NOLAN CREEK WATERSHED
TEXAS WATER DEVELOPMENT BOARD
FLOOD PROTECTION PLANNING STUDY
FINAL REPORT

September 13, 2019

PO 00121

PREPARED FOR:

CTCOG
central texas council of governments

Central Texas Council of Governments
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ACRONYMS:

ACS – American Community Survey
AMC – Antecedent Moisture Condition
BellCAD – Bell County Appraisal District
BRA – Brazos River Authority
CTCOG – Central Texas Council of Governments
EMCV – Emergency Management Coordinator
FEMA – Federal Emergency Management Agency
FEWS – Flood Early Warning System
FPP – Flood Protection Planning
GIS – Geographic Information System
GLO – Texas General Land Office
HSG – Hydrologic Soil Group
IHWCA – Industrial and Hazardous Waste Correction Action
LiDAR – Light Detection and Ranging
LAS – Log Ascii Standard
LPST – Leaking Petroleum Storage Tank
NAVD 88 – North American Vertical Datum 88
NRCS – Natural Resource Conservation Service
NWI – National Wetland Inventory
NWS – National Weather Service
RMSE – Root Mean Square Error
Tc – Time of Concentration
TCEQ – Texas Commission of Environmental Quality
THC – Texas Historical Commission
Tlag – Lag Time
TNRIS – Texas Natural Resource Information System
TPWD – Texas Parks and Wildlife Department
TR-55 – NRCS Technical Release 55
TRC – Texas Railroad Commission
TWDB – Texas Water Development Board
TxDOT – Texas Department of Transportation
TXNDD – Texas Natural Diversity Database
UH – Unit Hydrograph
USCB – United States Census Bureau
USGS – United States Geological Survey
USFWS – United States Fish and Wildlife Service
WCID 6 – Bell County Water Control and Improvement District 6

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EXECUTIVE SUMMARY

The Nolan Creek watershed, located in Bell County, TX has been the source of frequent flooding and drainage issues for the Cities of Killeen, Harker Heights, Nolanville and Belton. These communities have worked together over the years and have made good progress towards identifying and resolving many flooding issues in the region; however, there was still a need to better understand the regional flooding issues and identify regional solutions that could potentially be cost-shared among the entities moving forward. As a result of these needs, the communities, with the help of the Central Texas Council of Governments (CTCOG), Brazos River Authority, and Bell County WCID #6, applied for a Flood Protection Planning Grant to aid in the development of new hydrologic and hydraulic modeling, flood damage reduction alternative analyses, and an analysis of the existing flood early warning system and flood response strategies to aid in developing a long-range plan to better manage the Nolan Creek Watershed.

Hydrologic and hydraulic modeling was performed on the Nolan Creek watershed and eight tributaries. Detailed Light Detection and Ranging (LiDAR) elevation data as well as cross-section and bridge/culvert surveys (where available) were used to enhance the accuracy of the models. The modeling resulted in updated and more accurate flows and water surface elevations for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-yr events. The resulting hydrologic and hydraulic data was then used to analyze various flood reduction alternatives for the participating communities throughout the watershed with a regional perspective in mind.

Several flood reduction alternatives were analyzed during the flood damage reduction analysis portion of the study. Each alternative was evaluated by cost and potential for producing a favorable cost-benefit ratio. Alternatives were recommended that consist of regional detention, channel improvements, and improving roadway bridge/culvert capacity. In some cases, non-structural alternatives, such as buyouts, were also recommended where costs far outweighed the flood reduction benefits. In addition to flood reduction alternatives, the existing flood early warning system was analyzed in detail and recommendations for improvement were made. Flood response strategies of the participating communities were also analyzed and recommendations provided to help enhance overall flood response strategies throughout the Nolan Creek Watershed.

1.0 INTRODUCTION AND BACKGROUND

Located in central Texas between Austin and Waco, the Nolan Creek watershed drains approximately 114 square miles from the wooded cross timbers in the western part of the watershed to the fields and pastures of the Blackland Prairie in the east. Impacts to flow regime and flooding begin with Fort Hood at the upstream end continuing through the cities of Killeen, Harker Heights, Nolanville, and, finally, Belton at the downstream end near the confluence with the Leon River (see **Figure 1**). Flooding has been an issue in the watershed since the early 1900s when flooding caused five deaths in Belton. After extensive flooding occurred throughout the basin in April 1957, the Soil Conservation Service begin the design and construction of 13 flood control structures located throughout the watershed. Even with these flood control measures in place, flooding still occurs frequently with major recent flood events involving flood damage and/or loss of life occurring in December 1997, May 2007, September 2010 (Tropical Storm Hermine), March 2012, June 2015, and April 2017. Examples of flooding in downtown Belton during the Hermine and April 2017 events are shown in **Figure 2**.

Aware of the flood risk inherent within the watershed, the local communities have developed many independent drainage modeling and master planning efforts. However, to date, no effort has been made to develop a comprehensive, basin-wide modeling and planning effort to address regional flood early warning and flood reduction efforts. Examples of the need for a comprehensive, basin-wide modeling and planning effort are as follows. The Federal Emergency Management Agency FEMA) Map Modernization effort of the early 2000s incorporated updated modeling efforts from the City of Killeen with outdated model results from the previous flood insurance study. The Cities of Killeen, Harker heights and Belton have each developed their own drainage master plans but have not fully explored the possibilities of joint regional flood reduction alternatives. The City of Belton manages a series of flood early warning stage gages on Nolan Creek on behalf of the upstream communities but has not explored ways to optimize its functions and use.

In a collaborative effort, the Cities of Killeen, Harker Heights, Nolanville and Belton along with the Bell County Water Control and Improvement District 6 (WCID 6) and Brazos River Authority (BRA) teamed with Central Texas Council of Governments (CTCOG) to develop the Nolan Watershed Flood Protection Planning (FPP) Study with a 50% matching grant from the Texas Water Development Board (TWDB). The goals of the study are as follows:

- Develop a comprehensive basin-wide hydrology model as well as a continuous hydraulic model for Nolan Creek from Ft. Hood to Belton. In addition to the mainstem of Nolan Creek, South Nolan, Little Nolan, Trimmier Road Ditch, Old Florence Ditch, Nolanville, Nolanville West, and Shaw Branch tributaries are also included for a total of 57.2 stream miles.
- Analyze the existing system of five flood early warning stage gages along Nolan Creek and develop recommendations for improving the infrastructure and more effective and useful display and dissemination of data during flood events.
- Develop recommendations for improving the collaborative flood response strategies between the communities within the Nolan watershed.

To accomplish these goals, CTCOG, contracted with Scheibe Consulting, LLC team (prime firm plus Moody Engineering, Texas A&M Agricultural Extension Service, and Walker Partners

Engineers and Surveyors). The City of Killeen staff also assisted with some of the field survey, Geographic Information System (GIS) data development, hydraulic model development, and preliminary alternative analysis. Input on the study process and results was obtained through a series of stakeholder meetings as well as five public meetings. The first three public meetings were held in September 2018 followed by a fourth meeting in December 2018 and a final meeting in May 2019. Notices for these meetings are provided in **Figure 3**. The following report details the analysis and findings of the Nolan Creek watershed Flood Protection Planning Study.

Figure 2: Examples of flooding in downtown Belton (top) at the Gin Complex during Hermine and (bottom) at I-35 service road during April 2017 event

PRESS RELEASE

CTCOG
central texas council of governments

Central Texas Council of Governments
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Public Input Needed for Nolan Creek Flood Protection Planning Study

Central Texas weather can be unpredictable. In recent years, our region has experienced significant flood events resulting in damage to infrastructure and property as well as loss of human life. To help mitigate future flood events and help protect citizens from dangerous flooding, the Central Texas Council of Governments is receiving a grant through the Texas Water Development Board (TWDB) to develop an early warning system and flood protection plan for Nolan Creek. Stakeholders in this study include the cities of Belton, Harker Heights, Killeen and Nolanville as well as the Brazos River Authority and Bell County Water Control & Improvement District #6. The Nolan Creek Flood Protection Planning Study started in February 2017 and will conclude in August 2019.

Some of the tasks in this study include the following: identifying flood early warning system improvements and flood response implementation strategies; developing both a hydrological and hydraulic model; identifying flood problem areas; establishing flood protection criteria; and evaluating flood mitigation alternatives. This information will all be published in the final report.

Public involvement is essential for the Nolan Creek Flood Protection Planning Study. Throughout the study, there will be four rounds of public meetings to gather input on known flooding issues and to inform the public of the final project results. CTCOG highly encourages the public to submit any data they may have such as flood damage, high water marks, and any other helpful information by going to www.ctcog.org and using the online public comment form. CTCOG has published an interactive flood mapping tool for the public to use to pinpoint locations where flooding has occurred. This data is essential in understanding where flooding occurred and the amount of flood damage at a particular location.

The Nolan Creek Flood Protection Planning Study will present data and findings useful for protecting our region from flooding. With the help of our stakeholders and the public, the study will provide our region with a safe, comprehensive flood protection plan that may help prevent property damage and save human lives.

Round 1 Public Meetings to Solicit Input - Dates, Times and Locations

Wednesday, September 13, 2017 6:00pm-8:00pm Central Texas Council of Gov. 2180 N. Main Street Belton, Texas 76513 254-770-2200	Wednesday, September 20, 2017 6:00pm-8:00pm Harker Heights Activities Center 400 Indian Trail Drive Harker Heights, Texas 76548 254-953-5466	Wednesday, September 27, 2017 6:00pm-8:00pm Killeen Civic & Conference Center 3601 South W.S. Young Drive Killeen, Texas, 76542 254-501-3888

NOTICE OF PUBLIC MEETING
Nolan Creek Flood Protection Study
Monday, December 17, 2018
6:00p.m.
Killeen Civic & Conference Center
3601 South W.S. Young Drive
Killeen, Texas 76542

The purpose of this meeting is to solicit input from the public on preliminary 100-year flood risk maps developed as part of this project. This meeting will include a brief presentation of the analyses done to date, what these 100-year flood risk maps mean, and the effort remaining to complete this project. For more information, visit our website at www.ctcog.org/regional-planning, or contact Kendra Coufal at (254) 770-2363 or kendra.coufal@ctcog.org.

NOTICE OF PUBLIC MEETING
Updated:
Nolan Creek Flood Protection Study
Thursday, May 16, 2019
6:00 p.m.
Harker Heights Activity Center
400 Indian Trail
Harker Heights, TX 76548

The purpose of this public meeting is to present the current status of this project, present the existing flood risk maps developed in December 2018, and present the preliminary flood risk reduction alternatives considered as part of this project. There will also be an opportunity for the general public to ask questions and provide comments on the project findings. For more information, visit www.ctcog.org/regional-planning, or contact Kendra Coufal at (254) 770-2363.

Figure 3: Public meeting notices

2.0 TERRAIN DEVELOPMENT

Sub-basins and floodplain delineations were developed using the most recent Light Detection and Ranging (LiDAR) elevation dataset. The primary source of terrain data used was developed from the 2011 StratMap LiDAR available for download on the Texas Natural Resources Information System (TNRIS) website. This LiDAR dataset has an average point spacing of 50 cm and vertical accuracy meeting the FEMA standard 18.5 RMSE (root mean square error) criteria. The LiDAR data was received from TNRIS as Log Ascii Standard (LAS) files, the standard open format for storing LiDAR point records. The LAS data was processed by Scheibe Consulting to create a seamless topographic dataset for the study area. A 10 ft. X 10 ft. digital elevation model (DEM) was created for use in developing inputs for the hydrologic modeling. A 3 ft. X 3 ft. DEM was created for use in developing the hydraulic modeling and floodplain mapping.

3.0 HYDROLOGIC ANALYSIS

A detailed hydrologic analysis was performed on the Nolan Creek watershed with the goal of providing a validated existing base conditions model. This model was used in developing flood mitigation alternatives and quantifying the impacts of these alternatives to the surrounding area. The new, georeferenced hydrologic analysis was performed using the US Army Corps of Engineers HEC-HMS software, version 4.2. Peak flows and flow hydrographs were developed for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-yr events. Frequency rainfall data for these events was derived from the Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas (SIR 2004-5041) and is provided in **Table 1**. The new Atlas 14 rainfall data was not available for use when this study was initiated.

Table 1: Rainfall depth-duration-frequency data for Nolan Creek watershed

Duration	Recurrence Interval (years)							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	250-yr	500-yr
	Depth (inches)							
5 min	0.40	0.50	0.56	0.66	0.73	0.81	0.92	1.02
15 min	0.98	1.30	1.52	1.86	2.14	2.47	2.98	3.43
30 min	1.36	1.78	2.08	2.49	2.83	3.21	3.78	4.27
1 hr	1.76	2.32	2.73	3.30	3.79	4.34	5.19	5.92
2 hr	2.23	2.98	3.52	4.32	5.01	5.8	7.02	8.11
3 hr	2.36	3.2	3.81	4.69	5.45	6.31	7.65	8.83
6 hr	2.68	3.61	4.28	5.23	6.04	6.96	8.35	9.57
12 hr	3.11	4.14	4.89	5.97	6.91	7.97	9.61	11.07
24 hr	3.58	5.08	6.17	7.68	8.91	10.25	12.17	13.77

Sub-basins for Nolan Creek watershed were delineated from the 2011 StratMap LiDAR data for Bell County using GIS-based tools. Sub-basins were delineated with the target of about 0.25 sq. mi. for urbanized areas and 1 sq. mi. for non-urbanized areas. Final sub-basin areas ranged from 0.08 to 1.46 sq. miles for a total of 242 sub-basins. Initial sub-basin delineations were checked against stormdrain GIS data and previous study sub-basin delineations obtained from Fort Hood, City of Killeen, and City of Belton and corrected to accurately reflect the existing drainage patterns. **Figure 4** illustrates the overall watershed and sub-basin layout for the study. Sub-basin areas are provided in the hydrologic parameters table in **Appendix A**.

Runoff losses were computed using the US Department of Agriculture Natural Resource Conservation Service (NRCS) curve number method. This method considers factors such as soil characteristics, land use, hydrologic land condition, and antecedent moisture condition (AMC) to establish rainfall/runoff relationship within an area. The base CN for each drainage area was assumed based on Hydrologic Soil Group (HSG) and a land use of open space in fair conditions. Percent impervious cover was developed based on existing land use for each sub-basin. An existing land use dataset was developed from existing zoning and land use data provided by the participating communities. The datasets were compiled into a uniform land use layer and checked against 2017 aerial imagery. Land use in areas outside the datasets provided by the cities was assigned according to the 2017 aerial imagery as well. The complete land use dataset is illustrated in **Figure 5**. The NRCS Web Soil Survey for Bell County was used to determine the spatial distribution of HSG within the watershed. HSG for soils within the study area is illustrated in **Figure 6**. Base curve numbers (AMC type II), land use, and corresponding % impervious cover assumptions are provided in **Table 2**. Final curve numbers were calculated by weighting AMC II and AMC I curve numbers according to procedures documented in the Texas Department of Transportation (TxDOT) Hydraulic Design Manual. Final curve numbers and % impervious cover for each sub-basin are provided in the hydrologic parameters table in **Appendix A**.

Table 2: Land use category, AMC II curve numbers, and % impervious cover

Land Use Category	Hydrologic Soil Group			%IC
	B	C	D	
Commercial	69	79	84	80%
Industrial	69	79	84	65%
Institutional	69	79	84	40%
Multi-Family Residential	69	79	84	50%
Parks/Open Space	69	79	84	5%
Pasture	69	79	84	0%
Low Density Residential	69	79	84	25%
Rural Residential	69	79	84	10%
Medium Density Residential	69	79	84	45%
Transportation	69	79	84	90%
Woods/Brush	58	71.5	78	0%
Water	98	98	98	0%

The NRCS unit hydrograph (UH) method was used to generate runoff hydrographs for each sub-basin. The lag time inputs for the NRCS UH method were calculated using methods outlined in NRCS Technical Release 55 (TR-55). First, longest flow paths were delineated for each sub-basin using GIS tools and available LIDAR topographic data. The longest flowpath is the runoff path from the most hydrologically remote point to the outlet for each sub-basin. Next, the flowpaths were divided into sheet, shallow concentrated, and channel flow segments and travel time for each segment was computed using TR-55 methodology. Maximum sheet flow length was assumed to be 200 feet, after which it is assumed to be shallow concentrated flow. The transition from shallow concentrated flow to channel flow was assumed to occur when the flowpath entered the street gutter or channel section. Channel flow was usually a combination of gutter flow, stormdrain and natural channel flow. Stormdrain slopes and sizes were taken from data provided by the participating cities. Time of concentration (Tc) or total travel time for each sub-basin was calculated by summing the travel times of the flowpath segments. The final Tc values were converted to lag times (Tlag) using the equation Tlag = 0.6*Tc. Final lag times for each sub-basin are included in the hydrologic parameters table in **Appendix A**.

Routing reaches were also developed to route computed discharge hydrographs through the various segments of natural channel. Multiple methods were used in the hydrologic modeling and include the Modified Puls method, Muskingum-Cunge method, and linear reservoir routing. Storage-outflow tables and data for routing step calculations for the Modified Puls method were derived from routing hydraulic models for the current study stream reaches. Some Killeen tributary reaches that were studied in the early 2000s as part of the FEMA Map Mod effort coincide with reaches in the current model and routing data from those reaches was incorporated into the current model. Remaining routing reaches were modeled with the Muskingum-Cunge method with 8-point cross sections derived from LiDAR and length and slope inputs calculated from GIS data. Linear reservoir routing was used for modeling the 13 NRCS dams located within Nolan Creek watershed. Data for the elevation-storage curves and outlet works (primary spillway, emergency spillway, and dam top) for the dams were taken from as-built plan sets received from the NRCS office in Temple, TX. Modified Puls storage-outflow tables, Muskingum-Cunge 8-point sections, and NRCS dam elevation-storage tables are provided in **Appendix A**.

4.0 HYDRAULIC ANALYSIS

New geo-referenced, steady-state hydraulic analyses were performed for 57.2 stream miles using US Army Corps of Engineers HEC-RAS software version 5.0.3. Cross-section layouts were created for each of the study streams using GIS tools. In the Killeen area, cross-section layouts were available from previous modeling efforts for South Nolan Creek, Little Nolan Creek, Old Florence Ditch, Trimmier Road Ditch, and Nolan Creek upstream of Roy Reynolds Dr. These original layouts were used with minor adjustments to better match the current LiDAR and field survey data. The remaining study stream reaches did not have any available previous study data, therefore new cross-section layouts were developed for these reaches. During cross-section layout development, cross-sections were added to ensure proper modeling of bridges and culverts as well as other bends and transitions along the study streams. Cross-section spacing varied depending on location, with larger spacing in rural areas and smaller spacing in urbanized areas. Flowbreak locations were assigned to cross sections to appropriately distribute the peak flows from the hydrologic modeling. The cross-section layouts and flowbreak locations for the study streams can be seen in **Figure 7**.

