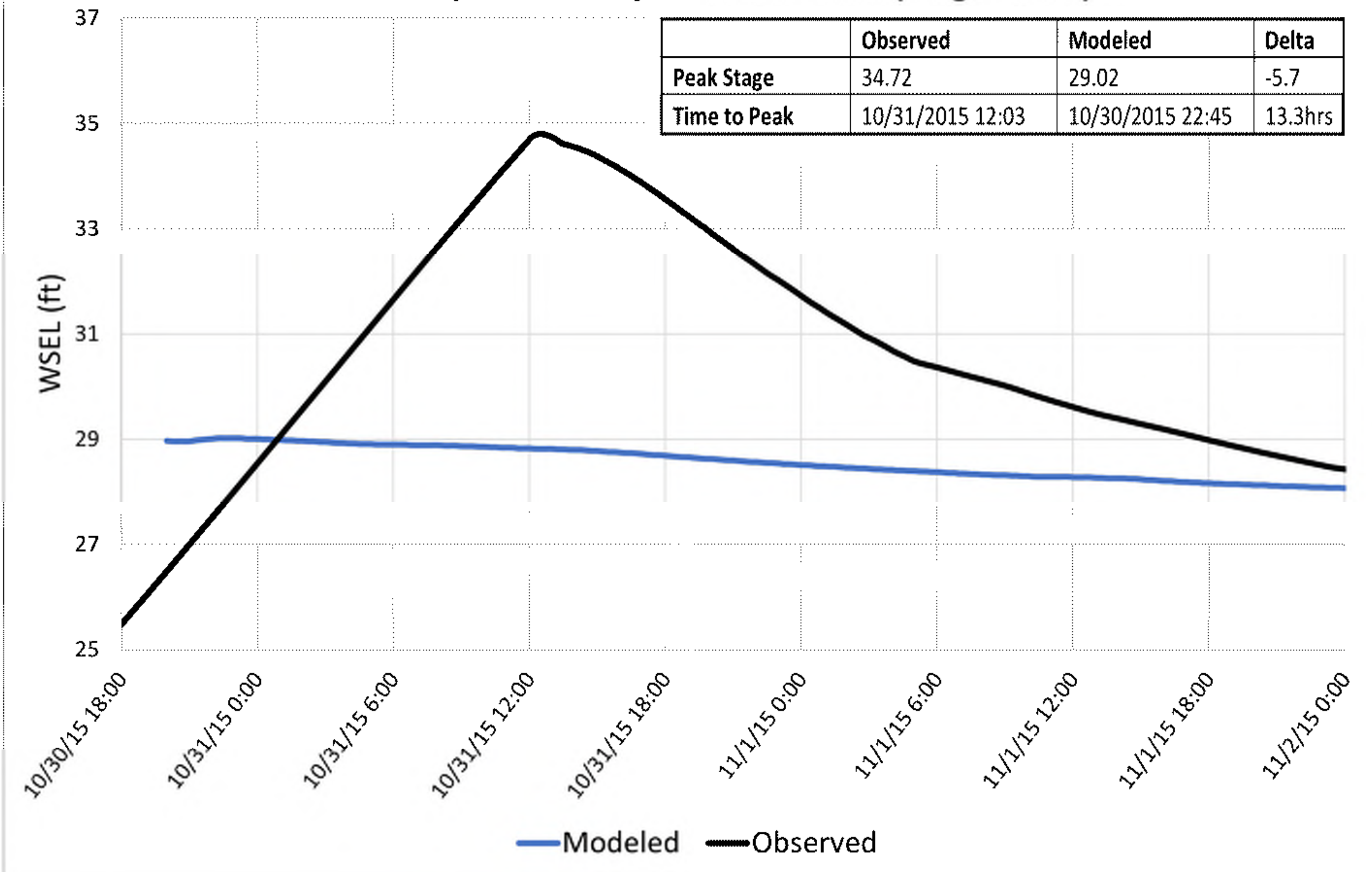
	Observed	Modeled	Delta
Peak Stage	13.1	12.45	-0.65
Time to Peak	9/19/2019 12:58	9/19/2019 12:15	0.71hrs

Attachment #1 Interim Deliverable



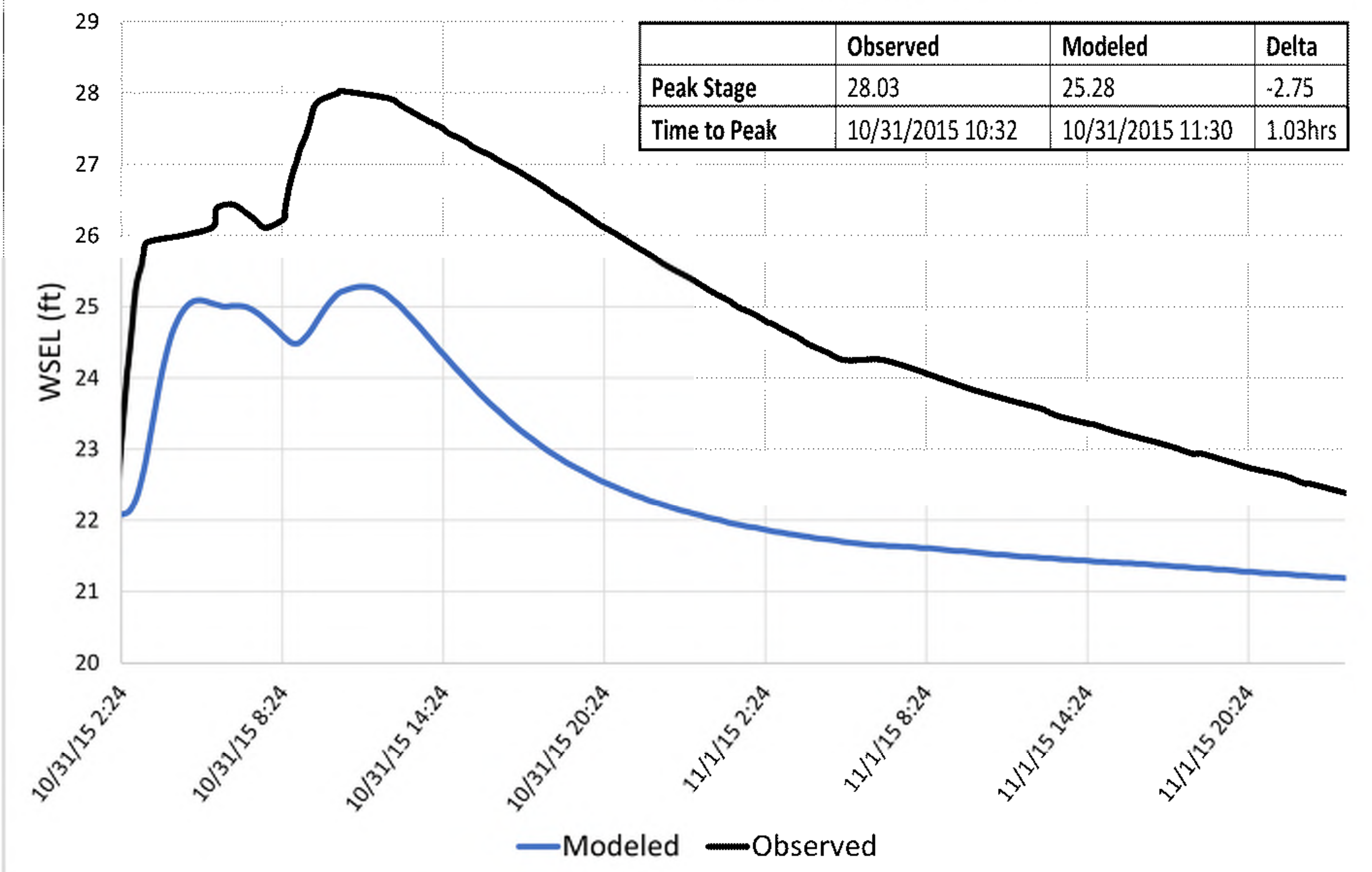
2015 October Halloween Event Stage Hydrograph Comparison at Carpenters Bayou Watershed (Gage 1460)

	Observed	Modeled	Delta
Peak Stage	34.72	29.02	-5.7
Time to Peak	10/31/2015 12:03	10/30/2015 22:45	13.3hrs



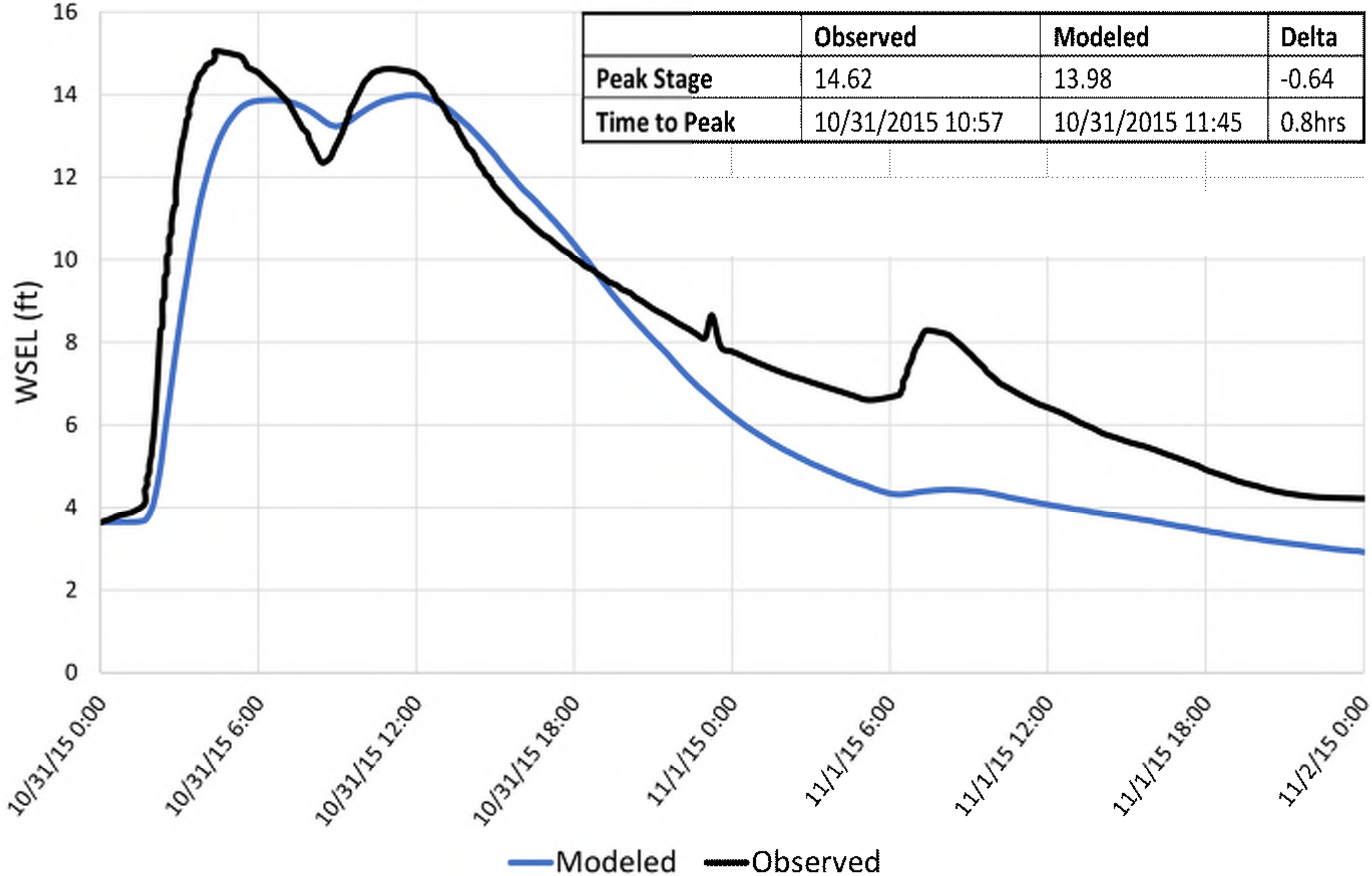
2015 October Halloween Event Stage Hydrograph Comparison at Carpenters Bayou Watershed (Gage 1440)

	Observed	Modeled	Delta
Peak Stage	28.03	25.28	-2.75
Time to Peak	10/31/2015 10:32	10/31/2015 11:30	1.03hrs

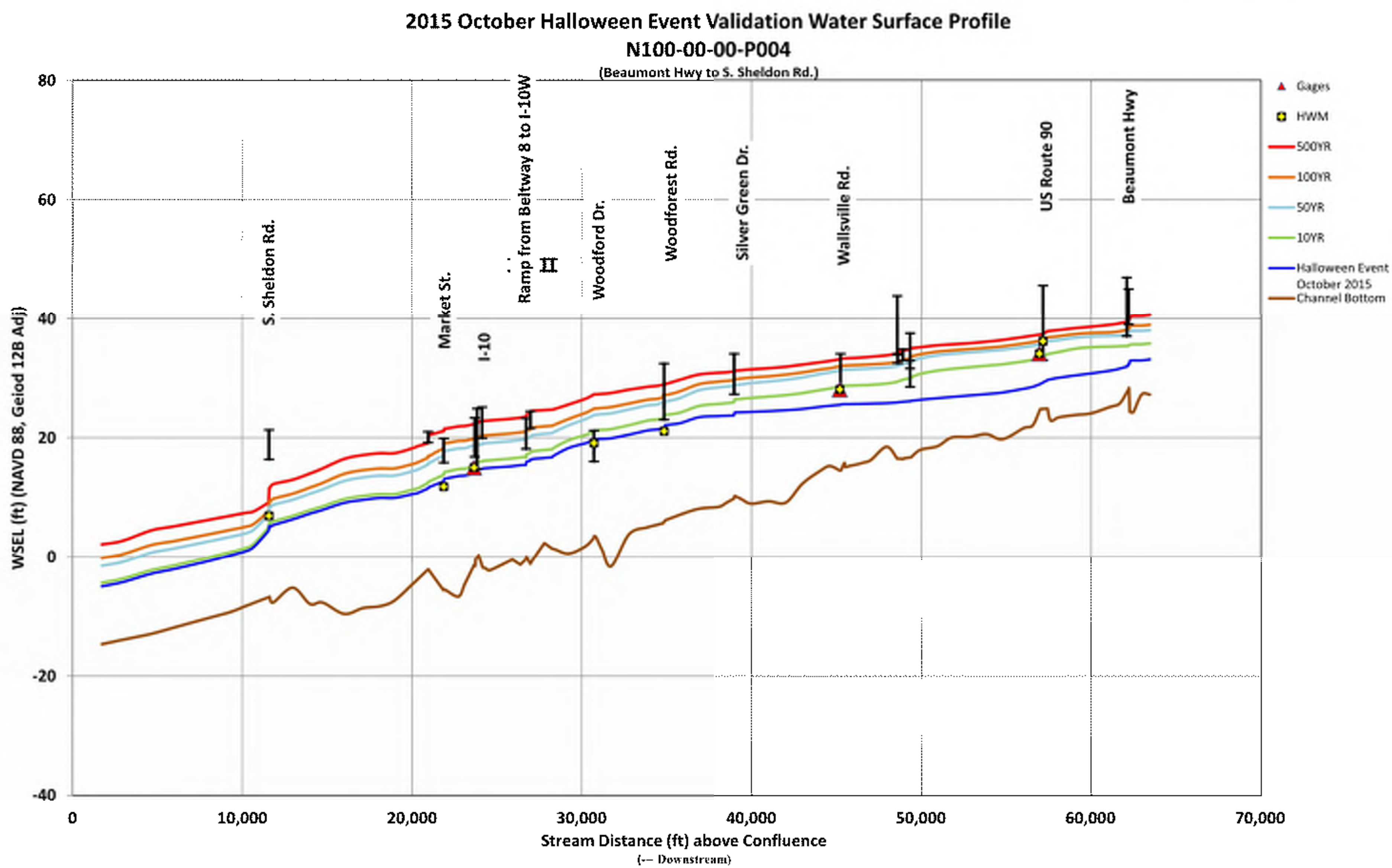


2015 October Halloween Event Stage Hydrograph Comparison at Carpenters Bayou Watershed (Gage 1420)

	Observed	Modeled	Delta
Peak Stage	14.62	13.98	-0.64
Time to Peak	10/31/2015 10:57	10/31/2015 11:45	0.8hrs



Attachment #1 Interim Deliverable



Appendix C

Problem Area Metrics

Miles of Inundated Roadway (10-year)

10 year Rainfall Event								
Miles of Inundated Roadway Above 0 ft					Miles of Inundated Roadway Above 1 ft			
PA	Category 1 (Interstate, Other Freeways, and Expressways)	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)		PA	Category 1 (Interstate, Other Freeways,	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)
1		1.80	9.62		1		1.46	7.82
2		0.99	8.97		2		0.29	1.31
3		2.52	10.45		3		2.12	8.93
4		2.69	10.40		4		1.88	8.51
5		0.67	1.52		5		0.44	1.36
6		1.08	2.15		6		0.36	0.15
7	0.39	0.34	5.78		7	0.26	0.34	4.78
8	0.09	0.07	0.44		8	0.02	0.03	
9		0.04	0.27		9		0.02	
10		0.24	0.06		10		0.20	0.05
11			0.08		11			0.07

Miles of Inundated Roadway (50-year)

50 year Rainfall Event								
Miles of Inundated Roadway Above 0 ft					Miles of Inundated Roadway Above 1 ft			
PA	Category 1 (Interstate, Other Freeways, and Expressways)	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)		PA	Category 1 (Interstate, Other Freeways, and Expressways)	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)
1		2.25	9.99		1		1.86	9.10
2		1.55	11.92		2		0.38	2.28
3		2.66	10.66		3		2.60	10.35
4		2.92	11.47		4		2.49	10.21
5		0.80	1.61		5		0.62	1.49
6		1.35	2.58		6		0.46	0.30
7	0.4	0.34	6.29		7	0.33	0.34	5.66
8	0.05	0.06	0.64		8		0.01	0.00
9		0.01	0.39		9		0.01	0.38
10		0.49	0.09		10		0.45	0.09
11			0.13		11			0.08

Miles of Inundated Roadway (100-year)

100 year Rainfall Event								
Miles of Inundated Roadway Above 0 ft					Miles of Inundated Roadway Above 1 ft			
PA	Category 1 (Interstate, Other Freeways, and Expressways)	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)		PA	Category 1 (Interstate, Other Freeways, and Expressways)	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)
1		2.31	10.08		1		2.10	9.45
2		1.62	13.06		2		0.39	3.02
3		2.74	10.66		3		2.64	10.56
4		2.98	11.63		4		2.64	10.83
5		0.60	1.63		5		0.60	1.53
6		1.54	2.81		6		0.57	0.46
7	0.41	0.34	6.38		7	0.35	0.34	5.91
8	0.14	0.09	0.67		8	0.02	0.04	0.05
9		0.53	0.39		9		0.43	0.39
10		0.50	0.09		10		0.49	0.09
11			0.12		11			0.10

Miles of Inundated Roadway (500-year)

500 year Rainfall Event								
Miles of Inundated Roadway Above 0 ft					Miles of Inundated Roadway Above 1 ft			
PA	Category 1 (Interstate, Other Freeways, and Expressways)	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)		PA	Category 1 (Interstate, Other Freeways, and Expressways)	Category 2 (Other Arterials and Major Collectors)	Category 3 (All other local roadways)
1		2.49	10.33		1		2.30	9.93
2		2.21	14.96		2		0.72	7.07
3		2.85	10.66		3		2.76	10.66
4		3.18	11.70		4		2.89	11.55
5		0.84	1.65		5		0.79	1.61
6		1.87	3.26		6		0.84	1.21
7	0.43	0.34	6.44		7	0.4	0.34	6.32
8	0.18	0.09	0.77		8	0.03	0.04	0.42
9		0.54	0.39		9		0.54	0.39
10		0.32	0.09		10		0.32	0.09
11			0.16		11			0.11

Problem Area Scoring

Weighting Factor	45%	10%	45%	Scoring (%)			
Problem Area	TPASF50	Total Miles of Inundated Roadway for 100yr [Flooded > 1ft]	Flood Claims (Count)	TPASF50	Total Miles of Inundated Roadway for 100yr [Flooded > 1ft]	Flood Claims (Count)	Total Score
PA 1	853.9	13.59	64	22.9	5.6	45.0	73.5
PA 2	1680.5	24.09	12	45.0	10.0	8.4	63.4
PA 3	867.2	11.37	21	23.2	4.7	14.8	42.7
PA 4	661.9	3	32	17.7	1.2	22.5	41.5
PA 5	569.8	1.53	25	15.3	0.6	17.6	33.5
PA 6	198.1	0.06	12	5.3	0.0	8.4	13.8
PA 7	30.7	5.91	4	0.8	2.5	2.8	6.1
PA 8	78.3	0.48	3	2.1	0.2	2.1	4.4
PA 9	111.1	0.39	1	3.0	0.2	0.7	3.8
PA 10	20.5	0.09	2	0.5	0.0	1.4	2.0
PA 11	71.7	0.1	0	1.9	0.0	0.0	2.0
MAX	1680.5	24.09	64				

Appendix D

Geomorphological Assessment

Geomorphological Assessment

Stream Name	Torres & Associates Geomorphological Assessment							
	Unit ID	Linear Reference	Cross Section ID	Channel Condition Score	Riparian Buffer Parameter	Aquatic Use Parameter	Reach Condition Index(RCI)	Color Code
Carpenters Bayou	N100-00-00	0-6062.10	63000-56945.8	3	3	2	2.7	orange
Carpenters Bayou	N100-00-00	6062.10-13650.4	56945.8-50887.3	3	3	2	2.7	orange
Carpenters Bayou	N100-00-00	13650.4-14336.79	50887.3-47941.3	2.5	3	3	2.8	orange
Carpenters Bayou	N100-00-00	14336.79-26807.83	47941.3-35246.0	3	2	3	2.7	orange
Carpenters Bayou	N100-00-00	26807.83-32573.71	35246.0-29239.0	3	2	3	2.7	orange
Carpenters Bayou	N100-00-00	32573.71-33427.77	29239.0-28255.5	3.5	2.5	3	3.0	yellow
Carpenters Bayou	N100-00-00	33427.77-33965.72	28255.5-27780.5	3	2	1	2.0	orange
Carpenters Bayou	N100-00-00	33965.72-35898.35	27780.5-25896.5	2.5	2	1	1.8	red
Carpenters Bayou	N100-00-00	35898.35-37576.62	25896.5-24159.3	3.5	3	1	2.5	orange
Carpenters Bayou	N100-00-00	37576.62-38040.32	24159.3-23653.7	3	2	1	2.0	orange
Carpenters Bayou	N100-00-00	38040.32-39589.61	23653.7-21894.0	3.5	2	1	2.2	orange
Carpenters Bayou	N100-00-00	39589.61-49503.48	21894.0-12968.0	4	4	1	3.0	yellow
Carpenters Bayou	N100-00-00	49503.48-60034.07	12968.0-1727.0	2	1.5	1	1.5	red
Carpenters Bayou	N117-00-00	0-2857.98	8530.0-73.0	4.5	4	1	3.2	yellow
Carpenters Bayou	N104-00-00	0-713.92	11246.0-10354.0	3	2	2	2.3	orange
Carpenters Bayou	N104-00-00	713.92-1315.34	10354.0-9793.5	3	2	2	2.3	orange
Carpenters Bayou	N104-00-00	1315.34-2861.29	9793.5-7912.0	2.5	2	2	2.2	orange
Carpenters Bayou	N104-00-00	2861.29-8925.58	7912.0-2231.6	2	2	2	2.0	orange
Carpenters Bayou	N104-00-00	8925.58-11450.13	2231.6-736.0	4	4.5	4	4.2	blue
Carpenters Bayou	N110-00-00	0-5149.64	11156-5539	2	2	1	1.7	red
Carpenters Bayou	N110-00-00	5149.64-11116.04	5539-112	2	2	1	1.7	red
Carpenters Bayou	N110-02-00	0-2472.85	2446-1214	2	2	2	2.0	orange
Carpenters Bayou	N111-00-00	0-7300.35	7255-111	2	2	4	2.7	orange
Carpenters Bayou	N111-01-00	0-3993.91	5914-2073	2	2	2	2.0	orange
Carpenters Bayou	N111-01-00	3993.91-5890.37	2073-208	2	2	2	2.0	orange
Carpenters Bayou	N109-00-00	0-5403.78	5397-40	1.5	1.5	2	1.7	red
Carpenters Bayou	N109-01-00	0-5056.52	5082-294	2.5	1.5	1	1.7	red

Attachment #2

Technical Memorandum #2

INTERIM REVIEW ONLY
This document was submitted for interim review only and is not intended for construction, bidding, permit, or final submittal purposes.

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Carpenters Bayou Watershed Plan

Technical Memorandum #2:

Strategies for Improvements

March 3, 2021

Prepared by:

Torres & Associates, LLC

Table of Contents

Acknowledgements

This planning project represents a key milestone towards the greater management and success of the Harris County 2018 Bond Projects for Flood Mitigation and is the product of interdisciplinary coordination between HCFCD, engineering consultants, key stakeholders, and the general public. Torres & Associates is particularly grateful to HCFCD staff for their invested time, effort, and commitment towards providing Torres & Associates with necessary data, background, interim deliverable reviews, logistical guidance, and general insights on day-to-day, watershed-wide operations ranging from permitting reviews to ROW acquisition. This coordination was instrumental for evaluating effective and feasible flood risk management solutions with Carpenters Bayou watershed, as well as the successful management of the broader Harris County 2018 Bond Projects for Flood Mitigation.

List of Figures

List of Tables

Acronyms

1D	1-Dimensional
2D	2-Dimensional
BDF	Basin Development Factor
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
FWS	Flood Warning System
H&H	Hydrology & Hydraulics
HAZMAT	Hazardous Materials
HCAD	Harris County Appraisal District
HCFCD	Harris County Flood Control District
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
LOS	Level-of-Service
LiDAR	Light Detection and Ranging
MAAPnext	Modeling, Assessment and Awareness Project
NLCD	National Landover Cover Dataset
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OPCC	Opinion of Probable Construction Cost (OPCC)
TxDOT	Texas Department of Transportation
USGS	United States Geological Survey
CBW	Carpenters Bayou Watershed
WPP	Watershed Planning Project
WSEL	Water Surface Elevation
WSP	Water Surface Profile
OPCC	Opinion of Probable Construction Cost

PA	Problem Area
PER	Preliminary Engineering Report
ROW	Right-of-Way

1. Introduction

1.1. Overview of Watershed Planning Project

The Carpenters Bayou Watershed Planning Project (WPP) identifies a suite of recommended projects capable of advancing towards preliminary engineering reports (PER) and design as well as to formulate a broader watershed-wide regional strategy that helps mitigate inherent flood risks. The WPP is funded under the Harris County 2018 Bond Program. Methods employed in this WPP include hydrologic and hydraulic (H&H) analyses, related to 1D/2D modeling, environmental assessments, cost estimates, right-of-way (ROW) assessments, and communications. The Carpenters Bayou (HCFCD Unit No: N100-00-00) watershed is located in the east portion of Harris County, Texas (**Exhibit 1**), with an area of approximately 25 square miles and 44 miles of open streams.

Goal #1 of the project focused on identification and evaluation of problem areas (PA) within the watershed with the aid of 1D/2D modeling and computed flood metrics. The analysis was summarized in Technical Memorandum #1. Goal #2 focuses on further evaluation of PA and development of potential solutions that best mitigate flood risk. This Technical Memorandum #2 summarizes the work accomplished for Goal #2.

1.2. Pupose and Scope

The purpose of this effort is to evaluate a suite of drainage improvements that best mitigate persistent flooding for PAs classified at the "Tier 1" and "Tier 2" levels. Please refer to Technical Memorandum #1 for a description of the "Tier" classification system. For this effort, drainage alternatives were identified and hydrologically evaluated. These alternatives were derived based on modeled output from Baseline Conditions, available ROW, constructability considerations, HCFCD input, understanding of prior studies, and general knowledge of the watershed. Alternatives served well for filtering up to three (3) candidate projects for detailed modeling under Proposed Conditions and PER consideration. Technical Memorandum # 2 incorporates the following factors:

- Review and evaluation of prior engineering reports
- Identification of alternative improvements for the Tier 1 and Tier 2 PAs to best mitigate existing flood risks.
- Preliminary impacts identification
- Regional-Level recommendations that provide watershed wide benefits; and
- Analysis of the potential for future drainage problems associated with new development or re-development within the watershed

2. Prior Studies

To effectively derive candidate alternatives for proposed conditions analysis, a collection of prior studies and reports were reviewed to gather general insights on prior approaches. These are listed in **Table 1**, ranging from Regional engineering studies ("Category 1") to smaller local studies and analyses ("Category 2"). Considerations for "Category" are indicated in the following table captions. Relevant studies and reports are further elaborated in **Section 2.2**.

2.1. Prior Studies and Reports

Table 1. Category 1 (Regional Studies)

Report:	Description:
Sparks & Barlow, Inc. (1986). "Preliminary Engineering Report, Carpenters Bayou Watershed (Unit N100-00-00)," Submitted to Harris County Flood Control District.	The purpose of this report was to propose improvements to N100-00-00 which would provide adequate outfall capacity for drainage of the Carpenters Bayou watershed under the levels of development at that time without the need for detention.
Sparks & Barlow, Inc. (1991). "Carpenters Bayou Watershed (Unit N100-00-00), Main Channel and Regional Detention Study" Submitted to Harris County Flood Control District.	The purpose of this study was to reduce flood risk caused by out-of-bank flooding from Wallisville Road downstream to Market Street. The ultimate design plan proposes two detention basins, one upstream of Wallisville Road and one upstream of Market Street. The detention basin north of Wallisville Road can be confirmed through aerial imagery. The detention basin north of Market Street cannot be confirmed.
J.A. Costanza & Associates Engineering, Inc. (1996) "Letter of Map Revision for Carpenters Bayou Watershed (Unit N100-00-00 and Unit N500-01-00)" (Volume 1), Submitted to Harris County Flood Control District	The purpose of this study was to identify necessary drainage improvements, identify construction costs associated with the selected improvements for the purpose of determining future funding requirements and to determine a viable interim channel improvement project. The study recommended certain channel improvements coupled with regional detention facilities to remove most of the floodplain delineation.
J.A. Costanza & Associates Engineering, Inc. (1996) "Letter of Map Revision for Carpenters Bayou Watershed (Unit N100-00-00 and Unit N500-01-00)" (Volume 2), Submitted to Harris County Flood Control District	Letter of Map Revision computer model name index.
J.A. Costanza & Associates Engineering, Inc. (1996) "Letter of Map Revision for Carpenters Bayou Watershed (Unit N100-00-00 and Unit N500-01-00)" (Volume 3), Submitted to Harris County Flood Control District	Updated version of the Volume 1 report with additional information as requested by FEMA.
HDR Engineering, Inc. (1998) "Sheldon Reservoir Study" Submitted to Harris County Flood Control District, Texas Parks and Wildlife	The purpose of this study was to conduct hydrological assessments of the reservoir and contributing watershed to identify and evaluate water

Department, Texas Department of Transportation and McCord Development Communities	supply enhancement alternatives necessary to ensure adequate seasonal water levels in Sheldon reservoir.
Pate Engineers (2001) "Carpenters Bayou Watershed (Unit N100-00-00 and Unit N104-00-00) Regional Plan Update" Submitted to Harris County Flood Control District	The purpose of this study was to develop a master plan for existing and future flow conditions within Carpenters Bayou watershed (Unit No. N100-00-00 and N104-00-00).
S&B Infrastructures, LTD. (2003) "TSARP Hydrologic Analysis for Carpenters Bayou (Unit N100-00-00)" Submitted to Harris County Flood Control District	This plan outlined the hydrologic analysis conducted that was used to develop the hydrology for Carpenters Bayou watershed to aid the hydraulic contractor in developing the flood delineation for this watershed.
S&B Infrastructures, LTD. (2004) "TSARP Carpenters Bayou (Unit N100-00-00) Final Hydrology" Submitted to Harris County Flood Control District	This plan outlined the hydrologic analysis conducted that was used to develop the hydrology for Carpenters Bayou watershed to aid the hydraulic contractor in developing the flood delineation for this watershed.
Watershed Concepts. (2005) "TSARP Carpenters Bayou Watershed (Unit N100-00-00) Final Hydraulics" Submitted to Harris County Flood Control District	This report provides detailed descriptions of methodologies and assumptions used in the hydraulic analysis for the three studied streams N100-00-00, N104-00-00 and N117-00-00. These streams were the studied streams that were updated according to 2018 LIDAR for the Baseline Conditions model.

Table 2. Category 2 (Local Studies)

Report:	Description:
Jones & Carter, Inc. (1995) "Drainage Analysis (Unit N111-00-00 and Unit N111-01-00) for Harris County Municipal Utility District No.285" Submitted to Harris County Flood Control District.	This project included the drainage analysis of Harris County MUD No.285 for the proposed construction of a new athletic complex in Galena Park ISD. No detention was proposed according to the report.
Binkley & Barfield, Inc. (1998) "Preliminary Engineering Report Dell Dale Street (IH-10 to Woodforest Blvd)" Submitted to Harris County Public Infrastructure Department Engineering Division	The purpose of this PER was to provide specific design recommendations and cost estimates for the right-of-way acquisition and the reconstruction of Dell Dale Street with associated drainage improvements from Woodforest Boulevard to IH-10 in the south.
Dodson & Associates, Inc. (2010) "Updated Drainage Analysis for 40-Acre Tract along Carpenters Bayou" Submitted to Harris County Public Infrastructure Department Engineering Division	The purpose of this report was to update the drainage analysis of a 40 acre lot bounded to the north by Wallisville Road, to the west by Carpenters Bayou (Unit No. N100-00-00) and to the south by HCFCD Unit No. N113-00-00. The site is proposed to be developed as a new school facility in the Channelview Independent School District (ISD). Total required basin volume was 36.59 acre-feet.
Klotz and Associates, Inc. (2010) "Hydraulic Impact Analysis for Sheldon Road Bridge Widening (Unit N100-00-00)" Submitted to Harris County Public Infrastructure Department Architecture & Engineering Division	This purpose of this report was to address the impact on water surface elevations along Carpenters Bayou associated with widening the Sheldon Road Bridge. Concrete abutments are proposed to either side of the bridge to increase the conveyance beneath the bridge in order to mitigate for the impacts of bridge widening.
Pate Engineers, Inc. (2011) "Master Drainage Study for Generation Park" Submitted to Harris County Municipal Utility District No. 424, 425, 426, 427, 428 and 429	The purpose of this study was to present the master drainage plan and proposed stormwater detention facilities for the Generation Park development.
R.G. Miller Engineers, Inc. (2012) "Freeport Street Drainage Analysis" Submitted to Harris County Flood Control District	Harris County planned to improve the southern segment of Freeport Street from an existing 2-land asphalt roadway to a 3-lane asphalt roadway. This report provides a plan to provide adequate drainage for the improved roadway and to generally improve drainage in the project area and alleviate flooding along Freeport Street.
Arceneaux & Gates Consulting Engineers, Inc. (2013) "Impact Analysis Report for Commercial Development Submitted for Keystone Pipeline Moore Junction Terminal" Submitted to Harris County	The purpose of this report was to determine impact due to the development of the delivery station at the Moore Junction Terminal. It was concluded that the potential raise in water surface elevation due to this development would be insignificant.
Brown & Gay Engineers, Inc. (2015) "Jacintoport Tract W Phase 2, Drainage Impact Study Carpenters Bayou (HCFCD Unit N100-00-00)" Submitted to Harris County Flood Control District	The purpose of this report was to present that hydrologic and hydraulic analysis for the proposed Jacintoport Tract W development located in southeast Harris County. A detention basin is proposed to accommodate the increase in peak flow rates for the

	addition of 39.8 acres to the existing industrial development.
Edminster, Hinshaw, Russ & Associates (2016) "Miller Road 2 (Unit N100-00-00, N115-00-00 and N500-02-00)" Submitted to Harris County Flood Control District	The purpose of this study was to conduct a drainage impact analysis to determine the required amount of storm water detention because of the proposed expansion of Miller Road 2. It was determined that detention and channel improvements to N115-00-00 would be required.
WGA Consulting Engineers (2019) "Sterling Forest Subdivision Drainage Assessment" Submitted to Harris County Engineering Department	The Sterling Forest Subdivision Drainage Assessment helped identify the flooding that occurs due to inadequate flow paths to accommodate extreme storm event runoff. The proposed feature recommended for improving drainage within the subdivision is the construction of five concrete structures to accommodate a direct overland flow path out of the subdivision to the N109-00-00 channel for extreme storm events.

2.2. Relevant Studies and Projects

Each report offered unique value, but few were as relevant to Carpenters Bayou's current drainage and hydrology issues as the recommendations made in the Sterling Forest Subdivision Drainage Improvements Report (WGA 2019), Generation Park Master Drainage Study (Pate Engineers 2011), and the *Freeport Street Drainage Analysis (R.G. Miller 2012)*.

Sterling Forest Subdivision Drainage Assessment" Submitted to Harris County Engineering Department (WGA 2019). The Sterling Forest Subdivision Drainage Assessment helped identify inadequate flow paths for accommodating sheet flow conditions under heavy rainfall. The analysis supports the modeled results for Baseline ("Existing") Conditions, that flooded structures stem largely from sheet flow driven conditions, with flood risks compounded by insufficient drainage capacity and aging infrastructure. The Sterling Forest subdivision is located in a Tier 1 PA according to the recent analysis. The proposed project for this area requires the construction of five significant concrete swale-like structures to accommodate better direct overland flow path into the N109-00-00 tributary under extreme storm events. The overall length of the structure measured in the direction of flow is approximately 120 feet.

Master Drainage Study for Generation Park (Pate Engineers 2011). This study explored a drainage plan for the development of Generation Park north of Lake Sheldon. The analysis proposed several mitigation techniques including low impact development practices, a combination amenity Lake/stormwater detention facility, series of open and closed storm sewer systems and open channels. This study was among the first to highlight potential impact from new development. The study also states that current Flood Insurance Study (FIS) flows and drainage area of Carpenter's Bayou watershed do not accurately reflect existing conditions and there exists a natural drainage overflow from the Carpenters Bayou watershed into the San Jacinto River watershed.

Freeport Street Drainage Analysis (R.G. Miller 2012). This report provided a plan for adequate drainage in conjunction with the roadway improvements from a point approximately 198 feet north of Alderson Street southward to IH-10, and to generally improve drainage in the project area and alleviate flooding along Freeport Street. One proposed project is the limited diversions of storm water from HCFCD Unit Nos: N110-00-00 and P102-00-00 to P103-00-00 during 2yr to 5yr storm events. Two detention basins were previously considered in the overall drainage plan, but it was determined that property buyouts along HCFCD Unit P103-00-00 might provide for a more effective solutions due to tailwater influences from Greens Bayou watershed (HCFCD Unit No: P100-00-00). For proposed project alternatives a diversion to P103-00-00 is also being considered specifically for PA02 and PA04 instead of detention, since both areas are densely populated with minimal vacant lots for detention.

3. Problem Area Analysis

In Technical Memorandum #1, eleven (11) PAs were identified as heavily susceptible to flooding (**Figure 1**) and classified into three (3) tiers. PAs with severe flooding – based on flood claims and modeled analyses – were classified as "Tier 1." In general, PAs classified as "Tier 1" and "Tier 2" are considered to have concentrated flooding problems of sufficient magnitude to warrant more detailed H&H analyses and development of potential improvement projects which might be funded with 2018 Bond or other County revenues in the near-term future. PAs of "Tier 3" classification should be studied in forthcoming analyses with efforts geared towards identifying regional solutions, ROW needs, preemptive stakeholder engagement, and sponsorship mechanisms to facilitate phasing towards project implementation. **Table 3** concisely summarizes the PA classification according to the methodology provided by HCFCD.

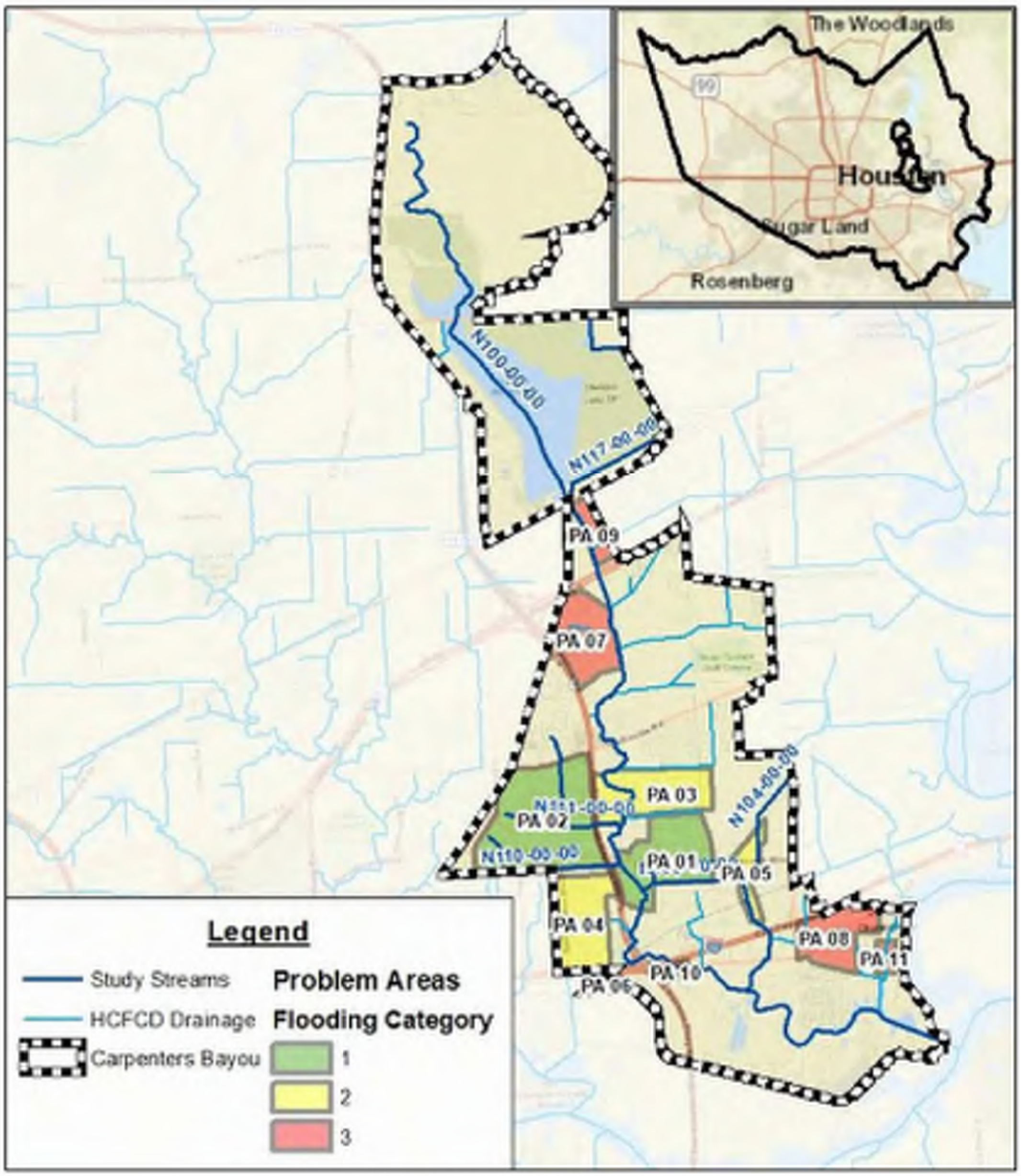


Figure 1: Updated PA layout

Table 3. Problem area classification

				Historical Actual Flooding (45%)		*Predicted Structural Flooding (45%)*			*Non-Structural Flooding (10%)*			
[1] Problem Area Name	[1a] Watershed/Subwatershed	[2] Primary Jurisdiction	[3] Flooding Source	[4] Historical Flooding Data	[5] Historical Flooding	[6] Total Predicted Structural Flooding (1% AEP)*	[7] Predicted Structural Flooding (TPASF50)	[8] Predicted Structural Flooding	[9] Predicted Roadway Flooding (Total Length >1-foot during 1% AEP)	[10] Predicted Roadway Flooding	[11] Total Weighted Score	[12] Tier Classification
				(number of homes)	(propotional value)	(number of structures)	(structures per year)	(proportional value)	(miles)	(proportional value)		
PA01	N100I	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	64	100	427	853.9	51	13.6	56	74	Tier 1
PA02	N100H	Unincorporated Harris County/ Cloverleaf	Sheet flow from adjoining area and Local stormwater drainage limitation	12	19	785	1680.5	100	24.1	100	63	Tier 1
PA03	N100G	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	21	33	526	867.2	52	11.4	47	43	Tier 2
PA04	N100J	Unincorporated Harris County/ Cloverleaf	Local stormwater drainage limitation and sheet flow from adjoining area	32	50	206	661.9	39	3.0	12	41	Tier 2
PA05	N104	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	25	39	218	569.8	34	1.5	6	33	Tier 2
PA06	N100K	Unincorporated Harris County	Sheet flow from adjoining area and Local stormwater drainage limitation	12	19	46	198.1	12	0.1	0	14	Tier 3
PA07	N100E/N100F	Unincorporated Harris County	Overbank flow and local stormwater drainage limitation	4	6	18	30.7	2	5.9	25	6	Tier 3
PA08	N104/N100L	Unincorporated Harris County/ Channelview	Local stormwater drainage limitation and sheet flow from adjoining area	3	5	36	78.3	5	0.5	2	4	Tier 3
PA09	N100D	Unincorporated Harris County	Overbank flow	1	2	60	111.1	7	0.4	2	4	Tier 3
PA10	N100K	Unincorporated Harris County/ Channelview	Overbank flow	2	3	10	20.5	1	0.1	0	2	Tier 3
PA11	N100L	Unincorporated Harris County/ Channelview	Sheet flow from adjoining area and Local stormwater drainage limitation	0	0	16	71.7	4	0.1	0	2	Tier 3

PAs classified as Tiers 1 and 2 in **Table 3** (PAs 1 to 5) were scoped in this effort for alternatives analysis. For each PA, this involved the formulation of different proposed alternatives for consideration and were coordinated with HCFCD and guided based on a combination of level-of-service (LOS) driven interests, available ROW, constructability considerations, and design constraints. Each of the alternatives involved combinations of channel/detention improvements, voluntary buyouts, and drainage improvements. Structural improvements for each alternative consisted of (1) channel improvements (traditional grass-lined, concrete-lined, rectangular sections), (2) stormwater detention (offline, inline, wet/dry bottom basins), and (3) local drainage improvements (subsurface storm sewer, box/round culverts and use of swales). Preference was given to formulating alternatives that – in lieu of detailed modeling under Proposed Conditions – appear to best mitigate existing flood risks, maximize existing HCFCD ROW, efficiently utilize vacant lots, minimize constructability concerns, adhere to HCFCD design criteria, and minimize environmental impacts.

There were five alternatives considered for PAs 1 through 4 and were standardized for consistency at the neighborhood-level to benchmark the degree of flood reduction benefits. These alternatives include (1) No Project alternative, (2) Reduced LOS alternative, (3) Target LOS alternative, (4) Inundated structures above 1 foot of 100-year depth, and (5) Inundated structures of 100-year storm event. The descriptions of each of these alternatives and their general purpose are further described in the Proposed Methodology (**Sections 3.1**). Detail on the favorable utility of employing a Basin Development Factor (BDF) based hydrologic approach for characterizing planning-level and LOS-based structural alternatives is also described.

3.1. Proposed Methodology

Because a substantial portion of the PAs identified in Carpenters Bayou experience neighborhood-level flooding (sheet flow driven), a flexible hydrologic approach for evaluating potential recommendations (at the neighborhood-level) was warranted. In other words, some PAs or neighborhoods located sufficiently away from jurisdictional waterways may not – in some circumstances – directly benefit from traditional channel improvements or inline detention along studied streams or tributaries. Fortunately, the Basin Development Factor (BDF) (Sauer et al. 1983; Asquith et al. 2011) – when used in conjunction with Clark Unit Hydrograph – provides for a flexible and robust approach for characterizing small catchment and urbanized watersheds under Baseline and Proposed Condition scenarios. In short, BDF is a measure of urbanization and drainage system improvements, with indices ranging from 0 to 12 and is relatively easy to characterize and implement. HCFCD has adapted a BDF-based approach to facilitate MAAPnext hydrologic standards (Liscum and Massey 1980; Liscum 2001; Barret 2011, Barrett 2019). The quantification of hydrograph differences between Baseline and Proposed Conditions using a BDF-based Clark Unit Hydrograph approach for a range of storms, provides for a theoretical mitigation volume for a similar suite of drainage improvements. For a given neighborhood, or PA, the BDF-based hydrologic approach allows for Proposed Conditions (planning-level) that include improvement considerations to (1) curb and gutter, (2) storm sewers, (3) channel improvements, and (4) channel lining.

Details on the applications of BDF are provided in the related references. Slight variations to BDF applications have been adopted throughout the years, but in ways that better tailor for the region in consideration (i.e. traditional versus weighted BDF). Traditional use involves subdividing an urban catchment into three regions (upper, middle, and lower) with each third scored against four improvement indices (i.e. presence of channel improvements, channel lining, curb and gutter and storm sewers). Illustrations on how each third was subdivided is provided in **Exhibits 2** to **5**. Scores are totaled to obtain an overall BDF score characterizing that catchment's level of urbanization and drainage efficiency (**Figure 2**). The BDF is then incorporated into the following Clark Unit Hydrograph relationship to calculate, time of concentration, Tc, and storage coefficient, R, values for Existing and Proposed Conditions.

$$Tr = 10^{-0.05288 \times BDF + 0.4028 \times \log_{10} A + 0.3926}$$

$$Tc = Tr + (A^{0.5}/2)$$

$$R = 8.271 e^{-0.1167 * BDF} A^{0.3856}$$

where Tr= Time of recession in hours, A= Area of subbasin/watershed in square miles, Tc= Time of concentration in hours and R= Storage Coefficient.

PRE BDF PA01 (Existing Conditions)	10-year storm		
	Upper	Middle	Lower
Channel Improvements	0	1	1
Channel Linings	0	1	0
Storm Sewers	1	0.5	0.5
Curb and Gutter Streets	1	1	1
Sub-Totals	2	3.5	2.5
Overall Total BDF			8

Figure 2: Example of BDF improvement indices and scoring

Other key BDF points – as they relate to the Carpenters Bayou WPP – include:

- ***Channel Improvements Index***. A high value BDF was assigned to a third with any visible channel improvements. For example, the lower third in PA01 (**Figure 2**) contains the mainstem Unit no. N100-00-00, thus the lower third was given a BDF value of 1 to characterize Existing Conditions drainage capacity.

- ***Storm Sewer Index***. If storm sewers were constructed before 1984 then a value of 0.5 was applied. In lieu of not having adequate storm sewer data, it was assumed that if the average age of surrounding structures (as determined from HCAD) was built before 1984, then the storm sewer was similarly constructed before 1984 and a BDF value of 0.5 was assigned to that one-third area, unless noted otherwise from site visits.

- ***Curb and Gutter Index***. For the curb and gutter, if there was a lack of inlet density then a value of 0.5 was assigned for Existing Conditions and a value of 1 was assigned for Proposed Conditions.

With these understandings and available guidelines, a BDF-based approach was used to define Existing and Proposed Conditions. Tc and R values were calculated for Existing and Proposed Conditions for each PA. HEC-HMS was then used to create pre and post hydrographs using the Clark Unit Hydrograph method to determine a mitigation volume (**Figure 3**). Detailed Tc and R value calculations can be found in **Appendix B**.

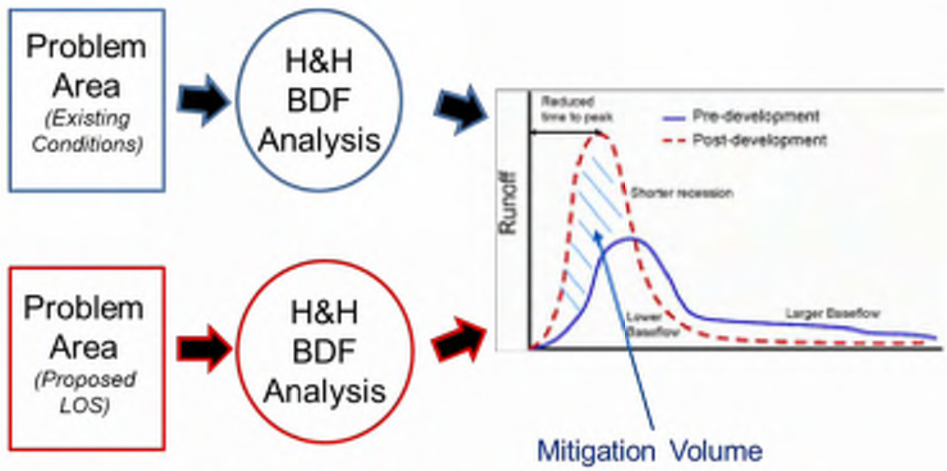


Figure 3: Methodology used for planning-level alternatives analysis

The methodology formulated in this planning-level effort identified up to five alternatives for each PA. Since a substantial portion of the PAs identified in Carpenters Bayou experience neighborhood-level flooding (sheet flow driven), a flexible hydrologic approach for evaluating potential recommendations (at the neighborhood-level) was necessary. The Reduced LOS alternative and Target LOS alternative help identify potential solutions for the neighborhood level flooding issues. A mitigation volume for the Reduced and Target LOS alternative is proposed using BDF analysis discussed previously. The following alternatives were used to compare the benefits associated with using this approach and a preliminary cost analysis helped identify the feasibility of these recommendations. The five alternatives considered for PAs 1 through 4 are described as follows:

No Project alternative. "No Project alternative" is a short-term strategy to allow other pre-requisite projects to take place such that a potential for indirect benefits can occur first. This could include flood reduction from proposed nearby projects located upstream in which downstream benefits are experienced. The "No Project alternative" is also meant to provide a lower bound for costing purposes while still allowing for indirect benefit.

Reduced LOS alternative. The "Reduced" LOS alternative is meant to provide maximum flood reduction benefit in consideration of near-term budget constraints. The "Reduced" LOS alternative can be considered a precursor to the Target LOS alternative with subsequent improvements over time.

Target LOS alternative. The "Target" LOS alternative implies an "optimal" LOS – in which a LOS storm of greater magnitude does not yield significant flood reduction benefits beyond the solution for a Target LOS alternative for that PA or community. The Target LOS alternative is meant to be cost-effective prior to ling a diminishing return on benefit, and can be achieved in phases, starting with a "Reduced LOS" as gradual improvements at the neighborhood level take place towards the "Target LOS alternative."

Inundated Structures > 1 Foot Flood Depth (100-year). Includes HCAD appraisal values for inundated structures at flood depths greater than 1 foot for the computed 100-year storm. This alternative emphasizes structure buyouts that are at higher flood risk.

All Inundated Structures (100-year). Includes HCAD appraisal values for all structures that experience flooding for the computed 100-year storm event. The "All Inundated structures" is also meant to provide an upper bound on potential acquisition costing.

3.2. Level-of-Service Analysis

The Reduced and Target LOS alternative was identified for PAs that experience sheet flow driven flooding due to insufficient drainage systems. A Target LOS alternative is defined as the smallest storm event that the drainage system must handle to achieve the most significant reduction in damages. If the proposed drainage system is even larger, very few additional damages are removed. Identification of the Target LOS for each PA required the incremental subtraction of hyetographs of smaller storm events (e.g. 2-year, 10-year, 25-year, 50-year) from a benchmark storm (100-year) until the Target LOS was obtained. The subtracted storm events represent the required LOS functioning of the associated drainage system. The Reduced LOS alternative for each PA can be considered a precursor to the Target LOS alternative with subsequent drainage improvements over time. For example, if the 50-year storm resulted in the Target LOS alternative for a given PA, the Reduced LOS alternative would likely be considered the 25-year storm for the same PA.

In the example below (**Figure 4**), the Target LOS alternative was obtained by the subtraction of the 25-year rainfall event from the 100-year event. The associated area in this example would require a drainage system with a 25-year LOS. **Table 4** summarizes the Target LOS alternative for PAs 1 through 4.

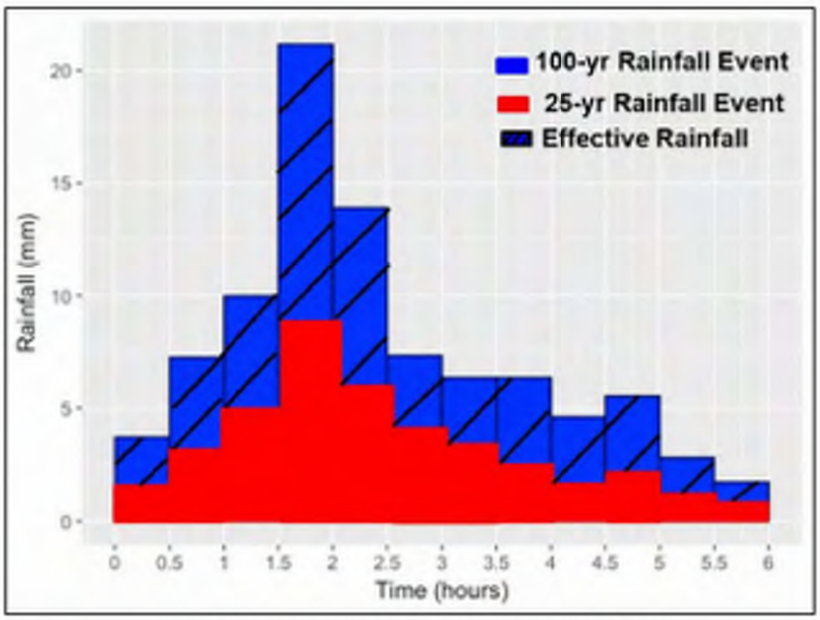


Figure 4: Explanation of "Target LOS alternative"

Table 4: Target LOS alternative for PAs 1 through 4

Problem Area	"Target" LOS	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Total HCAD market value of Residual Properties ($)
PA01	25	417	10	$598,000
PA02	50	782	3	$319,000
PA03	25	525	1	$69,000
PA04	50	188	18	$844,000

After identification of the Target LOS, the BDF approach was used to determine the mitigation volume proposed for mitigation purposes to achieve that "Target" storm.

3.3. Problem Area #1 (PA01) (Tier 1)

PA01 is part of unincorporated Harris County and lies within the community of Channelview. It includes Sterling Green South and Sterling Forest neighborhoods. HCFCD Tributaries Unit No: N109-00-00, N109-01-00, and a small portion of the mainstem N100-00-00 lie within this PA (**Figure 5**).

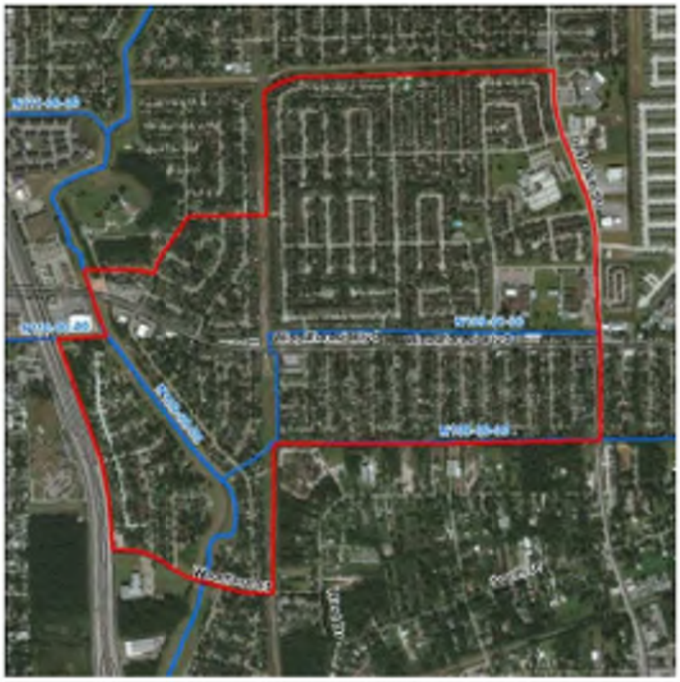


Figure 5: PA01

Modeled Baseline Conditions reveal that HCFCD Unit No: N109-00-00, N109-01-00 have less than a 10-year existing LOS and N100-00-00 in proximity to PA01 has less than a 50-year existing LOS, respectively. Further investigation reveals most structures were built between 1940 and 1980, with newer structures built between 1980 and 2020 north of Woodforest Boulevard. The historical flood claims in this area are in the Sterling Forest neighborhood and along the banks of N100-00-00. There are two critical facilities (elementary schools) and a few hazardous materials (HAZMAT) sites in this area. The primary source of flooding for PA01 is related to insufficient capacity of tributaries within PA01, overland sheet flow and deteriorating drainage infrastructure. PA01 includes the Sterling Forest Subdivision. The Sterling Forest Subdivision Drainage Assessment helped identify that flooding occurs due to inadequate flow paths to accommodate extreme storm event runoff. The analysis states that flooding in the study area occurs because of the existing roadway drainage facilities and their limited ability to safely convey the storm water runoff from extreme event storms to the receiving streams. **Exhibit 6** shows computed flooded structures, inundated roadway and area of inundation for a modeled sheet flow 100-year storm event.

The project alternatives considered for PA01 were:

- *Voluntary buyouts for all flooded structures*
- *Voluntary buyouts for flooded structures > 1ft*

Table 5: Flood Damage estimates for PA01

	Computed 100-year Flooded Structures (count)	Total HCAD market value of computed 100-year Flooded Structures ($)
All	427	$27.4M
>1ft	122	$8.3 M

- *Drainage system improvements to the Reduced LOS alternative.*

The Reduced LOS alternative approach revealed that the subtraction of the 10-year rainfall event from the benchmark 100-year storm event resulted in 89% reduction in flooded structures (**Table 6 and Figure 6**).

Table 6: Reduced LOS alternative impact for PA01

Problem Area	Reduced LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA01	10-year LOS	89.2	381	46	2.9 M

(a) (b)

Figure 6: Reduced LOS alternative Analysis for PA01 (a) 100-year computed flooded structures (b) Computed residual flooded structures after 10-year LOS for PA01

BDF H&H analysis revealed that a detention basin with a volume of 18 ac-ft would be required to offset the increased peak flows from a Reduced LOS alternative drainage improvement project in this neighborhood. (**Figure 7**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

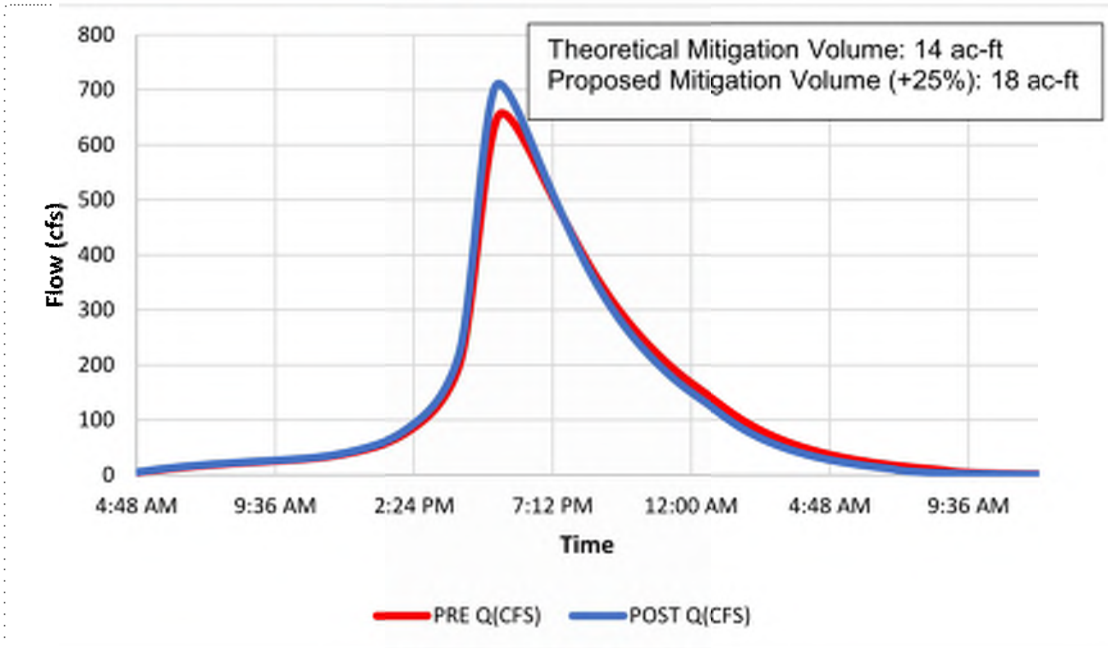


Figure 7: Pre BDF and Post BDF Hydrographs

- *Drainage system improvements to the Target LOS alternative*

The Target LOS alternative approach revealed that the subtraction of the 25-year rainfall event from the benchmark 100-year storm event resulted in 97.7% reduction in flooded structures (**Table 7 & Figure 8**).

Table 7: Target LOS alternative impact for PA01

Problem Area	Target LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA01	25-year LOS	97.7	417	10	0.6 M

Figure 8: Target LOS alternative Analysis for PA01 (a) 100-year computed flooded structures (b) Computed residual flooded structures after 25-year LOS for PA01

BDF H&H analysis revealed that a detention basin with a volume of 22 ac-ft would be required to offset the increased peak flows from a Target LOS alternative drainage improvement project in this neighborhood (**Figure 9**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

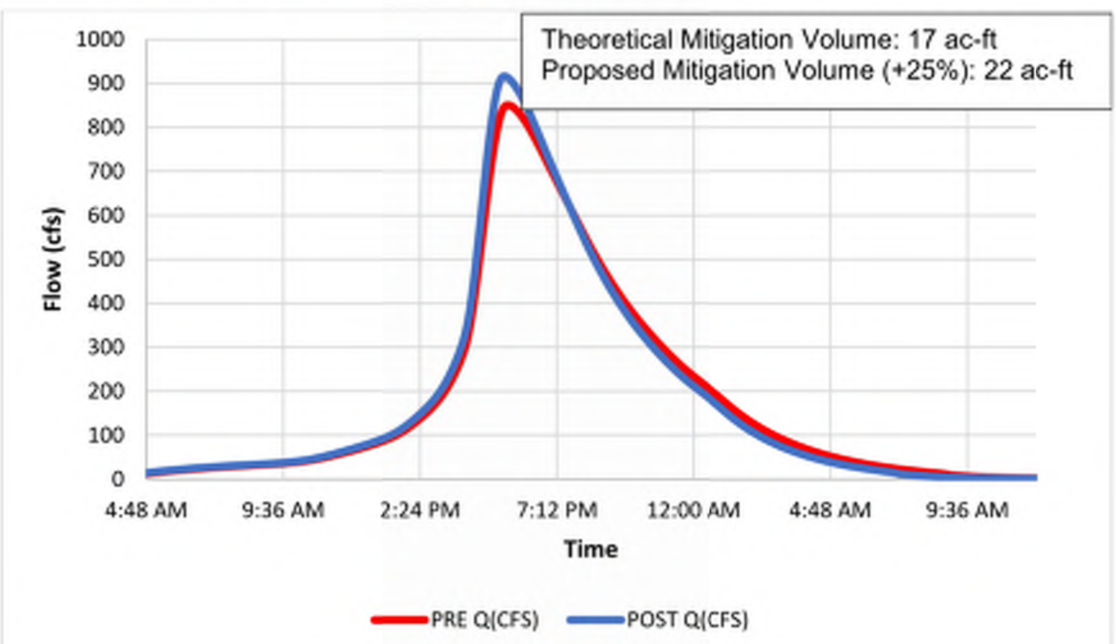
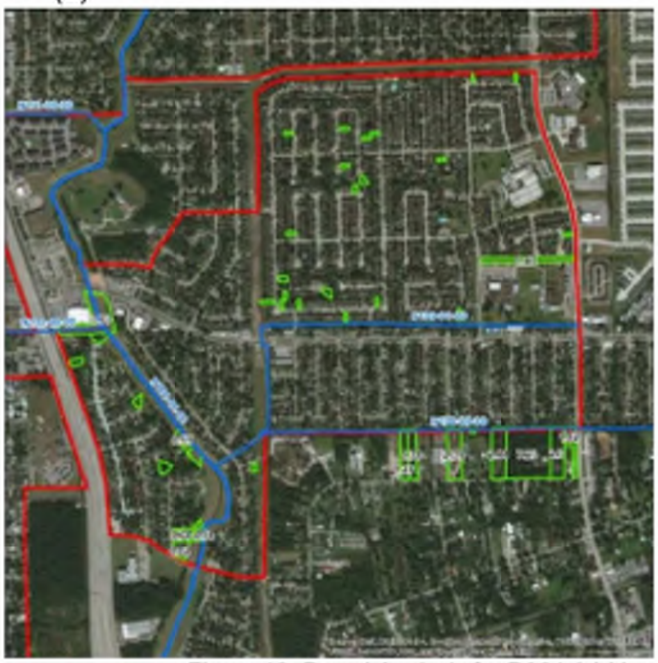


Figure 9: Pre BDF and Post BDF Hydrographs

Vacant lots analysis and buyouts assessment was conducted to determine whether any lots could be acquired for detention purposes. A few vacant lots south of the PA were identified that could be used for detention (**Figure 10**). Potential buyouts were identified for the use of detention within PA01, outfall location and flood claims data were used to inform potential buyouts for mitigation (**Figure 10**). It is recommended to buyout residential structures that flood frequently and are located at the natural outfalls of the PA for detention purposes instead of using open spaces in critical facilities. With a pond depth of six feet, an approximate area of three and four acres is proposed for detention for the Reduced LOS alternative and the Target LOS alternative, respectively. The figures show the area in acres of some lots identified.

(a)



(b)

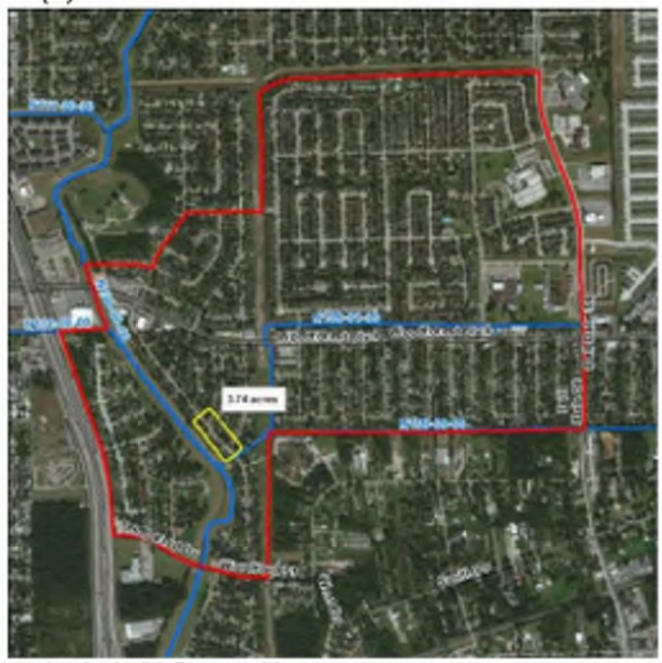


Figure 10: Parcel Analysis for PA01 (a) Vacant Lot Analysis (b) Potential buyout assessment

Some drainage improvement projects were identified that could potentially be used to achieve the identified Target/Reduced LOS alternatives. Since these projects would be conducted at the neighborhood level, partnerships with Harris County and the community of Channelview are recommended. Regional recommendations that apply to PA01 and come mainly under HCFCD jurisdiction are discussed in section 4.1 of this memorandum.

Suggested drainage improvements:

- *Increasing pipe capacity at N109-01 and replacing inlets*

  Some HAZMAT sites located in PA01 are within a 1000ft of N109-01-00 and N100-00-00. Upsizing this enclosed tributary (N109-01-00) might pose an impact because of the proximity of the HAZMAT sites. An O&G pipeline passes under the enclosed tributary N109-01-00 and poses a potential constraint for upsizing N109-01-00.

Figure 11: Propose resizing N109-01-00

- *Sterling Forest Project*

The Sterling Forest project proposes the construction of five (5) concrete structures to accommodate a direct overland flow path out of the subdivision to the N109-00-00 channel for extreme storm events.

A preliminary cost analysis was conducted to determine the cost of the Reduced and Target LOS alternatives. The table below provides the cost estimates. Expanded cost analysis tables are provided in **Appendix B**.

Table 8: Summary of preliminary cost analysis for Target and Reduced LOS alternatives.

REDUCED LOS (10yr) PA01	Cost
Drainage Improvements	13.6 M
Detention Excavation, Haul Disposal	282K
Construction Costs	**13.9M**
Engineering and Contingencies	**7.9M**
ROW Acquisition	**8.0M**
Total Estimated Cost	**29.8M**

TARGET LOS (25yr) PA01	Cost
Drainage Improvements	15.3M
Detention Excavation, Haul Disposal	363K
Construction Costs	**15.3 M**
Engineering and Contingencies	**8.7 M**
ROW Acquisition	**10 M**
Total Estimated Cost	**34 M**

Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39 (This equation was used for estimating drainage improvement costs-obtained from cost tool). Assumes that all the roadway in a Problem Area will be upsized.
The detention basin cost was also added to OPCC estimated.
The overall price had a 30% contingency added to it.

PA01 computed sheet flow 100-year storm event reveals that there are multiple clusters of flooded structures within the entire area and the flooding at the neighborhood level is sheet flow driven while flooding in the vicinity of the mainstem is related to overbank flooding. The proposed mitigation strategy for sheet flow driven flooding consists of problem area-wide drainage improvements (e.g. improved inlet placement and storm sewer system) to the Target LOS alternative using the methodology described in sections 3.1 and 3.2. Partnership between Harris County, the community of Channelview and HCFCD are recommended for these improvements. Other potential partners also include Galena Park ISD and Channelview ISD for ROW acquisition. Since large-scale secondary drainage improvements cannot be implemented immediately, it is suggested that area for detention purposes should be explored through partnerships with Harris County and the community of Channelview so that neighborhood level improvements can take place in multiple phases with mitigation in place. Other alternatives considered for PA01 are channel improvements (discussed in section 4.1 of this memorandum) and previously proposed projects (e.g. Sterling Forest). This will result in substantially lower levels of structural flooding during high and low frequency events as well as lower levels of inundated roadways around N109-01-00.

3.4. Problem Area #2 (PA02) (Tier 1)

PA02 primarily lies in the community of Cloverleaf and is a part of the unincorporated Harris County. Tributaries Unit No: N110-00-00, N110-02-00, N111-00-00 and N111-01-00 all lie within this PA (**Figure 12**).

Figure 12: PA02

Modeled Baseline Conditions show that N110-02-00 and N111-00-00 have less than a 100-year LOS and N110-00-00 and N111-01-00 have less than a 500-year LOS. The structures were mainly built in the 1940-1980 range with newer structures (1980-2020) north of N111-00-00. The historical flood claims in this area are widespread. There are five critical facilities (elementary and middle schools) and a few HAZMAT sites present in this area. The primary source of flooding for PA02 is related to overland sheet flow and an insufficient drainage network. **Exhibit 7** shows computed flooded structures, inundated roadway, and area of inundation for a modeled sheet flow 100-year storm event.

The project alternatives considered for PA02 were:

- *Voluntary buyouts for all flooded structures*
- *Voluntary buyouts for flooded structures > 1ft*

Table 9: Flood Damage estimates for PA02

	Computed 100-year Flooded Structures (Count)	Total HCAD market value of computed 100-year Flooded Structures ($)
All	785	$85.5 M
>1ft	108	$14 M

- *Drainage system improvements to the Reduced LOS.*

The Reduced LOS alternative approach revealed that the subtraction of the 25-year rainfall event from the benchmark 100-year storm event resulted in 97.1% reduction in flooded structures (**Table 10, Figure 13**).

Table 10: Reduced LOS alternative impact for PA02

Problem Area	Reduced LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA02	25-year LOS	97.1	762	23	2.6 M

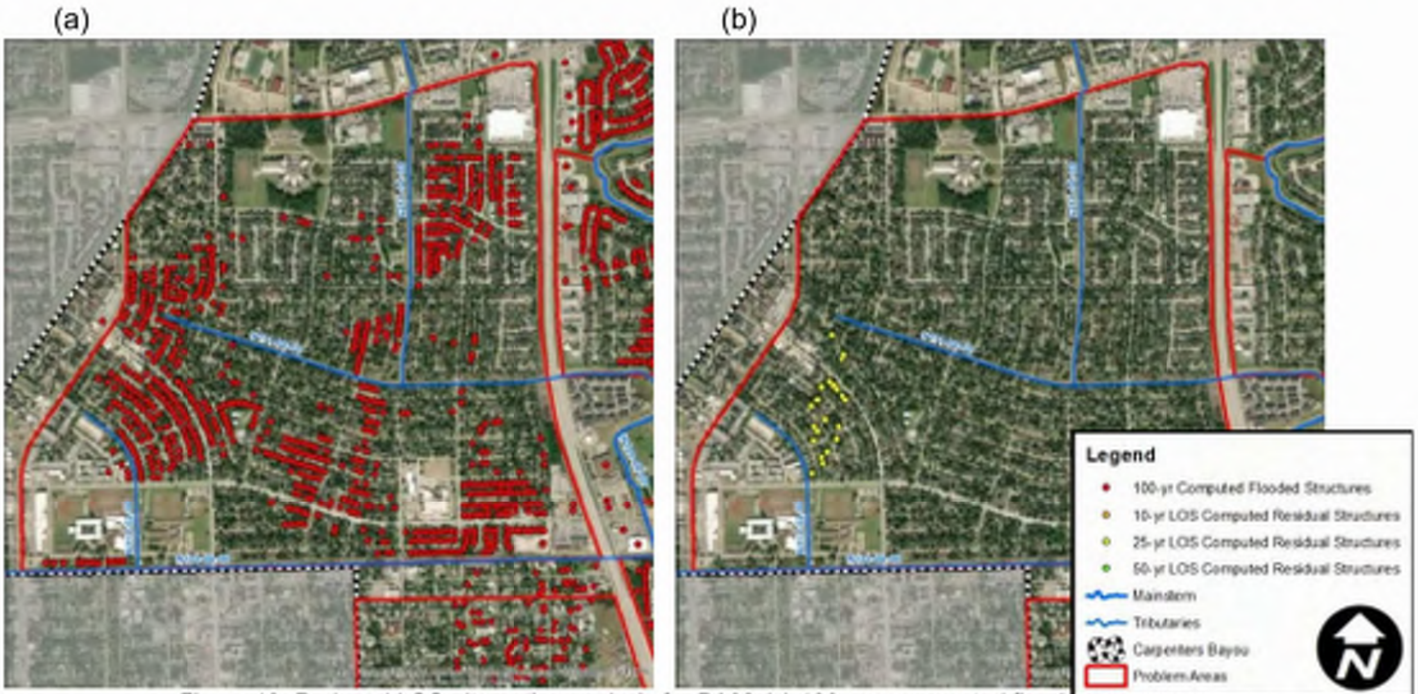


Figure 13: Reduced LOS alternative analysis for PA02 (a) 100-year computed flooded structures (b) Computed residual flooded structures after 50-year LOS for PA02

BDF H&H analysis revealed that a detention basin with a volume of 63 ac-ft would be required to offset the increased peak flows from a Reduced LOS alternative drainage improvement project in this neighborhood (**Figure 14**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

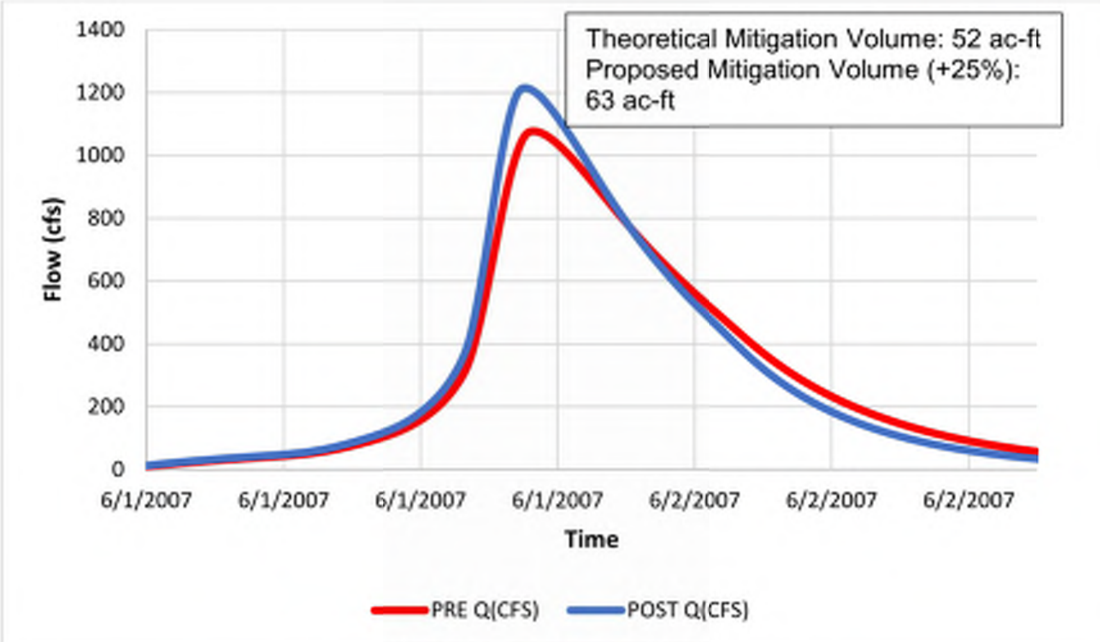


Figure 14: Pre BDF and Post BDF Hydrographs

- *Drainage system improvements to the Target LOS alternative.*

The Target LOS alternative approach revealed that the subtraction of the 50-year rainfall event from the benchmark 100-year storm event resulted in 99.6% reduction in flooded structures (**Table 11 & Figure 15**).

Table 11: Target LOS alternative impact for PA02

Problem Area	Target LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA02	50-year LOS	99.6	782	3	0.3 M

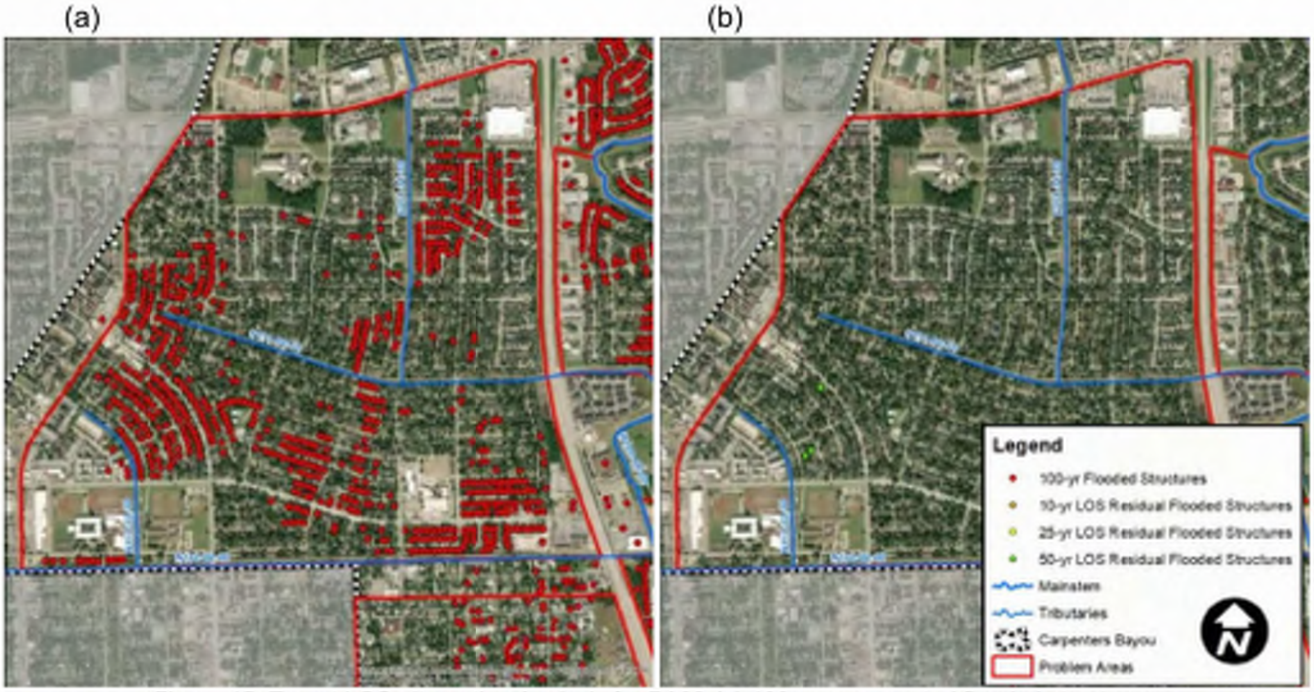


Figure 15: Target LOS alternative Analysis for PA02 (a) 100-year computed flooded structures (b) Computed residual flooded structures after 50-year LOS for PA02

BDF H&H analysis revealed that a detention basin with a volume of 77 ac-ft would be required to offset the increased peak flows from a Target LOS alternative drainage improvement project in this neighborhood (**Figure 16**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

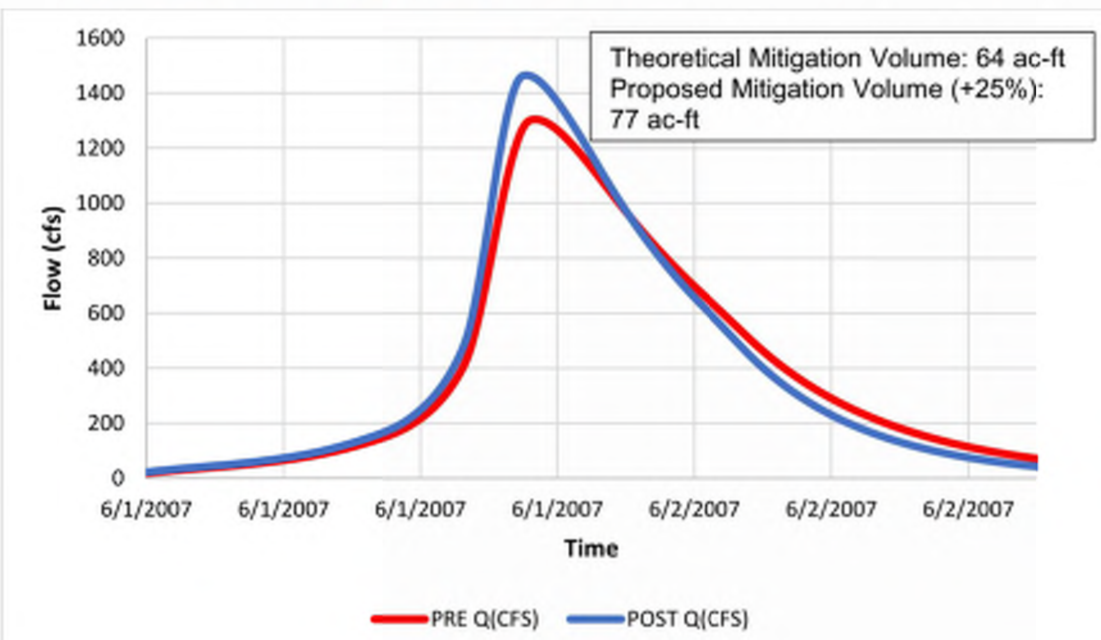


Figure 16: Pre BDF and Post BDF Hydrographs

An assessment of vacant lots was conducted to determine whether any empty lots could be acquired for mitigation purposes. Since PA02 is highly populated with many residential structures, no viable options were found (**Figure 17**). Potential buyouts were identified for the use of detention within PA02, outfall location and flood claims data were used to inform potential buyouts for mitigation. (**Figure 17**). It is recommended to buyout residential structures that flood frequently and are located at the natural outfalls of the PA for detention purposes. The use of vacant lots in schools for detention can be explored through meetings with school districts. With a pond depth of six feet, an approximate area of 11 acres and 13 acres is proposed for detention for the Reduced LOS alternative and the Target LOS alternative, respectively.

(a) (b)

Figure 17: Parcel Analysis for PA02 (a) Vacant Lot Analysis (b) Potential buyout assessment

Some drainage improvement projects were identified that could potentially be used to achieve the identified Target/Reduced LOS alternatives. Since these projects would be conducted at the neighborhood level, partnerships with Harris County, the community of Cloverleaf and the community of Northshore are recommended. Regional recommendations that apply to PA02 come mainly under HCFCD jurisdiction and are discussed in section 4.2 of this memorandum.

Suggested drainage improvements:

- *Improvement 1: Drainage improvements along Foxford Way*
  It is recommended that a dedicated flow path be built to accommodate the extreme storm events overland flow at the downstream end of Foxford Way. A mandatory buyout is suggested for this recommendation. N110-02 receives flow through Foxford Way, increasing the storm sewer capacity here would make for less ponding and flooded structures in the surrounding streets (**Figure 18**).

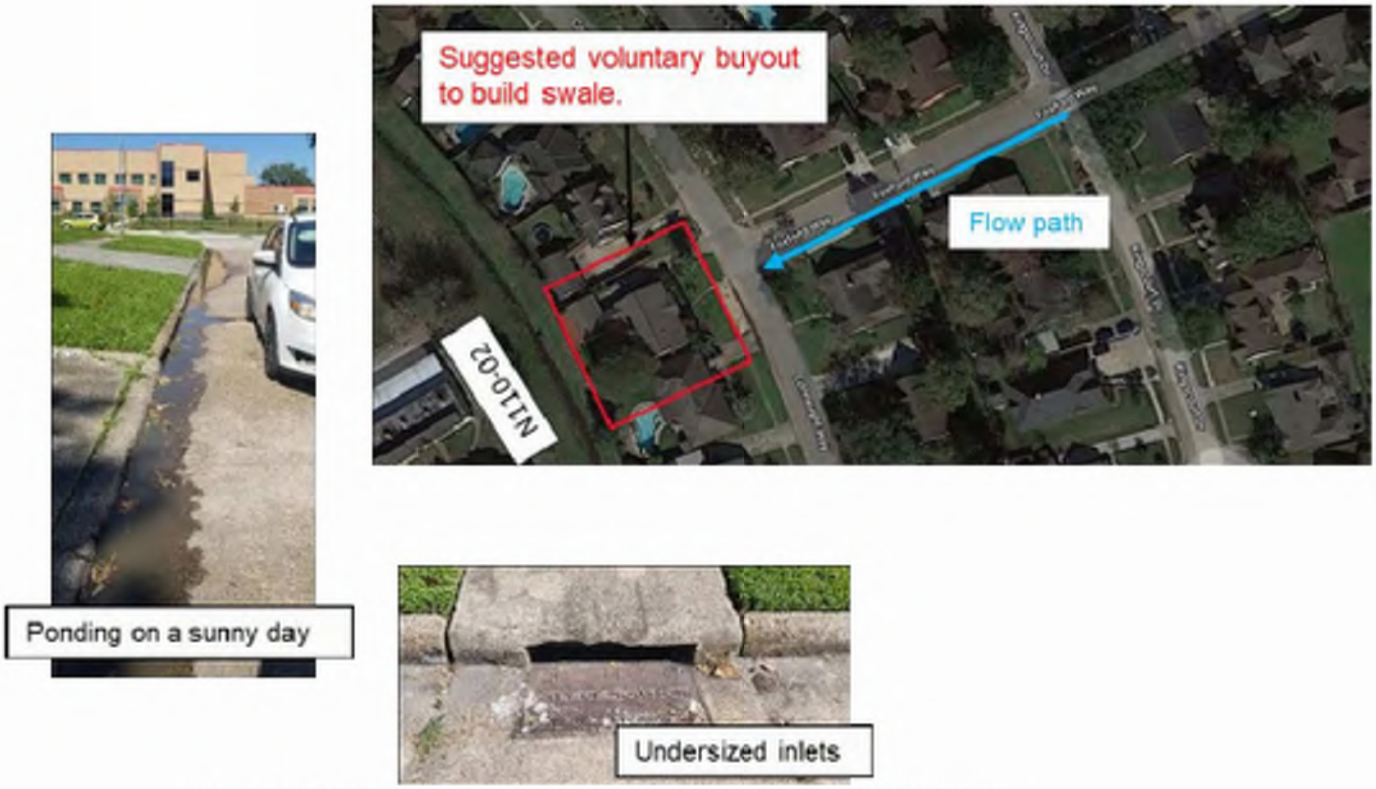


Figure 18: Existing conditions and proposed alternatives along Foxford Way

- *Improvement 2: Increasing storm sewer capacity on Woodforest Blvd and optimal inlet placement with swales on the downstream end of Posthorn Ln and Taranto Ln*

Figure 19: Existing conditions and proposed alternatives along Woodforest Blvd

A preliminary cost analysis was conducted to determine the cost of the Target LOS alternative and Reduced LOS alternative. The tables below provides the cost estimates. Expanded cost analysis tables are provided in **Appendix B**.

Table 12: Summary of preliminary cost analysis for Target and Reduced LOS alternatives.

REDUCED LOS (25yr) PA02	Cost
Drainage Improvements	20.4 M
Detention Excavation, Haul Disposal	1.0 M
Construction Costs	**21.5 M**
Engineering and Contingencies	**12.3 M**
ROW Acquisition	**28.3 M**
Total Estimated Cost	**62.1M**

TARGET LOS (50yr) PA02	Cost
Drainage Improvements	22.5 M
Detention Excavation, Haul Disposal	1.3 M
Construction Costs	**23.8 M**
Engineering and Contingencies	**13.6 M**
ROW Acquisition	**34.6 M**
Total Estimated Cost	**71.9 M**

Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39 (This equation was used for estimating drainage improvement costs-obtained from cost tool). Assumes that all the roadway in a Problem Area will be upsized.
The detention basin cost was also added to OPCC estimated.
The overall price had a 30% contingency added to it.

PA02 computed sheet flow 100-year storm event reveals that there are multiple clusters of flooded structures within the entire area and the flooding is mainly sheet flow driven. Therefore, the recommended mitigation strategy consists of problem area-wide drainage improvements (e.g. improved inlet placement and storm sewer system) to the Target LOS alternative using the methodology described in sections 3.1 and 3.2. Partnership between Harris County, the community of Cloverleaf, community of Northshore and HCFCD are recommended for these improvements. Other potential partners also include Galena Park ISD for ROW acquisition. Since large-scale secondary drainage improvements cannot be implemented immediately, it is suggested that area for detention purposes should be explored through partnerships with Harris County and the community of Cloverleaf so that neighborhood level improvements can take place in multiple phases with mitigation in place. Another alternative considered for PA02 is the diversion of flow to the tributary P103-00-00 located in Greens Bayou and is further discussed in section 4.2. These improvements are expected to result in lower levels of nuisance yard flooding and structural flooding around N110-00-00 and N111-00-00 tributaries during high and low frequency events.

3.5. Problem Area #3 (PA03) (Tier 2)

PA03 is a part of the unincorporated Harris County and the community of Channelview. It incorporates the Sterling Green neighborhood. A small portion of the mainstem N100-00-00 lies within this PA (**Figure 20**).

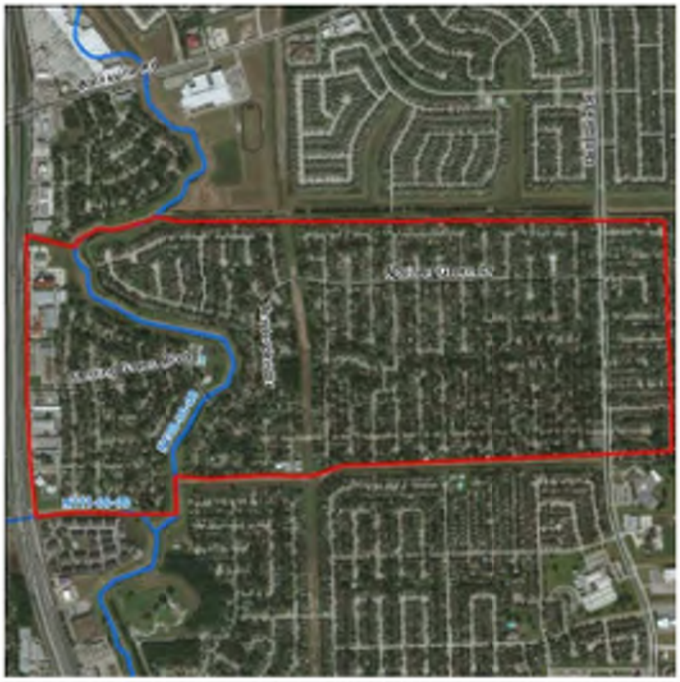


Figure 20: PA03

Modeled Baseline Conditions show that the mainstem (N100-00-00) in PA03 has less than a 50-year LOS. Most structures were mainly built in the 1980-2020 range with older structures (1940-1980) west of N100-00-00 and along the banks of the mainstem. The historical flood claims in this area are widespread in the Sterling Green neighborhood and along the banks of N100-00-00. There are a few cultural resources, an O&G well and an O&G pipeline present in this area. The primary source of flooding is related to overbank flooding and overland sheet flow. **Exhibit 8** shows computed flooded structures, inundated roadway and area of inundation for a modeled sheet flow 100-year storm event.

The project alternatives considered for PA03 were:

- *Voluntary buyouts for all flooded structures*
- *Voluntary buyouts for flooded structures > 1ft*

Table 13: Flood Damage estimates for PA03

	Computed 100-year Flooded Structures (Count)	Total HCAD market value of computed 100-year Flooded Structures ($)
All	526	$ 49 M
>1ft	212	$ 22.1 M

- *Drainage system improvements to the Reduced LOS.*

The Reduced LOS alternative approach revealed that the subtraction of the 10-year rainfall event from the benchmark 100-year storm event resulted in 94.5% reduction in flooded structures (**Table 14 & Figure 21**).

Table 14: Reduced LOS alternative impact for PA03

Problem Area	Reduced LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA03	10-year LOS	94.5	497	29	2.2 M

Figure 21: Reduced LOS alternative Analysis for PA03 (a) 100-year computed flood... (b) Computed residual flooded structures after 10-year LOS for PA03

BDF H&H analysis revealed that a detention basin with a volume of 23 ac-ft would be required to offset the increased peak flows from a Reduced LOS alternative drainage improvement project in this neighborhood (**Figure 22**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

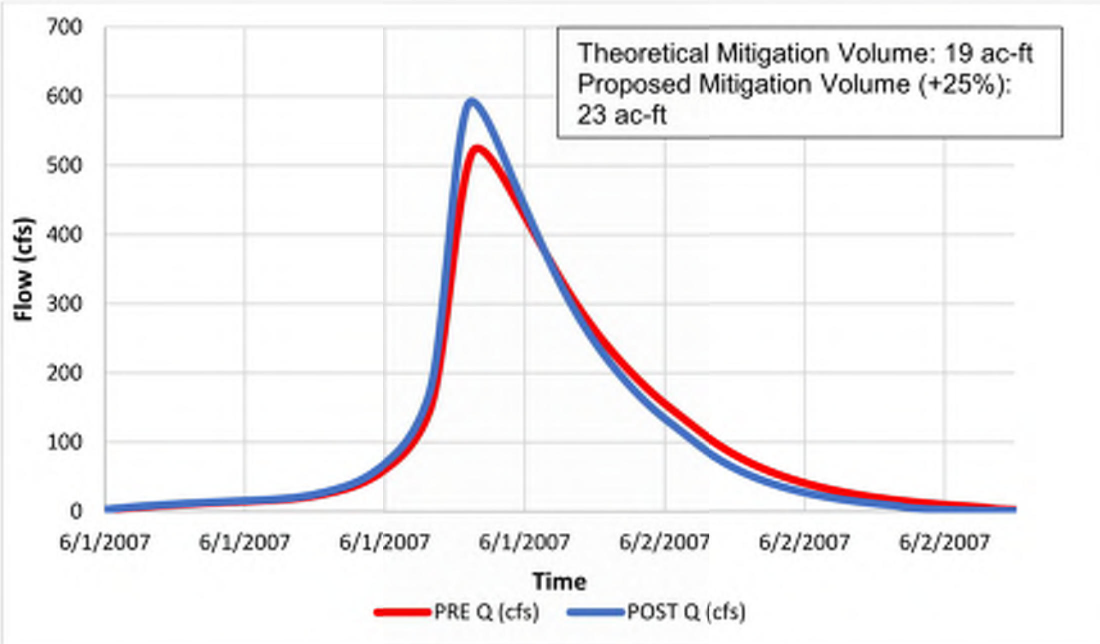


Figure 22: Pre BDF and Post BDF Hydrographs

- *Drainage system improvements to the Target LOS alternative*

The Target LOS alternative approach revealed that the subtraction of the 25-year rainfall event from the benchmark 100-year storm event resulted in 99.8% reduction in flooded structures (**Table 15 & Figure 23**).

Table 15: Target LOS alternative impact for PA03

Problem Area	Target LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA03	25-year LOS	99.8	525	1	69,000

Figure 23: Target LOS alternative Analysis for PA03 (a) 100-year computed flooded structures (b) Computed residual flooded structures after 25-year LOS for PA03

BDF H&H analysis revealed that a detention basin with a volume of 34 ac-ft would be required to offset the increased peak flows from a Reduced LOS alternative drainage improvement project in this neighborhood (**Figure 24**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

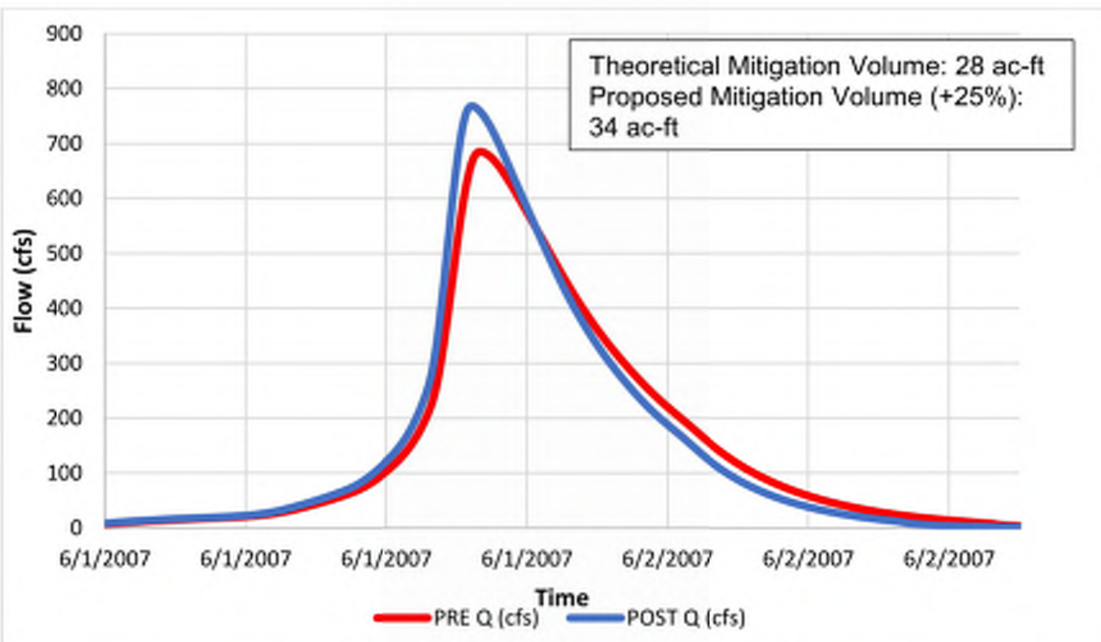


Figure 24: Pre BDF and Post BDF Hydrographs

An assessment of vacant lots was conducted to determine whether any empty lots could be acquired for detention purposes. Since PA03 is highly populated with many residential structures, no viable options for detention were found (**Figure 25**). Potential buyouts were identified for the use of detention within PA03, flood claims data and the natural outfall was used to inform potential buyouts for mitigation.

(**Figure 25**). The use of vacant lots in schools for detention can be explored through meetings with school districts. With a pond depth of six feet, an approximate area of four acres and six acres is proposed for mitigation for the Reduced LOS alternative and the Target LOS alternative, respectively.

(a) (b)

Figure 25: Parcel Analysis for PA03 (a) Vacant Lot Analysis (b) Potential Buyout assessment

Some drainage improvement projects were identified that could potentially be used to achieve the identified Target/Reduced LOS alternatives. Since these projects would be conducted at the neighborhood level, partnerships with Harris County and the community of Channelview are recommended. Regional recommendations that apply to PA03 and come mainly under HCFCD jurisdiction are discussed in section 4.1 of this memorandum.

Suggested drainage improvements

- *Improvement 1: Upsizing Storm Sewer Capacity along Welbeck Dr with swales to direct sheet flow to N100. Partial buyouts are recommended for the construction of these swales.*

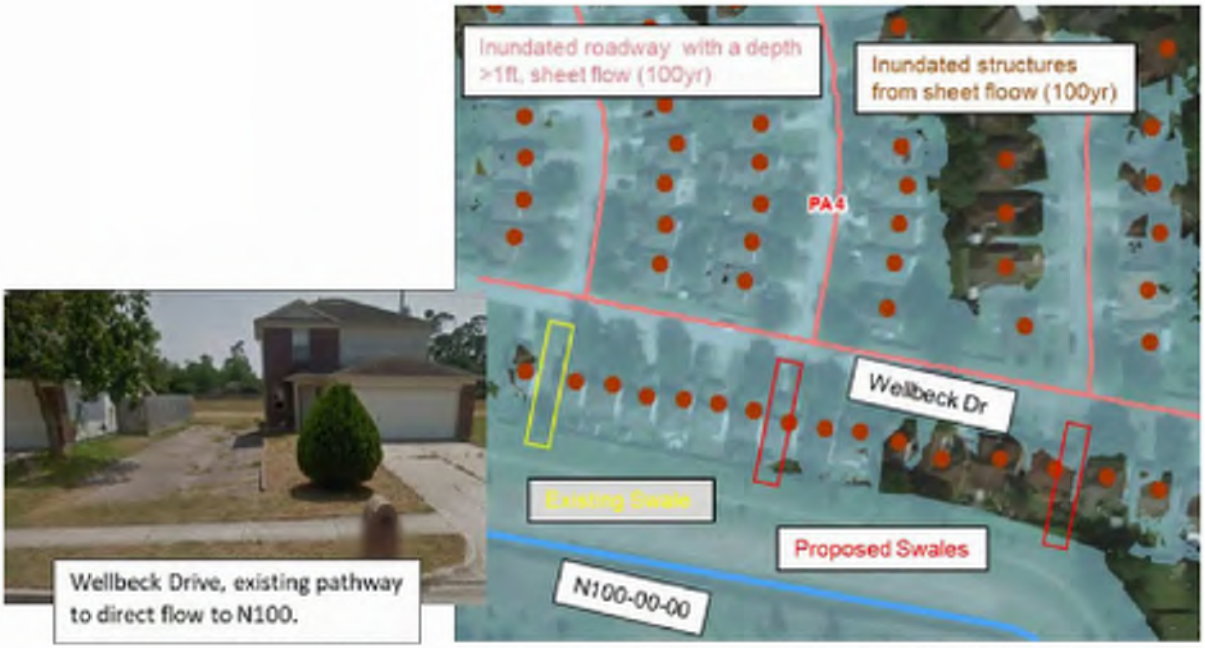


Figure 26: Proposed drainage improvement 1 at the neighborhood level for PA03

- *Improvement 2: Upsizing Storm Sewer Capacity along Easingwold Dr to convey flow to N100 efficiently.*

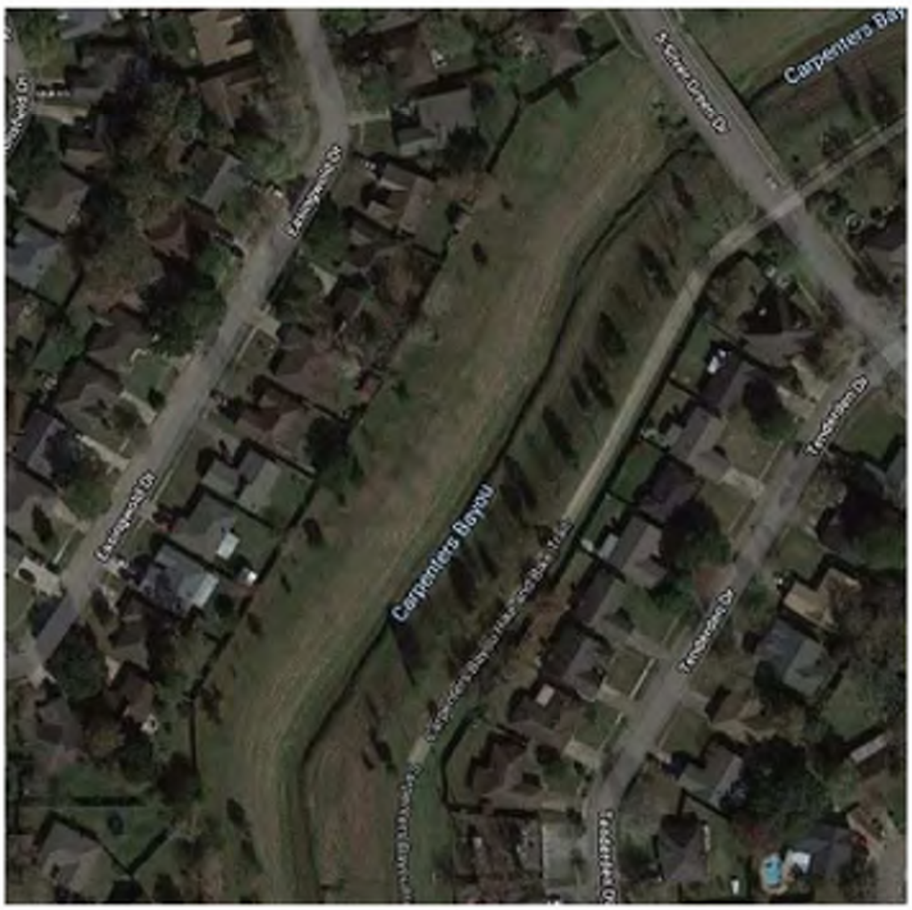


Figure 27: Proposed drainage improvement 2 at the neighborhood level for PA03

A preliminary cost analysis was conducted to determine the cost of the Target LOS alternative and the Reduced LOS alternative. The table below provides the cost estimates. Expanded cost analysis tables are provided in **Appendix B**.

Table 16: Summary of preliminary cost analysis for Reduced and Target LOS alternative

REDUCE LOS (10yr) PA03	Cost
Drainage Improvements	9.7 M
Detention Excavation, Haul Disposal	383 K
Construction Costs	**10.1 M**
Engineering and Contingencies	**5.8 M**
ROW Acquisition	**10.5 M**
Total Estimated Cost	**26.4 M**

TARGET LOS (25yr) PA03	Cost
Drainage Improvements	10.7 M
Detention Excavation, Haul Disposal	565 K
Construction Costs	**11.2 M**
Engineering and Contingencies	**6.4 M**
ROW Acquisition	**14.7 M**
Total Estimated Cost	**32.4 M**

PA03 computed sheet flow 100-year storm event reveals that there are flooded structures around the mainstem (N100-00-00) and multiple clusters of flooded structures within the neighborhood. The flooding at the neighborhood level is sheet flow driven while flooding in the vicinity of the mainstem is related to overbank flooding. The proposed mitigation strategy for sheet flow driven flooding consists of problem area-wide drainage improvements (e.g. improved inlet placement and storm sewer system) to the Target LOS alternative using the methodology described in sections 3.1 and 3.2. Partnerships with Harris County, the community of Channelview and HCFCD are recommended for these improvements. Other potential partners also include Galena Park ISD and Channelview ISD for ROW acquisition. Since large-scale secondary drainage improvements cannot be implemented immediately, it is proposed that area for detention purposes should be explored through partnerships with Harris County and the community of Channelview so that neighborhood level improvements can take place in multiple phases with mitigation in place. Other proposed mitigation strategies for PA03 are channel improvements (discussed in section 4.1 of this memorandum). These improvements are expected to result in substantially lower levels of structural flooding along the banks of N100-00-00 and neighborhood-level nuisance yard flooding during higher frequency events.

3.6. Problem Area #4 (PA04) (Tier 2)

PA04 primarily lies in the community of Cloverleaf and is a part of the unincorporated Harris County (**Figure 28**). None of the Carpenters Bayou watershed tributaries or mainstem pass through this area. The PA is characterized by roadside ditches and old residential structures.

Figure 28: PA04

Modeled Baseline Conditions show that the mainstem N100-00-00 that PA04 outfalls to, has less than a 50-year LOS. The structures were mainly built in the 1940-1980 range with a few older structures (1900-1940) and a few newer structures (1980-2020) scattered throughout the PA. The historical flood claims in this area are widespread. There is one critical facility (elementary school), a cemetery, a wetland area, and a few cultural resources in the vicinity of the PA. The primary source of flooding is related to overland sheet flow and deteriorating drainage infrastructure. **Exhibit 9** shows computed flooded structures, inundated roadway, and area of inundation for a modeled sheet flow 100-year storm event.

The project alternatives considered for PA04 were:

- *Voluntary buyouts for all flooded structures*
- *Voluntary buyouts for flooded structures > 1ft*

Table 17: Flood Damage estimates for PA04

	Computed 100-year Flooded Structures (Count)	Total HCAD market value of computed 100-year Flooded Structures ($)
All	206	$13.6 M
>1ft	41	$2.2 M

- *Drainage system improvements to the Reduced LOS.*

The Reduced LOS alternative approach revealed that the subtraction of the 25-year rainfall event from the benchmark 100-year storm event resulted in 77.2% reduction in flooded structures (**Table 18 & Figure 29**).

Table 18: Reduced LOS alternative impact for PA04

Problem Area	Reduced LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA04	25-year LOS	77.2	159	47	2.7 M

(a) (b)

Figure 29: Reduced LOS alternative Analysis for PA04 (a) 100-year computed flooded structures (b) Computed residual flooded structures after 25-year LOS for PA04

BDF H&H analysis revealed that a detention basin with a volume of 106 ac-ft would be required to offset the increased peak flows from a Reduced LOS alternative drainage improvement project in this neighborhood (**Figure 30**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

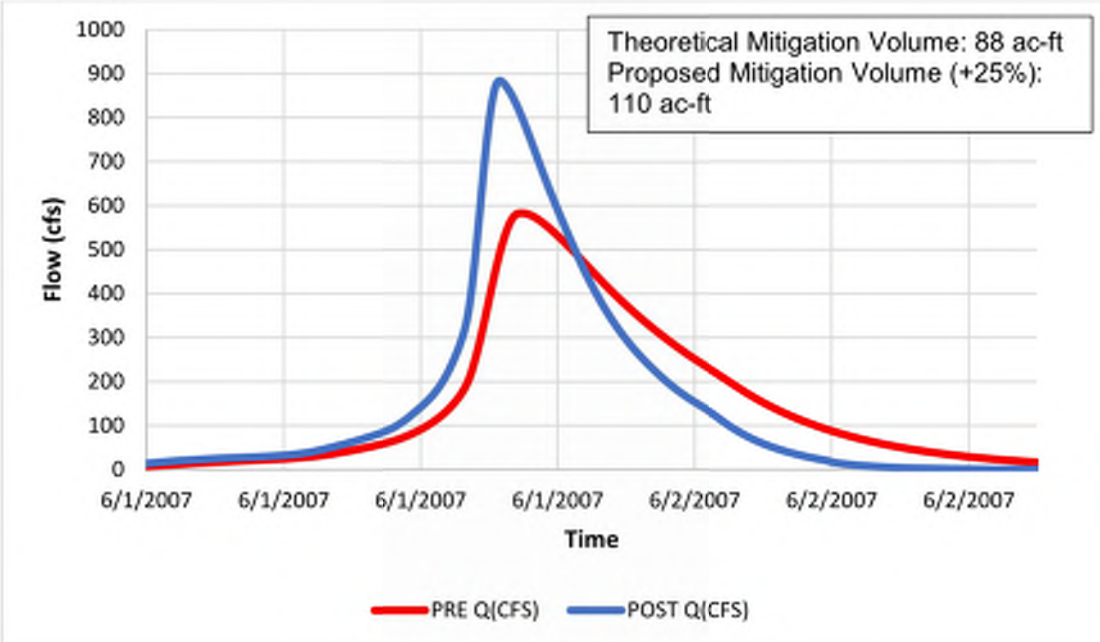


Figure 30: Pre BDF and Post BDF Hydrographs

- *Drainage system improvements to the Target LOS alternative*

The Target LOS alternative approach revealed that the subtraction of the 50-year rainfall event from the benchmark 100-year storm event resulted in 91.3% reduction in flooded structures (**Table 19 & Figure 31**).

Table 19: Target LOS alternative impact for PA04

Problem Area	Target LOS	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA04	50-year LOS	91.3	188	18	0.8 M

Figure 31: Target LOS alternative Analysis for PA04 (a) 100-year computed flooded structures (b) Computed residual flooded structures after 50-year LOS for PA04

BDF H&H analysis revealed that a detention basin with a volume of 130 ac-ft would be required to offset the increased peak flows from a Reduced LOS alternative drainage improvement project in this neighborhood (**Figure 32**). Refer to **Appendix A** for the BDF factor tables and the Tc and R tables used.

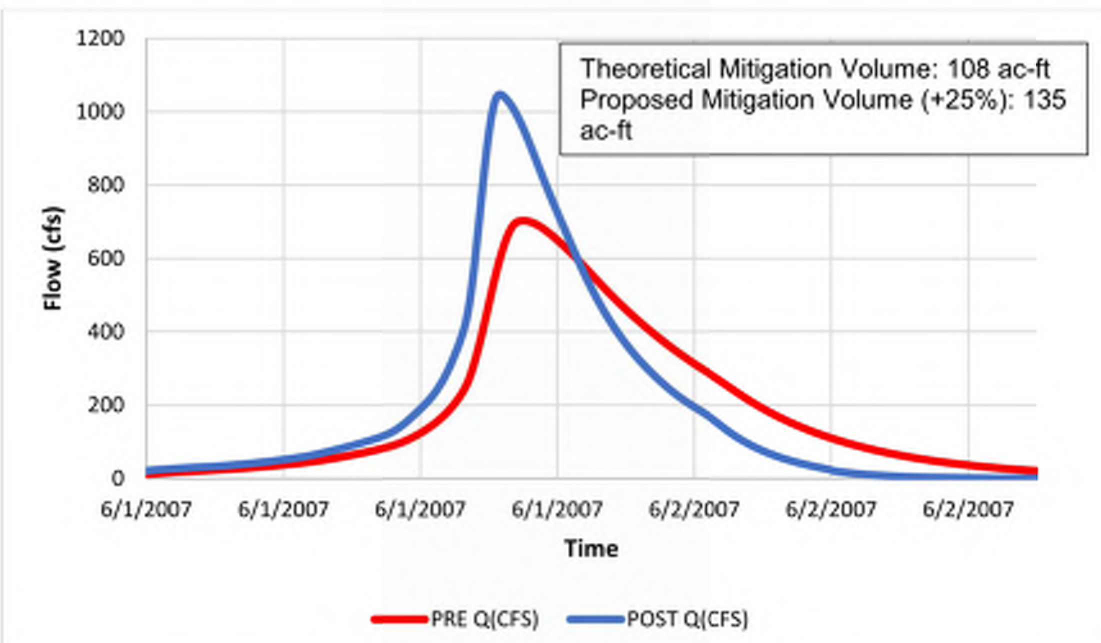


Figure 32: Pre BDF and Post BDF Hydrographs

An assessment of vacant lots was conducted to determine whether any empty lots could be acquired for mitigation purposes. Since PA04 is highly populated with many residential structures, the only availability for detention was in the vacant lots present in the land owned by the cemetery (**Figure 33**). Potential buyouts were identified for the use of detention within PA04, flood claims data and natural outflow locations were used to inform potential buyouts for mitigation purposes. Structures with flood claims near each other were identified as potential buyouts (**Figure 33**). It is recommended to buyout residential structures that flood frequently and use those areas for detention purposes. With a pond depth of six feet, an approximate area of 18 acres and 22 acres is proposed for mitigation for the Reduced LOS alternative and the Target LOS alternative, respectively.

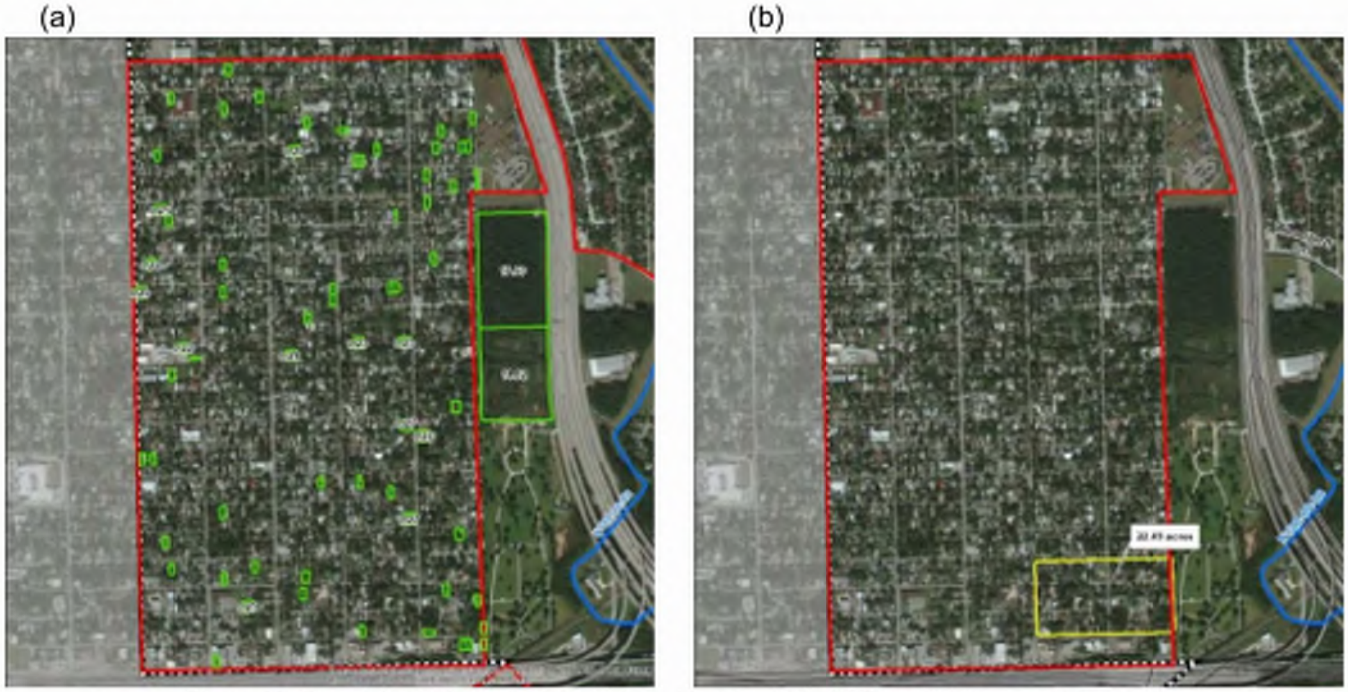


Figure 33: Parcel Analysis for PA04 (a) Vacant Lot Analysis (b) Potential buyout assessment

- Centered trunk lines to capture lateral flow from neighborhoods, outfalls into N100

A drainage improvement alternative that proposed the addition of two trunk lines in the locations shown in **Figure 34** was explored. The addition of trunk lines given that the neighborhood drains through branch lines to these main trunk lines is expected to provide capacity for the Target LOS identified. A preliminary analysis shows that a volume of approximately 80 ac-ft is required for detention through BDF analysis.

Figure 34: Suggested drainage improvement to PA04: Centered trunk lines to capture lateral flow

A preliminary cost analysis was conducted to determine the cost of the centered trunk lines alternative. Table 20 provides the cost estimates. Expanded cost analysis tables are provided in Appendix B.

Table 20: Summary of preliminary cost analysis for addition of trunk lines

Addition of Trunk Lines	Cost
Detention Excavation, Haul Disposal	$1.3M
10x7 RCB Trunk Line 1	$4.1 M
9X6 RCB Trunk Line 2	$2.4 M
Construction Costs	**$6.9 M**
Engineering and Contingencies	**$4.4 M**
ROW Acquisition	**$9.7 M**
Total Estimated Cost	**$22 M**

PA04 computed sheet flow 100-year storm event reveals that flooded structures are widespread. The flooding at the neighborhood level is sheet flow driven. The proposed mitigation strategy for this PA consists of the addition of two trunk lines to provide capacity for the Target LOS identified. Partnerships between Harris County, the community of Cloverleaf and HCFCD are recommended for this alternative. Other potential partners also include Galena Park ISD for ROW acquisition. This will result in substantially lower levels of nuisance yard flooding and ponding in older neighborhoods during high and low frequency events. Outfall improvements will cause lower levels of structural flooding near the outfall.

There is a cemetery located in close proximity to PA04 and contains an area with a dense vegetative cover that could potentially be used for detention. Since PA04 is densely populated with a large amount of residential structures, this land was being considered as a potential buyout for mitigation purposes. The use of this land needs to be explored further through stakeholder engagement meetings and with property owner discussions.

3.7. Problem Area #5 (PA05) (Tier 2)

PA05 is a part of the unincorporated Harris County and the Channelview community. Tributary Unit No. N104-00-00 lies within this PA (**Figure 35**). This PA is comprised of the neighborhoods West Acres, Shadowglen and Old River Terrace.

Figure 35: PA05

Modeled Baseline Conditions show that the stream N104-00-00 in PA05 has less than a 10-year LOS. Most structures were mainly built in the 1940-1980 range. The historical flood claims in this area are along the banks of N104-00-00 and in the 100-year FEMA Effective floodplain. There are a few HAZMAT sites and an O&G pipeline present in this area. PA05 is unique because it floods mostly because of topping of the overbanks of tributary N104-00-00. **Exhibit 10** shows computed flooded structures, inundated roadway and area of inundation for a modeled sheet flow 100-year storm event.

Table 21: Flood Damage estimates for PA05

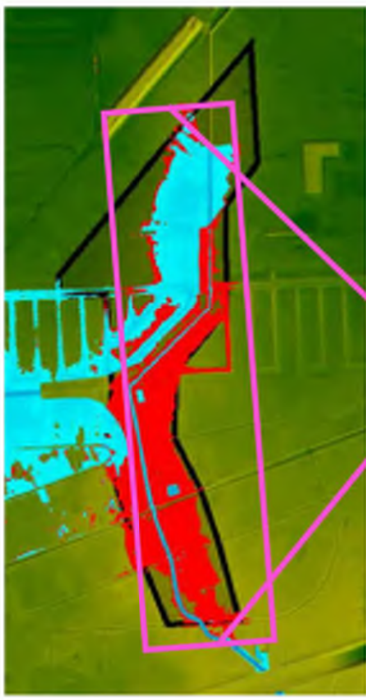
	Computed 100-year Flooded Structures (Count)	Total HCAD market value of computed 100-year Flooded Structures ($)
All	98	$8.3 M
>1ft	22	$1.8 M

PA05 is unique to the watershed as it is largely affected by overbank flooding. Baseline Conditions model revealed that N104-00-00 has less than a 10-year LOS. Channel improvements would provide benefit and cause a reduction in computed flooded structures. Generally, if channel improvements are left unmitigated, impacts downstream of these improvements can be adverse. Stream unit no. N104-00-00 however, outfalls to the downstream end of the mainstem unit no. N100-00-00 towards the Houston Ship Channel, the effects of channel widening/deepening might not cause an adverse impact on the surrounding areas because of the proximity to the Houston Ship Channel.

The project alternative considered for PA05 was a channel improvement at N104-00-00 with a 20 ft bottom width and a slope of 0.0008ft/ft (**Figure 36 and Exhibit 11**). A preliminary analysis was conducted to determine the ROW acquisition required for these channel improvements. The cost estimates include the cost of ROW acquisition. Refer to **Exhibit 12** for a display of the inundation map and the reduction in computed flooded structures from this alternative.

Table 22: Channel improvement impact on PA05

Problem Area	Percent Reduction in Flooded Structures (%)	Reduction in Flooded Structures (count)	Residual Flooded Structures (count)	Cumulative HCAD market value of Residual Properties ($)
PA05	57	56	42	0.9 M



Channel Improvements along N104-00-00 (100-year):

- Existing area of inundation (Baseline conditions): **94 acres**
- Area of Inundation (Channel Improvements): **39 acres**
- Computed flooded structure count (Baseline Conditions): **98**
- Computed flooded structure count (Channel Improvements): **42**

Figure 36: PA05 inundation map Baseline conditions (100-year) vs. Proposed conditions (100-year)

(a) (b)

Figure 37: Channel improvements alternative Analysis for PA05 (a) 100-year computed baseline flooded structures (b) Computed residual flooded structures channel improvements (20ft bottom width)

A preliminary analysis of the water surface profile at N104-00-00 demonstrated a no rise impact (**Appendix C**). An assessment on vacant lots was still conducted to determine whether any empty lots could be acquired for mitigation purposes. PA05 has a few HCFCD owned lots available with a total area of 1 acre and a few vacant lots owned by other owners (**Figure 38**). Potential buyouts were identified for the use of detention within PA05, flood claims data was used to inform potential buyouts for mitigation. Structures with flood claims and flooded structures near each other were identified as potential buyouts (**Figure 38**).

(a) (b)

Figure 38: Parcel Analysis for PA05 (a) Vacant Lot Analysis (b) Potential Buyouts Assessment

A preliminary cost analysis was conducted to determine the cost of this alternative. The table below provides the cost estimates. Expanded cost analysis tables are provided in **Appendix B**.

Table 23: Summary of preliminary cost analysis for Channel Improvements with a 20ft bottom width

Channel Improvements N104	Cost
Clearing, Grubbing, and Disposal	$300K
Utility Adjustments (pipeline)	$86.4K
Excavation (Off-Site Haul)	$1.8 M
Construction Costs	**$2.2 M**
Engineering and Contingencies	**$1.2 M**
ROW Acquisition	**$3.7 M**
Total Estimated Cost	**$7.1 M**

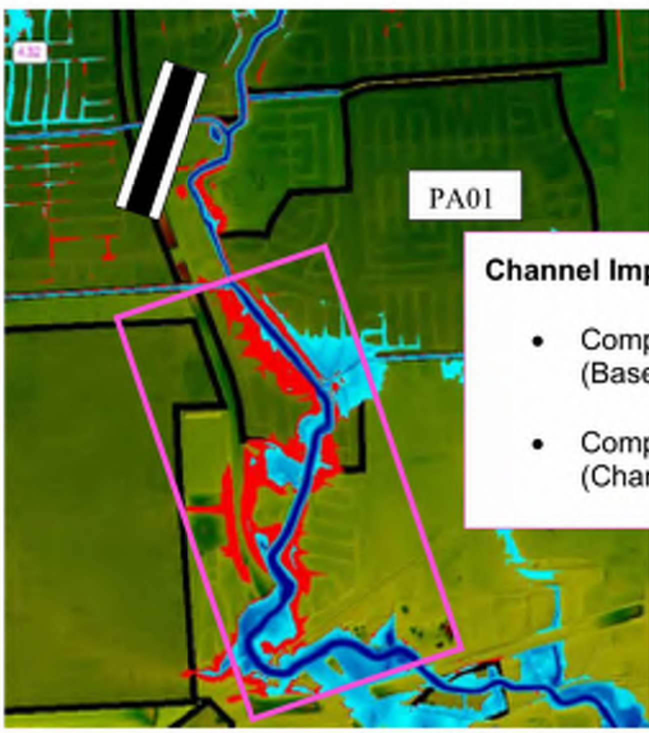
For PA05 an O&G pipeline and a railroad pass through a proposed channel improvement. Further analysis needs to be conducted to determine whether this pipeline poses a significant challenge. The channel improvements can be moved upstream or downstream of the pipeline if constraint is significant.

4. Regional-Level Strategies

The improvements evaluated in this section are geared towards providing watershed wide benefits.

4.1. Channel Improvements (Unit No. N100-00-00)

Channel improvements along the segments of the mainstem Unit N100-00-00 would provide a regional solution to several identified PAs including PA01 and PA03. For this analysis, stream segments were examined by reviewing aerial imagery and the terrain topography. Stream segments that could be widened and deepened without impacting the adjacent developed parcels and segments that cause the least geomorphic impacts in the form of steep or flat longitudinal and cross-sectional channel slopes were selected for improvements. Several runs with varying bottom widths and channel slopes were conducted on stream segments to determine the combination that would yield the most benefit. A preliminary analysis revealed that a bottom width of 50 ft and a slope of 0.00083ft/ft along the segment shown in **Figure 39 and Exhibit 13** reduced the count of computed flooded structures along the banks of N100-00-00 (**Exhibit 14**). There was no impact on water surface elevations downstream of these channel improvements. Refer to **Appendix C** for the comparison of water surface profiles between baseline conditions and proposed channel improvements for the 100-year storm event. In the previous sections, vacant lots/ buyouts assessment was conducted, and a few lots were identified that could be used for mitigation purposes.



Channel Improvements along N100-00-00 (100-year):

- Computed flooded structure count along N100-00-00 (Baseline Conditions): **112**
- Computed flooded structure count along N100-00-00 (Channel Improvements): **36**

Figure 39: Channel improvements along N100-00-00 proposed to reduce computed flooded structures along the banks of N100

A preliminary cost analysis was conducted to determine the cost of this improvement. The table below provides the cost estimates. Expanded cost analysis tables are provided in **Appendix B**.

Table 24: Summary of preliminary cost analysis for channel improvements with a 50ft bottom width

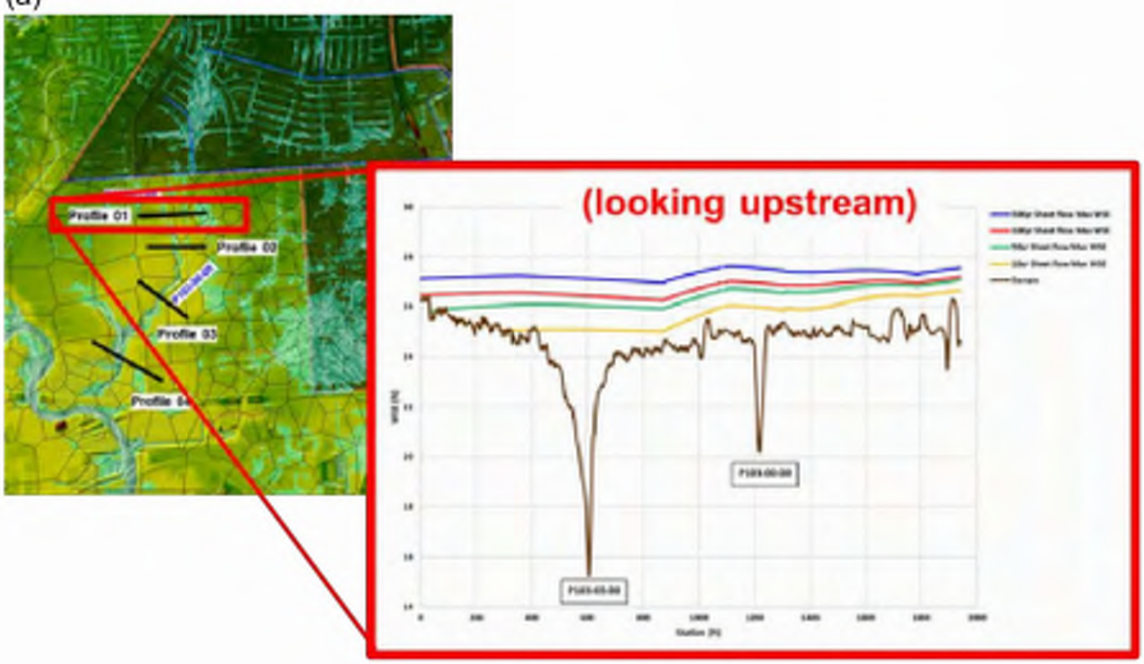
Channel Improvements N100	Cost
Clearing, Grubbing, and Disposal	$171K
Utility Adjustments (pipeline)	$262K
Excavation (Off-Site Haul)	$2.6 M
Construction Costs	**$3.0 M**
Engineering and Contingencies	**$1.7 M**
ROW acquisition	**$17.5 M**
Total Estimated Cost	**$21.5 M**

An O&G pipeline and railroad pass through a proposed channel improvement. Further analysis needs to be conducted to determine whether this pipeline poses a significant challenge. A preliminary analysis indicates minimal channel improvements in this area.

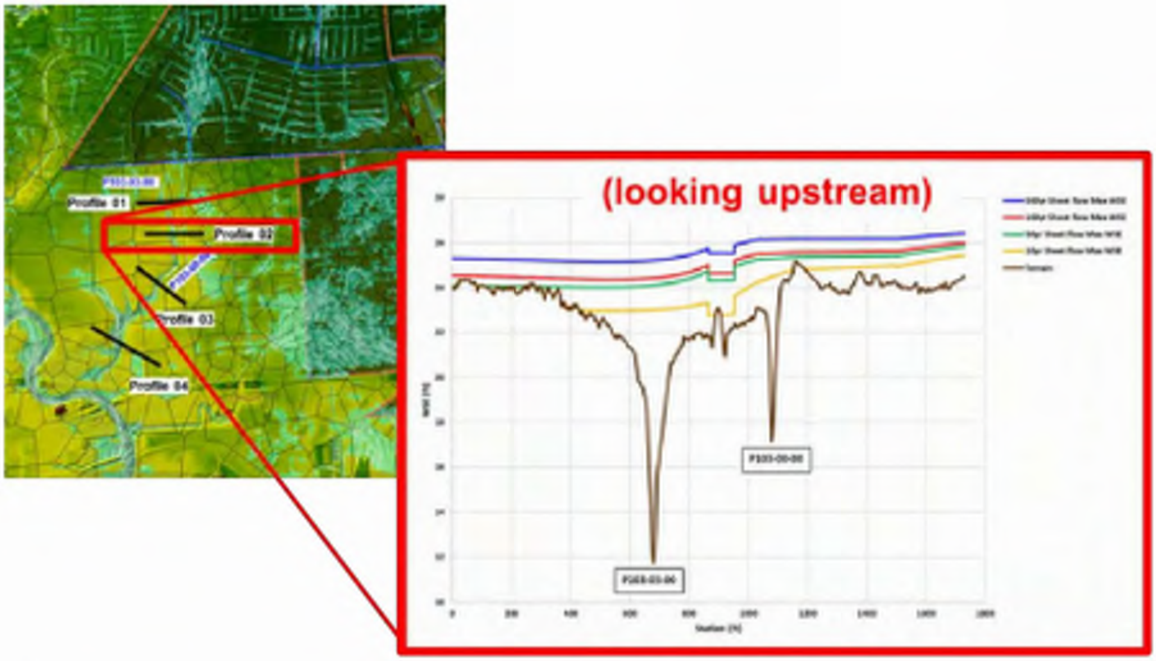
4.2. Diversion towards lower Greens Bayou (P103-00/P103-03)

The baseline conditions model revealed an overflow into Greens Bayou from Carpenters Bayou along tributary N110-00-00. A diversion to the P103-00-00 and P103-03-00 tributary located in lower Greens Bayou was explored. Existing conditions sheet flow model was used to determine the capacity of P103. **Figure 40** shows the water surface elevation of the 10-year, 50-year, 100-year and 500-year storm events.

