CITY OF CASTLE HILLS

MASTER DRAINAGE PLAN – TASK ORDER 2

WATERSHEDS I, IV AND V

UPPER SAN ANTONIO RIVER WATERSHED

Prepared For

CASTLE HILLS, TEXAS

May 2016

Prepared By

RPS klotz associates

Texas PE Firm Reg. #F-929

Project No. 1161.001.003

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WATERSHEDS I, IV AND V

UPPER SAN ANTONIO RIVER WATERSHED

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EXECUTIVE SUMMARY

The City of Castle Hills, Texas (the City) is located in Bexar County, Precinct 3, and is surrounded by The City of San Antonio. The City of Castle Hills (City) is affected by periodic flooding throughout most of the city limits, with flooding extents ranging from localized nuisance flooding of roads and driveways, to larger scale watershed flooding that floods structures. Soil erosion from rainfall events is also a problem. The flooding is caused by a number of factors, yet the major causes can be summarized as follows:

- undersized (or non-existing) storm drains,
- excessive upstream runoff,
- minimal street grades, and
- low conveyance in channels.

The purpose of this study is to determine the causes of the flooding and propose solutions to minimize, or possibly eliminate flooding within the primary waterways within watershed areas I, IV and V (Fox Hall, Lemonwood, Travertine, and Atwater, respectively). Structural flood controls such as detention ponds, flood diversion improvements, conveyance improvements, etc., are construction projects that could potentially be built in an effort to alter the flood condition of a watershed. Conveyance improvements are the improvements that have been proposed for this report. The peak flows were determined using the Rational Method and the proposed solutions were developed using the Manning's equation as described in the City of San Antonio's (COSA) drainage criteria (Section 25-504, Stormwater Management, COSA UDC).

Fox Hall Watershed – The proposed improvements for the Fox Hall watershed include approximately 300 linear feet of channel improvements and two culvert crossings at Fox Hall Lane and Hibiscus Lane. The proposed channel improvements would convey floodwaters along Fox Hall Lane and Hibiscus Lane to utilize as much existing right-of-way (ROW) as possible and to minimize the need of acquiring additional easements from existing property owners.

Lemonwood – The proposed storm drain system would increase overall system capacity by adding catch inlets throughout the alignment. The inlets would outfall into a pipe network that would start off as a single 24-inch diameter pipe at the alleyway and then increase in size to twin 48-inch diameter pipes at the TxDOT outfall just north of Interstate 410.

Travertine – The proposed storm drain system would increase overall system capacity by adding catch inlets throughout the alignment. The inlets would outfall into a pipe network that would start off as a 36-inch diameter pipe and then increase in size to a 54-inch diameter pipe at the outfall in Jackson Keller Road.

Atwater – The proposed storm drain system would increase overall system capacity by adding a catch inlet at Antler Drive and possibly along the proposed stormsewer alignment. The stormsewer would start off as a 48-inch diameter pipe and then increase in size to a 60-inch diameter pipe at the outfall in Jackson Keller Road.

A graphical representation of the recommended improvements proposed for each of the watersheds can be found in Appendix D.

SECTION 1 Introduction

1.1 Background

The City of Castle Hills, Texas (City) is located in Bexar County (refer to EXHIBIT A) between IH-10 and US HWY 281, and intersected by Loop 410. The City's jurisdictional area is roughly 2.5 square miles, with roughly two-thirds of the City's area located on the north side of Loop 410. The City zoning is primarily residential, followed by commercial and institutional zoning (schools, churches).

- The City of Castle Hills consists of five (5) watershed areas, and for the purpose of this Phase II report, efforts are focused on key problem areas in Watersheds I, IV and V only (see EXHIBIT B-1). Watershed I, also known as Fox Hall, conveys runoff that eventually runs into Olmos Creek, just west of the Loop 410/Jackson-Keller intersection,
- Watershed IV is comprised of two main sub areas named Lemonwood and Travertine and conveys runoff that eventually runs into Olmos Creek, just east of the Loop 410/Jackson-Keller intersection,
- Watershed V is also known as Atwater and conveys runoff that eventually runs into Olmos Creek. The convergence point of the stream from Atwater to Olmos Creek occurs outside of City of Castle Hills boundaries,
- The headwaters of all watersheds are located within the City of San Antonio (COSA), which conveys a significant amount of runoff through the City of Castle Hills,
- All five (5) of the watersheds within the City are part of the Upper San Antonio River watershed.

1.2 Purpose

The City has experienced repeated flooding of its roads and private property during light rainfall events. Therefore, the purpose of this study is to determine the causes of the flooding and propose solutions to minimize, or possibly eliminate existing flooding problems in the City. This report is part of the second phase of the project and includes an analysis of the remainder of the City not analyzed in the drainage report published in July 2015, and proposed solutions to improve the drainage systems and reduce flooding.

1.3 Authorization

This study was authorized by the City of Castle Hills as part of the Agreement issued on February 3, 2015 and approved by council on February 10, 2015. This second phase was authorized on September 22, 2015.

1.4 Overview of Approach

The work phases have been performed during the development of this study and are briefly discussed below:

- Coordinate with the surveyor to collect elevation data for the drainage system.
- Collect data from the City, TxDOT, Bexar County, City of San Antonio and others as appropriate to better understand the drainage systems.
- Conducted field reconnaissance to confirm outfalls and connections.
- Evaluate drainage patterns and meet with City staff and City Drainage Committee to better understand the nature of the drainage issues.
- Meet with City of San Antonio and TxDOT to discuss issues and solicit input their input to determine if downstream improvements are being, or will be, considered by those agencies to reduce flooding.
- Perform hydrologic and hydraulic calculations using City design criteria to develop solutions for each watershed.
- Propose solutions to minimize, or possibly eliminate flooding within the primary waterways within watershed areas I, IV and V (Fox Hall, Lemonwood, Travertine, and Atwater, respectively).
- Develop an opinion of probable cost for the conceptual improvements of each watershed.

SECTION 2 Data Collection and Watershed Evaluation

2.1 Purpose

Data was collected for the purpose of delineating drainage areas for calculation purposes as well as identifying and characterizing flooding problems in the City. For the purpose of this study, only drainage areas that are entirely contained within the City boundaries and have outfalls to known storm sewer or channels were analyzed. Data included public domain information, site inspection, specific survey points and LiDAR data courtesy of the City of San Antonio and the San Antonio River Authority.

2.2 General Description of the Study Area

Watershed I, Watershed IV and Watershed V are approximately 352, 297, and 231 acres, respectively, within the Castle Hills city limits (see EXHIBIT B-1). However, for the purposes of this analysis the drainage areas were analyzed based on their interim outfalls. Within each watershed, the City has identified several key locations based on known infrastructure that would provide solutions to existing flooding problems. Therefore, the analysis of Watershed I became the 82 acres of Fox Hall, Watershed IV became the two separate areas of Lemonwood (68 acres) and Travertine (81 acres) and Watershed V was analyzed based on the 31 acres of Atwater.

The watersheds are primarily zoned residential with some lower density business/commercial, and parks. The study areas contribute to the Upper San Antonio River watershed.

The overall slope of the project area is from north to south, with elevations ranging from 905 feet in the northern portion to 788 feet in the southern areas. The total watershed (within limits of the City of Castle Hills) can generally reach elevations around 940 feet.

2.3 Data Collection

One foot topographic contours were downloaded from the San Antonio River Authority (SARA) for the Castle Hill area. They were developed from LiDAR data collected between March 2010 and November 2011. These contours were used to manually delineate drainage areas in ArcGIS. Additional information was used to help insure accurate delineation of drainage areas, such as: 6-inch aerial imagery of Bexar County, downloaded from Texas Natural Resource Information System

(TNRIS); spatial data files downloaded from the City of San Antonio which represents stormwater infrastructure (channels, inlets, manholes, outfalls, underground pipes); Google Earth Imagery/ Street View; and information gathered from field visits.

2.4 Hydrologic and Hydraulic Calculations and Modeling

Hydrologic and hydraulic models were not available, therefore hydrology and hydraulics needed to be determined from contour and aerial imagery information and confirmed and adjusted based on site visits.

2.4.1 Hydrology

Runoff calculations were performed in accordance with City of San Antonio (COSA) drainage criteria (Section 25-504, Stormwater Management, COSA UDC) and the City of Castle Hills Subdivision ordinance Chapter 40, Article V, Section 40-212. The proposed improvements for each of the watercourses are anticipated to consist of a combination of earthen channel improvements, stormsewer upgrades, and culvert crossings. Based on drainage facility requirements described in Section 40-213 of the City of Castle Hills Storm Drainage Design Criteria, both the 25-year and 100-year peak flow rates were determined. A summary of the hydrologic analysis as well as the time of concentration calculations can be found in Appendix C.

The Rational Method equation was used to calculate the peak flows associated with each subarea in each of the watersheds. The Rational Method is calculated as follows:

$$Q=I(\Sigma CA)$$

Where:

Q	=	Flow (cfs)
I	=	Intensity (in/hr)
C	=	Runoff Coefficient
A	=	Area (Acres)

Finding and determining the areas was the first step in determining the equation. As discussed earlier in Section 2.3, multiple data sets were downloaded and used to manually delineate drainage areas in

ArcGIS. This allowed the specific analysis of just the areas known to direct runoff into existing storm sewer systems and drainage channels. These sub-areas were created and drawn preliminarily through LiDAR data as well as aerial imagery and of course data files representing stormwater infrastructure (channels, inlets, manholes, outfalls, underground pipes). After a site visit completed on November 10, 2015, adjustments were made to the areas and remaining calculations could begin.

2.4.1.1 Intensity

Intensity is a function of the time of concentration. The time of concentration is the time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed (NRCS 1985). The time of concentration may be estimated by calculating and summing the travel time for each subreach defined by the flow type: sheet flow, shallow concentrated flow, and channelized flow (including roadways, storm sewers, and natural/manmade channels). The methods prescribed in the NRCS' Technical Release 55 (TR55) are used to determine the times of concentration for each flow segment in this analysis. Typical time of concentration flow segments are presented below.

Sheet Flow (≤ 300 feet)

Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (Manning's n) is an effective roughness coefficient that includes the effect of raindrop impact, of drag over the plane surface and obstacles such as litter, crop ridges, and rocks, and of erosion and transportation of sediment. These n values are for very shallow flow depths of approximately 0.1 foot. Assuming sheet flow of less than or equal to 300 feet, travel time is computed as follows:

$$Tt = (0.007 \times (n \times L)^{0.8}) / (P_2^{0.5} \times s^{0.4}) \qquad \text{Equation 1}$$

Where:

Tt	=	travel time (hr),
n	=	Manning's roughness coefficient,
L	=	flow length (ft),
P_2	=	2-year, 24-hour rainfall (in), and
s	=	slope of hydraulic grade line (land slope, ft/ft).

