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March 1, 2012

Mr. Dane Schneider, P.E.
Managing Engineer
Engineering Branch
Engineering and Construction Division
Department of Public Works and Engineering
City of Houston
611 Walker
Houston, TX 77002

Attn: Lynn Stracener

Re: Rampart Drainage Improvements-Additional Modeling for Storm Sewer Design
Phase II-Final Design for Rampart Street (Beechnut to Glenmont) Drainage Improvements Sub-Projects Number 1 and II (Westmoreland, Sharpstown, Braeburn and Maplewood Areas)
WBS #M-000265-0001-3
Ord. No. 2011-0893
Contract No. 4600007672
Klotz Associates, Inc. Proj. No. 0101.059.002

Dear Mr. Schneider:

Pursuant to our approved scope of work and our notice to proceed as provided by Mr. Ravi Kaleyatodi, P.E., Senior Assistant Director, in his letter dated October 21, 2011, we are submitting this letter report summarizing modeling and modeling results for the proposed Rampart Sewer Improvement Project ("Project") identified above. This letter report provides information validating the Rampart Sewer Improvement design previously developed in the Preliminary Engineering Report for this project.

Project Description

The Rampart Project proposes storm sewer improvements to the existing storm sewer along Rampart between Glenmont and Pine, the existing storm sewer along Pine from Rampart to Renwick, and the existing storm sewer along Renwick between Pine and Beechnut (i.e., Renwick south of Pine). All improvements occur along or adjacent to the existing sewer lined. No changes are proposed for the Renwick sewer system north of Pine and downstream of Beechnut. This drainage system outfalls via two parallel box culverts (referred to as the "Renwick Outfalls") to Brays Bayou in the vicinity of Mullins.

For descriptive purposes, the Project incorporates three primary watersheds (see Exhibit 1): the Rampart Watershed, which discharges storm waters collected directly by the Rampart and Renwick sewer systems and discharged to the Renwick Outfalls; 2) areas to the west of the Rampart watershed, referred to as the West Watershed, that have the potential for surface or subsurface drainage into or out of the Rampart Watershed; and 3) areas to the east of the Rampart Watershed that have the potential for surface or subsurface drainage into or out of the Rampart Watershed. The Rampart Watershed is essentially the watershed used in the PER ("Preliminary Engineering Report, Storm Sewer Improvements to Westmoreland, Sharpstown, Braeburn, and Maplewood" for preliminary design of the Rampart Project; and represents the general area targeted for improvement by construction of the proposed Project.

The existing and proposed storm sewer layouts are shown in Exhibits 2 and 3, respectively. Exhibit 3 delineates the portions of the existing system to be improved.

Evaluated as one overall watershed, the present analysis provides a more comprehensive description of drainage conditions than evaluated in the PER for the Project. Collectively, the Project evaluation area composed of the three watersheds covers approximately 4,500 acres.

The drainage analysis of this study used 2-dimensional modeling with 2D-XP-SWMM (2009 Version) to evaluate both pipe flow and surface flow conditions.

Findings

The SWMM modeling, as demonstrated by inundation plots (computer generated plots which show the maximum extent and depth of surface inundation), shows the following:

- For the 2-year storm event: only limited flooding (i.e., inundation by storm waters) occurs at isolated areas in the Rampart Watershed for both the existing and proposed storm sewer systems; see Exhibits 4 and 5. Note that inundation is eliminated for the proposed system 2-year storm event in the vicinity of the sewers being modified. Little change in inundation occurs beyond the area of the improved sewer lines along Rampart, Pine, and Renwick (south of Pine).

- Outside the Rampart Watershed in the East and West Watersheds where no improvements to existing sewers are proposed, inundation for both the existing and proposed conditions is virtually unchanged for the 2-year storm event.

- For the 100-year storm event, as illustrated by Exhibits 6 and 7, there is noticeably less inundation for the proposed condition than for the existing condition in the general area of the Rampart sewer line. Lesser inundation extent is particularly evident along Rampart between Bellaire Boulevard and Gulfton and along Pine.

Also to be considered is the impact upon structures in the Rampart Watershed. The PER identified drainage problem areas as evidenced by the number of 311 call complaints to the City about flooding conditions. In the Rampart Watershed, significant problem areas were found along Renwick between Bellaire Boulevard and Gulfton Street, along Rampart south of Bissonnet, and along the southward extension of Rampart south of Beechnut in the area generally lying in the 100-year floodplain.

Exhibit 6 for the existing conditions illustrates noticeable flooding for 100-year storm event along Renwick north of Bellaire Boulevard, along Renwick immediately north and south of Bissonnet, and along Renwick south of Beenchnut. This is approximately consistent with the 311-call flooding complaints. For proposed conditions much of the flooding north of Bellaire for the 100-year storm event to be noticeably reduced for the 100-year storm event (see Exhibit 7). South of Bissonnet, flooding is also reduced for the proposed conditions but not eliminated. South of Beechnut (where much of the area lies in the 100-year floodplain), virtually no change in inundation patterns occur.

Supplementary analyses of the effects of tailwater levels on flooding levels in the study area are discussed in the Appendix. Raising the tailwaters at Brays Bayou significantly increased the extent of inundation for the proposed improvements (compare Exhibits 7 and 9). These latter supplementary analyses demonstrate that the predominate factor in affecting inundation in the Rampart system is the outfall tailwater level at Brays Bayou.

This dominance of tailwater level is illustrated by the peak discharges to Brays Bayou from the Rampart-Renwick trunk lines shown in the following Table 1. The table compares the 100-year discharges for an outfall tailwater level set at the top of the outfall pipe vs. a level set 2-feet below the top of bank (at Brays Bayou). It is seen that the peak discharge is reduced by more than a factor two when the tailwater is raised from the top of outfall pipe to 2-feet below the top of bank. (Raising the tailwater from top of pipe to 2 feet below bank raises the tailwater at the Renwick outfalls a height of 8.56 feet.)

Table 1. Peak Discharge of Renwick Outfalls (Out111 and Out112) to Brays Bayou

	Event	Existing or Proposed	Tailwater Condition (see discussion in Appendix)	Peak Discharge (cfs)	Increase in Discharge (cfs)
Model distinctions are discussed in Appendix	2-yr	Existing	Top of Pipe	1049	
	2-yr	Proposed	Top of Pipe	1092	43
	100-yr	Existing	2' Below Top of Bank	614	
	100-yr	Proposed	2' Below Top of Bank	718	104
	100-yr	Existing	Top of Pipe	1492	
	100-yr	Proposed	Top of Pipe	1881	389

Conclusions

The 2D-XPSWMM modeling for existing conditions demonstrates general consistency with reported flooding in the Rampart Watershed area, the intended area of drainage improvement for the Project.

