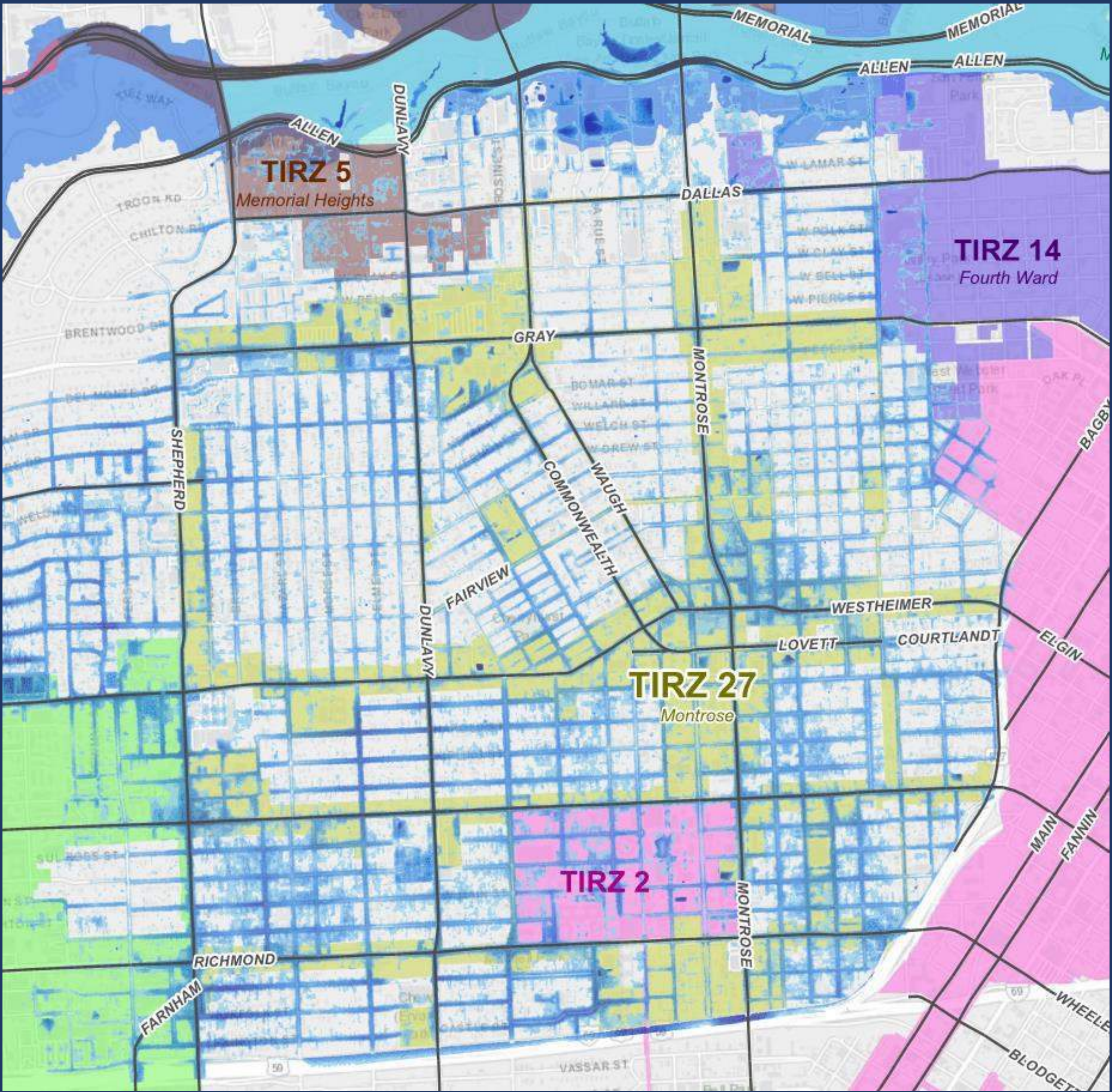


Montrose Drainage Study

TAX INCREMENT REINVESTMENT ZONE 27

Montrose Drainage Study

Prepared for:

MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

Tax Increment Reinvestment Zone 27

Prepared By:

Gauge
ENGINEERING

Gauge Engineering, LLC (F-20017)

3200 Wilcrest Drive, Suite 220 • Houston, TX 77042

02/22/2021

STATE OF TEXAS
HEATHER W. GOODPASTURE
126705
LICENSED
PROFESSIONAL ENGINEER

Heather Goodpasture

February 2021

Contents

Figures

Tables

Appendices

1. INTRODUCTION

The Montrose Tax Increment Reinvestment Zone 27 (Montrose) contracted Gauge Engineering. LLC (Gauge) to perform a regional drainage study to identify current drainage problems and provide short- and long-term solutions for addressing drainage concerns throughout the Montrose area. Initial efforts of the study included data gathering, existing conditions modeling, and inventory and mapping of drainage concerns. The objective of these efforts was to develop a broad understanding of the Montrose drainage issues in terms of locations, causes, and risks.

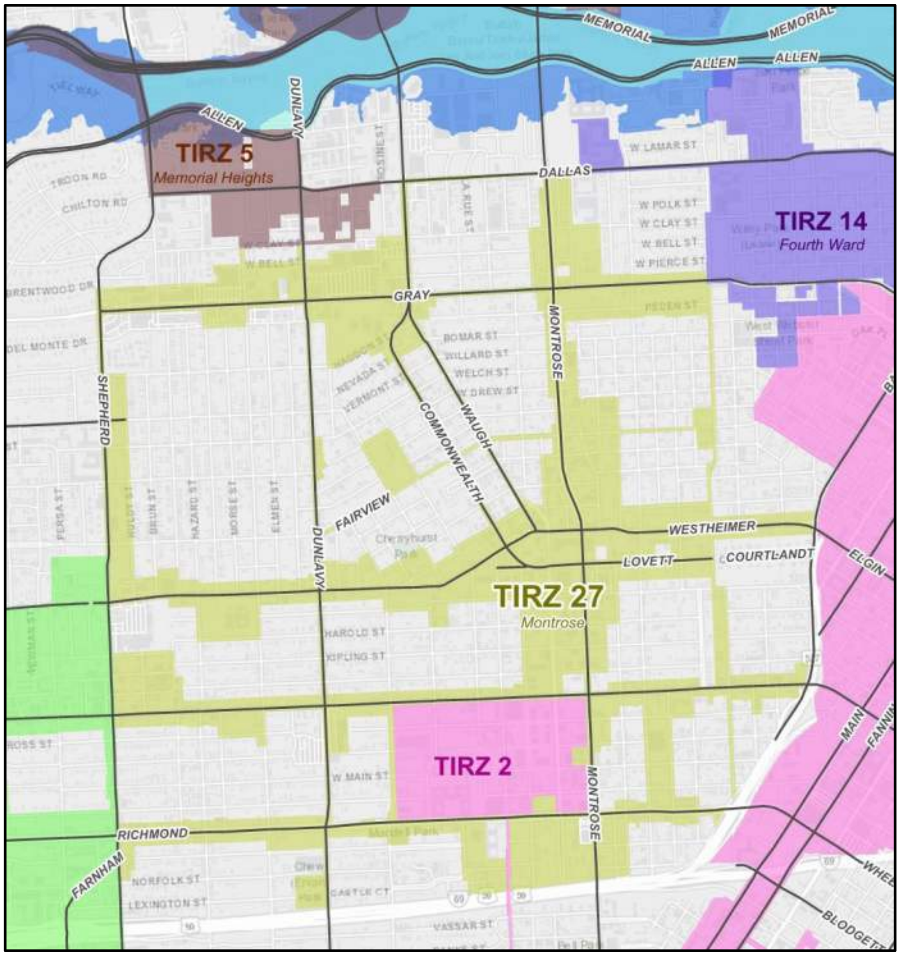


Figure 1 - Location Map

Once the source of flooding was understood, conceptual drainage solutions concepts were developed through alternatives analysis that approximated detention or conveyance sizing with limited modeling to test their effectiveness at flood reduction. The primary goal of the drainage analysis was to develop a cohesive plan to improve the drainage infrastructure within the Montrose region, and to provide key information to guide the development of the 5-year Capital Improvement Plan (CIP).

This study was conducted in accordance with the City of Houston Standards, including the City of Houston Infrastructure Design Manual, Technical Paper 100, and Technical Paper 101. Finally, the efforts in this study have provided a starting point for the identification of future grant and funding opportunities, but did not include the development of a formal benefit cost ratio.

2. DATA COLLECTION

Data was collected from various sources as detailed below.

A. GIS DATA

Available drainage related and basemap data, including existing studies, hydrologic and hydraulic models, and Geographic Information System (GIS) mapping data, was gathered, and reviewed. Sources include the City of Houston, Houston-Galveston Area Council of Governments (H-GAC), Federal Emergency Management Program (FEMA), and Harris County. Most data were background mapping data for political subdivision jurisdictional boundaries, parcel boundaries, street names, creek centerlines, and FEMA flood hazard zones.

B. SITE DATA

Gauge conducted site visits to investigate potential drainage concerns around the Montrose region to determine contributing factors and to assess the severity of each identified issue. Through a combination of field and desktop reviews, gauge estimated the size, location, and condition for key sub surface and surface drainage infrastructure throughout the study region. This data was utilized in the existing conditions modeling effort.

C. HISTORIC FLOODING DATA

The Montrose region has experienced numerous significant flood events over the last several years, including Memorial Day 2015, Halloween 2015, Hurricane Harvey (2017), and Tropical Storm Imelda (2019), to name a few. Available flooding reports from these events were collected from the Harris County and City of Houston databases.

Rainfall data for the Hurricane Harvey event was collected from the nearby HCFCD rain gauge at Buffalo Bayou and Shepherd Drive (Site 2240).

3. EXISTING CONDITIONS MODELING

Gauge performed an existing conditions hydrologic and hydraulic analysis utilizing Infoworks ICM to simulate a preliminary assessment of existing conditions throughout the Montrose region. The model was not developed to establish detailed results, but rather to act as a screening tool to identify potential areas at risk of flooding. A rapid assessment "rain-on-mesh" model was created for the 2-, 10-, and 100-yr storm. A "rain-on-mesh" model simulates rainfall directly on a surface and utilizes two-dimensional hydraulic computations to compute overland and channel flow.

A. MODEL DEVELOPMENT

The best available surface data for the region is the 2018 H-GAC LiDAR. The LiDAR was processed to develop a detailed topographic surface that accurately represents the ground conditions. This topography data was processed with breaklines and Manning's roughness zones to provide additional detail at specific locations to create a 2D mesh to be used within the ICM model. Breaklines were applied to the gutter line of the streets in order to provide better definition of potential street conveyance and greater elevation detail. Figure 2 below shows a view of the model with the underlying 2D mesh as well as the storm sewer and inlet detail.

Sub-surface drainage infrastructure can have a significant influence on surface drainage patterns. The best available storm drain information was acquired from the City of Houston GIMS website and supplemented with available record drawing data. Much of the data acquired had inaccurate or no elevation data. Therefore, Gauge leveraged a process developed for a similar past study to efficiently process the storm drain data into a usable format. Some of the storm drain data possessed good survey information that was restored. Other information appeared to be several feet too high, or too low, and was translated with the assumption of a survey datum shift. Some data had little or no vertical information and was assumed to be 2 feet below ground. All data was screened and revised to ensure positive sloping pipes throughout the system. Each of the assumptions and data sources were documented within excel spreadsheets, the GIS database, and the final ICM model. The comprehensive network of storm drains within the project area is shown in **Appendix A**.

The 10- and 100-year Atlas 14 rainfall hyetograph was developed and applied directly to the surface of the 2D mesh. The model parameters were set specific to the project area, and various simulations were run to produce existing conditions results.

B. HURRICANE HARVEY VALIDATION

The rainfall hyetograph for Hurricane Harvey was collected from HCFFCD rain gauge 2240 and applied within the ICM model to simulate the flooding experience during this major flood event. Inundation mapping for this simulation is provided in **Appendix B**. With a few exceptions, the flooding generally matches observed flooding based on available data from the City of Houston and Harris County Flood Control District.

C. INUNDATION MAPPING

Inundation areas from the 2-, 10-, and 100-yr storm event "rain-on-mesh" models are provided in **Appendix B.**

Figure 2 - ICM 2D Mesh with Storm Drain Infrastructure

4. PROBLEM AREA IDENTIFICATION

The results of the existing conditions modeling were reviewed to assess the source and extent of each drainage concern. Gauge created an inventory of the known areas of concern to track drainage problems and develop a comprehensive view of the issues throughout the project area. Information for each problem area was documented in the sections below. Problem areas were assigned a unique ID based upon their location within the area. A total of 7 drainage concerns were identified as shown in Figure 3 and in **Appendix C**.

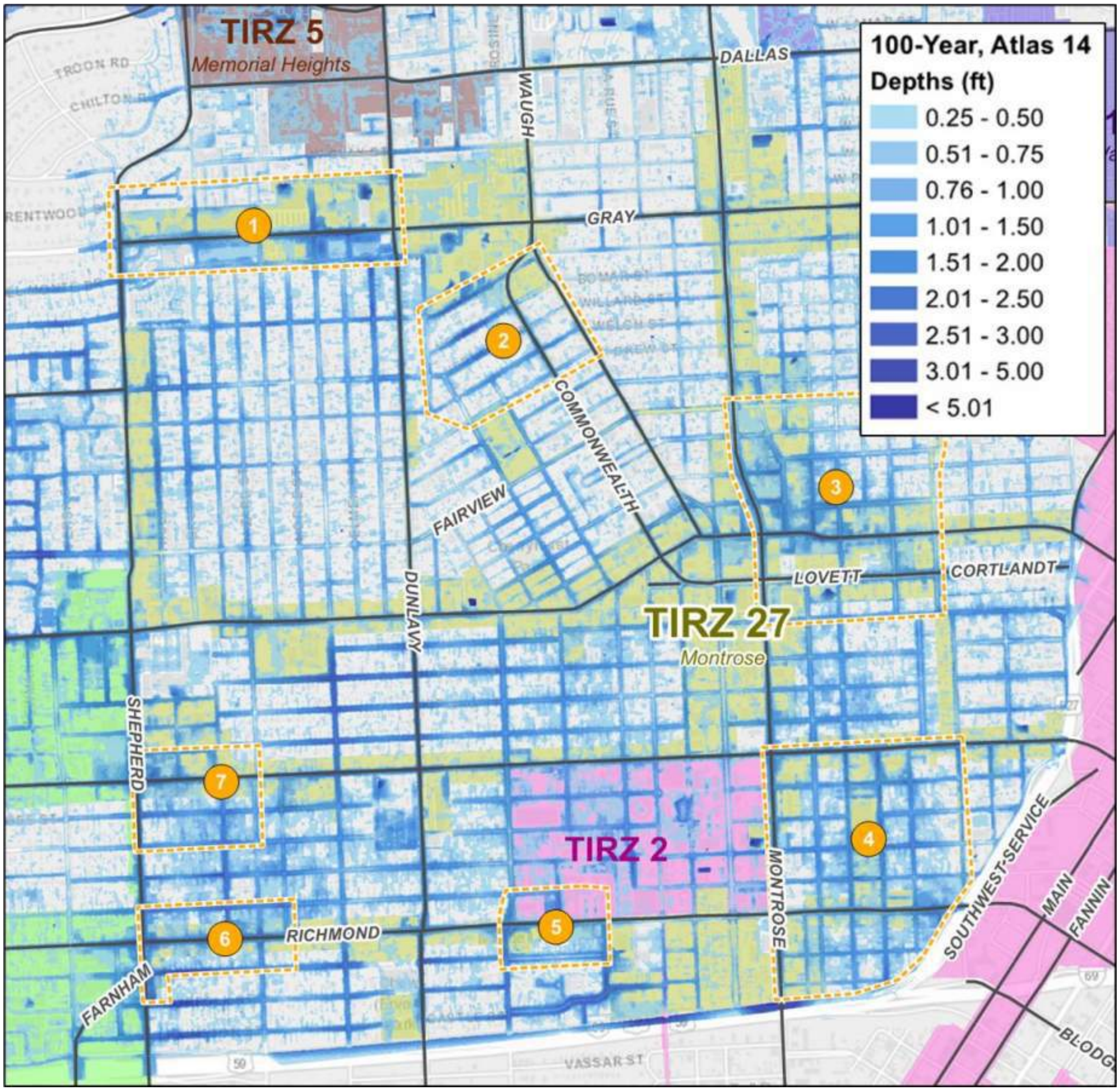


Figure 3 - Drainage Problem Areas

A. PROBLEM AREA 1 – GRAY & WOODHEAD

Problem Area 1 is located at the Northwest region of the TIRZ, near the intersection of Gray and Woodhead Streets. The 100-year simulated inundation is shown in Figure 5.

Figure 4 - Problem Area 1 Simulated Flooding

Observed Problem:	Various structures along Gray Street appear to be inundated during the 100-year storm event. Gray Street is also inundated for a long period of time.
Flooding Source:	Approximately 240 acres of contributing surface drainage area flow to this location from the West. Two storm drain systems are designed to carry runoff from this drainage area to discharge into Buffalo Bayou, however the systems only convey about the 2-year storm event and are overwhelmed during larger events. Surface runoff flows across Shepherd and is generally conveyed along Gray Street.
Storm Drain System:	Upstream of the project area and to the West is an existing 84-inch storm drain trunk under Shepherd Drive that discharges into Buffalo Bayou. Adjacent to the project site is a 24" lateral storm drain system that feeds into a 48" trunkline that drains north into Buffalo Bayou.
Duration of Flooding:	Gray Street shows potential for being inundated for over 2-hours at a depth higher than 6" during a 100-year event.
Downstream:	Downstream of the Problem Area 1, surface runoff continues to sheet flow to the Southeast into Problem Area 2.
Flood Complaints:	No FEMA Repetitive Loss complaints were identified for Problem Area 1 in the collected databases. Two structures reported Harvey flooding.

B. Problem Area 2 - Commonwealth

Problem Area 2 is located to the Southeast of problem area 1, in the vicinity of Commonwealth and Haddon Streets. The 100-year simulated inundation is shown in Figure 5.

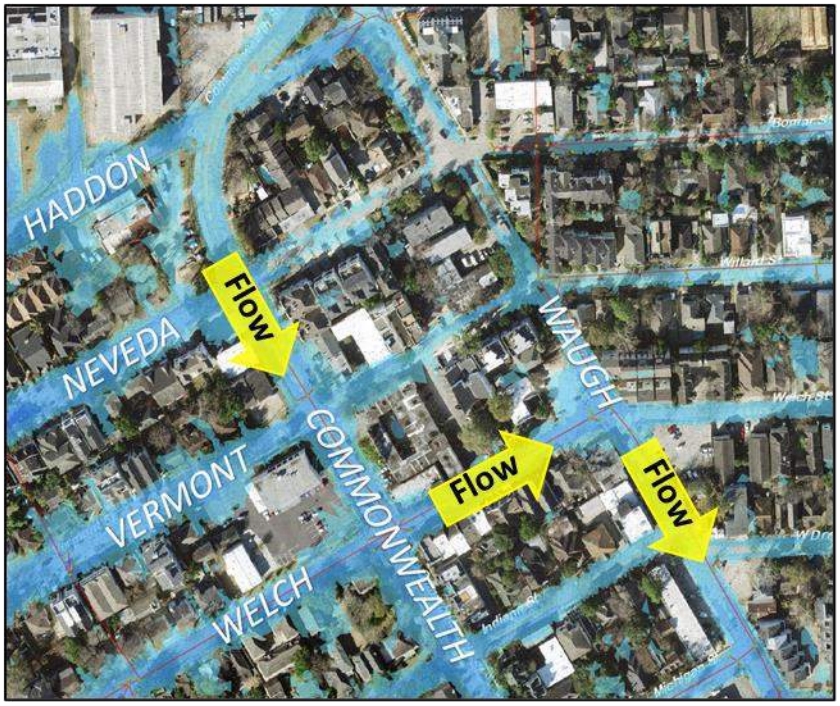


Figure 5 - Problem Area 2 Simulated Flooding

Observed Problem:	The simulated flooding appears to show multiple potential for shallow flooding at various residential and commercial properties. Street flooding is observed throughout the entire problem area.
Flooding Source:	Surface flooding is conveyed to the problem area primarily from three streets that each contribute over 100 cfs in a 100-year event. Ridgewood Street conveys overflow from Problem Area 1 into this region, and Vermont Street and Welch Street also contribute stormwater runoff from the West.
Storm Drain System:	Problem area 2 is served by a large 60" trunkline under Welch Street. The trunkline increases to 120" just downstream of the problem area and drains north to discharge into Buffalo Bayou. Only 2 laterals drain the local flooding from Problem Area 2 into this trunkline resulting in inadequate surface drainage. The 60" trunkline is undersized, but at the transition to the 120" size the system appears to be adequate to convey the 100-year event.
Duration of Flooding:	Street flooding appears to be a major concern as depths indicate potential for over 2' of flooding at peak flooding. The 100-year simulation indicates up to a 4-hour duration of 6"+ flooding at many of the streets.
Downstream:	Surface runoff from this problem area overflows to the Southeast into problem area 3.
Flood Complaints:	No FEMA Repetitive Loss complaints were identified for Problem Area 1 in the collected databases. Multiple structures reported Harvey flooding on the west side of the problem area between Vermont and Welch Streets.

C. PROBLEM AREA 3 – MONTROSE & WESTHEIMER

Problem Area 3 is in the vicinity of the intersection of Montrose Boulevard and Westheimer Road. The 100-year simulated inundation is shown in Figure 6.

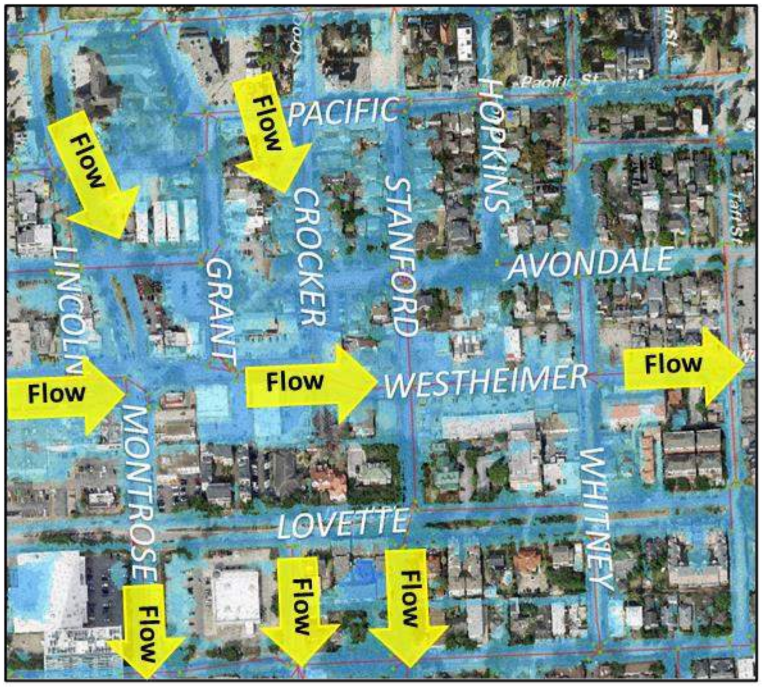


Figure 6 - Problem Area 3 Simulated Flooding

Observed Problem:	Large amounts of surface flow enter the problem area from both the East and the North. Numerous streets convey significant amounts of water that overwhelm the capacity and spill out of the ROW.
Flooding Source:	Surface flow from much of the TIRZ area from the West and North enters Problem Area 3 when local storm drain systems become overwhelmed. Both Problem Area 1 and 2 contribute to the runoff at Problem Area 3. Flow conveyed down both Westheimer and Grant Street contribute a considerable amount of water into the problem area during large events.
Storm Drain System:	Multiple storm drain systems drain Project Area 3. Three of the systems drain to the East and discharge to the Midtown area before ultimately draining to Buffalo Bayou. Other smaller portions of the problem area drain into systems that drain to the north and discharge into Buffalo Bayou.
Duration of Flooding:	Most roadways in the problem area are significantly inundated during large storm events up to depths of 2’. Flooding over 6” is shown to last for over 2 hours on many of the streets.
Downstream:	Sheet flow discharges to the East and South of the problem area.
Flood Complaints:	Multiple FEMA Repetitive Loss complaints were identified for Problem Area 1 and various structures reported flooding during Harvey.