Shallow Concentrated Flow

After a maximum of 300 feet, sheet flow usually becomes shallow concentrated flow. The average velocity for this flow can be determined from the following figure in which average velocity is a function of watercourse slope and type of channel (TR-55). The flow is still considered shallow in depth and flows in a swale or gutter instead of a channel, which has greater depth.

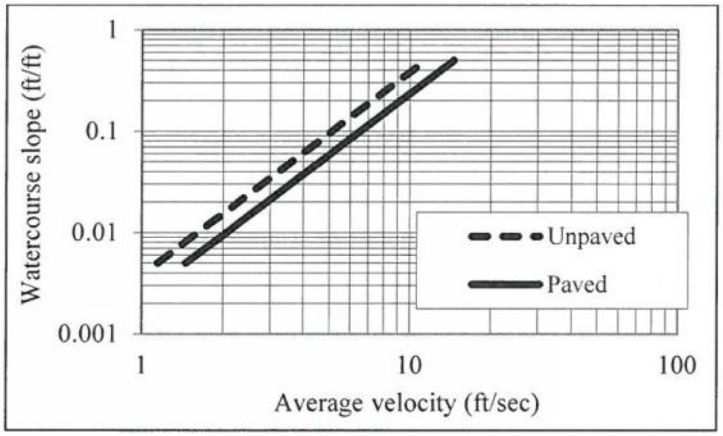

Figure 1 - Avg. Velocities for Estimating Travel Time in Shallow Concentrated Flow Segments

After determining the average velocity, the following equation is used to compute travel time:

$$Tt = L / (3600 \times V) \qquad \text{Equation 2}$$

Where:

Tt	=	travel time (hr),
L	=	flow length (ft),
V	=	average velocity (ft/sec), and
3,600	=	conversion factor from seconds to hours.

Channelized Flow

In the case of this analysis, channel flow computations are used for flow in open channels and storm drains. Mannings's equation is used to estimate the average flow velocity for the time of concentration computations.

2.4.1.2 Runoff Coefficient

Based on the UDC, the coefficients used could not be less than the values indicated in Table 504-1A or Table 504-1B in the UDC. Both tables based the C values for a type of land based on the character of the area and the slope. Table 504-1A broke down the character of the area more off of types of zoning, while Table 504-1B broke the areas down by how much grass cover there was. In order to maintain more uniformity, Table 504-1A was used and all areas were determined to be within the following description listed "Closely built residential areas and school sites or Zoning Districts MF, R-4".

2.4.1.3 Area

The sub-areas were created and drawn using LiDAR data and various drainage area maps acquired from TXDOT and other developments throughout the watersheds. Numerous site visits were made to corroborate the watershed boundaries.

2.4.2 Hydraulics

The hydraulic analysis for this study was completed using Manning's equations to compare the ability of existing infrastructure to convey 25-year and 100-year flows. Existing drainage paths, watercourses, and drainage infrastructure were approximated using 1 ft. LIDAR (March 2010 – November 2011) contours obtained from the SARA GIS website. Additional information was gathered at specific crossings to determine culvert sizes and quantities, slopes, material, headwall and roadway elevations. Existing channel roughness values were estimated from a combination of aerial imagery and site investigation.

Once the existing drainage flows were determined, the existing drainage configurations were analyzed. Based on Manning's equations for open channels and circular pipes, a baseline of what designs would be required to handle the 25-year flood events was determined. The following Manning's equation was used:

$Q = (1.49/n)(AR(2/3))(S(1/2))$ Equation 3

Where:

Q	= Flow (cfs)
n	= Manning's Number (approx. 0.030 = grass lined, 0.020 = CMP & 0.013 = RCP)
A	= Area (ft^2)
R	= Hydraulic Radius (ft)
S	= Slope (%)

A summary of the hydraulic analyses and supporting documentation can be found in EXHIBIT C.

SECTION 3 Proposed Improvements

3.1 Overview

The project scope includes identifying solutions to the localized flooding experienced within the Fox Hall, Travertine, Lemonwood, and Atwater areas.

Structural flood controls such as detention ponds, flood diversion improvements, conveyance improvements, etc., are construction projects that could potentially be built in an effort to alter the flood condition of a watershed. These projects have a high variability in complexity and cost. Regional detention ponds are large impoundments of floodwater that reduce peak flow rates downstream. Flood diversion improvements consist of redirecting floodwaters away from the main source of flooding. Conveyance improvements include structural improvements that increase the flood carrying capacity of the stream, such as the addition or enlargement of storm drain systems, bridge/culvert upgrades, and channel improvements.

Because of the unavailability of suitable land a regional detention pond is not a viable option and therefore not considered. Therefore, conveyance improvement based solutions will be necessary in order to reduce flooding that is currently being experienced in each of these watersheds.

3.2 Fox Hall

The Fox Hall watershed is an open channel system that follows the natural watercourse of the area and outfalls into Olmos Creek. The drainage patterns have been altered and/or encroached upon by the residential development within the watershed. Because of the size of the contributing drainage area of Fox Hall the drainage improvements include enlargement of the existing open channels within the watershed. Additionally, drainage culverts would need to be added at Fox Hall Lane and Hibiscus where the new channel crosses each respective road. A graphical representation of the proposed improvements can be found on Exhibit D-2.

Engineers Opinion of Probable Construction Cost
Fox Hall Improvements

Description	Quantity	Unit	Unit Price		Amount	
Channel Excavation	6000	CY	$	30	$	180,000
Misc. Demolition	1	LS	$	25,000	$	25,000
Road Repair/Culverts	2	EA	$	50,000	$	100,000
Misc. Erosion & Sedimentation Controls	1	LS	$	25,000	$	25,000
Planting & Revegetation	1	LS	$	50,000	$	50,000
Subtotal					$	380,000
Engineering and Permitting (Federal, State & Local)	30%				$	114,000
Construction Contingency	35%				$	133,000
Acquisition of Easements					$	100,000
Total Project Cost					**$**	**727,000**

Table 1 – Cost Estimate for Fox Hall

The natural path of the watercourse traverses northeast by northwest between Fox Hall Lane and Hibiscus Lane. The presence of existing homes makes an open channel solution along this route impractical. The proposed improvements for the Fox Hall watershed include approximately 300 lf of channel improvements and two culvert crossings at Fox Hall Lane and Hibiscus Lane. The proposed channel improvements would convey floodwaters along Fox Hall Lane and Hibiscus Lane to utilize as much existing right-of-way (ROW) as possible and to minimize the need of acquiring additional easements from existing property owners.

3.3 Lemonwood

The Lemonwood watershed is also an open channel man made system that starts at NW Military Hwy and runs southwest towards Interstate 410. The alignment of the watercourse follows a narrow corridor starting in an alleyway that discharges onto Roleto Drive and then concentrates into a concrete flume structure running parallel to Lemonwood Drive along a property line towards City Hall. At City Hall, the channel opens up and drains around City Hall and continues to the culvert outfall at Interstate 410. There is insufficient horizontal space to construct a drainage channel to convey the runoff through the watershed. The presence of homes, buildings, and streets leaves very little room to do more than what currently exists. The only option available is to add an enclosed storm drain system under the existing open channel system to increase the system's capacity to convey stormwater. A graphical representation of the proposed improvements can be found on Exhibit D-3.

Engineers Opinion of Probable Construction Cost
Lemmonwood Improvements

Description	Quantity	Unit	Unit Price		Amount	
Misc. Demolition	1	LS	$	50,000	$	50,000
36-in RC Pipe	880	LF	$	150	$	132,000
48-in RC Pipe	900	LF	$	250	$	225,000
Parallel 48-in RC Pipes	1100	LF	$	450	$	495,000
Inlet	6	EA	$	5,000	$	30,000
Manhole	3	EA	$	8,000	$	24,000
Street Repair	850	LF	$	250	$	212,500
Misc. Erosion & Sedimentation Controls	1	LS	$	10,000	$	10,000
Planting & Revegetation	1	LS	$	25,000	$	25,000
Subtotal					$	1,203,500
Engineering and Permitting (Federal, State & Local)	30%				$	361,050
Construction Contingency	35%				$	421,225
Total Project Cost					**$**	**1,985,775**

Table 2 – Probable Cost Estimate for Lemonwood

The existing open drainage channel serves as a collection system for the Lemonwood watershed. Unfortunately, its capacity to convey stormwater is limited. The proposed storm drain system would increase overall system capacity by adding catch inlets throughout the alignment. The inlets would outfall into a pipe network that would start off as a single 24 inch diameter pipe at the alleyway and then increase in size to twin 48 inch diameter pipes at the TxDOT outfall just north of Interstate 410.

3.4 Travertine

The Travertine watershed is a combination of open channel and enclosed storm drain system. The alignment of the watercourse follows a narrow corridor starting off in Twinleaf Lane and runs between houses through Trillium Lane, discharges onto Bluet Lane, and then concentrates into a concrete flume structure that runs parallel to Shalimar Drive and discharges into a culvert system at Jackson Keller Road. There is insufficient horizontal space to construct a drainage channel to convey the runoff through the watershed. The presence of homes, buildings, and streets leaves very little room to do more than what exists currently. The only option available is to add an enclosed storm drain system throughout the watershed in order to increase the system's capacity to convey stormwater. Given the limited space between homes between TwinLeaf and Bluet, there will need to be as many as four homes removed in order to accommodate the necessary space required to construct and place the proposed system. A graphical representation of the proposed improvements can be found on Exhibit D-4.

Engineers Opinion of Probable Construction Cost Travertine Improvements						
Description	Quantity	Unit		Unit Price		Amount
Misc. Demolition	1	LS	$	50,000	$	50,000
36-in RC Pipe	3300	LF	$	150	$	495,000
48-in RC Pipe	880	LF	$	250	$	220,000
54-in RC Pipe	1730	LF	$	300	$	519,000
Inlet	14	EA	$	5,000	$	70,000
Manhole	10	EA	$	8,000	$	80,000
Street Repair	5850	LF	$	250	$	1,462,500
Planting & Revegetation	1	LS	$	5,000	$	5,000
Misc. Erosion & Sedimentation Controls	1	LS	$	10,000	$	10,000
Subtotal					$	2,911,500
Engineering and Permitting (Federal, State & Lc	30%				$	873,450
Construction Contingency	35%				$	1,019,025
House Buyout (including closing costs, etc.)	4	EA	$	300,000	$	1,200,000
Total Project Cost					**$**	**6,003,975**

Table 3 – Cost Estimate for Travertine

The capacity of the system within Jackson Keller to receive the runoff within the Travertine watershed is not known. Should this project be considered, additional analysis for the storm drain system within Jackson Keller will be needed. The above-described estimate does not include downstream improvements should a future analysis conclude that improvements are needed. The proposed storm drain system would increase overall system capacity by adding catch inlets throughout the alignment. The inlets would outfall into a pipe network that would start off as a 36-inch diameter pipe and then increase in size to a 54-inch diameter pipe at the outfall in Jackson Keller Road.