For a 2-year storm event, the SWMM modeling demonstrates the proposed design prevents flooding in the areas along and near the proposed sewer system improvements.

For non-extreme flooding conditions (i.e., for lower tailwater conditions) in Brays Bayou, the proposed Rampart Drainage Improvement Project appears to significantly reduce the concentrated areas of flooding north of Bissonnet. Only limited improvement is achieved for the area south of Bissonnet where improvements are not proposed and much of the area lies in the 100-year floodplain.

Table 1 shows that the proposed Rampart Drainage Improvements will increase the peak discharges to Brays Bayou. A mitigation study to eliminate such increases is warranted.

Tailwaters levels dominate the extent of inundation both north and south of Bissonnet. Tailwaters at a level of 2-feet below the top of bank produce proposed conditions which differ little from existing conditions for the 100-year flood condition (compare Exhibits 8 and 9); dropping the tailwater to the top of outfall pipe for the 100-year flood condition provides readily identifiable inundation reduction between existing and proposed conditions in the vicinity of the proposed improvements.

Sincerely,

STATE OF TEXAS
M. A. COLLINS
39270
REGISTERED PROFESSIONAL ENGINEER
3/1/2012

Michael A. Collins, P.E.

Attachments: Exhibits 1 to 9

Appendix

Background

The 2D-XPSWMM (version 2009) software package was used to model the behavior of the "Rampart Project", which is Alternative 3 of the projects evaluated in the previous report entitled "Preliminary Engineering Report, Storm Sewer Improvements to Westmoreland, Sharpstown, Braeburn, and Maplewood." (PER). This SWMM modeling was done to validate the proposed storm sewer design and provide a refined evaluation of the drainage behavior for the 2-year and 100-year storm events.

The Rampart Project proposes storm sewer improvements to the existing storm sewer along Rampart between Glenmont and Pine Street, the existing storm sewer along Renwick between Pine and Beechnut, and an additional cross connection along Pine between Rampart and Renwick. These systems join at Pine and Rampart and drain southward along Renwick along parallel lines to outfall to Brays Bayou in the vicinity of Mullins (these outfalls are identified as the "Renwick Outfalls"). The existing Renwick outfalls are not proposed for modification in the proposed Rampart Project.

Project Area

For descriptive purposes, three project watersheds were identified for defining the Project area: 1) the Rampart Watershed discharges storm waters collected directly by the Rampart and Renwick sewer systems and discharges them to the Renwick Outfalls; 2) the areas to the west of the Rampart watershed, referred as the West Watershed, that have the potential for surface or subsurface drainage into the Rampart Watershed; and 3) the areas to the east of Rampart Watershed, referred as the East Watershed, that have the potential for surface or subsurface drainage into the Rampart Watershed. These three watersheds are delineated in Exhibit 1. The Rampart Watershed is basically the watershed delineated in the PER for preliminary design of the Rampart Project.

The Rampart Watershed, the West Watershed, and East Watershed have areas of approximately 1,060 acres, 1,600 acres, and 1,840 acres, respectively. In the SWMM modeling, all three watersheds were connected by subsurface conduits of various sizes and locations and by surface flow pathways. The SWMM modeling analyzed the three watersheds as a single, combined watershed with a total drainage area of approximately 4,500 acres.

Hydrologic Systems and Their Characterization

The surface and subsurface drainage in the three Project Areas are interconnected. The subsurface drainage is connected by a few cross drainage connectors between the three watersheds. The surface drainage is determined by topography and overflow of surcharging sewers. The SWMM modeling allows surface and subsurface storm water to move between adjacent watersheds in either direction, depending upon hydraulic conditions.

The surface drainage is controlled by storm water accumulation on the land surface, the hydraulic head it produces, and the topography of the land surface. In general terms, the surface drainage is from northwest to southeast; surface flow from the West Watershed generally drains toward the Rampart Watershed; and surface flow from the Rampart Watershed generally drains toward the East Watershed. Topography and the locations of receiving waters (i.e., channels and bayous) were used to generally define the overall boundary of the three combined Watersheds.

Topography of the Project Area was broadly defined by 2008 LiDAR obtained from the Harris County Flood Control District (HCFCD), with minor modification for consistency with PER data. LiDAR data rectification problems identified by HCFCD after this study was undertaken were reviewed and considered of little impact for several reasons:

1. The rectification problems identified were problems of overall vertical height of the topography; i.e., absolute elevation. Surface drainage patterns are defined by relative elevations, not absolute elevation.
2. Based upon discussion with HCFCD, the potential vertical elevation error in the LiDAR data was minor in the general area of the Project Area. The more severe areas of errors were located in areas far from the Project Area.
3. The accuracy, as opposed to the precision, of LiDAR is considered not sufficient to make a significant impact on the drainage patterns in the Project areas between 2001 versus 2008 LiDAR, particularly in light of the fact that the LiDAR-based elevation data is defined, for modeling purposes, on a 15-foot x 15-foot grid size.

The topography of the Project Area was used to initially identify drainage areas for defining surface inflows to manhole collection points using ArcHydro Tools. These initially identified areas were modified to reduce the number of nodal points to a number within the capacity of the SWMM model and provide more rapid execution of the model. In the Rampart Watershed the initial delineation was modified by combining some small drainage areas into somewhat larger drainage areas to provide more consistency with the

boundaries of the drainage areas used in the PER. In the East and West Watersheds, some smaller drainage areas were combined into larger watersheds to reduce the number of nodal points for surface inflow to the subsurface pipe system.

Nodal points for inflow from the various drainage areas into the subsurface pipe system were selected so that each drainage area had one point of surface inflow. Exhibit 1 shows the revised drainage areas used in the SWMM modeling. The nodal inflow points were approximate representations of manholes collecting surface inflow from nearby surrounding inlets.

Hydrology

The temporal variation of rainfall was described with an Exceedance Probability Rainfall Distribution Graph based upon intensity-duration-frequency data from Harris County Flood Control.

Surface runoff hydrographs for inflow to the subsurface pipe system at nodal inflow points were determined using the Clark Unit Hydrograph Tc+R method in conjunction with the Rational Method.

The peak discharge at each nodal inflow point was computed for a 2-year storm event using the Rational Method. Time of concentration was based upon a longest pathway to drain the entire drainage area assuming first flow along non-paved surfaces followed by flow along streets to the inflow point. Runoff speed over non-paved surfaces was assumed to be 0.25 feet/second while that over paved surface was assumed to be 1.25 feet/second. The rational runoff coefficient was estimated from land use codes assigned to each parcel from the City of Houston.