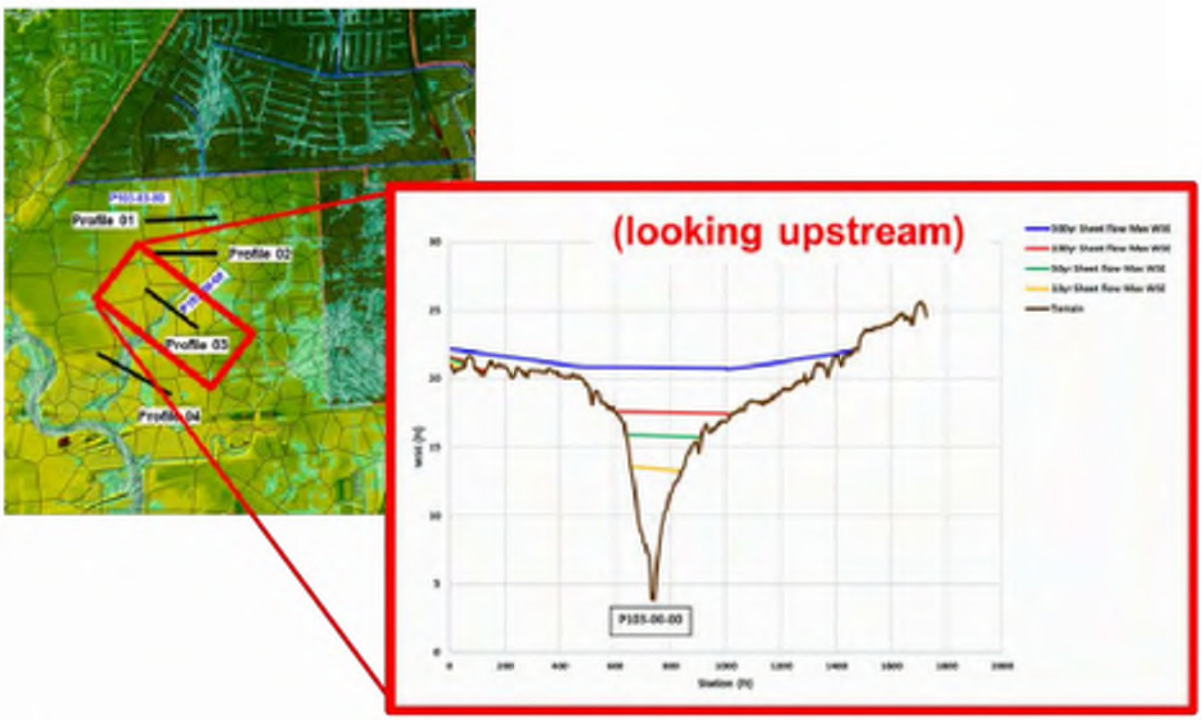
(a)



(b)


Profile 01
Profile 02
Profile 03
Profile 04
(looking upstream)

(c)


Profile 01
Profile 02
Profile 03
Profile 04
(looking upstream)
P103-00-00

(d)

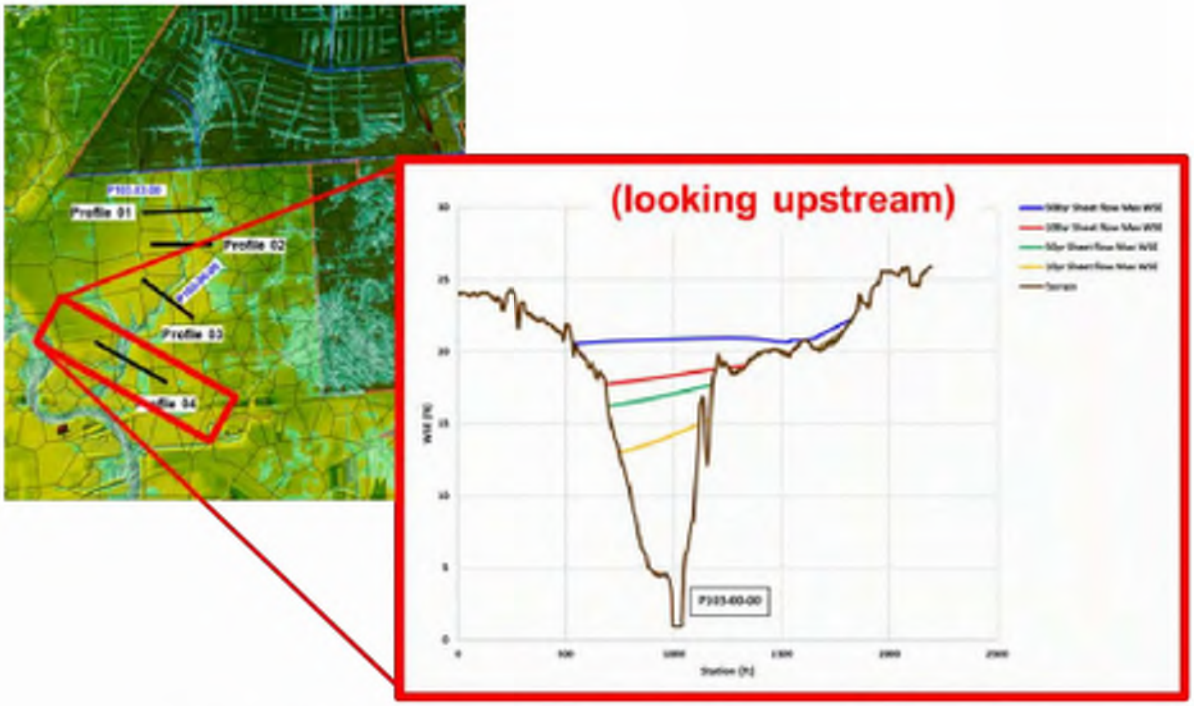


Figure 40 : P103-00-00/P103-03-00 WSEL (ft) profiles. (a) Profile 01 (b) Profile 02 (c) Profile 03 (d) Profile 04

It was determined that P103-00/P103-03 lacks capacity in the upstream reaches but has enough capacity downstream as it connects with the mainstem. Channel improvements can be conducted in the upper reaches of P103-00/P103-03 to facilitate overflow from Carpenters Bayou into Greens Bayou. It was concluded that further analysis needs to be conducted to determine the project feasibility. Further communications between HCFCD and the lower Greens Bayou study team is recommended since this alternative improvement involves two watersheds.

4.3. Lake Sheldon Reservoir

The presence of Lake Sheldon in the Carpenters Bayou watershed provides for a unique opportunity in multi-purpose use. As development continues to move northward, the use of Lake Sheldon as a flood mitigation resource can be explored. A preliminary analysis was conducted to determine the benefits Lake Sheldon would provide as a storage facility. The flows from N100A, N100B, N100C and N117 were zeroed out and downstream benefits were observed. The zeroing out of the flows served to model Lake Sheldon as a storage facility. **Figure 41** shows the Inundation map for the 100-year storm event. As predicted the storage facility provides benefit to the northern region of the watershed where there is a potential for development. This alternative can be considered a long-term improvement project that can be implemented as future development takes place.

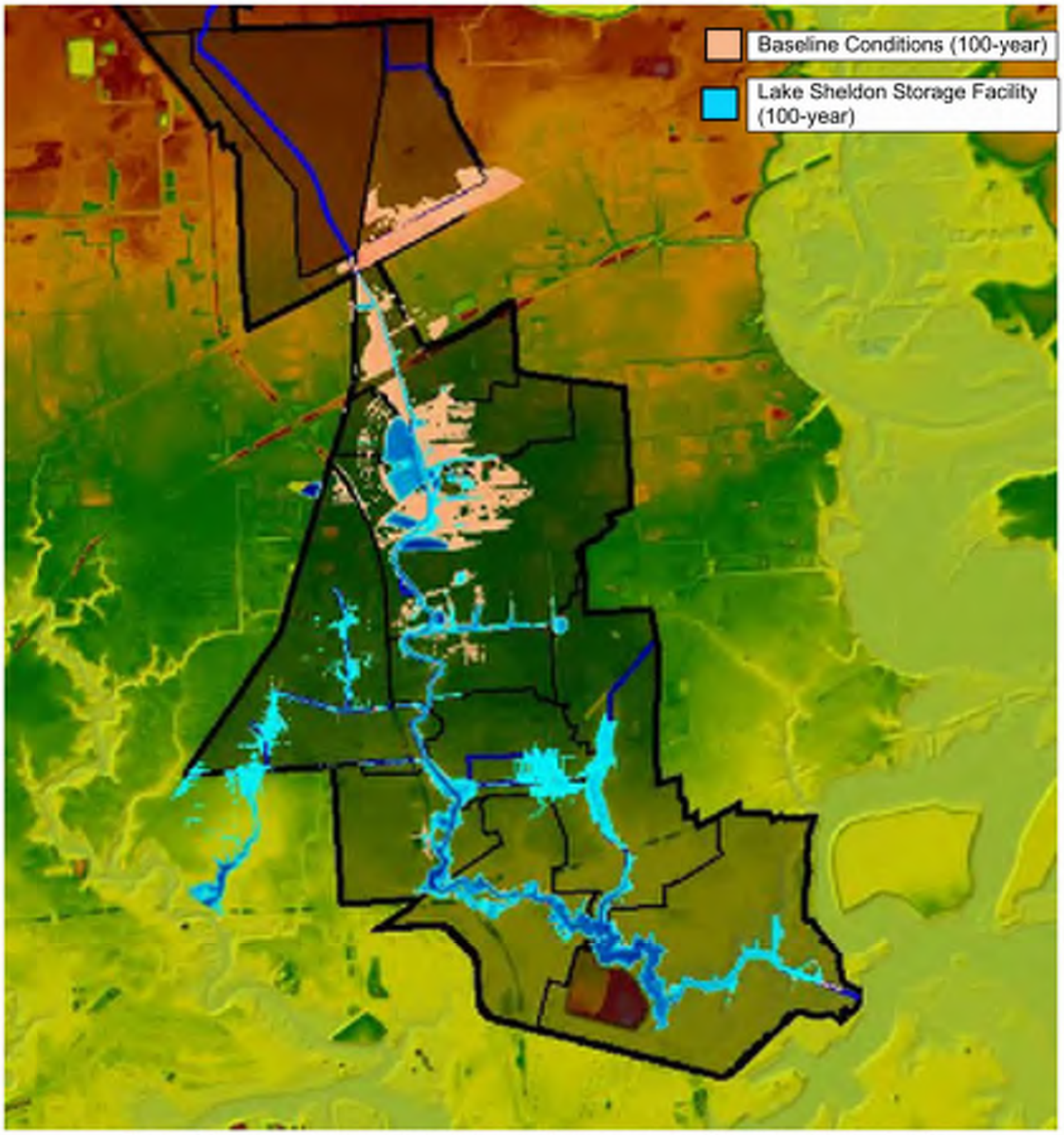


Figure 41: Inundation map baseline conditions vs. Lake Sheldon storage facility

5. Summary of Recommendations

The table below shows the recommended mitigation strategies to address sheet flow driven flooding for the five scoped PAs and the potential partnerships needed for implementation of these recommendations (Table 25). In the Proposed Conditions modeling task, the feasibility and impacts of these alternatives will be realized and alternatives will be finalized accordingly. The purpose of these alternatives is to provide a consistent basis of viable recommendations at the PA level. Final recommendations will follow more detailed Proposed Conditions analysis and may entail some combination of the five alternatives described.

Table 25: Summary of Recommendations

Problem Area	Computed Structures Flooded (1% AEP)	Predicted Miles of Inundated Roadway (>1 ft during 1% AEP)	Source of Flooding	Mitigation Strategy	Potential Partnerships
1	427	13.6	**SF, OB**	**BO, CW, DT**	Channelview, HC, TxDOT, CenterPoint, Midcon
2	785	24.1	**SF**	**BO, DT, LD**	Cloverleaf, HC, HCFCD
3	526	11.4	**SF, OB**	**CW, DT, LD**	Channelview, HC, HCFCD, CenterPoint
4	206	3.0	**SF**	**LD, OI, RD**	Cloverleaf, HC, HCFCD
5	80	1.94	**SF, OB**	**CW**	Channelview, HC, HCFCD, Midcon

Symbol	Definition
SF	Sheet Flow
OB	Overbank Flooding
BO	Voluntary Buyouts
CM	Channel Maintenance
CW	Channel Widening
DT	Added Detention
DV	Diversion
LD	Local Drainage Improvements
OI	Outfall Improvements
RD	Roadside Ditch Improvements

6. Preliminary Analysis of Impacts

6.1. Potential Detention Requirements

Discussions on potential detention requirements have been covered in detail under section 3.0.

6.2. Potential Environmental Impacts

HAZMAT Sites:

There are quite a few HAZMAT sites in every PA. There are 25 HAZMAT sites in PA01, 57 in PA02, 11 in PA03, 14 in PA04 and 4 in PA05. Some HAZMAT sites located in PA01 are within 1000 feet of N109-01-00 and N100-00-00. Upsizing this enclosed tributary (N109-01-00) might pose an impact because of the proximity of the HAZMAT sites. If channel improvements along N100-00-00 are implemented, impacts to air quality, surface water quality and groundwater quality in the vicinity of these HAZMAT sites should be evaluated prior to construction.

Detention ponds are proposed in areas located far from HAZMAT sites. Potential buyouts for mitigation purposes should be conducted so that HAZMAT sites are a minimum of 1000 feet from the proposed site.

O&G Pipelines:

O&G Pipelines pass through PA01, PA03 and PA05. Recommended improvements for these areas include local drainage improvements and channel improvements.

For PA01 the O&G pipeline passes under the enclosed tributary N109-01-00, upsizing N109-01-00 could provide benefit and reduce the count of flooded structures. This O&G pipeline provides a constraint for the this proposed alternative.

For PA05 the O&G pipeline passes through a proposed channel improvement. Further analysis needs to be conducted to determine whether this pipeline poses a significant challenge. The channel improvements can be moved upstream or downstream of the pipeline if constraint is significant.

Cemetery:

There is one cemetery identified in Carpenters Bayou watershed, the San Jacinto cemetery. This cemetery is in close proximity to PA04 and contains an area with a dense vegetative cover that could potentially be used for detention. Since PA04 is densely populated with a large amount of residential structures, this land was being considered as a potential buyout for mitigation purposes. The use of this land needs to be explored further through stakeholder engagement meetings and with property owner discussions.

Wetlands:

No impact to wetlands is expected with implementation of proposed projects.

Cultural Resources:

Cultural resources have been identified in PA03 and PA04 using data provided by HCFCD. The presence of cultural resources in Carpenters Bayou watershed should not pose a constraint on the recommended projects across the watershed.

O&G Wells:

There is one O&G well located in PA03 and improvements within this PA will not have an impact on the well.

Landfills:

No impact to landfills is expected with implementation of proposed projects.

Endangered Species:

No impact on endangered species is expected with implementation of proposed projects.

7. Development Issues

Potential Impact of New Development

As mentioned in Technical Report #1, the age of structures and site visits confirmed that future development will occur in the northern regions of Carpenters Bayou watershed, south and north of Lake Sheldon. Aerial imagery shows the availability of land in this area of the watershed. Any land development that occurs in these regions would have to include detention facilities for mitigation purposes. If future development upstream north and south of Lake Sheldon is left unmitigated, it would pose potential adverse impacts downstream. Carpenters Bayou watershed is primarily driven by sheet flow inundation thus if future development has adequate storm sewer capacity and detention, no adverse impacts are expected.

Recommended Regulatory Program Revisions

The analyses of the watershed reveal that flooding problems arise primarily from poor drainage infrastructure. It is recommended that the storm sewer systems used for future development should be designed to have adequate capacity to safely facilitate neighborhood drainage and reduce flooding. The potential development that is expected to occur south of Lake Sheldon and north of Wallisville Road will not significantly affect the mainstem as all new development will need to follow current County policy to provide separate detention facilities which will be evaluated together with Carpenters Bayou to ensure there are no impacts created due to detention. Impacts caused by timing differences in the hydrographs and additional volume of stormwater in different areas can be reduced by future mitigation studies being extended to the outfall of the watershed.

Future development can also be considered in the Proposed Conditions modeling task of the current study. This could be achieved by considering future development in certain areas and updating the hydrology accordingly to analyze impacts. This might come in the form of an Upper Carpenters Bayou Watershed Master Plan that can leverage available storage capacity in Lake Sheldon or other regional detention features.

Additional Recommended Infrastructure

As new development takes place north of Lake Sheldon, there is a potential of Lake Sheldon to be used as a storage facility. Currently this functionality of Lake Sheldon has not been explored. Prior reports revealed that under historical conditions Sheldon reservoir was full about 60% of the time, a diversion to San Jacinto River caused Sheldon Reservoir to be full 35% of the time (HDR, 1998). Since most of the identified flooding in Carpenters Bayou watershed is related to overland sheet flow, the immediate use of Lake Sheldon reservoir as a storage facility would not provide significant benefits. A detailed study of the potential use of Lake Sheldon as a storage facility as new development north of Lake Sheldon occurs needs to be conducted.

8. References

Asquith WH, Cleveland TG, Roussel MC (2011). "A method for estimating peak and time of peak streamflow from excess rainfall for 10- to 640-acre watersheds in the Houston, Texas metropolitan area," U.S. Geological Survey Scientific Investigations Report.

Arceneaux & Gates Consulting Engineers, Inc. (2013) "Impact Analysis Report for Commercial Development Submitted for Keystone Pipeline Moore Junction Terminal" Submitted to Harris County

Barrett D. (2019). "Recommendations for: Hydrologic Methods in Harris County"." MAAPnext White Paper prepared by HDR Engineering, Inc. for the Harris County Flood Control District.

Barrett D. (2011). "Use of the Basin Development Factor in Hydrologic Calculations and Watershed Modeling in Harris County, Texas." A Research White Paper prepared by R.G. Miller Engineers, Inc. for the Harris County Flood Control District.

Binkley & Barfield, Inc. (1998) "Preliminary Engineering Report Dell Dale Street (IH-10 to Woodforest Blvd)" Submitted to Harris County Public Infrastructure Department Engineering Division

Brown & Gay Engineers, Inc. (2015) "Jacintoport Tract W Phase 2, Drainage Impact Study Carpenters Bayou (HCFCD Unit N100-00-00)" Submitted to Harris County Flood Control District

Dodson & Associates, Inc. (2010) "Updated Drainage Analysis for 40-Acre Tract along Carpenters Bayou" Submitted to Harris County Public Infrastructure Department Engineering Division

Edminster, Hinshaw, Russ & Associates (2016) "Miller Road 2 (Unit N100-00-00, N115-00-00 and N500-02-00)" Submitted to Harris County Flood Control District

HDR Engineering, Inc. (1998) "Sheldon Reservoir Study" Submitted to Harris County Flood Control District, Texas Parks and Wildlife Department, Texas Department of Transportation and McCord Development Communities

J.A. Costanza & Associates Engineering, Inc. (1996) "Letter of Map Revision for Carpenters Bayou Watershed (Unit N100-00-00 and Unit N500-01-00)" (Volume 1), Submitted to Harris County Flood Control District

J.A. Costanza & Associates Engineering, Inc. (1996) "Letter of Map Revision for Carpenters Bayou Watershed (Unit N100-00-00 and Unit N500-01-00)" (Volume 2), Submitted to Harris County Flood Control District

J.A. Costanza & Associates Engineering, Inc. (1996) "Letter of Map Revision for Carpenters Bayou Watershed (Unit N100-00-00 and Unit N500-01-00)" (Volume 3), Submitted to Harris County Flood Control District

Jones & Carter, Inc. (1995) "Drainage Analysis (Unit N111-00-00 and Unit N111-01-00) for Harris County Municipal Utility District No.285" Submitted to Harris County Flood Control District.

Klotz and Associates, Inc. (2010) "Hydraulic Impact Analysis for Sheldon Road Bridge Widening (Unit N100-00-00)" Submitted to Harris County Public Infrastructure Department Architecture & Engineering Division

Liscum, F and Massey, BC (1980), "Technique for Estimating the Magnitude and Frequency of Floods in the Houston, Texas Metropolitan Area." USGS Water-Resources Report 80-17.

Liscum, F (2001). "Effects of Urban Development on Stormwater Runoff Characteristics for the Houston, Texas, Metropolitan Area," U.S. Geological Survey, Water Resources Investigations Report 01-4071.

PowerPoint Presentation prepared by HDR Engineering, Inc. (2014) "Exploration of the Basin Development Factor Concept" Submitted to Harris County Flood Control District

Pate Engineers (2001) "Carpenters Bayou Watershed (Unit N100-00-00 and Unit N104-00-00) Regional Plan Update" Submitted to Harris County Flood Control District

Pate Engineers, Inc. (2011) "Master Drainage Study for Generation Park" Submitted to Harris County Municipal Utility District No. 424, 425, 426, 427, 428 and 429

R.G. Miller Engineers, Inc. (2012) "Freeport St. Drainage Analysis" Submitted to Harris County Flood Control District

Sauer VB, Thomas WO, Jr Stricker VA, Wilson KV, (1983). "Flood characteristics of urban watersheds in the United States," U.S. Geological Survey Water-Supply Paper 2207, Prepare in Cooperation with U.S. Department of Transportation Federal Highway Administration

S&B Infrastructures, LTD. (2003) "TSARP Hydrologic Analysis for Carpenters Bayou (Unit N100-00-00)" Submitted to Harris County Flood Control District

S&B Infrastructures, LTD. (2004) "TSARP Carpenters Bayou (Unit N100-00-00) Final Hydrology" Submitted to Harris County Flood Control District

Sparks & Barlow, Inc. (1986). "Preliminary Engineering Report, Carpenters Bayou Watershed (Unit N100-00-00)," Submitted to Harris County Flood Control District.

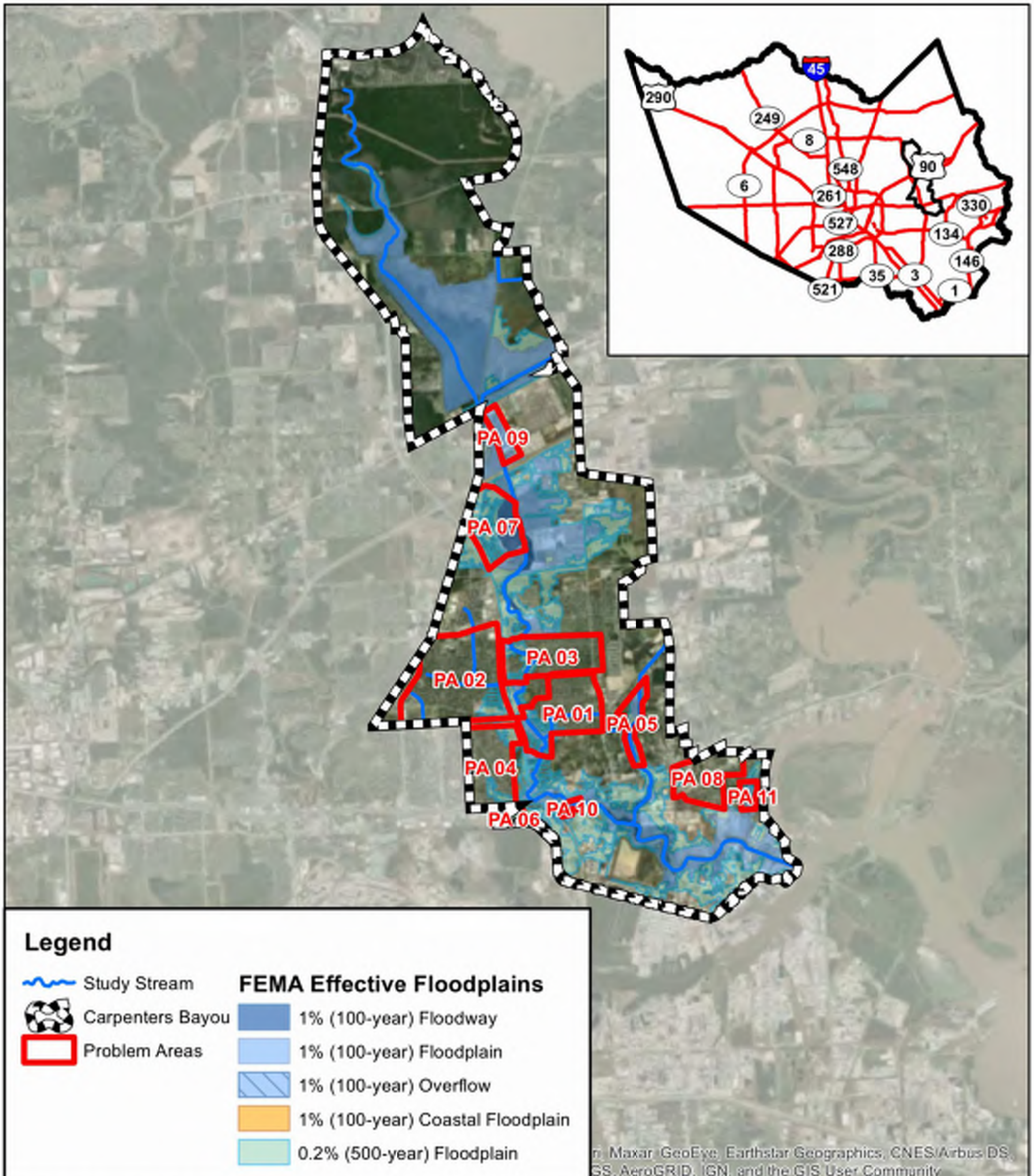
Sparks & Barlow, Inc. (1991). "Carpenters Bayou Watershed (Unit N100-00-00), Main Channel and Regional Detention Study" Submitted to Harris County Flood Control District.

Watershed Concepts. (2005) "TSARP Carpenters Bayou Watershed (Unit N100-00-00) Final Hydraulics" Submitted to Harris County Flood Control District

WGA Consulting Engineers (2019) "Sterling Forest Subdivision Drainage Assessment" Submitted to Harris County Engineering Department

List of Exhibits

List of Appendices



Technical Memorandum 2

Exhibit 01
Carpenters Bayou Study Area

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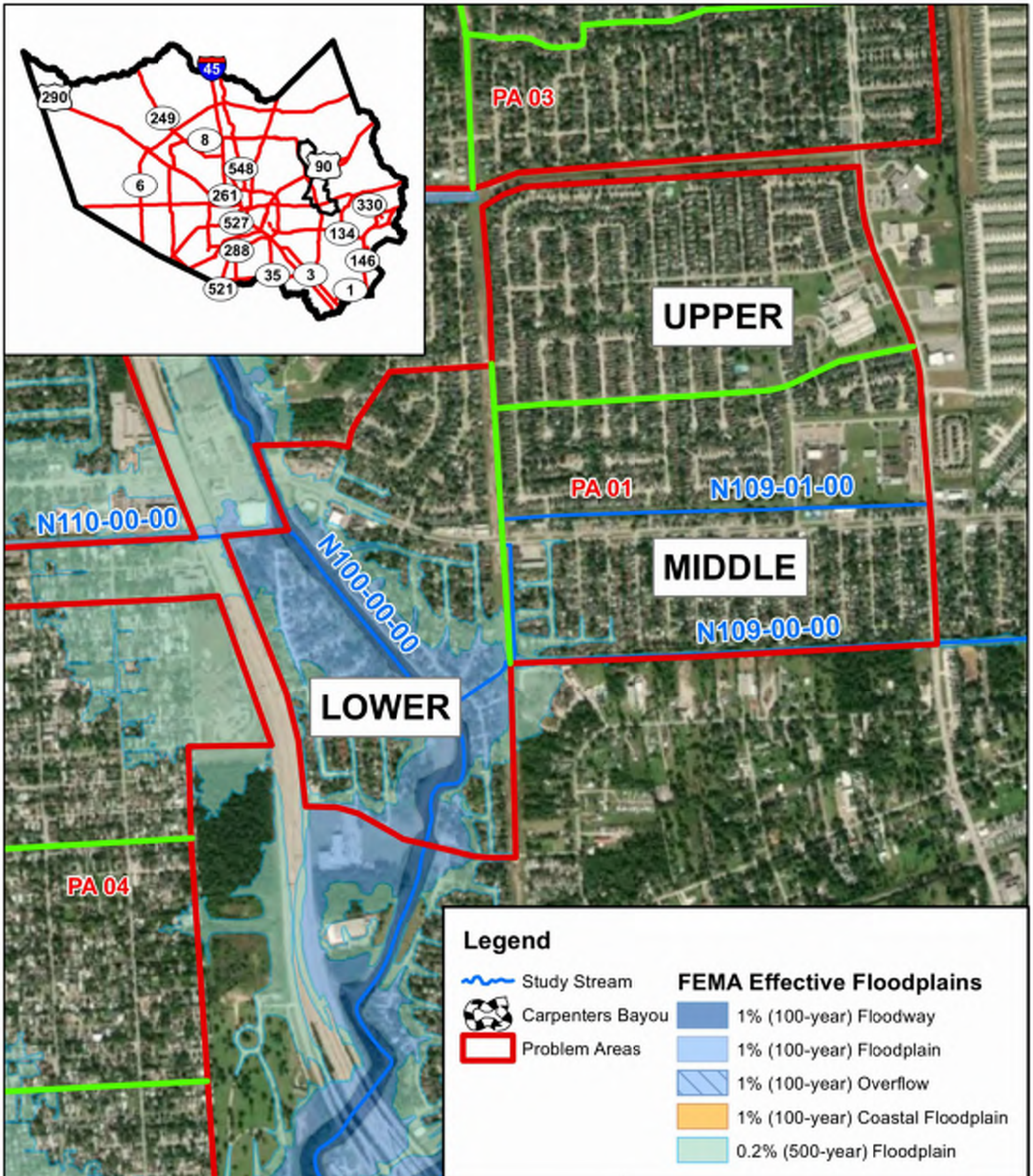
Created: 6/16/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 2

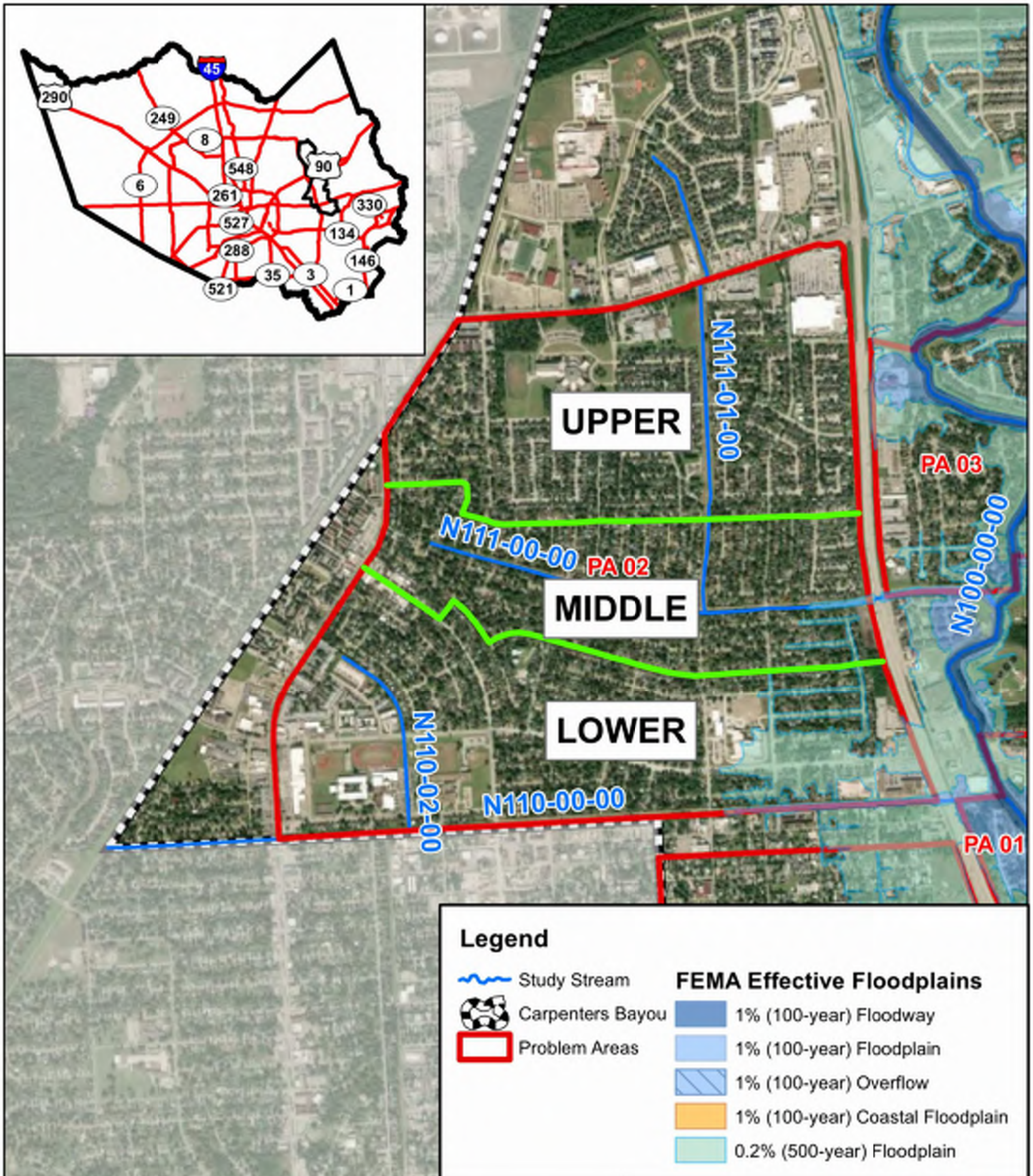
Exhibit 02
Problem Area 1 BDF Analysis

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 2

Exhibit 03
Problem Area 2 BDF Analysis

Miles
0 0.1 0.2 0.4

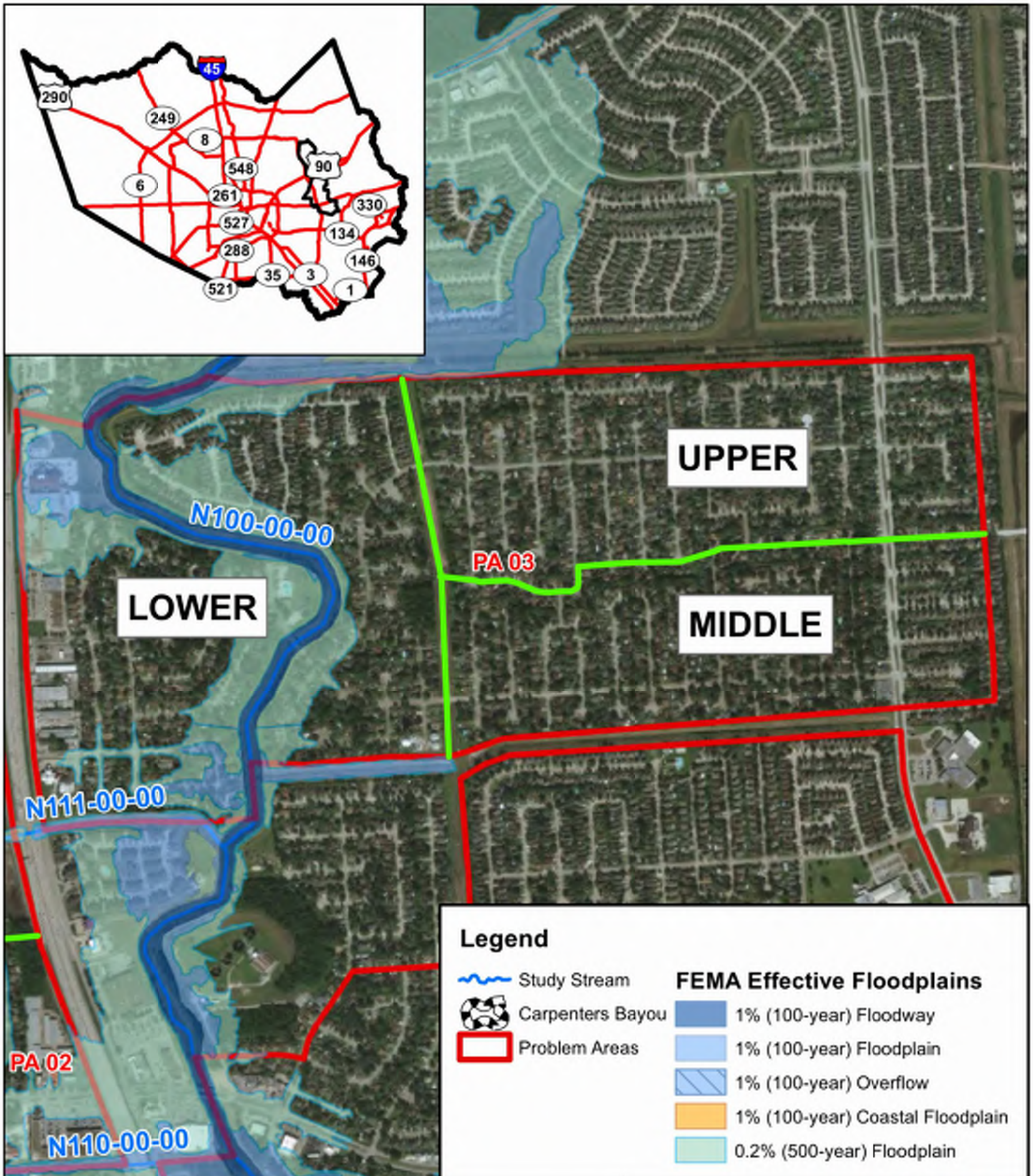
N

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 2

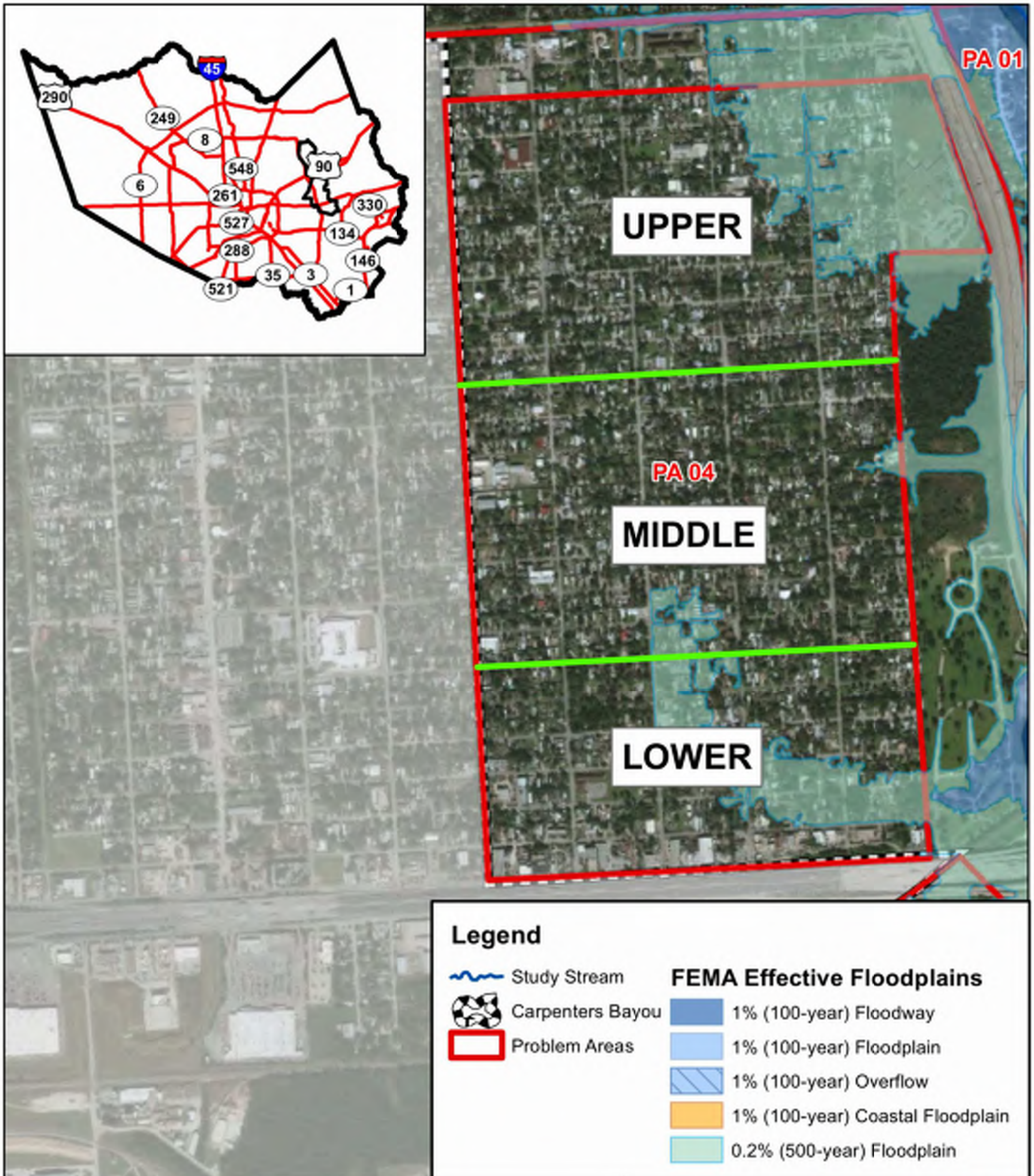
Exhibit 04
Problem Area 3 BDF Analysis

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 2

Exhibit 05
Problem Area 4 BDF Analysis

Miles
0 0.05 0.1 0.2

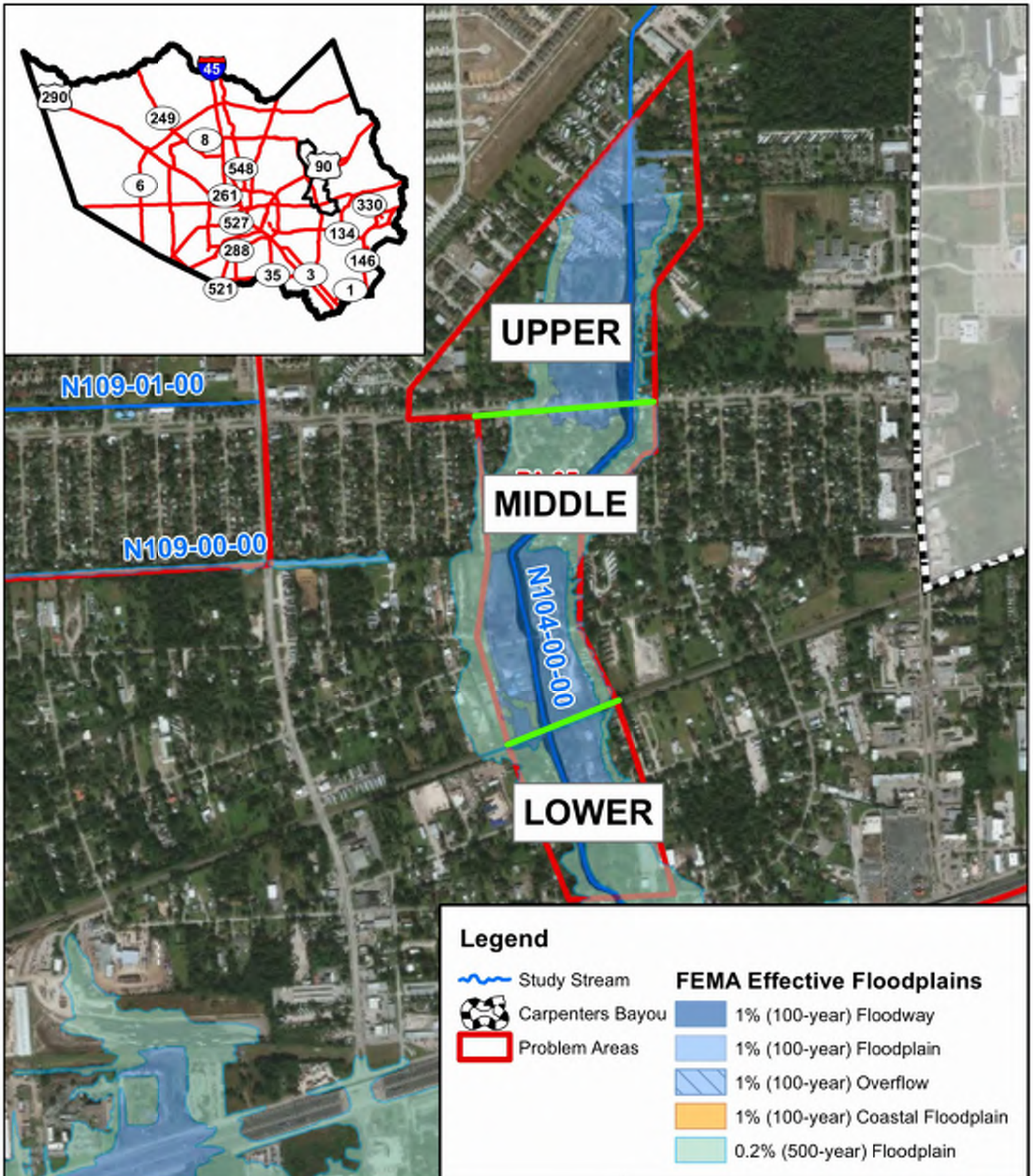
N

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 2

Exhibit 06
Problem Area 5 BDF Analysis

Miles
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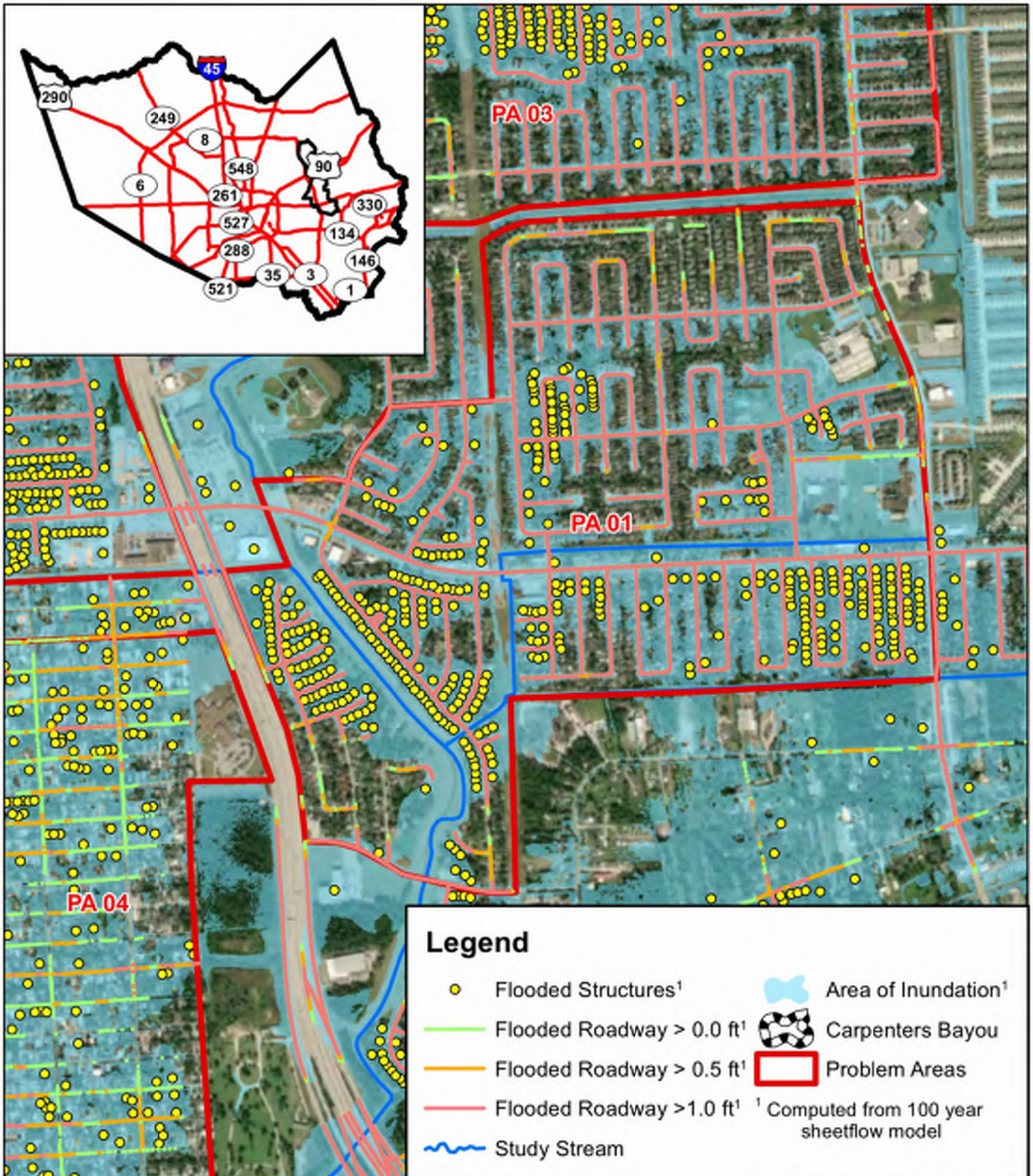
N

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 2

Exhibit 07
Problem Area 1 Computed Flood Metrics

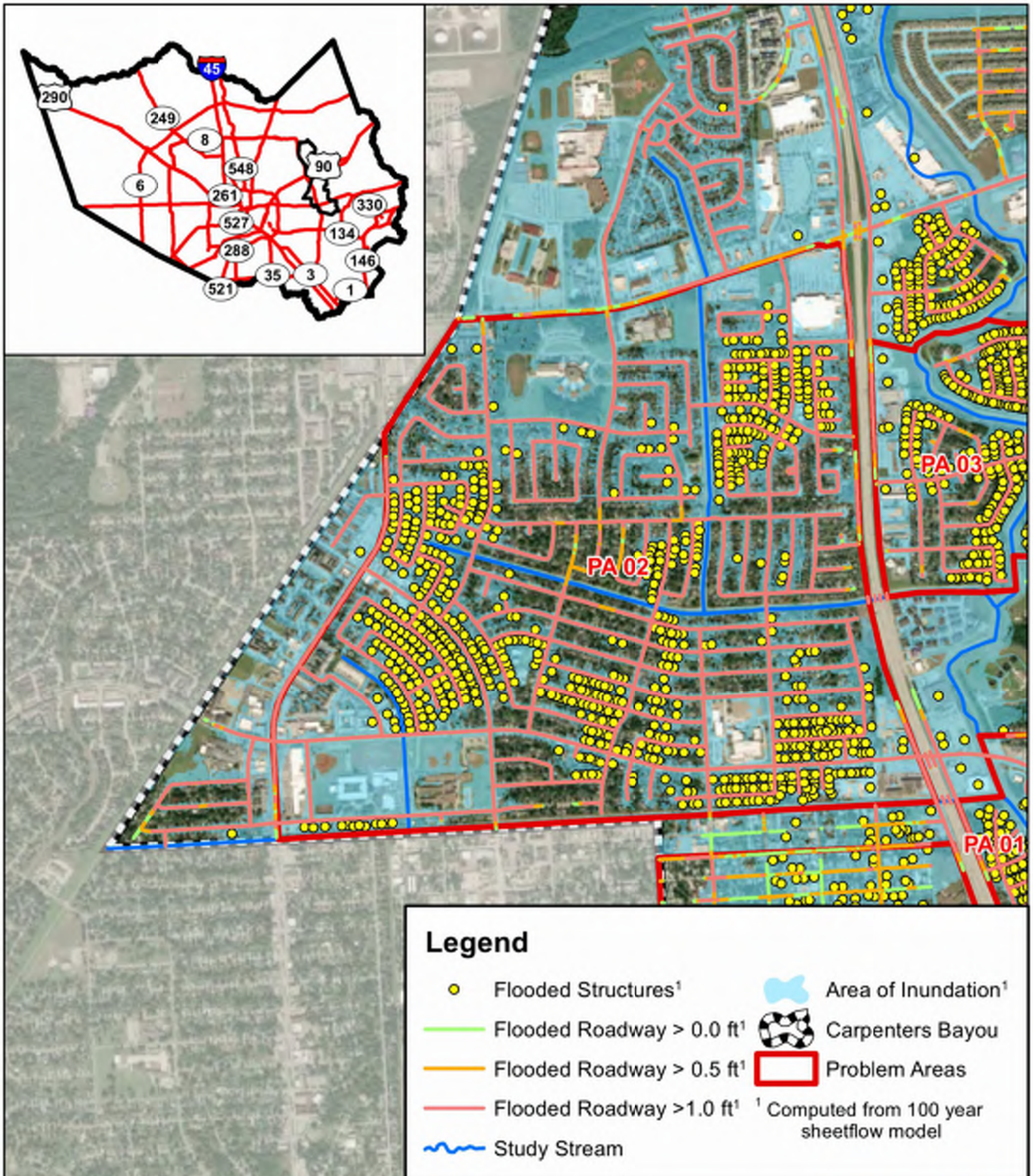
Miles
0 0.050.1 0.2

N

Created: 6/17/2020

Carpenters Bayou

Watershed Plan



Technical Memorandum 2

Exhibit 08
Problem Area 2 Computed Flood Metrics

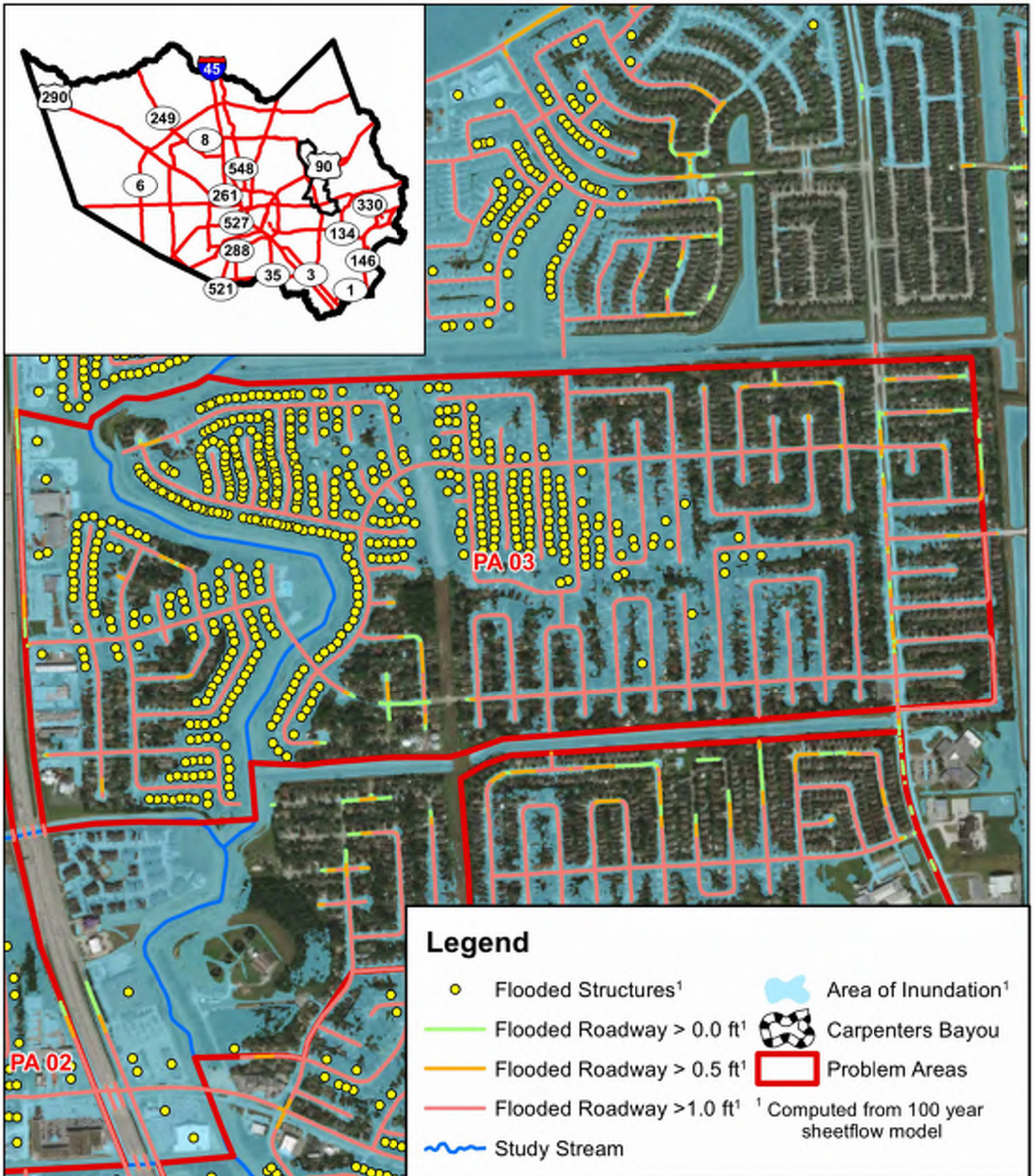
Miles
0 0.1 0.2 0.4

N

Created: 6/17/2020

Carpenters Bayou

Watershed Plan



Technical Memorandum 2

Exhibit 09
Problem Area 3 Computed Flood Metrics

Miles
0 0.05 0.1 0.2

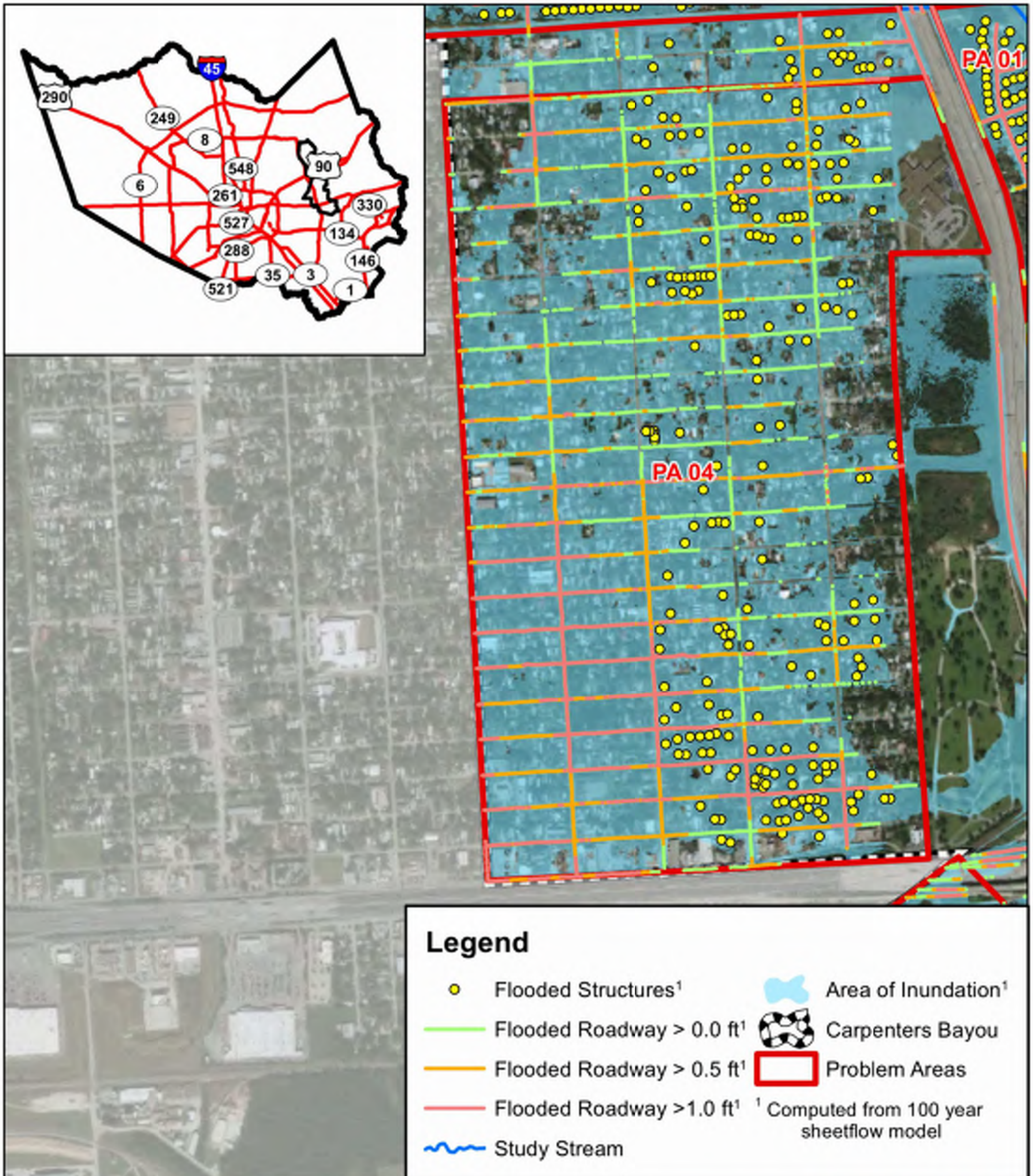
N

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Legend

- Flooded Structures[1]
- Flooded Roadway > 0.0 ft[1]
- Flooded Roadway > 0.5 ft[1]
- Flooded Roadway >1.0 ft[1]
- Study Stream
- Area of Inundation[1]
- Carpenters Bayou
- Problem Areas

[1] Computed from 100 year sheetflow model

Technical Memorandum 2

Exhibit 10
Problem Area 4 Computed Flood Metrics

Miles
0 0.05 0.1 0.2

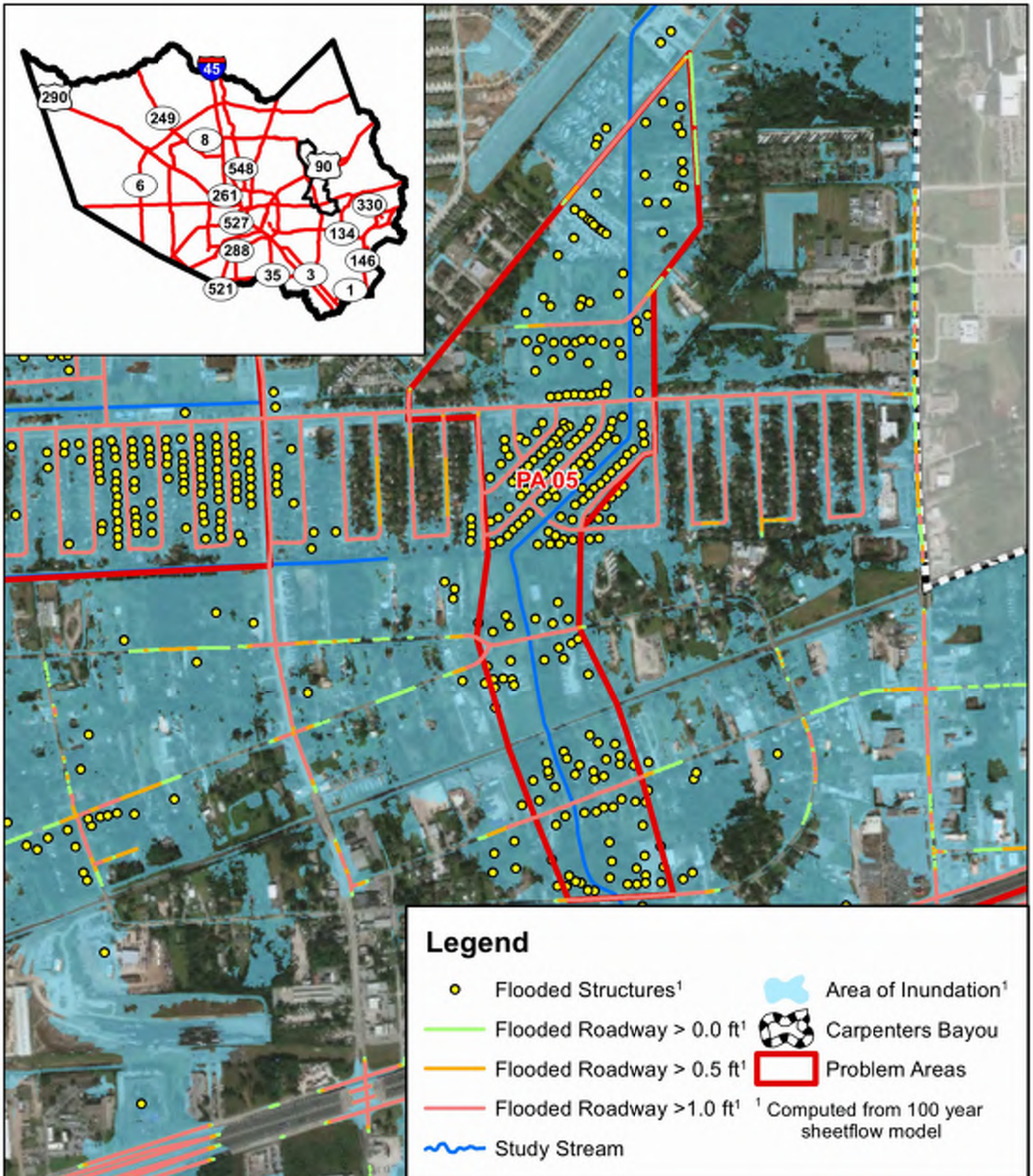
N

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 2

Exhibit 11
Problem Area 5 Computed Flood Metrics

Created: 6/17/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

Appendix A

BDF Calculations

BDF Scores for PA01

PRE BDF PA01	10-year storm			25-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	0	1	1	0	1	1
Channel Linings	0	1	0	0	1	0
Storm Sewers	1	0.5	0.5	1	0.5	0.5
Curb and Gutter Streets	1	1	1	1	1	1
Sub-Totals	2	3.5	2.5	2	3.5	2.5
Overall Total BDF			8			8

PRE				
Drainage Area=	544.921	acres	0.851439	sq.miles
PRE BDF=	8			
Impervious Cover =	45.57	%		
Tr	0.881223	hours		
Tc	1.34259	hours	80.55542	minutes
R	3.056102453			

POST BDF PA01	10-year storm			25-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	0	1	1	0	1	1
Channel Linings	0	1	0	0	1	0
Storm Sewers	1	1	1	1	1	1
Curb and Gutter Streets	1	1	1	1	1	1
Sub-Totals	2	4	3	2	4	3
Overall Total BDF			9			9

POST				
Drainage Area=	544.921	acres	0.851439	sq.miles
POST BDF=	9			
Impervious Cover =	45.57	%		
Tr	0.7802	hours		
Tc	1.241567	hours	74.49403	minutes
R	2.719479212			

BDF Scores for PA02

PRE BDF PA02	25-year storm			50-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	1	1	1	1	1	1
Channel Linings	0	0	0	0	0	0
Storm Sewers	0	0	1	0	0	1
Curb and Gutter Streets	0.5	0.5	0.5	0.5	0.5	0.5
Sub-Totals	1.5	1.5	2.5	1.5	1.5	2.5
Overall Total BDF			5.5			5.5

POST BDF PA02	25-year storm			50-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	1	1	1	1	1	1
Channel Linings	0	0	0	0	0	0
Storm Sewers	0	0	1	0	0	1
Curb and Gutter Streets	1	1	1	1	1	1
Sub-Totals	2	2	3	2	2	3
Overall Total BDF			7			7

PRE				
Drainage Area=	984.431	acres	1.538173	sq.miles
PRE BDF=	5.5			
Impervious Cover =	42.44	%		
Tr	1.516162	hours		
Tc	2.136278	hours	128.1767	minutes
R	5.13943472			

POST				
Drainage Area=	984.431	acres	1.538173	sq.miles
POST BDF=	7			
Impervious Cover =	42.44	%		
Tr	1.263065	hours		
Tc	1.883181	hours	112.9908	minutes
R	4.314118847			

BDF Scores for PA03

PRE BDF PA03	10-year storm			25-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	1	1	1	1	1	1
Channel Linings	0	0	0	0	0	0
Storm Sewers	1	1	0	1	1	0
Curb and Gutter Streets	0.5	0.5	0.5	0.5	0.5	0.5
Sub-Totals	2.5	2.5	1.5	2.5	2.5	1.5
Overall Total BDF			6.5			6.5

PRE				
Drainage Area=	482.132	acres	0.753331	sq.miles
PRE BDF=	6.5			
Impervious Cover =	31	%		
Tr	1.006908	hours		
Tc	1.440882	hours	86.4529	minutes
R	3.472879677			

POST BDF PA03	10-year storm			25-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	1	1	1	1	1	1
Channel Linings	0	0	0	0	0	0
Storm Sewers	1	1	0	1	1	0
Curb and Gutter Streets	1	1	1	1	1	1
Sub-Totals	3	3	2	3	3	2
Overall Total BDF			8			8

POST				
Drainage Area=	482.132	acres	0.753331	sq.miles
POST BDF=	8			
Impervious Cover =	31	%		
Tr	0.838822	hours		
Tc	1.272796	hours	76.36773	minutes
R	2.915187464			

BDF Scores for PA04

PRE BDF PA04	25-year storm			50-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	0.5	0.5	0.5	0.5	0.5	0.5
Channel Linings	0.5	0.5	0.5	0.5	0.5	0.5
Storm Sewers	0.5	0.5	0.5	0.5	0.5	0.5
Curb and Gutter Streets	0	0	0	0	0	0
Sub-Totals	1.5	1.5	1.5	1.5	1.5	1.5
Overall Total BDF			4.5			4.5

PRE				
Drainage Area=	473	acres	0.739	sq.miles
PRE BDF=	4.5			
Impervious Cover =	42.44	%		
Tr	1.274647	hours		
Tc	1.704473	hours	102.2684	minutes
R	4.353490179			

POST BDF PA04	25-year storm			50-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	0.5	0.5	0.5	0.5	0.5	0.5
Channel Linings	1	0.5	1	1	0.5	1
Storm Sewers	1	1	1	1	1	1
Curb and Gutter Streets	1	1	1	1	1	1
Sub-Totals	3.5	3	3.5	3.5	3	3.5
Overall Total BDF			10			10

POST				
Drainage Area=	473	acres	0.739	sq.miles
POST BDF=	10			
Impervious Cover =	42.44	%		
Tr	0.652454	hours		
Tc	1.08228	hours	64.93678	minutes
R	2.291319525			

BDF Scores for addition of Trunk Lines

PRE BDF PA04	25-year storm			50-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	0.5	0.5	0.5	0.5	0.5	0.5
Channel Linings	0.5	0.5	0.5	0.5	0.5	0.5
Storm Sewers	0.5	0.5	0.5	0.5	0.5	0.5
Curb and Gutter Streets	0	0	0	0	0	0
Sub-Totals	1.5	1.5	1.5	1.5	1.5	1.5
Overall Total BDF			4.5			4.5

PRE				
Drainage Area=	473	acres	0.739063	sq.miles
PRE BDF=	4.5			
Impervious Cover =	42.44	%		
Tr	1.274691	hours		
Tc	1.704534	hours	102.2721	minutes
R	4.35363215			

POST BDF PA04	25-year storm			50-year storm		
	Upper	Middle	Lower	Upper	Middle	Lower
Channel Improvements	0.5	0.5	0.5	0.5	0.5	0.5
Channel Linings	1	1	1	1	1	1
Storm Sewers	1	1	1	1	1	1
Curb and Gutter Streets	0	0	0	0	0	0
Sub-Totals	2.5	2.5	2.5	2.5	2.5	2.5
Overall Total BDF			7.5			7.5

POST				
Drainage Area=	473	acres	0.739063	sq.miles
POST BDF=	7.5			
Impervious Cover =	42.44	%		
Tr	0.884636	hours		
Tc	1.31448	hours	78.8688	minutes
R	3.067645943			

Appendix B

Cost Analysis

Problem Area 01 Cost Estimates

REDUCED LOS (10yr) PA01	Quantity	Unit	Unit Cost	Cost	Comment
Drainage Improvements	96710	LF	$ 140.61	$ 13,598,393.10	Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39
Detention Excavation, Haul Disposal	28233.275	CY	$ 10.00	$ 282,332.75	
Construction Costs			**Subtotal**	**$ 13,880,725.85**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 694,036.29	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 1,665,687.10	Percentage of construction costs
Construction Management	1	%	10%	$ 1,388,072.59	Percentage of construction costs
Contingencies	1	%	30%	$ 4,164,217.76	Percentage of construction costs
			Subtotal	**$ 7,912,013.73**	
ROW Acquistition					
Average ROW cost	175570	SF	$ 18.15	$ 3,186,595.50	
Total ROW acquisition cost			**Subtotal**	**$ 7,966,488.75**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 29,759,228.33**	

TARGET LOS (25yr) PA01	Quantity	Unit	Unit Cost	Cost	Comment
Drainage Improvements	96710	LF	$ 154.58	$ 14,949,431.80	Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39
Detention Excavation, Haul Disposal	36299.925	CY	$ 10.00	$ 362,999.25	
Construction Costs			**Subtotal**	**$ 15,312,431.05**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 765,621.55	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 1,837,491.73	Percentage of construction costs
Construction Management	1	%	10%	$ 1,531,243.11	Percentage of construction costs
Contingencies	1	%	30%	$ 4,593,729.32	Percentage of construction costs
			Subtotal	**$ 8,728,085.70**	
ROW Acquistition					
Average ROW cost	219978	SF	$ 18.15	$ 3,992,600.70	
Total ROW acquisition cost			**Subtotal**	**$ 9,981,501.75**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 34,022,018.50**	

Total HCAD market value of computed 100-year flooded structures for PA01

HCAD market value of computed 100 yr flooded structures for Problem Area 1			
Item no.	Description	Quantity	Flood Damage
1	**Total Land Aquisition**		
	Residential	425	$ 27,139,097.00
	Commercial	1	$ 248,124.00
	Critical	1	$ -
2	**Total HCAD market value**	**427**	**$ 27,387,221.00**

Structures flooded at a depth > 1ft for the 100 yr storm event			
Item no.	Description	Quantity	Flood Damage
1	**Total Land Aquisition**		
	Residential	121	$ 8,279,842.00
	Commercial	0	$ -
	Critical	1	$ -
2	**Total HCAD market value**	122	$ 8,279,842.00

Problem Area 02 Cost Estimates

REDUCED LOS (25yr) PA02	Quantity	Unit	Unit Cost	Cost	Comment
Drainage Improvements	155023	LF	$ 132.06	$ 20,472,337.38	Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39
Detention Excavation, Haul Disposal	104866.45	CY	$ 10.00	$ 1,048,664.50	
Construction Costs			**Subtotal**	**$ 21,521,001.88**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 1,076,050.09	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 2,582,520.23	Percentage of construction costs
Construction Management	1	%	10%	$ 2,152,100.19	Percentage of construction costs
Contingencies	1	%	30%	$ 6,456,300.56	Percentage of construction costs
			Subtotal	**$ 12,266,971.07**	
ROW Acquistition					
Average ROW cost	615502.8	SF	$ 18.37	$ 11,306,786.44	
Total ROW acquisition cost			**Subtotal**	**$ 28,266,966.09**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 62,054,939.04**	

TARGET LOS (50yr) PA02	Quantity	Unit	Unit Cost	Cost	Comment
Drainage Improvements	155023	LF	$ 145.11	$ 22,495,387.53	Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39
Detention Excavation, Haul Disposal	129066.4	CY	$ 10.00	$ 1,290,664.00	
Construction Costs			**Subtotal**	**$ 23,786,051.53**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 1,189,302.58	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 2,854,326.18	Percentage of construction costs
Construction Management	1	%	10%	$ 2,378,605.15	Percentage of construction costs
Contingencies	1	%	30%	$ 7,135,815.46	Percentage of construction costs
			Subtotal	**$ 13,558,049.37**	
ROW Acquistition					
Average ROW cost	752715.65	SF	$ 18.37	$ 13,827,386.49	
Total ROW acquisition cost			**Subtotal**	**$ 34,568,466.23**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 71,912,567.13**	

Total HCAD market value of computed 100-year flooded structures for PA02

HCAD market value of computed 100 yr flooded structures for Problem Area 2			
Item no.	Description	Quantity	Flood Damage
1	**Total Land Aquisition**		
	Residential	775	$ 80,448,281.00
	Commercial	6	$ 2,237,845.00
	Critical	3	$ 2,798,138.00
2	**Total HCAD market value**	784	$ 85,484,264.00
Structures flooded at a depth > 1ft for the 100 yr storm event			
Item no.	Description	Quantity	Flood Damage
1	**Total Land Aquisition**		
	Residential	105	$ 10,862,431.00
	Commercial	1	$ 631,400.00
	Critical	2	$ 2,537,840.00
2	**Total HCAD market value**	108	$ 14,031,671.00

Problem Area 03 Cost Estimates

REDUCED LOS (10yr) PA03	Quantity	Unit	Unit Cost	Cost	Comment
Drainage Improvements	73881	LF	$ 132.00	$ 9,752,292.00	Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39
Detention Excavation, Haul Disposal	38316.5875	CY	$ 10.00	$ 383,165.88	
Construction Costs			**Subtotal**	**$ 10,135,457.88**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 506,772.89	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 1,216,254.95	Percentage of construction costs
Construction Management	1	%	10%	$ 1,013,545.79	Percentage of construction costs
Contingencies	1	%	30%	$ 3,040,637.36	Percentage of construction costs
			Subtotal	$ 5,777,210.99	
ROW Acquistition					
Average ROW cost	227835	SF	$ 18.42	$ 4,196,720.70	
Total ROW acquisition cost			**Subtotal**	**$ 10,491,801.75**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 26,404,470.61**	

TARGET LOS (25yr) PA03	Quantity	Unit	Unit Cost	Cost	Comment
Drainage Improvements	73881	LF	$ 145.11	$ 10,720,871.91	Pipe Culvert Unit Price ($/LF) = (CS Area x ($14 per ft^2) + $76.39
Detention Excavation, Haul Disposal	56466.55	CY	$ 10.00	$ 564,665.50	
Construction Costs			**Subtotal**	**$ 11,285,537.41**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 564,276.87	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 1,354,264.49	Percentage of construction costs
Construction Management	1	%	10%	$ 1,128,553.74	Percentage of construction costs
Contingencies	1	%	30%	$ 3,385,661.22	Percentage of construction costs
			Subtotal	$ 6,432,756.32	
ROW Acquistition					
Average ROW cost	318423.6	SF	$ 18.42	$ 5,865,362.71	
Total ROW acquisition cost			**Subtotal**	**$ 14,663,406.78**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 32,381,700.51**	

Total HCAD market value of computed 100-year flooded structures for PA03

HCAD market value of computed 100 yr flooded structures for Problem Area 3			
Item no.	Description	Quantity	Flood Damage
1	**Total Land Aquisition**		
	Residential	521	$ 40,490,366.00
	Commercial	2	$ 1,784,180.00
	Critical	3	$ 6,702,878.00
2	**Total HCAD market value**	**526**	**$ 48,977,424.00**

Structures flooded at a depth > 1ft for the 100 yr storm event			
Item no.	Description	Quantity	Flood Damage
1	**Total Land Aquisition**		
	Residential	210	$ 16,660,114.00
	Commercial	1	$ 156,542.00
	Critical	1	$ 5,313,266.00
2	**Total HCAD market value**	**212**	**$ 22,129,922.00**

Trunk Line System Cost Estimates

Trunk Lines	Quantity	Unit	Unit Cost	Cost	Comment
Detention Excavation, Haul Disposal	129066	CY	$ 10.00	$ 1,290,660.00	
9X7 RCB Trunk Line 1	2946	LF	$ 850.00	$ 2,504,100.00	From cost tool and mannings calculation, along Hershe St and Nancy Rose St
10x7 RCB Trunk Line 2	5666	LF	$ 715.00	$ 4,051,190.00	From cost tool and mannings calculation, along Muscatine St and Barbara Mae Street
Construction Costs			**Subtotal**	**$ 7,845,950.00**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 392,297.50	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 941,514.00	Percentage of construction costs
Construction Management	1	%	10%	$ 784,595.00	Percentage of construction costs
Contingencies	1	%	30%	$ 2,353,785.00	Percentage of construction costs
			Subtotal	**$ 4,472,191.50**	
ROW Acquisition					
61 parcels	100%	%	$ 3,868,874.00	$ 3,868,874.00	100% buyout
Total ROW acquisition cost			**Subtotal**	**$ 9,672,185.00**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 21,990,326.50**	

Total HCAD market value of computed 100-year flooded structures for PA04

HCAD market value of computed 100 yr flooded structures for Problem Area 4			
Item no.	**Description**	**Quantity**	**Flood Damage**
1	**Total Land Aquisition**		
	Residential	191	$ 11,982,711.00
	Commercial	15	$ 1,589,565.00
	Critical	0	$ -
2	**Total HCAD market value**	**206**	**$ 13,572,276.00**

Structures flooded at a depth > 1ft for the 100 yr storm event			
Item no.	**Description**	**Quantity**	**Flood Damage**
1	**Total Land Aquisition**		
	Residential	40	$ 2,064,102.00
	Commercial	1	$ 130,365.00
	Critical	0	$ -
2	**Total HCAD market value**	**41**	**$ 2,194,467.00**

Channel Improvements N104 Cost Estimates

Channel Improvements N104	Quantity	Unit	Unit Cost	Cost	Comment
Clearing Grubbing, and Disposal	48.4	AC	$ 6,200.00	$ 300,080.00	
Utility Adjustments (pipeline)	270	LF	$ 320.00	$ 86,400.00	Equistar Chemicals, LP closest to Missouri Pacific Railroad
Excavation (Off-Site Haul)	148065	CY	$ 12.00	$ 1,776,780.00	Proposed conditions model used for quantity
Construction Costs			**Subtotal**	**$ 2,163,260.00**	
			Engineering and Contingencies		
Mobilization/Demobilization	1	%	5%	$ 108,163.00	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 259,591.20	Percentage of construction costs
Construction Management	1	%	10%	$ 216,326.00	Percentage of construction costs
Contingencies	1	%	30%	$ 648,978.00	Percentage of construction costs
			Subtotal	**$ 1,233,058.20**	
			ROW Acquistition		
32 parcels	5%	%	$ 4,344,708.00	$ 217,235.40	5% of market value
12 parcels	12%	%	$ 1,325,204.00	$ 159,024.48	12% of market value
14 parcels	30%	%	$ 1,192,433.00	$ 357,729.90	30% of market value
11 parcels	50%	%	$ 729,801.00	$ 729,801.00	full buyout market value used
1 parcel	100%	%	Owned by HCFCD	-	
Total ROW acquisition cost			**Subtotal**	**$ 3,659,476.95**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	$ 7,055,795.15	

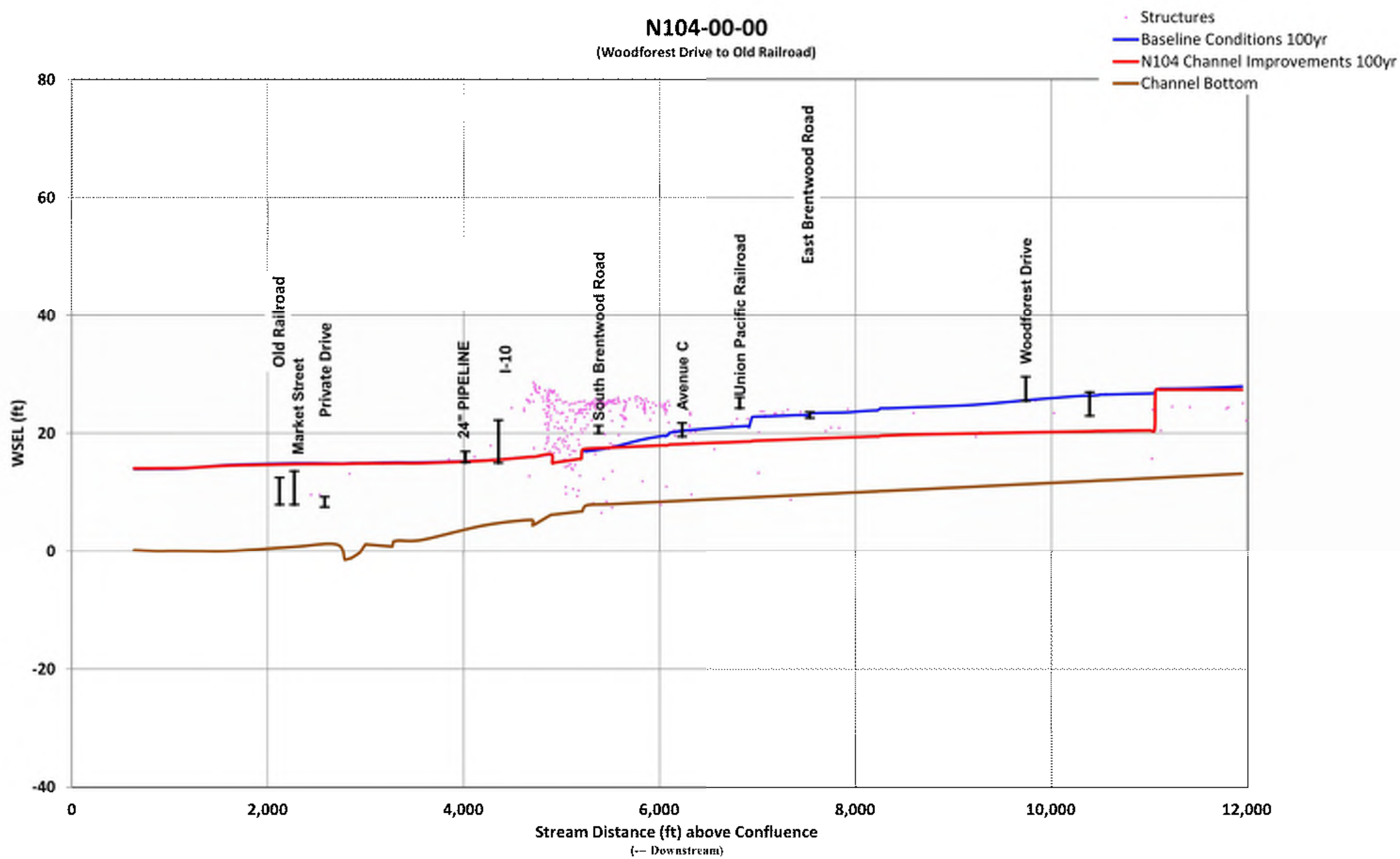
Channel Improvements N100 Cost Estimates

Channel Improvements N100	Quantity	Unit	Unit Cost	Cost	Comment
Clearing Grubbing, and Disposal	27.5	AC	$ 6,200.00	$ 170,500.00	
Utility Adjustments (pipeline)	819	LF	$ 320.00	$ 262,080.00	Colonial Pipeline closest to Missouri Pacific Railroad
Excavation (Off-Site Haul)	213006	CY	$ 12.00	$ 2,556,072.00	Proposed conditions model used for quantity
Construction Costs			Subtotal	**$ 2,988,652.00**	
Engineering and Contingencies					
Mobilization/Demobilization	1	%	5%	$ 149,432.60	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 358,638.24	Percentage of construction costs
Construction Management	1	%	10%	$ 298,865.20	Percentage of construction costs
Contingencies	1	%	30%	$ 896,595.60	Percentage of construction costs
			Subtotal	**$ 1,703,531.64**	
ROW Acquistition					
89 parcels	100%	%	$ 6,720,257.00	$ 6,720,257.00	Full Buyout
Total ROW acquisition cost			**Subtotal**	**$ 16,800,642.50**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 21,492,826.14**	

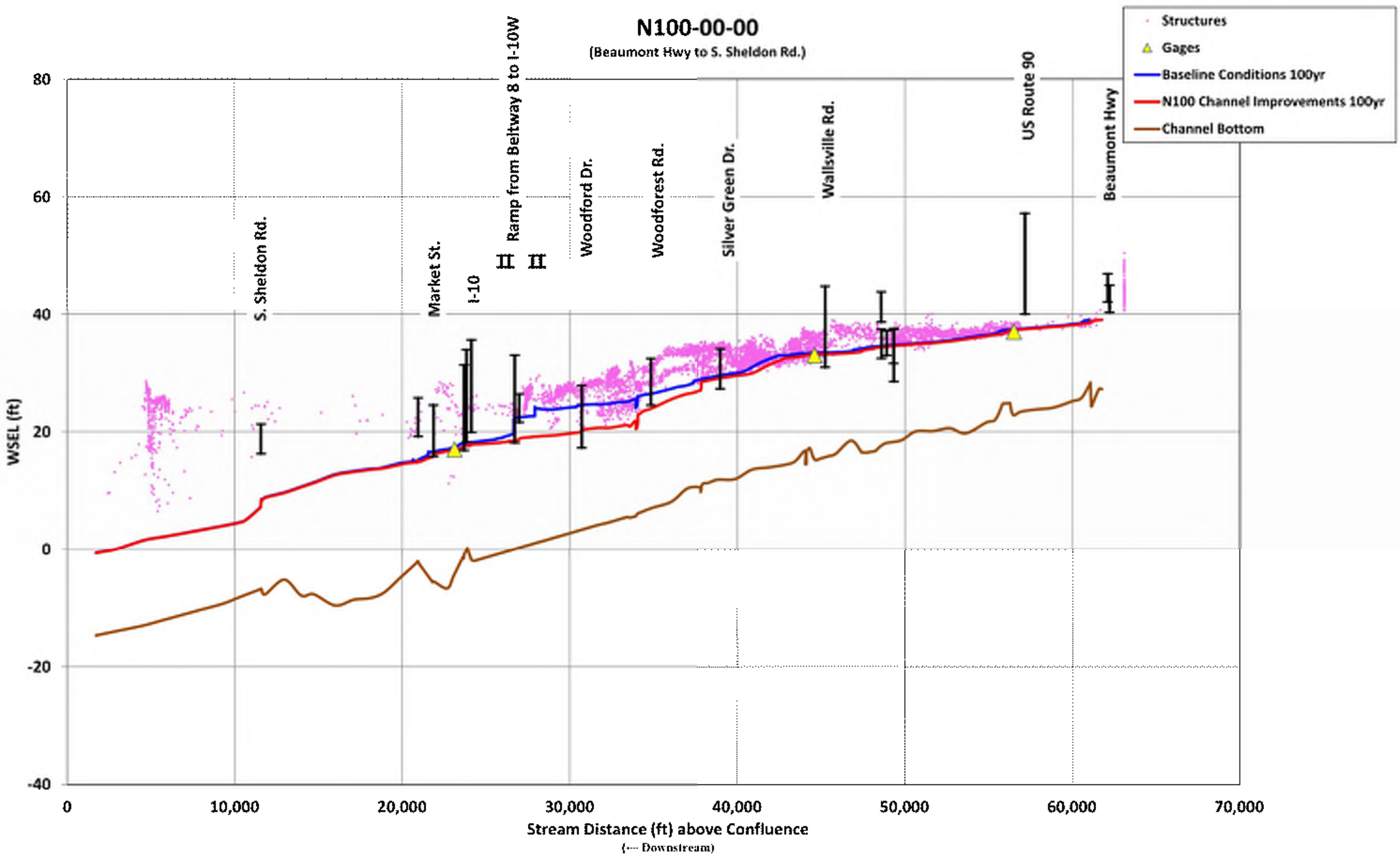
Appendix C

Water Surface Profiles for Channel Improvements

Attachment #2 Interim Deliverable



Attachment #2 Interim Deliverable



Appendix D

Comment Response

Carpenters Watershed Planning Project (N100-P004)

Planning-Level Alternatives Analysis Technical Memorandum # 2 Review

[1] This form addresses comments from HCFCD with appropriate responses.

Date:	8/10/2020	Review Deadline:	
Client:	HCFCD	Actual Review:	
Project No:	N100-P004	Allocated Hours:	
Project Manager:	Jacob Torres, PhD, PE, CFM	Actual Hours:	
Reviewed by:	Lubaina Selani, EIT		

ITEM NO.	COMMENTS (HCFCD/ David)	RESPONSE (TORRES)
1	This might be a good location for the Acknowledgments paragraph. If not here, then please find another suitable place and include that paragraph in all future reports as well.	Concur. Acknowledgements paragraph has been added.
2	Not sure I understand this sentence. Are you suggesting we have two categories, Regional and Local instead of major and smaller? I agree that might be better classifications. If so, let's just change them now to that terminology.	Concur. The terminology was updated to Regional and Local.
3	It sounds like we are saying that the sterling forest study stated or concluded this. Let's change this implication. Perhaps it is best to only reference actual conclusions from this study and not editorialize in this paragraph.	Concur. Only actual conclusions from the report were referenced.
4	In general, these areas are considered to have concentrated flooding problems of sufficient magnitude to warrant more detailed H&H analyses and development of potential improvement projects which might be funded with 2018 Bond or other County revenues in the near term future.	Concur. This paragraph was changed accordingly.
5	It seems your example would be improved and more appropriate if there were some differences in the assignments for the upper, middle, and lower watershed. Perhaps you could choose another area for this example.	Concur. As per the comments in the report, PA04 was replaced with PA01 for this Figure.
6	I suggest adding an appropriate noun for each adjective. It could be Alternative, Solution, Approach, etc. I think "alternative" works just fine but whatever is used should be added throughout this section and the next section.	Concur. As per the comments "alternative" was added for each instance in which LOS was being used as an adjective.
7	I think your explanation is totally correct but it is very difficult to follow since is describes a "greater storm magnitude that does not yield flood reduction benefits". This is sort of a double negative since a storm does not really create flood reduction benefits. Perhaps it could be explained better by the simple approach you use for each problem area (i.e this is the smallest storm event that the drainage system must handle to achieve the most significant reduction in damages? If the proposed drainage system is even larger, very few additional damages are removed. Not sure if this helps or not.	Concur, the explanation was updated accordingly.
8	Let's go with the more formal "100-year" wording for all frequency quotes	Concur. This specific change was made in the report overall.
9	If these are the actual values and not just fictitious examples, we probably need to better define the columns and perhaps add the mitigation volumes that were calculated for each to the table.	Concur, all tables in the memo were updated according to the suggestion.
10	What does this value represent? If it is the HCAD market value of the 10 properties, let's not call it residual flood damages. Perhaps "Total HCAD market value of the residual properties" if there were room. An alternative is to label the two columns together as "Residual Flooded Structures" and then show the left column as "Count" and right column as "HCAD Value $"	Concur, all tables in the memo were updated according to the suggestion.
11	Some of the changes recommended in this section also apply to other alternatives or to other problem areas discussed in subsequent sections of the report. Please try to replicate these changes when appropriate to the other paragraphs and sections as well.	Concur. All changes made for PA01 according to the comments provided were replicated for other problem area discussions if applicable.
12	You might consider using this map (with enhancements) for Figure 2 instead of the one you are using now	Concur
13	In some areas of the report, we use LOS to mean Level of Service. In other areas of the report we use LOS as a substitute for LOS Alternative. Please review and clarify those instances when LOS is an adjective for the alternative solution.	Concur. These instances have been reviewed and clarified.
14	Suggest adding the actual number of structures removed as an additional column in this table.	Concur. This column has been added.
15	I think we need to take pains to clarify that this "mitigation" volume is not what is required to reduce the existing flood problem. It is only the detention necessary to mitigate the potential increase in peak flow created by the "optimum" solution for improved drainage in the neighborhood. In other reports, mitigation volume is used to suggest reduction of peak flows in the channel to allow reduced backwater surface elevations in the neighborhood leading to reduced flood damages.	Concur. Changes have been made to this paragraph according to the comment for all PAs.
16	The challenge here is distinguishing between the entire PA01 solution and the Sterling Forest solutions proposed in previous studies. You may need some basic changes to how this is discussed in order to reduce that confusion factor	Concur. A pargraph has been added where appropritae to clarify this point.

Carpenters Watershed Planning Project (N100-P004)

Planning-Level Alternatives Analysis Technical Memorandum # 2 Review

[1] This form addresses comments from HCFCD with appropriate responses.

Date:	8/10/2020	**Review Deadline:**	
Client:	HCFCD	**Actual Review:**	
Project No:	N100-P004	**Allocated Hours:**	
Project Manager:	Jacob Torres, PhD, PE, CFM	**Actual Hours:**	
Reveiwed by:	Lubaina Selani, EIT		

ITEM NO.	COMMENTS (HCFCD/ David)	RESPONSE (TORRES)
17	For the Reduced and Target LOS, we cannot call this table a summary of PA01 project alternatives if it does not include the cost of the actual improvements required to mitigate the flood damages we are showing (i.e. this is the OPCC only for mitigating the adverse impacts of the drainage improvements, not the actual improvements. I fear this is true throughout the report.	Concur. All cost tables have been updated according to this suggestion so that the cost of detedntion vs. the cost of drainage improvements can be recognized.
18	Let's add the school district to this list of potential partners. It will either be Channelview ISD, Sheldon ISD, or Galena Park ISD, but you should check the jurisdictional boundaries. Let's include the appropriate ISD in the list of potential partners for each PA.	Concur. The schhol districts have been added to list of potential partners for PAs 1 through 4.
19	Could we get 23 acre-feet of storage in this school campus to serve as mitigation for the downstream neighborhood?	Concur. Schools have been added to the list of potential partners.
20	It is not clear whether these swales could be located between existing structures or if they would require purchase of the entire lot and removal of the houses to achieve the desired results.	Concur. This paragraph was updated to say that a partial buyout is recommended.
21	Let's discuss this section and how it fits in the overall watershed planning project. I think there may be a better characterization of these alternatives than regional-level	Concur. The heading was updated to Regional-Level strategies.
22	I think we need to go ahead and expand this section cover the schematic layout of the channel improvements and the cost and benefits thereof. This consideration belongs in this tech memo. The selection of the local versus regional and overall recommended strategy will go in the tech memo 3.	Concur. This section has been updated to include a more detailed analysis on channel improvements and other regional considerations.
23	Let's consider the slicing and dicing issue related to these factors. There are good arguments both ways but I think it works better to take each of the 5 areas and discuss the issues related to that specific together. Yes there is some repetition but it is easier to think about all of the potential constraints for each project separately. You might be able to pull out in advance those issues that are not relevant for any problem area and then discuss the remaining relevant issues only for each project.	Concur. A paragraph on environmental impacts has been added to each PA section.
24	I may be over-simplifying, but I think of "cultural resources" as historical or archeological artifacts from previous occupation which are buried below the surface. We know of some because a previous study was done. Must we have no idea about until they are discovered. We can assume they are potentially everywhere. You might re-write this item with that attitude.	Concur. The paragraph on cultural resources has been updated accordingly.
25	Appendix	Concur. The appendix has been updated incorporating all the additional Information In the Teck Memo #2 resubmittal.
26	All format changes	Concur. All necessary format changes were made throughout the report as per the comments.
27	There is a slight possibility that some of these reports will actually be printed and bound so we have been asking everyone for a minimum 3/4-inch binding margin.	Concur. The document margin was edited to be 3/4-inches.
28	Since this is but a "book-end". I suggest we provide the data for each problem area with no multiplier added.	Concur. The headings were updated for all PAs and the costs are reflective of the HCAd value without the multiplier
29	Assume this is cumulative value so the average market value of these properties is $60,000.	Concur, the heading was updated to read "cumulative" instead of "total" for all PAs.
30	Because of the uncertainty for what this might represent, suggest we simply call this "Engineering and Contingencies"	Concur, all cost tables were updated accordingly.
31	I prefer for planning studies to simply call this "Total" or "Total Estimated Cost" if you prefer.	Concur, all cost tables were updated accordingly.
32	Lake (throughout this paragraph)	Concur.

Attachment #3

Technical Memorandum #3

INTERIM REVIEW ONLY

This document was submitted for interim review only and is not intended for construction, bidding, permit, or final submittal purposes.

Engineer: Jacob M. Torres
PE Registration Number: 111737
Firm: Torres & Associates, LLC
Firm ID: 20741

Carpenters Bayou Watershed Plan

Technical Memorandum #3:

Refined Strategies and Recommendations

March 3, 2021

Prepared by:

Torres & Associates, LLC

Table of Contents

Acknowledgements

This planning project represents a key milestone towards the greater management and success of the Harris County 2018 Bond Projects for Flood Mitigation and is the product of interdisciplinary coordination between HCFCD, engineering consultants, key stakeholders, and the general public. Torres & Associates is particularly grateful to HCFCD staff for their invested time, effort, and commitment towards providing Torres & Associates with necessary data, background, interim deliverable reviews, logistical guidance, and general insights on day-to-day, watershed-wide operations ranging from permitting reviews to ROW acquisition. This coordination was instrumental for evaluating effective and feasible flood risk management solutions with Carpenters Bayou watershed, as well as the successful management of the broader Harris County 2018 Bond Projects for Flood Mitigation.

List of Figures

List of Tables

Acronyms

1D	1-Dimensional
2D	2-Dimensional
BDF	Basin Development Factor
CBW	Carpenters Bayou Watershed
FEMA	Federal Emergency Management Agency
H&H	Hydrology & Hydraulics
HAZMAT	Hazardous Materials
HCAD	Harris County Appraisal District
HCFCD	Harris County Flood Control District
HEC-RAS	Hydrologic Engineering Center River Analysis System
HEC-HMS	Hydrologic Engineering Center Hydrologic Modeling System
LOS	Level-of-Service
MUD	Municipality Utility District
PA	Problem Area
PER	Preliminary Engineering Report
PSF	Probable Structural Flooding
PSF(50)	Total cumulative probable structural flooding over the 50-year period
ROG	Rain-On-Grid
ROW	Right-of-Way
TM#2	Technical Memorandum #2
TM#3	Technical Memorandum #3
TxDOT	Texas Department of Transportation
USGS	United States Geological Survey
WPP	Watershed Planning Project
WSEL	Water Surface Elevation
WSP	Water Surface Profile

1. Introduction

1.1. Overview of Watershed Planning Project

The Carpenters Bayou Watershed Planning Project (WPP) identifies a suite of recommended projects capable of advancing towards preliminary engineering reports (PER) and design as well as to formulate a broader watershed-wide regional strategy that helps mitigate inherent flood risks. The WPP is funded under the Harris County 2018 Bond Program. Methods employed in this WPP include hydrologic and hydraulic (H&H) analyses, related to 1D/2D modeling, environmental assessments, cost estimates, right-of-way (ROW) assessments, and communications. The Carpenters Bayou (HCFCD Unit No: N100-00-00) watershed is located in the east portion of Harris County, Texas (**Exhibit 1**), with an area of approximately 25 square miles and 44 miles of open streams.

Goal #1 of the project focused on identification and evaluation of problem areas (PA) within the watershed with the aid of 1D/2D modeling and computed flood metrics. The analysis was summarized in Technical Memorandum #1. Goal #2 focused on further evaluation of PA and development of potential solutions that best mitigate flood risk. Technical Memorandum #2 (TM#2) summarized the work accomplished for goal #2. Goal #3 focuses on the prioritization of projects identified in goal #2 based on damage reduction, feasibility of the project, environmental constraints, and overall cost estimates. Technical Memorandum #3 (TM#3) describes the recommended projects and summarizes the analysis conducted for goal #3.

1.2. Pupose and Scope

The purpose of this task is to prioritize projects into three distinct categories of "immediate," "near-term," and "long-term" projects for implementation purposes. Please refer to TM#2 for the details of all strategies considered for improvements at the PA level as well as for improvements considered at the regional level. TM#3 entails refined strategies that more efficiently balance flood risk mitigation measures defined in TM#2 in a more holistic manner of constructability and environmental concerns. For this effort, identified projects were hydrologically and hydraulically evaluated with the aid of 1D/2D modeling. TM#3 incorporates the following factors:

- Project Recommendations – based on identification of partnerships, potential constraints, adoption of multi-purpose objectives, flood damage reduction and insights from proposed conditions modeling.
- Cost Estimates - developing cost estimates for recommended projects using insights developed from sight visits, engineering judgement, proposed conditions modeling, and a uniform cost estimation tool provided by HCFCD.
- Strategy Development - developing a strategy of implementation that follows a critical path for each project.

1.3. Previous Updates

A suite of hydraulic simulations was analyzed for the proposed conditions modeling task. **Table 1** shows a matrix of the more significant runs conducted to gain insights into feasibility, practicality, and other ancillary benefits.

Table 1. Proposed conditions model plans

HEC-RAS Plan	Model Type	Scale	500-year	100-year	50-year	25-year	10-year
Sheet Flow	2D Sheet Flow	Watershed-Wide	X	X	X		X
Baseline Conditions	Coupled 1D/2D	Watershed-Wide	X	X	X		X
PA01_25yrTargetLOS	2D Sheet Flow	Problem Area-Level				X	
PA01_10yrReducedLOS	2D Sheet Flow	Problem Area-Level					X
PA02_50yrTargetLOS	2D Sheet Flow	Problem Area-Level			X		
PA02_25yrReducedLOS	2D Sheet Flow	Problem Area-Level				X	
PA03_25yrTargetLOS	2D Sheet Flow	Problem Area-Level				X	
PA03_10yrReducedLOS	2D Sheet Flow	Problem Area-Level					X
PA04Trunklines	2D Sheet Flow	Problem Area-Level	X	X	X		X
PA04TrunklinesFlowHydrographs	2D Sheet Flow	Problem Area-Level	X	X	X		X
N104ChannelImprovV1	Coupled 1D/2D	Problem Area-Level	X	X	X		X
N104ChannelImprovV2	Coupled 1D/2D	Problem Area-Level	X	X	X		X
N104ChannelImprovV3	Coupled 1D/2D	Problem Area-Level	X	X	X		X
Regional Improvements							
N100N109ChannelImprovV1	Coupled 1D/2D	Watershed-Wide	X	X	X		X
N100N109ChannelImprovV2	Coupled 1D/2D	Watershed-Wide	X	X	X		X
Lake Sheldon	Coupled 1D/2D	Watershed-Wide		X			
P103-00 Diversion	2D Sheet Flow	Watershed-Wide		X			

2D sheet flow models were used to determine insights and benefits to sheet flow driven flooding and the 1D/2D coupled model was used to determine benefits in comparison to the existing baseline model. These simulations helped determine the effectiveness of each considered alternative and helped guide project recommendations.

2. Improvement Projects

To effectively derive projects for PER purposes, an array of alternatives was modeled, and the analysis revealed six projects that could potentially be implemented. After computing flood metrics, identifying constraints, assessing feasibility, and estimating costs, five projects are recommended for near and mid-term implementation. These projects range from being problem area focused to providing watershed wide benefits. The following sections provide details of all recommended projects. Please refer to **Appendix A** for the summary table of the PA rankings from TM#2.

2.1. WP01-Cloverleaf Flood Risk Reduction Project

The sheet flow model, flood claims data and site visits revealed that the lower Cloverleaf community specifically PA04 is highly affected by sheet flow driven flooding. Cloverleaf lies in the southern portion of the Carpenters Bayou and comprises of older residential structures built between the 1940's and 1980's, with roadside ditches generally lacking in sufficient drainage capacity. The preliminary project for this area consists of a proposed combination of a (1) dual trunk line system (trunk line #1 and trunk line #2) and a (2) 109 acre-feet stormwater detention facility north of the San Jacinto Funeral Home & Memorial Park, for an approximate combined 50yr Level-of-Service (LOS) (**Figure 1**). This project is aimed at providing much needed drainage relief for this portion of Cloverleaf with the use of stormwater trunk lines serving as centralized drainage "arteries" and for allowing lateral tie-ins from roadside ditch connections (**purple** and **blue** dash lines in **Figure 1**), before safely out falling into proposed detention or tying into existing drainage systems. The project provides a flexible means for phasing trunk lines based on need and funding sources; as well as growing in drainage capacity with the community.

Proposed trunk line #1 (**blue** line **Figure 1, Exhibit 02**) consists of a buried 9 feet x 7 feet reinforced concrete box (RCB) with an alignment along Nancy Rose Street beginning with its headwaters near Victoria Street, turning eastward along Hillsboro Street, and out falling into the proposed detention facility north of the San Jacinto Funeral Home & Memorial Park. It is important to note that there is flexibility in the placement of the tailwater of trunk line #1 depending on the placement of the detention basin within the vacant parcel identified. Trunk line #1 has an approximate length of 2,950 feet. Proposed trunk line #2 (**purple** line in **Figure 1, Exhibit 02**) consists of a buried 10 feet x 7 feet RCB with an alignment along Cloverleaf Street, beginning with its headwaters near Hershe Street, and heading southbound before tying into the Interstate Highway (IH-10) frontage drainage system westward with an eventual outfall into the P102-00-00 drainage system. Trunk line #2 has an approximate length of 6,870 feet.

Figure 1. Cloverleaf Flood Risk Reduction Project

Proposed Detention (**red** polygon in **Figure 1, Exhibit 02**) provides approximately 109 acre-feet of potential storage for mitigating conveyance impacts from the Cloverleaf Flood Risk Reduction Project . The volume required to mitigate conveyance impacts from WP01 was evaluated using BDF (Basin Development Factor) analysis and the increase in drainage area for existing and proposed conditions (**pink** and **blue** polygons in **Figure 2, Exhibit 03**).

Figure 2. Existing and Proposed Conditions drainage boundaries Phase 1

Preliminary analysis of this proposed basin assumes a partial parcel acquisition of approximately 15.8 acres (**red** polygon in **Figure 1**) and a pond depth of approximately 10 feet. The detention basin entails acquisition of already vacant lots (based on aerial imagery and site visits), owned by NorthStar Cemetery Texas San Jacinto LLC with an appraisal value of $2.3M (Harris County Appraisal District 2019). There is also potential for expanding the basin capacity to include the full buyout of the parcel with an additional 1.8 acres (**yellow** hatched polygon in **Figure 1**) which is part of the existing 17.6 acre parcel, yielding a maximum potential storage capacity of approximately 125 acre-feet for the proposed basin. The basin would be equipped with the necessary gravity-driven outlet structure for tying into the existing outfall that appears to traverse eastwardly through Beltway 8 before out falling into HCFCD Unit No. N100-00-00.

The project lends itself to a phasing strategy between trunk lines #1 and #2 and the simultaneous acquisition of property while other key project components are under construction. Trunk lines #1 and #2 are synonymous to phases 1 and 2, respectively. The damage reduction and cost estimates are thus broken into Phase 1 and Phase 2 (**Figure 1 & Exhibit 02**). Phase 1 might include the property acquisition and permitting for the detention basin and simultaneous construction of trunk line #1, while a feasibility analysis on the IH-10 frontage road drainage system is underway. Phase 2 of the implementation strategy might include the construction of trunk line #2.

Phase 2 can also be considered a flexible enhancement to Phase 1 or the broader Cloverleaf community in that various options for outfall tie-ins are available depending on budget constraints and partnership potential. For example, Phase 2 trunk line tie-in options can include outfall into P104-00-00 directly south of IH-10, P102-00-00 westward on IH-10 frontage, the existing Freeport Road drainage system west of Hollywood Street or the existing southern outfall that passes through the cemetery given outfall improvements occur that provide adequate capacity for the flow received from trunk line 2. All these tie-in options require a more detailed drainage analysis for determining available system capacity through further feasibility analyses.

2.1.1. Damage Reduction

Damage reduction was estimated using the reduction in flooded structures (100-year) and the reduction in PSF(50) between baseline conditions and proposed conditions (**Table 2**). The incremental rainfall analysis was used to quantify the damage reduction for WP01. Based on 2D sheet flow modeling assessments, and the project's estimated 50-year LOS, project benefits (trunk lines #1 and #2 [with assumed roadside ditch improvements for lateral tie-ins] and detention) have the potential for substantial flood damage reductions based on quantities of flooded structure removals for the 100-year storm; with the removal of approximately 107 structures for phase 1 improvements (100-year) (**Table 2 & Exhibit 04**) and the removal of 187 structures for phase 1 and phase 2 improvements (**Exhibit 05**). These benefits require further detailed analyses for verifying performance benefits, but such detailed evaluations are commonly reserved at the feasibility or preliminary engineering report (PER) project phase.

Table 2. Reduction in Flooded Structures

	Flooded Structures (100-year)		PSF(50)	
Phase	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
Phase 1	206	99	661.9	370.1
Phase 1 & 2	206	19	661.9	24.4

*PSF(50): Total cumulative probable structural flooding over the 50-year period

2.1.2. Cost Estimate

Construction cost for the Cloverleaf Flood Risk Reduction Project was determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects. The cost estimate for this approach is provided in **Table 3**. A multiplier of 2.5 was used for property acquisition estimates. Altogether, the total opinion of probable construction costs is estimated to be $16.9M for Phase 1. The costs include a 30% contingency on construction costs (noting that the roadside ditch improvements are included in the cost estimates for Phase 1). Please refer to **Appendix B** for a slightly more extended cost table.

Table 3. Cost Estimates for Phase 1 Cloverleaf Flood Risk Reduction Project

Phase 1- Cloverleaf Flood Risk Reduction Project	Cost ($ M)
Detention Basin Construction Cost	$3.01
Clearing and Grubbing	$0.01
Excavation and Disposal Trunk Line 1	$0.16
9x7 RCB Trunk Line 1	$2.51
Pavement Removal	$0.02
Concrete Pavement Replacement	$0.49
Subbase Replacement	$0.02
Regrade Roadside Ditch	$0.87
Construction Costs	**$7.08**
Engineering and Contingencies*	**$4.03**
ROW Acquisition	**$5.78**
Total Estimated Cost	**$16.89**

* There is a 30% contingency on construction costs.

2.1.3. Known Constraints

For the proposed trunk lines, the vacant cemetery land is being considered for mitigation purposes. This could be a potential constraint as property acquisition is dependent on negotiations with the parcel landowners. This parcel is also partially classified as a wetland (**Figure 3**). Permitting can potentially be required for the use of this piece of land as a detention basin. Two potential landfill sites are also located south of this parcel, adjacent to the existing northern outfall.

Figure 3. Constraints for Phase 1 Cloverleaf Flood Risk Reduction Project

2.1.4. Additional Benefits

Given that this is a planning-level analysis, our approach was to identify projects that could yield a higher likelihood of options during feasibility and design phases. The proposed detention basin invites opportunities for promoting neighborhood uplift with open green space, walking and bike trails around the basin perimeter, and other outdoor recreational activities.

2.1.5. Potential Partners

Partnerships between Harris County and HCFCD are recommended for this alternative. Other potential partners also include Galena Park ISD for the potential use of an existing detention pond located north of the proposed detention basin. The construction of the detention basin entails acquisition of already vacant lots (based on aerial imagery and site visits), owned by NorthStar Cemetery Texas San Jacinto LLC. The vacant parcel is also a part of the Municipality Utility District (MUD) (District ID: 3722000) in Harris County. The use of this land is recommended to be explored further through stakeholder engagement meetings and with property owner discussions.

2.2. WP02 – N100-00-00 Channel Improvements

The baseline conditions model revealed that the main stem N100-00-00 and tributary N109-00-00 experience out-of-bank flooding. A suite of alternatives for channel improvements were modeled and analyzed to identify the alternative with low costs, high community uplift and high feasibility. The preliminary project for this area consists of a proposed combination of (1) A segment of N100-00-00 channel improvements with a 60 feet bottom width and 4:1 side slope with an average slope of 0.00085 feet/feet and (**Figure 4 & 5**) (2) a small segment of N109-00-00 channel improvements with a 20 feet bottom width and 4:1 side slopes with an average slope of 0.002 feet/feet (**Figure 5**).

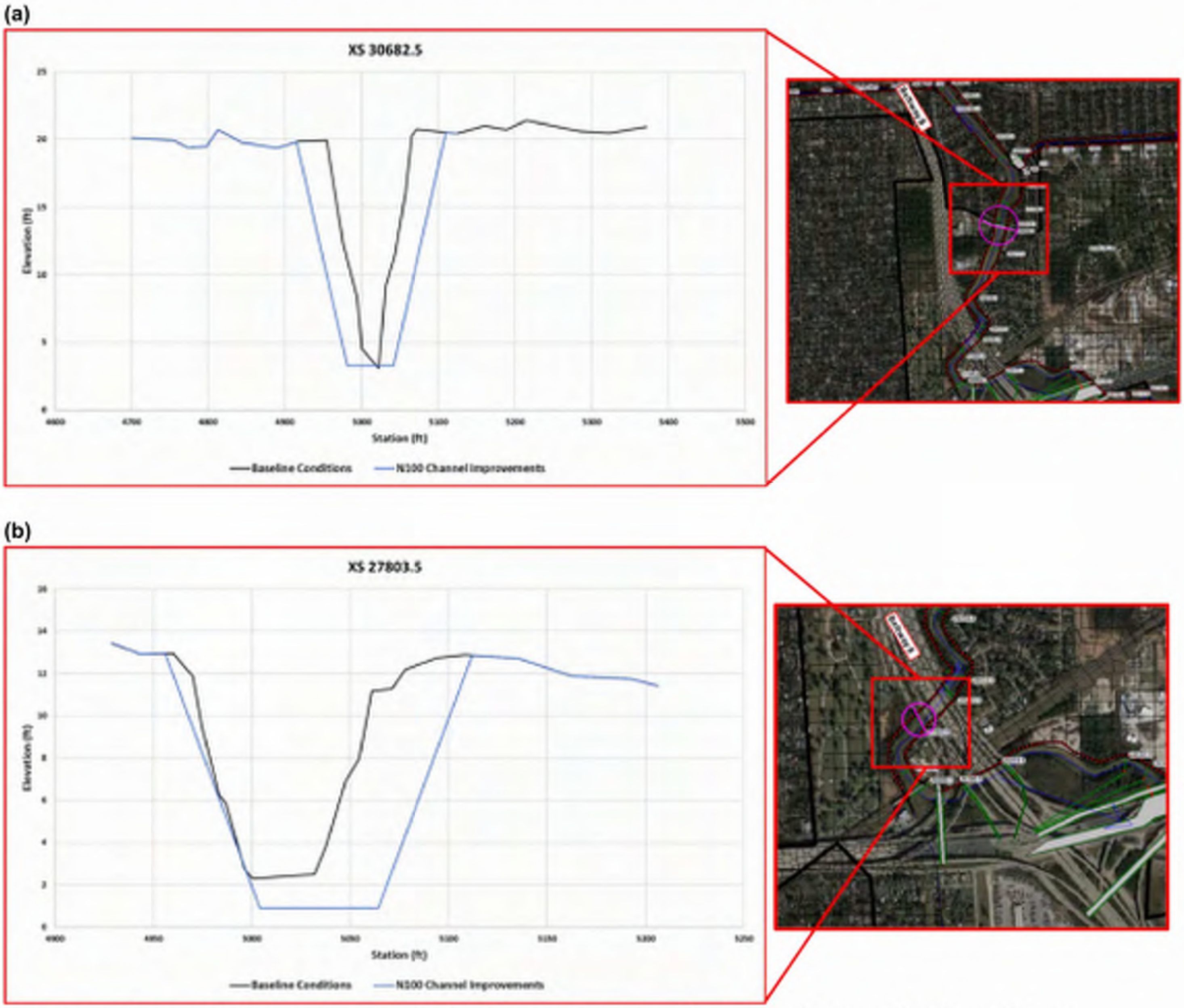


Figure 4. Examples of channel widening across two cross-sections between Baseline and Proposed Conditions (a) Cross-section 30682.5 (b) Cross-Section 27803.5

It is important to note that enhancements to the existing baffles at the steep drop upstream of the confluence of N109-00-00 and N100-00-00 are also recommended and have been modeled and that the dual culvert system at Overbluff Street upstream of the confluence was modeled using the existing dimensions however adjustments to the placement of the dual culvert boxes are expected at the feasibility or preliminary engineering report (PER) project phase.

It was determined that channelizing the segment of N100-00-00 starting downstream from IH-10 and moving upstream to the N100-00-00 and N109-00-00 confluence provided high benefit with low associated costs (**green** line in **Figure 5, Exhibit 06**). The length of channel improvements is approximately 7800 feet. A small segment of N109-00-00 is also recommended to be channelized starting just downstream of the pipeline owned by the Colonial pipeline company and moving downstream to the confluence of N100-00-00 and N109-00-00 tying into the N100-00-00 channel improvements (**yellow** line in **Figure 5**). The length of channel improvements on N109-00-00 is approximately 500 feet.

Figure 5. Segment of Channel Improvements at N109-00-00 and N100-00-00

Recommended N100 channel improvements intersect some HCFCD owned parcels and some occupied lots. The **red** polygons in **Figure 6** represent non-voluntary buyouts considered for ROW acquisition with N100-00-00 channel improvements.

Figure 6. Recommended ROW acquisition for Channel Improvements at N109-00-00 and N100-00-00

A preliminary analysis shows a no rise impact downstream of the improvements for the 500-year and 100-year storm events. These no rise impacts could be associated with the channel morphology downstream of IH-10 and the channels close proximity to the Houston Ship Channel. The 10-year and 50-year storm events show impacts downstream. These impacts require further detailed analyses, but such detailed evaluations are commonly reserved at the feasibility or PER project phase. **Appendix C** and **Figure 7** show the 100-year proposed channel improvements profile versus the 100-year existing baseline model. **Table 3** shows the reduction in WSEL at corresponding cross sections from the baseline and proposed conditions models. This improvement is considered to have regional benefits since it provides benefit to structures along the mainstem in PA03, PA01 and downstream of PA01.

2.2.1. Damage Reduction

Damage reduction was estimated using the reduction in flooded structures (100-year) and the reduction in PSF(50) between baseline conditions and proposed conditions (**Table 4**). The proposed channel improvements show large benefits along the main stem (N100-00-00) and at the confluence of N100-00-00 and N109-00-00.

Table 4. Reduction in Flooded Structures

Location	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
N100-00-00	121	4	148.7	20.2
Watershed-wide	342	216	455.2	314.9

*PSF(50): Total cumulative probable structural flooding over the 50-year period

N100-00-00 channel improvements span approximately a total distance of 8099 feet starting at the confluence of N109-00-00 and N100-00-00 and ending before IH-10. WSEL reductions are observed starting at Silver Green Drive and extending all the way to the Ship Channel. **Figure 7** and **Table 5** show the observed reductions in WSEL. Overall, approximately 188 acres of watershed area would potentially no longer be inundated during the 100-year event under proposed conditions when compared to the baseline existing conditions floodplain (8% reduction) (**Exhibits 08-11**).

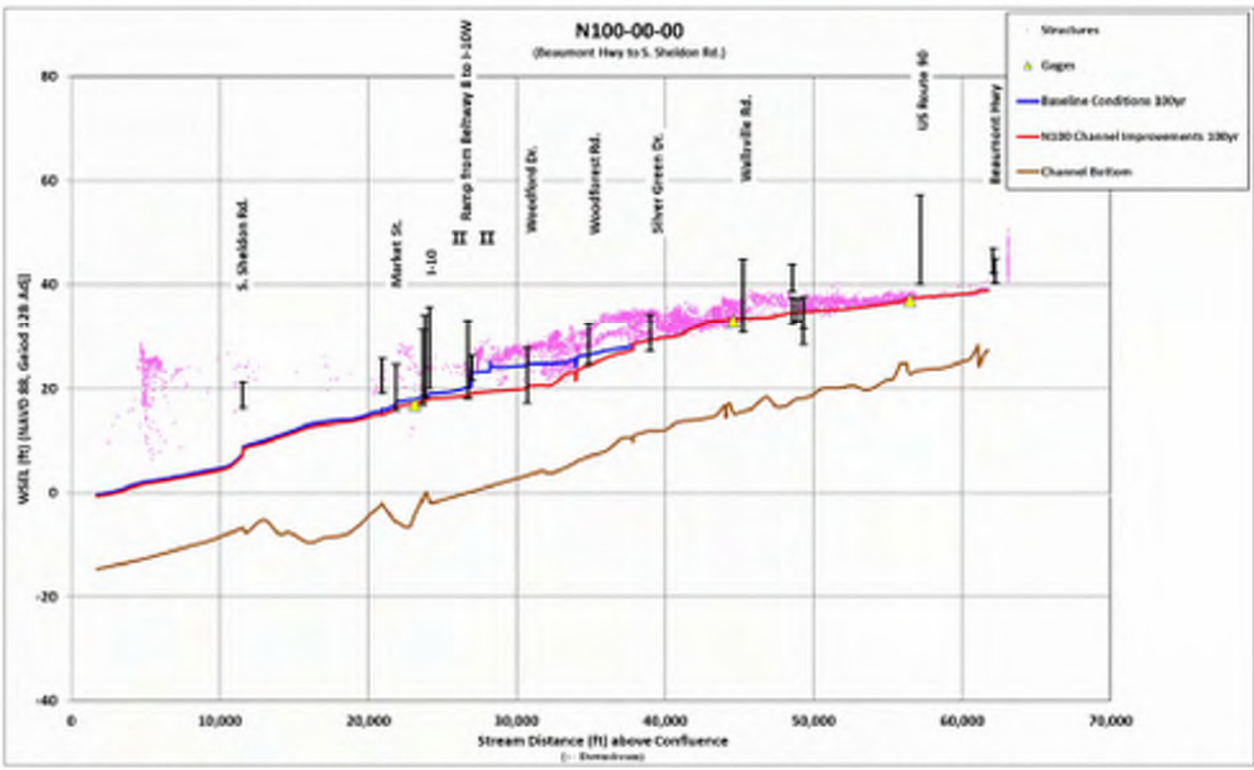


Figure 7. Water Surface Profile N100-00-00, Baseline Conditions (Existing) vs. Proposed Improvements [100-year]

Table 5. Reduction in WSEL (100-year)

HEC-RAS XS	Bridge/Culvert	Baseline Conditions WSEL (ft) [100-year]	Proposed Channel Improvements WSEL (ft) [100-year]	100-year Peak WSEL Reductions (ft)
38969.0	Silver Green Dr	28.18	27.84	-0.34
34841.0	Woodforest Road	25.90	23.92	-1.98
30712.0	Woodford Drive	24.42	20.68	-3.74
28244.0	Beltway 8 Flyover Piers	23.33	19.66	-3.67
27792.0	Beltway 8 Flyover Piers	22.63	19.79	-2.84
26974.0	Missouri Pacific Railroad	21.88	19.47	-2.41
26717.0	Ramp from Beltway 8 to I-10W	21.27	19.25	-2.02
26379.0	Beltway 8 Flyover Piers	20.67	19.19	-1.48
25908	Beltway 8 Flyover Piers	20.03	18.96	-1.07
24126.0	Access Road West to Beltway 8	18.98	18.53	-0.45
23835.0	I-10	18.68	18.29	-0.39
23691.0	South Access Road I-10	18.60	17.58	-1.02
21866.0	Market Street	17.18	16.24	-0.94
20948.0	Old Railroad Bed	16.69	15.81	-0.88

2.2.2. Cost Estimate

Excavation costs for N100-00-00 channel improvements were determined using the cut and fill volume from HEC-RAS 1D/2D model. The utility adjustment and construction costs were determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects. Partial and non-voluntary buyouts were considered for ROW acquisition with N100-00-00 channel improvements (**Exhibit 07**). Please refer to **Appendix B** for a slightly more extended cost table.

Table 6. Cost Estimates for N100-00-00 channel improvements

Channel Improvements N100	Cost ($ M)
Clearing, Grubbing, and Disposal	$0.31
Utility Adjustments (pipeline)	$0.26
Excavation (Off-Site Haul)	$2.88
Rock Rip-Rap	$0.30
Backslope Swale	$0.08
Backslope Drain Structure	$0.57
Construction Costs	**$4.41**
Engineering and Contingencies	**$2.52**
ROW Acquisition	**$10.30**
Total Estimated Cost	**$17.23**

* There is a 30% contingency on construction costs.

2.2.3. Known Constraints

The channel improvements are proposed to end before IH-10 (**Exhibit 06**). A small portion of Beltway 8 and the Missouri Pacific railroad are recommended to be channelized. Only Texas 8 Beltway Frontage Road crossing is recommended to be deepened by approximately 1.40 feet, all other bridge crossings will be filled or widened to achieve the proposed improvement. There is an Oil & Gas pipeline (Colonial Pipeline Company) that crosses this portion of the channel however, since there is no deepening (only widening) recommended in this portion of the channel, it is expected that there will be no conflict with this pipeline (**Figure 8**). This assumption will have to be verified by a utility survey.

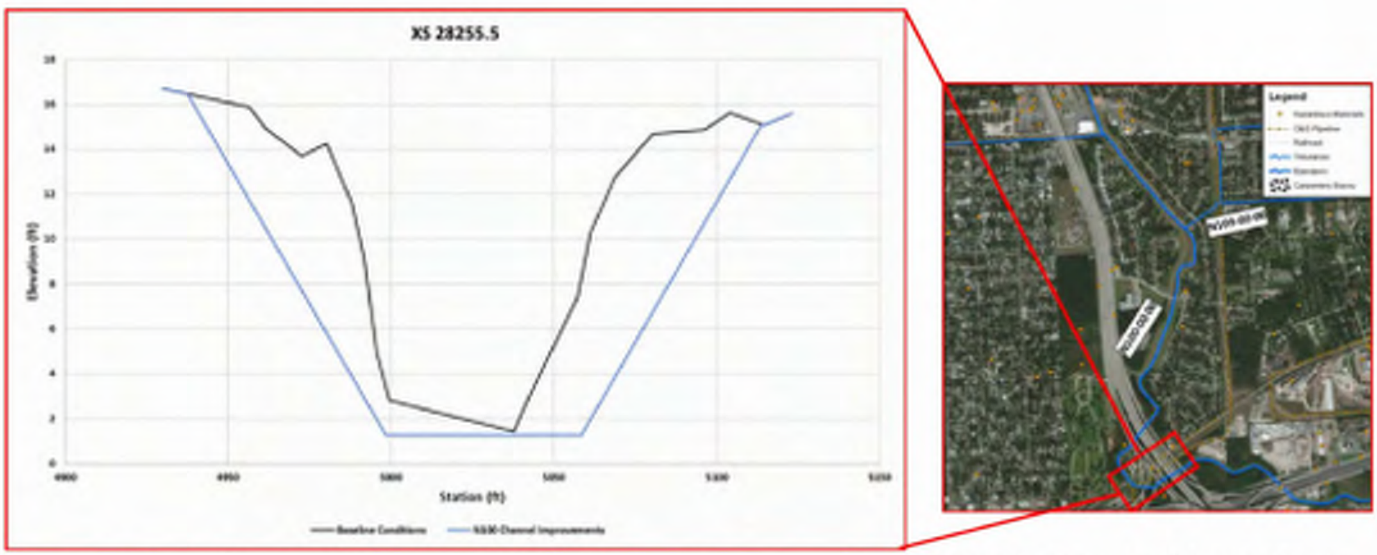


Figure 8. Potential Constraints in proposed N100-00-00 channel improvements: Missouri Pacific Railroad and Colonial Pipeline

2.2.4. Additional Benefits

Given that this is a planning-level analysis, our approach was to identify projects that could yield a higher likelihood of options during feasibility and design phases. To achieve the maximum benefits for this proposed improvement, alternatives were explored to reduce ROW acquisition, increase environmental benefits, and uplift the neighboring community. The following scenarios were not modeled but were considered and are recommended to be explored further during feasibility and design phases:

- Shifting the centerline of the channel 60 feet west. If the centerline of the channel improvements is shifted 60 feet to the west, it would save on ROW acquisition. Instead of acquiring \$9.0M worth of parcels, only \$7.2M would be acquired. Furthermore, there are two parcels that make up more than half of the ROW acquisition costs; one structure is a church and the other is a Hutchison-Hayes Separation Inc commercial building. Both structures are only built on a small part of the land, most of the parcel is vacant. It is recommended that a partial buyout of these two parcels is considered since this would largely decrease ROW acquisition costs (the estimated costs assume partial acquisition). **Figure 9** shows the area needed to be acquired for channel improvements.

Figure 9. N100-00-00 Channel Improvements and partial ROW acquisition.

- It is recommended to add a jogging trail to the ROB at Woodford Street moving downstream to Woodforest Boulevard. This segment of N100-00-00 is located upstream of the N100-00-00 and N109-00-00 confluence and the proposed trail is recommended to provide community uplift (**Figure 10**).

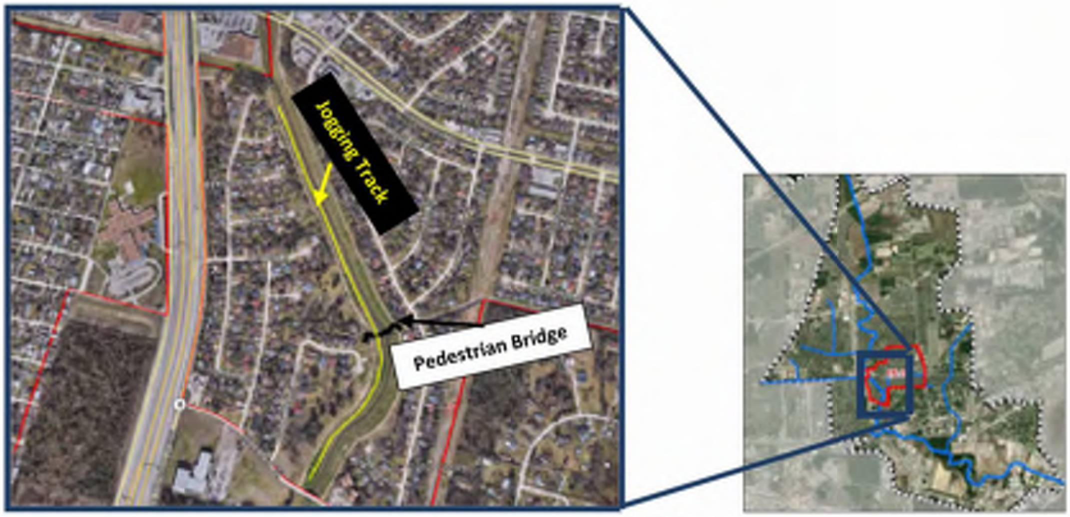


Figure 10. Addition of a jogging track, community uplift.

- The use of natural stable channel design for the channel improvements to provide environmental benefits.

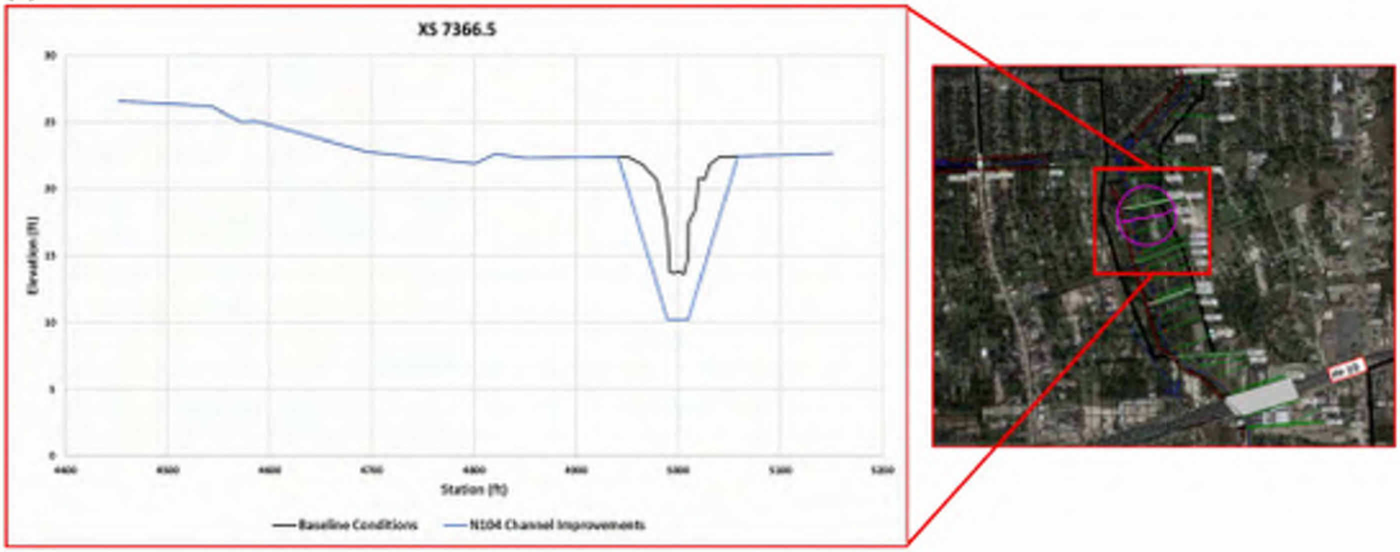
2.2.5. Potential Partners

Channel Improvements are mainly under HCFCD jurisdiction. Since the size and depth at which the pipeline is located are unknown, a potential partner might be the utility owner of Colonial Pipeline. Communication with the utility owner is recommended for better cost estimates and impact analysis of the channel improvements in this area. These channel improvements also intersect the MUD (District ID: 3722000). Communication with the appropriate stakeholders and property owners is recommended for this improvement.

2.3. WP03-N104 Channel Improvements

The baseline conditions model revealed that N104-00-00 experiences out-of-bank flooding. A suite of alternatives for channel improvements were modeled and analyzed to identify the alternative with low costs, high community uplift and high feasibility. The preliminary project for this area consists of a segment of N104-00-00 channel improvements with a 20 feet bottom (**Figure 11**) width and 4:1 side slope (**green** line in **Figure 12**) with an average slope of 0.0008 feet/feet.