D. Problem Area 4 – Richmond & Montrose

Problem Area 4 is in the vicinity of the intersection of Montrose Boulevard and Richmond Avenue. The 100-year simulated inundation is shown in Figure 7.

Figure 7 - Problem Area 4 Simulated Flooding

Observed Problem:	Surface flooding occurs due to water coming to the problem area from both the North and the West, and is held back by the major highways to both the East and the South. Multiple structures are at high risk of flooding, and street flooding occurs for very long durations.
Flooding Source:	Most of the surface runoff for this problem area comes from street conveyance from the North. Some additional water is also conveyed from the West, mostly along Colquitt and Main.
Storm Drain System:	Many small storm drain systems serve Problem Area 4 and discharge to the Spur Highway to the East. These systems are quickly filled with runoff creating surface ponding in large rain events.
Duration of Flooding:	Flooding duration is a major concern for this project area since the water is not able to leave through surface drainage. Simulations indicate up to 9 hours of inundation duration over 6” during a 100-year event.
Downstream:	The elevated highways to the South and East of Problem Area 4 create a dam effect that does not allow water to discharge. This creates ponding within the area with runoff not able to leave until the storm drain systems have capacity to drain the area.
Flood Complaints:	No FEMA Repetitive Loss complaint was identified for Problem Area 4 in the collected databases. Multiple structures reported Harvey throughout the problem area.

E. Problem Area 5 – Richmond & Mandell

Problem Area 5 is in the vicinity of the intersection Richmond Avenue and Mandell Street. The 100-year simulated inundation is shown in Figure 8.

Figure 8 - Problem Area 5 Simulated Flooding

Observed Problem:	Multiple homes near Bonnie Brae are at risk of flooding along with significant and long duration street ponding.
Flooding Source:	Surface runoff from both the North and the West enter the problem area. Most of the runoff is conveyed down Richmond Avenue and Mandell Street.
Storm Drain System:	Problem Area 5 has a storm drain trunkline that drains under Richmond Avenue that eventually discharges to the South at US 59.
Duration of Flooding:	Flooding duration greater than 6" for the streets within the problem area are between 5 and 7 hours.
Downstream:	Surface runoff that is not conveyed through Storm Drains overflows to the East and into Problem Area 4.
Flood Complaints:	No FEMA Repetitive Loss complaints or Harvey reported flooding was identified for Problem Area 4 in the collected databases.

F. Problem Area 6 – Richmond & Shepherd

Problem Area 6 is in the vicinity of the intersection of Richmond Avenue and Shepherd Drive. The 100-year simulated inundation is shown in Figure 9. This project area may be influenced by an ongoing City of Houston TIRZ 19 project on Shepherd, which has not been included in the analysis for this study.

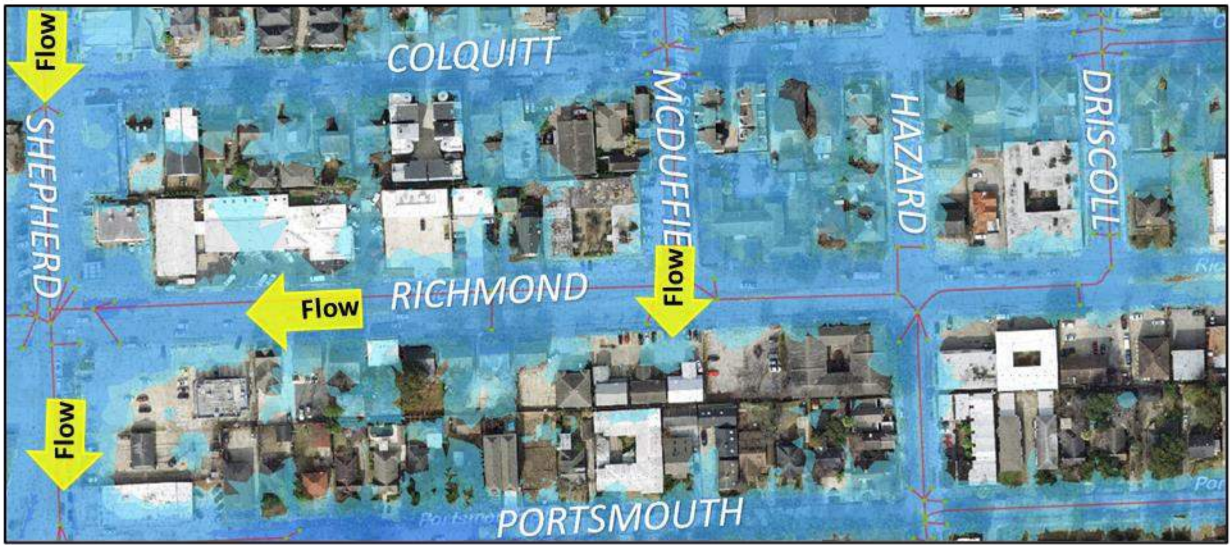


Figure 9 - Problem Area 6 Simulated Flooding

Observed Problem:	Multiple structures show a high risk of flooding during large flood events along both Shepherd and Richmond. Roads are completely inundated at depths up to 2'.
Flooding Source:	Surface flow from the North is carried into the problem area from various streets. Shepherd provides the majority of the surface runoff that enters the area.
Storm Drain System:	Two storm drain systems carry runoff from the problem area to the South and discharge into US 59 systems.
Duration of Flooding:	Richmond Avenue is shown to be inundated at over 6" for up to 4-hours during a 100-year event.
Downstream:	Most of the overflow discharges to the south being carried by Shepherd and Hazard Street. Some flow leaves the problem area to the East along Richmond Avenue.
Flood Complaints:	One FEMA Repetitive Loss complaint was identified for Problem Area 1 in the collected databases. Multiple structures reported Harvey throughout the problem area.

G. Problem Area 7 – Alabama & Shepherd

Problem Area 7 is in the vicinity of the intersection of Alabama Street and Shepherd Drive. The 100-year simulated inundation is shown in Figure 10. This project area may be influenced by an ongoing City of Houston TIRZ 19 project on Shepherd, which has not been included in the analysis for this study.

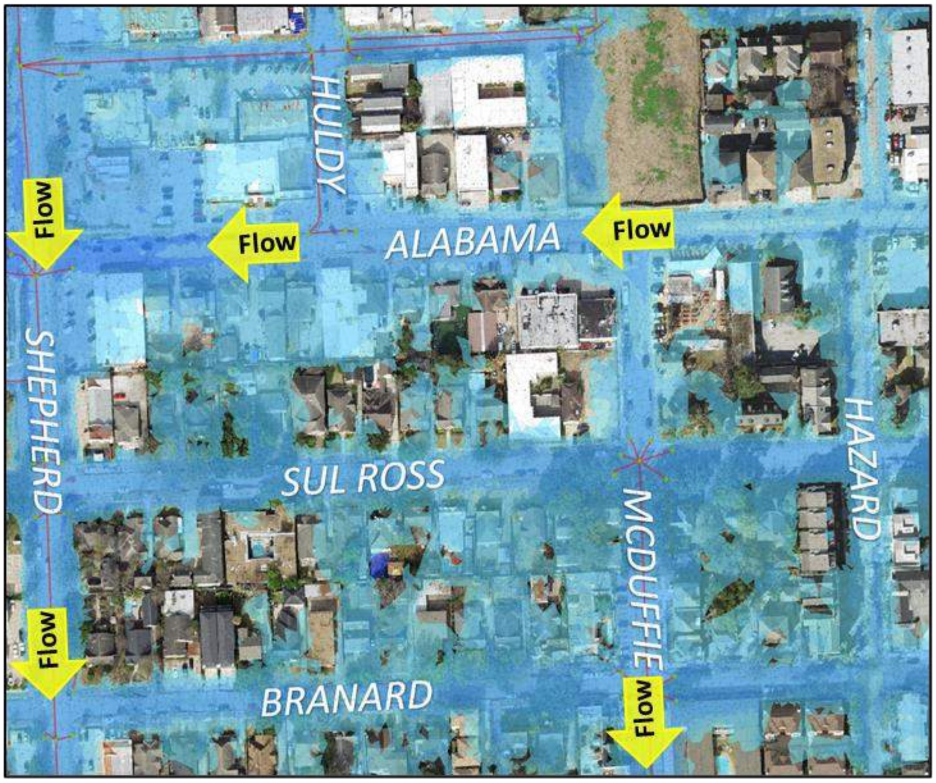


Figure 10 - Problem Area 7 Simulated Flooding

Observed Problem:	Cascading sheet flow is observed throughout the problem area showing a significant risk for structural flooding.
Flooding Source:	Water is conveyed primarily from the West along various streets including Alabama, Sul Ross, and Branard. Additional water flows into the problem area from the north.
Storm Drain System:	Much of the problem area does not have storm drain systems. A few small laterals drain to a major trunkline under Shepherd that eventually discharges to the South into a US 59 system.
Duration of Flooding:	Street flooding over 6” inches is common in the problem area, with durations of up to 4 hours.
Downstream:	Most of the overflow from the problem area drains south through street conveyance.
Flood Complaints:	Two FEMA Repetitive Loss complaints were identified for Problem Area 7, one of which was observed as having flooding during Harvey.

5. INITIAL SOLUTION CONCEPT DEVELOPMENT

Conceptual solutions consisting of major trunkline improvements were developed throughout the study area to address the identified problem areas. To ensure that the proposed projects are multi-purpose, proposed trunkline improvements were kept within the limits of proposed TIRZ and City of Houston corridor mobility projects. Since most drainage trunklines are placed under roadways, and require the demolition of existing pavement to construct, matching proposed trunkline improvements with the identified corridor projects will help reduce overall construction cost and reduce mobility impacts during to construction. This provides a road map of well-planned comprehensive drainage improvements that accompany planned mobility projects.

A. FLOOD REDUCTION ANALYSES

Gauge utilized the InfoWorks ICM model created for the Existing Conditions analysis to simulate the benefits of proposed storm drain trunklines. Trunklines were strategically proposed in areas overlapping with identified corridor projects that would also benefit identified problem areas and street flooding. Existing utility data along each corridor was reviewed to assess the maximum size trunkline allowable. Existing trunklines were then upsized to the maximum allowable size and flowline data was adjusted to ensure a minimum 3 feet of cover and positive drainage. Trunkline sizes should be optimized for each project corridor prior to final design. The InfoWorks ICM inlet parameters along each trunkline were adjusted to simulate improved inlet capacity along the roadways. The locations of the proposed trunklines and their sizes are provided in **Appendix D**.

Three different alternatives all utilizing the same trunkline location and sizing were analyzed. The difference between these three modeled alternatives was different levels of restriction on the outfalls. Of these three alternatives, Alternative 1 is preferred.

Alternative 1 – Free Outfall

Alternative 1 included no restrictions to the proposed trunklines which resulted in increased peak flow at the storm drain outfalls into Buffalo Bayou. The overall reduction in surface storage from Existing Conditions to Alternative 1 is 204 Ac-ft. Although the peak flow from the study area into Buffalo Bayou is increased, there are no adverse impacts to Buffalo Bayou. No adverse impacts are observed because the study area is at the downstream end of the Buffalo Bayou watershed and the time to peak of the study area is decreased with larger storm drain, which shifts the project area peak further away from the Buffalo Bayou peak. A detailed analysis of potential impacts of Alternative 1 on the Buffalo Bayou watershed is presented in **Appendix F**. Inundation exhibits showing the benefits of Alternative 1 are provided in **Appendix E.**

Alternative 2 – Partially Restricted Outfall

Alternative 2 placed some restriction on the proposed storm drain trunklines to use more of the trunkline capacity as storage and restrict the peak flows into Buffalo Bayou. An increase in peak flow into Buffalo Bayou is still observed, which would need to be offset using surface storage if no increase in peak flow is desired. The overall reduction in natural surface storage between Existing Conditions and Alternative 2 is approximately 168 ac-ft. Several potential mitigation areas were identified that could potentially provide approximately 55.1 ac-ft of surface storage all together; however, it was determined that Alternative 2 is not desirable due to the cost of acquiring the proposed mitigation sites and constructing the surface storage. Inundation exhibits showing the benefits of Alternative 2 are provided in **Appendix *E***.

Alternative 3 – Outfall Restricted to Existing Conditions Discharge

Alternative 3 placed further restriction on the proposed storm drain trunklines to fully eliminate peak flow increases into Buffalo Bayou. This alternative greatly reduced the benefits of the proposed trunklines and is therefore not recommended as a standalone improvement strategy. However, this improvement approach can be implemented as an interim approach to a future full conveyance solution. The storm drain layout for Alternative 3 is very similar to Alternatives 1 and 2, except that instead of constructing a new outfall at Dunlavy, the storm drain would be brough east along W. Gray Street to meet with the existing system at Waugh. See **Appendix D** for the proposed drain layout. Inundation exhibits showing the benefits of Alternative 3 are provided in **Appendix *E***.

B. Opinion of Probable Project Costs

An opinion of probable cost, provided in ***Appendix G***, was developed for each proposed project to assist the TIRZ in their budgeting and planning efforts. The opinion of probable cost includes estimates for the project construction costs, professional services to complete the preliminary and final design, and construction phase services. All unit costs provided are in 2020 dollars and are based on recent construction bid data and Gauge's experience with similar projects. A summary of the opinion of probable project costs is provided in Table 3. These estimated project costs include storm drain and inlet improvements, as well as planning level estimates for roadway replacement in each project area. A 25% contingency was included in construction cost estimates due to the preliminary nature of the conceptual designs. Professional services and construction phase services were estimated using a percent of the construction cost.

Table 3: Opinion of Probably Project Costs Summary

CIP Projects	Construction (25% Contingency)	PER/Design (8%)	CM&I (6%)	Total
Alabama	$6,967,000	$557,360	$418,020	$7,942,380
Dunlavy	$21,319,000	$1,705,520	$1,279,140	$24,303,660
Fairview	$2,589,000	$207,120	$155,340	$2,951,460
Gray	$6,857,000	$548,560	$411,420	$7,816,980
Montrose	$40,300,000	$3,224,000	$2,418,000	$45,942,000
Richmond	$9,035,000	$722,800	$542,100	$10,299,900
Westheimer	$4,098,000	$327,840	$245,880	$4,671,720
Total	**$91,165,000**	**$7,293,200**	**$5,469,900**	**$103,928,100**

C. Project Prioritization

A ranking matrix was developed to objectively prioritize the drainage projects. Three ranking criteria were identified based on severity of street flooding, problem area benefit from proposed projects, and dependency on other drainage projects. Gauge developed a weight for each scoring criterion which resulted in a maximum score of 40%. A maximum score of 40% was chosen because the maximum score for drainage in the CIP scoring was set to 40%. A detailed description of each scoring criterion as well as the categories and weights are provided in **Appendix *H***. After the scoring criteria and weighting were established, Gauge objectively scored each individual project. The individual category scores, total score, and rank of each problem area is provided below in Table 4.

A summary sheet for each project describing the proposed solution, benefited problem areas, the projects' dependencies, project ranking, estimated cost, and assumptions is provided in **Appendix *I*.**

Table 4: Project Ranking

Corridor	Street Flooding	Benefit Zones	Dependency	Total	Ranking
Montrose	20%	10%	10%	40%	1
Dunlavy	20%	6%	10%	36%	2
Alabama	10%	6%	0%	16%	3
Richmond	10%	6%	0%	16%	3
Fairview*	10%	3%	0%	13%	4
Westheimer*	10%	3%	0%	13%	4
Gray	0%	3%	0%	3%	5

**Street flooding criteria was upgraded due to engineering judgement based on potential local ponding benefits the project will achieve.*

6. CONCLUSIONS AND RECOMMENDATIONS

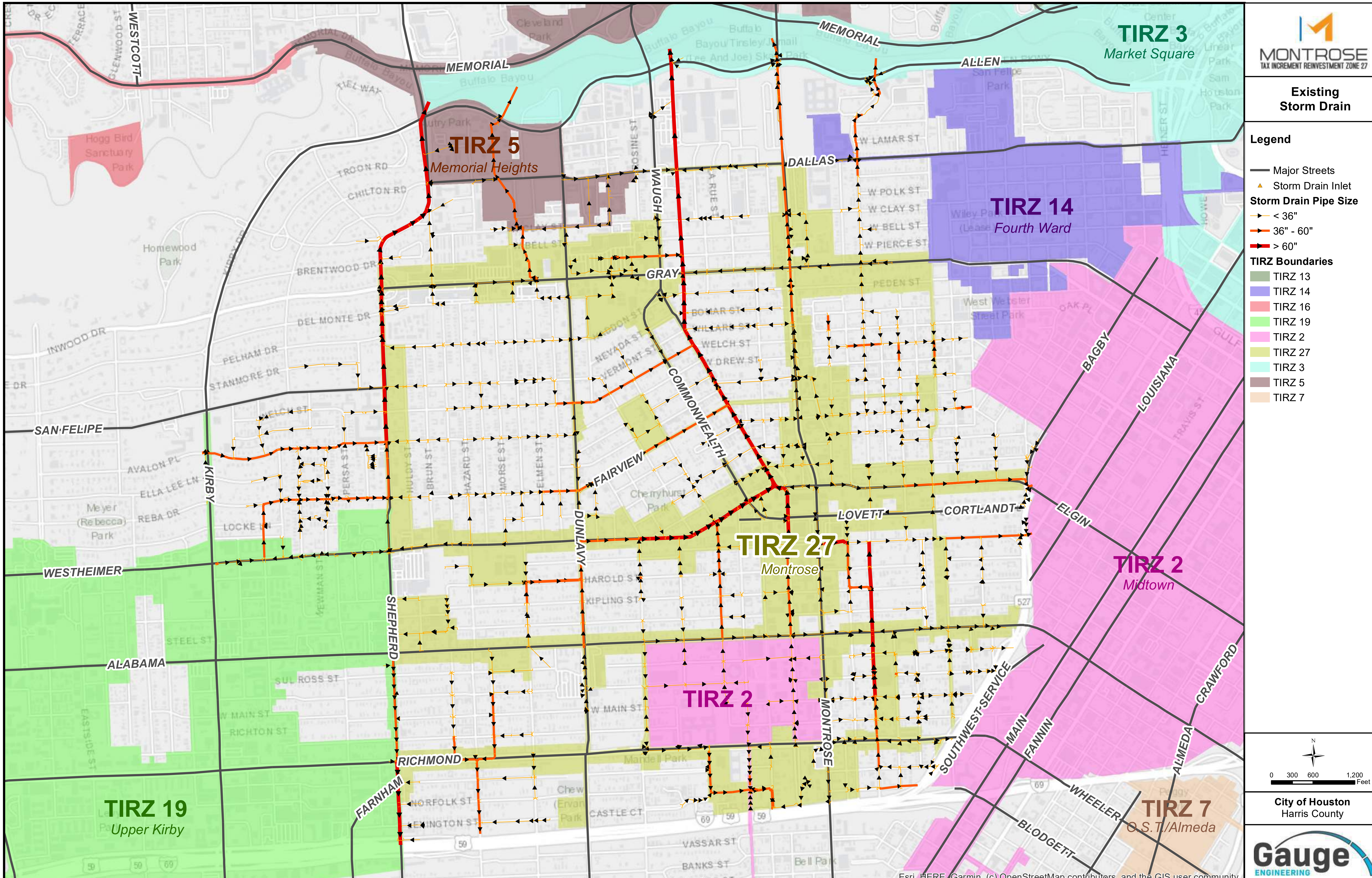
In the Montrose Drainage Study, Gauge Engineering performed a regional drainage analysis to identify current drainage problems and provide short- and long-term solutions for addressing drainage concerns throughout the Montrose area. In this analysis, seven problem areas were identified, and improvement options were developed to decrease ponding depths in these areas. Three alternative solution concepts were developed to help reduce ponding in the Montrose Area. These three alternatives all have the same pipe infrastructure, but they have different levels of restriction on the outfall pipes. Alternative 1 would provide no restriction and allow full conveyance of flow to the Bayou. Alternative 2 would provide some restriction and surface detention, and Alternative 3 would restrict flows coming from the system down to the existing discharge. The estimated total cost of all the recommended CIP projects with drainage components is **$103,928,200.**

Drainage projects were proposed on the main CIP corridor areas for TIRZ #27 and other agencies. The proposed storm drain layout includes main trunkline improvements along Montrose Blvd. and Dunlavy St., and proposed lateral storm drains on Alabama, Richmond, Fairview, Westheimer, and Gray St. After performing an analysis to evaluate potential impacts downstream, the recommended approach to achieve the most benefit is Alternative 1, which does not restrict the outfall and provides full conveyance of stormwater to Buffalo Bayou. Gauge approached HCFCD with this option and submitted a variance request for HCFCD to allow increased discharge to Buffalo Bayou from the Montrose Area. This request was based on the concept that the Montrose area is far downstream in the Buffalo Bayou watershed, and that with enlarged storm drains, the Montrose area would drain faster than in existing conditions, thereby moving water to the Bayou ahead of the Buffalo Bayou peak flow and reducing the overall peak discharge in Buffalo Bayou.

HCFCD responded in late 2020 and denied the variance request, explaining that at this time increased discharges are not being considered anywhere in the County. However, as a result of the variance request, HCFCD indicated an interest in a HCFCD led study to evaluate the possibility of approving increased discharges in the lower portions of watersheds that drain to the ship channel or directly to the bay. Gauge recommends that in the short and near term, Alternative 3 should be constructed with a restrictor at the Buffalo Bayou outfall locations to maintain existing conditions discharge. In the future, if HCFCD does allow increased discharges into the downstream portions of Buffalo Bayou, the restrictors can then be removed, and a new outfall can be constructed at Dunlavy to achieve the full benefit of Alternative 1.