HEC-HMS (version 3.3) was used to model the runoff from each drainage area for a 2-year storm using the Tc+R method. The R in the model input parameters was estimated by trial and error such that the peak 2-year discharge determined using the Rational Method was equal to or less than plus or minus 10%, of the peak 2-year discharge determined using HEC-HMS modeling.

Subsurface Drainage System

The subsurface drainage system for the existing Rampart Watershed was initially taken from the GIMS database and, after review, revised to reflect more realistic conditions and

survey data in the PER. Only trunk lines and larger pipes (18-inch and above) were retained for modeling purposes.

Proposed conditions conduits for the Rampart Watershed were taken from the PER.

The subsurface pipe system for the East and West Watersheds were initially delineated using GIMS data. Only larger pipes (generally 24-inch and above) were retained for modeling to stay within model capabilities.

Exhibit 2 shows the existing subsurface system modeled while Exhibit 3 shows the proposed system.

While individual inlets were not modeled, nodal capacity limitations as controlled by inlet capacity were included in the modeling to reflect the impact of inlet capacity. The effect of inlet capacity limitations was accomplished by estimating the number of inlets draining to each inlet node and assigning a capacity to the inlet node which was the sum of the individual inlet capacities. The capacity of individual inlets draining to the inlet node was estimated as that for Type B-B inlets (with individual capacity of 5 cfs) since the majority of the inlets (based upon GIMS data) were of this type. Nodal capacity was the inlet capacity times the estimated number of inlets draining directly to the node. By combining inlets at a single manhole, the effective capacity of surface inflow points were generally between 35 to 45 cubic feet per second.

Outfalls

All outfalls draining pipes in the Rampart, East, and West Watersheds were included in the SWMM model. Outfalls characteristics for the proposed design were unchanged from the existing conditions. The various outfalls identified for the watersheds are given in Table 1 (see page 3). The tailwater level for all outfalls was set at the top of the outfall conduit for the initial analyses.

Supplemental analyses were also made for the 100-year event in which the tailwater levels were set to approximately 2 feet below the top of bank of the receiving water channel at the location of the outfall.

SWMM Model Execution

The SWMM modeling (for results presented in this report) used a 24-hour duration storm event for both a 2-year event and a 100-year event.

- A 2D topographic grid of 100-feet by 100-feet was used.
- A modeling time step of 15 seconds was used.

In addition to tabular results in the SWMM output files, plots of maximum inundation over the course of a storm in all grid cells was determined and plotted as "inundation plots." Screen capture of pertinent inundation plots was done for inclusion in this report to demonstrate the drainage efficacy of existing and proposed drainage systems.

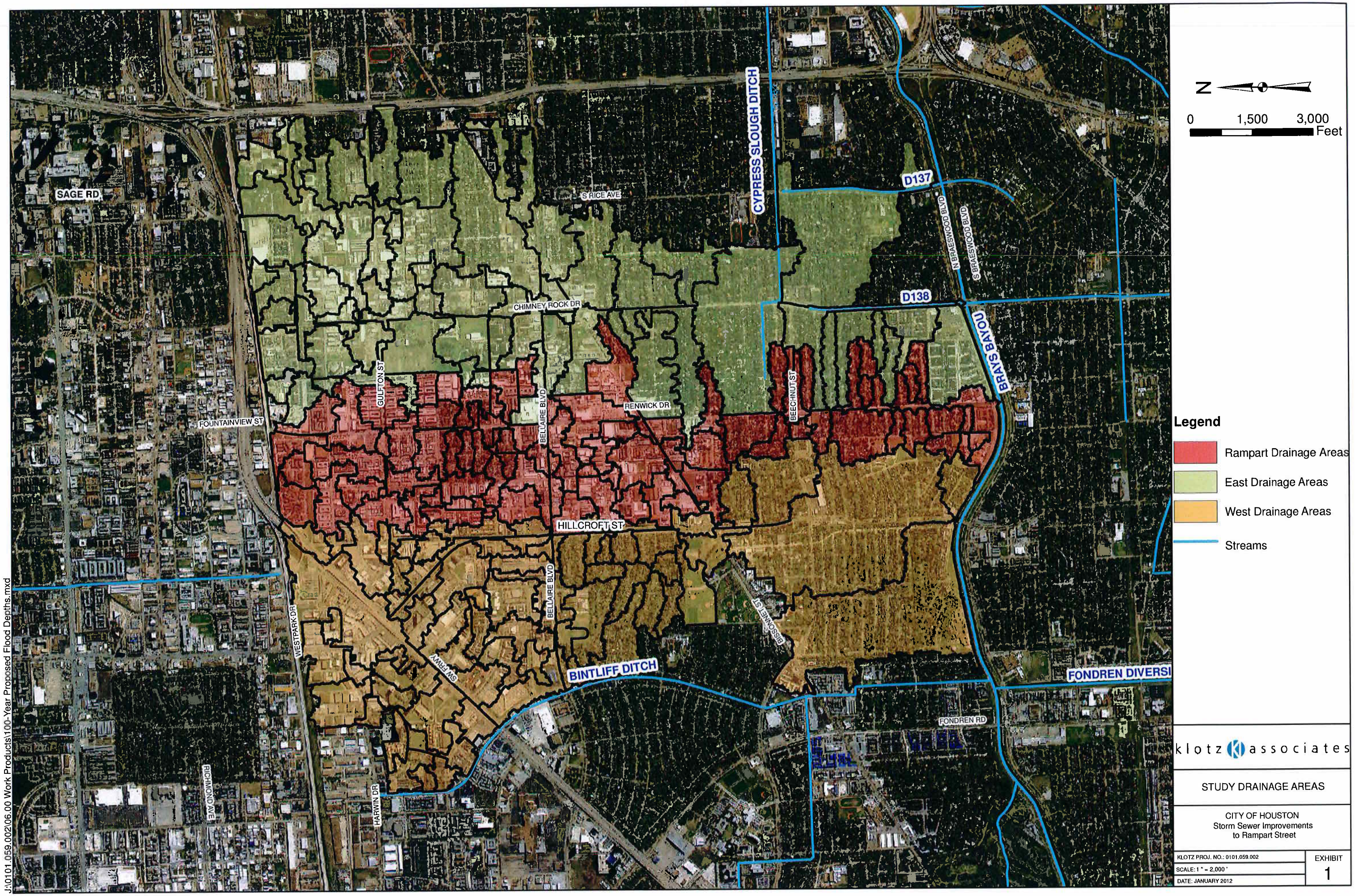
Results of Analyses

Exhibits 4 and 6 show the maximum extent of inundation for the existing drainage system for the 2-year and 100-year storm events. Color gradation is used to show the approximate maximum depth of storm water accumulation. Only depths in excess of 0.25 feet are shown since smaller depths are insignificant in impact and are generally indistinguishable from overland flow depths for flow draining to a collection point.