3.5 Atwater

The existing open drainage channel does serve as a collection system for the Atwater watershed. Unfortunately, its capacity to convey stormwater is limited. The proposed storm drain system would increase overall system capacity by adding a catch inlet at the beginning of the system near Antler drive and convey runoff in a single 48-inch diameter pipe to Jackson Keller Road.

Engineers Opinion of Probable Construction Cost
Atwater Improvements

Description	Quantity	Unit		Unit Price		Amount
Misc. Demolition	1	LS	$	250,000	$	250,000
48-in RC Pipe	750	LF	$	250	$	187,500
60-in RC Pipe	750	LF	$	325	$	243,750
Inlet	2	EA	$	5,000	$	10,000
Manhole	2	EA	$	8,000	$	16,000
Misc. Erosion & Sedimentation Controls	1	LS	$	5,000	$	5,000
Planting & Revegetation	1	LS	$	25,000	$	25,000
Subtotal					$	737,250
Engineering and Permitting (Federal, State & Local)	30%				$	221,175
Construction Contingency	35%				$	258,038
Total Project Cost					**$**	**1,216,463**

Table 4 – Cost Estimate for Atwater

The capacity of the system within Jackson Keller to receive the runoff within the Atwater watershed is not known. Should this project be considered, additional analysis for the storm drain system within Jackson Keller will be needed. The above-described estimate does not include downstream improvements should a future analysis conclude that improvements are needed. The proposed storm drain system would increase overall system capacity by adding a catch inlet at Antler Drive and possibly along the proposed stormsewer alignment. The stormsewer would start off as a 48-inch diameter pipe and then increase in size to a 60-inch diameter pipe at the outfall in Jackson Keller Road.

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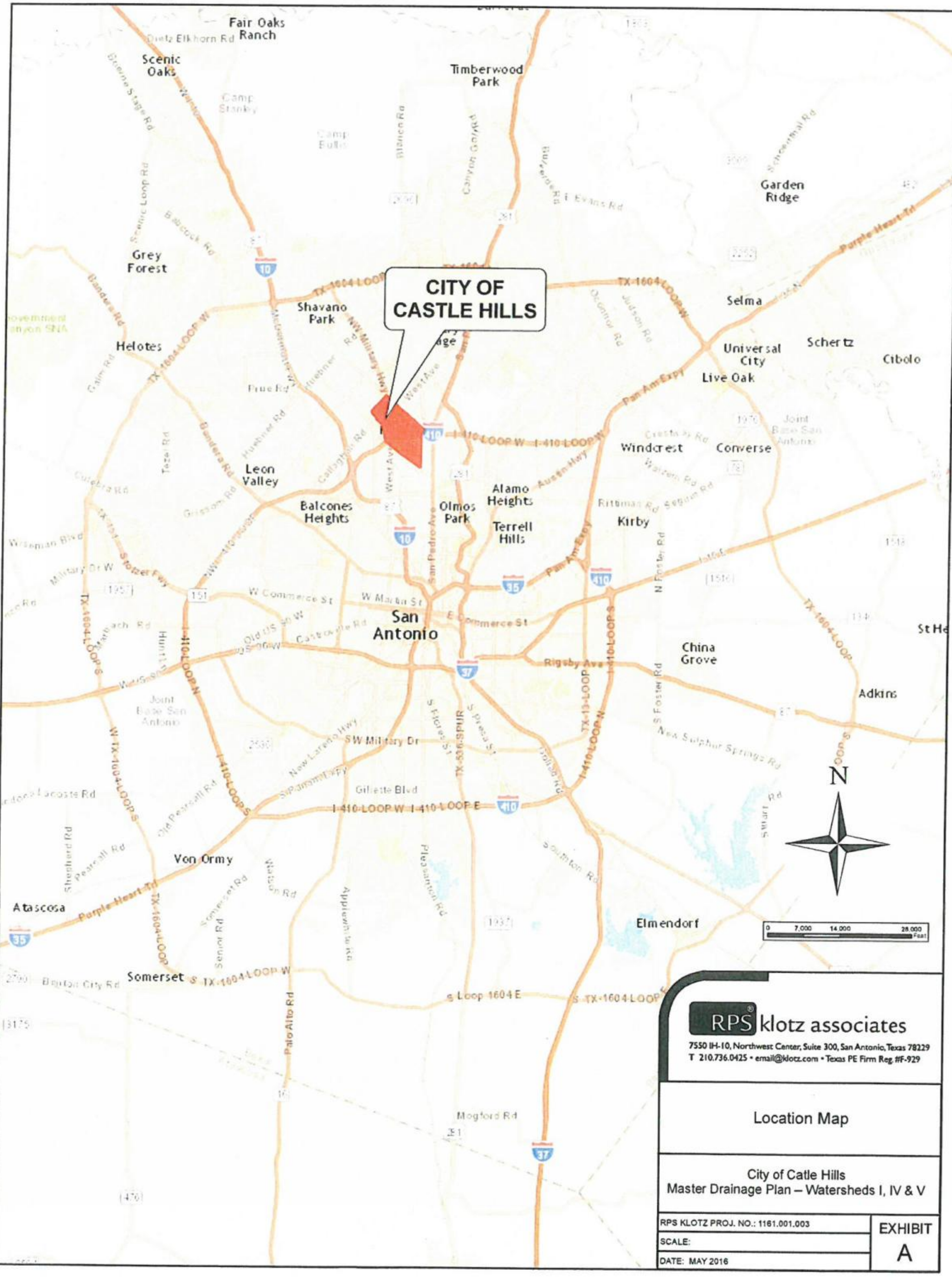
Exhibit A Location Map



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Location Map

City of Catle Hills
Master Drainage Plan – Watersheds I, IV & V

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DATE: MAY 2016	

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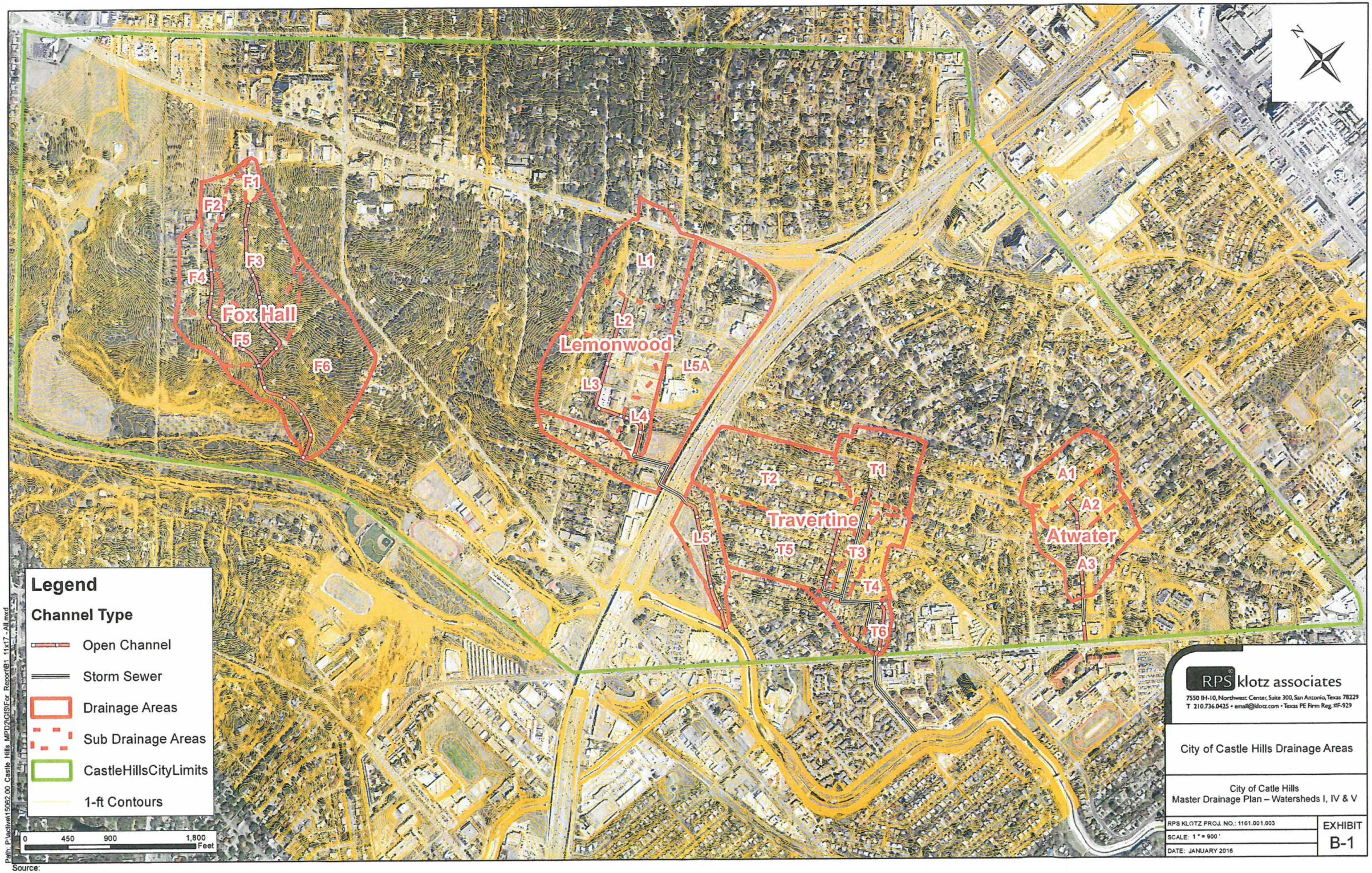
Exhibit B Drainage Area Maps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Fox Hall
F1
F2
F3
F4
F5
F6
Lemonwood
L1
L2
L3
L4
L5
L5A
Travertine
T1
T2
T3
T4
T5
T6
Atwater
A1
A2
A3
Legend
Channel Type
Open Channel
Storm Sewer
Drainage Areas
Sub Drainage Areas
CastleHillsCityLimits
1-ft Contours
0 450 900 1,800 Feet
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City of Castle Hills Drainage Areas
City of Catle Hills
Master Drainage Plan – Watersheds I, IV & V
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Source:

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Source:

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Source:

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A1
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A2
7.79
Atwater
13.33
A3
Legend
Channel Type
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Storm Sewer
Drainage Areas
Sub Drainage Areas
CastleHillsCityLimits
1-ft Contours
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B-4
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Source:

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Exhibit C Hydraulic and Hydrologic Computations

DRAINAGE AREA CALCULATIONS

Drainage Area	Area (Acres)	Cumulative Area (Acres)	C	ΣCA	Length (Feet)	Velocity (fps)	T_c	I, Intensity						Q, Runoff					
								2-year	5-year	10-year	25-year	50-year	100-year	2-year	5-year	10-year	25-year	50-year	100-year
							(min)	(in/hr)	(in/hr)	(in/hr)	(in/hr)	(in/hr)	(in/hr)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
F1	1.53	1.53	0.80	1.22		3.51	19.85	4.10	4.84	5.56	6.36	7.31	8.45	5.02	5.92	6.81	7.78	8.95	10.34
F3	20.94	22.47	0.80	17.98	1,289	2.99	27.04	3.45	4.02	4.51	5.28	5.96	6.58	62.07	72.21	81.14	94.99	107.05	118.21
F2	3.76	3.76	0.77	2.90		2.17	26.57	3.52	4.10	4.62	5.39	6.09	6.76	10.19	11.86	13.36	15.61	17.63	19.56
F4	7.43	11.19	0.77	8.62	744	2.11	32.44	3.14	3.65	4.07	4.81	5.41	5.91	27.07	31.45	35.10	41.48	46.59	50.93
F5	14.16	47.82	0.80	38.26	772	3.07	36.63	2.91	3.39	3.79	4.49	5.07	5.58	111.17	129.69	144.88	171.77	194.11	213.51
F6	33.61	81.43	0.80	65.14	1,236	3.20	43.07	2.58	3.03	3.39	4.04	4.61	5.12	168.20	197.52	220.97	263.38	300.25	333.34
L1	17.46	17.46	0.77	13.44		2.51	19.13	4.10	4.84	5.56	6.36	7.31	8.45	55.11	65.02	74.78	85.46	98.33	113.59
L2	12.87	30.33	0.77	23.35	495	2.46	22.49	3.82	4.48	5.10	5.89	6.71	7.61	89.12	104.53	119.06	137.46	156.78	177.72
L3	21.55	51.88	0.77	39.95	1,000	4.92	25.88	3.59	4.18	4.73	5.50	6.23	6.95	143.25	167.14	188.75	219.83	248.83	277.52
L4	5.87	57.75	0.77	44.47	607	3.12	29.11	3.34	3.87	4.33	5.09	5.71	6.25	148.30	172.00	192.37	226.30	253.95	277.92
L5A	45.02	102.77	0.77	79.13	423	3.12	31.37	3.21	3.72	4.16	4.91	5.50	6.00	253.94	294.61	328.80	388.15	435.31	475.03
L5	10.12	112.89	0.80	90.31	1,524	3.19	39.33	2.76	3.22	3.60	4.28	4.86	5.37	248.81	291.17	325.48	386.81	438.83	484.70
T1	14.14	14.14	0.77	10.89		2.81	6.48	6.68	7.84	8.83	10.33	11.65	12.88	72.77	85.32	96.14	112.48	126.82	140.20
T2	26.06	26.06	0.77	20.07		2.52	17.00	4.33	5.13	5.94	6.74	7.81	9.15	86.85	102.92	119.23	135.27	156.64	183.55
T5	21.29	21.29	0.77	16.39	668	2.52	14.34	4.73	5.64	6.56	7.40	8.61	10.19	77.56	92.47	107.51	121.29	141.11	167.08
T3	6.02	67.51	0.80	54.01	1,099	3.45	22.32	3.82	4.48	5.10	5.89	6.71	7.61	206.09	241.74	275.33	317.89	362.56	411.00
T4	10.48	77.99	0.84	65.51	398	4.70	23.73	3.73	4.37	4.97	5.75	6.54	7.37	244.62	286.42	325.27	376.63	428.51	483.02
T6	3.03	81.02	0.77	62.39	602	6.36	25.31	3.59	4.18	4.73	5.50	6.23	6.95	223.71	261.02	294.77	343.31	388.60	433.39
A1	9.84	9.84	0.77	7.58		3.51	5.52	7.20	8.40	9.41	11.10	12.43	13.54	54.55	63.65	71.32	84.10	94.19	102.61
A2	7.79	17.63	0.80	14.10	389	3.51	7.37	6.28	7.38	8.37	9.72	11.03	12.34	88.53	104.10	117.98	137.12	155.50	174.06
A3	13.33	30.96	0.80	24.77	665	4.56	9.80	5.67	6.70	7.66	8.81	10.08	11.51	140.34	165.85	189.67	218.11	249.64	285.18

FOX HALL

Time of Concentration Calculations

TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			F1	F2	F3	F4	F5	F6
Sheet Flow	variable	units						
Manning's roughness coef.	n	n/a	0.15	0.15	0.15	0.15	0.15	0.15
Flow Length	L	feet	300	300	99	119	184	276
2-year, 24-hour rainfall	P2	inches	4.44	4.44	4.44	4.44	4.44	4.44
Slope	s	ft/ft	0.023	0.023	0.045	0.017	0.019	0.029
Travel time	Tt	hours	0.316	0.316	0.099	0.170	0.230	0.269
Shallow Concentrated Flow		min.	18.9	18.9	6.0	10.2	13.8	16.2
Flow Length	L	feet	191	995	69	120	304	994
Slope	s	ft/ft	0.047	0.018	0.034	0.017	0.036	0.039
Surface (1=paved or 2=unpaved)		n/a	2	2	2	2	2	2
Velocity	V	ft/sec	3.51	2.17	2.99	2.11	3.07	3.20
Travel time	Tt	hours	0.015	0.127	0.006	0.016	0.027	0.086
Manning's Equation		min.	0.9	7.6	0.4	0.9	1.6	5.2
Flow Type (n/a, open, box, circular)			n/a	n/a	open	open	open	open
Flow Length	L	feet			1443	866	765	1193
Slope	S	ft/ft			0.034	0.028	0.035	0.037
roughness	n	n/a			0.050	0.050	0.050	0.050
Open Channel								
Bottom Width	BW	feet			2	2	2	2
Side Slopes (H:1)	H	feet			4	4	4	4
Depth	d	feet			2	2	2	2
...or Closed Conduit								
Rise (box) or Diameter (circular)	R or D	feet						
Span (0 if circular)	S	feet						
Cross-Sectional Area	X-A	feet^2	n/a	n/a	20.00	20.00	20.00	20.00
Flow Rate	Q	cfs	n/a	n/a	115.79	105.08	117.48	120.79
Velocity	V	ft/sec	0.00	0.00	5.79	5.25	5.87	6.04
Travel time	Tt	hours	-	-	0.069	0.046	0.036	0.055
Total Travel Time	TC	hours	0.331	0.443	0.175	0.232	0.294	0.410
	TC	min.	19.8	26.6	10.5	13.9	17.6	24.6

LEMMONWOOD

Time of Concentration Calculations

TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			L1	L2	L3	L4	L5
Sheet Flow	variable	units					
Manning's roughness coef.	n	n/a	0.09	0.15	0.15	0.15	0.15
Flow Length	L	feet	219	276	143	252	29
2-year, 24-hour rainfall	P2	inches	4.44	4.44	4.44	4.44	4.44
Slope	s	ft/ft	0.009	0.024	0.024	0.028	0.016
Travel time	Tt	hours	0.237	0.290	0.172	0.254	0.056
Shallow Concentrated Flow		min.	14.2	17.4	10.3	15.2	3.4
Flow Length	L	feet	42	426	88	589	1,228
Slope	s	ft/ft	0.024	0.023	0.057	0.023	0.024
Surface (1=paved or 2=unpaved)		n/a	2	2	1	1	1
Velocity	V	ft/sec	2.51	2.46	4.92	3.12	3.19
Travel time	Tt	hours	0.005	0.048	0.005	0.052	0.107
Manning's Equation		min.	0.3	2.9	0.3	3.1	6.4
Flow Type (n/a, open, box, circular)			open	circular	open	open	open
Flow Length	L	feet	1085	281	1498	534	246
Slope	S	ft/ft	0.010	0.011	0.018	0.013	0.098
roughness	n	n/a	0.040	0.013	0.050	0.050	0.050
Open Channel							
Bottom Width	BW	feet	2		2	2	2
Side Slopes (H:1)	H	feet	4		4	4	4
Depth	d	feet	2		2	2	2
...or Closed Conduit							
Rise (box) or Diameter (circular)	R or D	feet		2			
Span (0 if circular)	S	feet					
Cross-Sectional Area	X-A	feet^2	20.00	3.14	20.00	20.00	20.00
Flow Rate	Q	cfs	78.50	23.79	84.25	71.60	196.59
Velocity	V	ft/sec	3.92	7.57	4.21	3.58	9.83
Travel time	Tt	hours	0.077	0.010	0.099	0.041	0.007
Total Travel Time	TC	hours	0.319	0.349	0.275	0.348	0.170
	TC	min.	19.1	20.9	16.5	20.9	10.2