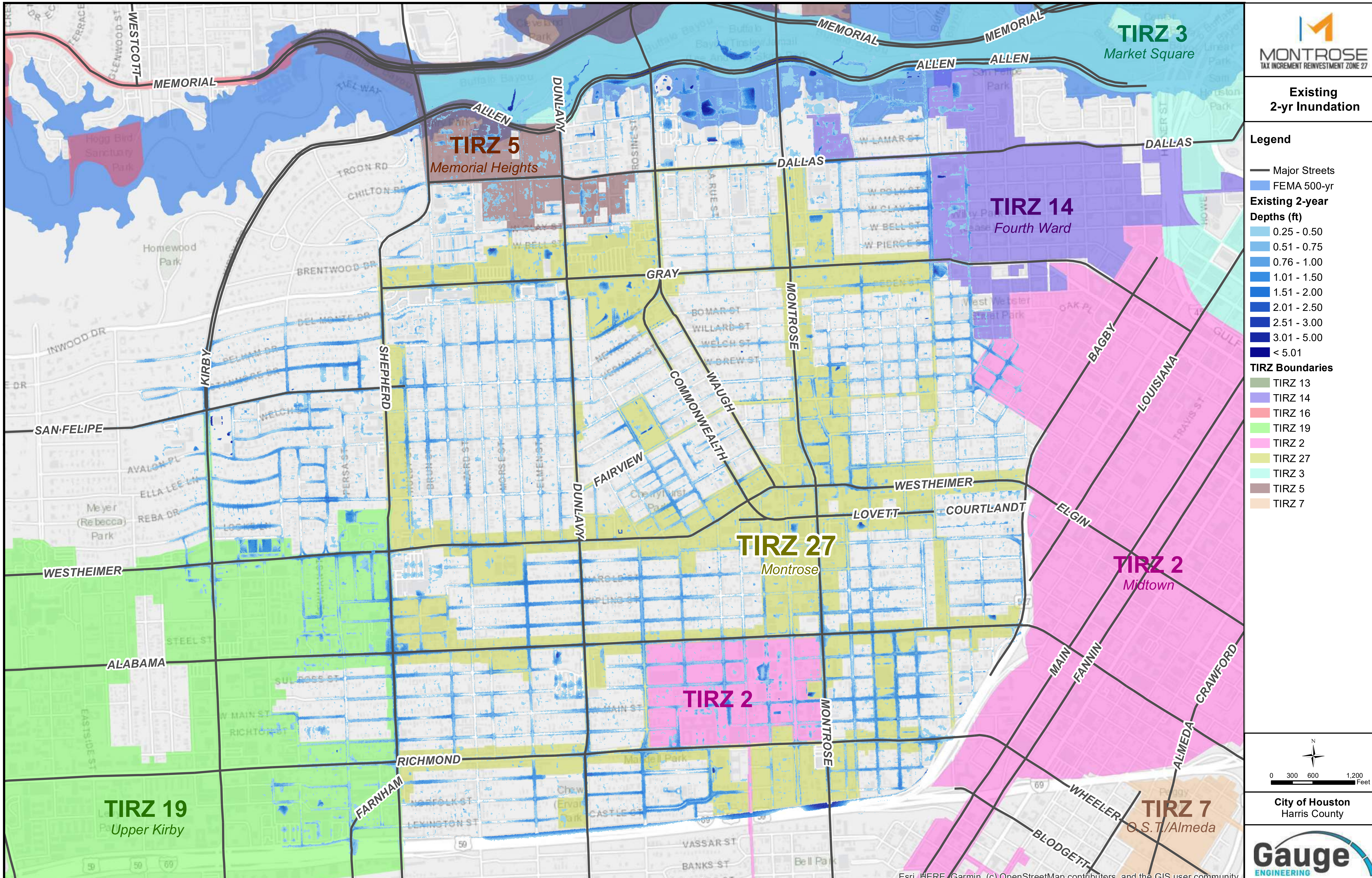
APPENDIX A

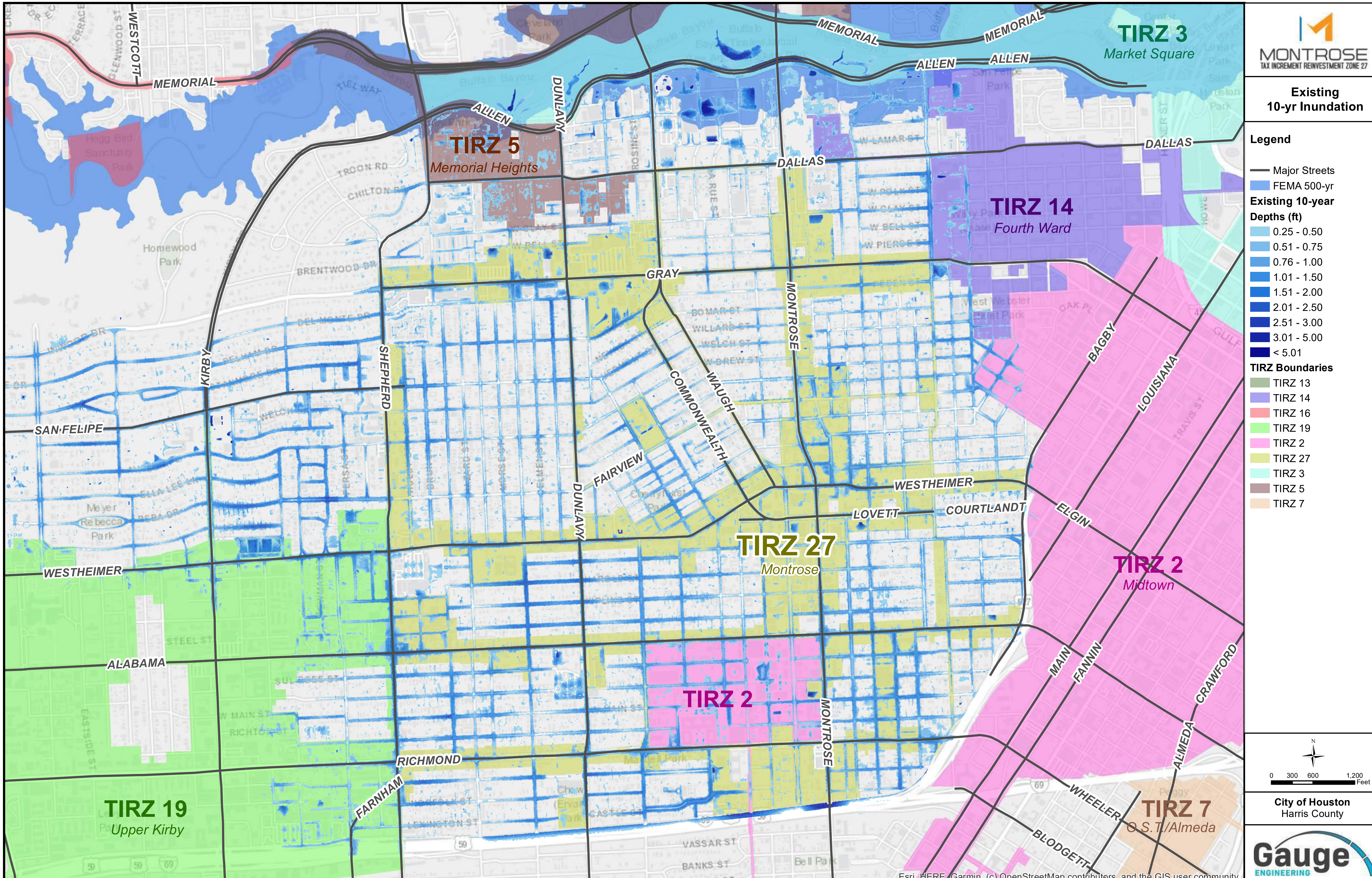
Existing Storm Drain Infrastructure

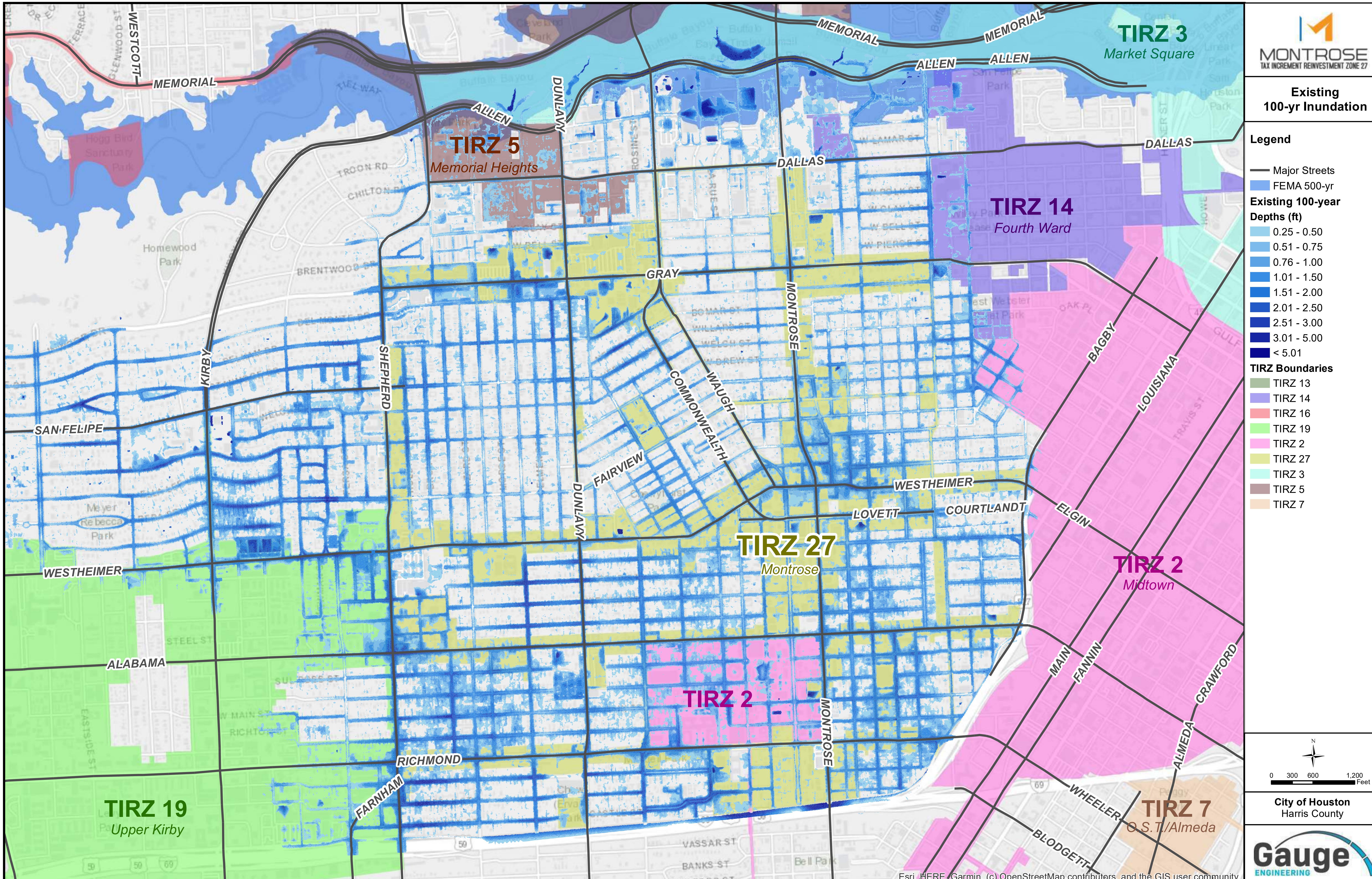

MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Existing Storm Drain
Legend
Major Streets
Storm Drain Inlet
Storm Drain Pipe Size
< 36"
36" - 60"
> 60"
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
N
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge
ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTCOTT
WAUGH
COMMONWEALTH
FAIRVIEW
SAN FELIPE
KIRBY
WESTHEIMER
SHEPHERD
DUNLAVY
LOVETT
CORTLANDT
ELGIN
BAGBY
LOUISIANA
ALABAMA
RICHMOND
FARNHAM
MONTROSE
SOUTHWEST SERVICE
MAIN
FANNIN
ALMEDA
CRAWFORD
WHEELER
BLODGETT
W LAMAR ST
W POLK ST
W CLAY ST
W BELL ST
W PIERCE ST
PEDEN ST
BOMAR ST
WELCH ST
W DREW ST
HAROLD ST
KIPLING ST
W MAIN ST
NORFOLK ST
CASTLE CT
VASSAR ST
BANKS ST
Hogg Bird Sanctuary Park
Homewood Park
Meyer (Rebecca) Park
Cherryhurst Park
Mandell Park
Bell Park
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

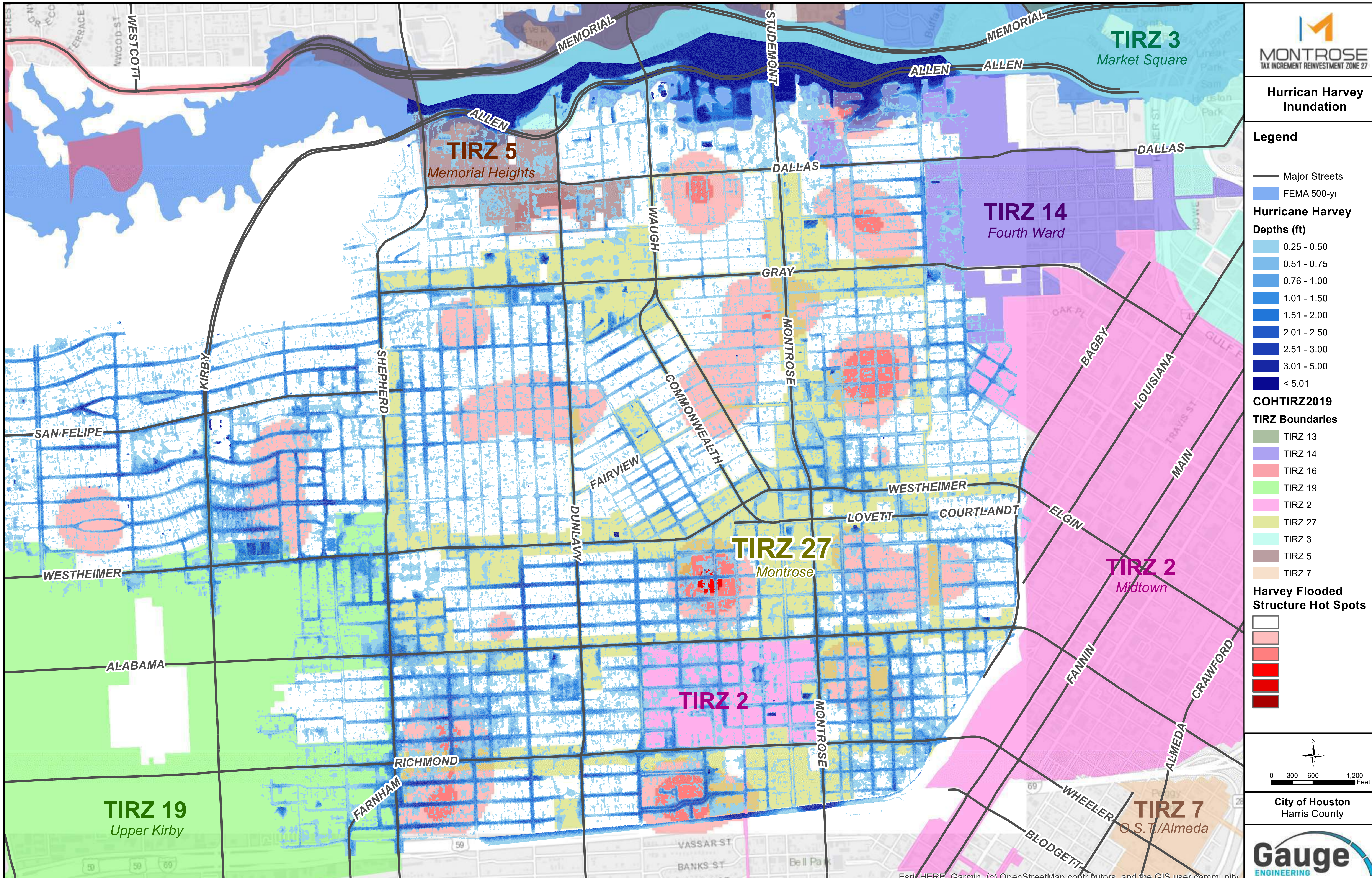
APPENDIX B

Existing Inundation Maps (2-yr, 10-yr, 100-yr, Harvey)


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Existing
2-yr Inundation
Legend
Major Streets
FEMA 500-yr
Existing 2-year
Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge
ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTHEIMER
SAN FELIPE
ALABAMA
RICHMOND
KIRBY
SHEPHERD
DUNLAVY
MONTROSE
WAUGH
COMMONWEALTH
FAIRVIEW
LOVETT
COURTLANDT
ELGIN
BAGBY
LOUISIANA
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
FARNHAM
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Existing
10-yr Inundation
Legend
Major Streets
FEMA 500-yr
Existing 10-year
Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge
ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTCOTT
KIRBY
SHEPHERD
DUNLAVY
MONTROSE
COMMONWEALTH
WAUGH
FAIRVIEW
SAN FELIPE
WESTHEIMER
LOVETT
COURTLANDT
ELGIN
BAGBY
LOUISIANA
ALABAMA
RICHMOND
FARNHAM
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

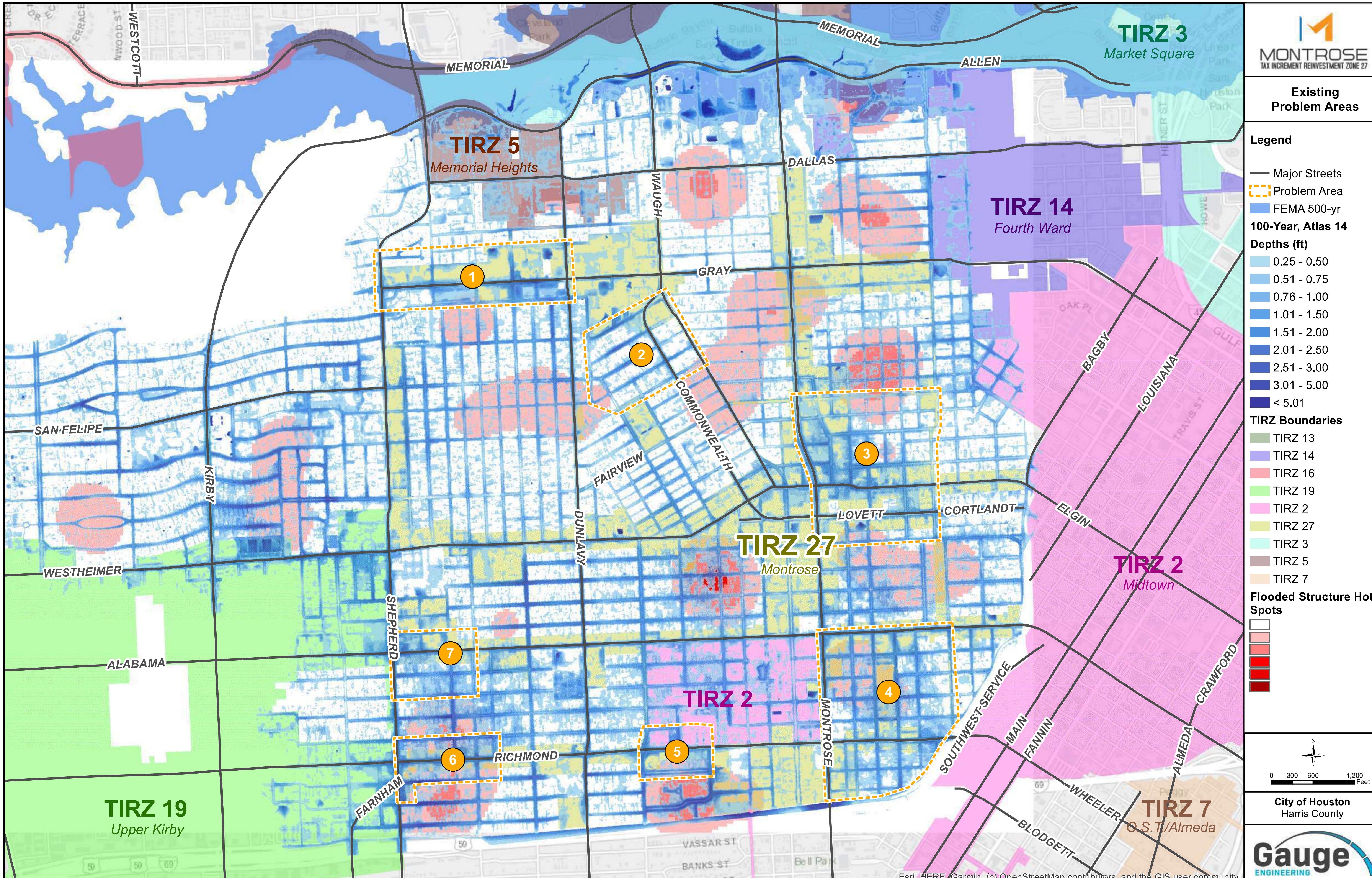

MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Existing
100-yr Inundation
Legend
Major Streets
FEMA 500-yr
Existing 100-year
Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
0 300 600 1,200 Feet
N
City of Houston
Harris County
Gauge
ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTHEIMER
LOVETT
COURTLANDT
SAN FELIPE
ALABAMA
RICHMOND
FARNHAM
KIRBY
SHEPHERD
DUNLAVY
MONTROSE
WAUGH
COMMONWEALTH
FAIRVIEW
BAGBY
LOUISIANA
ELGIN
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
WESTCOTT
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Hurrican Harvey Inundation
Legend
Major Streets
FEMA 500-yr
Hurricane Harvey Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
COHTIRZ2019
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
Harvey Flooded Structure Hot Spots
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTCOTT
STUDEMONT
WAUGH
MONTROSE
KIRBY
SHEPHERD
SAN FELIPE
COMMONWEALTH
FAIRVIEW
WESTHEIMER
LOVETT
COURTLANDT
ELGIN
BAGBY
LOUISIANA
MAIN
DUNLAVY
ALABAMA
FANNIN
CRAWFORD
ALMEDA
RICHMOND
FARNHAM
WHEELER
BLODGETT
VASSAR ST
BANKS ST
MILFORD ST
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