Exhibits 5 and 7 show the maximum extent of inundation for the proposed drainage system for the 2-year and 100-year storm events.

Comparison of the 2-year inundation conditions shows little inundation for both the existing and proposed conditions. The extent of inundation for the 100-year storm event for the proposed system is noticeably less in extent and depth than that for the existing drainage system. Note, as well, that changes in inundation from existing to proposed conditions beyond the approximate limits of the Rampart Watershed are very limited.

When the outfall tailwaters were set 2-feet below the top of bank, inundation for the proposed conditions had only limited differences from the existing conditions, as illustrated by the comparison of Exhibits 8 and 9.


N
0
1,500
3,000
Feet
Legend
Rampart Drainage Areas
East Drainage Areas
West Drainage Areas
Streams
SAGE RD
S RICE AVE
CYPRESS SLOUGH DITCH
D137
N BRAESWOOD BLVD
S BRAESWOOD BLVD
D138
BRAYS BAYOU
CHIMNEY ROCK DR
GULFTON ST
BELLAIRE BLVD
RENWICK DR
BEECHNUT ST
FOUNTAINVIEW ST
HILLCROFT ST
WESTPARK DR
BISSONNET ST
SW FRWY
BINTLIFF DITCH
FONDREN DIVERSI
FONDREN RD
RICHMOND AVE E
HARWIN DR
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STUDY DRAINAGE AREAS
CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street
KLOTZ PROJ. NO.: 0101.059.002
SCALE: 1 " = 2,000 '
DATE: JANUARY 2012
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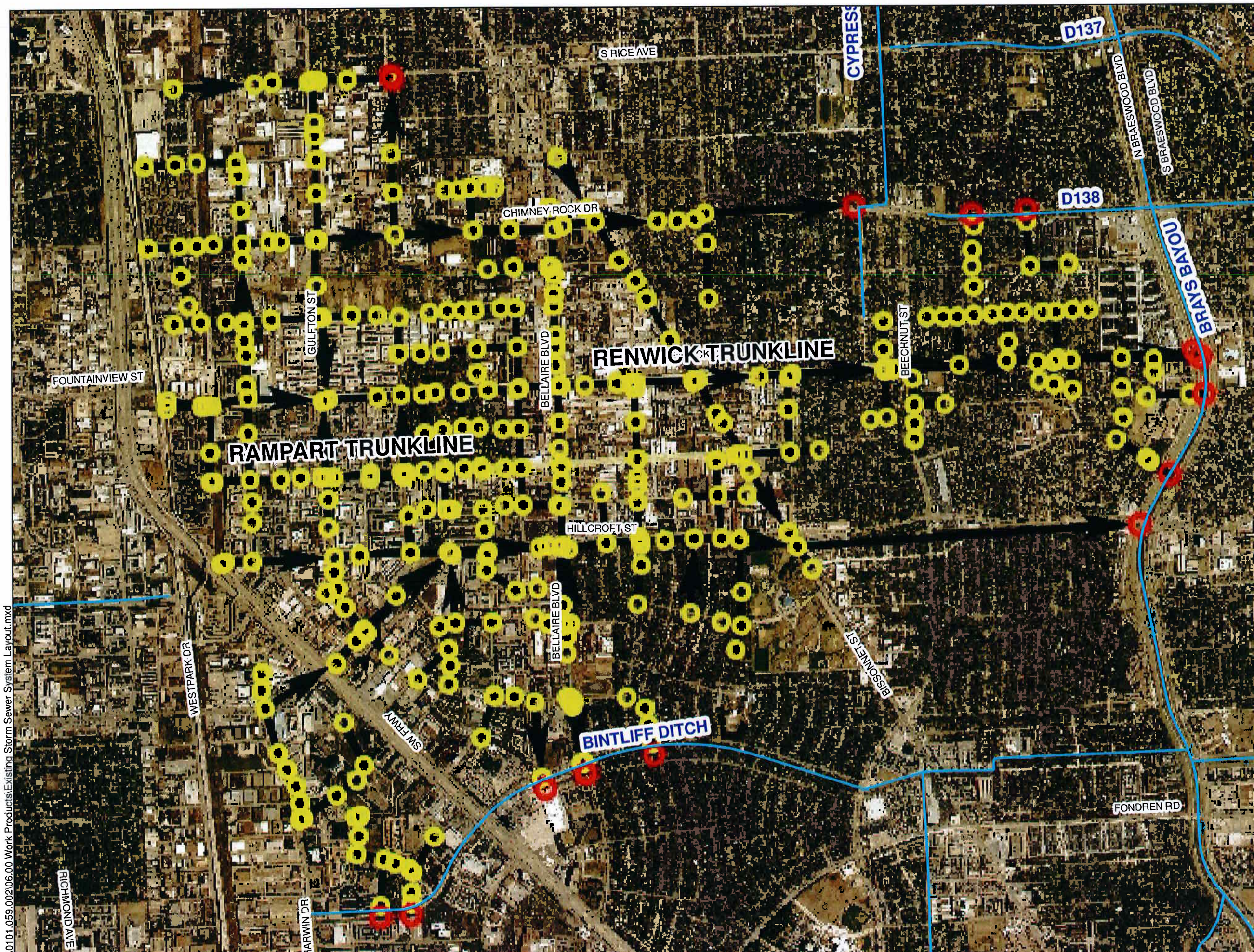

N

0 1,000 2,000 Feet

Legend

- XPSWMM Outfall
- XPSWMM Node
- XPSWMM Link
- Streams

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EXISTING STORM SEWER SYSTEM LAYOUT

CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street

KLOTZ PROJ. NO.: 0101.059.002
SCALE: 1" = 1,500'
DATE: JANUARY 2012

EXHIBIT 2

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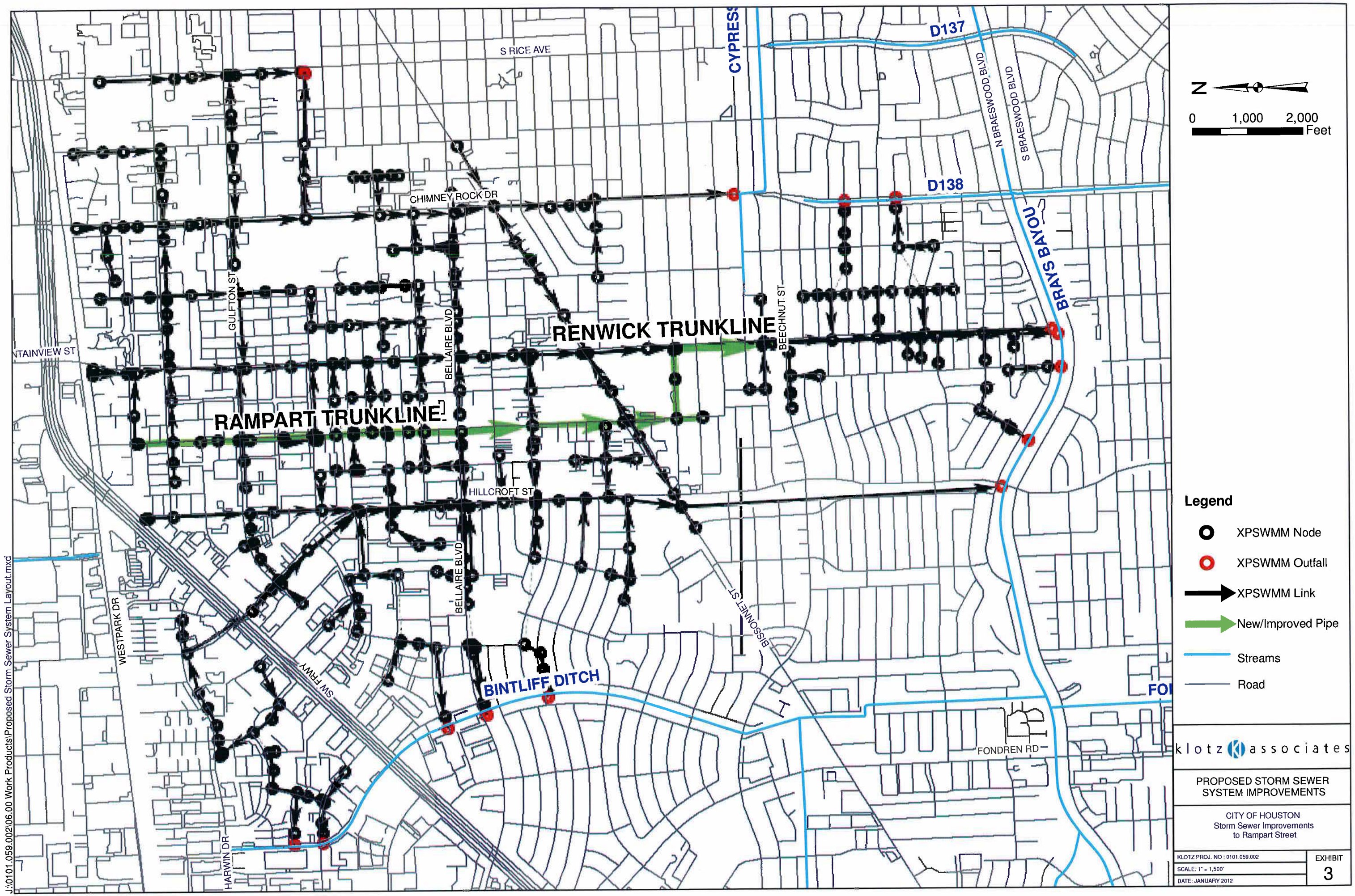
S RICE AVE
CYPRESS
D137
N BRAESWOOD BLVD
S BRAESWOOD BLVD
D138
CHIMNEY ROCK DR
BRAYS BAYOU
GULFTON ST
BELLAIRE BLVD
RENWICK TRUNKLINE
BEECHNUT ST
NTAINVIEW ST
RAMPART TRUNKLINE
HILLCROFT ST
BELLAIRE BLVD
BISSONNET ST
WESTPARK DR
SW FRWY
BINTLIFF DITCH
FONDREN RD
HARWIN DR
N
0 1,000 2,000 Feet
Legend
XPSWMM Node
XPSWMM Outfall
XPSWMM Link
New/Improved Pipe
Streams
Road
klotz associates
PROPOSED STORM SEWER SYSTEM IMPROVEMENTS
CITY OF HOUSTON
Storm Sewer Improvements to Rampart Street
KLOTZ PROJ. NO : 0101.059.002
SCALE: 1" = 1,500'
DATE: JANUARY 2012
EXHIBIT 3
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N

0 1,000 2,000 Feet

Legend

- Outfall
- Node
- Major Trunklines
- Storm Sewer Pipe
- Streams

Flooding Depth (ft)

- 0.25
- 0.50
- 0.73
- 0.96
- 1.19
- 1.41
- 1.64
- 1.87
- 2.10
- 2.33

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EXISTING CONDITIONS
2-YR FLOODING DEPTH

CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street

KLOTZ PROJ. NO.: 0101.059.002	EXHIBIT
SCALE: 1" = 1,500'	4
DATE: JANUARY 2012	

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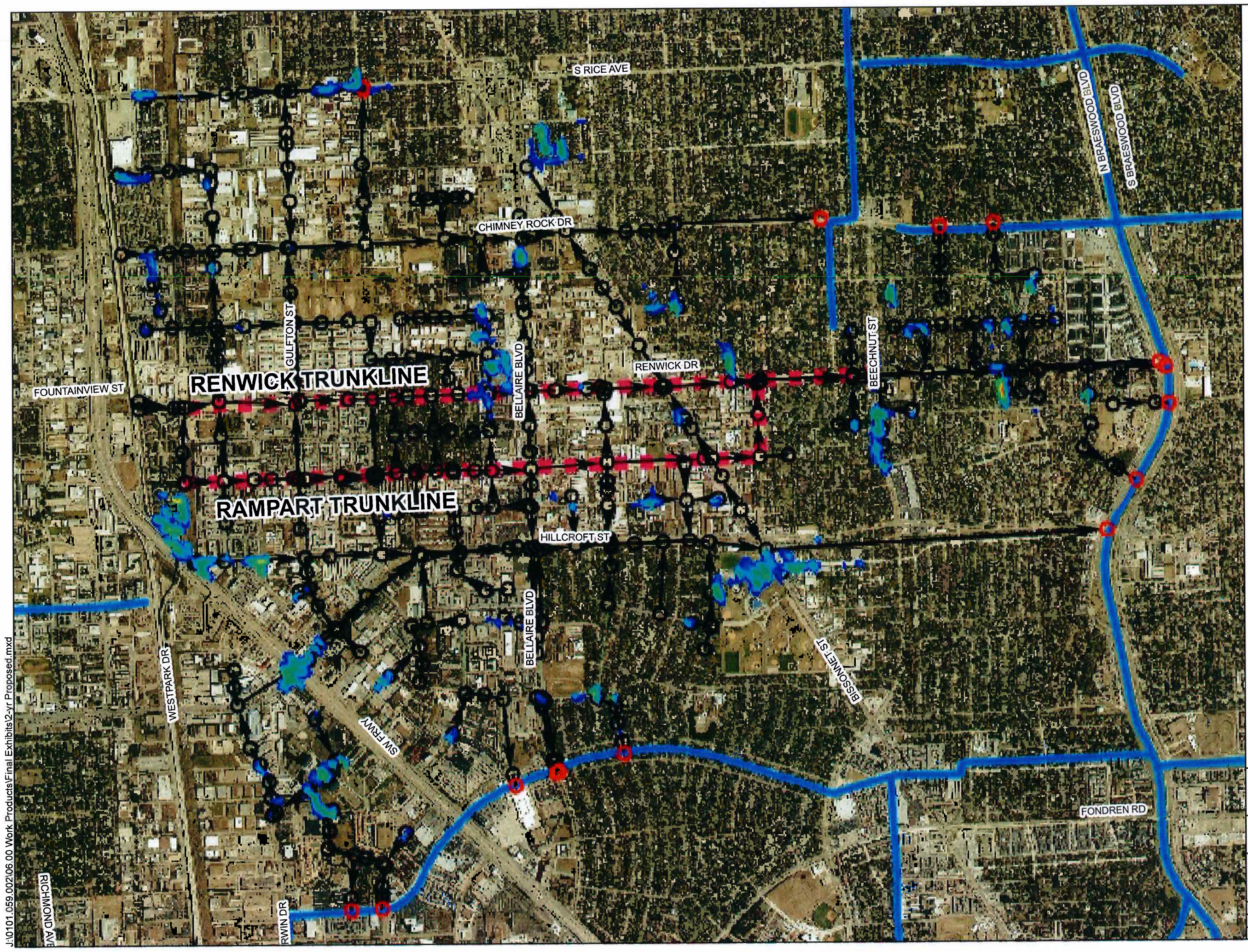