(a)



(b)

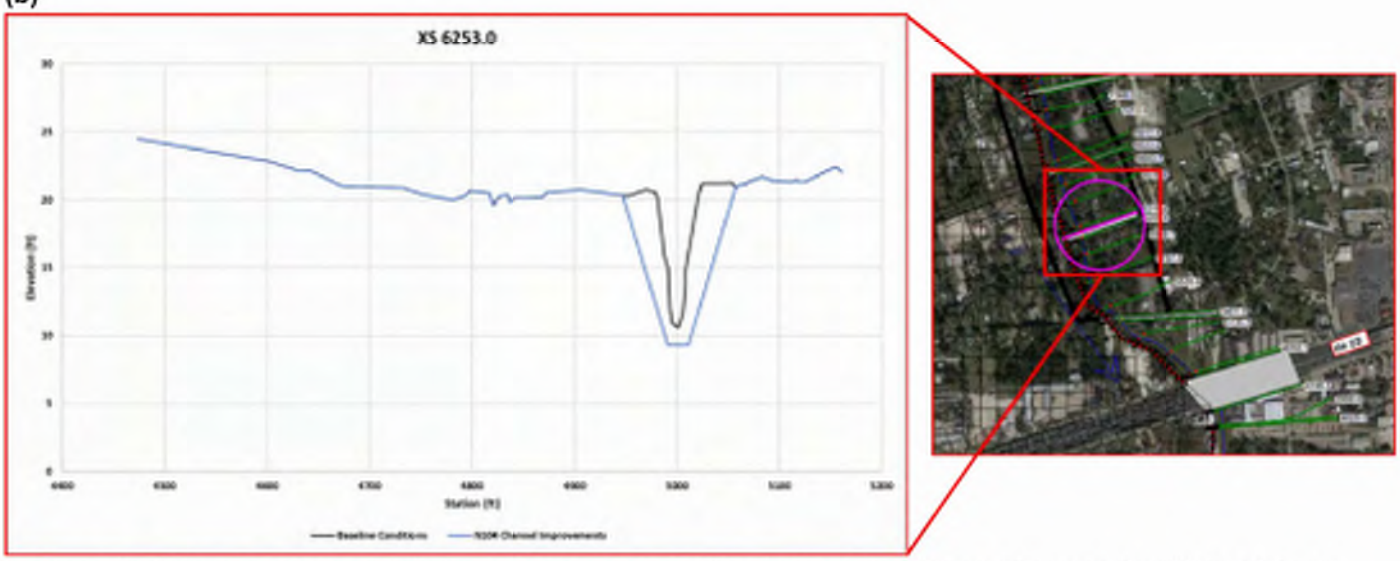


Figure 11. Examples of channel widening across two cross-sections between Baseline and Proposed Conditions (a) Cross-section 7366.5 (b) Cross-Section 6253.0

A preliminary analysis shows a no rise impact downstream of the improvements for the 500-year and 100-year storm events. These no rise impacts could be associated with the channel morphology downstream of IH-10 and the channels close proximity to the Houston Ship Channel. The 10-year and the 50-year storm event shows impacts downstream. These impacts require further detailed analyses, but such detailed evaluations are commonly reserved at the feasibility or PER project phase. **Appendix C** shows the profile of the channel improvements versus the 100-year existing baseline model. The improvements show a reduction in WSEL downstream of Woodforest Boulevard (**Table 6**). This improvement is considered to have PA focused benefits since it provides benefit to structures along the N104-00-00 tributary located in PA05.

Figure 12. Segment of Channel Improvements at N104-00-00.

2.3.1. Damage Reduction

Damage reduction was estimated using the reduction in flooded structures (100-year) and the reduction in PSF(50) between baseline conditions and proposed conditions (**Table 7**). The proposed channel improvements show large benefits downstream of Woodforest Drive. The existing channel segment has <10-year LOS and after channel improvements, the segment has <100-year LOS downstream of Woodforest Drive.

Table 7. Reduction in Flooded Structures (100-year)

	Flooded Structures (100-year)		PSF(50)	
Location	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
N104-00-00	79	31	114.4	59.3

*PSF(50): Total cumulative probable structural flooding over the 50-year period

N104-00-00 channel improvements span approximately a total distance of 3998 feet starting downstream of the Shadowglen neighborhood and ending upstream of IH-10. WSEL reductions are observed starting at Woodforest Drive and extending all the way to the Ship Channel. **Figure 13** and **Table 8** show the observed reductions in WSEL. Overall, approximately 100 acres of PA05 area would potentially no longer be inundated during the 100-year event under proposed conditions when compared to the baseline existing conditions floodplain (69% reduction) (**Exhibits 14-17**).

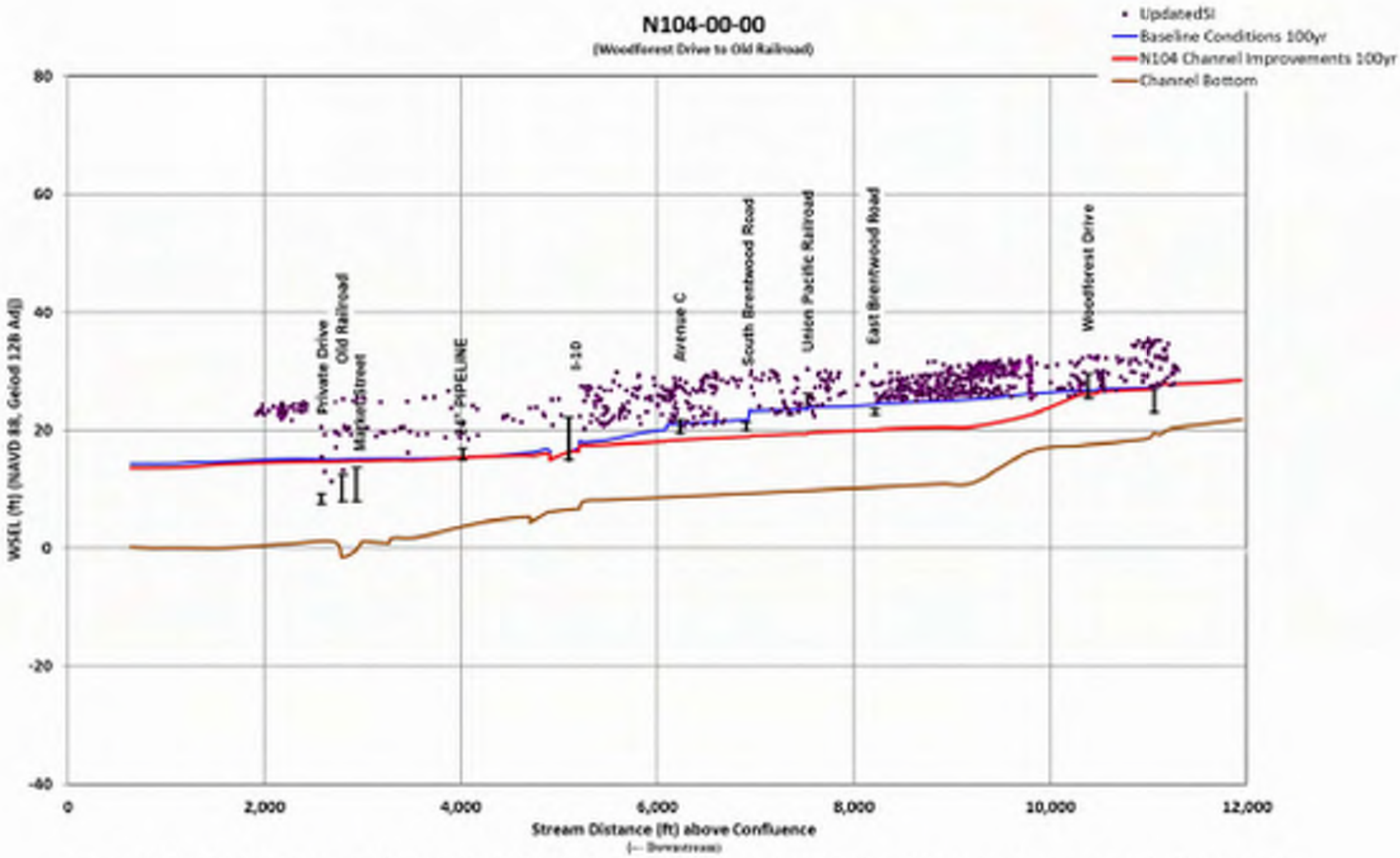


Figure 13. Water Surface Profile N104-00-00, Baseline Conditions (Existing) vs. Proposed Improvements [100-year]

Table 8. Reduction in WSEL (100-year)

HEC-RAS XS	Bridge/Culvert	Baseline Conditions WSEL (ft) [100-year]	Proposed Channel Improvements WSEL (ft) [100-year]	100-year Peak WSEL Reductions (ft)
10388.0	Elgin Road	27.72	27.68	-0.04
9736.0	Woodforest Drive	26.92	26.21	-0.71
7532.0	East Brentwood Road	24.19	20.01	-4.18
6816.0	Union Pacific Railroad	23.35	19.50	-3.85
6229.0	Avenue C	22.83	19.11	-3.72
5377.0	South Brentwood Road	20.11	18.49	-1.62

2.3.2. Cost Estimate

Excavation costs for N104-00-00 channel improvements were determined using the cut and fill volume from the HEC-RAS 1D/2D model. The utility adjustment and construction costs were determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects. Full and non-voluntary buyouts were considered with N104-00-00 channel improvements for a conservative approach (**Exhibit 13 & Figure 14**). It is important to note that if partial buyouts are considered, the cost for ROW acquisition will significantly decrease from \$6.1M to \$2.3M (these costs include a 2.5 multiplier). Please refer to **Appendix B** for a slightly more extended cost table.

Figure 14. Partial ROW acquisition vs full ROW acquisition for N104 channel improvements.

Table 9. Cost Estimates for N104-00-00 channel improvements

Channel Improvements N104	**Cost ($ M)**
Clearing, Grubbing, and Disposal	\$0.11
Utility Adjustments (pipeline)	\$0.09
Excavation (Off-Site Haul)	\$0.85
Rock Rip-Rap	\$0.08
Backslope Swale	\$0.04
Backslope Drain Structure	\$0.28
Construction Costs	**\$1.45**
Engineering and Contingencies	**\$0.83**
ROW Acquisition	**\$6.09**
Total Estimated Cost	**\$8.37**

2.3.3. Known Constraints

The channel improvements at N104-00-00 are proposed to end before IH-10. There is a pipeline and railroad crossing intersecting N104-00-00 (**Figure 15**), channelization was continued through this crossing because the benefits of channelizing through the pipeline and railroad crossing outweighed avoiding these constraints. The railroad and the pipeline are located adjacent to one another. The cross section at the railroad is recommended to be deepened by approximately 4 feet, the pipeline and railroad crossing might be a potential constraint and further analysis is recommended at the PER level to determine additional costs associated with this constraint. The pipeline adjustment has been added to the cost estimate for this project using the cost tool.

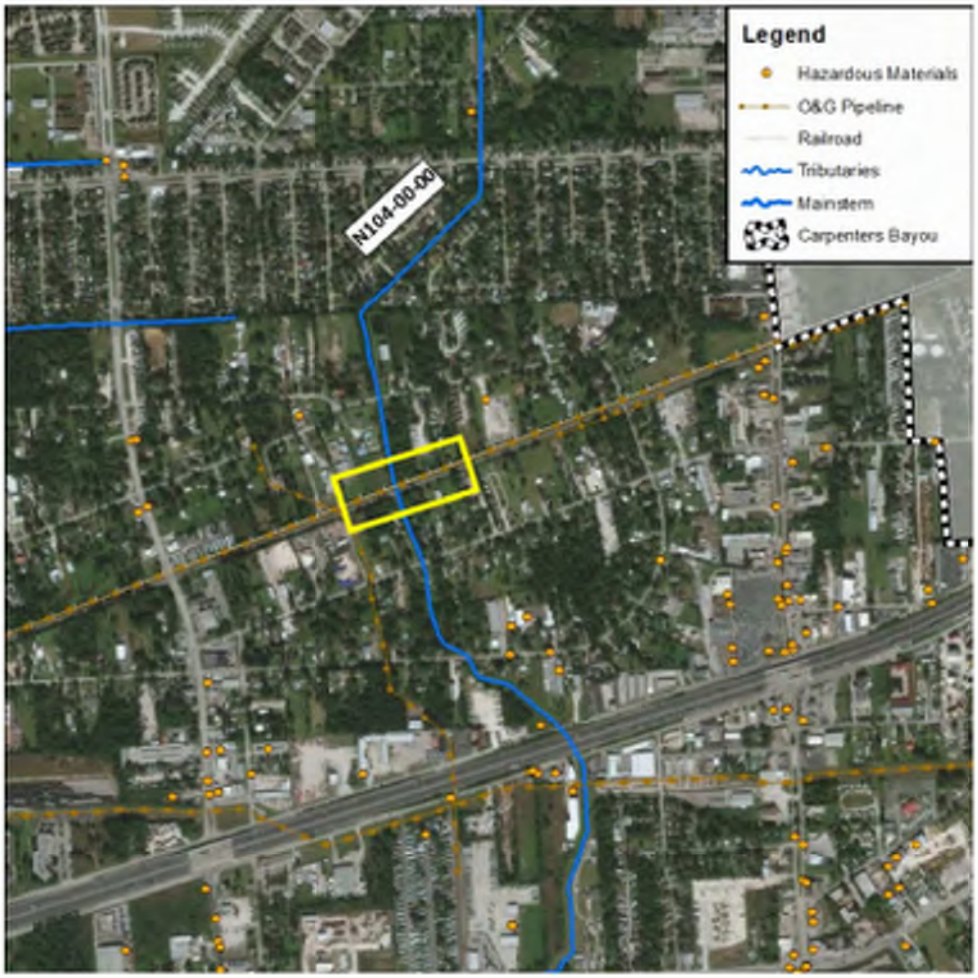


Figure 15. Constraints in proposed channel improvements at N104-00-00

2.3.4. Additional Benefits

Given that this is a planning-level analysis, our approach was to identify projects that could yield a higher likelihood of options during feasibility and design phases. To achieve the maximum benefits for this proposed improvement, alternatives were explored to reduce ROW acquisition, increase environmental benefits, and uplift the neighboring community. The following scenarios were not modeled but were considered and are recommended to be explored further during feasibility and design phases:

- Partial buyouts for ROW acquisition.
- Natural stable channel design to improve the geomorphological index and decrease environmental impacts.

2.3.5. Potential Partners

Channel Improvements are mainly under HCFCD jurisdiction. Since the size and depth at which the pipeline is located are unknown, a potential partner might be the utility owner of Equistar Chemicals, LP. Communication with the utility owner is recommended for better cost estimates and impact analysis of the channel improvements in this area. Communication with the appropriate stakeholder for the Missouri Pacific Railroad crossing is also recommended.

2.4. WP04-P103-00/P103-03 Diversion

The rain-on-grid (ROG) model revealed an overflow into Greens Bayou from Carpenters Bayou along tributary N110-00-00 (**Figure 14 & Exhibit 14**). A diversion to the P103-00-00 and P103-03-00 tributary located in lower Greens Bayou was explored. Existing conditions sheet flow model was used to determine the capacity of P103. It was determined that P103-00/P103-03 lacks capacity in the upstream reaches but has enough capacity downstream as it connects with the mainstem. Channel improvements can be conducted in the upper reaches of P103-00/P103-03 to facilitate overflow from Carpenters Bayou into Greens Bayou. It was concluded that further analysis needs to be conducted to determine the project feasibility.

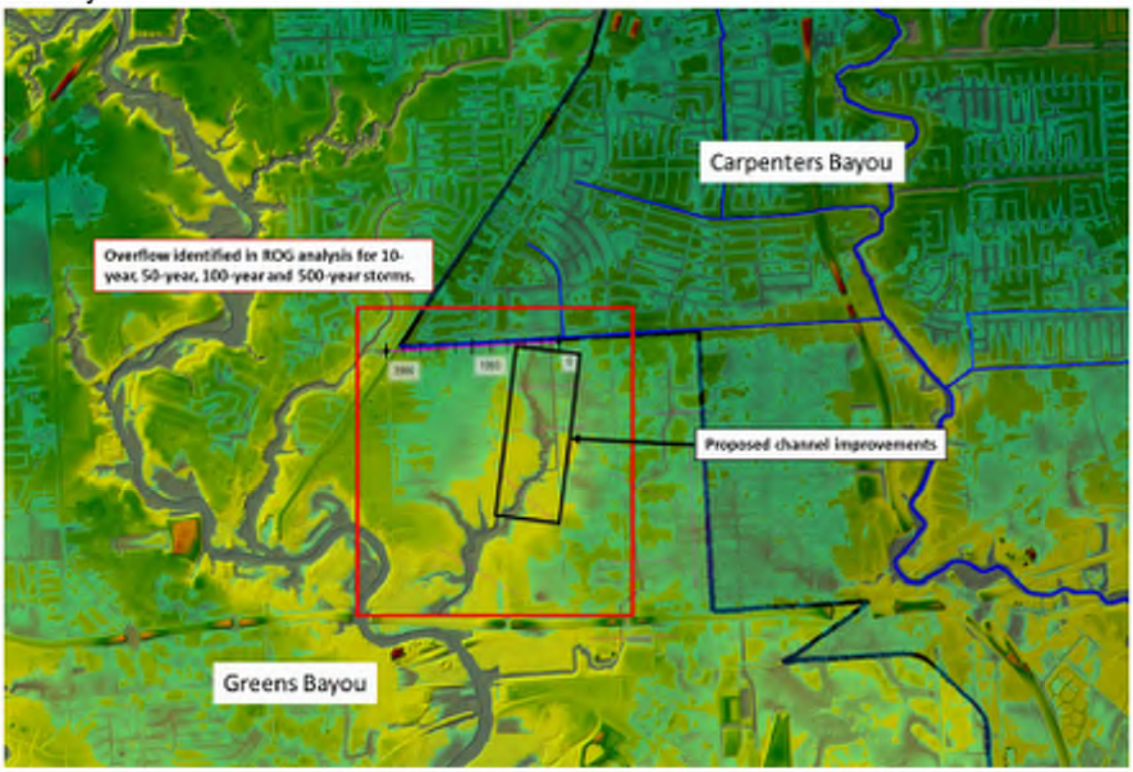


Figure 16. Identified overflow into Greens Bayou watershed

2.4.1. Damage Reduction

Damage reduction was estimated using the reduction in flooded structures (100-year) and the reduction in PSF(50) between baseline conditions and proposed conditions (**Table 10 & Exhibits 19-22**). The proposed diversion is assumed to save structures upstream of the diversion in PA02 (**yellow** line **Figure 17**). Almost 20% of the PA will have a reduction in flooded structures. The damage reduction was based on this assumption.

Table 10. Reduction in Flooded Structures

Location	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
PA02	785	627	1680.5	1158.5

*PSF(50): Total cumulative probable structural flooding over the 50-year period

Figure 17. Location of PA02

2.4.2. Cost Estimate

The cost estimates for this project are based on wide assumptions because of the limited information available, thus the contingency for this project is higher (55%) (**Table 11**). The tributaries P103-03 and P103-00 have not been modeled so far and thus the effects of channel widening/deepening have not been analyzed. The proposed improvements are assumed to provide enough capacity for the flow to be diverted from PA02 to P103. It is important to note that ROW acquisition costs are not included for this project.

Table 11. Cost Estimates for P103 Diversion

P103-03/P103-00 Diversion*	Cost ($ M)
Clearing, Grubbing, and Disposal	$0.08
Utility Adjustments (pipeline)	-
Excavation (Off-Site Haul)	$0.36
Rock Rip-Rap	$0.09
Backslope Swale	$0.03
Backslope Drain Structure	$0.20
Construction Costs	**$0.76**
Engineering and Contingencies	**$0.43**
ROW Acquisition	**-**
Total Estimated Cost (without ROW)	**$1.19**

*This cost estimate does not include ROW acquisition costs.

2.4.3. Known Constraints

The proposed project is outside of Carpenters Bayou watershed thus further communications between HCFCD and the lower Greens Bayou study team is recommended since this alternative improvement involves two watersheds and further analysis. No other constraints were identified for this project.

2.4.4. Additional Benefits

PA02 is densely populated with few vacant lots. By diverting flow, the channel N110-00-00 will not have to be modified and thus ROW acquisition costs will be minimal. A previous report from R.G. Miller Engineers, Inc. (2012) "Freeport St. Drainage Analysis" discusses the acquisition of structures along P103-03 and P103-00. This project proposes channel modifications of P103-03 and the ROW acquisition for these improvements might coincide with the proposed buyouts from that report. This area also experiences flooding due to Greens Bayou back water effects, a project in this area would benefit two watersheds.

2.4.5. Potential Partners

PA02 lies within the bounds of Northshore community. The Northshore Plan is a community plan aimed at enhancing mobility, connectivity, land use, housing, and economic development within the Northshore community. Collaboration with the Northshore Plan committee is recommended as this could provide insights into the problem area and opportunities for potential sources of funding. PA02 also lies within a MUD (District ID: 3727000). Channel Improvements are mainly under HCFCD jurisdiction.

3. Improvement Project Summary

HCFCD provided a tool for the prioritization of projects based on the following criteria:

- Flood Risk Reduction
- Existing Conditions Drainage Level of Service
- Social Vulnerability Index (SVI)
- Project Efficiency
- Partnership Funding
- Environmental Impacts and
- Potential for Multiple Benefits

Table 12 provides a summary of the project prioritization sheet. The Cloverleaf Flood Risk Reduction Project (WP01) scored the highest according to these criteria. It is important to note that WP04 was not scored because further analysis is required to assess the project efficiency and flood risk reductions for this project. Refer to **Appendix D** for the Project Scoring Summary.

Table 12. Project prioritization summary table

Project ID	Description	Total Score Scenario #1 (100-year)
N100-WP01	Cloverleaf Flood Risk Reduction Project-Phase 1	7.70
N100-WP01	Cloverleaf Flood Risk Reduction Project-Phase 1 & 2	8.20
N100-WP02	N100-00-00 Channel Improvements	5.88
N104-WP03	N104-00-00 Channel Improvements	6.33
N110-WP04	P103 Diversion	0.0

4. Implementation Strategy

The implementation strategy is meant to provide a critical path for each recommended project. The timeline for a project can be long term but a component within that project can be characterized as a near term goal. Near-term projects/phases represent a one to five-year timeline, mid-term represent a five to ten-year timeline and long-term represent a timeline beyond ten-years. **Figure 18** represents the timeline identified for each recommended project.

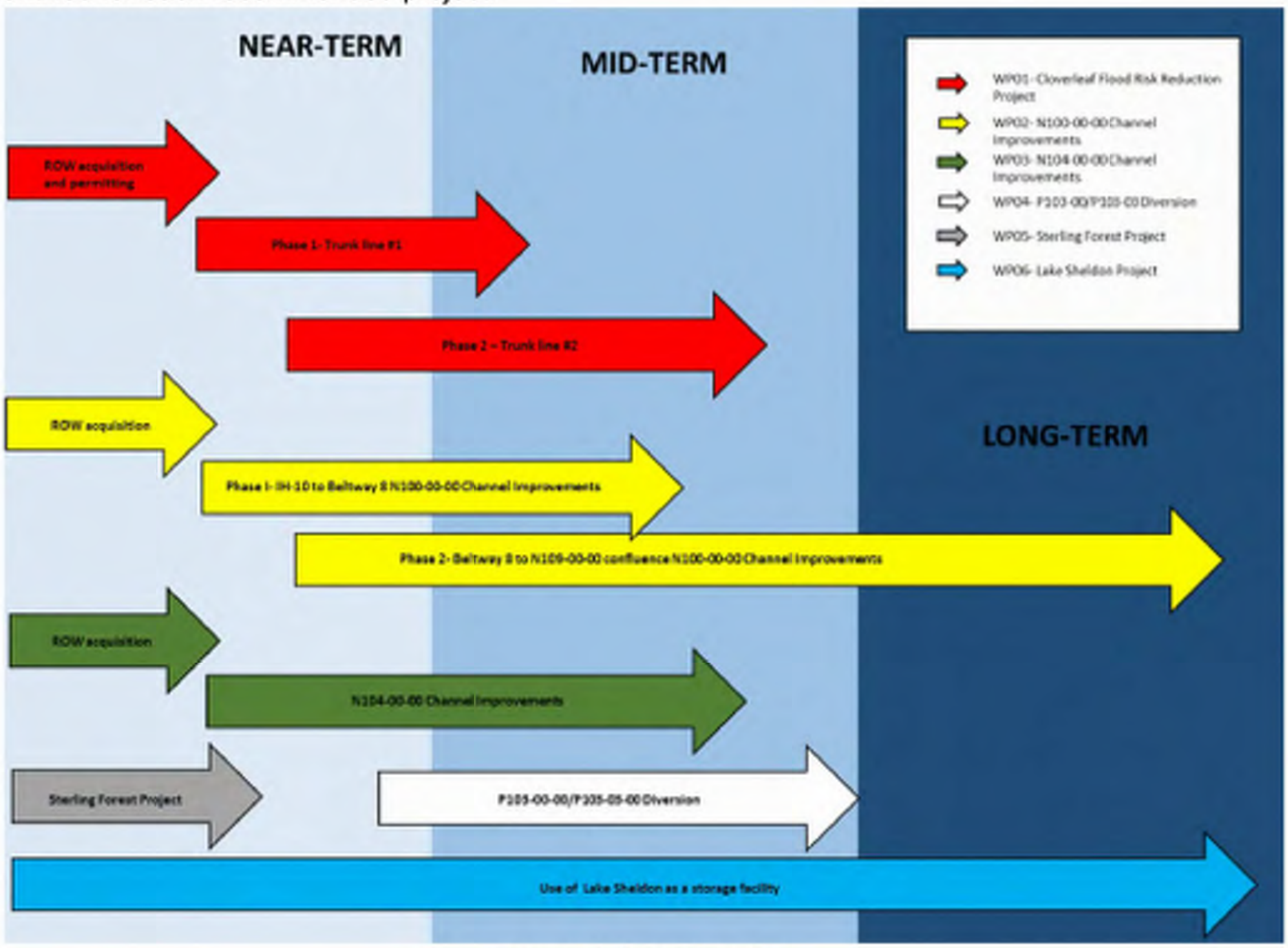


Figure 18. Project Timeline

4.1. Near-Term (1 to 5 years)

- **Cloverleaf Flood Risk Reduction Project (Phase 1 – Trunk line #1)**

  Phase 1 might include the ROW acquisition and permitting for the detention basin and simultaneous construction of trunk line #1, while a feasibility analysis on the IH-10 frontage road drainage system is underway.

- **Sterling Forest Concrete Swales**

  The WGA report proposed the construction of concrete swales. The analysis was conducted using EPA-SWMM and concluded that the flooding within the subdivision during extreme storm events is a direct result of the inadequate capacity of the existing roadway and storm sewer system to safely convey storm water runoff to the receiving streams. Therefore, the proposed feature recommended for improving drainage within the subdivision by the construction of five (5) concrete structures to accommodate a direct overland flow path out of the subdivision to the

N109-00-00 channel for extreme storm events. Refer to **Appendix D** for the report "Sterling Forest Subdivision Drainage System" by WGA consulting engineers. Further analysis might be required to assess detention requirements for the addition of the concrete swales using the BDF analysis.

- **N104-00-00 Channel Improvements Right-of-Way Acquisition**

  Recommended phase 1 of N104-00-00 channel improvements is ROW acquisition of the parcels needed for these improvements. This is because acquisition of parcels can take up to two years and for any improvements to take place, ROW is a primary requirement.

4.2. Mid-Term (5 to 10 years)

- **Cloverleaf Flood Risk Reduction Project (Phase 2 –Trunk line #2)**

  After an analysis of the conveyance capacity of the drainage system of IH-10 is determined, it will reveal the optimal placement of trunk line #2. This will take a longer time to determine and finalize and thus is a mid-term plan that falls under phase 2 of WP01.

- **N104-00-00 Channel Improvements**

  Phase 1 of WP03 is the ROW acquisition of land for channel improvements, phase 2 of this project are the recommended channel improvements along tributary N104-00-00.,

- **N100-00-00 Channel Improvements (Phase 1 – IH-10 to Beltway 8 and ROW acquisition)**

  Phase 1 of WP02 is channel improvements from IH-10 to Beltway 8 since that land is either owned by Harris County or public utilities (**green** line in **Figure 19**). While Phase 1 of WP02 is in progress, it is recommended that ROW acquisition for the remaining channel improvements takes place so that the project can move forward at a steady pace.

Figure 19. Phase I channel improvements N100-00-00

- **P103 Diversion**

  A preliminary analysis is recommended for this project before any improvements can take place. WP04 is a mid-term project, team meetings and preliminary analysis are required before a plan for the project is determined.

4.3. Long-Term (beyond 10 years)

- **N100-00-00 Channel Improvements (Phase 2 – Beltway 8 to N109-00-00 Confluence)**

  Since N100-00-00 channel improvements will have to occur in phases, the overall project will take more than ten years to complete and thus phase II is characterized as a long-term project. The **green** line in **Figure 20** shows the extent of phase II channel improvements.

Figure 20. Phase II channel improvements N100-00-00

- **Lake Sheldon**

  There have been multiple developments and projects occurring in the northern regions of Carpenters Bayou particularly north of Wallisville road. As development continues to grow, it is imperative to plan ahead and make use of existing facilities that can offer benefit. The use of Lake Sheldon as a storage facility provides great benefit to the northern regions of the watershed and thus is considered a long-term project. The use of Lake Sheldon as a storage facility could potentially reduce the need for detention ponds for mitigation purposes as development continues to grow. The **yellow** polygons in **Figure 21** shows some projects that are currently under way in the northern regions of Carpenters Bayou. Refer to TM#2 for the benefits associated with the use of Lake Sheldon as a storage facility.

Figure 21. Ongoing Project Locations

4.4. Carpenters Bayou "Vision Plan" (100yr Level-of-Service)

The Carpenters Bayou "Vision Plan" consists of a plan that provides a 100-year LOS for the entire watershed. It is meant to be a plan implemented if there were no financial constraints involved. The vision plan will consider all recommended projects in TM#3 and a few others which will be a part of one master model. This section will be revised and updated after the completion of Technical Memorandum #4 and updates will be reflected in the Final Engineering Report.

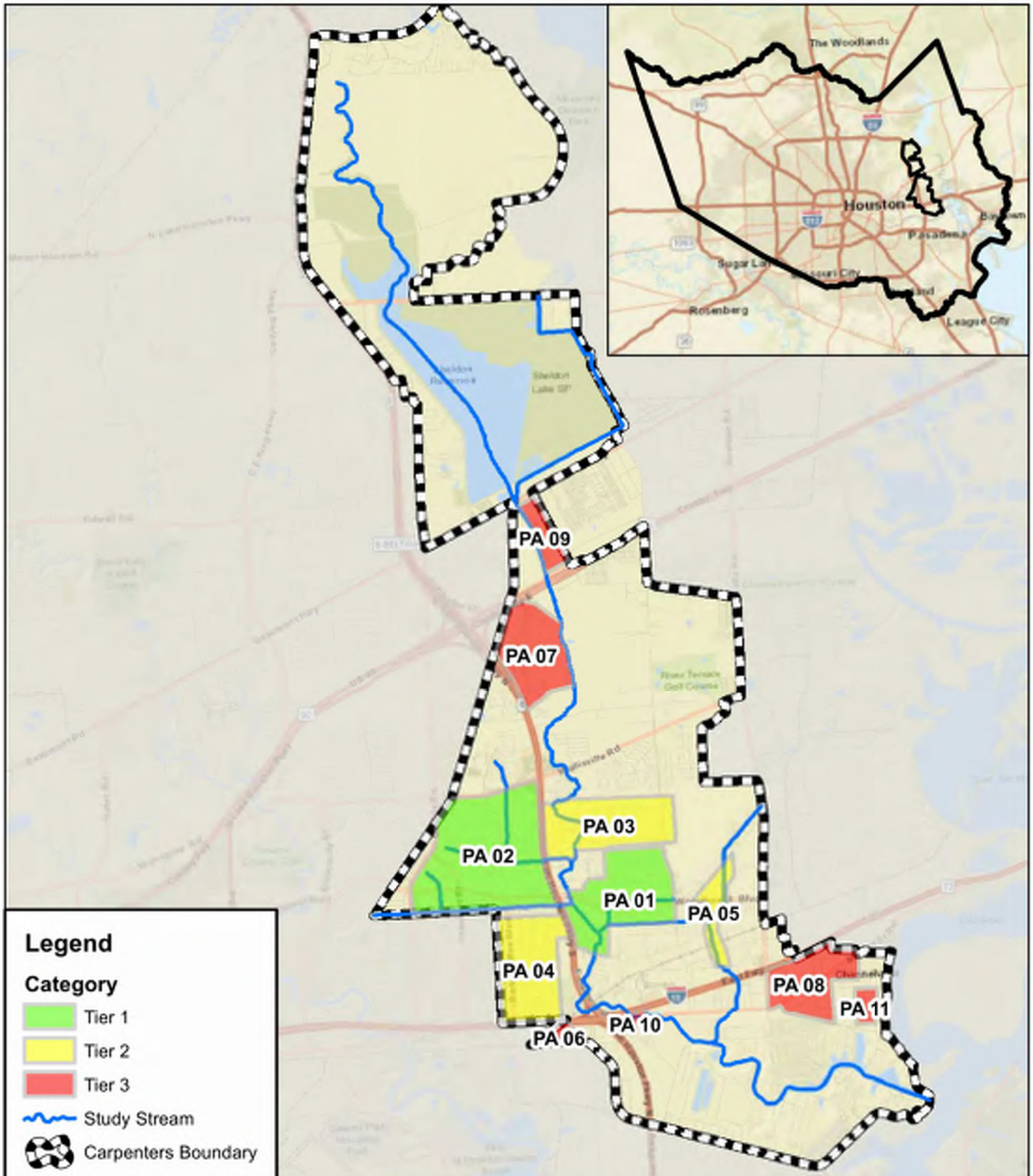
5. References

R.G. Miller Engineers, Inc. (2012) "Freeport St. Drainage Analysis" Submitted to Harris County Flood Control District

WGA Consulting Engineers (2019) "Sterling Forest Subdivision Drainage Assessment" Submitted to Harris County Engineering Department

List of Exhibits

List of Appendices



Technical Memorandum 3

Exhibit 01
Problem Area Classification

Miles
0 0.45 0.9 1.8

N

Created: 9/1/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

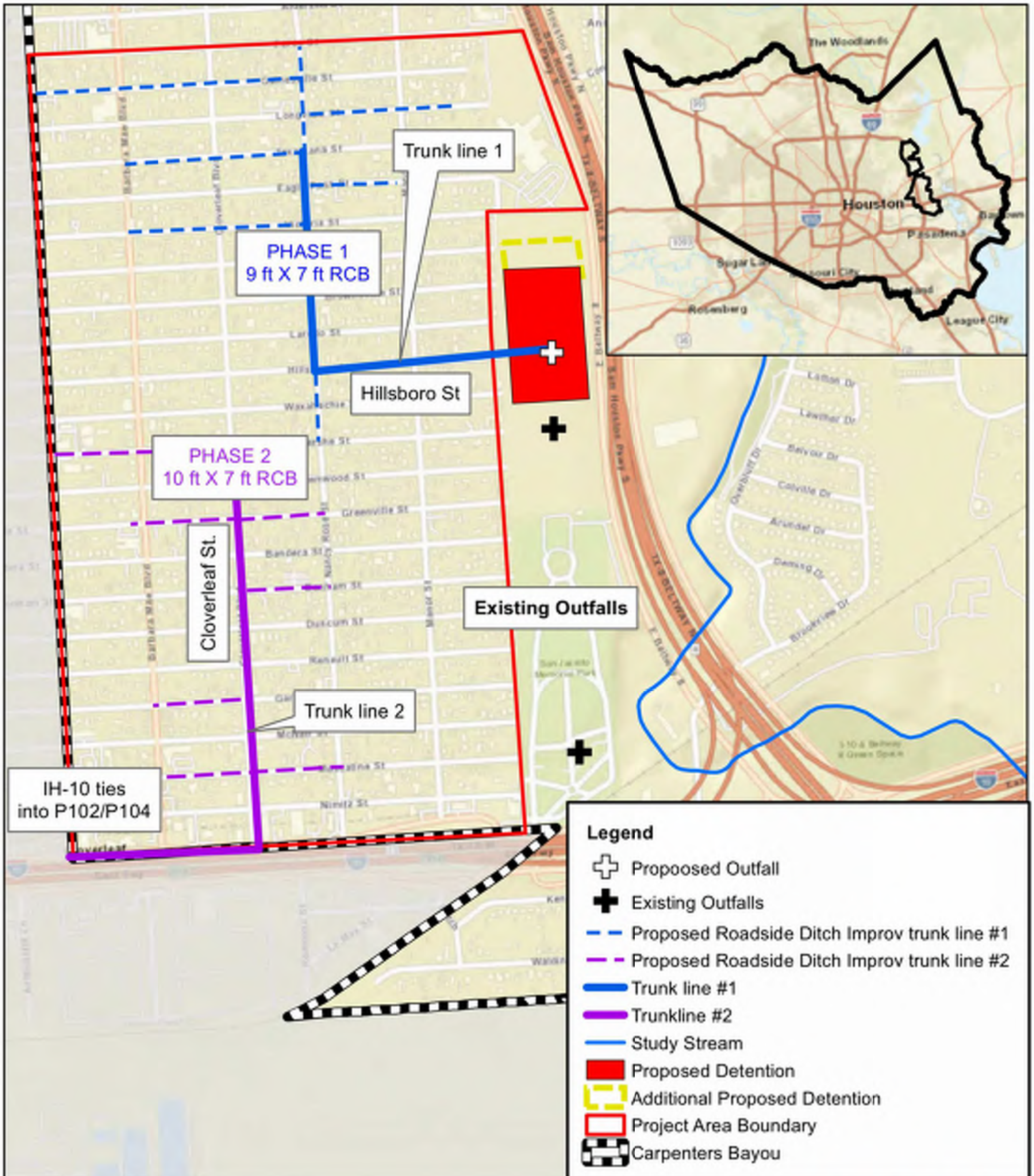


Exhibit 02
WP01-Cloverleaf Drainage Improvement

Created: 9/17/2020

Carpenters Bayou Watershed Plan

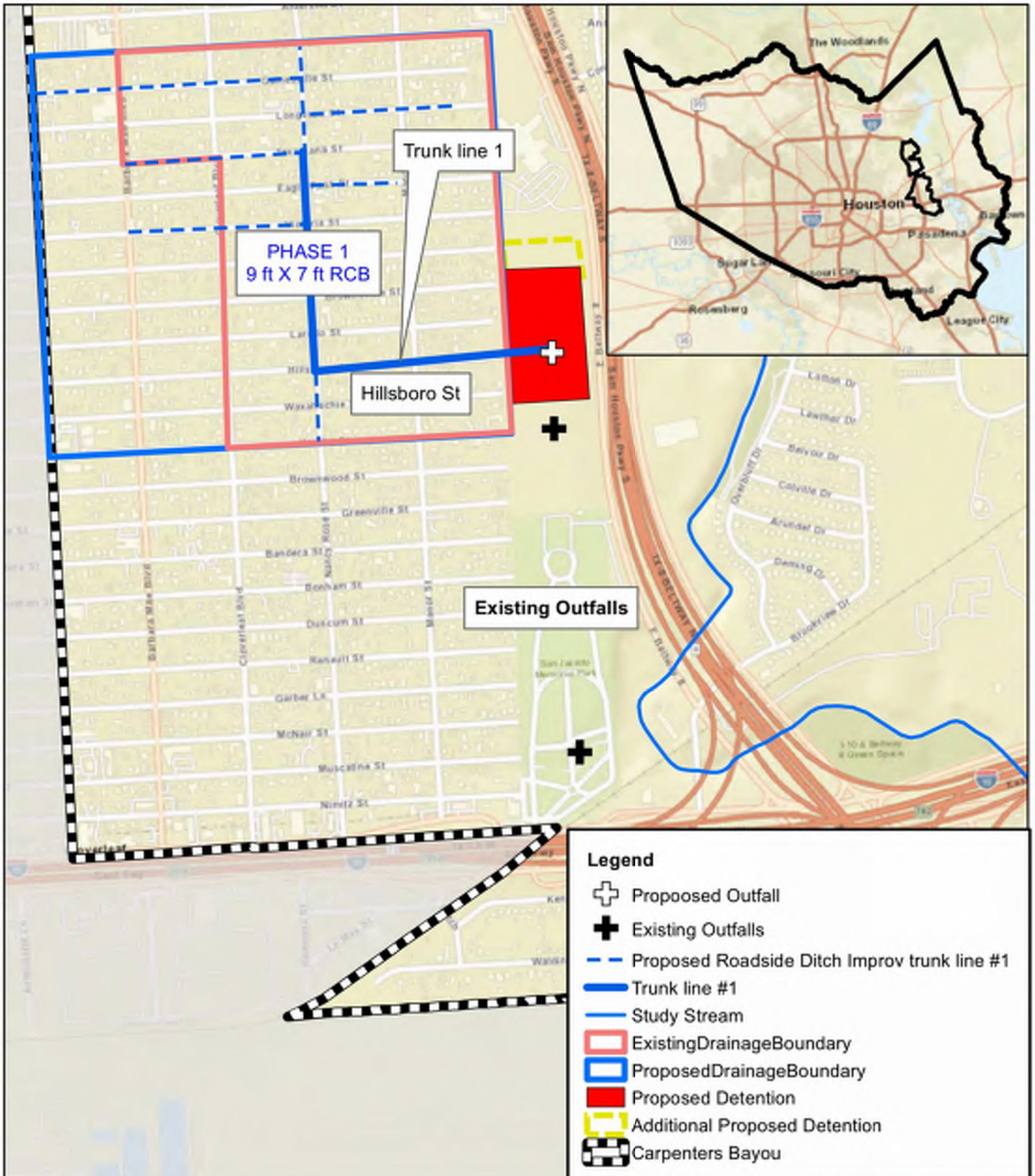


Exhibit 03
WP01-Cloverleaf Drainage Improvement Boundaries Phase 1

Miles
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N

Created: 9/17/2020

Carpenters Bayou

Watershed Plan

FLOOD CONTROL DISTRICT

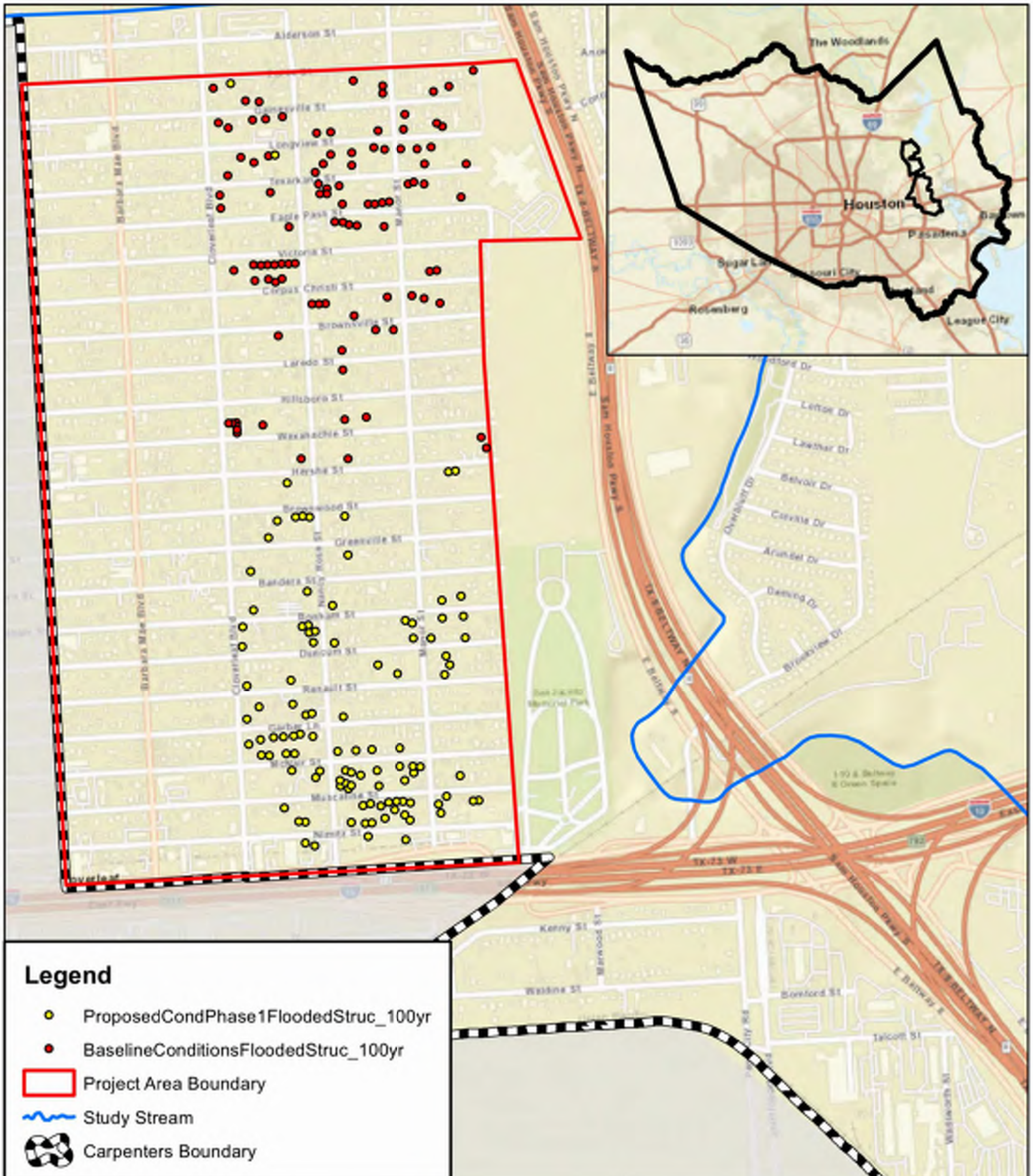

Exhibit 04
Damage Reduction Phase 1

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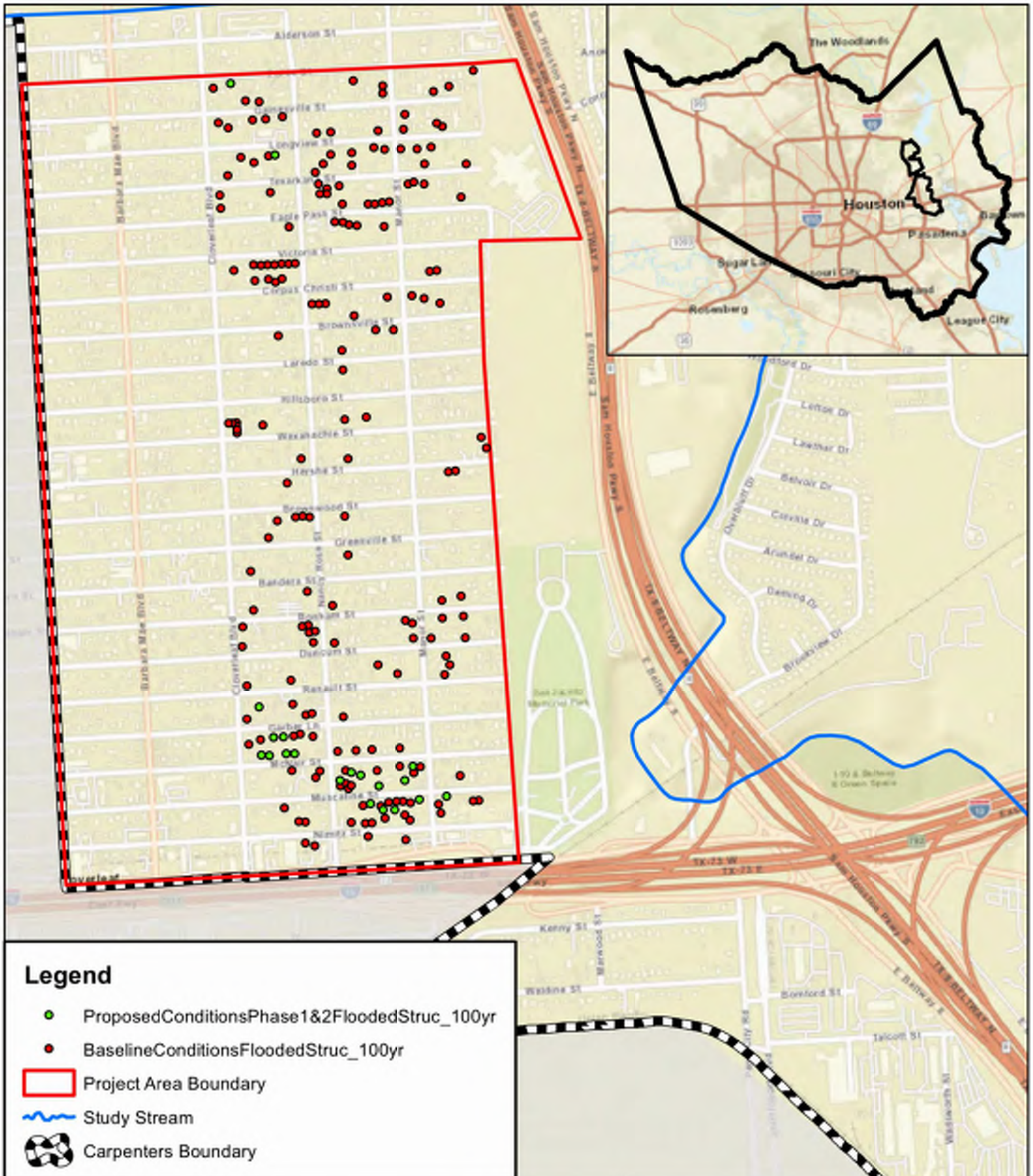
Created: 9/17/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Legend

- ProposedConditionsPhase1&2FloodedStruc_100yr
- BaselineConditionsFloodedStruc_100yr
- Project Area Boundary
- Study Stream
- Carpenters Boundary

Exhibit 04
Damage Reduction Phase 1

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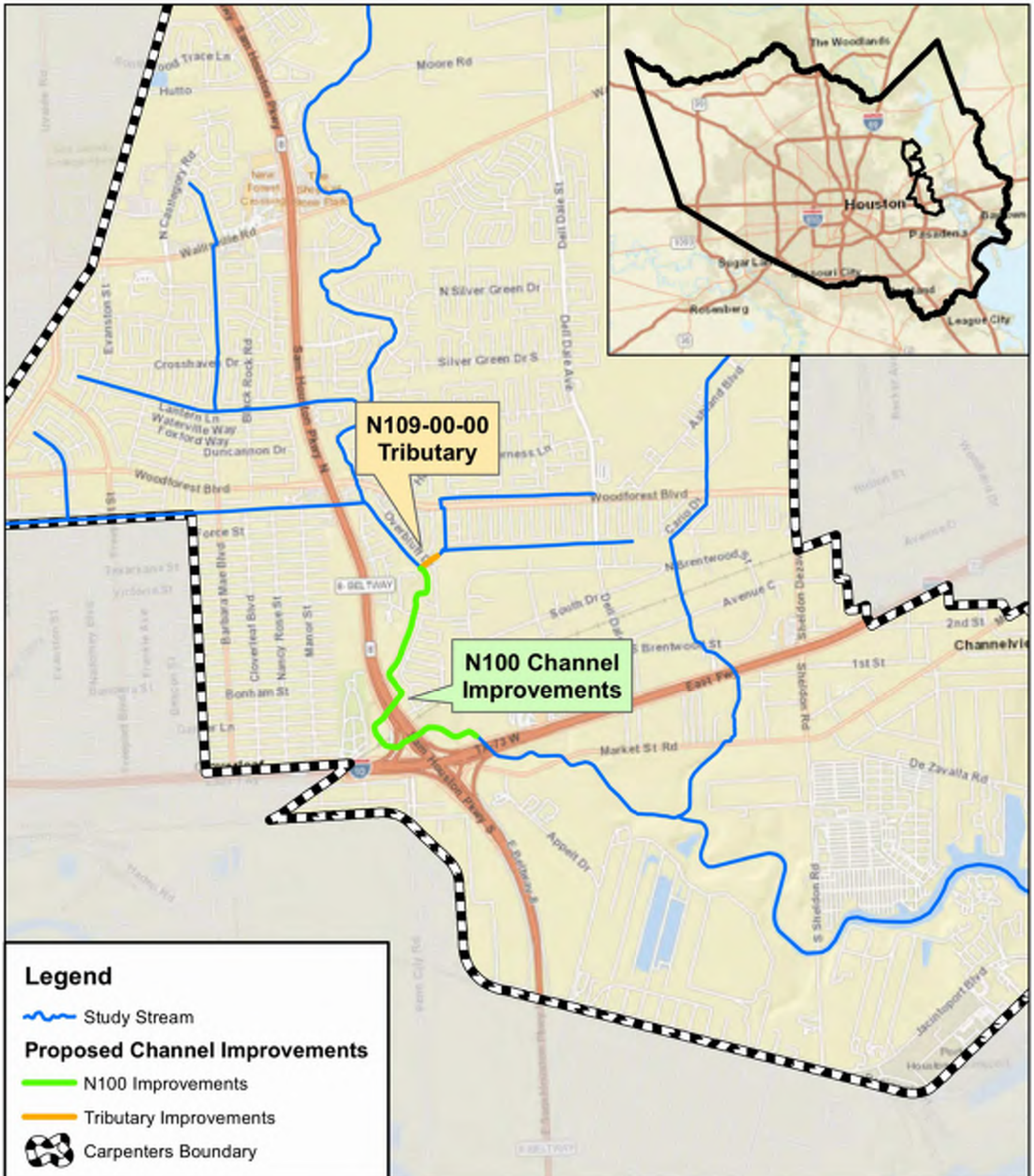
Created: 9/17/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 06
Project2

Miles
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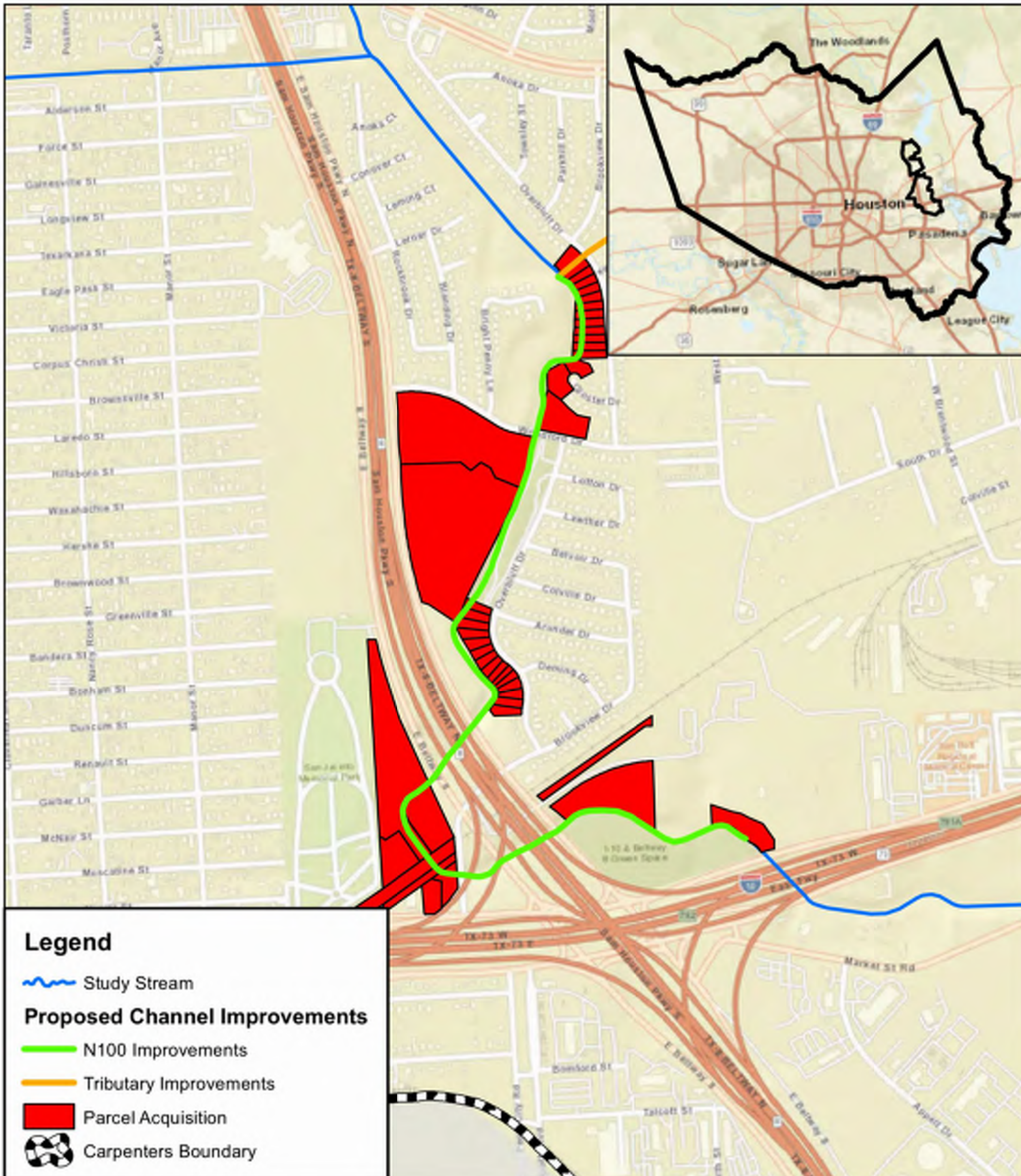
N

Created: 9/2/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 07
Project2 ROW Acquisition

Miles

0 0.05 0.1 0.2

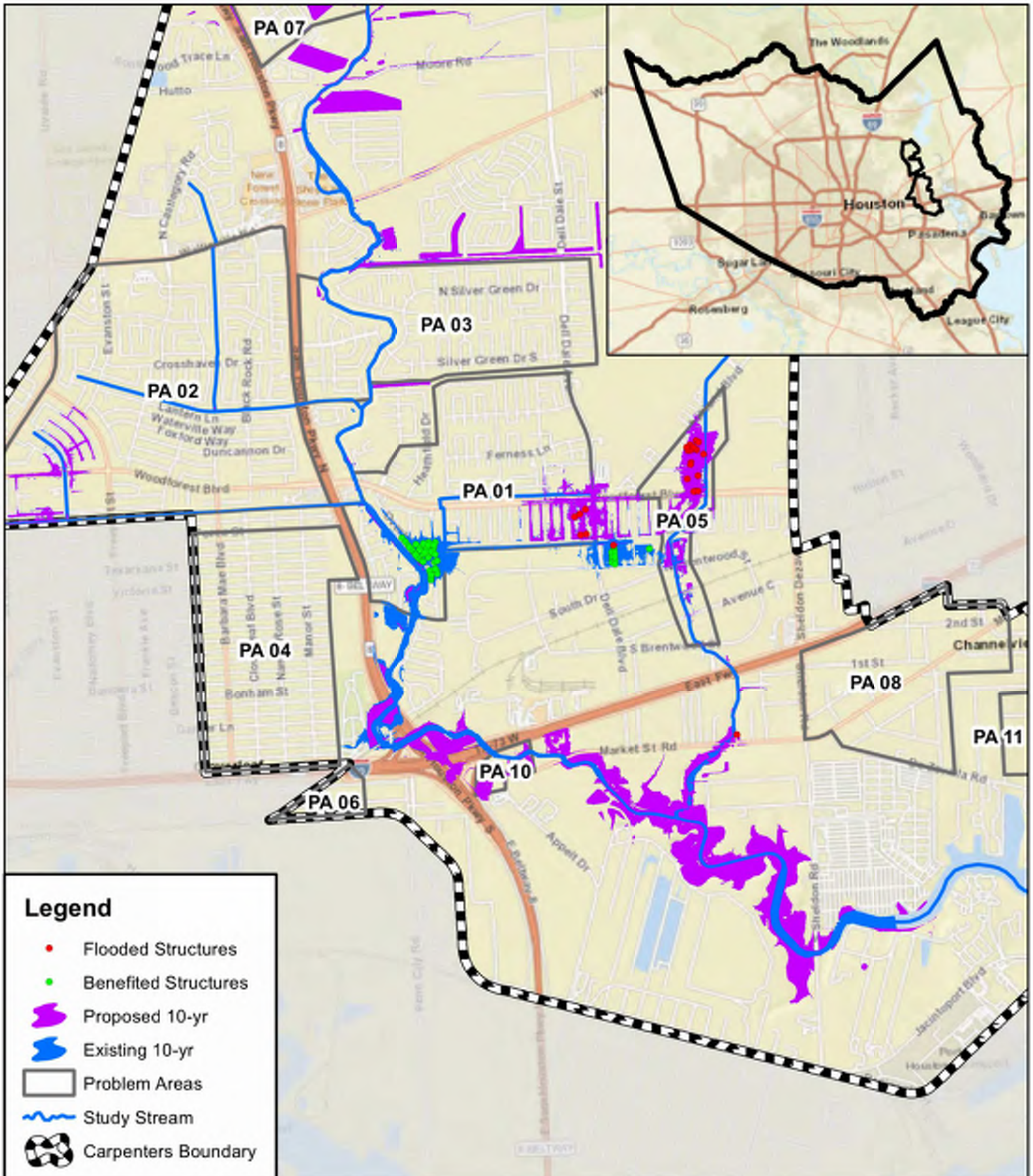
N

Created: 9/2/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 08
Project2 10-yr

Miles
0 0.2 0.4 0.8

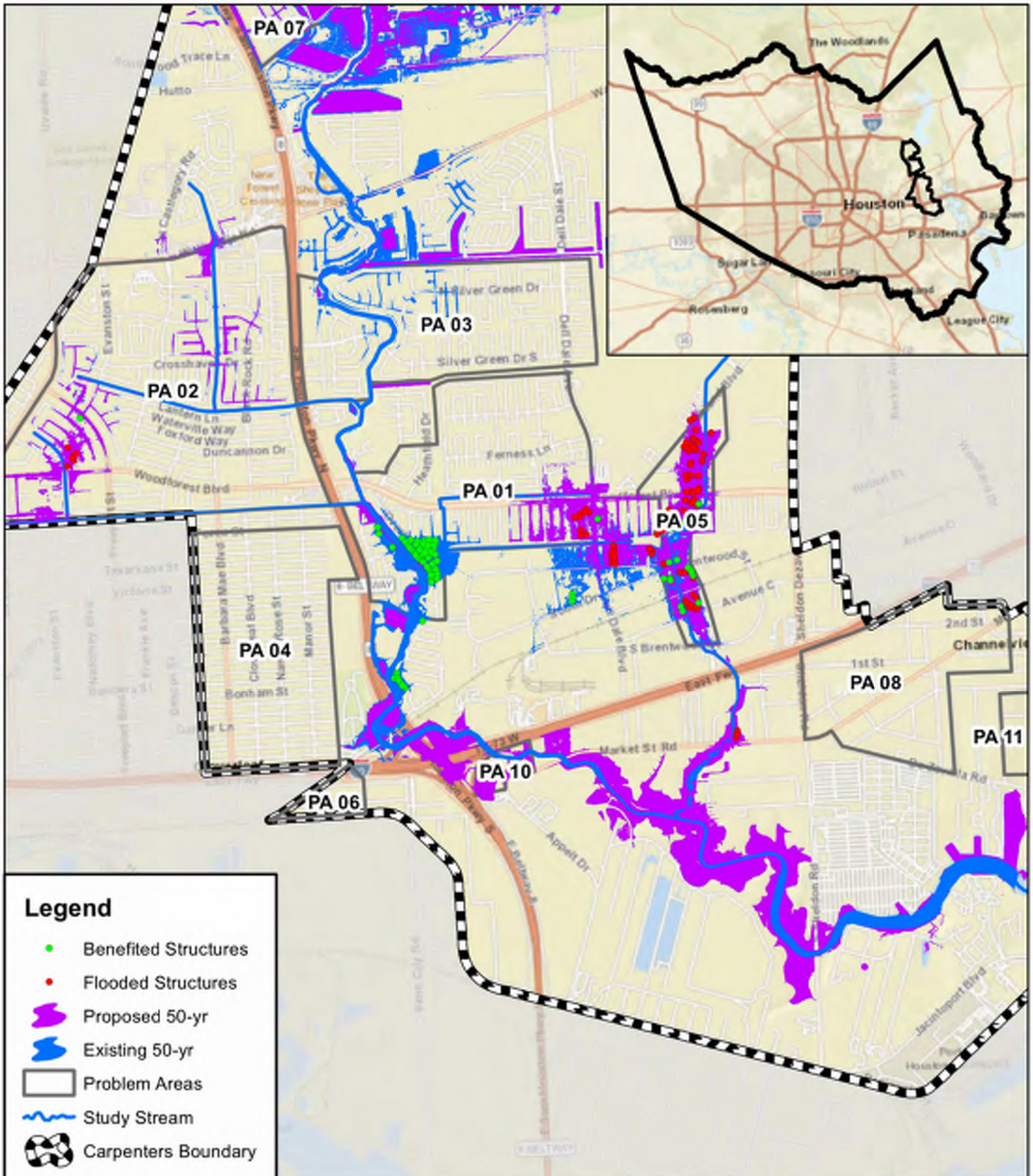
N

Created: 9/2/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

Attachment #3 Interim Deliverable



Technical Memorandum 3

Exhibit 09
Project2 50-yr

Miles
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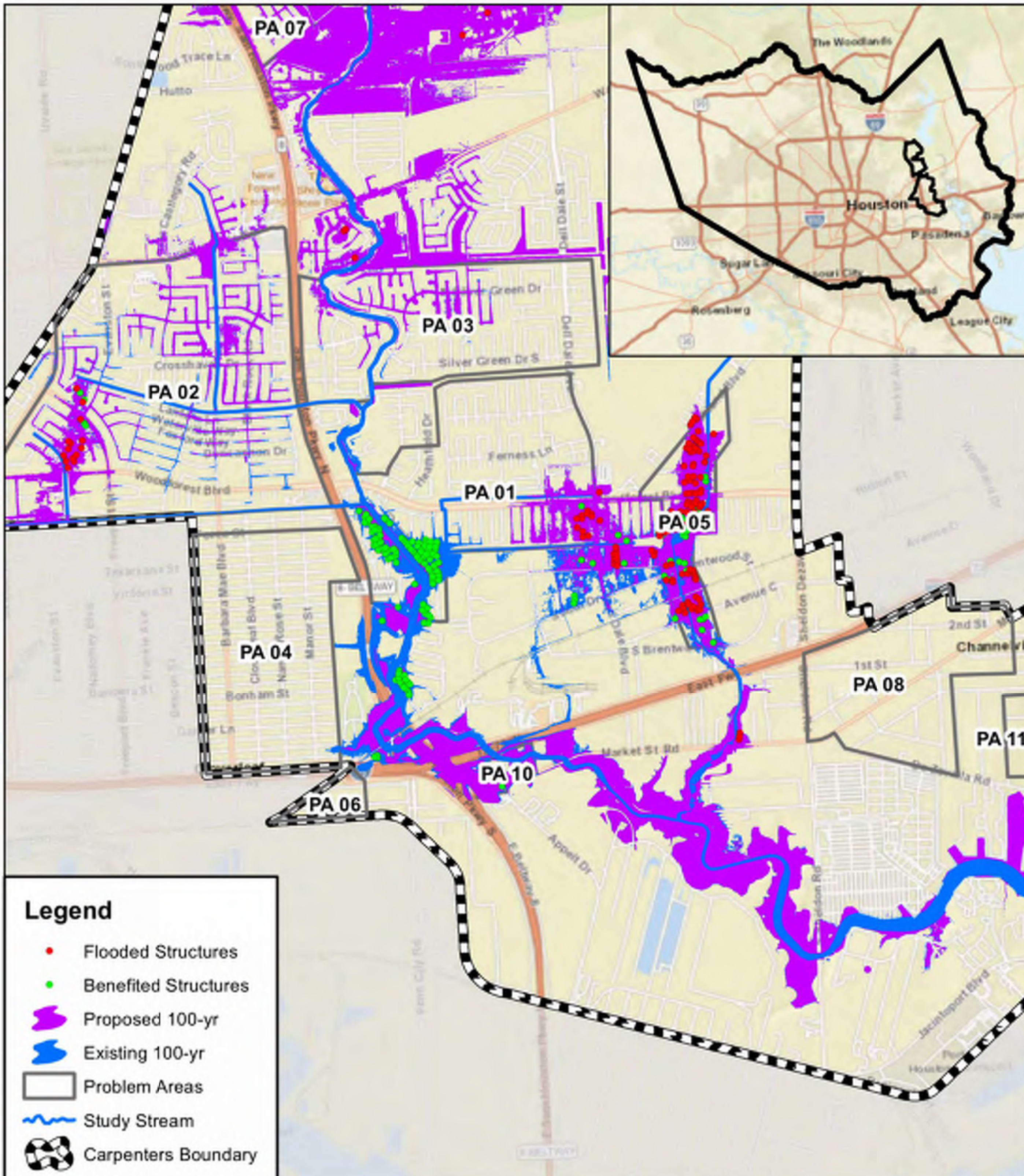
N

Created: 9/2/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 10
Project2 100-yr

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N

Created: 9/2/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

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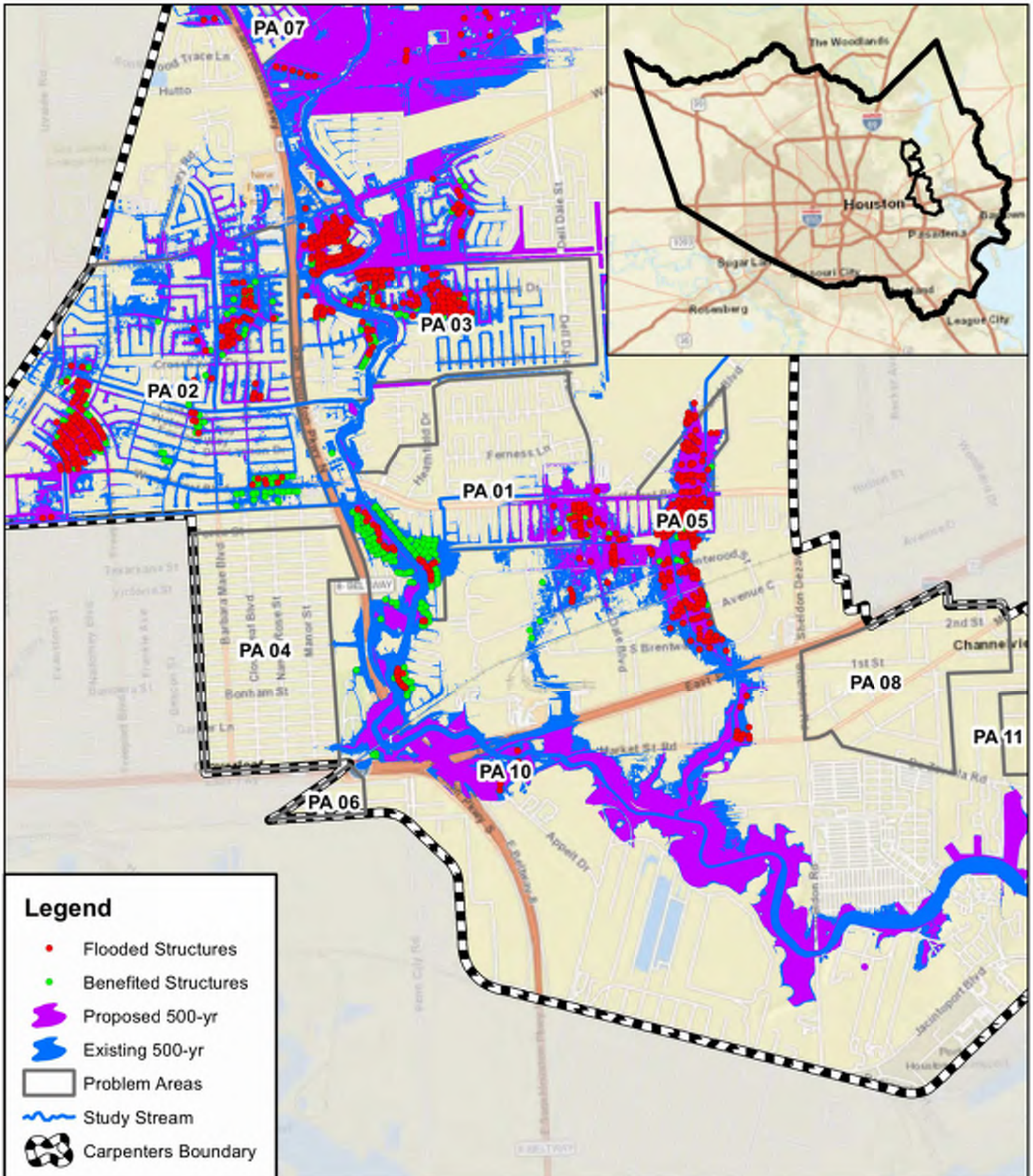


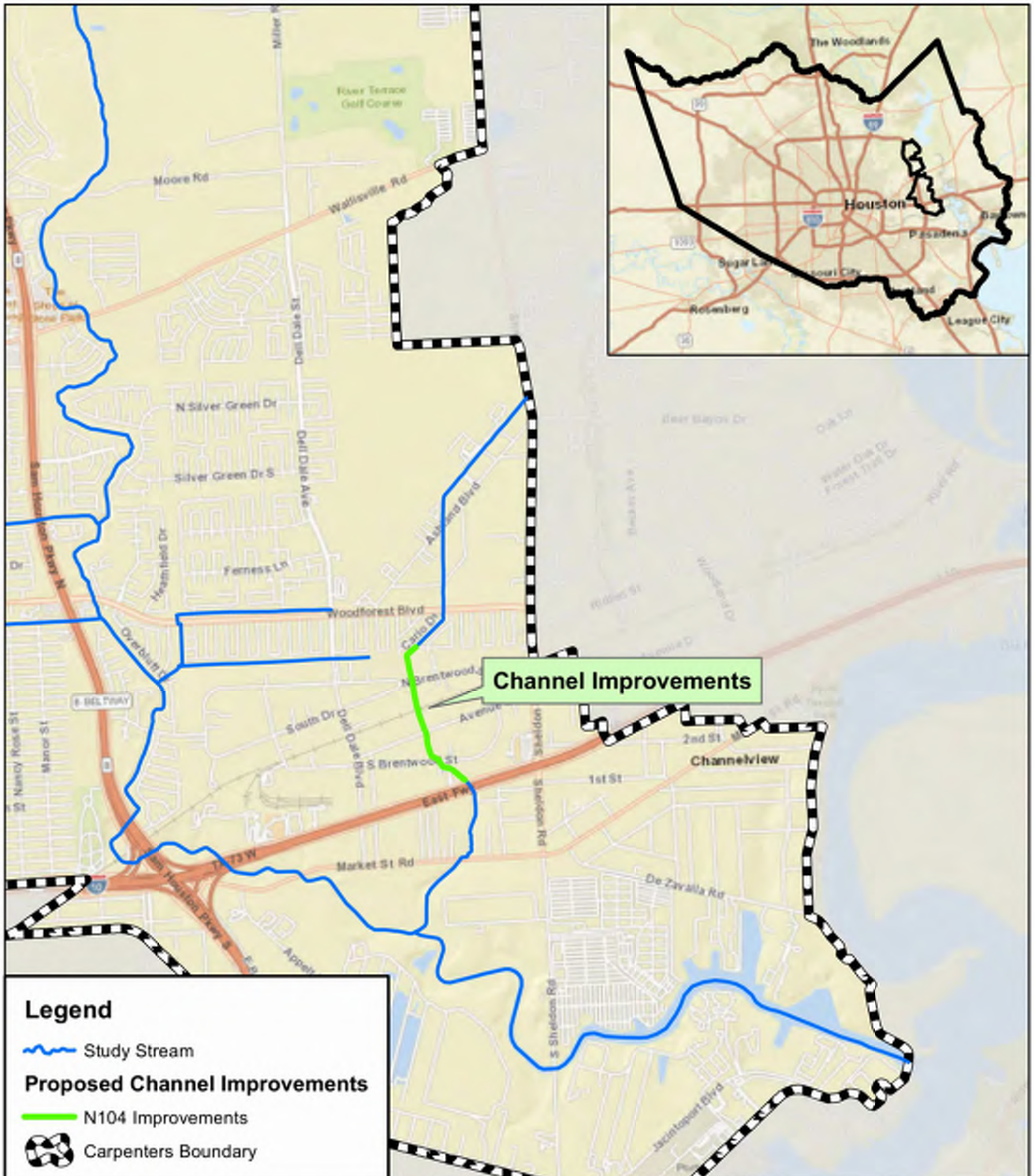
Technical Memorandum 3

Exhibit 11
Project2 500-yr

Created: 9/2/2020

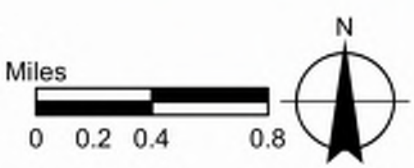
Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

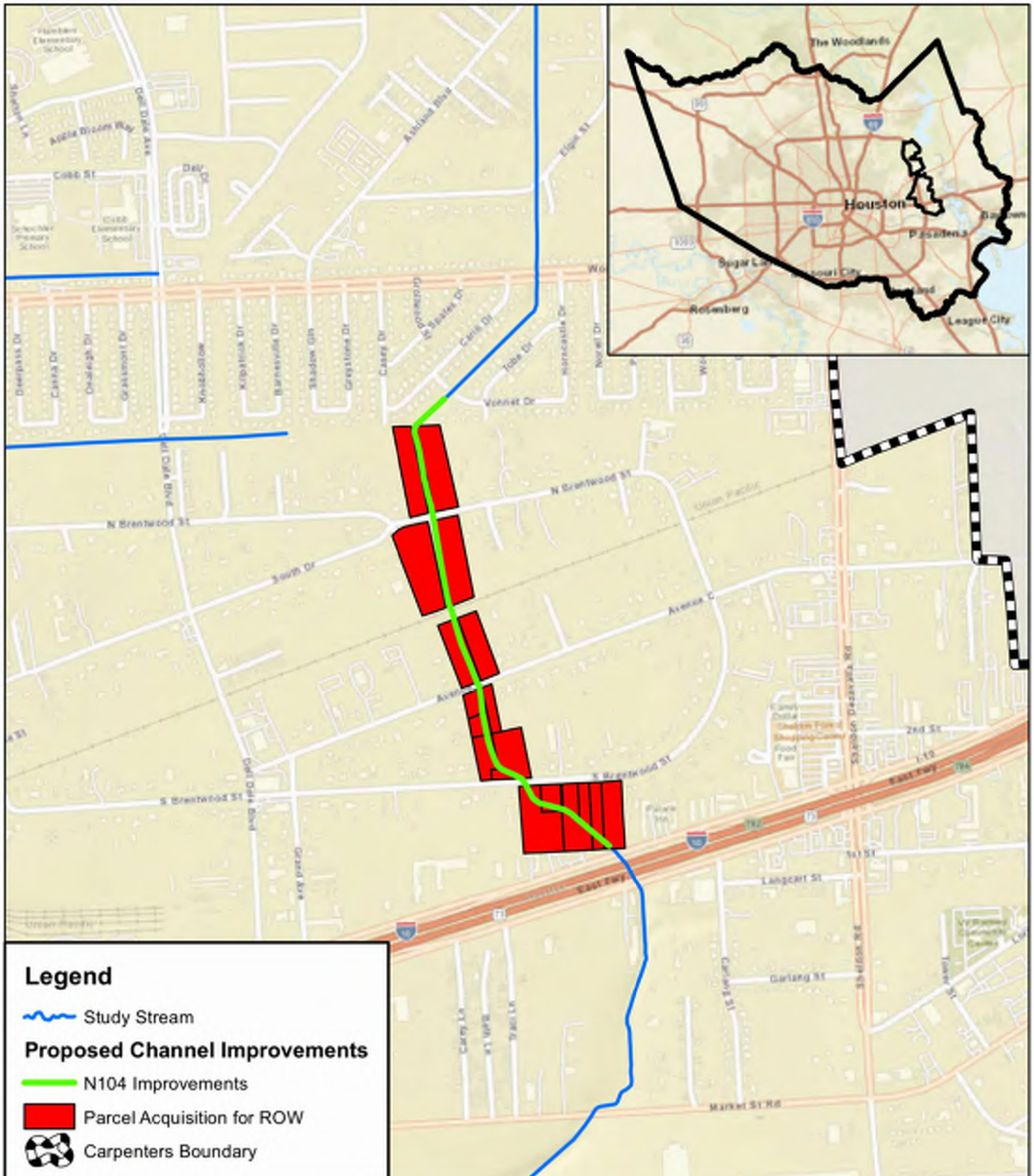
Exhibit 12
Project 3



Created: 9/2/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 13
Project 3 ROW Acquisition

Miles

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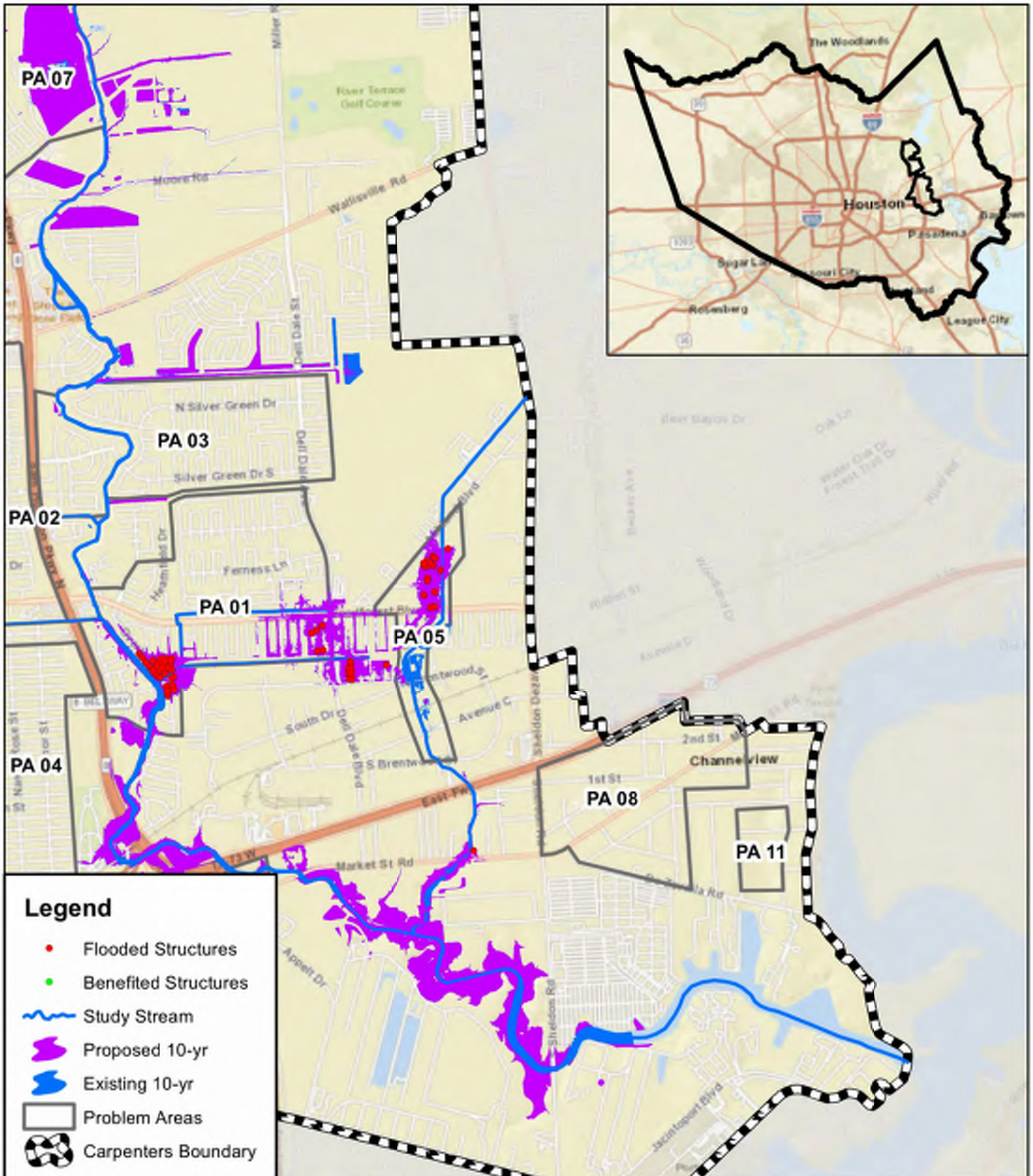
Created: 9/2/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 14
Project 3 10-yr

Miles
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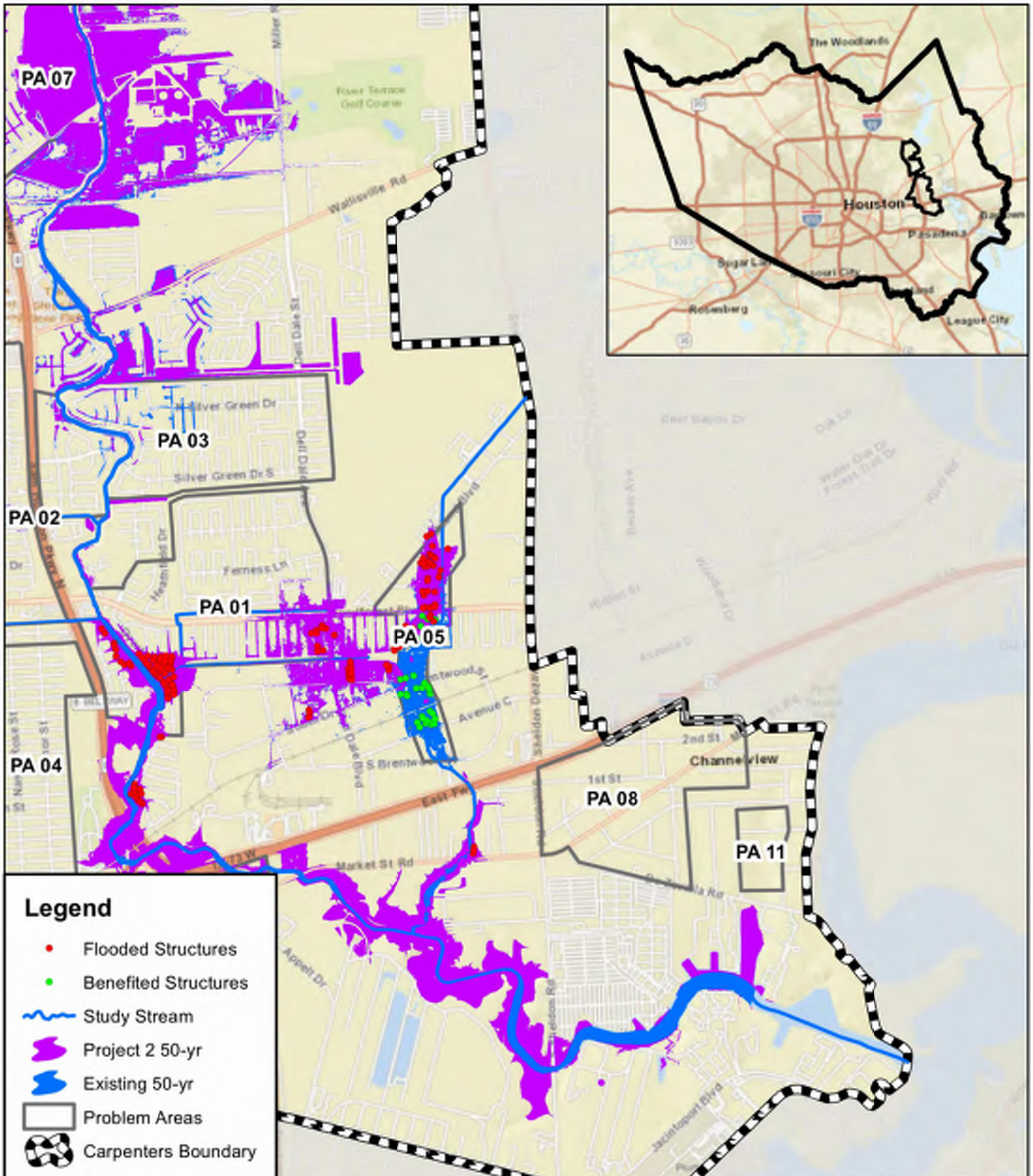
Created: 9/2/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



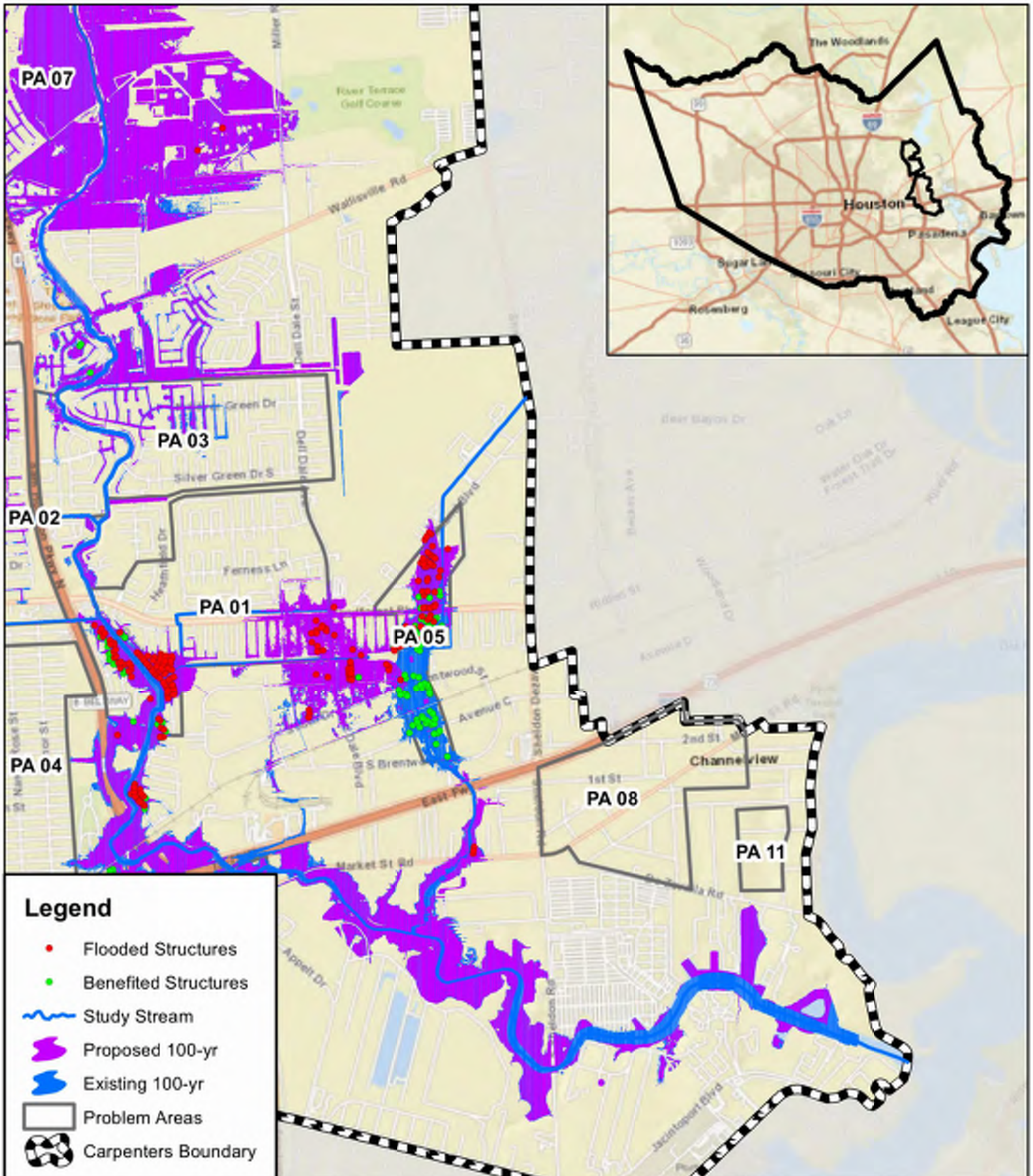
Technical Memorandum 3

Exhibit 15
Project 3 50-yr

Created: 9/2/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 16
Project 3 100-yr

Miles
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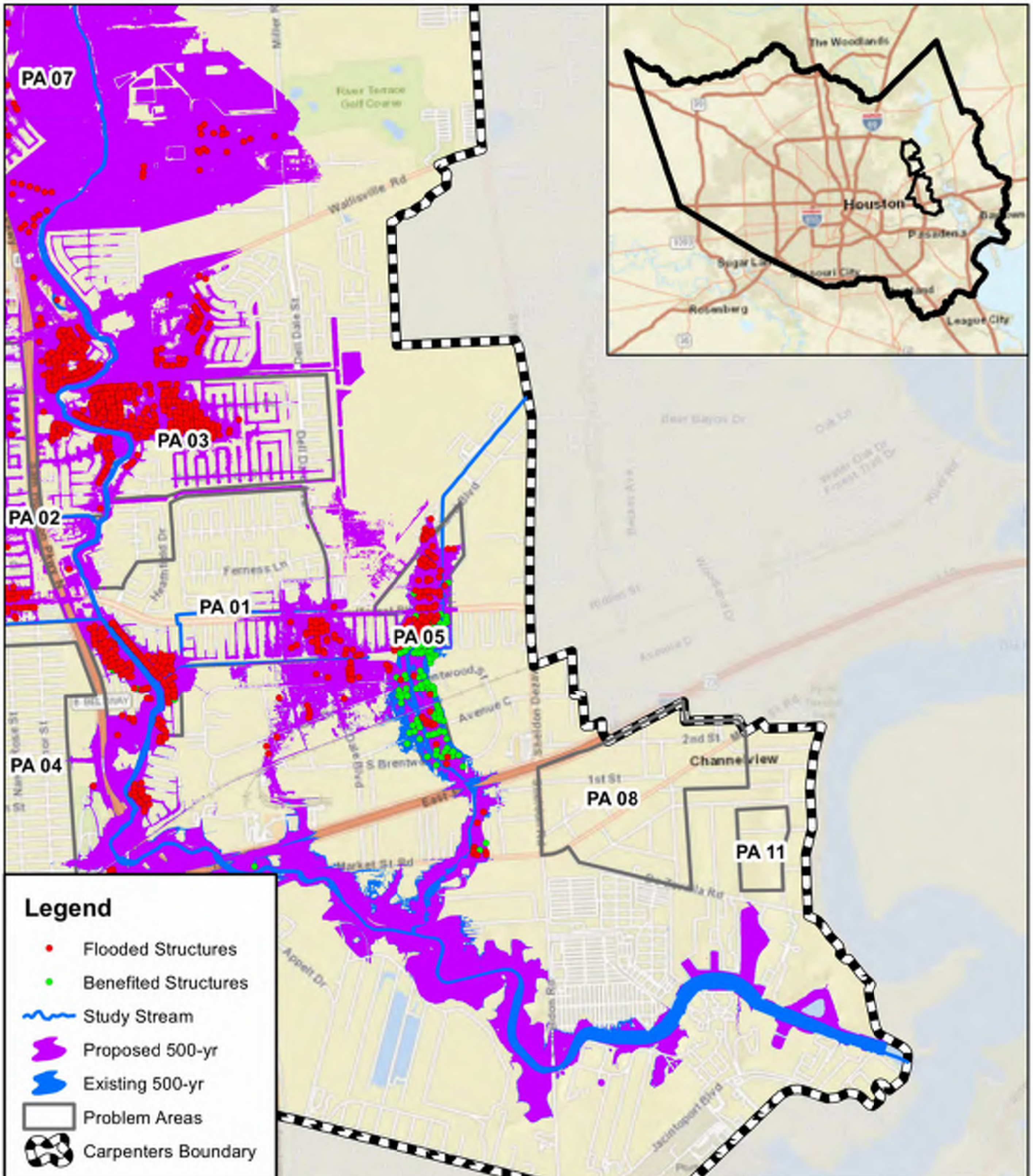
Created: 9/2/2020

Carpenters Bayou
Watershed Plan

FLOOD CONTROL DISTRICT

Attachment #3 Interim Deliverable



Technical Memorandum 3

Exhibit 17
Project 3 500-yr

Miles
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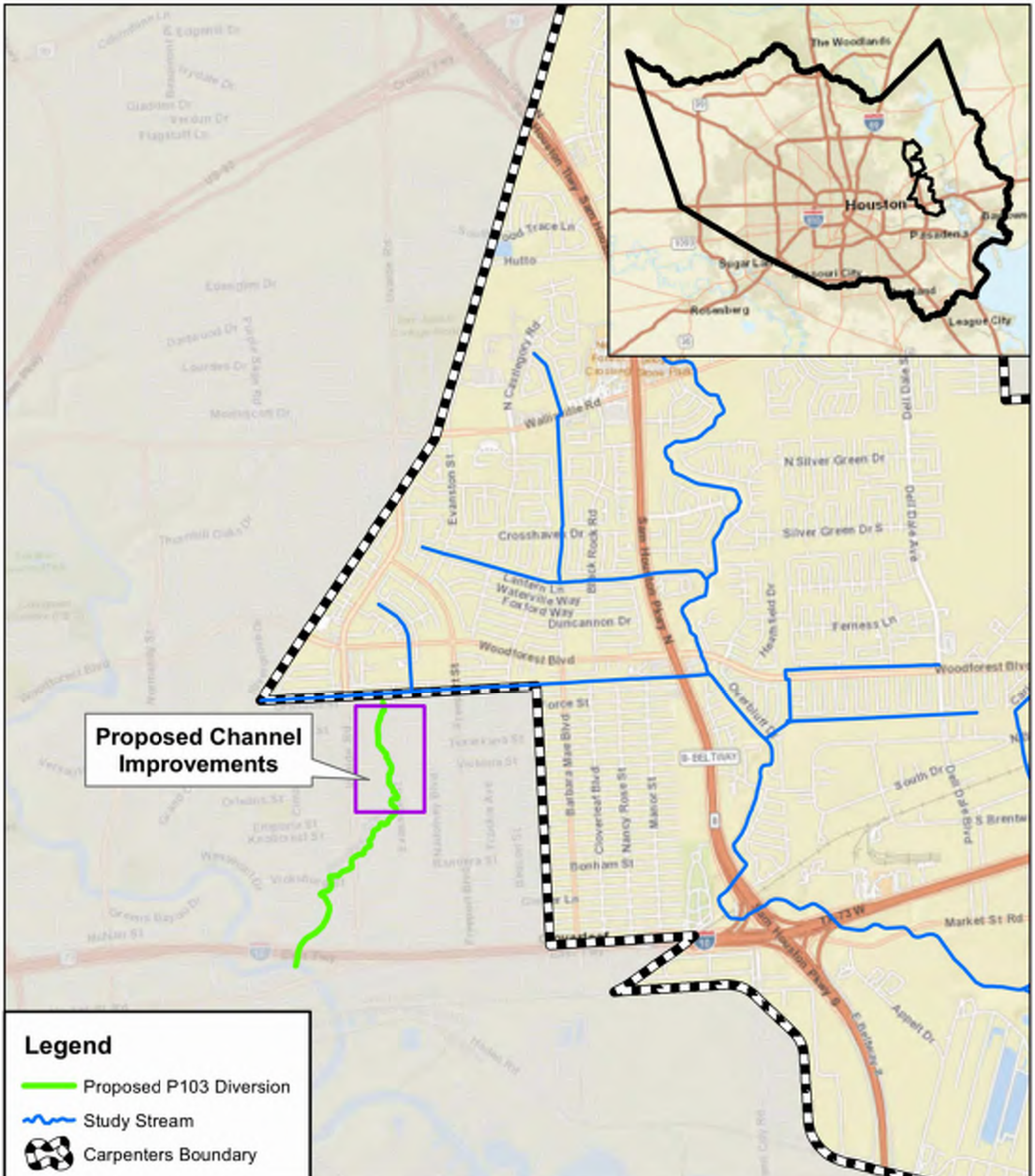
Created: 9/2/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Legend

- Proposed P103 Diversion
- Study Stream
- Carpenters Boundary

Technical Memorandum 3

Exhibit 18
Project 4

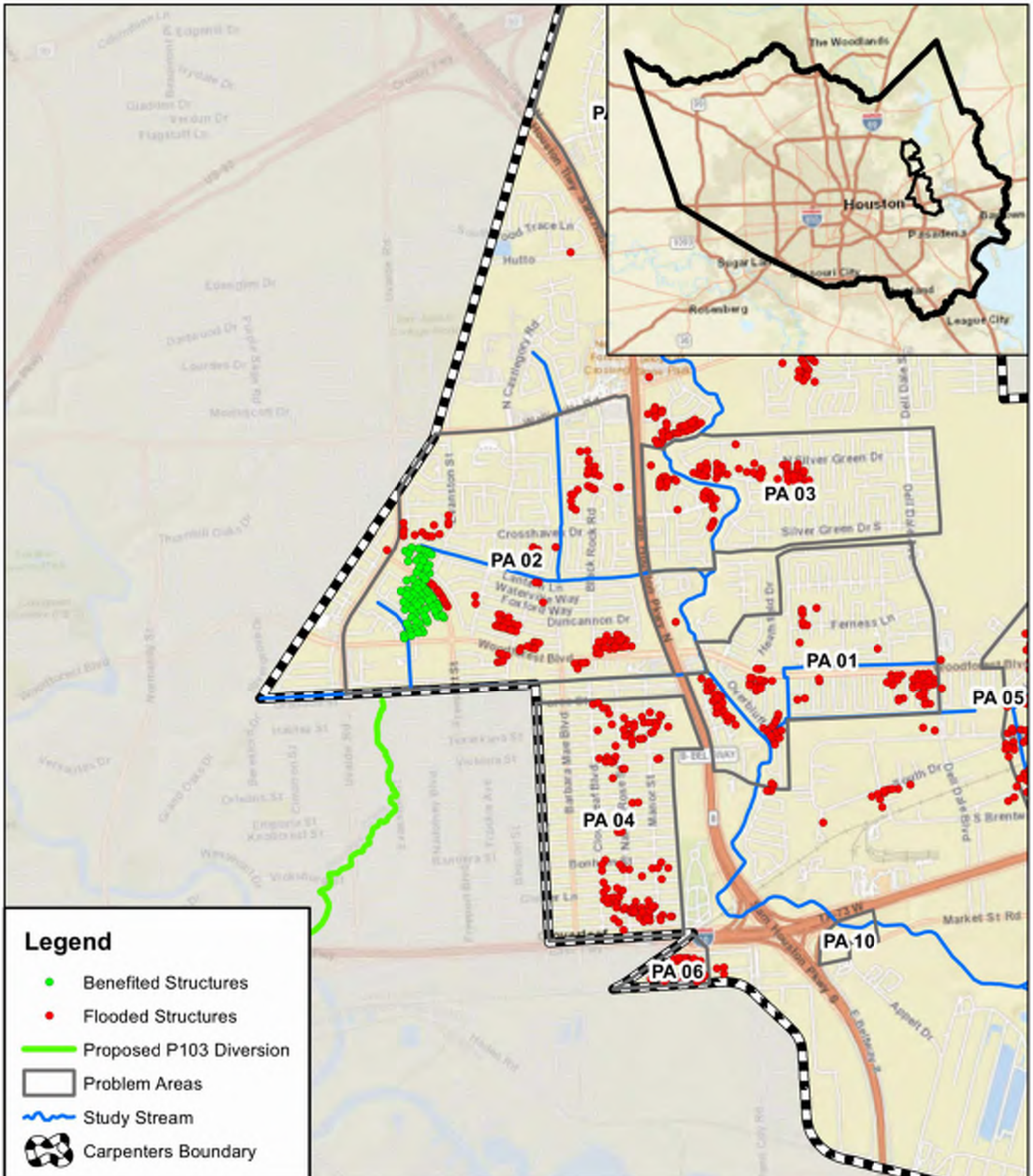
Miles
0 0.2 0.4 0.8

N

Created: 9/2/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



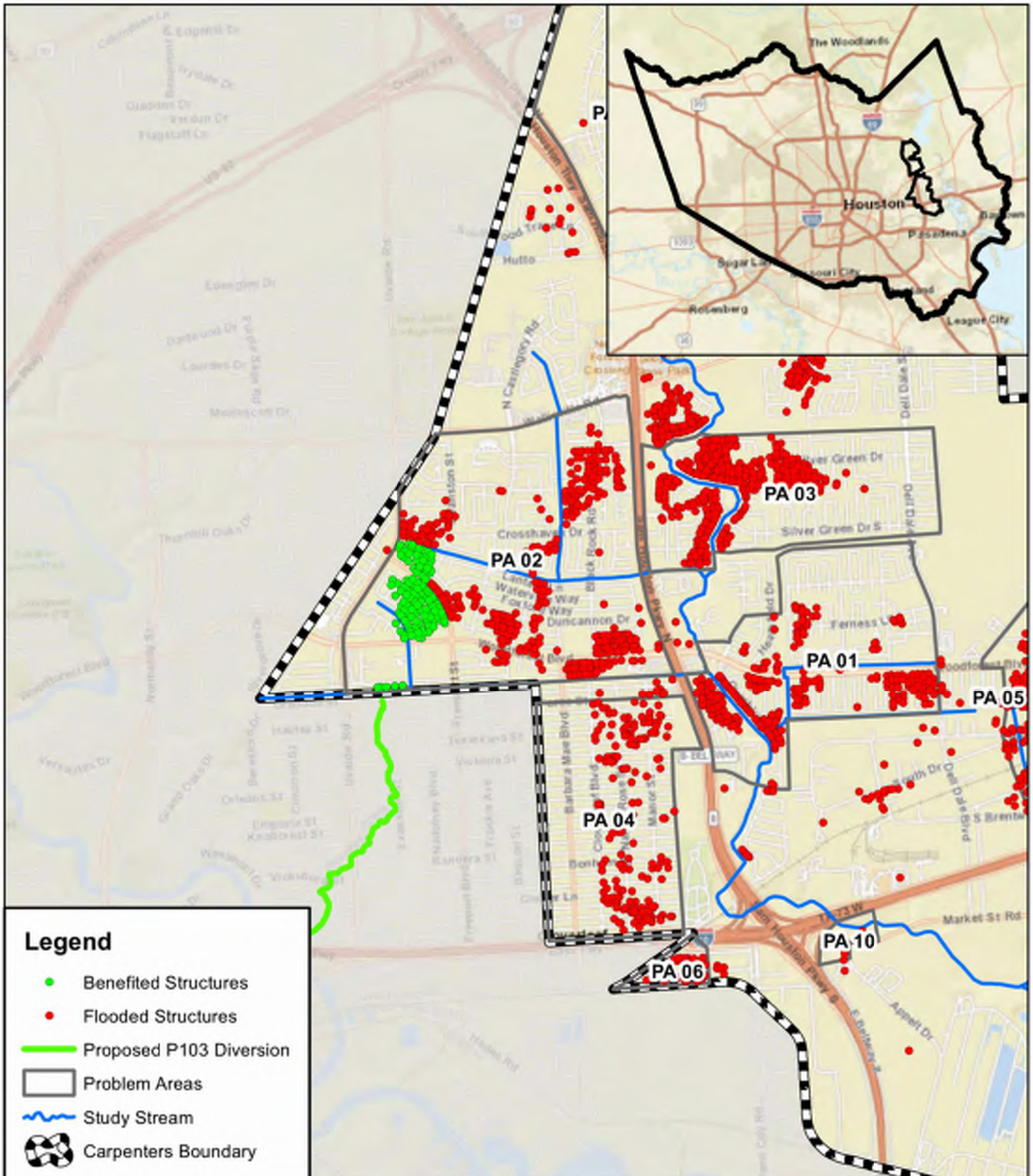
Technical Memorandum 3

Exhibit 19
Project 3 10-yr

Created: 9/2/2020

Carpenters Bayou

Watershed Plan



Technical Memorandum 3

Exhibit 20
Project 4 50-yr

Miles
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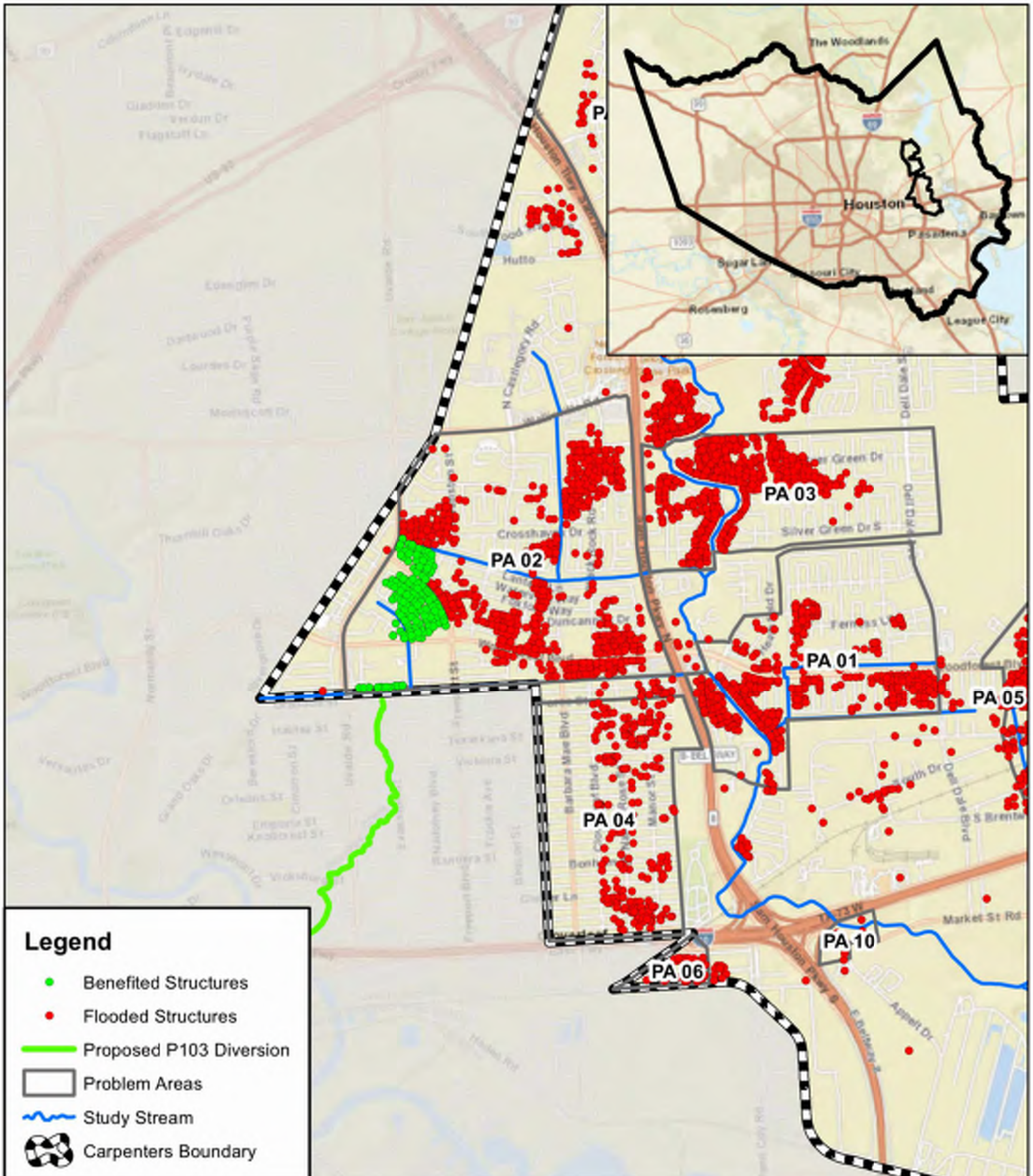
Created: 9/2/2020

Carpenters Bayou

Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



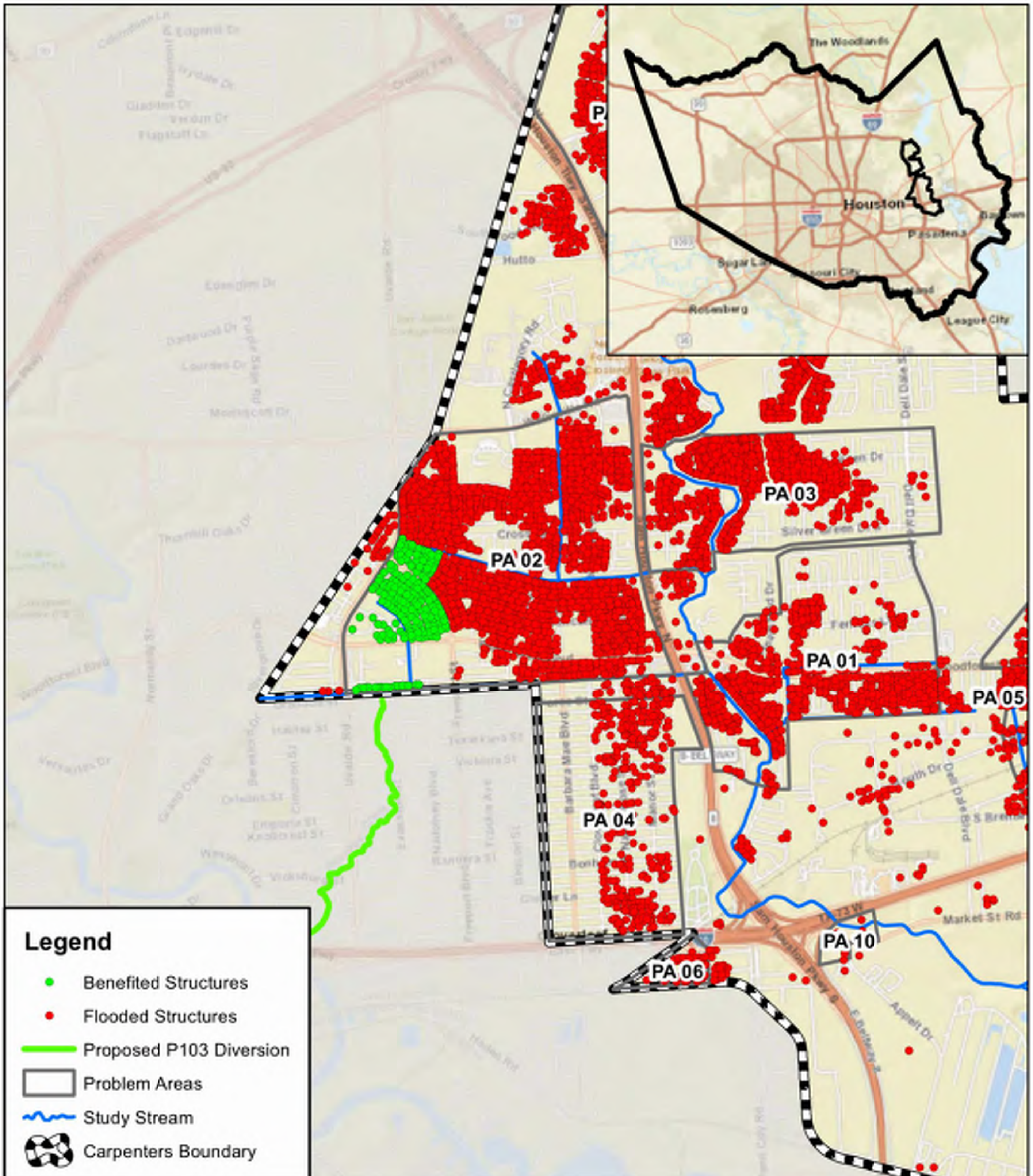
Technical Memorandum 3

Exhibit 21
Project 4 100-yr

Created: 9/2/2020

Carpenters Bayou Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT



Technical Memorandum 3

Exhibit 22
Project 4 500-yr

Miles
0 0.2 0.4 0.8

N

Created: 9/2/2020

Carpenters Bayou
Watershed Plan

HARRIS COUNTY FLOOD CONTROL DISTRICT

Appendix A

PA Summary Table

Problem Area Name	Primary Jurisdiction	Flooding Source	Historical Flooding Data	Total Predicted Structural Flooding (1% AEP)*	Predicted Structural Flooding (PSF50)	Predicted Roadway Flooding (Total Length >1-foot during 1% AEP)	Classification	Comments
			(number of homes)	(number of structures)	(structures per year)	(miles)		
PA01	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	64	427	853.9	13.6	Tier 1	
PA02	Unincorporated Harris County/ Cloverleaf	Sheet flow from adjoining area and Local stormwater drainage limitation	12	785	1680.5	24.1	Tier 1	
PA03	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	21	526	867.2	11.4	Tier 2	
PA04	Unincorporated Harris County/ Cloverleaf	Local stormwater drainage limitation and sheet flow from adjoining area	32	206	661.9	3.0	Tier 2	
PA05	Unincorporated Harris County/ Channelview	Overbank flow and local stormwater drainage limitation	25	218	569.8	1.5	Tier 2	
PA06	Unincorporated Harris County	Sheet flow from adjoining area and Local stormwater drainage limitation	12	46	198.1	0.1	Tier 3	
PA07	Unincorporated Harris County	Overbank flow and local stormwater drainage limitation	4	18	30.7	5.9	Tier 3	
PA08	Unincorporated Harris County/ Channelview	Local stormwater drainage limitation and sheet flow from adjoining area	3	36	78.3	0.5	Tier 3	
PA09	Unincorporated Harris County	Overbank flow	1	60	111.1	0.4	Tier 3	
PA10	Unincorporated Harris County/ Channelview	Overbank flow	2	10	20.5	0.1	Tier 3	
PA11	Unincorporated Harris County/ Channelview	Sheet flow from adjoining area and Local stormwater drainage limitation	0	16	71.7	0.1	Tier 3	

Notes and Abbreviations:

Historical Flooding (data value)= Total historical flooding from the multiple events recorded in the HCFCD database – (Events include Imelda 2019, Harvey 2017, Memorial Day 2015, Tax Day 2016, Halloween 2015, Ike 2008, and others). They do not include storm events prior to 2015 such as Tropical Storm Allison (2001), Carpenters Bayou watershed flooded extensively during this storm event.

Predicted Structural Flooding (1% AEP)- Number of homes predicted to flood during storm event with a 1% annual exceedance probability.

Predicted Structural Flooding (total TPASF50) = Total Probable Annual Structural Flooding (all structures) predicted to occur in the problem area over a 50-year period. This statistic based on four predicted frequency events, i.e. [(N10yr x 5) + (N50yr x 1) + (N100yr x 0.5) + (N500yr x 0.1)] = theoretical annual flooding of homes over a 50-year period within each problem area.

Predicted Roadway Flooding (Total Length >1-foot in 1% AEP) =Total Length of all roadways flooded by more than 1 foot during 1% AEP storm event for each problem area. The total length is the cumulative sum of linear feet inundation for all classfications of roadways within the problem area.

Appendix B

Cost Analysis

Attachment #3 Interim Deliverable

Cloverleaf Drainage Improvement Recommendation (WP01)

Cloverleaf Drainage Improvement (Phase 1)	Quantity	Unit	Unit Cost	Cost	Comment
Detention Basin					
Clearing, Grubbing, and Disposal	15.8	AC	$ 6,200	$ 98,000	From HCFCD Cost Tool
Excavation (Off-Site Haul)	213,893	CY	$ 12	$ 2,567,000	From HCFCD Cost Tool
Concrete Pilot Channels	4,225	SY	$ 55	$ 233,000	From HCFCD Cost Tool
Turf Establishment (Sodding / Seeding)	13	AC	$ 3,600	$ 49,000	From HCFCD Cost Tool
Backslope Swale	3,410	FT	$ 5	$ 18,000	From HCFCD Cost Tool
Backslope Drain Structure	10	EA	$ 3,500	$ 35,000	From HCFCD Cost Tool
Backslope Interceptor Rip-rap	100	SY	$ 80	$ 8,000	From HCFCD Cost Tool
Detention Basin Construction Cost			**Subtotal**	**$ 3,006,000**	
Site Preparation					
Clearing and Grubbing (Trunk line #1)	1.4	AC	$ 6,500	$ 9,000	
Earthwork					
Excavation and Disposal Trunk Line #1	16,394	CY	$ 10	$ 164,000	The volume was based on a 15ft width, trunk line length and 10 ft depth
Storm Sewer					
9x7 RCB Trunk Line #1	2,951	LF	$ 850	$ 2,509,000	Using cost tool and Manning's equation calculation, along Hershe St and Nancy Rose St
Pavement Removal	6,558	SY	$ 3	$ 20,000	Unit cost from cost tool
Concrete Pavement Replacement	6,558	SY	$ 75	$ 492,000	Unit cost from cost tool
Subbase Replacement	7,214	SY	$ 2	$ 15,000	Unit cost from cost tool
Regrade Roadside Ditch (Gainesville St)	6780	LF	$ 10	$ 68,000	length of road multipiled by 2
Regrade Roadside Ditch (Longview St)	6760	LF	$ 10	$ 68,000	length of road multipiled by 2
Regrade Roadside Ditch (Texarkana St)	6760	LF	$ 10	$ 68,000	length of road multipiled by 2
Regrade Roadside Ditch (Eagle Pass St)	6760	LF	$ 10	$ 68,000	length of road multipiled by 2
Regrade Roadside Ditch (Victoria St)	6660	LF	$ 10	$ 67,000	length of road multipiled by 2
Regrade Roadside Ditch (Corpus Christi St)	6740	LF	$ 10	$ 68,000	length of road multipiled by 2
Regrade Roadside Ditch (Brownsville St)	6700	LF	$ 10	$ 67,000	length of road multipiled by 2
Regrade Roadside Ditch (Laredo St)	6700	LF	$ 10	$ 67,000	length of road multipiled by 2
Regrade Roadside Ditch (Hillsboro St)	4020	LF	$ 10	$ 41,000	length of road multipiled by 2
Regrade Roadside Ditch (Waxahachie St)	6700	LF	$ 10	$ 67,000	length of road multipiled by 2
Regrade Roadside Ditch (Nancy Rose St)	4000	LF	$ 10	$ 40,000	length of road multipiled by 2
Regrade Roadside Ditch (Manor St)	5920	LF	$ 10	$ 60,000	length of road multipiled by 2
Regrade Roadside Ditch (Barbara Mae St)	5880	LF	$ 10	$ 59,000	length of road multipiled by 2
Regrade Roadside Ditch (Cloverleaf St)	5900	LF	$ 10	$ 59,000	length of road multipiled by 2
Construction Costs (incuding Detention Bain)			Subtotal	**$ 7,076,000**	
			Engineering and Contingencies		
Feasability Study	1	%	5%	$ 354,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 850,000	Percentage of construction costs
Construction Management	1	%	10%	$ 708,000	Percentage of construction costs
Contingencies	1	%	30%	$ 2,123,000	Percentage of construction costs
			Subtotal	**$ 4,033,000**	
			ROW Acquistition		
Texas San Jacinto Memorial Park & Funeral Home	100%	%	$ 2,312,250	$ 2,313,000	Value as of January 1st, 2019, HCAD
Total ROW acquisition cost			**Subtotal**	**$ 5,781,000**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 16,890,000**	

Cloverleaf Drainage Improvement Recommendation (WP01)

Cloverleaf Drainage Improvement (Phase 2)	Quantity	Unit	Unit Cost	Cost	Comment
Site Preparation					
Clearing and Grubbing	3.2	AC	$ 6,500	$ 21,000	
Earthwork					
Excavation and Disposal Trunk Line 2	38,178	CY	$ 10	$ 382,000	The volume was based on a 15ft width, trunk line length and 10 ft depth
Storm Sewer					
10X7 RCB Trunk Line 2	6,872	LF	$ 715	$ 4,914,000	Using cost tool and Manning's equation calculation, along Cloverleaf St and I-10
Pavement Removal	15,271	SY	$ 3	$ 46,000	Unit cost from cost tool
Concrete Pavement Replacement	15,271	SY	$ 75	$ 1,146,000	Unit cost from cost tool
Subbase Replacement	16,798	SY	$ 2	$ 34,000	Unit cost from cost tool
Construction Costs			Subtotal	**$ 6,541,000**	
		Engineering and Contingencies			
Feasability Study	1	%	5%	$ 328,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 785,000	Percentage of construction costs
Construction Management	1	%	10%	$ 655,000	Percentage of construction costs
Contingencies	1	%	30%	$ 1,963,000	Percentage of construction costs
			Subtotal	**$ 3,729,000**	
			ROW Acquistition		
		%	$ -	$ -	
Total ROW acquisition cost			**Subtotal**	**$ -**	
			Total Estimated Cost	**$ 10,269,000**	

WP02-N100-00-00 Channel Improvements

Channel Improvements N100	Quantity	Unit	Unit Cost	Cost	Comment
Clearing Grubbing, and Disposal	50	AC	$ 6,200.00	$ 310,000.00	ROW width=264 ft, length of channel= 8165 ft
Utility Adjustments (pipeline)	819	LF	$ 320.00	$ 262,080.00	Colonial Pipeline closest to Missouri Pacific Railroad
Excavation (Off-Site Haul)	239,988.00	CY	$ 12.00	$ 2,879,856.00	Proposed conditions model used for quantity
Rock Rip-Rap	76210	SY	$ 80.00	$ 304,840.00	Portion of Channel Depth to Rip-Rap = 30% (5% of channel length is assumed to be Rip-Rap)
Backslope Swale	16330	LF	$ 5.00	$ 81,650.00	assumed to be along the length of the channel improvements
Backslope Drain Structure	164	EA	$ 3,500.00	$ 574,000.00	backslope structure spacing at every 100 ft
Construction Costs			**Subtotal**	**$ 4,412,426.00**	
			Engineering and Contingencies		
Feasability Study	1	%	5%	$ 220,621.30	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 529,491.12	Percentage of construction costs
Construction Management	1	%	10%	$ 441,242.60	Percentage of construction costs
Contingencies	1	%	30%	$ 1,323,727.80	Percentage of construction costs
			Subtotal	**$ 2,515,082.82**	
			ROW Acquistition		
1 parcel	13%	%	$ 3,315,544.00	$ 417,500.25	Church
1 parcel	10%	%	$ 2,218,843.00	$ 219,665.06	Hutchison and Hays Services Inc.
24 parcels	100%	%	$ 3,483,793.00	$ 3,483,793.00	Full Buyout (channel shift west)
Total ROW acquisition cost			**Subtotal**	**$ 10,302,395.79**	Subtotal*2.5 (multiplier) Assumed non-voluntary buyouts
			Total Estimated Cost	**$ 17,229,904.61**	

WP03-N104-00-00 Channel Improvements

Channel Improvements N104	Quantity	Unit	Unit Cost	Cost	Comment
Clearing Grubbing, and Disposal	18	AC	$ 6,200.00	$ 111,600.00	ROW width=192 ft, length of channel= 4000 ft
Utility Adjustments (pipeline)	270	LF	$ 320.00	$ 86,400.00	Equistar Chemicals, LP closest to Missouri Pacific Railroad
Excavation (Off-Site Haul)	71,043.00	CY	$ 12.00	$ 852,516.00	Proposed conditions model used for quantity
Rock Rip-Rap	19560	SY	$ 80.00	$ 78,240.00	Portion of Channel Depth to Rip-Rap = 30% (5% of channel length is assumed to be Rip-Rap)
Backslope Swale	8000	LF	$ 5.00	$ 40,000.00	assumed to be along the length of the channel improvements
Backslope Drain Structure	80	EA	$ 3,500.00	$ 280,000.00	backslope structure spacing at every 100 ft
Construction Costs			**Subtotal**	**$ 1,448,756.00**	
			Engineering and Contingencies		
Feasability Study	1	%	5%	$ 72,437.80	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 173,850.72	Percentage of construction costs
Construction Management	1	%	10%	$ 144,875.60	Percentage of construction costs
Contingencies	1	%	30%	$ 434,626.80	Percentage of construction costs
			Subtotal	**$ 825,790.92**	
			ROW Acquistition		
20 parcels	100%	%	$ 2,439,551.00	$ 2,439,551.00	Full buyout, market value
Total ROW acquisition cost			**Subtotal**	**$ 6,098,877.50**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 8,373,424.42**	

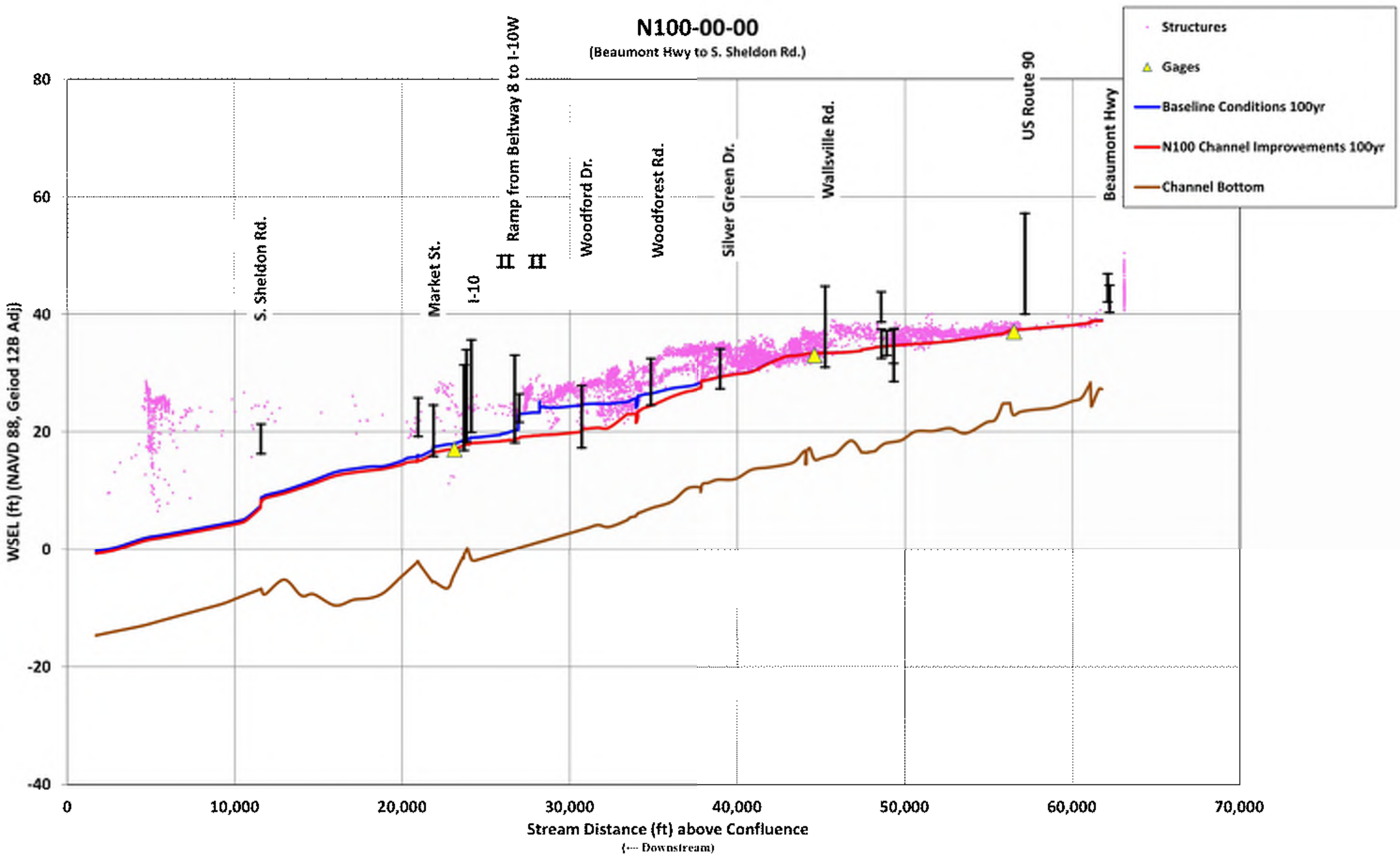
WP04- P103 Diversion

P103 Diversion	Quantity	Unit	Unit Cost	Cost	Comment
Clearing Grubbing, and Disposal	13	AC	$ 6,200.00	$ 80,600.00	ROW width=190 ft, length of channel= 2800 ft
Utility Adjustments (pipeline)	0	LF	$ 320.00	-	
Excavation (Off-Site Haul)	30,080.00	CY	$ 12.00	$ 360,960.00	Cost estimate tool used
Rock Rip-Rap	23030	SY	$ 80.00	$ 92,120.00	Portion of Channel Depth to Rip-Rap = 30% (5% of channel length is assumed to be Rip-Rap)
Backslope Swale	5600	LF	$ 5.00	$ 28,000.00	assumed to be along the length of the channel improvements
Backslope Drain Structure	56	EA	$ 3,500.00	$ 196,000.00	backslope structure spacing at every 100 ft
Construction Costs			**Subtotal**	**$ 757,680.00**	
			Engineering and Contingencies		
Feasability Study	1	%	5%	$ 37,884.00	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 90,921.60	Percentage of construction costs
Construction Management	1	%	10%	$ 75,768.00	Percentage of construction costs
Contingencies	1	%	30%	$ 227,304.00	Percentage of construction costs
			Subtotal	**$ 431,877.60**	
			ROW Acquistition		
Total ROW acquisition cost			**Subtotal**	**$ -**	No ROW acquisition costs included
			Total Estimated Cost (ROW cost not included)	**$ 1,189,557.60**	

Appendix C

Water Surface Profiles for Channel Improvements

Attachment #3 Interim Deliverable



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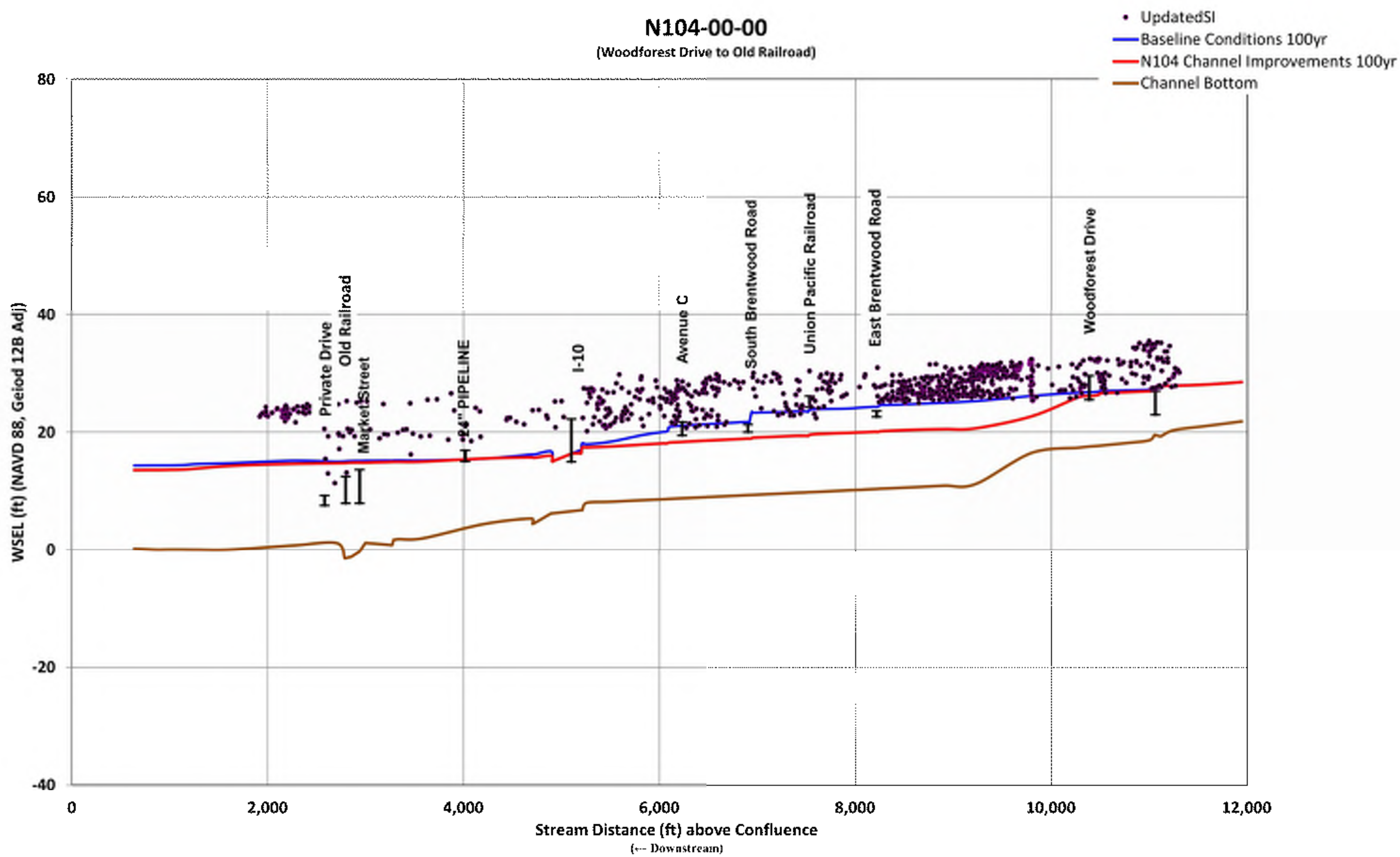


Appendix D

Project Prioritization Sheets

Harris County Flood Control District Project Scoring Form

Scenario #1 (100-Year Event) SUMMARY

SCORING CRITERIA:			1	2	3	4	5	6	7	8		
		Weight:	25%	20%	20%	10%	10%	5%	5%	5%		
Problem Area:	Project ID:	Tier:	Flood Risk (100-Year Event) Reduction	Existing Conditions Drainage LOS	Social Vulnerability Index (SVI)	Project Efficiency	Partnership Funding	Long Term Maintenance Costs	Minimize Environmental Impacts	Potential for Multiple Benefits	TOTAL SCORE	Channel / Trib
PA-05	N104-WP03	2	2.00	1.20	1.73	0.40	0.20	0.30	0.30	0.20	6.33	N104
Regional	N100-WP02	1	2.50	0.80	1.38	0.20	0.00	0.50	0.30	0.20	5.88	N100
PA-04	N100-WP01-Phase 1 & 2	2	2.50	2.00	2.00	0.40	0.20	0.30	0.30	0.50	8.20	N100
PA-02	N110-WP04	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	N110
PA-04	N100-WP01-Phase 1	2	2.00	2.00	2.00	0.40	0.20	0.30	0.30	0.50	7.70	N100

Attachment #4

Technical Memorandum #4 (Preliminary 100-year Level-of-Service “Vision Plan”)

INTERIM REVIEW ONLY
This document was submitted for interim review only and is not intended for construction, bidding, permit, or final submittal purposes.

Engineer: Jacob M. Torres
PE Registration Number: 111737
Firm: Torres & Associates, LLC
Firm ID: 20741

Carpenters Bayou Watershed Plan

Technical Memorandum #4:

Carpenters Bayou 100-Year Level-of-Service ("Vision Plan")

March 3, 2021

Prepared by:

Torres & Associates, LLC

Table of Contents

Acknowledgements

This planning project represents a key milestone towards the greater management and success of the Harris County 2018 Bond Projects for Flood Mitigation and is the product of interdisciplinary coordination between HCFCD, engineering consultants, key stakeholders, and the general public. Torres & Associates ("Torres") is particularly grateful to HCFCD staff for their invested time, effort, and commitment towards providing Torres with necessary data, background, interim deliverable reviews, logistical guidance, and general insights on day-to-day, watershed-wide operations ranging from permitting reviews to ROW acquisition. This coordination was instrumental for evaluating effective and feasible flood risk management solutions with Carpenters Bayou watershed, as well as the successful management of the broader Harris County 2018 Bond Projects for Flood Mitigation.