Cross-section station and elevation data was extracted using GIS tools and a 3 ft. X 3 ft. DEM created from LiDAR data. Once the cross-sections were imported into the hydraulic model as-built plan data and field survey data were incorporated, where available. Previous study field survey sources include survey from the 2013 Little Nolan LOMR as well as survey from the previous Map Mod studies within the City of Killeen. As-built plan data was provided by both TXDOT for on-system highways and NRCS for the two NRCS dams. **Figure 8** illustrates the types and locations of the different data sources used to model bridges, dams, and culverts. New field survey was collected by Walker Partners Surveyors using survey grade GPS and Total Station equipment or City of Killeen staff using only survey grade GPS. TxDOT and NRCS as-built plan data were verified with survey spot shots collected by City of Killeen staff. Killeen staff also collected several open channel sections throughout the study area. Some of the survey grade GPS shots collected by the city were affected by vegetation, were not able to be corrected, and therefore were not used. All survey data were collected using the North American Vertical Datum of 1988 (NAVD 88) with current geoid and aligned well with the 2011 LiDAR used in the study.

Once cross-section layouts were complete and updated with survey data, hydraulic model parameters were added, such as n-values, ineffective areas, obstructions, contraction/ expansion coefficients, and downstream boundary conditions. Manning's "n" roughness values ranging from 0.03 to 0.12 were assigned to channel and overbanks. Channel n-values were assigned using site visits, survey photos, and 2017 aerial imagery. Overbank n-values were assigned by land use type and adjusted where needed based on 2017 aerial imagery. **Table 3** contains the land use types and assigned overbank n-values used in this study. Ineffective areas were used to model transitions into and out of bridges and culverts as areas of potential overbank storage. Obstructed areas were used to model ponds or bermed areas that do not contribute to overbank storage or conveyance. Higher contraction/ expansion coefficients were added at bridges and culverts as well as other locations to model sharp transitions in cross-section geometry. Downstream boundary conditions were set to normal depth for each model with the appropriate friction slope.

Table 3: Land use category and associated overbank Manning's n-values

Land Use Category	Overbank N-value
Commercial	0.12
Industrial	0.12
Institutional	0.12
Multi-Family Residential	0.12
Parks/Open Space	0.06
Pasture	0.06
Low Density Residential	0.09
Rural Residential	0.07
Medium Density Residential	0.12
Transportation	0.03
Woods/Brush	0.10
Water	0.03

The following is a list of assumptions made and/or modeling issues related to hydraulic model development.

- There is evidence from the hydraulic modeling that overflows may occur along I-14 in the 100-yr event at the two Nolan Creek crossings near Nolanville. It was assumed that these potential overflows do not have a significant impact on the results of the study and therefore were not included in the hydraulic analysis. These overflows may require additional 2D hydraulic analysis to better define their potential impact.

- Multiple opening analysis was used at structures where there were multiple bridge openings or a combination of bridge and parallel conveyance. Table 4 contains the locations where multiple opening analysis was used.
- NRCS Dam 1 on Nolan Creek and Dam 11 on Shaw Branch were modeled as inline structures with culverts. Backwater elevations were assigned to the cross-sections upstream of the dams based on results from the hydrologic model.
- A lateral weir was used on Nolanville West Tributary to account for water leaving the system into an adjacent railroad right-of-way. Flow diverted over the later weir to the railroad right-of-way was assumed to be minor and was not modeled as part of this study.

5.0 HYDROLOGIC AND HYDRAULIC MODELING RESULTS

Validation

To ensure the accuracy and validity of our modeling results, data for three flood events were run and compared to best available highwater mark data. The three events were September 2010 (Tropical Storm Hermine), March 2012, and April 2017. Rainfall data for these events was obtained from the National Weather Service (NWS) in XMRG format, the standard format for 4 km gridded rainfall data. Sub-basin hyetographs for each event were created by processing the XMRG datasets using HEC-MetVue software recently developed by the U.S. Army Corps of Engineers.

Hydrology runs were created with the rainfall data producing model flows for each event, which were then input into the hydraulic model for Nolan Creek. There are currently five stage gages deployed along Nolan Creek that are used for flood early warning purposes. Unfortunately, there are no rating curves developed for these gage locations to produce corresponding flow data and the data itself was not useable for establishing flood elevations due to lack of gage elevation datum information. Scheibe staff performed a surveying effort to lock-in the vertical datum of each gauge, but during this exercise it became apparent that the vertical elevation of the pressure transducers at each gauge may have been adjusted or moved over time; thus invalidating any comparison between our modeling results and these gauge historic records. As a result, comparison of the hydraulic model results for each event were made to flood elevations from high water mark locations estimated from respective flood photos. This exercise was somewhat of an art but attempted to locate each flood photo of a given point in the LiDAR DEM, thereby estimating a flood elevation. The accuracy of this effort was not intended to be exact, but rather provide a level of confidence that the modeling results where within a reasonable range of known high water estimates. From the initial comparison, it was determined that the previously mentioned curve number adjustment per TxDOT methodology should be applied. The final comparisons of hydraulic model results to estimated high-water marks for the three events are provided in **Table 4**. Note that most of the estimated elevations at high water marks are within 3 feet of the hydraulic model results and were considered valid given the limited accuracy of estimating high-water mark locations from photos.

Table 4: Comparison of model results to photo estimated high-water marks

Location	Est. HWM Elev.	Model Elev.	Diff. (HWM -Model)
Hermine (Sept. 2010)			
Approx. 300 ft. downstream of Penelope St.	509.5	509.8	-0.3
Approx. 55 ft. upstream of Penelope St.	510.4	512.5	-2.1
Approx. 360 ft. downstream of Central Ave. south side of county jail	511.8	515.5	-3.7
Halfway between Amy Ln. and FM 3219 near WWTP	722.0	723.7	-1.7
Approx. 1200 ft. downstream of Amy. Ln. near soccer fields	729.0	726.6	2.4
at Amy Lane near mobile homes	727.0	729.2	-2.2
Just downstream of Roy Reynolds Dr.	741.0	739.7	1.3
March 2012			
Location	**Est. HWM Elev.**	**Model Elev.**	**Diff. (HWM -Model)**
I-35 southbound frontage road	502.5	503.3	-0.8
Approx. 110 ft. upstream of Main St.	509.4	511.4	-2.1
Approx. 290 ft. upstream of 2nd St.	516.2	516.3	-0.1
April 2017			
Location	**Est. HWM Elev.**	**Model Elev.**	**Diff. (HWM -Model)**
Approx. 470 ft. downstream of Penelope St.	504.8	506.7	-1.9
Approx. 320 ft. downstream of Penelope St.	506.0	506.9	-0.9
At Penelope St.	507.0	508.8	-1.8
Approx. 130 ft. downstream of Main St.	508.0	509.4	-1.4
Approx. 130 ft. downstream of Central Ave. in Yettie Polk Park	509.0	511.8	-2.8
At Wheat Rd.	552.6	555.5	-2.9
At Paddy Hamilton	605.3	608.9	-3.6
Just upstream of I-14 westbound frontage	695.9	696.4	-0.5
Just upstream of Roy Reynolds Dr.	737.4	739.9	-2.5

A second validation of model results was performed by comparing 100-yr frequency flow results to those of recent studies near the Nolan Creek watershed study area. Comparison to the recent San Gabriel FPP Study in Williamson County and current effective FEMA flows were made on a 100-yr discharge per drainage area basis. A figure showing the comparison to these previous studies is provided in **Figure 9**. This comparison shows Nolan watershed results are higher than the San Gabriel FPP results, which is likely due to differing curve number adjustment methodologies and a larger overall percent impervious cover within the study watershed. The comparison also shows FEMA effective flows in the upper Nolan watershed are just slightly higher on average due the use of AMC II curve numbers in the recent FEMA Map Mod study for the upper Nolan watershed. The lower Nolan watershed current effective FEMA flows are much lower as they are from a study that is over 30 years old and reflects a much lower amount of impervious cover and more rural land uses. A quick review of Google Earth historical imagery revealed that the City of Killeen alone had a large increase in impervious cover over the last 30 years, further justifying the differences found between this study and the previous FEMA flows. The points circled in red (in **Figure 9**) represent locations affected by NRCS dams. As a result of these two validations, it can be concluded that the hydrology model for the study represents current watershed conditions and compares reasonably well with available data from previous flood events and other recent drainage studies.

Hydrologic Results

The validated hydrology model was utilized to produce flows for the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-yr frequency flood events. Rainfall data for the frequency flood events was derived fusing methodologies developed by the United States Geological Survey (USGS) and documented in "Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas" (2004). Note that new National Oceanic and Atmospheric Association Atlas 14 rainfall data was not used for the is study, as this new rainfall data was not available at the time this project started. Areal reduction of point rainfall was applied to all locations with contributing drainage area greater than 10 sq. mi. and is based on areal reduction factors developed as part of U.S. Weather Bureau Technical Paper 40. The depth-area function in HEC-HMS was utilized to apply areal reduction factors and produce reduced peak flows for affected computation points. A summary of existing conditions frequency flow results at key locations along the study streams is provided in **Appendix B**. All hydrologic modeling and associated GIS data for the frequency runs, as well as the three storm events used in the model validation are included with the digital data located in **Appendix F**.

Hydraulic Results

The frequency flows produced from the hydrologic modeling were input into hydraulic models for the study streams to produce water surface elevations for all modeled frequencies and a floodplain for the 100-yr event. The 100-yr floodplain was produced using the RAS mapper tool in HEC-RAS and cleaned up in GIS to remove islands and disconnected ponds with an area less than 1 acre. Small backwater areas and transitions at study stream confluences were delineated by hand where needed according to model results and existing contours. The resulting water surface elevations and floodplain extents for the 100-yr event are provided on the hydraulic workmaps included in **Appendix B**. All hydraulic modeling and associated GIS data for the frequency runs as well as the three storm events used in the model validation are included with the digital data located in **Appendix F**.

6.0 FLOOD DAMAGE REDUCTION ALTERNATIVES

Alternative Analysis

The alternative analysis for Nolan Creek watershed included flood damage reduction alternatives for the Cities of Belton, Nolanville, Harker Heights, and Killeen. Consultations were held with representatives of each city to determine key flooding areas and potential alternatives to reduce flooding in those areas. The types of alternatives analyzed are as follows:

- Regional Detention – The goal of regional detention options is to detain water at an upstream location to reduce flooding in downstream reaches. Regional detention can either be inline or offline. Offline detention options are more efficient at reducing flood peaks as they require less volume to produce similar results to inline options. The objective of detention alternatives analyzed was to determine the volume required to reduce the existing100-yr peak flow to the 50- or 25-yr peak flow, depending on the amount of area available for storage.
- Channel Modification – Increasing channel conveyance reduces the amount of overbank storage required to pass a given flood flow thus reducing flood elevations. Channel modification options were assumed to be simple trapezoidal cuts benched above the natural channel invert to account for likely environmental permitting requirements, specifically impacts to the "Ordinary High-Water Mark", which is a term used in Section 404 (of the Clean Water Act) permitting requirements. Proposed channel cuts were made to avoid impacting existing structures adjacent to the channel while optimizing reduction in flood elevations.
- Culvert/Bridge Improvements – Undersized bridges and culverts can cause upstream flooding due to high headwater elevations. Options to remove or enlarge these structures can provide relief from flooding in the upstream area but can also result in adverse impacts downstream. Impacts of these improvements were quantified by updating the hydraulic modeling and comparing to the existing conditions results.
- Flood Diversion – Diversion of flood waters can provide relief from flooding to downstream locations. Specifically, a diversion of flood waters from North Nolan to Lake Belton was analyzed as part of this study. The objective of the analyzed diversion was to reduce the 100-yr peak flow to the 10-yr peak flow on North Nolan Creek, while simultaneously providing additional water supply storage in Lake Belton, during flood events.

A total of 27 alternatives, with options, were analyzed and are presented in detail in **Appendix C** of this report, including flood reduction results and detailed opinions of probable cost. Each alternative evaluated, was performed to a schematic/master planning level and will likely require additional engineering analysis if deemed a viable alternative. Future engineering efforts will likely include a Preliminary Engineering Report (PER), followed by detailed engineering design and construction documents. As each of these future phases are performed, additional findings and more refined construction cost estimates will likely result, which may trigger a go/no-go decision for the communities. The alternatives evaluated are listed below in **Table 5** with descriptions, value of structures removed, and total opinion of probable cost. The color coding in **Table 5** indicates the level of priority associated with the alternative, as determined by the project stakeholders (green = high priority, yellow = medium priority, red = low priority). **Figure 10** shows the location of each alternative analyzed within the Nolan Creek watershed. Structure values were determined from improvement values taken from Bell County Appraisal District (Bell CAD) property records. Opinion of probable cost for each alternative is based on construction elements with unit costs derived from the TXDOT average low bid data and a 25% contingency. Probable costs also include potential land acquisition and engineering costs. Land acquisition and easement values are very rough and subject to some fluctuation during future phases of analysis. Care should be taken when utilizing these rough estimates for future planning and Capital Improvement Plans (CIPs).

Table 5: Summary of flood reduction alternatives

Alt #	Stream Name	Description	#/Value of Structures Removed	Total Probable Cost
1	Nolan Creek	Removal of East Central Avenue low water crossing	N/A	N/A
2	Nolan Creek	Increase opening through I-35 frontage bridges	N/A	N/A
3	Nolan Creek	Channel improvements from Penelope Street to I-35	71/$14,711,744	$1,852,000
4	Nolan Creek	Channel improvements from 2nd Street to Main Street	30/$3,139,203	$2,467,000
5	Nolan Creek	Channel improvement upstream of 2nd Street	21/$752,101	$5,163,000
6	Nolan Creek	Combination of alternatives 3 and 4	102/$19,334,790	$4,242,000
7	Nolan Creek	Combination of alternatives 3, 4, and 5	113/$19,642,674	$9,328,000
8	Nolan Creek	Regional detention at Nolan/North Nolan confluence	139/$23,497,053	$7,892,000
9	North Nolan Creek	Flood diversion channel from North Nolan to Lake Belton	5/$135,000	$12,435,000
10	Nolanville Tributary	Culvert improvements at I-14 main lanes and frontage	1/$55,000	$460,000
11	Nolanville Tributary	Alternative 11 with 10th St culvert upgrade and channel improvements	3/$165,000	$922,000
12	Nolanville Tributary	Regional detention near FM 439	1/$55,000	$1,363,000
13	Nolanville Tributary	Combination of alternatives 11, 12, and 13	6/$330,000	$1,765,000
14	Nolanville West Trib	Culvert improvements at I-14	3/$165,000	$722,000
15	Nolanville West Trib	Culvert improvements at I-14 and Ave. I	3/$165,000	$794,000
16	Nolanville West Trib	Regional detention upstream of Avenue I	5/$275,000	$4,281,000
17	Nolanville West Trib	Combination of Alternatives 15, 16, and 17	9/$495,000	$5,075,000
18	Nolan Creek	Channel Improvements Harker Heights	65/$2,515,400	$12,490,000
19A	Nolan Creek	Regional detention at Nolan/Little Nolan confluence	120/$21,114,100	$27,607,000
19B	Nolan Creek	Maximum Regional detention at Nolan/Little Nolan confluence	173/$23,913,100	$39,380,000
20	Little Nolan Creek	Channel improvements upstream and downstream of MLK Jr. Blvd	39/$4,323,350	$1.979.000

Alt #	Stream Name	Description	#/Value of Structures Removed	Total Probable Cost
21A	Trimmier Road Ditch	Culvert improvements at I-14 and W.S. Young Option A	3/$632,900	$9,108,000
21B	Trimmier Road Ditch	Culvert improvements at I-14 and W.S. Young Option B	8/$1,556,320	$16,844,000
22A	Trimmier Road Ditch	Detention/channel improvements upstream of Florence Rd	6/$550,000	$442,000
22B	Trimmier Road Ditch	Detention Only upstream of Florence Rd	13/$1,633,000	$2,069,000
23	Trimmier Road Ditch	Culvert/channel improvements at Clairidge and Caprock	2/$196,000	$556,000
24A	Little Nolan Creek	Regional detention at Little Nolan/Old Florence Ditch confluence – 10-yr Option	17/$1,671,000	$5,040,000
24B	Little Nolan Creek	Regional detention at Little Nolan/Old Florence Ditch confluence – 5-yr Option	18/$1,724,000	$7,710,000
25A	Old Florence Ditch	Channel improvements upstream of Trimmier Rd	2/$420,000	$505,000
25B	Old Florence Ditch	Channel/pond improvements upstream of Trimmier Rd	2/$420,000	$617,000
26	Little Nolan Creek	Culvert improvement at W.S. Young Dr.	2/$252,880	$1,528,000
27	South Nolan Creek	Channel improvement downstream of Robinett Rd.	0/$0	$565,000

Environmental Constraints Summary

A desktop level environmental constraints investigation was performed for this project area. The intent of this environmental constraint investigation was to identify any key, known, environmental constraints that could impact various alternatives that were evaluated. This investigation is not a comprehensive environmental assessment and did not include any field investigations. For the purposes of the environmental constraints review, the project area includes the entire Nolan Creek watershed. 99% of Nolan Creek watershed is within Bell County and includes the cities of Killeen, Harker Heights, Nolanville, and Belton as well as the Fort Hood Army Base. Numerous sources were reviewed to identify potential environmental constraints in the study area. Items included: socio-economic data, Texas Parks & Wildlife threatened and endangered species by county & element of occurrence locations, United States Fish & Wildlife Service (USFWS), Texas

Parks and Wildlife Department (TPWD) and Texas General Land Office (GLO) species habitat, protected areas and national wetland inventory, Texas Commission of Environmental Quality (TCEQ) hazardous materials including leaking petroleum storage tank locations (LPST), cultural resources data from the Texas Historical Commission (THC), and other spatial information including roads, railroads, and water wells. An online Texas Railroad Commission (TRC) mapper was utilized to extrapolate the locations of various well data including shut-in oil/gas, oil, gas, plugged oil/gas, permitted locations, injection/disposal, and dry wells. Oil and gas pipeline data was also gathered from the TRC. The occurrences of these constraints are displayed in **Figure 11**.