APPENDIX C

Identified Problem Areas

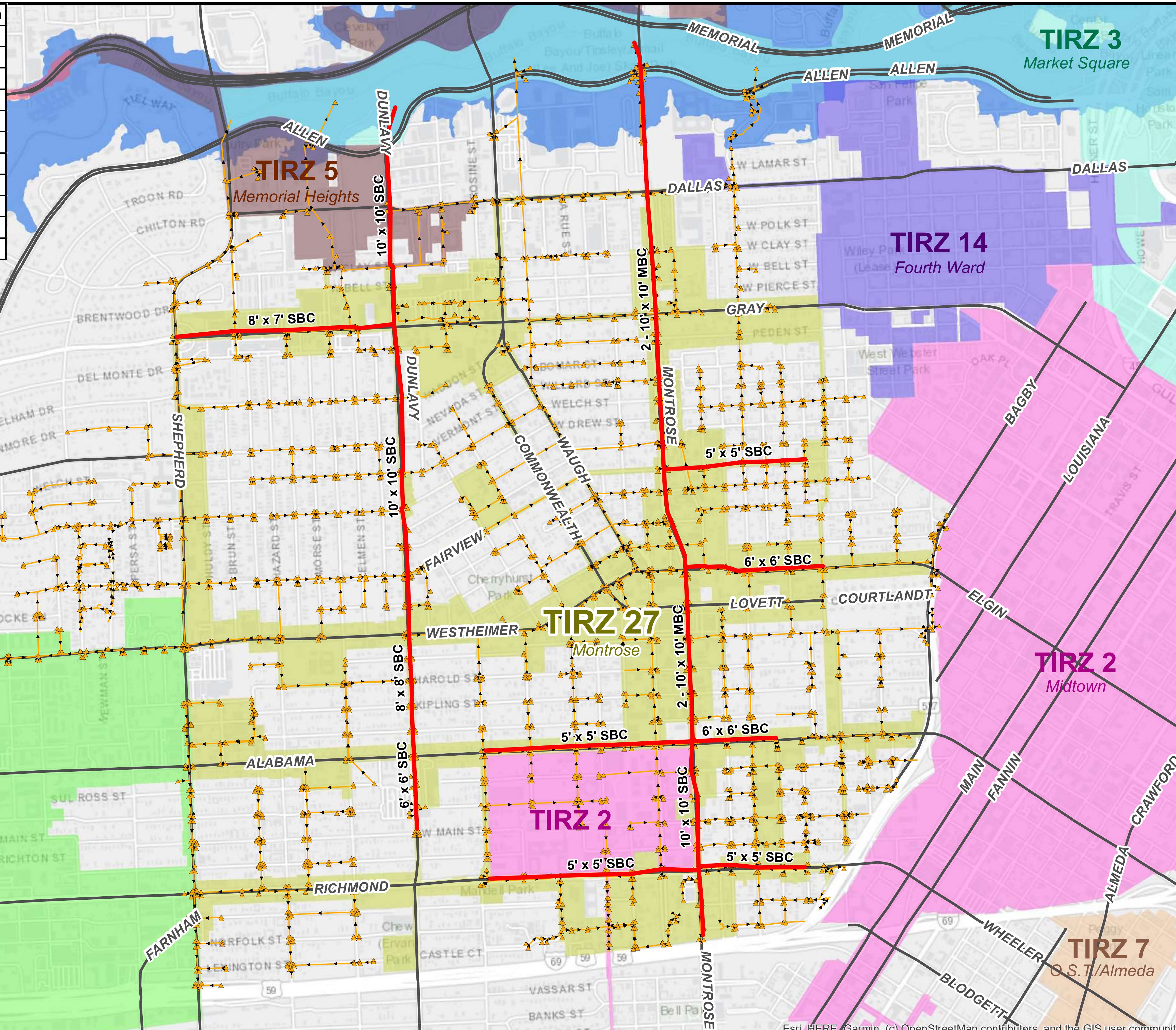


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Existing Problem Areas
Legend
Major Streets
Problem Area
FEMA 500-yr
100-Year, Atlas 14 Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
Flooded Structure Hot Spots
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge
ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
WAUGH
GRAY
BAGBY
LOUISIANA
COMMONWEALTH
FAIRVIEW
SAN FELIPE
KIRBY
DUNLAVY
LOVETT
CORTLANDT
ELGIN
WESTHEIMER
SHEPHERD
ALABAMA
MONTROSE
SOUTHWEST SERVICE
MAIN
FANNIN
CRAWFORD
ALMEDA
RICHMOND
FARNHAM
WHEELER
BLODGETT
WESTCOTT
VASSAR ST
BANKS ST
MILFORD ST
1
2
3
4
5
6
7
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

APPENDIX D

Proposed Storm Drain Trunklines

Street	Size	Total Length
Gray	8' x 7'	2690
Dunlavy	6' x 6'	1240
	8' x 8'	1170
	10' x 10'	6530
Montrose	10' x 10'	2440
	2 - 10' x 10'	8600
Alabama	5' x 5'	2590
	6' x 6'	1050
Westheimer	6' x 6'	1720
Fairview	5' x 5'	1750
Richmond	5' x 5'	3880



MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

Alternatives 1 and 2 Proposed Storm Drain Layout

Legend

- Major Streets
- Existing SD Inlet
- Existing SD Pipe
- Proposed SD Trunkline

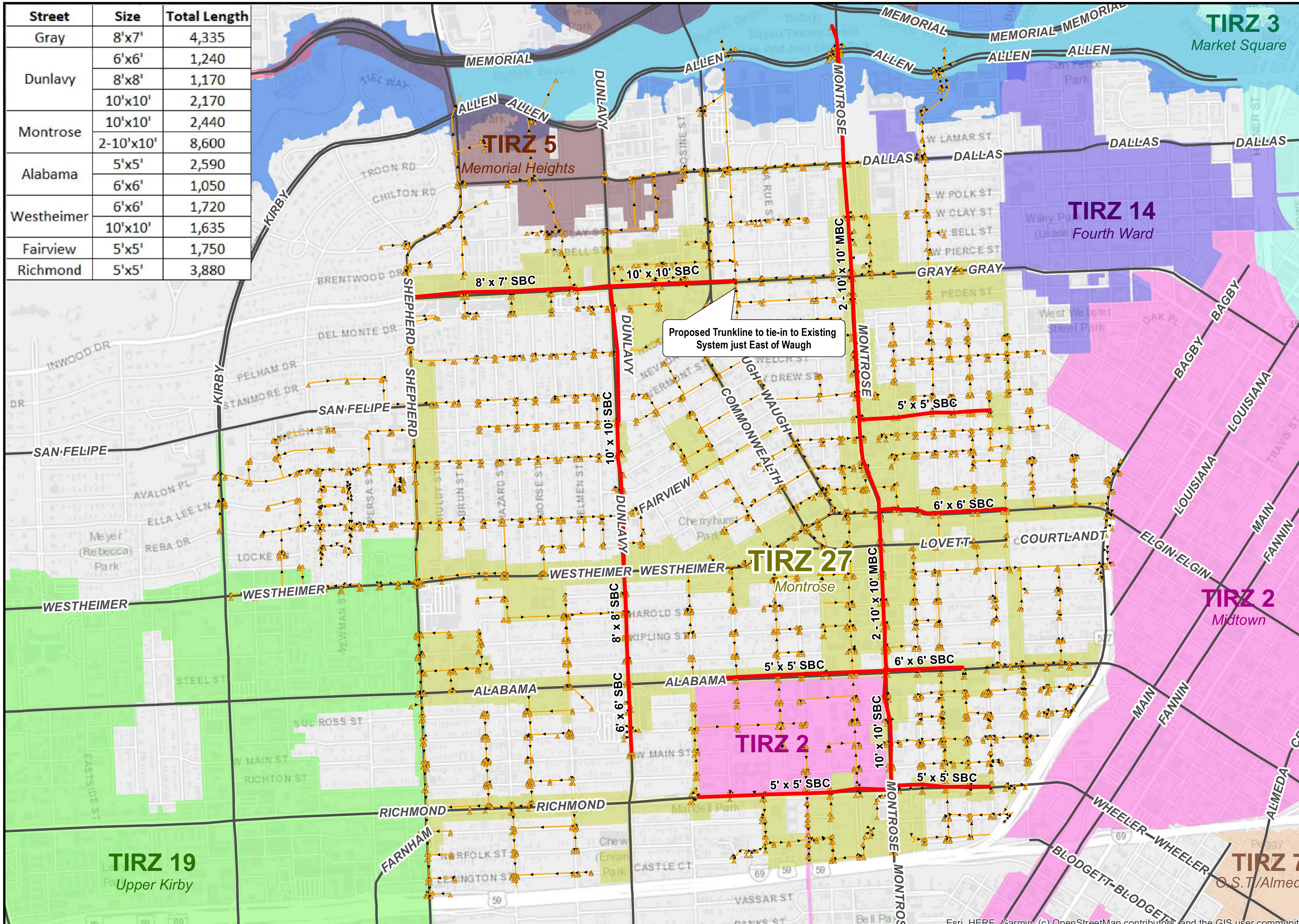
TIRZ Boundaries

- TIRZ 13
- TIRZ 14
- TIRZ 16
- TIRZ 19
- TIRZ 2
- TIRZ 27
- TIRZ 3
- TIRZ 5
- TIRZ 7

City of Houston
Harris County

Gauge ENGINEERING

Street	Size	Total Length
Gray	8'x7'	4,335
Dunlavy	6'x6'	1,240
	8'x8'	1,170
	10'x10'	2,170
Montrose	10'x10'	2,440
	2-10'x10'	8,600
Alabama	5'x5'	2,590
	6'x6'	1,050
Westheimer	6'x6'	1,720
	10'x10'	1,635
Fairview	5'x5'	1,750
Richmond	5'x5'	3,880



MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

Alternative 3
Proposed Storm Drain Trunklines

Legend

- Existing SD Inlet
- Existing SD Pipe
- Proposed SD Trunkline

TIRZ Boundaries

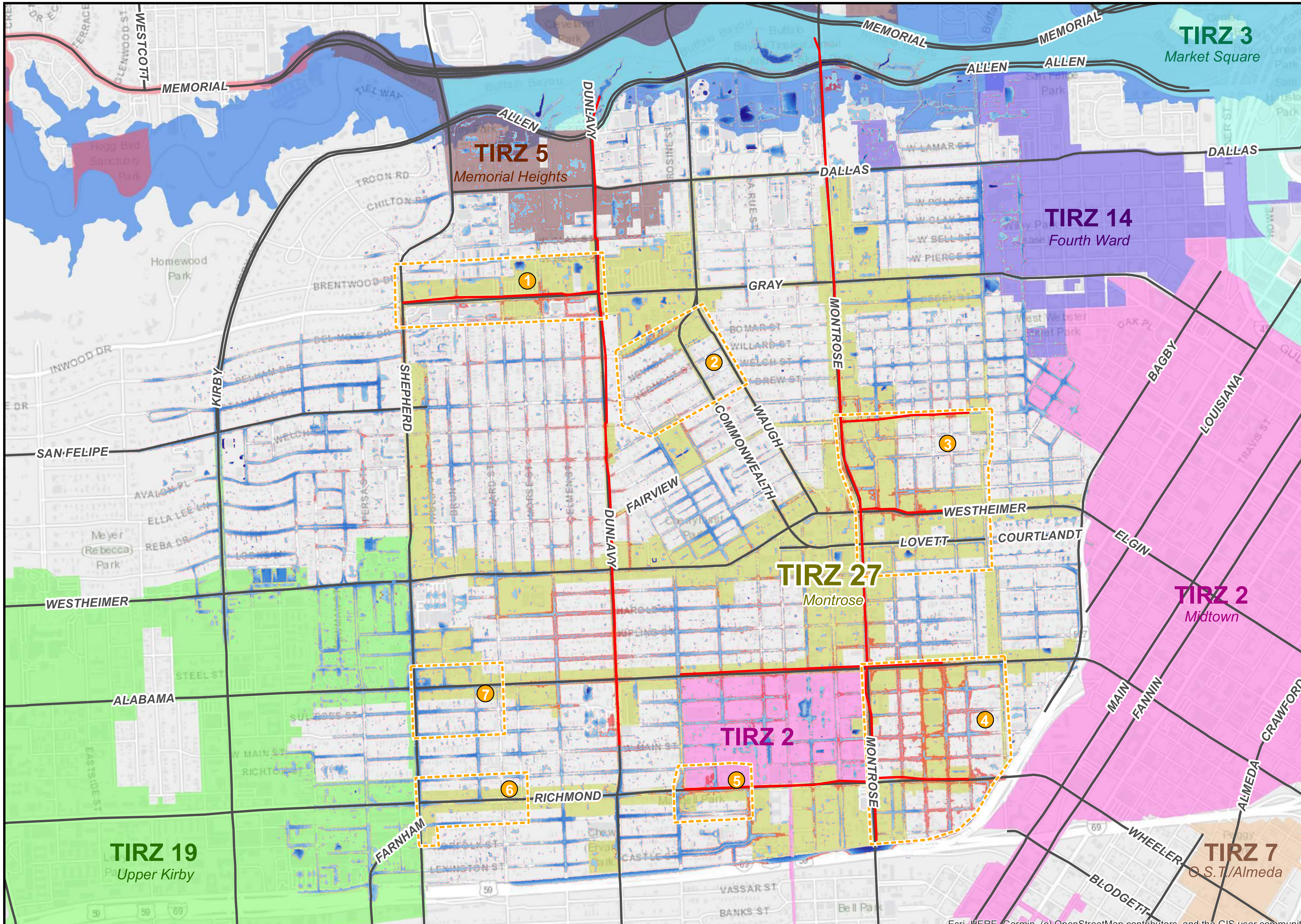
- TIRZ 13
- TIRZ 14
- TIRZ 16
- TIRZ 19
- TIRZ 2
- TIRZ 27
- TIRZ 3
- TIRZ 5
- TIRZ 7

City of Houston
Harris County

Gauge
ENGINEERING

APPENDIX E

Proposed Inundation Maps



MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

Proposed ALT 1
2-yr Inundation

Legend

- Major Streets
- FEMA 500-yr
- Problem Area
- Proposed SD Trunkline
- Existing 2-yr

Proposed 2-yr Depths (ft)

- 0.25 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- 3.01 - 5.00
- < 5.01

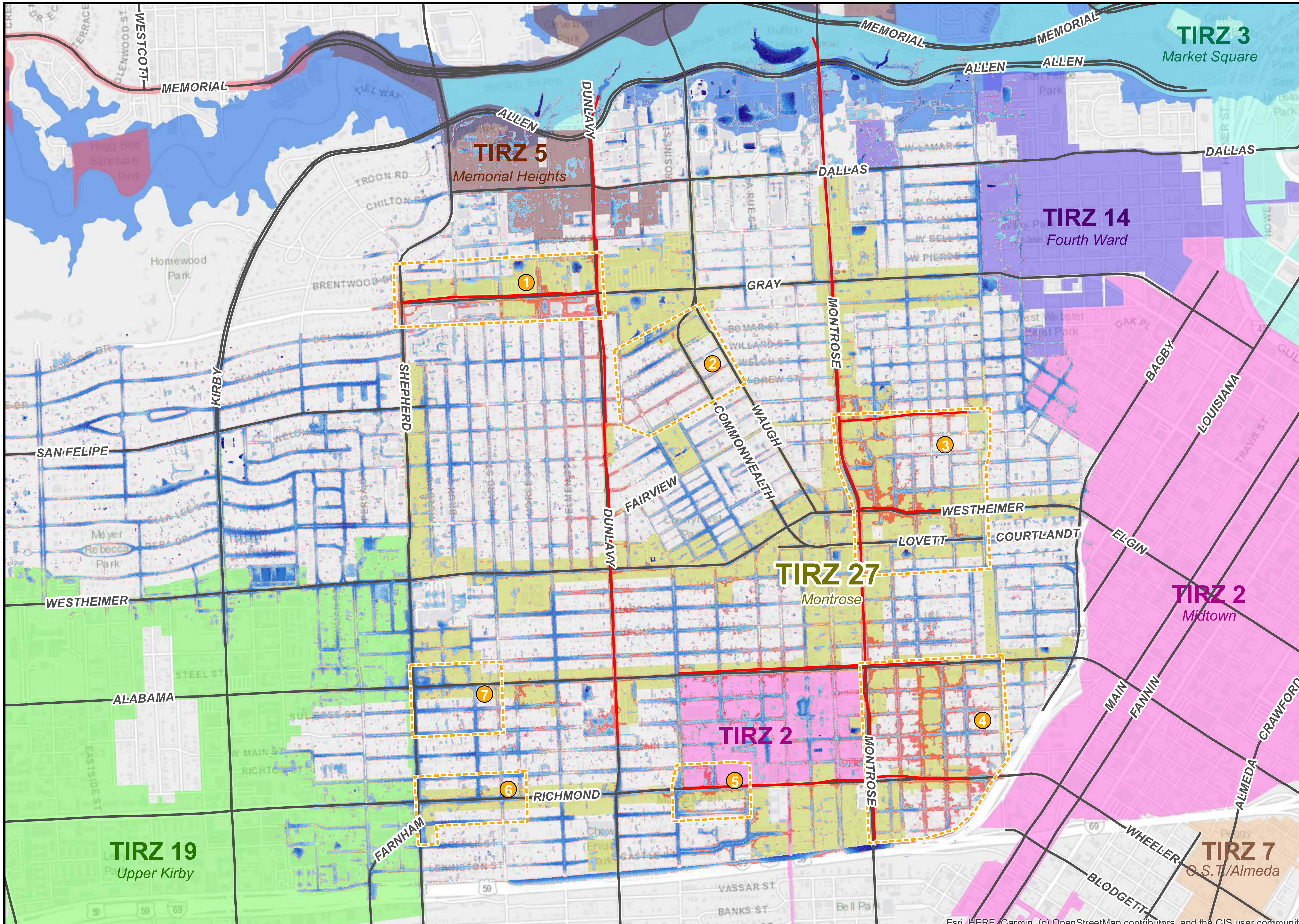
TIRZ Boundaries

- TIRZ 13
- TIRZ 14
- TIRZ 16
- TIRZ 19
- TIRZ 2
- TIRZ 27
- TIRZ 3
- TIRZ 5
- TIRZ 7

N
0 300 600 1,200 Feet

City of Houston
Harris County

Gauge
ENGINEERING



MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

Proposed ALT 1
10-yr Inundation

Legend

- Major Streets
- FEMA 500-yr
- Problem Area
- Proposed SD Trunkline
- Existing 10-yr

Proposed 10-yr Depths (ft)

- 0.25 - 0.50
- 0.51 - 0.75
- 0.76 - 1.00
- 1.01 - 1.50
- 1.51 - 2.00
- 2.01 - 2.50
- 2.51 - 3.00
- 3.01 - 5.00
- < 5.01

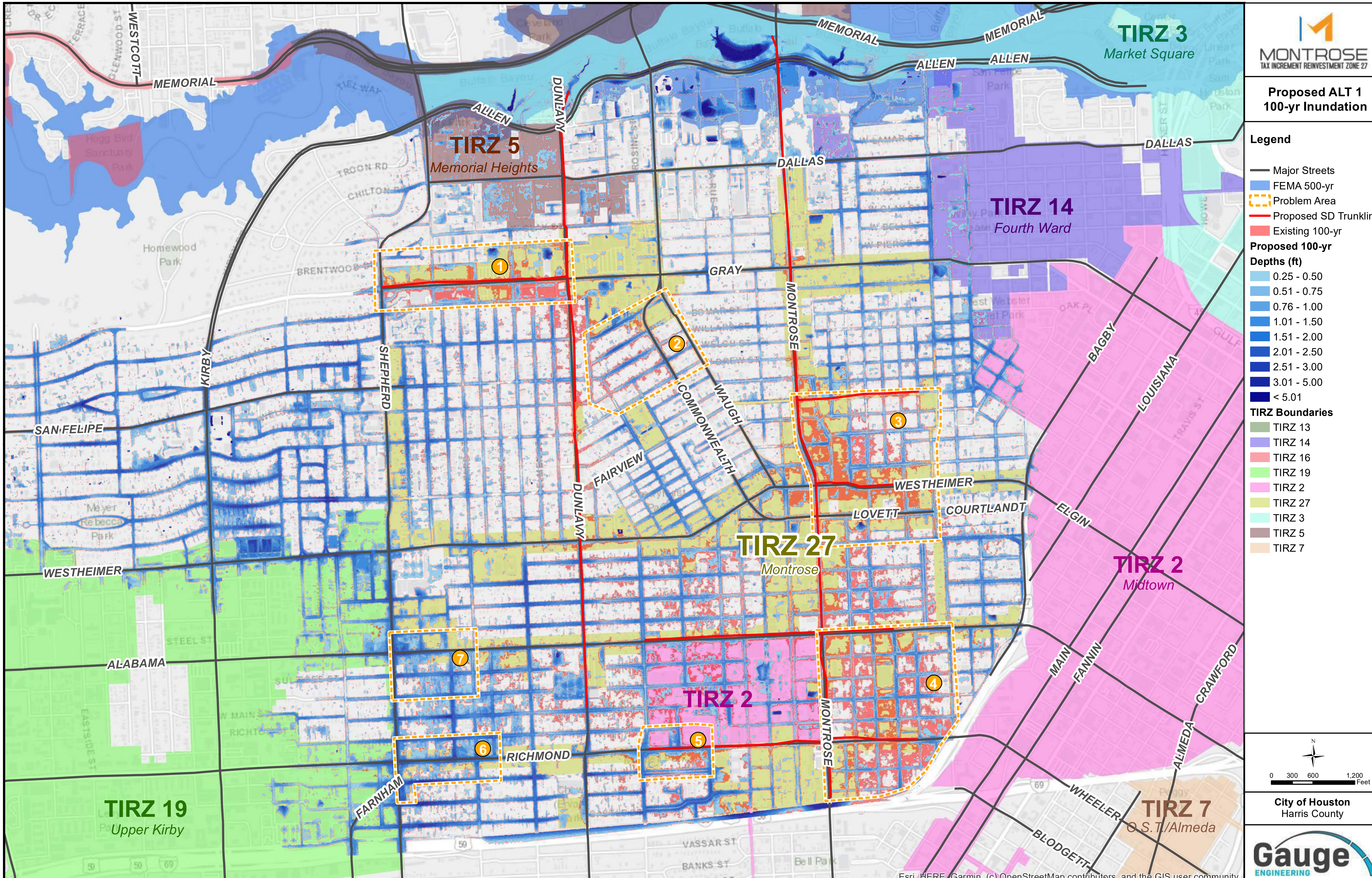
TIRZ Boundaries

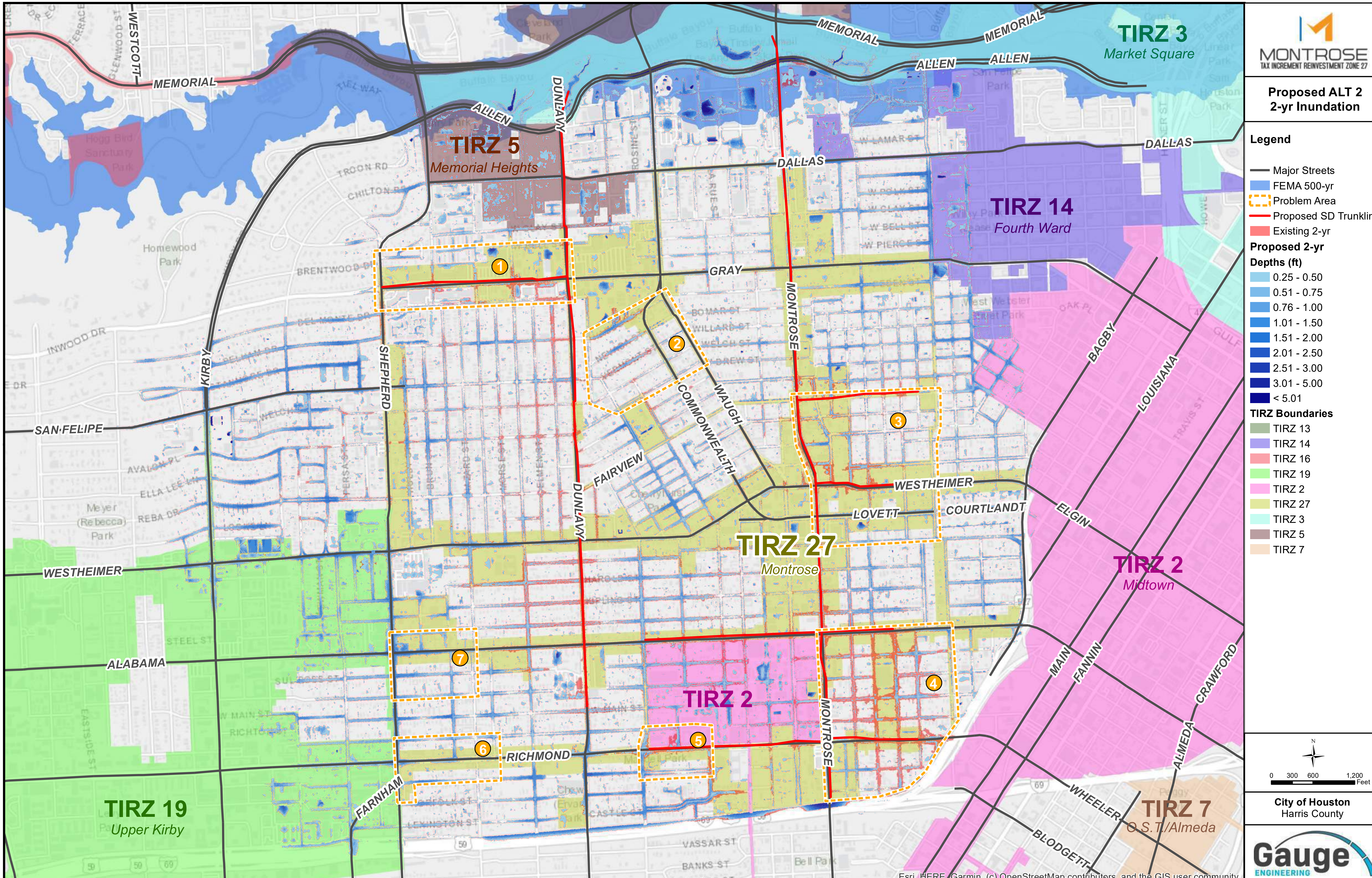
- TIRZ 13
- TIRZ 14
- TIRZ 16
- TIRZ 19
- TIRZ 2
- TIRZ 27
- TIRZ 3
- TIRZ 5
- TIRZ 7