TRAVERTINE

Time of Concentration Calculations

TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			T1	T2	T3	T4	T5	T6
Sheet Flow	variable	units						
Manning's roughness coef.	n	n/a	0.011	0.011	0.011	0.011	0.011	0.15
Flow Length	L	feet	143	150	57	150	90	21
2-year, 24-hour rainfall	P2	inches	4.44	4.44	4.44	4.44	4.44	5.44
Slope	s	ft/ft	0.024	0.007	0.009	0.057	0.010	0.024
Travel time	Tt	hours	0.021	0.036	0.015	0.016	0.021	0.033
Shallow Concentrated Flow		min.	1.3	2.2	0.9	0.9	1.2	2.0
Flow Length	L	feet	811	2,246	430	756	1,982	596
Slope	s	ft/ft	0.030	0.015	0.028	0.052	0.015	0.007
Surface (1=paved or 2=unpaved)		n/a	2	1	1	1	1	1
Velocity	V	ft/sec	2.81	2.52	3.45	4.70	2.52	1.72
Travel time	Tt	hours	0.080	0.247	0.035	0.045	0.218	0.096
Manning's Equation		min.	4.8	14.8	2.1	2.7	13.1	5.8
Flow Type (n/a, open, box, circular)			open	n/a	open	n/a	n/a	open
Flow Length	L	feet	171		1081			123
Slope	S	ft/ft	0.035		0.032			0.041
roughness	n	n/a	0.040		0.050			0.050
Open Channel								
Bottom Width	BW	feet	2		2			2
Side Slopes (H:1)	H	feet	4		4			4
Depth	d	feet	2		2			2
...or Closed Conduit								
Rise (box) or Diameter (circular)	R or D	feet						
Span (0 if circular)	S	feet						
Cross-Sectional Area	X-A	feet^2	20.00	n/a	20.00	n/a	n/a	20.00
Flow Rate	Q	cfs	146.85	n/a	112.33	n/a	n/a	127.15
Velocity	V	ft/sec	7.34	0.00	5.62	0.00	0.00	6.36
Travel time	Tt	hours	0.006	-	0.053	-	-	0.005
Total Travel Time	TC	hours	0.108	0.283	0.103	0.083	0.239	0.135
	TC	min.	6.5	17.0	6.2	5.0	14.3	8.1

ATWATER

Time of Concentration Calculations

TR-55 Method of Computing the Time of Concentration EXISTING CONDITIONS			A1	A2	A3
Sheet Flow	variable	units			
Manning's roughness coef.	n	n/a	0.011	0.011	0.011
Flow Length	L	feet	150	150	150
2-year, 24-hour rainfall	P2	inches	4.44	4.44	4.44
Slope	s	ft/ft	0.026	0.036	0.064
Travel time	Tt	hours	0.021	0.019	0.015
Shallow Concentrated Flow		min.	1.3	1.1	0.9
Flow Length	L	feet	893	379	428
Slope	s	ft/ft	0.029	0.029	0.049
Surface (1=paved or 2=unpaved)		n/a	1	1	1
Velocity	V	ft/sec	3.51	3.51	4.56
Travel time	Tt	hours	0.071	0.030	0.026
Manning's Equation		min.	4.2	1.8	1.6
Flow Type (n/a, open, box, circular)			n/a	open	open
Flow Length	L	feet		813	443
Slope	S	ft/ft		0.036	0.014
roughness	n	n/a		0.050	0.050
Open Channel					
Bottom Width	BW	feet		2	2
Side Slopes (H:1)	H	feet		4	4
Depth	d	feet		2	2
...or Closed Conduit					
Rise (box) or Diameter (circular)	R or D	feet			
Span (0 if circular)	S	feet			
Cross-Sectional Area	X-A	feet^2	n/a	20.00	20.00
Flow Rate	Q	cfs	n/a	119.15	74.30
Velocity	V	ft/sec	0.00	5.96	3.72
Travel time	Tt	hours	-	0.038	0.033
Total Travel Time	TC	hours	0.092	0.087	0.083
	TC	min.	5.5	5.2	5.0

PROPOSED FOX HALL DRAINAGE IMPROVEMENTS

FOX HALL LANE Drainage Channel		HIBISCUS LANE Drainage Channel	
Area	F3	Area	F5
100-Year Flow	118.21	100-Year Flow	213.51
TRAPEZOIDAL CHANNEL		TRAPEZOIDAL CHANNEL	
MANNING'S EQUATION		MANNING'S EQUATION	
SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW	
$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$	
Depth of Channel (ft)	**2.5**	Depth of Channel (ft)	**3**
Side Slope (H:V)	**4**	Side Slope (H:V)	**4**
Base (ft)	**3**	Base (ft)	**3**
Slope, S (%)	**2.00%**	Slope, S (%)	**2.00%**
Manning's Number, n	**0.05**	Manning's Number, n	**0.05**
FLOW, Q (cfs)	169.5	FLOW, Q (cfs)	261.8
VELOCITY, V (ft/sec)	5.21	VELOCITY, V (ft/sec)	5.82
AREA, A (ft^2)	32.50	AREA, A (ft^2)	45.00
HYDRAULIC RADIUS, R (ft)	1.376	HYDRAULIC RADIUS, R (ft)	1.622
TOP WIDTH (ft)	23	TOP WIDTH (ft)	27

Culvert Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. | Thursday, May 19 2016

Fox Hall Lane

Invert Elev Dn (ft)	= 842.00
Pipe Length (ft)	= 30.00
Slope (%)	= 1.00
Invert Elev Up (ft)	= 842.30
Rise (in)	= 36.0
Shape	= Circular
Span (in)	= 36.0
No. Barrels	= 2
n-Value	= 0.012
Culvert Type	= Circular Concrete
Culvert Entrance	= Square edge w/headwall (C)
Coeff. K,M,c,Y,k	= 0.0098, 2, 0.0398, 0.67, 0.5

Embankment

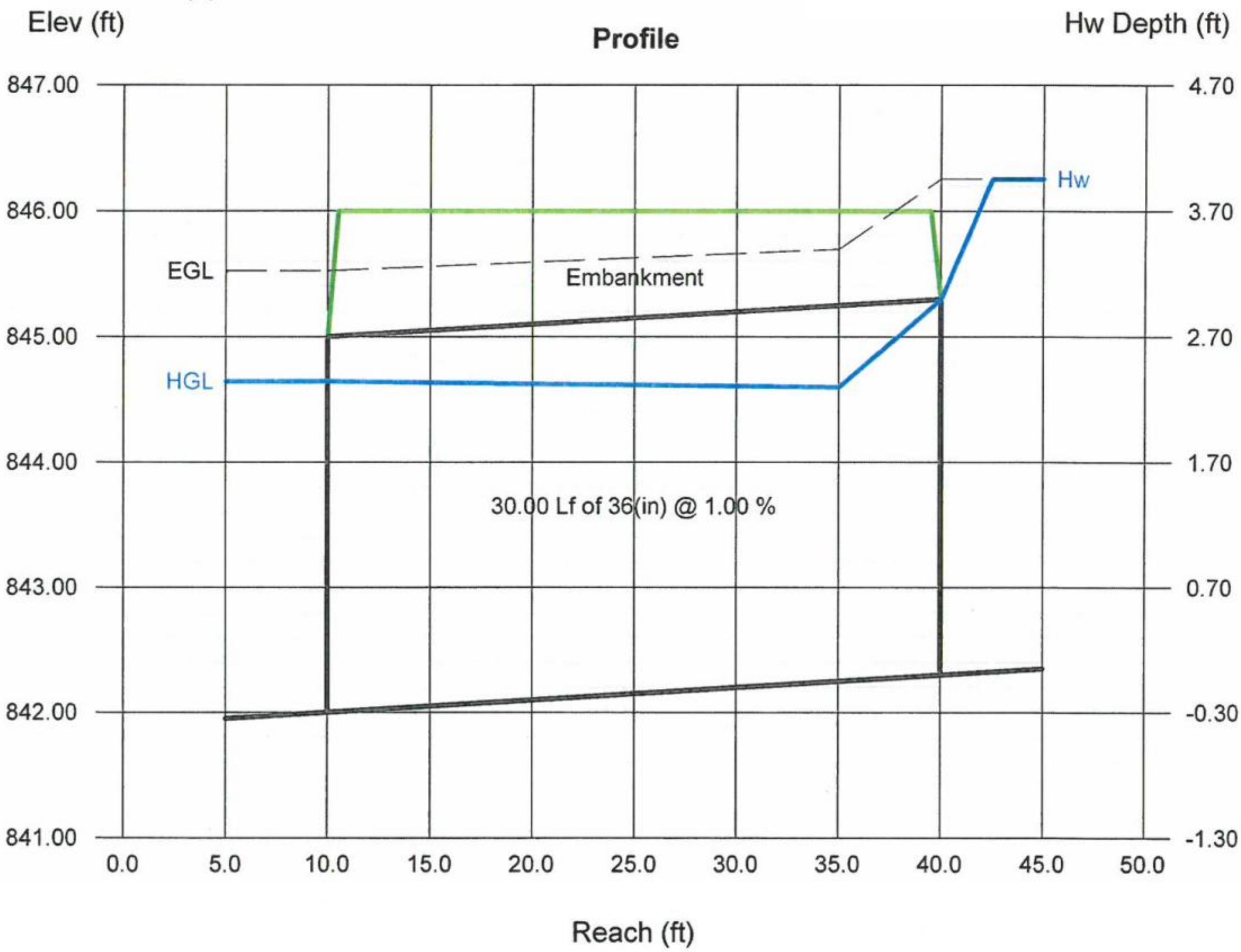
Top Elevation (ft)	= 846.00
Top Width (ft)	= 29.00
Crest Width (ft)	= 50.00

Calculations

Qmin (cfs)	= 0.00
Qmax (cfs)	= 120.00
Tailwater Elev (ft)	= (dc+D)/2

Highlighted

Qtotal (cfs)	= 120.00
Qpipe (cfs)	= 99.20
Qovertop (cfs)	= 20.80
Veloc Dn (ft/s)	= 7.52
Veloc Up (ft/s)	= 8.56
HGL Dn (ft)	= 844.65
HGL Up (ft)	= 844.59
Hw Elev (ft)	= 846.25
Hw/D (ft)	= 1.32
Flow Regime	= Inlet Control



Culvert Report

Hydraflow Express Extension for Autodesk® AutoCAD® Civil 3D® by Autodesk, Inc. Thursday, May 19 2016

Hibiscus Lane

Invert Elev Dn (ft)	= 827.00
Pipe Length (ft)	= 30.00
Slope (%)	= 1.00
Invert Elev Up (ft)	= 827.30
Rise (in)	= 36.0
Shape	= Circular
Span (in)	= 36.0
No. Barrels	= 3
n-Value	= 0.012
Culvert Type	= Circular Concrete
Culvert Entrance	= Square edge w/headwall (C)
Coeff. K,M,c,Y,k	= 0.0098, 2, 0.0398, 0.67, 0.5