Socioeconomics/Environmental Justice:

Executive Order 12898 "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations" requires each Federal agency to "make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies and activities on minority populations and low-income populations."

The study area is associated with 41 Census Tracts within Bell and Coryell Counties, as defined by the United States Census Bureau (USCB) 2010 Census. These Census Tracts have a total population of 161,739 while Bell County has a combined total population of 310,235 indicating about half of the County population lives within Nolan Creek watershed. According to the Texas Almanac, the primary industries Bell County vary, but include manufacturing, agribusiness, and Fort Hood (military related). Demographic data was reviewed to determine if minority or low-income persons have the potential to be adversely affected by the proposed project. The data was retrieved from the USCB on May 20, 2019. Block group data from the 2010 Census indicates that approximately 47 percent of the population in the project area is comprised of minorities. Although income data is not available in the 2010 Census, the American Community Survey (ACS) provides a 5-year average of income and poverty information for the investigated geographies. The ACS is an ongoing nationwide survey that provides social, economic, and housing data every year. All ACS data are estimates; therefore, the USCB provides a margin of error (MOE) for every ACS estimate. The 2019 United States Department of Health and Human Services (USDHHS) poverty guideline for a family or household of four is $24,600. The ACS data for 2013-2017 indicate that the median household income for Bell County is $52,583 (MOE +/- 994). Therefore, the County data shows that the median household income for all investigated geographies is greater than the 2019 United States Department of Housing and Human Services (USDHHS) poverty guideline; however, the 2013-2017 ACS data indicates that low-income individuals live in the project area.

Although minority and low-income persons are located within the project area, the proposed action is not expected to have adverse or disproportionate impacts on minority or low-income populations. The benefits of the flood control project are expected to equally benefit residents of all socio-economic backgrounds. Public outreach planning for any future public involvement activities should take into consideration low-income and minority population.

Biological Resources:

USFWS lists 6 federal threatened and endangered species in Bell County; however, TPWD lists 15 state threatened and endangered species. This data was retrieved from the USFWS and TPWD county lists of Texas special species for Bell County on May 20, 2019. It is recommended that a search of the Texas Natural Diversity Database (TXNDD) be performed to determine if there are any recorded sightings of any of these endangered species within the project area. Given the small proportion of public versus private land in Texas, the TXNDD does not include a representative inventory of rare resources in the state. Although it is based on the best data available to TPWD regarding rare species, the data cannot provide a definitive statement as to the presence, absence, or condition of special species, natural communities, or other significant features in any area. The data cannot substitute for on-site evaluation by qualified biologists. The TXNDD information is intended to assist users in avoiding harm to rare species or significant ecological features. Refer all requests back to the TXNDD to obtain the most current information

Wetlands:

Wetlands are identified as those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. A search of the USFWS national wetland inventory (NWI) database indicates that there are numerous wetlands in the study area. These wetlands may be jurisdictional under Section 404 of the Clean Water Act and may require a permit prior to filling or dredging. **Figure 11** shows NWI locations within the Nolan Creek watershed. It is recommended that a jurisdictional determination be performed in the field prior to construction in order to determine potential impacts to the waters of the United States.

Potential Hazardous Materials:

The TCEQ known hazardous materials database was reviewed for the study area. The data includes superfund sites, municipal solid waste sites, industrial and hazardous waste correction action (IHWCA) locations, and leaking petroleum storage tank (LPST) locations. 1 superfund site, 6 municipal solid waste sites, 3 IHWCA sites and 11 LPST locations (LPSTs documented within last 10 years) were identified within the study area. The level of contamination at the LPST sites range from “minor soil contamination” to “ground water impacts”. Three of the LPST sites are currently in active status and have not been resolved. TRC data was used to determine location of oil and gas wells and pipelines within the study area. According to TRC data, there are gas transmission pipelines within the watershed but no known wells. TRC and TCEQ data are included in **Figure 11**. Once the perimeters of the projects are established during future design phase, a comprehensive database review and site visit are recommended to determine the level of assessment necessary. A Phase I Environmental Assessment may be needed prior to construction.

Physical Constraints:

Physical constraints, such as railroads and roads, are depicted in **Figure 11** according to Texas Natural Resource Information Systems (TNRIS) data. Other constraints, such as water wells, are also shown. A field reconnaissance is recommended prior to construction to determine any conflicts with existing infrastructure.

Cultural Resources:

Cultural resources are structures, buildings, archeological sites, districts (a collection of related structures, buildings, and/or archeological sites), cemeteries, and objects. Both federal and state laws require consideration of cultural resources during project planning. At the federal level, the National Environmental Policy Act and the National Historic Preservation Act of 1966, as amended, among others, apply to projects such as this one. In addition, state laws such as the Antiquities Code of Texas apply to these projects. Compliance with these laws often requires consultation with the THC/Texas State Historic Preservation Officer and/or federally recognized tribes to determine the project's effects on cultural resources. To comply with federal and state laws regarding review and coordination, a site visit by an architectural historian and an archeologist to determine the likelihood of impacts on significant cultural resources would likely be required prior to construction. If any historical or archeological constituents are unexpectedly encountered in the study area during construction operations, appropriate measures should be taken with local, state, and federal officials.

Implementation

Potential funding sources for recommended alternatives can include FEMA grant programs such as the Hazard Mitigation Grant Program, Severe Repetitive Loss Grants, and Flood Mitigation Assistance Grants. These grants must involve a project with a benefit to cost ratio greater than one and be combined with matching local funds from the affected communities. Other sources of funding include local drainage utility fees or portions of city budgets allocated to drainage capital improvement projects. In addition, the State of Texas has recently passed bills in 2019 that allow for approximately $3 Billion in funds from the "Rainy Day Fund" to be allocated to drainage and flood control projects via loans and grants to help fund studies, designs, and construction projects needed to mitigate flood risk throughout the State. It is recommended that the Nolan Creek communities keep a close watch on these funds over the coming months.

7.0 FLOOD EARLY WARNING SYSTEM ANALYSIS

The purpose of the flood early warning system (FEWS) analysis was to review the existing flood warning infrastructure within the Nolan Creek Watershed, interview community officials/users of the existing system, review state-of-the-art procedures that have been implemented by other FEWS users, and identify enhancement goals for the system. Texas A&M Agricultural Extension Service was hired as a subconsultant to assist with this overall effort, and their findings and recommendations are as follows:

1. It is recommended that an overarching regional management entity be put in charge of this overall system (especially if the regional communities desire to expand the system beyond its current use);
2. Improved operational documentation;
3. Formally define regional goals;
4. Expand the data-gathering network;
5. Consideration of real-time inundation mapping system linked to a stage gauge network; &
6. Consideration of community-wide response planning.

Additional details and findings are provided in the Texas A&M Agricultural Extension Service report in Appendix D.

To reach the goal of expanding the data gathering network and improving the data required for community-wide flood response, an investment must be made to upgrade old equipment and install new equipment were needed. Tables 6 and 7 contain cost analysis for various types of rainfall and stage gauges discussed in the Texas A&M Agricultural Extension Service report. These costs can be used in conjunction with the report recommendations to develop a budget for upgrading and improving the existing flood early warning rainfall and stage gauge network.

Table 6: Summary of cost analysis for rain gauge equipment

Manufacturer	Model	Gauge Type	Accuracy[1]	Cost	Ancillary Equipment needs	Ancillary Equipment Costs	Total Cost[2]
Texas Electronics	TR-525USW	8" Tipping Bucket	+/- 1% (at 0 – 2 in./hr.)	$450.00	Dual Reed Switch, Siphon, data logger, bird spikes, field calibration device, Solar panel, sapphire jewel option, battery, solar panel, transmission antenna, cabling, & enclosure box	$3,050.00	$18,500.00
SUTRON	5600-0525-6	~8" Tipping Bucket	+/- 2% (at 0 – 10 in./hr.	$1,250.00	Assuming cellular data logger/telemetry (X link 500), Siphon, cell service, battery, solar panel, transmission antenna, cabling, & enclosure box	$3,650.00	$19,900.00
SUTRON	OTT Pluvio[2]	8" Weighing	+/- 0.002"	$4,300.00	Assuming cellular data logger/telemetry (X link 500), cell service, battery, solar panel, transmission antenna, cabling, & enclosure box	$3,650.00	$22,950.00
Young	50202	5.5" Capacitive	+/- 0.04"	$1,600.00	Meteorological translator, mounting panel, gauge	$3,500.00	$20,100.00

Manufacturer	Model	Gauge Type	Accuracy[1]	Cost	Ancillary Equipment needs	Ancillary Equipment Costs	Total Cost[2]
					calibrator, battery, solar panel, transmission antenna, & cabling		

1. Accuracy is as per manufacturer and is not necessarily based on independent test results.
2. Total cost includes equipment costs and assumed installation costs. Installation costs are assumed to be $15k per unit. Annual maintenance costs are not provided herein. Annual maintenance may be on the order of $4,000.00 for bi-annual maintenance (every 4 sites) (*courtesy of sales rep. for Sutron, 2019*). Use of trained in-house staff will likely result in lower maintenance costs.

Table 7: Summary of cost analysis for stage gauge equipment

Manufacturer	Model	Gauge Type	Accuracy[1]	Cost	Ancillary Equipment needs	Ancillary Equipment costs	Total Cost[2]
SUTRON	Single Orifice Const. Flow Bubble Gauge	Bubble w/ non-submersible P.T.	+/- 0.05%	$4,000.00	100 LF PVC orifice line (data logger not needed), battery, solar panel, transmission antenna, & cabling	$1,700.00	$23,700.00
SUTRON	OTT RLS	Radar Gauge	+/- 0.1% (@ 115 ft)	$2,900.00	Assuming cellular data logger/telem. (X link 500), cell service, battery, solar panel, transmission antenna, & cabling	$3,650.00	$24,550.00
SUTRON	OTT PLS	Submers-ible P.T.	+/- 0.1% (at full range)	$2,100.00	Humidity absorber box, cartridge, data logger/telem. (X link 500), cell service, battery, solar panel, transmission antenna, & cabling	$3,800.00	$23,900.00

1. Accuracy is as per manufacturer and is not necessarily based on independent test results.
2. Total cost includes equipment costs and assumed installation costs. Installation costs are assumed to be $18k per unit. Annual maintenance costs are not provided herein. Annual maintenance may be on

the order of $4,000.00 for bi-annual maintenance (every 4 sites) (*courtesy of sales rep. for Sutron, 2019*). Use of trained in-house staff will likely result in lower maintenance costs.

8.0 FLOOD EMERGENCY RESPONSE PLANNING

Administrative and Information Framework for Flood Response

In order to assess the current state of emergency response planning in the Nolan Creek watershed, a survey was distributed to administration and emergency management officials in the cities and county.

This survey, attached as **Appendix E** seeks to understanding the existing administrative framework for coordination in a flood response effort, the information sources utilized in response activities, and whether this provides time in response. The survey solicits input on the adequacy and sufficiency of information used by emergency managers and the interagency communication.

The following are key findings from this survey.

1. All communities have a designated Emergency Management Coordinator (EMC).
2. In most of the communities, the EMC is the Fire Chief. In the City of Nolanville, which is served by a volunteer fire department, the Chief of Police is the EMC.
3. The larger cities have a written flood management protocol or response plan, as part of the Bell County Response Plan.
4. All communities have an interlocal agreement in place with Bell County.
5. None of the communities stated that the interlocal agreement needed to be updated, or that any are in process of updating.
6. The City of Nolanville has an interlocal with Central Bell County Fire & Rescue.
7. All communities have areas of known flooding to which they deploy barricades.
8. During a flood event, the communities are most frequently in contact with Bell County, TxDoT, and the Brazos River Authority (BRA), in regard to the wastewater treatment plant.
9. This communication usually involves the respective EMC, Fire Department, Police Department, Public Works, City Manager, Bell County EMC, Bell County 911 Center, and Central Bell County Fire & Rescue.
10. The communities relayed that the communication was based on “good relationships with all entities” and that the communities “work well”, using direct phone calls and text messages.
11. The communities all review multiple sources of information in anticipation of flooding.
12. The State Operations Center provides briefings based on NWS data.
13. The United States Geological Survey (USGS) gauges are considered accurate and monitored.
14. Police, fire, and public works staff make visual inspection of known areas.

15. All this information is considered in initiating the flood protocol.
16. 80% of the respondents state that this provides more than 12 hours of lead time.
17. 40% of the respondents state that this provides more than 24 hours of lead time.
18. 20% of the respondents state that this provides more than 48 of lead time.
19. The responses which indicated that the lead time was not enough also indicated that the information provided between 12-24 hours of lead time.
20. Respondents indicated that equipment is generally adequate.
21. Equipment that could be used in providing a better response in the future:
    - Permanent barricades
    - monitor that links to CodeRED
    - Flood Early Warning System (FEWS)
    - Better equipped rescue boat which can be easily deployed and is specific to swift water conditions.

Framework for Using High-Water Mark Data

Another important part of the response effort is the collection of high-water mark data. This information helps in two principal ways: A) it helps refine the modeling to reduce uncertainty, and thus provide better predictive capability; and B) it can serve as a reminder to the community about the level of risk.

There are three steps to this process: 1) marking in the field, 2) collecting the data (including initial cataloging and surveying points), and 3) incorporating this information in a calibration run with the models. There can also be additional benefits of collecting this information outside of the realm of flood response but within the realm of community mitigation planning, such as streamlining for federal recovery assistance and preparing elevation certificates as a means of leveraging the FEMA programs.