List of Figures

List of Tables

1. Introduction

1.1. Pupose and Scope

The purpose of this report is to describe the efforts conducted to provide a 100-year LOS (i.e., the Vison Plan) for the mainstem N100-00-00 of Carpenters Bayou watershed. This entailed:

- Combing all HEC-RAS 1D/2D models developed in the proposed conditions modeling phase of the Watershed Planning Project (WPP) and making one combined master model.
- Analyzing and developing a watershed wide plan that uses the recommended projects from Technical Memorandum #3 (TM#3) and adds further projects as needed.
- Developing a strategy that will provide a 100-year LOS for the mainstem N100-00-00.
- Developing cost estimates for the proposed recommendations.

Please refer to Technical Memorandum #2 (TM#2) for the detailed strategies considered for improvements at the Problem Area (PA) level as well as at the regional level. TM#3 entails refined strategies that more efficiently balance flood risk mitigation measures defined in TM#2 in a more holistic manner to address constructability and environmental concerns. In Technical Memorandum #4 (TM#4), identified projects were hydrologically and hydraulically evaluated with the aid of 1D/2D modeling by combining previous projects and additional projects that reduce flood risk for the entire Carpenters Bayou watershed significantly.

1.2. Study Area

The Carpenters Bayou (HCFCD Project No: N100-00-00) watershed is in the east portion of Harris County, Texas (**Exhibit 1**), with an area of approximately 25 square miles. The land use north of US 90 consists primarily of agricultural land with a few commercial lots and a residential neighborhood. This area also includes the Sheldon Lake State Park and Environmental Learning Center. Downstream of Lake Sheldon the land use consists of mixed commercial and residential land cover. Carpenters Bayou watershed has been impacted by many historical flood events. Additionally, tidal influence controls the lower Carpenters Bayou channel which makes that area susceptible to inundation from hurricane storm surges.

2. Baseline Conditions

Carpenters Bayou watershed has been impacted by 32 of the previous 46 historical flood events since 1979. More recently, the watershed has experienced neighborhood-wide flooding from Tropical Storm Imelda (2019), Hurricane Harvey (2017), and the October Halloween Event (2015) (**Figure 1**). Flooding of the structures in this watershed resulted from various reasons such as overland sheet flow, overbank flooding, insufficient drainage capacity, or deteriorating drainage infrastructure. Model results for baseline ("existing") conditions (coupled 1D/2D analysis and sheet flow analysis with Atlas 14 rainfall update) revealed that flooded structures are caused largely from sheet flow driven conditions and out-of-bank flooding, with flood risks compounded by insufficient drainage capacity and aging infrastructure. Comparison of modeled results, flood claim history, and reconnaissance level assessments confirm these observations (**Figure 1, Exhibit 2**). Please refer to TM#1 for details of the modeled results.

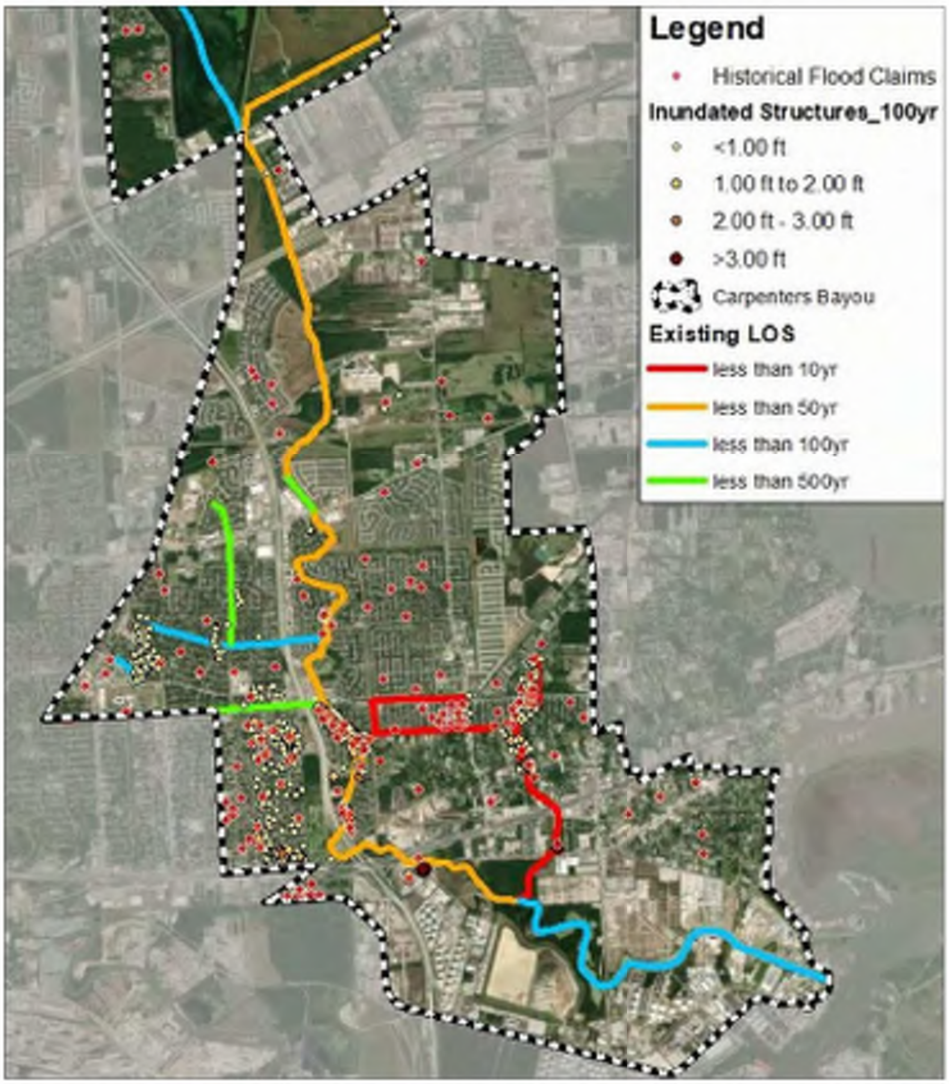


Figure 1. Computed flooded structures (100-year) vs. Historical Flood Claims (FSI.gdb)

The approach to reduce flood risk in the entire watershed was to target areas which experience most severe flooding issues in the form of inundated structures, and to combine the different improvements determined at the planning level to evaluate the associated benefit. The following sections describe the model development process and the recommended projects. Refer to Section 5 of this report for the damage reductions achieved through the Vision Plan.

3. Vision Plan ("100-Year LOS") Model Development

Both 1D and 2D hydraulic models were developed using HEC-RAS 5.0.7 (USACE 2016). The model development methodologies and project recommendations are described in the following sections.

3.1. Model Development

The Vision Plan was built on the calibrated and validated baseline conditions model for Carpenters Bayou watershed. The model consists of eight tributaries (HCFCD Unit no. N104-00-00, N117-00-00, N109-00-00, N109-01-00, N110-00-00, N110-02-00, N111-00-00 and N111-01-00) and the mainstem (HCFCD Unit no. N100-00-00).

The NOAA Atlas 14 rainfall updates for the 100-year frequency storm was used as an input to HMS. 2018 LiDAR was used to create a high-resolution DEM and 2016 NLCD data was used for land use and land cover.

The baseline conditions flow file for the 100-year storm event provided the starting for the Vision Plan. The Vision Plan unsteady flow file has 36 boundary conditions which entail 22 uniform flow hydrographs, 11 flow hydrographs, 1 lateral inflow and 2 normal depth boundary conditions.

In the proposed conditions modeling phase of this watershed planning project, three recommendations were modeled as stand-alone improvements including: Cloverleaf Flood Risk Reduction Project phase 1, N100-00-00 channel improvements, and N104-00-00 channel improvements. These improvements showed benefits in different areas within Carpenters Bayou. For the Vision Plan, it was important to combine these modeled improvements in a single master model to determine overall combined benefit and impact for the 100-year storm event (**Figure 2**). Additionally, Cloverleaf Flood Risk Reduction phase 2, N109-01 tributary improvements and extended N104-00-00 channel improvements were also added to the Vision Plan model. This model was built on the calibrated and validated model developed for this planning project.

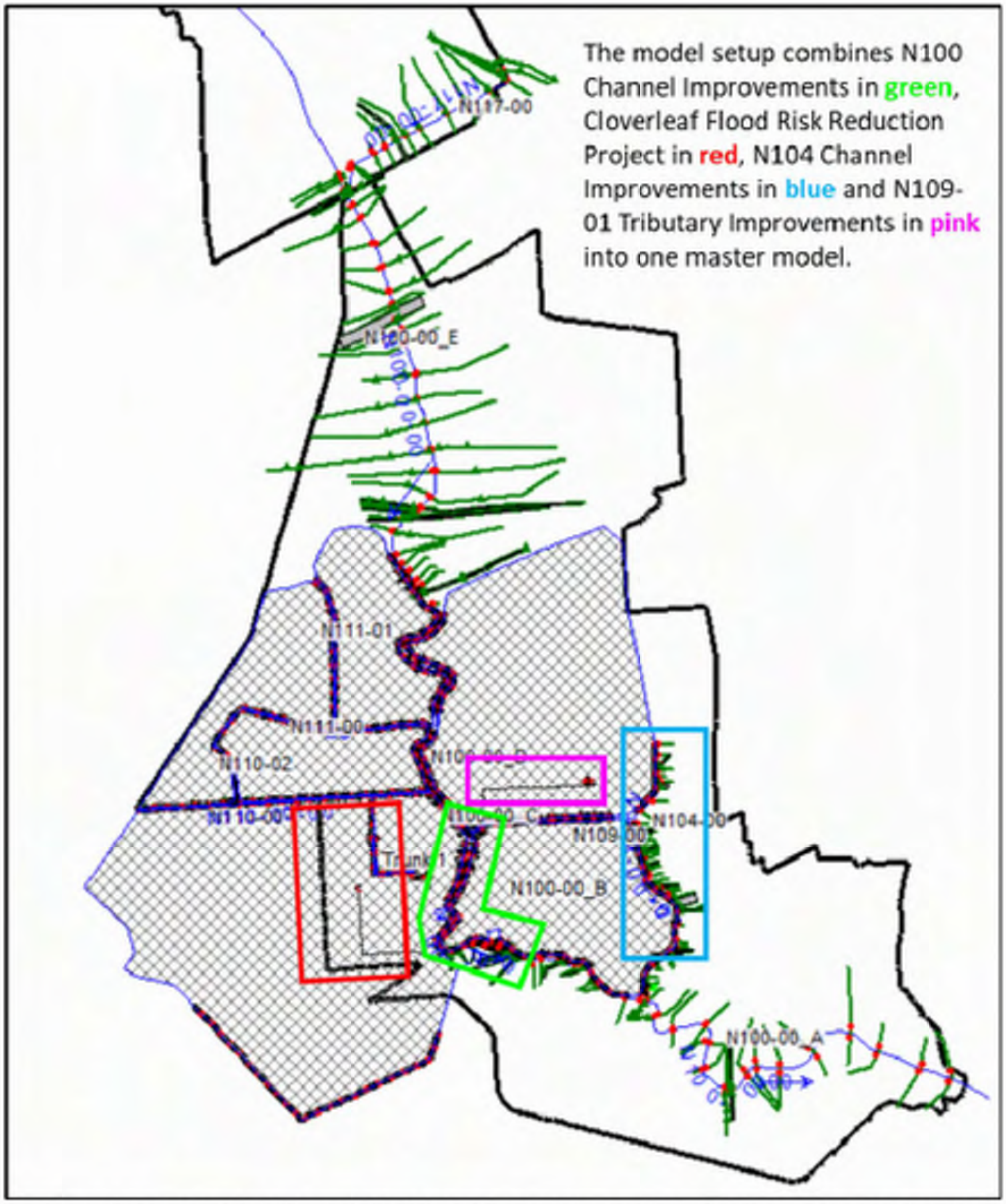


Figure 2. Proposed Conditions HEC-RAS 1D/2D coupled watershed-wide Vision Plan model setup

3.2. Recommended Projects

The Vision Plan consists of five recommendations (**Figure 3**), the Cloverleaf Flood Risk Reduction Project and N100 Channel Improvements have been described in detail in the Preliminary Project Plan and N104 Channel Improvements have been discussed in detail in TM#3, N110 Drainage Improvements and N109-01 Tributary Improvements have been discussed in Sections 3.2.4 and 3.2.5 of this report. All five recommendations have been included in a single watershed wide 1D/2D coupled HEC-RAS model. These recommendations combined provide significant reductions in flood risk. The following sections outline these alternatives in more detail.

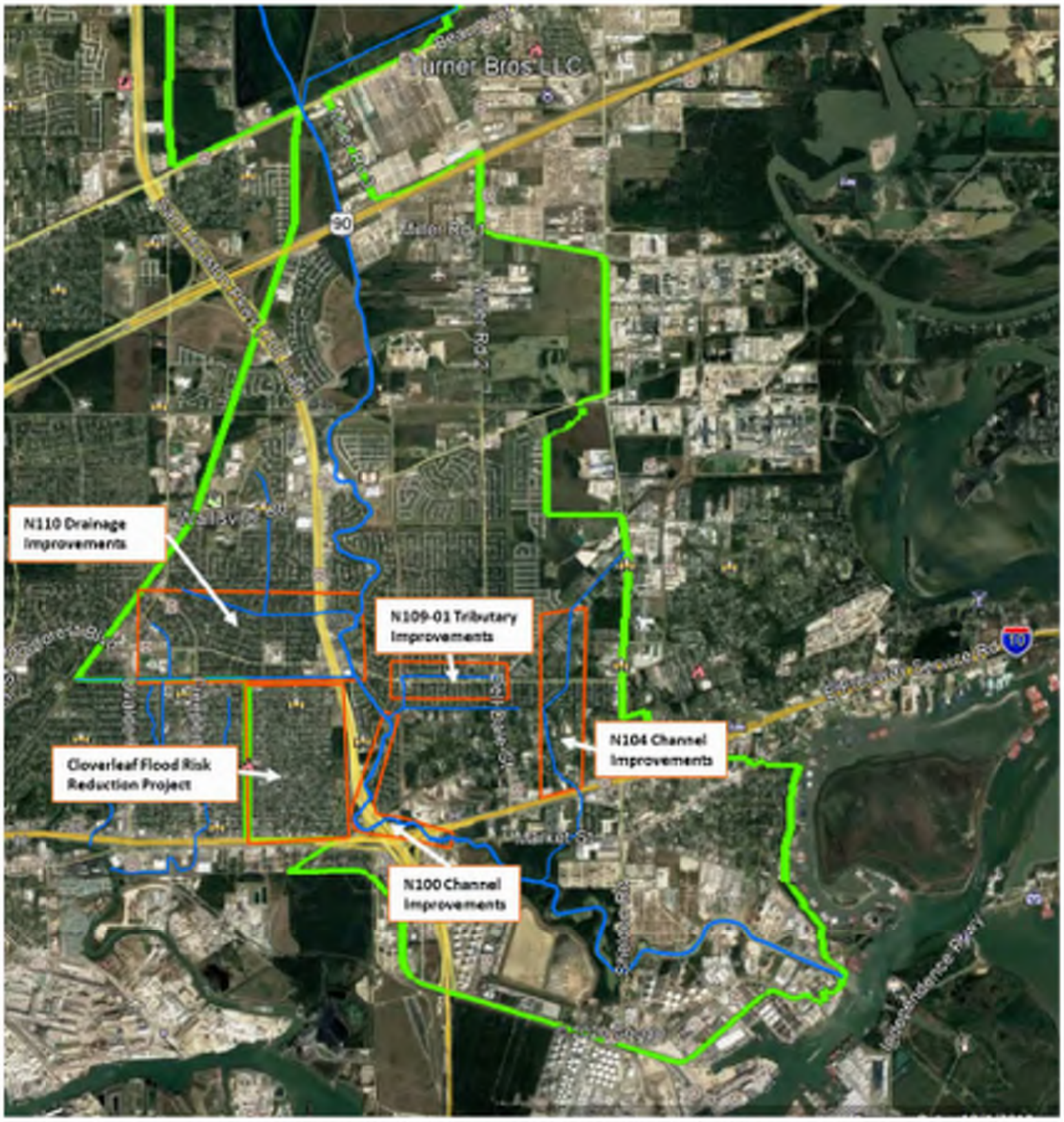


Figure 3. Recommendations for the Vision Plan

3.2.1. *Cloverleaf Flood Risk Reduction*

The proposed preliminary project consists of a combination of: (1) a dual trunk line system (trunk line #1 and trunk line #2) and (2) a 109 acre-feet stormwater detention facility north of the San Jacinto Funeral Home and Memorial Park, for an approximate combined 50-yr Level-of-Service (LOS) (**Figure 4**). This project will provide much needed drainage relief for this portion of Cloverleaf with the use of stormwater trunk lines serving as centralized drainage "arteries" and for allowing lateral tie-ins from roadside ditch connections (**purple** and **blue** dash lines in **Figure 4**). The trunklines are proposed to outfall into a proposed detention or to tie into existing drainage systems along Interstate Highway 10 (IH-10) frontage roads and eventually outfalling into HCFCD Unit No.: N100-00-00 or P102-00-00 or P104-00-00. Phase 1 trunk line is proposed to outfall into the proposed detention. For phase 2 trunk line, various options for outfall tie-ins are available depending on budget constraints and partnership potential. For example, phase 2 trunk line tie-in options can include outfall into P104-00-00 directly south of IH-10, P102-00-00 westward on IH-10 frontage, the existing Freeport Road drainage system west of Hollywood Street, or the existing southern outfall passing through the cemetery. All these tie-in options require a more detailed drainage analysis for determining available system capacity through further feasibility analyses. Phase 2 has been modeled in the 100-year LOS plan assuming the box culvert outfalls into the existing southern outfall. The project provides a flexible means for *phasing* trunk lines based on need and funding resources; as well as growing in drainage capacity with the community. Please refer to the Preliminary Project Plan for details of this recommendation.

Figure 4. Cloverleaf Flood Risk Reduction Project description

3.2.2. *N100-00-00 Channel Improvements*

The preliminary project for this area consists of a proposed combination of (1) a segment of N100-00-00 channel improvements designed for an expanded natural stable channel with grass-lined cross-section using an average channel longitudinal slope of 0.05%, (2) channel improvements at the bridge crossings using concrete lined cross-sections with 60 feet bottom width and 1:1 side slope with an average channel longitudinal slope of 0.05%, (3) a short segment of N109-00-00 channel improvements with a 20 feet maximum bottom width and concrete-lined cross-sections at 2:1 side slopes with an average channel longitudinal slope of 0.2%, and (4) 182 acre-feet stormwater detention to mitigate impacts downstream resulting from the channel improvements.

It was determined that channelizing the segment of N100-00-00 starting downstream with tailwater limits just south of IH-10 and moving upstream to the confluence with N109-00-00 yielded the highest hydraulic benefits (**green** line in **Figure 5**). The length of channel improvements is approximately 9,900 feet. A short segment of N109-00-00 is recommended for channelization starting just downstream of the Colonial pipeline and improving downstream down to the confluence of N100-00-00 (**yellow** line in **Figure 4**). The length of channel improvements on N109-00-00 is approximately 500 feet. Please refer to the Preliminary Project Plan for details of this recommendation.

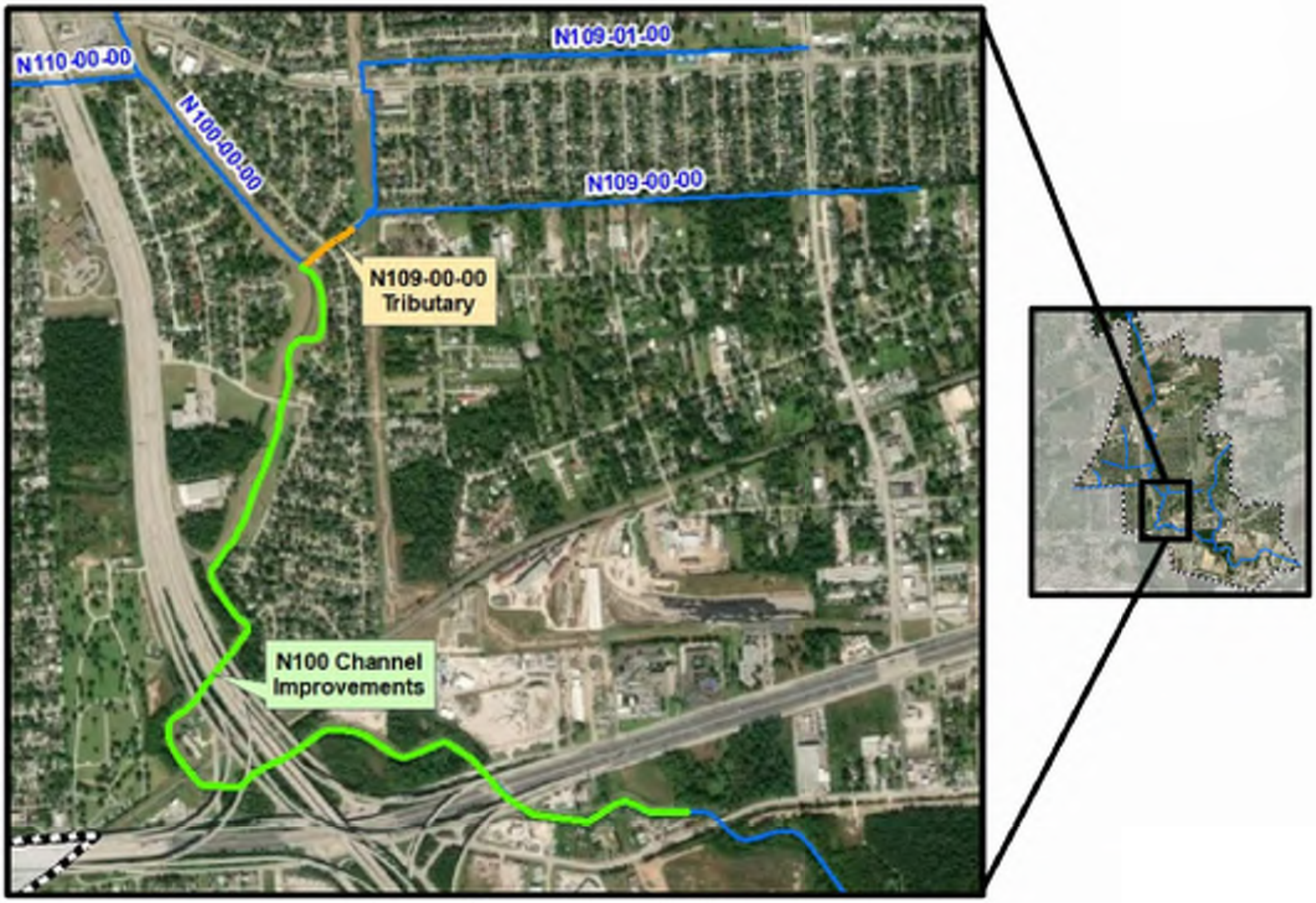


Figure 5. Segment of N100-00-00 channel improvements

3.2.3. *N104-00-00 Channel Improvements*

The baseline conditions model revealed that N104-00-00 experiences out-of-bank flooding. A suite of alternatives for channel improvements were modeled and analyzed to identify the alternative with low costs, high community uplift and high feasibility. The preliminary project for this area consists of a segment of N104-00-00 channel improvements with a 20 feet bottom width and 4:1 side slope (**green** line in **Figure 6**) with an average longitudinal slope of 0.08%. In the proposed conditions modeling phase of the WPP, the channel improvements are proposed to begin just downstream of the Shadowglen neighborhood; however, the area upstream of these improvements is still experiencing out-of-bank flooding (Refer to TM#3). For the Vision Plan, N104-00-00 channel improvements are proposed to extend to the most upstream cross-section of the tributary (**orange** line in **Figure 6**) and the dual culvert system at Elgin Road is proposed to be removed and replaced by a bridge to provide a 100-Year LOS. This modification will reduce the flood risk significantly and WSEL reductions will occur starting at Elgin Road and extending all the way to the Ship Channel. N104-00-00 channel improvements are extended in this plan to provide more comprehensive improvements.

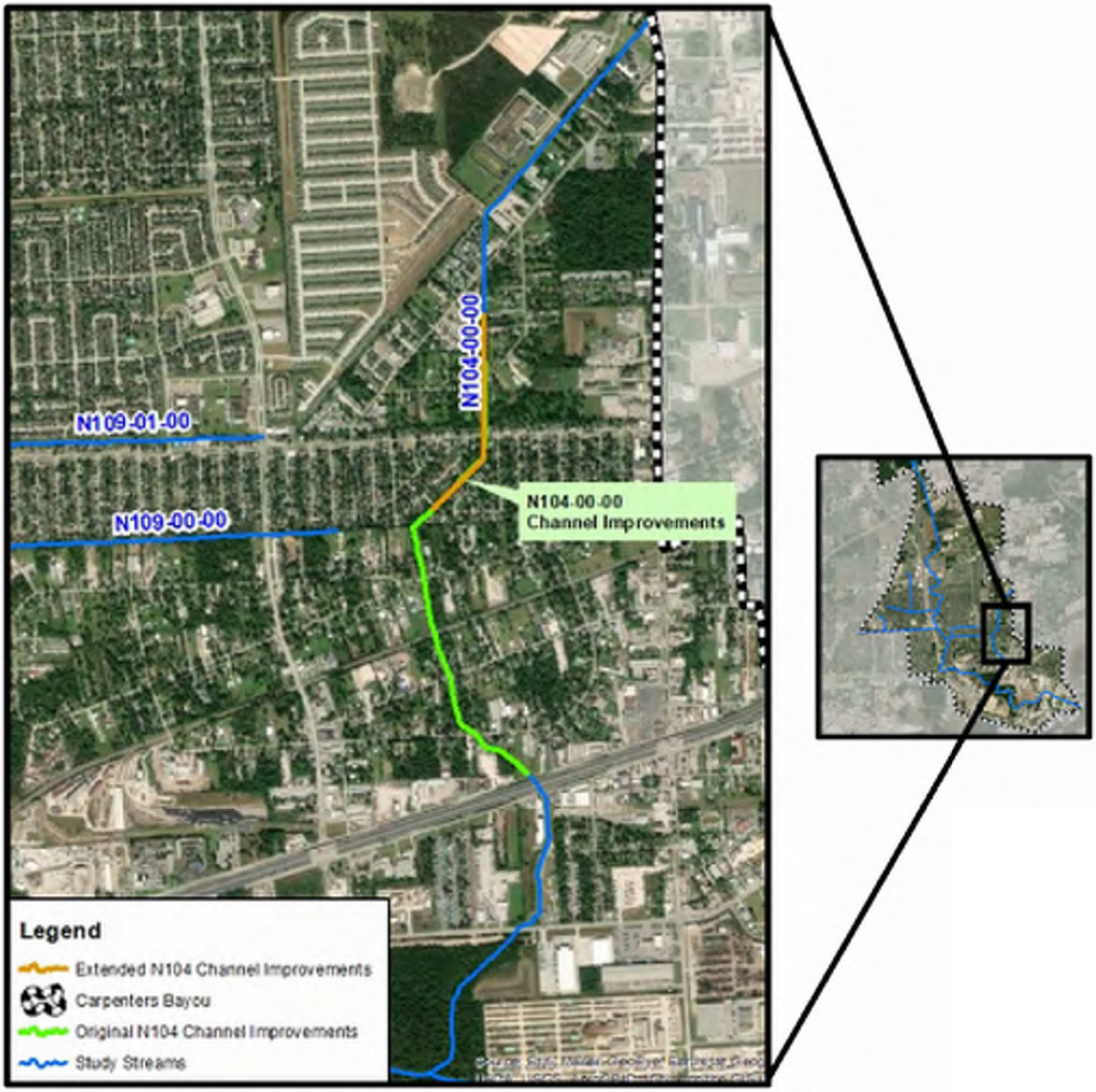


Figure 6. Segment of Channel Improvements at N104-00-00.

3.2.4. *N109-01-00 Tributary Improvements*

Tributary N109-01-00 was modeled as an enclosed 3-foot diameter pipe in the baseline conditions model. The tributary was identified as not having sufficient capacity for the runoff that is expected to drain from the surrounding neighborhood. The enclosed 3-foot diameter pipe is proposed to be replaced with a 12-ft X 6-ft box culvert which helps reduce flood risk in the Sterling Forest neighborhood (yellow line in **Figure 7**).

Figure 7. N109-01-00 tributary improvements

3.2.5. *Directing flow to N110-00-00*

The baseline conditions 1D/2D model revealed that the N110-00-00 segment downstream of the N110-02-00 confluence does not convey flow to its full capacity (**red** line in **Figure 8**). Modeling results, as corroborated by flood claim data and site visits, reveal that flooding in this neighborhood is sheet flow driven. Drainage improvements such as optimal placement of inlets and upsizing pipe sizes can help direct runoff more efficiently to N110-00-00 and prevent ponding and reduce sheet flow flooding in the neighborhood. By making appropriate improvements and directing flow from the surrounding neighborhood to this segment of N110-00-00, the increase in peak flows within N110-00-00 was estimated for the 100-year storm event, and it was determined that N110-00-00 has enough capacity to safely convey the additional flow to N100-00-00. Costs for neighborhood wide drainage improvements (e.g., storm sewer) has been estimated at conservatively, with the assumption that an outfall tie-in can occur into the downstream portion of N110-00-00. Exact locations of where proposed detention could be placed to mitigate the increased flows are currently unknown, thus accurate ROW acquisition costs for detention are pending. Costs assume all the streets located north of N110-00-00 and south of N111-00-00 may require some storm sewer drainage improvements and in the interest of conservatism, use a value of $1200 per linear foot based on the cost of an average RCP class III pipe ranging from 18" to 42". Please refer to **Appendix A** for an extended cost table. An advanced feasibility study is necessary to realize the overall benefits and accurate costs associated with this project.

Furthermore, a diversion from N110-00-00 to the P103-00-00 and P103-03-00 tributary located in lower Greens Bayou, south of N110-00-00 was explored in Technical Memorandum #3. Channel improvements are proposed in the upper reaches of P103-03-00 to facilitate overflow from Carpenters Bayou into Greens Bayou. This project is expected to provide further benefit and is currently being studied by the Greens Bayou study team and has not been included in the cost estimates. Further analysis is required to determine the engineering details and damage reduction associated with the P103 channel improvements and the N110 and N111 storm sewer improvements collectively.

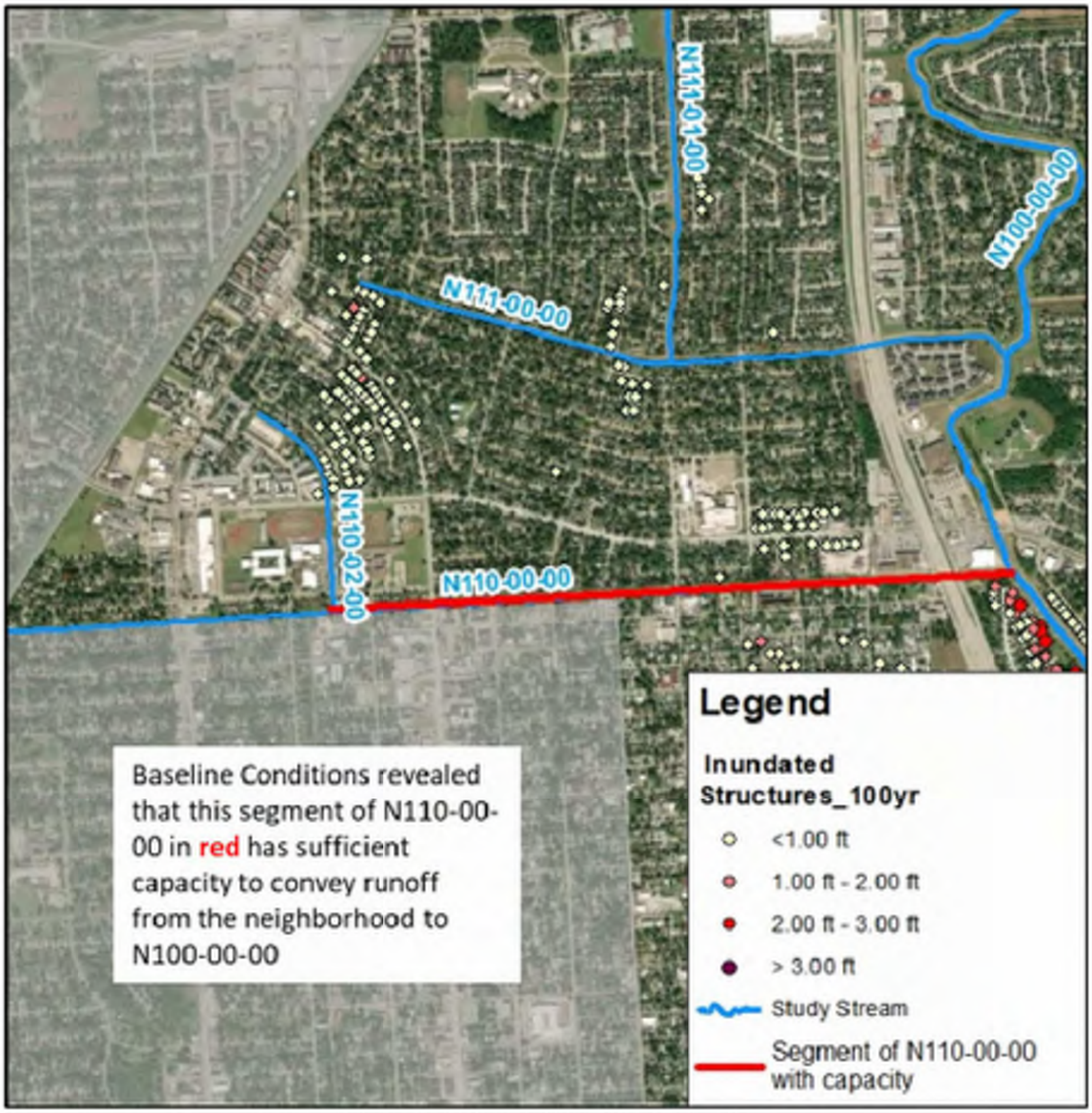


Figure 8: Tributary N110-00-00 capacity

3.2.6. *Potential Buyouts*

After considering all the identified improvements described in the previous sections, under 100-year proposed conditions the flooded structure count reduces from 549 to 75. These remaining flooded structures are generally scattered throughout and are mainly predicted to be caused by sheet flow driven conditions. It is recommended for the Vision Plan that these remaining flooded structures be considered for future buyouts. **Figure 9** shows the structures so designated. It is possible that for some small, isolated neighborhoods there may be an opportunity to reduce the existing flooding risks more cost effectively than by resorting to property buy-outs; however, in order to be conservative, the Vision Plan assumes buy-outs will be required for these 50-75 homes. The area around tributaries N111-00-00 and N111-01-00 was not studied in detail, some combination of channel/storm sewer improvements may be possible to achieve a more economical solution than a straight buyout solution for this area. However, a buyout is a conservative choice for this level of study.

Figure 9. Residual Flooded Structures considered for buyouts under proposed conditions (100-year)

4. Proposed ROW Acquisition

ROW acquisition for the Vision Plan consists of acquiring parcels for mitigation of channel improvements. Partial acquisition of parcels has been considered where possible. **Figure 10** and **Exhibit 3** display the ROW requirements for the projects within the Vision Plan which have received planning level analysis, and for which specified parcels have been identified as candidates for acquisition. For the other projects, a more approximate ROW acquisition cost estimate has been developed based on typical land and home buyout costs for the required improvements. The figures below describe the ROW acquisition for proposed full and partial buyouts. It is important to note that actual acreage both full and of partial buyouts is subject to more detailed study for feasibility analysis. This study assumes a representative partial acquisition needed to achieve proposed channel cross-section improvements with partial acquisitions reflected in cost estimates.

(a)

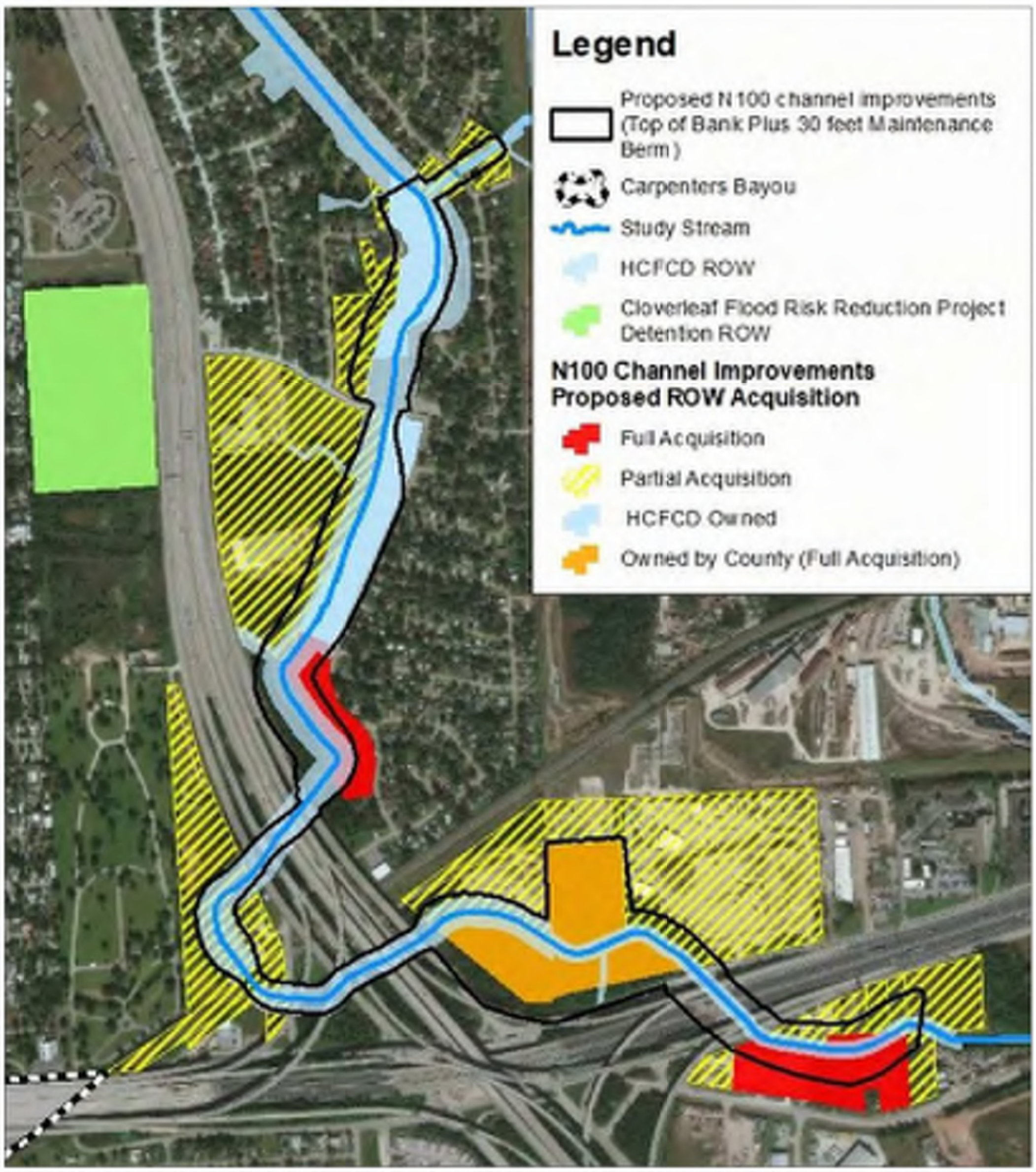


Figure 10. ROW acquisition for (a) N100-00-00 channel improvements and Cloverleaf Flood Risk Reduction Project

(b)

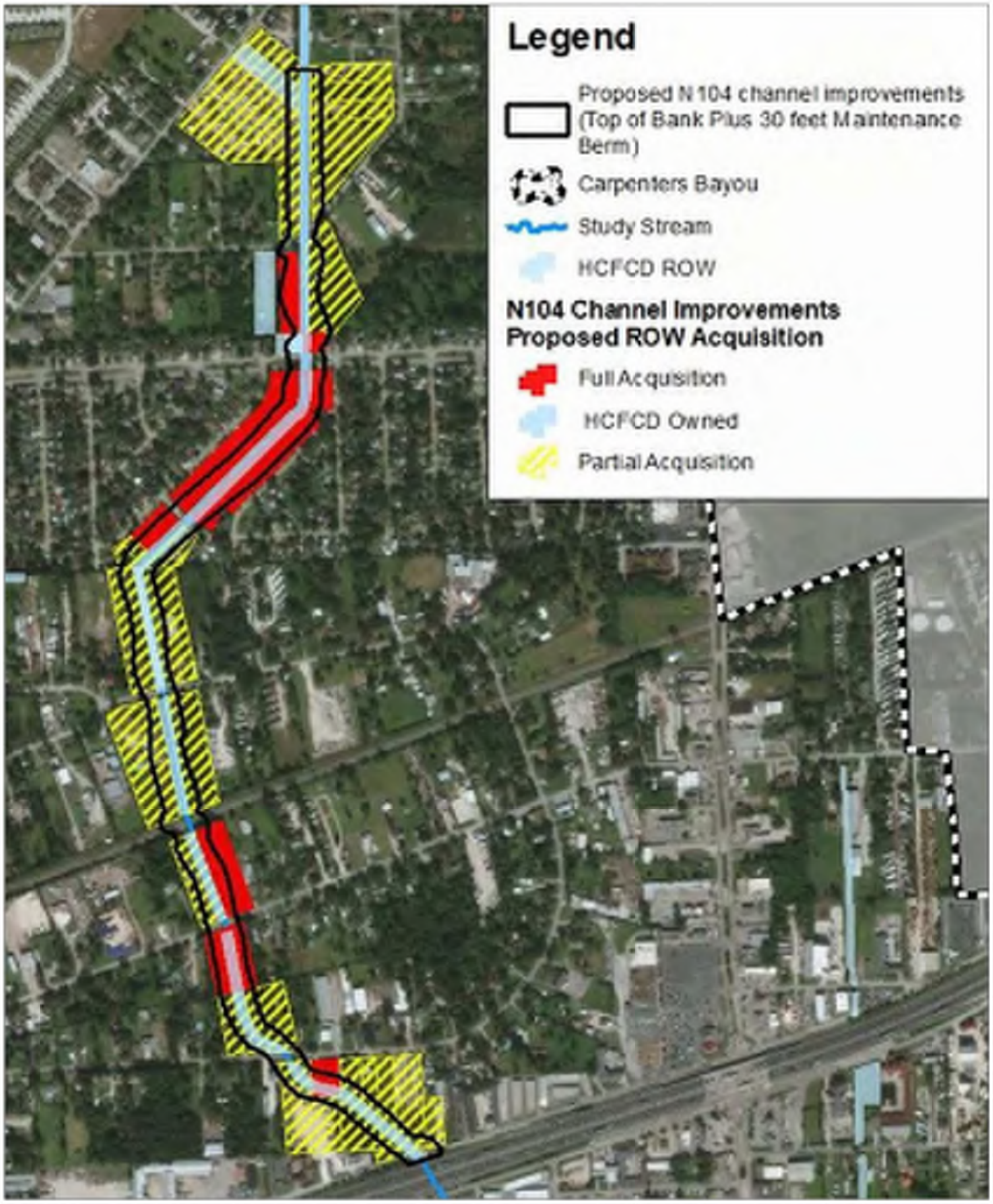


Figure 10. ROW acquisition for (b) N104-00-00 channel improvements

5. Damage Reductions

The Vision Plan has the potential for substantial flood damage reductions for the watershed. For the 100-year event, the number of flooded structures, acres of inundation, and miles of inundated roadway that will be removed are shown in Table 1 and Exhibit 4. (**Table 1, Exhibit 4**).

Table 1. Flood Metrics under Existing and Proposed Conditions

Metrics	Existing Conditions	Proposed Conditions
Flooded Structures (count)	549	75
Miles of Inundated Roadway (above road)	85	51
Acres of Land Flooded (acres)	3028	2117

The proposed improvements show large benefits along the main stem (N100-00-00), at tributary N104-00-00, and in the southern Cloverleaf community. Overall, approximately 911 acres of watershed area would potentially no longer be inundated during the 100-year storm event under proposed conditions when compared to the baseline existing conditions floodplain (30% reduction, **Figure 11, Exhibit 5**).

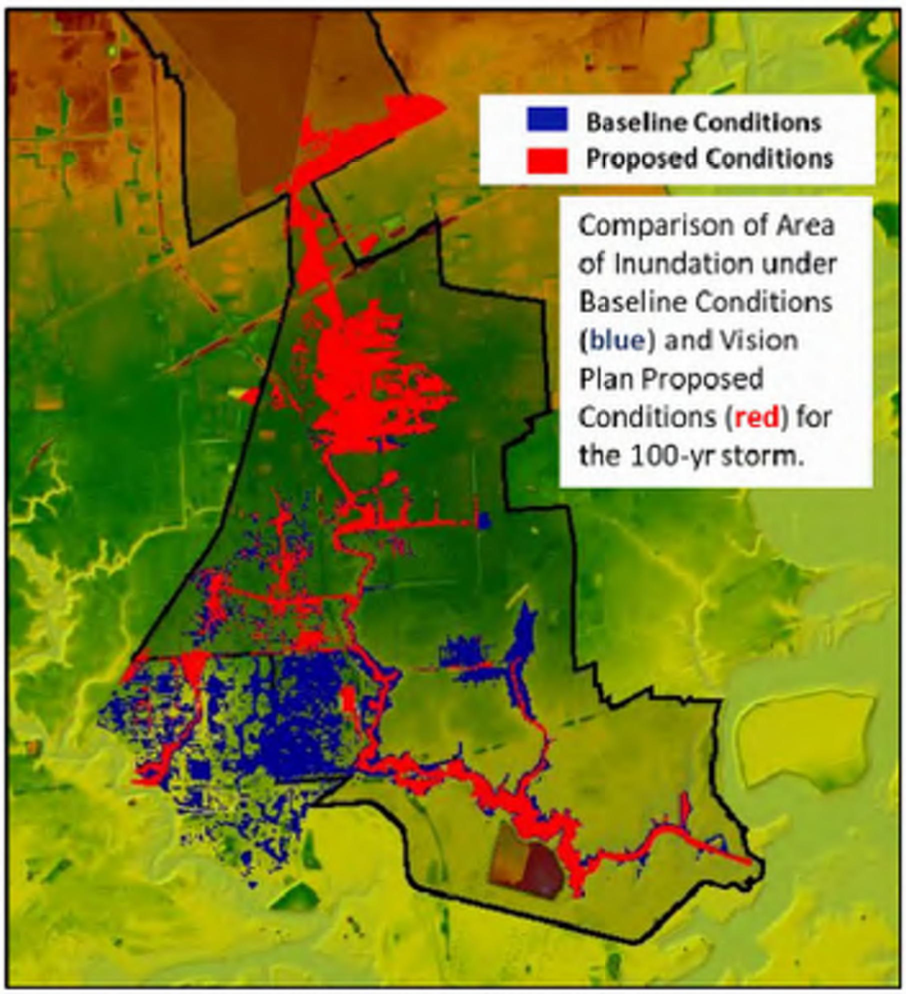


Figure 11. Comparison of Area of Inundation

6. Estimated Project Costs

The summary of estimated cost for each identified project is provided in **Table 2** which creates a total of $222M for the Vision Plan. Please refer to **Appendix A** for slightly more extended cost tables. Construction cost were estimated using the unit costs provided by HCFCD and as currently being used on other watershed planning projects. The excavation costs for the channel improvements were determined using the cut and fill volumes from the HEC-RAS model. A multiplier of 2.5 times 2020 HCAD estimated property values was used for property acquisition estimates.

Table 2. Estimated cost for Vision Plan.

Vision Plan	Cost (x $1,000,000)
Phase 1- Cloverleaf Flood Risk Reduction Project	$17.57
Phase 2- Cloverleaf Flood Risk Reduction Project	$12.80
N100-00-00 Channel Improvements	$30.98
N104-00-00 Channel Improvements	$20.10
N109-01-00 Tributary Improvements	$12.38
Drainage Improvements around Tributary N110-00-00	$104.3
Residual Flooded Structures Buyouts Consideration	$23.60
Use of Lake Sheldon as a Storage Facility	-
Total Estimated Cost	**$222**

These cost estimates are based on a planning-level assessment and require further detailed analyses at the PER level.

7. Uncertainties

For this high-level planning analysis, many broad assumptions were required to create the Vison Plan. The assumptions which create the most uncertainty is related to bridge crossings, environmental conflicts, ROW acquisition, and future development.

7.1. Bridge Crossings.

N100 Channel Improvements. There are eleven bridge crossings that intersect this segment of channel improvements as outlined and summarized in **Table 3**. As with any channel widening project, most of these crossings will require significant negotiations with the bridge owners and significant time to implement. One of these crossings is the Missouri Pacific Railroad. The railroad crossing is proposed to be widened by approximately 60 feet with 1:1 side slope. The sloping abutments at the crossing have not been proposed for modification. Since the railroad is a major crossing, a detailed survey and detailed structural analysis will need to be conducted to determine whether the widening of the channel under the railroad will pose any increased risk or additional costs to achieve. Also, significant time would likely be required to reach agreement with the railroad company for this improvement. All bridge crossings except IH-10 have been modeled with 60 ft bottom width and 1:1 side slope and assume concrete lining 100 feet upstream and downstream of each bridge with most bridge abutments left unchanged. This causes the channel to narrow down at the bridge flattening out to the proposed channel natural stable side slope when the concrete lining ends.

Woodford Drive (**RS 30712.0**) and the ramp crossing from Beltway 8 to IH-10 (**RS 26717.0**) bridge abutments likely will require modification; therefore, coordination with the Texas Department of Transportation (TxDOT) will be required to determine whether the existing bridge abutments can be replaced or removed. It is important to note that enhancements to the existing energy baffles at the steep drop upstream of the confluence of N109-00-00 and N100-00-00 are also recommended for modification as an inline structure. Finally, the dual culvert system at Overbluff Street upstream of the confluence will likely need adjustments to the placement of the dual culvert boxes. The channel is proposed to be deepened by approximately 4 feet in this segment.

The cost estimates include a significant component for modifications at all eleven bridges but there are uncertainties that will require more detailed analyses and designs involving the bridge owners to properly resolve. The channel design can be adjusted to accommodate any reasonable constraints at the bridge crossings.

Table 3. Bridge modifications along N100-00-00 channel improvements

Reach	Station	Bridge Intersections	Sloping Abutments
N100-00-00_B	30712.0	Woodford Drive	Modified
N100-00-00_B	28244.0	Frontage Rd East-Fly over piers	N/A
N100-00-00_B	27792.0	Frontage West-Fly Over piers	N/A
N100-00-00_B	26974.0	Missouri Pacific Railroad	Not modified
N100-00-00_B	26717.0	Ramp from Beltway to I-10	Not Modified
N100-00-00_B	26379.0	Frontage East-Flyover piers	N/A
N100-00-00_B	25908.0	Frontage West-Flyover piers	N/A
N100-00-00_B	24126.0	Access Road West to Beltway 8	Modified
N100-00-00_B	23835.0	Interstate 10	N/A
N100-00-00_B	23691.0	South Access Road Interstate 10	N/A
N109-00-00	100	Overbluff Street	N/A

N104 Channel Improvements. There are also six bridge crossings that intersect this segment of channel improvements. One of these crossings is the Union Pacific Railroad. The railroad crossing is proposed to be widened by approximately 20 feet using a 4:1 side slope. Since the railroad is a major crossing, a detailed survey and detailed structural analysis will need to be conducted to determine whether the widening of the channel under the railroad will pose any increased risk or additional costs to achieve. Also, significant time would likely be required to reach agreement with the railroad company for this improvement. The sloping abutments at the crossing have been modified (**Table 4**). All bridge crossings have been modeled with a 20 ft bottom width and 4:1 side slope, the sloping abutments for all bridges have been modified. The cost estimates include bridge modifications for N104 channel improvements.

Table 4. Bridge modifications along N104-00-00 channel improvements

Reach	Station	Bridge Intersections	Structural Modifications
N104-00-00	10388.0	Elgin Road	Dual culvert system removed, added piers
N104-00-00	9736.0	Woodforest Drive	Sloping abutments removed, added piers
N104-00-00	7532.0	East Brentwood Road	N/A
N104-00-00	6816.0	Union Pacific Railroad	Sloping abutments modified
N104-00-00	6229.0	Avenue C	Sloping abutments modified
N104-00-00	5377.0	South Brentwood Road	N/A

7.2. Environmental and Utility Conflicts.

Cloverleaf Flood Risk Reduction Project. The parcel (**red** polygon in **Figure 12**) under consideration for acquisition for the construction of the detention basin is partially classified as a wetland (**green** polygon in **Figure 12**). It is unknown if individual 404 permits will be required for the proposed detention basin. Two potential landfill sites are also located south of this parcel, adjacent to the existing northern outfall. Confirmation is needed on the type of refuse or landfill material currently residing in this area and what impact that might have on the design of the detention basin. Both issues could add time and cost to the current estimate for this project.

Figure 12. Constraints for Phase 1 Cloverleaf Flood Risk Reduction Project

N100 Channel Improvements. There is an Oil & Gas pipeline (Colonial Pipeline Company) that is located adjacent to the Missouri Pacific Railroad crossing. Since 1:1 side slope is recommended in this portion of the channel, it is assumed that the widening of the cross-section will not cause a conflict with this pipeline. Furthermore, concrete lining the channel at this crossing minimizes erosion of the banks over the pipeline. This assumption will have to be verified by a more detailed utility survey and coordination with the pipeline company. Since the segment of channelized N100-00-00 improvements has already been modified previously, minimal environmental permitting requirements are expected.

N104 Channel Improvements. The channel improvements at N104-00-00 are proposed to end just north of IH-10. There is a pipeline and railroad crossing intersecting N104-00-00 (**Figure 13**), channelization was continued through this crossing area because the benefits of channelizing through the pipeline and railroad crossing are expected to outweigh avoiding these constraints. The railroad and the pipeline are located adjacent to one another. Since the cross section at the railroad is recommended to be deepened by approximately 4 feet, the pipeline and railroad crossing represent significant uncertainties and additional costs associated with this project.

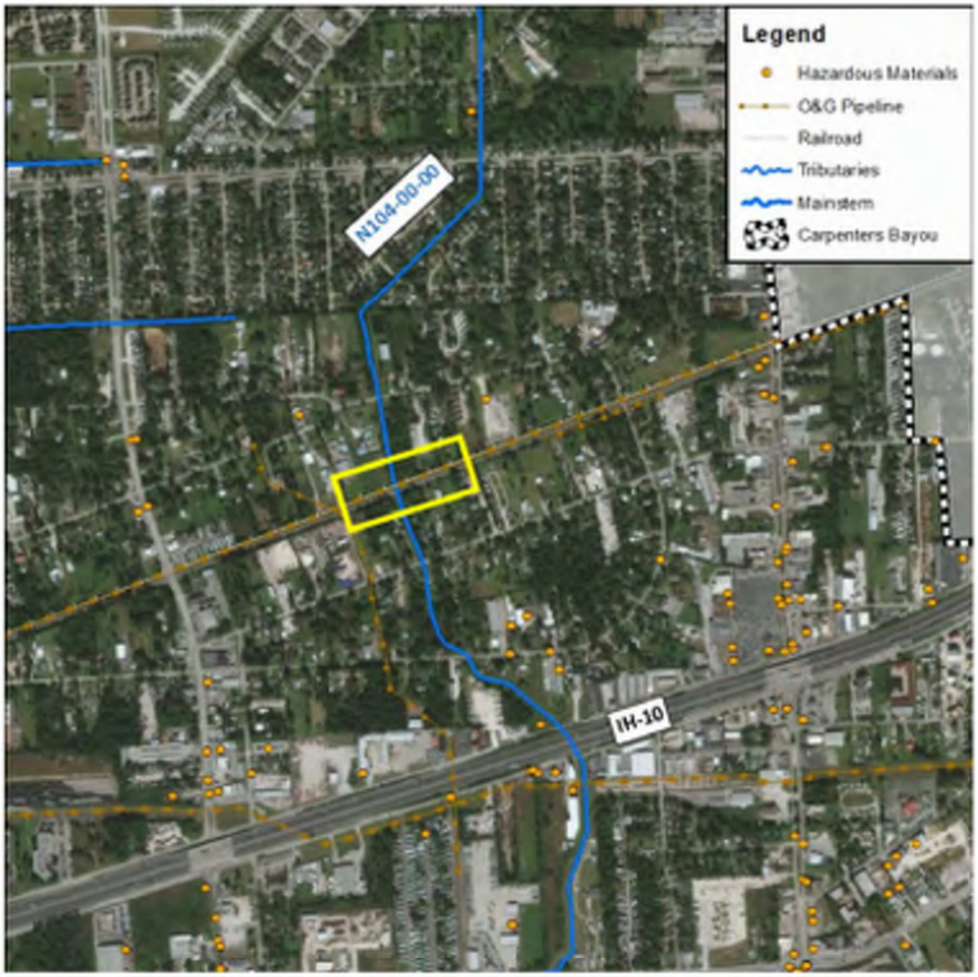


Figure 13. Constraints in proposed channel improvements at N104-00-00

N109-01-00 Tributary Improvements. The existing 3-foot diameter pipe does not have enough capacity to convey 100-year flows to N100-00-00. It is recommended under proposed conditions to upsize this enclosed tributary to a 12-ft x 6-ft box culvert. The tributary is located adjacent to a pipeline owned by Colonial Pipeline Company; this pipeline provides uncertainty in the placement of the proposed box culvert (**Figure 14**).

Figure 14. Environmental Constraints in proposed N109-01 Tributary Improvements

7.3. Peak Flow Mitigation Requirements and Detention Basin Property Acquisition.

Cloverleaf Flood Risk Reduction Project Phase 2. The peak flow mitigation required for phase 2 of the Cloverleaf Flood Risk Reduction Project has not been determined since it is dependent on the placement of trunk line #2. It is possible that the mitigation volume delivered for phase 1 will also adequately mitigate phase 2 as well. The Vision Plan hydraulic model shows no impacts downstream of the proposed project in the mainstem (N100-00-00). However, the uncertainty for phase 2 is higher than phase 1 because of these factors.

N100 Channel Improvements. The detention basins are proposed to use potential available storage areas for planning purposes. The design of the detention basins requires further detailed analyses, beyond the scope of this study.

7.4. Future Development

Channel Improvements in Carpenters' Upper Watershed. The existing conditions 100-year floodplain in the northern regions of the watershed is widespread due to the <50-year LOS for Carpenters Bayou main channel. Future channel improvements will likely need to be considered for this area of the watershed to reduce the extent of the floodplain as this develops further. Future developers should be informed of the ROW requirements that are needed if channel improvements are considered in this region of the watershed. Mitigation requirements will also need to be explored; however, there is currently sufficient vacant land in this region of the watershed to provide adequate detention basins for mitigation purposes. The yellow polygons in Figure 15 shows some projects that are currently under way in the northern regions of Carpenters Bayou.

Figure 15. Ongoing Project locations in the northern regions of the watershed

8. Summary and Conclusions

HCFCD commissioned the Vision Plan as part of a strategic effort to help identify the projects that best mitigate the watershed's inherent flood risk for the 100-year frequency storm. This plan identifies a comprehensive suite of improvements that mitigate flood risk under existing hydrologic conditions, as well as provide a strategy for future improvements as additional development occurs in this region. The details described in this report – including the hydrologic and hydraulic analyses, cost estimates and proposed ROW acquisition, served as the technical basis for this planning level assessment.

The objective of the Vision Plan is to verify – based on modeled results – that proposed flood risk mitigation strategies (i.e., the combination channel modifications and drainage improvements) are hydraulically feasible based on a targeted level of service and can together provide adequate flood level reductions under existing hydrologic conditions. The modeling methodology consisted of combining the models developed under the proposed conditions task of the WPP into one unified unsteady 1D/2D hydraulic framework and evaluating combinations of proposed stormwater drainage improvements and channel modifications for the 100-year storm event.

Based on the modeled analyses, it was determined that the collective hydraulic performance of the recommended projects can help provide significant flood level reductions in the 100-year storm event when compared to existing conditions. In addition, the proposed improvements will not create adverse hydraulic impacts to the downstream WSELs in the 100-year storm event.

Overall benefits of the Vision Plan have been corroborated by this technical analysis, the highlights of which include the following:

- Total count of flooded structures removed was approximately 474 for the 100-year storm event.
- Total storage volume of approximately 315 acre-feet required to meet total storage volume.
- Excavation volume of approximately 282 acre-feet for channel modifications
- Total estimated cost of approximately $222 Million estimated for the Vision Plan.
- 911 acres would no longer be inundated during the 100-year event (30% reduction) under Vision Plan when compared to existing conditions floodplain.

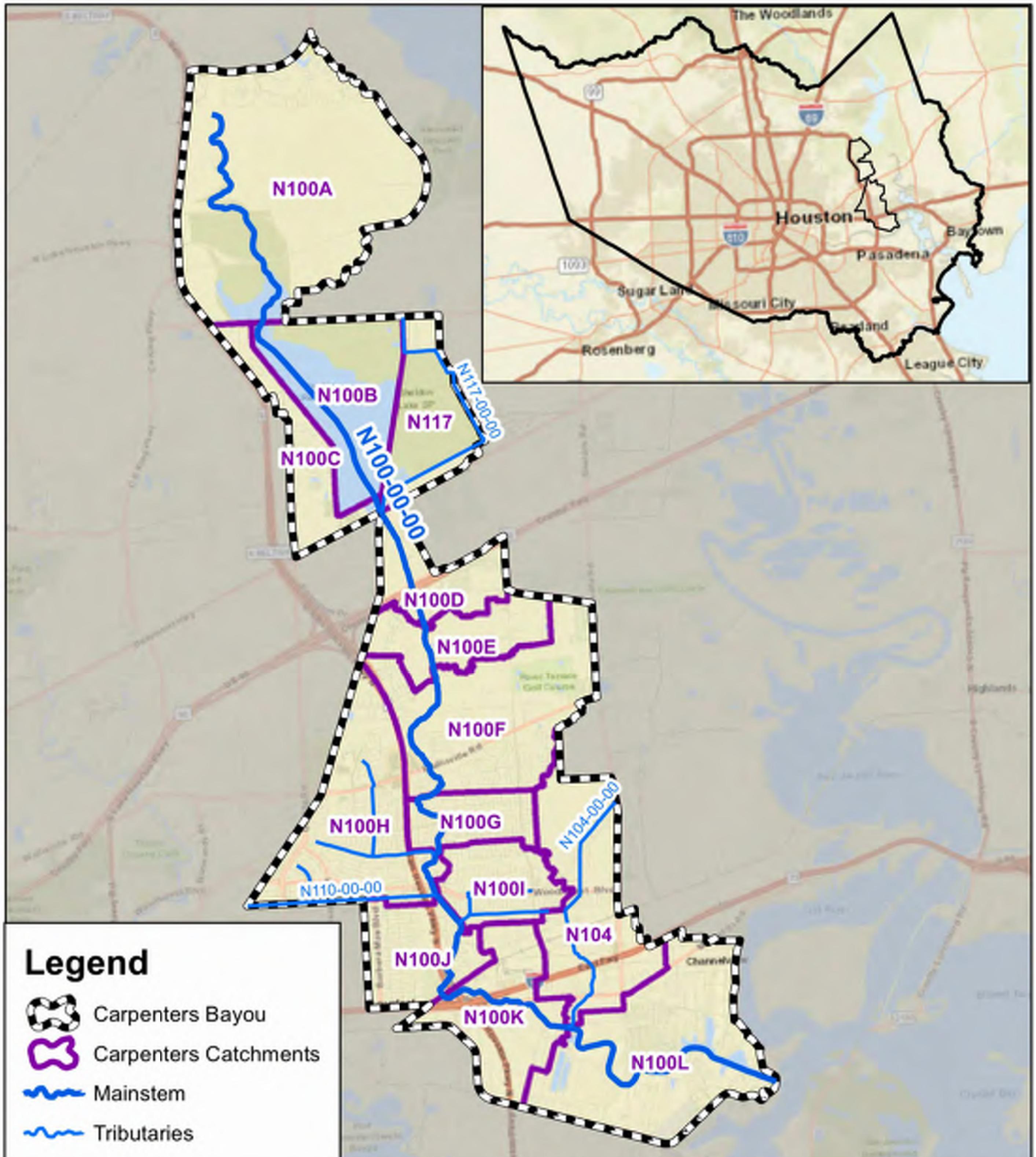
Recommendations moving forward include the following:

- Consider 500 feet of proposed ROW along N100-00-00 and critical tributaries for future natural stable channel design to be incorporated as land becomes available by way of stakeholder participation and donation. Actual development trends are likely to vary from what is assumed for this analysis and acquisition of undeveloped ROW allows for flexibility in meeting needs as development occurs.
- Develop an implementation strategy that effectively monitors, controls, and manages the Vision Plan. Location and pace of development in the watershed will be exclusively driven by the landowners and developers. This on-going effort will include phasing and sequencing excavation of basins and channels to align with development trends and subsequent needs for outfall depth and mitigation.
- Perform preliminary engineering reports for each recommendation to determine feasibility, recreation and environmental features, ROW, outlet structure configurations, etc.
- Use the MAAPnext models to re-evaluate performance metrics of the Vision Plan.

- The proposed detention basins to mitigate impacts for N100-00-00 channel improvements were modeled as 1D storage areas in the Vision Plan model and these basins require further detailed modeling to evaluate their performance more accurately.
- Consider drop structures where necessary at tributary confluences with N100-00-00 to dissipate energy due to higher velocities from steeper tributaries relative to the mild-sloped mainstem.
- Conduct a feasibility study for potential future use of Lake Sheldon as a flood mitigation storage facility.

List of Exhibits

List of Appendices



Vision Plan 100-year LOS

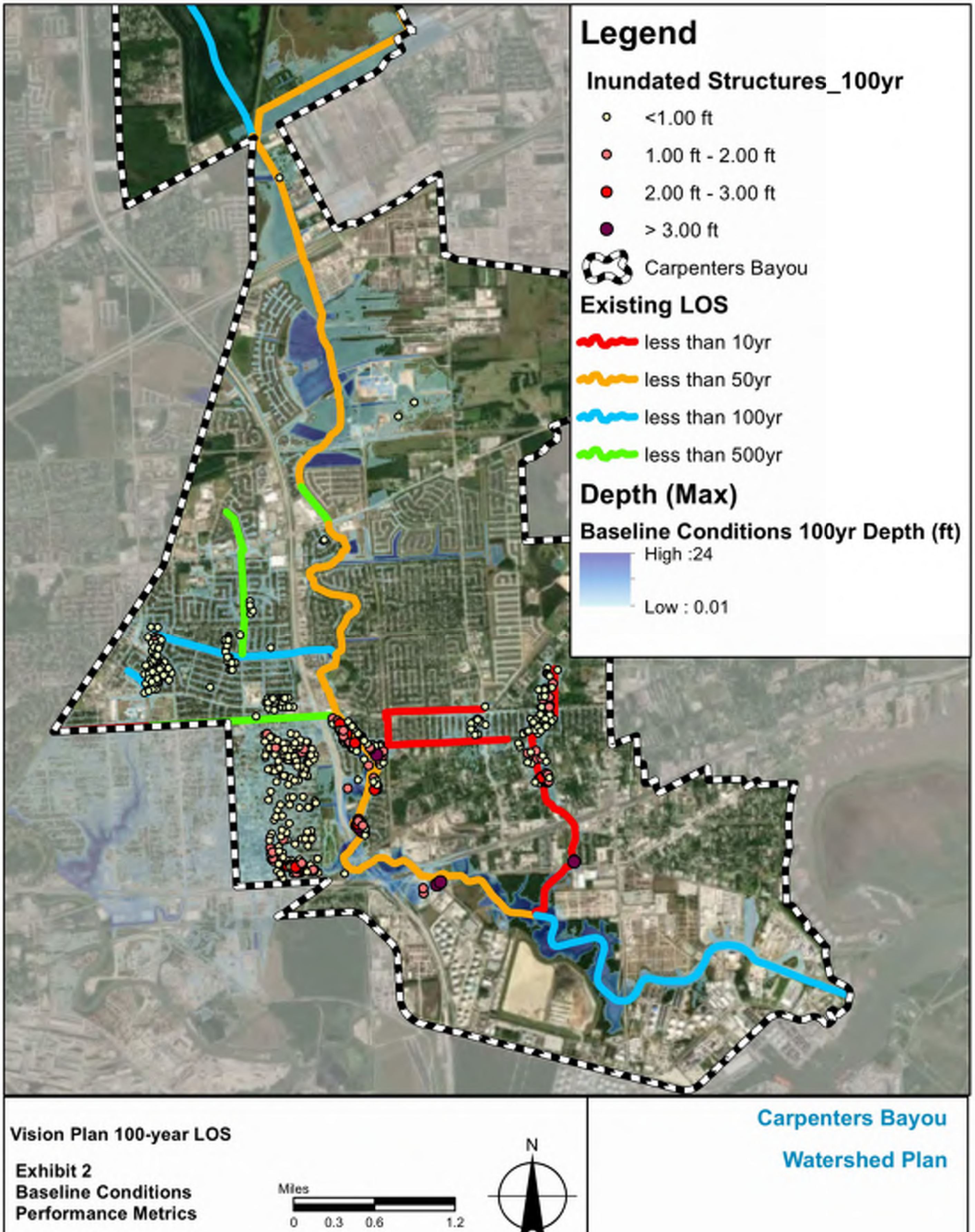
Exhibit 1
Study Area Map

Created: 2/1/2021

Carpenters Bayou

Watershed Plan

Attachment #4 Interim Deliverable

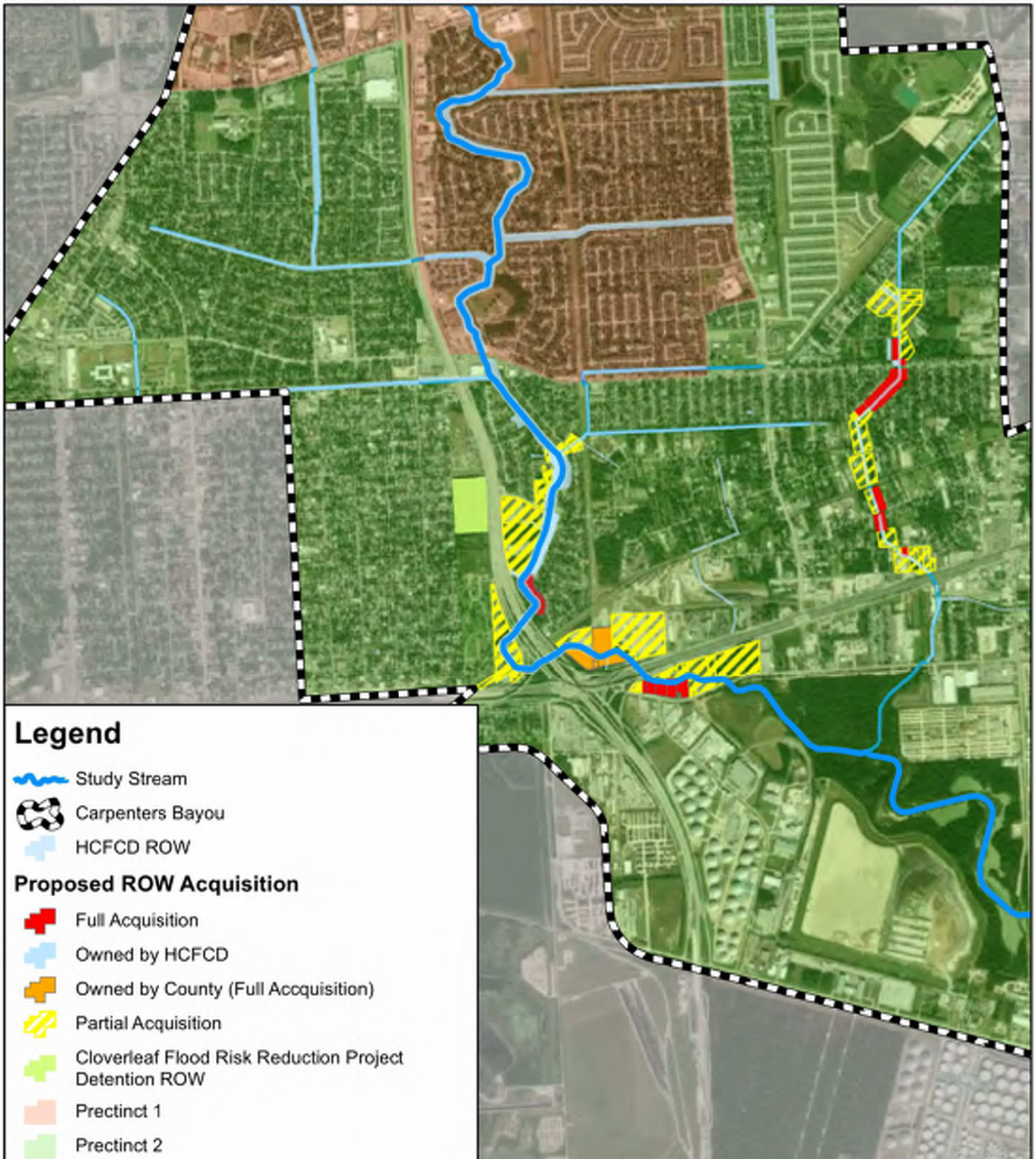


Vision Plan 100-year LOS

Exhibit 2
Baseline Conditions
Performance Metrics

Created: 12/11/2020

Carpenters Bayou
Watershed Plan



Vision Plan 100-year LOS

Exhibit 3
Vision Plan Proposed ROW

Miles
0 0.175 0.35 0.7

N

Created: 12/11/2020

Carpenters Bayou

Watershed Plan

Vision Plan 100-year LOS

Exhibit 4
Vision Plan
Performance Metrics

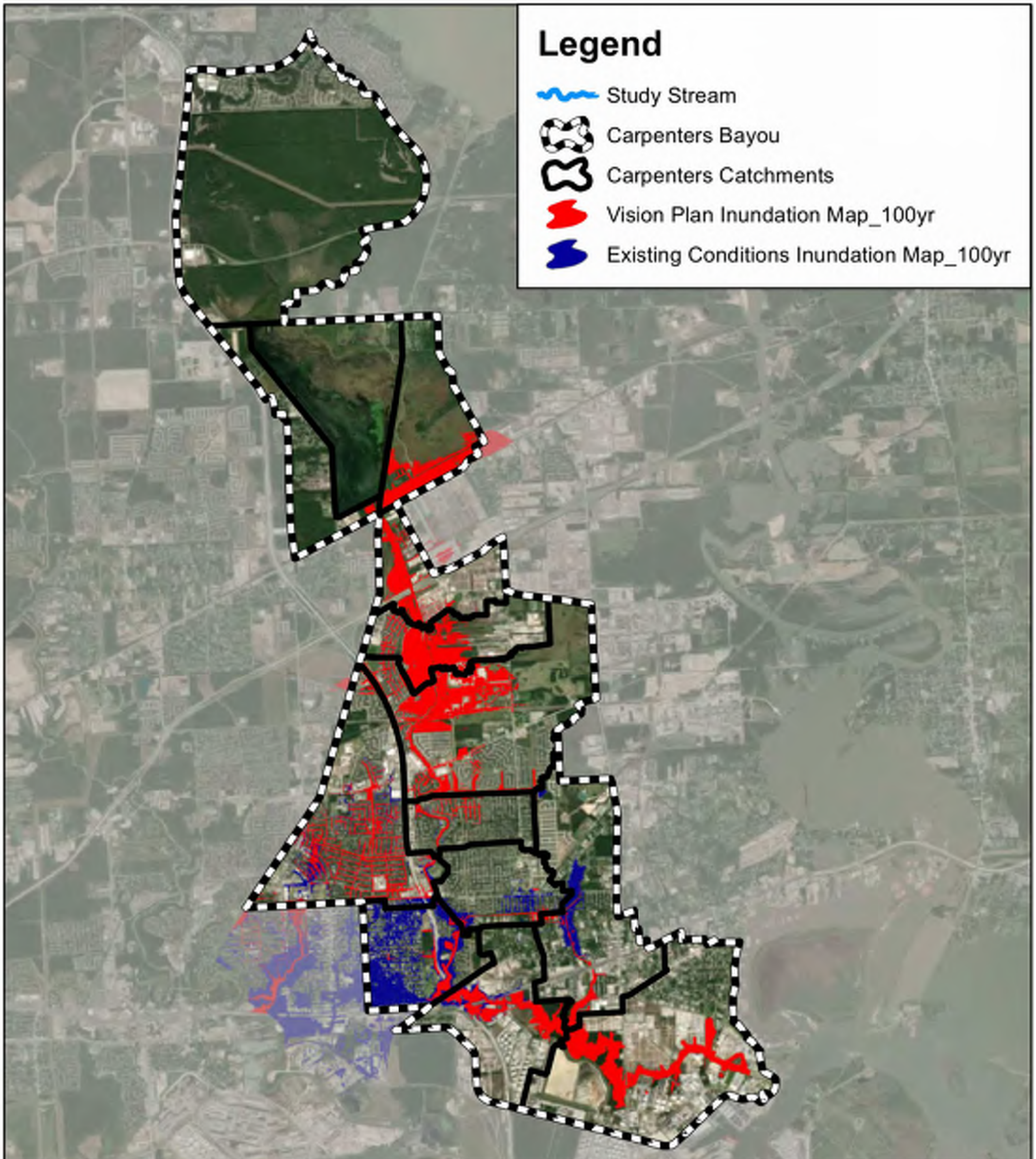
Miles
0 0.3 0.6 1.2

N

Created: 2/1/2021

Carpenters Bayou

Watershed Plan



Vision Plan 100-year LOS

Exhibit 5
Inundation Map
Comparison 100yr

Created: 12/11/2020

Carpenters Bayou

Watershed Plan

Appendix A

Cost Estimates

Vision Plan-Cloverleaf Flood Risk Reduction Project (Phase 1)

Cloverleaf Flood Risk Reduction Project (Phase 1)	Quantity	Unit	Unit Cost	Cost	Cost	Comment
Detention Basin						
Clearing, Grubbing, and Disposal	15.8	AC	$ 6,200	97,854	$ 98,000	From HCFCD Cost Tool
Excavation (Off-Site Haul)	213,893	CY	$ 12	2,566,718	$ 2,567,000	From HCFCD Cost Tool
Concrete Pilot Channels	4,225	SY	$ 55	232,393	$ 233,000	From HCFCD Cost Tool
Turf Establishment (Sodding / Seeding)	13	AC	$ 3,600	48,562	$ 49,000	From HCFCD Cost Tool
Backslope Swale	3,410	FT	$ 5	17,050	$ 18,000	From HCFCD Cost Tool
Backslope Drain Structure	10	EA	$ 3,500	35,000	$ 35,000	From HCFCD Cost Tool
Backslope Interceptor Rip-rap	100	SY	$ 80	8,000	$ 8,000	From HCFCD Cost Tool
Detention Basin Construction Cost			**Subtotal**	**3,005,577**	**$ 3,006,000**	
Site Preparation						
Clearing and Grubbing (Trunk line #1)	1.4	AC	$ 6,500	8,807	$ 9,000	
Earthwork						
Excavation and Disposal Trunk Line #1	16,394	CY	$ 10	163,944	$ 164,000	The volume was based on a 15ft width, trunk line length and 10 ft depth
Storm Sewer						
9x7 RCB Trunk Line #1	2,951	LF	$ 850	2,508,350	$ 2,509,000	Using cost tool and Manning's equation calculation, along Hershe St and Nancy Rose St
Pavement Removal	6,558	SY	$ 3	19,673	$ 20,000	Unit cost from cost tool
Concrete Pavement Replacement	6,558	SY	$ 75	491,833	$ 492,000	Unit cost from cost tool
Subbase Replacement	7,214	SY	$ 2	14,427	$ 15,000	Unit cost from cost tool
Regrade Roadside Ditch (Gainesville St)	6780	LF	$ 15	101,700	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Longview St)	6760	LF	$ 15	101,400	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Texarkana St)	6760	LF	$ 15	101,400	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Eagle Pass St)	6760	LF	$ 15	101,400	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Victoria St)	6660	LF	$ 15	99,900	$ 100,000	length of road multipiled by 2
Regrade Roadside Ditch (Corpus Christi St)	6740	LF	$ 15	101,100	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Brownsville St)	6700	LF	$ 15	100,500	$ 101,000	length of road multipiled by 2
Regrade Roadside Ditch (Laredo St)	6700	LF	$ 15	100,500	$ 101,000	length of road multipiled by 2
Regrade Roadside Ditch (Hillsboro St)	4020	LF	$ 15	60,300	$ 61,000	length of road multipiled by 2
Regrade Roadside Ditch (Waxahachie St)	6700	LF	$ 15	100,500	$ 101,000	length of road multipiled by 2
Regrade Roadside Ditch (Nancy Rose St)	4000	LF	$ 15	60,000	$ 60,000	length of road multipiled by 2
Regrade Roadside Ditch (Manor St)	5920	LF	$ 15	88,800	$ 89,000	length of road multipiled by 2
Regrade Roadside Ditch (Barbara Mae St)	5880	LF	$ 15	88,200	$ 89,000	length of road multipiled by 2
Regrade Roadside Ditch (Cloverleaf St)	5900	LF	$ 15	88,500	$ 89,000	length of road multipiled by 2
Construction Costs (incuding Detention Bain)			Subtotal	**$ 7,506,812.23**	**$ 7,507,000**	
Engineering and Contingencies						
Feasability Study	1	%	5%	$ 375,340.61	$ 376,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 900,817.47	$ 901,000	Percentage of construction costs
Construction Management	1	%	10%	$ 750,681.22	$ 751,000	Percentage of construction costs
Contingencies	1	%	30%	$ 2,252,043.67	$ 2,253,000	Percentage of construction costs
			Subtotal	**$ 4,278,882.97**	**$ 4,279,000**	
ROW Acquisition						
Texas San Jacinto Memorial Park & Funeral Home	100%	%	$ 2,312,250	$ 2,312,250.00	$ 2,313,000	Value as of January 1st, 2019, HCAD
Total ROW acquisition cost			**Subtotal**	**$ 5,780,625.00**	**$ 5,781,000**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 17,566,320.19**	**$ 17,567,000**	

Vision Plan-Cloverleaf Flood Risk Reduction Project (Phase 2)

Cloverleaf Flood Risk Reduction Project (Phase 2)	Quantity	Unit	Unit Cost	Cost	Cost	Comment
Site Preparation						
Clearing and Grubbing	3.2	AC	$ 6,500	20,509	$ 21,000	
Earthwork						
Excavation and Disposal Trunk Line 2	38,178	CY	$ 10	381,778	$ 382,000	The volume was based on a 15ft width, trunk line length and 10 ft depth
Storm Sewer						
10X7 RCB Trunk Line 2	6,872	LF	$ 715	4,913,480	$ 4,914,000	Using cost tool and Manning's equation calculation, along Cloverleaf St and I-10
Pavement Removal	15,271	SY	$ 3	45,813	$ 46,000	Unit cost from cost tool
Concrete Pavement Replacement	15,271	SY	$ 75	1,145,333	$ 1,146,000	Unit cost from cost tool
Subbase Replacement	16,798	SY	$ 2	33,596	$ 34,000	Unit cost from cost tool
Regrade Roadside Ditch (Brownwood St)	6760	LF	$ 15	$ 101,400	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Greenville St)	6796	LF	$ 15	$ 101,940	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Bandera St)	6738	LF	$ 15	$ 101,070	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Bonham St)	6718	LF	$ 15	$ 100,770	$ 101,000	length of road multipiled by 2
Regrade Roadside Ditch (Duncum St)	6698	LF	$ 15	$ 100,470	$ 101,000	length of road multipiled by 2
Regrade Roadside Ditch (Renault St)	6770	LF	$ 15	$ 101,550	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Garber Ln)	6684	LF	$ 15	$ 100,260	$ 101,000	length of road multipiled by 2
Regrade Roadside Ditch (Mc Nair St)	6736	LF	$ 15	$ 101,040	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Muscatine St)	6778	LF	$ 15	$ 101,670	$ 102,000	length of road multipiled by 2
Regrade Roadside Ditch (Nimitz St)	6676	LF	$ 15	$ 100,140	$ 101,000	length of road multipiled by 2
Regrade Roadside Ditch (Barbara Mae St)	5934	LF	$ 15	$ 89,010	$ 90,000	length of road multipiled by 2
Regrade Roadside Ditch (Cloverleaf St)	5934	LF	$ 15	$ 89,010	$ 90,000	length of road multipiled by 2
Regrade Roadside Ditch (Nancy Rose St)	5952	LF	$ 15	$ 89,280	$ 90,000	length of road multipiled by 2
Regrade Roadside Ditch (Manor St)	5728	LF	$ 15	$ 85,920	$ 86,000	length of road multipiled by 2
Construction Costs			**Subtotal**	**$ 7,904,039.61**	**$ 7,905,000**	
			Engineering and Contingencies			
Feasability Study	1	%	5%	$ 395,201.98	$ 396,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 948,484.75	$ 949,000	Percentage of construction costs
Construction Management	1	%	10%	$ 790,403.96	$ 791,000	Percentage of construction costs
Contingencies	1	%	35%	$ 2,766,413.86	$ 2,767,000	Percentage of construction costs
			Subtotal	**$ 4,900,504.56**	**$ 4,901,000**	
			Total Estimated Cost	**$ 12,804,544.17**	**$ 12,805,000**	

Vision Plan-N100-00-00 Channel Improvements

Channel Improvements N100	Quantity	Unit	Unit Cost	Cost	Comment
Detention Basin 1					
Detention Excavation, Haul Disposal	205861	CY	$12	$2,470,332.00	
Clearing Grubbing, and Disposal	8.5	AC	$6,200	$52,700.00	
Detention Basin 2					
Detention Excavation, Haul Disposal	88894	CY	$12	$1,066,728.00	
Clearing Grubbing, and Disposal	5.5	AC	$6,200	$34,100.00	
Channel Improvements					
Clearing Grubbing, and Disposal	45.5	AC	$ 6,200.00	$ 282,100.00	ROW width=200 ft, length of channel= 9900 ft
Utility Adjustments (pipeline)	819	LF	$ 320.00	$ 262,080.00	Colonial Pipeline closest to Missouri Pacific Railroad
Excavation (Off-Site Haul)	307,598.00	CY	$ 12.00	$ 3,691,176.00	Proposed conditions model used for quantity
Rock Rip-Rap	55930	SY	$ 80.00	$ 223,720.00	Portion of Channel Depth to Rip-Rap = 30% (60% of channel length is assumed to be Rip-Rap)
Backslope Swale	9900	LF	$ 5.00	$ 49,500.00	assumed to be along the length of the channel improvements
Backslope Drain Structure	99	EA	$ 3,500.00	$ 346,500.00	backslope structure spacing at every 100 ft
Bridge Modifications					
Woodford Drive	609	SF	$75	$ 45,675.00	Assumed change in opening width
Beltway 8 Frontage N	46	SF	$75	$ 3,450.00	Assumed change in opening width
Beltway 8 Frontage S	30	SF	$75	$ 2,250.00	Assumed change in opening width
Missouri Pacific Railroad	848	SF	$75	$ 63,600.00	Assumed change in opening width
Ramp to I-10W	1926	SF	$75	$ 144,450.00	Assumed change in opening width
Beltway 8 Frontage S	388	SF	$75	$ 29,100.00	Assumed change in opening width
Beltway 8 Frontage N	452	SF	$75	$ 33,900.00	Assumed change in opening width
Access to Beltway 8	4433	SF	$75	$ 332,475.00	Assumed change in opening width
I-10	12665	SF	$75	$ 949,875.00	Assumed change in opening width
Access to I-10	3979	SF	$75	$ 298,425.00	Assumed change in opening width
Overbluff Street	6480	SF	$75	$ 486,000.00	Assumed change in opening width
Construction Costs			**Subtotal**	**$10,868,136.00**	
			Engineering and Contingencies		
Feasability Study	1	%	5%	$ 543,406.80	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 1,304,176.32	Percentage of construction costs
Construction Management	1	%	10%	$ 1,086,813.60	Percentage of construction costs
Contingencies	1	%	35%	$ 3,803,847.60	Percentage of construction costs
			Subtotal	**$ 6,738,244.32**	
			ROW Acquistition		
34 Partial Buyouts	1%-75%	%	$ 1,848,722.36	$ 1,848,722.36	
10 HCFCD Owned Parcels	100%	%	$436,790.27	$436,790.27	
4 County Owned Parcels	100%	%	$993,822.00	$ 993,822.00	
23 Full Buyouts	100%	%	$2,071,416.27	$ 2,071,416.27	
Total ROW acquisition cost			**Subtotal**	**$ 13,376,877.27**	Subtotal*2.5 (multiplier) Assumed non-voluntary buyouts
			Total Estimated Cost	**$ 30,983,257.59**	

Vision Plan-N104-00-00 Channel Improvements

Channel Improvements N104	Quantity	Unit	Unit Cost	Cost	Comment
Channel Improvements					
Clearing Grubbing, and Disposal	28.3	AC	$ 6,200.00	$ 175,460.00	
Utility Adjustments (pipeline)	270	LF	$ 320.00	$ 86,400.00	Equistar Chemicals, LP
Excavation (Off-Site Haul)	147,704.00	CY	$ 12.00	$ 1,772,448.00	Proposed conditions model used for quantity
Rock Rip-Rap	19560	SY	$ 80.00	$ 78,240.00	Portion of Channel Depth to Rip-Rap = 30% (60% of channel length is assumed to be Rip-Rap)
Backslope Swale	7000	LF	$ 5.00	$ 35,000.00	assumed to be along the length of the channel improvements
Backslope Drain Structure	70	EA	$ 3,500.00	$ 245,000.00	backslope structure spacing at every 100 ft
Bridge Modifications					
Elgin Road	5520	SF	$75	$ 414,000.00	Top width*deck width
Woodforest Drive	12160	SF	$75	$ 912,000.00	Top width*deck width
East Brentwood Road	2940	SF	$75	$ 220,500.00	Top width*deck width
Union Pacific Railroad	1814.4	SF	$75	$ 136,080.00	Top width*deck width
Avenue C	3080	SF	$75	$ 231,000.00	Top width*deck width
South Brentwood Road	3192	SF	$75	$ 239,400.00	Top width*deck width
Construction Costs			**Subtotal**	**$4,545,528.00**	
Engineering and Contingencies					
Feasability Study	1	%	5%	$ 227,276.40	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 545,463.36	Percentage of construction costs
Construction Management	1	%	10%	$ 454,552.80	Percentage of construction costs
Contingencies	1	%	35%	$ 1,590,934.80	Percentage of construction costs
			Subtotal	**$ 2,818,227.36**	
ROW Acquistition					
30 partial buyouts	8%-78%	%	-	$ 1,301,819.89	
2 HCFCD owned parcels	95%	%	-	$ 24,039.00	
41 parcels full acquisition	100%	%	-	$ 3,769,211.00	
Total ROW acquisition cost			**Subtotal**	**$ 12,737,674.72**	Subtotal*2.5 (multiplier) Assumed non-voluntary buyouts
			Total Estimated Cost	**$20,101,430.08**	

Vision Plan- N109-01 Tributary Improvements

N109-01 Tributary Improvements	Quantity	Unit	Unit Cost	Cost	Cost	Comment
Site Preparation						
Clearing and Grubbing (N109-01-00)	2.5	AC	$ 6,500	16,116	$ 17,000	
Earthwork						
Excavation and Disposal Tributary N109-01-00	28,000	CY	$ 10	280,000	$ 280,000	The volume was based on a 20ft width, culvert length and 7 ft depth
Upsizing N109-01-00 Costs						
12x6 RCB Trunk Line #1	5,400	LF	$ 1,150	6,210,000	$ 6,210,000	12ft X 6ft RCB
Pavement Removal	12,000	SY	$ 3	36,000	$ 36,000	Unit cost from cost tool
Concrete Pavement Replacement	12,000	SY	$ 75	900,000	$ 900,000	Unit cost from cost tool
Subbase Replacement	13,200	SY	$ 2	26,400	$ 27,000	Unit cost from cost tool
Utility Adjustments (pipeline)	1300	LF	$ 320	416,000	$ 416,000	Colonial Pipeline Company
Construction Costs			**Subtotal**	**$ 7,884,515.70**	**$ 7,885,000**	
			Engineering and Contingencies			
Feasability Study	1	%	5%	$ 394,225.79	$ 395,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 946,141.88	$ 947,000	Percentage of construction costs
Construction Management	1	%	10%	$ 788,451.57	$ 789,000	Percentage of construction costs
Contingencies	1	%	30%	$ 2,365,354.71	$ 2,366,000	Percentage of construction costs
			Subtotal	**$ 4,494,173.95**	**$ 4,495,000**	
			Total Estimated Cost	**$ 12,378,689.65**	**$ 12,379,000**	

Vision Plan- Drainage Improvements around N110-00-00

Drainage Improvements around N110	Quantity	Unit	Unit Cost	Cost	Cost	Comment
Storm Sewer Improvements						
Pavement Removal	124,160	SY	$ 3	372,480	$ 373,000	Unit cost from cost tool
Concrete Pavement Replacement	124,160	SY	$ 75	9,312,000	$ 9,312,000	Unit cost from cost tool
Subbase Replacement	136,576	SY	$ 2	273,152	$ 274,000	Unit cost from cost tool
Storm sewer drainage improvements (Connaught Way)	3250	LF	$ 1,200	3,900,000	$ 3,900,000	length of road multipiled by 2
Storm sewer drainage improvements (Kingscourt Drive)	2642	LF	$ 1,200	3,170,400	$ 3,171,000	length of road multipiled by 2
Storm sewer drainage improvements (Stonehenge Ln)	3814	LF	$ 1,200	4,576,800	$ 4,577,000	length of road multipiled by 2
Storm sewer drainage improvements (Queenstown Road)	5750	LF	$ 1,200	6,900,000	$ 6,900,000	length of road multipiled by 2
Storm sewer drainage improvements (St Finans Way)	3908	LF	$ 1,200	4,689,600	$ 4,690,000	length of road multipiled by 2
Storm sewer drainage improvements (Sevenhampton Ln)	5380	LF	$ 1,200	6,456,000	$ 6,456,000	length of road multipiled by 2
Storm sewer drainage improvements (Barbara Mae St)	4612	LF	$ 1,200	5,534,400	$ 5,535,000	length of road multipiled by 2
Storm sewer drainage improvements (Black Rock Rd)	6960	LF	$ 1,200	8,352,000	$ 8,352,000	length of road multipiled by 2
Storm sewer drainage improvements (Taranto Ln)	648	LF	$ 1,200	777,600	$ 778,000	length of road multipiled by 2
Storm sewer drainage improvements (Posthorn Ln)	652	LF	$ 1,200	782,400	$ 783,000	length of road multipiled by 2
Storm sewer drainage improvements (Freeport St)	7756	LF	$ 1,200	9,307,200	$ 9,308,000	length of road multipiled by 2
Storm sewer drainage improvements (Lantern Ln)	10902	LF	$ 1,200	13,082,400	$ 13,083,000	length of road multipiled by 3
Storm sewer drainage improvements (Waterville Way)	9550	LF	$ 1,200	11,460,000	$ 11,460,000	length of road multipiled by 4
Storm sewer drainage improvements (Foxford Way)	9550	LF	$ 1,200	11,460,000	$ 11,460,000	length of road multipiled by 5
Storm sewer drainage improvements (Duncannon Drive)	8160	LF	$ 1,200	9,792,000	$ 9,792,000	length of road multipiled by 6
Storm sewer drainage improvements (Wadebridge Way)	8362	LF	$ 1,200	10,034,400	$ 10,035,000	length of road multipiled by 7
Storm sewer drainage improvements Roundstone Ln)	8740	LF	$ 1,200	10,488,000	$ 10,488,000	length of road multipiled by 8
Storm sewer drainage improvements (Woodforest Blvd)	11108	LF	$ 1,200	13,329,600	$ 13,330,000	length of road multipiled by 9
Construction Costs			**Subtotal**	**$ 64,404,032.00**	**$ 64,405,000**	
Engineering and Contingencies						
Feasability Study	1	%	5%	$ 3,220,201.60	$ 3,221,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 7,728,483.84	$ 7,729,000	Percentage of construction costs
Construction Management	1	%	10%	$ 6,440,403.20	$ 6,441,000	Percentage of construction costs
Contingencies	1	%	35%	$ 22,541,411.20	$ 22,542,000	Percentage of construction costs
			Subtotal	**$ 39,930,499.84**	**$ 39,931,000**	
			Total Estimated Cost	**$ 104,334,531.84**	**$ 104,335,000**	

Attachment #4 Interim Deliverable

Vision Plan-Buyout Considerations

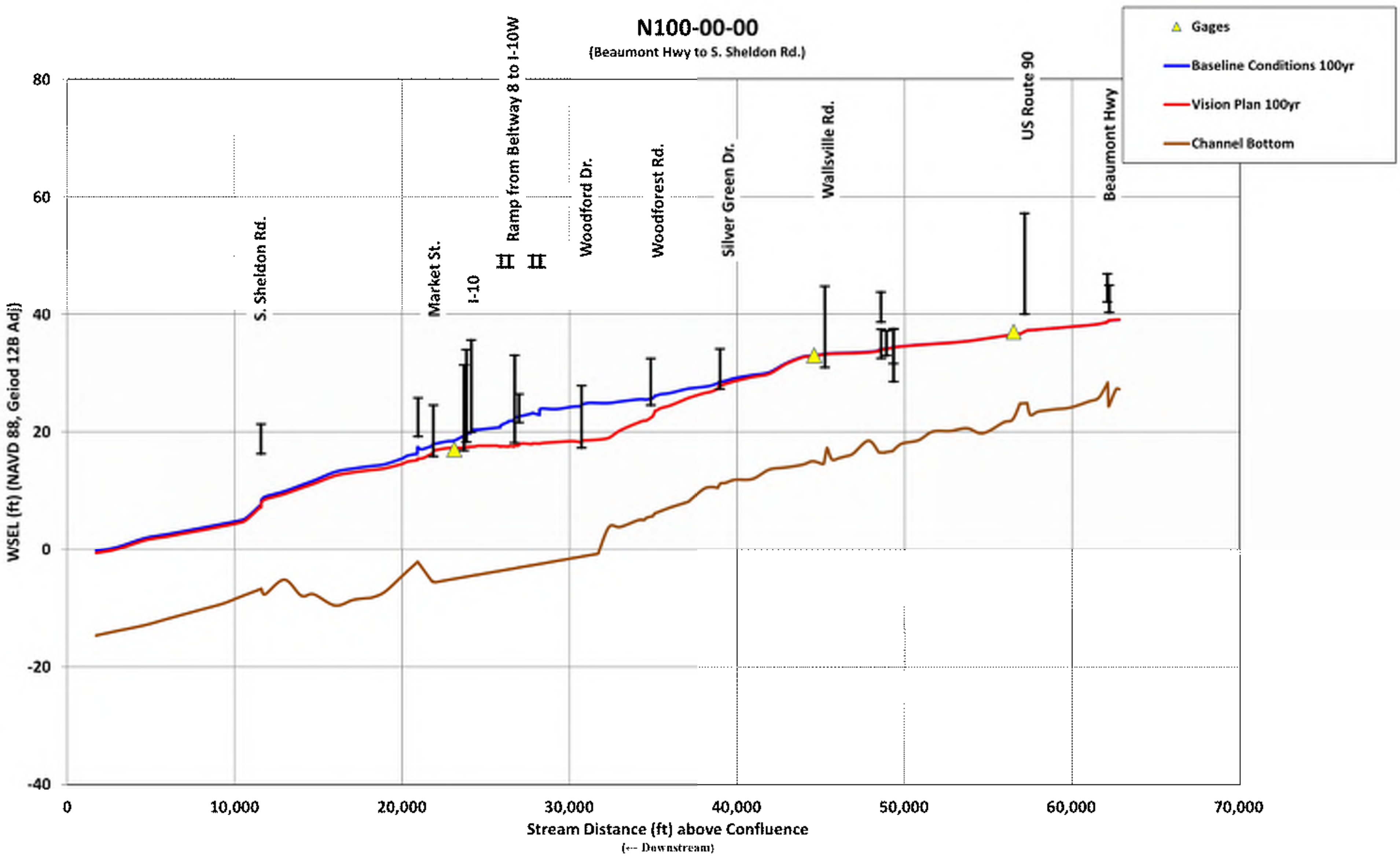
HCAD Number	Owner Name	Total Market Value
410320000016	RIECK ALBERT E	$ 33,124.00
410320000016	RIECK ALBERT E	$ 33,124.00
410320000015	ORDONEZ JHONY F	$ 121,812.00
420930000121	DAOMILLSPAUGH HUONG NGOC	$ 376,067.00
420930000121	DAOMILLSPAUGH HUONG NGOC	$ 376,067.00
420930000121	DAOMILLSPAUGH HUONG NGOC	$ 376,067.00
984420000025	MARTIN JOHN W	$ 30,243.00
984420000026	TOLENTINO ISMAEL & IRMA	$ 91,940.00
984420000027	PEREZ EDUARDO R & ENRIQUETA F	$ 135,157.00
650910230045	HERNANDEZ JOSE G	$ 221,979.00
650910230045	HERNANDEZ JOSE G	$ 221,979.00
1013040000026	JONES CAROL G	$ 165,786.00
1013040000044	ROSSELLI JOHN C	$ 152,433.00
1013040000038	GARMANY GATLING C & WILMA	$ 146,027.00
1002180000002	STEGALL RONNY D	$ 106,752.00
1013060000007	PEREZ MELESIO & MARIA E	$ 151,807.00
1013060000011	WILLIAMS DIANA F	$ 136,000.00
1013060000016	VANWAGNER FLOYD L JR	$ 126,000.00
1013060000018	AYALA REYNALDO	$ 137,718.00
1013060000013	TIBBS MARJORIE A	$ 134,598.00
1013060000014	BUXTON OLIE	$ 144,031.00
1013060000021	JOHN JOHN M & MARIAMMA	$ 124,078.00
1013060000022	HUCKABEE LELIA FAYE	$ 106,744.00
970120000016	ALBAYERO JOSE E	$ 147,632.00
992930000015	AUSTIN CHAD W	$ 134,270.00
992930000016	LANKFORD MAX W	$ 130,000.00
1020800000055	COLE JANET F	$ 133,778.00
1020800000054	ANDREWS JOHN H JR	$ 155,418.00
992920000003	COLLINS NATHANIEL & JAYNE	$ 133,784.00
992920000002	KRENEK BARBARA ELLIS	$ 134,420.00
1020800000052	YNOSENCIO REBECCA M	$ 142,952.00
1002120000048	BRETZKE STEVEN R & HOLLY I	$ 176,711.00
1020800000051	BANSAL MOHIT	$ 110,000.00
1020800000050	MARIN-GONZALEZ GERSOM S	$ 159,668.00
992910000002	CALLAWAY ROBERT R	$ 127,055.00
992910000001	RIVAS AMALIA	$ 127,948.00
1044590000077	RODRIGUEZ ROSA E	$ 139,138.00
1020820000004	REYES DORA V	$ 166,036.00
1020830000002	FARGO YOLANDA	$ 114,950.00
1044590000075	HERNANDEZ JESSE G	$ 180,552.00
1020820000005	JLA IRA LLC	$ 75,000.00
1044590000073	ZAPOLI CAROLE A	$ 126,597.00
1020830000005	INGERMAN DEBRA R	$ 156,543.00
1020830000007	SANDLER FABIAN M & SALLY J	$ 160,649.00
1044590000070	GONZALEZ SERGIO A	$ 127,577.00
1044590000069	MATA ROY & HILDA	$ 157,005.00
1044590000068	MERCADO HECTOR & MARVELIA	$ 138,101.00
1044590000067	ESPINAL LORENA	$ 135,816.00
1044580000036	BURI BERNICE J	$ 129,806.00
1020850000003	MURRAY DENNIS J & PAMELA J	$ 139,771.00
1020840000016	MCCOLLUM MICHAEL DONALD	$ 105,000.00
1159370090033	ALEMAN HECTOR S & MARA D	$ 113,500.00
1138330000039	VARGAS HERMILO & CHRISTINA	$ 98,920.00
1138330000040	GUERRA JESUS A	$ 89,611.00
1231660010020	REYES KARINA	$ 249,034.00
1231660010010	NARVAEZ MONICA	$ 156,095.00
502230000098	ABURTO DEFIGO & JUANITA	$ 92,000.00
630430030018	RICHEY ALBERT A	$ 36,270.00
630430030010	SANCHEZ MERCED	$ 48,647.00
630430040002	SPEARS TERRY A	$ 65,703.00
630430050010	CARTER RANDY L	$ 193,995.00
630430050003	CARTER MAUDENE H	$ 36,302.00
630430050019	SERRANO GUADALUPE	$ 83,762.00
630430050006	SAENZ OSCAR JR	$ 55,266.00
630430050006	SAENZ OSCAR JR	$ 55,266.00
630430050024	VACA CRISPIN	$ 40,588.00
650660560010	GALLEGOS OSCAR DANIEL HERNANDEZ	$ 47,993.00
650660560006	ABREGO VENTURES INC	$ 38,277.00
650660560009	GARZA ZACARIAS & LYSBETH	$ 53,293.00
650660560007	GEORGE THOMAS & MINI	$ 46,135.00
650660560012	PENA JUAN C	$ 61,439.00
650660560013	GONZALEZ JUAN	$ 67,526.00
650660580002	GARCIA FRANCISCO G ET AL	$ 108,335.00
650700880020	VILLEGAS SAMUEL & ANTONIA	$ 53,609.00
650700920008	WALKER LOURDES R	$ 32,252.00

Residual Flooded Structures Buyouts	Cost ($M)
HCAD Market value of residual flooded structures under	$ 9.44
Total estimated non-voluntary buyout cost	$ 23.60

Appendix B

N100-00-00 Water Surface Profile Baseline Conditions vs. Proposed Conditions (100-year)

Attachment #4 Interim Deliverable



Attachment #5

Preliminary Project Plan

INTERIM REVIEW ONLY
This document was submitted for interim review only and is not intended for construction, bidding, permit, or final submittal purposes.

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Preliminary Project Plan for Cloverleaf and N100-00-00 Facilities in the Carpenters Bayou Watershed

March 12, 2021

Prepared by:

Torres & Associates, LLC

Table of Contents

Acknowledgments

This planning project represents a key milestone towards the greater management and success of the Harris County 2018 Bond Projects for Flood Mitigation and is the product of interdisciplinary coordination between HCFCD, engineering consultants, key stakeholders, and the general public. Torres & Associates, LLC is particularly grateful to HCFCD staff for their invested time, effort, and commitment towards providing necessary data, background, interim deliverable reviews, logistical guidance, and general insights on day-to-day watershed-wide operations ranging from permitting reviews to right-of-way (ROW) acquisition. This coordination was instrumental for evaluating effective and feasible flood risk management solutions for the Carpenters Bayou watershed, as well as the successful management of the broader Harris County 2018 Bond Projects for Flood Mitigation.

List of Figures

List of Tables

Acronyms

1D	1-Dimensional
2D	2-Dimensional
CBW	Carpenters Bayou Watershed
HCFCD	Harris County Flood Control District
HEC-RAS	Hydrologic Engineering Center River Analysis System
H&H	Hydrology & Hydraulics
HSC	Houston Ship Channel
LOS	Level-Of-Service
O&G	Oil & Gas
OPCC	Opinion of Probable Construction Costs
PER	Preliminary Engineering Report
PSF (50)	Total cumulative probable structural flooding over the 50-year period.
ROW	Right-of-Way
SUE	Subsurface Utility Engineering
TxDOT	Texas Department of Transportation
USACE	United States Army Corps of Engineers
WSEL	Water Surface Elevation
WSP	Water Surface Profile
WPP	Watershed Planning Project

1. Cloverleaf Flood Risk Reduction Project

1.1. Project Area

The Cloverleaf project area is located in the Carpenters Bayou Watershed (CBW) (HCFCD Unit No: N100-00-00) in east Harris County; bounded to the west by Greens Bayou watershed (HCFCD Unit No: P100-00-00) and to the east by San Jacinto River watershed (HCFCD Unit No: G100-00-00). The project area is approximately 473 acres within the Cloverleaf Community ("Cloverleaf"). Cloverleaf lies in the southwest portion of the CBW (**Figure 1**) and comprises of mostly older residential structures built between the 1940's and 1980's, with shallow roadside ditches that generally lack in sufficient drainage capacity. Modeled analyses reveal that flooding in this area is primarily driven by overland sheet flow runoff, insufficient drainage capacity, and aging infrastructure. Comparison of modeled results, flood claim history, and reconnaissance level assessments confirm these observations. Cloverleaf includes one critical facility (elementary school), a cemetery, a wetland area, and the project area has been surveyed for cultural resources.

Figure 1. General Cloverleaf Community Area

1.2. Project Description

The proposed preliminary project consists of a combination of: (1) a dual trunk line system (trunk line #1 and trunk line #2) and a (2) 109 acre-feet stormwater detention facility north of the San Jacinto Funeral Home and Memorial Park, for an approximate combined 50yr Level-of-Service (LOS) (**Exhibit 1**). This project aims to provide much needed drainage relief for this portion of Cloverleaf with the use of stormwater trunk lines serving as centralized drainage "arteries" and for allowing lateral tie-ins from roadside ditch connections (**purple** and **blue** dash lines in **Figure 2**), before safely out falling into a proposed detention or tying into existing drainage systems along Interstate Highway 10 (IH-10) frontage roads and eventually out falling into HCFCD Unit No.: P102-00-00 or P104-00-00. The project provides a flexible means for *phasing* trunk lines based on need and funding resources; as well as growing in drainage capacity with the community.

Proposed Phase #1 (Trunk line #1 and Cloverleaf Detention). Phase #1 comprises a proposed trunk line #1 (**blue** line in **Figure 2**) consisting of a buried 9 feet x 7 feet reinforced concrete box (RCB) with an alignment along Nancy Rose Street beginning with its headwaters near Victoria Street, turning eastward along Hillsboro Street, and out falling into the proposed detention facility north of the San Jacinto Funeral

Home and Memorial Park. Please note there is flexibility in the outfall placement of trunk line #1 depending on the placement of the detention basin within the best vacant parcels identified. Trunk line #1 has an approximate length of 2,950 feet. Similarly, the true placement of trunk line #1's headwater is flexible and depends on stakeholder engagement and available funding sources. It is currently proposed that segments along Nancy Rose Street – but north of Victoria Street – will entail improved roadside ditches on both sides of Nancy Rose Street to provide comparable drainage capacity before tying into the proposed RCBs. Flood relief at the community-level assumes future roadside ditch improvements for lateral street connections (**blue** dashed line in **Figure 2**) intersecting with trunk line #1 for improving sheet flow collection and drainage efficiency. An approximation of roadside ditch drainage improvements has been reflected in these planning-level cost estimates (based on the assumption that all streets north of Hershe Street will require roadside ditch improvements).

Figure 2. *Cloverleaf Flood Risk Reduction Project description*

Proposed Phase #2 (Trunk line #2). Phase #2 comprises a proposed trunk line #2 (**purple** line in **Figure 2**) consisting of a buried 10 feet x 7 feet RCB with an alignment along Cloverleaf Street, beginning with its headwaters near Hershe Street, and heading south before tying into the IH-10 frontage drainage system (westbound) with an eventual outfall into the P102-00-00 drainage system. Trunk line #2 has an approximate length of 6,870 feet. Phase 2 can also be considered a flexible enhancement to Phase 1 or the broader Cloverleaf community. Various options for outfall tie-ins are available depending on budget constraints and partnership potential. For example, Phase 2 trunk line tie-in options can include outfall into P104-00-00 directly south of IH-10, P102-00-00 westward on IH-10 frontage, the existing Freeport Road drainage system west of Hollywood Street or the existing southern outfall passing through the cemetery. All these tie-in options require a more detailed drainage analysis for determining available system capacity through further feasibility analyses.

Proposed Detention. The proposed detention (**red** and **yellow** polygons in **Figure 2**) provides approximately 109 acre-feet of potential storage for mitigating conveyance impacts from Phase 1 Cloverleaf Flood Risk Reduction Project. Preliminary analysis of this proposed basin assumes a partial parcel acquisition of approximately 15.8 acres (**red** polygon in **Figure 2**) and a pond depth of approximately 10 feet. The detention basin entails acquisition of already vacant lots (based on aerial imagery and site visits), owned by NorthStar Cemetery Texas San Jacinto LLC with an appraisal value of $2.3M (Harris County Appraisal District 2019). There is potential for expanding the basin capacity to include the full buyout of the parcel with an additional 1.8 acres (**yellow** dashed polygon in **Figure 2**) of the existing 17.6 acre parcel, yielding a maximum potential storage capacity of 125 acre-feet for the proposed basin. The basin would be equipped with the necessary gravity-driven outlet structure for tying into the existing outfall that appears to traverse eastwardly through Beltway 8 before out falling into HCFCD Unit No. N100-00-00.

Implementation Strategy. The overall project recommendations for the community of Cloverleaf lends itself to a phasing strategy with Phase #1 ("trunk line #1") and Phase #2 ("trunk line #2") and the simultaneous acquisition of property while other key project components are under construction. The damage reduction and cost estimates are thus broken into Phases 1 and 2 (**Figure 2** and **Exhibit 1**). Phase 1 can include the property acquisition and permitting for the detention basin and simultaneous construction of trunk line #1, while a feasibility analysis on the IH-10 frontage road drainage system is underway. Phase 2 of the implementation strategy might include the construction of trunk line #2.

1.3. Modeling Details and Results

Manning's Equation was used for sizing the proposed trunk lines. The proposed detention (**red** polygon in **Figure 3**) provides approximately 109 acre-feet of potential storage for mitigating conveyance impacts from Phase 1 Cloverleaf Flood Risk Reduction Project. The volume required to mitigate conveyance impacts from Phase 1 was evaluated using a Basin Development Factor (BDF) based approach for characterizing future drainage conditions combined with re-assessing changes in drainage area collection between existing and proposed conditions (**pink** [existing] and **blue** [proposed] polygons in **Figure 3, Exhibit 2**). The existing drainage area boundary delineation was informed by the existing conditions sheet flow model. The proposed drainage area boundary was delineated with the assumption that all roadside ditches north of Hershe Street will be graded to outfall into the proposed drainage basin under Phase 1 of the Cloverleaf Flood Risk Reduction Project.

Figure 3. Existing and Proposed Conditions drainage boundaries

Phase 1 of the Cloverleaf Flood Risk Reduction Project was modeled in HEC-RAS using coupled 1D/2D unsteady modeling techniques (**Figure 4**). The trunk line was modeled using lidded cross sections and the detention basin was burned into the terrain.

Figure 4: Maximum Depth for the 50-year storm event

Table 1 summarizes the project related assumptions used to model Phase 1. For example, the trunk line in the HEC-RAS 1D/2D unsteady model applies a series of distributed and ratioed flow hydrographs as lateral inflow boundary conditions from the associated N100J Carpenters Bayou Effective M3 HEC-HMS subbasin. The ratioed flows are based on the contributing drainage area that is expected to outfall into the proposed detention basin. The peak flow of this ratioed hydrograph is 338 cubic feet per second (cfs) for the 50yr rainfall event (NOAA Atlas 14 update). Phase 1 was also coupled with the HEC-RAS 1D/2D watershed wide model to more accurately capture tailwater conditions in HCFCD Unit No: N100-00-00.

Table 1. Phase 1 Preliminary Project Details

Phase 1 project component	Details on Phase 1
Trunk line #1	RCB Dimensions: 9 feet x 7 feet Slope of trunk line: 0.001 feet/feet Minimum cover: 0.5 feet Potential Constraints: Underground utilities
Detention Basin	Minimum capacity required:109 acre-feet Depth of basin: 10 feet Outfall weir elevation: 27 ft Outfall pipe diameter: 5 feet Side slope of basin: 4:1 Acquisition of full parcel (17.6 acres) for detention basin Potential Constraints: Permitting for wetland area and property acquisition

1.4. Potential Project Benefits

Based on 2D sheet flow modeling assessments, and the project's estimated 50yr LOS, project benefits (trunk lines [with assumed roadside ditch improvements for lateral tie-ins] and detention) have the potential for substantial flood damage reductions based on number of flooded structures removal for the 100yr storm; with the removal of approximately 187 structures (100yr) (**Exhibits 3** through **5, Table 2**). These benefits require further detailed analyses for verifying performance benefits, but such detailed evaluations are commonly reserved at the feasibility or Preliminary Engineering Report (PER) project phase. The proposed detention basin also invites opportunities for promoting neighborhood uplift with open green space, walking and bike trails surrounding the basin perimeter, and other outdoor recreational activities.

Table 2. Damage Reductions for Cloverleaf Flood Risk Reduction Project

Phase	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
Phase 1	206	99	661.9	373.1
Phase 1 & 2	206	19	661.9	24.4

*PSF(50): Total cumulative probable structural flooding over the 50-year period.

1.5. Opinion of Probable Construction Costs (OPCC)

Construction cost for the Cloverleaf Flood Risk Reduction Project was determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently being used on other watershed planning projects. The cost estimate summary for Phase 1 is provided in **Table 3**. A multiplier of 2.5 was used for property acquisition estimates. The total opinion of probable construction costs (OPCC) is estimated at $16.9M for Phase 1. These costs include a 30% contingency on construction costs (noting the roadside ditch improvements are included in the cost estimates for Phase 1). Please refer to **Appendix A** for a slightly more extended cost table for Phase 1 and Phase 2 of the Cloverleaf Flood Risk Reduction Project.

Table 3. OPCC estimates Cloverleaf Drainage Improvement

Phase 1- Cloverleaf Flood Risk Reduction Project	Cost ($ M)
Detention Basin Construction Cost	$3.01
Clearing and Grubbing	$0.01
Excavation and Disposal Trunk Line 1	$0.16
9x7 RCB Trunk Line 1	$2.51
Pavement Removal	$0.02
Concrete Pavement Replacement	$0.49
Subbase Replacement	$0.02
Regrade Roadside Ditch	$0.87
Construction Costs	**$7.08**
Engineering and Contingencies*	**$4.03**
ROW Acquisition	**$5.78**
Total Estimated Cost	**$16.89**

* There is a 30% contingency on construction costs.

1.6. Constraints

In this planning level analysis, there exist several likely constraints in need of re-evaluation at the PER level. Such constraints include underground utilities, environmental constraints, parcel and property acquisition, and the appropriate hydraulic modeling framework.

Property Acquisition. The detention basin entails acquisition of an already vacant lot (based on aerial imagery and site visits), owned by NorthStar Cemetery Texas San Jacinto LLC with an appraisal value of $2.3M (Harris County Appraisal District 2019). This could be a potential constraint as property acquisition is dependent on negotiations with the parcel landowners.

Environmental Constraints. The parcel under consideration for acquisition for the construction of the detention basin is partially classified as a wetland (**Figure 5**). It is unknown if permits will be required for the proposed detention basin and requires additional confirmation for regulatory compliance. Two potential landfill sites are also located south of this parcel, adjacent to the existing northern outfall. Confirmation is needed on the type of refuse or landfill material currently residing in this area.

Figure 5. Constraints for Phase 1 Cloverleaf Flood Risk Reduction Project

Feasibility Study. For the construction of Phase 2 (trunk line #2) there are three identified tie-in options identified: P102-00-00, P104-00-00 and the existing southern outfall that passes through the San Jacinto Memorial Park and Funeral Home (**Figure 6**). An analysis on the capacity of the culvert under IH-10 that connects with P104-00-00 is recommended. Tie in options for trunk line #2 can be finalized once a feasibility analysis is conducted on all three available options.

Figure 6. Tie-in Options for trunk line #2

Hydraulic Modeling. HEC-RAS 1D/2D unsteady model was used to model trunk line #1 and the proposed detention basin using lidded cross-sections and 2D flow areas. A 5 feet diameter pipe is used as the primary outfall control structure for establishing a hydraulic connection between the detention basin and N10-00-00. Phase 1 was coupled with the HEC-RAS 1D/2D watershed wide model to more accurately capture tailwater conditions in HCFCD Unit No: N100-00-00. Roadside ditch improvements have not been explicitly modeled and are recommended to be included in more detail at the PER level.

Underground Utilities. There are no apparent underground utilities identified in the preliminary analysis for the project area. It is recommended this assumption be verified with subsurface utility engineering (SUE) specifically along the streets where trunk lines are expected to be placed so that there are no conflicts with the trunk line and underground utilities.

2. N100-00-00 Channel Improvements

2.1. Project Limits

The channel improvements are recommended along a segment of N100-00-00 and are mainly located within the Channelview Community (**Figure 7, Exhibit 6**). The baseline conditions model revealed that the main stem N100-00-00 and tributary N109-00-00 experience out-of-bank flooding. A suite of alternatives for channel improvements were modeled and analyzed to identify the cost-effective alternative with potential for community uplift, and constructability. Comparison of modeled results, flood claim history, and reconnaissance level assessments confirm these observations. For this analysis, stream segments were examined by reviewing aerial imagery and the terrain topography. Stream segments that could be widened and deepened while minimizing disturbance to adjacent parcels as well as providing geomorphic stability were selected for improvements. Several channel improvements with varying bottom widths and channel slopes were conducted on stream segments to determine a combination that best and most likely maximizes flood risk reduction benefits to the riparian corridor along this segment of N100-00-00.

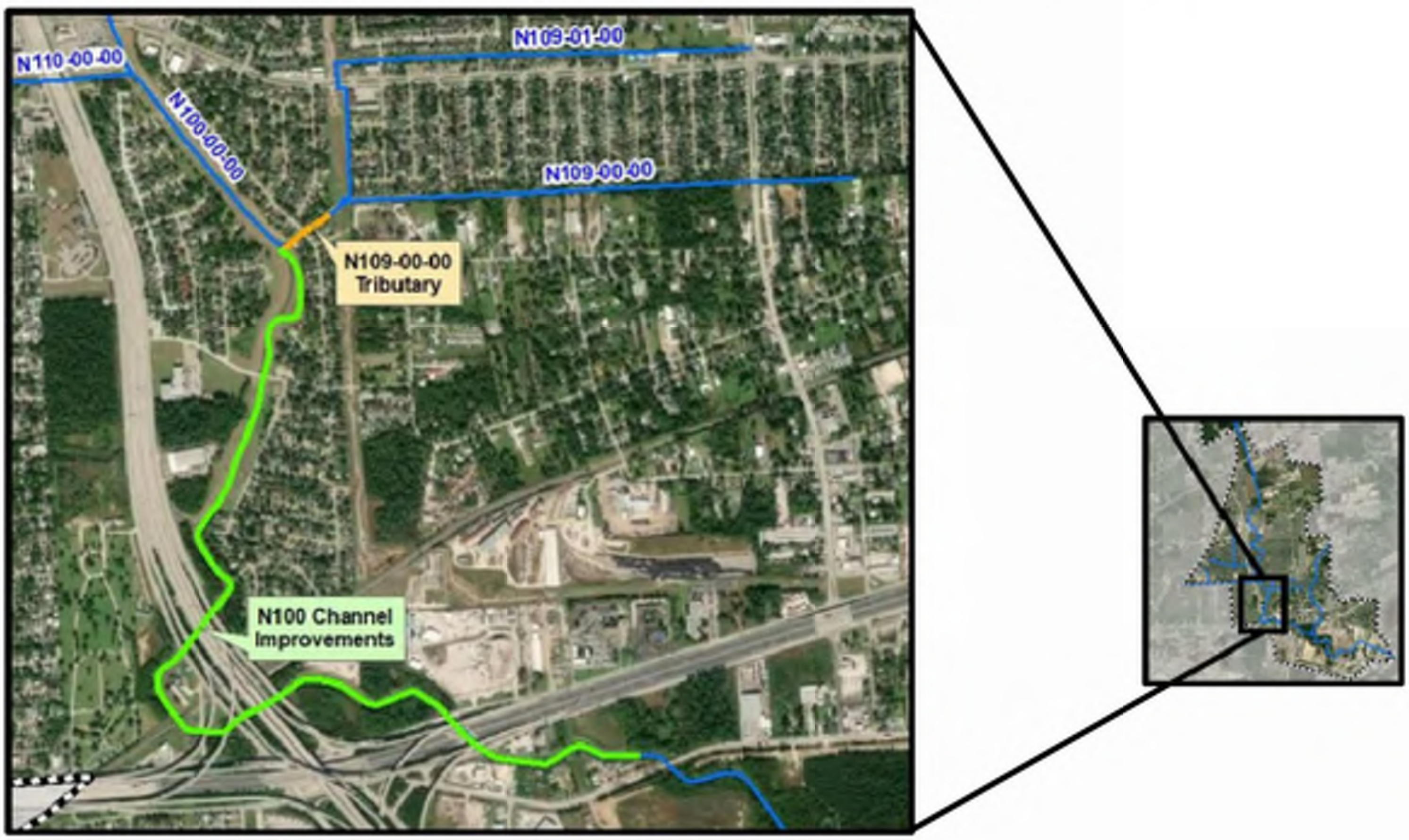


Figure 7. Segment of N100-00-00 channel improvements

2.2. Project Description

The preliminary project for this area consists of a proposed combination of (1) a segment of N100-00-00 channel improvements with a natural stable channel design grass-lined cross-section with, an average channel longitudinal slope of 0.05% (See **Figure 8** below for details of the cross section), (2) channel improvements at the bridge cross-sections, concrete lined with 60 feet bottom width and 1:1 side slope with an average channel longitudinal slope of 0.05%, (3) a short segment of N109-00-00 channel improvements with a 20 feet maximum bottom width and concrete-lined cross-sections at 2:1 side slopes with an average channel longitudinal slope of 0.2% and (4) 182 acre-feet stormwater detention facility to mitigate impacts downstream caused by the channel improvements.

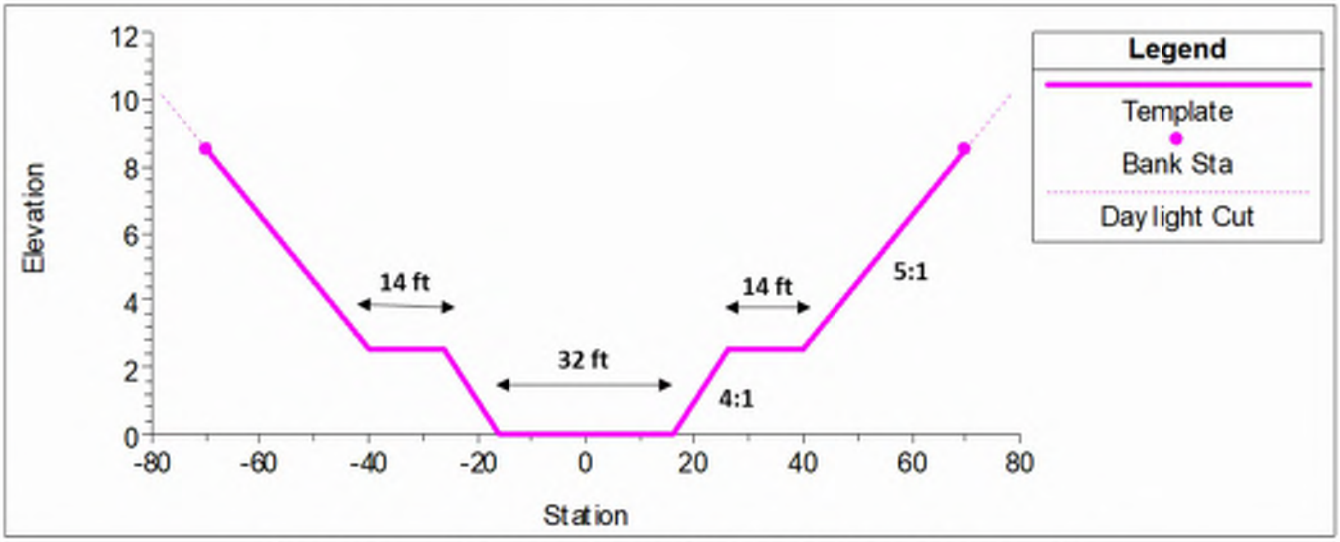


Figure 8: natural stable channel design for N100-00-00 channel improvements

It was determined that channelizing the segment of N100-00-00 starting downstream with tailwater limits just south of IH-10 and moving upstream to the confluence with N109-00-00 yielded the highest hydraulic benefits (**green** line in **Figure 7**). The length of channel improvements is approximately 9900 feet. A short segment of N109-00-00 is recommended for channelization starting just downstream of the pipeline owned by the Colonial pipeline company and improving downstream to the confluence of N100-00-00, tying into the N100-00-00 channel improvements (**yellow** line in **Figure 7**). The length of channel improvements on N109-00-00 is approximately 500 feet.

It is worth noting that – at the outfall with N100-00-00 – there is an existing N109-00-00 drop structure with baffles for dissipating high flow velocities. Consideration for additional drop structure enhancements warrant design re-evaluation with proposed N109-00-00 channel improvements near the general outfall vicinity. The dual culvert system at Overbluff Street upstream of the confluence was modeled with minor adjustments for transitioning surrounding channel improvements. Final placement of Overbluff Street RCB boxes, and their topographic transition into the N109-00-00 channel improvements are expected to be finalized at the feasibility or PER project phase.

Proposed Phase #1 (N100 Channel Improvements and Detention). Recommended phase 1 is ROW acquisition and construction of the detention facility and N100-00-00 channel improvements starting south of IH-10 to east of Beltway 8 (**green** line in **Figure 9**).

Figure 9. Phase #1 channel improvements N100-00-00

ROW acquisition consists of residential and commercial parcels. HCFCD owned parcels are located downstream of the confluence of N109-00-00 and N100-00-00 (**Figure 10**). While phase 1 is in progress, it is recommended that ROW acquisition for the remaining channel improvements take place so that project implementation can progress efficiently. The channel improvements for phase 1 start just downstream of IH-10 (**RS 22741.0**) and end at the Beltway 8 Frontage Road (**RS 28244.0**). The improvements cross IH-10, Beltway 8, the Missouri Pacific Railroad, and the Colonial/Explorer Pipeline. Phase 1 improvements are expected to take 5-10 years and is characterized as a mid-term to long-term project. Potential constraints with these improvements are discussed in section 2.6 of this report.

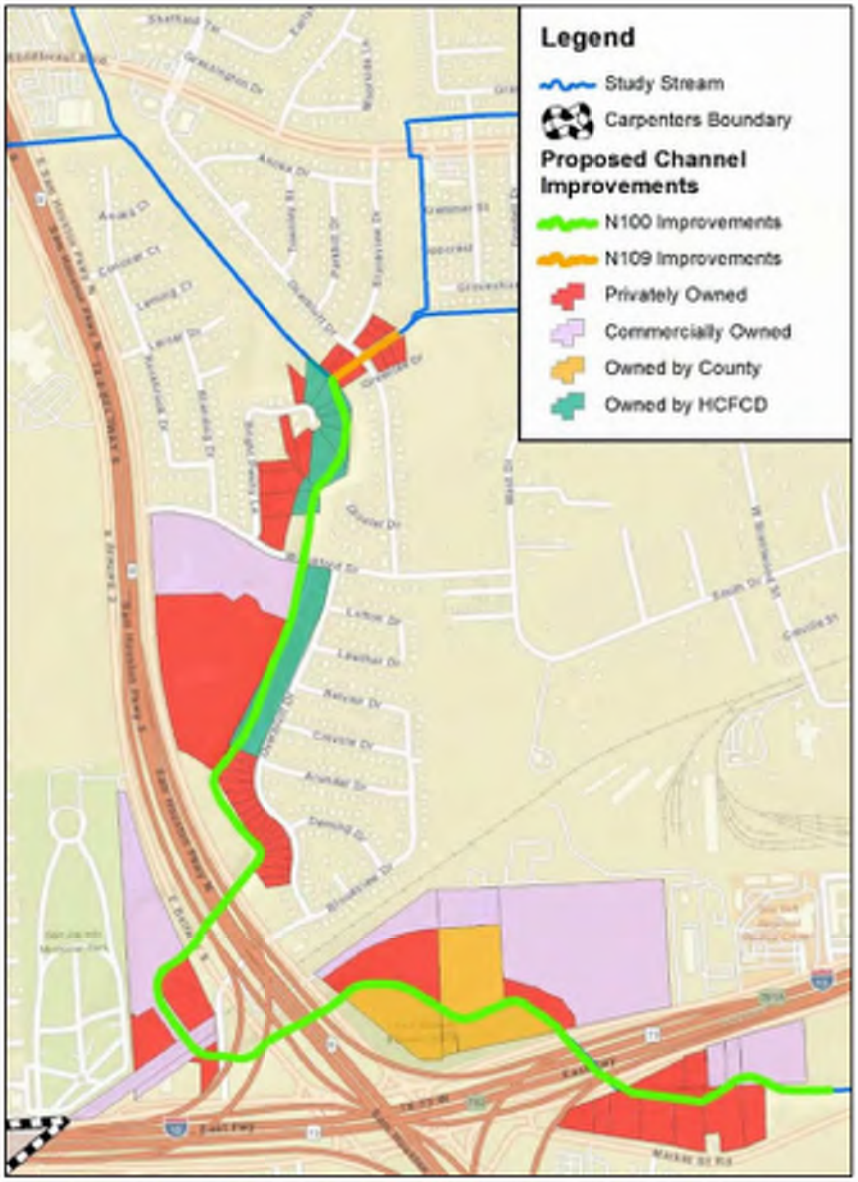


Figure 10. ROW acquisition for N100-00-00 channel improvements

N100 Channel Improvements, Proposed Phase #2 – Phase 2 consists of the remaining N100-00-00 channel improvements and N109-00-00 channel improvements. The **green** and **yellow** lines in **Figure 11** show the extent of phase 2 channel improvements. The N100-00-00 channel improvements for phase 2 start just upstream of Beltway 8 Frontage Road (**RS 28244.0**) and end at the confluence of N100-00-00 and N109-00-00 (**RS 31729.0**). The N109-00-00 channel improvements for phase 2 start downstream of the existing Colonial pipeline (**RS 511**) and tie in to the N100-00-00 channel improvements (**RS 30**). There is an existing N109-00-00 drop structure with baffles for dissipating high flow velocities located at the confluence. Consideration for additional drop structure enhancements warrant design re-evaluation with proposed N109-00-00 channel improvements near the general outfall vicinity. The dual culvert system at Overbluff Street upstream of the confluence was modeled with minor adjustments for transitioning surrounding channel improvements. Under phase 2 design details for these improvements are recommended to be re-evaluated and finalized. Phase 2 is expected to begin after phase 1 and overall, the project is expected to take beyond 10 years (long-term project). Potential constraints with these improvements are discussed in section 2.6 of this report.

Figure 11. Phase #2 channel improvements N100-00-00

Proposed Detention. The proposed detention (**red** and **yellow** polygons in **Figure 12**) provides approximately 182 acre-feet of potential storage for mitigating conveyance impacts from N100 channel improvements. Preliminary analysis of this proposed basin assumes a full parcel acquisition of approximately 8.5 acres and 5.5 acres (**red** and **yellow** polygons in **Figure 12**) and a pond depth of approximately 15 feet for the **red** polygon and 10 feet for the **yellow** polygon. The detention basin entails acquisition of already vacant lots (based on aerial imagery and site visits), owned by Harris County with an appraisal value of $1.0M (Harris County Appraisal District 2019). The proposed basin has a maximum potential storage capacity of 182 acre-feet. The basin would be equipped with the necessary side weir to allow flow from N100-00-00 channel improvements to enter the detention basins and a gravity-driven outlet structure for tying back into the channel downstream of the detention. Details of design of the detention basin, side weir, and outlet structures will be determined at the PER level.

Figure 12. Phase #2 Detention

2.3. Modeling Details and Results

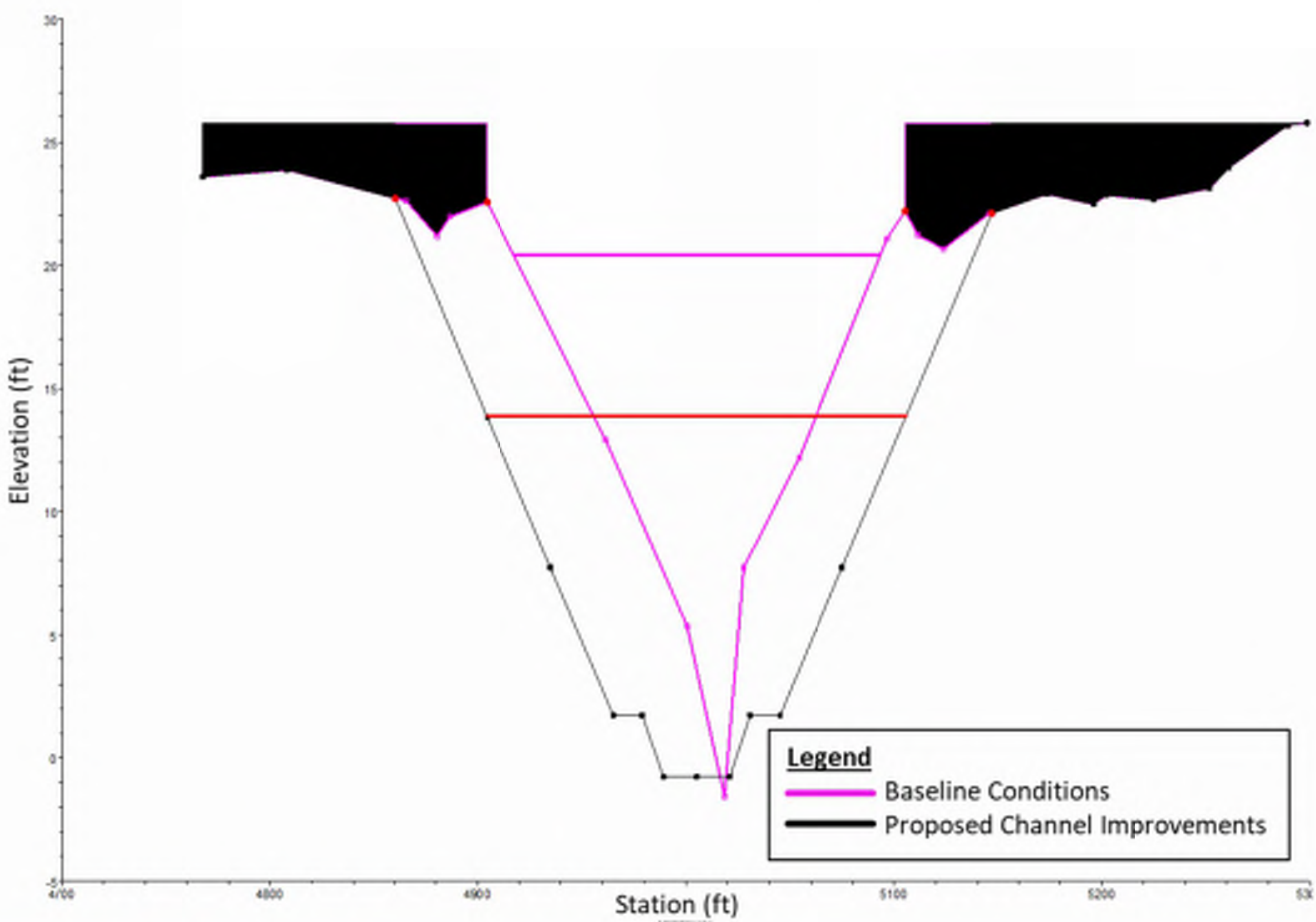
Channel improvements were modeled using HEC-RAS 1D/2D unsteady analysis. The channel improvements start from RS 22741.0 to RS 31729.0 with a natural stable channel design and a slope of

0.05%. **Table 4** and **Figure 13** describe the widening and deepening at bridge and culvert intersections and particular cross-sections under the proposed project.