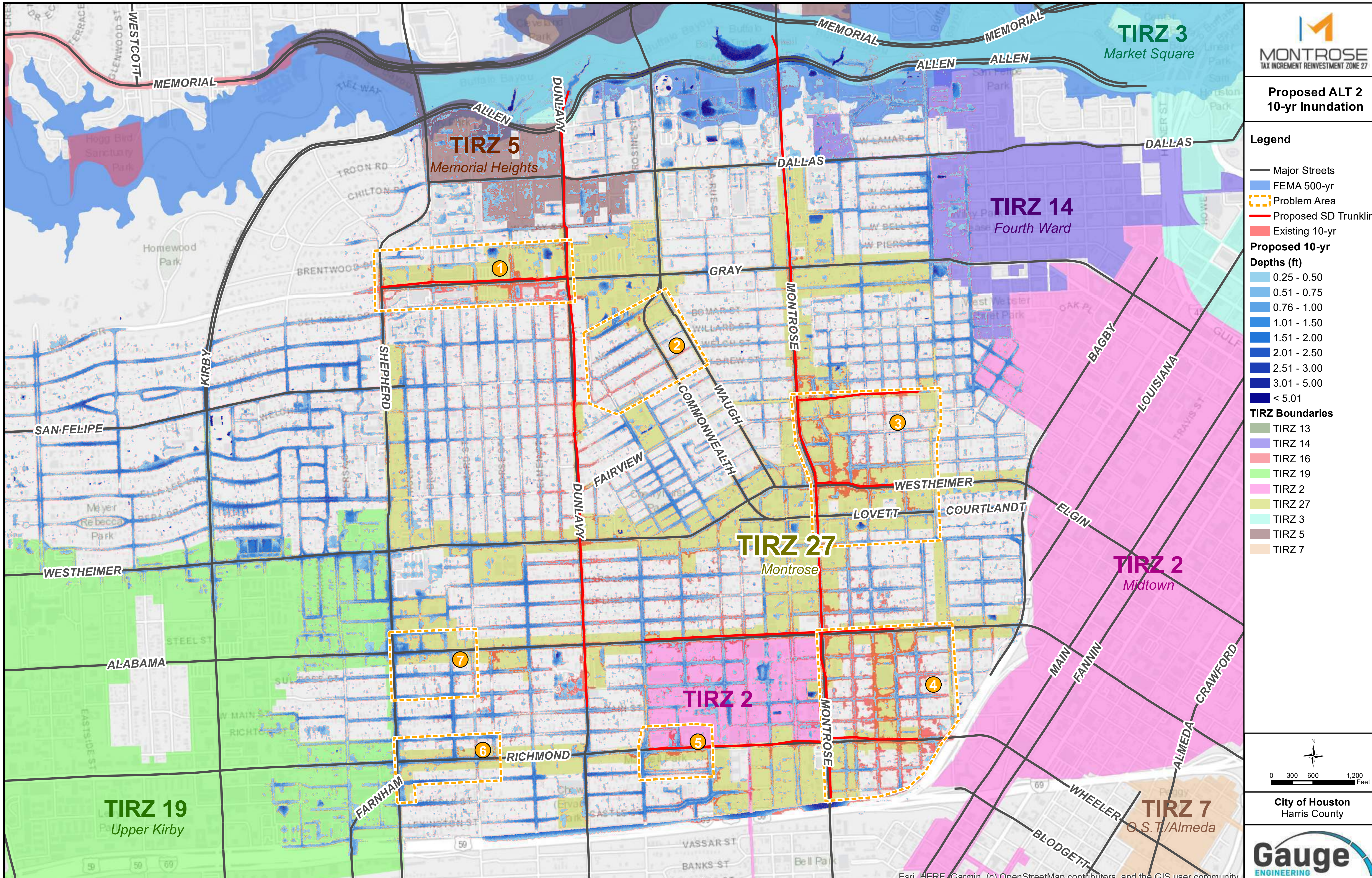
N
0 300 600 1,200 Feet

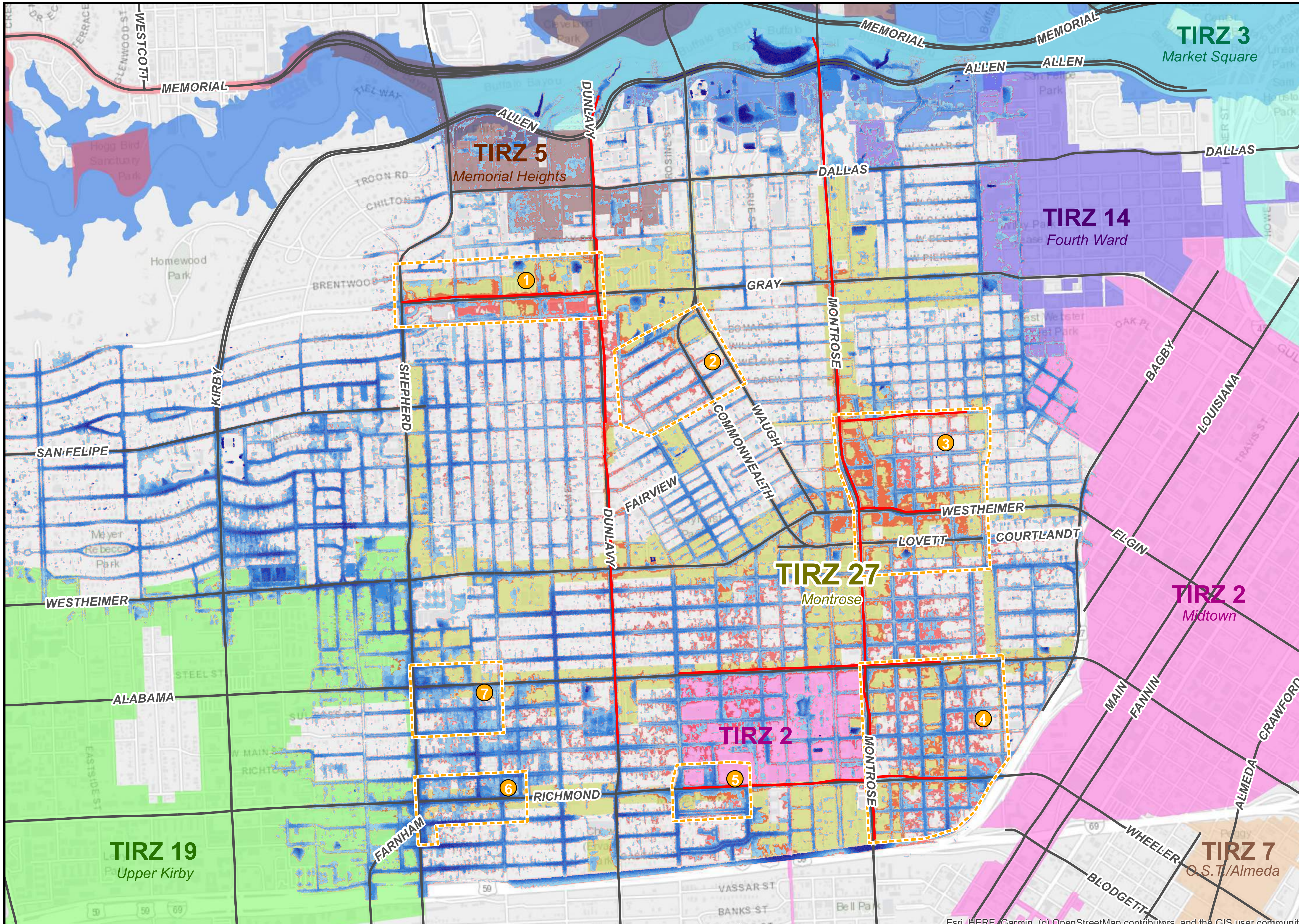
City of Houston
Harris County

Gauge
ENGINEERING


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Proposed ALT 1
100-yr Inundation
Legend
Major Streets
FEMA 500-yr
Problem Area
Proposed SD Trunkline
Existing 100-yr
Proposed 100-yr
Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
0 300 600 1,200
Feet
City of Houston
Harris County
Gauge
ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTHEIMER
SAN FELIPE
ALABAMA
RICHMOND
SHEPHERD
KIRBY
DUNLAVY
MONTROSE
WAUGH
COMMONWEALTH
FAIRVIEW
LOVETT
COURTLANDT
ELGIN
BAGBY
LOUISIANA
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
FARNHAM
WESTCOTT
1
2
3
4
5
6
7
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Proposed ALT 2
2-yr Inundation
Legend
Major Streets
FEMA 500-yr
Problem Area
Proposed SD Trunkline
Existing 2-yr
Proposed 2-yr
Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge
ENGINEERING
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTHEIMER
LOVETT
COURTLANDT
ALABAMA
RICHMOND
SAN FELIPE
KIRBY
SHEPHERD
DUNLAVY
MONTROSE
WAUGH
COMMONWEALTH
FAIRVIEW
BAGBY
LOUISIANA
ELGIN
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
FARNHAM
WESTCOTT
1
2
3
4
5
6
7
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Proposed ALT 2
10-yr Inundation
Legend
Major Streets
FEMA 500-yr
Problem Area
Proposed SD Trunkline
Existing 10-yr
Proposed 10-yr
Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
1
2
3
4
5
6
7
MEMORIAL
ALLEN
DALLAS
GRAY
WESTHEIMER
LOVETT
COURTLANDT
SAN FELIPE
ALABAMA
RICHMOND
SHEPHERD
KIRBY
DUNLAVY
MONTROSE
WAUGH
COMMONWEALTH
FAIRVIEW
FARNHAM
BAGBY
LOUISIANA
ELGIN
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
WESTCOTT
0 300 600 1,200
Feet
City of Houston
Harris County
Gauge
ENGINEERING
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

Proposed ALT 2
100-yr Inundation

Legend

Major Streets
FEMA 500-yr
Problem Area
Proposed SD Trunkline
Existing 100-yr

Proposed 100-yr Depths (ft)

0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01

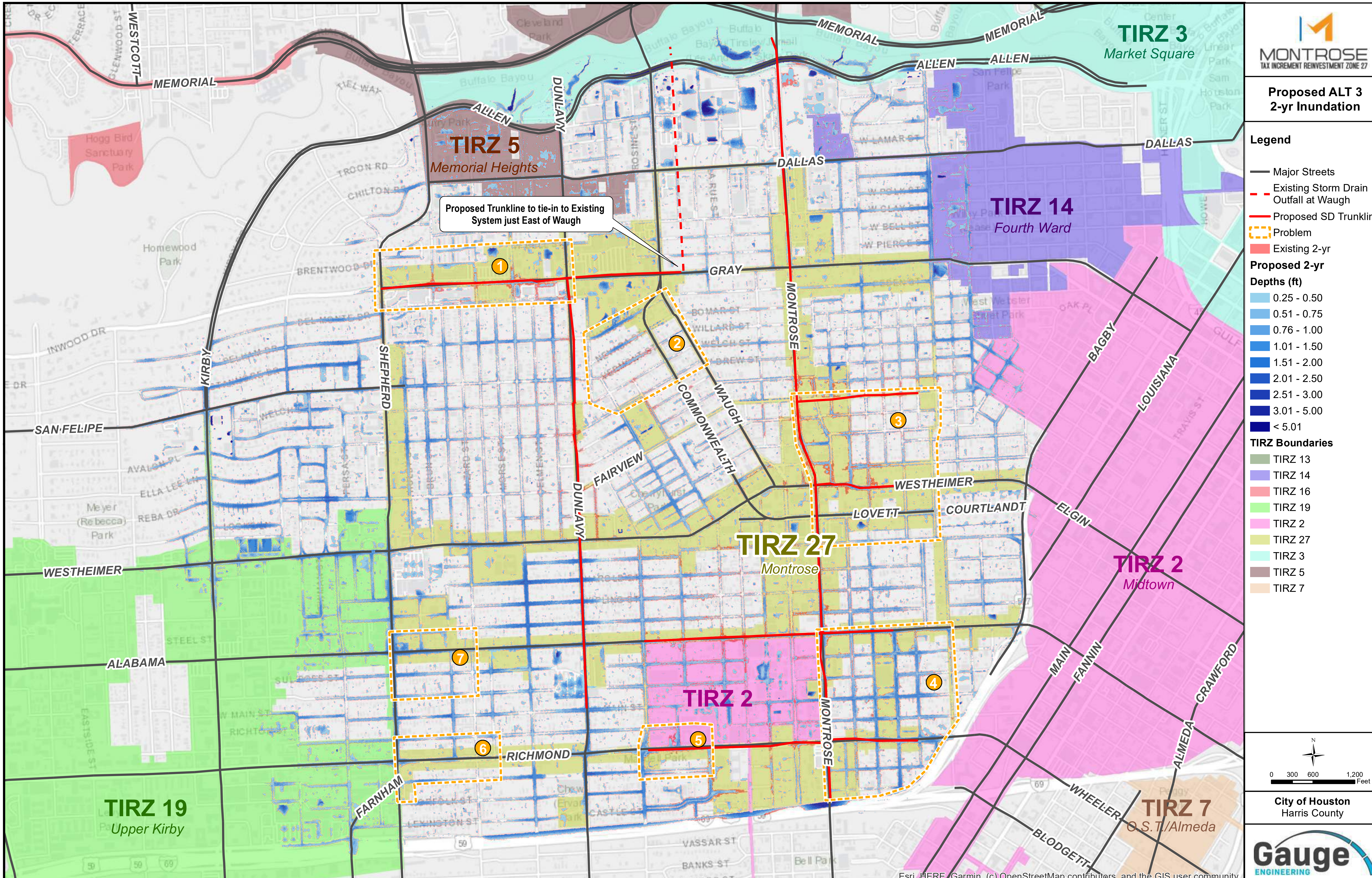
TIRZ Boundaries

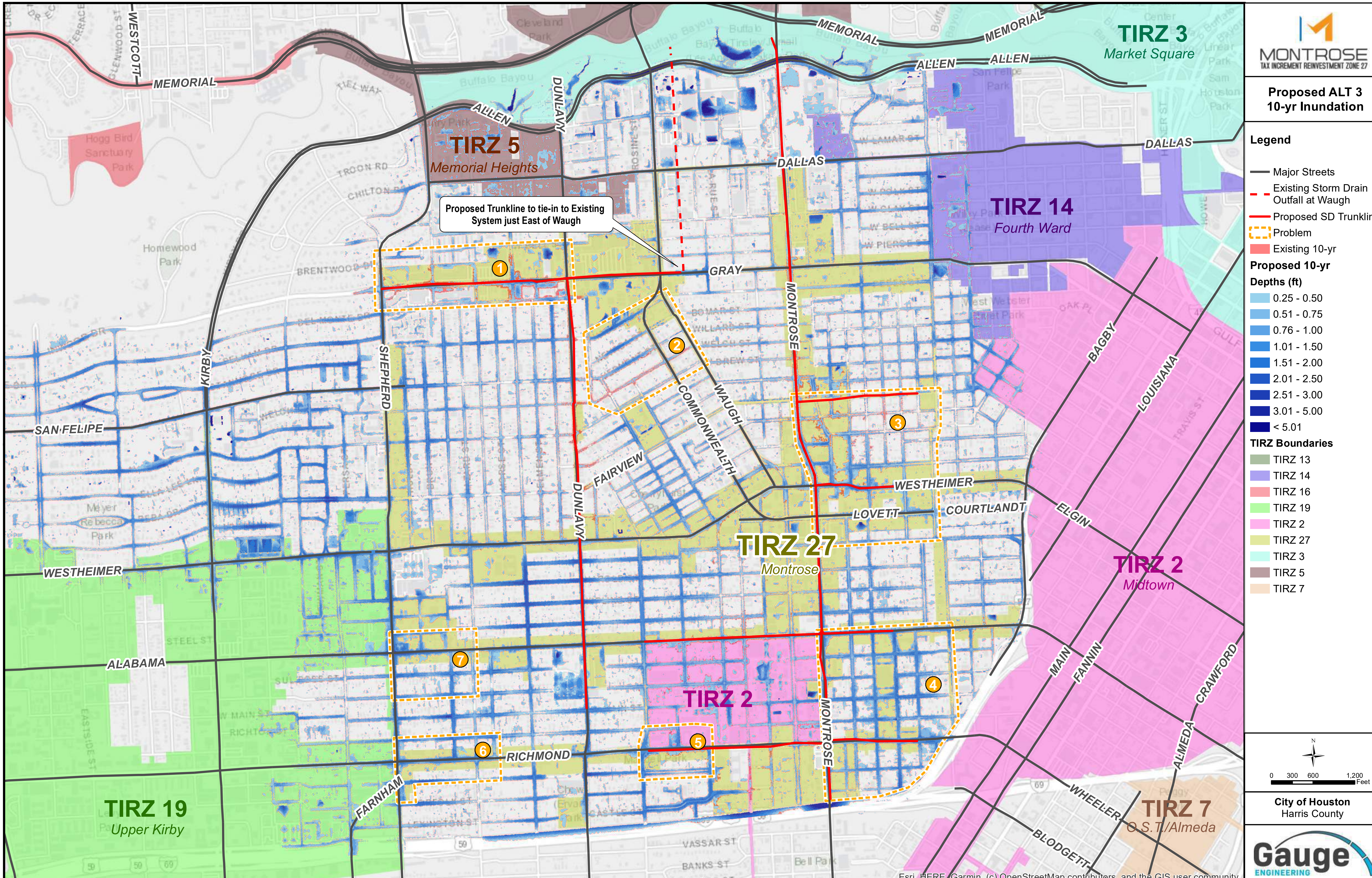
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7

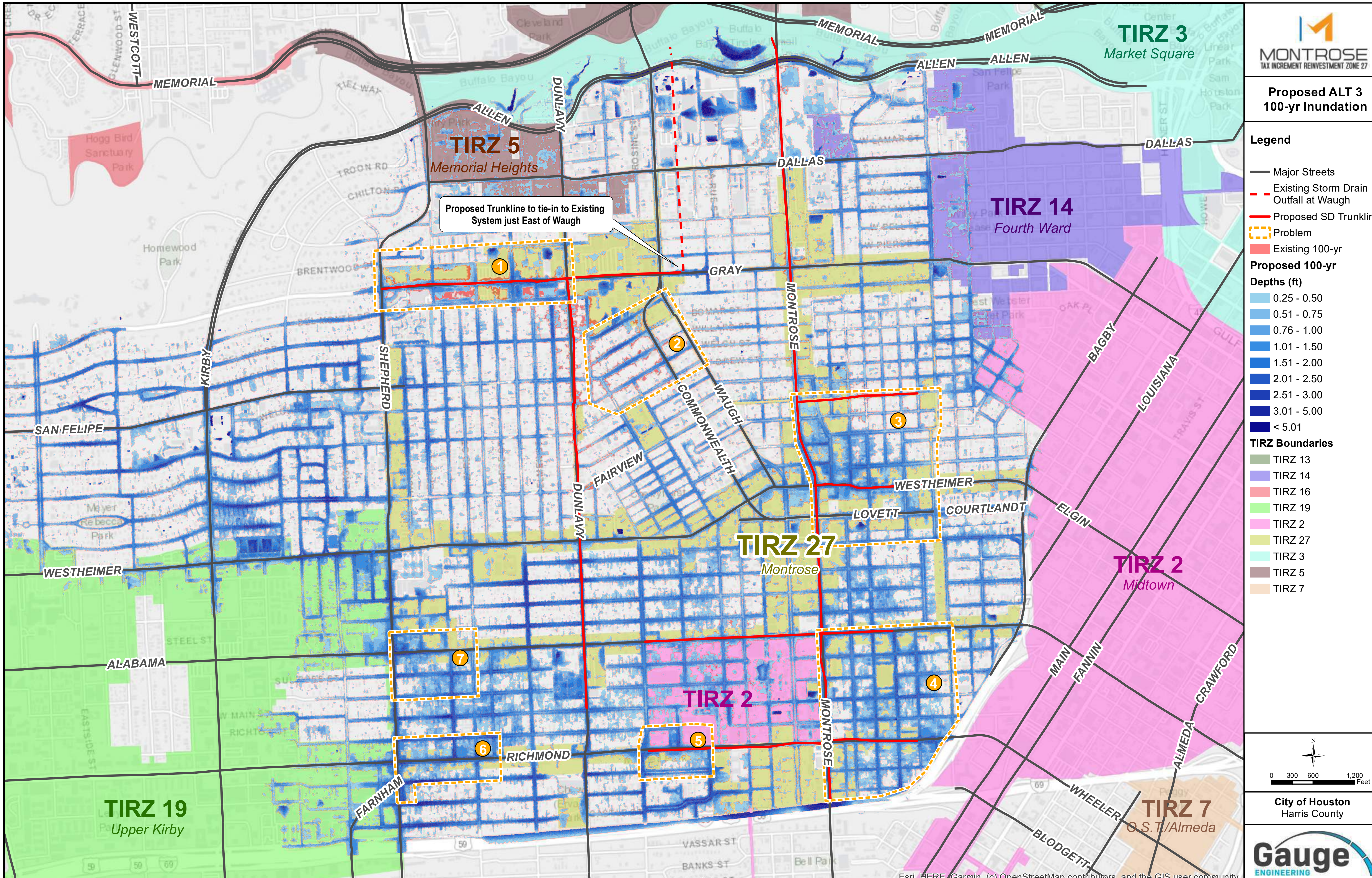
N
0 300 600 1,200 Feet

City of Houston
Harris County

Gauge
ENGINEERING


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Proposed ALT 3
2-yr Inundation
Legend
Major Streets
Existing Storm Drain Outfall at Waugh
Proposed SD Trunkline
Problem
Existing 2-yr
Proposed 2-yr Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge ENGINEERING
Proposed Trunkline to tie-in to Existing System just East of Waugh
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
MONTROSE
WAUGH
COMMONWEALTH
FAIRVIEW
DUNLAVY
SHEPHERD
KIRBY
SAN FELIPE
WESTHEIMER
LOVETT
COURTLANDT
ALABAMA
RICHMOND
FARNHAM
BAGBY
LOUISIANA
ELGIN
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
1
2
3
4
5
6
7
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Proposed ALT 3
10-yr Inundation
Legend
Major Streets
Existing Storm Drain Outfall at Waugh
Proposed SD Trunkline
Problem
Existing 10-yr
Proposed 10-yr Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge
ENGINEERING
Proposed Trunkline to tie-in to Existing System just East of Waugh
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTHEIMER
SAN FELIPE
ALABAMA
RICHMOND
MONTROSE
DUNLAVY
SHEPHERD
KIRBY
WAUGH
COMMONWEALTH
FAIRVIEW
LOVETT
COURTLANDT
ELGIN
BAGBY
LOUISIANA
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
FARNHAM
WESTCOTT
1
2
3
4
5
6
7
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27
Proposed ALT 3
100-yr Inundation
Legend
Major Streets
Existing Storm Drain Outfall at Waugh
Proposed SD Trunkline
Problem
Existing 100-yr
Proposed 100-yr Depths (ft)
0.25 - 0.50
0.51 - 0.75
0.76 - 1.00
1.01 - 1.50
1.51 - 2.00
2.01 - 2.50
2.51 - 3.00
3.01 - 5.00
< 5.01
TIRZ Boundaries
TIRZ 13
TIRZ 14
TIRZ 16
TIRZ 19
TIRZ 2
TIRZ 27
TIRZ 3
TIRZ 5
TIRZ 7
Proposed Trunkline to tie-in to Existing System just East of Waugh
TIRZ 3
Market Square
TIRZ 5
Memorial Heights
TIRZ 14
Fourth Ward
TIRZ 27
Montrose
TIRZ 2
Midtown
TIRZ 2
TIRZ 19
Upper Kirby
TIRZ 7
O.S.T./Almeda
MEMORIAL
ALLEN
DALLAS
GRAY
WESTHEIMER
SAN FELIPE
ALABAMA
RICHMOND
SHEPHERD
KIRBY
DUNLAVY
MONTROSE
WAUGH
COMMONWEALTH
FAIRVIEW
LOVETT
COURTLANDT
ELGIN
BAGBY
LOUISIANA
MAIN
FANNIN
CRAWFORD
ALMEDA
WHEELER
BLODGETT
FARNHAM
WESTCOTT
1
2
3
4
5
6
7
0 300 600 1,200 Feet
City of Houston
Harris County
Gauge
ENGINEERING
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