FIGURES

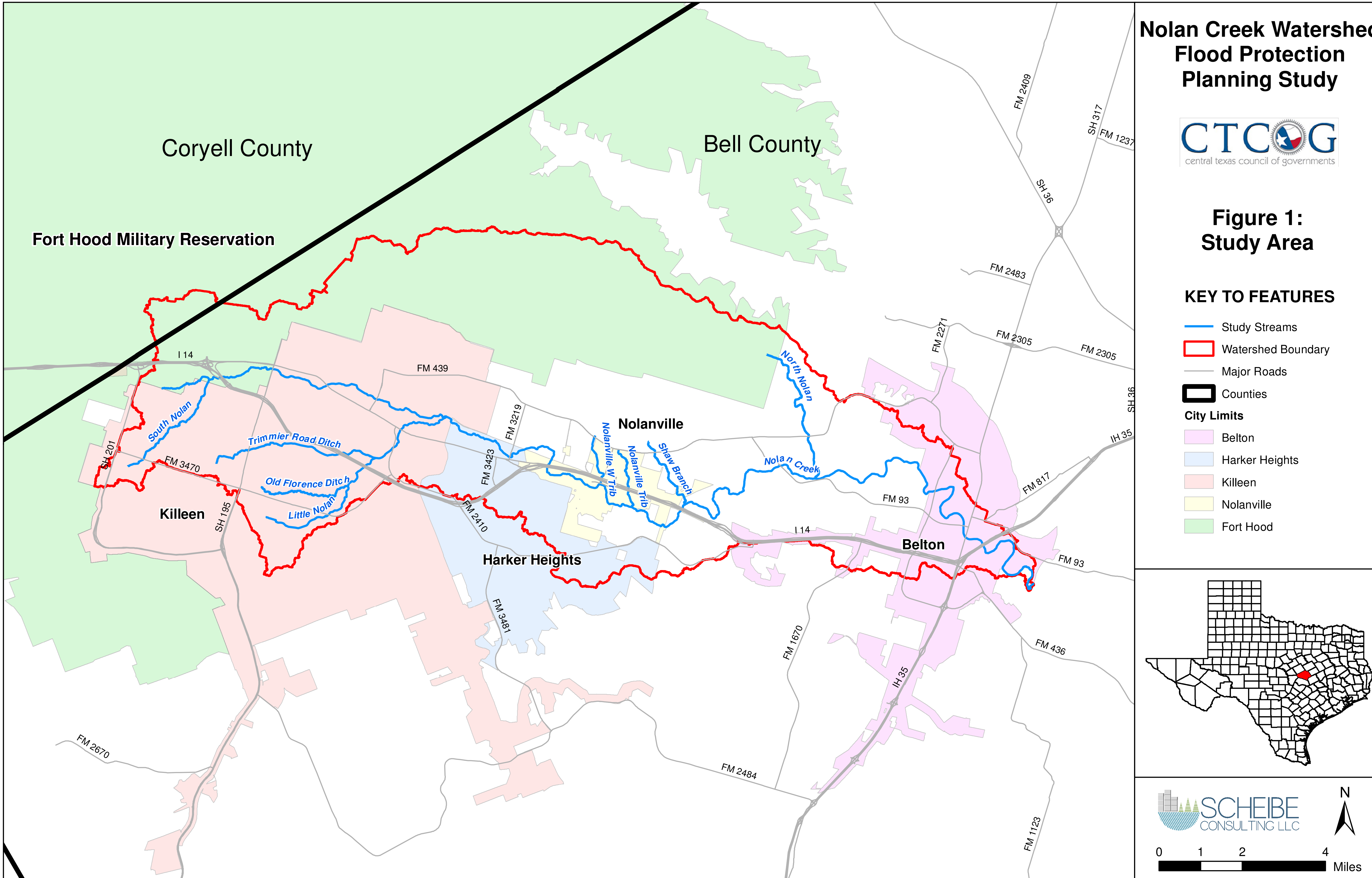

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Figure 1: Study Area

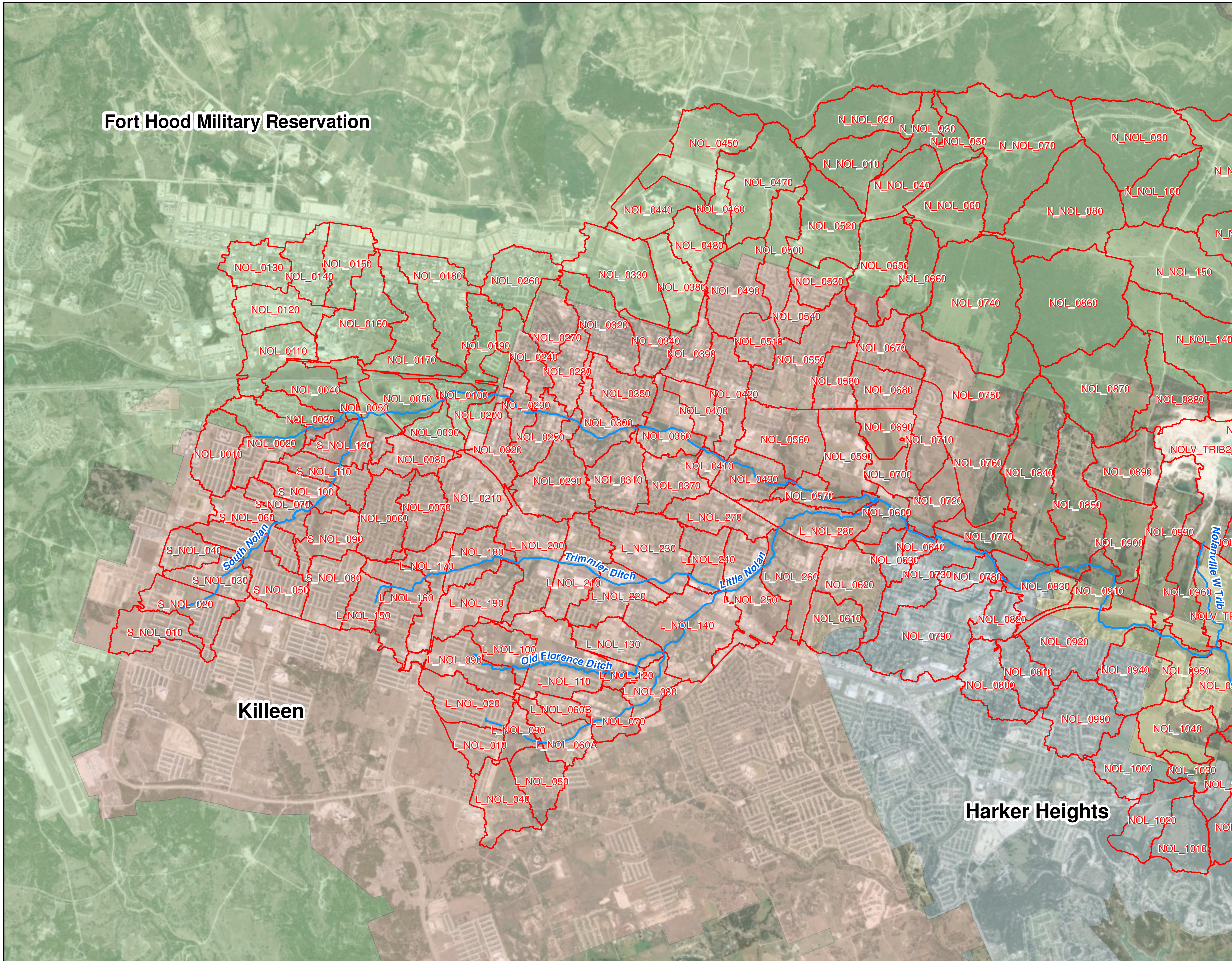

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Figure 4: Sub-basin Layout Map 1 of 2

KEY TO FEATURES

- Study Streams
- Subbasins

City Limits

- Belton
- Harker Heights
- Killeen
- Nolanville
- Fort Hood

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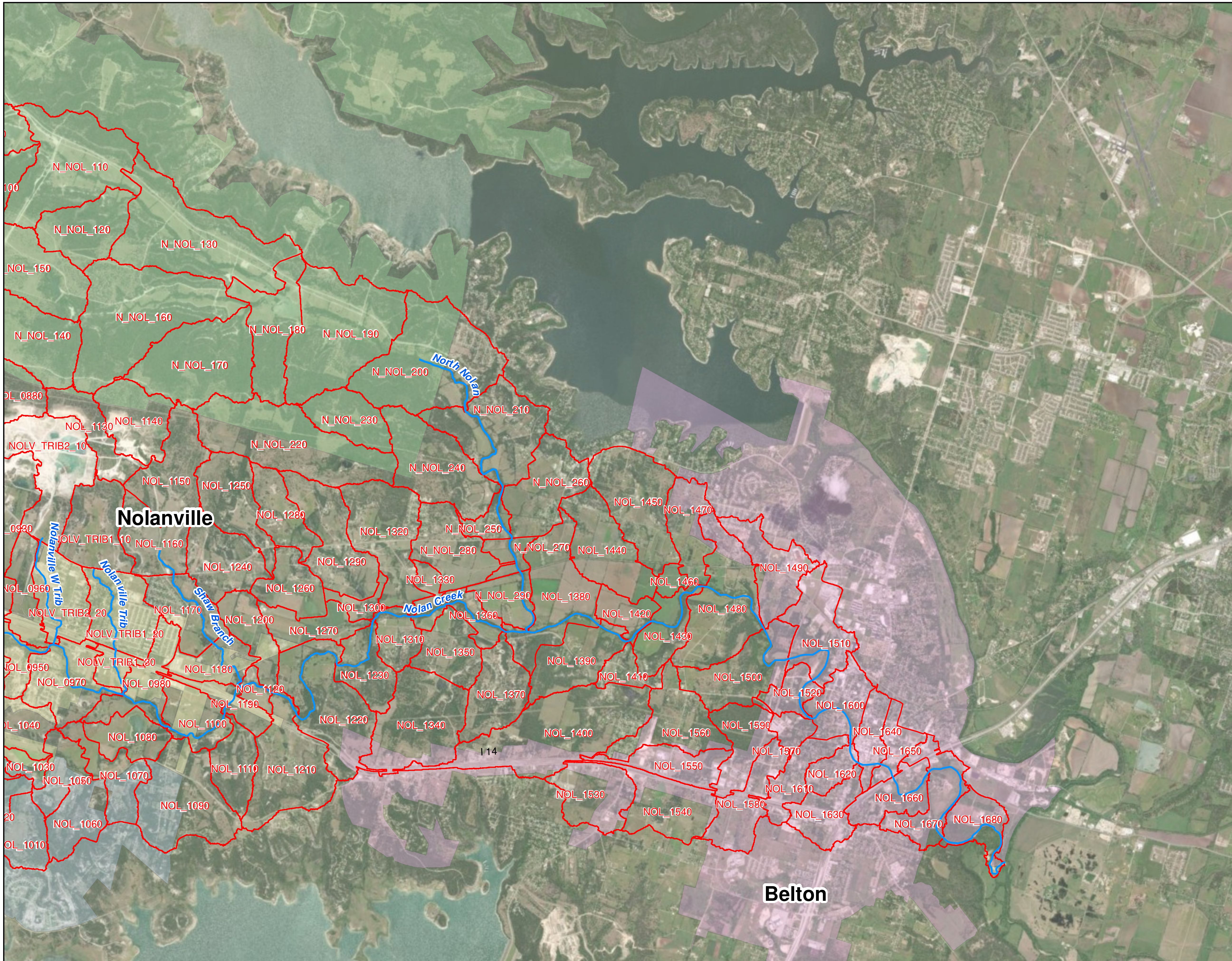
Figure 4: Sub-basin Layout Map 2 of 2



KEY TO FEATURES

- Study Streams
- Subbasins

City Limits

- Belton
- Harker Heights
- Killeen
- Nolanville
- Fort Hood

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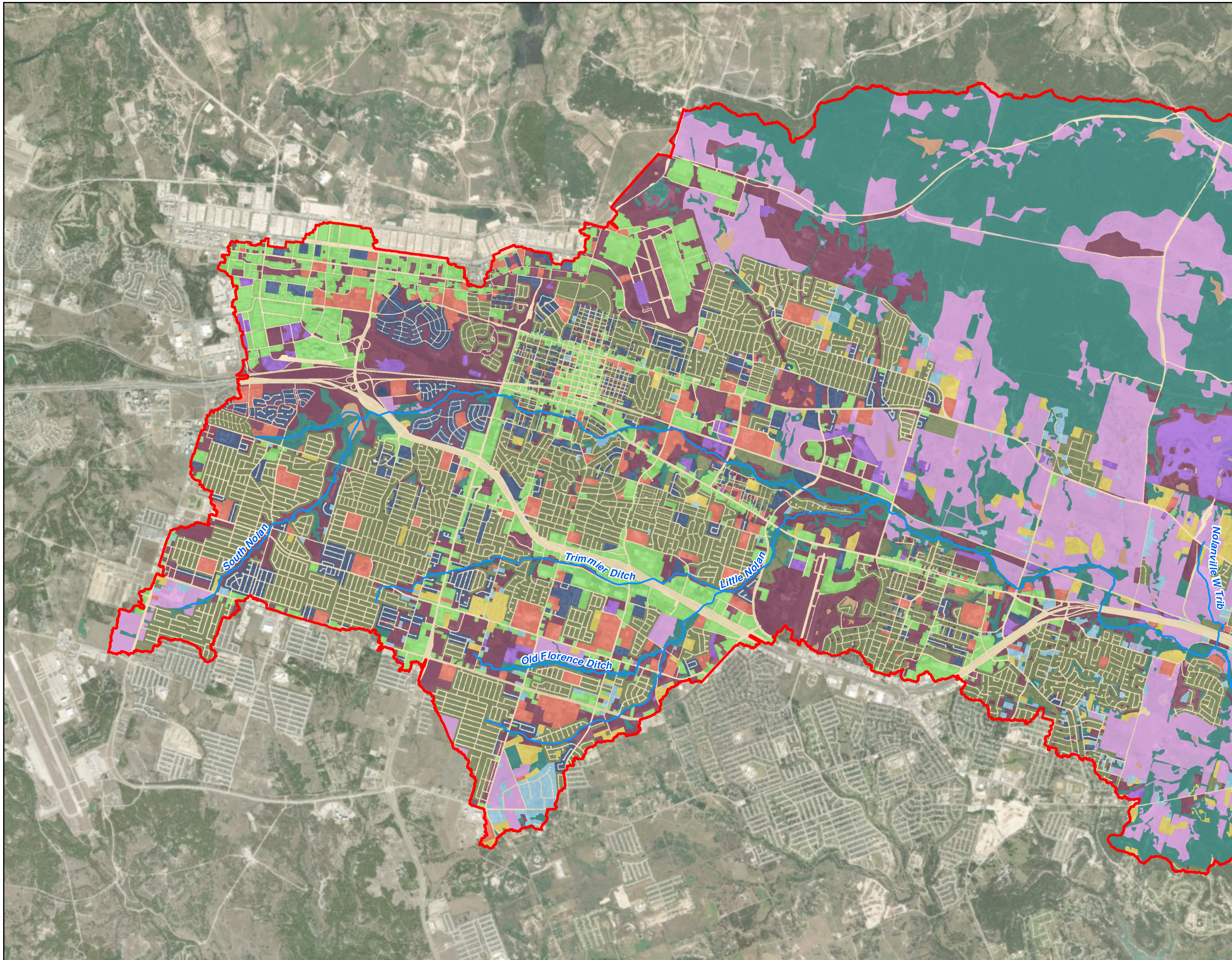

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Figure 5: Landuse Types Map 1 of 2

KEY TO FEATURES

Study Streams
Watershed Boundary

Existing Landuse

Commercial
Industrial
Institutional
Low Density Residential
Medium Density Residential
Multi-Family Residential
Open Space
Pasture
Rural Residential
Transportation
Water
Woods/Brush

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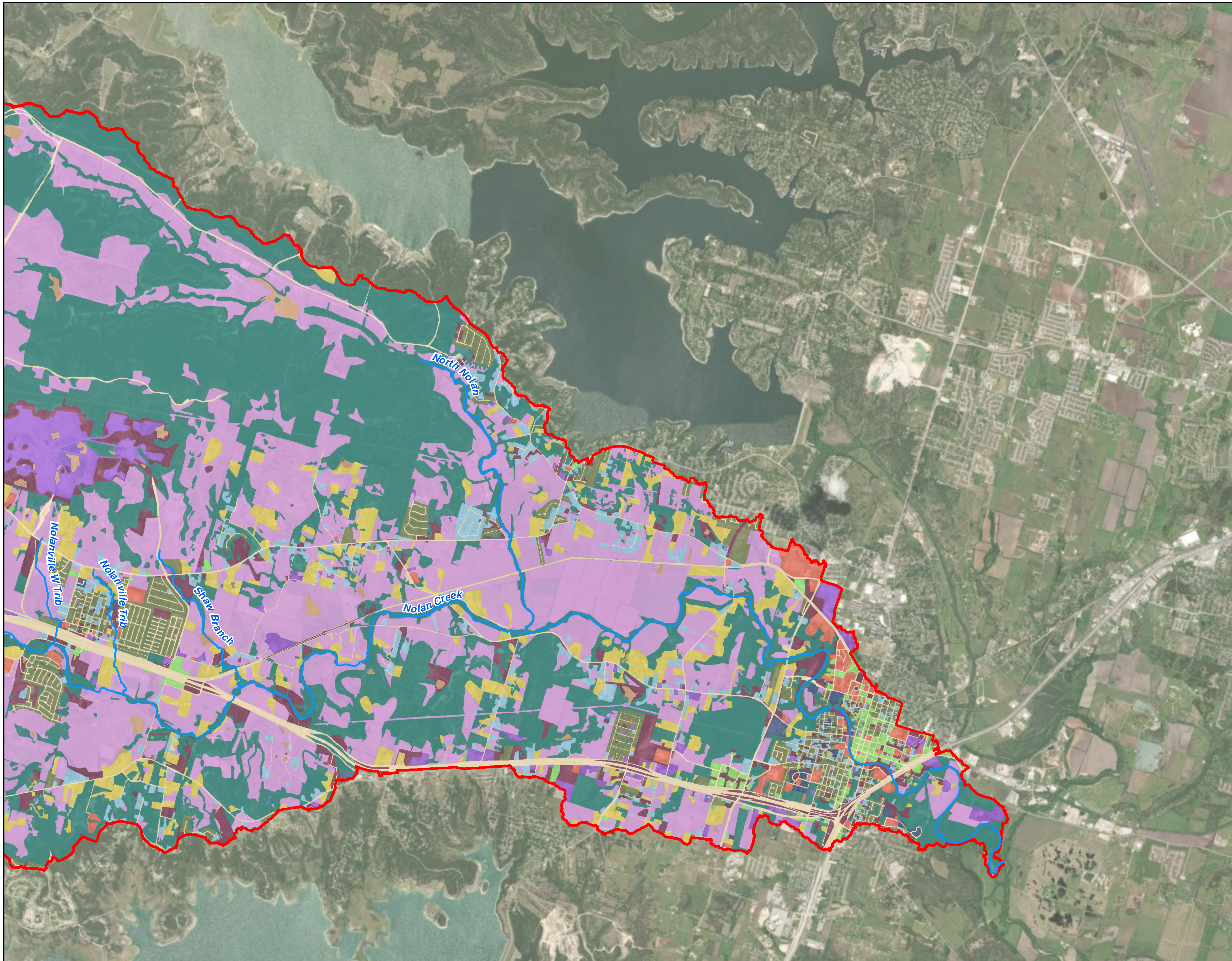

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Figure 5: Landuse Types Map 2 of 2

KEY TO FEATURES

Study Streams
Watershed Boundary

Existing Landuse

Commercial
Industrial
Institutional
Low Density Residential
Medium Density Residential
Multi-Family Residential
Open Space
Pasture
Rural Residential
Transportation
Water
Woods/Brush

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0 0.5 1 2 Miles

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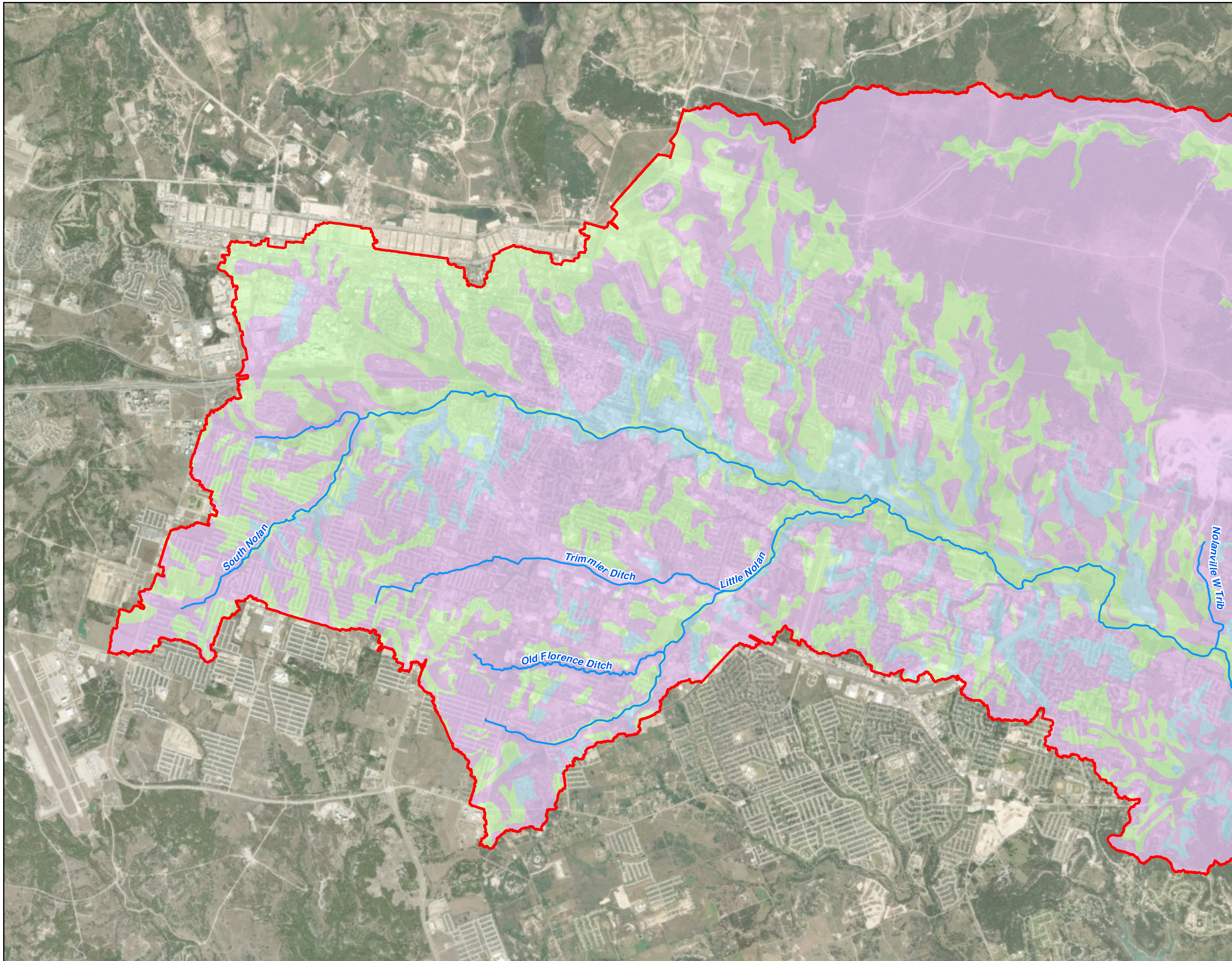
Figure 6: Soil Types Map 1 of 2