Embankment

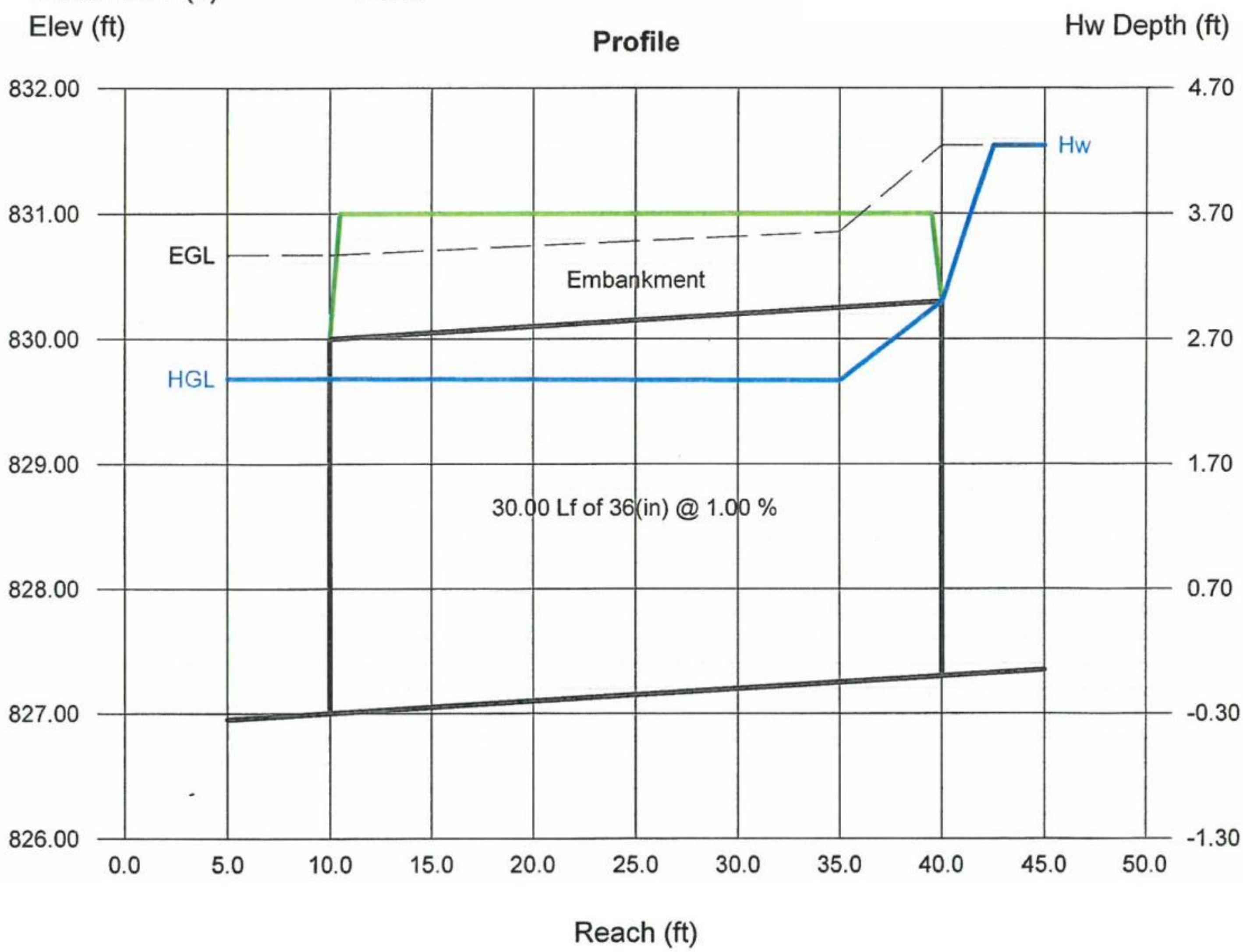
Top Elevation (ft)	= 831.00
Top Width (ft)	= 29.00
Crest Width (ft)	= 50.00

Calculations

Qmin (cfs)	= 0.00
Qmax (cfs)	= 220.00
Tailwater Elev (ft)	= (dc+D)/2

Highlighted

Qtotal (cfs)	= 220.00
Qpipe (cfs)	= 159.39
Qovertop (cfs)	= 60.61
Veloc Dn (ft/s)	= 7.96
Veloc Up (ft/s)	= 8.88
HGL Dn (ft)	= 829.68
HGL Up (ft)	= 829.67
Hw Elev (ft)	= 831.54
Hw/D (ft)	= 1.41
Flow Regime	= Inlet Control



PROPOSED LEMMONWOOD STORM DRAIN SYSTEM

ROLETO DRIVE Storm Drain		PERSIMMON DRIVE Storm Drain		LEMONWOOD DRIVE Storm Drain		INTERSTATE 410 OUTFALL Storm Drain	
Area	L1	Area	L2	Area	L2	Area	L4
25-Year Flow	85.46	100-Year Flow	177.72	100-Year Flow	277.52	100-Year Flow	277.92
CIRCULAR PIPE		CIRCULAR PIPE		CIRCULAR PIPE		CIRCULAR PIPE	
MANNING'S EQUATION		MANNING'S EQUATION		MANNING'S EQUATION		MANNING'S EQUATION	
SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW	
$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$	
Slope (%)	2.000	Slope (%)	2.000	Slope (%)	2.000	Slope (%)	2.000
Manning's Number, n	0.013	Manning's Number, n	0.013	Manning's Number, n	0.013	Manning's Number, n	0.013
Pipe Diameter (in)	36	Pipe Diameter (in)	48	Pipe Diameter (in)	48	Pipe Diameter (in)	48
FLOW, Q (cfs)	**94.58**	**FLOW, Q (cfs)**	**203.69**	**FLOW, Q (cfs)**	**203.69**	**FLOW, Q (cfs)**	**203.69**
VELOCITY, V (ft/sec)	**13.38**	**VELOCITY, V (ft/sec)**	**16.21**	**VELOCITY, V (ft/sec)**	**16.21**	**VELOCITY, V (ft/sec)**	**16.21**
AREA, A (ft^2)	**7.07**	**AREA, A (ft^2)**	**12.57**	**AREA, A (ft^2)**	**12.57**	**AREA, A (ft^2)**	**12.57**
HYDRAULIC RADIUS, R (ft)	**0.75**	**HYDRAULIC RADIUS, R (ft)**	**1.00**	**HYDRAULIC RADIUS, R (ft)**	**1.00**	**HYDRAULIC RADIUS, R (ft)**	**1.00**
		TRAPEZOIDAL CHANNEL		TRAPEZOIDAL CHANNEL		TRAPEZOIDAL CHANNEL	
		MANNING'S EQUATION		MANNING'S EQUATION		MANNING'S EQUATION	
		SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW	
		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$	
		Depth of Channel (ft)	1	Depth of Channel (ft)	2	Depth of Channel (ft)	2
		Side Slope (H:V)	2	Side Slope (H:V)	4	Side Slope (H:V)	4
		Base (ft)	1	Base (ft)	3	Base (ft)	3
		Slope, S (%)	2.00%	Slope, S (%)	2.00%	Slope, S (%)	2.00%
		Manning's Number, n	0.015	Manning's Number, n	0.05	Manning's Number, n	0.05
		FLOW, Q (cfs)	28.2	**FLOW, Q (cfs)**	100.5	**FLOW, Q (cfs)**	100.5
		VELOCITY, V (ft/sec)	9.41	**VELOCITY, V (ft/sec)**	4.57	**VELOCITY, V (ft/sec)**	4.57
		AREA, A (ft^2)	3.00	**AREA, A (ft^2)**	22.00	**AREA, A (ft^2)**	22.00
		HYDRAULIC RADIUS, R (ft)	0.548	**HYDRAULIC RADIUS, R (ft)**	1.129	**HYDRAULIC RADIUS, R (ft)**	1.129
		TOP WIDTH (ft)	5	**TOP WIDTH (ft)**	19	**TOP WIDTH (ft)**	19
TOTAL FLOW	**94.58**	**TOTAL FLOW**	**231.92**	**TOTAL FLOW**	**304.20**	**TOTAL FLOW**	**304.20**

PROPOSED TRAVERTINE STORM DRAIN SYSTEM

TOWNE VUE DRIVE and TWINLEAF LANE Storm Drain		TRILLIUM LANE BLUET LANE Storm Drain		TRAVERTINE LANE BLUET LANE Storm Drain		SHALIMAR DRIVE Storm Drain	
Area	T2	Area	T5	Cumulative Area at	T3	Cumulative Area at	T6
25-Year Flow	135.27	25-Year Flow	121.29	100-Year Flow	317.89	100-Year Flow	343.31
Half Flow for Each Street	67.63	Half Flow for Each Street	60.65				
CIRCULAR PIPE		CIRCULAR PIPE		CIRCULAR PIPE		CIRCULAR PIPE	
MANNING'S EQUATION		MANNING'S EQUATION		MANNING'S EQUATION		MANNING'S EQUATION	
SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW	
$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$	
Slope (%)	1.000	Slope (%)	1.000	Slope (%)	0.700	Slope (%)	0.800
Manning's Number, n	0.013	Manning's Number, n	0.013	Manning's Number, n	0.013	Manning's Number, n	0.013
Pipe Diameter (in)	36	Pipe Diameter (in)	36	Pipe Diameter (in)	54	Pipe Diameter (in)	54
FLOW, Q (cfs)	66.88	FLOW, Q (cfs)	66.88	FLOW, Q (cfs)	164.97	FLOW, Q (cfs)	176.36
VELOCITY, V (ft/sec)	9.46	VELOCITY, V (ft/sec)	9.46	VELOCITY, V (ft/sec)	10.37	VELOCITY, V (ft/sec)	11.09
AREA, A (ft^2)	7.07	AREA, A (ft^2)	7.07	AREA, A (ft^2)	15.90	AREA, A (ft^2)	15.90
HYDRAULIC RADIUS, R (ft)	0.75	HYDRAULIC RADIUS, R (ft)	0.75	HYDRAULIC RADIUS, R (ft)	1.13	HYDRAULIC RADIUS, R (ft)	1.13
				NUMBER OF PIPES	2	NUMBER OF PIPES	2
TOTAL FLOW	66.88	TOTAL FLOW	66.88	TOTAL FLOW	329.94	TOTAL FLOW	352.72

PROPOSED ATWATER STORM DRAIN SYSTEM

ATWATER DRIVE Storm Drain		JACKSON KELLER Storm Drain	
Cumulative Area at	A2	Cumulative Area at	A3
25-Year Flow	137.12	25-Year Flow	218.11
CIRCULAR PIPE		CIRCULAR PIPE	
MANNING'S EQUATION		MANNING'S EQUATION	
SOLVE FOR MAXIMUM FLOW		SOLVE FOR MAXIMUM FLOW	
$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$		$Q=(1.49/n)(AR^{(2/3)})(S^{(1/2)})$	
Slope (%)	1.000	Slope (%)	1.000
Manning's Number, n	0.013	Manning's Number, n	0.013
Pipe Diameter (in)	48	Pipe Diameter (in)	60
FLOW, Q (cfs)	144.03	FLOW, Q (cfs)	261.14
VELOCITY, V (ft/sec)	11.46	VELOCITY, V (ft/sec)	13.30
AREA, A (ft^2)	12.57	AREA, A (ft^2)	19.63
HYDRAULIC RADIUS, R (ft)	1.00	HYDRAULIC RADIUS, R (ft)	1.25
TOTAL FLOW	144.03	TOTAL FLOW	261.14