APPENDIX F

Variance Request Technical Memorandum

10/23/18 Update

REQUEST FOR VARIANCE
FROM HARRIS COUNTY FLOOD CONTROL DISTRICT

Example of information to provide for your request for variance. Always provide additional documentation (i.e. 1 page +/- narrative, maps, report or design plan excertps, etc.

Submitted By: Derek St. John Phone: 713.269.7782 Email: dstjohn@gaugeengineering.com

Company: Gauge Engineering, LLC Date: 10-23-2020

Proposed Project Description

Name: Montrose TIRZ 27 Drainage Study

e-Permits Project # ____________

Type: Drainage Study to Develop Improvement Concepts to Reduce Flooding

Location: South of Buffalo Bayou and West of Downtown - See map in tech memo (include map)

Existing Condition (show information on map or drawing)

HCFCD Maintained Facilities: Buffalo Bayou, W100-00-00

Existing Right-of-Way for HCFCD facility: Yes. ROW Varies

Topography: Flat terrain with overland flow issues.

Other Pertinent Data Related to Variance Request:
A technical memorandom supporting the variance request is included with additional information

Variance Request

Specific criteria you want to vary: Detention mitigation typically necessary to maintain peak discharge rates to HCFCD facilities

Explain why the criteria needs to be varied or is not applicable: By detaining runoff you increase the discharge rate on the tail of the discharging hydrograph which coincides with the peak on the receiving Buffalo Bayou causing flooding. See Tech Memo

Explain how the basis for the criteria will be satisfied: The general no impact criteria will be satisfied by not detaining.

List attachments supporting variance request (preliminary design report excerpt, construction drawings, calculations, photographs, maps, etc.): Variance Request Report

HCFCD to fill in this area DEV ID # ____________ Variance Request # ____________

Dept./Section	Reviewer	Date	Comments/Recommendation
☐ Project Review ☐ Property Mgnt ☐ Planning ☐ Environmental ☐ Other			

Justification of Decision: ____________

Approval of Final Decision: ____________ ____________
(Signature) (Date)

TIRZ-27 Montrose Drainage Study

Variance Request Technical Memorandum

MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

October 2020

STATE OF TEXAS
DEREK A. ST. JOHN
96623
LICENSED
PROFESSIONAL ENGINEER

10/25/2020

Gauge Engineering, LLC
Firm F-20017

Prepared by:

Derek St. John, PE, CFM

Gauge ENGINEERING
3200 Wilcrest Drive, Suite 220 • Houston, TX 77042

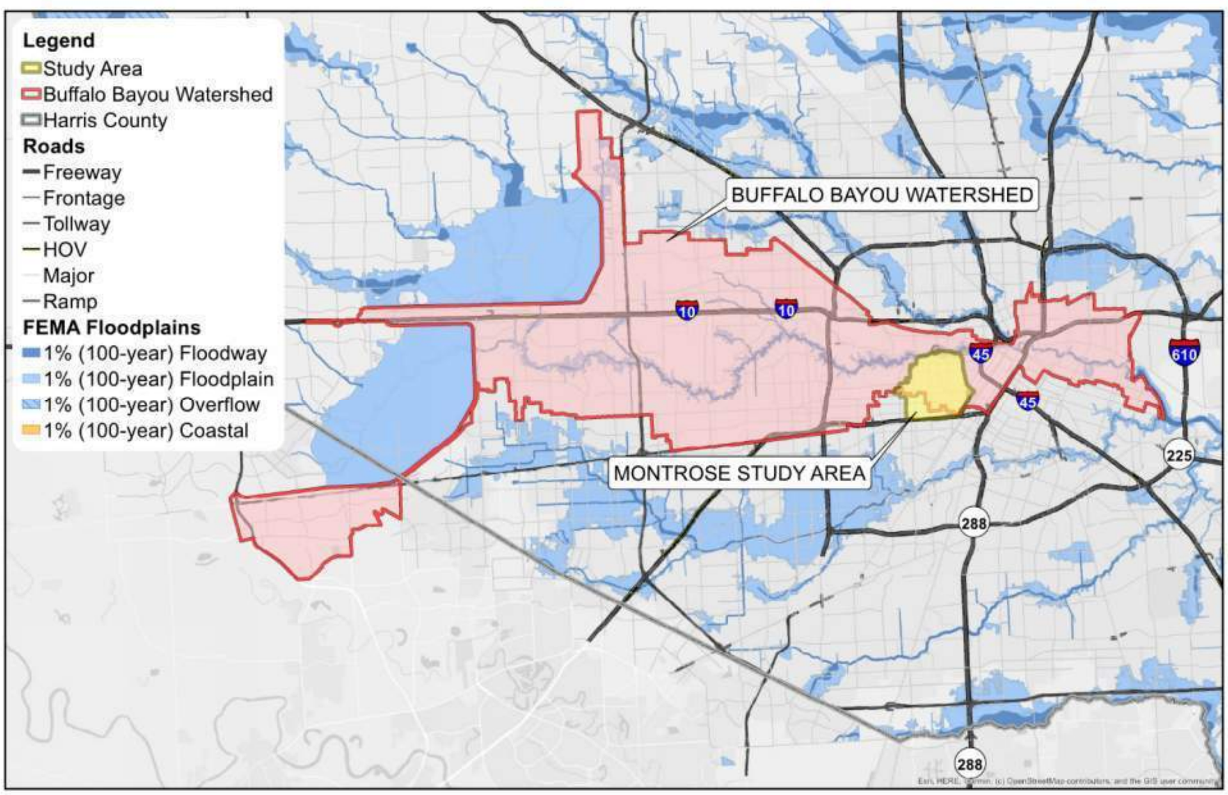
Texas PE Firm #20017

Variance Request

Stormwater Mitigation Detention

The Montrose Tax Increment Reinvestment Zone 27 (Montrose) contracted Gauge Engineering, LLC (Gauge) to perform a high-level regional drainage study to identify current drainage problems and provide short- and long-term solutions for addressing drainage concerns throughout the Montrose area. The preliminary analysis for this study has demonstrated that various large drainage conveyance systems are required throughout the study area to alleviate flooding. The purpose of this memo is to demonstrate that the proposed conceptual drainage improvements do not worsen the flooding conditions in Buffalo Bayou and to request consideration of a variance for detention mitigation that is typically necessary to maintain peak discharge rates to Buffalo Bayou. The basis of the variance request is the timing of the discharge from the proposed drainage improvements relative to the timing of the peak discharge on the receiving channel Buffalo Bayou. The Montrose drainage improvements will increase discharges to Buffalo Bayou in advance of the peak on Buffalo Bayou and decrease discharges during the peak on Buffalo Bayou. This is primarily due to the location of the Montrose region in the bottom third of the Buffalo Bayou watershed. See **Figure 1 Buffalo Bayou Watershed – Study Limit**. Detailed hydrologic and hydraulic analysis results are included as supporting information.

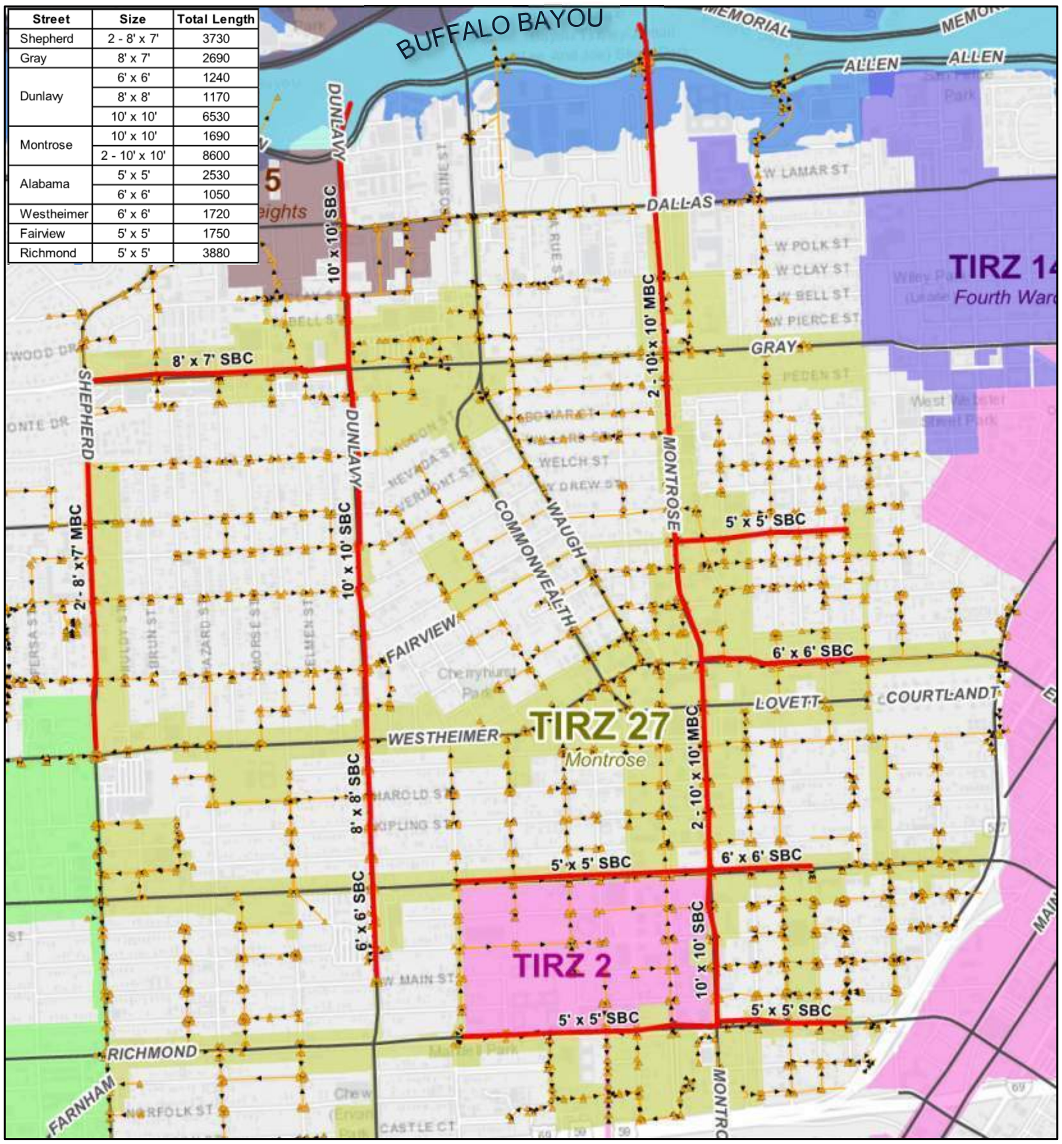
Figure – 1 Buffalo Bayou Watershed – Study Limit



1. PROJECT DESCRIPTION

The Montrose area experiences frequent street and structural flooding. A combination of various proposed trunk line improvements along major roads has been conceptually developed to alleviate flooding to the region. These proposed large trunklines discharge into Buffalo Bayou as shown in **Figure – 2 Proposed Improvements**. There are not readily available tracts of open land that can easily be acquired for detention to assist in alleviating the flooding. Therefore, the proposed improvements focus on increasing conveyance to the project outfall Buffalo Bayou. The improvements are designed to achieve an approximate 100-year level of protection. To maintain discharge rates to Buffalo Bayou the proposed trunklines will require restriction greatly diminishing the effectiveness of the investment and reducing the level of protection to approximately a 5-year event.

Figure – 2 Proposed Improvements



Street	Size	Total Length
Shepherd	2 - 8' x 7'	3730
Gray	8' x 7'	2690
Dunlavy	6' x 6'	1240
	8' x 8'	1170
	10' x 10'	6530
Montrose	10' x 10'	1690
	2 - 10' x 10'	8600
Alabama	5' x 5'	2530
	6' x 6'	1050
Westheimer	6' x 6'	1720
Fairview	5' x 5'	1750
Richmond	5' x 5'	3880

2. HYDROLOGIC ANALYSIS

HCFCD requires detention for any project that increases peak discharge to a receiving HCFCD facility. While this policy is appropriate for most situations where runoff is increased due to an increase in impervious cover (and thus total runoff volume) it may or may not be appropriate for localized flood improvement projects where no additional impervious cover is proposed. The location of a project outfall in relation to the watershed area may influence the potential impacts a project has to the receiving channel based on coincident hydrograph peak times. It is possible that by detaining runoff and delaying discharge to Buffalo Bayou you may cause an increase in the peak on Buffalo Bayou.

Potential adverse impacts due to the proposed Montrose Drainage Improvements projects were conceptually analyzed through various methods to determine the need for detention.

All analysis conducted for this feasibility study utilized the Pre-Atlas 14 500-year rainfall data as a surrogate for the Atlas 14 100-year rainfall.

2.1 Infoworks ICM Hydrologic Impacts Analysis

Infoworks ICM 2D modeling was utilized on the project to identify existing conditions and propose conceptual improvements to reduce flooding in the area. The Infoworks 2D model represented Buffalo Bayou as a time-varied tailwater elevation boundary condition. Therefore, peak flow impacts were only able to be assessed for any flow leaving the project area through storm sewer or surface overflow. Peak flow impacts within Buffalo Bayou were not able to be analyzed within the ICM model.

2.1.1 ICM Storm Sewer Flows

Storm sewer pipes for both existing and proposed conditions were included in the model. The existing and proposed peak runoff for each outfall within the project area that discharge to Bayou are shown in **Table -1** below.

Table - 1 Existing & Post-Project Storm Sewer Peak Flow Comparison

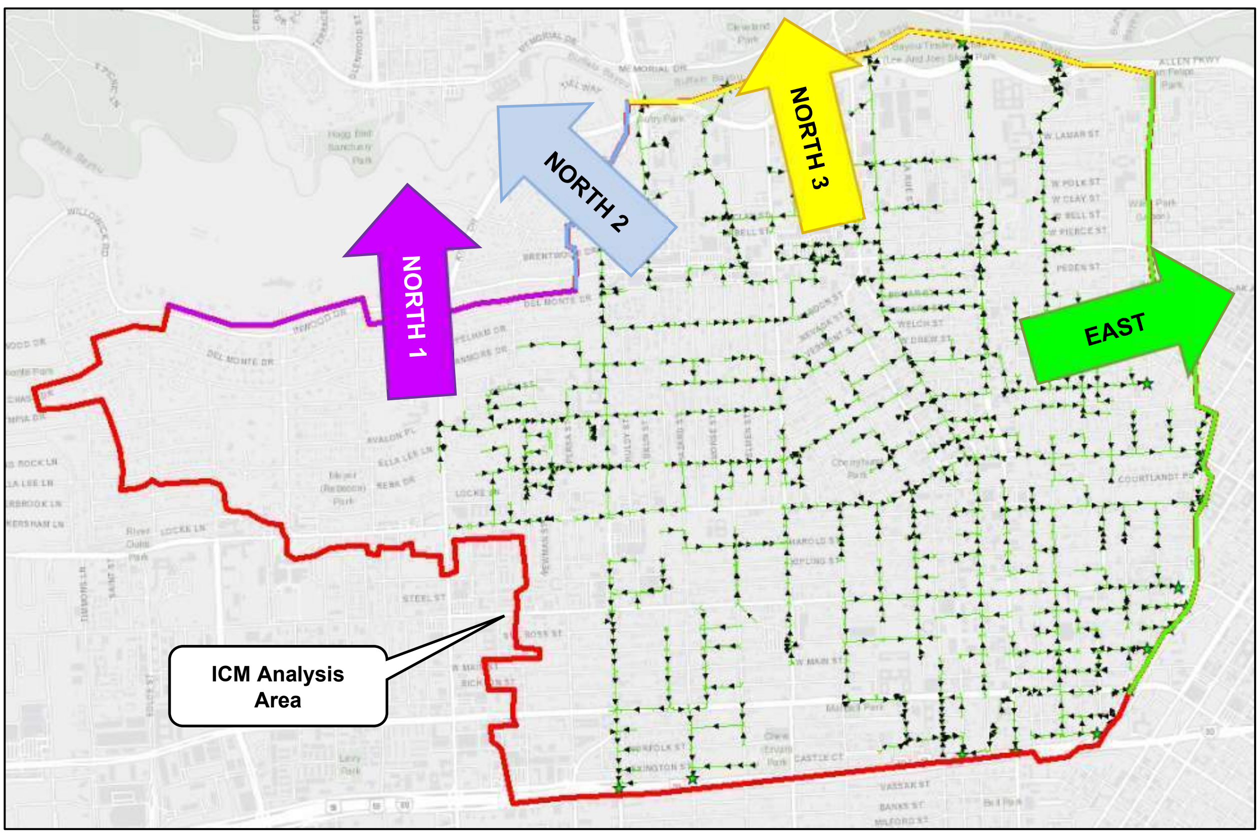
Outfall ID	Location	Existing Peak CFS	Post-Project Peak CFS	Difference Peak CFS
1-01-01_O	Shepherd	558	556	-2
2-01-01	Buffalo Park	217	209	-8
3-01-01_O	Waugh	1392	1384	-8
4-01-01	Montrose	226	2282	+2056
PR_OUT	Dunlavy	0	1303	+1303
6-01-01	Welch	57	26	-32
07-01-01	Hyde Park	121	66	-56
8-01-01_O	Westheimer	272	99	-173
9-01-01	Hawthorne	175	85	-90
10-01-01	Alabama	62	27	-35
11A-01-01	Richmond	42	16	-26
11B-01-01		72	12	-60
11C-01-01		20	9	-11
11D-01-01		23	-10	-33

All major outfalls show a reduction in peak runoff except the new outfall location proposed adjacent to Dunlavy Street, and the major upgraded trunkline system along Montrose Boulevard. These two proposed systems serve as the major conveyance systems that most proposed improvements drain to, and therefore saw large increases to the peak discharge.

2.1.2 ICM Storm Overland Flows

Surface flow unable to drain through storm sewer pipes was represented on the 2D surface. The project area shows a large amount of surface flow that causes significant street and structural flooding to the region due to inadequate surface conveyance that leaves the public right-of-way. Much of this surface flow leaves the project area to both the north and east. Surface flow leaving to the north directly enters Buffalo Bayou. Surface flow leaving to the east eventually make it to Buffalo Bayou through a longer route. Four surface cross sections were cut at the project area limits within ICM to quantity the existing and post-project surface flow that enters Buffalo Bayou as shown in **Figure – 3 Surface Flow** below.

Figure – 3 Surface Flow



Hydrographs for each of the surface flow cross sections was exported from the ICM model. The peak for each overland flow section is shown in **Table – 2.**

Table – 2 Existing & Post-Project Overland Peak Comparison

Outfall ID	Existing	Post-Project	Difference
	Peak CFS	Peak CFS	Peak CFS
North 1	921	915	-6
North 2	146	101	-45
North 3	193	191	-2
East	1023	1185	162

*Note that these are the individual peak flows for each section and do not represent differences in timing

2.1.3 ICM Storm Combined Flows

Hydrographs for both the pipe and surface discharge into Buffalo Bayou from the Montrose project area were exported from ICM. For each model timestep, the associated flow discharge from each source was added together to obtain a cumulative discharge into Buffalo Bayou. The resulting peak discharge of the combination hydrographs for existing and post-project conditions is shown in the **Table - 3.**

Table – 3 Existing & Post-Project Combined Peak Flow Comparison

Outfall ID	Existing	Post-Project	Difference
	Peak CFS	Peak CFS	%
ICM Total Flow into Buffalo Bayou	4447	7267	63%

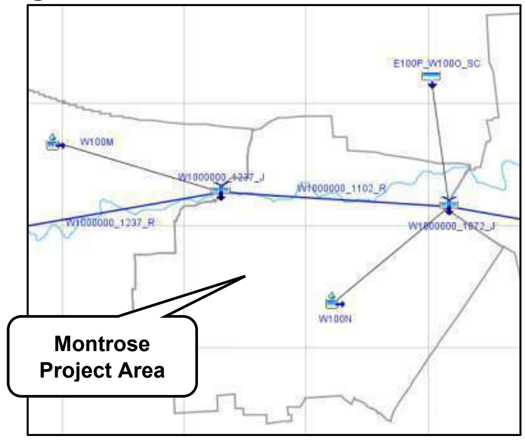
2.2 HEC-HMS Hydrologic Impacts Analysis

The effective HEC-HMS models for the Buffalo Bayou watershed were utilized to evaluate the benefits/impacts of the proposed drainage system improvements on Buffalo Bayou. The effective HEC-HMS model was acquired from the HCFCD M3 website for this analysis. The western side of Basin W100N represents the Montrose project area that was simulated with the Infoworks ICM 2D model.