KEY TO FEATURES

Study Streams

Watershed Boundary

Hydrologic Soil Group

B

C

D

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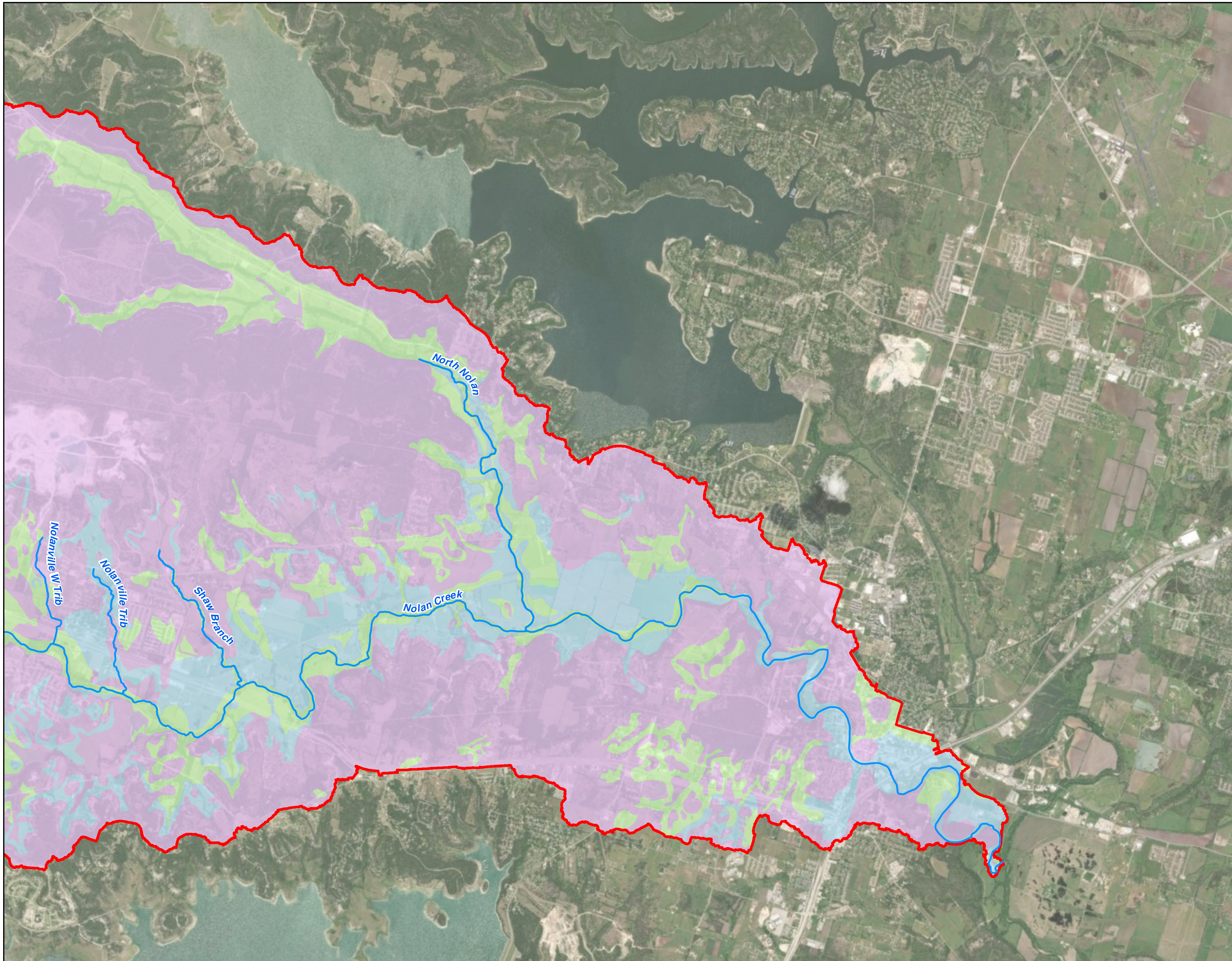

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Figure 6: Soil Types Map 2 of 2

KEY TO FEATURES

Study Streams

Watershed Boundary

Hydrologic Soil Group

B

C

D

SCHEIBE CONSULTING LLC

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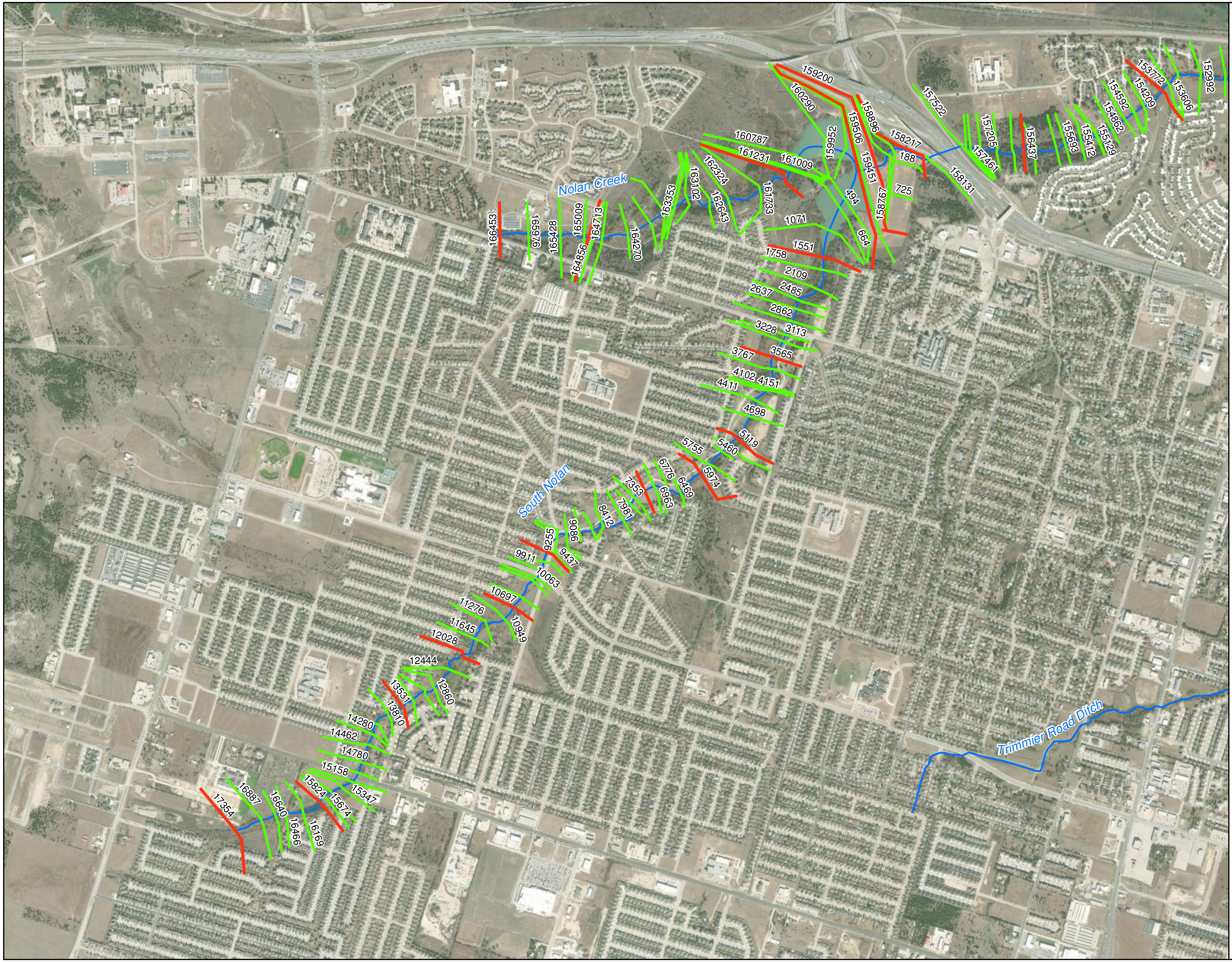

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Figure 7: Cross-section Layout Map 1 of 10

Nolan Creek
South Nolan Creek

KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

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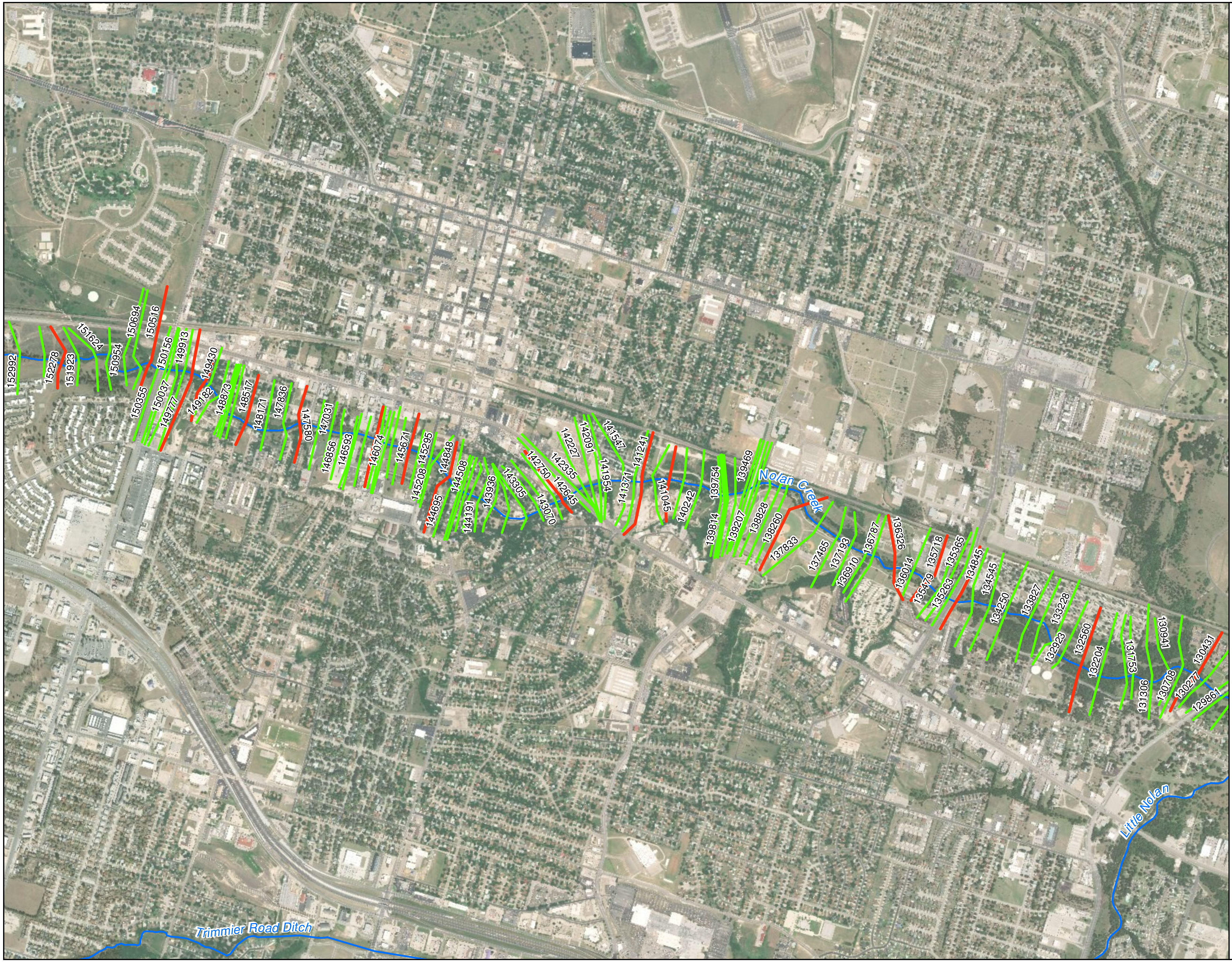
Feet



Nolan Creek Watershed Flood Protection Planning Study

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Figure 7: Cross-section Layout Map 2 of 10

Nolan Creek

KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

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Nolan Creek Watershed Flood Protection Planning Study

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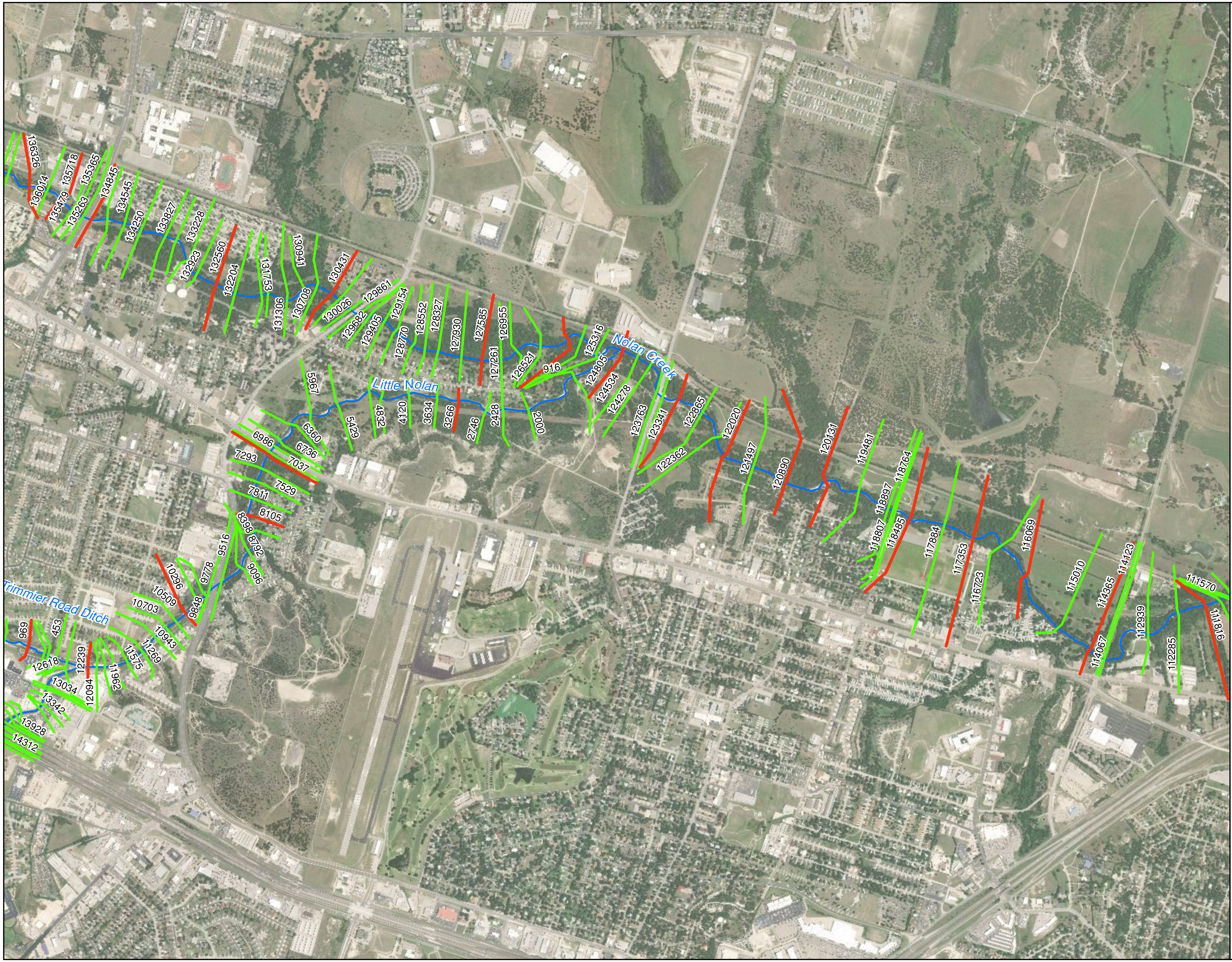

Figure 7: Cross-section Layout Map 3 of 10

Little Nolan Creek
Trimmier Road Ditch
Old Forence Ditch

KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000 Feet

Nolan Creek Watershed Flood Protection Planning Study

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Figure 7: Cross-section Layout Map 4 of 10