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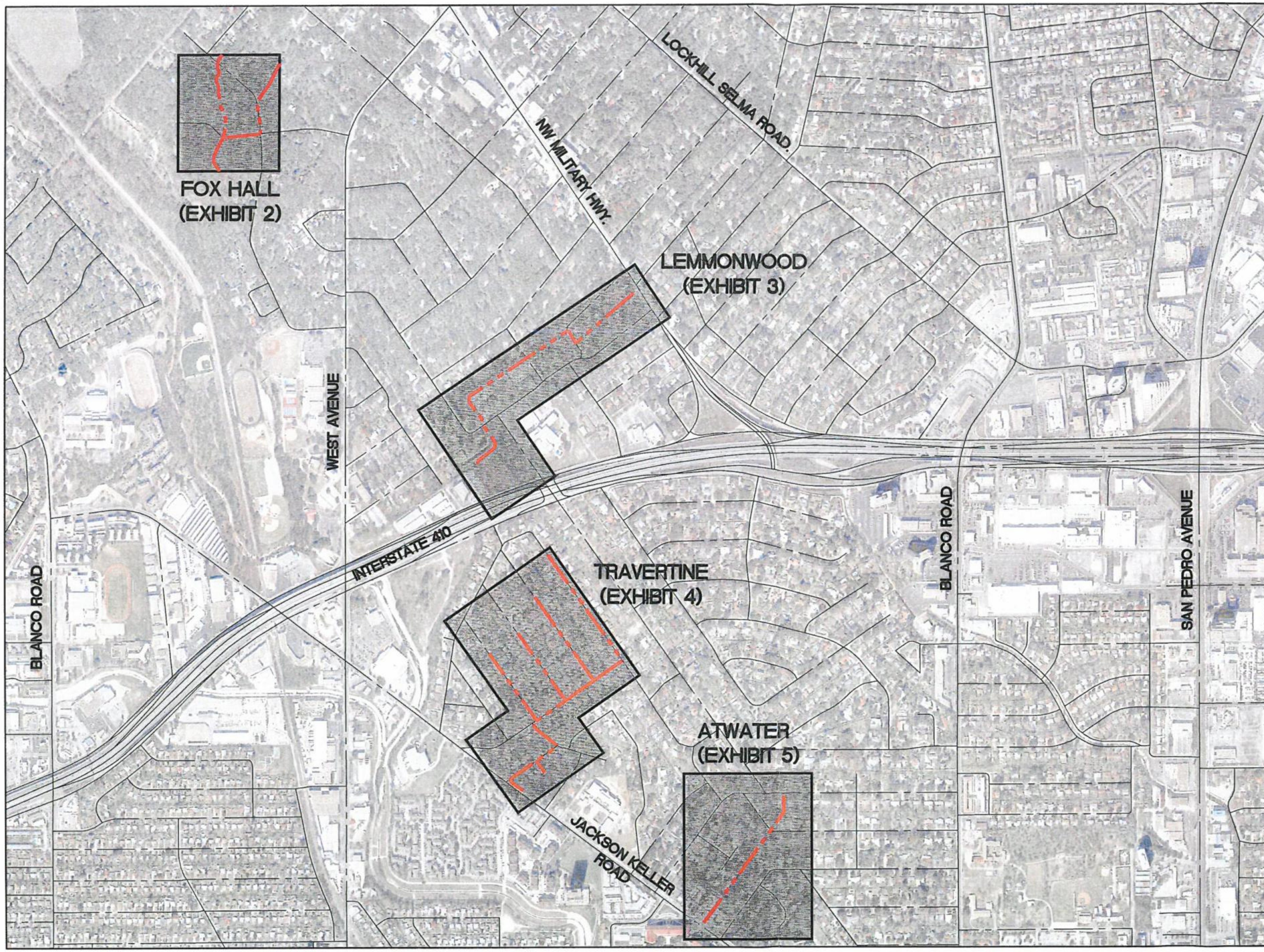
Exhibit D Proposed Drainage Improvements



N

0 500' 1000'
SCALE IN FEET

LEGEND

PROPOSED DRAINAGE IMPROVEMENTS

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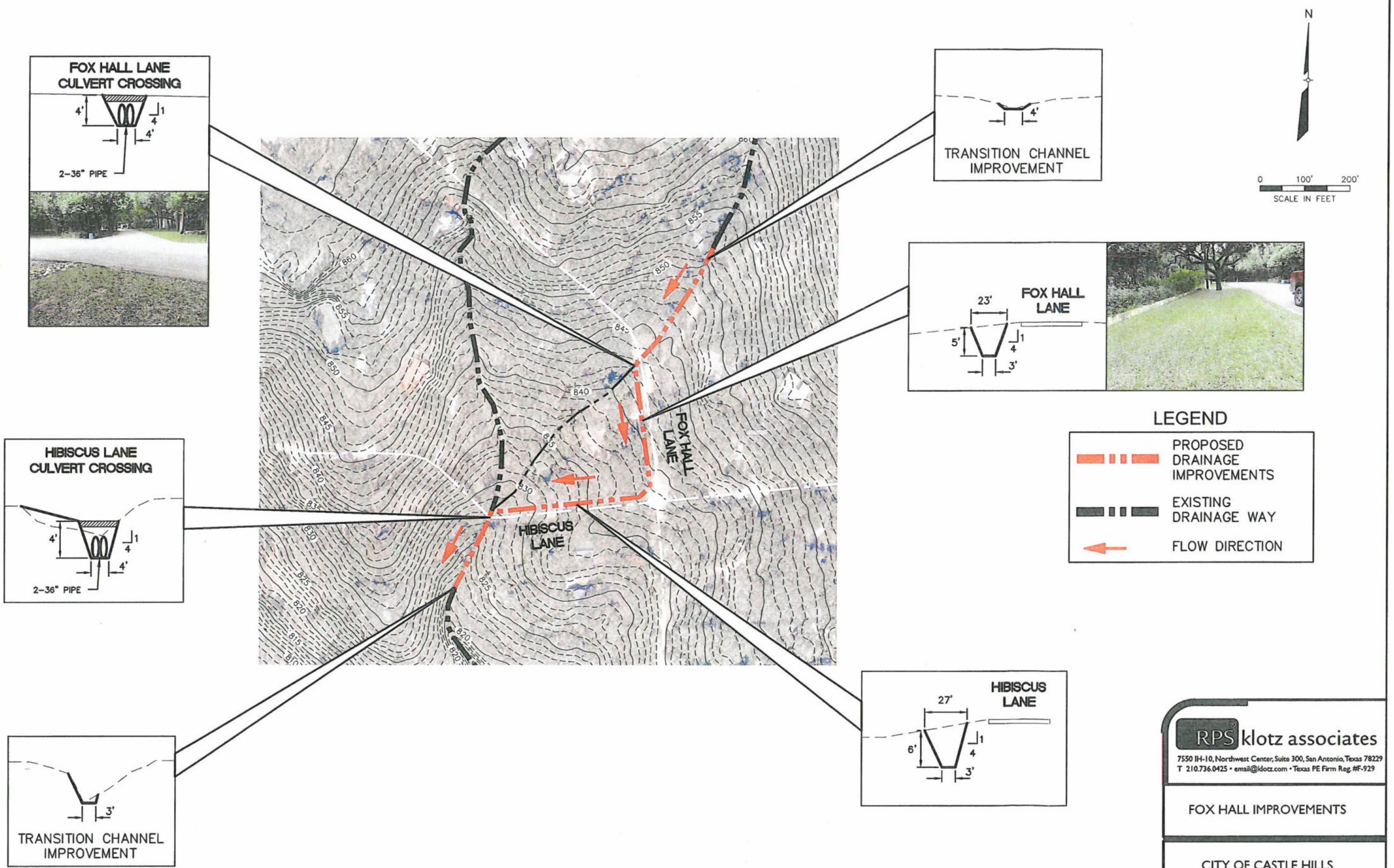
VICINITY MAP