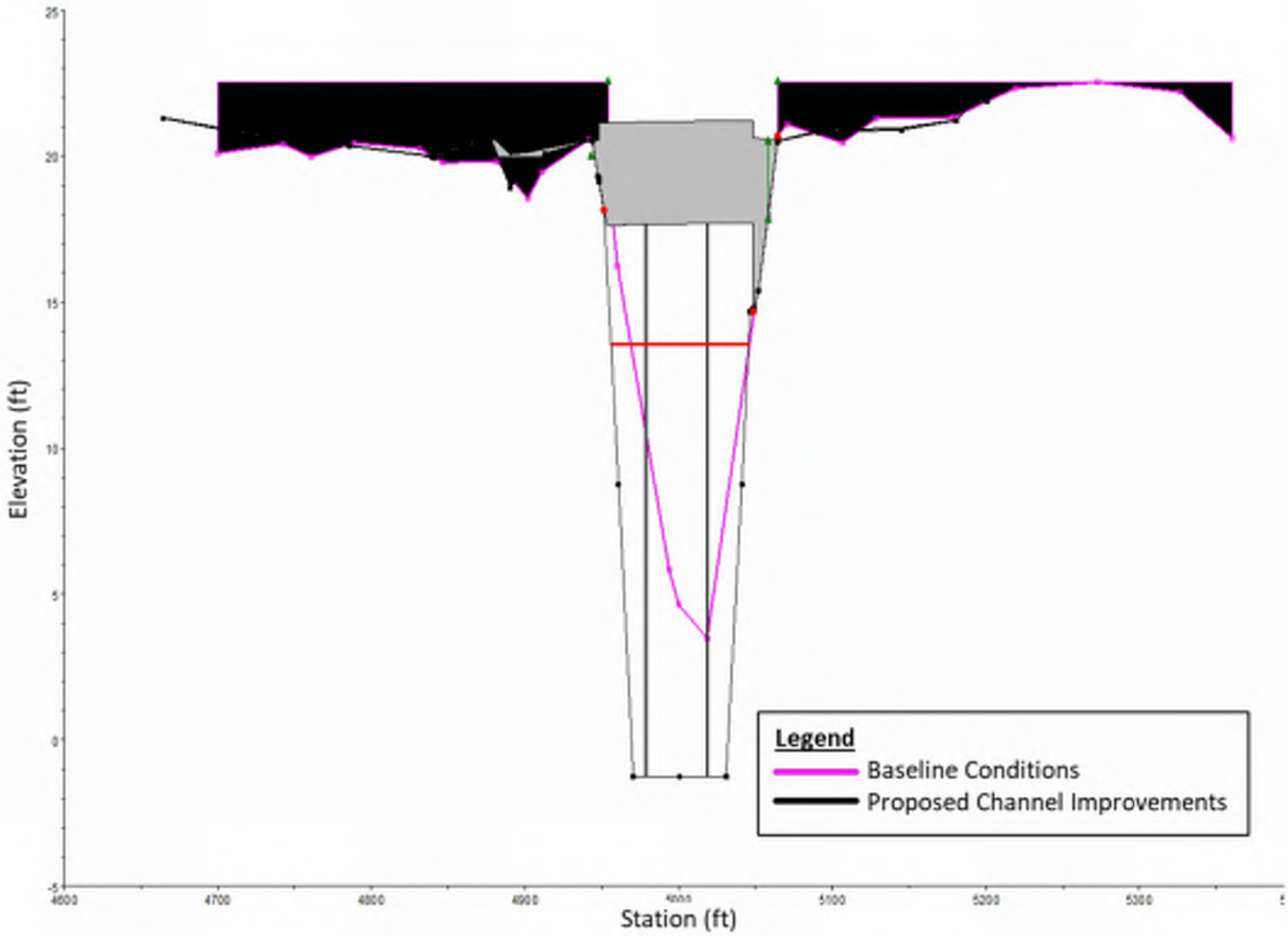
Table 4. Bridge modifications along N100-00-00 channel improvements

Reach	Station	Bridge Intersections	Sloping Abutments
N100-00-00_B	30712.0	Woodford Drive	Modified
N100-00-00_B	28244.0	Frontage Rd East-Fly over piers	N/A
N100-00-00_B	27792.0	Frontage West-Fly Over piers	N/A
N100-00-00_B	26974.0	Missouri Pacific Railroad	Not modified
N100-00-00_B	26717.0	Ramp from Beltway to I-10	Not Modified
N100-00-00_B	26379.0	Frontage East-Flyover piers	N/A
N100-00-00_B	25908.0	Frontage West-Flyover piers	N/A
N100-00-00_B	24126.0	Access Road West to Beltway 8	Modified
N100-00-00_B	23835.0	Interstate 10	N/A
N100-00-00_B	23691.0	South Access Road Interstate 10	N/A
N109-00-00	100	Overbluff Street	N/A

(a)



(b)


Elevation (ft)
Station (ft)
Legend
Baseline Conditions
Proposed Channel Improvements

(c)

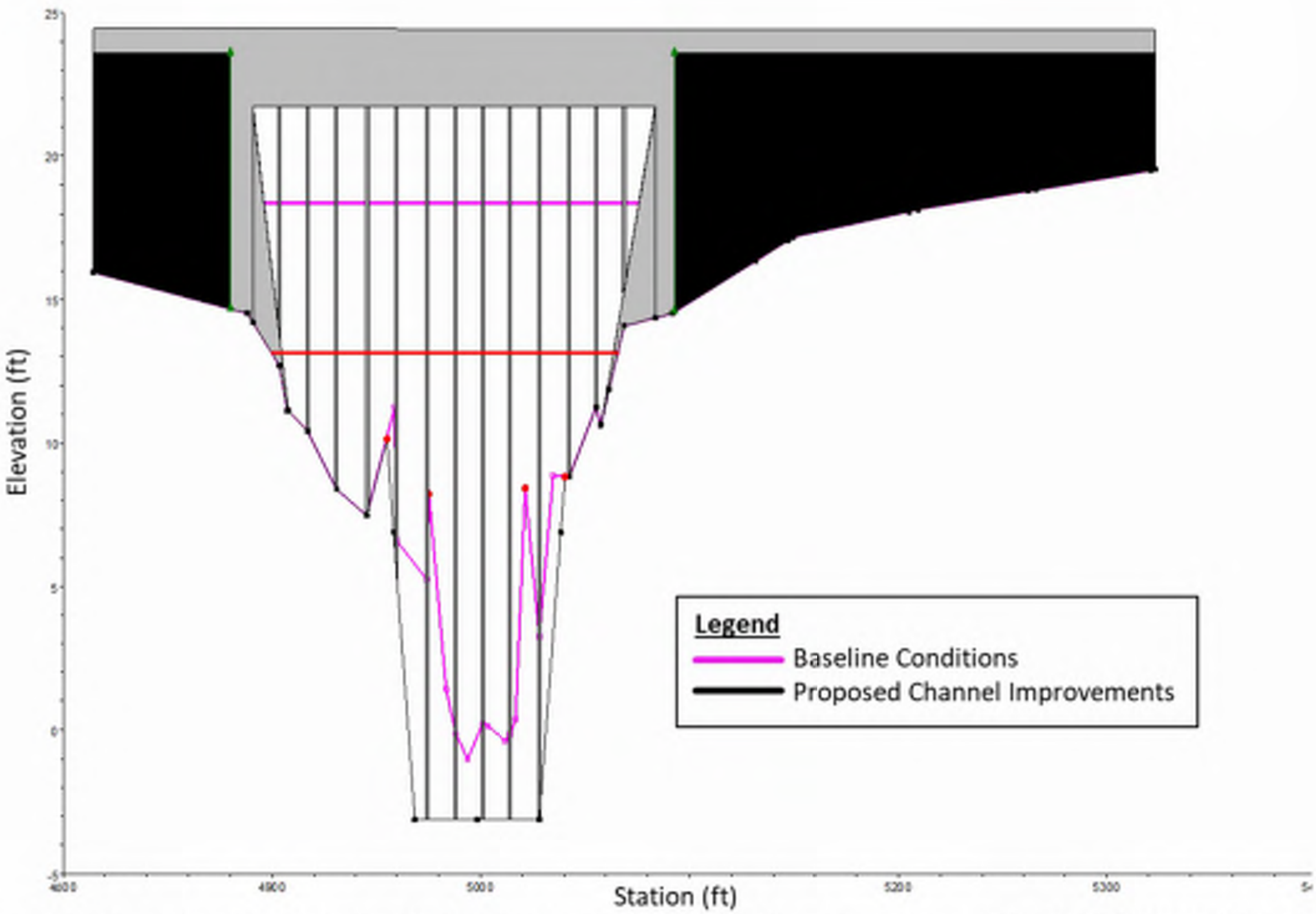


Figure 13. Comparison of cross-sections for Baseline Conditions vs. N100 Channel Improvements (a) RS 31729.0 (b) RS 30712.0- Woodford Drive and (c) RS 26974.0- Missouri Pacific Railroad

Generally, the channel improvements cause the water surface elevation to decrease downstream of Silver Green Drive extending out to HSC (**Exhibit 6**, **Table 5**). These reductions help reduce flood risk along this segment of the main stem. Generally, if channel improvements are left unmitigated, impacts downstream of these improvements can be adverse. A preliminary analysis shows an impact downstream of the improvements for the 100-year and 10-year storm events. This impact can be mitigated through the use of detention. These detention facilities have been modeled in HEC-RAS through the use of storage areas, a preliminary analysis shows that these facilities provide enough storage capacity to mitigate the impacts caused by channel improvements. The details of the design of the detention basins requires further detailed analyses, but such detailed evaluations are commonly reserved at the feasibility or PER project phase. The water surface profiles for the 10-year and 100-year storm events have been provided in **Appendix B**. The reduction in water surface elevations for the 10-year and the 100-year storm event is provided in **Table 5**.

Table 5. WSEL Reductions (100yr)

HEC-RAS XS	Bridge/Culvert	Baseline Conditions WSEL (ft) [100-year]	N100 Channel Improvements WSEL (ft) [100-year]	100-year Peak WSEL Reductions (ft)	Baseline Conditions WSEL (ft) [10-year]	N100 Channel Improvements WSEL (ft) [10-year]	10-year Peak WSEL Reductions (ft)
38969.0	Silver Green Dr	28.40	27.27	-1.13	25.27	24.2	-1.07
34841.0	Woodforest Road	26.15	23.14	-3.01	22.26	20.36	-1.9
30712.0	Woodford Drive	24.61	17.57	-7.04	20.28	13.78	-6.5
28244.0	Beltway 8 Flyover Piers	23.54	17.19	-6.35	19.14	13.43	-5.71
27792.0	Beltway 8 Flyover Piers	22.92	17.16	-5.76	18.85	13.39	-5.46
26974.0	Missouri Pacific Railroad	22.51	17.08	-5.43	18.55	13.36	-5.19
26717.0	Ramp from Beltway 8 to IH-10W	22.25	16.93	-5.32	18.23	13.24	-4.99
26379.0	Beltway 8 Flyover Piers	21.75	16.86	-4.89	17.75	13.18	-4.57
25908	Beltway 8 Flyover Piers	21.30	16.81	-4.49	17.53	13.14	-4.39
24126.0	Access Road West to Beltway 8	20.20	16.49	-3.71	16.76	12.88	-3.88
23835.0	IH-10	20.02	16.46	-3.56	16.64	12.85	-3.79
23691.0	South Access Road IH-10	19.18	16.35	-2.83	14.39	12.74	-1.65
21866.0	Market Street	17.84	15.89	-1.95	13.32	12.26	-1.06
20948.0	Old Railroad Bed	17.26	15.01	-2.25	12.37	11.38	-0.99
11570.0	South Sheldon Road	9.14	8.37	-1.13	4.88	4.84	-0.04

2.4. Potential Project Benefits

N100-00-00 channel improvements have the potential for substantial flood damage reductions based on number of flooded structures removal for the 100yr storm; with the removal of approximately 119 structures (100yr) (**Table 6, Exhibit 7**).

Table 6. Reduction in Flooded Structures

Location	Flooded Structures (100-year)		PSF(50)	
	Existing Conditions	Proposed Conditions	Existing Conditions	Proposed Conditions
N100-00-00	122	3	149.1	18.8
Watershed-wide	354	182	460	235.8

*PSF(50): Total cumulative probable structural flooding over the 50-year period.

The proposed channel improvements show large benefits along the main stem (N100-00-00) and at the confluence of N100-00-00 and N109-00-00. WSEL reductions are observed starting at Silver Green Drive and extending all the way to the Ship Channel for. **Appendix B** show the observed reductions in WSEL. Overall, approximately 188 acres of watershed area would potentially no longer be inundated during the 100-year storm event under proposed conditions when compared to the baseline existing conditions floodplain (8% reduction).

2.5. Opinion of Probable Construction Costs (OPCC)

Excavation costs for N100-00-00 channel improvements were determined using the cut and fill volume from HEC-RAS 1D/2D model. The utility adjustment and construction costs were determined using the unit costs provided by HCFCD in the form of a cost estimating tool currently used on watershed planning projects with a 2.5 multiplier. Partial and non-voluntary buyouts were considered for ROW acquisition with N100-00-00 channel improvements (**Exhibit 7**). Costs for the mitigation for the 10-year and 100-year storm events is included at a high planning-level. Thus, the contingency on construction costs for this project is higher than other projects (35%). Please refer to **Appendix A** for a slightly more extended cost table.

Table 7. Cost Estimates for N100-00-00 channel improvements

Channel Improvements N100	Cost ($ M)
Detention Basin 1 Construction Cost	$2.47
Detention Basin 1 Clearing and Grubbing	$0.05
Detention Basin 2 Construction Cost	$1.07
Detention Basin 2 Clearing and Grubbing	$0.03
Clearing, Grubbing, and Disposal	$0.28
Utility Adjustments (pipeline)	$0.26
Excavation (Off-Site Haul)	$3.69
Rock Rip-Rap	$0.22
Backslope Swale	$0.05
Backslope Drain Structure	$0.35
Bridge Modifications	$2.39
Construction Costs	**$10.87**
Engineering and Contingencies*	**$6.74**
ROW Acquisition	**$13.38**
Total Estimated Cost	**$30.98**

* There is a 35% contingency on construction costs.

2.6. Constraints

In this planning level analysis, there were several assumptions made to build the N100-00-00 channel improvements proposed conditions hydraulic models. These assumptions will need to be re-evaluated at the PER level. The assumptions are based on multiple bridge crossings, environmental constraints, ROW acquisition, hydraulic modeling, and channel design.

Bridge Crossings. There are eleven bridge crossings that intersect the segment of channel improvements. One of these crossings is the Missouri Pacific Railroad. The railroad crossing is proposed to be widened by approximately 60 feet with 1:1 side slope. The sloping abutments at the crossing have not been modified. Since the railroad crossing is a major crossing, a survey needs to be conducted to determine whether the widening of the railroad crossing will pose any constraint or additional costs. All bridge crossings except IH-10 have been modeled with 60 ft bottom width and 1:1 side slope and assume concrete lining 100 feet upstream and downstream of each bridge with most bridge abutments left unchanged. This causes the channel to narrow down at the bridge flattening out to the proposed channel natural stable side slope when the concrete lining ends. The IH-10 crossing has been modeled with the natural stable channel design (concrete-lined).

Woodford Drive (**RS 30712.0**) and the Ramp from Beltway 8 to IH-10 (**RS 26717.0**) abutments have been modified in the model, coordination with the Texas Department of Transportation (TxDOT) will determine whether the existing bridge abutments can be replaced or removed. It is important to note that enhancements to the existing baffles at the steep drop upstream of the confluence of N109-00-00 and N100-00-00 are also recommended and have been modeled as an inline structure. Moreover, the dual culvert system at Over bluff Street upstream of the confluence was modeled using the existing dimensions. However, adjustments to the placement of the dual culvert boxes are expected at the feasibility or PER project phase. The channel has been deepened by approximately 4 feet in this segment. The cost estimates include an estimate of modifications at all bridges. The channel design can be adjusted to accommodate any constraints at the bridge crossings.

Environmental Constraints. There is an Oil & Gas pipeline (Colonial Pipeline Company) that is located adjacent to the Missouri Pacific Railroad crossing. Since 1:1 side slope is recommended in this portion of the channel, it is assumed that the widening of the cross-section will not cause a conflict with this pipeline. Furthermore, concrete lining the channel at this crossing minimizes erosion of the banks over the pipeline. This assumption will have to be verified by a utility survey. Since the segment of channelized N100-00-00 improvements has already been modified previously, minimal environmental permitting requirements are expected.

ROW. The proposed parcels for ROW acquisition are either owned by HCFCD, privately owned, or commercially owned. Under proposed conditions, channel widening results in acquisition of 71 parcels for ROW along a segment of the main channel N100-00-00. If the centerline of the channel is shifted 80 feet to the west, starting from the confluence of N109 and N100 and ending at the outlet structure under Beltway 8 (**red** line in **Figure 14**), there is potential for substantial reductions in ROW acquisition costs because a lot of parcels on the west are owned by HCFCD. Furthermore, by shifting the centerline in this segment, modifications to the existing jogging trail can be avoided. Downstream of Beltway 8, a centerline shift of approximately 80 feet to the west is also recommended to avoid acquisition of land of a wastewater plant and save on ROW acquisitions through partial buyouts (**green** polygon in **Figure 14**). The segment of improvements between the outlet structure under Beltway 8 and Sam Houston Tollway is recommended to be shifted 60 feet east to maintain a 30 feet buffer between Sam Houston Tollway and the N100-00-00 channel improvements. **Figure 14** below shows comparisons between the ROW acquisition with the existing centerline and the shifted centerline.

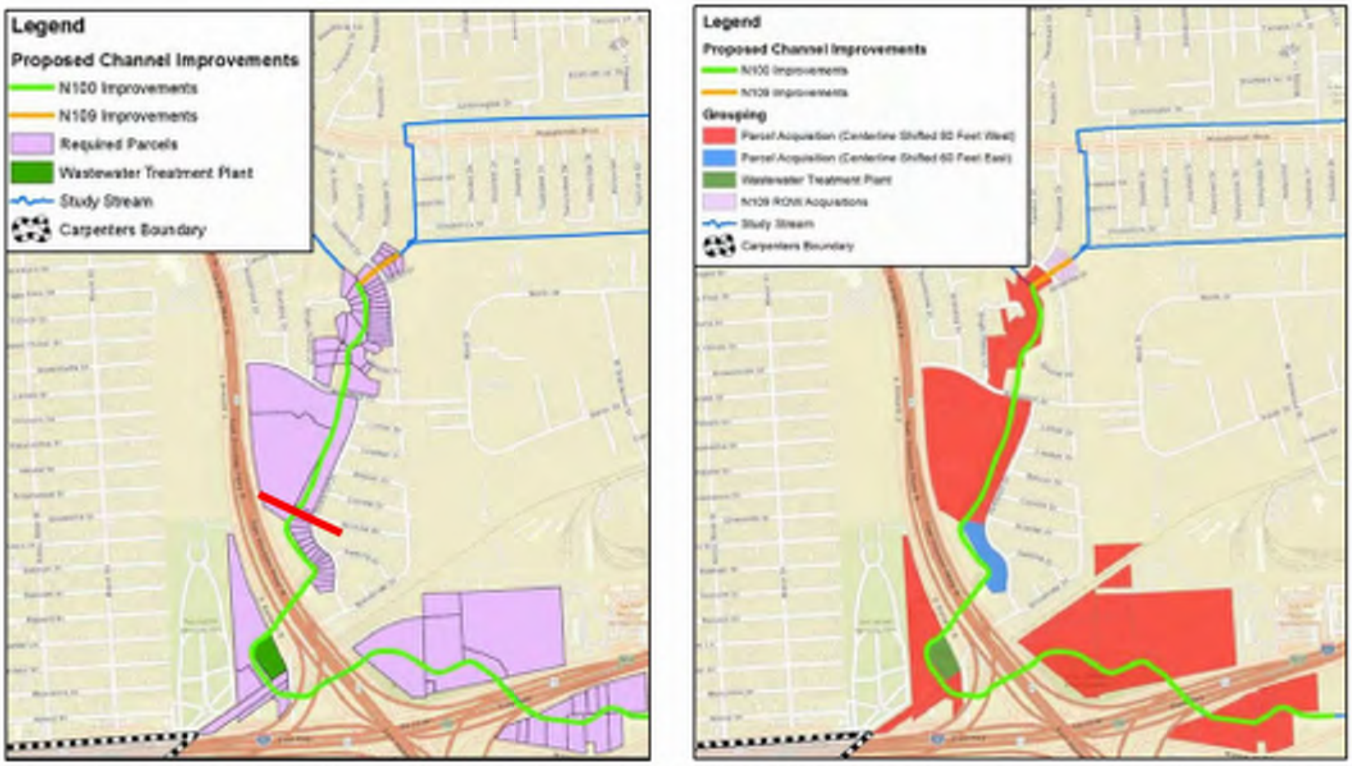


Figure 14. Comparison of ROW acquisition caused by centerline shift for N100 Channel Improvements (a) Existing centerline (b) Shifted Centerline

The cost estimates in section 2.5 use partial land acquisition for several parcels and full non-voluntary buyouts for others. **Figure 15** shows the parcels considered for full buyouts versus partial buyouts, and the parcels owned by HCFCD and Harris County. Overall, if there is no shift in centerline and full buyouts are considered for all intersecting parcels, the ROW acquisition costs would be approximately $15.4M, however with the centerline shift and considering partial buyouts the overall costs reduce to $6.0M. In section 2.5 the ROW cost estimates have an additional multiplier of 2.5 associated with them as per HCFCD guidelines. Land acquisition is dependent on negotiations with the landowners and thus is subject to change. If these parcels cannot be acquired, then the channel improvements will need to be adjusted.

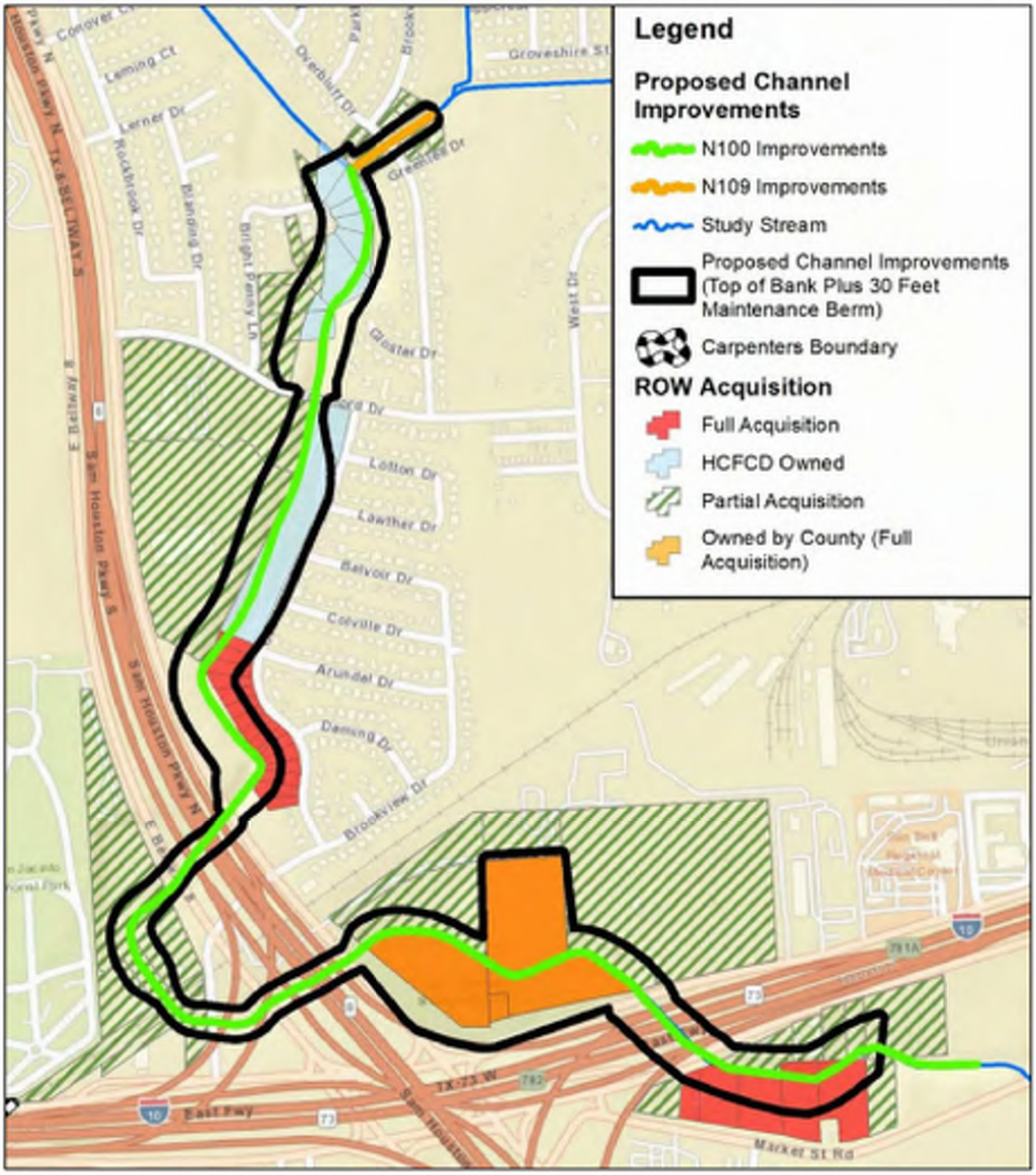


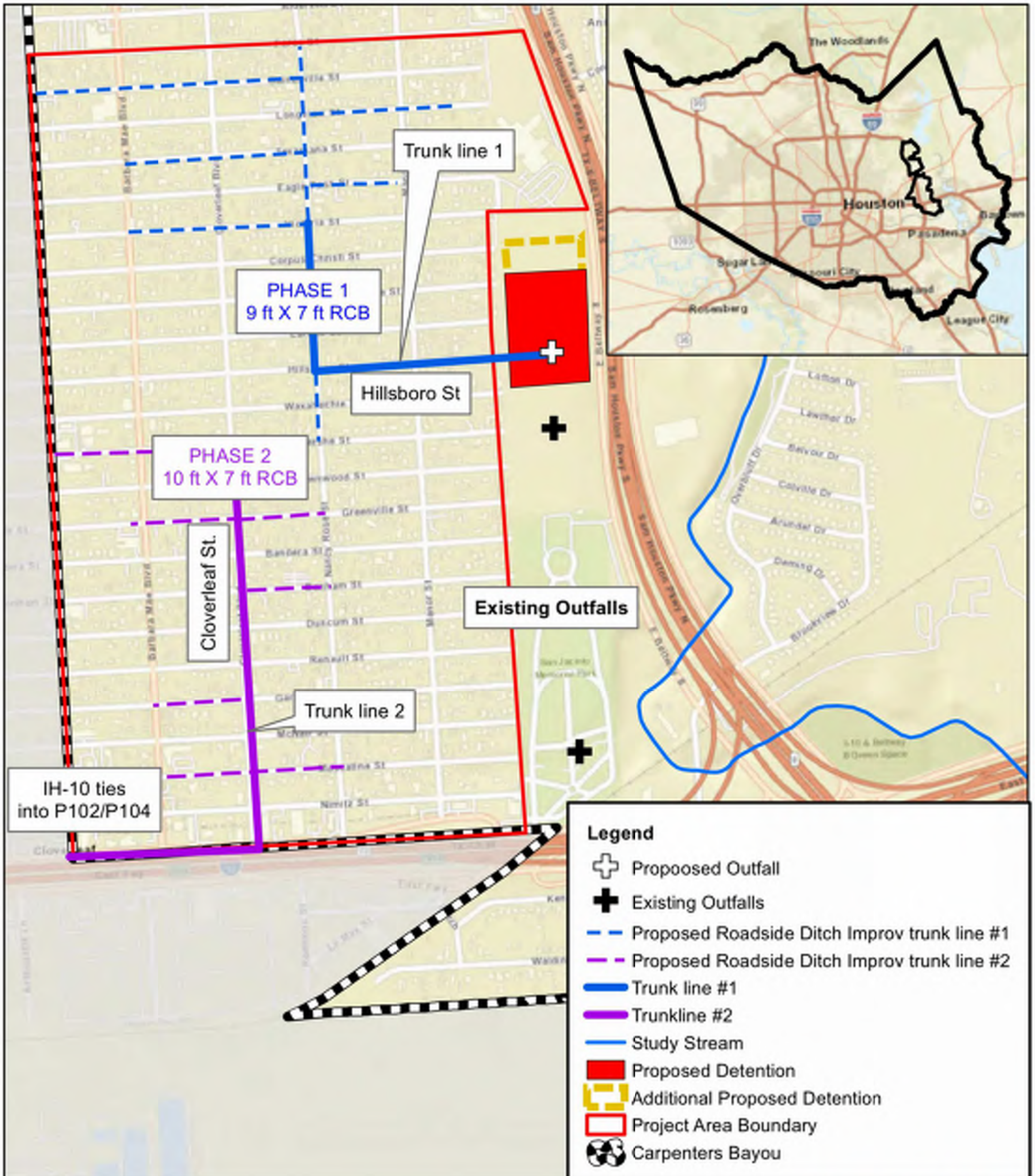
Figure 15. ROW acquisition for proposed Full and Partial Buyouts. (Note: Actual acreage of partial buyouts are subject to change and require further feasibility. This study assumes a representative partial acquisition needed to achieve proposed channel cross-section improvements with partial acquisitions reflected in cost estimates).

Mitigation Requirements. The detention basins recommended have been modeled using storage areas for planning purposes. The details of the design of the detention basins requires further detailed analyses, but such detailed evaluations are commonly reserved at the feasibility or PER project phase.

Hydraulic Modeling. The hydraulic models will need to be modified to include updates of Manning's n roughness coefficients, survey data for the channels and bridges, and any channel bathymetry. It is expected that the 1D/2D watershed-wide MAAPnext models will be available for use during the preliminary engineering analysis phase. It is recommended that these models be used for the final PER analysis of the recommended improvements.

List of Exhibits

List of Appendices

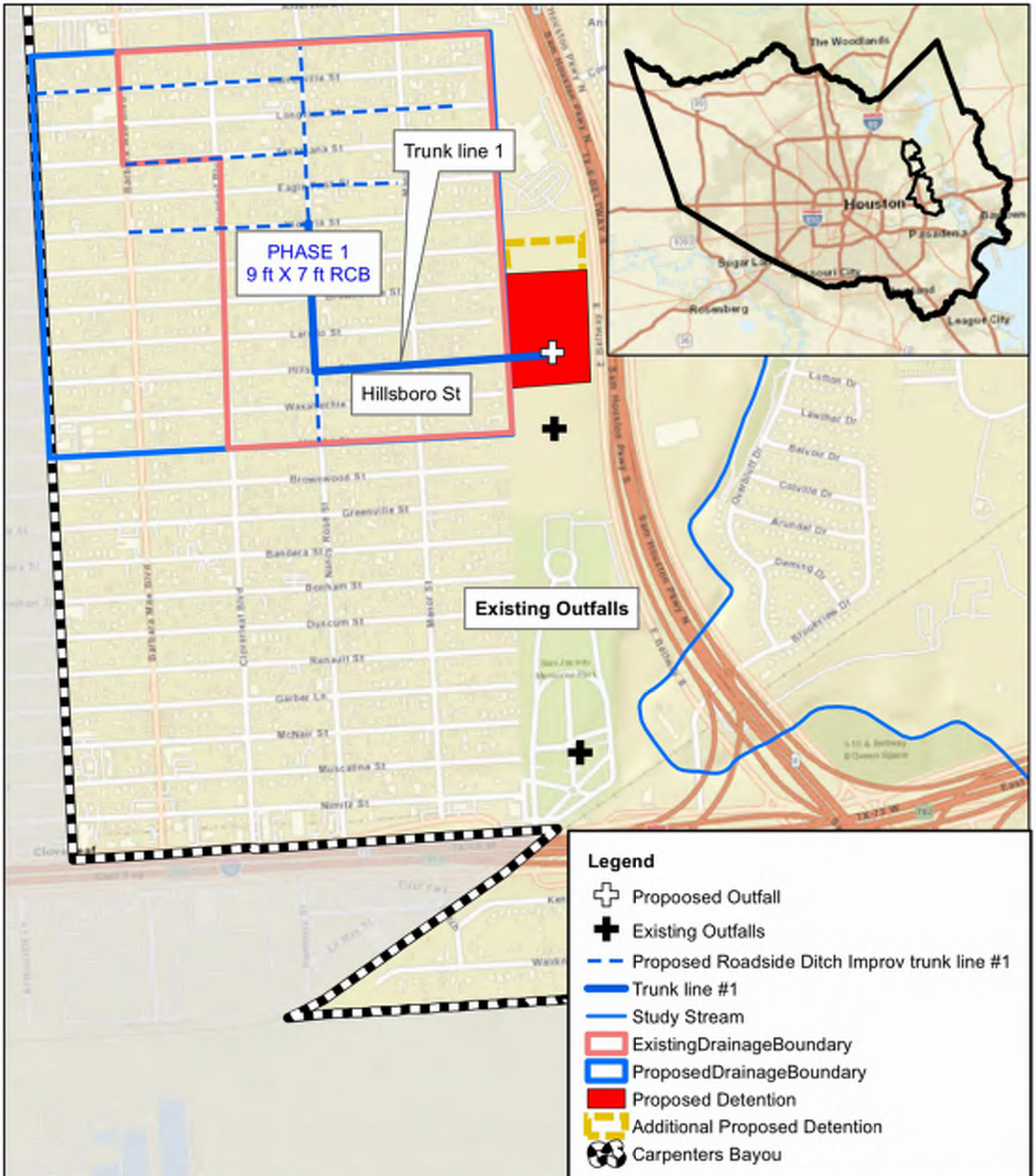


Preliminary Project Plan

Exhibit 01
Cloverleaf Flood Risk Reduction Project

Created: 10/27/2020

Carpenters Bayou Watershed Plan



Preliminary Project Plan

Exhibit 02
Cloverleaf Flood Risk Reduction Project
Drainage Boundaries Phase 1

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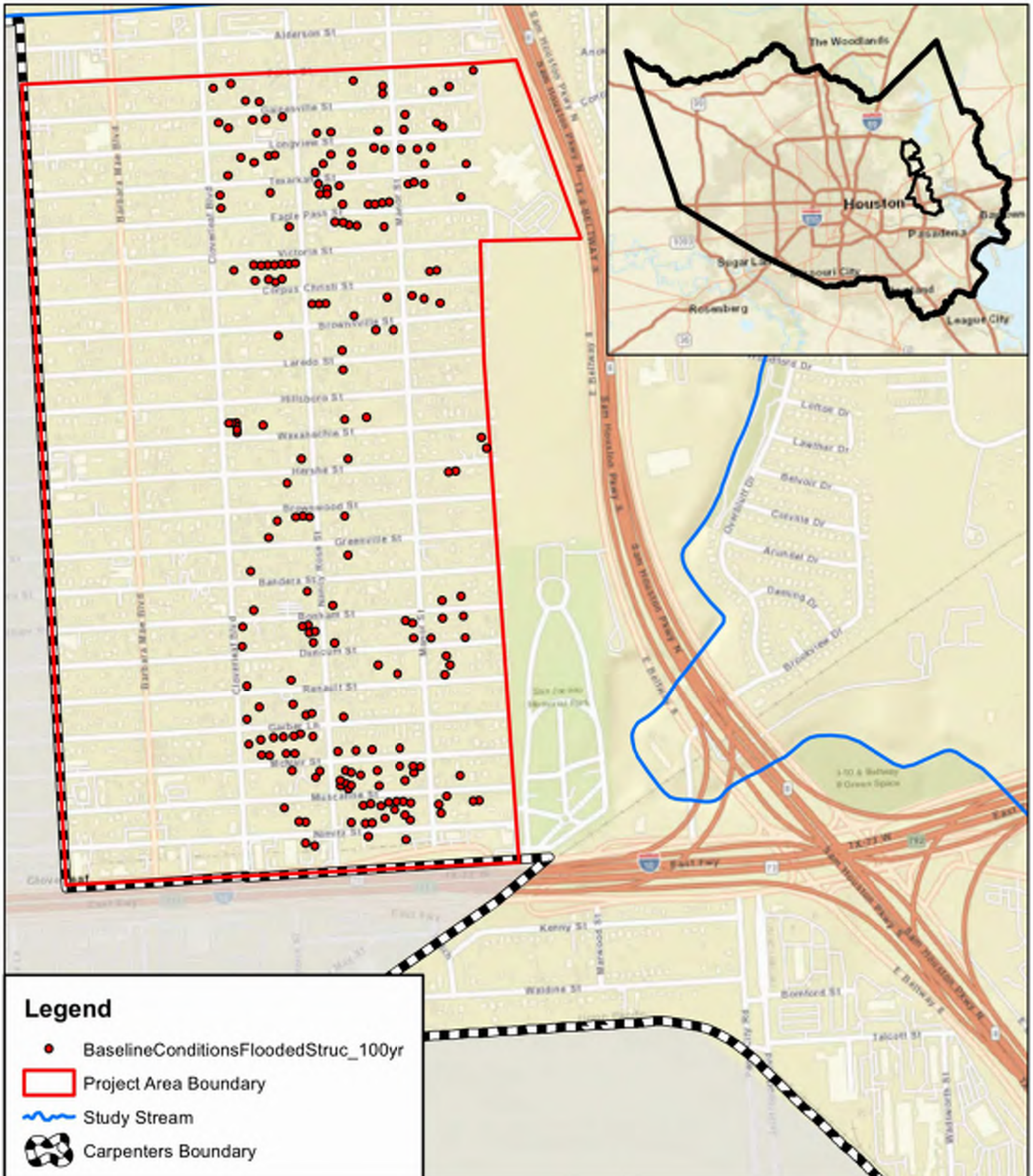
Created: 10/27/2020

Carpenters Bayou

Watershed Plan



Preliminary Project Plan

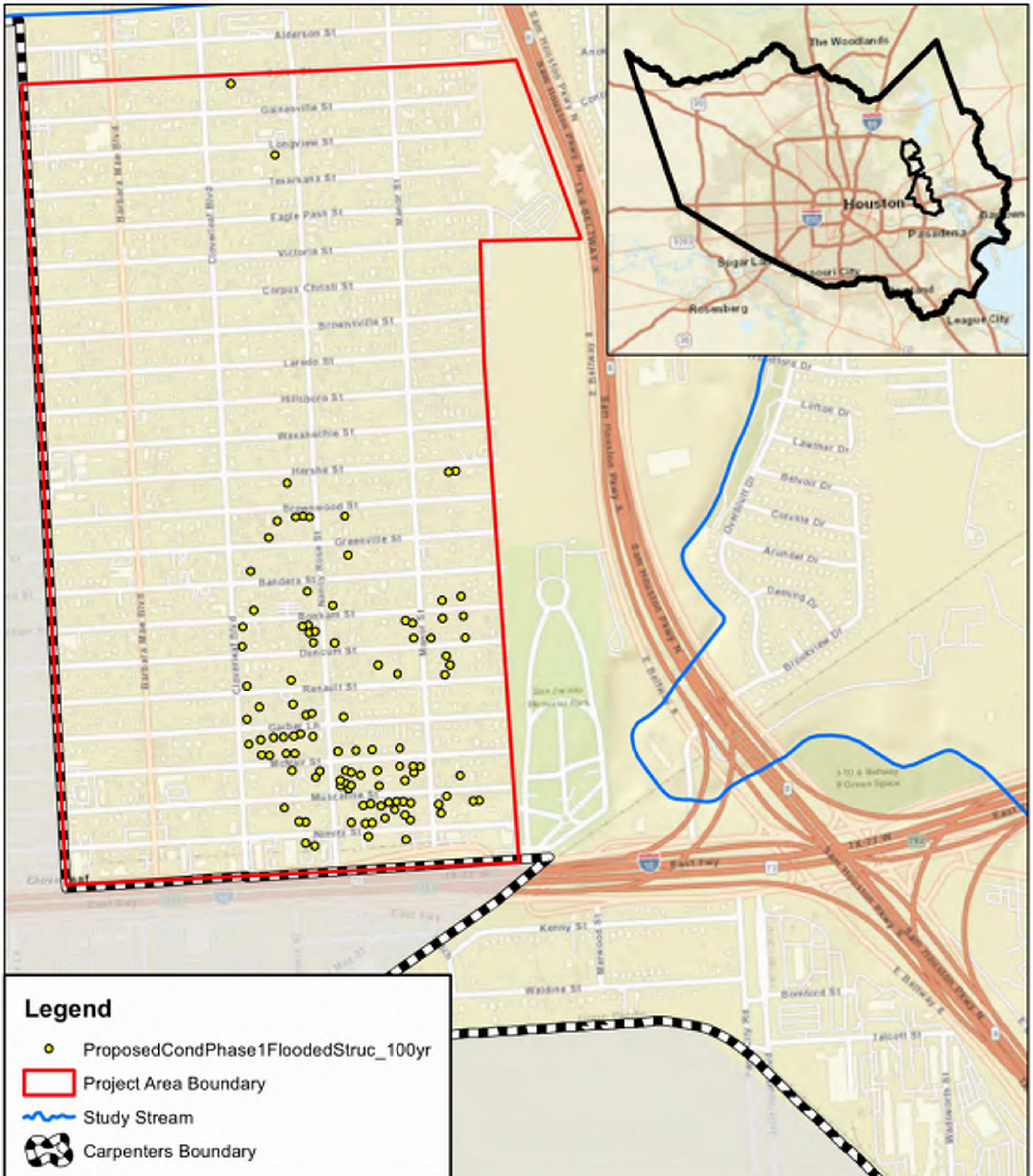
Exhibit 03
Cloverleaf Flood Risk Reduction Project Existing Conditions Flooded Structures 100-year

Created: 10/27/2020

Carpenters Bayou

Watershed Plan

Attachment #5 Interim Deliverable



Preliminary Project Plan

Exhibit 04
Cloverleaf Flood Risk
Reduction Project
Damage Reduction 100-year
Phase 1

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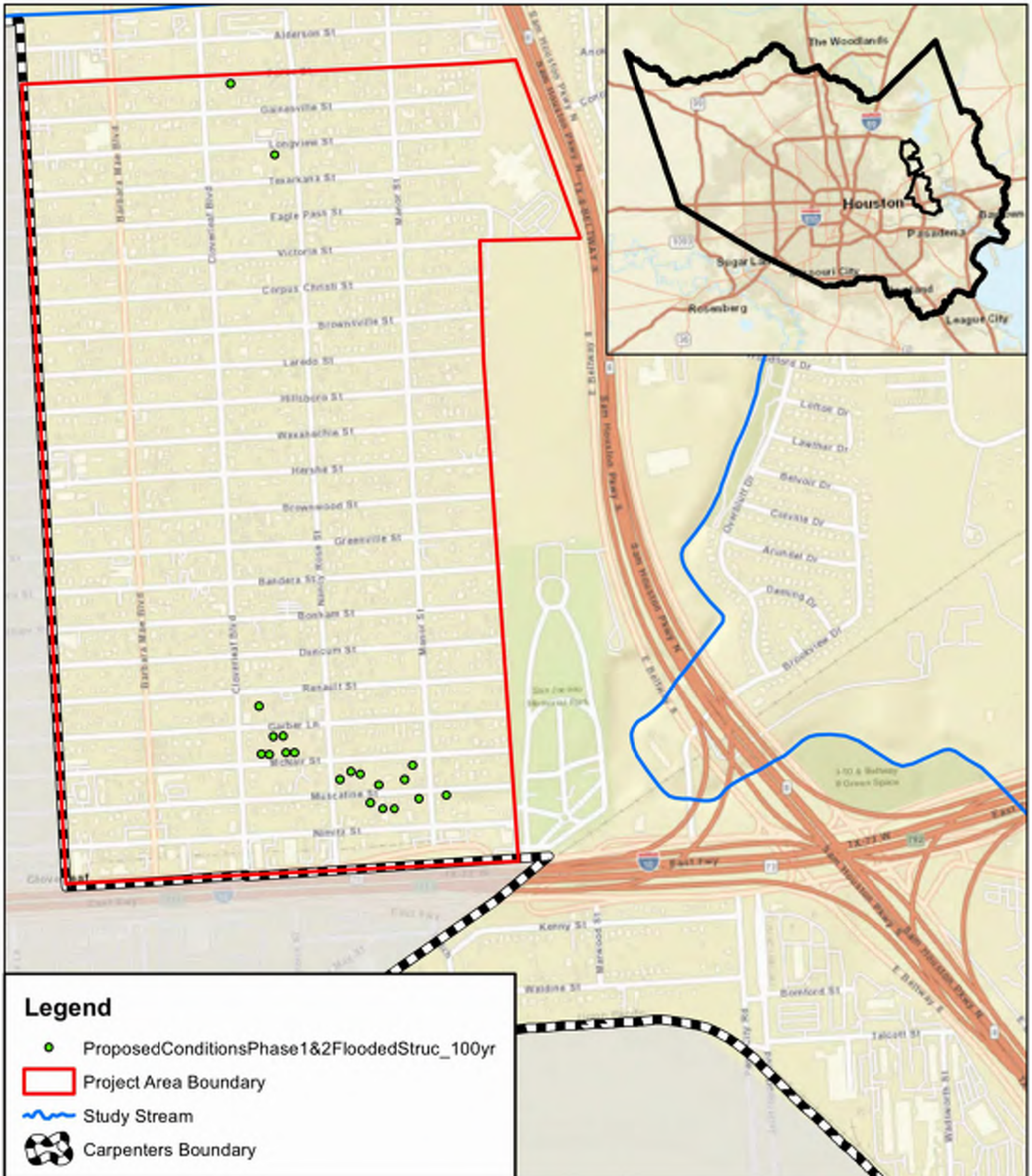
Created: 10/27/2020

Carpenters Bayou
Watershed Plan

Attachment #5 Interim Deliverable



Preliminary Project Plan

Exhibit 05
Cloverleaf Flood Risk Reduction Project
Damage Reduction 100-year
Phase 1 and Phase 2

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Created: 10/27/2020

Carpenters Bayou

Watershed Plan

Preliminary Project Plan

Miles

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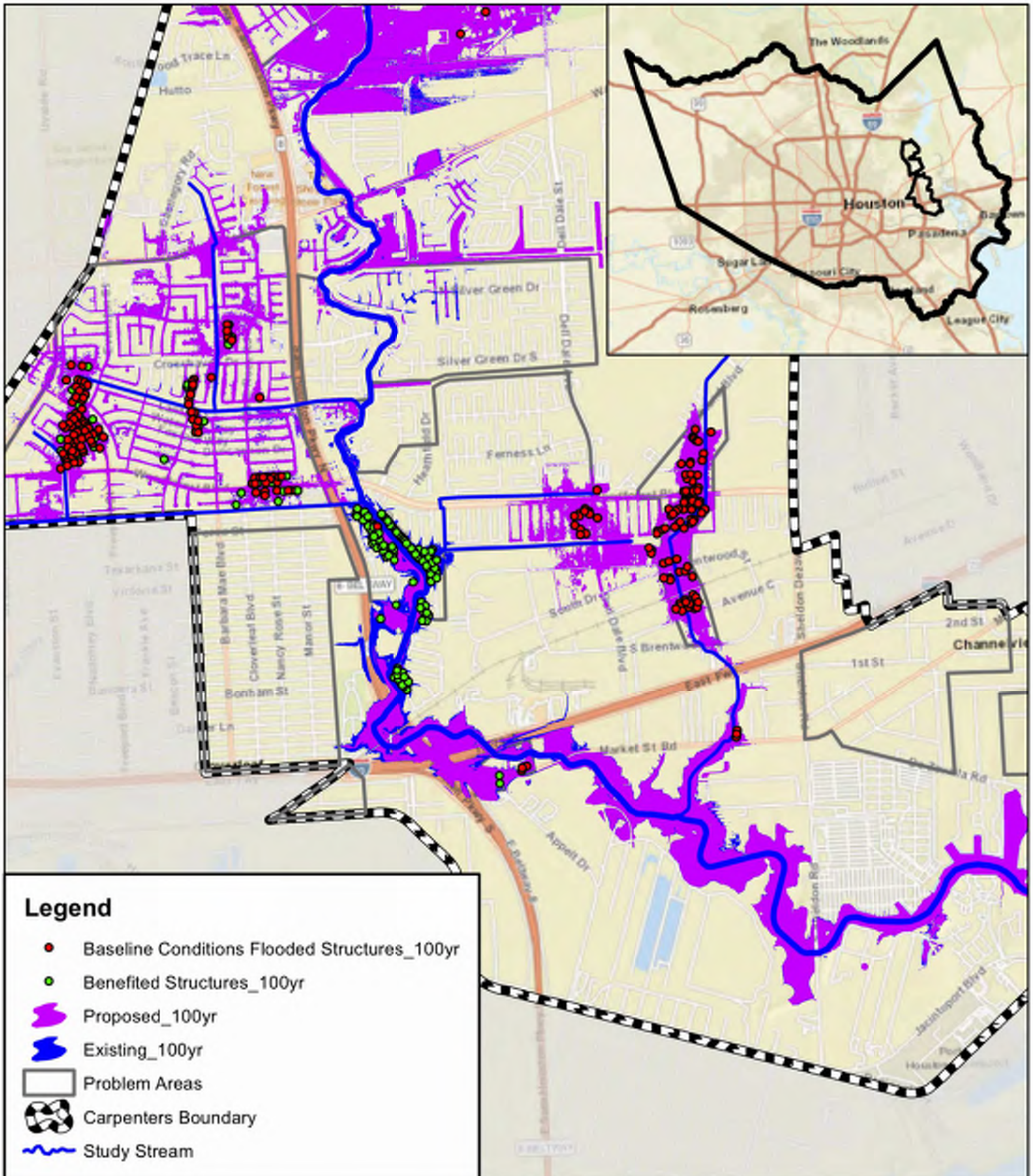
Exhibit 06
N100-00-00
Channel Improvements

Created: 12/1/2020

Carpenters Bayou
Watershed Plan

Attachment #5 Interim Deliverable



Preliminary Project Plan

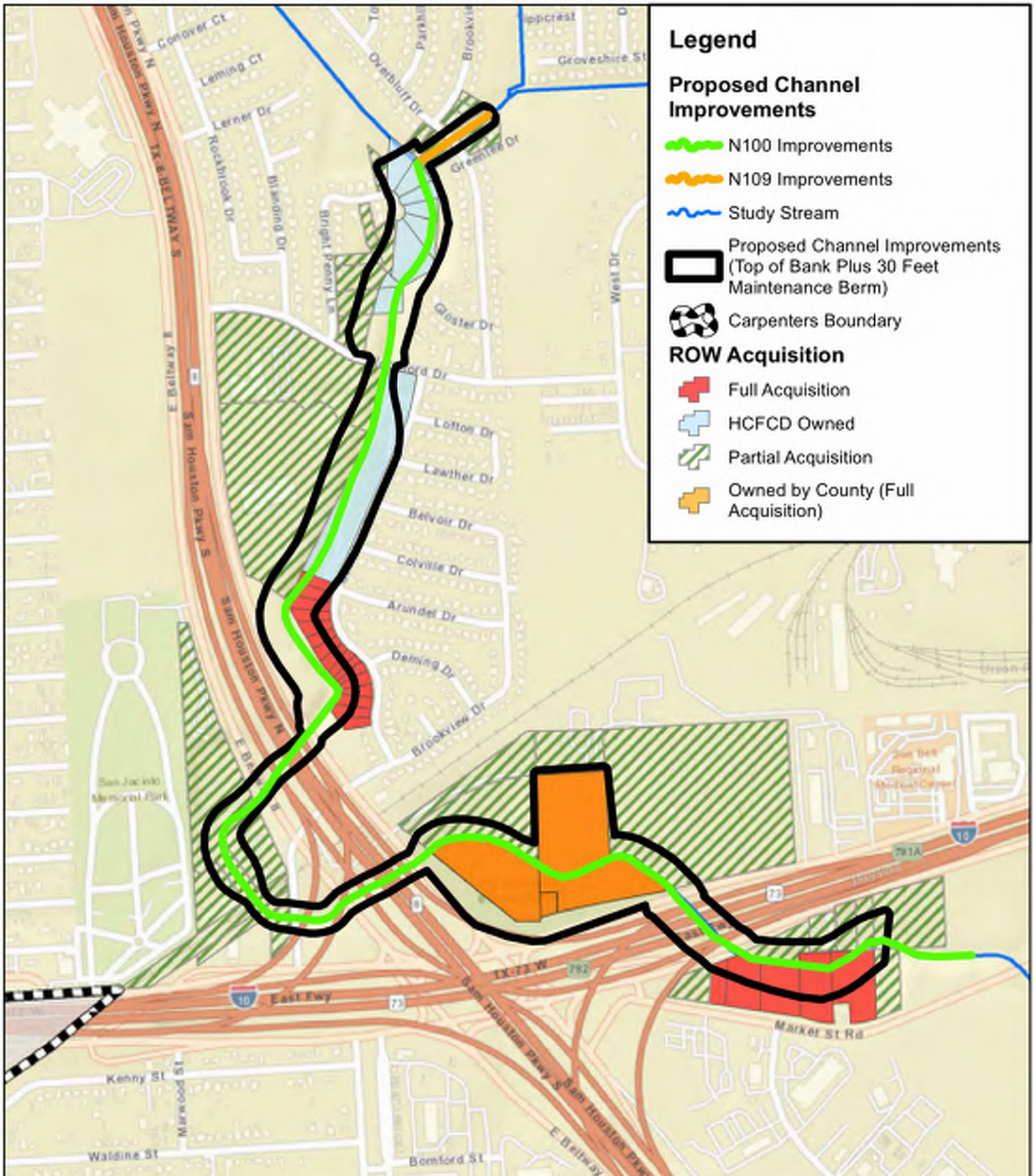
Exhibit 07
N100-00-00
Channel Improvements
Flooded Structures and
Inundation Map 100-year

Created: 10/27/2020

Carpenters Bayou

Watershed Plan

Attachment #5 Interim Deliverable



Preliminary Project Plan

Exhibit 08
N100-00-00
Channel Improvements
ROW Acquisition

Miles
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Created: 12/1/2020

Carpenters Bayou Watershed Plan

Appendix A

Cost Estimates

Cloverleaf Flood Risk Reduction Project (Phase 1)

Cloverleaf Drainage Improvement	Quantity	Unit	Unit Cost	Cost	Comment
Detention Basin					
Clearing, Grubbing, and Disposal	15.8	AC	$ 6,200	$ 98,000	From HCFCD Cost Tool
Excavation (Off-Site Haul)	213,893	CY	$ 12	$ 2,567,000	From HCFCD Cost Tool
Concrete Pilot Channels	4,225	SY	$ 55	$ 233,000	From HCFCD Cost Tool
Turf Establishment (Sodding / Seeding)	13	AC	$ 3,600	$ 49,000	From HCFCD Cost Tool
Backslope Swale	3,410	FT	$ 5	$ 18,000	From HCFCD Cost Tool
Backslope Drain Structure	10	EA	$ 3,500	$ 35,000	From HCFCD Cost Tool
Backslope Interceptor Rip-rap	100	SY	$ 80	$ 8,000	From HCFCD Cost Tool
Detention Basin Construction Cost			**Subtotal**	**$ 3,006,000**	
Site Preparation					
Clearing and Grubbing (Trunk line #1)	1.4	AC	$ 6,500	$ 9,000	
Earthwork					
Excavation and Disposal Trunk Line #1	16,394	CY	$ 10	$ 164,000	The volume was based on a 15ft width, trunk line length and 10 ft depth
Storm Sewer					
9x7 RCB Trunk Line #1	2,951	LF	$ 850	$ 2,509,000	Using cost tool and Manning's equation calculation, along Hershe St and Nancy Rose St
Pavement Removal	6,558	SY	$ 3	$ 20,000	Unit cost from cost tool
Concrete Pavement Replacement	6,558	SY	$ 75	$ 492,000	Unit cost from cost tool
Subbase Replacement	7,214	SY	$ 2	$ 15,000	Unit cost from cost tool
Regrade Roadside Ditch (Gainesville St)	6780	LF	$ 10	$ 68,000	length of road multiplied by 2
Regrade Roadside Ditch (Longview St)	6760	LF	$ 10	$ 68,000	length of road multiplied by 2
Regrade Roadside Ditch (Texarkana St)	6760	LF	$ 10	$ 68,000	length of road multiplied by 2
Regrade Roadside Ditch (Eagle Pass St)	6760	LF	$ 10	$ 68,000	length of road multiplied by 2
Regrade Roadside Ditch (Victoria St)	6660	LF	$ 10	$ 67,000	length of road multiplied by 2
Regrade Roadside Ditch (Corpus Christi St)	6740	LF	$ 10	$ 68,000	length of road multiplied by 2
Regrade Roadside Ditch (Brownsville St)	6700	LF	$ 10	$ 67,000	length of road multiplied by 2
Regrade Roadside Ditch (Laredo St)	6700	LF	$ 10	$ 67,000	length of road multiplied by 2
Regrade Roadside Ditch (Hillsboro St)	4020	LF	$ 10	$ 41,000	length of road multiplied by 2
Regrade Roadside Ditch (Waxahachie St)	6700	LF	$ 10	$ 67,000	length of road multiplied by 2
Regrade Roadside Ditch (Nancy Rose St)	4000	LF	$ 10	$ 40,000	length of road multiplied by 2
Regrade Roadside Ditch (Manor St)	5920	LF	$ 10	$ 60,000	length of road multiplied by 2
Regrade Roadside Ditch (Barbara Mae St)	5880	LF	$ 10	$ 59,000	length of road multiplied by 2
Regrade Roadside Ditch (Cloverleaf St)	5900	LF	$ 10	$ 59,000	length of road multiplied by 2
Construction Costs (incuding Detention Bain)			**Subtotal**	**$ 7,076,000**	
			Engineering and Contingencies		
Feasability Study	1	%	5%	$ 354,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 850,000	Percentage of construction costs
Construction Management	1	%	10%	$ 708,000	Percentage of construction costs
Contingencies	1	%	30%	$ 2,123,000	Percentage of construction costs
			Subtotal	**$ 4,033,000**	
			ROW Acquistition		
Texas San Jacinto Memorial Park & Funeral Home	100%	%	$ 2,312,250	$ 2,313,000	Value as of January 1st, 2019, HCAD
Total ROW acquisition cost			**Subtotal**	**$ 5,781,000**	Subtotal*2.5 (multiplier)
			Total Estimated Cost	**$ 16,890,000**	

Cloverleaf Flood Risk Reduction Project (Phase 2)

Cloverleaf Drainage Improvement (Phase 2)	Quantity	Unit	Unit Cost	Cost	Cost	Comment
Site Preparation						
Clearing and Grubbing	3.2	AC	$ 6,500	20,509	$ 21,000	
Earthwork						
Excavation and Disposal Trunk Line 2	38,178	CY	$ 10	381,778	$ 382,000	The volume was based on a 15ft width, trunk line length and 10 ft depth
Storm Sewer						
10X7 RCB Trunk Line 2	6,872	LF	$ 715	4,913,480	$ 4,914,000	Using cost tool and Manning's equation calculation, along Cloverleaf St and I-10
Pavement Removal	15,271	SY	$ 3	45,813	$ 46,000	Unit cost from cost tool
Concrete Pavement Replacement	15,271	SY	$ 75	1,145,333	$ 1,146,000	Unit cost from cost tool
Subbase Replacement	16,798	SY	$ 2	33,596	$ 34,000	Unit cost from cost tool
Construction Costs			**Subtotal**	**$ 6,540,509.61**	**$ 6,541,000**	
			Engineering and Contingencies			
Feasability Study	1	%	5%	$ 327,025.48	$ 328,000	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 784,861.15	$ 785,000	Percentage of construction costs
Construction Management	1	%	10%	$ 654,050.96	$ 655,000	Percentage of construction costs
Contingencies	1	%	30%	$ 1,962,152.88	$ 1,963,000	Percentage of construction costs
			Subtotal	**$ 3,728,090.48**	**$ 3,729,000**	
			ROW Acquistition			
		%	$ -	$ -	$ -	
Total ROW acquisition cost			**Subtotal**	**$ -**	**$ -**	
			Total Estimated Cost	**$ 10,268,600.09**	**$ 10,269,000**	

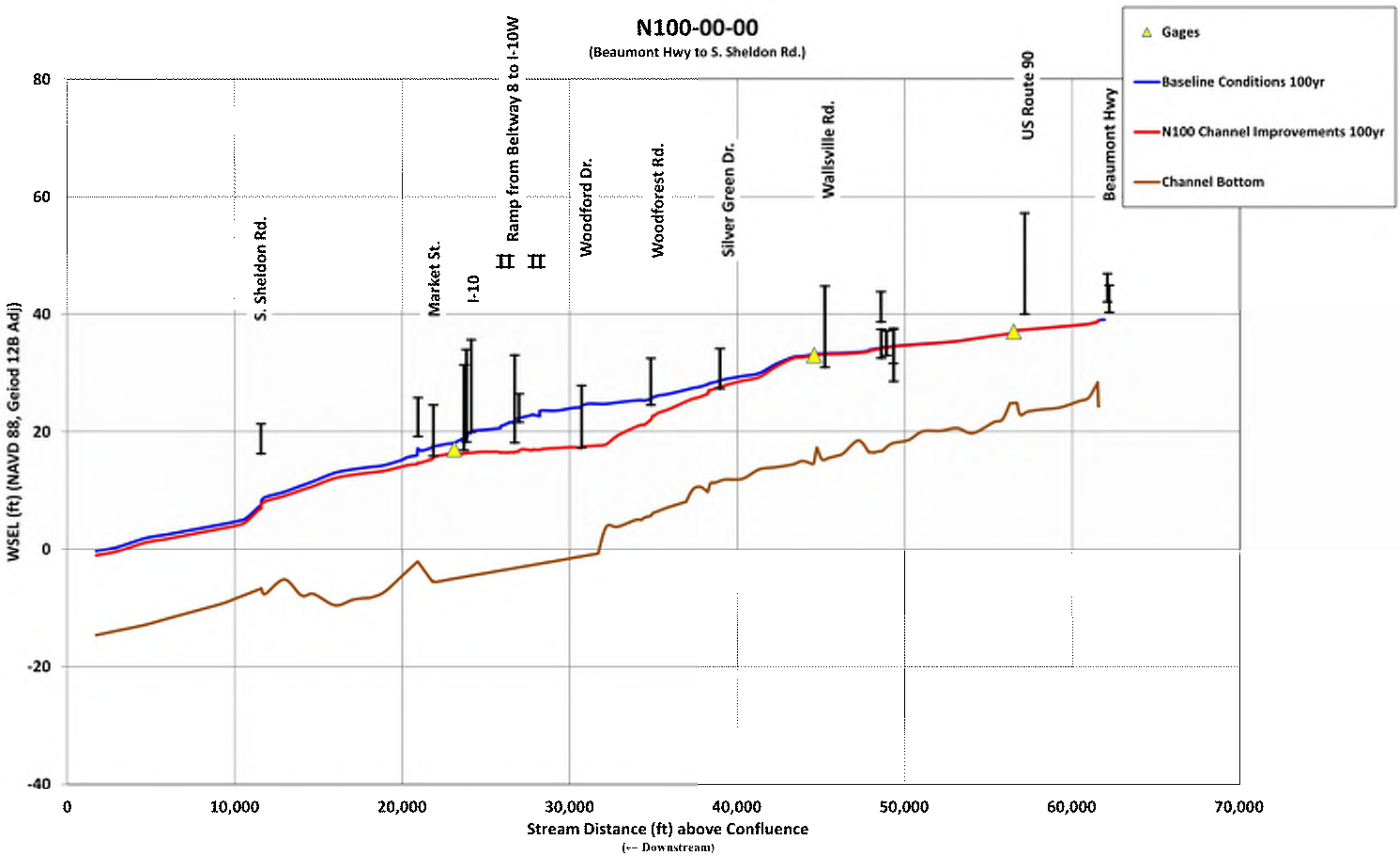
Preliminary Project Plan-N100-00-00 Channel Improvements

Channel Improvements N100	Quantity	Unit	Unit Cost	Cost	Comment
Detention Basin 1					
Detention Excavation, Haul Disposal	205861	CY	$12	$2,470,332.00	
Clearing Grubbing, and Disposal	8.5	AC	$6,200	$52,700.00	
Detention Basin 2					
Detention Excavation, Haul Disposal	88894	CY	$12	$1,066,728.00	
Clearing Grubbing, and Disposal	5.5	AC	$6,200	$34,100.00	
Channel Improvements					
Clearing Grubbing, and Disposal	45.5	AC	$ 6,200.00	$ 282,100.00	ROW width=200 ft, length of channel= 9900 ft
Utility Adjustments (pipeline)	819	LF	$ 320.00	$ 262,080.00	Colonial Pipeline closest to Missouri Pacific Railroad
Excavation (Off-Site Haul)	307,598.00	CY	$ 12.00	$ 3,691,176.00	Proposed conditions model used for quantity
Rock Rip-Rap	55930	SY	$ 80.00	$ 223,720.00	Portion of Channel Depth to Rip-Rap = 30% (60% of channel length is assumed to be Rip-Rap)
Backslope Swale	9900	LF	$ 5.00	$ 49,500.00	assumed to be along the length of the channel improvements
Backslope Drain Structure	99	EA	$ 3,500.00	$ 346,500.00	backslope structure spacing at every 100 ft
Bridge Modifications					
Woodford Drive	609	SF	$75	$ 45,675.00	Assumed change in opening width
Beltway 8 Frontage N	46	SF	$75	$ 3,450.00	Assumed change in opening width
Beltway 8 Frontage S	30	SF	$75	$ 2,250.00	Assumed change in opening width
Missouri Pacific Railroad	848	SF	$75	$ 63,600.00	Assumed change in opening width
Ramp to I-10W	1926	SF	$75	$ 144,450.00	Assumed change in opening width
Beltway 8 Frontage S	388	SF	$75	$ 29,100.00	Assumed change in opening width
Beltway 8 Frontage N	452	SF	$75	$ 33,900.00	Assumed change in opening width
Access to Beltway 8	4433	SF	$75	$ 332,475.00	Assumed change in opening width
I-10	12665	SF	$75	$ 949,875.00	Assumed change in opening width
Access to I-10	3979	SF	$75	$ 298,425.00	Assumed change in opening width
Overbluff Street	6480	SF	$75	$ 486,000.00	Assumed change in opening width
Construction Costs			**Subtotal**	**$10,868,136.00**	
			Engineering and Contingencies		
Feasability Study	1	%	5%	$ 543,406.80	Percentage of construction costs
Planning, Engineering, and Design	1	%	12%	$ 1,304,176.32	Percentage of construction costs
Construction Management	1	%	10%	$ 1,086,813.60	Percentage of construction costs
Contingencies	1	%	35%	$ 3,803,847.60	Percentage of construction costs
			Subtotal	**$ 6,738,244.32**	
			ROW Acquistition		
34 Partial Buyouts	1%-75%	%	$ 1,848,722.36	$ 1,848,722.36	
10 HCFCD Owned Parcels	100%	%	$436,790.27	$436,790.27	
4 County Owned Parcels	100%	%	$993,822.00	$ 993,822.00	
23 Full Buyouts	100%	%	$2,071,416.27	$ 2,071,416.27	
Total ROW acquisition cost			**Subtotal**	**$ 13,376,877.27**	Subtotal*2.5 (multiplier) Assumed non-voluntary buyouts
			Total Estimated Cost	**$ 30,983,257.59**	

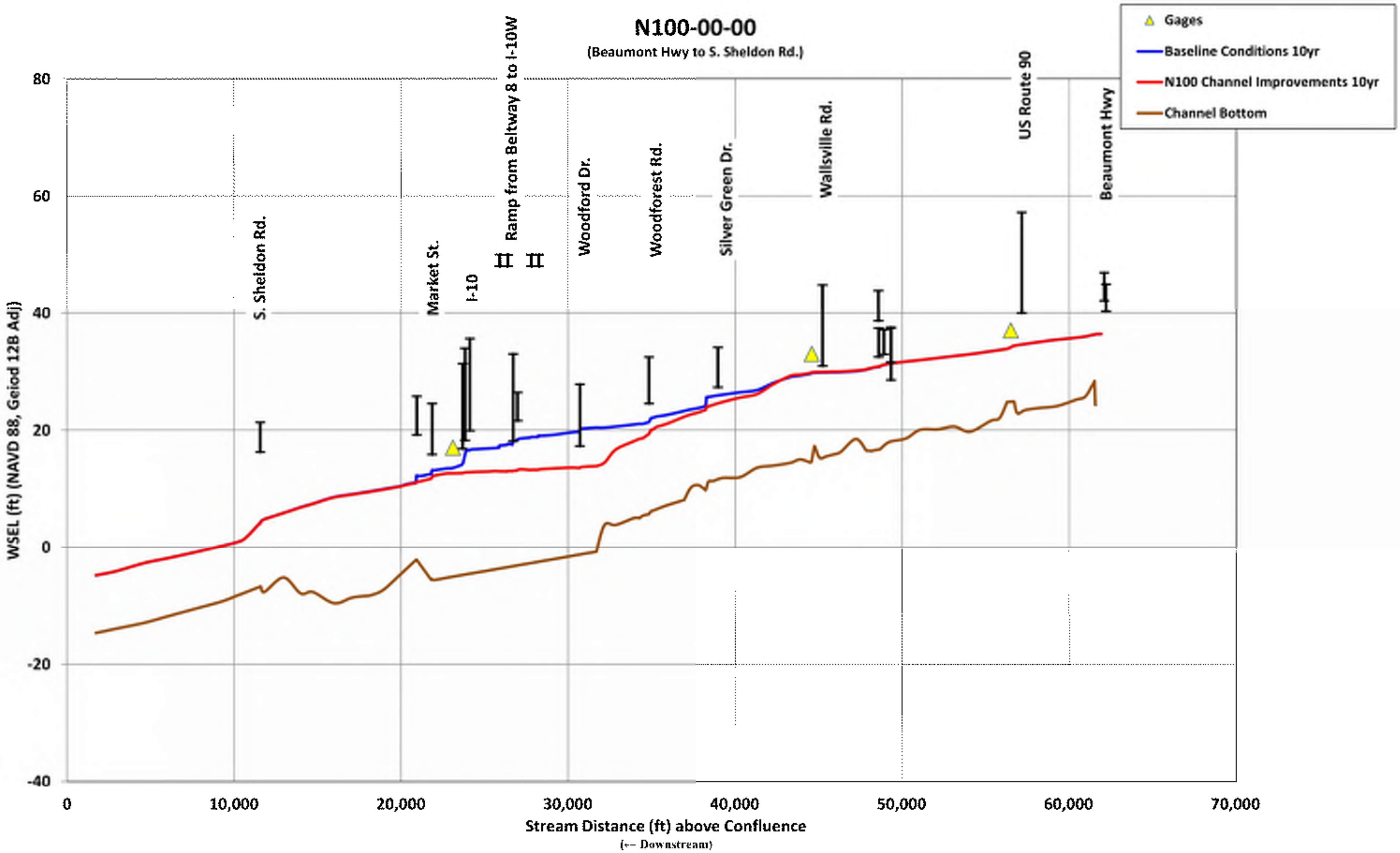
Appendix B

Water Surface Profiles for Channel Improvements

Attachment #5 Interim Deliverable



Attachment #5 Interim Deliverable



Attachment #6

Watershed Plan Summary Report

INTERIM REVIEW ONLY
This document was submitted for interim review only and is not intended for construction, bidding, permit, or final submittal purposes.

Engineer: Jacob M. Torres
PE Registration Number: 111737
Firm: Torres & Associates, LLC
Firm ID: 20741

Attachment #7

Presentation Slides for Workshops and Coordination Meetings

INTERIM REVIEW ONLY
This document was submitted for interim review only and is not intended for construction, bidding, permit, or final submittal purposes.

Engineer: Jacob M. Torres
PE Registration Number: 111737
Firm: Torres & Associates, LLC
Firm ID: 20741

Appendix 5-4AH:
White Oak Bayou – E116 Tributary Modifications and Detention

TECHNICAL MEMORANDUM

To: Gary Bezemek, PE
Harris County Flood Control District – Planning Department

From: Mujahid Chandoo, PE

Date: February 25, 2023

Subject: The White Oak Bayou Tributary Planning Project (E116-00-00)
Benefit Cost Analysis (BCA)

The White Oak Bayou Tributary Planning project proposes to develop a comprehensive flood damage reduction plan aimed at decreasing riverine and urban flood risk. The project area is located entirely within the City of Houston and Harris County Commissioner Precinct 1 in central Harris County within the White Oak Bayou watershed (E100-00-00). The 2 square mile study area generally drains from north to south and outfalls to the White Oak Bayou mainstem just upstream of West 43rd Street and consists of the main tributary (E116-00-00) and two major sub-tributaries.

Project Description

The White Oak Bayou Tributary Planning project is based on a recommendation from the Pape-Dawson Final Engineering Report, dated August 2022. The E116-00-00 study area was divided into five distinct problem areas, with the severity and magnitude of flooding investigated for each area. The severity of flooding was based upon historical structural flooding data from various sources and predicted future flooding using the hydrologic and hydraulic modeling efforts conducted. An overall flood reduction strategy was identified as being a potential, but not required, joint effort between the City of Houston and the Harris County Flood Control District (HCFCD). An overall flood reduction strategy was developed aimed at addressing both City of Houston and HCFCD infrastructure however due to funding constraints, the project being evaluated in this analysis is the initial phasing plan serving as the first step in an overall flood reduction strategy. The initial recommended project identified for HCDFD infrastructure includes providing channel improvements, upsizing of culverts, siltation removal and a stormwater detention basin. The initial recommended project identified for the City of Houston infrastructure consists of local drainage system improvements and providing micro-detention basins within selected roadway medians.

Structure Inventory

Two (2) datasets were used to obtain the information for Finished Floor Elevation (FFE), building footprint and building category.

- **Structure Inventory Dataset**: This information was obtained from Harris County Flood Control District (HCFCD). The FFE was obtained from this dataset.
- **National Structure Inventory (NSI):** The building (structure type) category (i.e., residential commercial and industrial) and building footprint (sq. ft) was obtained with this dataset.

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Office: 713-954-5300 | mbakerintl.com

Using ArcGIS these datasets were joined together using the parcel information.

Project Schedule

The E116-00-00 study area was divided into five distinct problem areas (PA01-PA05). The overall project addresses PA01, PA02 partial, and PA04 partial. Project schedule is listed below broken out by problem area number:

- PA-01
  - Project 1A Item 1 – Conveyance Capacity Expansion
  - Project 1A Item 2 – Junction Box Replacement with Culvert
  - Project 1B Item 1 – Micro-detention in Medians
  - Project 1B Item 2 – Micro-detention Interconnecting Pipes
- PA-02
  - Project 2A Item 1 – Siltation removal from Rosslyn Rd to Ella Blvd
  - Project 2A Item 2 – Ella Blvd/Lehman Rd Culvert Crossing
  - Project 2B Item 1 – Ella Blvd/Pinemont Dr Storm Drain Expansion
- PA-04
  - Project 4A Item 1 – E116-00-00 Channel Improvements
  - Project 4A Item 2 – E116-00-00/W Tidwell Rd Culvert Crossing
  - Project 4A Item 3 – South Detention Basin

BCA Assumptions

Project costs estimated in August 2022 were adjusted to September 2020 dollars using a factor 0.85 and rounded to nearest thousand. The adjusted project costs were input to the TWDB BCA Input Workbook v1.2 to calculate the project's cost discounted by 7 percent over an assumed total project construction period of 20 years. The discounted cost is $4.44 million. Non-discounted costs are itemized as follows:

Project Costs

Cost Categories	HCFCD Cost 2020 Dollars*	City of Houston Cost 2020 Dollars*	Combined Cost 2020 Dollars*
Construction (including Excavation & Removal)	$ 4,035,000	$ 729,000	$ 4,764,000
Engineering and Contingencies*	$ 2,301,000	$ 417,000	$ 2,718,000
ROW Acquisition	$ 893,000	-	$ 893,000
Total Project Cost	**$ 7,229,000**	**$ 1,146,000**	**$ 8,375,000**

* - Adjusted from August 2022 cost estimate (Pape-Dawson Engineers Flood Reduction Feasibility Study pdf page 46 of 550)

* - 30% contingency on construction costs.

ROW acquisition costs for the North Basin in PA04 in the Final Engineering Report are based on a 2.5 multiplier to the current market value reported by the Harris County Appraisal District for each property. ROW acquisition costs assumed in PA02, PA04, and PA05 for channel widening and ditch expansion were based off a few $/SF values along the corridor for properties on active sale during early 2022. These costs may vary widely depending on the timing of the construction of the project.

For purposes of the BCA, project benefits are elimination of flooding damages to residential, commercial, and industrial structures. Benefits were quantified by inputting structure FFE's and flood depths to the BCA_Pilot_v5, provided by FNI. The output compares the baseline structure damages without the project to the project conditions in the 10-, 25-, 50- and 100-year storm scenarios:

Benefits Summary (non-discounted)

	100 - year storm		50 - year storm		25 – year storm		10 - year storm	
	Baseline	w/Project	Baseline	w/Project	Baseline	w/Project	Baseline	w/Project
Residential Flood Damage	$82,558,244	$85,330,287	$55,017,647	$54,347,323	$34,935,632	$26,259,806	$23,198,545	$20,766,260
Commercial Flood Damage	$10,280,934	$9,493,093	$8,540,361	$7,739,015	$480,016	$226,053	$4,915,595	$3,593,253
Industrial Damages	$12,546,686	$10,402,968	$10,633,133	$8,420,050	$6,764,888	$8,981,038	$7,362,764	$5,121,409
Total Damages	$105,385,864	$105,226,349	$74,191,140	$70,506,388	$42,180,536	$35,466,896	$35,476,905	$29,480,921
Net Benefit by Storm		**$159,516**		**$3,684,752**		**$6,713,640**		**$5,995,984**

Total Benefit: $16,553,892 (non-discounted)

Discounted Benefits

Total benefits discounted at 7 percent over the project's 30-year duration are $6,527,915 including $24,746 in residual value from right-of-way acquisition. These benefits only include the mitigated damages to residential, commercial. and industrial structures identified and no other additional mitigation.

Benefit Cost Ratio

Discounted Project Benefits (damages calculated in FEMA BCA toolkit)	$6,503,169
Discounted Residual Value (ROW)	$24,746
Total Benefits	$6,527,915
Discounted Project Cost	$4,441,656
Final BCR	**1.47**

August 2022

PAPE-DAWSON ENGINEERS

Transportation | Water Resources | Land Development | Surveying | Environmental

E116-00-00
FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

August 2022

TABLE OF CONTENTS

PAPE-DAWSON ENGINEERS

List of Figures

List of Exhibits

List of Tables

List of Appendices

EXECUTIVE SUMMARY

This feasibility study provided a detailed analysis of flooding conditions in the White Oak Bayou tributary E116-00-00 study area and developed a comprehensive flood damage reduction plan aimed at decreasing riverine and urban flood risk. This Final Engineering Report presents the overall strategy developed based on hydraulic considerations that provide flood reduction benefit to the study area.

The study area is located entirely within the City of Houston (COH) and Harris County Commissioner Precinct 1 in central Harris County within the White Oak Bayou watershed (E100-00-00). The 2 square mile study area generally drains from north to south and outfalls to the White Oak Bayou mainstem just upstream of West 43rd Street and consists of the main tributary (E116-00-00) and two major sub-tributaries, as shown in Exhibit 1.

Activities completed as part of this feasibility study include 1) identifying and quantifying the flooding sources for all problem areas; 2) evaluating alternative improvement projects; 3) recommending the most feasible projects for implementation; and 4) creating a prioritized, comprehensive flood risk reduction strategy consisting of short-term projects and guidance for future projects, all using potential partnerships to improve the benefits of the combined improvements.

To implement the mutually beneficial nature of the flood reduction improvements recommended in this feasibility study, a partnership between COH and Harris County Flood Control District (Flood Control District) is recommended but not required. Improvements are recommended to drainage infrastructure maintained by both jurisdictions including roadside ditches and storm sewers that exist in this urbanized area. Results from this feasibility study help recommend and sequence future flood damage reduction projects that reduce the risk of flooding in the entire E116-00-00 study area, regardless of jurisdictional authority.

The Phase 1 MAAPnext model of White Oak Bayou served as the basis of the best available hydrologic and hydraulic modeling for the study area. Some specific revisions were made to these models to provide the level of detail necessary to create a comprehensive flood damage reduction plan for this study area. The E116-00-00 study area was divided into five distinct problem areas, with the severity and magnitude of flooding investigated for each area. The severity of flooding was based upon historical structural flooding data from various sources and predicted future flooding using the hydrologic and

hydraulic modeling efforts conducted for this study. A summary of the flood-related metrics used by this study are provided in Figure ES.1.

Figure ES.1. Summary of Problem Area Flooding Data

		Predicted Structural Flooding (1% AEP)	Predicted Roadway Flooding (+1-foot for 1% AEP)	FEMA Claims (1978-2020)	FEMA Repetitive Losses
	(count of structures)	(count of structures)	(miles)	(count of claims)	(count recorded)
PA01	98	22	4.7	94	13
PA02	101	26	6.2	120	17
PA03	73	27	2.1	105	25
PA04	98	29	3.0	42	8
PA05	13	5	1.3	5	0

The overall flood reduction strategy identified for Flood Control District infrastructure consists of providing channel conveyance improvements, upsizing of culverts, siltation removal and stormwater detention basins, at a cost of approximately $16.3 million. The overall flood reduction strategy identified for COH infrastructure consists of providing expanded roadside ditches, additional storm drainage systems and micro-detention within selected roadway medians, at a cost of approximately $18.7 million. The specific detailed components of the overall flood reduction strategy are presented in Exhibit 6.1 at a total cost of $35 million. A phasing plan has been developed because the strategy presented herein does not reflect current available funding by the Flood Control District or COH.

An initial recommended project has been identified for construction as a first step to the overall strategy. The initial recommended project identified for Flood Control District infrastructure includes providing channel improvements, upsizing of culverts, siltation removal and a stormwater detention basin at a cost of approximately $8.5 million. The initial recommended project identified for the COH infrastructure consists of local drainage system improvements and providing micro-detention basins within selected roadway medians, at a cost of approximately $1.4 million. The components of the recommended project are presented in Exhibit 6.4 at a total cost of $9.9 million. Flood reduction benefits within the study area will be achieved by this initial recommended project; however, expansion of these improvements to the overall flood reduction strategy, discussed above, would provide even greater benefits.

1 INTRODUCTION

1.1 Overview of Feasibility Study

This feasibility study provided a detailed analysis of flooding conditions in the White Oak Bayou tributary E116-00-00 study area and developed a comprehensive flood damage reduction plan to decrease riverine and urban flood risk. Results from this feasibility study were developed to guide the selection of future drainage improvement projects to reduce the risk of flooding in the E116-00-00 study area. This study area has significant drainage infrastructure needing improvement within the normal jurisdictional responsibility of both the Harris County Flood Control District (Flood Control District) and the City of Houston (COH); therefore, partnerships between the Flood Control District and COH is anticipated to best achieve the intended flood reduction benefit. Improvements are recommended to the drainage infrastructure of both jurisdictions. At this point, that partnership is assumed in order to realize the intended flood reduction benefit; however, no formal agreement has been initiated to date.

Existing hydrology and hydraulic models were revised to identify problem areas defined by historical flooding, structural flooding, and non-structural (roadway) flooding. The information presented in this feasibility study includes conceptual improvement projects, mitigation alternatives, design concepts, and construction cost estimates. Activities completed as part of this feasibility study include:

- Identify problems:
  - Revise 1D/2D Phase 1 MAAPnext hydrologic and hydraulic models to determine the location and severity of existing flooding concerns.
  - Define problem areas based on updated modeling techniques.
  - Identify potential challenges which could hinder the implementation of potential projects, specifically development and utilities.
- Evaluate problems and potential alternative improvements for flood reduction:
  - Evaluate previous studies and recommendations.

  - Define potential drainage improvement projects that could be constructed to provide flood damage reductions.
  - Assess the potential for downstream impacts from potential projects and develop mitigation alternatives.
- Develop a comprehensive plan:
  - Evaluate potential opportunities for partnering with other agencies and creating multi-use facilities.
  - Estimate the potential damage reduction benefits from potential improvements.
  - Create estimates of probable construction cost for potential improvements for the infrastructure of both the Flood Control District and COH.
  - Select potential projects using Flood Control District prioritization criteria.
  - Develop a strategy for implementing future recommended improvements.

1.2 Feasibility Study Objectives

This Final Engineering Report has been prepared to record the culmination of engineering activities necessary to accomplish the following objectives, as set forth by the Flood Control District:

1. Take full advantage of Flood Control District and COH knowledge, analyze databases of historical flood information, and previous engineering studies.
2. Quantify the location and severity of existing flood problems within the study area.
3. Identify the range of opportunities and major challenges that affect the available options for improvement.
4. Engage potential project partners throughout the planning process and the public at appropriate milestones.

5. Identify the short-term opportunities for implementation of an improvement project that will provide the most flood risk reduction benefit to the study area.

6. Develop long-term strategies to address future drainage improvements required for further flood damage reductions in the study area.

7. Outline additional planning, regulatory and financial measures to minimize flooding problems resulting from future development and redevelopment.

8. For projects with anticipated near-term funding, develop plans to enable rapid progression into land acquisition, engineering and permit activities.

2 STUDY AREA DESCRIPTION

The tributary E116-00-00 study area is located in central Harris County within the White Oak Bayou watershed (E100-00-00). The study area generally drains from north to south and outfalls in a western direction to E100-00-00 (White Oak Bayou main stem) just upstream of West 43rd Street, as shown in Exhibit 2.1. Approximately 2 square miles are covered by the study area, consisting of the main tributary (E116-00-00) and two significant sub-tributaries (E116-01-00 and E116-05-00), as shown in Exhibit 2.1. The effective floodplain indicates that the Zone AE special flood hazard area is contained within the existing channels for most of E116-00-00, all of E116-01-00, and most of E116-05-00, per FIRM panels 48201C0655M and 48201C0660M, dated 06/09/2014. Out-of-bank floodplain is predicted at the lower end E116-00-00 where backwater from E100-00-00 governs and at the upper end of E116-05-00, as shown in Exhibit 2.1.

All three channels are grass-lined, with a generally trapezoidal cross-section shape. The stream centerlines are generally straight with 90-degree turns to fit within the development of the study area. The open channel infrastructure is limited to the southern portions of the study area. All runoff from the northern upstream portions of the study area is conveyed by subsurface storm drains or flows overland based on the general lay-of-the-land topography. Some roadside ditches are present within the most upstream portion of the study area. The roadside ditches are undersized—providing a level of service (LOS) defined by the channel capacity, of less than the 10% annual exceedance probability (AEP).

The study area is located entirely within COH, and also within Harris County Commissioner Precinct 1. The study area is fully developed and dominated by single-family residential development interspersed with several multi-family residential properties. Industrial development is found through the central part of the study area along Pinemont Drive. Within the northern portion of the study area, the single-family residential development is predominantly built on large lots in the Acres Homes superneighborhood. In the southern portion of the study area, the neighborhoods include Candlelight, Marbella, Shepherd Park Terrace, Ella Lee Forest, and Ella Park Terrace.

2.1 Flood Control District Channels and Right-of-Way (ROW)

The study area contains three tributary channel reaches which were hydraulically modeled as one-dimensional (1D) reaches, including E116-00-00 and its tributaries of E116-01-00 and E116-05-00. These

1D reaches comprise a total length of approximately 16,200 linear feet of open channel infrastructure maintained by the Flood Control District, within Flood Control District right-of-way (ROW) within the study area, as shown in Exhibit 2.2. A review of COH Public Works GIS (GIMS) spatial storm utility data indicates smaller open channel infrastructure, attributed to be owned and maintained by the Flood Control District, present within and near the study area that were evaluated within the two-dimensional (2D) mesh area of the model in this study. The COH GIMS storm utility data also presents roadside ditch infrastructure, attributed to be owned and maintained by COH.

2.2 Flood Control District Stormwater Detention Basins

A stormwater detention basin is located in the northeast corner of the intersection of E116-00-00 with E116-05-00, as shown in Exhibit 2.2, named COH Pinemont Drive and described as Flood Control District Unit No. E516-01-00. This stormwater detention basin was approved for construction by the Flood Control District in April 2010 as part of an improvement project to Pinemont Drive and provides 8.7 ac-ft of detention storage volume while utilizing E116-00-00 as an outfall.

2.3 Other Stormwater Detention Basins

No other regional stormwater detention basins exist in the E116-00-00 study area boundary. LiDAR topography indicates multiple small, private stormwater detention basins within the study area, which appear to be mitigation for more recent individual private site developments.

2.4 Study Area Challenges

The primary challenge in the E116-00-00 study area is the lack of available space for additional drainage infrastructure. The study area, especially the southern downstream region, is fully developed with limited opportunities for stormwater detention basins or additional ROW for increased open channel capacity. In the northern upstream portion of the study area, there are a few vacant and partially developed tracts of land.

A review of spatial data from the Texas Railroad Commission indicates no wells, railroads, cemeteries, or airports located within the study area. One petroleum product pipeline is identified in the northern portion of the study area, as shown in Exhibit 2.2.

A secondary challenge in the E116-00-00 study area is rapid redevelopment. Several low-density single-family residential areas are undergoing redevelopment into higher-density residential developments, fundamentally altering the hydrologic characteristics of the study area, and potentially inhibiting open channel ROW expansions.

2.5 Previous Improvement Projects

Plans for various previous projects within the study area were provided by the Flood Control District. These past projects include normal repair operations, channel restoration projects and channel enclosure projects. Drainage improvements associated with street improvements are also documented. All of these previous projects were deemed to be adequately included in the existing conditions currently defined for the study area.

2.6 Ongoing Projects

A project funded by COH has been recently concluded to document and propose improvements for the existing drainage conditions in the Shepherd Park Terrace (SPT) subdivision. SPT is a single-family subdivision with curb and gutter drainage infrastructure located at the southeast corner of Wheatley Street and West Tidwell Road as shown in Exhibit 2.2. The purpose of the SPT project is to evaluate the 50% and 1% AEP storm events and propose improvements such that the 50% AEP storm event would be contained within the storm drain system, and the 1% AEP storm event would be contained within the ROW. The project was initiated in response to significant flooding problems in the subdivision as documented by resident complaints. Results and recommendations from the SPT project were reviewed as a part of this study but are not being included in the recommendations for this E116-00-00 Feasibility Study. Improvements proposed within the SPT project will not require participation by the Flood Control District.

3 DATA COLLECTION

The Flood Control District provided the Phase 1 MAAPnext HEC-HMS v4.3 and HEC-RAS v5.0.7 models, applicable studies and reports, a GIS database with a Watershed Master Plan tool, historical flooding counts, public ROW data, COH Public Works GIS (GIMS) storm utility data, and pertinent construction documents. These items also included building footprints, parcel data, and FEMA insurance claims for the project area. This information was used during modeling and evaluation of the existing conditions. A detailed list of the data received is included in Table 1.

3.1 Field Reconnaissance

Field reconnaissance was completed by Pape-Dawson personnel on March 29, 2022. Photos are provided in Appendix A. Locations of the photos are presented in Exhibit 3.

3.2 Flooding History

The E116-00-00 study area has experienced numerous flood events in recent history. Based on data from the past six years, structures within the study area boundary were inundated during five of the six tracked storm events. The majority of the structural flooding incidents were reported during Hurricane Harvey in 2017. Further discussion of the flooding history in the study area is included in Section 5.1.1.

4 HYDROLOGIC AND HYDRAULIC ANALYSIS

4.1 Basis of Models

The Phase 1 MAAPnext model of the White Oak Bayou watershed was used as the basis to evaluate the urban flood risks in and around the E116-00-00 channel and its tributaries, which outfall to E100-00-00 (White Oak Bayou). The MAAPnext methodology utilized the 1D/2D hydraulics where primary open channels are modeled as 1D reaches with cross sections while the overbanks, and smaller open channels, are modeled within 2D areas. This approach allowed for the entire study area to be evaluated for inundation in a single model. Hydrologic modeling was updated to the new BDF methodology and utilized Atlas 14 rainfall depths.

4.2 Modeling Revisions

4.2.1 Model Version

The Phase 1 MAAPnext model utilized HEC-RAS v5.0.7. New tools have been added to HEC-RAS v6.1 that were deemed to be advantageous to this study, including the ability to modify the terrain and include bridges inside 2D flow areas, along with numerous improvements to RAS Mapper. As a result, the model was executed in HEC-RAS v6.1 and the resulting water surface elevation (WSEL) raster was compared to that of the Phase 1 MAAPnext model from HEC-RAS v5.0.7. Within the E116-00-00 study area, the vast majority of the area showed a difference in WSEL of +/- 0.10 feet, with a large part of that area at a tighter tolerance of +/- 0.02 feet. Isolated pockets showed greater differences with a maximum difference of +/- 0.20 feet. Based on these favorable comparative results, the decision was made to convert the modeling to HEC-RAS v6.1 for use in this study.

4.2.2 Hydrology Revisions

Since one important objective is to identify problem areas susceptible to damaging inundations in and around the E116-00-00 channel, the Rain-on-Grid (ROG) feature within HEC-RAS v6.1 was used to identify any concerns of flooding due to sheet flows caused by local rainfall. This approach determines the flow patterns and inundation resulting from overland sheet flow, in contrast to the MAAPnext model which only assesses riverine flooding by assuming all runoff is already in the Flood Control District channels. The full precipitation hyetograph from the Phase 1 MAAPnext model is applied for the ROG hydrology. The new capability to account for infiltration directly within HEC-RAS v6.1 was used for this study. The infiltration layer is based upon the Green-Ampt parameters from the Phase 1 MAAPnext model.

4.2.3 Boundary Conditions

In order to improve model run times for the feasibility study, the MAAPnext model was truncated to isolate the E116-00-00 study area. The model extents are shown in Exhibit 4.1. The 1D main channel for E100-00-00 starts at River Station (RS) 61181 which is just south of Holly View Drive on the right overbank and Garapan Street on the left overbank. The truncated E100-00-00 reach ends downstream near the intersection of White Oak Bayou Greenway Trail and West TC Jester Boulevard (at RS 44973). The entire 1D reaches for E116-01-00, E116-05-00 and E116-00-00 are within the truncated model used in this analysis. The E117-00-00 and E115-00-00 channels are truncated to only include the reaches downstream of the Burlington Northern Santa Fe (BNSF) railroad bridge. The 2D mesh extent to the west also terminates at the BNSF railroad. To the east, the 2D mesh extends slightly beyond the West Montgomery Road and North Shepherd Drive intersection.

As part of the truncation, modeling boundary conditions were revised. The revised boundary conditions are documented in Exhibit 4.1. The flow hydrograph from RS 61181 of the Phase 1 MAAPnext model was manually input as the upstream boundary condition to the 1D E100-00-00 reach in the truncated model. Overbank sheet flow entered the truncated 2D mesh boundary in multiple locations. This flow into the truncated model was captured using flow hydrographs from profile lines from the Phase 1 MAAPnext model and added as external boundary conditions to replicate the sheet flow conditions in the truncated model. Similarly, flow hydrographs to the upstream cross sections of E117-00-00 (RS 59399) and E115-00-00 (RS 48995) were manually input from the Phase 1 MAAPnext model. Drainage areas along the left overbank of E100-00-00 were accounted for in the ROG mesh; therefore, those flows were not applied as a boundary condition in the 1D cross sections to avoid double counting of flows. A summary of the boundary conditions is included in Tables 2.1 and 2.2.

The drainage areas directly assigned as flow inputs to the E100-00-00 1D cross-sections were revised to account for the ROG mesh now representing a portion of these drainage areas in this truncated model. The boundary condition at the downstream cross section of E100-00-00 (RS 44973) is applied as the stage hydrograph from the Phase 1 MAAPnext model.

4.2.4 Additional Hydraulic Revisions

In order to better replicate physical conditions, storm sewers (pipes with a diameter in excess of 36 inches and all box culverts) from the COH GIMS data were added into the geometry, as shown in Exhibit 4.2. Adjustments to storm sewer flowlines were made by using the 2018 LiDAR elevations in reference to the manhole rim elevations, as several of the flowlines seemed to be using varying temporary benchmark data from earlier surveys. Additional breaklines were added around drainage areas that potentially sheet flow towards the E116-00-00 channel. Breaklines were mainly added along major roads and channels within the 2D mesh. Additionally, overriding Manning's n-value layers were added around those roads that have storm sewers and roads further north of the E116-00-00 study area to better replicate physical conditions by using a Manning's n-value of 0.02, as is recommended for pavement for ROG simulations. The 1D cross sections and lateral structures within the truncated model remain unchanged from the Phase 1 MAAPnext model.

4.3 Modeling Results

The ROG analysis demonstrates the majority of flooding within the E116-00-00 study area is the result of overland sheet flow and not out-of-bank riverine flooding, resulting in widespread inundation of roadways and structures before runoff can reach the Flood Control District channels. This situation is evident by the flow vectors in RAS Mapper, as shown in Figure 4.1. The sheet flow patterns indicate flow through major arterial and collector streets, which frequently overflows into the adjacent residential, commercial, and industrials sites. Detailed descriptions of the sheet flow patterns are included in Section 5.0.

Figure 4.1 RAS Mapper Flow Vectors

Evaluation of the Flood Control District infrastructure (E116-00-00, E116-01-00, and E116-05-00) indicates available capacity for the 1% AEP for segments of E116-00-00, based on the revised modeling for this study that allows for sheet flow runoff to overflow in other directions, away from the open channel infrastructure. Each channel reach is classified by the level of service (LOS) provided, defined as the storm event wholly contained within the channel. As shown in Exhibit 4.3, E116-00-00 provides a 1% AEP LOS except at the confluence of E116-00-00 with E100-00-00, where the backwater from E100-00-00 controls. E116-01-00 provides a 2% AEP LOS, reduced to 10% AEP upstream approaching Ella Boulevard. E116-05-00 provides a 2% AEP LOS before reducing upstream to 10% AEP, further upstream. Flooding depths from the revised existing modeling are documented in Exhibits 4.4 to 4.7.

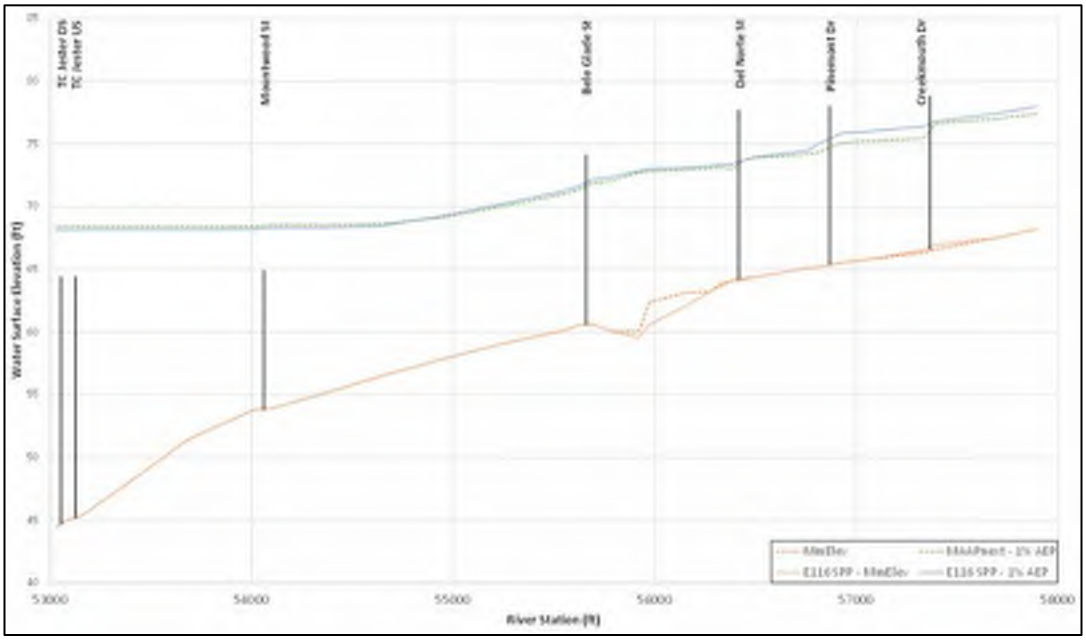
The ROG evaluation also identifies several locations where runoff sheet flows out of the E116-00-00 study area but not directly to the main stem channel of E100-00-00, as documented in Exhibit 4.8. The primary overflows occur to the east towards E101-00-00 subbasins and south towards E107-00-00 subbasins. Further discussion of the overflows out of the study area is included in Section 5.0.

4.4 Comparison to MAAPnext

A comparison of the results from the revised modeling to the Phase 1 MAAPnext modeling demonstrates differences in flooding conditions. These differences are primarily the result of the revised hydrologic boundary conditions. The ROG hydrology approach causes two changes to the flooding condition measured in the study area. First, sheet flow patterns are more readily identified and demonstrate the path rainfall travels to reach the open channel infrastructure. By modeling these paths from rainfall to the open channels, additional areas of flooding concern are located. The area of inundation for the 1% AEP event is much larger for the revised modeling than the MAAPnext results.

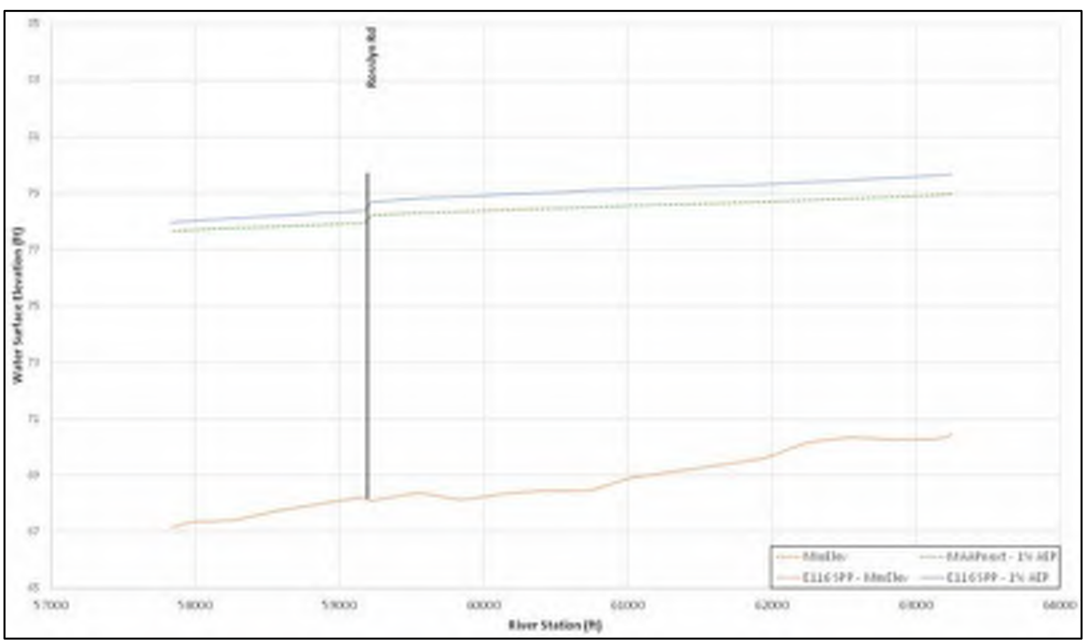
The ROG hydrology also alters the timing of runoff, which subsequently causes changes in the peak discharge measured within the 1D open channels. As shown in Figure 4.2, the revised modeling indicates the WSEL within E116-00-00 remains consistent with Phase 1 MAAPnext modeling for the downstream portion of the channel, with an increase (average of + 0.5 feet) starting upstream of Del Norte Street, where an increase in the peak discharge is also measured.

Figure 4.2. E116-00-00 Profile Comparison (1% AEP)



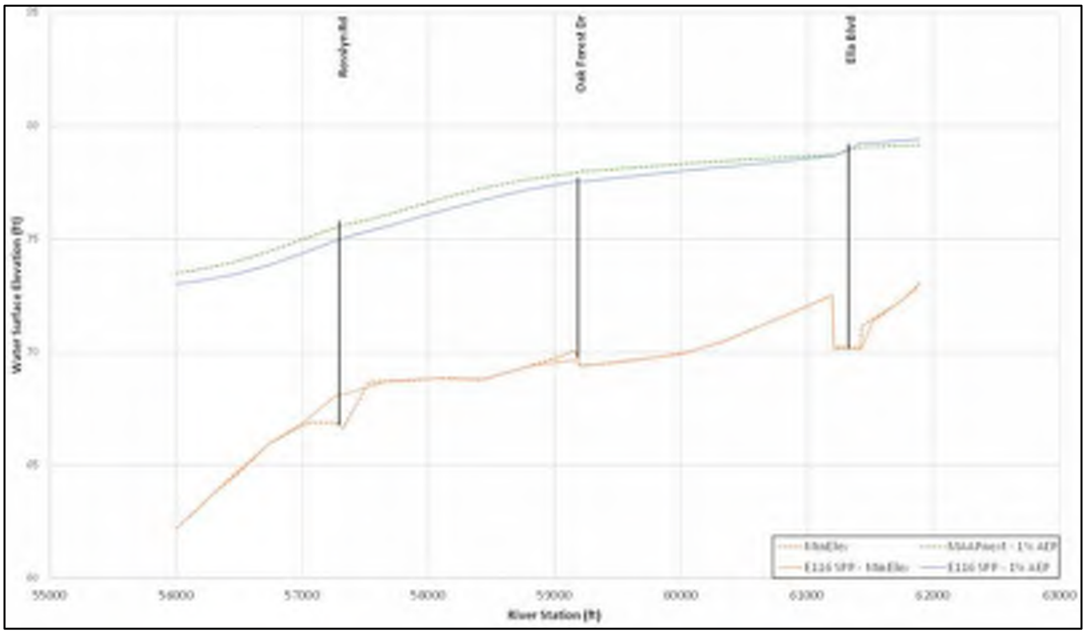
The revised modeling also indicates an increase in WSEL for the entire E116-01-00 channel, with an average increase of + 0.50 feet for the 1% AEP storm event, as shown in Figure 4.3. An increase in peak discharge within E116-01-00 is measured for the entire channel.

Figure 4.3. E116-01-00 Profile Comparison (1% AEP)



Within E116-05-00, the revised modeling indicates an increase in WSEL within the upstream portion of the reach, with an average of + 0.2 feet, but a decrease at the downstream portion of the reach, with a maximum difference of - 0.6 feet, as shown in Figure 4.4. The differences in WSEL are attributed to differences in the peak discharge measured in the channel, with a decrease in the downstream reach but an increase in the upstream reach.

Figure 4.4. E116-05-00 Profile Comparison (1% AEP)



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5 PROBLEM AREA IDENTIFICATION

The E116-00-00 study area was subdivided into five discrete problem areas based on the subwatershed boundaries. The severity of flooding within each problem area has been quantified, as explained below.

5.1 Flooding Metrics

In order to target the area with the most severe flooding, several metrics were used for comparison. These metrics for each defined problem area are outlined below and include:

1. the number of buildings indicated to have actual recorded damages from historical flooding,
2. the number of buildings predicted to have flood damages from various storm events based on current modeling,
3. predicted lengths of roadway flooding during various storm events,
4. the estimated level of service for channels modeled in 1D reaches, and
5. the number of previous FEMA claims for flood damages.

5.1.1 Historical Flooding

Historical flooding was based upon a Flood Control District-provided database of reported flooding from six major storm events dating back to 2015. An overview of the historical flooding recorded within the five problem areas of the E116-00-00 study area is provided in Figure 5.1. Earlier historical flooding has also occurred in most of these neighborhoods, but was not used for this analysis since this more recent data is thought to be more representative of current conditions.

Figure 5.1. Historical Flooding Data within E116-00-00 Problem Areas

Storm Event	Flooded Structures
Imelda, 2019	16
Harvey, 2017	356
Memorial Day 2016	0
Tax Day 2016	1
Halloween 2015	4
Memorial Day 2015	6

5.1.2 Predicted Structural Flooding

Predicted structural flooding was evaluated using the Structural Inventory data provided by the Flood Control District in August 2021. The average WSEL within the building footprint associated with the structural inventory point was calculated for the 10%, 4%, 2%, and 1% AEP storm events, as documented by the raster-based WSEL grids. This WSEL was then compared to the finished floor elevation provided in the Structural Inventory database to determine if the structure could potentially be inundated during the given storm event.

5.1.3 Predicted Roadway Flooding

Predicted roadway flooding was quantified in a similar fashion as the predicted structural flooding. From the revised hydraulic modeling, raster-based depth grids were created. The depth grids were utilized in conjunction with roadway alignment data provided by the Flood Control District to estimate if the roadway was inundated, and to what depth, by a given storm event. The roadways are categorized into three classes: interstate highway, arterial or major collector, and neighborhood streets. Since all roadways are designed for some amount of stormwater conveyance, the depth grids were used to determine whether the roadway was inundated by a depth of less than one foot or greater than one foot.

5.1.4 Level of Service

As discussed above in Section 4.3, the open channel infrastructure currently provides varying levels of service (LOS), as documented in Exhibit 4.3. The LOS provided by open channels was only used as a reference when evaluating the problem areas since some areas are not serviced by open channels, which is discussed further in subsequent sections.

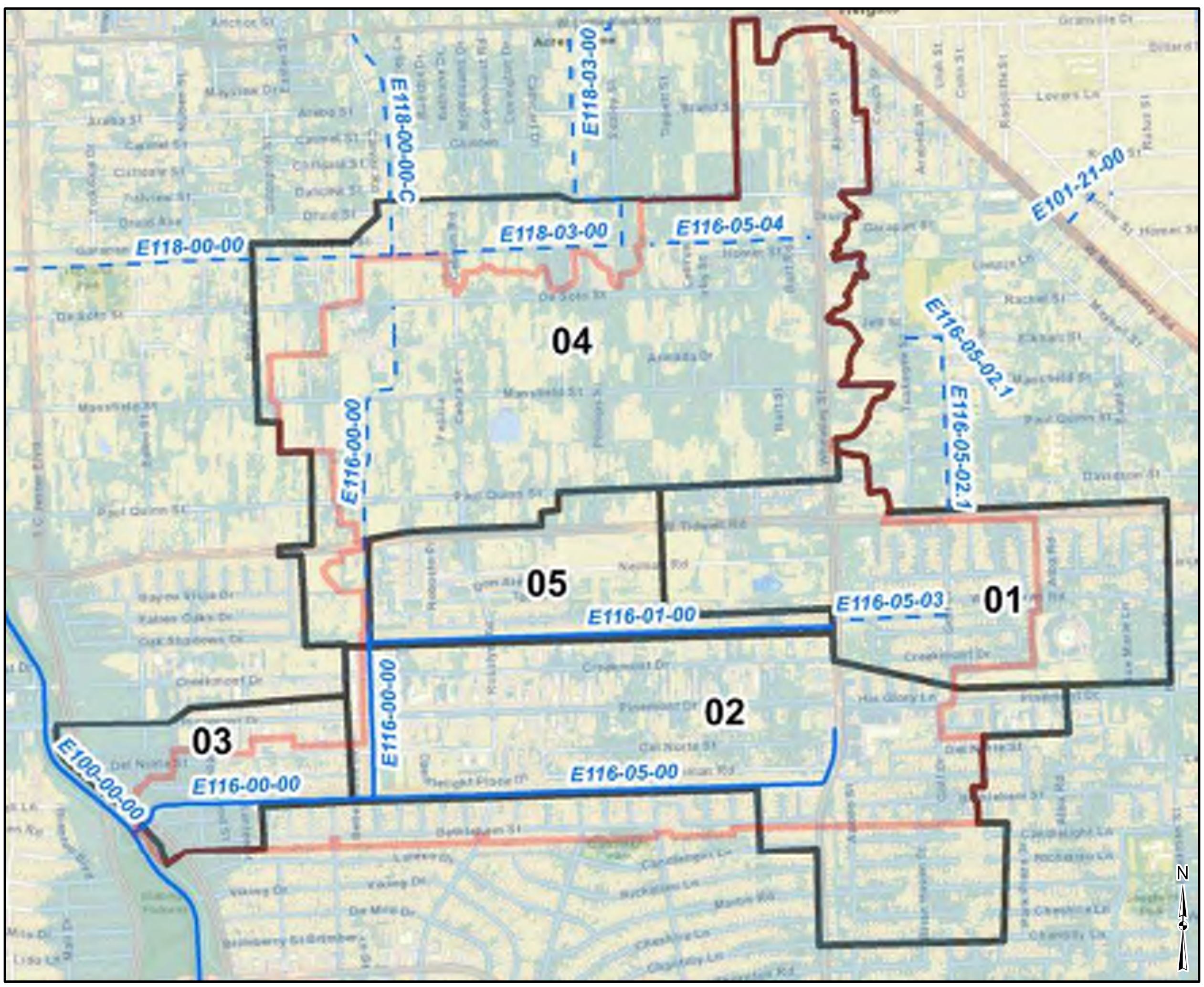
5.1.5 Previous FEMA Claims

Documentation of previous FEMA claims and FEMA repetitive losses was provided by the Flood Control District. A total of 366 claims have been processed, and 63 repetitive losses have been recorded within the problem areas of the E116-00-00 study area. FEMA claim and repetitive loss records exceed that of the historical flooding due to the scope of the database provided by the Flood Control District, with FEMA claims dating from 1978-2020. As discussed in Section 5.1.1., the recent historical event flooding data ranges from only 2015-2019.

5.2 Problem Area Descriptions

Problem areas were delineated based on the cause or source of flooding and the areas which may potentially benefit from the flood reduction projects identified by this study. All neighborhoods within the E116-00-00 study area were assigned to a distinct problem area so the defined flooding metrics could be quantified, as shown in Figure 5.2 and in Exhibit 5.1. Potential improvement projects to reduce flood risk were prioritized based on the Flood Control District-provided criteria rather than the severity of the problem area in which the potential improvement is located. The severity of flooding in each problem area was used to guide the level of study effort and the number of alternatives to be evaluated for each area.

Figure 5.2. Overview of Problem Areas



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Due to the overflows from the study area, the problem area boundaries extend beyond the MAAPnext drainage subbasins but are refined to the limits of potential improvement project benefits. Detailed metrics for each of the problem areas are documented in Table 3.1. A summary of those metrics is provided in Figure 5.3.

Figure 5.3. Summary of Problem Area Flooding Data

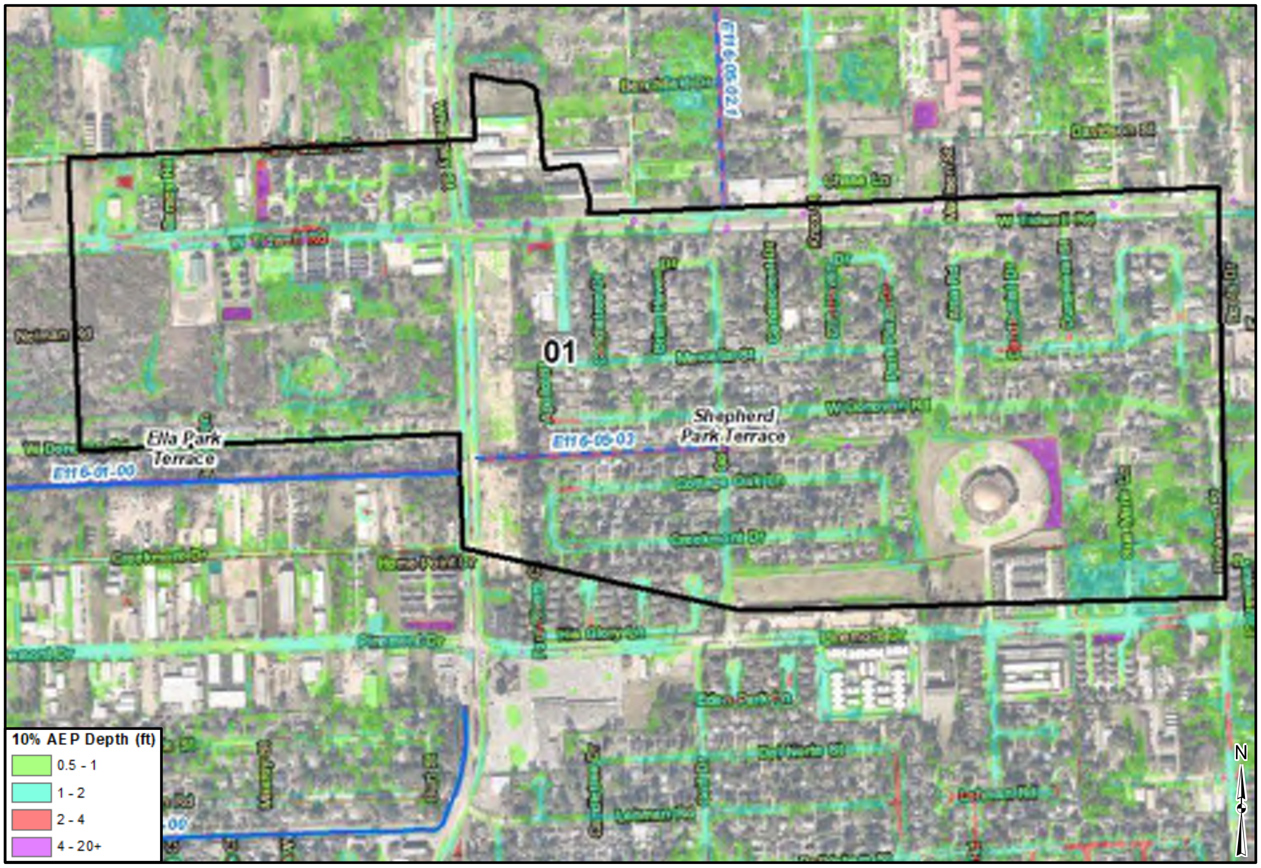
		Predicted Structural Flooding (1% AEP)	Predicted Roadway Flooding (> 1-foot for 1% AEP)	FEMA Claims (1978-2020)	FEMA Repetitive Losses
	(count of structures)	(count of structures)	(miles)	(count of claims)	(count recorded)
PA01	98	22	4.7	94	13
PA02	101	26	6.2	120	17
PA03	73	27	2.1	105	25
PA04	98	29	3.0	42	8
PA05	13	5	1.3	5	0

5.2.1 Problem Area 01

PA01 is located adjacent to the terminus of E116-01-00, from Brinkman Street to approximately 2,060 feet west of the intersection of Wheatley Street with West Tidwell Road (see Exhibit 5.2). The flood prone Shepherd Park Terrace (SPT) neighborhood is located within this problem area. PA01 was identified with the highest density of non-repetitive loss flooding, numerous structures recorded to have flooded from 2015-2019, and extensive roadway flooding over one foot predicted for the 1% AEP event (see Table 3.2). Revised modeling demonstrates high levels of overland sheet flow traveling from the northwest to the southeast across Wheatley Street and West Tidwell Road, causing significant inundation within this problem area and SPT.

The SPT project identified runoff from West Tidwell Road as the primary source of flooding within the neighborhood. E116-01-00 is not adequately sized to convey all runoff approaching it. Insufficient capacity within storm drains and surface ROW also contribute to the flooding concerns. During a 10% AEP storm event, widespread inundation is predicted within the problem area, with most roadways inundated by more than one foot, impacting mobility, and four structures are predicted to experience flooding. Depth of flooding in PA01 during a 10% AEP storm event is shown in Figure 5.4.

Figure 5.4. PA01 Flooding Depth for 10% AEP

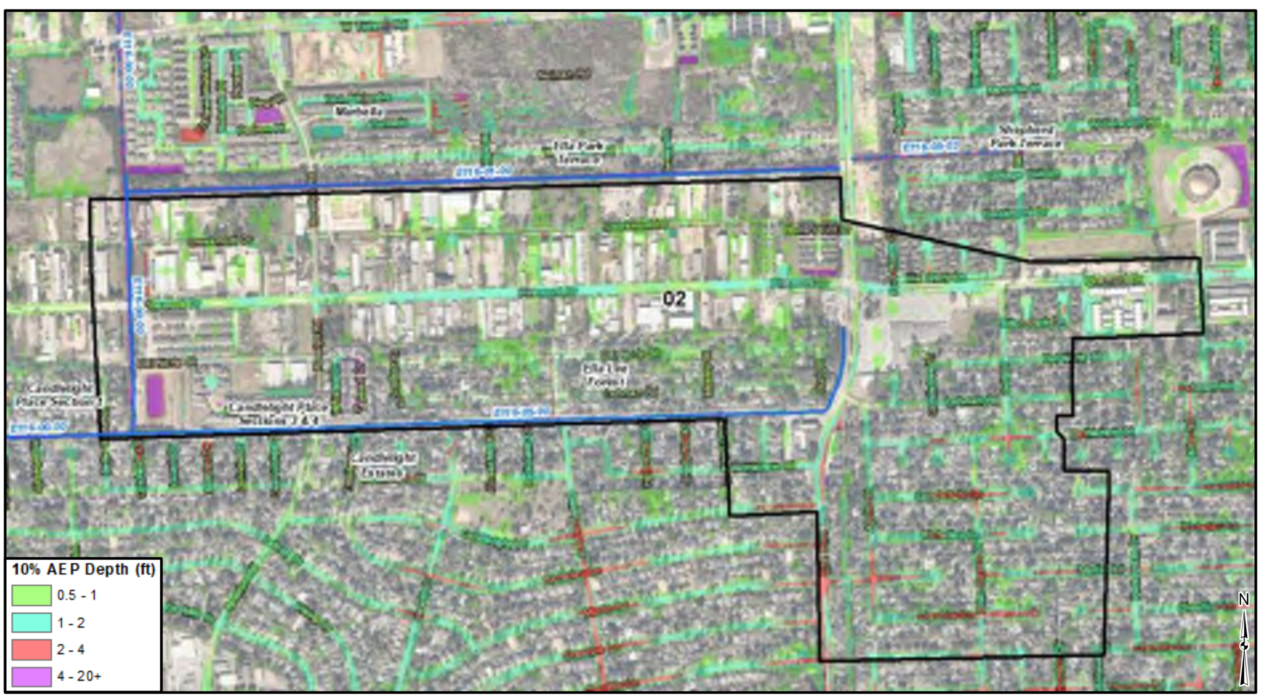


While the majority of the problem area boundary lies within the E116-00-00 subbasin, the easternmost third of PA01 drains to overflow towards E101-00-00 to the east. However, the problem area is identified for E116-00-00 based on intended outfall of subsurface drainage infrastructure. The SPT project has identified a junction box under Wheatley Street which collects incoming flows from SPT, via E116-05-03, and directs approximately half to E116-01-00 and the other half further south into E116-05-00. Improvements to reduce overflows from West Tidwell Road and Wheatley Street by conveyance improvements further upstream within the E116-00-00 study area can provide flood reduction benefits to PA01. Additional flood reduction measures will be realized by localized improvements from the SPT project completed by COH.

5.2.2 Problem Area 02

PA02 is located along the E116-05-00 channel, bounded by the left overbanks of E116-05-00 and E116-01-00 (see Exhibit 5.3). Detention basin E516-01-00, the sole Flood Control District stormwater detention basin in the study area, is located in this problem area. PA02 is identified by the highest counts of historical flooded structures and FEMA claims, as well as the most predicted roadway flooding over one foot of depth during a 1% AEP storm event (see Table 3.3). Modeling demonstrates overflow from the upstream end of E116-05-00 due to inadequate capacity, along with an undersized culvert at Lehman Road / Ella Boulevard, contributes to inundating structures along Ella Boulevard. Overland sheet flow escaping the surface ROW of Pinemont Drive and traveling south through industrial sites contributes to inundation within the Ella Lee Forest neighborhood. Widespread inundation is predicted during a 10% AEP storm event in PA02, with 26,000 linear feet of roadways predicted to flood by over one foot and two structures experiencing flooding. Depth of flooding in PA02 during a 10% AEP storm event is shown in Figure 5.5.

Figure 5.5. PA02 Flooding Depth for 10% AEP

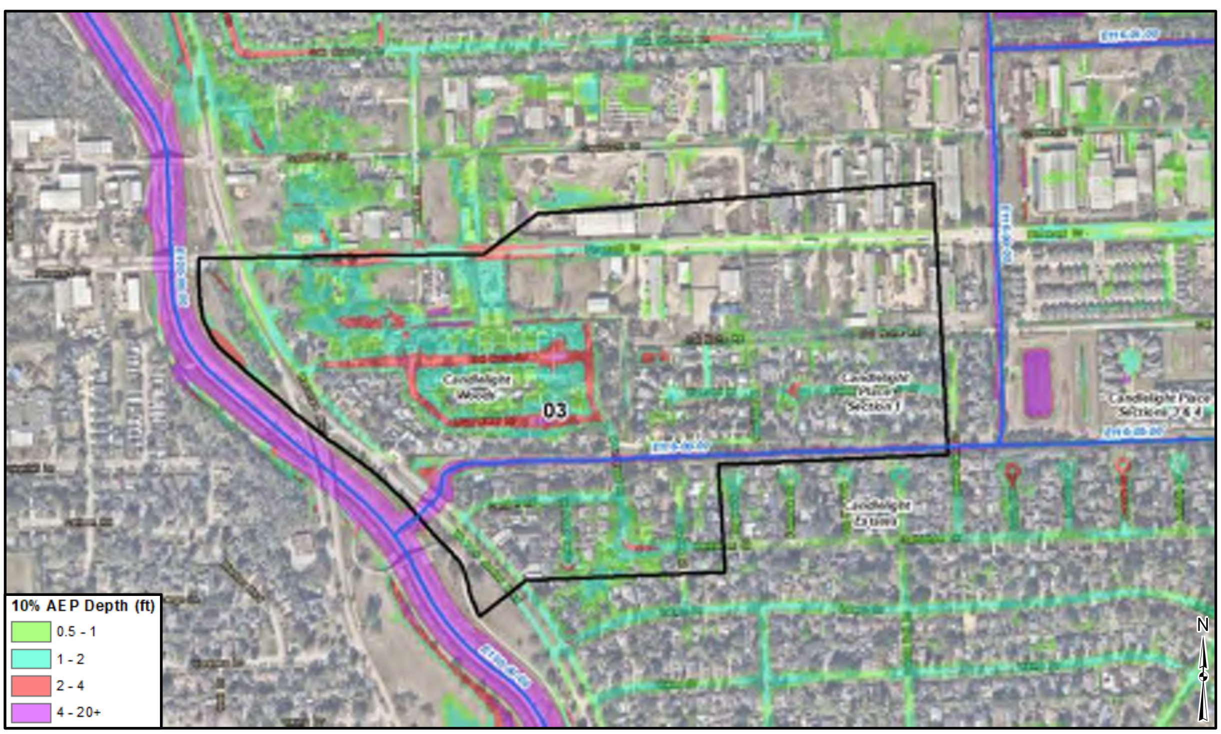


Improvements to reduce runoff from industrial sites into the developments to the south, reduce overflow from Pinemont Drive, and increase capacity at the upstream end of E116-05-00 can provide flood reduction benefits to PA02.

5.2.3 Problem Area 03

PA03 is located at the downstream reach of E116-00-00, with a portion of the channel within the backwater from White Oak Bayou E100-00-00 (see Exhibit 5.4). The single-family residential development of Candlelight Woods downstream of Mountwood Street (N/S street located just east of TC Jester Boulevard) demonstrates numerous historical and predicted flooded structures, with flooding depths in excess of one foot (see Table 3.4). Backwater from White Oak Bayou causes an elevated WSEL within E116-00-00. The revised modeling indicates that elevated WSEL within White Oak Bayou inhibits the flow of overland sheet flow from entering the open channel infrastructure. Even during a 10% AEP storm event, widespread inundation is documented within the problem area, with PA03 experiencing the highest number of predicted flooded structures for such an event. Depth of flooding during a 10% AEP storm event is shown in Figure 5.6.

Figure 5.6. PA03 Flooding Depth for 10% AEP



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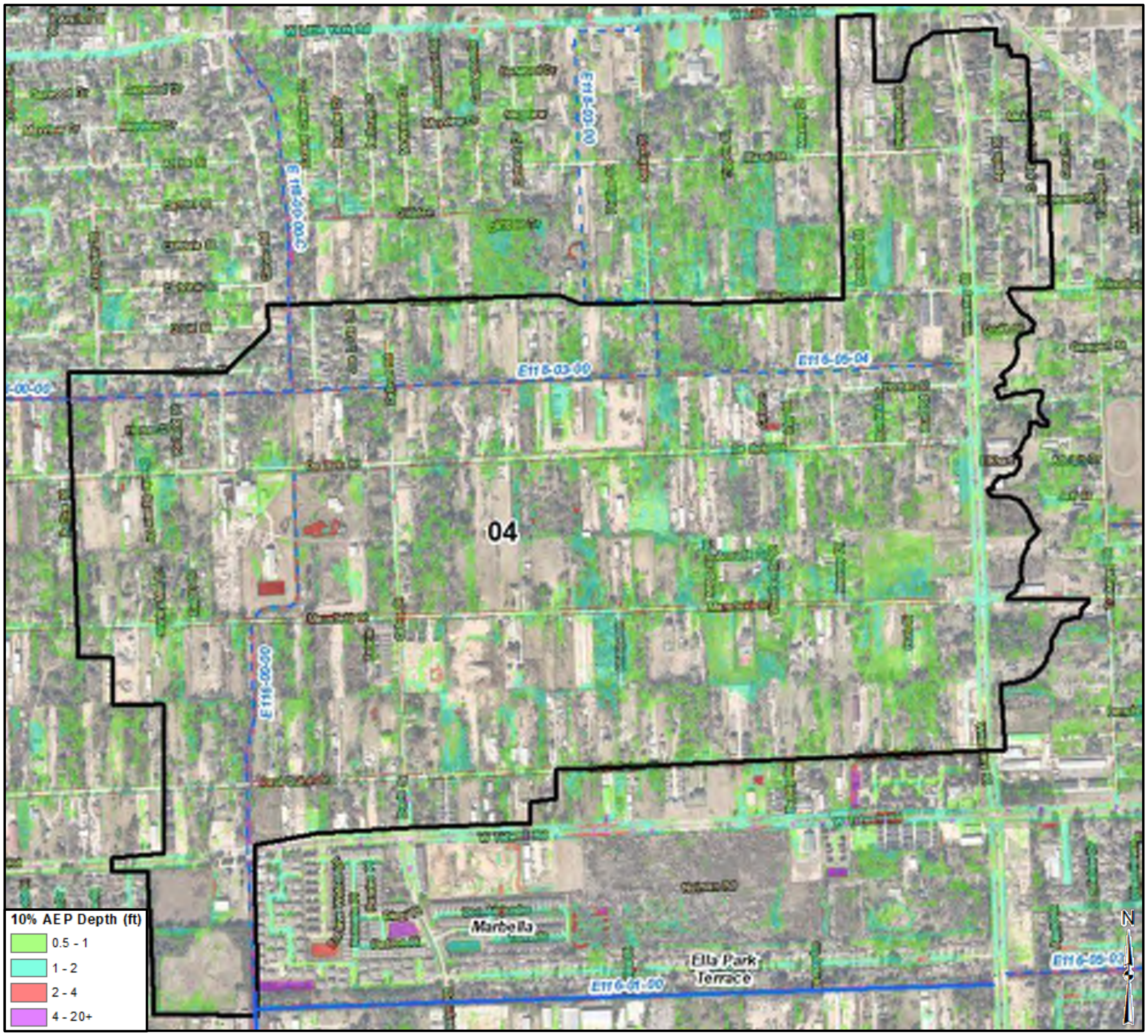
Potential improvements within PA03 would require lowering the WSEL in White Oak Bayou and increasing capacity within local storm drains. Consequently, lowering these tailwater conditions would require major projects beyond the scope and funding of this feasibility study. One other option to reduce the flooding damages in this area is the voluntary buyout and removal of homes in the Candlelight Woods development or re-construction of homes with a higher slab elevation. This type of option appears to be the most viable option to cost-effectively reduce flood risk for this area.

5.2.4 Problem Area 04

PA04 is located at the terminus of E116-00-00 ROW owned by the Flood Control District and comprises the northern half of the study area (see Exhibit 5.5). Portions of the E118-00-00 and E118-03-00 channels are located towards the northern edge of this problem area. PA04 generally ranges from Wilburforce Street to West Tidwell Road with the southwestern corner extending south to the E116-00-00 confluence with E116-01-00 and the northeastern corner extending north to West Little York Road. Though the Flood Control District ROW for E116-00-00 terminates at Paul Quinn Street, the channel itself extends further north to De Soto Street. Larger, partially developed tracts of land served by roadside ditches dominate the area.

Historical and predicted flooded structures are found throughout PA04, with clusters in smaller residential tracts (see Table 3.5). Most roadways are inundated in a 10% AEP storm event, particularly Wheatley Street, De Soto Street and Mansfield Street which creates an emergency access concern. Revised modeling indicates the primary cause of flooding to be overland sheet flow entering from the north, generally traveling northwest to southeast. Overflow from E118-03-00 and inadequate capacity within the roadside ditches and surface ROW contribute to the inundation. In events as small as a 10% AEP storm, widespread flooding occurs, with PA04 experiencing extensive roadway flooding and six structures inundated. Depth of flooding during a 10% AEP storm event is shown in Figure 5.7.

Figure 5.7. PA04 Flooding Depth for 10% AEP



Increased stormwater drainage capacity along Wheatley Street and increased capacity in local street surface ROW can provide flood reduction benefits in PA04. Improvements to E118-00-00 open channel infrastructure may reduce offsite overflow from entering this problem area, but such improvements are beyond the scope of this feasibility study. Additional capacity may be required in existing E116-00-00 open channel infrastructure to provide an adequate outfall for street surface ROW drainage. Reducing overland sheet flow in PA04 can provide benefits to other downstream problem areas. The concept of micro-detention was considered for this problem area based on the nature of the large-lot

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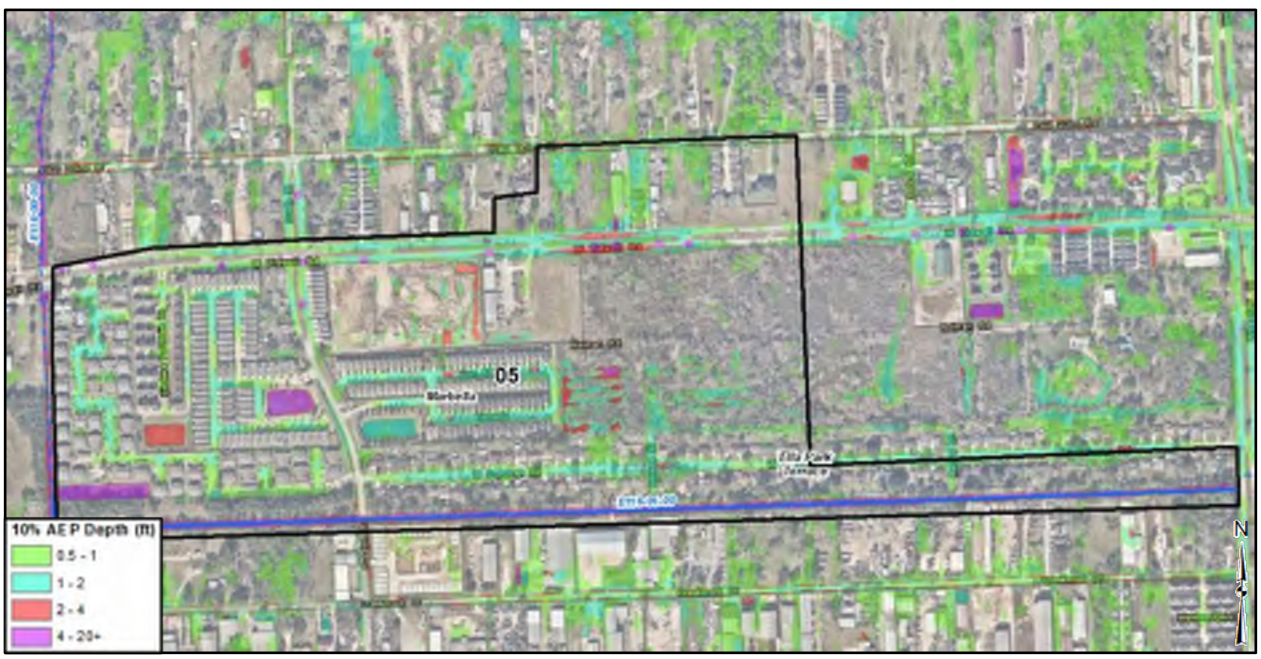
development; however, this option was not determined to provide significant benefits or be readily viable.