Nolan Creek

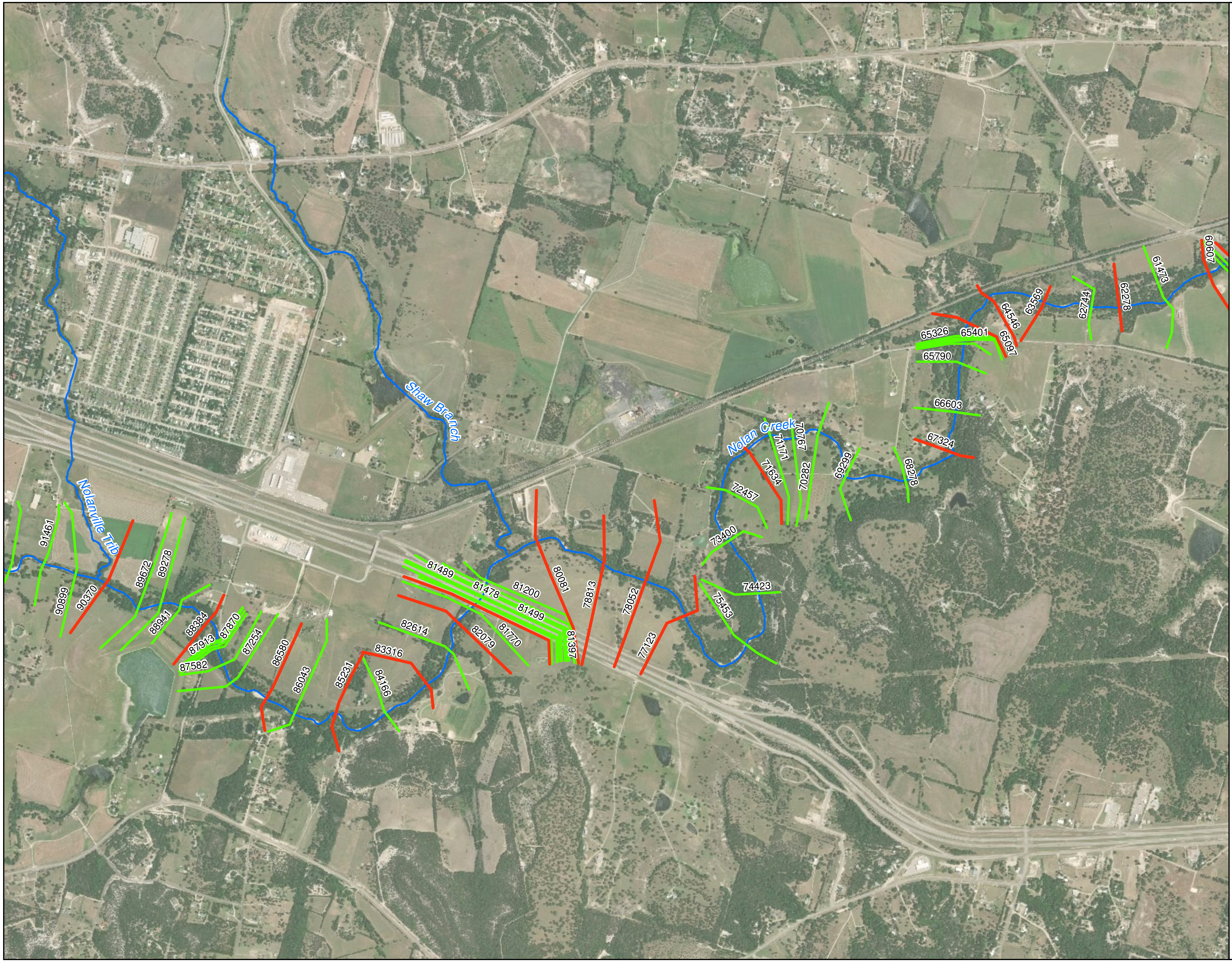
KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000 Feet



Nolan Creek Watershed Flood Protection Planning Study

CTCOG
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Figure 7: Cross-section Layout Map 5 of 10

Nolan Creek

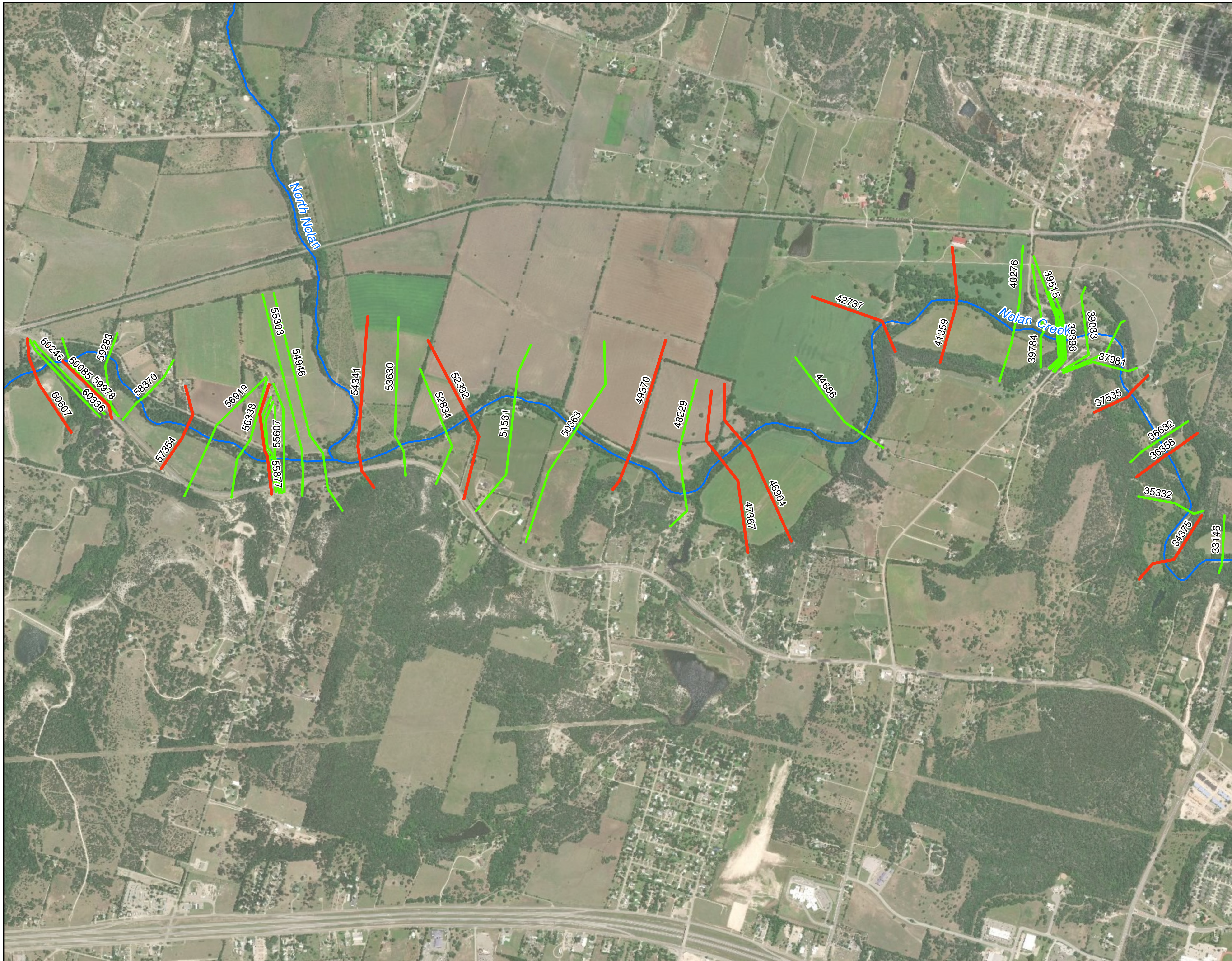
KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000 Feet



Nolan Creek Watershed Flood Protection Planning Study

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central texas council of governments

Figure 7: Cross-section Layout Map 6 of 10

Nolan Creek

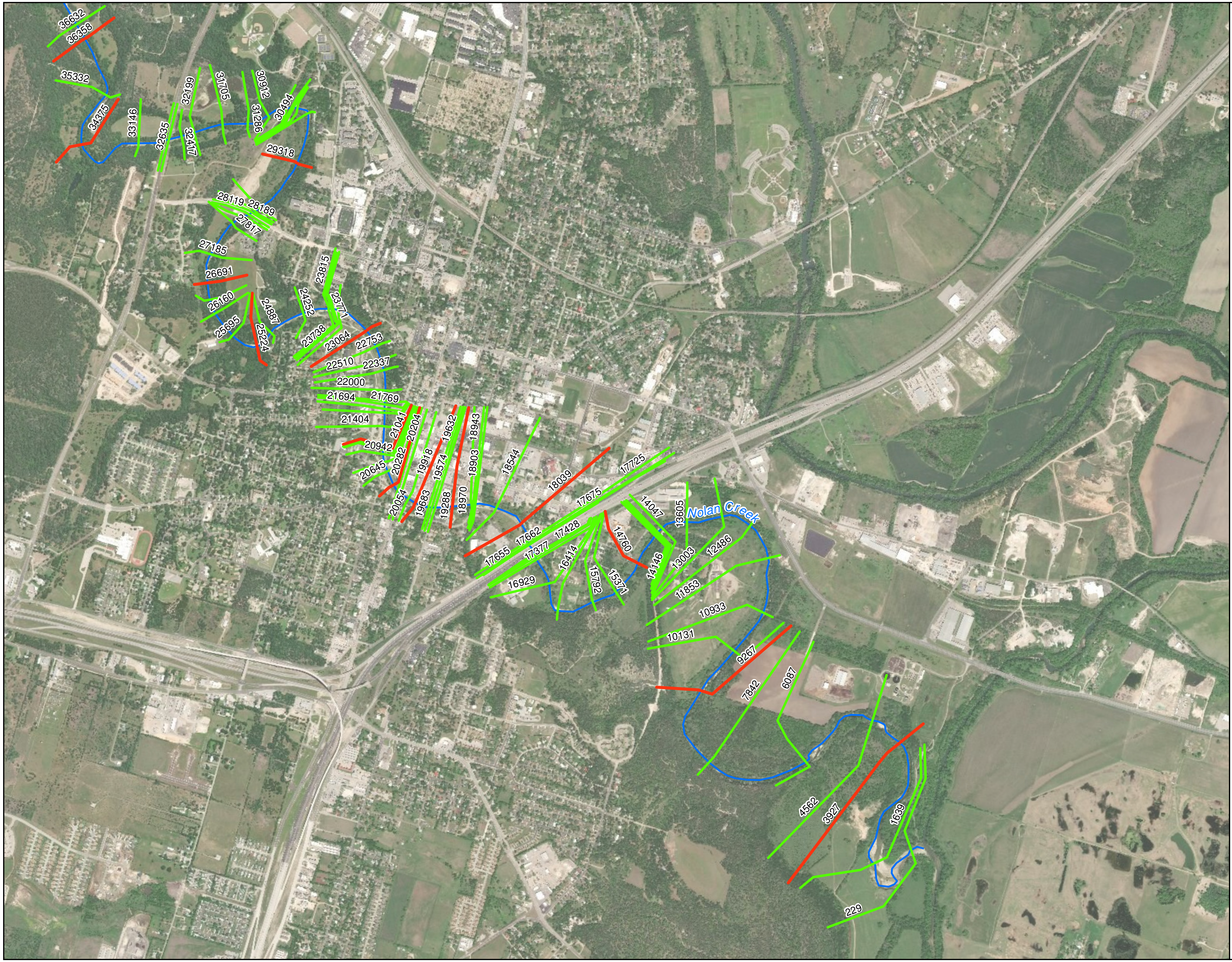
KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000 Feet



Nolan Creek Watershed Flood Protection Planning Study

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Figure 7: Cross-section Layout Map 7 of 10

Nolan Creek

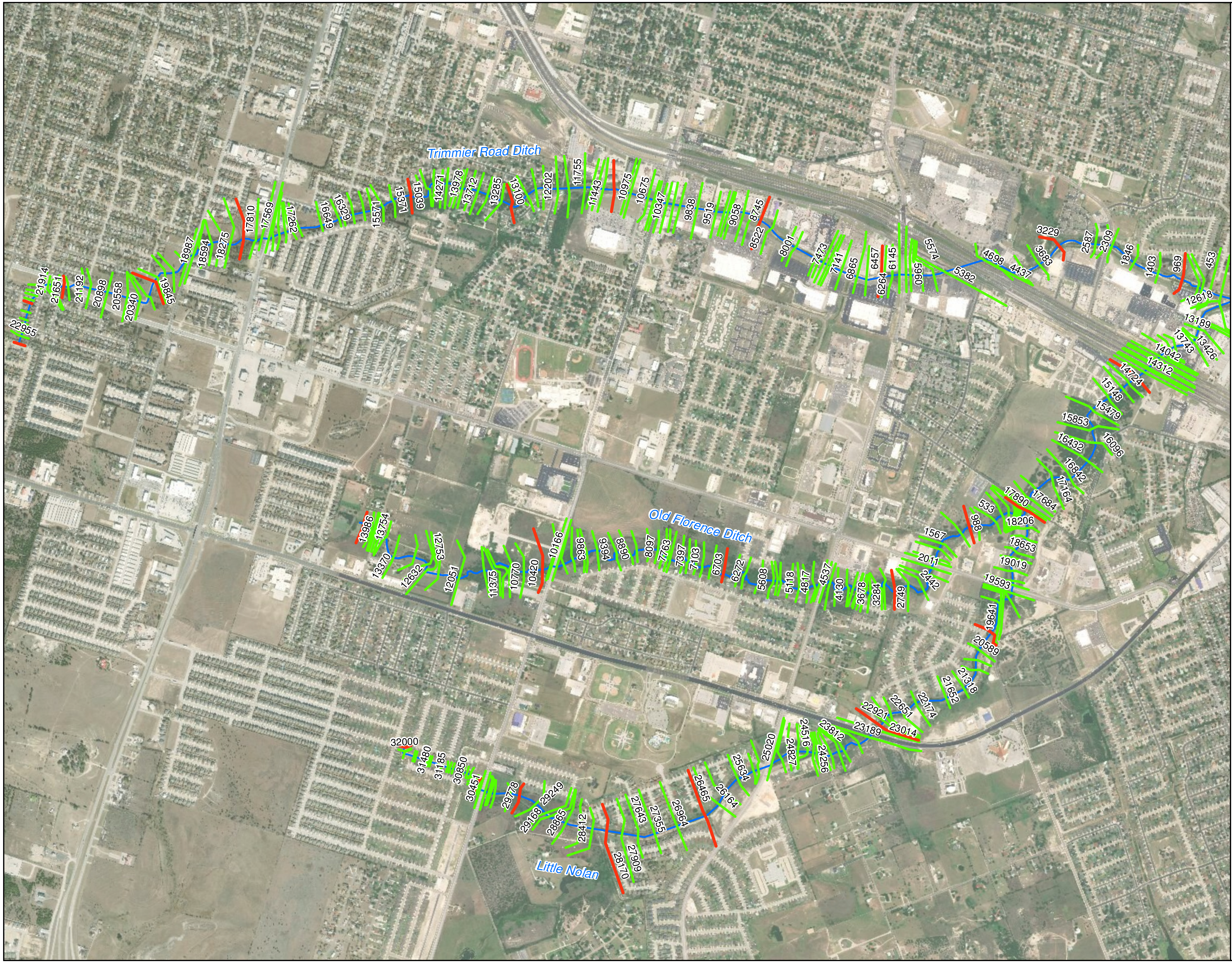
KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000 Feet



Nolan Creek Watershed Flood Protection Planning Study

Figure 7: Cross-section Layout Map 8 of 10

Little Nolan Creek
Trimmier Road Ditch
Old Forence Ditch

KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000 Feet

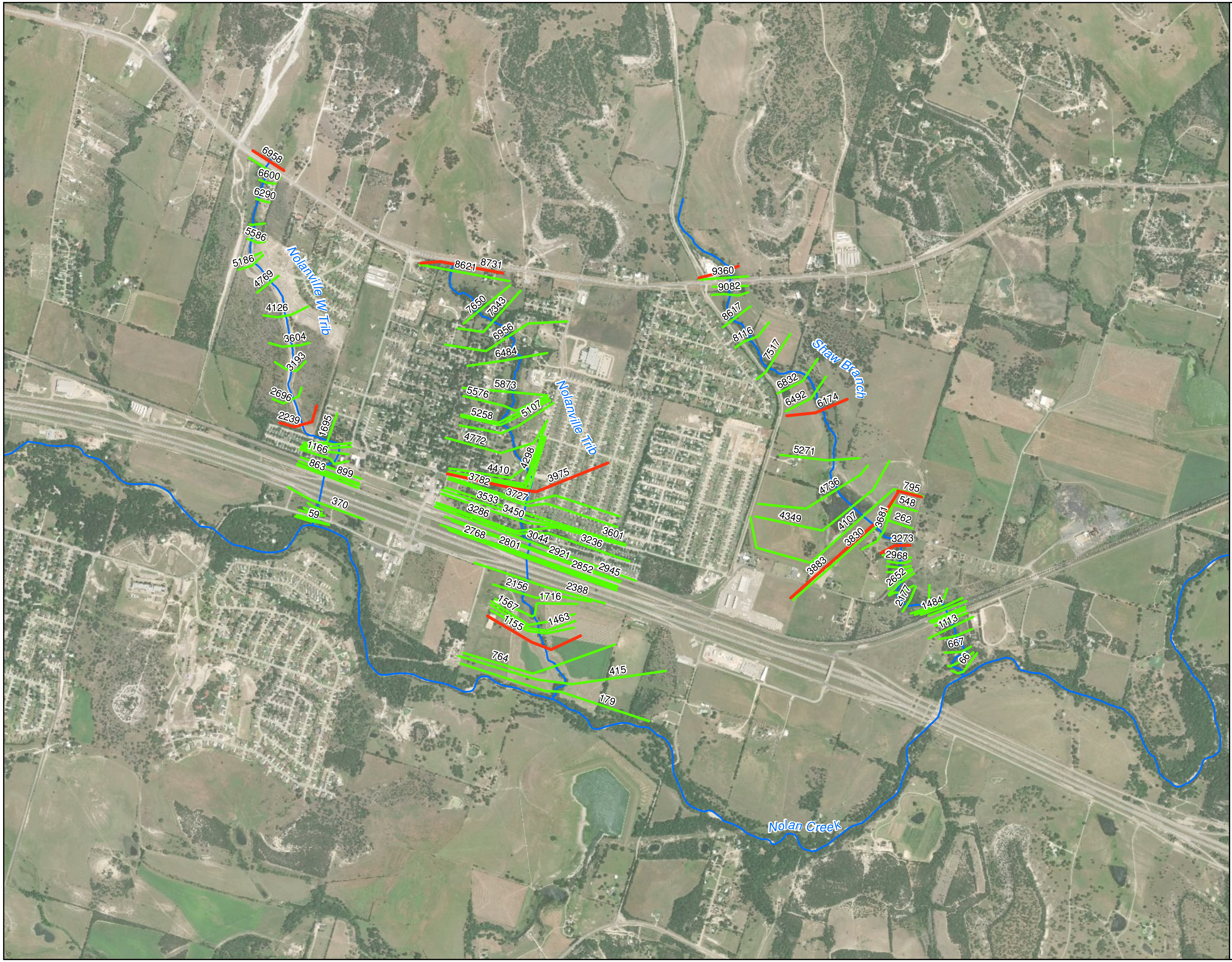


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Figure 7: Cross-section Layout Map 9 of 10