CITY OF CASTLE HILLS

RPS Klotz Proj. No: 1161.001.003	Exhibit
Scale: N.T.S.	D1
Date: MAY 2016	

P:\active\15062.00 Castle Hills MPD2\CADD\Exh 5/20/2016 12:16 PM



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FOX HALL IMPROVEMENTS

CITY OF CASTLE HILLS

RPS Klotz Proj. No: 1161.001.003	Exhibit
Scale: N.T.S.	D2
Date: MAY 2016	

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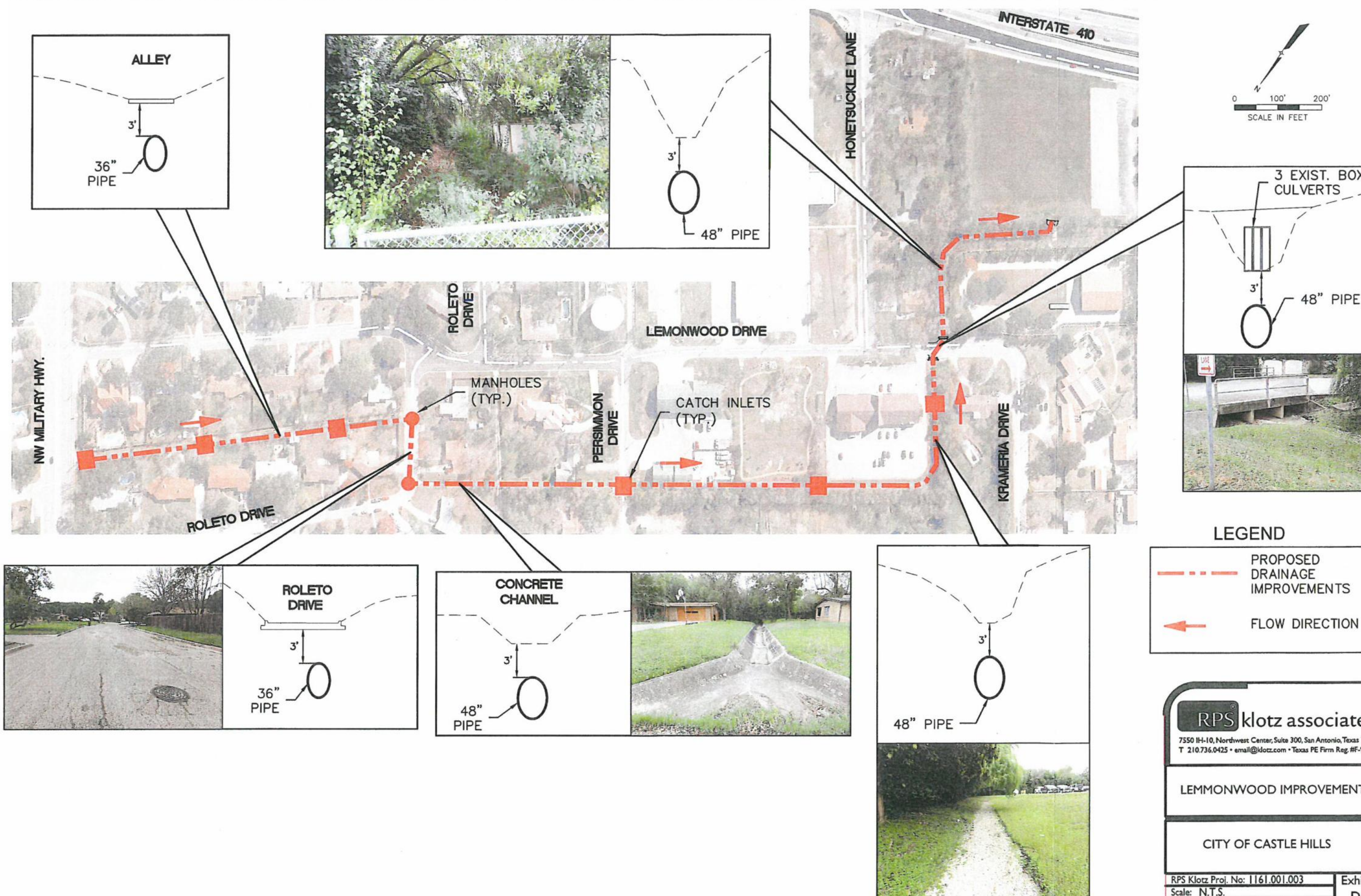

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LEMMONWOOD IMPROVEMENTS

CITY OF CASTLE HILLS

RPS Klotz Proj. No: 1161.001.003	Exhibit D3
Scale: N.T.S.	
Date: MAY 2016	

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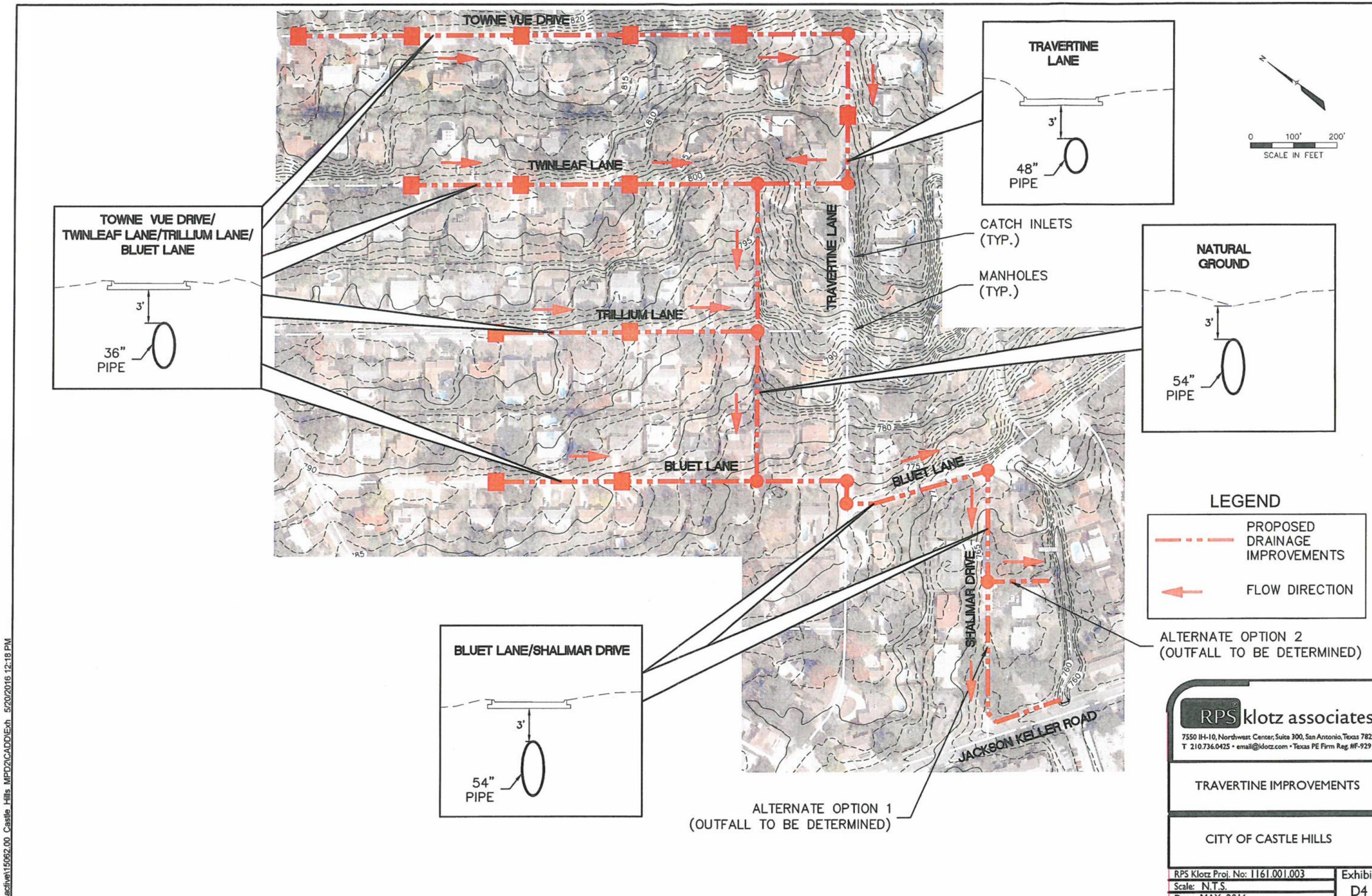

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TRAVERTINE IMPROVEMENTS

CITY OF CASTLE HILLS

RPS Klotz Proj. No: 1161.001.003	Exhibit
Scale: N.T.S.	D4
Date: MAY 2016	

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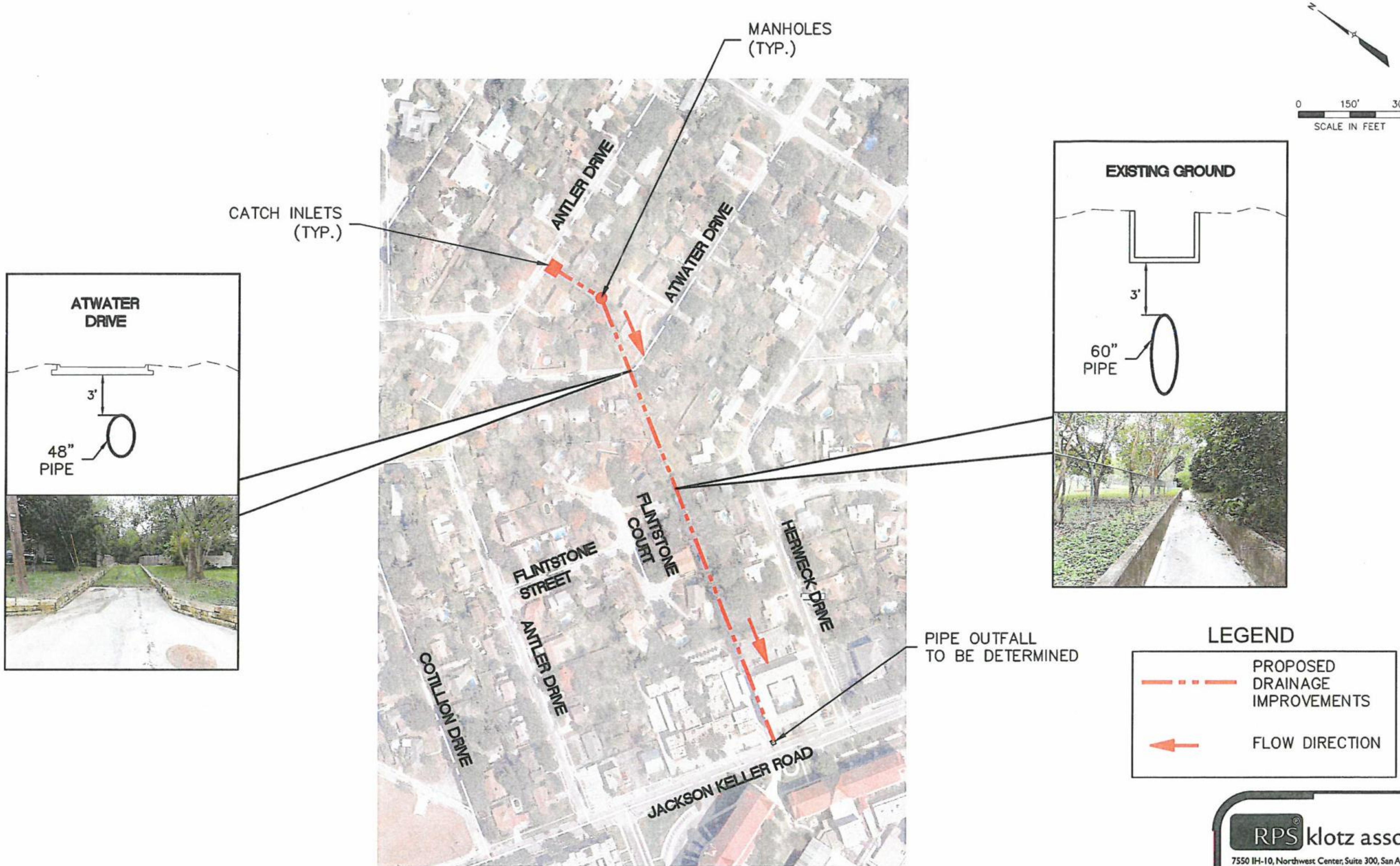

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ATWATER IMPROVEMENTS

CITY OF CASTLE HILLS

RPS Klotz Proj. No: 1161.001.003	Exhibit
Scale: N.T.S.	D5
Date: MAY 2016	

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