N

0 1,000 2,000 Feet

Legend

- Outfall
- Node
- Major Trunklines
- Storm Sewer Pipe
- Streams

Flooding Depth (ft)

- 0.25
- 0.50
- 0.73
- 0.96
- 1.19
- 1.41
- 1.64
- 1.87
- 2.10
- 2.33

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PROPOSED CONDITIONS
2-YR FLOODING DEPTH

CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street

KLOTZ PROJ. NO.: 0101.059.002
SCALE: 1" = 1,500'
DATE: JANUARY 2012

EXHIBIT
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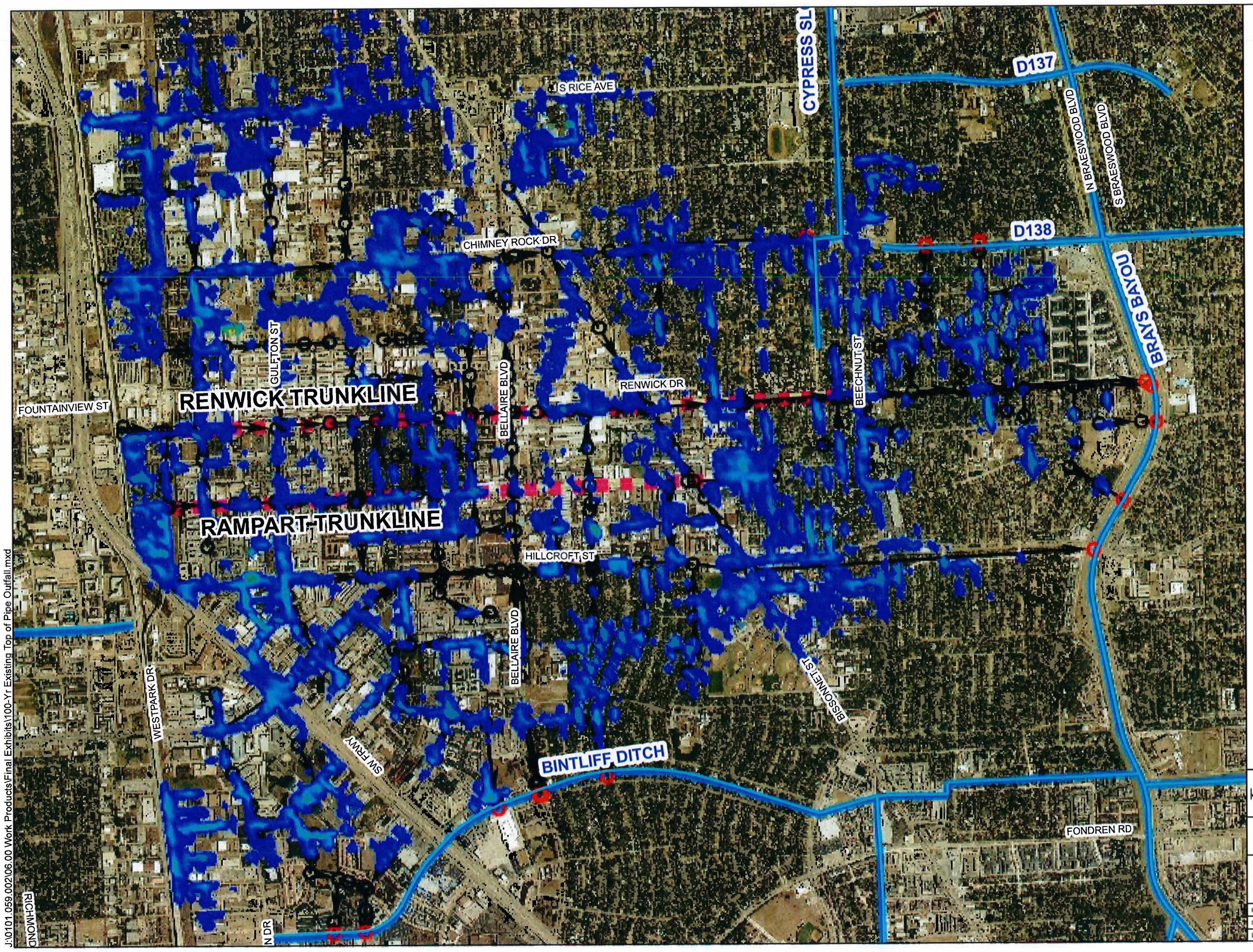

N

0 1,000 2,000 Feet

Legend

- Outfall
- Node
- Major Trunklines
- Storm Sewer Pipe
- Streams

Flooding Depth (ft)

- 0.25
- 1.05
- 1.79
- 2.53
- 3.26
- 4.00
- 4.74
- 5.47
- 6.21
- 6.95

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EXISTING CONDITIONS
100-YR FLOODING DEPTH
TOP OF PIPE OUTFALL CONDITION

CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street

KLOTZ PROJ. NO.: 0101.059.002
SCALE: 1" = 1,500'
DATE: JANUARY 2012

EXHIBIT
6

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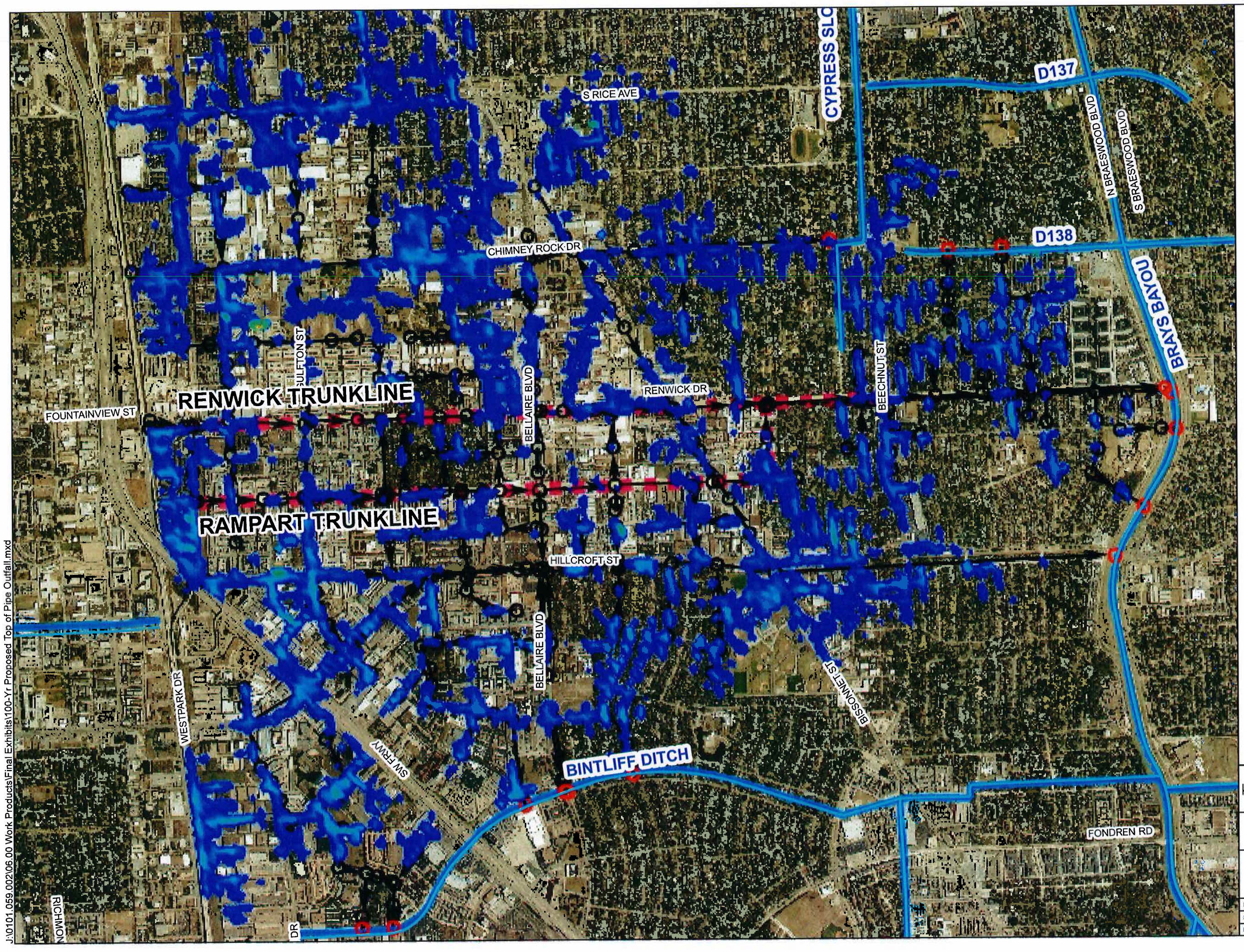

N

0 1,000 2,000 Feet

Legend

- Outfall
- Node
- Major Trunklines
- Storm Sewer Pipe
- Streams

Flooding Depth (ft)

- 0.25
- 1.05
- 1.79
- 2.53
- 3.26
- 4.00
- 4.74
- 5.47
- 6.21
- 6.95

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PROPOSED CONDITIONS
100-YR FLOODING DEPTH
TOP OF PIPE OUTFALL CONDITION

CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street

KLOTZ PROJ. NO.: 0101.059.002
SCALE: 1" = 1,500'
DATE: JANUARY 2012

EXHIBIT 7

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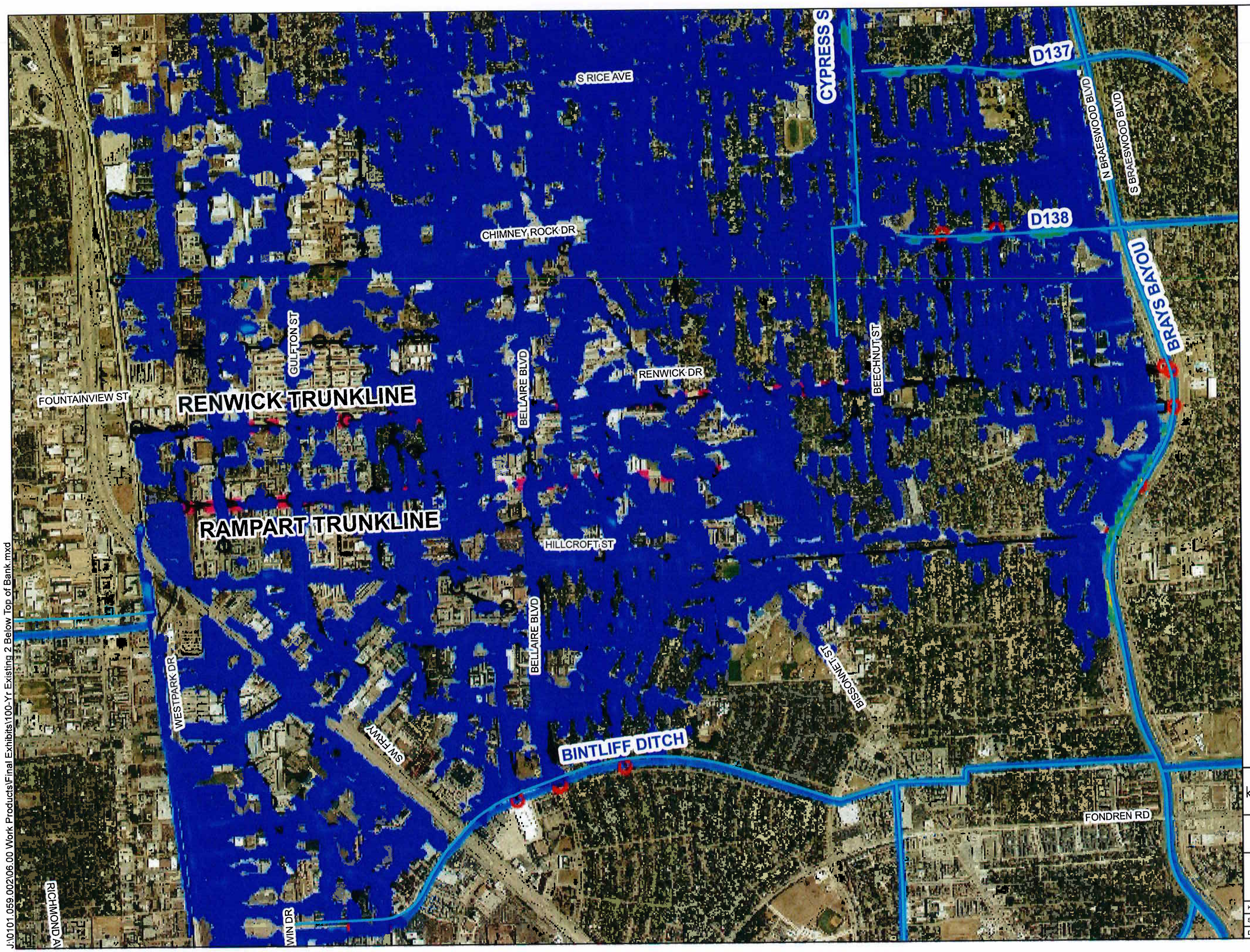