2.2.1 HEC-HMS Effective Model Revisions

The Effective Buffalo Bayou HEC-HMS model was revised to better represent and analyze the potential benefits/impacts of the proposed project improvements within the Montrose project area. Basin W100N includes much more than the Montrose Project Area and initial analysis of the entire W100N basin proved difficult to match HEC-HMS results to the ICM results due to the discrepancy in contributing drainage area. The HEC-HMS schematic layout of the effective model is shown in **Figure – 4 HEC-HMS W100N Subbasin**.

Figure – 4 HEC-HMS W100N Subbasin



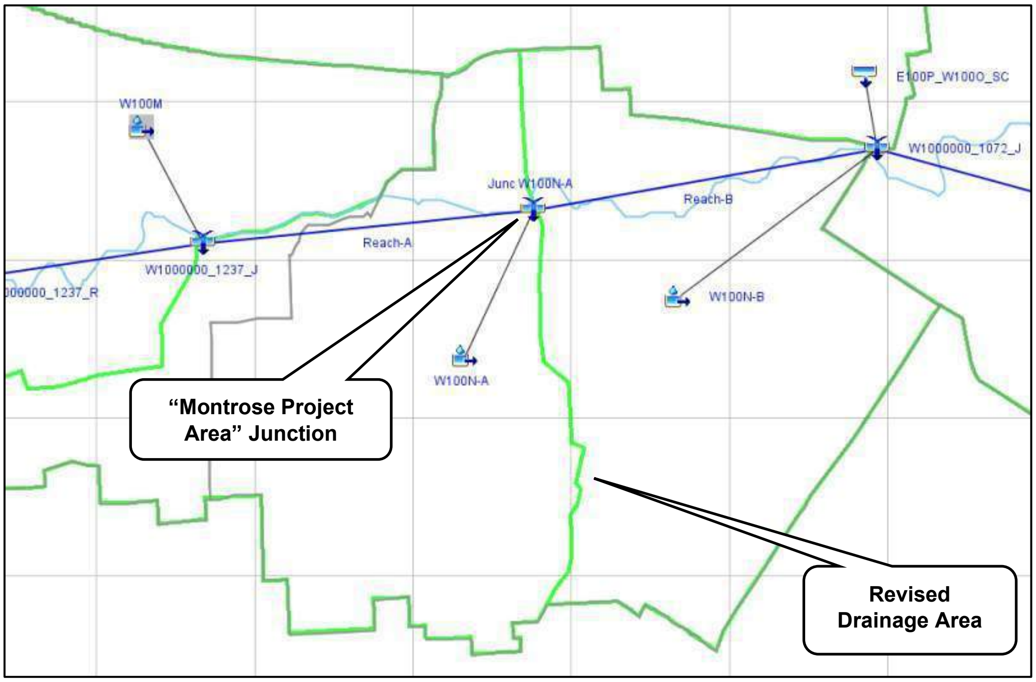
Basin W100N was split into 2 basins named W100N-A and W100N-B. The ICM analysis also indicated that the drainage area for basin W100N-A includes additional surface flow from the west. To represent this drainage condition, the W100N-A basin was extended to the west, and basin W100M was reduced by the same amount. **Table – 4** below summaries the drainage area changes and demonstrates no overall in drainge area. The only change to basins W100N and W100M was the drainage area, with the Clark Unit Hydrograph parameters remaining the same.

Table – 4 Drainage Area Change

HMS Element	Effective HMS DA (Acres)	Revised Effective HMS DA (Acres)
W100N (Basin)	3776	N/A
W100N-A (Basin)	N/A	2446
W100N-B (Basin)	N/A	1933
W100M (Basin)	4417	3814
Total	**8193**	**8193**

Due to the subdivision of the basin W100N, a split of the routing reach W1000000_1102R was also required. In the effective model, this routing reach is represented with a Modified Puls storage-discharge function. Two new routing reaches were created and called Reach-A and Reach B. The stream length for each representative reach was measured and the ratio of each new reach length divided by the combined reaches length was multiplied by the W1000000_1102R storage value respectively. This created a Modified Puls storage-discharge table for Reach-A and Reach B that in combination would perform similarly to the effective reach W1000000_1102R. The revised HEC-HMS schematic layout is shown in the **Figure – 5 HEC-HMS Subbasin Division**.

Figure – 5 HEC-HMS Subbasin Division



The revised HEC-HMS model was simulated to confirm the downstream Buffalo Bayou junction W1000000_1072_J results were generally close to the effective model. This comparison of flows is shown in the table below (**Table – 5**) and shows the revised effective model does not significantly change the results within Buffalo Bayou downstream of the Montrose project area.

Table – 5 Effective & Revised Peak Comparison

HMS ID	Effective HMS	Revised Effective HMS
	Peak CFS	Peak CFS
W1000000_1072_J	80,561	80,711

2.2.2 HEC-HMS Post-Project Model

The ICM simulation indicated that the proposed large trunkline improvements would increase the overall peak flow leaving the Montrose area by approximately 63% in post-project conditions. This is due to the proposed trunk lines conveying the surface drainage more efficiently and quickly to Buffalo Bayou.

The effective HMS model utilizes the Clark Unit Hydrograph to route stormwater runoff through basins. This method includes two parameters: Time of Concentration (Tc), and the Storage Coefficient (R). Through various sensitivity runs, it was found that manipulation of the Storage Coefficient was the most appropriate way to simulate the loss of surface storage due to the proposed project. The Storage Coefficient was iteratively modified until the increase in peak flow for Basin W100N-A was increased by 63% to match the increase in peak flow observed in the ICM modeling for the Montrose Project Area. Ultimately, the post-project storage coefficient was decreased by a little over one half from 7.13 in existing conditions to 3.34 in post-project conditions. No other model parameters were changed in the post-project scenario.

2.2.3 HEC-HMS Model Results

Table – 6 below shows the results of the existing and post-project peak flows for the revised HEC-HMS analysis.

Table – 6 Existing & Post-Project HMS Comparison

HMS Element	Existing		Post-Project		Difference
	Time of Peak	Peak Flow	Time of Peak	Peak Flow	Peak Flow
	HH:MM	(cfs)	HH:MM	(cfs)	(cfs)
W100N-A (Basin)	18:15	2919	17:30	4766	**1847**
W100N-B (Basin)	18:15	2308	18:15	2308	**0**
Junc W100N-A (Junction)	28:15	25921	28:15	25332	**-589**
W1000000_0809_J (Junction)	28:00	80711	27:45	80238	**-473**

The results indicate that the onsite peak discharge increases, but the peak flow at nearby junctions along Buffalo Bayou decrease. This phenomenon is explained through the subsequent hydrograph graphics. The first graphic (**Figure – 6a**) shows the overall rising limb of Buffalo Bayou near the project outfalls, along with the hydrograph for WN100-A. **Figure - 6b** shows a zoom in of the Basin WN100-A peak. **Figure – 6c** shows a zoom in of the Buffalo Bayou hydrograph (Junc W100N-A) at the time of the WN100-A peak. **Figure – 6d** shows the reduction in peak flow during the peak at Buffalo Bayou due to the proposed project.

Figure – 6a Overall HMS Hydrograph Comparison

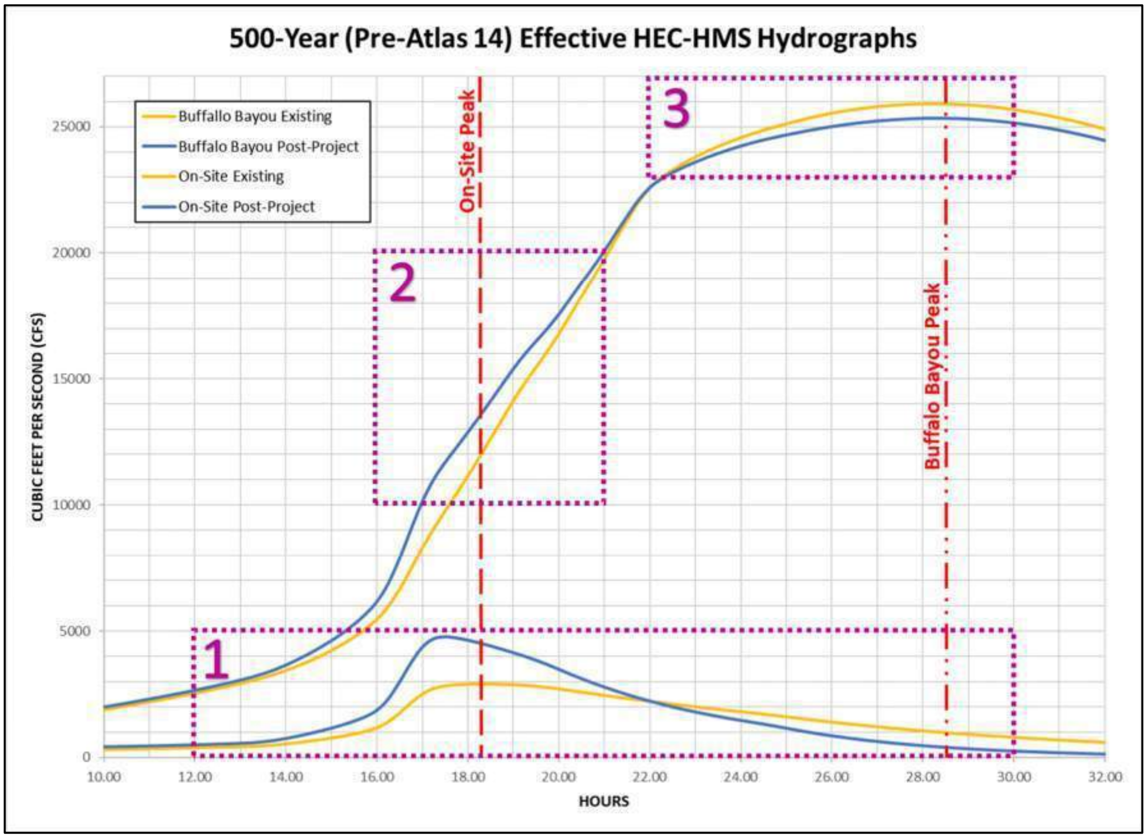


Figure – 6b Basin WN100-A Peak

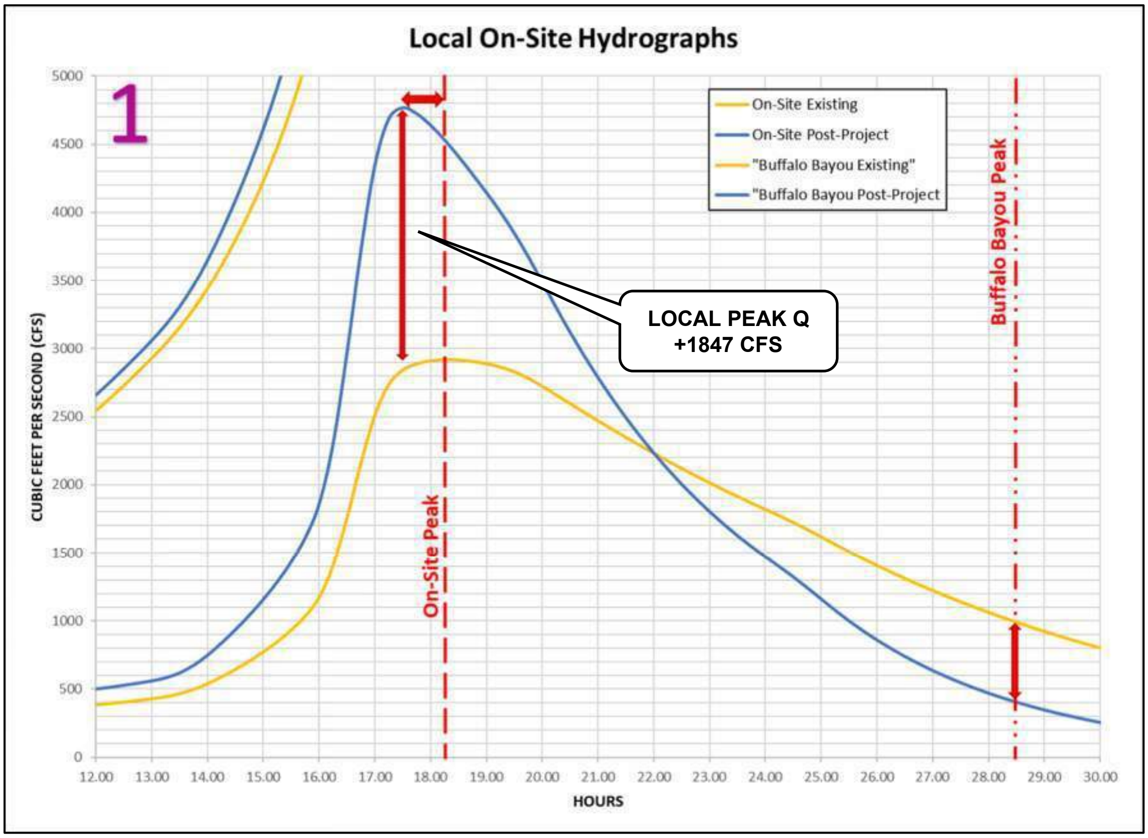


Figure – 6c Buffalo Bayou Increase

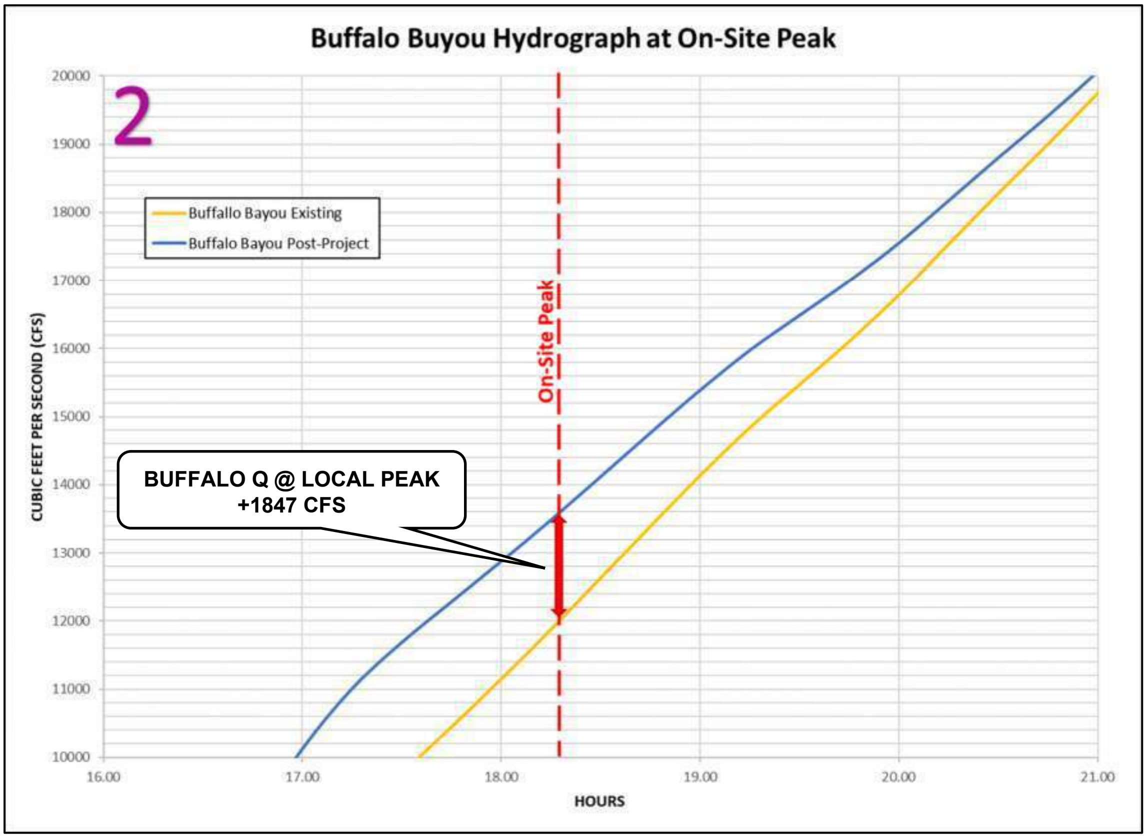
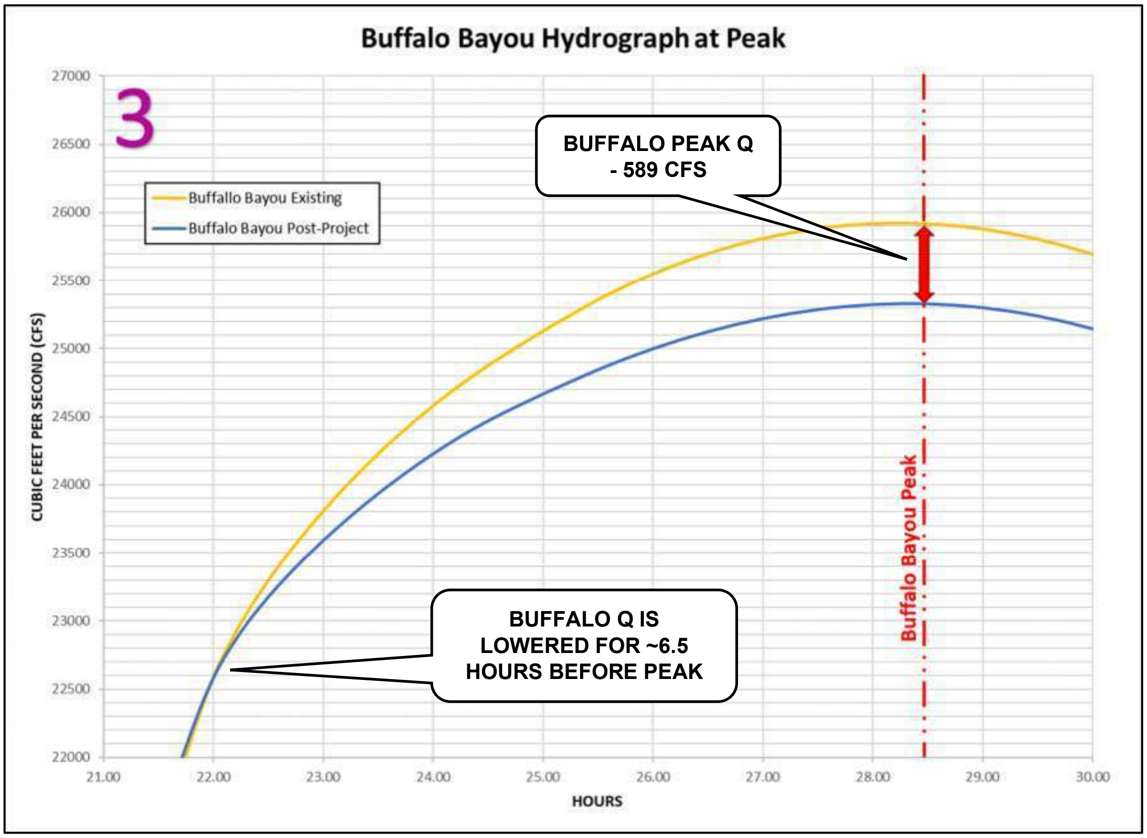


Figure – 6d Buffalo Bayou Decrease



2.3 Conceptual Detention Analysis

The Infoworks ICM model was utilized to determine the approximate sizing that would be needed to provide on-site detention mitigation at the project outfalls. It is estimated that to fully mitigate on-site flows, more than 100 acre-feet of volume would be required. Additionally, potential impacts of the detention on Buffalo Bayou would need to be considered in final design and would likely further increase required volumes. This amount of detention volume is not readily available on the surface within the project area and would likely require a combination of both surface and underground detention. Costs for this amount of storage volume would likely cause the project to not be feasible.

3. CONCLUSIONS

The conceptual analysis of the potential benefits/impacts that the Montrose Drainage Improvements projects may have on Buffalo Bayou indicate that improving conveyance of surface flooding in the area should not require detention to mitigate for increases in peak flow discharge rates to the bayou. The following list summarizes the results of the analysis:

- The overall stormwater runoff volume is not significantly changed due to the proposed project
  - No additional impervious cover is proposed
- The proposed large box storm sewer systems do change the shape of the project area (on-site) hydrograph
  - The on-site peak discharge is sooner and higher in proposed conditions

    - The falling limb of the hydrograph is lower in the proposed conditions
- The proposed projects conceptually demonstrate at the location of Buffalo Bayou near the project site, shifting the on-site hydrograph shape to peak sooner lowers the peak flooding within Buffalo Bayou
    - This is due to timing differences in Buffalo Bayou and the localized (on-site) stormwater runoff
- Including proposed on-site detention to match peak on-site runoff will stretch the on-site hydrograph to discharge over a longer period of time
    - This will likely result in a higher peak at Buffalo Bayou, necessitating additional detention
    - The requirement to detain for both on-site flows and the Buffalo Bayou peak flow would make the project not feasible due to cost and available land.

This technical memo formally requests a variance to the traditional county requirements to maintain peak discharge rates to HCFCD maintained channels. This variance request is based on technical merit and is supported by the analysis summarized in this memo. Montrose Tax Increment Reinvestment Zone 27 is focused on responsible improvements that improve resilience. We appreciate your consideration of this variance request.

APPENDIX G

Opinion of Probable Cost

10/31/2020

ROADWAY AND DRAINAGE PROJECTS

OPINION OF PROBABLE COST

MONTROSE BLVD

Montrose Blvd - Phase I (6,150 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	10' x 10' CBC	LF	12,350	$977.00	$12,065,950.00
2	Inlet And Lateral Pipe	EA	117	$8,175.00	$956,475.00
3	Roadway Replacement	LN-MI	4.66	$1,500,000.00	$6,988,636.36
			Subtotal		$20,011,062.00
	*Westheimer Rd To Allen Pkwy		Contingency 25%		$5,002,766.00
				TOTAL COST	**$25,014,000.00**

Montrose Blvd - Phase II (4,600 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	10' x 10' CBC	LF	5,875	$977.00	$5,739,875.00
2	Inlet And Lateral Pipe	EA	69	$8,175.00	$564,075.00
3	Roadway Replacement	LN-MI	3.48	$1,700,000.00	$5,924,242.42
			Subtotal		$12,228,193.00
	* I-69 Ave To Westheimer Rd		Contingency 25%		$3,057,049.00
				TOTAL COST	**$15,286,000.00**

Montrose Blvd - Phases I & II - I-69 To Allen Pakwy (9,800 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	10' x 10' CBC	LF	18,225	$1,954.00	$17,805,825.00
2	Inlet And Lateral Pipe	EA	186	$16,350.00	$1,520,550.00
3	Roadway Replacement	LN-MI	8.14	$3,200,000.00	$12,912,878.79
			Subtotal		$32,239,254.00
			Contingency 25%		$8,059,814.00
				TOTAL COST	**$40,300,000.00**

WEST GRAY ST.