Nolanville Tributary
Nolanville West Tributary
Shaw Branch

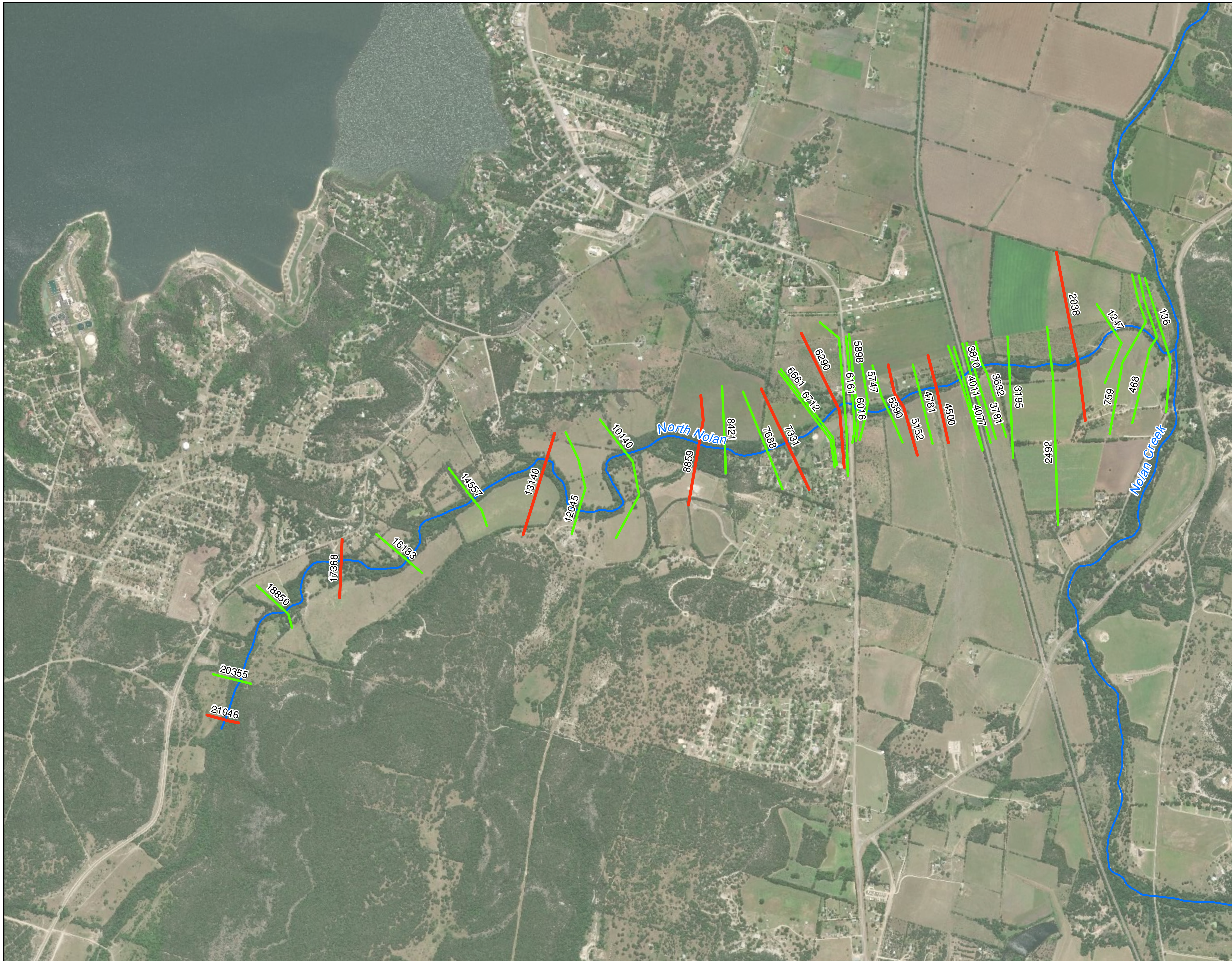
KEY TO FEATURES

- Cross-section Cutlines
- Flow Break Locations
- Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000 Feet



Nolan Creek Watershed Flood Protection Planning Study

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Figure 7: Cross-section Layout Map 10 of 10

North Nolan Creek

KEY TO FEATURES

Cross-section Cutlines
Flow Break Locations
Study Streams

SCHEIBE CONSULTING LLC

N

0 750 1,500 3,000
Feet

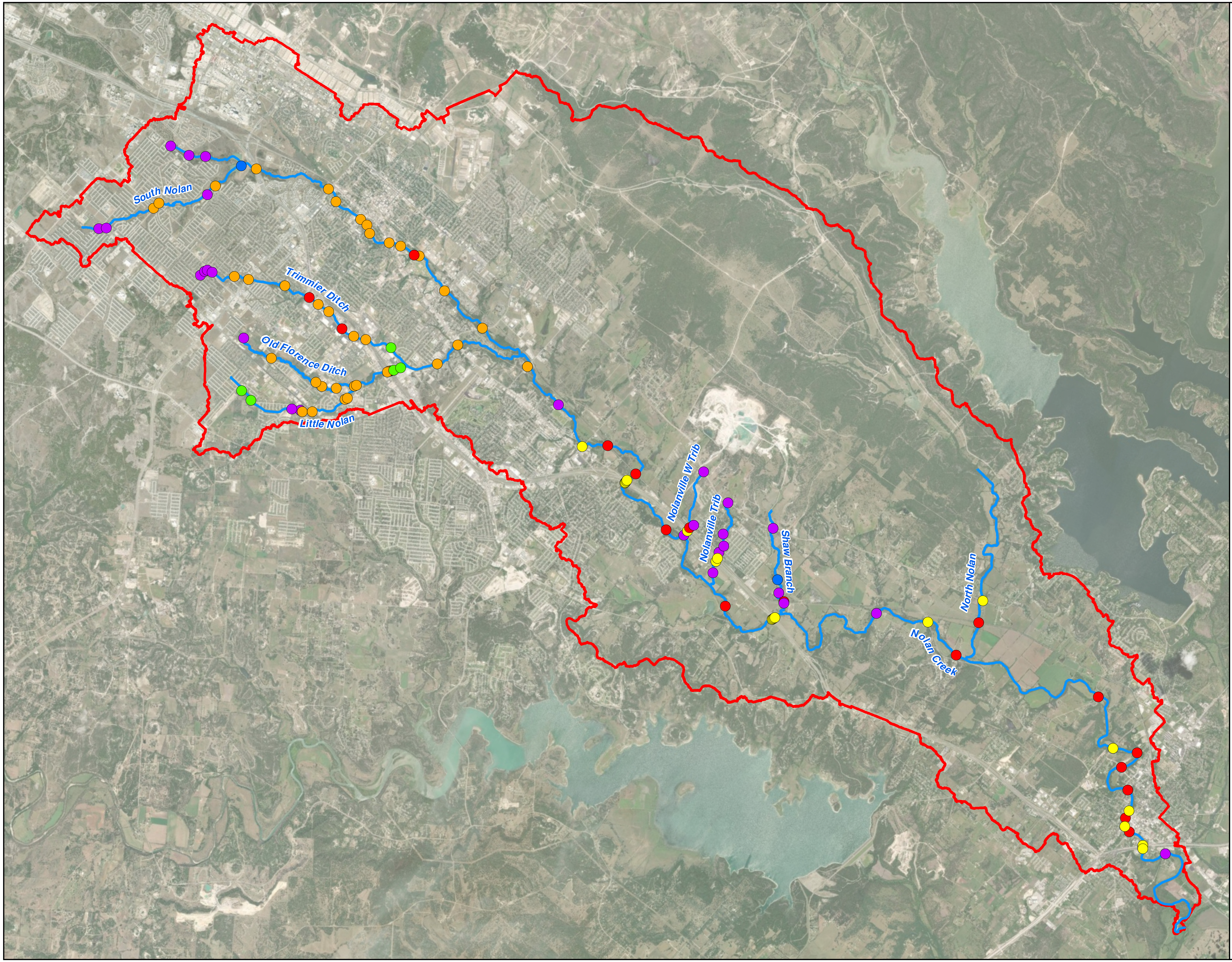

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Figure 8: Bridge/Culvert Data Sources

KEY TO FEATURES

- Study Streams
- Watershed Boundary

Data Source

- 2013 LOMR Survey
- Killeen Survey
- Map Mod Survey
- NRCS As-Built
- TXDOT As-Built
- Walker Survey

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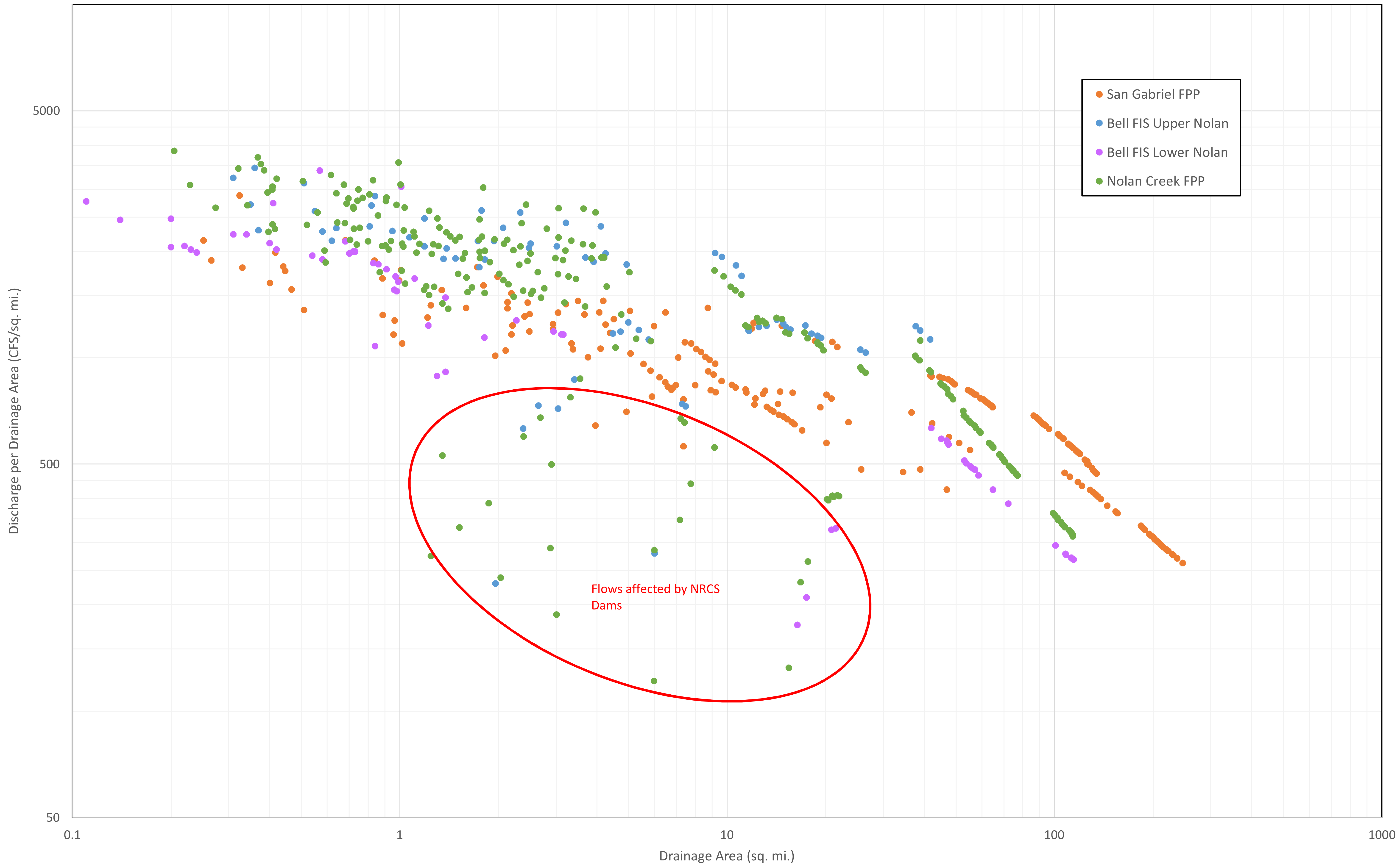
0 0.75 1.5 3 Miles

N

Figure 9: 100-yr discharge comparison to recent area studies



Nolan Creek Watershed Flood Protection Planning Study

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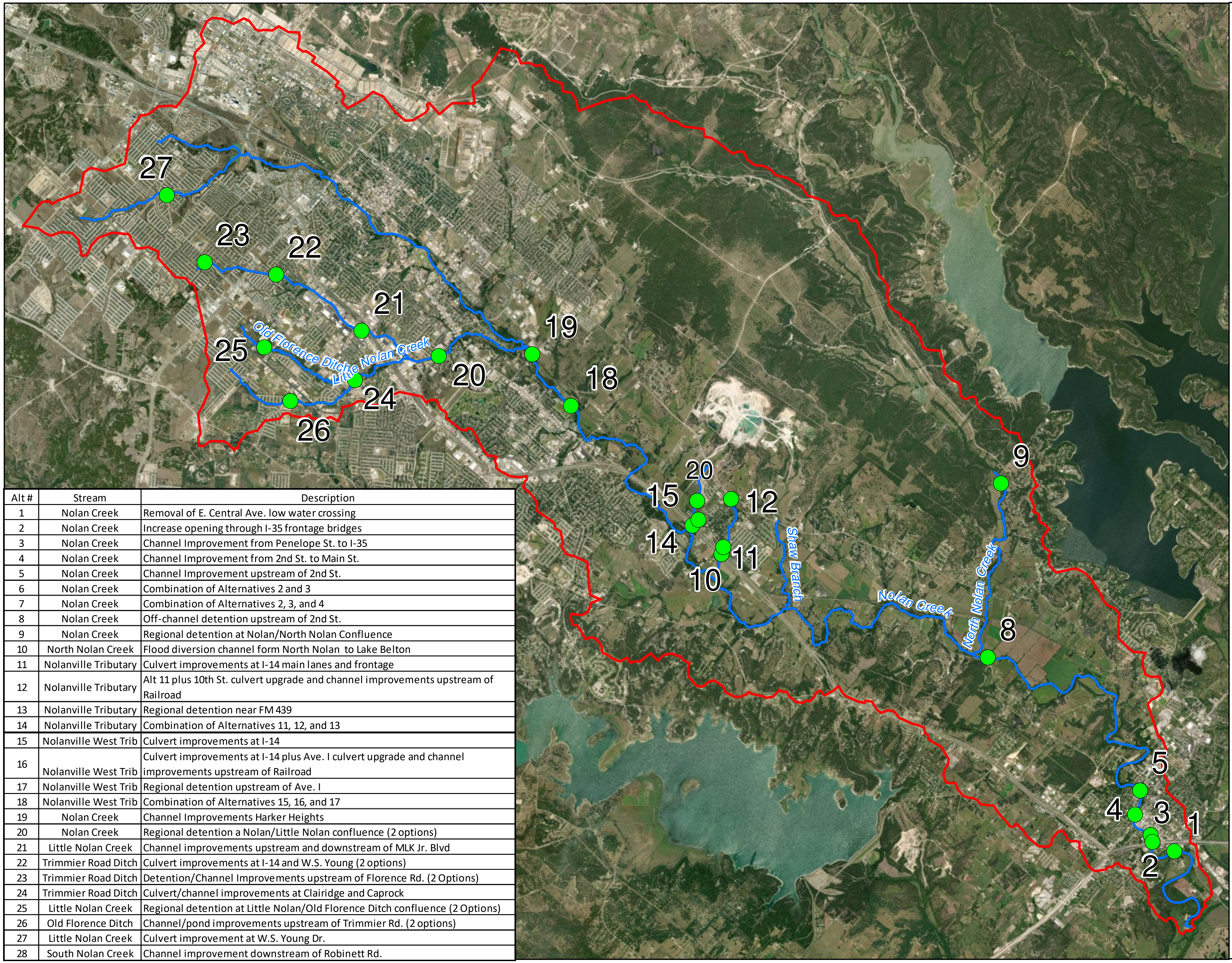
Figure 10: Location of Alternatives



Alt #	Stream	Description
1	Nolan Creek	Removal of E. Central Ave. low water crossing
2	Nolan Creek	Increase opening through I-35 frontage bridges
3	Nolan Creek	Channel Improvement from Penelope St. to I-35
4	Nolan Creek	Channel Improvement from 2nd St. to Main St.
5	Nolan Creek	Channel Improvement upstream of 2nd St.
6	Nolan Creek	Combination of Alternatives 2 and 3
7	Nolan Creek	Combination of Alternatives 2, 3, and 4
8	Nolan Creek	Off-channel detention upstream of 2nd St.
9	Nolan Creek	Regional detention at Nolan/North Nolan Confluence
10	North Nolan Creek	Flood diversion channel form North Nolan to Lake Belton
11	Nolanville Tributary	Culvert improvements at I-14 main lanes and frontage
12	Nolanville Tributary	Alt 11 plus 10th St. culvert upgrade and channel improvements upstream of Railroad
13	Nolanville Tributary	Regional detention near FM 439
14	Nolanville Tributary	Combination of Alternatives 11, 12, and 13
15	Nolanville West Trib	Culvert improvements at I-14
16	Nolanville West Trib	Culvert improvements at I-14 plus Ave. I culvert upgrade and channel improvements upstream of Railroad
17	Nolanville West Trib	Regional detention upstream of Ave. I
18	Nolanville West Trib	Combination of Alternatives 15, 16, and 17
19	Nolan Creek	Channel Improvements Harker Heights
20	Nolan Creek	Regional detention a Nolan/Little Nolan confluence (2 options)
21	Little Nolan Creek	Channel improvements upstream and downstream of MLK Jr. Blvd
22	Trimmier Road Ditch	Culvert improvements at I-14 and W.S. Young (2 options)
23	Trimmier Road Ditch	Detention/Channel Improvements upstream of Florence Rd. (2 Options)
24	Trimmier Road Ditch	Culvert/channel improvements at Clairidge and Caprock
25	Little Nolan Creek	Regional detention at Little Nolan/Old Florence Ditch confluence (2 Options)
26	Old Florence Ditch	Channel/pond improvements upstream of Trimmier Rd. (2 options)
27	Little Nolan Creek	Culvert improvement at W.S. Young Dr.
28	South Nolan Creek	Channel improvement downstream of Robinett Rd.