5.2.5 Problem Area 05

PA05 is located along the E116-01-00 channel, generally bound by West Tidwell Road to the north (see Exhibit 5.6). Several historical flooded structures and FEMA claims are contained in this area, concentrated in the Ella Park Terrace neighborhood along West Donovan Road on the right overbank of E116-01-00. Flooded roadways are the primary flooding concern in the problem area, with most at a depth of one foot or more during a 1% AEP storm event (see Table 3.6). PA05 is also undergoing rapid redevelopment, particularly around the Marbella subdivision. Revised modeling indicates E116-01-00 currently provides a 2% AEP LOS, reduced to 10% upstream as demonstrated in Exhibit 4.3. Overland sheet flow from the north is overwhelming the inadequate surface ROW along West Tidwell Road and contributing to the flood inundation. Depth of flooding during a 10% AEP storm event is shown in Figure 5.8. Reducing overflows from W Tidwell Road can provide flood reduction benefits to PA05.

Figure 5.8. PA05 Flooding Depth for 10% AEP



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5.3 Flooding Complaints

Harris County Commissioner Precinct 1 was not aware of any flooding complaints nor upcoming flood risk reduction projects within the study area, with the exception of SPT. COH provided a database of calls to the 3-1-1 Houston Service Helpline regarding flooding and storm sewer inspection complaints submitted by residents, dated 2014-2021. This database included complaints both within the E116-00-00 study area as well as an area of interest comprising of an approximate half-mile radius around the study area. Analysis of the 3-1-1 complaints supported the determination of concentrations of both historical structural flooding and predicted roadway flooding as developed for this study.

6 PROPOSED FLOOD REDUCTION PROJECTS

Given the large volumes of sheet flow occurring in the study area – due to a sparsity of open channel infrastructure – the maximum benefit from proposed flood reduction projects can only be realized when improvements are implemented for both Flood Control District and COH drainage infrastructure. In the following sections, the proposed improvements are categorized by the owner of the infrastructure to be improved.

6.1 Overall Strategy

A strategy to reduce the flooding throughout the entire study area has been identified. An overview of this strategy is included in Exhibit 6.1. Components of the strategy are based upon maximizing available vacant land and existing ROW. Various alternatives were considered, and the most promising options were selected for inclusion in the strategy for each problem area.

6.1.1 Problem Area 01

Proposed improvements identified for the Flood Control District infrastructure within PA01 include conveyance improvements using concrete or other hardened liners for E116-05-03, accompanied by larger culverts under Wheatley Street connecting to E116-01-00 – which replace the existing junction box. These improvements provide greater conveyance and lower tailwater to drain the Shepherd Park Terrace neighborhood.

Proposed improvements identified for the COH infrastructure within PA01 include micro-detention specifically within the raised medians of West Tidwell Road and Wheatley Street. This project would propose to depress the medians inside the curbs to provide a capture basin of sheet flow approaching these medians. Using depressions of ranging from two to three feet deep, approximately 4.7 acre-feet of volumetric storage is anticipated to be created. The depressed medians would be connected via 24-inch RCP that outfall to the newly improved culverts at E116-01-00. An overview of these improvements is shown in Figure 6.1. A detailed opinion of probable construction cost (OPCC) for these improvements is provided in Table 4.1, and a summary of those costs is shown in Figure 6.2.

Figure 6.1. Strategy for PA01

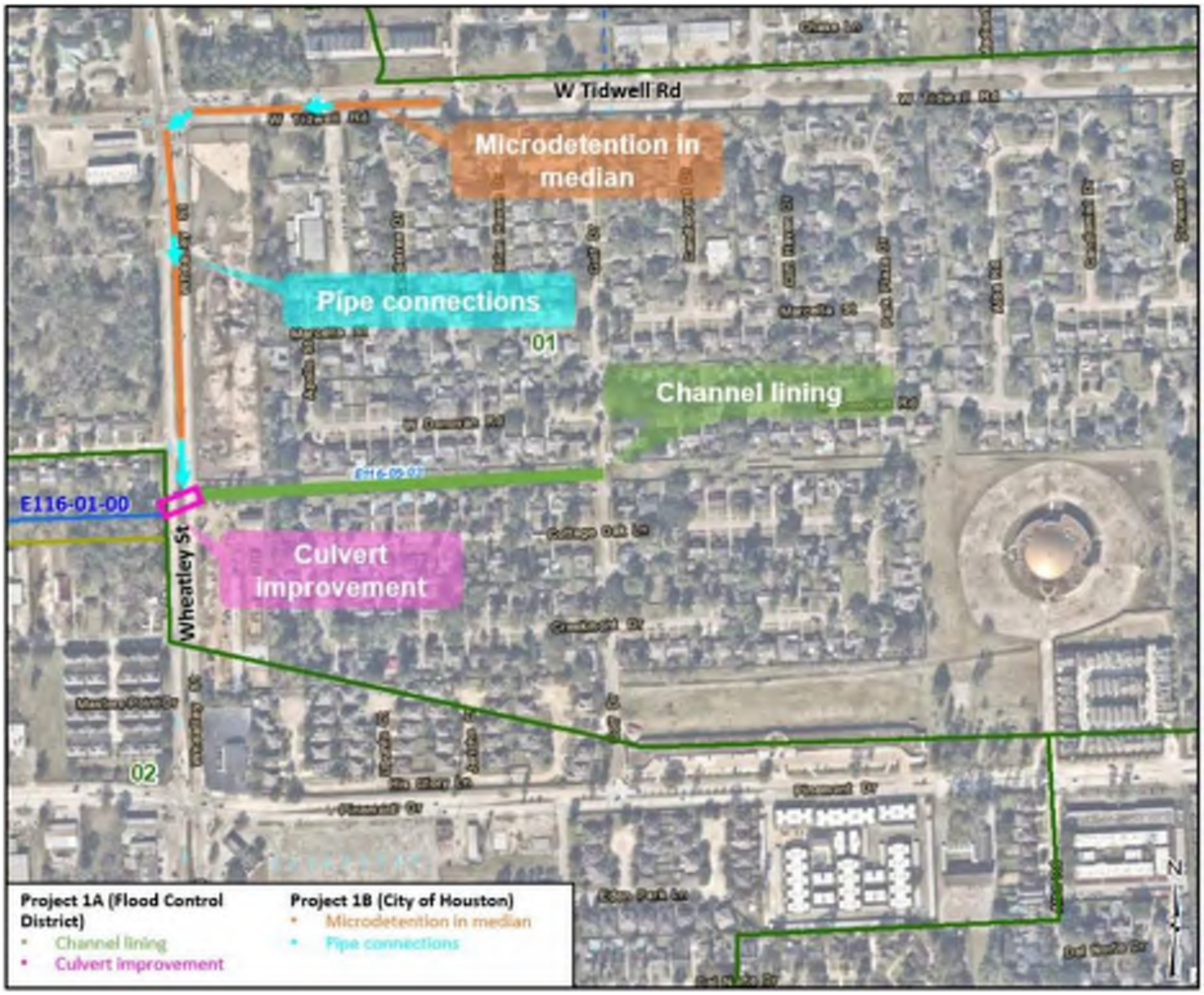

Figure 6.2. PA01: Opinion of Probable Construction Cost

	Flood Control District	City of Houston	Combined
Direct Construction	$ 1,750,000	$ 320,000	$ 2,070,000
Engineering and Contingencies	$ 998,000	$ 183,000	$ 1,181,000
ROW Acquisition	-	-	-
TOTAL	**$ 2,747,000**	**$ 502,000**	**$ 3,249,000**

6.1.2 Problem Area 02

Proposed improvements identified for the Flood Control District infrastructure within PA02 include conveyance improvements with the upsizing of the box culvert at Ella Boulevard and Lehman Road at E116-05-00 along with removal of siltation along E116-05-00 between Rosslyn Road and Ella Boulevard.

Proposed improvements identified for the COH infrastructure within PA02 include localized conveyance systems with expanded storm drain system at Ella Boulevard along with maintenance and expansion of existing roadside ditches throughout the Ella Lee Forest neighborhood. An overview of these improvements is shown in Figure 6.3. The proposed improvements will not fit within the existing public ROW. As a result, ROW acquisition costs are necessary to provide sufficient space for the widened roadside ditches. A detailed OPCC for these improvements is provided in Table 4.2, and a summary of those costs is shown in Figure 6.4.

Figure 6.3. Strategy for PA02

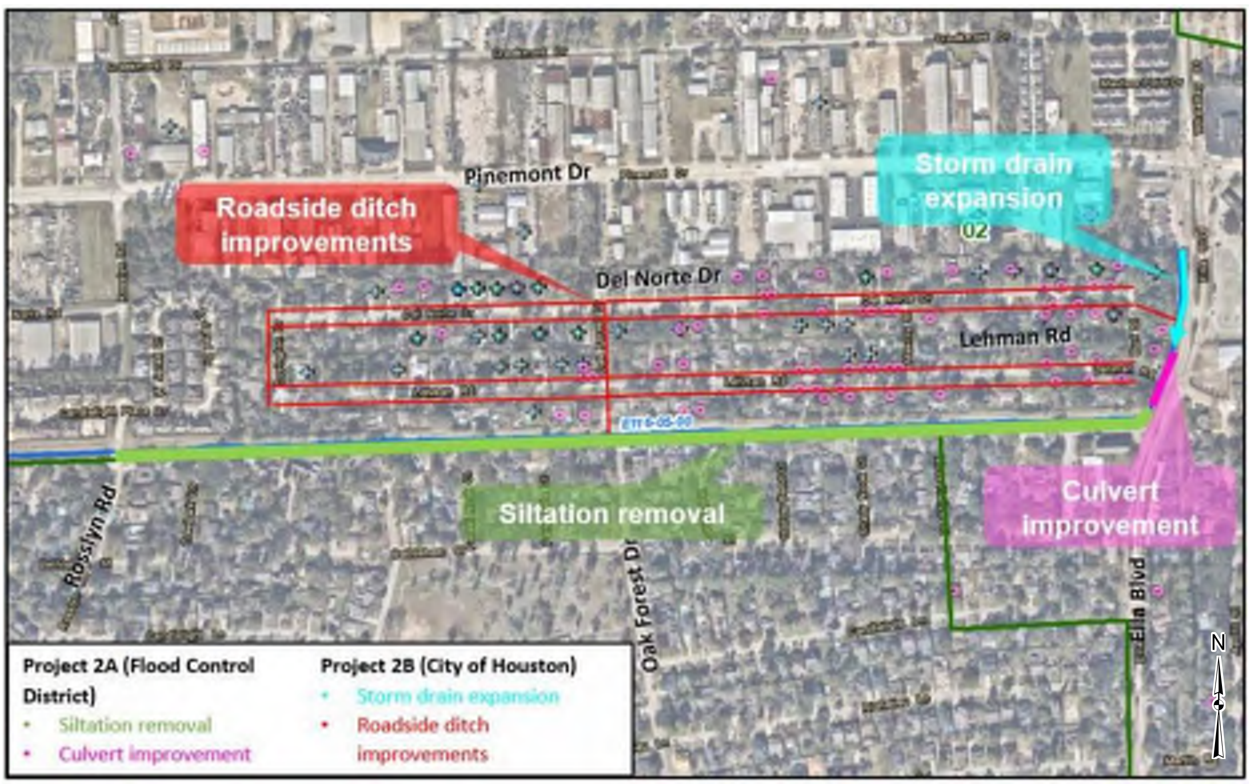

Figure 6.4. PA02: Opinion of Probable Construction Cost

	Flood Control District	City of Houston	Combined
Direct Construction	$ 1,916,000	$ 5,452,000	$ 7,368,000
Engineering and Contingencies	$ 1,093,000	$ 3,108,000	$ 4,201,000
ROW Acquisition Cost	-	$ 2,850,000	$ 2,850,000
TOTAL	**$ 3,008,000**	**$ 11,409,000**	**$ 14,417,000**

6.1.3 Problem Area 03

As discussed above in Section 5.2.1, the primary source of flooding within PA03 is backwater from E100-00-00. Proposing a structural improvement to improve the widespread flooding in this area is beyond the scope of this feasibility study. As a result, the primary option considered to create a potentially viable project to reduce flooding in this area is voluntary buyouts in the Candlelight Woods neighborhood. The cost of this voluntary buyout is anticipated to range from $10 million to $20 million. It should be noted that the cost of the project is based solely on the appraised value with no additional mark-up for relocation costs since this buyout option is considered to be strictly voluntary.

6.1.4 Problem Area 04

Proposed improvements identified for the Flood Control District infrastructure within PA04 include conveyance improvements via channel widening to E116-00-00, which will also require expanded ROW, and upsizing the culvert crossing at West Tidwell Road. The total length of channel improvements is 6,000 LF. Proposed improvements identified for the COH infrastructure within PA04 include expanding the existing roadside ditches along three streets – De Soto Street, Mansfield Street, and Paul Quinn Street. The total length of expanded roadside ditches is approximately 15,330 LF.

The 1D/2D modeling of the proposed improvements indicates that the increased conveyance system does not induce any increases in WSEL at any point downstream of the improvements, primarily based on the timing of the watershed. However, conveyance improvements are typically accompanied by stormwater detention basin storage to offset the increased efficiency of the system. As a result, two stormwater detention basins have been added within the problem area to be maintained under the financial responsibility of the Flood Control District.

The North Basin is a relatively shallow basin located around several existing antenna towers which will not require any home relocations, but will require cooperative agreements with the property owners and careful construction to avoid disturbance to any of the existing infrastructure on site. At the location of the South Basin, two existing stormwater detention basins have already been constructed – the eastern one was constructed as part of private development, while the western one is the existing Flood Control District stormwater detention basin E516-01-00, as discussed in Section 2.2. This project would propose to combine those two existing basins by excavating the embankment currently located between them and thereby providing additional volume for peak flow attenuation. These improvements are anticipated to provide an additional 90 and 20.4 acre-feet of storage for the North and South Basins, respectively.

An overview of these improvements is shown in Figure 6.5. The proposed improvements will not fit within the existing public ROW. As a result, ROW acquisition costs are necessary to provide sufficient space for the widened channels and roadside ditches along with the new stormwater detention basin. A detailed OPCC for these improvements is provided in Table 4.3, and a summary of those costs is shown in Figure 6.6.

Figure 6.5. Strategy for PA04

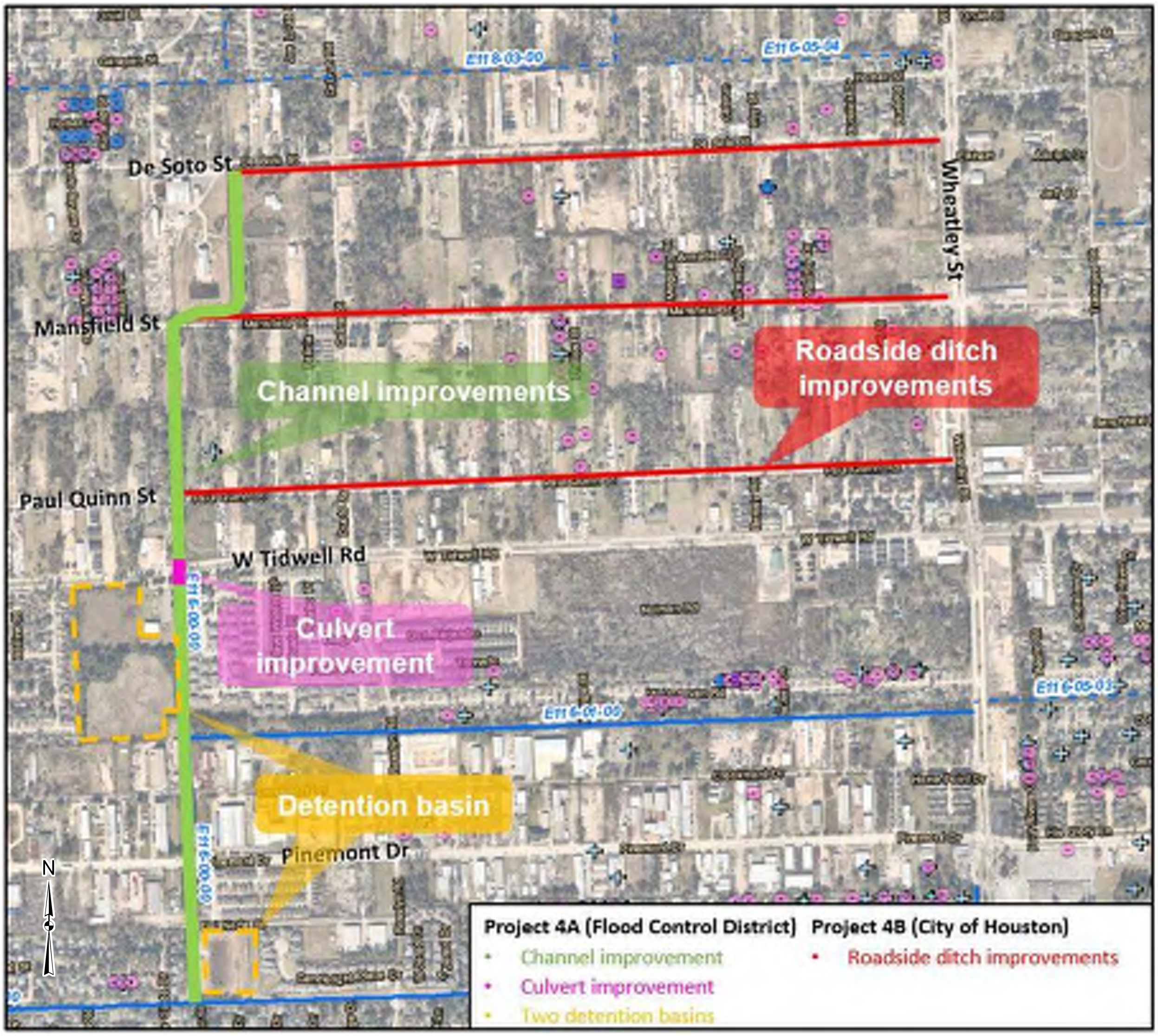

Figure 6.6. PA04: Opinion of Probable Construction Cost

	Flood Control District	City of Houston	Combined
Direct Construction	$ 2,473,000	$ 2,480,000	$ 4,953,000
Engineering and Contingencies	$ 1,410,000	$ 1,414,000	$ 2,824,000
ROW Acquisition	$ 6,638,000	$ 1,628,000	$ 8,266,000
TOTAL	**$ 10,520,000**	**$ 5,522,000**	**$ 16,042,000**

6.1.5 Problem Area 05

Proposed improvements identified for the Flood Control District infrastructure within PA05 include upsizing the culvert crossing of E116-00-00 at West Tidwell Road, which is also proposed as part of the improvements in PA04. Proposed improvements identified for COH infrastructure within PA05 include expanded roadside ditch along the north side of West Tidwell Road to convey runoff to E116-00-00 more efficiently. The total length of expanded roadside ditches is 3,200 LF.

An overview of these improvements is shown in Figure 6.7. The proposed improvements will not fit within the existing public ROW. As a result, ROW acquisition costs are necessary to provide sufficient space for the widened roadside ditches. A detailed OPCC for these improvements is provided in Table 4.4, and a summary of those costs is shown in Figure 6.8.

Figure 6.7. Strategy for PA05

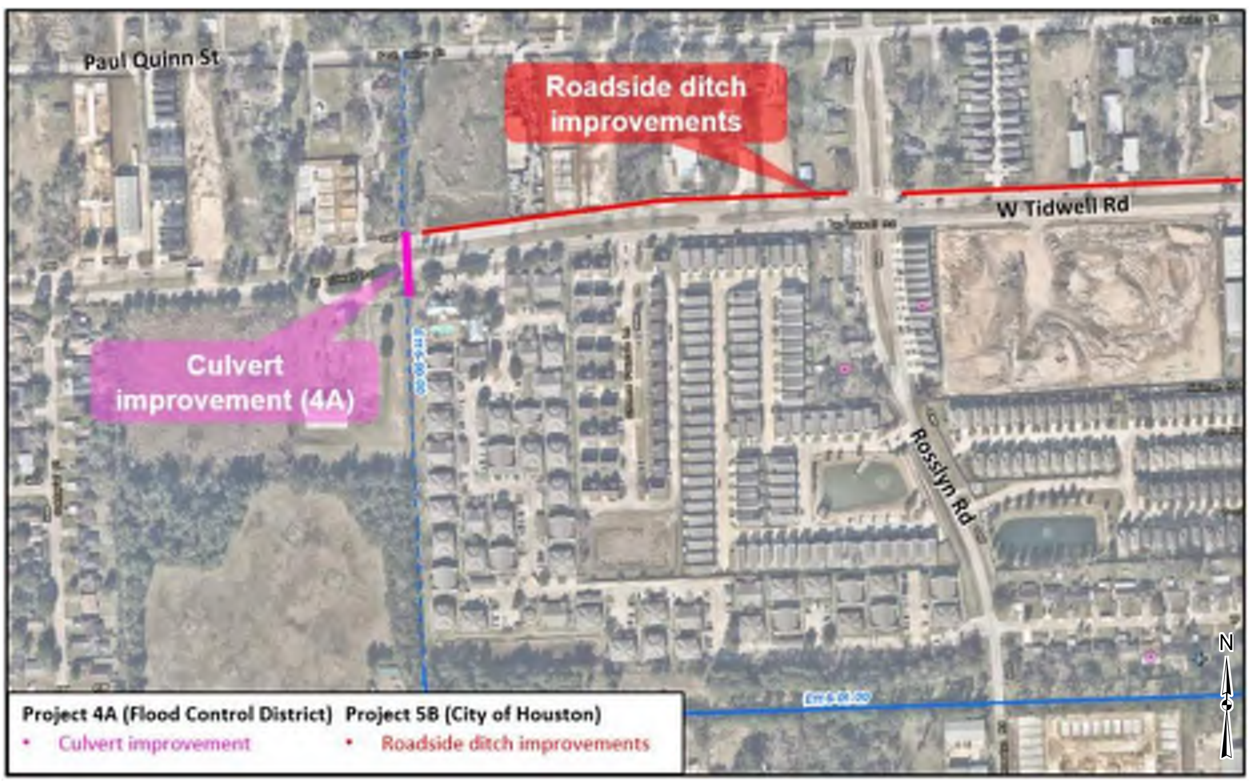

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Figure 6.8. PA05: Opinion of Probable Construction Cost

	Flood Control District	City of Houston	Combined
Direct Construction	-	$ 512,000	$ 512,000
Engineering and Contingencies	-	$ 292,000	$ 292,000
ROW Acquisition Cost	-	$ 480,000	$ 480,000
TOTAL	**-**	**$ 1,284,000**	**$ 1,284,000**

6.1.6 Estimate of Flood Risk Reductions

The benefits to the study area from the combined effect of the overall flood reduction strategy can be seen in Exhibit 6.2. Reductions in the 1% AEP WSEL of ~0.10 feet are widespread with a reduction as great as 0.50 feet measured in many locations in the study area. The overall flood reduction strategy also creates more efficient overflow patterns as shown in Exhibit 6.3.

The damage reduction estimates for the overall watershed strategy are provided in Figure 6.9. Full benefit is defined as structures or roadways where inundation is eliminated. Partial benefit is defined as the depth of inundation is reduced by more than 0.10 feet across the building footprint. A partial benefit is not relevant to non-structural flooding. Total benefitted is the sum of the full and partial benefits. Detailed calculations of the flooding metrics for each problem area are included in Tables 5.1 to 5.6.

Figure 6.9. Flooding Metrics Related to Overall Strategy

Flood Risk Metric	Existing Condition Flood Risk	Full Benefit	Partial Benefit	Total Benefitted
Predicted Structural Flooding (Any Depth)		**Counts**		
10% AEP	19	3	0	3
4% AEP	35	6	3	9
2% AEP	72	12	6	18
1% AEP	109	20	12	32
Non-Structural Flooding (+1-ft Depth, 1% AEP)		**Linear Footage**		
Interstate, Freeways, Expressways	0	0	-	0
Arterials, Major Collectors	25,500	5,500	-	5,500
Local Roadways	65,600	4,800	-	4,800

6.1.7 *Opinion of Probable Construction Cost*

The total feasibility-level cost estimates for the overall flood reduction strategy used the unit prices provided in the cost estimating tool developed by the Flood Control District for feasibility studies based on 2019 bid tabulations. Quantities were based on linear estimates for the ditch and channel improvements. Using guidance from the Flood Control District Property Department, ROW acquisition costs are based on a 2.5 multiplier to the current market value reported by the Harris County Appraisal District for each property. For display purposes, all costs are rounded to the thousands.

Given the current trends in inflation, an estimated increase of 60% in construction prices was observed from 2019 to 2022. This escalation value is considered to be conservative based on the current volatility of the construction industry and supply chain difficulties. As these potential projects progress further towards construction, a thorough review of the costs should be completed to apply relevant, up-to-date unit prices in lieu of the assumptions applied in this study. A summary of the cost for the overall watershed strategy is shown in Figure 6.10.

Figure 6.10. Overall Flood Reduction Strategy OPCC

	Flood Control District	City of Houston	Combined
Direct Construction	$ 6,139,000	$ 8,764,000	$ 14,903,000
Engineering and Contingencies	$ 3,501,000	$ 4,997,000	$ 8,498,000
ROW Acquisition	$ 6,638,000	$ 4,958,000	$ 11,596,000
TOTAL	**$ 16,278,000**	**$ 18,719,000**	**$ 34,997,000**

6.2 Recommended Project

There was no allocation of funding from the 2018 Bond Program for capital improvements within the study area; however, an initial recommended project with a target estimated cost of $10 million has been identified for potential near-term construction as future funding becomes available through other sources. This initial project would serve as the first step for implementation of the overall flood reduction strategy. If greater or lesser funding amounts are eventually identified for this area, the initial recommended project can be increased or decreased accordingly.

6.2.1 Project Details

The recommended project includes select components discussed in Section 6.1 from PA01, PA02, and PA04, as shown in Exhibit 6.4 and presented in Figure 6.11.

Figure 6.11. Recommended Project Components

Problem Area	Flood Control District Infrastructure	City of Houston Infrastructure
PA01	• Lining of channel E116-05-03 • Replace junction box with larger culverts under Wheatley St	• Micro-detention within medians of W Tidwell Rd and Wheatley St • Storm sewers to connect median sections
PA02	• Siltation removal from E116-05-00 from Rosslyn Rd to Ella Blvd • Upsize box culverts at crossing of Ella Blvd and Lehman Rd at E116-05-00	• Storm drainage system expansion along Ella Blvd
PA04	• Channel widening to E116-00-00 • Upsize culvert crossing at W Tidwell Rd • South detention basin enlargement	• None

6.2.2 Estimate of Flood Risk Reductions

The benefits to the study area from the initial recommended project can be seen in Exhibits 6.5 to 6.8, for all storm events calculated. Despite not providing the full benefit of the overall flood reduction strategy, the recommended project provides measurable benefit to the study area.

The damage reduction estimates for the recommended project are provided in Figure 6.12. Full benefit is defined as structures or roadways where inundation is eliminated. Partial benefit is defined as the depth of inundation is reduced by more than 0.10 feet across the building footprint. A partial benefit is not relevant to non-structural flooding. Total benefitted is the sum of the full and partial benefits. Detailed calculations of the flooding metrics for each problem area are included in Tables 6.1 to 6.6.

Figure 6.12. Flooding Metrics Related to Recommended Project

Flood Risk Metric	Existing Condition Flood Risk	Full Benefit	Partial Benefit	Total Benefitted
Predicted Flooding (Any Depth)		**Counts**		
10% AEP	19	1	0	1
4% AEP	35	2	1	3
2% AEP	72	8	1	9
1% AEP	109	12	6	18
Non-Structural Flooding (+1-ft Depth, 1% AEP)		**Linear Footage**		
Interstate, Freeways, Expressways	0	0	-	0
Arterials, Major Collectors	25,500	1,900	-	1,900
Local Roadways	65,600	2,700	-	2,700

6.2.3 Opinion of Probable Construction Cost

Detailed OPCC calculations for the recommended project, by problem area, are provided in Table 4.5, with an overall summary of the recommended project in relation to the overall flood reduction strategy included in Table 4.6. A summary of the cost for the recommended project is shown in Figure 6.13.

Figure 6.13. Recommended Project OPCC

	Flood Control District	City of Houston	Combined
Direct Construction	$ 4,747,000	$ 858,000	$ 5,605,000
Engineering and Contingencies	$ 2,707,000	$ 490,000	$ 3,197,000
ROW Acquisition	$ 1,050,000	-	$ 1,050,000
TOTAL	**$ 8,504,000**	**$ 1,348,000**	**$ 9,852,000**

6.3 Future Planning Projects

Components of the overall flood reduction strategy to be considered for future implementation include all of the structural components not included in the initial recommended project, as presented in Figure 6.14. Detailed discussion of these items is included in Section 6.1. A summary of the cost for the future planning projects is shown in Figure 6.15.

Figure 6.14. Future Planning Projects

Problem Area	Flood Control District Infrastructure	City of Houston Infrastructure
PA01	• None; all components included in recommended project	• None; all components included in recommended project
PA02	• None; all components included in recommended project	• Maintenance and expansion of existing roadside ditches within Ella Lee Forest neighborhood
PA03	• None; components considered long-term	• No recommended improvements
PA04	• North detention basin	• Expanded roadside ditches along DeSoto St, Mansfield St, Paul Quinn St
PA05	• No recommended improvements	• Expanded roadside ditch along W Tidwell Rd

Figure 6.15. Future Planning Projects OPCC

	Flood Control District	City of Houston	Combined
Direct Construction	$ 1,392,000	$ 7,906,000	$ 9,298,000
Engineering and Contingencies	$ 794,000	$ 4,507,000	$ 5,301,000
ROW Acquisition	$ 5,588,000	$ 4,958,000	$ 10,546,000
TOTAL	**$ 7,774,000**	**$ 17,371,000**	**$ 25,145,000**

6.4 Long-Term Planning Projects

6.4.1 Problem Area 03

Voluntary buyouts are considered to be a potential option for reducing flood damages, and thus considered for long-term implementation. A large structural project along White Oak Bayou (E100-00-00) could provide reductions in flooding for the homes affected in PA03. However, in the absence of such improvements to E100-00-00, voluntary buyouts should then be considered. The cost of this voluntary buyout is anticipated to be $10 million to $20 million. In some instances, there may be a potential to physically raise the floor slab elevation above the predicted flood levels for the habited portion of the homes. This option is acceptable and might be preferred for some homeowners in lieu of voluntary buyouts.

6.4.2 E118-00-00 Channel Improvements

Review of the study area indicates significant sheet flow from north to south, particularly crossing the northern boundary of the study area. A small Flood Control District-maintained channel (E118-00-00) is located in the area; however, the channel was not modeled as a 1D reach in the Phase 1 MAAPnext model.

As part of this feasibility study, the potential to reduce flood damages in the E116-00-00 study area by constructing channel improvements along E118-00-00 was considered (thereby reducing overflows into the E116-00-00 study area). The predicted benefits were shown to be relatively small within this Flood Reduction Feasibility Study. Further evaluation of this option for the E118-00-00 area may be appropriate. Localized benefits along E118-00-00 could be realized by providing channel conveyance improvements for that channel. A secondary feasibility study should be completed to quantify the cost and potential benefits to the E118-00-00 area from these improvements.

6.5 Project Ranking Criteria

Project prioritization scoring criteria were provided by the Flood Control District in relation to the 2018 Bond Prioritization Framework. Eight criteria, each with a weighting factor, were used to evaluate the projects identified for each problem area. The criteria (and weighting factors) include:

1. Flood Risk Reduction (25%) – number of structures that experience full benefit of being completely removed from the predicted structural flooding, along with those receiving a partial benefit where the flood depth is reduced by 0.25 feet or more, but not completed eliminated; considers 10%, 2% and 1% AEP events.

2. Existing Conditions Drainage Level of Service (20%) – considers the count of structures predicted to be inundated by the 10%, 2%, and 1% AEP events; includes a modification factor for channels with insufficient ROW (less than 110 feet).

3. Social Vulnerability Index; SVI (20%) – area-weighted average of the federally calculated index for each problem area.

4. Project Efficiency (10%) – indicator of the Flood Control District project cost per structures with full or partial benefit in the 10%, 2%, and 1% AEP events; modified to assign an average value of $266,000 per structure benefitted.

5. Partnership Funding (10%) – based on percentage of potential cost sharing by others.

6. Long Term Maintenance Costs (5%) – indicator of typical, frequent/additional, or specialized maintenance requirements for the project.

7. Environmental Impacts (5%) – indicator of the extent of environmental impacts, specifically wetlands, and associated permitting requirements.

8. Potential for Multiple Benefits (5%) – indicator of the opportunity for multiple benefits of recreation and / or environmental benefits.

The proposed improvements recommended for the overall flood reduction strategy were scored using these criteria, as shown in Tables 7.1 to 7.7, and summarized in Figure 6.16.

Figure 6.16. Project Prioritization Scoring for Proposed Improvements in Overall Strategy

Problem Area	Crit. 1	Crit. 2	Crit. 3	Crit. 4	Crit. 5	Crit. 6	Crit. 7	Crit. 8	Total Score
PA01	0.01	0.15	2.00	0.00	0.40	0.50	0.50	0.15	3.71
PA02	0.01	0.35	1.07	0.00	0.80	0.50	0.40	0.00	3.13
PA03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA04	0.04	0.25	2.00	0.00	0.60	0.50	0.40	0.00	3.80
PA05	0.01	0.16	2.00	1.00	1.00	0.50	0.40	0.00	5.07
All PA	0.07	0.95	1.68	0.00	0.60	0.30	0.40	0.00	4.00

NOTE: To accommodate spacing, the table headings correlate to the numbering presented in the discussion immediately prior to the figures.

The proposed improvements included in the initial recommended project were also scored separately using the same criteria, as shown in Tables 7.8 to 7.12, and summarized in Figure 6.17.

Figure 6.17. Project Prioritization Scoring for Proposed Improvements in Recommended Project

Problem Area	Crit. 1	Crit. 2	Crit. 3	Crit. 4	Crit. 5	Crit. 6	Crit. 7	Crit. 8	Total Score
PA01	0.01	0.15	2.00	0.00	0.40	0.50	0.50	0.15	3.71
PA02	0.01	0.35	1.07	0.00	0.40	0.50	0.40	0.00	2.73
PA04	0.01	0.25	2.00	0.00	0.00	0.50	0.40	0.00	3.16
All PA	0.04	0.86	1.68	0.00	0.40	0.50	0.40	0.15	3.83

NOTE: To accommodate spacing, the table headings correlate to the numbering presented in the discussion immediately prior to the figures.

7 OTHER CONSIDERATIONS

7.1 Potential Mitigation Detention Basin Requirements

Discussion of stormwater detention basins is included in Section 6 as it relates to mitigation of adverse impacts from the proposed infrastructure improvements. No additional detention other than that discussed in Section 6 is expected to be necessary; however, possible adverse impacts should be further evaluated as a part of the future PER phase for all the proposed improvements.

7.2 Potential Impact of Improvements to Housing and Open Space

All the improvements discussed herein relate to improving living conditions, reducing nuisance structural flooding and providing better access during storm events for emergency vehicles and improved mobility to residents and commercial/industrial operations in their respective problem areas. Some of the increased ROW for channel improvements and for proposed detention basin sites will need to be acquired from privately-owned tracts of land, which may create an undesirable effect of loss of developable land within the County; however, care has been taken to limit the required additional ROW to avoid impacting existing insurable structures and to minimize required relocations associated with the acquisition.

7.3 Improved Mobility

Based on the existing conditions of the study area, several streets experience flood depths in excess of one foot, with many areas exceeding two feet during the 1% AEP storm. Important stretches of arterial streets including West Tidwell Road, Pinemont Drive, Wheatley Street, Mansfield Street, and De Soto Street show flood depths ranging from two to four feet which may pose concerns, particularly for emergency vehicles. With the improvements in the recommended project, flood depths in these roadways are reduced to a range of one to three feet, thus providing significantly improved mobility along these arterial corridors. After the overall flood reduction strategy is implemented, the benefits will become even greater.

7.4 Potential Impact of New Development

Review of recent trends indicate that the study area is subject to rapid re-development. Areas of older large-lot residential development tend to re-develop into more dense residential development resulting in increased impervious cover. One primary impediment to further high-quality development with respect to stormwater drainage is the significant amount of sheet flow running across tracts caused by the lack of adequate surface and subsurface conveyance systems.

In addition, the relative flatness of the area and the shallow drainage infrastructure is problematic for the stormwater detention basins necessary to mitigate adverse impacts caused by the increase in impervious cover that accompanies re-development. A shallow stormwater detention basin will be inefficient at providing storage volume with respect to the surface area allocated for mitigation. Stormwater detention basins that use pumps in order to provide additional storage at greater depths should be avoided based on the unreliable performance of such systems.

7.5 Recommended Regulatory Program Revisions

No specific revisions are recommended to the current Flood Control District and COH regulatory programs. All future re-development in the study area must be designed to current County and City policies to account for offsite sheet flow patterns and mitigate for increased impervious cover to avoid adverse impacts to adjacent property owners. This study provides new information regarding the depth and patterns of existing sheet flow during various storm events, and it is recommended that the City and County use this study's results to further guide the appropriate habitable slab elevations of new insurable structures that are currently being planned in the E116-00-00 subwatershed. One potential strategy for properly elevating structures without significant alteration to the sheet flow patterns is to use pier and beam slab construction specifically designed to allow for sheet flow patterns to remain largely unchanged, and thus avoiding additional adverse impacts to adjacent properties. In some instances, newly constructed structures that are not adequately elevated will continue to experience severe structural flooding, even during low rainfall storm events. These suggestions related to re-development are most especially pertinent for the Acres Homes area.

7.6 Additional Recommended Infrastructure

The overall flood reduction strategy proposes improvements to infrastructure that would fall under the operational and maintenance jurisdiction of both the Flood Control District and COH. The recommended project improvements include only minimal components recommended for COH infrastructure. However, in order to realize increased benefits for the study area, significant remaining infrastructure improvements from the overall flood reduction strategy should be implemented by the Flood Control District and COH. COH should also implement the Shepherd Park Terrace neighborhood drainage improvements in order to provide better drainage system performance during high frequency storm events.

Additional steps need to be taken by both the Flood Control District and COH to provide improved performance in the areas adjacent to the E116-00-00 subwatershed. This recommendation stems primarily from the need to reduce the large amount of sheet flow entering this subwatershed from the north near E118-00-00 and from the area just to the north of SPT and West Tidwell Road. Formulating solutions for these adjacent systems is beyond the scope of this study; however, recognizing their need to provide a comprehensive solution in the E116-00-00 subwatershed is worth noting and should be addressed with similar flood reduction feasibility initiatives in these adjacent areas.

8 PLAN FOR 1% AEP LEVEL OF SERVICE

For long range planning purposes, it is helpful for the Flood Control District to have a rough plan for what might be necessary to convey a 1% AEP flow within the Flood Control District infrastructure, assuming that localized drainage systems are sufficient to carry all stormwater runoff to the Flood Control District open channels.

8.1 Methodology

Hydrology is based upon the boundary conditions at the E116-00-00 study area boundary. For the purposes of this analysis, it was assumed that all adjacent drainage systems have adequate conveyance to handle the 1% AEP storm, which means that all existing overflows into the E116-00-00 subwatershed from these adjacent systems are assumed to be zero.

To determine how best to distribute the 1% AEP stormwater flows, a rough layout of additional channels was prepared, running from Wheatley Street in the east to the main stem of E116-00-00 in the west. These additional channels are proposed to be located at back of lot boundaries between De Soto Street, Mansfield Street, and Paul Quinn Street to collect and convey sheet flow being accumulated between these major arterials to E116-00-00. The contributing drainage to these additional channels, as well as to the current Flood Control District infrastructure of E116-00-00, E116-01-00, and E116-05-00, were delineated and site runoff curves were used to determine the 1% AEP peak flow values.

Normal depth calculations were applied to determine the size of the existing and additional channels required to convey the 1% AEP peak flows as calculated. Similarly, roadway crossings at the improved open channel reaches were expanded to achieve minimal head loss through the structures.

8.2 Proposed Improvements

The proposed improvements to provide the 1% AEP channel capacity are composed of channel lowering and widening and of roadway crossing upgrades, as presented in Exhibit 7. The proposed improvements include recommendations for both the enlargement of existing Flood Control District open channel infrastructure, along with newly proposed channels in the upper portion of the study area.

The increased efficiency of these channel improvements would be accompanied by the potential for increases in peak flows on downstream infrastructure. Peak flow mitigation measures may be necessary before discharging into White Oak Bayou. Based on the simplified methodology used in this exercise to quantify the size of the infrastructure needed, the required mitigation volume in a stormwater detention basin was not quantified nor modeled. During a more thorough study and design of a project to convey the 1% AEP event, the required mitigation volume will need to be evaluated and quantified.

8.3 Opinion of Probable Construction Cost

Detailed OPCC calculations for the improvements required to handle 1% AEP storm for each problem area are provided in Tables 4.7 to 4.11. A summary of those costs is shown in Figure 8.1. Note that these costs do not include any stormwater detention basins as mitigation measures.

Figure 8.1. 1% AEP Level of Service Plan OPCC

	Flood Control District	City of Houston	Combined
Direct Construction	$ 16,512,000	$ 8,764,000	$ 25,276,000
Engineering and Contingencies	$ 9,414,000	$ 4,997,000	$ 14,411,000
ROW Acquisition	$ 51,226,000	$ 2,850,000	$ 54,116,000
TOTAL	**$ 77,148,000**	**$ 16,609,000**	**$ 93,757,000**

9 QUALITY ASSURANCE AND QUALITY CONTROL PROCEDURES

Quality Assurance and Quality Control procedures were implemented throughout the activities of this E116-00-00 Flood Reduction Feasibility Study. All aspects of this study – including hydrology, hydraulics, mapping, OPCC, and flood metrics – were reviewed by the appropriate Principal, Project Manager, and Practice Leader. Technical review of the hydraulic model was performed with revisions made in response. The QA/QC forms, along with responses to the comments, are provided in Appendix B.

10 STAKEHOLDER ENGAGEMENT

The E116-00-00 Flood Reduction Feasibility Study is an informal partnership project with COH and the Flood Control District. The study is not subject to the existing blanket inter-local agreement signed between the Flood Control District and COH; however, the City has participated and assisted the Flood Control District throughout the conduct of this study. It is anticipated that potential flood damage reduction projects proposed for this study area may become formal partnership projects in the future and involve the Flood Control District, Harris County, and/or COH. All feasibility study materials and meetings have been open and available to personnel from these agencies.

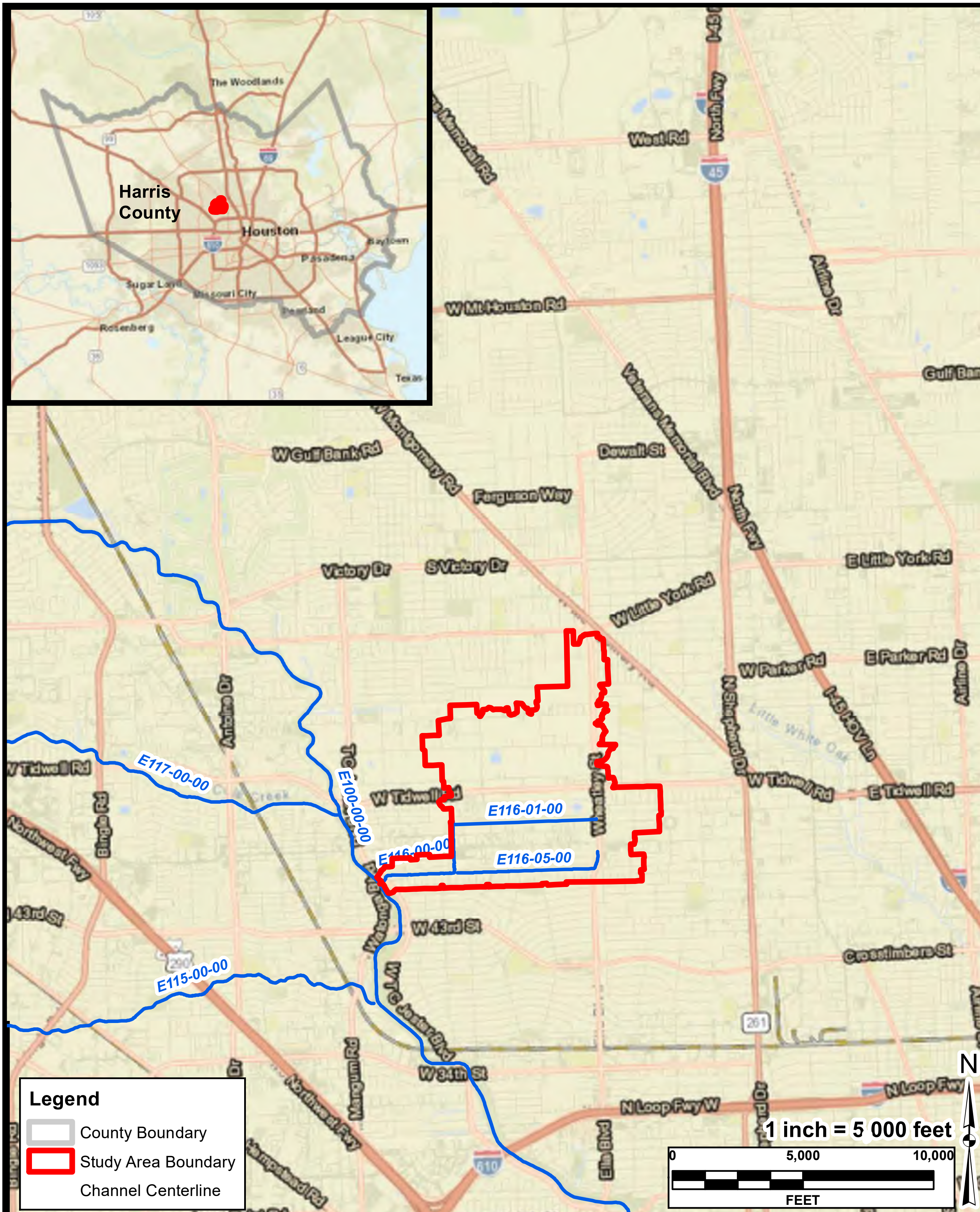
Specific engagement activities included:

- Bimonthly meetings with the Flood Control District conducted from May 2021 through August 2022. A copy of the meetings notes from each meeting is included in Appendix C.
- Two technical workshops were conducted to present the findings and recommendations of this study to personnel at the Flood Control District and receive additional feedback. A copy of the presentation from each workshop is included in Appendix C.
- Five briefings were completed to present the findings and recommendations of this study to Harris County Commissioner Precincts #1 and #4, COH executives and Flood Control District executives to receive additional feedback. A copy of the presentation from each briefing is included in Appendix C.
- One public meeting may be hosted by the Flood Control District to present the findings and recommendations of this study to members of the general public and receive additional feedback. As of the publication of this report, that public meeting has not yet been scheduled.

EXHIBITS

EXHIBITS

1. Vicinity Map



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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX
Vicinity Map

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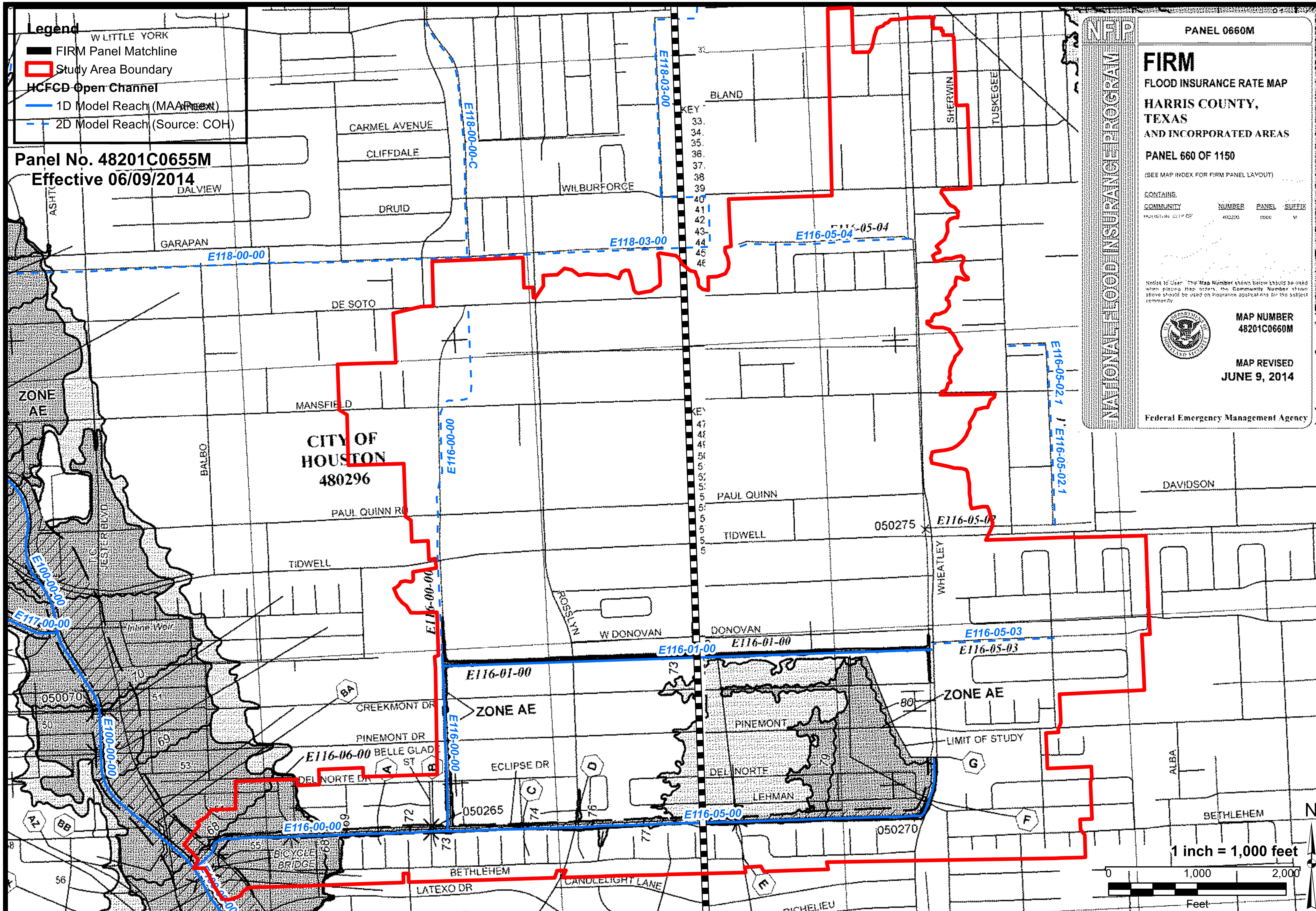
EXHIBITS

2. Study Area Description Exhibits
    2.1. Effective Floodplain
    2.2. Study Area Overview



E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Effective Floodplain

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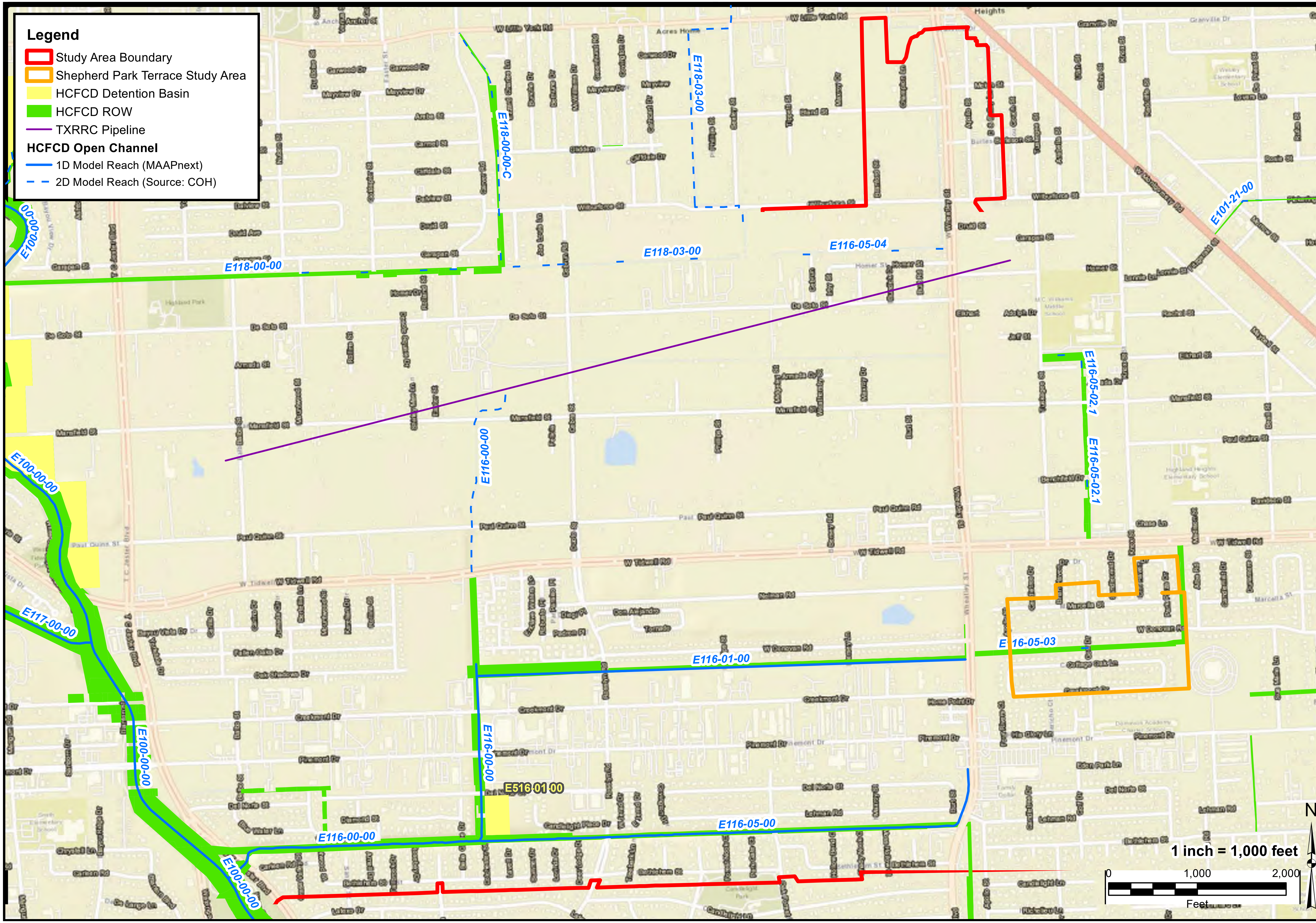

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Study Area Overview

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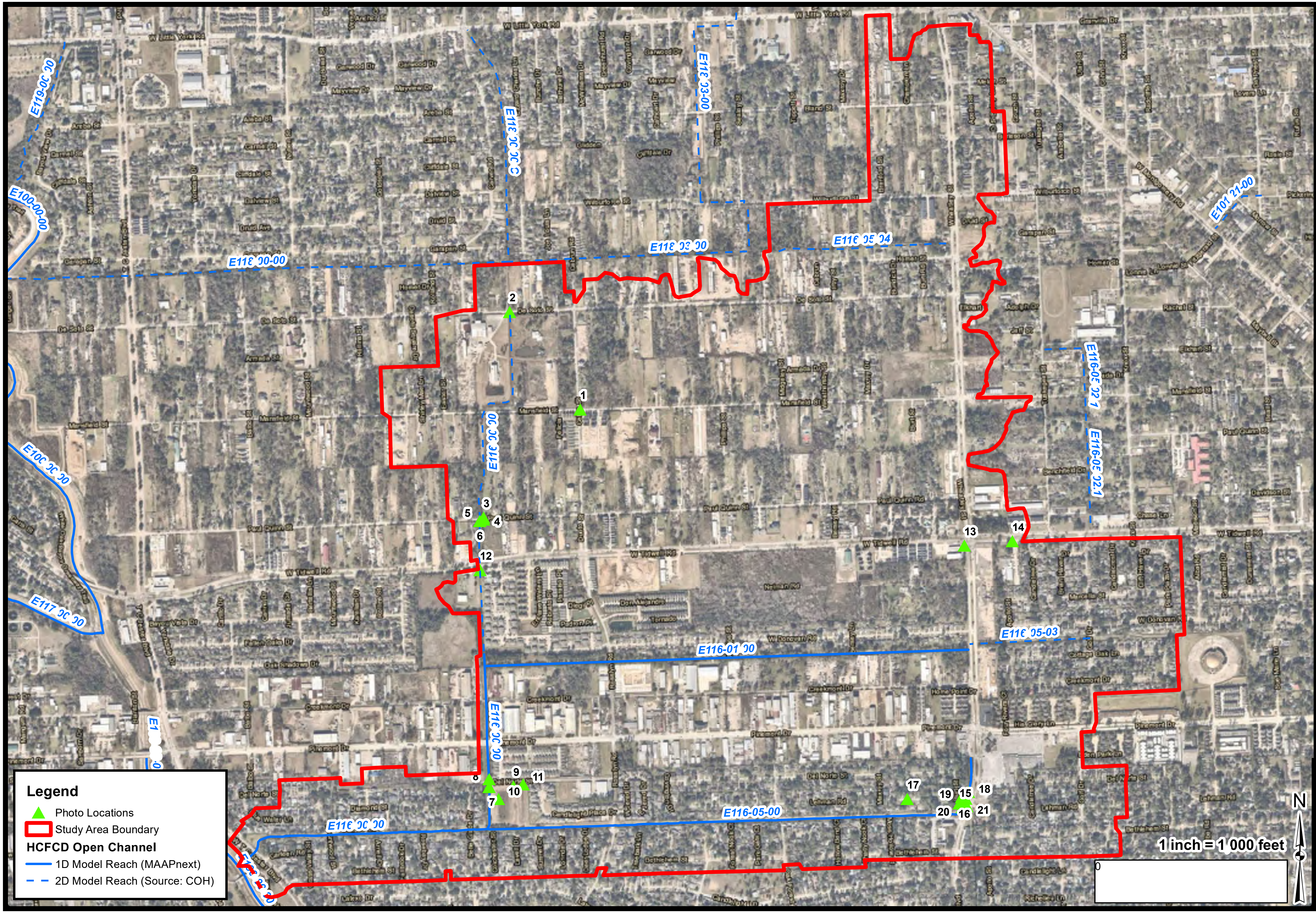
EXHIBITS

3. Field Photo Location Map
(see Appendix A for photos)



E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Field Photo Location Map

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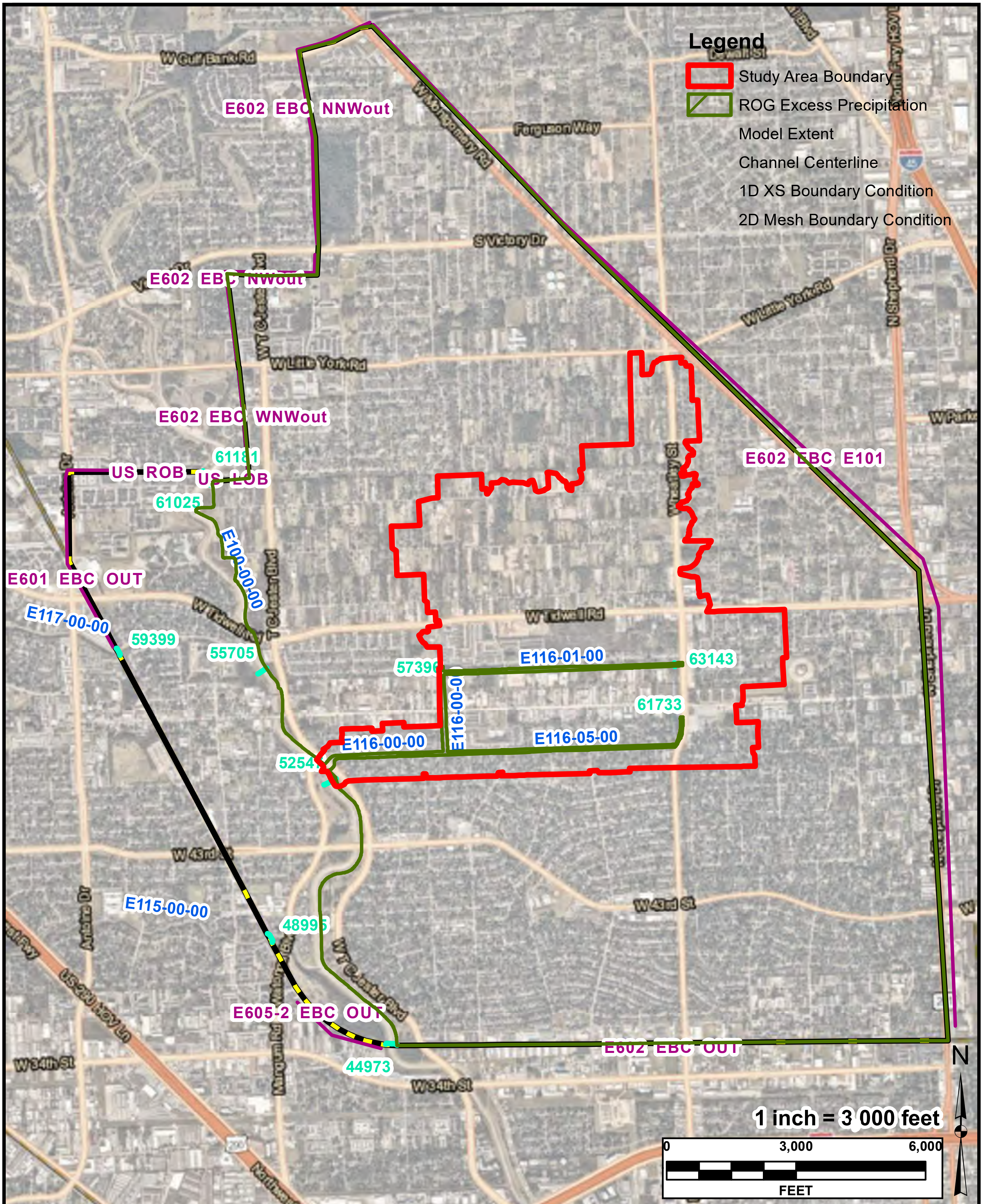
EXHIBITS

4. Hydrologic and Hydraulic Analysis Exhibits
    4.1. Modeling Geometry Details
    4.2. Modeled Storm Sewers
    4.3. Level of Service
    4.4. Existing 10% AEP Floodplain
    4.5. Existing 4% AEP Floodplain
    4.6. Existing 2% AEP Floodplain
    4.7. Existing 1% AEP Floodplain
    4.8. Existing Overflow Patterns



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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX
Model Geometry Details

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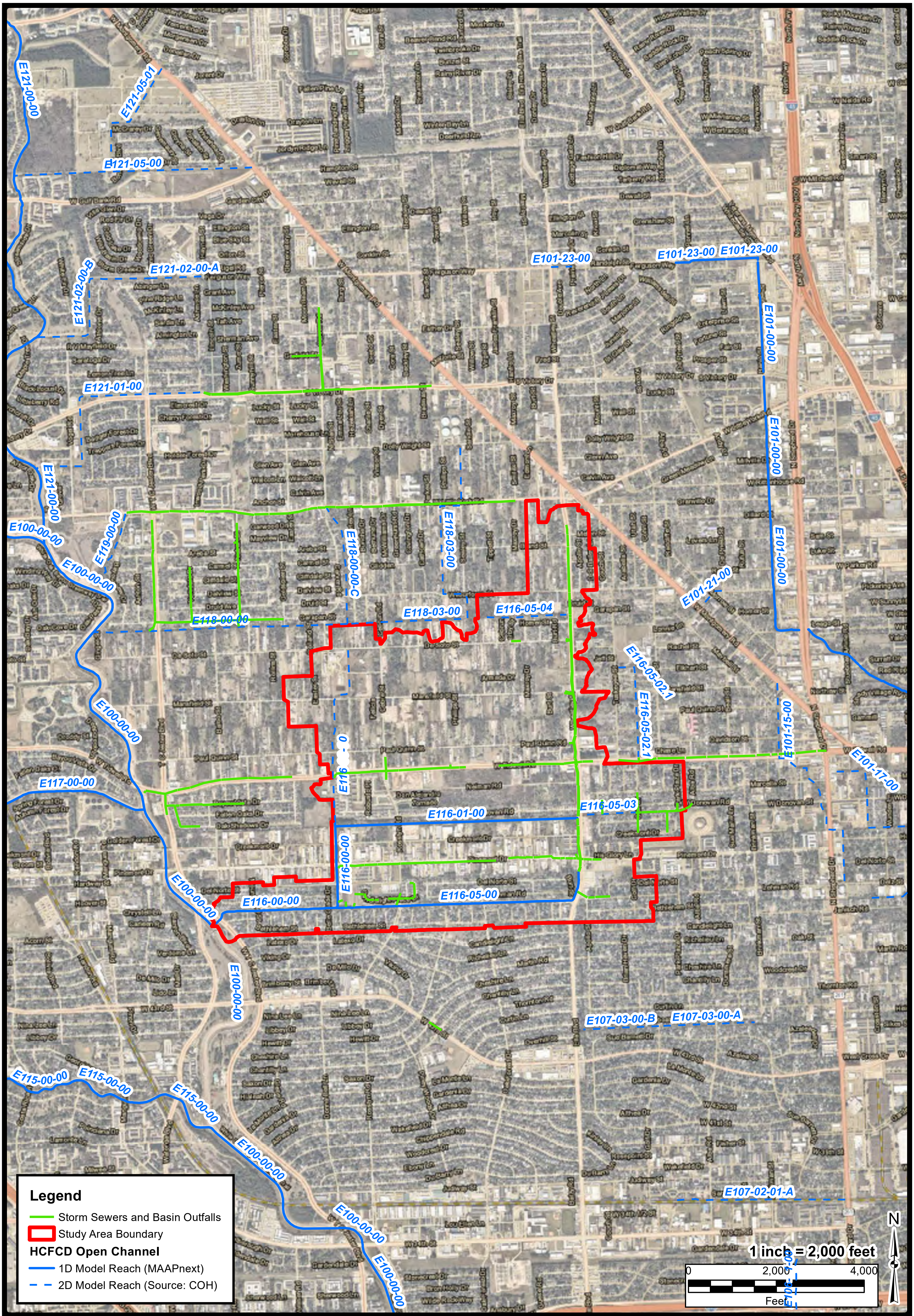

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Modeled Storm Sewers

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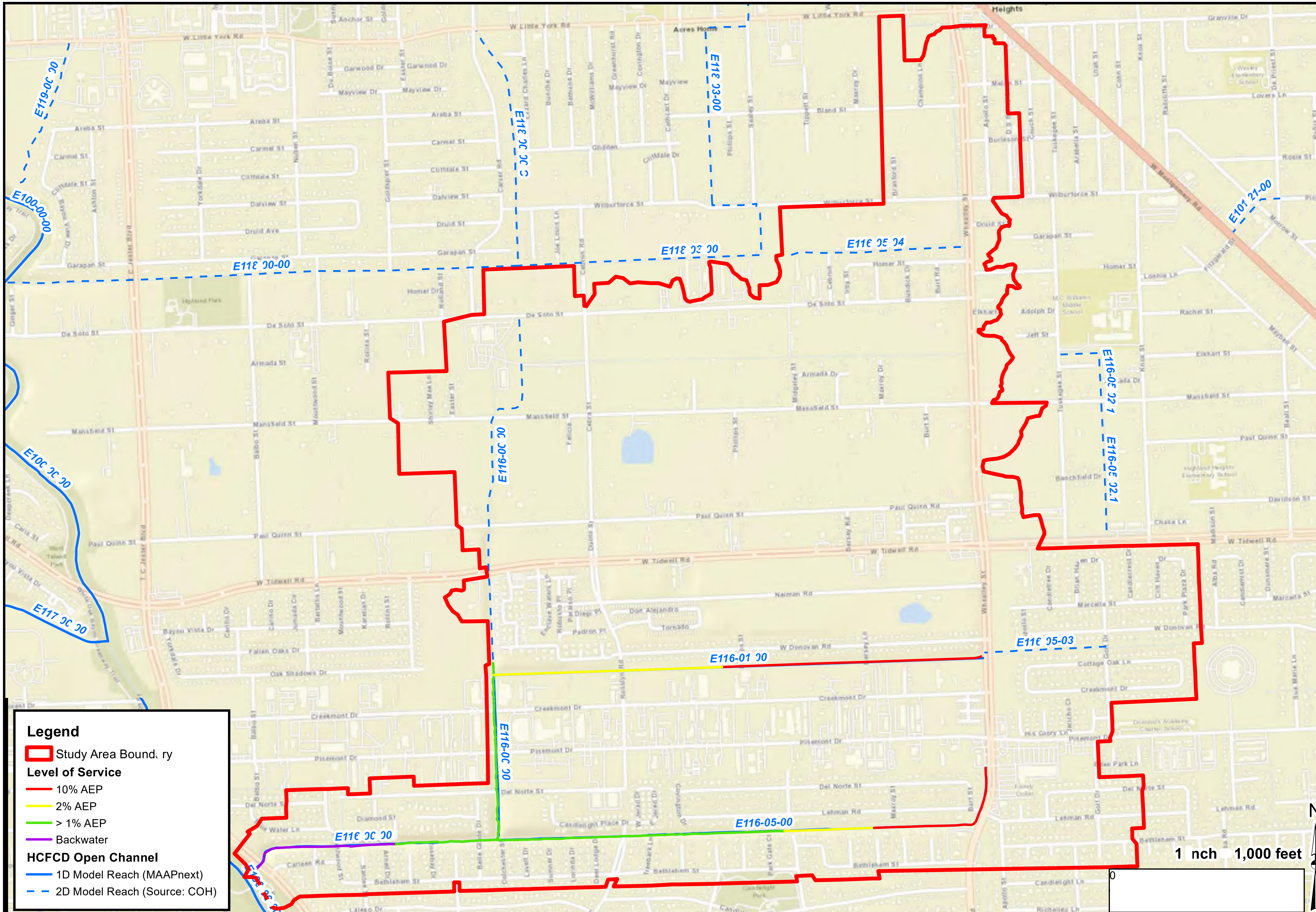

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Level of Service

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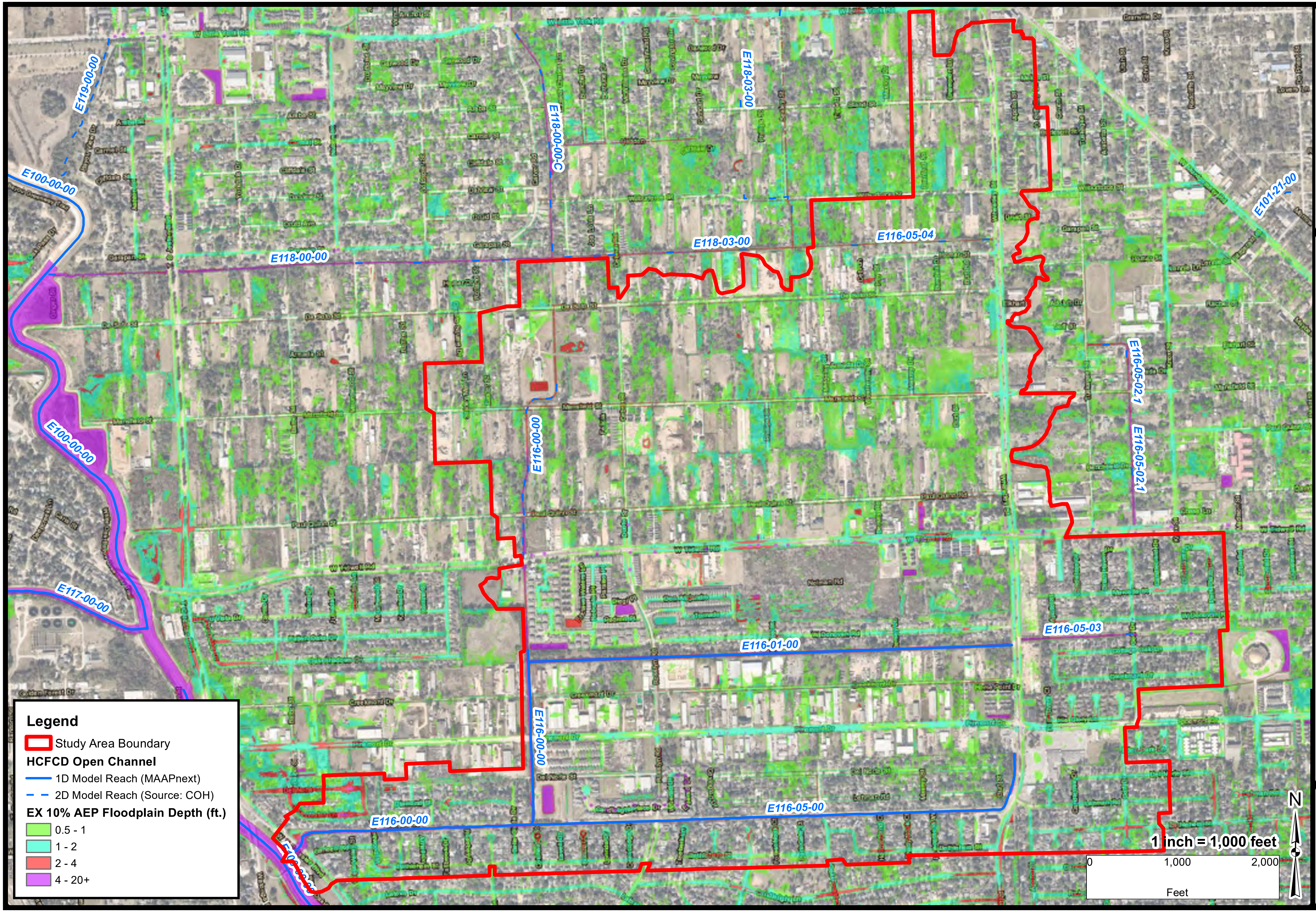

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Existing 10% AEP Floodplain

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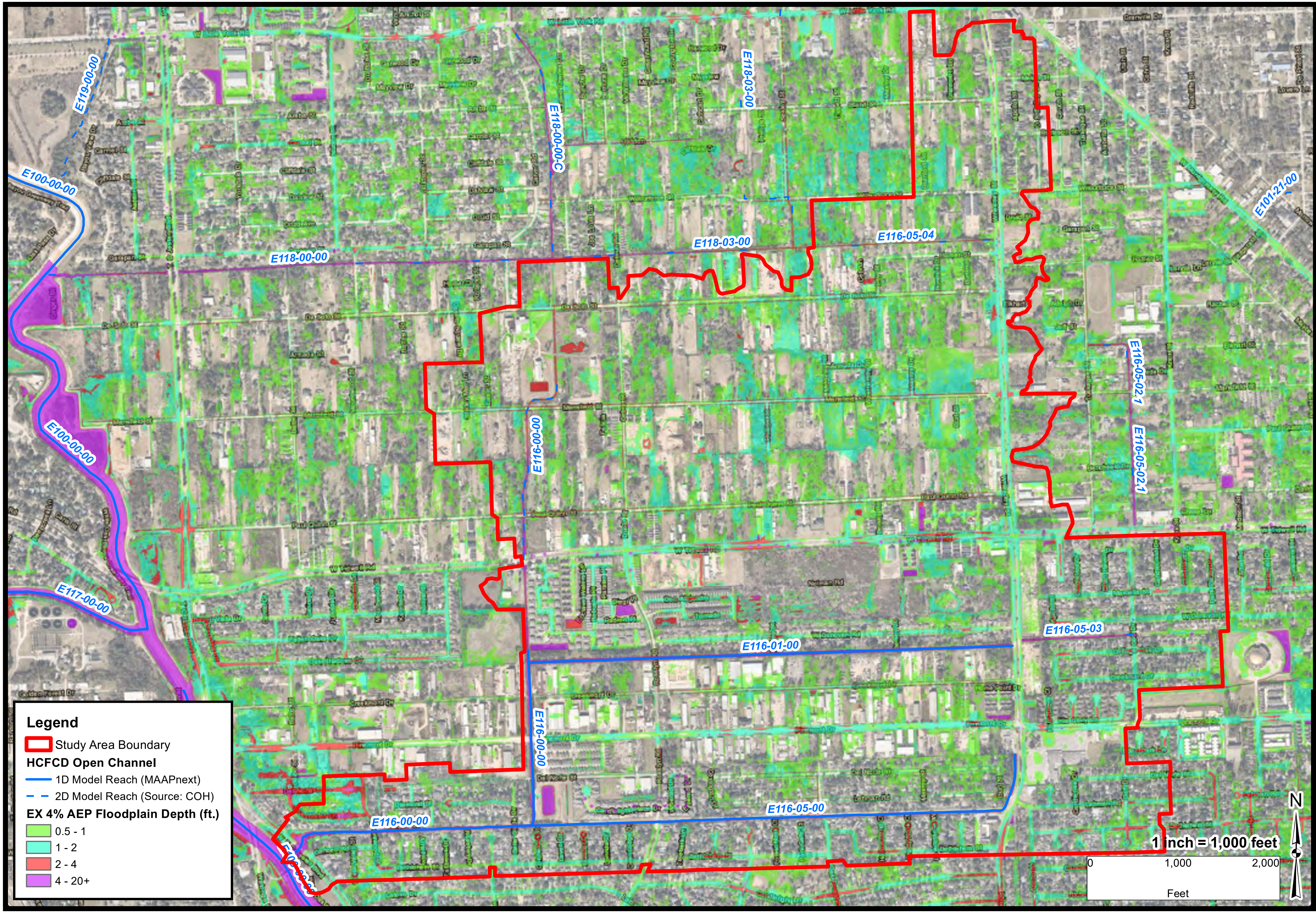

E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Existing 4% AEP Floodplain

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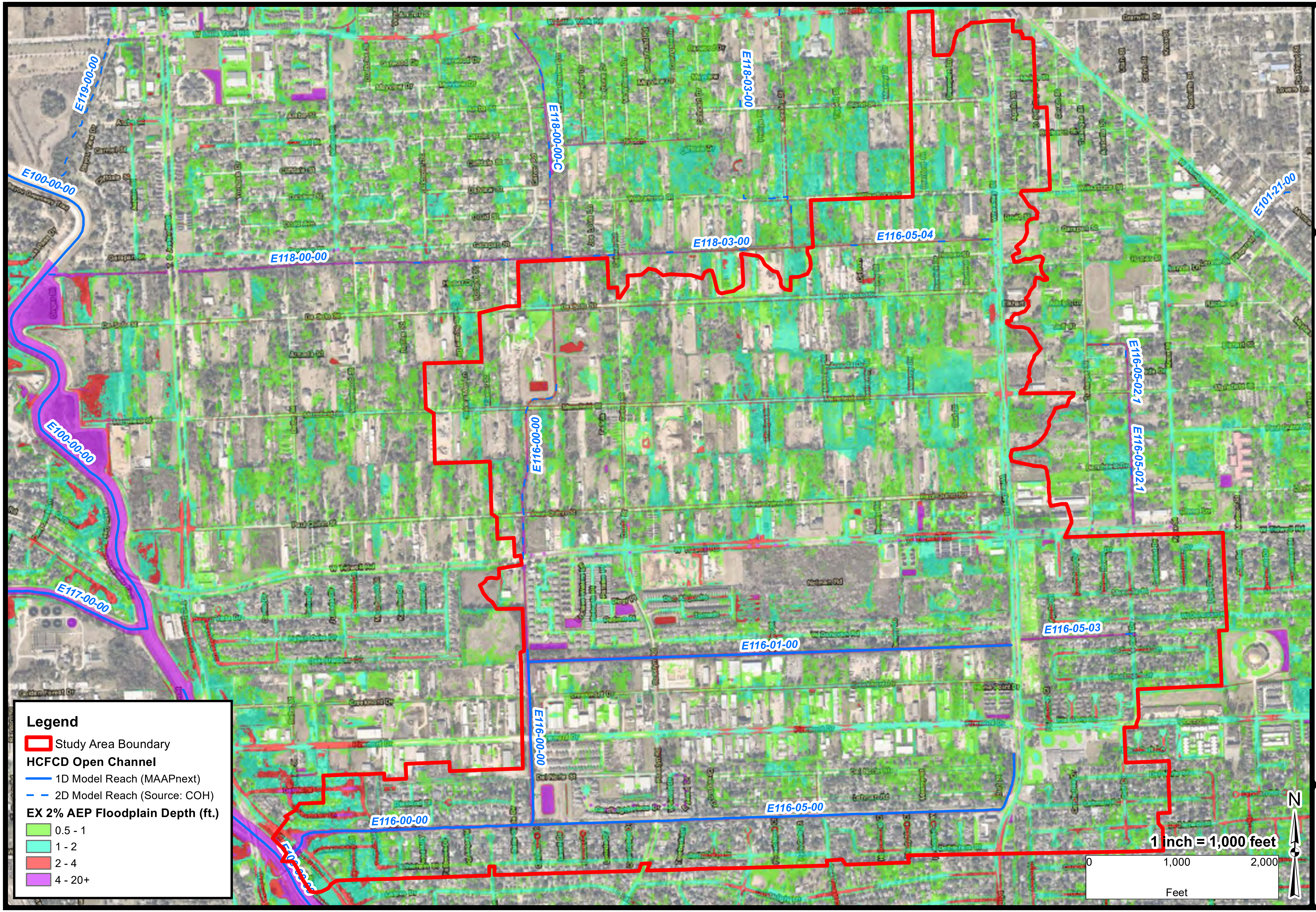

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX
Existing 2% AEP Floodplain

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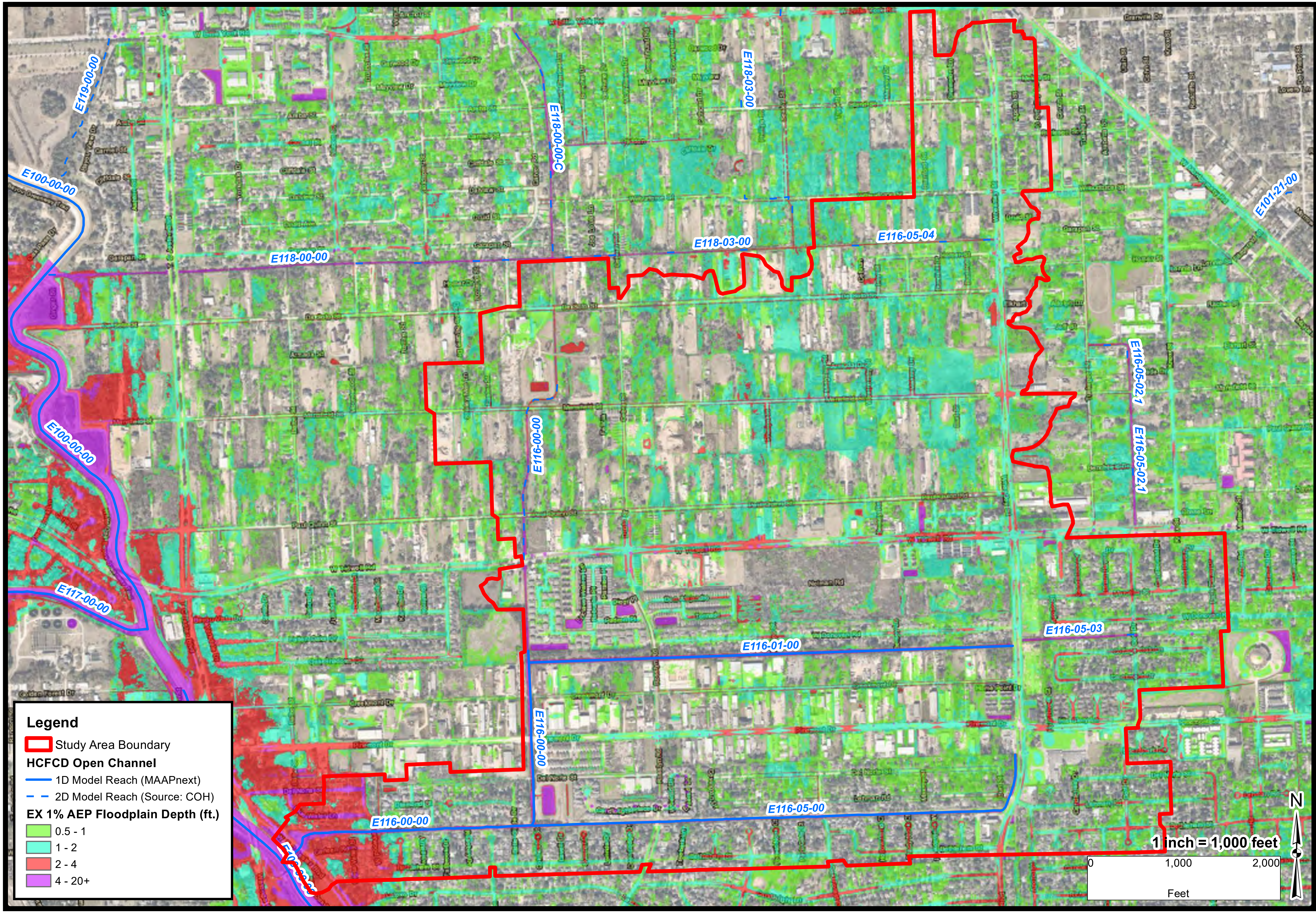

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Existing 1% AEP Floodplain

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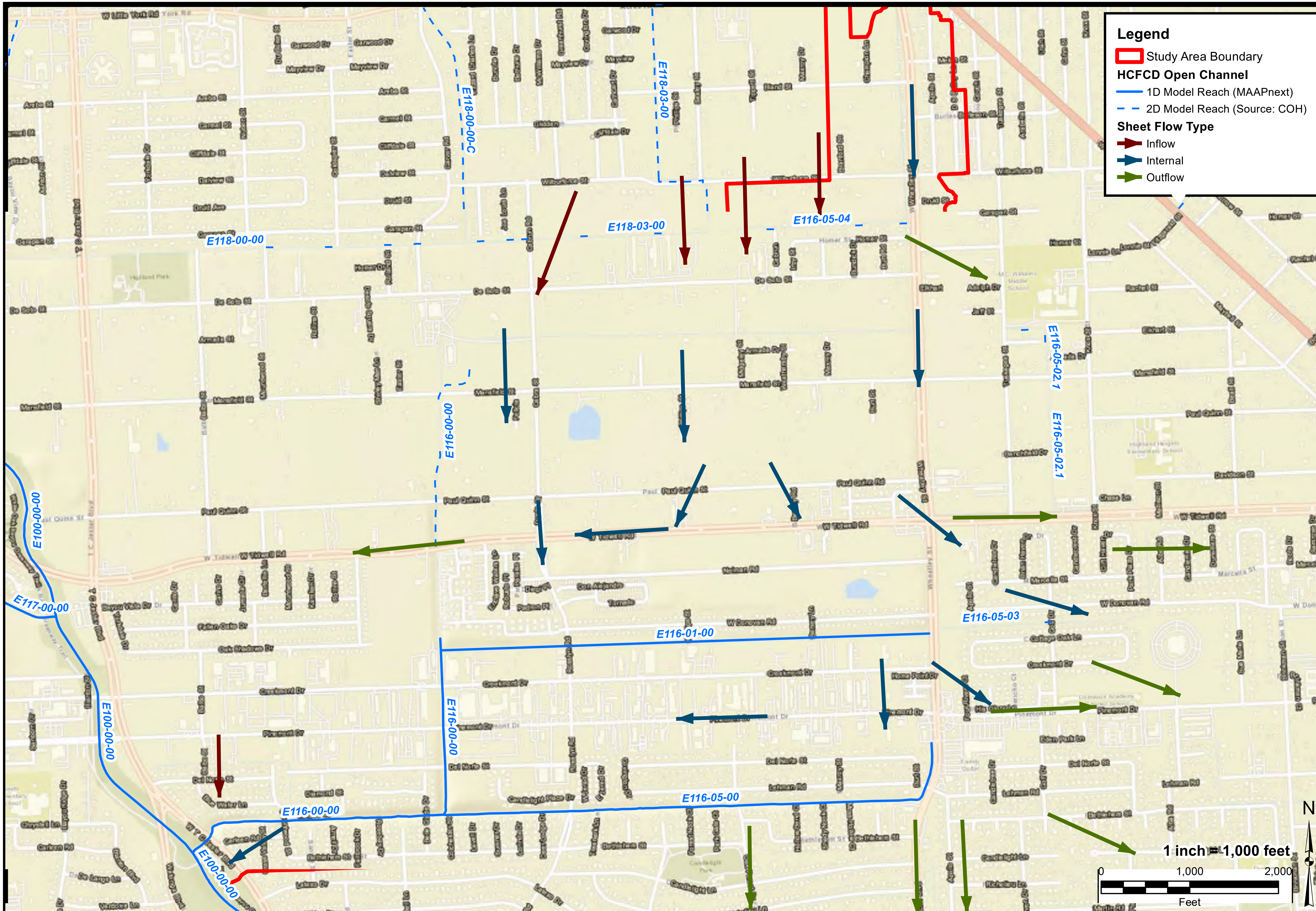

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Existing Overflow Patterns

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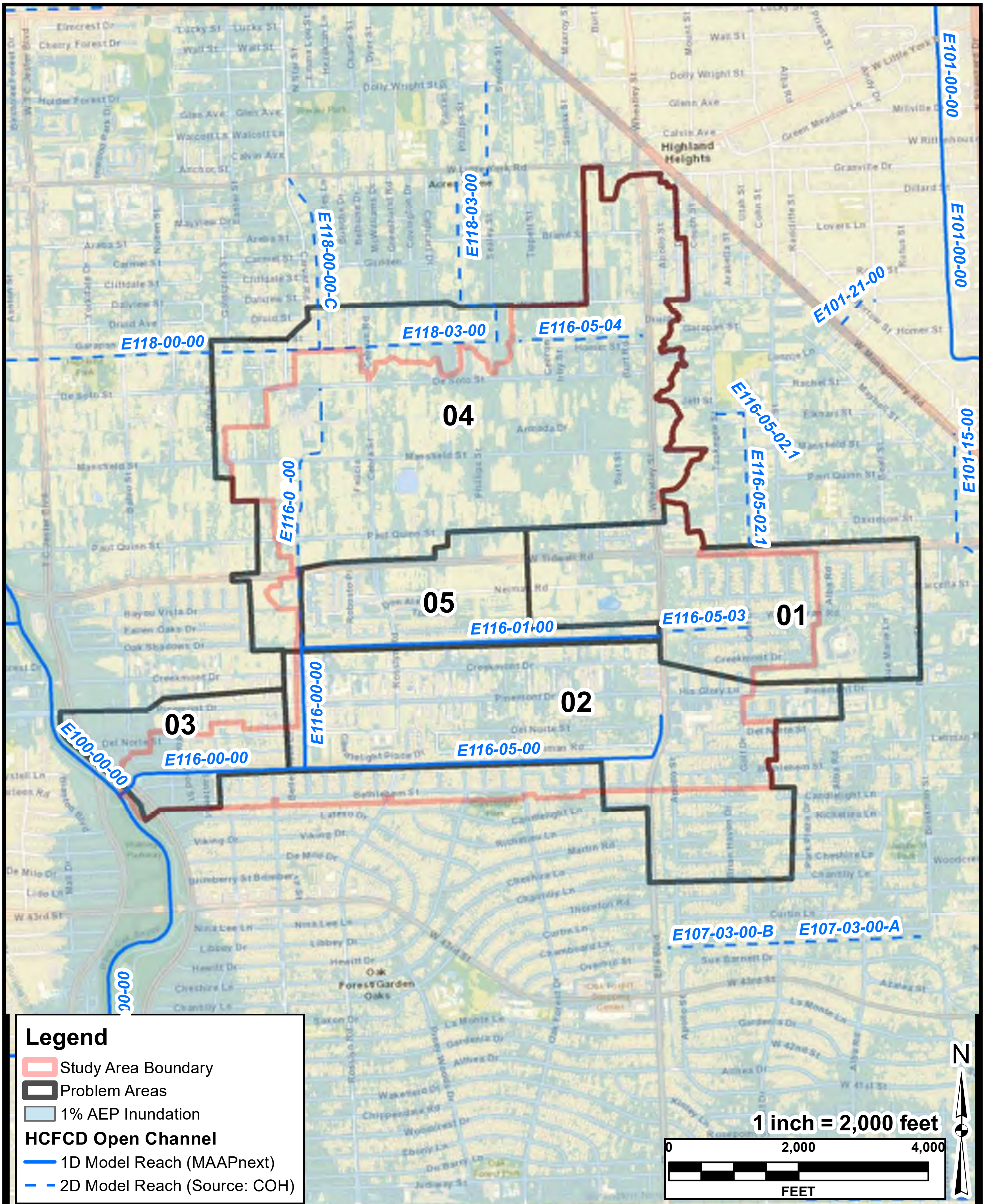
EXHIBITS

5. Problem Area Identification Exhibits
    5.1. Summary of Problem Areas
    5.2. Problem Area 01
    5.3. Problem Area 02
    5.4. Problem Area 03
    5.5. Problem Area 04
    5.6. Problem Area 05



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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX
Summary of Problem Areas

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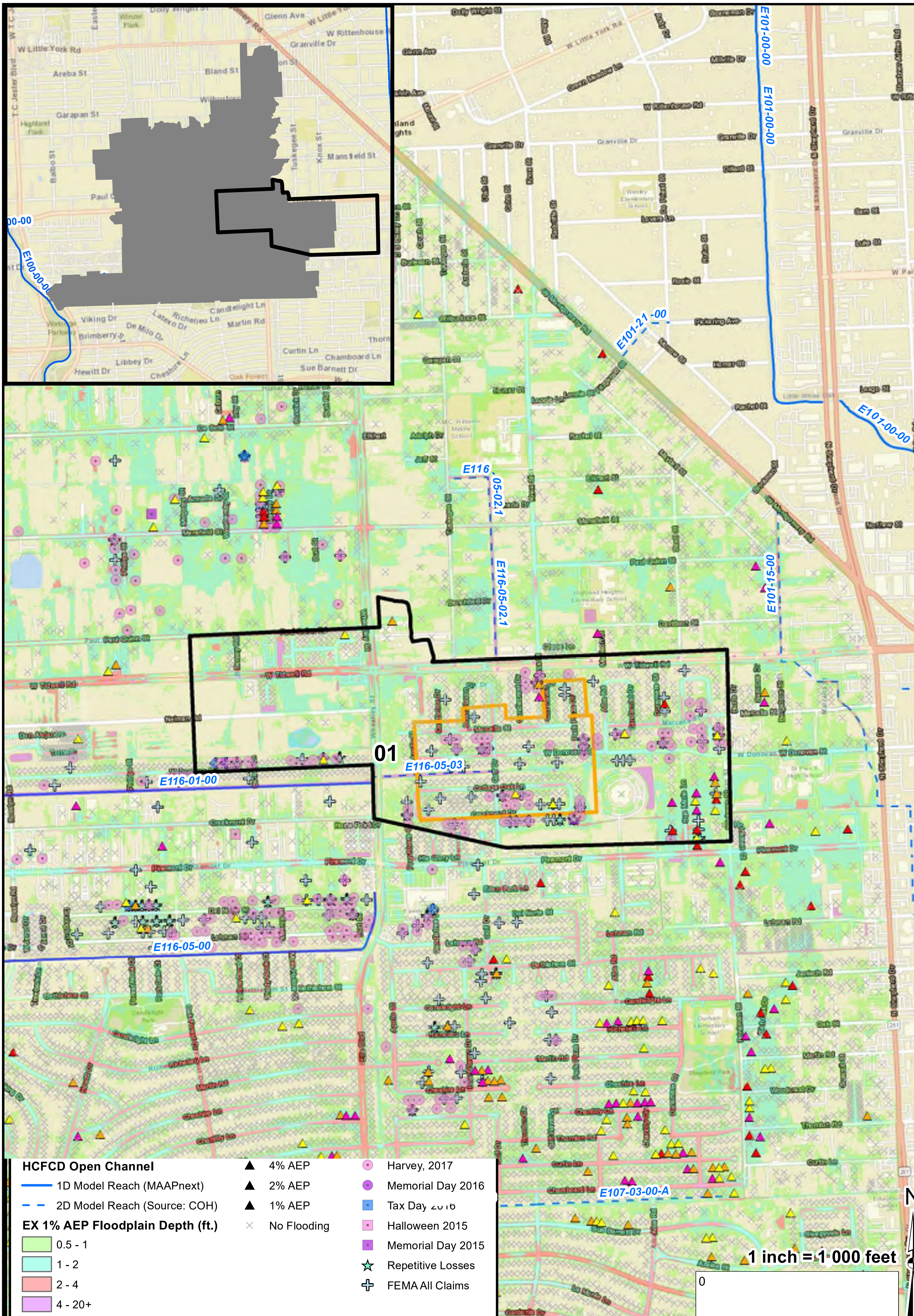

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Problem Area 01

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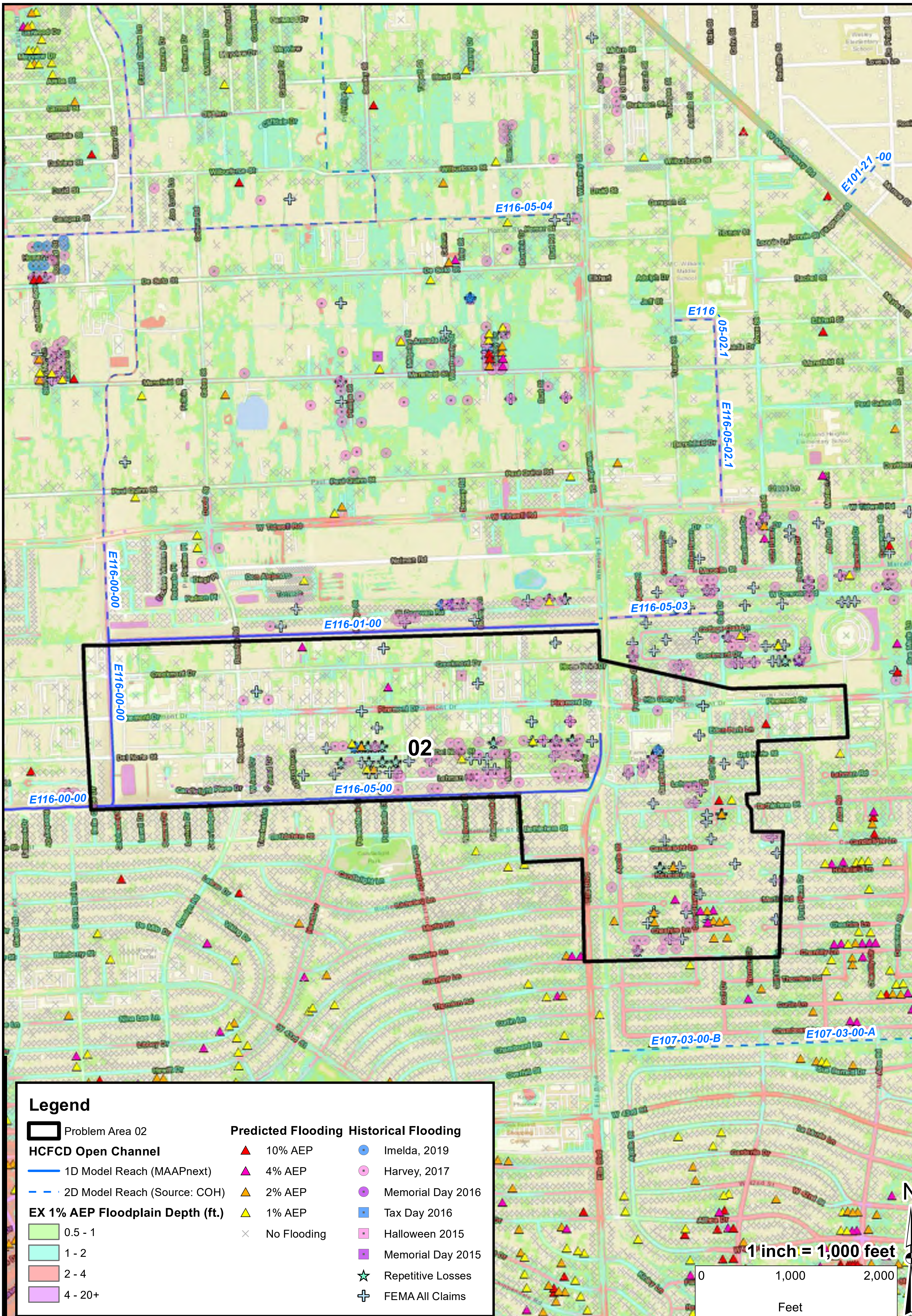

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX
Problem Area 02

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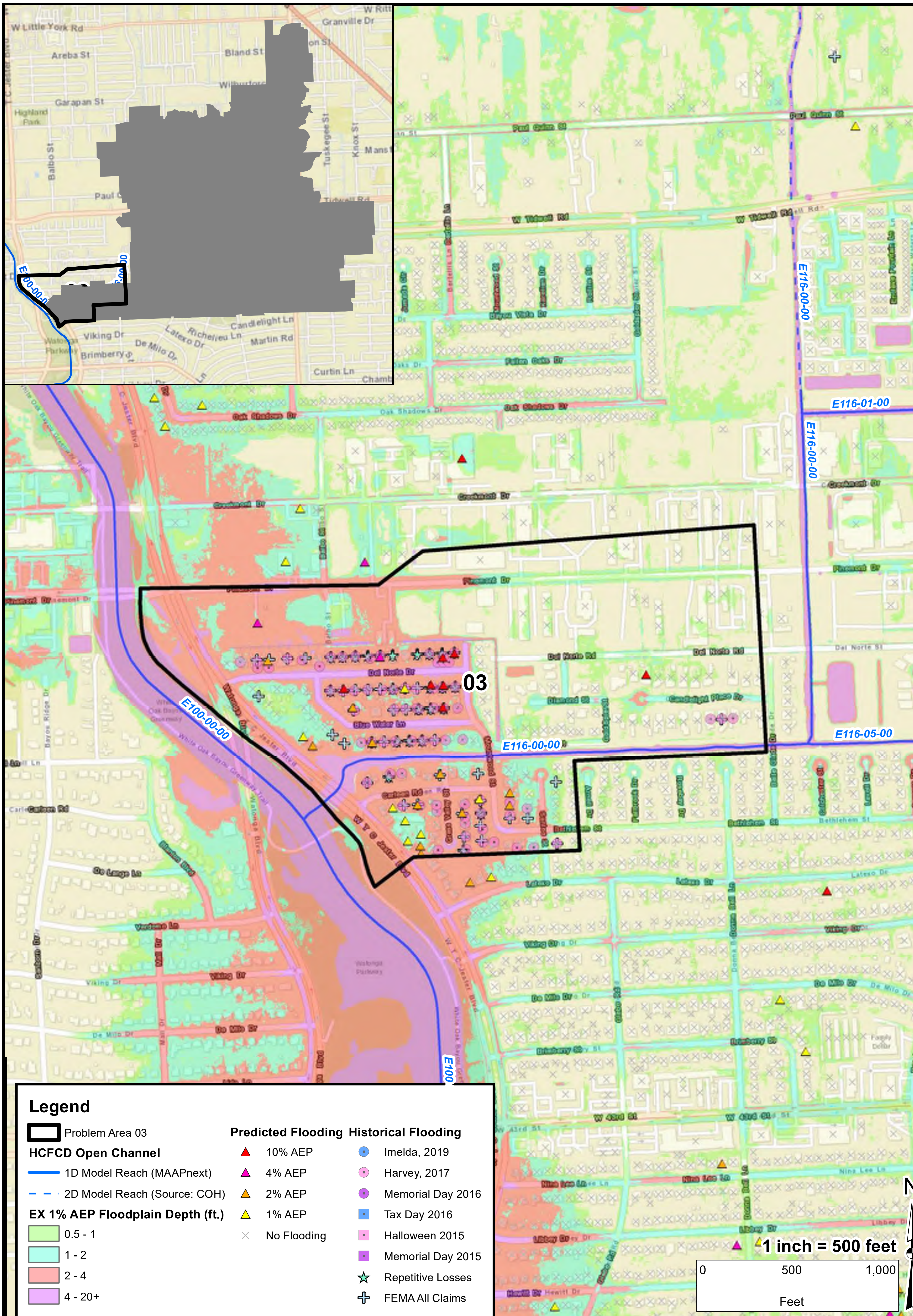

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Problem Area 03

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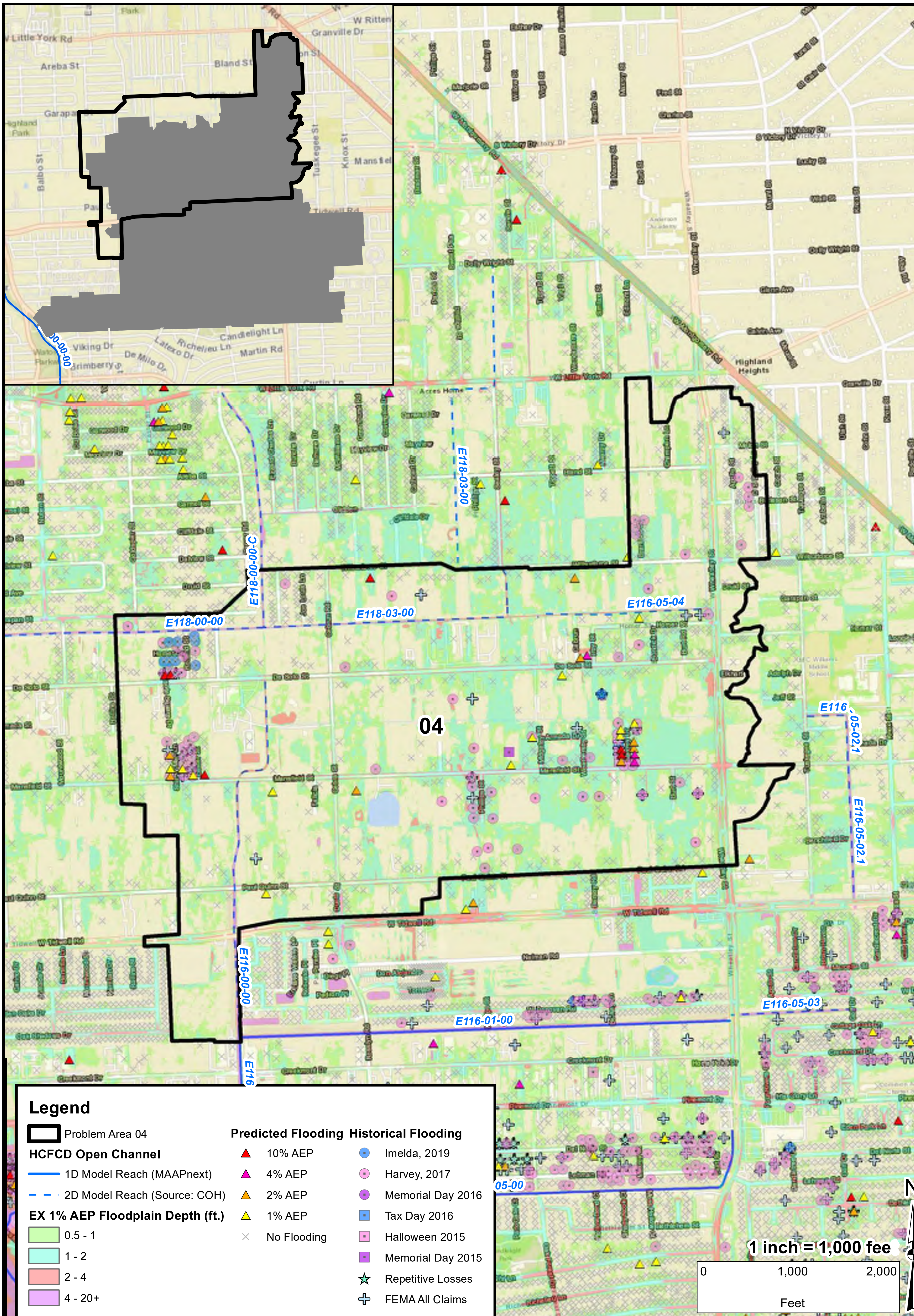

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Problem Area 04

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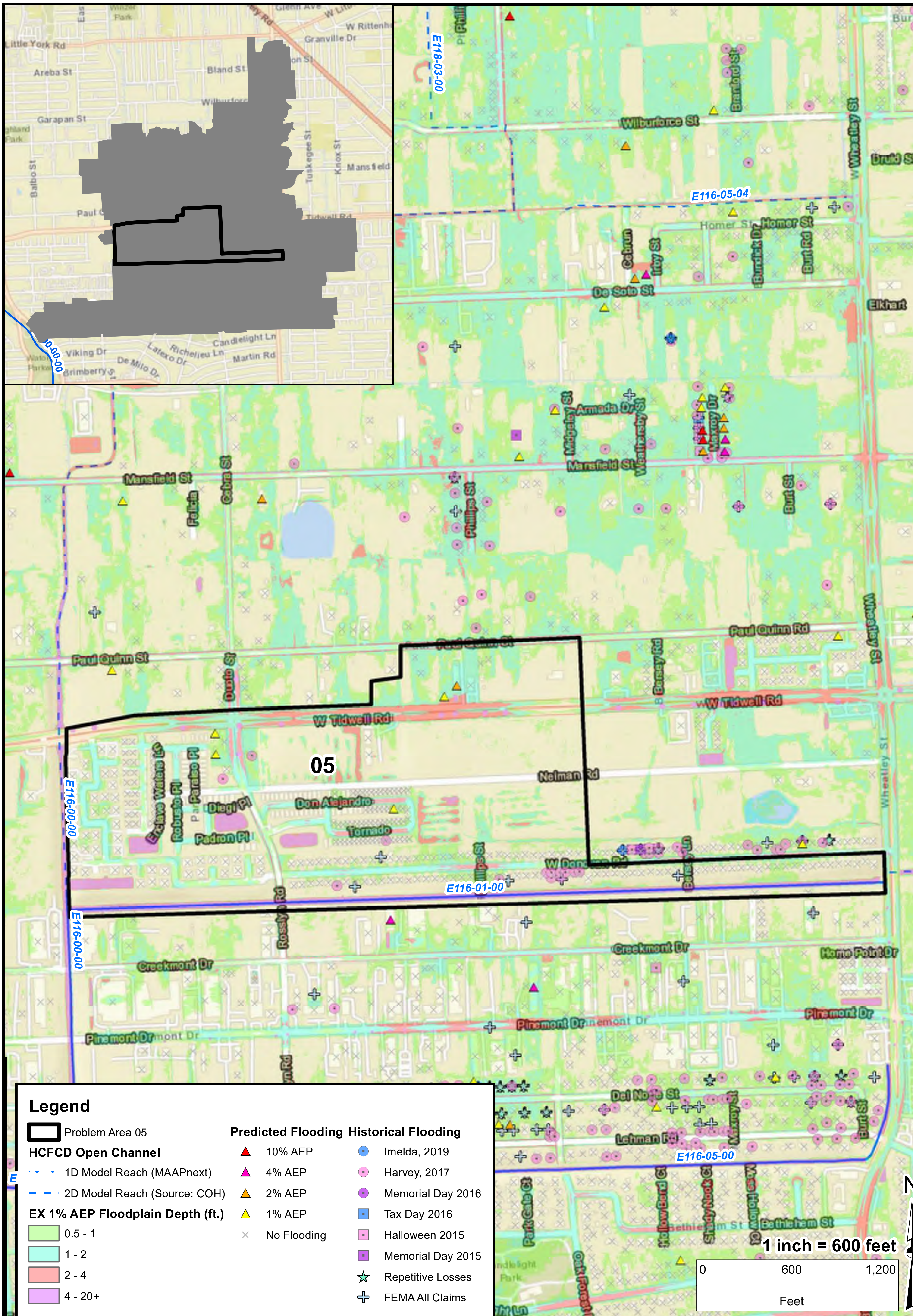

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Problem Area 05

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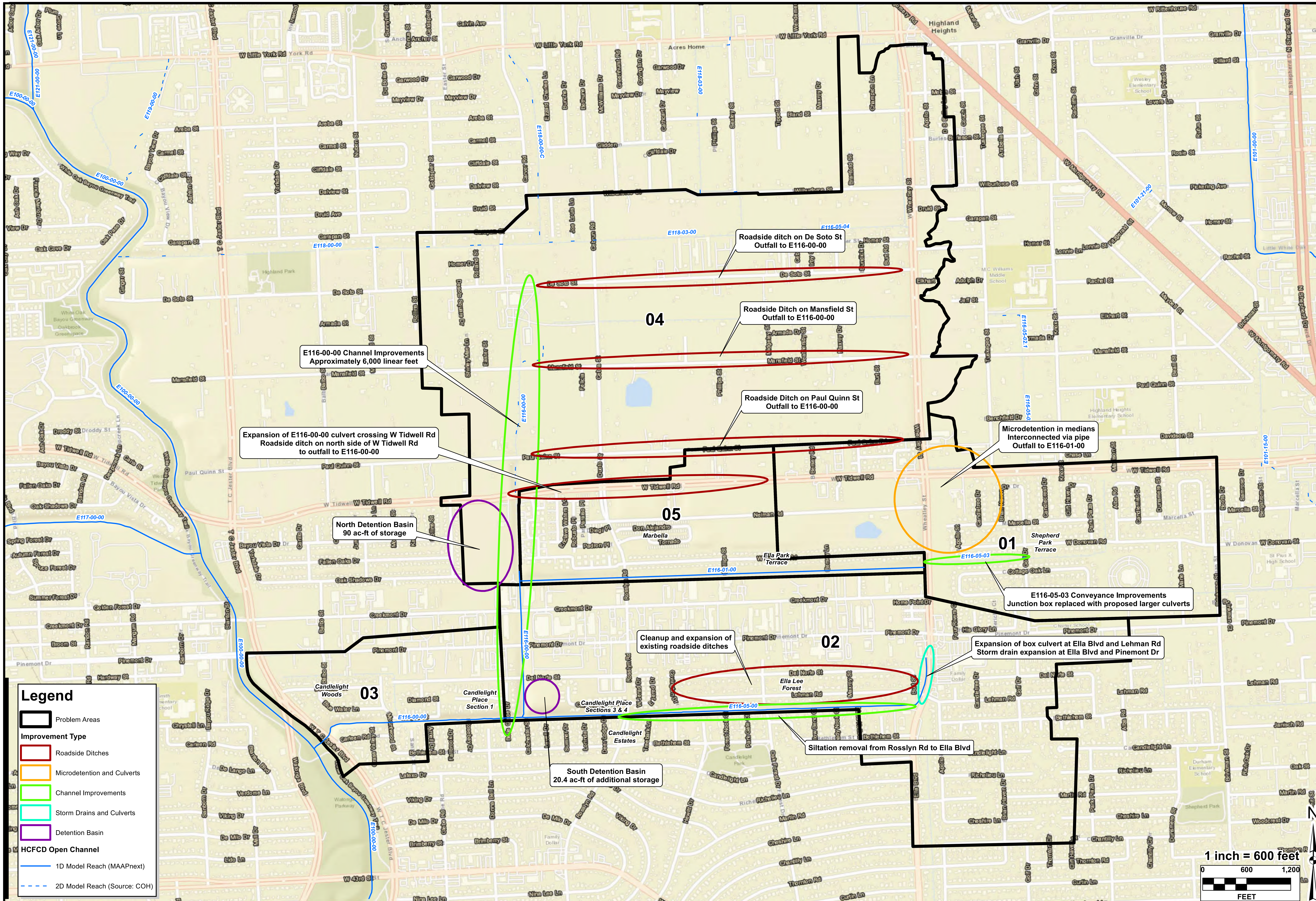
EXHIBITS

6. Proposed Flood Reduction Projects Exhibits
    6.1. Overall Strategy
    6.2. 1% AEP Flood Risk Reduction– Overall Strategy
    6.3. Proposed Overflow Patterns – Overall Strategy
    6.4. Recommended Project
    6.5. 10% AEP Flood Risk Reduction – Recommended Project
    6.6. 4% AEP Flood Risk Reduction – Recommended Project
    6.7. 2% AEP Flood Risk Reduction – Recommended Project
    6.8. 1% AEP Flood Risk Reduction – Recommended Project



E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Overall Strategy

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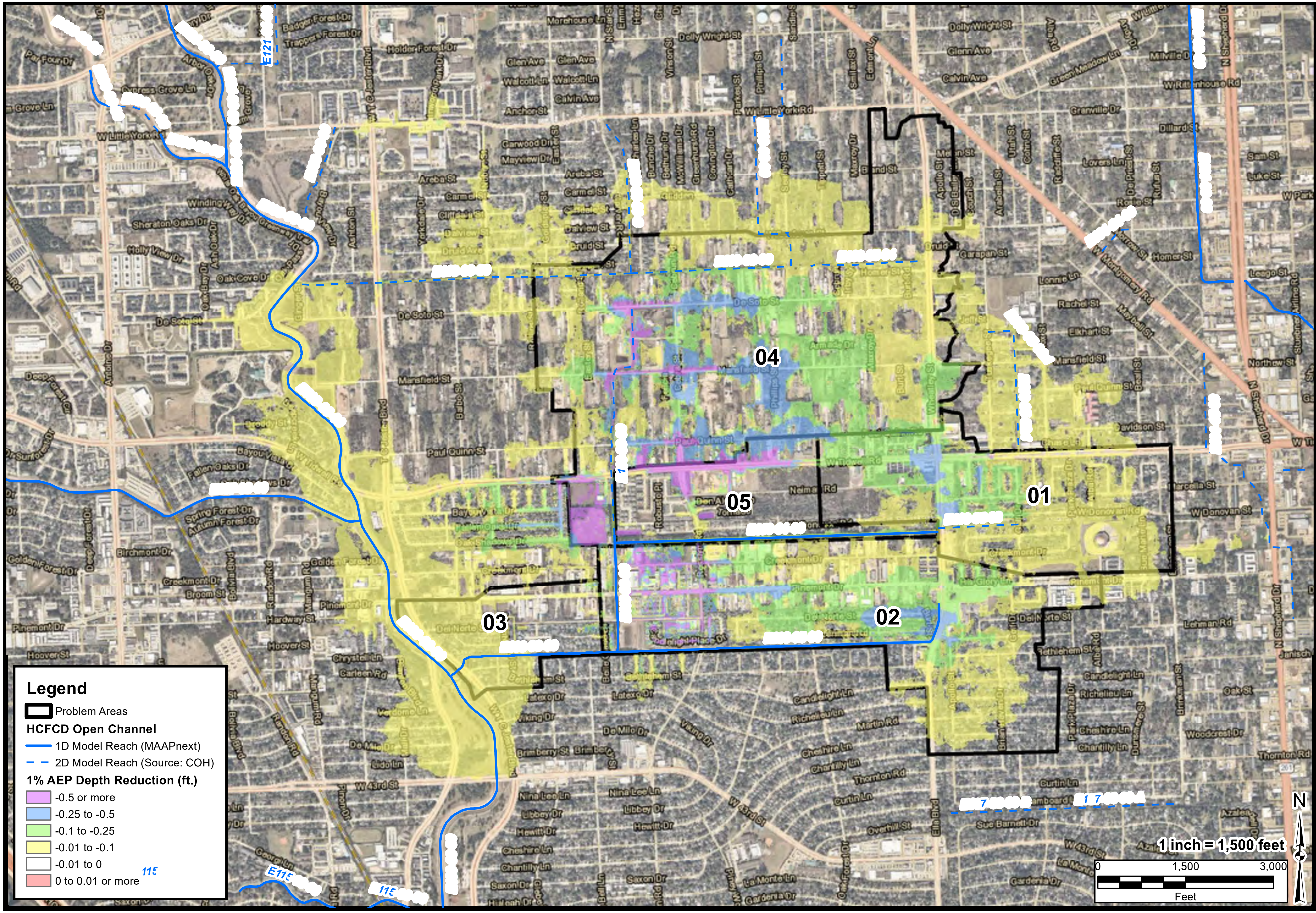

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E116 Flood Reduction Feasibility Study

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1% AEP Flood Risk Reduction - Overall Strategy

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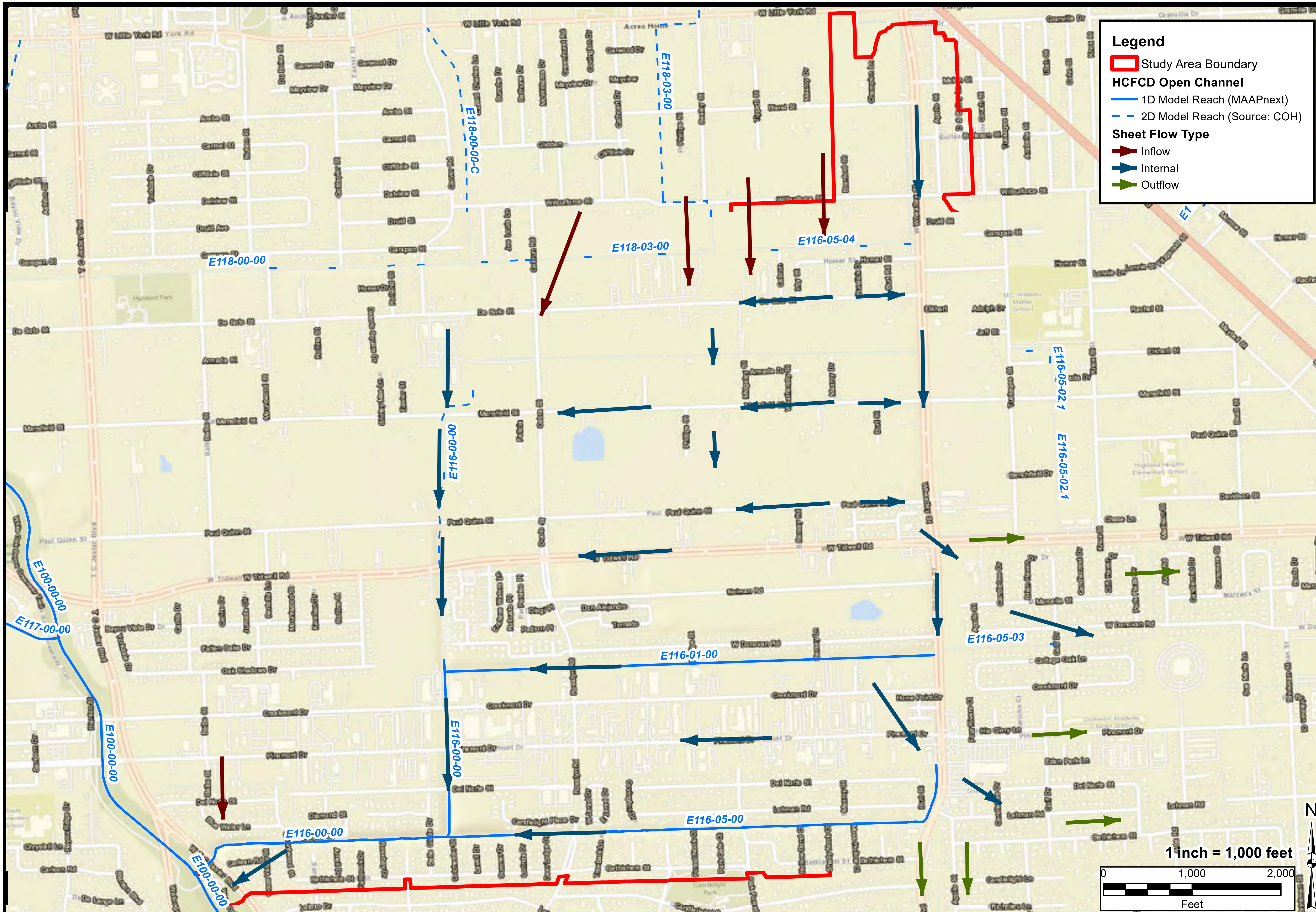

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City of Houston, Harris County, TX

Proposed Overflow Patterns - Overall Strategy

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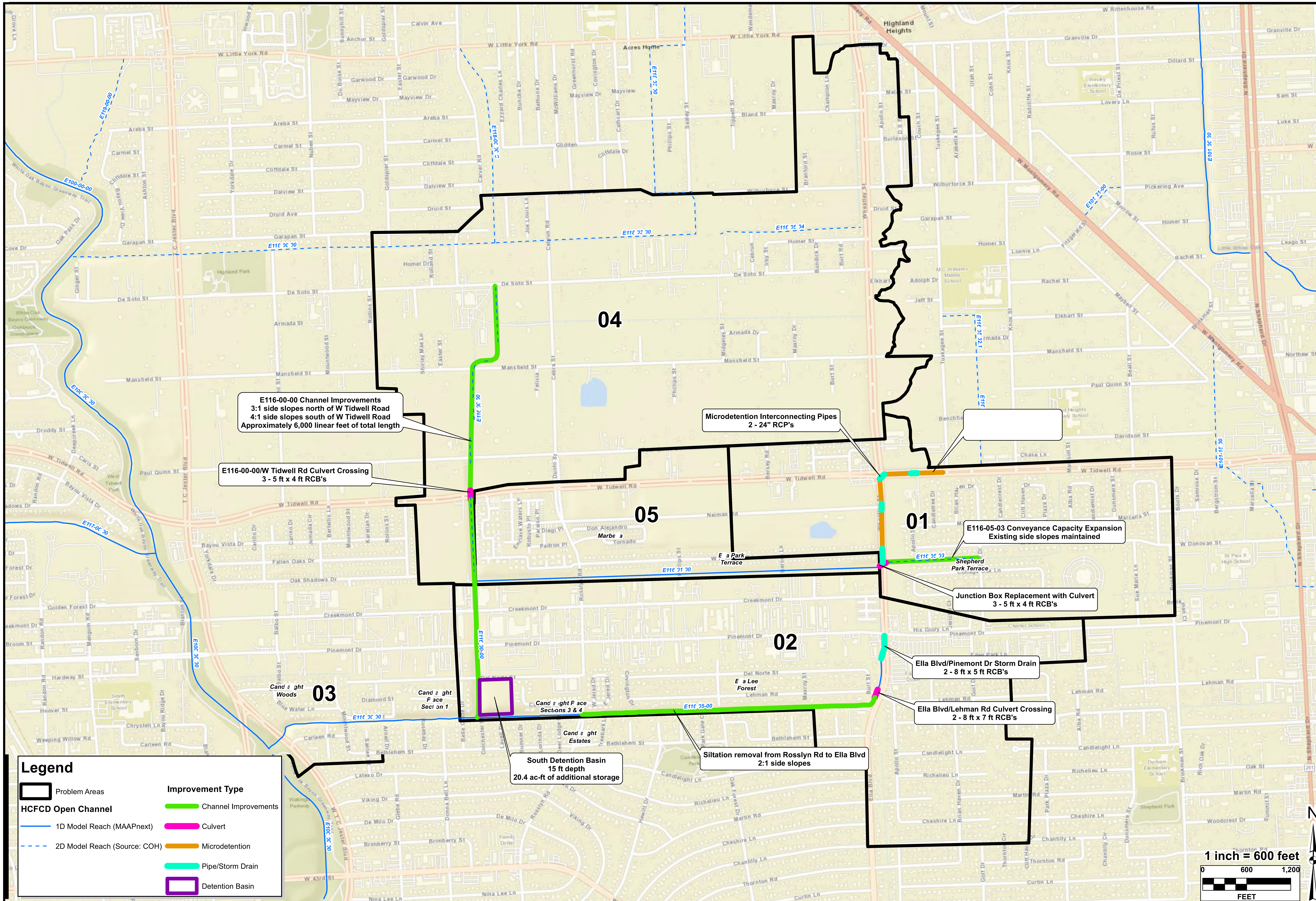

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Recommended Project

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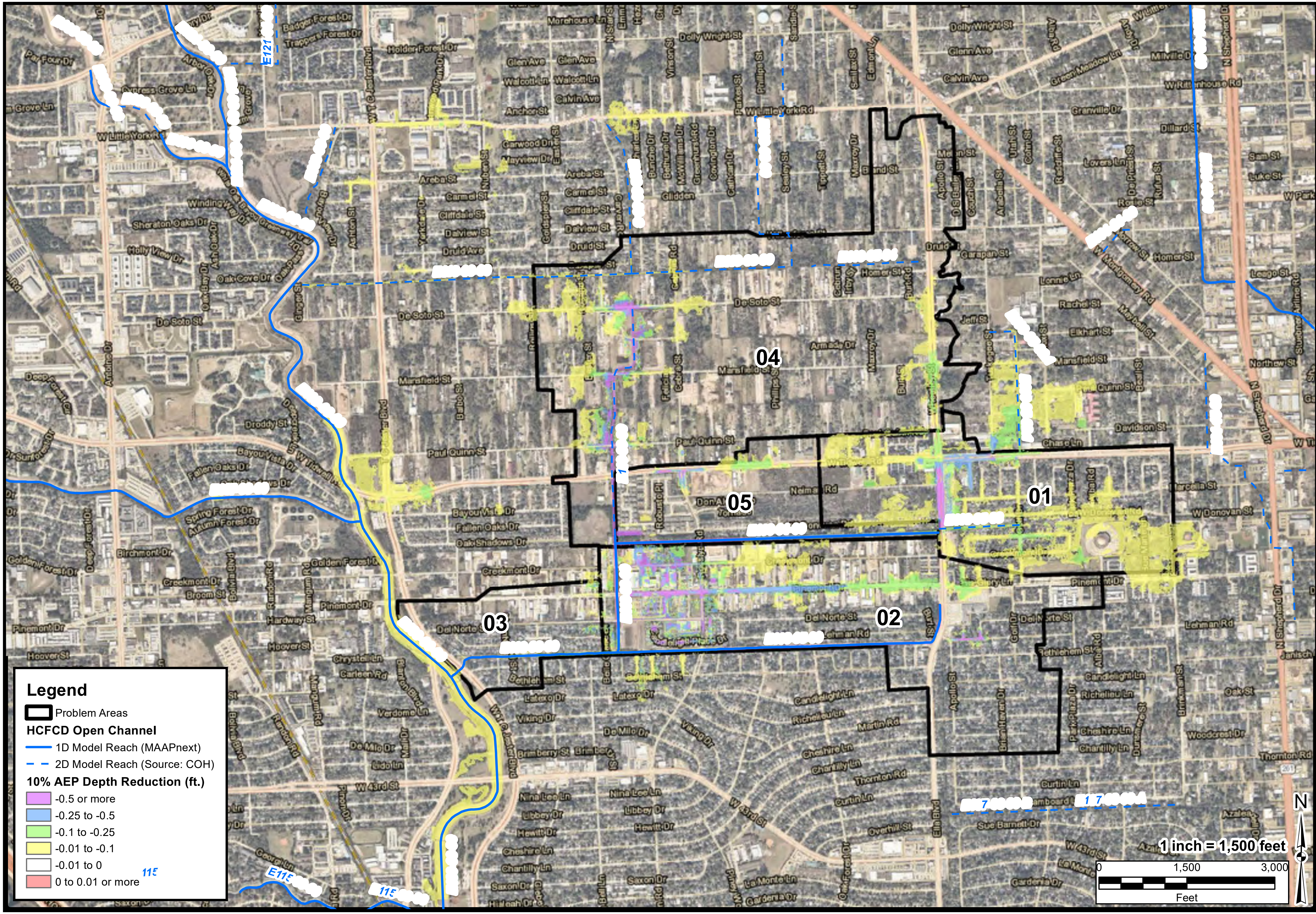

E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

10% AEP Flood Risk Reduction - Recommended Project

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CHECKED	ZRS
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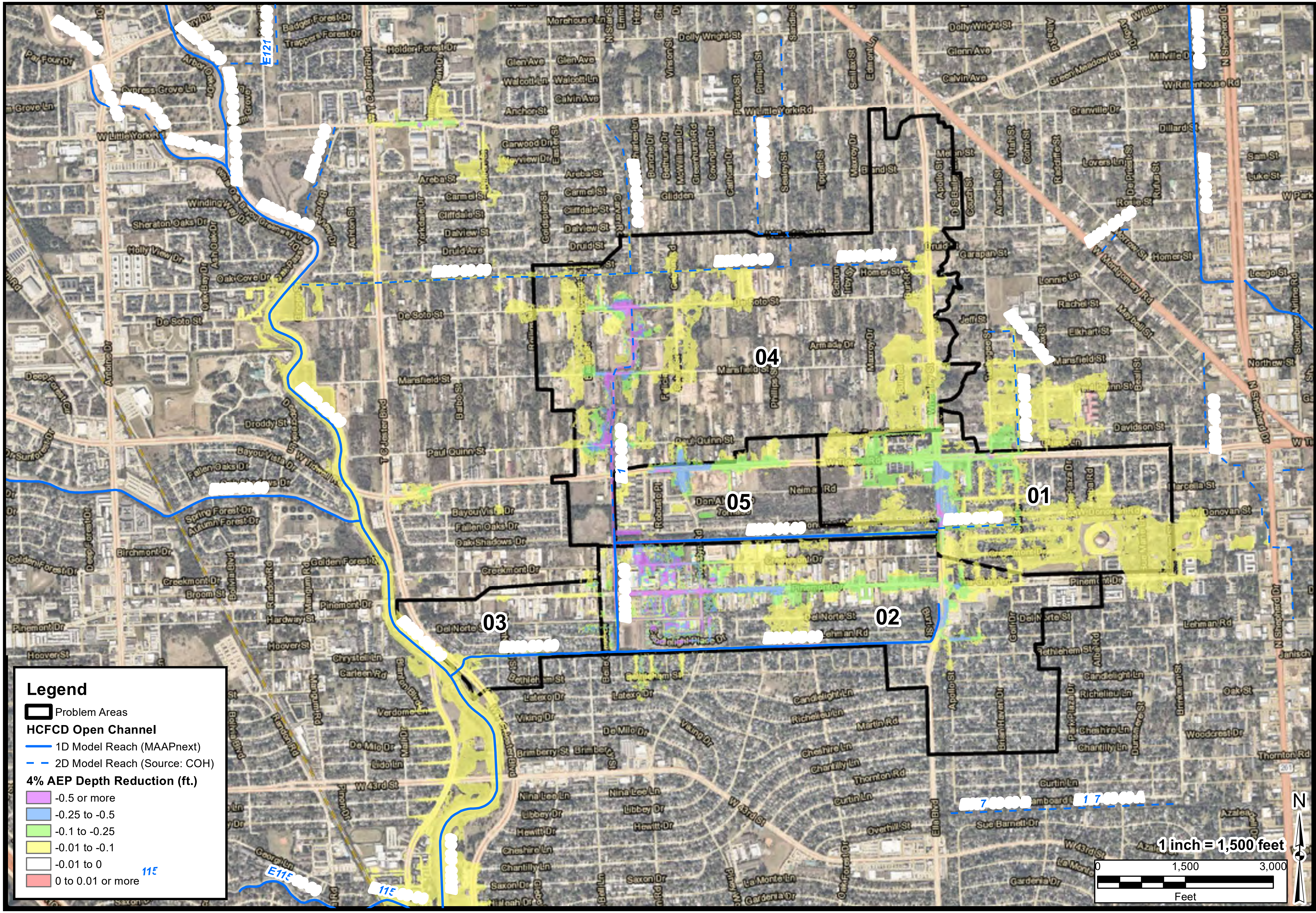

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

4% AEP Flood Risk Reduction - Recommended Project

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DATE	May 2022
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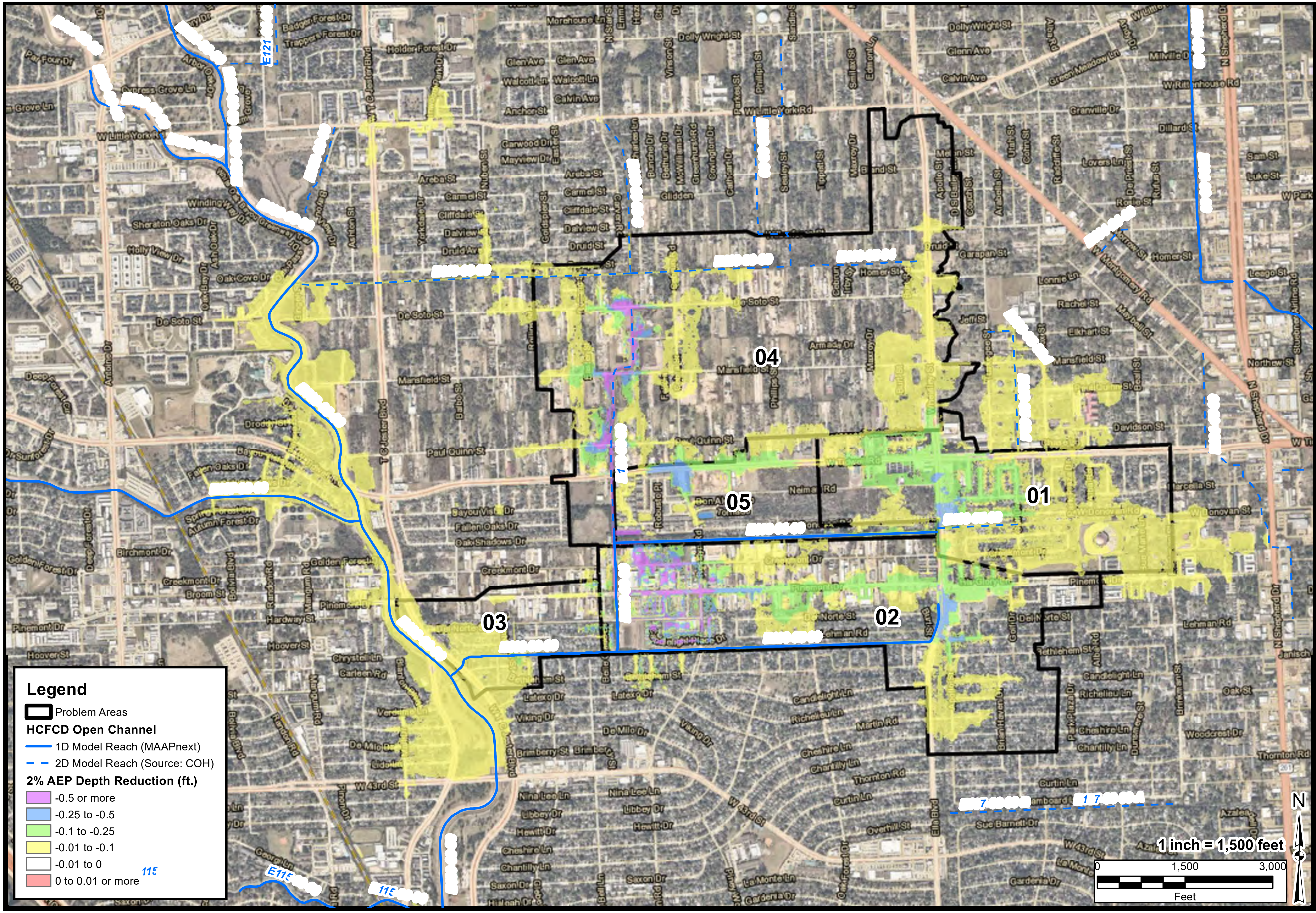