W Gray St (2,700 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	8' x 7' CBC	LF	2,690	$777.00	$2,090,130.00
2	Inlet And Lateral Pipe	EA	40	$8,175.00	$327,000.00
3	Roadway Replacement	LN-MI	2.05	$1,500,000.00	$3,068,181.82
			Subtotal		$5,485,312.00
			Contingency 25%		$1,371,328.00
				TOTAL COST	**$6,857,000.00**

FAIRVIEW

Fairview St (1,700 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	5' X5 CBC	LF	1,750	$527.00	$922,250.00
2	Inlet And Lateral Pipe	EA	42	$8,175.00	$343,350.00
3	Roadway Replacement	LN-MI	0.64	$1,250,000.00	$804,924.24
			Subtotal		$2,070,525.00
			Contingency 25%		$517,632.00
				TOTAL COST	**$2,589,000.00**

WESTHEIMER

Westheimer (1,700 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	6' x 6' CBC	LF	1,720	$602.00	$1,035,440.00
2	Inlet And Lateral Pipe	EA	38	$8,175.00	$310,650.00
3	Roadway Replacement	LN-MI	1.29	$1,500,000.00	$1,931,818.18
			Subtotal		$3,277,909.00
			Contingency 25%		$819,478.00
				TOTAL COST	**$4,098,000.00**

WEST ALABAMA

W Alabama (3,600 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	5' x 5' CBC	LF	2,530	$527.00	$1,333,310.00
2	6' x 6' CBC	LF	1,050	$602.00	$632,100.00
3	Inlet And Lateral Pipe	EA	66	$8,175.00	$539,550.00
4	Roadway Replacement	LN-MI	2.05	$1,500,000.00	$3,068,181.82
			Subtotal		$5,573,142.00
			Contingency 25%		$1,393,286.00
				TOTAL COST	**$6,967,000.00**

RICHMOND AVE

Richmond Ave (4,000 LF)					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	5' x 5' CBC	LF	3,880	$527.00	$2,044,760.00
2	Inlet And Lateral Pipe	EA	78	$8,175.00	$637,650.00
3	Roadway Replacement	LN-MI	3.03	$1,500,000.00	$4,545,454.55
			Subtotal		$7,227,865.00
			Contingency 25%		$1,806,967.00
				TOTAL COST	**$9,035,000.00**

DUNLAVY ST

Dunlavy (2,400 LF) - Phase II - W Main St To Westheimer Rd					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	6' x 6' CBC	LF	1,240	$602.00	$746,480.00
2	8' x 8' CBC	LF	1,170	$802.00	$938,340.00
3	Inlet And Lateral Pipe	EA	46	$8,175.00	$376,050.00
4	Roadway Replacement	LN-MI	1.36	$1,300,000.00	$1,772,727.27
			Subtotal		$3,833,598.00
			Contingency 25%		$958,400.00
				TOTAL COST	**$4,792,000.00**

Dunlavy (6,000 LF) - Phase I - Westheimer Rd To Allen Pkwy					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	10' x 10' CBC	LF	6,530	$977.00	$6,379,810.00
2	Inlet And Lateral Pipe	EA	114	$8,175.00	$931,950.00
3	Roadway Replacement	LN-MI	4.55	$1,300,000.00	$5,909,090.91
			Subtotal		$13,220,851.00
			Contingency 25%		$3,305,213.00
				TOTAL COST	**$16,527,000.00**

Dunlavy (8,400 LF)-Phases I & II - W Main St to Allen Pkwy					
Item	**Item Description**	**Unit**	**Quantity**	**Unit Price**	**Total Price**
1	6' x 6' CBC	LF	1,240	$602.00	$746,480.00
2	8' x 8' CBC	LF	1,170	$802.00	$938,340.00
3	10' x 10' CBC	LF	6,530	$977.00	$6,379,810.00
4	Inlet And Lateral Pipe	EA	160	$8,175.00	$1,308,000.00
5	Roadway Replacement	LN-MI	5.91	$1,300,000.00	$7,681,818.18
			Subtotal		$17,054,449.00
			Contingency 25%		$4,263,613.00
				TOTAL COST	**$21,319,000.00**

APPENDIX H

Project Prioritization Criteria

MONTROSE FLOOD FEASIBILITY STUDY

Project Ranking Criteria

Benefit Zones

How many problem areas are benefited by the project?

Value	Description
0%	No problem areas are benefited
3%	One problem area is benefited
6%	Two problem areas are benefited
10%	Three problem areas are benefited

Street Flooding

Does the project address areas that have significant street flooding?

Value	Description
0%	Includes less than 10% of the total number of intersections with >1' flood depth
10%	Includes greater than 10% of the total number of intersections with >1' flood depth
20%	Includes greater than 20% of the total number of intersections with >1' flood depth

*Intersection flooding was determined by comparing the number of intersections with a 100-yr flooding depth greater than 1' to the total number of intersections of all corridors (86).

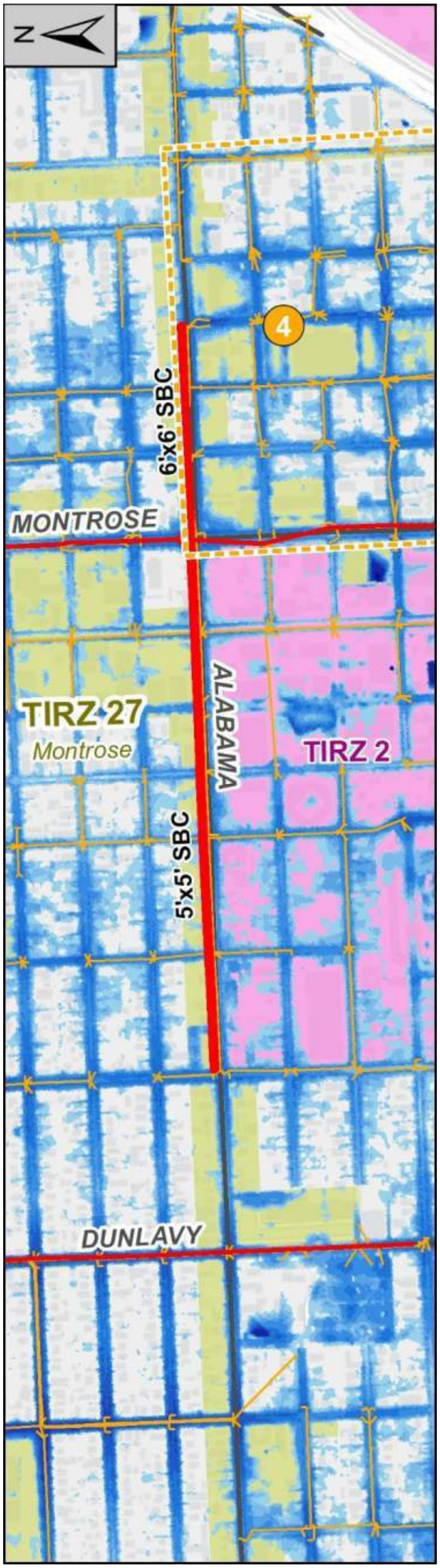
Project Dependency

Is the project dependent on additional downstream capacity that may be constructed with another CIP.

Value	Description
0%	Yes
10%	No

APPENDIX I

Project Summary Sheets



Project Summary Sheet: Alabama

Proposed Improvements:

- 2590 LF of 5' x 5' CBC from Mandell St to Montrose Blvd
- 1050 LF of 6' x 6' CBC from Montrose Blvd to Greeley St

Project Dependencies:

The Alabama project is dependent on construction of the Montrose project from Alabama St to the outfall at Buffalo Bayou north of Allen Parkway.

Ranking Criteria:

Category	Score
Benefit Zones	6%
Street Flooding	10%
Project Dependency	0%
Total	**16%**

Cost Estimate:

Category	Cost
Construction	$ 6,967,000
PER/Design	$ 557,360
CM&I	$ 418,020
Total	**$ 7,942,380**

Problem Areas Benefitted:

Problem Area 4: Reduces flooding by providing additional downstream capacity for the existing storm drain in Problem Area 4.

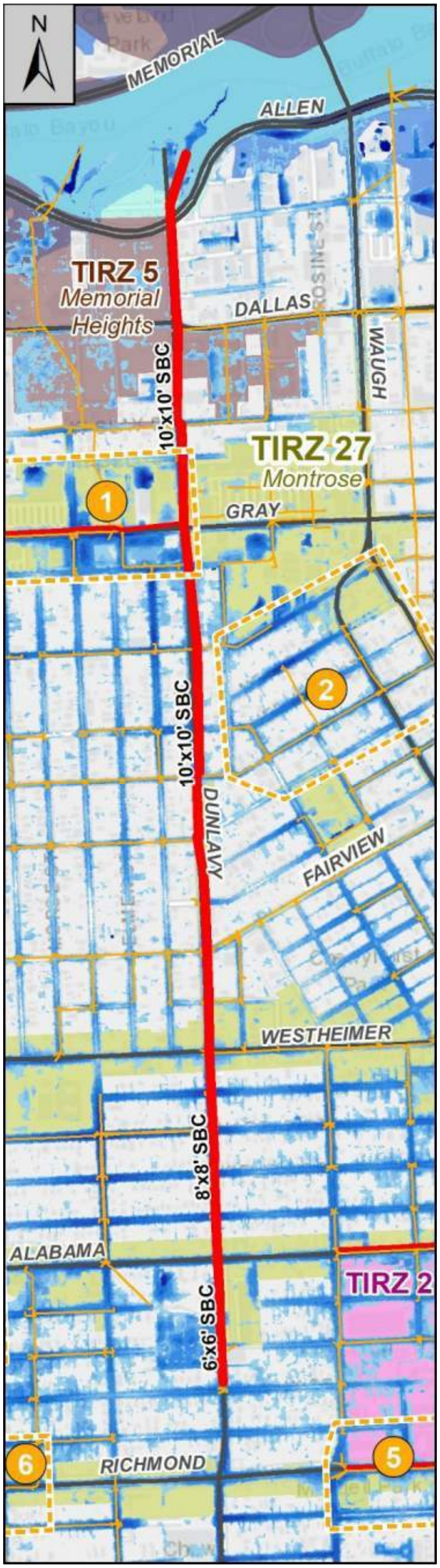
Problem Area 5: Reduces flooding by capturing more flow on Alabama street which surface flows into Problem Area 5 in existing conditions.

Assumptions:

Two inlet systems at the intersections with Yoakum Blvd, Yupon St, and Stanford St tie into trunklines heading north on their respective intersecting streets. These systems will need to be disconnected and tied into the new Alabama trunkline.

Project Graphic (Left): Red is proposed storm drain (thick red is current project, thin red is other projects), orange is existing storm drain, dashed orange outlines problem areas, inundation shown represents pre-project 100-year

MONTROSE FLOOD FEASIBILITY STUDY



Project Summary Sheet: Dunlavy

Proposed Improvements:

- 1240 LF of 6’ x 6’ CBC from W Main St to Marshall St
- 1170 LF of 8’ x 8’ CBC from Marshall St to Westheimer Road
- 6530 LF of 10’ x 10’ CBC from Westheimer Road to Buffalo Bayou

Project Dependencies:

HCFCD review and approval of increased discharge to Buffalo Bayou, based on timing.

Ranking Criteria:

Category	Score
Benefit Zones	6%
Street Flooding	20%
Project Dependency	10%
Total	**36%**

Cost Estimate:

Category	Cost
Construction	$ 21,319,000
PER/Design	$ 1,705,520
CM&I	$ 1,279,140
Total	**$ 24,303,660**

Problem Areas Benefitted:

Problem Area 1: Reduces flooding by increasing downstream conveyance and tying in the Gray system.

Problem Area 2: Reduces flooding by removing all the flow to the west of Dunlavy from the existing storm drain in Problem Area 2.

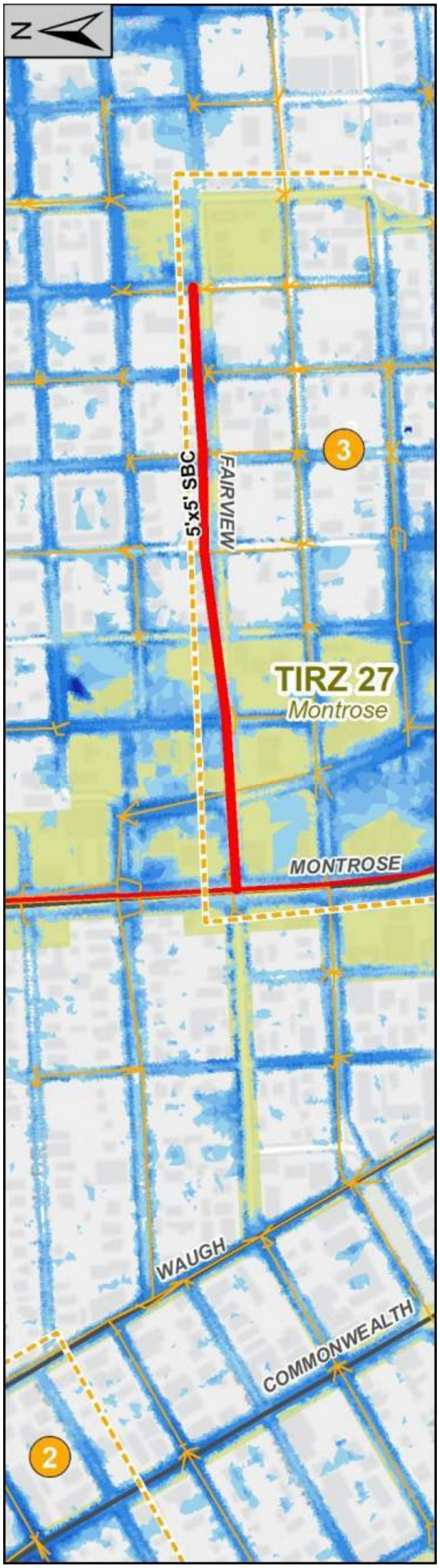
Assumptions:

In the existing conditions there are several large trunklines that cross Dunlavy and eventually tie into the Waugh system. These trunklines need to be tied into the proposed Dunlavy system to lower the tailwater and reduce the loading on the Waugh system.

The project is dependent on the assumption that a new outfall can be added into Buffalo Bayou near Dunlavy or the trunkline can be tied into the Waugh system with capacity improvements.

Project Graphic (Left): Red is proposed storm drain (thick red is current project, thin red is other projects), orange is existing storm drain, dashed orange outlines problem areas, inundation shown represents pre-project 100-year

MONTROSE FLOOD FEASIBILITY STUDY



Project Summary Sheet: Fairview

Proposed Improvements:

- 1750 LF of 5' x 5' CBC from Morgan St to Montrose Blvd

Project Dependencies:

The Fairview project is dependent on construction of the Montrose project from Fairview Ave to the outfall at Buffalo Bayou north of Allen Parkway.

Ranking Criteria:

Category	Score
Benefit Zones	3%
Street Flooding	10%
Project Dependency	0%
Total	**13%**

Cost Estimate:

Category	Cost
Construction	$ 2,589,000
PER/Design	$ 207,120
CM&I	$ 155,340
Total	**$ 2,951,460**

Problem Areas Benefitted:

Problem Area 3: Reduces flooding by capturing flow on Fairview and tying in several inlet systems along Fargo St which reduces the flow in the existing Hyde Park Blvd system in Problem Area 3.

Assumptions:

All of the existing inlet systems along Fairview as well as the laterals from Fargo St will need to be tied into the new Fairview trunkline.

Project Graphic (Left): Red is proposed storm drain (thick red is current project, thin red is other projects), orange is existing storm drain, dashed orange outlines problem areas, inundation shown represents pre-project 100-year

MONTROSE FLOOD FEASIBILITY STUDY

Project Summary Sheet: Gray

Proposed Improvements:

- 2690 LF of 8' x 7' CBC from S Shepard Dr to Dunlavy St

Project Dependencies:

The Gray project is dependent on construction of the Dunlavy project from W Gray St to the outfall at Buffalo Bayou north of Allen Parkway.

Ranking Criteria:

Category	**Score**
Benefit Zones	3%
Street Flooding	0%
Project Dependency	0%
Total	**3%**

Cost Estimate:

Category	**Cost**
Construction	$ 6,857,000
PER/Design	$ 548,560
CM&I	$ 411,420
Total	**$ 7,816,980**

Problem Areas Benefitted:

Problem Area 1: Reduces flooding throughout by improving trunkline capacity and reducing the flow on the existing trunklines heading north from Gray Street to Buffalo Bayou.

Assumptions:

The trunklines crossing Gray St from the South will need to be tied into the proposed Gray trunkline. The Gray trunkline will also need to be tied into the existing Shepherd System to divert flow from Shepherd and into Dunlavy.

Project Graphic (Left): Red is proposed storm drain (thick red is current project, thin red is other projects), orange is existing storm drain, dashed orange outlines problem areas, inundation shown represents pre-project 100-year

MONTROSE FLOOD FEASIBILITY STUDY

MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27

Project Summary Sheet: Montrose

Proposed Improvements:

- 2440 LF of 10’ x 10’ CBC from Richmond Ave to W Alabama St
- 8600 LF of 2 - 10’ x 10’ CBC from W Alabama St to Buffalo Bayou

Project Dependencies:

HCFCD review and approval of increased discharge to Buffalo Bayou, based on timing.

Ranking Criteria:

Category	Score
Benefit Zones	10%
Street Flooding	20%
Project Dependency	10%
Total	**40%**

Cost Estimate:

Category	Cost
Construction	$ 40,300,000
PER/Design	$ 3,224,000
CM&I	$ 2,418,000
Total	**$ 45,942,000**

Problem Areas Benefitted:

Problem Areas 3, 4 and 5: Reduces flooding in combination with projects: Richmond (4 & 5), Alabama (4), Westheimer (3), and Fairview (3) by improving conveyance to Buffalo Bayou and decreasing the tailwater on existing systems.

Assumptions:

There are several inlet systems along Montrose that connect to trunklines down intersecting streets. These inlet systems will need to be disconnected and tied into the proposed Montrose trunkline.

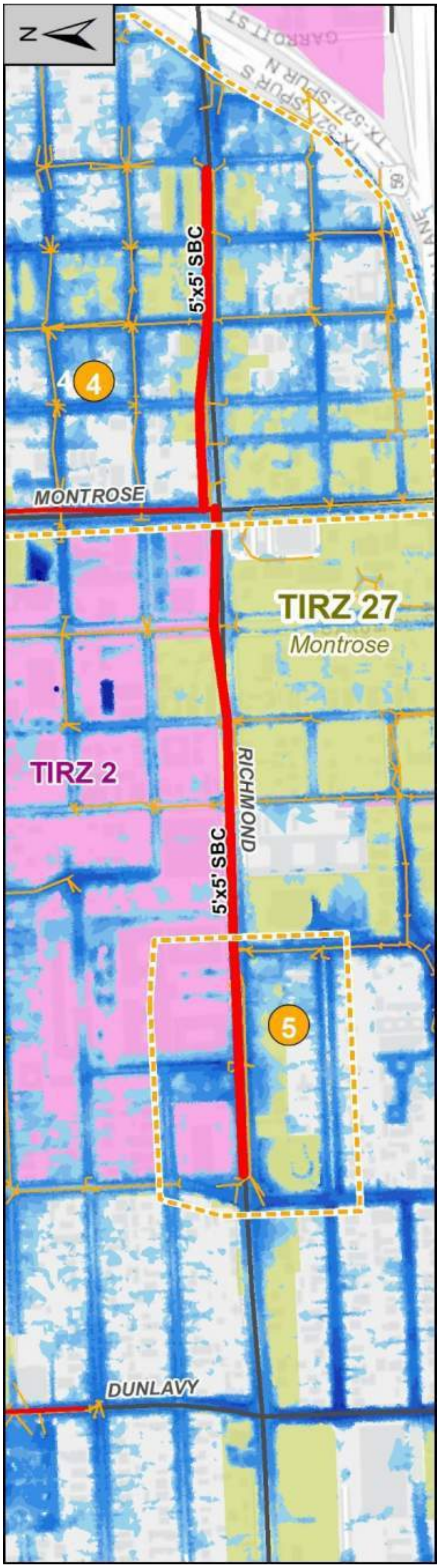
The benefits of the Montrose projects on Problem Areas 3, 4, and 5 is dependent on the construction of the Richmond, Alabama, Westheimer, and Fairview projects.

Project Graphic (Left): Red is proposed storm drain (thick red is current project, thin red is other projects), orange is existing storm drain, dashed orange outlines problem areas, inundation shown represents pre-project 100-year

Gauge
ENGINEERING

MONTROSE FLOOD FEASIBILITY STUDY

MONTROSE
TAX INCREMENT REINVESTMENT ZONE 27



Project Summary Sheet: Richmond

Proposed Improvements:

- 3880 LF of 5’ x 5’ CBC from Mandell St to Jack St

Project Dependencies:

The Richmond project is dependent on construction of the entire Montrose project from Richmond Ave to the outfall at Buffalo Bayou north of Allen Parkway.

Ranking Criteria:

Category	Score
Benefit Zones	6%
Street Flooding	10%
Project Dependency	0%
Total	**16%**

Cost Estimate:

Category	Cost
Construction	$ 9,035,000
PER/Design	$ 722,800
CM&I	$ 542,100
Total	**$ 10,299,900**

Problem Areas Benefitted:

Problem Area 4 & 5: Reduces flooding by improving trunkline capacity and removing flow from the undersized existing systems that drain to IH 69.

Assumptions:

All inlet systems along Richmond Ave will need to be tied into the new Richmond Trunkline along with any crossing lateral systems.

Project Graphic (Left): Red is proposed storm drain (thick red is current project, thin red is other projects), orange is existing storm drain, dashed orange outlines problem areas, inundation shown represents pre-project 100-year

Gauge
ENGINEERING

MONTROSE FLOOD FEASIBILITY STUDY

Project Summary Sheet: Westheimer

Proposed Improvements:

- 1720 LF of 6' x 6' CBC from Taft St to Montrose Blvd

Project Dependencies:

The Westheimer project is dependent on construction of the Montrose project from Westheimer Rd to the outfall at Buffalo Bayou north of Allen Parkway.

Ranking Criteria:

Category	Score
Benefit Zones	3%
Street Flooding	10%
Project Dependency	0%
Total	**13%**

Cost Estimate:

Category	Cost
Construction	$ 4,098,000
PER/Design	$ 327,840
CM&I	$ 245,880
Total	**$ 4,671,720**

Problem Areas Benefitted:

Problem Area 3: Reduces flooding by increasing trunkline capacity down Westheimer and lowering tailwater on the existing laterals.

Assumptions:

The existing trunkline down Westheimer from Montrose Blvd to Taft St flows from west to east. This trunkline needs to be reversed in this area to flow from east to west and into the proposed Montrose trunkline.

Project Graphic (Left): Red is proposed storm drain (thick red is current project, thin red is other projects), orange is existing storm drain, dashed orange outlines problem areas, inundation shown represents pre-project 100-year