N

0 1,000 2,000 Feet

Legend

- Outfall
- Node
- Major Trunklines
- Storm Sewer Pipe
- Streams

Flooding Depth (ft)

- 0.25
- 3.14
- 5.79
- 8.44
- 11.09
- 13.73
- 16.38
- 19.03
- 21.68
- 24.33

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EXISTING CONDITIONS
100-YR FLOODING DEPTH
2' BELOW TOP OF BANK OUTFALL

CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street

KLOTZ PROJ. NO.: 0101.059.002	EXHIBIT
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DATE: JANUARY 2012	

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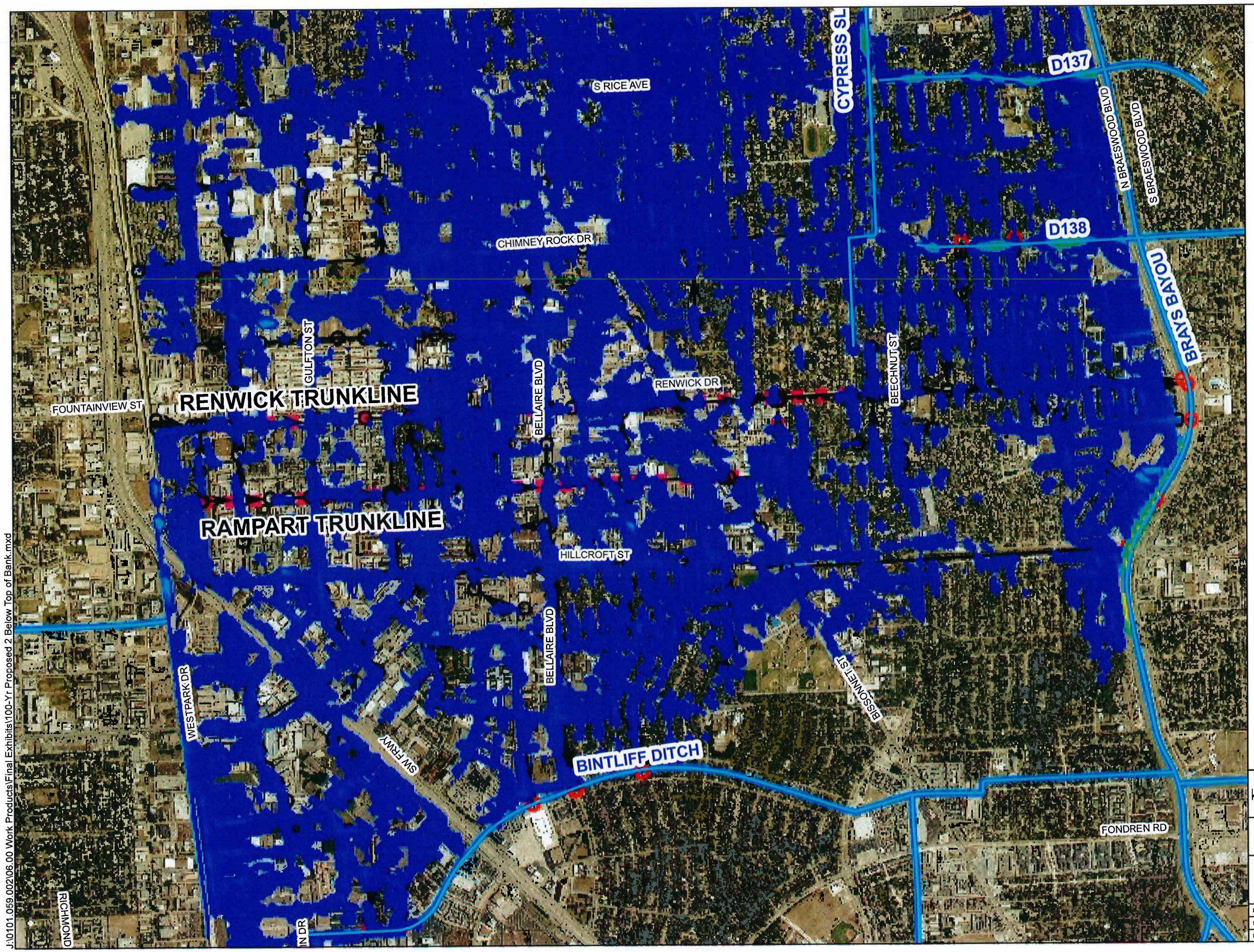

N

0 1,000 2,000 Feet

Legend

- Outfall
- Node
- Major Trunklines
- Storm Sewer Pipe
- Streams

Flooding Depth (ft)

- 0.25
- 3.14
- 5.79
- 8.44
- 11.09
- 13.73
- 16.38
- 19.03
- 21.68
- 24.33

klotz associates

PROPOSED CONDITIONS
100-YR FLOODING DEPTH
2' BELOW TOP OF BANK OUTFALL

CITY OF HOUSTON
Storm Sewer Improvements
to Rampart Street

KLOTZ PROJ. NO.: 0101.059.002	EXHIBIT
SCALE: 1" = 1,500'	9
DATE: JANUARY 2012	

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