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E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

2% AEP Flood Risk Reduction - Recommended Project

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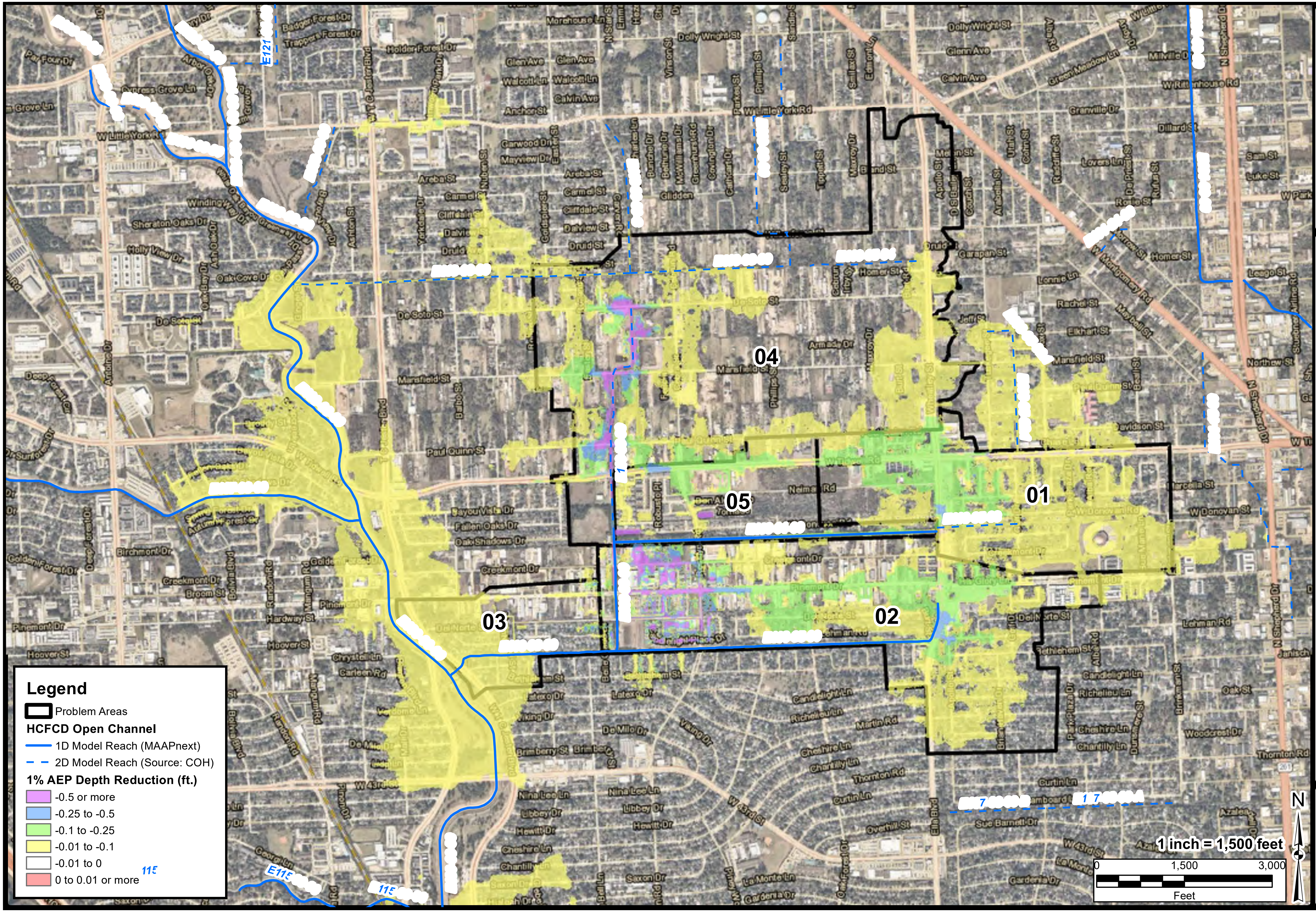
SHEET	EX 6.7



E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

1% AEP Flood Risk Reduction - Recommended Project

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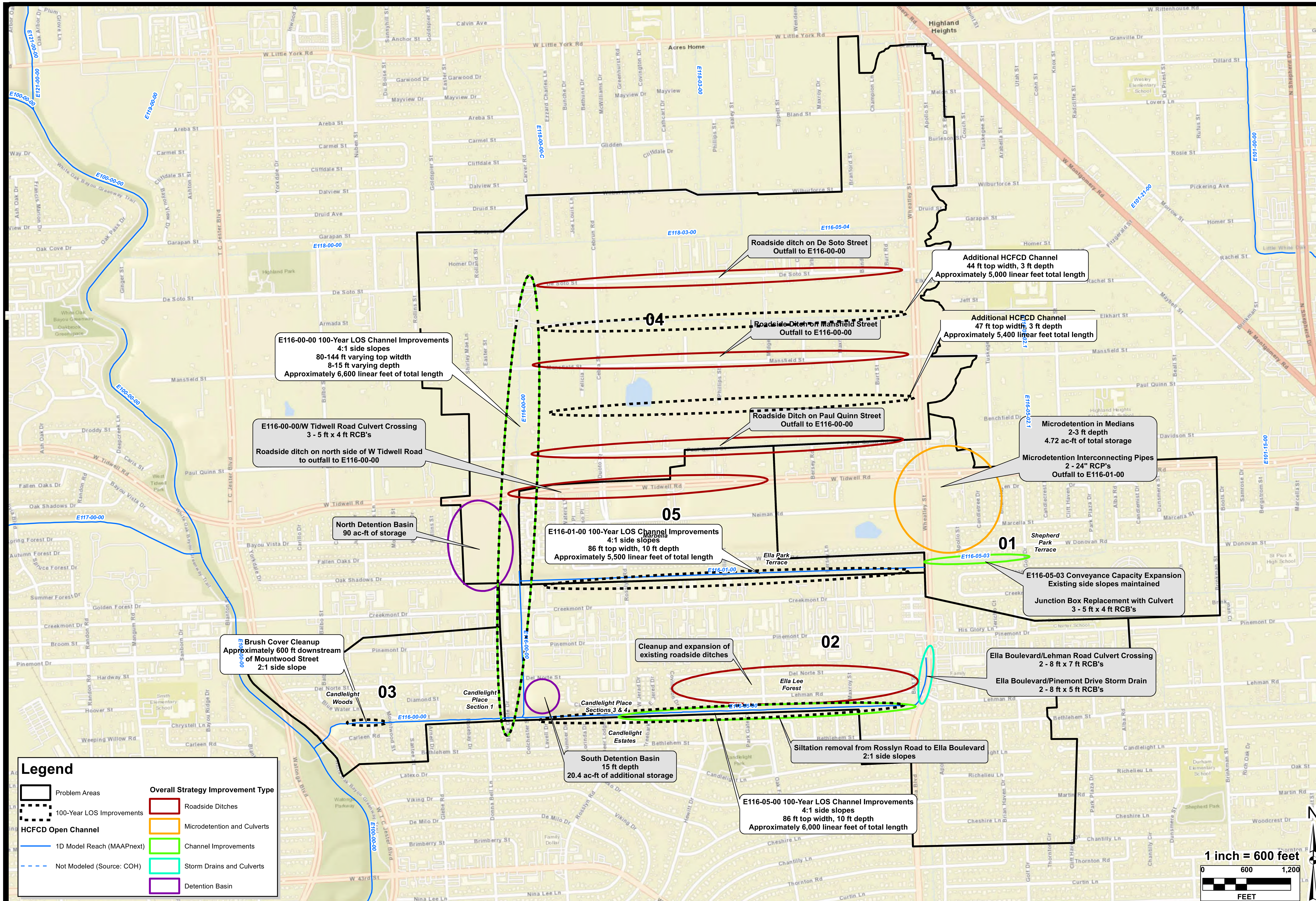
EXHIBITS

7. Improvements for 1% AEP LOS Map



E116 Flood Reduction Feasibility Study

City of Houston, Harris County, TX

Improvements for 1% AEP LOS Map

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TABLES

TABLES

1. Data Collection Summary

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 1
Data Collection Summary

Date Received	Source	Content	Other Information
5/24/2021	HCFCD	Extracted files from HCFCD system related to E116	Includes various plans from within study area
6/7/2021	HCFCD	MAAPnext modeling	HEC-HMS and HEC-RAS files from White Oak Bayou for Phase 1 of MAAPnext, dated April 2021
8/11/2021	HCFCD	Revised Project Prioritization Framework	Includes revised spreadsheet for scoring projects as well as notes to describe the process; dated 7/19/2021
8/19/2021	HCFCD	Spatial data	Includes Structure Inventory, topography, COH utility data, and various shapefiles (demographics, parcesl, ROW, FEMA claims, repetitive losses, flooded structures, roadway data, etc)
9/13/2021	HCFCD	Construction Plans	E516-01-00
11/9/2021	COH	Spatial data	Includes 3-1-1 reports shapefile, Excel table of 3-1-1 shapefile data, and 3-1-1 reports map
2/11/2022	HCFCD	Construction Plans	Redevelopment along the southeastern corner of Wheatley Street and W Tidwell Road

TABLES

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 2.1
Boundary Condition Summary

Riverine Locations

River Station	Type	Flow Source/ HEC-HMS Element	Other Information	Min. flow (cfs)	Multiplier	River	Reach
61181	Flow Hydrograph	MAAPnext model cross section	-	-	-	E100-00-00	E100-00-00_0001
61025	Lateral Inflow Hydrograph	E100_18	-	-	0.11	E100-00-00	E100-00-00_0001
55705	Uniform Lateral Inflow	E100_19	DS RS: 53063	-	0.65	E100-00-00	E100-00-00_0001
52547	Uniform Lateral Inflow	E100_20	DS RS: 47813	-	0.46	E100-00-00	E100-00-00_0001
44973	Stage Hydrograph	MAAPnext model cross section	-	-	-	E100-00-00	E100-00-00_0001
48995	Flow Hydrograph	MAAPnext model cross section		-	-	E115-00-00	E115-00-00_0476
57396	Uniform Lateral Inflow	Model Stability Purpose	DS RS: 53030	20	-	E116-00-00	E116-00-00_0530
63143	Uniform Lateral Inflow	Model Stability Purpose	DS RS: 57972	20	-	E116-01-00	E116-01-00_0578
61733	Uniform Lateral Inflow	Model Stability Purpose	DS RS: 61431	20	-	E116-05-00	E116-05-00_0560
59399	Flow Hydrograph	MAAPnext model cross section	-	-	-	E117-00-00	E117-00-00_0562

Table 2.2
Boundary Condition Summary

Storage Area / 2D Mesh

Storage Area/Boundary Name	Location	Type	Other Information
US_ROB	West of RS 61181	Flow Hydrograph	Overbank Inflows from the Phase 1 MAAPnext model
US_LOB	East of RS 61181	Flow Hydrograph	
E602_EBC_WNWout	West of the 2D mesh E602	Normal Depth	S=0.0005
E602_EBC_NWout	North-West of 2D mesh E602	Normal Depth	S=0.005
E602_EBC_NNWout	North of 2D mesh E602	Normal Depth	S=0.0005
E602_EBC_E101	East of 2D mesh E602	Normal Depth	S=0.0015
E602_EBC_OUT	South of 2D mesh E602	Normal Depth	S=0.0015
E605-2_EBC_OUT	South-West of 2D mesh E605-2	Normal Depth	S=0.0015
E601_EBC_OUT	North-West of 2D mesh E601	Normal Depth	S=0.005
E11601_SAJ_US	Upstream of E116-01-00 channel	Lateral Inflow	Model Stability Purposes
E11605_SAJ_US	Upstream of E116-05-00 channel	Lateral Inflow	Model Stability Purposes
E116_SAJ_US	Upstream of E116-00-00 channel	Lateral Inflow	Model Stability Purposes
E116_SAJ_DS	Downstream of E116-00-00 channel	Lateral Inflow	Model Stability Purposes

TABLES

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 3.1
Flooding Metrics Related to Existing Condition

Problem Area Summary

Predicted Structural Flooding

Problem	Any Depth				Depth over 1'			
Area	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
01	4	9	13	22	0	0	0	0
02	2	8	21	26	0	0	0	0
03	7	9	20	27	0	0	1	23
04	6	9	17	29	0	0	0	0
05	0	0	1	5	0	0	0	0
TOTAL	19	35	72	109	0	0	1	23

Actual Structural Flooding

	Historical Storm Event								
Problem	Imelda	Harvey	Memorial Day	Tax Day	Halloween	Memorial Day		FEMA	Repetitive
Area	2019	2017	2016	2016	2015	2015	TOTAL	Claims	Losses
01	3	90	0	0	0	5	98	94	13
02	2	98	0	0	1	0	101	120	17
03	0	73	0	0	0	0	73	105	25
04	11	82	0	1	3	1	98	42	8
05	0	13	0	0	0	0	13	5	0
TOTAL	16	356	0	1	4	6	383	366	63

Non-Structural Flooding, Total Roadway Length (feet)

Problem	Any Depth				Depth over 1'			
Area	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
01	30,300	31,400	32,200	33,200	19,300	22,000	23,600	24,600
02	46,400	48,100	49,300	50,800	26,000	28,900	30,700	32,900
03	12,700	13,300	14,200	14,400	7,300	8,000	10,200	11,000
04	38,200	42,600	44,500	45,900	4,000	8,100	11,300	15,600
05	8,400	9,200	9,500	9,800	3,800	4,600	5,600	7,000
TOTAL	136,000	144,600	149,700	154,100	60,400	71,600	81,400	91,100

Table 3.2
Flooding Metrics Related to Existing Condition

Problem Area 01

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	4	9	12	20	0	0	0	0
Residential - Multi	0	0	0	1	0	0	0	0
Commercial	0	0	1	1	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL FLOODING	4	9	13	22	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	3
Harvey, 2017	90
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	5
FEMA Claims	94
Repetitive Losses	13

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	3,800	4,300	4,500	4,900	1,100	1,700	2,200	2,600
3. Local Roadways	26,500	27,100	27,700	28,300	18,200	20,300	21,400	22,000
Total Length (feet)	30,300	31,400	32,200	33,200	19,300	22,000	23,600	24,600

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

Table 3.3
Flooding Metrics Related to Existing Condition

Problem Area 02

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	1	5	18	23	0	0	0	0
Residential - Multi	1	1	1	1	0	0	0	0
Commercial	0	2	2	2	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL FLOODING	2	8	21	26	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	2
Harvey, 2017	98
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	1
Memorial Day 2015	0
FEMA Claims	120
Repetitive Losses	17

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	11,200	11,700	12,100	12,600	5,500	6,800	7,100	8,000
3. Local Roadways	35,200	36,400	37,200	38,200	20,500	22,100	23,600	24,900
Total Length (feet)	46,400	48,100	49,300	50,800	26,000	28,900	30,700	32,900

Other Criteria

Social Vulnerability	4
Low-Moderate Income	No

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 3.4
Flooding Metrics Related to Existing Condition

Problem Area 03

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	7	8	17	21	0	0	1	19
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	1	3	6	0	0	0	4
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL FLOODING	7	9	20	27	0	0	1	23

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	0
Harvey, 2017	73
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	0
FEMA Claims	105
Repetitive Losses	25

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	4,000	4,500	5,300	5,400	1,300	1,700	3,500	3,900
3. Local Roadways	8,700	8,800	8,900	9,000	6,000	6,300	6,700	7,100
Total Length (feet)	12,700	13,300	14,200	14,400	7,300	8,000	10,200	11,000

Other Criteria

Social Vulnerability	4
Low-Moderate Income	No

Table 3.5
Flooding Metrics Related to Existing Condition

Problem Area 04

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	5	7	13	23	0	0	0	0
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	1	3	5	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	1	1	1	1	0	0	0	0
TOTAL FLOODING	6	9	17	29	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	11
Harvey, 2017	82
Memorial Day 2016	0
Tax Day 2016	1
Halloween 2015	3
Memorial Day 2015	1
FEMA Claims	42
Repetitive Losses	8

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	16,700	18,400	19,000	19,600	2,000	4,400	6,100	8,400
3. Local Roadways	21,500	24,200	25,500	26,300	2,000	3,700	5,200	7,200
Total Length (feet)	38,200	42,600	44,500	45,900	4,000	8,100	11,300	15,600

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 3.6
Flooding Metrics Related to Existing Condition

Problem Area 05

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	1	0	0	0	0
Residential - Multi	0	0	0	2	0	0	0	0
Commercial	0	0	1	2	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL FLOODING	0	0	1	5	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	0
Harvey, 2017	13
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	0
FEMA Claims	5
Repetitive Losses	0

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	2,600	3,300	3,600	3,800	400	900	1,700	2,600
3. Local Roadways	5,800	5,900	5,900	6,000	3,400	3,700	3,900	4,400
Total Length (feet)	8,400	9,200	9,500	9,800	3,800	4,600	5,600	7,000

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

TABLES

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 4.1
Opinion of Probable Construction Cost - PA01

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source Sheet Flow (PA01)
Date of OPCC April 29, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 01 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 01 - Construction Cost								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19		$0	7,400	$142,080	Surface Area 1.4 AC., Average Depth of Basin: 3.4'
	Clearing, Grubbing, Sodding, Grading	AC	$16,000		$0		$0	Surface Area: # AC, Heavy Wooded Area (10K/ac)
	Clearing, Grubbing	AC	$800		$0	1.4	$1,120	Surface Area: 1.4 AC. (basin, minimum vegitation cover)
	Demolish Existing Bridge	SF	$32		$0		$0	
	Bridge	SF	$160		$0		$0	
	5' x 3' CBC	LF	$491	435	$213,501		$0	Box Area * 10.425 + 192.08
	CBC Headwall	EA	$20,000	2	$40,000		$0	TxDOT Detail 3:1 Headwall (5'X3' CBC) 10 CY; $1,250/CY
	24 In. Class III Reinf. Conc. Pipe	LF	$160		$0	540	$86,400	Pipe Area * 14.004 + 76.391
	Channel Lining	CY	$1,600	920	$1,472,000		$0	1.14 ac, 6" thickness lining, $1,000/C.Y.
	Pavement Removal & Replacement	SY	$176	134	$23,584		$0	2*24'W x 25'L Concrete Pavement (small Quantity)
	Hydromulch Seeding	AC	$7,040		$0	1.4	$9,856	
	Utility Relocation	EA	$80,000		$0	1	$80,000	Mid. Complexity Utility Relocation
	Stabilized Construction Entrance	CY	$192		$0		$0	estimate 2 SCEs, 50'*16'*12" each, $120/CY
	SWPPP	AC	$1,600		$0		$0	Estimate $1,000/AC large site
	Silt Fence	LF	$8		$0		$0	PW 2018 Average Bid + 5%
	Television Inspection for Storm Drain	LF	$6		$0		$0	PW 2018 Average Bid + 5%
Construction Cost Subtotal					**$1,750,000**		**$320,000**	**PA01 Direct Construction Cost (Rounded to ,000)**
Engineering & Contingencies								
	Mobilization/Demobilization	%	5%	1	$87,500	1	$16,000	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$210,000	1	$38,400	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$175,000	1	$32,000	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$525,000	1	$96,000	30% * (Direct Construction Cost)
Engineering & Contingencies Subtotal					**$998,000**		**$183,000**	**Engineering & Contingencies Cost (Rounded to ,000)**
ROW Acquisition								
Residual Property Buyout (X structures)	ROW Acquisition (Partial) (### XXXXXX Road, HCAD Acct: #############)	LS	$0	0	$0	0	$0	HCAD Market Value x 2.5
ROW Acquisition Subtotal					**$0**		**$0**	**ROW Acquisition Cost (Rounded to ,000)**
Problem Area 01 TOTAL (Construction Cost + Engineering & Contingencies + ROW Acquisition)					**$2,747,000**		**$502,000**	**TOTAL PROBLEM AREA 01 OPCC (Rounded to ,000) = $3,249,000**

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 4.2
Opinion of Probable Construction Cost - PA02

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source Sheet Flow (PA02)
Date of OPCC April 29, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost Problem Area 02 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 02 - Construction Cost								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	22,510	$432,192		$0	E116-00-00 Channel and E116-05-00 Channel cleanup
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	33,080	$635,136		$0	South Basin Surface Area 4.28 AC., Average Depth of Basin: 4.79'
	8' x 7' CBC (2*160LF)	LF	$688	880	$605,440		$0	Box Area * 10.425 + 192.08
	CBC Headwall (8'X7')	EA	$56,000	2	$112,000		$0	TxDOT Detail 3:1 Headwall (8'X7' CBC) 28 CY; $1,250/CY
	8' x 5' CBC (2*160LF)	LF	$656		$0	600	$393,600	Box Area * 10.425 + 192.08
	CBC Headwall (8'X5')	EA	$34,000		$0	1	$34,000	TxDOT Detail 3:1 Headwall (8'X5' CBC) 17 CY; $1,250/CY
	Concrete Pavement Removal & Replacement	SY	$176	62	$10,912	585	$102,960	1*11'W x 160'L Concrete Pavement (small Quantity)
	Hydromulch Seeding	AC	$7,040	17	$119,680	1	$7,040	
	4' Max. Depth Roadside Ditch Improvements	LF	$160		$0	30,710	$4,913,600	$160/LF for Excavation, Hydromulch, Driveway Culverts, Pavement Remove/Replace
			Contruction Cost Subtotal		**$1,916,000**		**$5,452,000**	**PA02 Direct Construction Cost (Rounded to ,000)**
				Engineering & Contingencies				
	Mobilization/Demobilization	%	5%	1	$95,800	1	$272,600	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$229,920	1	$654,240	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$191,600	1	$545,200	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$574,800	1	$1,635,600	30% * (Direct Construction Cost)
			Engineering & Contingencies Subtotal		**$1,093,000**		**$3,108,000**	**Engineering & Contingencies Cost (Rounded to ,000)**
				ROW Acquisition				
Roadside Ditches	ROW Acquisition (Partial) - 30,800 LF by 5'	SF	$15	0	$0	190,000	$2,850,000	$15/SF determined as 2022 Appraised Value rate for properties along alignment
			ROW Acquisition Subtotal		**$0**		**$2,850,000**	**ROW Acquisition Cost (Rounded to ,000)**
			Problem Area 02 TOTAL (Construction Cost Engineering & Contingencies + ROW Acquisition)		**$3,008,000**		**$11,409,000**	**TOTAL PROBLEM AREA 02 OPCC (Rounded to ,000) = $14,417,000**

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 4.3
Opinion of Probable Construction Cost - PA04

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source W Tidwell and Sheet Flow (PA04)
Date of OPCC April 29, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 04 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 04 - Construction Cost								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	29,140	$559,488		$0	E116-00-00 Channel
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	71,150	$1,366,080		$0	North Basin Surface Area 13.6 AC., Average Depth of Basin: 3.3'
	Clearing, Grubbing (North Basin)	AC	$800	14	$11,200		$0	Surface Area: 1.4 AC. (basin, minimum vegetation cover)
	5' x 4' CBC (Tidwell 3*120LF + Paul Quinn 3*40LF)	LF	$512	480	$245,760		$0	Box Area * 10.425 + 192.08
	CBC Headwall (5'X4')	EA	$26,000	4	$104,000		$0	TxDOT Detail 3:1 Headwall (5'X4' CBC) 13 CY; $1,250/CY
	4' x 3' CBC (Mansfield 3*36LF)	LF	$448	108	$48,384		$0	Box Area * 10.425 + 192.08
	CBC Headwall (4'X3')	EA	$18,000	2	$36,000		$0	TxDOT Detail 3:1 Headwall (4'X3' CBC) 9 CY; $1,250/CY
	30 In. Class III Reinf. Conc. Pipe	LF	$214	100	$21,351		$0	Pipe Area * 14.004 + 76.391
	36 In. Class III RCP (Del Soto 3*36LF)	LF	$280	108	$30,240		$0	Pipe Area * 14.004 + 76.391
	Pipe Headwall (3*36" RCP)	EA	$14,600	2	$29,200		$0	TxDOT Detail 3:1 Headwall (36" RCP) 13 CY; $1,250/CY
	Hydromulch Seeding	AC	$7,040	3	$21,120		$0	
	4' Max. Depth Roadside Ditch Improvements	LF	$160		$0	15,500	$2,480,000	$160/LF for Excavation, Hydromulch, Driveway Culverts, Pavement Remove/Replace
			Contruction Cost Subtotal		**$2,473,000**		**$2,480,000**	**PA04 Direct Construction Cost (Rounded to ,000)**
				Engineering & Contingencies				
	Mobilization/Demobilization	%	5%	1	$123,650	1	$124,000	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$296,760	1	$297,600	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$247,300	1	$248,000	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$741,900	1	$744,000	30% * (Direct Construction Cost)
			Engineering & Contingencies Subtotal		**$1,410,000**		**$1,414,000**	**Engineering & Contingencies Cost (Rounded to ,000)**
				ROW Acquisition				
North Basin	ROW Acquisition (Complete) (0 Creekmont Road, HCAD Acct: 0432100000059)	LS	$1,133,933	1	$2,834,833	0	$0	2022 HCAD Market Value x 2.5
North Basin	ROW Acquisition (Complete) (0 W Tidwell Road, HCAD Acct: 1231240000003)	LS	$1,100,940	1	$2,752,350	0	$0	2022 HCAD Market Value x 2.5
E116-00-00 Widening	ROW Acquisition (Partial) - 3,500LF by 30'	SF	$10	105,000	$1,050,000	0	$0	$10/SF determined as 2022 Appraised Value rate for properties along alignment
Paul Quinn Roadside Ditch	ROW Acquisition (Partial) - 5,400LF by 15'	SF	$7	0	$0	81,000	$567,000	$7/SF determined as 2022 Appraised Value rate for properties along alignment
Mansfield Roadside Ditch	ROW Acquisition (Partial) - 5,100LF by 15'	SF	$7	0	$0	76,500	$535,500	$7/SF determined as 2022 Appraised Value rate for properties along alignment
DeSoto Roadside Ditch	ROW Acquisition (Partial) - 5,000LF by 15'	SF	$7	0	$0	75,000	$525,000	$7/SF determined as 2022 Appraised Value rate for properties along alignment

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source W Tidwell and Sheet Flow (PA04)
Date of OPCC April 29, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 04 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
ROW Acquisition Subtotal					**$6,638,000**		**$1,628,000**	**ROW Acquisition Cost (Rounded to ,000)**
Problem Area 04 TOTAL (Construction Cost + Engineering & Contingencies + ROW Acquisition)					**$10,520,000**		**$5,522,000**	**TOTAL PROBLEM AREA 04 OPCC (Rounded to ,000) = $16,042,000**

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 4.4
Opinion of Probable Construction Cost - PA05

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source Sheet Flow from Desoto, Mansfield, Paul Quinn Rd (PA05)
Date of OPCC April 29, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 05 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 05 - Construction Cost								
	4' Max. Depth Roadside Ditch Improvements	LF	$160		$0	3,200	$512,000	$160/LF for Excavation, Hydromulch, Driveway Culverts, Pavement Remove/Replace
			Contruction Cost Subtotal		**$0**		**$512,000**	**PA05 Direct Construction Cost (Rounded to ,000)**
Engineering & Contingencies								
	Mobilization/Demobilization	%	5%	1	$0	1	$25,600	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$0	1	$61,440	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$0	1	$51,200	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$0	1	$153,600	30% * (Direct Construction Cost)
			Engineering & Contingencies Subtotal		**$0**		**$292,000**	**Engineering & Contingencies Cost (Rounded to ,000)**
ROW Acquisition								
W Tidwell Roadside Ditch	ROW Acquisition (Partial) - 3,200LF by 15'	SF	$10	0	$0	48,000	$480,000	$10/SF determined as 2022 Appraised Value rate for properties along alignment
			ROW Acquisition Subtotal		**$0**		**$480,000**	**ROW Acquisition Cost (Rounded to ,000)**
			Problem Area 05 TOTAL (Construction Cost + Engineering & Contingencies + ROW Acquisition)		**$0**		**$1,284,000**	**TOTAL PROBLEM AREA 05 OPCC (Rounded to ,000) = $1,284,000**

Table 4.5

Opinion of Probable Construction Cost - Recommended Project

HCFCD Project Name	E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID	E116-00-00_P001
Consultant Name	Pape-Dawson Engineers, Inc.
Flooding Source	Recommended Project (PA01, PA02 partial, and PA04 partial)
Date of OPCC	April 29, 2022
Engineers Notes	HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Immediate Recommended Project Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Recommended Project Construction Cost in Problem Area 01								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19		$0	7,400	$142,080	Surface Area 1.4 AC., Average Depth of Basin: 3.4'
	Clearing, Grubbing, Sodding, Grading	AC	$16,000		$0		$0	Surface Area: # AC, Heavy Wooded Area (10K/ac)
	Clearing, Grubbing	AC	$800		$0	1.4	$1,120	Surface Area: 1.4 AC. (basin, minimum vegitation cover)
	Demolish Existing Bridge	SF	$32		$0		$0	
	Bridge	SF	$160		$0		$0	
	5' x 3' CBC	LF	$491	435	$213,501		$0	Box Area * 10.425 + 192.08
	CBC Headwall	EA	$20,000	2	$40,000		$0	TxDOT Detail 3:1 Headwall (5'X3' CBC) 10 CY; $1,250/CY
	24 In. Class III Reinf. Conc. Pipe	LF	$160		$0	540	$86,400	Pipe Area * 14.004 + 76.391
	Channel Lining	CY	$1,600	920	$1,472,134		$0	1.14 ac, 6" thickness lining, $1,000/C.Y.
	Pavement Removal & Replacement	SY	$176	134	$23,584		$0	2*24'W x 25'L Concrete Pavement (small Quantity)
	Hydromulch Seeding	AC	$7,040		$0	1.4	$9,856	
	Utility Relocation	EA	$80,000		$0	1	$80,000	Mid. Complexity Utility Relocation
	Stabilized Construction Entrance	CY	$192		$0		$0	estimate 2 SCEs, 50'*16'*12" each, $120/CY
	SWPPP	AC	$1,600		$0		$0	Estimate $1,000/AC large site
	Silt Fence	LF	$8		$0		$0	PW 2018 Average Bid + 5%
	Television Inspection for Storm Drain	LF	$6		$0		$0	PW 2018 Average Bid + 5%
	Recommended Project Construction Cost Subtotal in Problem Area 01				**$1,750,000**		**$320,000**	**Recommended Project PA01 Direct Construction Cost (Rounded to ,000)**
Recommended Project Construction Cost in Problem Area 02								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	22,510	$432,192		$0	E116-00-00 Channel and E116-05-00 Channel cleanup
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	33,080	$635,136		$0	South Basin Surface Area 4.28 AC., Average Depth of Basin: 4.79'
	8' x 7' CBC (2*160LF)	LF	$688	880	$605,440		$0	Box Area * 10.425 + 192.08
	CBC Headwall (8'X7')	EA	$56,000	2	$112,000		$0	TxDOT Detail 3:1 Headwall (8'X7' CBC) 28 CY; $1,250/CY
	8' x 5' CBC (2*160LF)	LF	$656		$0	600	$393,600	Box Area * 10.425 + 192.08
	CBC Headwall (8'X5')	EA	$34,000		$0	1	$34,000	TxDOT Detail 3:1 Headwall (8'X5' CBC) 17 CY; $1,250/CY
	Concrete Pavement Removal & Replacement	SY	$176	62	$10,912	585	$102,960	1*11'W x 160'L Concrete Pavement (small Quantity)
	Hydromulch Seeding	AC	$7,040	17	$119,680	1	$7,040	
	Recommended Project Construction Cost Subtotal in Problem Area 02				**$1,916,000**		**$538,000**	**Recommended Project PA02 Direct Construction Cost (Rounded to ,000)**

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 4.5
Opinion of Probable Construction Cost - Recommended Project

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source Recommended Project (PA01, PA02 partial, and PA04 partial)
Date of OPCC April 29, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Immediate Recommended Project Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Recommended Project Construction Cost in Problem Area 04								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	29,140	$559,488		$0	E116-00-00 Channel
	5' x 4' CBC (Tidwell 3*120LF + Paul Quinn 3*40LF)	LF	$512	480	$245,760		$0	Box Area * 10.425 + 192.08
	CBC Headwall (5'X4')	EA	$26,000	4	$104,000		$0	TxDOT Detail 3:1 Headwall (5'X4' CBC) 13 CY; $1,250/CY
	4' x 3' CBC (Mansfield 3*36LF)	LF	$448	108	$48,384		$0	Box Area * 10.425 + 192.08
	CBC Headwall (4'X3')	EA	$18,000	2	$36,000		$0	TxDOT Detail 3:1 Headwall (4'X3' CBC) 9 CY; $1,250/CY
	30 In. Class III Reinf. Conc. Pipe	LF	$214	100	$21,352		$0	Pipe Area * 14.004 + 76.391
	36 In. Class III RCP (Del Soto 3*36LF)	LF	$280	108	$30,240		$0	Pipe Area * 14.004 + 76.391
	Pipe Headwall (3*36" RCP)	EA	$14,600	2	$29,200		$0	TxDOT Detail 3:1 Headwall (36" RCP) 13 CY; $1,250/CY
	Hydromulch Seeding	AC	$7,040	1	$7,040		$0	
	Recommended Project Construction Cost Subtotal in Problem Area 04				**$1,082,000**		**$0**	**Recommended Project PA04 Direct Construction Cost (Rounded to ,000)**
	Recommended Project Construction Cost Subtotal				**$4,747,000**		**$858,000**	**Recommended Project Direct Construction Cost (Rounded to ,000)**
Engineering & Contingencies								
	Mobilization/Demobilization	%	5%	1	$237,400	1	$42,900	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$569,760	1	$102,960	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$474,800	1	$85,800	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$1,424,400	1	$257,400	30% * (Direct Construction Cost)
	Recommended Project Engineering & Contingencies Subtotal				**$2,707,000**		**$490,000**	**Recommended Project Engineering & Contingencies Cost (Rounded to ,000)**
ROW Acquisition								
PA04 E116-00-00 Widening	ROW Acquisition (Partial) - 3,500LF by 30'	SF	$10	105,000	$1,050,000	0	$0	$10/SF determined as 2022 Appraised Value rate for properties along alignment
	ROW Acquisition Subtotal				**$1,050,000**		**$0**	**ROW Acquisition Cost (Rounded to ,000)**
Recommended Project TOTAL (Construction Cost + Engineering & Contingencies + ROW Acquisition)					**$8,503,000**		**$1,347,000**	**TOTAL RECOMMENDED PROJECT OPCC (Rounded to ,000) = $9,850,000**

Table 4.6
Opinion of Probable Construction Cost - Summary

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Date of OPCC 04/29/22
Engineer's Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - E116-00-00 Inflation 2019--> 2022 60%

Problem Area	HCFCD				City of Houston				TOTAL OPCC	Summary
	Direct Construction	Engineering & Contingencies	ROW Acquisition	Total Cost	Direct Construction	Engineering & Contingencies	ROW Acquisition	Total Cost		
PA01	$ 1,750,000	$ 998,000	$ -	$ 2,748,000	$ 320,000	$ 183,000	$ -	$ 503,000	$ 3,251,000	Micro detention basins
PA02	$ 1,916,000	$ 1,093,000	$ -	$ 3,009,000	$ 5,452,000	$ 3,108,000	$ 2,850,000	$ 11,410,000	$ 14,419,000	Channel widening, roadside ditches, and expansion of existing HOA/HCFCD ponds
PA04	$ 2,473,000	$ 1,410,000	$ 6,638,000	$ 10,521,000	$ 2,480,000	$ 1,414,000	$ 1,628,000	$ 5,522,000	$ 16,043,000	Main channel widening, inline culvert remove/replace, roadside ditches
PA05	$ -	$ -	$ -	$ -	$ 512,000	$ 292,000	$ 480,000	$ 1,284,000	$ 1,284,000	Channel Widening, roadside ditches, and North Basin
Watershed	**$ 6,139,000**	**$ 3,501,000**	**$ 6,638,000**	**$ 16,278,000**	**$ 8,764,000**	**$ 4,997,000**	**$ 4,958,000**	**$ 18,719,000**	**$ 34,997,000**	
Recommended Projects	$ 4,747,000	$ 2,707,000	$ 1,050,000	$ 8,504,000	$ 858,000	$ 490,000	$ -	$ 1,348,000	$ 9,852,000	**HCFCD**: PA01 + PA02 + PA04 (not including North Basin) **COH**: PA01 + PA02 Improvements on Ella Blvd. only (no neighborhood roadside ditch improvements)

Table 4.7
1% AEP Level of Service Opinion of Probable Construction Cost - PA01

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source Sheet Flow (PA01)
Date of OPCC May 3, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 01 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 01 - Construction Cost								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19		$0	7,400	$142,080	Surface Area 1.4 AC., Average Depth of Basin: 3.4'
	Clearing, Grubbing	AC	$800		$0	1.4	$1,120	Surface Area: 1.4 AC. (basin, minimum vegitation cover)
	5' x 3' CBC	LF	$491	435	$213,501		$0	Box Area * 10.425 + 192.08
	CBC Headwall	EA	$20,000	2	$40,000		$0	TxDOT Detail 3:1 Headwall (5'X3' CBC) 10 CY; $1,250/CY
	24 In. Class III Reinf. Conc. Pipe	LF	$160		$0	540	$86,400	Pipe Area * 14.004 + 76.391
	Channel Lining	CY	$1,600	920	$1,472,000		$0	1.14 ac, 6" thickness lining, $1,000/C.Y.
	Pavement Removal & Replacement	SY	$176	134	$23,584		$0	2*24'W x 25'L Concrete Pavement (small Quantity)
	Hydromulch Seeding	AC	$7,040		$0	1.4	$9,856	
	Utility Relocation	EA	$80,000		$0	1	$80,000	Mid. Complexity Utility Relocation
Construction Cost Subtotal					**$1,750,000**		**$320,000**	**PA01 Direct Construction Cost (Rounded to ,000)**
Engineering & Contingencies								
	Mobilization/Demobilization	%	5%	1	$87,500	1	$16,000	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$210,000	1	$38,400	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$175,000	1	$32,000	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$525,000	1	$96,000	30% * (Direct Construction Cost)
Engineering & Contingencies Subtotal					**$998,000**		**$183,000**	**Engineering & Contingencies Cost (Rounded to ,000)**
ROW Acquisition								
Residual Property Buyout (X structures)	ROW Acquisition (Partial) (### XXXXXX Road, HCAD Acct: #############)	LS	$0	0	$0	0	$0	HCAD Market Value x 2.5
ROW Acquisition Subtotal					**$0**		**$0**	**ROW Acquisition Cost (Rounded to ,000)**
Problem Area 01 TOTAL (Construction Cost + Engineering & Contingencies + ROW Acquisition)					**$2,747,000**		**$502,000**	**TOTAL PROBLEM AREA 01 OPCC (Rounded to ,000) = $3,249,000**

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 4.8
1% AEP Level of Service Opinion of Probable Construction Cost - PA02

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Flooding Source Sheet Flow (PA02)
Date of OPCC May 3, 2022
Engineers Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 02 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 02 - Construction Cost								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	86,236	$1,655,731		$0	E116-00-00 Channel and E116-05-00 Channel.
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	33,080	$635,136		$0	South Basin Surface Area 4.28 AC., Average Depth of Basin: 4.79'
	Clearing, Grubbing, Sodding, Grading (E116-00 and E116-05 channel)	AC	$16,000	28	$454,400		$0	Surface Area: 28 AC, Heavy Wooded Area (10K/ac)
	Demolish Existing Bridge	SF	$32	19,895	$636,629		$0	Bridges at Creekmouth, Pinemont and Del Norte along E116-00 and Rosslyn Rd along E116-05
	Bridge Construction	SF	$160	19,895	$3,183,147		$0	Bridges at Creekmouth, Pinemont and Del Norte along E116-00 and Rosslyn Rd along E116-05
	8' x 7' CBC (2*160LF)	LF	$688	880	$605,440		$0	Box Area * 10.425 + 192.08
	CBC Headwall (8'X7')	EA	$56,000	2	$112,000		$0	TxDOT Detail 3:1 Headwall (8'X7' CBC) 28 CY; $1,250/CY
	8' x 5' CBC (2*160LF)	LF	$656		$0	600	$393,600	Box Area * 10.425 + 192.08
	CBC Headwall (8'X5')	EA	$34,000		$0	1	$34,000	TxDOT Detail 3:1 Headwall (8'X5' CBC) 17 CY; $1,250/CY
	Concrete Pavement Removal & Replacement	SY	$176	62	$10,912	585	$102,960	1*11'W x 160'L Concrete Pavement (small Quantity)
	Hydromulch Seeding	AC	$7,040	17	$119,680	1	$7,040	
	SWPPP	AC	$1,600	28	$45,440		$0	Estimate $1,000/AC large site
	Silt Fence	LF	$8	7,800	$62,400		$0	PW 2018 Average Bid + 5%
	Stabilized Construction Entrance	CY	$192	8	$1,536		$0	Estimated SCEs, 50'*16'*12" each, 6 along the E116-05 channel and 2 along the E116-00 channel
	4' Max. Depth Roadside Ditch Improvements	LF	$160		$0	30,710	$4,913,600	$160/LF for Excavation, Hydromulch, Driveway Culverts, Pavement Remove/Replace
			Contruction Cost Subtotal		**$7,523,000**		**$5,452,000**	**PA02 Direct Construction Cost (Rounded to ,000)**
				Engineering & Contingencies				
	Mobilization/Demobilization	%	5%	1	$376,150	1	$272,600	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$902,760	1	$654,240	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$752,300	1	$545,200	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$2,256,900	1	$1,635,600	30% * (Direct Construction Cost)
			Engineering & Contingencies Subtotal		**$4,289,000**		**$3,108,000**	**Engineering & Contingencies Cost (Rounded to ,000)**
				ROW Acquisition				
E116-00-00 Widening between E116-01-00 and E116-05-00	ROW Acquisition (Partial) - 1,900LF by 70'	SF	$25	133,000	$3,325,000	0	$0	$25/SF determined as 2022 Appraised Value rate for properties along alignment
E116-05-00 Widening	ROW Acquisition (Partial) - 6,000LF by 60'	SF	$50	360,000	$18,000,000	0	$0	$50/SF determined as 2022 Appraised Value rate for properties along alignment
Roadside Ditches	ROW Acquisition (Partial) - 30,800 LF by 5'	SF	$15	0	$0	190,000	$2,850,000	$15/SF determined as 2022 Appraised Value rate for properties along alignment
			ROW Acquisition Subtotal		**$21,325,000**		**$2,850,000**	**ROW Acquisition Cost (Rounded to ,000)**
			Problem Area 02 TOTAL (Construction Cost + Engineering & Contingencies + ROW Acquisition)		**$33,136,000**		**$11,409,000**	**TOTAL PROBLEM AREA 02 OPCC (Rounded to ,000) = $44,545,000**

Table 4.9
1% AEP Level of Service Opinion of Probable Construction Cost - PA04

HCFCD Project Name	E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID	E116-00-00_P001
Consultant Name	Pape-Dawson Engineers, Inc.
Flooding Source	W Tidwell and Sheet Flow (PA04)
Date of OPCC	May 3, 2022
Engineers Notes	HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 04 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 04 - Construction Cost								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	139,734	$2,682,888		$0	E116-00-00 Channel upstream of confluence with E116-01-00 and downstream of confluence with E116-05-00.
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	30,331	$582,348		$0	Additional HCFCD Channel excavation between DeSoto & Mansfield and Mansfield & Paul Quinn Roads
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	71,150	$1,366,080		$0	North Basin Surface Area 13.6 AC., Average Depth of Basin: 3.3'
	Clearing, Grubbing, Sodding, Grading (E116-00-00 channel)	AC	$16,000	27	$436,480		$0	Surface Area: 27 AC, Heavy Wooded Area (10K/ac)
	Clearing, Grubbing, Sodding, Grading (Additional Channels between DeSoto, Mansfield, and Paul Quinn)	AC	$16,000	18	$285,120			Surface Area: 18 AC, Heavy Wooded Area (10K/ac)
	Clearing, Grubbing (North Basin)	AC	$800	14	$11,200		$0	Surface Area: 1.4 AC. (basin, minimum vegetation cover)
	5' x 4' CBC (Tidwell 3*120LF + Paul Quinn 3*40LF)	LF	$512	480	$245,760		$0	Box Area * 10.425 + 192.08
	CBC Headwall (5'X4')	EA	$26,000	4	$104,000		$0	TxDOT Detail 3:1 Headwall (5'X4' CBC) 13 CY; $1,250/CY
	4' x 3' CBC (Mansfield 3*36LF)	LF	$448	108	$48,384		$0	Box Area * 10.425 + 192.08
	CBC Headwall (4'X3')	EA	$18,000	2	$36,000		$0	TxDOT Detail 3:1 Headwall (4'X3' CBC) 9 CY; $1,250/CY
	30 In. Class III Reinf. Conc. Pipe	LF	$214	100	$21,351		$0	Pipe Area * 14.004 + 76.391
	36 In. Class III RCP (Del Soto 3*36LF)	LF	$280	108	$30,240		$0	Pipe Area * 14.004 + 76.391
	Pipe Headwall (3*36" RCP)	EA	$14,600	2	$29,200		$0	TxDOT Detail 3:1 Headwall (36" RCP) 13 CY; $1,250/CY
	Hydromulch Seeding	AC	$7,040	3	$21,120		$0	
	SWPPP	AC	$1,600	45	$72,160		$0	Estimate $1,000/AC large site
	Silt Fence	LF	$8	12,750	$102,000		$0	PW 2018 Average Bid + 5%
	Stabilized Construction Entrance	CY	$192	17	$3,264		$0	Estimate 17 SCEs, 50'*16'*12" each, $120/CY. 5 each along the Desoto & Mansfield and Mansfield & Paul Quinn back of lot ditches, and 4 along the E116-00 channel north of E116-01 and 3 downstream of E116-05 confluence.
	4' Max. Depth Roadside Ditch Improvements	LF	$160		$0	15,500	$2,480,000	$160/LF for Excavation, Hydromulch, Driveway Culverts, Pavement Remove/Replace
Contruction Cost Subtotal					**$6,078,000**		**$2,480,000**	**PA04 Direct Construction Cost (Rounded to ,000)**
Engineering & Contingencies								
	Mobilization/Demobilization	%	5%	1	$303,900	1	$124,000	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$729,360	1	$297,600	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$607,800	1	$248,000	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$1,823,400	1	$744,000	30% * (Direct Construction Cost)
Engineering & Contingencies Subtotal					**$3,465,000**		**$1,414,000**	**Engineering & Contingencies Cost (Rounded to ,000)**

Table 4.9
1% AEP Level of Service Opinion of Probable Construction Cost - PA04

HCFCD Project Name	E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID	E116-00-00_P001
Consultant Name	Pape-Dawson Engineers, Inc.
Flooding Source	W Tidwell and Sheet Flow (PA04)
Date of OPCC	May 3, 2022
Engineers Notes	HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - Problem Area 04 — Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
ROW Acquisition								
North Basin	ROW Acquisition (Complete) (0 Creekmont Road, HCAD Acct: 0432100000059)	LS	$1,133,933	1	$2,834,833	0	$0	2022 HCAD Market Value x 2.5
	ROW Acquisition (Complete) (0 W Tidwell Road, HCAD Acct: 1231240000003)	LS	$1,100,940	1	$2,752,350	0	$0	2022 HCAD Market Value x 2.5
E116-00-00 Widening US of E116-01-00	ROW Acquisition (Partial) - 1,700LF by 70'	SF	$10	119,000	$1,190,000	0	$0	$10/SF determined as 2022 Appraised Value rate for properties along alignment
E116-00-00 Widening DS of E116-05-00	ROW Acquisition (Partial) - 3,000LF by 90'	SF	$25	270,000	$6,750,000	0	$0	$50/SF determined as 2022 Appraised Value rate for properties along alignment. Since several of these properties are in the SFHA Zone AE of E100-00-00, a 50% discount was applied to the $/SF assumed in unit price.
Addtional HCFCD Channel between Paul Quinn & Mansfield	ROW Acquisition (Partial) - 5,400LF by 80'	SF	$5	432,000	$2,160,000	0	$0	$5/SF determined as 2022 Appraised Value rate for properties along alignment
Addtional HCFCD Channel between Mansfield & DeSoto	ROW Acquisition (Partial) - 5,000LF by 75'	SF	$7	375,000	$2,625,000	0	$0	$7/SF determined as 2022 Appraised Value rate for properties along alignment
ROW Acquisition Subtotal					**$18,313,000**		**$0**	**ROW Acquisition Cost (Rounded to ,000)**
Problem Area 04 TOTAL (Construction Cost + Engineering & Contingencies + ROW Acquisition)					**$27,855,000**		**$3,894,000**	**TOTAL PROBLEM AREA 04 OPCC (Rounded to ,000) = $31,749,000**

Table 4.10
1% AEP Level of Service Opinion of Probable Construction Cost - PA05

HCFCD Project Name	E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID	E116-00-00_P001
Consultant Name	Pape-Dawson Engineers, Inc.
Flooding Source	Sheet Flow from Desoto, Mansfield, Paul Quinn Rd (PA05)
Date of OPCC	May 3, 2022
Engineers Notes	HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost Problem Area 05 Inflation 2019--> 2022 60%

Item No.	Item	Unit	Unit Cost	HCFCD		City of Houston		Comments
				QTY	Cost	QTY	Cost	
Problem Area 05 - Construction Cost								
	Unclassified Site Excavation & Disposal (offsite)	CY	$19	15,730	$302,015		$0	E116-01-00 Channel
	Clearing, Grubbing, Sodding, Grading	AC	$16,000	18	$295,520		$0	Surface Area: 18 AC, Heavy Wooded Area (10K/ac)
	Demolish Existing Bridge	SF	$32	2,545	$81,448		$0	Bridge at Rosslyn Rd along E116-01
	Bridge Construction	SF	$160	2,545	$407,238		$0	Bridge at Rosslyn Rd along E116-01
	SWPPP	AC	$1,600	18	$29,552		$0	Estimate $1,000/AC large site
	Silt Fence	LF	$8	5,500	$44,000		$0	PW 2018 Average Bid + 5%
	Stabilized Construction Entrance	CY	$192	5	$960		$0	Estimate 5 SCEs, 50'*16'*12" each, $120/CY. They are all along the E116-01 channel.
	4' Max. Depth Roadside Ditch Improvements	LF	$160		$0	3,200	$512,000	$160/LF for Excavation, Hydromulch, Driveway Culverts, Pavement Remove/Replace
Contruction Cost Subtotal					**$1,161,000**		**$512,000**	**PA05 Direct Construction Cost (Rounded to ,000)**
Engineering & Contingencies								
	Mobilization/Demobilization	%	5%	1	$58,050	1	$25,600	5% * (Direct Construction Cost)
	Planning, Engineering, and Design	%	12%	1	$139,320	1	$61,440	12% * (Direct Construction Cost)
	Construction Management	%	10%	1	$116,100	1	$51,200	10% * (Direct Construction Cost)
	Contingencies	%	30%	1	$348,300	1	$153,600	30% * (Direct Construction Cost)
Engineering & Contingencies Subtotal					**$662,000**		**$292,000**	**Engineering & Contingencies Cost (Rounded to ,000)**
ROW Acquisition								
North Basin	ROW Acquisition (Complete) (0 Creekmont Road, HCAD Acct: 0432100000059)	LS	$1,133,933	1	$2,834,833	0	$0	2022 HCAD Market Value x 2.5
North Basin	ROW Acquisition (Complete) (0 W Tidwell Road, HCAD Acct: 1231240000003)	LS	$1,100,940	1	$2,752,350	0	$0	2022 HCAD Market Value x 2.5
E116-01-00 Widening	ROW Acquisition (Partial) - 4.800LF by 50'	SF	$25	240,000	$6,000,000	0	$0	$25/SF determined as 2022 Appraised Value rate for properties along alignment
ROW Acquisition Subtotal					**$11,588,000**		**$0**	**ROW Acquisition Cost (Rounded to ,000)**
Problem Area 05 TOTAL (Construction Cost Engineering & Contingencies + ROW Acquisition)					**$13,410,000**		**$804,000**	**TOTAL PROBLEM AREA 05 OPCC (Rounded to ,000) = $14,214,000**

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 4.11
1% AEP Level of Service Opinion of Probable Construction Cost - Summary

HCFCD Project Name E116-00-00 Flood Reduction Feasibility Study
HCFCD Project ID E116-00-00_P001
Consultant Name Pape-Dawson Engineers, Inc.
Date of OPCC 05/03/22
Engineer's Notes HCFCD 2019 Cost Tool used for Unit Prices inflated by 60%

Engineer's Opinion of Probable Construction Cost - E116-00-00 Inflation 2019--> 2022 60%

Problem Area	HCFCD				City of Houston				TOTAL OPCC	Summary
	Direct Construction	Engineering & Contingencies	ROW Acquisition	Total Cost	Direct Construction	Engineering & Contingencies	ROW Acquisition	Total Cost		
PA01	$ 1,750,000	$ 998,000	$ -	$ 2,747,000	$ 320,000	$ 183,000	$ -	$ 502,000	$ 3,249,000	Micro detention basins
PA02	$ 7,523,000	$ 4,289,000	$ 21,325,000	$ 33,136,000	$ 5,452,000	$ 3,108,000	$ 2,850,000	$ 11,409,000	$ 44,545,000	Channel widening, roadside ditches, and expansion of existing HOA/HCFCD ponds, South Basin
PA04	$ 6,078,000	$ 3,465,000	$ 18,313,000	$ 27,855,000	$ 2,480,000	$ 1,414,000	$ -	$ 3,894,000	$ 31,749,000	Main channel widening, inline culvert remove/replace, roadside ditches
PA05	$ 1,161,000	$ 662,000	$ 11,588,000	$ 13,410,000	$ 512,000	$ 292,000	$ -	$ 804,000	$ 14,214,000	Channel Widening, roadside ditches, and North Basin
Watershed	**$ 16,512,000**	**$ 9,414,000**	**$ 51,226,000**	**$ 77,148,000**	**$ 8,764,000**	**$ 4,997,000**	**$ 2,850,000**	**$ 16,609,000**	**$ 93,757,000**	

TABLES

Table 5.1
Flooding Metrics Related to Overall Strategy

Problem Area Summary

Predicted Structural Flooding

Problem Area	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
01	4	7	11	20	0	0	0	0
02	2	8	19	23	0	0	0	0
03	7	8	18	27	0	0	0	23
04	3	6	12	18	0	0	0	0
05	0	0	0	1	0	0	0	0
TOTAL	16	29	60	89	0	0	0	23

Actual Structural Flooding

Problem Area	Historical Storm Event							FEMA Claims	Repetitive Losses
	Imelda 2019	Harvey 2017	Memorial Day 2016	Tax Day 2016	Halloween 2015	Memorial Day 2015	TOTAL		
01	3	90	0	0	0	5	98	94	13
02	2	98	0	0	1	0	101	120	17
03	0	73	0	0	0	0	73	105	25
04	11	82	0	1	3	1	98	42	8
05	0	13	0	0	0	0	13	5	0
TOTAL	16	356	0	1	4	6	383	366	63

Non-Structural Flooding, Total Roadway Length (feet)

Problem Area	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
01	29,400	30,700	31,700	32,400	18,300	21,000	23,200	23,900
02	40,400	42,200	43,200	44,300	23,000	26,500	28,200	29,800
03	12,600	13,200	14,200	14,500	7,100	7,800	10,100	10,900
04	32,100	33,300	39,500	42,400	2,300	4,000	7,900	11,500
05	7,000	7,700	8,900	9,300	3,400	3,900	4,200	4,700
TOTAL	121,500	127,100	137,500	142,900	54,100	63,200	73,600	80,800

Structures with Full Benefit

Problem Area	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
01	0	2	2	2
02	0	0	2	3
03	0	1	2	0
04	3	3	5	11
05	0	0	1	4
TOTAL	3	6	12	20

Structures with Partial Benefit

Problem Area	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
01	0	0	0	0
02	0	0	0	2
03	0	0	0	0
04	0	3	6	10
05	0	0	0	0
TOTAL	0	3	6	12

Total Structures Benefitted

Problem Area	10% AEP	4% AEP	2% AEP	1% AEP
01	0	2	2	2
02	0	0	2	5
03	0	1	2	0
04	3	6	11	21
05	0	0	1	4
TOTAL	3	9	18	32

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 5.2
Flooding Metrics Related to Overall Strategy

Problem Area 01

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	4	7	11	20	0	0	0	0
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	4	7	11	20	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	3
Harvey, 2017	90
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	5
FEMA Claims	94
Repetitive Losses	13

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	3,500	4,000	4,400	4,700	1,000	1,700	2,400	2,200
3. Local Roadways	25,900	26,700	27,300	27,700	17,300	19,300	20,800	21,700
Total Length (feet)	29,400	30,700	31,700	32,400	18,300	21,000	23,200	23,900

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	2	1	0
Residential - Multi	0	0	0	1
Commercial	0	0	1	1
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	2	2	2

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	0	0

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	2	1	0
Residential - Multi	0	0	0	1
Commercial	0	0	1	1
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	2	2	2

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 5.3
Flooding Metrics Related to Overall Strategy

Problem Area 02

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	1	5	16	20	0	0	0	0
Residential - Multi	1	1	1	1	0	0	0	0
Commercial	0	2	2	2	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	2	8	19	23	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	2
Harvey, 2017	98
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	1
Memorial Day 2015	0
FEMA Claims	120
Repetitive Losses	17

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	9,500	9,700	10,000	10,500	3,800	5,600	6,300	6,800
3. Local Roadways	30,900	32,500	33,200	33,800	19,200	20,900	21,900	23,000
Total Length (feet)	40,400	42,200	43,200	44,300	23,000	26,500	28,200	29,800

Other Criteria

Social Vulnerability	4
Low-Moderate Income	No

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	2	3
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	2	3

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	2
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	0	2

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	2	5
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	2	5

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 5.4
Flooding Metrics Related to Overall Strategy

Problem Area 03

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	7	7	15	21	0	0	0	19
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	1	3	6	0	0	0	4
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	7	8	18	27	0	0	0	23

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	0
Harvey, 2017	73
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	0
FEMA Claims	105
Repetitive Losses	25

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	3,900	4,400	5,300	5,400	1,300	1,600	3,500	3,900
3. Local Roadways	8,700	8,800	8,900	9,100	5,800	6,200	6,600	7,000
Total Length (feet)	12,600	13,200	14,200	14,500	7,100	7,800	10,100	10,900

Other Criteria

Social Vulnerability	4
Low-Moderate Income	No

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	1	2	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	1	2	0

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	0	0

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	1	2	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	1	2	0

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 5.5
Flooding Metrics Related to Overall Strategy

Problem Area 04

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	2	5	8	14	0	0	0	0
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	0	3	3	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	1	1	1	1	0	0	0	0
TOTAL	3	6	12	18	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	11
Harvey, 2017	82
Memorial Day 2016	0
Tax Day 2016	1
Halloween 2015	3
Memorial Day 2015	1
FEMA Claims	42
Repetitive Losses	8

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	14,000	12,500	16,900	18,100	1,200	2,200	4,300	6,300
3. Local Roadways	18,100	20,800	22,600	24,300	1,100	1,800	3,600	5,200
Total Length (feet)	32,100	33,300	39,500	42,400	2,300	4,000	7,900	11,500

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	3	2	5	9
Residential - Multi	0	0	0	0
Commercial	0	1	0	2
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	3	3	5	11

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	3	6	10
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	3	6	10

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	3	5	11	19
Residential - Multi	0	0	0	0
Commercial	0	1	0	2
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	3	6	11	21

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 5.6
Flooding Metrics Related to Overall Strategy

Problem Area 05

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	1	0	0	0	0
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	0	0	0	1	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	0
Harvey, 2017	13
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	0
FEMA Claims	5
Repetitive Losses	0

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	1,500	1,900	3,000	3,400	100	200	400	800
3. Local Roadways	5,500	5,800	5,900	5,900	3,300	3,700	3,800	3,900
Total Length (feet)	7,000	7,700	8,900	9,300	3,400	3,900	4,200	4,700

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	2
Commercial	0	0	1	2
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	1	4

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	0	0

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	2
Commercial	0	0	1	2
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	1	4

TABLES

6. Flooding Metrics Related to Recommended Project
   - 6.1. Problem Area Summary
   - 6.2. Problem Area 01
   - 6.3. Problem Area 02
   - 6.4. Problem Area 03
   - 6.5. Problem Area 04
   - 6.6. Problem Area 05

Table 6.1
Flooding Metrics Related to Recommended Project

Problem Area Summary

Predicted Structural Flooding

Problem	Any Depth				Depth over 1'			
Area	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
01	4	7	11	20	0	0	0	0
02	2	8	20	23	0	0	0	0
03	7	9	18	27	0	0	0	23
04	5	9	15	24	0	0	0	0
05	0	0	0	3	0	0	0	0
TOTAL	18	33	64	97	0	0	0	23

Actual Structural Flooding

	Historical Storm Event								
Problem	Imelda	Harvey	Memorial Day	Tax Day	Halloween	Memorial Day		FEMA	Repetitive
Area	2019	2017	2016	2016	2015	2015	TOTAL	Claims	Losses
01	3	90	0	0	0	5	98	94	13
02	2	98	0	0	1	0	101	120	17
03	0	73	0	0	0	0	73	105	25
04	11	82	0	1	3	1	98	42	8
05	0	13	0	0	0	0	13	5	0
TOTAL	16	356	0	1	4	6	383	366	63

Non-Structural Flooding, Total Roadway Length (feet)

Problem	Any Depth				Depth over 1'			
Area	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
01	29,900	31,000	31,800	32,600	17,900	21,200	23,200	24,900
02	41,400	43,700	44,300	45,500	23,200	27,000	28,700	30,600
03	12,600	13,200	14,200	14,500	7,100	7,800	10,000	10,900
04	36,400	40,400	42,300	44,300	3,300	7,300	10,100	13,900
05	8,200	8,700	9,300	9,700	3,500	4,200	4,800	6,200
TOTAL	128,500	137,000	141,900	146,600	55,000	67,500	76,800	86,500

Structures with Full Benefit

Problem	Structures with Inundation Eliminated			
Area	10% AEP	4% AEP	2% AEP	1% AEP
01	0	2	2	2
02	0	0	1	3
03	0	0	2	0
04	1	0	2	5
05	0	0	1	2
TOTAL	1	2	8	12

Structures with Partial Benefit

Problem	Depth Reduced by More than 0.10 feet			
Area	10% AEP	4% AEP	2% AEP	1% AEP
01	0	0	0	0
02	0	0	0	2
03	0	0	0	0
04	0	1	1	2
05	0	0	0	2
TOTAL	0	1	1	6

Total Structures Benefitted

Problem Area	10% AEP	4% AEP	2% AEP	1% AEP
01	0	2	2	2
02	0	0	1	5
03	0	0	2	0
04	1	1	3	7
05	0	0	1	4
TOTAL	1	3	9	18

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 6.2
Flooding Metrics Related to Recommended Project

Problem Area 01

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	4	7	11	20	0	0	0	0
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	0	0	0	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	4	7	11	20	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	3
Harvey, 2017	90
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	5
FEMA Claims	94
Repetitive Losses	13

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	3,600	4,100	4,400	4,700	900	1,800	2,500	3,200
3. Local Roadways	26,300	26,900	27,400	27,900	17,000	19,400	20,700	21,700
Total Length (feet)	29,900	31,000	31,800	32,600	17,900	21,200	23,200	24,900

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	2	1	0
Residential - Multi	0	0	0	1
Commercial	0	0	1	1
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	2	2	2

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	0	0

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	2	1	0
Residential - Multi	0	0	0	1
Commercial	0	0	1	1
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	2	2	2

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 6.3
Flooding Metrics Related to Recommended Project

Problem Area 02

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	1	5	17	20	0	0	0	0
Residential - Multi	1	1	1	1	0	0	0	0
Commercial	0	2	2	2	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	2	8	20	23	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	2
Harvey, 2017	98
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	1
Memorial Day 2015	0
FEMA Claims	120
Repetitive Losses	17

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	9,300	9,800	10,000	10,600	4,000	5,900	6,400	7,000
3. Local Roadways	32,100	33,900	34,300	34,900	19,200	21,100	22,300	23,600
Total Length (feet)	41,400	43,700	44,300	45,500	23,200	27,000	28,700	30,600

Other Criteria

Social Vulnerability	4
Low-Moderate Income	No

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	1	3
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	1	3

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	2
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	0	2

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	1	5
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	1	5

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 6.4
Flooding Metrics Related to Recommended Project

Problem Area 03

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	7	8	15	21	0	0	0	19
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	1	3	6	0	0	0	4
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	7	9	18	27	0	0	0	23

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	0
Harvey, 2017	73
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	0
FEMA Claims	105
Repetitive Losses	25

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	3,900	4,400	5,300	5,400	1,300	1,600	3,500	3,900
3. Local Roadways	8,700	8,800	8,900	9,100	5,800	6,200	6,500	7,000
Total Length (feet)	12,600	13,200	14,200	14,500	7,100	7,800	10,000	10,900

Other Criteria

Social Vulnerability	4
Low-Moderate Income	No

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	2	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	2	0

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL FLOODING	0	0	0	0

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	2	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	2	0

E116-00-00 FLOOD REDUCTION FEASIBILITY STUDY
Final Engineering Report

Table 6.5
Flooding Metrics Related to Recommended Project

Problem Area 04

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	4	7	11	19	0	0	0	0
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	1	3	4	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	1	1	1	1	0	0	0	0
TOTAL	5	9	15	24	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	11
Harvey, 2017	82
Memorial Day 2016	0
Tax Day 2016	1
Halloween 2015	3
Memorial Day 2015	1
FEMA Claims	42
Repetitive Losses	8

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	16,000	17,800	18,500	19,100	1,500	4,000	5,400	7,400
3. Local Roadways	20,400	22,600	23,800	25,200	1,800	3,300	4,700	6,500
Total Length (feet)	36,400	40,400	42,300	44,300	3,300	7,300	10,100	13,900

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	1	0	2	4
Residential - Multi	0	0	0	0
Commercial	0	0	0	1
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	1	0	2	5

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	1	1	2
Residential - Multi	0	0	0	0
Commercial	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL FLOODING	0	1	1	2

Total Structures Benefitted

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	1	1	3	6
Residential - Multi	0	0	0	0
Commercial	0	0	0	1
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	1	1	3	7

Table 6.6
Flooding Metrics Related to Recommended Project

Problem Area 05

Predicted Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	1	0	0	0	0
Residential - Multi	0	0	0	0	0	0	0	0
Commercial	0	0	0	2	0	0	0	0
Zero Tax - Fire/Police/Hospital	0	0	0	0	0	0	0	0
Zero Tax - Other	0	0	0	0	0	0	0	0
TOTAL	0	0	0	3	0	0	0	0

Actual Structural Flooding

	Total Flooded Structures
Imelda, 2019	0
Harvey, 2017	13
Memorial Day 2016	0
Tax Day 2016	0
Halloween 2015	0
Memorial Day 2015	0
FEMA Claims	5
Repetitive Losses	0

Non-Structural Flooding

	Any Depth				Depth over 1'			
	10% AEP	4% AEP	2% AEP	1% AEP	10% AEP	4% AEP	2% AEP	1% AEP
1. Interstate, Freeways, Expressways	0	0	0	0	0	0	0	0
2. Arterials, Major Collectors	2,300	2,800	3,400	3,700	200	500	1,000	2,100
3. Local Roadways	5,900	5,900	5,900	6,000	3,300	3,700	3,800	4,100
Total Length (feet)	8,200	8,700	9,300	9,700	3,500	4,200	4,800	6,200

Other Criteria

Social Vulnerability	10
Low-Moderate Income	Yes

Structures with Full Benefit

	Structures with Inundation Eliminated			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	2
Commercial	0	0	1	0
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	1	2

Structures with Partial Benefit

	Depth Reduced by More than 0.10 feet			
	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	0
Commercial	0	0	0	2
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL FLOODING	0	0	0	2

Floodplain Removal from Structures

	10% AEP	4% AEP	2% AEP	1% AEP
Residential - Single	0	0	0	0
Residential - Multi	0	0	0	2
Commercial	0	0	1	2
Zero Tax - Fire/Police/Hospital	0	0	0	0
Zero Tax - Other	0	0	0	0
TOTAL	0	0	1	4

TABLES

7. Project Scoring
    - 7.1. Overall Strategy Summary
    - 7.2. Overall Strategy for PA01
    - 7.3. Overall Strategy for PA02
    - 7.4. Overall Strategy for PA03
    - 7.5. Overall Strategy for PA04
    - 7.6. Overall Strategy for PA05
    - 7.7. Overall Strategy for All PA
    - 7.8. Recommended Project Summary
    - 7.9. Recommended Project for PA01
    - 7.10. Recommended Project for PA02
    - 7.11. Recommended Project for PA04
    - 7.12. Recommended Project for All PA

Table 7.1
Project Scoring - Overall Strategy

Harris County Flood Control District Project Scoring Form

E116-00-00 Overall Strategy

SCORING CRITERIA:		1	2	3	4	5	6	7	8	
	Weight:	25%A	20%A	20%A	10%A	10%A	5%A	5%A	5%A	
Project Area:	Project ID:	Flood Risk (100-Year Event) Reduction	Existing Conditions Drainage LOS	Social Vulnerability Index (SVI)	Project Efficiency	Partnership Funding	Long Term Maintenance Costs	Minimize Environmental Impacts	Potential for Multiple Benefits	TOTAL SCORE
PA01A	E116_OS-PA01	0.01	0.15	2.00	0.00	0.40	0.50	0.50	0.15	3.71
PA02A	E116_OS-PA02	0.01	0.35	1.07	0.00	0.80	0.50	0.40	0.00	3.13
PA03A	E116_OS-PA03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PA04A	E116_OS-PA04	0.04	0.25	2.00	0.00	0.60	0.50	0.40	0.00	3.80
PA05A	E116_OS-PA05	0.01	0.16	2.00	1.00	1.00	0.50	0.40	0.00	5.07
LLA	E116_OS-All	0.07	0.95	1.68	0.00	0.60	0.30	0.40	0.00	4.00

Table 7.2
Project Scoring - Overall Strategy - PA01

Harris County Flood Control District Project Scoring Form

USERS: *Only type in cells that are ORANGE shaded.*	***NOTES:***
GREY cells are automatic calculations (Do not type in these cells).	
* *YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the*	***Prioritization Scoring Framework VERSION:*** **July 19, 2021 (6-7)**

TOTAL PROJECT SCORE:	***3.71***	**Project Area:**	PA01
		Project ID:	**E116_OS-PA01**
		Project Name:	E116-00-00 Overall Strategy
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	**(E) White Oak Bayou** *

1. What is the **OVERALL** project cost?	$ 3,249,000	USD.	$ 2,747,000	DISTRICT COST (After Partnership / Grant)
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	**Partnership or Grant funding is expected to cover 5% - 30% of Project Costs** *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	15%	*If unknown, enter "0%"*		

	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	# of Structures	4	13	22
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	# of Structures	0	2	1
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	# of Structures	0	0	0

4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	2,148	FEET	0.41	MILES

5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	Area (Acres)	Percentage	Project Area: PA01
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	0	0%	***269 acres***
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	0	0%	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	0	0%	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	268.5	100%	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	**No requirements for special maintenance have been identified.** *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	**No known wetland impacts** *
Is there any knowledge of **CULTURAL ARTIFACTS**?	**No** *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	**50% of the Project is not expected to have potential for recreational features** *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	**50% of the Project has potential for environmental enhancements** *

E116_OS-PA01, PM: Zubin Sukheswalla (Pape-Dawson)	PA01	*(E) White Oak Bayou*		*Project Score:*	3.71

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

						SCORE	WEIGHT	WEIGHTED SCORE
Structure Flooding Reduction Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	**0.03**	**25%**	**0.01**
1 Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	**0.025**	*0.03*			
	0.000	**0.020**	**0.005**					
Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	**0.000**				
	0.000	**0.000**	**0.000**					

						SCORE	WEIGHT	WEIGHTED SCORE
Existing Conditions Drainage Level of Service Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	**0.75**	**20%**	**0.15**
2 Structures in Existing Floodplain	*0.025*	*0.01*	*0.005*	**0.340**	*0.7*			
	0.100	**0.130**	**0.110**					
Channel Length	**2,148**	*0.41*		**0.4**				

			SCORE	WEIGHT	WEIGHTED SCORE
Social Vulnerability Index (SVI) for Project Area:		*PERCENTAGE OF SERVICE AREA*	**10.00**	**20%**	**2.00**
SVI indicates low level of vulnerability (less than 0.25)	0	**0.0%**			
3 *SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)*	4	**0.0%**			
SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	**0.0%**			
SVI indicates high level of vulnerability (Greater than 0.7501)	10	**100.0%**			

						SCORE	WEIGHT	WEIGHTED SCORE
Project Efficiency Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	**0.00**	**10%**	**0.00**
4 Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	**0.002**	*0.00*			
	0.000	**0.002**	**0.000**			$ 266,000	*Structure Value*	
Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	**0.000**		$ 2,747,000	*District Cost*	
	0.000	**0.000**	**0.000**			0.0968	*PEF*	

			SCORE	WEIGHT	WEIGHTED SCORE
Partnership Funding Scoring Criteria:		**Partnership or Grant funding is expected to cover 5% - 30% of Project Costs**	**4.00**	**10%**	**0.40**
No funding partner or grant.	0	**4**			
Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
5 *Partnership or Grant funding is expected to cover 5% - 30% of Project Costs*	4				
Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				

			SCORE	WEIGHT	WEIGHTED SCORE
Long Term Maintenance Costs Scoring Criteria:		**No requirements for special maintenance have been identified.**	**10.00**	**5%**	**0.50**
Project is expected to require extensive or specialized maintenance that will incur costs.	0	**10**			
6 *Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.*	6				
No requirements for special maintenance have been identified.	10				

					SCORE	WEIGHT	WEIGHTED SCORE
Minimize Environmental Impacts Scoring Criteria:		**No known wetland impacts**			**10.00**	**5%**	**0.50**
No known wetland impacts	10	**10**					
Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8						
7 *0.1 to 0.5 acres of wetlands expected to be impacted*	6						
0.5 to 2 acres of wetlands expected to be impacted	4	**No**	Modification Factor - Artifacts:				
2 to 5 acres of wetlands expected to be impacted	2	**0**	*Yes*	-1			
More than 5 acres of wetlands expected to be impacted	0		*No*	0			

			SCORE	WEIGHT	WEIGHTED SCORE
Potential for Multiple Benefits Scoring Criteria:		**50% of the Project is not expected to have potential for recreational features**	**3.00**	**5%**	**0.15**
50% of the Project is not expected to have potential for recreational features	0	**0**			
50% of the Project has potential for recreational features	1				
A possible partner has been identified for potential recreational features over 50% of the Project	2				
A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
8		**50% of the Project has potential for environmental enhancements**			
50% of the Project is not expected to have environmental enhancement	0	**3**			
50% of the Project has potential for environmental enhancements	3				
A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.3
Project Scoring - Overall Strategy - PA02

Harris County Flood Control District Project Scoring Form

USERS: *Only type in cells that are ORANGE shaded.*	***NOTES:***
GREY cells are automatic calculations (Do not type in these cells).	
* *YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the*	***Prioritization Scoring Framework VERSION:*** **July 19, 2021 (6-7)**

TOTAL PROJECT SCORE:	***3.13***	**Project Area:**	PA02
		Project ID:	**E116_OS-PA02**
		Project Name:	E116-00-00 Overall Strategy
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	**(E) White Oak Bayou** *

1. What is the **OVERALL** project cost?	$ 14,417,000	*USD.*	$ 3,008,000	*DISTRICT COST (After Partnership / Grant)*

2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	**Partnership or Grant funding is expected to cover 60% - 90% of Project Costs** *
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	**79%** ***If unknown, enter "0%"***

3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	**2**	**21**	**26**
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	**0**	**2**	**3**
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	**0**	**0**	**0**

4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	**7,154**	*FEET*	**1.35**	*MILES*

5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	**Area (Acres)**	**Percentage**	**Project Area: PA02**
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	**157.9**	**38%**	***415 acres***
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	**58.8**	**14%**	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	**0**	**0%**	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	**198.7**	**48%**	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	**No requirements for special maintenance have been identified.** *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	**Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known** *
Is there any knowledge of **CULTURAL ARTIFACTS**?	**No** *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	**50% of the Project is not expected to have potential for recreational features** *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	**50% of the Project is not expected to have environmental enhancement** *

E116_OS-PA02, PM: Zubin Sukheswalla (Pape-Dawson)	PA02	*(E) White Oak Bayou*		***Project Score:***	**3.13**

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
	Structure Flooding Reduction Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	**0.04**	**25%**	**0.01**
1	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	**0.035**	*0.04*			
		0.000	**0.020**	**0.015**					
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	**0.000**				
		0.000	**0.000**	**0.000**					
	Existing Conditions Drainage Level of Service Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	**1.74**	**20%**	**0.35**
2	Structures in Existing Floodplain	*0.025*	*0.01*	*0.005*	**0.390**	*1.7*			
		0.050	**0.210**	**0.130**					
	Channel Length	**7,154**	*1.35*		**1.4**				

#	Social Vulnerability Index (SVI) for Project Area:		PERCENTAGE OF SERVICE AREA	SCORE	WEIGHT	WEIGHTED SCORE
				5.35	**20%**	**1.07**
3	*SVI indicates low level of vulnerability (less than 0.25)*	0	38.0%			
	SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	14.2%			
	SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
	SVI indicates high level of vulnerability (Greater than 0.7501)	10	47.8%			

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
	Project Efficiency Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	**0.00**	**10%**	**0.00**
4	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	**0.003**	*0.00*	$ 266,000	*Structure Value*	
		0.000	**0.002**	**0.001**			$ 3,008,000	*District Cost*	
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	**0.000**		0.0884	*PEF*	
		0.000	**0.000**	**0.000**					

#	Criteria	Points	Form Answer	SCORE	WEIGHT	WEIGHTED SCORE
	Partnership Funding Scoring Criteria:		**Partnership or Grant funding is expected to cover 60% - 90% of Project Costs**	**8.00**	**10%**	**0.80**
5	*No funding partner or grant.*	0	8			
	Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4				
	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
	Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
	Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				
	Long Term Maintenance Costs Scoring Criteria:		**No requirements for special maintenance have been identified.**	**10.00**	**5%**	**0.50**
6	*Project is expected to require extensive or specialized maintenance that will incur costs.*	0	10			
	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6				
	No requirements for special maintenance have been identified.	10				
	Minimize Environmental Impacts Scoring Criteria:		**Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known**	**8.00**	**5%**	**0.40**
7	*No known wetland impacts*	10	8			
	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8				
	0.1 to 0.5 acres of wetlands expected to be impacted	6				
	0.5 to 2 acres of wetlands expected to be impacted	4	No / Modification Factor - Artifacts:			
	2 to 5 acres of wetlands expected to be impacted	2	0 / *Yes*: -1			
	More than 5 acres of wetlands expected to be impacted	0	*No*: 0			
	Potential for Multiple Benefits Scoring Criteria:		**50% of the Project is not expected to have potential for recreational features**	**0.00**	**5%**	**0.00**
8	*50% of the Project is not expected to have potential for recreational features*	0	0			
	50% of the Project has potential for recreational features	1				
	A possible partner has been identified for potential recreational features over 50% of the Project	2				
	A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
			50% of the Project is not expected to have environmental enhancement			
	50% of the Project is not expected to have environmental enhancement	0	0			
	50% of the Project has potential for environmental enhancements	3				
	A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
	A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.4
Project Scoring - Overall Strategy - PA03

Harris County Flood Control District Project Scoring Form

USERS: *Only type in cells that are ORANGE shaded.*	***NOTES:***
GREY cells are automatic calculations (Do not type in these cells).	
* *YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the*	***Prioritization Scoring Framework VERSION:*** **July 19, 2021 (6-7)**

TOTAL PROJECT SCORE:	***0.00***	**Project Area:**	PA03
		Project ID:	**E116_OS-PA03**
		Project Name:	E116-00-00 Overall Strategy
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	**(E) White Oak Bayou** *

1. What is the **OVERALL** project cost?	$ -	*USD.*	$ -	*DISTRICT COST (After Partnership / Grant)*
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	**Partnership or Grant funding is expected to cover 60% - 90% of Project Costs** *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	**75%**	***If unknown, enter "0%"***		
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	**7**	**20**	**27**
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	**7**	**20**	**27**
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	**0**	**0**	**0**
4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	**1,610**	*FEET*	**0.30**	*MILES*

5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	**Area (Acres)**	**Percentage**	**Project Area: PA03**
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	**0**	**0%**	***103 acres***
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	**102.5**	**100%**	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	**0**	**0%**	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	**0**	**0%**	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	**Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.** *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	**No known wetland impacts** *
Is there any knowledge of **CULTURAL ARTIFACTS**?	**No** *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	**50% of the Project has potential for recreational features** *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	**50% of the Project has potential for environmental enhancements** *

E116_OS-PA03, PM: Zubin Sukheswalla (Pape-Dawson)	PA03	(E) White Oak Bayou			Project Score:	0.00

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
1	**Structure Flooding Reduction Scoring Criteria:**						0.51	25%	0.00
	Structures Fully Benefitted	0.025	0.01	0.005	0.510	0.51			
		0.175	0.200	0.135					
	Structures Partially Benefitted (Min 0.25' depth)	0.0125	0.005	0.0025	0.000				
		0.000	0.000	0.000					
2	**Existing Conditions Drainage Level of Service Scoring Criteria:**	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.81	20%	0.00
	Structures in Existing Floodplain	0.025	0.01	0.005	0.510	0.8			
		0.175	0.200	0.135					
	Channel Length	1,610	0.30		0.3				

#	Social Vulnerability Index (SVI) for Project Area:		PERCENTAGE OF SERVICE AREA	SCORE	WEIGHT	WEIGHTED SCORE
3				4.00	20%	0.00
	SVI indicates low level of vulnerability (less than 0.25)	0	0.0%			
	SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	100.0%			
	SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
	SVI indicates high level of vulnerability (Greater than 0.7501)	10	0.0%			

#	Project Efficiency Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
4							#DIV/0!	10%	0.00
	Structures Fully Benefitted	0.025	0.01	0.005	#DIV/0!	#DIV/0!	$ 266,000	Structure Value	
		#DIV/0!	#DIV/0!	#DIV/0!					
	Structures Partially Benefitted (Min 0.25' depth)	0.0125	0.005	0.0025	#DIV/0!		$ -	District Cost	
		#DIV/0!	#DIV/0!	#DIV/0!			#DIV/0!	PEF	

#	Partnership Funding Scoring Criteria:		Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	SCORE	WEIGHT	WEIGHTED SCORE
5			8	8.00	10%	0.00
	No funding partner or grant.	0				
	Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4				
	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
	Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
	Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				

#	Long Term Maintenance Costs Scoring Criteria:		Project is expected to require maintenance outside of District's regular maintenance practices	SCORE	WEIGHT	WEIGHTED SCORE
6			6	6.00	5%	0.00
	Project is expected to require extensive or specialized maintenance that will incur costs.	0				
	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6				
	No requirements for special maintenance have been identified.	10				

#	Minimize Environmental Impacts Scoring Criteria:		No known wetland impacts			SCORE	WEIGHT	WEIGHTED SCORE
7			10			10.00	5%	0.00
	No known wetland impacts	10						
	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8						
	0.1 to 0.5 acres of wetlands expected to be impacted	6						
	0.5 to 2 acres of wetlands expected to be impacted	4	No	Modification Factor - Artifacts:				
	2 to 5 acres of wetlands expected to be impacted	2	0	Yes	-1			
	More than 5 acres of wetlands expected to be impacted	0		No	0			

#	Potential for Multiple Benefits Scoring Criteria:		50% of the Project has potential for recreational features	SCORE	WEIGHT	WEIGHTED SCORE
8			1	4.00	5%	0.00
	50% of the Project is not expected to have potential for recreational features	0				
	50% of the Project has potential for recreational features	1				
	A possible partner has been identified for potential recreational features over 50% of the Project	2				
	A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
			50% of the Project has potential for environmental enhancements			
			3			
	50% of the Project is not expected to have environmental enhancement	0				
	50% of the Project has potential for environmental enhancements	3				
	A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
	A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.5
Project Scoring - Overall Strategy - PA04

Harris County Flood Control District Project Scoring Form

USERS: *Only type in cells that are ORANGE shaded.*	***NOTES:***
GREY cells are automatic calculations (Do not type in these cells).	
* *YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the*	***Prioritization Scoring Framework VERSION:*** **July 19, 2021 (6-7)**

TOTAL PROJECT SCORE:	***3.80***	**Project Area:**	PA04
		Project ID:	**E116_OS-PA04**
		Project Name:	E116-00-00 Overall Strategy
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	**(E) White Oak Bayou** *

1. What is the **OVERALL** project cost?	$ **16,042,000**	*USD.*	$ **10,520,000**	*DISTRICT COST (After Partnership / Grant)*

2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	**Partnership or Grant funding is expected to cover 30% - 60% of Project Costs** *	
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	**34%**	***If unknown, enter "0%"***

	EVENT	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	*# of Structures*	**6**	**17**	**29**
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	*# of Structures*	**3**	**5**	**10**
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	*# of Structures*	**0**	**0**	**0**

4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	**4,186**	*FEET*	**0.79**	*MILES*

5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	**Area (Acres)**	**Percentage**	**Project Area: PA04**
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	**0**	**0%**	***658 acres***
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	**0**	**0%**	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	**0**	**0%**	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	**657.7**	**100%**	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	**No requirements for special maintenance have been identified.** *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	**Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known** *
Is there any knowledge of **CULTURAL ARTIFACTS**?	**No** *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	**50% of the Project is not expected to have potential for recreational features** *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	**50% of the Project is not expected to have environmental enhancement** *

E116_OS-PA04, PM: Zubin Sukheswalla (Pape-Dawson)	PA04	*(E) White Oak Bayou*		***Project Score:***	**3.80**

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
1	**Structure Flooding Reduction Scoring Criteria:**						0.18	25%	0.04
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.175	*0.18*			
		0.075	**0.050**	**0.050**					
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000				
		0.000	**0.000**	**0.000**					

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
2	**Existing Conditions Drainage Level of Service Scoring Criteria:**						1.26	20%	0.25
	Structures in Existing Floodplain	*0.025*	*0.01*	*0.005*	0.465	*1.3*			
		0.150	**0.170**	**0.145**					
	Channel Length	**4,186**	*0.79*		**0.8**				

#	Social Vulnerability Index (SVI) for Project Area:		PERCENTAGE OF SERVICE AREA	SCORE	WEIGHT	WEIGHTED SCORE
3				10.00	20%	2.00
	SVI indicates low level of vulnerability (less than 0.25)	0	0.0%			
	SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	0.0%			
	SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
	SVI indicates high level of vulnerability (Greater than 0.7501)	10	100.0%			

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
4	**Project Efficiency Scoring Criteria:**						0.00	10%	0.00
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.004	*0.00*	$ 266,000	*Structure Value*	
		0.002	**0.001**	**0.001**			##########	*District Cost*	
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000		0.0253	*PEF*	
		0.000	**0.000**	**0.000**					

#	Partnership Funding Scoring Criteria:		Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	SCORE	WEIGHT	WEIGHTED SCORE
5				6.00	10%	0.60
	No funding partner or grant.	0	6			
	Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4				
	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
	Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
	Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				

#	Long Term Maintenance Costs Scoring Criteria:		No requirements for special maintenance have been identified.	SCORE	WEIGHT	WEIGHTED SCORE
6				10.00	5%	0.50
	Project is expected to require extensive or specialized maintenance that will incur costs.	0	10			
	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6				
	No requirements for special maintenance have been identified.	10				

#	Minimize Environmental Impacts Scoring Criteria:		Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known			SCORE	WEIGHT	WEIGHTED SCORE
7						8.00	5%	0.40
	No known wetland impacts	10	8					
	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8						
	0.1 to 0.5 acres of wetlands expected to be impacted	6						
	0.5 to 2 acres of wetlands expected to be impacted	4	No	Modification Factor - Artifacts:				
	2 to 5 acres of wetlands expected to be impacted	2	0	*Yes*	-1			
	More than 5 acres of wetlands expected to be impacted	0		*No*	0			

#	Potential for Multiple Benefits Scoring Criteria:		50% of the Project is not expected to have potential for recreational features	SCORE	WEIGHT	WEIGHTED SCORE
8				0.00	5%	0.00
	50% of the Project is not expected to have potential for recreational features	0	0			
	50% of the Project has potential for recreational features	1				
	A possible partner has been identified for potential recreational features over 50% of the Project	2				
	A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
			50% of the Project is not expected to have environmental enhancement			
	50% of the Project is not expected to have environmental enhancement	0	0			
	50% of the Project has potential for environmental enhancements	3				
	A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
	A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.6
Project Scoring - Overall Strategy - PA05

Harris County Flood Control District Project Scoring Form

USERS: *Only type in cells that are ORANGE shaded.*	**NOTES:**
GREY cells are automatic calculations (Do not type in these cells).	
* *YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the*	***Prioritization Scoring Framework VERSION:*** **July 19, 2021 (6-7)**

TOTAL PROJECT SCORE:	***5.07***	**Project Area:**	PA05
		Project ID:	**E116_OS-PA05**
		Project Name:	E116-00-00 Overall Strategy
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	**(E) White Oak Bayou** *

1. What is the **OVERALL** project cost?	$ 1,284,000	USD.	$ 0	DISTRICT COST (After Partnership / Grant)
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	**Partnership or Grant funding is expected to cover 90% or more of Project Costs** *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	100%	*If unknown, enter "0%"*		

	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	# of Structures	0	1	5
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	# of Structures	0	1	4
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	# of Structures	0	0	0

4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	4,106	FEET	0.78	MILES

5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	**Area (Acres)**	**Percentage**	**Project Area: PA05**
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	0	0%	***134 acres***
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	0	0%	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	0	0%	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	133.5	100%	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	**No requirements for special maintenance have been identified.** *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	**Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known** *
Is there any knowledge of **CULTURAL ARTIFACTS**?	**No** *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	**50% of the Project is not expected to have potential for recreational features** *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	**50% of the Project is not expected to have environmental enhancement** *

E116_OS-PA05, PM: Zubin Sukheswalla (Pape-Dawson)	PA05	*(E) White Oak Bayou*		*Project Score:*	5.07

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

		10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
1	**Structure Flooding Reduction Scoring Criteria:**						0.03	25%	0.01
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	**0.030**	*0.03*			
		0.000	**0.010**	**0.020**					
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	**0.000**				
		0.000	**0.000**	**0.000**					

		10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
2	**Existing Conditions Drainage Level of Service Scoring Criteria:**						0.81	20%	0.16
	Structures in Existing Floodplain	*0.025*	*0.01*	*0.005*	**0.035**	*0.8*			
		0.000	**0.010**	**0.025**					
	Channel Length	**4,106**	*0.78*		**0.8**				

			PERCENTAGE OF SERVICE AREA	SCORE	WEIGHT	WEIGHTED SCORE
3	**Social Vulnerability Index (SVI) for Project Area:**			10.00	20%	2.00
	SVI indicates low level of vulnerability (less than 0.25)	0	0.0%			
	SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	0.0%			
	SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
	SVI indicates high level of vulnerability (Greater than 0.7501)	10	100.0%			

		10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
4	**Project Efficiency Scoring Criteria:**						10.00	10%	1.00
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	**6214953.447**	*10.00*			
		0.000	**2071651.149**	**4143302.298**			$ 266,000	*Structure Value*	
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	**0.000**		$ 0	*District Cost*	
		0.000	**0.000**	**0.000**			###########	*PEF*	

			Partnership or Grant funding is expected to cover 90% or more of Project Costs	SCORE	WEIGHT	WEIGHTED SCORE
5	**Partnership Funding Scoring Criteria:**			10.00	10%	1.00
	No funding partner or grant.	0	10			
	Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4				
	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
	Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
	Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				

			No requirements for special maintenance have been identified.	SCORE	WEIGHT	WEIGHTED SCORE
6	**Long Term Maintenance Costs Scoring Criteria:**			10.00	5%	0.50
	Project is expected to require extensive or specialized maintenance that will incur costs.	0	10			
	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6				
	No requirements for special maintenance have been identified.	10				

			Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known			SCORE	WEIGHT	WEIGHTED SCORE
7	**Minimize Environmental Impacts Scoring Criteria:**					8.00	5%	0.40
	No known wetland impacts	10	8					
	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8						
	0.1 to 0.5 acres of wetlands expected to be impacted	6						
	0.5 to 2 acres of wetlands expected to be impacted	4	No	Modification Factor - Artifacts:				
	2 to 5 acres of wetlands expected to be impacted	2	0	*Yes*	-1			
	More than 5 acres of wetlands expected to be impacted	0		*No*	0			

			50% of the Project is not expected to have potential for recreational features	SCORE	WEIGHT	WEIGHTED SCORE
8	**Potential for Multiple Benefits Scoring Criteria:**			0.00	5%	0.00
	50% of the Project is not expected to have potential for recreational features	0	0			
	50% of the Project has potential for recreational features	1				
	A possible partner has been identified for potential recreational features over 50% of the Project	2				
	A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
			50% of the Project is not expected to have environmental enhancement			
	50% of the Project is not expected to have environmental enhancement	0	0			
	50% of the Project has potential for environmental enhancements	3				
	A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
	A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.7
Project Scoring - Overall Strategy - All PA

Harris County Flood Control District Project Scoring Form

USERS: Only type in cells that are ORANGE shaded.	**NOTES:**
GREY cells are automatic calculations (Do not type in these cells).	
* YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the	Prioritization Scoring Framework VERSION: July 19, 2021 (6-7)

TOTAL PROJECT SCORE:	**4.00**	Project Area:	ALL
		Project ID:	E116_OS-All
		Project Name:	E116-00-00 Overall Strategy
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	(E) White Oak Bayou *

1. What is the **OVERALL** project cost?	$ 34,997,000	USD.	$ 16,278,000	DISTRICT COST (After Partnership / Grant)
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	53%	If unknown, enter "0%"		
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	19	72	109
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	3	12	18
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	0	0	0
4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	18,304	FEET	3.47	MILES

	Area (Acres)	Percentage	Project Area: ALL
5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?			
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	157.9	10%	1578 acres
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	161.3	10%	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	0	0%	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	1258.4	80%	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs. *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known *
Is there any knowledge of **CULTURAL ARTIFACTS**?	No *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	50% of the Project is not expected to have potential for recreational features *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	50% of the Project is not expected to have environmental enhancement *

E116_OS-All, PM: Zubin Sukheswalla (Pape-Dawson)	ALL	(E) White Oak Bayou		Project Score:	4.00

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

						SCORE	WEIGHT	WEIGHTED SCORE
Structure Flooding Reduction Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.29	25%	0.07
1 Structures Fully Benefitted	0.025	0.01	0.005	0.285	0.29			
	0.075	0.120	0.090					
Structures Partially Benefitted (Min 0.25' depth)	0.0125	0.005	0.0025	0.000				
	0.000	0.000	0.000					
Existing Conditions Drainage Level of Service Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	4.74	20%	0.95
2 Structures in Existing Floodplain	0.025	0.01	0.005	1.740	4.7			
	0.475	0.720	0.545					
Channel Length	18,304	3.47		3.0				
Social Vulnerability Index (SVI) for Project Area:		PERCENTAGE OF SERVICE AREA				8.39	20%	1.68
SVI indicates low level of vulnerability (less than 0.25)	0	10.0%						
3 SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	10.2%						
SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%						
SVI indicates high level of vulnerability (Greater than 0.7501)	10	79.8%						
Project Efficiency Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.00	10%	0.00
4 Structures Fully Benefitted	0.025	0.01	0.005	0.004	0.00			
	0.001	0.002	0.001			$ 266,000	Structure Value	
Structures Partially Benefitted (Min 0.25' depth)	0.0125	0.005	0.0025	0.000		##########	District Cost	
	0.000	0.000	0.000			0.0163	PEF	
Partnership Funding Scoring Criteria:		Partnership or Grant funding is expected to cover 30% - 60% of Project Costs				6.00	10%	0.60
No funding partner or grant.	0	6						
Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2							
5 Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4							
Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6							
Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8							
Partnership or Grant funding is expected to cover 90% or more of Project Costs	10							
Long Term Maintenance Costs Scoring Criteria:		Project is expected to require maintenance outside of District's regular maintenance practices				6.00	5%	0.30
Project is expected to require extensive or specialized maintenance that will incur costs.	0	6						
6 Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6							
No requirements for special maintenance have been identified.	10							
Minimize Environmental Impacts Scoring Criteria:		Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known				8.00	5%	0.40
No known wetland impacts	10	8						
Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8							
7 0.1 to 0.5 acres of wetlands expected to be impacted	6							
0.5 to 2 acres of wetlands expected to be impacted	4	No	Modification Factor - Artifacts:					
2 to 5 acres of wetlands expected to be impacted	2	0	Yes	-1				
More than 5 acres of wetlands expected to be impacted	0		No	0				
Potential for Multiple Benefits Scoring Criteria:		50% of the Project is not expected to have potential for recreational features				0.00	5%	0.00
50% of the Project is not expected to have potential for recreational features	0	0						
50% of the Project has potential for recreational features	1							
A possible partner has been identified for potential recreational features over 50% of the Project	2							
A partner is expected to commit funding for potential recreational features over 50% of the Project	3							
8		50% of the Project is not expected to have environmental enhancement						
50% of the Project is not expected to have environmental enhancement	0	0						
50% of the Project has potential for environmental enhancements	3							
A possible partner has been identified for potential environmental enhancements over 50% of the Project	4							
A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7							

Table 7.8
Project Scoring - Recommended Project

Harris County Flood Control District Project Scoring Form

E116-00-00 Recommended Project

SCORING CRITERIA:		1	2	3	4	5	6	7	8	
	Weight:	25%A	20%A	20%A	10%A	10%A	5%A	5%A	5%A	
Project Area:	Project ID:	Flood Risk (100-Year Event) Reduction	Existing Conditions Drainage LOS	Social Vulnerability Index (SVI)	Project Efficiency	Partnership Funding	Long Term Maintenance Costs	Minimize Environmental Impacts	Potential for Multiple Benefits	TOTAL SCORE
PA01A	E116_RP-PA01	0.01	0.15	2.00	0.00	0.40	0.50	0.50	0.15	3.71
PA02A	E116_RP-PA02	0.01	0.35	1.07	0.00	0.40	0.50	0.40	0.00	2.73
PA04A	E116_RP-PA04	0.01	0.25	2.00	0.00	0.00	0.50	0.40	0.00	3.16
LLA	E116_RP-All	0.04	0.86	1.68	0.00	0.40	0.30	0.40	0.15	3.83

Table 7.9
Project Scoring - Recommended Project - PA01

Harris County Flood Control District Project Scoring Form

USERS: *Only type in cells that are ORANGE shaded.*	**NOTES:**
GREY cells are automatic calculations (Do not type in these cells).	
* *YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the*	***Prioritization Scoring Framework VERSION:*** **July 19, 2021 (6-7)**

TOTAL PROJECT SCORE:	***3.71***	**Project Area:**	PA01
		Project ID:	**E116_RP-PA01**
		Project Name:	E116-00-00 Recommended Project
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	**(E) White Oak Bayou** *

1. What is the **OVERALL** project cost?	$ 3,250,000	*USD.*	$ 2,748,000	*DISTRICT COST (After Partnership / Grant)*
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	**Partnership or Grant funding is expected to cover 5% - 30% of Project Costs** *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	15%	***If unknown, enter "0%"***		
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	4	13	22
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	0	2	1
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	*EVENT*	*10-yr (10%)*	*50-yr (2%)*	*100-yr (1%)*
	# of Structures	0	0	0
4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	2,148	*FEET*	0.41	*MILES*

5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	**Area (Acres)**	**Percentage**	**Project Area: PA01**
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	0	0%	***269 acres***
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	0	0%	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	0	0%	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	268.5	100%	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	**No requirements for special maintenance have been identified.** *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	**No known wetland impacts** *
Is there any knowledge of **CULTURAL ARTIFACTS**?	**No** *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	**50% of the Project is not expected to have potential for recreational features** *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	**50% of the Project has potential for environmental enhancements** *

E116_RP-PA01, PM: Zubin Sukheswalla (Pape-Dawson)	PA01	*(E) White Oak Bayou*		*Project Score:*	3.71

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

						SCORE	WEIGHT	WEIGHTED SCORE
Structure Flooding Reduction Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.03	25%	0.01
1 Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.025	*0.03*			
	0.000	**0.020**	**0.005**					
Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000				
	0.000	**0.000**	**0.000**					

						SCORE	WEIGHT	WEIGHTED SCORE
Existing Conditions Drainage Level of Service Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.75	20%	0.15
2 Structures in Existing Floodplain	*0.025*	*0.01*	*0.005*	0.340	*0.7*			
	0.100	**0.130**	**0.110**					
Channel Length	**2,148**	*0.41*		0.4				

			SCORE	WEIGHT	WEIGHTED SCORE
Social Vulnerability Index (SVI) for Project Area:		PERCENTAGE OF SERVICE AREA	10.00	20%	2.00
3 *SVI indicates low level of vulnerability (less than 0.25)*	0	0.0%			
SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	0.0%			
SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
SVI indicates high level of vulnerability (Greater than 0.7501)	10	100.0%			

						SCORE	WEIGHT	WEIGHTED SCORE
Project Efficiency Scoring Criteria:	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.00	10%	0.00
4 Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.002	*0.00*	$ 266,000	*Structure Value*	
	0.000	**0.002**	**0.000**					
Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000		$ 2,748,000	*District Cost*	
	0.000	**0.000**	**0.000**			0.0968	*PEF*	

			SCORE	WEIGHT	WEIGHTED SCORE
Partnership Funding Scoring Criteria:		Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4.00	10%	0.40
No funding partner or grant.	0	4			
Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
5 *Partnership or Grant funding is expected to cover 5% - 30% of Project Costs*	4				
Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				

			SCORE	WEIGHT	WEIGHTED SCORE
Long Term Maintenance Costs Scoring Criteria:		No requirements for special maintenance have been identified.	10.00	5%	0.50
Project is expected to require extensive or specialized maintenance that will incur costs.	0	10			
6 *Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.*	6				
No requirements for special maintenance have been identified.	10				

					SCORE	WEIGHT	WEIGHTED SCORE
Minimize Environmental Impacts Scoring Criteria:		No known wetland impacts			10.00	5%	0.50
No known wetland impacts	10	10					
Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8						
7 *0.1 to 0.5 acres of wetlands expected to be impacted*	6						
0.5 to 2 acres of wetlands expected to be impacted	4	No	Modification Factor - Artifacts:				
2 to 5 acres of wetlands expected to be impacted	2	0	*Yes*	-1			
More than 5 acres of wetlands expected to be impacted	0		*No*	0			

			SCORE	WEIGHT	WEIGHTED SCORE
Potential for Multiple Benefits Scoring Criteria:		50% of the Project is not expected to have potential for recreational features	3.00	5%	0.15
50% of the Project is not expected to have potential for recreational features	0	0			
50% of the Project has potential for recreational features	1				
A possible partner has been identified for potential recreational features over 50% of the Project	2				
A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
8		50% of the Project has potential for environmental enhancements			
50% of the Project is not expected to have environmental enhancement	0	3			
50% of the Project has potential for environmental enhancements	3				
A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.10
Project Scoring - Recommended Project - PA02

Harris County Flood Control District Project Scoring Form

USERS: Only type in cells that are ORANGE shaded.	**NOTES:**
GREY cells are automatic calculations (Do not type in these cells).	
* YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the	**Prioritization Scoring Framework VERSION:** July 19, 2021 (6-7)

TOTAL PROJECT SCORE:	**2.73**	Project Area:	PA02
		Project ID:	E116_RP-PA02
		Project Name:	E116-00-00 Recommended Project
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	(E) White Oak Bayou *

1. What is the **OVERALL** project cost?	$ 3,853,000	USD.	$ 3,008,000	DISTRICT COST (After Partnership / Grant)
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	22%	If unknown, enter "0%"		
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	2	21	26
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	0	1	3
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	0	0	0
4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	7,154	FEET	1.35	MILES
5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	Area (Acres)	Percentage		Project Area: PA02
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	157.9	38%		415 acres
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	58.8	14%		
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	0	0%		
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	198.7	48%		
6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	No requirements for special maintenance have been identified. *			
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known *			
Is there any knowledge of **CULTURAL ARTIFACTS**?	No *			
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	50% of the Project is not expected to have potential for recreational features *			
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	50% of the Project is not expected to have environmental enhancement *			

E116_RP-PA02, PM: Zubin Sukheswalla (Pape-Dawson)	PA02	*(E) White Oak Bayou*		*Project Score:*	2.73

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

		10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
1	**Structure Flooding Reduction Scoring Criteria:**						0.03	25%	0.01
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.025	*0.03*			
		0.000	**0.010**	**0.015**					
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000				
		0.000	**0.000**	**0.000**					

		10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
2	**Existing Conditions Drainage Level of Service Scoring Criteria:**						1.74	20%	0.35
	Structures in Existing Floodplain	*0.025*	*0.01*	*0.005*	0.390	*1.7*			
		0.050	**0.210**	**0.130**					
	Channel Length	**7,154**	*1.35*		**1.4**				

			PERCENTAGE OF SERVICE AREA	SCORE	WEIGHT	WEIGHTED SCORE
3	**Social Vulnerability Index (SVI) for Project Area:**			5.35	20%	1.07
	SVI indicates low level of vulnerability (less than 0.25)	0	38.0%			
	SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	14.2%			
	SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
	SVI indicates high level of vulnerability (Greater than 0.7501)	10	47.8%			

		10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
4	**Project Efficiency Scoring Criteria:**						0.00	10%	0.00
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.002	*0.00*			
		0.000	**0.001**	**0.001**			$ 266,000	*Structure Value*	
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000		$ 3,008,000	*District Cost*	
		0.000	**0.000**	**0.000**			0.0884	*PEF*	

			Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	SCORE	WEIGHT	WEIGHTED SCORE
5	**Partnership Funding Scoring Criteria:**			4.00	10%	0.40
	No funding partner or grant.	0	4			
	Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4				
	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
	Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
	Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				

			No requirements for special maintenance have been identified.	SCORE	WEIGHT	WEIGHTED SCORE
6	**Long Term Maintenance Costs Scoring Criteria:**			10.00	5%	0.50
	Project is expected to require extensive or specialized maintenance that will incur costs.	0	10			
	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6				
	No requirements for special maintenance have been identified.	10				

			Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known			SCORE	WEIGHT	WEIGHTED SCORE
7	**Minimize Environmental Impacts Scoring Criteria:**					8.00	5%	0.40
	No known wetland impacts	10	8					
	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8						
	0.1 to 0.5 acres of wetlands expected to be impacted	6						
	0.5 to 2 acres of wetlands expected to be impacted	4	No	Modification Factor - Artifacts:				
	2 to 5 acres of wetlands expected to be impacted	2	0	*Yes*	-1			
	More than 5 acres of wetlands expected to be impacted	0		*No*	0			

			50% of the Project is not expected to have potential for recreational features	SCORE	WEIGHT	WEIGHTED SCORE
8	**Potential for Multiple Benefits Scoring Criteria:**			0.00	5%	0.00
	50% of the Project is not expected to have potential for recreational features	0	0			
	50% of the Project has potential for recreational features	1				
	A possible partner has been identified for potential recreational features over 50% of the Project	2				
	A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
			50% of the Project is not expected to have environmental enhancement			
	50% of the Project is not expected to have environmental enhancement	0	0			
	50% of the Project has potential for environmental enhancements	3				
	A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
	A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.11
Project Scoring - Recommended Project - PA04

Harris County Flood Control District Project Scoring Form

USERS: *Only type in cells that are ORANGE shaded.*	***NOTES:***
GREY cells are automatic calculations (Do not type in these cells).	
* *YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the*	***Prioritization Scoring Framework VERSION:*** **July 19, 2021 (6-7)**

TOTAL PROJECT SCORE:	***3.16***	**Project Area:**	PA04
		Project ID:	**E116_RP-PA04**
		Project Name:	E116-00-00 Recommended Project
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	**(E) White Oak Bayou** *

1. What is the **OVERALL** project cost?	$ 2,749,000	USD.	$ 2,749,000	DISTRICT COST (After Partnership / Grant)
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	**No funding partner or grant.** *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	0%	***If unknown, enter "0%"***		

	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
3a.How many structures are subject to flooding in the **BASELINE** (existing) condition?	# of Structures	6	17	29
3b.How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	# of Structures	0	2	4
3c.How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	# of Structures	0	0	0

4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	4,186	FEET	0.79	MILES

5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?	**Area (Acres)**	**Percentage**	**Project Area: PA04**
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	0	0%	***658 acres***
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	0	0%	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	0	0%	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	657.7	100%	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	**No requirements for special maintenance have been identified.** *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	**Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known** *
Is there any knowledge of **CULTURAL ARTIFACTS**?	**No** *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	**50% of the Project is not expected to have potential for recreational features** *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	**50% of the Project is not expected to have environmental enhancement** *

E116_RP-PA04, PM: Zubin Sukheswalla (Pape-Dawson)	PA04	(E) White Oak Bayou		Project Score:	3.16

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
1	**Structure Flooding Reduction Scoring Criteria:**						0.04	25%	0.01
	Structures Fully Benefitted	0.025	0.01	0.005	0.040	0.04			
		0.000	0.020	0.020					
	Structures Partially Benefitted (Min 0.25' depth)	0.0125	0.005	0.0025	0.000				
		0.000	0.000	0.000					
2	**Existing Conditions Drainage Level of Service Scoring Criteria:**						1.26	20%	0.25
	Structures in Existing Floodplain	0.025	0.01	0.005	0.465	1.3			
		0.150	0.170	0.145					
	Channel Length	4,186	0.79		0.8				

#	Social Vulnerability Index (SVI) for Project Area:		PERCENTAGE OF SERVICE AREA	SCORE	WEIGHT	WEIGHTED SCORE
3				10.00	20%	2.00
	SVI indicates low level of vulnerability (less than 0.25)	0	0.0%			
	SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	0.0%			
	SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
	SVI indicates high level of vulnerability (Greater than 0.7501)	10	100.0%			

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
4	**Project Efficiency Scoring Criteria:**						0.00	10%	0.00
	Structures Fully Benefitted	0.025	0.01	0.005	0.004	0.00	$ 266,000	Structure Value	
		0.000	0.002	0.002					
	Structures Partially Benefitted (Min 0.25' depth)	0.0125	0.005	0.0025	0.000		$ 2,749,000	District Cost	
		0.000	0.000	0.000			0.0968	PEF	

#	Criteria	Points	Form Answer	SCORE	WEIGHT	WEIGHTED SCORE
5	**Partnership Funding Scoring Criteria:**		No funding partner or grant.	0.00	10%	0.00
	No funding partner or grant.	0	0			
	Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4				
	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
	Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
	Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				
6	**Long Term Maintenance Costs Scoring Criteria:**		No requirements for special maintenance have been identified.	10.00	5%	0.50
	Project is expected to require extensive or specialized maintenance that will incur costs.	0	10			
	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6				
	No requirements for special maintenance have been identified.	10				
7	**Minimize Environmental Impacts Scoring Criteria:**		Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8.00	5%	0.40
	No known wetland impacts	10	8			
	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8				
	0.1 to 0.5 acres of wetlands expected to be impacted	6				
	0.5 to 2 acres of wetlands expected to be impacted	4	No — Modification Factor - Artifacts:			
	2 to 5 acres of wetlands expected to be impacted	2	0 — Yes: -1			
	More than 5 acres of wetlands expected to be impacted	0	No: 0			
8	**Potential for Multiple Benefits Scoring Criteria:**		50% of the Project is not expected to have potential for recreational features	0.00	5%	0.00
	50% of the Project is not expected to have potential for recreational features	0	0			
	50% of the Project has potential for recreational features	1				
	A possible partner has been identified for potential recreational features over 50% of the Project	2				
	A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
			50% of the Project is not expected to have environmental enhancement			
	50% of the Project is not expected to have environmental enhancement	0	0			
	50% of the Project has potential for environmental enhancements	3				
	A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
	A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

Table 7.12
Project Scoring - Recommended Project - All PA

Harris County Flood Control District Project Scoring Form

USERS: Only type in cells that are ORANGE shaded.	**NOTES:**
GREY cells are automatic calculations (Do not type in these cells).	
* YELLOW cells have dropdown for easy data input. Click on cell, then use drop down just outside the cell, to the	**Prioritization Scoring Framework VERSION:** July 19, 2021 (6-7)

TOTAL PROJECT SCORE:	**3.83**	Project Area:	ALL
		Project ID:	E116_RP-All
		Project Name:	E116-00-00 Recommended Project
		Project Manager:	Zubin Sukheswalla (Pape-Dawson)
		Project Watershed:	(E) White Oak Bayou *

1. What is the **OVERALL** project cost?	$ 9,852,000	USD.	$ 8,505,000	DISTRICT COST (After Partnership / Grant)
2. Does the project have potential for **PARTNERSHIP** or **GRANT** funding?	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs *			
2a. If estimated partner share is known, what is the estimated partner share responsibility of project cost?	14%	If unknown, enter "0%"		
3a. How many structures are subject to flooding in the **BASELINE** (existing) condition?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	19	72	109
3b. How many structures are proposed to have the **FULL BENEFIT** of floodplain removal for the respective events?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	1	8	10
3c. How many structures have a proposed **PARTIAL BENEFIT** floodplain depth reduction GREATER than 0.25-feet?	EVENT	10-yr (10%)	50-yr (2%)	100-yr (1%)
	# of Structures	0	0	0
4. How many linear feet of channel in the Project area have a **ROW WIDTH** less than 110-ft wide?	13,488	FEET	2.55	MILES

	Area (Acres)	Percentage	Project Area: ALL
5. What is the CDC **Social Vulnerability Index (SVI)** of the observed Project Area?			
5.a. Amount of Project Area with an SVI indicated as low level of vulnerability (0.25 or less)?	157.9	10%	1578 acres
5.b. Amount of Project Area with an SVI indicated as low to moderate level of vulnerability (0.2501 to 0.5)?	161.3	10%	
5.c. Amount of Project Area with an SVI indicated as moderate to high level of vulnerability (0.5001 to 0.75)?	0	0%	
5.d. Amount of Project Area with an SVI indicated as high level of vulnerability (0.7501 ot more)?	1258.4	80%	

6. What is the qualitative expectation of the projects need for **LONG TERM MAINTENANCE**?	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs. *
7. What is/are the project's potential **ENVIRONMENTAL** impacts?	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known *
Is there any knowledge of **CULTURAL ARTIFACTS**?	No *
8a. What is the projects potential to offer **RECREATIONAL FEATURES** as a benefit?	50% of the Project is not expected to have potential for recreational features *
8b. What is the projects potential to offer **ENVIRONMENTAL ENHANCEMENTS** as a benefit?	50% of the Project has potential for environmental enhancements *

E116_RP-All, PM: Zubin Sukheswalla (Pape-Dawson)	ALL	(E) White Oak Bayou			Project Score:	3.83	

PRIORITIZATION FRAMEWORK SCORING CRITERIA

Form Answers

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
1	**Structure Flooding Reduction Scoring Criteria:**	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.16	25%	0.04
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.155	*0.16*			
		0.025	**0.080**	**0.050**					
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000				
		0.000	**0.000**	**0.000**					
2	**Existing Conditions Drainage Level of Service Scoring Criteria:**	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	4.29	20%	0.86
	Structures in Existing Floodplain	*0.025*	*0.01*	*0.005*	1.740	*4.3*			
		0.475	**0.720**	**0.545**					
	Channel Length	**13,488**	*2.55*		2.6				

#	Social Vulnerability Index (SVI) for Project Area:	Points	PERCENTAGE OF SERVICE AREA	SCORE	WEIGHT	WEIGHTED SCORE
3				8.39	20%	1.68
	SVI indicates low level of vulnerability (less than 0.25)	0	10.0%			
	SVI indicates low to moderate level of vulnerability (Between 0.2501 and 0.5)	4	10.2%			
	SVI indicates moderate to high level of vulnerability (Between 0.5001 and 0.75)	7	0.0%			
	SVI indicates high level of vulnerability (Greater than 0.7501)	10	79.8%			

#	Criteria	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	SCORE	WEIGHT	WEIGHTED SCORE
4	**Project Efficiency Scoring Criteria:**	10-Yr (10%)	50-Yr (2%)	100-yr (1%)	TOTAL	SCORE	0.01	10%	0.00
	Structures Fully Benefitted	*0.025*	*0.01*	*0.005*	0.006	*0.01*	$ 266,000	*Structure Value*	
		0.001	**0.003**	**0.002**			$ 8,505,000	*District Cost*	
	Structures Partially Benefitted (Min 0.25' depth)	*0.0125*	*0.005*	*0.0025*	0.000		0.0313	*PEF*	
		0.000	**0.000**	**0.000**					

#	Criteria	Points	Answer	SCORE	WEIGHT	WEIGHTED SCORE
5	**Partnership Funding Scoring Criteria:**		Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4.00	10%	0.40
	No funding partner or grant.	0	4			
	Potential for partnership / grant is Unknown or expected to be less than 5% of Project Cost	2				
	Partnership or Grant funding is expected to cover 5% - 30% of Project Costs	4				
	Partnership or Grant funding is expected to cover 30% - 60% of Project Costs	6				
	Partnership or Grant funding is expected to cover 60% - 90% of Project Costs	8				
	Partnership or Grant funding is expected to cover 90% or more of Project Costs	10				
6	**Long Term Maintenance Costs Scoring Criteria:**		Project is expected to require maintenance outside of District's regular maintenance practices	6.00	5%	0.30
	Project is expected to require extensive or specialized maintenance that will incur costs.	0	6			
	Project is expected to require maintenance outside of District's regular maintenance practices and will incur some additional costs.	6				
	No requirements for special maintenance have been identified.	10				
7	**Minimize Environmental Impacts Scoring Criteria:**		Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8.00	5%	0.40
	No known wetland impacts	10	8			
	Less than 0.1 acres of wetlands expected to be impacted or wetland impacts are not known	8				
	0.1 to 0.5 acres of wetlands expected to be impacted	6				
	0.5 to 2 acres of wetlands expected to be impacted	4	No; Modification Factor - Artifacts:			
	2 to 5 acres of wetlands expected to be impacted	2	0; *Yes* -1			
	More than 5 acres of wetlands expected to be impacted	0	*No* 0			
8	**Potential for Multiple Benefits Scoring Criteria:**		50% of the Project is not expected to have potential for recreational features	3.00	5%	0.15
	50% of the Project is not expected to have potential for recreational features	0	0			
	50% of the Project has potential for recreational features	1				
	A possible partner has been identified for potential recreational features over 50% of the Project	2				
	A partner is expected to commit funding for potential recreational features over 50% of the Project	3				
			50% of the Project has potential for environmental enhancements			
	50% of the Project is not expected to have environmental enhancement	0	3			
	50% of the Project has potential for environmental enhancements	3				
	A possible partner has been identified for potential environmental enhancements over 50% of the Project	4				
	A partner is expected to commit funding for potential environmental enhancements over 50% of the Project	7				

APPENDICES

APPENDIX A

Site Visit Photos

Photo #1: New development in Acres Homes neighborhood (Mansfield-Cebra intersection)

Photo #2: Start of E116-00-00 at DeSoto (PA04)

Photo #3: Northern roadside ditch along Paul Quinn Road (PA04)

Photo #4: Southern roadside ditch along Paul Quinn Road (PA04)

Photo #5: E116-00-00 downstream of Paul Quinn Road crossing (PA04)

Photo #6: E116-00-00 upstream of Paul Quinn Road crossing (PA04)

Photo #7: E116-00-00 downstream of Del Norte Street crossing (PA02)

Photo #8: E116-00-00 upstream of Del Norte Street crossing (PA02)

Photo #9: HCFCD basin E516-01-00 looking south-west towards primary spillway (PA02)

Photo #10: HCFCD basin E516-01-00 primary spillway (PA02)

Photo #11: HOA detention basin to the east of HCFCD basin E516-01-00 (PA02)

Photo #12: E116-00-00 downstream of Tidwell Road crossing (PA04)

Photo #13: Tidwell Road medians looking East for microdetention project (PA01)

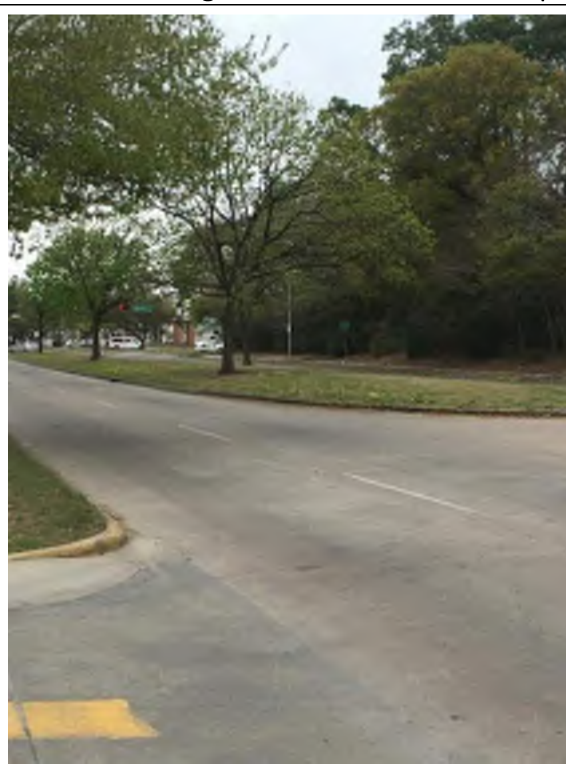

Photo #14: Tidwell Road medians looking West for microdetention project (PA01)

Photo #15: E116-05-00 channel downstream of Lehman Road crossing (PA02)

Photo #16: Lehman Road crossing at E116-05-00 looking upstream (PA02)

Photo #17: Lehman Road roadside ditch (southern) PA02

Photo #18: E116-05-00 channel upstream of Lehman Road crossing (PA02)

Photo #19: Upstream Face of Lehman Road culvert crossing at E116-05-00 (PA02)

Photo #20: Downstream Face of Lehman Road culvert crossing at E116-05-00 (PA02)

Photo #21: Parkway on top of Lehman Road culverts along E116-05-00 (PA02)

APPENDIX B

Quality Assurance and Control

Documentation

Project Name: E116-00-00 Subwatershed Planning Project
Project Number: 40339-79
Originator: Saatvik Satyaprakash
Reviewer: Lonnie Anderson
Review Date: 8/18/2021
Review Purpose: Existing condition HEC-RAS model

No.	Comment	Response
1	Adjust cell faces to avoid cutting across burned in pits.	done
2	reduce time step to 10s or less to improve stability	set to 5s
3	Mannings n-value for 2d is set for the 1D/2D run, needs to be the ROG values	set to rog in geometry
4	set stability factors to 3	done
5	pit for large box culverts should be larger than 5' diameter, maybe 20' for dual boxes. 5' for 24" and maybe 10' for 60" etc...this will improve stability and help approximate stormsewer volume.	adjusted some for improved stability
6	set inlet/outlet Cd to 0.2 on stormsewers...when open air discharge the .5/1 can be used.	done

PAPE-DAWSON ENGINEERS

HEC-RAS QA/QC Review Form

The following check-list represents key standards that should generally be applied to a 1D/2D unsteady flow HEC-RAS model. Not all standards will always be applicable (refer to project requirements and local regulations). The modeler may also deviate from some standards at their discretion, but they must provide a rationale.

INSTRUCTIONS:

When submitting the model for review, the modeler should note any criteria that does not apply as N/A. If criteria was purposefully not followed, the modeler should add rationale under the criteria. This will help expedite the review process. This will help expedite the review process.

The reviewer should provide written comments under the review item header, within the table, in dark red (use style "Comments"). Include screenshots if helpful.

After the review, the modeler should respond in *blue italic* (use style "Response") below the comment. Include screenshots if helpful or necessary.

PROJECT NAME:	E116 and Shepherd Park Terrace			STUDY AREA:	
PROJECT NUMBER:	40339-78				
DATE SUBMITTED:	varies	DATE REVIEWED:	varies	DATE RESPONDED:	varies
MODELER:	Saatvik Satyaprakash			REVIEWER:	Lonnie Anderson
MODEL STATUS:	☐ Draft	☒ Final			

GENERAL COMMENTS (OPTIONAL):

Modeling reviewed at various stages of development.

Some stability issues due to replicating storm sewer capacity but continuity error reasonable

Storage area connectors using weir equation added along areas with new channels to improve stability and comparison to existing conditions.

Rain on grid applied with full rainfall. RAS6.1 loss rate method applied to better capture varied impervious cover.

Document Updated: 2020-05-19

PROJECT NAME:	STUDY AREA:
DATE SUBMITTED:	DATE REVIEWED:
MODEL STATUS: ☐ draft ☐ final	

		Y	N	N/A

1. Setup

		Y	N	N/A
1.1	Has the latest version of the software been used, and if not, has a rationale been provided?	☐	☒	☐
V6.1 used as v6.2 came out too late in model phase to update				
1.2	Is the model component naming consistent, clear, and following guidelines where applicable?	☐	☐	☒
1.3	Are temporary runs deleted and output cleaned up?	☒	☐	☐
1.4	Are all components geo-referenced?	☒	☐	☐
1.5	Are all terrain sources documented?[1]	☒	☐	☐
1.6	Are all terrain files on the same datum?[1]	☒	☐	☐
1.7	For areas where high-resolution base terrain is available (i.e., less than 5-ft), do supplemental terrain(s) match the resolution of the base terrain (i.e., to avoid overly large output files)?[1]	☐	☐	☒

2. Plans

		Y	N	N/A
2.1	Do plan names represent the geometry and flow file and are descriptions included?	☒	☐	☐
2.2	Are run dates correct and long enough to capture the 500-yr peak water surface and flood extents (ideally the model should capture the drawdown of the system as well)?	☒	☐	☐
2.3	Is the computation interval (i.e., time step) appropriate (i.e., less than 1-min, typically 30-sec, and no less than 15-sec)?[2]	☐	☐	☒
Shorter timestep required for storm sewer modeling				
2.4	Are the hydrograph, detailed, and mapping output intervals set to 15-min, and if not, was a rationale provided?	☒	☐	☐
2.5	Under computation options, are stability factors and decay exponents set to 3.0, and if not, was a rationale provided?[2]	☐	☐	☒
2.6	If the mixed flow option was turned on, does the model exhibit mixed flow conditions (should only be used in mixed flow regimes)?[2]	☐	☐	☒
2.7	If computation options (except for stability and decay factors) are not set to default, was a rationale provided?[2]	☐	☐	☒
2.8	If friction slope methods are not set to defaults (not typical), was a rationale provided?[2]	☐	☐	☒
2.9	If the advanced time step control option is turned on (not typical), was a rationale provided (should only be used to determine the optimal time step)?[2]	☐	☐	☒

PROJECT NAME:		STUDY AREA:	
DATE SUBMITTED:		DATE REVIEWED:	
MODEL STATUS:	☐ draft	☐ final	

3. Cross-sections

		Y	N	N/A
3.1	Are downstream center reach lengths (i.e., cross-section spacing) less than 1,000-ft?[3]	☒	☐	☐
3.2	Is the overbank flow path connecting points reasonably located (e.g., near centroid of overbank area or approximately one-third of the distance from the high bank to the limits of the 1% AEP floodplain)?[3]	☒	☐	☐
3.3	Is the total reach length within 1% of the upstream minus downstream river stations and are differences at each cross-section minimal (i.e., less than 10-ft; use spreadsheet to highlight differences)?	☒	☐	☐
3.4	Do cross-sections with vertical or horizontal walls have at least 0.1-ft added to stations or elevations to create a minor slope (i.e., to improve stability)?[3]	☐	☐	☒
3.5	Does RASMapper include flow paths and bank lines and has the geometry been validated and any errors addressed?	☐	☐	☒
3.6	Are bank stations near the top of channel and not set low within the channel (review profiles to identify areas where the bank station may be low)?	☒	☐	☐
3.7	Are Manning's n values reasonable and is horizontal variation kept to a minimum (review composite L/C/R values in a table and/or profile view to identify potential errors)?[3]	☒	☐	☐
3.8	Are the Ratios of Cut Line Length to XS Length between 0.95 to 1.05 (turn on in the Geometry View Options window or use RASMapper Geometry Validation tool)?[2]	☐	☐	☐
3.9	Are ineffective areas located properly (e.g., at structures, bends, and backwater areas, are elevations set properly vs decks, are multiple blocked areas used for complex features, etc.) (note that maximum contraction occurs at 1:1 and expansion from 1:1 to 1:4; see references)?[2 3]	☒	☐	☐
3.10	Are ineffective areas set to permanent and/or non-permanent appropriately (e.g., typically non-permanent downstream of bridges and culverts)?[2 3]	☒	☐	☐
3.11	Does the channel profile look reasonable and are any sudden changes in elevation accurate?	☒	☐	☐
3.12	Does station-elevation data match as-builts and/or survey, and is there a note stating they are based on such data?	☒	☐	☐
3.13	Does station-elevation data match terrain file, and if not, was a rationale provided?	☒	☐	☐
3.14	Are HTAB starting elevations set equal to cross-section inverts (e.g., flowline)?[2]	☒	☐	☐
3.15	Are HTAB increments (i.e., spacing) set to 0.1-ft or less?[2]	☐	☐	☒
3.16	Are the HTAB number of points enough to extend at least 2-ft above the 500-year water surface?[2]	☒	☐	☐
3.17	Are cross-sections sufficiently located to capture significant changes in overbank volume?[2]	☒	☐	☐
3.18	Are cross-sections aligned perpendicular to the flow path?	☒	☐	☐
3.19	Do cross-sections extend past the top of bank and overlap 5 to 10-ft into the 2D Flow Area (i.e., should not be trimmed exactly to the 2D Flow Area boundary to avoid gaps in mapping and simplify ease of manipulating nodes)?[1]	☒	☐	☐
3.20	Are obstructions accurately used to represent areas that do not convey flow, should not be accounted for in storage volume routing, and/or are permanent water features (check where cross-sections overlap storage areas)?[2]	☒	☐	☐
3.21	Are pilot channel Manning's n values equal to or greater than channel Manning's n value (less than 0.1 n value is recommended)?[2]	☐	☐	☒
3.22	Are pilot channels less than 2-ft wide (ideally 0.5-ft)?[2]	☐	☐	☒

PROJECT NAME:		STUDY AREA:	
DATE SUBMITTED:		DATE REVIEWED:	
MODEL STATUS:	☐ draft	☐ final	

		Y	N	N/A
3.23	Do pilot channels minimize depth and provide a positive downstream slope (a variable slope is usually needed for long channels with a variable sloped flowline)?[2]	☒	☐	☐
3.24	Are contraction and expansion coefficients reasonable (e.g., 0.3/0.5 for steady flow at bridge/culvert bounding cross-sections and unchanged/unused for unsteady flow)?[2] [3]	☐	☐	☒
3.25	Are lidded cross-section station-elevation data correct (i.e., no gaps or slivers)?[2]	☐	☐	☒
3.26	Do lidded cross-sections that are pressurized (typical) use a Priessman Slot?[2]	☐	☐	☒
			☐	☒
3.28	If cross-sections extend over a storage area, are cross-section Manning's n values set to 0.02 (i.e., to represent water surface)?[2]	☐	☐	☒
3.29	If cross-sections were interpolated (not typical), was a rationale provided?[3]		☐	☒
3.30	If levee features were used (not typical), is rationale provided?[2]	☐	☐	☒

4. Inline Structures (bridges, weirs, and culverts)

		Y	N	N/A
4.1	Are all structures included in the model, and if not, was a rationale provided (compare to aerial images)?	☒	☐	☐
4.2	Do all structures look reasonable, in general?	☒	☐	☐
4.3	Are bounding cross-sections reasonably located (i.e., ideally four cross-sections with two near deck face; does not need to adhere rigidly to referenced guidelines)?[3]	☒	☐	☐
4.4	Are flows from 2D that flow parallel to crossing into the channel (e.g., roadside ditches) able to flow into 1D (e.g., are cross-sections placed close enough to the deck or bent towards the deck to allow flow transfer across lateral structures? If cross-sections were bent, were blocked areas used to reduce effective weir flow?)	☒	☐	☐
4.5	Are weir shapes selected according to the weir type (typically broad crested)?	☒	☐	☐
4.6	Are weir coefficients reasonable (e.g., broad crested 2.6-3.1; ogee crested 3.2-4.1; sharp crested 3.1-3.3)?[4]	☒	☐	☐
4.7	Are deck station-elevations consistent with bounding cross-sections?	☒	☐	☐
4.8	Is the roadway name, structure type, and any key information included in the description?	☐	☐	☒
4.9	Is the roadway name included in the node name table?	☐	☐	☒
4.10	Are lengths consistent with aerial images?	☐	☐	☒
4.11	If internal cross-sections were modified, was a description included?[2]	☐	☐	☒
4.12	If the settings in the Bridge/Culvert Editor > Options menu are not set to default, was a rationale provided?[2]	☐	☐	☒
4.13	Are multiple crossings modeled reasonably (e.g., as a single bridge when the distance between the crossings is less than the total width of the crossings combined, where a pipeline extends the low-chord, etc.)?[3]	☐	☐	☒
4.14	Do multiple crossings have a description?[3]	☐	☐	☒
4.15	Are HTAB headwater maximum elevations set to a minimum of 2-ft above the 500-yr water surface?[2]	☒	☐	☐

PROJECT NAME:		STUDY AREA:	
DATE SUBMITTED:		DATE REVIEWED:	
MODEL STATUS:	☐ draft	☐ final	

		Y	N	N/A
4.16	Are HTAB tailwater maximum elevations set to a minimum of 2-ft above the 500-yr water surface?[2]	☒	☐	☐
4.17	Are HTAB maximum flows set to a minimum of 125% of the 500-yr peak flow rate?[2]	☒	☐	☐
4.18	Are skews set up correctly (i.e., skew should only be applied if angle is greater than 30-degrees; in some cases, overbanks should not be skewed, requiring manual skewing outside of HEC-RAS)?[2 3]	☐	☐	☒

5. Bridges

5.1	Is Energy Method (Standard Step) used for low and high flow methods, and if not, has a rationale been provided (Momentum [for low flow] and Pressure and/or Weir [for high flow] may be used to improve model stability and/or accuracy if piers are not well represented by Energy)?[2 3]	☒	☐	☐
5.2	Are the location and number of piers consistent with aerial images, survey, and other available data?	☒	☐	☐
5.3	Have bridge piers elevations been set artificially high (above deck) and low (zero) to avoid slivers between the deck and channel flowline?	☒	☐	☐
5.4	If multiple openings are used (not typical), was it set up correctly and is it a better solution than splitting the reach or having part of the bridge/culvert modeled in 2D?[3]	☒	☐	☐

6. Culverts

6.1	Are the culvert chart and scale numbers set according to the culvert type?	☒	☐	☐
6.2	Are Manning's n values set according to the culvert material?	☒	☐	☐

7. Weirs

7.1	If used fictitiously to represent a steep drop in the flowline, was a note included in the description?[2]	☒	☐	☐
7.2	If an outlet rating curve was used to compute flow (not typical), was a rationale provided?[2]	☐	☐	☒

8. Flow 2D Areas

8.1	Are all land use rasters at 10-ft or higher resolution?[1]	☒	☐	☐
8.2	Does the mesh extend beyond the 500-yr floodplain or, at minimum, the 100-yr floodplain if the 500-yr is not modeled?	☐	☐	☒
8.3	Are cell sizes consistent with guidelines (e.g., 25-ft or 70-ft [with breaklines to represent streets] for detailed studies, 100-ft for urban watershed studies, and 200-ft for rural watershed studies)?[1]	☒	☐	☐
8.4	Do breaklines represent all major drainage ways and breaks in grade that obstruct, collect, and/or control drainage?[1]	☒	☐	☐

PROJECT NAME:	STUDY AREA:
DATE SUBMITTED:	DATE REVIEWED:

MODEL STATUS: ☐ draft ☐ final

		Y	N	N/A
8.5	Have gaps been avoided between the cross-section Interpolation Surface, Storage Areas, and the 2D Flow Area Perimeter (use RASMapper to identify gaps, with the Interpolation Surface set to 25% transparent and the 2D Flow Area Perimeter and Storage Area layers turned on)?	☐	☐	☒
8.6	Was a 2D Flow Area Refinement Zone assigned over the 1D channel to improve mesh generation and alignment to the 1D channel?	☐	☐	☒
8.7	For watershed studies, are Manning's n values for land use and n-value regions appropriate (i.e., per referenced guidelines; note that 1) for MAAPnext and surrounding regions, confirm that n values match the latest specific which may differ from HCFCD published guidelines, 2) that the HGAC land use dataset includes n values for Rain-on-Grid and that Direct-Applied models should have a Base value set to override the default)?[1]	☒	☐	☐
8.8	For impact studies, have Manning's n values been refined to reflect local, detailed land use (i.e., should not use the composite n values listed in Table 2-1 of (HCFCD, HEC-RAS 2D Modeling Guidelines))?[1]	☒	☐	☐
8.9	Do all 2D storage area connectors use the 2D equations, and if not (e.g., where freefall occurs), was a rationale provided?[1]	☐	☒	☐
V6.1 can use the 2d equation for stormsewers				

9. Lateral Structures

		Y	N	N/A
9.1	Are all lateral structure tailwater connections assigned to a 2D flow area or a storage area junction?	☒	☐	☐
9.2	Do lateral structures have GIS coordinates?[2]	☒	☐	☐
9.3	Do all lateral structures use the weir equation, and if not, was a rationale provided?[1 2]	☒	☐	☐
9.4	Are all weir equation coefficients set correctly (e.g., 0.5 typical for floodplain, 1 to 2 for tributary connections with depths greater than 6-ft, and 2.6 for actual weir flow conditions)?[1 2]	☒	☐	☐
9.5	Are station-elevation points filtered (typically 100-200 points or 10% of sampled points)?	☒	☐	☐
9.6	Do lateral structures follow logical paths, such as high points along top of bank (it is acceptable to set elevations lower if the 2D cell faces pick up detail and prevent flow “leakage”)?	☒	☐	☐
9.7	Are lengths generally less than 5,000-ft?[2]	☒	☐	☐
9.8	Are lateral structures subdivided to represent specific features with a unique weir coefficient (e.g., tributaries, spillways, etc.)?[2]	☒	☐	☐
9.9	Do lateral structures greater than 50-ft in length have at least 0.1-ft of elevation change?[2]	☒	☐	☐
9.10	Was "use velocity" checked under 2D boundary (typical)?	☐	☐	☒
9.11	If a diversion rating curve or linear routing were used (not typical), was a rationale provided?[2]	☐	☐	☒
9.12	If weir parameters were modified from the defaults (not typical), was a rationale provided (defaults: computation method standard weir flow; weir flow reference water surface; weir crest shape broad crested)?[1 2]	☐	☐	☒

10. Storage Areas

		Y	N	N/A
10.1	Are storage areas connections set up correctly to represent the conveyance system between storage areas?	☒	☐	☐
10.2	Do storage area outlines match the area being represented (i.e., geospatially accurate)?[2]	☒	☐	☐

PROJECT NAME:		STUDY AREA:	
DATE SUBMITTED:		DATE REVIEWED:	
MODEL STATUS:	☐ draft	☐ final	

		Y	N	N/A
10.3	Are storage area connectors drawn left to right looking downstream such that the headwater and tailwater are indicated correctly?[2]	☒	☐	☐
10.4	If a storage area uses the area times depth method (not typical), was a rationale provided?[2]	☒	☐	☐
10.5	If linear routing method was used (not typical), was a rationale provided?[2]	☐	☐	☒

11. Junctions

		Y	N	N/A
11.1	If storage areas were used to replace junctions and an area times depth rating curve was used, was the area less than 0.5-acre? If a stage-storage rating curve was used, was the maximum elevation set sufficiently high?[2]	☒	☐	☐
11.2	If storage areas were used to replace junctions, are all tributary reaches connected to the storage area?[2]	☒	☐	☐
11.3	If the force equal water surface elevations option was used to balance junctions, was a rationale provided?	☐	☐	☒

12. Boundary Conditions

		Y	N	N/A
12.1	Are all inflow and outflow locations represented?	☒	☐	☐
12.2	Are 1D downstream normal depth slopes representative of the reach's profile slope?[3]	☒	☐	☐
12.3	Are 2D flow hydrograph energy grade slopes estimated in the direction of flow from the terrain in the area where flow concentration is anticipated?[1]	☒	☐	☐
12.4	Are initial flows set correctly (e.g., increasing downstream except at a flow split and matching hydrograph initial flows and/or minimum flows; use the flow summary table to assist review)?[2]	☒	☐	☐
12.5	Are storage area initial elevations consistent with initial water surface elevations in the channel or are they left blank, and if not, was a rationale provided?[2]	☒	☐	☐
12.6	If initial stages are set at cross-sections (not typical), was a rationale provided?[2]	☒	☐	☐
12.7	If restart files were used for initial conditions (not typical), was a rationale and description of what scenario the restart file represents provided?[2]	☐	☐	☐
12.8	If a flow hydrograph was not used as the upstream boundary condition (not typical), was a rationale provided?[2]	☐	☐	☒
12.9	If normal depth was not used as the downstream boundary condition (not typical), was a rationale provided?[2]	☐	☐	☒
12.10	If any of the following were used as a boundary condition (not typical), was a rational and description of the data source provided: rating curves, gate opening time series, elevation-controlled gates, navigation dams, pump stations, stage hydrographs, and groundwater interflows?[2]	☐	☐	☒

13. Flow Inputs

		Y	N	N/A
13.1	Are all relevant nodes from the HEC-HMS model applied and not double counted for?	☐	☐	☐
13.2	Are flow hydrographs referencing the correct HEC-HMS nodes to avoid "double routing" of flows (i.e., should typically reference the HEC-HMS sub-basin, not the junction or reach)?	☒	☐	☐

		Y	N	N/A
13.3	Have the names of HEC-HMS nodes been assigned to all boundary conditions (see Unsteady Flow Editor > Options > Boundary Conditions Names)?	☐	☐	☒
13.4	Are all DSS file paths active and not missing (e.g., HEC-HMS can write each event to an individual DSS file or store all events in a single DSS and this often results in broken links; use the “plot all hydrographs” button to confirm any missing links)?	☒	☐	☐
13.5	Are all DSS file pathnames referencing the correct fields (use the DSS flow path summary table to review)?	☒	☐	☐
13.6	Are lateral inflow hydrographs applied upstream of the actual discharge location (i.e., HEC-RAS applies the flow to the downstream cross-section)?	☒	☐	☐
13.7	Are uniform lateral inflows based on subsurface drainage networks and overland flow paths (i.e., not simply based on the sub-basin boundary)?	☒	☐	☐
13.8	Are flow hydrographs applied to the 2D flow area reasonably located?	☒	☐	☐
13.9	Are uniform lateral inflows downstream cross-sections set correctly (this is a common error where the modeler forgot to revise the default cross-section)?		☐	☐
13.10	Were all basins sub-divided so that there are no flow ratios applied, and if not, was a rationale provided and do they add to 1 (use the flow summary table to assist review)?	☐	☐	☒
13.11	If minimum flow rates are set, are they less than 5% of the 1% AEP peak flow rate?	☒	☐	☐
13.12	If minimum flow rates are set, are inline or offline storage volumes not significantly reduced?	☐	☐	☒
13.13	If precipitation was applied directly to a 2D mesh (i.e., a precipitation-on-grid method), was the PRECIP-INC HEC-HMS record used such the 2D mesh accounts for initial losses (i.e., unless the area is well drained and initial abstraction within the surface is minimal, in which case PRECIP-EXCESS is recommended)?	☐	☒	☐
The loss function in v6.1 used				
13.14	If a precipitation-on-grid method was used as the basis for the study, were the peak flows compared to traditional methods (e.g., HCFCD Site Runoff Curves, Clark Tc&R method, Rational Method, etc.) and within 5% of the traditional 1% AEP peak flow?	☒	☐	☐

14. Results

		Y	N	N/A
14.1	Do water surface elevations and flow rates appear reasonable through each event (i.e., no significant, unexplained changes) (review profile, hydrographs, output tables), and if not, was a rationale provided?	☒	☐	☐
14.2	Do design storm water surface elevations increase at all locations (i.e., they should not cross; e.g., 2-yr water surface is greater than 5-yr, etc.), and if not, was a rationale provided?	☒	☐	☐
14.3	Are water surface profiles reasonable at bridge crossings throughout each event (e.g., no "stuck" profiles, reasonable head loss)?	☒	☐	☐
14.4	Are inundation limits within the model domain, or if not, is a boundary condition provided to allow for diversions out of the model?	☒	☐	☐
14.5	Are the 2D maximum velocities reasonable (i.e., not exhibiting spikes that may indicate model instabilities), and if not, was a rationale provided?	☒	☐	☐
14.6	Are the 2D Courant numbers generally less than 4, and if not, was a rationale provided?	☒	☐	☐
14.7	Are the 2D streamlines reasonable (i.e., do breaklines and the mesh accurately reflect major drainage features and prevent flow leakage)?	☒	☐	☐
14.8	Have all significant runtime messages, errors, and warnings been resolved, and if not, was a rationale provided?	☒	☐	☐

PROJECT NAME:	STUDY AREA:
DATE SUBMITTED:	DATE REVIEWED:

MODEL STATUS: ☐ draft ☐ final

	Y	N	N/A
14.9 Are all hydrographs of lateral structures, storage area connectors, and bridges/culverts reasonable, and if not, was a rationale provided?	☒	☐	☐
14.10 Do volumes compare closely between HEC-RAS and HEC-HMS and key locations?	☒	☐	☐
14.11 Is the HEC-RAS percentage error in volume (see BCO file) minimal (i.e., less than 0.5%)?	☒	☐	☐
14.12 Does the total runoff volume of HEC-HMS sub-basins match the total hydrograph volume (minus minimum flows) applied to HEC-RAS (confirm time windows match)?	☒	☐	☐

15. References

HCFCD. (n.d.). *H&H Guidance Manual.*

HCFCD. (n.d.). *HEC-RAS 1D Unsteady Guidance Manual.*

HCFCD. (n.d.). *HEC-RAS 2D Modeling Guidelines.*

USACE-HEC. (n.d.). *HEC-RAS Hydraulic Reference Manual.*

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[1] (HCFCD, HEC-RAS 2D Modeling Guidelines)
[2] (HCFCD, HEC-RAS 1D Unsteady Guidance Manual)
[3] (HCFCD, H&H Guidance Manual)
[4] (USACE-HEC)

MEMO

TO: Jose De La Pena, P.E.,
Feasibility Studies Department

DATE: 10/25/2021

FROM: Erin Stiggins, P.E., CFM

PROJECT NO.: 40339-79

CC: Zubin Sukheswalla, P.E., CFM
David Parkhill, P.E., D.WRE

RE: Response to Comments for Existing Conditions Modeling E116-00-00 comments received 09/17/2021

The following are responses to the comments from your office regarding the above referenced project.

1. Hydrology
   a. No hydrology was provided for review.
      Response: The model uses flow hydrographs that are linked to the HEC-DSSVue file. Atkins performed the hydrology calculations and set up the HEC-HMS model for the entire White Oak watershed as part of the MAAPnext study and we used their hydrology and subbasins data in our assessment. We did not perform any independent hydrology calculations except for subdividing the subbasins based on our truncated mesh.

   b. Inflows for HEC-RAS model was provided as part of DSS file (MAR2021_E100HMS). This file includes extraneous MAAPnext results such as historical storm event data used for calibration. I would suggest that this file be cleaned out to include only the information needed for this particular project.
      Response: This has been done and the updated DSS file is submitted along with this response letter.

2. Hydraulics.
   a. Model Version: HEC-RAS 6.0
      i. Description: Missing description about the project such as creation date, purpose, source of model and other pertinent data, vertical datum, etc. Please include.
         Response: The updated submittal includes these.

   b. Geometries:
      i. Single Geometry (AUG2021_GIMS_1) provided for review. Description is missing so please fill out.

Response: This geometry has been renamed to "2109_E116noSD". The description has been updated.

c. Flows

i. Only 100-year flow file was provided.

Response: The 10-, 50- and 100-year flow files and plans have now been included.

ii. Description is missing, please fill out.

Response: This has been updated accordingly.

iii. Flows were not checked in detail but appear to be correctly tied to DSS provided. A few flows/stages were manually inputted, but I suggest that a DSS file be created for this flow locations (single depository if additional storm events are run in the future).

Response: The DSS file has been updated to include the flows that were manually input and the flow files' descriptions have been updated accordingly explaining these.

iv. Boundary Condition Names: values are blank, so please consider adding names/descriptions to help clarify the source of the flows being used and the ratios of flows being applied for each boundary location.

Response: The description has been updated. Flow files' descriptions have been updated accordingly explaining this.

d. Plans

i. Only one plan provided (E100RAS_Aug2021_GIMSUpd_2).

Response: The updated submittal contains all the relevant plans.

ii. Description is missing.

Response: The description has been added.

iii. Plan runs with some 2D error though they appear small and occur within the 1st 9 hrs of simulation, so it's probably ok but just see if errors can be removed/reduced.

Response: These errors were reduced to a large extent by decreasing the computation time step to 5 seconds. By going further down on this, the errors may reduce slightly but won't change the results much. This would also cause longer model simulation times.

iv. Simulation window is 32 hours but please consider running the final run to 48 hrs to get more of the falling hydrograph limb on E100 and E116 (near confluence with E100).

Response: This has been updated accordingly.

e. Storm Sewer

ii. Manholes were modeled as 2D "holes" to allow for the transfer of flows between the 2D cell and the upstream and downstream pipe/culverts. A few of the storage area errors appear to be located at these 2D cells with manholes, so check to see what the issue might be.

Response: These errors are expected due to the very steep stage storage curve the holes create. They become more stable once the pipes become surcharged.

f. Results.

ii. A few of these “storm sewers” showed significant noise. There are limitations with how well HEC-RAS handles flows on long pipes/culverts and interfacing of 2D cells and storm sewer entrances/exits but check to see if there’s anything that can be done to smooth out some of this noise. A check of the flows and stages appear reasonable; velocities checked by approximate method (max Q/opening area) and they appear reasonable

Response: We have used slightly higher entrance and exist losses that what would typically be applicable in a storm sewer to be conservative in stage predictions and not under estimate stage. A very short timestep would help smooth hydrographs but peak stages will not be impacted by any notable amount. For this screening level modeling the “noise” is acceptable. Other software though should be used for design purposes.

APPENDIX C

Stakeholder Engagement

1. Progress Meetings
2. Technical Workshop #1
3. Technical Workshop #2
4. Precinct 4 Meeting #1
5. Precinct 1 Meeting #1
6. Precinct 1 Meeting #2
7. City of Houston Meeting
8. HCFCD Executive Briefing
9. Public Meeting

Progress Meetings

Meeting Minutes

Water Resources – Houston, Dallas, Fort Worth

MEETING TITLE:	Initial Kick-Off Meeting (Virtual Conference Call) Shepherd Park Terrace and E116-00-00-P001 Subwatershed Planning Project	**DATE:**	05/24/2021

ATTENDEES: *Present* = (x)

HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green ( ), Myron Jones ( ), William Sherman ( ), Beth Walters ( ), Jeremy Ratcliff ( ).
COH: Adam Eaton (x), Beto Moreno (x), Umer Khan (x), Tanu Hiremath (x), Manik Mitra (x), Braxton Coles (x).
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Brett Garrett (x), Raquel Escatel (x), Sergio Handal (x), Hussain Iftikhar ( ).

AGENDA TOPICS:

I) Introductions

1) HCFCD:
   a) David Parkhill – Staff Augmentation, Project Manager for E116.
   b) Gary Bezemek – Feasibility Studies Manager.
   c) Amy Stone – Communications Lead.
2) COH:
   a) Adam Eaton – Storm Water Planning Group.
   b) Beto Moreno – Storm Water Planning Group.
   c) Tanu Hiremath – Storm Water Action Team (SWAT).
   d) Umer Khan – Storm Water Action Team (SWAT).
3) P-D:
   a) Erin Stiggins – Project Manager for E116.
   b) Zubin Sukheswalla – Managing Vice President.
   c) Lonnie Anderson – Practice Leader.
   d) Brett Garrett – Water Resources Specialist.
   e) Raquel Escatel – Principal Engineer, project lead/ liaison with current Shepherd Park Terrace (SPT) project.

II) Project Description

1) Scope of work:
   a) E116-00-00-P001 Subwatershed Planning Project originated from the current COH's Shepherd Park Terrace (SPT) project.
      i) P-D is the engineering consultant for both E116-00-00-P001 and SPT.
      ii) COH is closely tracking SPT due to the high-visibility of the project.
      iii) COH initiated E116-00-00-P001 under the Storm Water Management Program (SWMP) project layout.
   b) E116-00-00-P001 is a project considered under the 2018 Bond Program.
      i) P-D is familiar as it was the same Bond Program as the Spring Gully Watershed Planning Project (SGWPP) – a previous watershed planning project recently performed by P-D (2020).
      ii) E116-00-00-P001 project is officially considered a partnership project with HCFCD and COH, governed by Interlocal Agreement.
      iii) Feasibility Stage – bond funding is the only available funding for feasibility; no construction budget allocated yet.

c) Scope summary provided by P-D:
   i) H&H analysis will be performed for entire E116-00-00 subwatershed – including all contributing tributaries – using Harris County MAAPnext methodology.
      (1) P-D is proficient with MAAPnext as it was also utilized for SGWPP.
      (2) 1D/2D hydraulic modeling will be performed with rain-on-grid analysis to confirm drainage areas.
      (3) The subwatershed will be further divided into multiple problem areas identified by applying criteria and metrics provided by HCFCD.
      (4) Thorough, detailed modeling will be completed for identified problem areas, including SPT.
      (5) Current and/or potential flooding problems will be identified, and potential solutions will be developed, including but not limited to mitigation, improvements, redevelopments (gentrification), etc.
   ii) Multiple deliverables will be completed, as discussed below.
   iii) P-D will support stakeholder engagement as requested by HCFCD Communications Lead.
d) Shepherd Park Terrace (SPT) project – COH SWAT Team and P-D:
   i) COH will be tracking SPT and providing comments as the project progresses.
   ii) E116-05-03 is the identified creek that traverses the SPT subdivision.
   iii) Primary objective: Reduce ponding depths in areas of concern.
      (1) Target LOS: 2-year within infrastructure, 100-year within ROW.
      (2) Observations of problems:
         (a) Multiple flooding losses and complaints have been historically reported in the SPT subdivision area.
         (b) Overland flow from Tidwell sheet flows into SPT subdivision, primarily to Areas 1 and 2.
         (c) David posed the question of whether insufficient capacity in E116-05-02 could be the cause of sheet flow from Tidwell.
         (d) Area 3 has issues with capacity and inlets appear to be undersized.
         (e) Desktop review indicates that residents are building fences potentially for aiding in keeping water out.
      (3) Initial recommendations:
         (a) Relocate storm drain laterals from private property.
         (b) Add inlets.
         (c) Upsize storm drain system.
         (d) No open channel improvements at this time.
      (4) Challenge: Mitigation for reduction in ponding.
         (a) SWAT projects must focus on rehabilitation with limited funds.
         (b) Space for mitigation in urban area is a concern.
         (c) Mitigation solutions haven't been considered by P-D because not included in scope.
         (d) May need to consider grants or partnerships to fund mitigation.

2) Deliverables schedule:
   a) TM1 – Identify Problems: 10/21/2021.
   b) TM2 – Watershed Strategy: 04/22/2022.
   c) FER – Watershed Plan: 05/27/2022.
   d) Stakeholder engagements – dates will be based on deliverables; further discussion will continue throughout the life of the project.

	3) *Schedule must be finalized for HCFCD Management review and baselining, no later than 06/10/2021. a) *Need to coordinate with Amy Stone to establish Communications schedule prior to baselining. b) Once baseline established, no further updates without justification.
III) City of Houston	1) SPT is a SWAT study. 2) Communications: a) COH staff will be included on all HCFCD communications. b) COH staff will be invited to all HCFCD meetings c) COH staff will be given the opportunity to review and comment on all deliverables. d) HCFCD and COH will share information across respective projects without following any formal process. e) HCFCD and COH will work together to comply with guidelines and requirements from Interlocal Agreement 3) HOA meetings: a) COH does not follow formal process for public engagement. b) Most important consideration is consistent messaging from HCFCD and COH during all public meetings. c) Precinct coordinators will reach out to HOA and consult with Amy Stone as needed.
IV) Public Involvement	1) Public engagement: a) P-D will support efforts on public engagement rather than leading them. b) Amy Stone – HCFCD Communications Lead and point of contact. c) Bond funding requires that a neighborhood meeting be held. d) Other meetings – content and audience – will be determined by Amy Stone and consultant. i) Separate Communications Kickoff meeting to be scheduled soon. ii) Set schedule for anticipated public meetings. 2) Public meetings: a) Virtual – Possibility of moving to a 'hybrid' approach but more participation and engagement has been noticed through utilizing virtual meetings. b) Shepherd Park Terrace neighborhood meetings. c) E116-00-00-P001 will be a larger community meeting. Will need to have consistent information being presented in both meetings. 3) Consultant support: Project will utilize HCFCD consultant for White Oak Bayou.
V) Project Administration	1) Project ID/ PO/ Name: a) Official Project ID: E116-00-00-P001. b) Shepherd Park Terrace and E116 Subwatershed Planning Project. 2) General communications: a) HCFCD recommends using experiences, processes, and methods learned from SGWPP as a foundation to build off of but E116-00-00-P001 could present its own challenges. b) Predominantly located in Precinct 1 and District B with a small portion located in Precinct 4 and District C. 3) Work authorization/ invoicing: a) Remain the same way as SGWPP. b) Invoicing forms in KiSSFLOW remains the same as SGWPP for now. c) New system anticipated during project.

	d) P-D to provide notice of approximately 2 weeks before needing new work authorization. e) HCFCD budget includes contingencies set aside to cover unanticipated costs that are unveiled throughout the life of this planning project. 4) Regular progress meetings: a) Required monthly 2-hour meeting schedule. i) At least one, 2-hour meeting per month. ii) Considered to be formal Progress meeting. iii) *HCFCD and P-D to begin e-mail correspondence to establish monthly meeting schedule. b) Optional monthly meetings i) Can be 1-hour or less. ii) Anticipated two weeks after formal Progress meeting. iii) Considered to be "Catch-up" meetings; flexible scheduling. iv) Can be multiple times per month or on an as-need basis. c) Anticipate continuing as virtual meetings via TEAMS. 5) Meeting summary notes: a) Remain diligent in capturing all action items. b) Provide pertinent dates of all deliverables when submitted, when comments are received, etc. c) Include action item in the records related to HCFCD review of draft deliverables.

ACTION ITEMS*:

II). 3)	Finalize schedule for HCFCD Management review and baseline. (06/10/2021)
II). 3) a)	Coordinate with Amy Stone to establish Communications schedule. (06/09/2021)
V). 4) a) iii)	HCFCD and P-D to begin e-mail correspondence to establish monthly meetings schedule. (05/28/2021)

DECISIONS MADE:

1) Officially referring to E116-00-00-P001 as a "Subwatershed Planning Project." This project isn't considered a watershed planning project because it is not considered a major watershed recognized by COH and HCFCD.

Meeting Minutes

Water Resources – Houston, Dallas, Fort Worth

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001. **DATE:** 06/10/2021

ATTENDEES: *Present* = (x)
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green ( ), Myron Jones (x), William Sherman (x), Beth Walters ( ).
COH: Adam Eaton ( ), Beto Moreno ( ), Umer Khan ( ), Tanu Hiremath ( ).
P-D: Lonnie Anderson (x), Zubin Sukheswalla ( ), Erin Stiggins (x), Brett Garrett (x).

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones/ deliverables discussion. a) Deliverable schedule and milestone timeline have been confirmed by P-D. b) Deliverable schedule and milestone timeline have been officially documented with Flood Control. 2) Schedule for HCFCD Management review and baselining. a) Baseline is currently in Flood Control's queue. b) *David will track down the status of finalizing the baseline; expects no longer than 2-weeks for final approval. 3) HCFCD communications kickoff meeting discussion → develop prior to baselining. a) HCFCD Communications department is actively working on a standardization process. Part of the standardization is to emphasize responsiveness to community's concerns rather than proactively searching for meetings. b) Meeting schedule can be flexible and can change after baselining. 4) Next scheduled Bi-Monthly Progress meeting – 06/24/2021. a) PD expects to have the White Oak Bayou hydraulics reviewed. b) This meeting date has the potential for being postponed and/or canceled. Both HCFCD and PD will continue to communicate and monitor the future potential status of this meeting. 5) Next scheduled Monthly Progress meeting – 07/08/2021.
II) Stakeholder / Public Engagement	1) Outlook for potential engagement meetings. a) Does HCFCD and PD need to schedule the Bond meeting? i) HCFCD states the Bond meeting date is flexible. ii) Currently, their master calendar shows the Bond meeting set for 10/2021 but a specific date has not been set. iii) Only requirement is that the date is finalized 2-3 weeks prior to the meeting in order to notify the public in advance. b) HCFCD suggests that engagement meetings can remain flexible and appropriately scheduled when applicable information and results from PD analysis are ready to be presented. c) Even though engagement meeting dates are flexible it's important to remain on-schedule with final deliverables. 2) HOA meetings. a) The responsibility for requesting community meetings resides with the pertinent HOAs and Civic Clubs.

	i) The Storm Water Management Plan (SWMP) is expected to be the primary interest of Shepherd Park Terrace (SPT) HOA. ii) It's anticipated that all HOA E116 meetings will be interrelated with SPT project details. b) Myron Jones has had previous communications with SPT's HOA however, it's been a while since SPT has reached out. Due to recent weather activity, there's an expectation to hear from SPT in the near future.
III) Administrative	1) Monthly invoicing. a) Due to project kickoff occurring in late May, P-D's June invoice will combine and include all May items. b) Moving forward, HCFCD requests one invoice submitted for each month. i) PD defines calendar months as invoicing months. 2) Short-hand project title for HCFCD project and COH project. a) HCFCD project will be called "E116 Project". b) COH project will be called "SPT Project". 3) Status of HCFCD and COH Interlocal Agreement (ILA). a) Both HCFCD and COH are in the process of verifying each other's inclusive requirements set forth by the ILA. b) All pertinent meetings related to SPT/ E116 Project must include meeting invitations sent to applicable COH employees. c) HCFCD and COH will provide any requirements needed from PD to follow ILA guidelines. 4) Updates from COH project (now "SPT Project") a) P-D report under 2nd COH review. b) P-D staff expects any further comments will lead to minimal changes.
IV) Data Transfer	1) No updates.
V) Data Collected, Reviewed, and Processed To-Date	1) OTG Folder – received 05/13/2021; contains as-builts and site photos. a) Currently, a general review has been conducted by P-D of the documents in the OTG folder. b) Applicable files will be clearer as E116 Project progresses. 2) White Oak Bayou MAAPnext Models – downloaded from HCFCD 06/07/2021. a) White Oak Bayou MAAPnext Model will be used as the base model and will be documented as the "source"; P-D will not be creating a model from scratch. b) White Oak Bayou MAAPnext Model has not been submitted to FEMA however, the model is considered to be 95% complete. i) The model currently shows some overflow from Buffalo into Little White Oak but that area is downstream of the E116 project area, so any related updates will not influence the base model for E116 Project. ii) *Lonnie is aware of another potential overflow from Buffalo Bayou. Need to confirm the location to determine the potential to influence the E116 project area.
VI) Data Requests	1) No updates.
VII) H&H Analysis	1) Hydraulics – progress to date. a) P-D expects to refine the analysis of the 1D/2D HEC-RAS model by increasing detail and expanding the model extents to include each contributing tributary. b) Storm sewer analysis is also expected to be included in the HEC-RAS model by incorporating data produced by the XPSWMM model currently being performed

	by the SPT Project. Consider using hydrograph output from XPSWMM as an input to HEC-RAS model. c) SPT Project will need to be cognizant of potential changes to recommendations based on the effects of the E116 Project. d) Potential off-peak and peak-on-peak analysis will need to be considered for flooding at the confluence of E116 and White Oak Bayou. e) Consideration for areas of mitigation is anticipated to be an area of concern for E116 Project due to the COH requirements of not increasing flows in the channels. i) Gary recommends considering detention in upstream portions of the subwatershed to potentially prevent downstream impacts. ii) May also consider options for inline detention. 2) Hydrology – progress to date. a) P-D expects to refine the hydrologic analysis to give greater detail to the increased detail of the HEC-RAS model. b) Subbasins from the MAAPnext modeling are anticipated to be subdivided to better represent the smaller streams of the subwatershed. 3) Potential survey needs. a) No needs have been identified at this juncture. Survey needs will be communicated as the project progresses. b) P-D will coordinate with SPT Project team to obtain applicable survey data that was collected for SPT Project.
VIII) Immediate Needs	1) HCFCD communications schedule. a) Continue to be flexible.

ACTION ITEMS*:

I) 2) a) i)	David will track down the status of finalizing the baseline; expects no longer than 2 weeks for final approval
V) 2) b) ii)	Lonnie is aware of another potential overflow from Buffalo Bayou. Need to confirm the location to determine the potential to influence the E116 project area.

DECISIONS MADE:

III) 2) a)	Project formally adopts convention of “E116 Project” to reference HCFCD project and “SPT Project to reference COH project to aid in obvious distinctions between the two efforts.

Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE: Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001. **DATE:** 06/24/2021

ATTENDEES: HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (x), Myron Jones (x), William Sherman (x), Beth Walters ( ).
COH: Adam Eaton ( ), Beto Moreno ( ), Umer Khan (x), Tanu Hiremath ( ).
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Brett Garrett (x).

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables discussion. a) P-D continues to be on-schedule. 2) Status of baseline approval from Flood Control. a) HCFCD confirmed baseline was approved. 3) Next scheduled Monthly Progress meeting – 07/08/2021. 4) Next scheduled Bi-Monthly Progress meeting – 07/22/2021. 5) Potential to record progress meetings. a) P-D may record progress meetings for internal use only. P-D shall not send any recordings to HCFCD. b) HCFCD will continue to rely on meeting minutes.
II) Stakeholder / Public Engagement	1) P-D has compartmentalized stakeholder meetings into the following groupings: a) Traditional / Bond. i) Open to the public and will be led by HCFCD as a virtual engagement for the foreseeable future. ii) E116 project scope and budget includes a Summary Report to be specifically created for public consumption. iii) P-D will provide technical support. b) HOA / Civic groups. i) Attendance of smaller groups of individuals encouraged in a way by invitation with potential for an in-person and / or hybrid engagement. ii) Will be initiated by individual groups and supported by HCFCD and/or COH as appropriate. iii) P-D will provide technical support. c) Harris County / HCFCD / COH. i) Briefings to executive management. ii) Workshops to refine potential projects. 2) HCFCD Communications department will refrain from scheduling engagement meetings until the project approaches final deliverables. a) Currently, HCFCD has two planning projects that are undertaking stakeholders. b) An internal Communications department meeting, along with the precinct coordinator, is recommended by HCFCD to accommodate the fluid schedules of diverse, ongoing feasibility studies.

III) Administrative	1) *P-D will provide May and June invoices by the next scheduled Monthly Progress Meeting – 07/08/2021. 2) All subsequent invoices from P-D will be delivered on a monthly, calendar basis.
IV) Data Collection and Review	1) No updates.
V) H&H Analysis	1) Hydrology – progress to date. a) P-D will verify drainage areas and surface / subsurface conveyance from MAAPNext model using Rain-on-Grid (ROG). b) P-D will subdivide drainage areas, and develop new hydrologic parameters, as appropriate for the desired level of detail for the hydraulics. 2) Hydraulics – progress to date. a) P-D will review and consider upgrading to utilize the newest HEC-RAS platform, version 6.0, to model E116 Project. i) The current MAAPNext White Oak Bayou HEC-RAS model is modeled in HEC-RAS version 5.0.7. ii) *P-D will compare WSEL rasters between the two versions to determine any differences between the calculations. iii) Version 6.0 provides new tools that will expedite the evaluation of proposed improvement alternatives. b) P-D may consider converting to all 2D modeling within E116 project area. Conversion may allow for better representation between surface and subsurface conveyance. c) P-D will truncate the current MAAPNext HEC-RAS model to be more specific to the scope of the E116 project area. Overflows from other subbasins will be used to set limits of truncated model. d) Exercise for extending centerlines from the M3 model and including other tributaries revealed potential roadside ditches and storm sewers as primary infrastructure. i) In small roadside ditch features, the effort to extend the 1D modeling length is not justified by improved hydraulic results. Further detail will be added to the mesh through breaklines and refinement areas to properly model these areas. ii) *HCFCD suggests that P-D use GEMS data to determine if a storm sewer system serves E116 drainage areas. e) *HCFCD requests for P-D to keep record of any changes / updates / modifications made to the MAAPNext models during the analysis. Recording these observations will be beneficial for future projects (feasibility study, impact analysis, etc.). 3) Potential survey needs. a) Expected to be ongoing as project progresses. b) Potential need in the near future will be field surveys, structure surveys, flowline measurements, and site visits.
VI) Immediate Needs	1) No updates.

ACTION ITEMS*:	
III) 1)	P-D will provide May and June invoices by the next scheduled Monthly Progress Meeting – 07/08/2021.
V) 2) a) ii)	P-D will compare WSEL rasters between the two versions to determine any differences between the calculations.
V) 2) d) ii)	P-D will use GEMS data to determine if a storm sewer system serves E116 drainage area.
V) 3) e)	P-D will record observations for changes / updated / modifications that are warranted to MAAPNext models to make more suitable for future projects (feasibility study, impact analysis, etc.)

DECISIONS MADE:	
II) 2)	HCFCD Communications department will refrain from scheduling engagement meetings until the project approaches final deliverables.
V) 2) a) iii)	P-D will truncate the current White Oak Bayou HEC-RAS model to be more specific to the scope of the E116 project area.

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Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001. **DATE:** 07/08/2021

ATTENDEES: HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (x), Myron Jones ( ), William Sherman ( ), Beth Walters ( ).
COH: Adam Eaton ( ), Beto Moreno ( ), Umer Khan (x), Tanu Hiremath ( ), Manik Mitra (x).
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Brett Garrett (x).

AGENDA TOPICS:

I) Schedule Discussion

1) Schedule of milestones / deliverables discussion.
   a) P-D continues to be on-schedule.
   b) Discussion on the schedule for Workshop 1:
      i) According to the scope, Workshop 1 is anticipated to take place early December 2021 after TM 1.
      ii) HCFCD suggests that Workshop 1 be the first milestone to include a formal meeting and presentation. Because the purpose of Workshop 1 is to go over models, identifying the potential problem areas, etc. it should be scheduled before or in conjunction with the Executive Briefing.
2) Next scheduled Bi-Monthly Progress meeting – 07/22/2021.
3) Next scheduled Monthly Progress meeting – 08/12/2021.
   a) If we are to maintain the 2-week Progress meeting schedule this date should be 08/05/2021.
   b) Decision to maintain the Monthly Progress meetings to be scheduled for the second Thursday of every month and the Bi-Monthly Progress meetings for the fourth Thursday of every month – TEAMS meeting schedules remain unchanged.
   c) COH confirmed that they have correct meeting invitations.

II) Stakeholder / Public Engagement

1) Traditional / Bond.
   a) No updates.
2) HOA / Civic groups.
   a) Confirmed that any meetings will be held at the request of the HOA / Civic groups unless COH and/or HCFCD decide to reach out to them.
3) Harris County / HCFCD / COH.
   a) Workshops led by P-D to develop potential projects.
      i) *A tentative date will need to be established for Workshop 1.
   b) COH corrected previously used “SWMP” to the correct term of “SWAT (Storm Water Action Team).”
      i) SWAT projects are governed under each given Council District and driven by the council members office.
      ii) COH will relay questions involving stakeholder/ public engagements to the public outreach group and let HCFCD know if a community outreach meeting will be scheduled.
      iii) Specifics aren’t needed, just if an outreach meeting will be scheduled.

III) Administrative	1) Monthly invoice. a) Awaiting approval from P-D accounting before submitting to HCFCD. b) In order to ensure that invoices are validated and confirmed, P-D will e-mail HCFCD a copy of the invoice every month to alert HCFCD of the invoice submittal. c) Discussion that P-D does not anticipate using a subconsultant for this project.
IV) Data Collection and Review	1) P-D has been working through data file management of data already received. Future data requests will become clearer as needs develop.
V) H&H Analysis	1) Hydrology – progress to date. a) P-D will verify drainage areas and surface / subsurface conveyance from MAAPNext model using Rain-on-Grid (ROG). i) Copying out MAAPNext models has created a longer QA/QC process due to validating all data is included and truncated properly. ii) P-D is utilizing the MAAPNext ROG to set the boundary conditions for the truncated model therefore, P-D will not be using a separate ROG. b) P-D will subdivide drainage areas, and develop new hydrologic parameters, as appropriate for the desired level of detail for the hydraulics. 2) Hydraulics – progress to date. a) P-D will review and consider upgrading to utilize the newest HEC-RAS platform, version 6.0, to model E116 Project. i) The current MAAPNext White Oak Bayou HEC-RAS model is modeled in HEC-RAS version 5.0.7. ii) *P-D will compare WSEL rasters between the two versions to determine any differences between the calculations and provide HCFCD with an analysis by 07/12/2021. iii) Version 6.0 provides new tools that will expedite the evaluation of proposed improvement alternatives. b) COH will research if any other projects in addition to the current ongoing Shepherd Park Terrace (SPT) project, is pertinent to E116 project area. i) *If pertinent SWAT project information is found by the COH, they will send all data/ information to HCFCD and P-D. ii) COH referenced the GIMS system that has public facing information containing all types of spatial and geographic data. (1) GIMS can be utilized to look at ongoing projects and includes utilities, infrastructure, services, etc. however, it doesn't contain Planning Studies. iii) *P-D will send information to Manik Mitra (COH) to get him oriented with the project. (1) Manik has recently stepped-in to assume further responsibility. iv) *P-D will investigate to see what HCFCD personnel previously coordinated with the COH and SPT. c) How is P-D incorporating the ongoing SWAT Shepherd Park Terrace (SPT) models and results for E116? i) Results haven't been finalized however, the primary concern is upstream of the SPT neighborhood with added difficulty of intercepting surface overflows.

	(1) HCFCD asked if the SPT study can analyze with and without intercepting surface overflow? (2) Can the 100-yr be contained in the ROW? ii) Coordination between HCFCD and COH will be critical when evaluating SPT. d) P-D may consider converting to all 2D modeling within E116 project area. Conversion may allow for better representation between surface and subsurface conveyance. e) P-D will truncate the current MAAPNext HEC-RAS model to be more specific to the scope of the E116 project area. Overflows from other subbasins will be used to set limits of truncated model. i) HCFCD suggests that P-D use GIMS data to determine if a storm sewer system serves E116 drainage areas. ii) From desktop analysis of the SPT project, E116-05-03 is a buried storm sewer and belongs to HCFCD. 3) Potential survey needs. a) Expected to be ongoing as project progresses. b) Potential need in the near future will be field surveys, structure surveys, flowline measurements, and site visits.
VI) Immediate Needs	1) No updates.

ACTION ITEMS*:

II) 3) b) i).	A tentative date will need to be established for Workshop 1.
V) 2) a) ii)	P-D will compare WSEL rasters between the two versions to determine any differences between the calculations and provide HCFCD with an analysis by 07/12/2021.
V) 2) b) i)	If pertinent SWAT project information is found by the COH, they will send all data/ information to HCFCD and P-D.
V) 2) b) iii)	P-D will send information to Manik Mitra (COH) to get him oriented with the project.
V) 2) b) iv)	P-D will investigate to see what HCFCD personnel previously coordinated with the COH and SPT.

DECISIONS MADE:

I) 3) a) i)	Decision to maintain the Monthly Progress meetings to be scheduled for the second Thursday of every month and the Bi-Monthly Progress meetings for the fourth Thursday of every month – TEAMS meeting schedules remain unchanged.

II) 3) b)	COH corrected previously used “SWMP” to the correct term of “SWAT (Storm Water Action Team).”
III) 1) b)	In order to ensure that invoices are validated and confirmed, P-D will e-mail HCFCD a copy of the invoice every month to alert HCFCD of the invoice submittal.

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Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE: Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001. **DATE:** 07/22/2021

ATTENDEES: HCFCD: David Parkhill (x), Gary Bezemek ( ), Amy Stone (x), Dena Green ( ), Myron Jones (x), William Sherman (x), Beth Walters ( ), Jonathan Luna (x).
COH: Adam Eaton ( ), Beto Moreno ( ), Umer Khan (x), Tanu Hiremath ( ), Manik Mitra (x).
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Brett Garrett (x).

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables discussion. a) Workshop 1 (WS #1) timeline discussion. i) Anticipate having WS #1 after problem areas have been identified and existing conditions have been established. According to the baseline schedule the original date for WS #1 is scheduled for 12/06/2021 however, it's been discussed that it would be beneficial to conduct WS #1 between the draft of Technical Memo 1 (TM #1) and TM #1 final deliverable date. (1) A tentative date for WS #1 has been re-scheduled to 10/06/2021. (2) HCFCD expects that WS #1 should not last more than 2.5-hours since it will most likely be virtual. ii) Expect to schedule a Precinct Briefing, aka Executive Briefing, 1-2 weeks after WS #1. (1) HCFCD expects that the Precinct Briefing should not last more than 1-hour due to the high-level nature of the meeting. 2) Next scheduled Monthly Progress meeting – 08/12/2021. 3) Next scheduled Bi-Monthly Progress meeting – 08/26/2021. a) Conflict with TFMA Technical Summit Conference. i) *Final decision on re-scheduling or cancelling the Bi-Monthly Progress meeting, currently scheduled for 08/26/2021, needs to be made at the next Monthly Progress meeting – 08/12/2021.
II) Stakeholder / Public Engagement	1) Traditional / Bond. a) No updates. 2) HOA / Civic groups. a) Harris County Communications are working on equity in communications framework to decrease scheduling meetings as the host. i) Anticipatory structure for the first two meetings to be scheduled by HOA, civic groups, etc.; the third meeting would be the only meeting scheduled and hosted by HCFCD. 3) Harris County / HCFCD / COH. a) Status on potential outreach meeting possibilities from the COH public outreach group. b) HCFCD Communications requested clarification for the public meeting dates that are displayed in the Baseline schedule.

	i) HCFCD and P-D confirmed that the dates and meetings are strictly placeholders intended to fulfill the requirements when establishing the overall Scope and Fees. ii) HCFCD Communications requests that P-D replace all dates for public meetings shown in the Baseline schedule with 'XXXX' to prevent confusion of any dates being scheduled and firm.
III) Administrative	1) Monthly invoice submitted / received. a) Invoice finalized and submitted to HCFCD on 07-12-2021. i) HCFCD confirmed that invoice has been received. ii) *P-D shall let HCFCD know if payment hasn't been received within 2-weeks after invoice receipt confirmation.
IV) Data Collection and Review	1) No updates.
V) H&H Analysis	1) Hydrology – progress to date. a) P-D is verifying drainage areas and surface / subsurface conveyance from MAAPNext model using Rain-on-Grid (ROG). i) P-D will also supplement the ROG with hydrographs, as needed, to help improve detail and accuracy. ii) E116/ SPT Project accounts for any overflows into or out of the project area from MAAPNext ROG. iii) P-D is utilizing the MAAPNext ROG to set the boundary conditions for the truncated model therefore, P-D will not be using a separate ROG. b) P-D is refining storm systems and hydrology. i) Subdividing drainage areas – including but not limited to the Acres Home area to capture any flows contributing to E116 Project area. (1) HCFCD suggests that mitigation techniques will most likely need to be accomplished in the Acres Home area with detaining flow in the north to mitigate for southern flooding. ii) P-D will be accounting for future conditions to include future Basin Development Factor (BDF) assumptions and future land use. iii) All future development will need to prove no adverse impacts downstream with on-site detention being used as the primary tool for mitigation. (1) Adverse impact is defined by an increase in peak stage. Increased volume is allowable as long as peak stage proves no increase. 2) Hydraulics – progress to date. a) P-D completed review and comparison of WSEL results from converting the previous RAS v5.0.7 model to v6.0. i) WSEL comparison results show +/- 0.02' differences with no changes in WSEL greater than 0.1'. ii) HCFCD asks if any updates were needed/made to convert to RAS v6.0? (1) P-D states that only 1 minor update was required to allow the model to run. b) Truncating the full White Oak Bayou MAAPNext model to the E116 Project area allows P-D to increase detail – including the underground storm drain system – and decrease the overall run time.

	c) HCFCD currently has a regional detention project being constructed – will that have an impact on E116 subwatershed?
	    i) P-D confirms that any project constructed since 2018 has already been incorporated in the model.
	    ii) HCFCD and COH will update P-D on any other projects that come down the pipeline that could possibly affect E116 Project area.
	d) COH will investigate if any other projects in addition to the current ongoing Shepherd Park Terrace (SPT) project, are pertinent to E116 project area.
	    i) Internet Explorer should be used to access the GIMS system.
	    ii) COH commented that the GIMS system contains outdated data and referred to a link that was previously shared with P-D's SPT team that contains updated data.
	    iii) Coordination between HCFCD, COH, and P-D will be important when evaluating SPT.
	e) *P-D plans to have an improved existing conditions model completed by the next Monthly Progress meeting – 08/12/2021.
	f) *HCFCD will provide updates to project scoring criteria for problem area identification in approximately 3 weeks from the date of this meeting.
	3) Potential survey needs.
	a) Expected to be ongoing as project progresses.
	b) Potential need in the near future will be field surveys, structure surveys, flowline measurements, and site visits.

VI) Immediate Needs	1) No updates.

ACTION ITEMS*:	
I) 3) a) i)	Final decision on re-scheduling or cancelling the Bi-Monthly Progress meeting, currently scheduled for 08/26/2021, needs to be made at the next Monthly Progress meeting – 08/12/2021.
III) 1) a) ii)	P-D shall let HCFCD know if payment hasn't been received within 2-weeks after invoice receipt confirmation.
V) 2) e)	P-D plans to have an improved existing conditions model completed by the next Monthly Progress meeting – 08/12/2021.
V) 2) f)	HCFCD will provide updates to project scoring criteria for problem area identification in approximately 3 weeks from the date of this meeting.

DECISIONS MADE:	
I) 1) a) i) 1)	A tentative date for WS #1 has been re-scheduled to 10/06/2021.
V) 1) b) iii)	All future development will need to prove no adverse impacts downstream with on-site detention being used as the primary tool for mitigation.
V) 2) d) i)	Internet Explorer should be used to access the GIMS system.

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Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001. **DATE:** 08/12/2021

ATTENDEES: HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green ( ), Myron Jones ( ), William Sherman ( ), Beth Walters ( )
COH: Adam Eaton ( ), Beto Moreno ( ), Umer Khan ( ), Tanu Hiremath ( ), Jonathan Luna (x), Manik Mitra (x).
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Brett Garrett (x), Ashton Lofquist (x).

AGENDA TOPICS:	
I) Schedule Discussion	1) Schedule of milestones / deliverables discussion a) P-D continues to be on-schedule b) 09/10/2021 – Draft copy of Technical Memo #1. 2) Next scheduled Monthly Progress meeting – 09/09/2021 a) Will be used to address any concerns regarding Technical Memo #1 3) Next scheduled Bi-Monthly Progress meeting – 08/26/2021 a) Decision made to cancel the 08/26/2021 Bi-Monthly Progress meeting due to a scheduling conflict with the TFMA conference 4) Adding Ashton Lofquist to take over duties from Brett Garrett
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No updates 2) HOA / Civic groups a) No updates 3) Harris County / HCFCD / COH a) Workshop 1 timeline discussion i) Decision made for Workshop 1 to take place on 09/23/2021 from 10:00am-12:30pm ii) *P-D will have Workshop 1 agenda ready with Technical Memo #1 submittal b) *HCFCD will send "Save the Date" Invitations c) *Meeting changes will be updated in the official project schedule and released by HCFCD
III) Administrative	1) Monthly invoice a) Two billing cycles are complete i) No problems have been encountered with Kissflow ii) P-D has notice from Kissflow that first invoice has been approved for payment b) P-D billing cycle schedule is 4-4-5 weeks, with quarters ending on a 5 week i) This allows for 12 billing cycles in a year rather than 13 ii) Sept. is a 5-week month, while Oct. and Nov. are 4-week months and Dec. is a 5-week month iii) *P-D will verify billing cycle schedule internally and inform HCFCD

IV) Data Collection and Review	1) P-D is requesting a structure inventory shapefile that covers the entire county a) *P-D will send an email to HCFCD with a specific request b) P-D has not received any data specifically for E116, such as Finished Floor Elevations (FFE), only the data from the Spring Gully Watershed Planning Project (SGWPP) i) The watershed master plan is being updated by HCFCD's GIS team, but the current status is unknown ii) *HCFCD will send updated geodatabase system files to P-D
V) H&H Analysis	1) Hydrology – progress to date a) Analysis primarily driven off Rain-on-Grid (ROG) method rather than the Basin Development Factor (BDF) used by MAAPNext or HEC-HMS hydrographs i) This approach will allow runoff to spread as sheet flow better as opposed to assuming flow gets to HCFCD infrastructure by assigning hydrograph to 1D open channel segments ii) HCFCD agreed it is reasonable to conclude water is not necessarily all getting into HCFCD infrastructure iii) Decision made to not develop a future condition model with different BDF values due to lack of available vacant land for future development 2) Hydraulics – progress to date a) P-D has upgraded to utilizing the newest HEC-RAS platform, version 6.0, to model E116 Project, based on WSEL raster results b) P-D has determined ROG analysis in 2D mesh accurately captures conveyance i) The MAAPNext model has been truncated ii) Sheet flow is escaping the model more than it is coming in iii) ROG is validated by MAAPNext's flooding results and is predicting significant flooding by 1-2 feet in some neighborhoods and at least two arterial roads c) The Shepherd Park Terrace (SPT) XP-SWMM model accurately captures conveyance in a manner better defined than what RAS can model i) P-D will defer to the XP-SWMM model ii) P-D RAS model will focus on flow changes while the XP-SWMM model for SPT conveys flows from the sub-surface system to the open channel iii) *P-D will calibrate the RAS model to reflect a more detailed XP-SWMM model as requested by HCFCD d) Decision made by HCFCD to have a third-party review P-D's models i) Expected to be a high-level review; HCFCD will preside over any decisions should major issues be found ii) *P-D will have the model completed, reviewed, and the documentation package—including a summary methodology and changes—ready for a formal submittal by 08/20/2021 iii) *HCFCD will send out potential dates to schedule a meeting between HCFCD, P-D, and the reviewers for the model package review, likely early in the week of 08/23/2021-08/27/2021 3) Potential survey needs a) *P-D will perform a "measure down" of manhole elevations for proper calibration since the GIMS data is currently showing elevations a few feet above ground b) Will be absorbed into the modeling budget

	4) Revised project scoring criteria a) P-D will not be able to utilize the project ranking/scoring until months down the line once potential projects have been identified b) HCFCD will determine if a scoring process is needed to rank problem areas. At this time, none is anticipated, or will only be qualitative in nature. 5) Project Documentation a) Decision made that technical memos may display and/or document any sensitive information b) *P-D will have conceptual solutions presented in Workshop 1 based on options for improvements to allow HCFCD to discuss possibilities moving forward c) *P-D will provide a 100-year Level of Service solution for the subwatershed as part of the Final Engineering Report
VI) Immediate Needs	1) No updates

ACTION ITEMS*:	
II) 3) a) ii).	P-D will have Workshop 1 agenda ready with Technical Memo #1 submittal.
II) 3) b)	HCFCD will send out “Save the Date” invitations for Workshop 1.
II) 3) c)	Meeting changes will be updated in the official project schedule and released by HCFCD.
III) 1) b) iii)	P-D will verify billing cycle schedule internally and inform HCFCD.
IV) 1) a)	P-D will send an email to HCFCD with a specific request for a structure inventory shapefile to support the E116 project.
IV) 1) b) ii)	HCFCD will send updated structure inventory geodatabase system files to P-D.
V) 2) c) iii)	P-D will calibrate the HEC-RAS model to reflect a more detailed XP-SWMM model as requested by HCFCD.
V) 2) d) ii)	P-D will have the model completed, reviewed, and the documentation package—including a summary methodology and changes—ready for a formal submittal by 08/20/2021.

V) 2) d) iii)	HCFCD will send out potential dates to schedule a meeting between HCFCD, P-D, and the reviewers for the model package review.
V) 3) a)	P-D will perform a "measure down" of manhole elevations for proper calibration since the WaterGEMS data is currently showing elevations a few feet above ground.
V) 5) b)	P-D will have conceptual solutions presented in Workshop 1 based on options for improvements to allow HCFCD to discuss possibilities moving forward.
V) 5) c)	P-D will provide a 100-year Level of Service solution for the subwatershed as part of the Final Engineering Report.

DECISIONS MADE:

I) 3) a)	Decision made to cancel the 08/26/2021 Bi-Monthly Progress meeting due to a scheduling conflict with the TFMA conference
II) 3) a) i)	Decision made for Workshop 1 to take place on 09/23/2021 from 10:00am-12:30pm.
V) 1) a) iii)	Decision made to not develop a future condition model with different BDF values due to lack of available vacant land for future development
V) 2) d)	Decision made by HCFCD to have a third-party review P-D's models
V) 5) a)	Decision made that technical memos may display and/or document any sensitive information

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Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 09/09/2021

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (), Amy Stone (x), Dena Green (), Myron Jones (), William Sherman (), Beth Walters ()
COH: Adam Eaton (), Beto Moreno (), Umer Khan (), Tanu Hiremath (), Jonathan Luna (), Manik Mitra (), Chris Garcia (x)
Third-Party Reviewer: Jose de la Pena (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Ashton Lofquist (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables discussion a) P-D continues to be on-schedule b) 09/09/2021 – Draft copy of Technical Memo #1. c) Review meeting schedule i) P-D has provided an updated schedule summary of deliverables and project meetings, including the final date for Workshop #1 and suggested date for Workshop #2 ii) *Upon review, HCFCD will send the schedule summary to internal scheduling department 2) Next scheduled Monthly Progress meeting – 10/14/2021 3) Next scheduled Bi-Monthly Progress meeting – 09/23/2021 a) Workshop #1 to take place during this time i) *P-D will provide a copy of the Workshop #1 presentation to HCFCD by 09/17/2021 b) Workshop Agenda to follow by 09/10/2021 i) *P-D will provide a timeline of workshop discussion within the agenda ii) Decision made to allocate final half hour of Workshop #1 to open discussion
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No updates 2) HOA / Civic groups a) No updates 3) Harris County / HCFCD / COH a) Precinct 1 and 4 Meeting #1 discussion i) Intended to field knowledge of flooding complaints as well as any projects within the Precincts' jurisdictions that are in the planning stages and currently unknown to HCFCD ii) Decision made to not host joint meeting due to potential scheduling conflicts with Precinct staff b) *HCFCD will send "Save the Date" Invitations i) Decision made to consider suggested date of 09/29/2021 as earliest practical date for meetings. ii) Meetings will likely take place during the 1st week of October, pending coordination with Precinct staff and P-D

	iii) *P-D will send Ms. Stone of HCFCD an email with the original thoughts and descriptions regarding stakeholder meeting schedule c) *HCFCD will conduct internal discussion regarding possible rollout of a standard of appearance or "style guide" for reports and map exhibits to be shared with the public
III) Administrative	1) Monthly invoice a) Payment has been received by P-D b) Request from HCFCD Accounting to separate tasks into different line items on monthly invoice has been fulfilled by P-D
IV) Data Collection and Review	1) *HCFCD will send database of flooding complaints from the precincts upon discussion with Precinct Coordinators 2) *HCFCD will send construction plans for Detention Pond E516-01-00 which is located within the E116 subwatershed
V) H&H Analysis	1) Hydrology – progress to date a) No changes since previous Monthly Progress Meeting 2) Hydraulics – progress to date a) No changes since previous Monthly Progress Meeting 3) Potential survey needs a) No updates 4) Project Documentation a) *P-D will include a Microsoft Word document in the Technical Memo #1 Draft package to allow for comments or terminology updates from HCFCD in addition to the provided PDF b) Decision made to refer to the partnership between HCFCD and COH as an "informal partnership" or "close coordination" within Technical Memo #1 and further reports c) *P-D will create a catalog in a spreadsheet or other format to make documents for the E116 Subwatershed Planning Project searchable, particularly engineering reports and construction plans for critical structures within the subwatershed 5) Third Party Review a) High-level review anticipated to be complete by week of 09/13/2021-09/17/2021 b) *HCFCD will provide the latest version of the project scoring criteria to the reviewer
VI) Immediate Needs	1) No updates

ACTION ITEMS*:

I) 1) c) ii).	Upon review, HCFCD will send the schedule summary of deliverables and project meetings to internal scheduling department
I) 3) a) i)	P-D will provide a copy of the Workshop #1 presentation to HCFCD by 09/17/2021

I) 3) b) i)	P-D will provide a timeline of workshop discussion within the Workshop #1 agenda
II) 3) b)	HCFCD will send “Save the Date” invitations for Precinct 1 and 4 Meeting #1
II) 3) b) iii)	P-D will send Ms. Stone of HCFCD an email with the original thoughts and descriptions regarding stakeholder meeting schedule
II) 3) c)	HCFCD will conduct internal discussion regarding possible rollout of a standard of appearance or “style guide” for reports and map exhibits to be shared with the public
IV) 1)	HCFCD will send flood complaints database to P-D upon discussion with Precinct Coordinators
IV) 2)	HCFCD will send construction plans for Detention Pond E516-01-00 to P-D
V) 4) a)	P-D will include a Microsoft Word document in the Technical Memo #1 Draft package to allow for comments or terminology updates from HCFCD in addition to the provided PDF
V) 4) c)	P-D will create a catalog of documents for the E116 Subwatershed Planning Project and submit to HCFCD upon completion
V) 5) b)	HCFCD will provide the latest version of the project scoring criteria to the reviewer

DECISIONS MADE:

I) 3) b) ii)	Decision made to allocate final half hour of Workshop #1 to open discussion
II) 3) a) ii)	Decision made to not host joint meeting due to potential scheduling conflicts with Precinct staff
II) 3) b) i)	Decision made to consider suggested date of 09/29/2021 as earliest practical date for meetings with Precincts 1 and 4
V) 4) b)	Decision made to refer to the partnership between HCFCD and COH as an “informal partnership” or “close coordination” within Technical Memo #1 and further reports

Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001. **DATE:** 10/14/2021

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (), William Sherman (x), Beth Walters ()
COH: Adam Eaton (), Beto Moreno (), Umer Khan (), Tanu Hiremath (), Manik Mitra (x), Chris Garcia (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Saatvik Satyaprakash (x), Ashton Lofquist (x)

AGENDA TOPICS:	
I) Schedule Discussion	1) Schedule of milestones / deliverables a) P-D remains on schedule b) 10/21/2021 – Final copy of Technical Memo #1 i) *HCFCD will provide COH with the final copy upon submittal and internal review c) Review meeting schedule—Precinct 1 Meeting #1 i) *HCFCD will schedule a meeting with Precinct 1 2) Next scheduled Monthly Progress meeting – 11/11/2021 3) Next scheduled Bi-Monthly Progress meeting – 10/28/2021
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) It may be pertinent to schedule an informal, non-public meeting with the leadership of the Shepherd Park Terrace HOA to discuss the E116 SWPP and PD's individual SPT project once the E116 SWPP near- and long-term benefits have been identified. 3) Harris County / HCFCD / COH a) No update
III) Administrative	1) Monthly invoice a) The most recent invoice was sent by P-D the week of 10/4-10/8 b) P-D has received payment for the first two invoices
IV) Data Collection and Review	1) Flooding Complaints from precincts a) P-D requests a database of flooding complaints sourced from both Precinct 1 and Precinct 4 in addition to COH i) The flooding complaints will need to capture several years of storm events with a documented timeline ii) Data may not be collected by precincts since entire study area is within COH iii) *HCFCD will provide this data if available, from either the precincts or COH sources b) Flooding complaints will be discussed in Precinct 1 Meeting #1 2) Redevelopment reconciliation within structural inventory

	a) P-D has noted areas within the E116 subwatershed where structures are not included in the structural inventory, particularly within areas of redevelopment or recent development i) HCFCD has confirmed P-D possesses the most up-to-date iteration of the structural inventory b) The missing data is not likely to be a concern due to the higher standards the recent structures are built to in comparison to the surrounding developments
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Progress a) Existing conditions hydraulics are complete b) Hydraulics will be continued to be modeled with the proposal of potential flood risk reduction projects c) The E116 SWPP model includes a full hydrograph of E100-00-00 i) Decision made to model the subwatershed hydraulics disconnected from E100-00-00 in a "what-if" scenario to assess potential positive impacts of improvements within PA04 without the influence of E100-00-00 backwater 3) PA02 Potential Project Modeling Concerns a) P-D's SPT project models stormwater conveyance through a culvert junction beneath Wheatley St that directs flow into E116-01-00 and E116-05-00, which has the potential to be used to check the accuracy of the E116 hydraulic models b) P-D will model the benefits of capturing varying amounts of overflows from the intersection i) The SWPP model can portray subsurface conveyance modifications easily; however, a more intricate XP-SWMM model would more accurately account for storm drain inlets. 4) PA02 Potential Projects a) Addition of multiple large inlets to subsurface infrastructure at the intersection and potentially along feeder roads upstream might reduce overflows b) Addition of subsurface box culverts within the medians of Wheatley St and W Tidwell Rd c) Upstream detention to capture sheet flow traveling down Wheatley St d) Improvements to E116-01-00 and E116-05-00 to increase capacity 5) PA03 Potential Projects a) Combine HCFCD detention basin E516-01-00 with adjacent detention basin for Candlelight Place Sec. 4 i) Potentially use wet-bottom design for more storage b) Channel improvements to increase capacity in segments of E116-05-00 with limited level of service through steepening side slopes and deepening channel i) Potentially line channel with concrete—though undesirable, such an option is not forbidden and could prevent erosion c) Subsurface infrastructure to capture overflow from Pinemont Dr and potentially route south down Rosslyn Rd 6) PA04 Potential Projects a) Reduce overflow from Pinemont Dr flowing into the eastern portion of the Candlelight Woods neighborhood i) Capture with inlets and route subsurface system south down Mountwood St into E116-00-00

	b) Quantify voluntary buyouts based on repetitive losses, FEMA claims, or design storm 7) PA05 Potential Projects a) Despite concerns of localized sheet flow, improvements to upstream problem areas could possibly provide benefits b) Some clusters of predicted structural flooding are likely to not be influenced by improvements within the E116 subwatershed 8) PA06 Potential Projects a) Increased capacity of roadside ditches within the Baldo Place neighborhood may be an efficient flood reduction project b) Addition of subsurface infrastructure along De Soto St to capture overflows i) Potentially could outfall west into HCFCD open channel within PA10 c) Microdetention in open spaces within heavy sheet flow “zones” i) Use of microdetention in undeveloped areas near two radio antennae present within problem area ii) Challenged by potential outfall depths to nearby roadside ditches iii) Challenged by competition for land to be used for redevelopment 9) PA07 Potential Projects a) Channel improvements to E116-01-00 increase capacity and sheet flow acceptance speed b) Reducing overflows from W Tidwell Rd with subsurface infrastructure may produce trickle-down flood reduction benefits to Ella Park Terrace neighborhoods c) Detention storage in open space under the towers of the power transmission corridor in the SW corner of PA07 10) Micro-detention may be considered in multiple problem areas a) May provide immediate benefit to the problem area b) May provide downstream benefits to other problem areas
VI) Immediate Needs	1) No updates

ACTION ITEMS*:

I) 1) b) i)	HCFCD will provide COH with the final copy of Technical Memo #1 upon submittal and internal review
I) 1) c) i)	HCFCD will schedule Precinct 1 Meeting #1
IV) 1) a) iii)	HCFCD will provide flooding complaint data from Precincts 1 and 4 in addition to COH if available

DECISIONS MADE:

V) 2) c) i)	Model the subwatershed hydraulics disconnected from E100-00-00 in a “what-if” scenario to assess potential positive impacts of improvements within PA04 without the influence of E100-00-00 backwater

Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE: Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 10/28/2021

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (), Dena Green (), Myron Jones (x), William Sherman (), Beth Walters ()
COH: Adam Eaton (), Beto Moreno (), Umer Khan (x), Tanu Hiremath (x), Manik Mitra (), Chris Garcia (), Jonathan Luna (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Saatvik Satyaprakash (), Ashton Lofquist (x)

AGENDA TOPICS:

I) Schedule Discussion

1) Schedule of milestones / deliverables
   a) P-D remains on schedule
   b) 10/21/2021 – Final copy of Technical Memo #1
      i) *P-D will incorporate comments received from HCFCD
      ii) Decision made to incorporate terminology approved by HCFCD Communications within technical memos and further formal documentation rather than within the Summary Report alone
      iii) *HCFCD will send the final copy of Technical Memo #1 to COH and any interested representatives of the precincts upon address of comments by P-D
   c) Review meeting schedule—Precinct 1 Meeting #1
      i) Meeting scheduled for 11/2/2021 at 1:00PM
2) Next scheduled Monthly Progress meeting – 11/11/2021
   a) Decision made to reschedule meeting for 11/9/2021 at 10:00AM due to conflict with Veteran's Day holiday
3) Next scheduled Bi-Monthly Progress meeting – 11/25/2021
   a) Decision made to cancel meeting due to conflict with Thanksgiving holiday
4) December meeting conflicts with holidays
   a) Decision made to reschedule December Monthly and Bi-Monthly meetings due to conflicts with holidays
      i) December Monthly Progress meeting – 12/2/2021
      ii) December Bi-Monthly Progress meeting – 12/16/2021
5) *HCFCD will send out meeting rescheduling notices to P-D and COH

II) Stakeholder / Public Engagement

1) Traditional / Bond
   a) No update
2) HOA / Civic groups
   a) No update
3) Harris County / HCFCD / COH
   a) *P-D will inform HCFCD of any meetings, future actions and scope activities, and subsequent findings of the Shepherd Park Terrace project
   b) *COH will inform HCFCD and P-D of any upcoming public works projects located within the subwatershed

III) Administrative	1) Monthly invoice a) Invoice covers up to 10/22/2021 b) *P-D will deliver final copy of monthly invoice to HCFCD
IV) Data Collection and Review	1) Flooding Complaints from precincts/COH a) *HCFCD will check Precinct 1's log of drainage complaints and share any pertinent information with P-D b) *COH will research any drainage complaints within 311 calls or a formal database and share any findings with HCFCD and P-D
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Progress a) Due to concerns of using same excess rainfall data over entire subwatershed, higher infiltration rates were included in the RAS model for the northern areas of the subwatershed while lower infiltration rates were used for the southern areas to account for differences in development density i) Resulted in insignificant changes in WSEL b) No consistent comparison trend of flowrates can be made between MAAPnext and this planning project due to variability caused by differing methodologies 3) Potential Project Progress a) Modeling addition of storm drains along Pinemont Dr between Rosslyn Rd and Wheatley St resulted in expected flood reduction trends i) Potential project would likely not score well due to cost-benefit analysis b) *P-D will continue refining the level of service (LOS) for the modeled channels i) LOS may need to be revised as modeling potential projects routes errant sheet flow into open channels and reduces available capacity c) *P-D will investigate potentially performing field investigation of study area, including measurements channel and culvert at the upstream end of E116-05-00 d) *P-D will investigate potential locations and needed depths for microdetention basins in low-density development areas in northern areas of the subwatershed i) Concerns include a lack of outfall locations and potential complications due to outfall structure tailwater ii) Potentially develop a set of criteria for determination of future microdetention needs and possible locations iii) Open space immediately NW of the cluster of flooding along Maxroy Dr in PA06 would be likely candidate iv) Microdetention designed for storms more frequent than 1% AEP would be acceptable v) Microdetention areas could also be turned into public parks e) Reduction of overflow across Tidwell/Wheatley intersection i) Would provide significant flood reduction benefits ii) Project may not score as high as other potential projects f) Potential Project: Expanding existing open channel network, particularly with channels along the back of lots g) Potential Project: Optimizing E516-01-00 detention basin i) Could install additional inlets and expand volume by combining with adjacent detention basin ii) Allowing an increase in WSEL in E116-05-00, then mitigating with basin E516-01-00 would create adverse impacts due to segments of channel lacking extra capacity; however, such an approach may work in E116-00-00

	iii) Channel restoration and improvements for E116-05-00, such as lining or erosion mats, could make mitigation with E516-01-00 basin possible h) Potential Project: Detention basin in the open tract northwest of the confluence of E116-00-00 with E116-01-00 e) Potential Project: Detention basin in the open tract between Neiman Rd and W Donovan Rd in PA07 f) *P-D will investigate disconnecting regional sheet flow on a "what-if" basis to compare local and regional benefits to modeled potential projects
VII) Immediate Needs	1) No updates

ACTION ITEMS*:

I) 1) b) i)	P-D will incorporate comments received from HCFCD into final copy of Technical Memo #1
I) 1) b) iii)	HCFCD will send the final copy of Technical Memo #1 to COH and any interested representatives of the precincts upon address of comments by P-D
I) 5)	HCFCD will send out meeting rescheduling notices to P-D and COH
II) 3) a)	P-D will inform HCFCD of any meetings, future actions and scope activities, and subsequent findings of the Shepherd Park Terrace project
II) 3) b)	COH will inform HCFCD and P-D of any upcoming public works projects located within the subwatershed
III) 1) b)	P-D will deliver final copy of monthly invoice to HCFCD
IV) 1) a)	HCFCD will check Precinct 1's log of drainage complaints and share any pertinent information with P-D
IV) 1) b)	COH will research any drainage complaints within 311 calls or a formal database and any findings with HCFCD and P-D
V) 3) b)	P-D will continue refining the level of service (LOS) for the modeled channels
V) 3) c)	P-D will investigate potentially performing field investigation of study area, including measurements channel and culvert at the upstream end of E116-05-00
V) 3) d)	P-D will investigate potential locations and needed depths for microdetention basins in low-density development areas in northern areas of the subwatershed
V) 3) f)	P-D will investigate disconnecting regional sheet flow on a "what-if" basis to compare local and regional benefits to modeled potential projects

DECISIONS MADE:

I) 1) b) ii)	Decision made to incorporate terminology approved by HCFCD Communications within technical memos and further formal documentation rather than within the Summary Report alone

I) 2) a)	Decision made to reschedule next Monthly Progress meeting for 11/9/2021 at 10:00AM due to conflict with holiday
I) 3) a)	Decision made to cancel next Bi-Monthly Progress meeting on 11/25/2021 due to conflict with federal holiday
I) 4) a)	Decision made to reschedule December Monthly and Bi-Monthly meetings due to conflicts with holidays

Meeting Minutes

E116 Planning Project

MEETING TITLE:	Monthly Progress Meeting (via TEAMS) E116-00-00-P001	**DATE:**	11/09/2021
ATTENDEES: *Present = (x)*	HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green ( ), Myron Jones ( ), William Sherman ( ), Beth Walters ( ) COH: Beto Moreno ( ), Umer Khan (x), Tanu Hiremath ( ), Manik Mitra (x), Chris Garcia (x) P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Ashton Lofquist (x), Saatvik Satyaprakash (x)		

AGENDA TOPICS:	
I) Schedule Discussion	1) Schedule of milestones / deliverables a) 3/10/2022 – Draft copy of Technical Memo #2 b) *P-D will implement HCFCD comments into the final copy of Technical Memo #1 and submit to HCFCD by 11/19/2021 2) Next scheduled Monthly Progress meeting – 12/02/2021 3) Next scheduled Bi-Monthly Progress meeting – 12/16/2021
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) No update 3) Harris County / HCFCD / COH a) No update
III) Administrative	1) Monthly invoice a) No update 2) Work authorization for additional tasks has been received by P-D 3) Purchase order received by HCFCD 4) *P-D will send the most recent certificate of insurance to HCFCD as soon as it becomes available
IV) Data Collection and Review	1) Flooding complaints from precincts/COH a) 3-1-1 call database within planning project area of interest received by P-D from COH b) *P-D will prepare a summary of this data to be presented at a future meeting
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Progress 3) Project scoring a) A “homes with reduced flooding” metric will be added to the HCFCD project prioritization framework to more accurately reflect project effectiveness on reducing flooding impacts, instead of only counting those removed completely

	b) Decision made to include as many problem area and potential project metrics as were considered in the report in the event such information is needed in the future c) Decision made to report multi-family, commercial/industrial, and critical infrastructure separately from single-family residential i) *P-D will identify only the infrastructure that experiences inundation for ease of viewing in exhibits; tables will present the classified information

VI) Potential Project Improvements	1) Channel Improvements
	  a) Concrete lining, side slope, and culvert improvements modeled for E116-05-00 and E116-01-00
	    i) Significant reductions in WSEL observed
	    ii) No flow escaping the channels observed, lower tailwater improves efficiency of sheet flow entering channel
	    iii) Mitigation analysis still ongoing
	  b) E116 study area draining faster may not show impacts to White Oak Bayou based on timing
	    i) Acceptability of this condition will be based on further scrutiny and modeling
	    ii) Need to consider sensitivity of the timing with respect to storms of variable rainfall as opposed to only design storm
	  c) Auxiliary drainage improvements needed in conjunction with channel improvements to capture overland sheet flow
	2) Detention Basins
	  a) Potential Basin 1 – Open tract immediately north of E116-01-00 and Ella Park Terrace neighborhood
	    i) 30 ac of surface area with potential 15 ft of depth, 225 ac-ft of storage volume, outfall into E116-01-00
	    ii) No landfill or pipeline concerns
	  b) Potential Basin 2 – Open tract northwest of Maxroy Dr and Baldo Place neighborhood
	    i) Microdetention site with 13 ac-ft of storage and potential 3 ft of depth
	    ii) *P-D will investigate easement/ROW availability for maintenance access and outfall location
	    iii) *P-D will remove channel E116-05-05 from future exhibits
	  c) Potential Basin 3 – Open tract immediately west of E116-01-00 confluence with E116-00-00
	    i) 70 ac-ft of storage volume
	    ii) Concern over optics due to location of potential basin outside of formally defined study area boundary; however, only feasible outfall is E116-00-00
	  d) Coordination with HCFCD Property Department
	    i) *HCFCD will set up a meeting with Property Department to investigate any known concerns associated with open tracts considered for potential basins
	    ii) *P-D will provide an exhibit of the potential basin sites to HCFCD
	3) Storm Sewer Installation
	  a) *P-D will model the placement of a storm sewer within Wheatley, or an equivalent potential project

	b) *P-D will incorporate subsurface infrastructure recommendations from the Shepherd Park Terrace project into modeling i) Improvement or modification to the existing culvert junction box beneath Wheatley St could be a potential improvement 4) Expanded ROW Requirements
VII) Immediate Needs	1) No update

ACTION ITEMS*:

I) 1) b)	P-D will implement HCFCD comments into the final copy of Technical Memo #1 and submit to HCFCD by 11/19/2021
III) 4)	P-D will send the most recent certificate of insurance to HCFCD as soon as it becomes available
IV) 1) b)	P-D will prepare a summary of the 3-1-1 call database information to be presented at a future meeting
V) 3) c) i)	P-D will identify only the infrastructure that experiences inundation for ease of viewing in exhibits; tables will present the classified information
VI) 2) b) ii)	P-D will investigate easement/ROW availability for maintenance access and outfall location of Potential Basin 2
VI) 2) b) iii)	P-D will remove channel E116-05-05 from future exhibits
VI) 2) d) i)	HCFCD will set up a meeting with Property Department to investigate any known concerns associated with open tracts considered for potential basins
VI) 2) d) ii)	P-D will provide an exhibit of the potential basin sites to HCFCD
VI) 3) a)	P-D will model the placement of a storm sewer within Wheatley, or an equivalent potential project
VI) 3) b)	P-D will incorporate subsurface infrastructure recommendations from the Shepherd Park Terrace project into modeling

DECISIONS MADE:

V) 2) b)	Decision made to include as many problem area and potential project metrics as were considered in the report in the event such information is needed in the future
V) 2) c)	Decision made to report multi-family, commercial/industrial, and critical infrastructure separately from single-family residential

Meeting Minutes

E116 Planning Project

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 12/02/2021

ATTENDEES: *Present = (x)*

HCFCD: David Parkhill (x), Gary Bezemek ( ), Amy Stone (x), Dena Green ( ), Myron Jones ( ), William Sherman (x), Beth Walters ( )
COH: Beto Moreno ( ), Umer Khan (x), Tanu Hiremath (x), Manik Mitra (x), Chris Garcia (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Saatvik Satyaprakash (x), Ashton Lofquist (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 3/10/2022 – Draft copy of Technical Memo #2 2) Next scheduled Monthly Progress meeting – 01/13/2022 3) Next scheduled Bi-Monthly Progress meeting – 12/16/2021
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) No update 3) Harris County / HCFCD / COH a) COH does not typically pursue stakeholder engagements for rehab projects b) *COH will closely coordinate any ongoing or upcoming projects within the E116 study area that may impact the planning project
III) Administrative	1) Monthly invoice a) No update
IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis a) P-D has continued to refine the model for existing conditions b) P-D will compile a guide of methods and procedures used in this planning project to adapt the MAAPnext model for use in future feasibility studies in other locations at the conclusion of this project
VI) Potential Project Improvements	1) E118-00-00 Channel Improvements a) ROG analysis indicates flow from the offsite channel E118-00-00 is escaping the channel and causing inundation within the E116 study area b) E118-00-00 will connect with E116-05-04 to take flow west to E100-00-00 i) 12’ channel bottom width with 4:1 SS within a 100’ ROW ii) Channel improvements create significant benefits ranging from E100-00-00 to Wheatley St

iii) ROW may need to expand to 140’ in areas further downstream to the west where more open space is available
iv) Major culverts would need to be upsized
c) *P-D will investigate the need to expand problem area boundaries further west to account for areas and/or structures that may be influenced by the channel improvements
d) E118-00-00 is currently modeled solely within the ROG 2D mesh
i) Not modeled as 1D reach in MAAPnext
ii) Modeling E118 in 1D reach would likely produce similar results to the current ROG modeling

2) E116-00-00 and Northern Roadside Ditch Channel Improvements
a) E116-00-00 upsized to 100’ top width with 160’ ROW from De Soto St to the confluence with E100-00-00
i) P-D will verify the ROW limits of E116-00-00, at a point later in design
b) Roadside ditches upsized to 50’ top width along northern sides of De Soto St, Mansfield St, Paul Quinn St, and W Tidwell Rd
i) COH does not typically have roadside ditches deeper than 4’; otherwise, a dual system is used
ii) COH provided a rough cost estimate of $100/LF/roadside ditch to account for replacing driveways and culverts during construction of improvements
iii) *P-D will revise roadside ditch depth to 4’ and extend improvements further upstream to Wheatley St
c) Improvements to E116-00-00 in conjunction with the larger roadside ditches result in improvements downstream to Shepherd Park Terrace (SPT)
i) Significant improvements noted along W Tidwell Rd
ii) Improvements will likely lead to a partnership with COH based on ownership of easements and facilities
iii) *P-D will isolate the benefits associated with each major component of improvement projects to aid in partnership discussions

3) Wheatley/Tidwell Intersection Improvements
a) Extending roadside ditches along streets to the north [see VI) 2) b)] further upstream will reduce sheet flow entering the Wheatley/Tidwell intersection
b) Extension of E116-01-00 north along Wheatley St may contribute to resolving tailwater problems within SPT
c) *P-D will investigate the need to reduce the boundaries of PA01, PA02 and PA05

4) Southern Roadside Ditch Improvements
a) Adding a roadside ditch along Pinemont Dr provided significant improvement to roadway flooding, but limited benefits to the Ella Lee Forest neighborhood to the south
i) *P-D will expand the ditch further east to Wheatley St
b) *P-D will investigate whether adding a swale through a bought-out home or installing a storm sewer to capture sheet flow along Del Norte Dr and route south along Oak Forest Dr will provide flood reduction benefits to the Ella Lee Forest neighborhood

5) E116-05-00 Channel and Culvert Improvements
a) Improved channel maintenance may improve conveyance without raising environmental concerns associated with altering channel side slopes

	b) Lining the channel with concrete and optimizing the culvert within E116-05-00 at the Lehman Rd/Ella Blvd intersection has produced reduced water surface elevation within the channel in the models c) *P-D will model the connection of any storm sewers under the cul-de-sacs in the Candlelight Estates neighborhood, located between E116-05-00 and Bethlehem St, to their outfall in E116-05-00 6) Storm Drain at Maxroy Street a) Concept discussed as part of VI) 4) b) 7) Utility conflicts a) Cost estimating tool provided to P-D as part of Spring Gully project provides unit prices for a variety of types and sizes for potential utility conflicts b) As analysis of potential projects progresses, specific utility conflicts will be identified and included in opinions of probable construction cost
VII) Immediate Needs	1) No update

ACTION ITEMS*:	
II) 3) b)	COH will closely coordinate any ongoing or upcoming projects within the E116 study area that may impact the planning project
VI) 1) c)	P-D will investigate the need to expand problem area boundaries further west to account for structures influenced by E118-00-00 channel improvements.
VI) 2) b) iii)	P-D will revise roadside ditch depth to 4' and expand improvements to Wheatley St
VI) 2) c) iii)	P-D will isolate the benefits associated with each major component of improvement projects to aid in partnership discussions
VI) 3) c)	P-D will investigate the need to reduce the boundaries of PA01, PA02 and PA05
VI) 4) a) i)	P-D will expand the roadside ditch along Pinemont Dr further east to Wheatley St
VI) 4) b)	P-D will investigate whether adding a swale through a bought-out home or installing a storm sewer to capture sheet flow along Del Norte Dr and route south along Oak Forest Dr will provide flood reduction benefits to the Ella Lee Forest neighborhood
VI) 5) c)	P-D will model the connection of any storm sewers under the cul-de-sacs in the Candlelight Estates neighborhood, located between E116-05-00 and Bethlehem St, to their outfall in E116-05-00

Meeting Minutes

E116 Planning Project

MEETING TITLE: Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 12/16/2021

ATTENDEES: *Present = (x)*

HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone ( ), Dena Green (x), Myron Jones ( ), William Sherman ( ), Beth Walters ( )
COH: Beto Moreno (x), Umer Khan ( ), Tanu Hiremath ( ), Manik Mitra (x), Chris Garcia (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Saatvik Satyaprakash ( ), Ashton Lofquist (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 3/10/2022 – Draft copy of Technical Memo #2 2) Next scheduled Monthly Progress meeting – 01/13/2022 3) Next scheduled Bi-Monthly Progress meeting – 01/27/2022
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) The Shepherd Park Terrace neighborhood association has requested a briefing on the E116 Planning Project i) Final SPT project report submitted to COH ii) E116 Planning Project does not have a detailed, feasible solution available at present to provide iii) *HCFCD will determine the best plan to execute this meeting request 3) Harris County / HCFCD / COH a) No update
III) Administrative	1) Monthly invoice a) Monthly invoice resubmitted b) Transition to new software platform anticipated at a later date i) Not likely to have a significant impact on P-D
IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis

VI) Potential Project Improvements	1) E118-00-00 channel improvements a) *P-D will investigate an alternative of performing no action on E118-00-00 2) E116-00-00 and roadside ditch channel improvements a) Roadside ditches along Pinemont Dr, Paul Quinn Rd, Mansfield St, and De Soto St expanded east to Wheatley Street, providing significant flood reduction benefits; all terminate at E116-00-00 rather than E100-00-00 b) E116-00-00 additional improvements along the east-west reach include 4:1 SS above the bottom 1-1.5’ of channel depth, using 100-120’ ROW, before ceasing near the Candlelight Woods neighborhood i) *P-D will investigate optimizing the downstream end of E116-00-00 near the confluence with E100-00-00 to determine any significant flood reduction benefits in the 10- and 25-year storms in addition to the 100-year; this consideration will be completed as part of the final recommendation for proposed projects ii) P-D may have the option to expand channel improvements into the maintenance berm of the east-west segment of E116-00-00, if the Infrastructure Team at HCFCD agrees iii) *P-D will include HCFCD Detention Basin E516-00-00 and a potential detention basin, at the confluence of E116-00-00 and E116-01-00, in the model as potential mitigation for the channel improvements, as the project progresses to final recommendations c) Decision made to note in the final report of this project that continuation of above mentioned E116-00-00 channel improvements [see VI) 2) b)] downstream to the confluence with E100-00-00 could be considered in the PER d) Due to concern of flooding impacts on high-density residential areas in the southern portions of the study area, it may be necessary to determine feasible potential improvements from the south to the north i) High-level cost estimates of the E116-00-00 channel and roadside ditch improvements will be provided at a later date ii) Cost evaluations will be performed at a later date to determine the feasibility of constructing back-of-lot drainage ditches as opposed to roadside ditches 3) Wheatley/Tidwell intersection improvements a) Final SPT report i) Report results provide options under two different assumptions regarding sheet flow entering the project site from outside the boundary ii) Further guidance from COH will be necessary to identify the planned course of action for coordination with the E116 recommendations b) Sheet flow entering SPT through intersection in existing condition can be partially intercepted using improvements discussed above [see VI) 2) a)] before reaching intersection 4) E116-05-00 channel and culvert improvements a) Storm sewers under the cul-de-sacs in the Candlelight Estates neighborhood, located between E116-05-00 and Bethlehem St, were connected to E116-05-00, which led to reductions in water surface elevation in several cul-de-sacs 5) Improvements to Ella Lee Forest neighborhood a) Roadside ditches along Pinemont Dr discussed as part of VI) 2) a)

	b) A roadside ditch along Del Norte Dr, located east of the Candlelight Place neighborhood, from Covington Dr to Oak Forest Dr and south along Oak Forest Dr to E116-05-00 did not provide any significant benefits i) Sheet flow is attempting to travel north to Pinemont Dr due to general lay-of-the-land ii) May see more significant benefits if ditch size was increased c) A roadside ditch along Del Norte Dr from Oak Forest Dr to E116-05-00 near Wheatley St did not provide any significant benefits i) May see more significant benefits if ditch size was increased 6) Problem area boundaries will be adjusted at a later date
VII) Immediate Needs	1) No update
ACTION ITEMS*:	
II) 2) a) iii)	HCFCD will determine the best plan to execute the meeting request from the neighborhood association of Shepherd Park Terrace
IV) 1) a)	P-D will investigate an alternative of performing no action on E118-00-00
IV) 2) b) i)	P-D will investigate optimizing the downstream end of E116-00-00 near the confluence with E100-00-00 to determine any significant flood reduction benefits in the 10- and 25-year storms in addition to the 100-year; this consideration will be completed as part of the final recommendation for proposed projects
IV) 2) b) iii)	P-D will include HCFCD Detention Basin E516, at the confluence of E116-00-00 and E116-05-00, and a potential detention basin, at the confluence of E116-00-00 and E116-01-00, in the model as potential mitigation for the channel improvements, as the project progresses to final recommendations
DECISIONS MADE:	
VI) 2) c)	Decision made to note in the final report of this project that continuation of E116-00-00 channel improvements [see VI) 2) b)] downstream to the confluence with E100-00-00 could be considered in the PER

Meeting Minutes

E116 Planning Project

MEETING TITLE: Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 01/13/2022

ATTENDEES: *Present = (x)*

HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green ( ), Myron Jones (x), William Sherman ( ), Beth Walters ( )
COH: Beto Moreno (), Umer Khan (x), Tanu Hiremath ( ), Manik Mitra (), Chris Garcia (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Saatvik Satyaprakash (x), Ashton Lofquist (x)

AGENDA TOPICS:	
I) Schedule Discussion	1) Schedule of milestones / deliverables a) 03/10/2022 – Draft copy of Technical Memo #2 b) 03/17/2022 – Workshop #2 2) Next scheduled Monthly Progress meeting – 02/10/2022 3) Next scheduled Bi-Monthly Progress meeting – 01/27/2022 4) Discuss potential revisions to sequencing of future meetings a) Decision made to modify meeting sequencing: 1) Workshop 2) COH meeting 3) Precincts 1 and 4 meeting 4) HCFCD executive briefing b) *HCFCD will verify the official approval timeline for the imminent precinct boundary update and inform P-D of updates applicable to the planning project c) *P-D will send out the most up-to-date iteration of the baseline schedule, with the modified meeting sequence
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) COH and Councilmember will be primary organizers ii) HCFCD and P-D will contribute information regarding E116 Planning Project upon request 3) Harris County / HCFCD / COH a) No update to meetings b) Shepherd Park Terrace Project i) Final SPT report provides alternatives based on assumptions related to sheet flow entering the project area ii) Final decision regarding which alternative will proceed will be made in conjunction with PER technical consultant, which has not yet been named iii) COH anticipates that SPT project will ignore the influence of sheet flow from outside the project area
III) Administrative	1) Monthly invoice a) Invoice has been submitted to HCFCD b) *P-D will make QC forms and senior-level participation documentation available to HCFCD
IV) Data Collection and Review	1) No update

V) H&H Analysis

1) Hydrology: Complete
2) Hydraulics: Alternatives Analysis
   a) South to north analysis approach may be appropriate to determine project phasing during watershed strategy development
   b) North to south approach is appropriate for alternatives analysis

VI) Potential Project Improvements

1) E118-00-00 Channel Improvements
   a) Comparison of other proposed improvements with and without improvements to E118-00-00
      i) Benefits without E118-00-00 are reduced, particularly in the northern portions of the study area during the 10% AEP storm, and reduced further into the study area during the 1% AEP storm
      ii) Improvements to E118-00-00 can influence up to ¾ of a mile into the study area
   b) Decision made to continue considering E118-00-00 improvements, despite concerns of the channel located primarily outside of defined study area boundary, until flood reduction benefits are determined
      i) Should a future decision be made to exclude E118-00-00 as a potential improvement, it should be documented in the PER that such improvements would likely be a good basis for future study
   c) Channel improvements to E118-00-00 currently produce a 10-year level of service and do not adversely impact E100-00-00 due to timing
      i) *P-D will analyze sensitivity of timing within the model on E100-00-00 performance and potential for adverse impacts
      ii) *P-D will determine if improvements to E118-00-00 can attain a 10-year level of service within current ROW
      iii) Decision made to include 4% AEP (25-year) storm in analysis despite not being part of the formal metrics
2) E116-00-00 Channel Improvements
   a) Optimizing detention basin E516-00-00 may be a viable means of providing mitigation for proposed channel improvements
   b) Detention basins may need to be among the first recommended projects due to redevelopment pressure
3) Structure counts
   a) 10% AEP Floodplain
      i) Structural flooding removed from 18 structures for proposed potential projects when E118-00-00 improvements are included
      ii) Structural flooding removed from 16 structures for proposed potential projects when E118-00-00 improvements are not included
   b) 1% AEP Floodplain
      i) Structural flooding removed from 39 structures for proposed potential projects when E118-00-00 improvements are included
      ii) Structural flooding removed from 30 structures for proposed potential projects when E118-00-00 improvements are not included
   c) *P-D will determine count of structures with reduced flooding, even if not removed completed, before the next meeting

VII) Immediate Needs

1) No update

ACTION ITEMS*:	
I) 4) b)	HCFCD will verify the official approval timeline for the imminent precinct boundary update and inform P-D of updates applicable to the planning project
I) 4) c)	P-D will send out the most up-to-date iteration of the baseline schedule, with the modified meeting sequence
III) 1) b)	P-D will make QC forms and senior-level participation documentation available to HCFCD
VI) 1) c) i)	P-D will analyze sensitivity of timing within the model on E100-00-00 performance and potential for adverse impacts
VI) 1) c) ii)	P-D will determine if improvements to E118-00-00 can attain a 10-year level of service within current ROW
VI) 3) c)	P-D will determine count of structures with reduced flooding, even if not removed completed, before the next meeting

DECISIONS MADE:	
I) 4) a)	Decision made to modify meeting sequencing: 1) Workshop 2) COH meeting 3) Precincts 1 and 4 meeting 4) HCFCD executive briefing
VI) 1) b)	Decision made to continue considering E118-00-00 improvements, despite concerns of the channel located primarily outside of defined study area boundary, until flood reduction benefits are determined
VI) 1) c) iii)	Decision made to include 4% AEP (25-year) storm in analysis despite not being part of the formal metrics

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Meeting Minutes

E116 Planning Project

MEETING TITLE: Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 01/27/2022

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (), William Sherman (x), Beth Walters ()
COH: Beto Moreno (), Umer Khan (), Tanu Hiremath (), Manik Mitra (x), Chris Garcia (x), Rita Bellard (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Saatvik Satyaprakash (x), Ashton Lofquist (x)

AGENDA TOPICS:	
I) Schedule Discussion	1) Schedule of milestones / deliverables a) 03/10/2022 – Draft copy of Technical Memo #2 b) 03/17/2022 – Workshop #2 2) Next scheduled Monthly Progress meeting – 02/10/2022 a) *Ben Setterbo and/or Raquel Escatel from P-D SPT project to attend 3) Next scheduled Bi-Monthly Progress meeting – 02/24/2022 a) Potential for postponement due to scheduling conflict
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace meeting request i) *HCFCD will set up a briefing with Precinct 1 to address meeting request with SPT HOA 3) Harris County / HCFCD / COH a) No update
III) Administrative	1) Monthly invoice a) No update
IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis
VI) Potential Project Improvements	1) Various channel improvements a) Proposed ditch running N/S along Wheatley St connecting the Wheatley/Tidwell intersection with E116-01-00 resulted in significant flood reductions i) Benefits from improvements observed starting in the 4% AEP storm event ii) WSEL reductions observed within channel itself despite increased flow b) Proposed improvements to small channel E116-05-03 south of SPT also result in flood reduction benefits i) Benefits observed starting in 4% AEP storm event

	ii) Would require some upgrades to the junction box beneath Wheatley that directs subsurface flow from SPT to E116-01-00 and E116-05-00 c) Decision by HCFCD to be made at a later date if E118-00-00 improvements should be considered part of the watershed strategy i) *P-D will develop a high-level OPCC for E118-00-00 improvements to be presented at next meeting 2) Shepherd Park Terrace a) Construction of townhomes adjacent to SPT may prevent some sheet flow in Wheatley/Tidwell intersection from entering SPT b) *COH will determine impacts on improvements to subsurface drainage pursuant to SPT project report c) *P-D will determine if improvements to channel E116-05-02.1, such as a buried storm sewer beneath the swale, could provide benefits 3) Structure counts a) Problem Areas redefined to limits of benefits from potential project improvements led to revised existing condition metrics i) PA01, PA02, and PA05 boundaries reduced; PA118 added to assess effects of E118-00-00 improvements b) 34 structures removed from 1% AEP floodplain; 20 structures removed from 2% AEP floodplain c) Looking solely at structure counts, E118-00-00 improvements don't appear to have a significant effect; however, widespread WSEL reductions observed 4) ROW discussion a) New HCFCD photogrammetry indicates open tracts are beginning to become unavailable i) *HCFCD will follow up on meeting request with Property Department to discuss open tracts for potential detention basins b) *P-D will document in PER that E116-00-00 north of Tidwell is heavily overgrown and requires regular maintenance i) *P-D will verify property ownership of channels discussed above [see VI) 1) b) and VI) 2) c)] as well as E118-00-00 and northern segments of E116-00-00 to determine HCFCD's maintenance requirements
VII) Immediate Needs	1) No update

ACTION ITEMS*:

I) 2) a)	P-D to invite Ben Setterbo and/or Raquel Escatel from P-D SPT project to attend next meeting
II) 2) a) i)	HCFCD will set up a briefing with Precinct 1 to address meeting request with SPT HOA
VI) 1) c) i)	P-D will develop a high-level OPCC for E118-00-00 improvements to be presented at next meeting
VI) 2) b)	COH will determine impacts on improvements to subsurface drainage pursuant to SPT project report

VI) 2) c)	P-D will determine if improvements to channel E116-05-02.1, such as a buried storm sewer beneath the swale, could provide benefits
VI) 4) a) i)	HCFCD will follow up on meeting request with Property Department to discuss open tracts for potential detention basins
VI) 4) b)	P-D will document in PER that E116-00-00 north of Tidwell is heavily overgrown and requires regular maintenance
VI) 4) b) i)	P-D will verify property ownership of channels discussed above [see VI) 1) b) and VI) 2) c)] as well as E118-00-00 and northern segments of E116-00-00 to determine HCFCD's maintenance requirements

DECISIONS MADE:

Meeting Notes

E116 Planning Project

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 02/10/2022

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (), Beth Walters ()
COH: Beto Moreno (), Umer Khan (x), Tanu Hiremath (), Manik Mitra (x), Chris Garcia (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Erin Stiggins (x), Ken Nwankpa (x), Saatvik Satyaprakash (x), Ben Setterbo (x), Raquel Escatel (x), Ashton Lofquist (x)

AGENDA TOPICS:	
I) Schedule Discussion	1) Schedule of milestones / deliverables a) 03/10/2022 – Draft copy of Technical Memo #2 b) 03/24/2022 – Workshop #2 i) Decision made to postpone Workshop #2 from 03/17/2022 to 03/24/2022 due to scheduling conflict ii) *HCFCD will distribute "Save the Date" invitations 2) Next scheduled Monthly Progress meeting – 03/03/2022 a) Decision made to reschedule meeting from 03/10/2022 to 03/03/2022 due to scheduling conflict 3) Next scheduled Bi-Monthly Progress meeting – 03/24/2022 a) Decision made to cancel meeting on 02/24/2022 pursuant to rescheduling of March Monthly Progress meeting b) Workshop #2 will take place during this time 4) Project Transitions a) Zubin Sukheswalla to take over duties as Project Manager from Erin Stiggins b) Adding Ken Nwankpa as Deputy Project Manager
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update ii) First fully public meeting anticipated to take place in May or June at the earliest 3) Harris County / HCFCD / COH a) *HCFCD will arrange internal coordination meeting with HCFCD Communications department regarding stakeholder engagement
III) Administrative	1) Monthly invoice a) Monthly invoice submitted to HCFCD b) *P-D will notify HCFCD Accounting department of summary table revision on monthly invoice

IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis
VI) Potential Project Improvements	1) Conceptual-Level OPCC a) Network of potential project improvements will need to be constructed downstream-to-upstream to provide adequate capacity b) Conceptual OPCC does not include cross-culvert pricing at present c) *P-D will provide a refined, tabulated OPCC at a later date d) Use of concrete lining for channels with the existing ROW may be similar in cost to acquiring additional ROW; however, other considerations may arise e) *P-D will develop an OPCC for excavation within existing ROW in addition to an OPCC for expanded ROW necessary for desired level of service 2) Shepherd Park Terrace Improvements Discussion a) SPT project recommends removal of lateral storm drains located within lots, expansion of the storm drain trunk line, and addition of storm drains located within streets i) No improvements to E116-05-03 recommended in project report due to additional street storm drains creating a longer path of storage b) Improvements to E116-05-03 to lower the flowline would improve flooding in SPT during large storm events, particularly related to increased outfall depth c) *HCFCD will provide submittal documentation for the developments under construction adjacent to SPT d) Building a wall on W Tidwell Rd to block or reduce incoming sheet flow would improve flooding in SPT; however, the potential for adverse impacts from the diversion must be evaluated e) Improvements suggested for W Tidwell Rd i) Depressing the medians within Tidwell and routing sheet flow through subsurface pipes towards Wheatley St would reduce increased street flooding resultant of wall construction ii) An existing storm drain system is located beneath the Tidwell medians and drains east toward E101-00-00 iii) *P-D will incorporate this existing storm drain system into models as it may alter predicted overflow into SPT iv) *P-D will investigate if additional subsurface storm drain capacity within Wheatley St would reduce sheet flow flooding in the area as an alternative to the long ditches that convey water all the way west to E116-00-00 3) ROW Discussion a) Potential detention basins i) Most promising potential basin site, immediately west of the E116-00-00 confluence with E116-01-00, would be smaller than initially thought due to antenna trenches and utilities ii) *P-D will prepare a "what-if" scenario for any potential basin site to identify an alternative in case the site becomes unavailable due to redevelopment iii) *P-D will research plans for the private detention pond adjacent to basin E516-01-00

	b) *P-D will modify Manning's n-values within models to reflect segments of E116-00-00 that are heavily overgrown c) E116-00-00 north of Paul Quinn St is not within HCFCD ROW i) *P-D will note in report that identification and possible transfer of ROW ownership and/or property rights to HCFCD will need to occur before improvements to E116-00-00 in this area can be made 4) Potential Project Improvements Final Selection a) Channel improvements to E116-00-00, E116-01-00, and E116-05-00 b) Improvements to roadside ditches along Paul Quinn St, Mansfield St, and De Soto St c) Detention Basin E516-01-00 optimization d) Localized potential project improvements to be refined e) *P-D will consider E118-00-00 improvements a long-term project f) *P-D will identify in report for phasing purposes which potential project improvements can be made by HCFCD without the need for partnerships with COH or other stakeholders
VII) Immediate Needs	1) No update

ACTION ITEMS*:	
I) 1) b) ii)	HCFCD will distribute "Save the Date" invitations for the rescheduled Workshop #2
II) 3) a)	HCFCD will arrange internal coordination meeting with HCFCD Communications department regarding stakeholder engagement
III) 1) b)	P-D will notify HCFCD Accounting department of summary table revision on monthly invoice
VI) 1) c)	P-D will provide a refined, tabulated OPCC at a later date
VI) 1) e)	P-D will develop an OPCC for excavation within existing ROW in addition to an OPCC for expanded ROW necessary for desired level of service
VI) 2) c)	HCFCD will provide submittal documentation for the developments under construction adjacent to SPT
VI) 2) e) iii)	P-D will incorporate the existing storm drain system beneath W Tidwell Rd draining toward E101-00-00 into models as it may alter predicted overflow into SPT
VI) 2) e) iv)	P-D will investigate if additional subsurface storm drain capacity within Wheatley St would reduce sheet flow flooding in the area as an alternative to the long ditches that convey water all the way west to E116-00-00
VI) 3) a) ii)	P-D will prepare a "what-if" scenario for any potential basin site to identify an alternative in case the site becomes unavailable due to redevelopment

VI) 3) a) iii)	P-D will research plans for the private detention pond adjacent to basin E516-01-00
VI) 3) b)	P-D will modify Manning's n-values within models to reflect segments of E116-00-00 that are heavily overgrown
VI) 3) c) i)	P-D will note in report that identification and possible transfer of ROW ownership and/or property rights to HCFCD will need to occur before improvements to E116-00-00 north of Paul Quinn St can be made
VI) 4) e)	P-D will consider E118-00-00 improvements a long-term project
VI) 4) f)	P-D will identify in report for phasing purposes which potential project improvements can be made by HCFCD without the need for partnerships with COH or other stakeholders

DECISIONS MADE:	
I) 1) b) i)	Decision made to postpone Workshop #2 from 03/17/2022 to 03/24/2022 due to scheduling conflict
I) 2) a)	Decision made to reschedule next Monthly Progress meeting from 03/10/2022 to 03/03/2022 due to scheduling conflict
I) 3) a)	Decision made to cancel Bi-Monthly meeting on 02/24/2022 pursuant to rescheduling of March Monthly Progress meeting

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Meeting Notes

E116 Planning Project

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 03/03/2022

ATTENDEES: *Present = (x)*

HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (), Beth Walters ()
COH: Beto Moreno (), Umer Khan (x), Tanu Hiremath (), Manik Mitra (), Chris Garcia (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Ken Nwankpa (x), Saatvik Satyaprakash (x), Ben Setterbo (x), Raquel Escatel (x), Ashton Lofquist (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 03/31/2022 – Draft copy of Technical Memo #2 b) 03/24/2022 – Workshop #2 2) Next scheduled Monthly Progress meeting – 04/14/2022 3) Next scheduled Bi-Monthly Progress meeting – 03/24/2022 a) Workshop #2 to take place during this time b) *P-D will send an agenda to HCFCD at least a week prior to Workshop #2 c) *HCFCD will arrange meeting with P-D to discuss workshop agenda and presentation
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update ii) A meeting between COH and the councilmember to discuss the SPT project anticipated to take place in May or June 3) Harris County / HCFCD / COH a) *HCFCD will arrange internal coordination meeting to brief HCFCD Executive Team prior to the meeting with SPT HOA
III) Administrative	1) Monthly invoice a) *P-D will submit monthly invoice to HCFCD
IV) Data Collection and Review	1) *HCFCD will send submittal documentation found through coordination with COH for the Wheatley St/Tidwell Rd area to P-D
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis

VI) Potential Project Improvements	1) Overall Modeling Updates a) Storm sewers along Tidwell Rd incorporated into hydraulic models for all conditions i) Reduced flooding depths observed in SPT as a result b) E118 removed from all modeling since no real impacts seen from it for existing or proposed conditions in E116 subwatershed c) Problem area boundaries renamed and refined to limits of measurable benefits from potential projects i) *P-D will continue to refine problem areas based on potential project revisions 2) Problem Area project discussion a) PA01, containing SPT i) Improvements to E116-05-03 immediately south of SPT to include concrete lining and expansion of outfall junction box to minimize head loss showed some minor improvements ii) Interconnected microdetention basins within the roadway medians near the Wheatley St/Tidwell Rd intersection, using E116-01-00 as an outfall helped reduce flooding depts in SPT and surrounding area b) PA02, containing E116-00-00 and E116-05-00 i) Expansion of box culvert along E116-05-00 at Ella Blvd/Lehman Rd intersection prevents existing backwater flooding in SPT area due to constriction ii) E116-05-00 channel restoration/maintenance from Rosslyn Rd to Ella Blvd to address siltation and provide more capacity to carry additional flow released due to culvert upsizing in VI.2.b.i. iii) Upsize storm sewers draining the Ella Blvd/Pinemont Dr intersection and maintenance of existing ditches and expansion in select locations of roadside ditches in the Ella Lee Forest neighborhood while improving outfalls to E116-05-00 to help with local neighborhood drainage c) PA03, containing Candlelight Woods neighborhood i) Recommendations for future improvements to E100-00-00 and/or home buyouts due to extent of E100-00-00 backwater d) PA04, containing E116-00-00 and E116-01-00 i) Improvements to E116-00-00 and upsizing of culvert crossing at Tidwell Rd to increase capacity ii) Addition of a roadside ditch on the north side of Tidwell Rd, tying in with the culvert crossing of E116-00-00, to reduce roadway flooding iii) *P-D will research depth and location of storm sewers along Tidwell Rd near crossing at E116-00-00 for potential use of median microdetention e) PA05, containing northern regions of study area i) Improvements to E116-00-00 to increase capacity ii) Roadside ditches along Paul Quinn St, Mansfield St, and De Soto St draining east to west from Wheatley St to E116-00-00 to intercept sheet flow f) *P-D will develop a hydraulic model demonstrating cumulative impacts of the revised potential projects in suggested project sequence 3) Detention Pond Sites a) Most feasible location for proposed detention pond is an open tract to the west of the confluence of E116-00-00 and E116-01-00

	i) Small open area immediately north may provide space for detention devoid of radio towers while still using E116-00-00 as an outfall
VII) Immediate Needs	1) No update

ACTION ITEMS*:	
I) 3) b)	P-D will send an agenda to HCFCD at least a week prior to Workshop #2
I) 3) c)	HCFCD will arrange meeting with P-D to discuss workshop agenda and presentation
II) 3) a)	HCFCD will arrange internal coordination meeting to brief HCFCD Executive Team prior to the meeting with SPT HOA
III) 1) a)	P-D will submit monthly invoice to HCFCD
IV) 1)	HCFCD will send submittal documentation found through coordination with COH for the Wheatley St/Tidwell Rd area to P-D
VI) 1) b) i)	P-D will continue to refine problem areas based on potential project revisions
VI) 2) d) iii)	P-D will research depth and location of storm sewers along Tidwell Rd near crossing at E116-00-00 for potential use of median microdetention
VI) 2) f)	P-D will develop a hydraulic model demonstrating cumulative impacts of the revised potential projects in suggested project sequence

DECISIONS MADE:	

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Meeting Notes

E116-00-00 Flood Reduction Feasibility Study

MEETING TITLE: **Monthly Progress Meeting (via TEAMS)** **DATE: 04/14/2022**
E116-00-00-P001

ATTENDEES: ***Present = (x)***

HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (), Beth Walters ()
COH: Beto Moreno (), Umer Khan (), Tanu Hiremath (), Manik Mitra (x), Chris Garcia (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Ken Nwankpa (), Saatvik Satyaprakash (x), Ben Setterbo (), Raquel Escatel (x), Ashton Lofquist (x)
Dry Land: Erin Stiggins (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 03/24/2022 – Workshop #2 completed b) 03/31/2022 – Technical Memo #2 delivered c) 04/13/2022 – TWDB data delivered d) 04/28/2022 – Draft of Final Engineering Report i) Date subject to change due to 100-year hydraulic system capacity analysis ii) Geodatabase of Spatial Features schedule to correspond with Final Engineering Report schedule 2) Next scheduled Monthly Progress meeting – 05/12/2022 3) Next scheduled Bi-Monthly Progress meeting – 04/28/2022
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update 3) Harris County / HCFCD / COH a) *HCFCD will distribute the Technical Workshop #2 presentation and meeting minutes to attendees i) HCFCD has confirmed these items have been sent to COH for internal distribution b) *HCFCD will organize meetings with Precinct 1 and the HCFCD Executive Board to discuss project progress and findings i) Precinct 1 meeting anticipated to take place in 2-3 weeks ii) HCFCD Executive Board meeting anticipated to take place in 4-6 weeks c) Decision made to no longer involve Precinct 4 in further feasibility study meetings and reports due to precinct boundary change
III) Administrative	1) Monthly invoice a) P-D remains on track for project schedule and budget b) Work Authorization #3 received

IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: a) Alternatives Analysis Complete b) 100-year hydraulic system capacity discussion i) Concern posed regarding use of “level of service” terminology due to clarity of understanding for public audiences ii) Decision made to define “level of service” in feasibility study documentation rather than replace terminology until further advised by HCFCD Communications department
VI) Potential Project Improvements	1) 100-year Hydraulic System Capacity Improvements a) Sheet flow within study area cannot fully reach open channel infrastructure to be captured i) Recommending sites of redevelopment be placed on pier-and-beam foundations would allow sheet flow to travel through the site without negatively affecting neighboring properties ii) Grading improvements on individual lots would likely be primary means of moving sheet flow to capturing infrastructure to attain a 100-year level of service b) Decision made to consider the 100-year level of service to be limited to HCFCD channels i) Assume all sheet flow reaches open channel infrastructure ii) Assume a future extension of the E116-00-00 channel and new E116 tributaries proposed iii) Assume E118-00-00 has a 100-year strategy in place to prevent overflow iv) Assume outflows from the E116-00-00 study area are contained within the study area c) *P-D will develop a 100-year level of service proposal of methodology and submit to HCFCD via email for approval d) Documentation of 100-year level of service analysis to include the following: i) Recognition that lot regrading would be necessary for sheet flow to reach improved channels ii) Cost estimate limited to the drainage improvements rather than including utility relocation, etc. iii) Qualitative discussion of challenges imposed by rapid redevelopment and potential recommendations for regulatory entities
VII) Immediate Needs	1) No update

ACTION ITEMS*:

II) 3) a)	HCFCD will distribute the Technical Workshop #2 presentation and meeting minutes to attendees

II) 3) b)	HCFCD will organize meetings with Precinct 1 and the HCFCD Executive Board to discuss project progress and findings
IV) 1) c)	P-D will develop a 100-year level of service proposal of methodology and submit to HCFCD via email for approval

DECISIONS MADE:	
II) 3) c)	Decision made to no longer involve Precinct 4 in further feasibility study meetings and reports due to precinct boundary change
V) 2) b) ii)	Decision made to define "level of service" in feasibility study documentation rather than replace terminology until further advised by HCFCD Communications department
VI) 1) b)	Decision made to consider the 100-year level of service to be limited to HCFCD channels

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Meeting Notes

E116-00-00 Flood Reduction Feasibility Study

MEETING TITLE: **Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001** **DATE:** **04/28/2022**

ATTENDEES: ***Present = (x)***

HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (x), Beth Walters ()
COH: Beto Moreno (), Umer Khan (), Tanu Hiremath (), Manik Mitra (), Chris Garcia (), Ratish Subedi (x)
P-D: Lonnie Anderson (x), Zubin Sukheswalla (x), Ken Nwankpa (x), Saatvik Satyaprakash (x), Ben Setterbo (), Raquel Escatel (), Ashton Lofquist (x)
Dry Land: Erin Stiggins ()

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 05/06/2022 – Draft of Final Engineering Report 2) Next scheduled Monthly Progress meeting – 05/12/2022 3) Next scheduled Bi-Monthly Progress meeting – 05/26/2022
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) COH will coordinate a meeting once final copy of Final Engineering Report has been distributed by HCFCD 3) Harris County / HCFCD / COH a) Precinct 1 Briefing scheduled for 05/11/2022 i) *HCFCD will send meeting invitations to attendees b) Executive Board briefing anticipated for late May to early June c) Decision made to develop a Summary Report as planned rather than release a modified copy of the Final Engineering Report to the public
III) Administrative	1) Monthly invoice a) Invoice for March submitted to HCFCD 2) Summary Report a) Additional Services budget to be used for development of Summary Report i) *P-D will submit a budget proposal to HCFCD
IV) Data Collection and Review	1) No update

V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: a) Alternatives Analysis Complete b) 100-year hydraulic system capacity calculations i) Excel-based calculation methodology based on assumed flow per acre
VI) Potential Project Improvements	1) 100-year Hydraulic System Capacity Improvements a) Proposed back-of-lot channels between De Soto St, Mansfield St, and Paul Quinn St in addition to roadside ditches in overall watershed strategy i) Approximately 1 mi. in length with 3' depth draining east to west towards E116-00-00 b) Proposed expanded improvements to E116-00-00 compared to overall watershed strategy to provide additional capacity i) Approximately 6,600 linear feet with variable depth and 4:1 side slopes c) Proposed cleanup of E116-00-00 west of Mountwood St near confluence with E100-00-00 i) Approximately 600 linear feet with 2:1 side slopes d) Proposed improvements increase efficiency of drainage infrastructure, but would require ROW acquisition exceeding the budget of this feasibility study
VII) Immediate Needs	1) No update

ACTION ITEMS*:	
II) 3) a) i)	HCFCD will send meeting invitations to attendees for Precinct 1 briefing on 05/11/2022
III) 2) a) i)	P-D will submit a budget proposal to HCFCD to use Additional Services budget for development of the Summary Report

DECISIONS MADE:	
II) 3) c)	Decision made to develop a Summary Report as planned rather than release a modified copy of the Final Engineering Report to the public

Meeting Notes

E116-00-00 Flood Reduction Feasibility Study

MEETING TITLE: Monthly Progress Meeting (via TEAMS)
E116-00-00-P001

DATE: 05/19/2022

ATTENDEES: *Present = (x)*

HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (x), Beth Walters ()
COH: Beto Moreno (), Umer Khan (), Tanu Hiremath (), Manik Mitra (), Chris Garcia ()
P-D: Zubin Sukheswalla (x), Ken Nwankpa (x), Saatvik Satyaprakash (), Ashton Lofquist (x)
Dry Land: Erin Stiggins (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 05/19/2022 – Final Engineering Report i) Revised draft of FER to be submitted to HCFCD as soon as possible 2) Next scheduled Monthly Progress meeting – 06/09/2022 3) Next scheduled Bi-Monthly Progress meeting – 06/23/2022
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update 3) Harris County / HCFCD / COH a) *HCFCD will organize a meeting with the HCFCD Engineering Department to discuss this study's recommended project i) Anticipated to be scheduled in July b) HCFCD Executive Board Briefing i) Anticipated to be scheduled in July following the meeting with the HCFCD Engineering Department c) Further briefings with Precinct 1 not currently anticipated
III) Administrative	1) Monthly invoice a) Invoice submitted to HCFCD
IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: a) Alternatives Analysis Complete

VI) Pending Deliverables	1) Comments received from David, Gary, Amy a) P-D currently reconciling comments b) Decision made to use a monochrome color scheme for problem area boundaries in report exhibits and figures as problem area tiering system is no longer being considered 2) Schedule for Revised Draft FER for release to other stakeholders a) HCFCD to review Revised Draft FER and return comments b) Revised Draft FER to be distributed to COH c) Final, sealed FER to be submitted following receipt of any comments from the HCFCD Engineering Department and Executive Board meetings 3) Watershed Summary Report Schedule a) Summary Report to be submitted after submittal of sealed FER b) P-D permitted to begin a first draft of the Summary Report prior to submittal of sealed FER if desired 4) Executive Briefing a) See above section [II) 3) b)] 5) Potential Suggestions for Additional Services Budget a) Scope Document for HCFCD Engineering Department PER b) Subsurface utility engineering areas of interest c) GIS database d) Preliminary project plan, similar to the Spring Gully project
II) Immediate Needs	1) No update

ACTION ITEMS*:

II) 3) a)	HCFCD will organize a meeting with the HCFCD Engineering Department to discuss this study's recommended project

DECISIONS MADE:

VI) 1) b)	Decision made to use a monochrome color scheme for problem area boundaries in report exhibits and figures as problem area tiering system is no longer being considered

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Meeting Notes

E116-00-00 Flood Reduction Feasibility Study

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 06/09/2022

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Dena Green (), Myron Jones (), Beth Walters ()
COH: Umer Khan (), Tanu Hiremath (), Manik Mitra (), Chris Garcia (x)
P-D: Zubin Sukheswalla (x), Saatvik Satyaprakash (), Ashton Lofquist (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 05/19/2022 – Final Engineering Report i) *COH will check on internal review status of the revised draft FER 2) Next scheduled Bi-Monthly Progress meeting – 06/23/2022
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update b) P-D has budget remaining to give assistance to graphics creation for public meetings; anticipated to be in a review capacity 3) Harris County / HCFCD / COH
III) Administrative	1) Monthly invoice a) Invoice submitted to HCFCD
IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis Complete
VI) Pending Deliverables	1) Executive Briefing a) HCFCD Executive Board Briefing scheduling coordination ongoing b) Decision made for P-D to develop graphics for the Executive Board meeting, but not currently anticipated to participate in meeting 2) Watershed Summary Report a) Decision made by HCFCD to begin creation of a first draft WSR i) *HCFCD will provide documents to use as a potential go-by since an official standard or guideline document for WSR does not exist ii) *HCFCD will provide a list of recommended and not-recommended terminology to use in the Summary Report b) WSR Format i) Decision made for WSR to have a more narrative context as opposed to technical

	ii) Emphasis should be placed on the Overall WSR with the explanation that the Recommended Project will be investigated in more detail during the PER iii) HCFCD Communications will ultimately determine styles and formatting 3) GIS data deliverable a) Decision made for deliverable to follow established template format from WPP projects, to include the Overall Watershed Strategy and the Recommended Project b) *P-D will include a shapefile breaking out the projects into potential HCFCD/COH responsibility and proposed phasing 4) Additional Services a) HCFCD would like a document listing implementation detail, uncertainties encountered during the study, and other items the HCFCD Engineering Department should be aware of during the PER i) Would be somewhat similar to the Immediate Project Plan from Spring Gully, but with a bit more detail ii) *P-D will generate a proposal with the scope, schedule, and budget for the creation of such a document; first draft to be sent to HCFCD during week of 06/13/22
VII) Immediate Needs	1) No update

ACTION ITEMS*:	
I) 1) a) i)	COH will check on internal review status of the revised draft FER
VI) 2) a) i)	HCFCD will provide documents to use as a potential go-by since an official standard or guideline document for Summary Reports does not exist
VI) 2) a) ii)	HCFCD will provide a list of recommended and not-recommended terminology to use in the Summary Report
VI) 3) b)	P-D will include a shapefile breaking out the projects into potential HCFCD/COH responsibility and proposed phrasing
VI) 4) a) ii)	P-D will generate a proposal with the scope, schedule, and budget for the creation of an implementation details document; first draft to be sent to HCFCD by week of 06/13/22

DECISIONS MADE:	
VI) 1) b)	Decision made for P-D to develop graphics for the Executive Board meeting, but not currently anticipated to participate in meeting
VI) 2) a)	Decision made by HCFCD to begin creation of a first draft Summary Report
VI) 2) b) i)	Decision made for Summary Report to have a more narrative context as opposed to technical
VI) 3) a)	Decision made for deliverable to follow established template format from Spring Gully, to include the Overall Watershed Strategy and the Recommended Project

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Meeting Notes

E116-00-00 Flood Reduction Feasibility Study

MEETING TITLE: Bi-Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 06/23/2022

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (), Myron Jones (x), Beth Walters ()
COH: Beto Moreno (), Umer Khan (), Tanu Hiremath (x), Manik Mitra (), Chris Garcia (), Ratish Subedi (x)
P-D: Zubin Sukheswalla (x), Ken Nwankpa (x), Ashton Lofquist (x)

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 05/19/2022 – Final Engineering Report 2) Next scheduled Monthly Progress meeting – 07/14/2022 a) Decision made by HCFCD to extend Monthly Progress meeting schedule to September 3) Next scheduled Bi-Monthly Progress meeting – 07/28/2022 a) Decision made by HCFCD to extend Bi-Monthly Progress meeting schedule to September b) *HCFCD will send out invitations for the extended meeting schedules
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update 3) Harris County / HCFCD / COH a) HCFCD Executive Briefing scheduled for 07/11/2022; Executive Director currently anticipated to attend but subject to change i) Expected to be a 15-minute presentation followed by discussion period ii) *P-D will send HCFCD the presentation slides from the HCFCD Engineering Department briefing iii) *P-D will create a presentation for the Executive Briefing following receipt of guidance from HCFCD regarding format and contents
III) Administrative	1) Monthly invoice a) Invoice has moved forward 2) Pending Deliverables and Additional Services a) Public-facing Watershed Summary Report expected to use existing project budget b) Engineering Package document for PER phase to use Additional Services budget
IV) Data Collection and Review	1) No update

V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis Complete
VI) Deliverables	1) Final Engineering Report – Submitted 2) Executive Briefing Update – Pending a) See above section [II) 3) a)] 3) Watershed Summary Report (WSR) – Pending a) *P-D will send an early draft of the WSR to HCFCD for guidance from HCFCD Communications 4) GIS data deliverable – Pending acceptance of all other deliverables 5) Engineering Package of Implementation Details a) Suggested to include recommendation for update of HCFCD Engineering unit cost tool to account for inflation b) *P-D will submit a proposal for this package to HCFCD by end of week of 06/20/22
VII) Immediate Needs	1) No update

ACTION ITEMS*:

I) 3) b)	HCFCD will send out invitations for the extended Monthly and Bi-Monthly meeting schedules
II) 3) a) ii)	P-D will send HCFCD the presentation slides from the HCFCD Engineering Department briefing
II) 3) a) iii)	P-D will create a presentation for the Executive Briefing following receipt of guidance from HCFCD regarding format and contents
VI) 3) a)	P-D will send an early draft of the Watershed Summary Report to HCFCD for guidance from HCFCD Communications
VI) 5) b)	P-D will submit a proposal for the implementation details engineering package to HCFCD by end of week of 06/20/22

DECISIONS MADE:

I) 2) a)	Decision made by HCFCD to extend Monthly Progress meeting schedule to September
I) 3) a)	Decision made by HCFCD to extend Bi-Monthly Progress meeting schedule to September

Meeting Notes

E116-00-00 Flood Reduction Feasibility Study

MEETING TITLE: Monthly Progress Meeting (via TEAMS) E116-00-00-P001 **DATE:** 07/14/2022

ATTENDEES: *Present = (x)*
HCFCD: David Parkhill (x), Gary Bezemek (x), Amy Stone (x), Myron Jones (), Beth Walters ()
COH: Beto Moreno (), Umer Khan (), Tanu Hiremath (), Manik Mitra (), Chris Garcia (),
P-D: Zubin Sukheswalla (x), Lonnie Anderson (x), Ashton Lofquist (x)

AGENDA TOPICS:	
I) Schedule Discussion	1) Schedule of milestones / deliverables a) 05/19/2022 – Final Engineering Report 2) Next scheduled Monthly Progress meeting – 08/11/2022 3) Next scheduled Bi-Monthly Progress meeting – 07/28/2022
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update 3) Harris County / HCFCD / COH a) Executive Briefing i) Change in terminology to be implemented in FER to consider the initial $10 million budget as the “target” since it was not officially allocated to this study ii) Further terminology changes to be made to remove emphasis on immediacy of feasibility study recommendations
III) Administrative	1) Monthly invoice
IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Alternatives Analysis Complete
VI) Pending Deliverables	1) Final Engineering Report Revisions a) See above section [II) 3) a)] b) Final signing and sealing of FER to occur after official email received from HCFCD notifying P-D of project conclusion c) *HCFCD will alert COH to revisions to FER 2) Watershed Summary Report (WSR) a) To be reviewed by HCFCD and HCFCD Communications b) *P-D will submit an early draft of WSR, including terminology changes pursuant to Executive Briefing, by 08/12/2022 i) Decision made to allow WSR draft submittal date to be moved if needed c) Completed WSR anticipated to be submitted by end of August 2022

	d) HCFCD Communications will expect to meet with SPT HOA following the WSR going live to the public 3) GIS data deliverable – Pending acceptance of all other deliverables 4) Engineering Package of Implementation Details (Pre-PER) a) More precise demarcation of E116-00-00 improvement areas to be included in Pre-PER package 5) Additional Technical Memo a) *P-D will send a proposal of the Harvey analysis with scope, budget, and schedule to HCFCD b) Harvey analysis will provide a validation to determine if models developed by P-D should be basis of PER or if more analysis is required c) Decision made to create a technical memo addendum to FER analyzing flood risk with use of Hurricane Harvey rainfall in both existing condition and proposed Overall Watershed Strategy
VII) Immediate Needs	1) No update

ACTION ITEMS*:

VI) 1) c)	HCFCD will alert COH to revisions to FER resulting from Executive Briefing
VI) 2) b)	P-D will submit an early draft of WSR, including terminology changes pursuant to Executive Briefing, by 08/12/2022
VI) 4) b)	P-D will send a revised proposal for the Pre-PER package with scope, budget, and schedule to HCFCD
VI) 5) c)	P-D will send a proposal of the Harvey analysis with scope, budget, and schedule to HCFCD

DECISIONS MADE:

VI) 2) b) i)	Decision made to allow WSR draft submittal date to be moved if needed
VI) 5) a)	Decision made to create a technical memo addendum to FER analyzing flood risk with use of Hurricane Harvey rainfall in both existing condition and proposed Overall Watershed Strategy

Meeting Notes

E116-00-00 Flood Reduction Feasibility Study

MEETING TITLE:	Monthly Progress Meeting (via TEAMS) E116-00-00-P001	**DATE:**	08/11/2022
ATTENDEES: *Present = (x)*	HCFCD: David Parkhill (x), Gary Bezemek (), Amy Stone (), Myron Jones (x), Beth Walters () COH: Umer Khan (), Tanu Hiremath (), Manik Mitra (), Chris Garcia (x), P-D: Zubin Sukheswalla (x), Lonnie Anderson (x), Ashton Lofquist (x) Dry Land: Erin Stiggins (x)		

AGENDA TOPICS:

I) Schedule Discussion	1) Schedule of milestones / deliverables a) 05/19/2022 – Final Engineering Report 2) Next scheduled Monthly Progress meeting – 09/08/2022 3) Next scheduled Bi-Monthly Progress meeting – 08/25/2022 a) May be cancelled or postponed due to scheduling conflict with TFMA
II) Stakeholder / Public Engagement	1) Traditional / Bond a) No update 2) HOA / Civic groups a) Shepherd Park Terrace Meeting Request i) No update 3) Harris County / HCFCD / COH a) No update
III) Administrative	1) Monthly invoice a) Invoices are current
IV) Data Collection and Review	1) No update
V) H&H Analysis	1) Hydrology: Complete 2) Hydraulics: Hydraulics complete, Harvey Analysis ongoing a) 10-15% of structures in Harvey historical records are predicted to flood with current analysis b) Discrepancies in Finished Floor Elevation (FFE) data noted, potential inaccuracies in historical records as well c) Current analysis is presenting clusters of flooding from Harvey precipitation in generally similar areas as the historical records; thus, HCFCD has confidence in the modeling used in this feasibility study d) *P-D will note in Engineering Package that future projects should determine FFE's in nearby areas with greater detail prior to analysis e) *P-D will send a revised Work Authorization for Harvey Analysis

VI) Pending Deliverables	1) Final Engineering Report Revisions a) Harvey Analysis will be added i) Decision made to include Harvey Analysis as part of Engineering Package due to FFE discrepancies b) FER will contain revisions resulting from Executive Briefing, with submittal anticipated in the near future 2) Watershed Summary Report (WSR) a) First submittal of WSR anticipated to follow finalization of FER 3) GIS data deliverable a) Will follow the deliverable template developed by P-D in previous watershed studies 4) Engineering Package of Implementation Details (Pre-PER) a) Anticipated to be developed while FER is under review by HCFCD
VII) Immediate Needs	1) No update

ACTION ITEMS*:

V) 2) d)	P-D will note in Engineering Package that future projects should determine FFE's in nearby areas with greater detail prior to analysis
V) 2) e)	P-D will send a revised Work Authorization for Harvey Analysis

DECISIONS MADE:

VI) 1) a) i)	Decision made to include Harvey Analysis as part of Engineering Package due to FFE discrepancies

Technical Workshop #1

PAPE-DAWSON ENGINEERS

Meeting Minutes

E116 Subwatershed Planning Project

MEETING TITLE:	Workshop #1 (via TEAMS) E116-00-00-P001	**DATE:** **TIME:**	09/23/2021 10:00a to 12:30p

INVITEES:

Present = (x)

HCFCD: David Parkhill (x), Gary Bezemek (x), Ataul Hannan (x), Dena Green (x), Myron Jones, William Sherman (x), Beth Walters, Wayne Crull (x), Summer Bragg (x), Kent Wu
COH: Alberto Moreno, Adam Eaton, Tanu Hiremath, Manik Mitra, Umer Khan (x), Chris Garcia (x)
P-D: Zubin Sukheswalla (x), Erin Stiggins (x), Lonnie Anderson (x), Ashton Lofquist (x), Saatvik Satyaprakash (x)
Other Engineers: Burton Johnson, Jose De La Pena

AGENDA TOPICS:

I) Team Introductions	1) Harris County Flood Control District 2) City of Houston 3) Pape-Dawson Engineers 4) Other Engineers
II) Subwatershed Overview	1) HCFCD Facilities and Goals of Project 2) Overview of Historical Flooding / Hot Spots 3) Past Studies / Ongoing Projects 4) Other Projects
III) Hydrology and Hydraulic Analysis	1) Modeling Methodology 2) Existing Conditions Results a) All results incorporate GIMS storm sewer data, otherwise the water surface elevations of the predicted floodplains would be overestimated b) *P-D will provide Mr. Hannan of HCFCD with the water surface elevation profiles to demonstrate the change in results from inclusion of GIMS storm sewer data 3) Current Floodplain and Inundation a) P-D has concluded the Rain on Grid (ROG) calculations match inflows and boundary conditions of the MAAPnext ROG and show similar results b) P-D ROG is more detailed than the MAAPnext ROG due to inclusion of GIMS data 4) Inflows and Outflows a) Majority of flooding is result of overland sheet flow, not out-of-bank riverine flooding b) Primary inflows originate in E110_18 and flow south into subwatershed near De Soto St and Wilburforce St c) Outflows exit subwatershed mostly along major roads i) To the south into E100_20 and E107_01 ii) To the west into E100_18 iii) To the southeast into E101_07 out of Shepherd Park Terrace
IV) Problem Areas	1) Problem Area Identification 2) Overview of Metrics

V) Tier I Problem Areas	1) Problem Area No. 1 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements 2) Problem Area No. 2 a) Overview b) Shepherd Park Terrace Project c) Flooding Source / Inflows and Outflows d) Metrics e) Potential Project Improvements i) Fencing separates W Tidwell Rd from the adjacent houses in Shepherd Park Terrace experiencing overflows from the road ii) While the fencing slows the overflow, a project dedicated to reducing overflow would likely be a significant improvement 3) Meeting Break: 11:01a-11:06a 4) Problem Area No. 3 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements 5) Problem Area No. 4 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements
VI) Tier II Problem Areas	1) Problem Area No. 5 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements 2) Problem Area No. 6 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements 3) Problem Area No. 7 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements 4) Problem Area No. 8 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements
VII) Tier III Problem Areas	1) Problem Area No. 9 a) Overview

	b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements i) Due to low-density residential development, ROW could potentially be available for detention mitigation 2) Problem Area No. 10 a) Overview b) Flooding Source / Inflows and Outflows c) Metrics d) Potential Project Improvements
VIII) Open Discussion	1) Revisions to Tier Classifications a) Tier classifications may change over the course of the project as problem areas are redefined based on limits of benefit from potential improvements beyond the subwatershed boundary b) Prioritization Framework is focused towards scoring and ranking projects, as opposed to problem areas i) Decision made that use of a tier system to prioritize Problem Areas in final engineering report will need to be coordinated with prioritization framework provided by HCFCD. ii) Potential improvement projects will be scored, regardless of tier classification for the problem area. iii) Project team will continue discussing applicability of ranking problem areas for final report. c) Decision made to set up coordination meetings with COH for potential projects out of HCFCD's jurisdiction i) Decision made to score potential projects outside HCFCD jurisdiction using prioritization framework; however, any recommendation will be developed in cooperation between HCFCD and COH, or any other potential partners. d) Final report should include problem identification, overall plan to address problems, and long-term funding strategy i) Funding strategy should identify potential partners and funding sources should overall plan exceed current budget ii) Addressing problems in phases could prove an effective funding strategy 2) Additional Topics as Needed a) Prioritization Framework and Roadway Flooding i) Roadway flooding not currently part of prioritization framework ii) Decision made to consider roadway flooding in final report since it poses a mobility/emergency access problem iii) *HCFCD will determine jurisdiction of flooded roadways iv) Comprehensive strategy for the subwatershed will be an important component of the final report, especially for communicating with residents about the problems experienced in the region along with the scope of improvements required to provide meaningful flood reduction measures
IX) Adjourn	1) Meeting adjourned at 12:15p

ACTION ITEMS*:	
III) 2) b)	P-D will provide Mr. Hannan of HCFCD with the water surface elevation profiles to demonstrate the change in results from inclusion of GIMS storm sewer data
VIII) 2) a) iii)	HCFCD will determine jurisdiction of flooded roadways

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Technical Workshop #2

Precinct 4 Meeting #1

Precinct 1 Meeting #1

PAPE-DAWSON ENGINEERS

Discussion Agenda
07/11/2022

E116-00-00-P001 Feasibility Study
Watershed Planning Project
Executive Briefing

Time and Date- 3:30-4:00 PM July 11, 2022
Location – Microsoft Teams; Phone 281-985-1862; Conference ID: (527 629 353 #)
Project ID –E116-00-00-P001

Discussion Agenda

1. Study Area Description
2. Existing Problems Identification
3. Recommended Project
4. Overall Recommendations (time permitting)
5. Adjourn 4:00 PM

Discussion Notes

The short Executive briefing was attended by Alan Black and Ataul Hannan, along with Gary Bezemek, Amy Stone, and David Parkhill. The only significant item which came up during this meeting was related to our statements in the meeting regarding the "allocation" of $10 M in 2018 bond funds for this project. This statement is erroneous in that no such allocation currently exists from the 2018 Bond for this specific study area. This study was added to the 2018 Bond program at the request of the City and has no current allocation of funds for construction. There are multiple options for future funding that were discussed including CIP, grants, partnerships, and possible bond re-allocations.

Public Meeting

As of the publication of this report, this meeting has not yet been scheduled.

Appendix 5-4AI:
Greens Mid-Reach

Results Report

TO: San Jacinto Regional Flood Planning Group

CC: Harris County
Texas Water Development Board

FROM: Brian Edmonson, PE, CFM

SUBJECT: Greens Bayou Mid-Reach Benefit-Cost Analysis

DATE: 10/18/2022

PROJECT: San Jacinto Regional Flood Plan

The initial evaluation for the Greens Bayou Mid-Reach Channel Conveyance Improvements was conducted in 2022 as a part of the Greens Bayou Mid-Reach Channel Conveyance Improvements Preliminary Engineering Report by CivilTech Engineering prepared for Harris County Flood Control District. The preliminary engineering report (PER) is included as Appendix 5D-X. The project stretches Greens Bayou from John F. Kennedy Blvd to Veterans Memorial Drive in Harris County Precincts 1 and 2.

The Texas Water Development Board (TWDB) requires each Flood Mitigation Project (FMP) included in a regional flood plan to have a benefit/cost analysis (BCA) performed. The PER prepared by CivilTech did not include a BCA. This memorandum documents to benefit cost analysis performed by Freese and Nichols within the regional flood planning process.

Benefit Cost Analysis

TWDB developed the Benefit-Cost Analysis (BCA) Input Tool to facilitate the calculation of flood mitigation benefits due to FMP. This tool receives input of existing and proposed conditions to determine expected benefits related to the construction of the FMP in question. The benefits considered in the analysis include the reduction in damages to residential structures, commercial structures, and social benefits. The BCA Input Tool was modified to handle the nearly 20,000 structures included in the analysis. The BCA Input Tool was used in conjunction with the Federal Emergency Management Agency (FEMA) BCA Toolkit v6.0.0. Social benefits used in the analysis were developed within the FMEA Benefit-Cost Calculator.

Project Costs

According to the PER, the overall cost to design and construct the Ultimate Project, Alternative 3, is estimated at $195,720,000 based on 2021 construction costs. The conveyance improvements were assumed to have a useful life of 30 years. The project cost used in the BCA includes Design (10%), Construction and Construction Phase Services (10%), Contingency (15%). The annual maintenance cost is estimated at $0. Harris County Flood Control District will be responsible for long-term maintenance of Greens Bayou.

Expected Flood Damages Without FMP

Building Information

The “Texas Buildings with SVI and Estimated Population (November 2021)” dataset provided by TWDB for Regional Flood Planning was used to determine building sizes and building types. The Finished Floor Elevations (FFE) for all structures was assumed to be 6 inches above ground level and all structures were assumed to be 1 story. Based on the provided building types, structures were reclassified as either residential, commercial, industrial, or agricultural. Public buildings were reclassified as commercial structures. Buildings marked as “Vacant or Unknown” in the TWDB dataset were reclassified as agricultural buildings.

Flood Hazard Data

The flood depths for each structure within the study area was determined for the 1 percent and 0.2 percent annual chance events. The flood hazard data was obtained from the PER, all hydrological and hydraulic analyses were completed by CivilTech. The baseline structural flood damages are included in Table 1.

Table 1: Project Impacts by Recurrence Interval

	100 - year storm		**500 - year storm**	
	Baseline	With Project	Baseline	With Project
Residential Flood Damage	$639,585,285	$459,116,182	$1,409,802,869	$1,210,873,571
Commercial Flood Damage	$402,979,760	$256,297,622	$835,552,554	$662,625,772
Total Structural Damage	$1,042,565,045	$715,413,804	$2,245,355,423	$1,1873,199,343

Expected Flood Damages After FMP Implementation

For the structures analyzed, the Greens Bayou Mid-Reach FMP results in $46,216,593 in standard mitigation benefits and $195,720,00 in total net benefits.

Flooded Streets

While it would be more accurate to determine the flooded streets impacted per flooded street, the combined benefits would be marginal compared to the benefits shown directly with reduced structural depth. Therefore, the largest major roadway inundated was evaluated to determine the reduction in flooded streets. The model was evaluated to determine the duration for which the roadway was impassible and get an estimate on the length of roadway impacted. The average daily traffic was pulled from the Texas department of transportation district traffic web viewer which displays statewide annual average daily traffic (AADT). The general area was scoped to evaluate the mileage and difference in commute timing with a detoured route due to the roadway being inundated. The average normal emergency medical services response time was estimated to be 10 minutes and that response time was estimated to be tripled during a storm event.

Green Infrastructure Benefits

Green infrastructure included as additional benefits of the project due to the project estimating 304 acres of green open space being added because of detention ponds.

Benefit-Cost Summary

The benefit-cost analysis for this project was completed using the FEMA BCA Tool Version 6.0. The final benefit-cost ratio BCR) with standard benefits is 0.24 and 0.42 with all benefits considered.

Results from BCA Toolkit:	
Total Standard Mitigation Benefits ($):	$46,216,593
Other Benefits (Not Recreation)	$36,839,340
Recreation Benefits	$0
Discounted Total Costs	$195,720,000
Net Benefits	$83,055,933
Net Benefits with Recreation	$83,055,933
Final BCR Standard	**0.24**
Final BCR with Other Benefits	**0.42**

Drainage report submitted with model files.