KEY TO FEATURES

- Alternatives
- Nolan Watershed
- Study Streams

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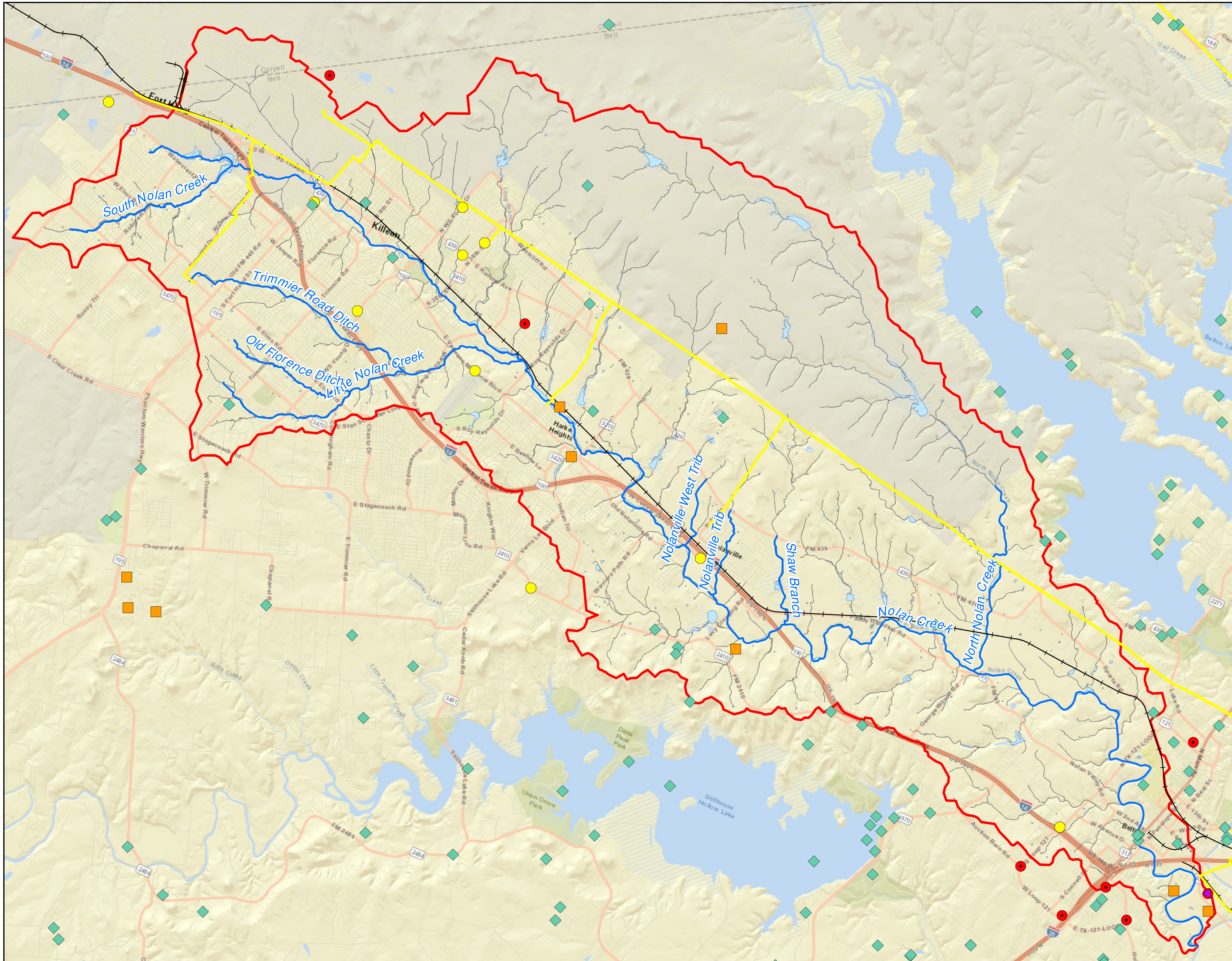
N

0 0.75 1.5 3 Miles

Nolan Creek Watershed Flood Protection Planning Study

Figure 11: Environmental Constraints Map



KEY TO FEATURES

- TWDB Water Wells
- Superfund
- TCEQ IHWCA
- MSW Sites
- TCEQ LPST
- Gas Transmission Lines
- Railroad
- Study Streams
- National Wetland Inventory
- Nolan Watershed

0 0.75 1.5 3 Miles

APPENDIX A:
HYDROLOGIC PARAMETERS

Hydrologic Parameters Summary Table

Name	Area (sq. mi.)	Area (Ac.)	AMC II	AMC I	Adjusted CN	% Imperv.	Lag time (min.)
L_NOL_010	0.2287	146.3	83	67	73	46.3	26.2
L_NOL_020	0.4156	266.0	83	68	74	46.8	43.7
L_NOL_030	0.1553	99.4	82	65	72	30.9	30.4
L_NOL_040	0.4084	261.4	81	64	70	25.0	34.5
L_NOL_050	0.3158	202.1	80	62	69	25.5	31.9
L_NOL_060	0.2983	190.9	81	64	71	40.5	34
L_NOL_070	0.2740	175.4	82	65	72	36.9	20.5
L_NOL_080	0.2310	147.8	81	64	71	35.1	29.4
L_NOL_090	0.4074	260.8	83	67	73	43.1	27.0
L_NOL_100	0.2800	179.2	83	67	73	26.8	36.4
L_NOL_110	0.6345	406.1	81	65	71	39.1	42.9
L_NOL_120	0.1037	66.3	82	66	72	36.4	19.6
L_NOL_130	0.3262	208.7	81	64	70	44.7	24.8
L_NOL_140	0.8165	522.5	80	62	69	52.9	35.2
L_NOL_150	0.2047	131.0	81	65	71	55.2	17.2
L_NOL_160	0.4345	278.1	82	65	72	43.3	32.1
L_NOL_170	0.3385	216.7	83	67	73	52.1	36.9
L_NOL_180	0.3235	207.0	84	68	75	51.6	28.8
L_NOL_190	0.4515	288.9	82	66	73	40.3	32.3
L_NOL_200	0.6003	384.2	83	68	74	58.5	33.3
L_NOL_210	0.4601	294.5	81	64	71	63.0	24.8
L_NOL_220	0.3897	249.4	82	66	72	68.8	24.3
L_NOL_230	0.6503	416.2	82	66	72	60.5	31.6
L_NOL_240	0.2820	180.5	83	68	74	52.9	28.9
L_NOL_250	0.6018	385.2	82	66	72	47.6	34.5
L_NOL_260	0.4848	310.3	82	66	73	52.6	30.3
L_NOL_270	0.3609	231.0	81	64	71	24.6	23.2
L_NOL_280	0.4424	283.1	79	61	68	24.5	29.8
N_NOL_010	0.4488	287.2	78	60	67	0.0	49.1
N_NOL_020	0.5888	376.8	79	61	68	0.0	53.7
N_NOL_030	0.1900	121.6	81	65	71	0.0	37.6
N_NOL_040	0.3820	244.5	81	64	71	4.0	37
N_NOL_050	0.2041	130.6	78	60	67	3.0	45.1
N_NOL_060	0.5646	361.3	79	61	68	2.8	48.5
N_NOL_070	1.2982	830.9	78	60	67	1.3	72.6
N_NOL_080	1.0704	685.1	79	61	68	1.1	52.5

Name	Area (sq. mi.)	Area (Ac.)	AMC II	AMC I	Adjusted CN	% Imperv.	Lag time (min.)
N_NOL_090	0.8568	548.4	79	61	68	3.9	52.7
N_NOL_100	0.3787	242.4	79	61	68	0.0	44.0
N_NOL_110	1.1869	759.6	78	60	68	4.3	46.5
N_NOL_120	0.5788	370.4	80	62	69	0.0	29.3
N_NOL_130	1.4113	903.2	78	60	67	2.4	62.4
N_NOL_140	0.8217	525.9	81	64	71	3.8	42.1
N_NOL_150	0.9978	638.6	83	67	74	3.2	45.3
N_NOL_160	1.4587	933.6	79	61	68	0.5	62.4
N_NOL_170	1.0101	646.5	78	60	67	1.5	44.4
N_NOL_180	0.6654	425.9	80	63	70	1.2	36.7
N_NOL_190	1.3079	837.1	78	60	67	1.8	52.0
N_NOL_200	1.3505	864.3	78	60	67	7.8	47.7
N_NOL_210	0.8858	566.9	77	59	66	7.9	48.3
N_NOL_220	1.2405	793.9	81	65	72	1.2	63.1
N_NOL_230	0.4208	269.3	79	61	68	0.0	43.9
N_NOL_240	0.8531	546.0	78	59	67	1.5	49.0
N_NOL_250	0.1664	106.5	75	56	64	20.4	25.3
N_NOL_260	0.6284	402.2	80	63	70	15.0	32.3
N_NOL_270	0.1593	102.0	81	64	71	7.2	23.9
N_NOL_280	0.5597	358.2	74	54	62	7.0	32.1
N_NOL_290	0.2959	189.4	71	51	59	2.6	47.1
NOL_0010	0.3851	246.5	82	66	73	52.6	22.5
NOL_0020	0.4720	302.1	80	63	70	42.3	33.4
NOL_0030	0.2446	156.5	80	63	70	25.4	16.9
NOL_0040	0.3588	229.6	81	64	71	24.2	32.2
NOL_0050	0.6468	414.0	79	61	68	35.9	37
NOL_0060	0.4294	274.8	82	66	72	53.3	29.8
NOL_0070	0.3418	218.7	80	62	69	53.2	31.2
NOL_0080	0.2642	169.1	78	59	67	60.4	14.1
NOL_0090	0.1936	123.9	74	54	62	49.1	18.9
NOL_0100	0.1922	123.0	79	61	68	28.3	19.9
NOL_0110	0.4084	261.4	81	64	71	56.8	27.2
NOL_0120	0.3996	255.8	79	61	68	78.1	24.4
NOL_0130	0.3211	205.5	80	63	70	61.5	22.2
NOL_0140	0.2957	189.2	80	63	70	65.4	14.3
NOL_0150	0.3736	239.1	80	62	69	68.4	14.4
NOL_0160	0.6311	403.9	79	62	69	51.8	21.1
NOL_0170	0.6261	400.7	80	63	70	39.7	26.4
NOL_0180	0.5877	376.1	80	62	69	51.8	22.2

Name	Area (sq. mi.)	Area (Ac.)	AMC II	AMC I	Adjusted CN	% Imperv.	Lag time (min.)
NOL_0190	0.3170	202.9	80	63	70	39.4	25.9
NOL_0200	0.2427	155.3	79	61	68	52.4	12.1
NOL_0210	0.5056	323.6	80	62	69	62.4	25.8
NOL_0220	0.2373	151.8	77	58	66	65.8	25.2
NOL_0230	0.1783	114.1	81	65	71	54.3	17.8
NOL_0240	0.2945	188.5	83	68	74	47.8	24.8
NOL_0250	0.2893	185.1	80	62	69	51.7	21.7
NOL_0260	0.4206	269.2	79	62	69	43.1	22.2
NOL_0270	0.3266	209.0	82	65	72	51.5	19.7
NOL_0280	0.2822	180.6	82	65	72	69.5	16.1
NOL_0290	0.5734	367.0	83	67	73	53.9	29.0
NOL_0300	0.3405	217.9	78	60	67	60.6	21.1
NOL_0310	0.4140	265.0	83	68	74	50.9	27.5
NOL_0320	0.4842	309.9	81	64	71	53.4	32.2
NOL_0330	0.6795	434.9	81	65	71	43.3	38.4
NOL_0340	0.2251	144.1	77	59	66	51.9	22.5
NOL_0350	0.3572	228.6	76	57	65	61.2	21.9
NOL_0360	0.3764	240.9	73	53	61	38.5	30.8
NOL_0370	0.3482	222.8	81	65	71	50.8	29.3
NOL_0380	0.3759	240.6	82	65	72	46.6	19.5
NOL_0390	0.2988	191.2	80	63	70	58.3	24.0
NOL_0400	0.2353	150.6	75	55	63	40.5	28.4
NOL_0410	0.0784	50.2	76	57	64	40.7	18.1
NOL_0420	0.4072	260.6	81	65	71	50.4	30.6
NOL_0430	0.3371	215.7	76	57	65	32.9	24.7
NOL_0440	0.4452	284.9	80	63	70	20.2	36.7
NOL_0450	0.7037	450.4	80	63	69	17.8	42.8
NOL_0460	0.1633	104.5	82	65	72	30.7	18.7
NOL_0470	0.7581	485.2	79	62	69	7.4	51.7
NOL_0480	0.2953	189.0	82	66	73	38.8	28.0
NOL_0490	0.5398	345.5	79	62	69	33.3	30.3
NOL_0500	0.4131	264.4	80	63	70	24.1	27.7
NOL_0510	0.2321	148.5	79	61	68	51.3	23.7
NOL_0520	0.5940	380.2	79	61	68	5.2	43.7
NOL_0530	0.2738	175.2	81	64	71	29.8	21.9
NOL_0540	0.1465	93.8	81	65	71	48.4	21.1
NOL_0550	0.7084	453.4	80	62	69	36.7	40.8
NOL_0560	0.5683	363.7	79	62	69	31.8	33.1
NOL_0570	0.2279	145.9	84	69	75	51.5	35.4

Name	Area (sq. mi.)	Area (Ac.)	AMC II	AMC I	Adjusted CN	% Imperv.	Lag time (min.)
NOL_0580	0.2738	175.2	73	53	61	35.2	24.8
NOL_0590	0.4492	287.5	76	57	65	26.2	23.6
NOL_0600	0.2000	128.0	75	56	64	17.3	24.8
NOL_0610	0.3685	235.9	82	66	72	28.6	16.2
NOL_0620	0.4603	294.6	78	60	67	43.3	25.8
NOL_0630	0.1778	113.8	79	61	68	40.7	20.1
NOL_0640	0.1003	64.2	79	61	68	30.5	21.7
NOL_0650	0.5446	348.6	79	62	69	7.5	40.5
NOL_0660	0.3809	243.8	79	61	68	5.3	36.7
NOL_0670	0.3272	209.4	83	67	73	46.8	24.6
NOL_0680	0.3057	195.7	83	67	73	54.7	21.0
NOL_0690	0.2699	172.7	80	63	70	20.0	16.3
NOL_0700	0.2052	131.3	71	51	59	27.8	31.2
NOL_0710	0.3540	226.5	78	60	67	26.4	26.0
NOL_0720	0.3000	192.0	75	56	63	2.9	41.1
NOL_0730	0.4116	263.4	79	62	69	41.3	32.4
NOL_0740	1.2033	770.1	79	61	68	0.1	54.0
NOL_0750	0.9450	604.8	78	60	68	6.7	47.8
NOL_0760	0.6115	391.4	76	57	65	4.5	29.0
NOL_0770	0.2493	159.5	77	58	65	5.7	32.8
NOL_0780	0.1633	104.5	80	62	69	44.2	28.2
NOL_0790	0.9745	623.7	80	63	70	53.2	36.7
NOL_0800	0.3948	252.7	81	64	71	55.2	28.6
NOL_0810	0.3020	193.3	76	57	64	44.3	29.0
NOL_0820	0.2099	134.3	76	58	65	39.5	27.0
NOL_0830	0.3974	254.4	76	57	65	25.8	29.2
NOL_0840	0.9314	596.1	80	62	69	7.5	52.9
NOL_0850	0.7101	454.4	79	62	69	15.0	38.0
NOL_0860	1.2727	814.5	78	60	67	0.2	52.3
NOL_0870	0.9543	610.8	78	60	67	1.1	47.4
NOL_0880	0.4736	303.1	80	63	70	8.4	38.2
NOL_0890	0.4870	311.7	78	60	68	11.7	27.0
NOL_0900	0.3856	246.8	76	57	65	3.1	35.1
NOL_0910	0.3048	195.1	74	54	62	18.0	21.5
NOL_0920	0.7887	504.8	77	59	66	42.3	36.0
NOL_0930	0.7056	451.6	81	64	71	17.3	40.2
NOL_0940	0.5228	334.6	79	62	69	31.8	39.5
NOL_0950	0.2185	139.8	80	63	70	10.8	20.8
NOL_0960	0.3461	221.5	81	64	71	19.4	42.8

Name	Area (sq. mi.)	Area (Ac.)	AMC II	AMC I	Adjusted CN	% Imperv.	Lag time (min.)
NOL_0970	0.6063	388.0	77	59	66	25.0	36.0
NOL_0980	0.4620	295.7	78	60	68	20.1	36.5
NOL_0990	0.5605	358.7	81	65	72	41.0	34.4
NOL_1000	0.4551	291.3	82	65	72	13.4	36.2
NOL_1010	0.3755	240.3	77	59	66	5.1	34.0
NOL_1020	0.3637	232.8	79	61	68	3.6	34.9
NOL_1030	0.1300	83.2	80	62	69	0.4	26.8
NOL_1040	0.4318	276.3	79	61	68	6.9	35.6
NOL_1050	0.3209	205.4	77	58	65	7.5	26.4
NOL_1060	0.4064	260.1	75	55	63	5.4	37.9
NOL_1070	0.4090	261.8	79	61	68	7.8	35.1
NOL_1080	0.3534	226.2	82	66	73	2.3	36.1
NOL_1090	0.9274	593.6	78	59	67	10.0	40.2
NOL_1100	0.3988	255.3	74	54	62	6.7	42.0
NOL_1110	0.3668	234.8	75	55	63	0.4	35.0
NOL_1120	0.2357	150.9	75	55	63	31.1	19.7
NOL_1130	0.4006	256.4	81	65	71	11.7	40.3
NOL_1140	0.5396	345.4	81	65	71	17.8	40.5
NOL_1150	0.6400	409.6	81	65	71	2.4	42.2
NOL_1160	0.4918	314.8	81	64	71	7.3	34.4
NOL_1170	0.4751	304.1	83	68	74	20.3	31.2
NOL_1180	0.3361	215.1	73	53	61	23.7	31
NOL_1190	0.1051	67.3	75	56	64	1.9	19.4
NOL_1200	0.3616	231.4	73	54	61	6.5	31.5
NOL_1210	0.8592	549.9	80	63	70	9.0	40.8
NOL_1220	0.9627	616.1	77	58	66	7.1	53.3
NOL_1230	0.3929	251.4	81	64	71	8.4	29.1
NOL_1240	0.5598	358.3	81	64	71	5.1	44.5
NOL_1250	0.5638	360.9	79	61	68	5.0	37.1
NOL_1260	0.3885	248.6	70	49	57	9.7	30.3
NOL_1270	0.3573	228.7	77	59	66	2.0	37.7
NOL_1280	0.3971	254.1	82	66	73	3.7	36.4
NOL_1290	0.7156	458.0	80	62	69	7.0	42.3
NOL_1300	0.1317	84.3	68	48	56	2.9	18.8
NOL_1310	0.2701	172.9	76	57	65	7.5	35.1
NOL_1320	0.8203	525.0	78	59	67	11.3	39.2
NOL_1330	0.1872	119.8	75	56	64	7.4	22.0
NOL_1340	0.9151	585.6	80	63	70	4.6	44.4
NOL_1350	0.4333	277.3	75	56	64	2.8	49.6

Name	Area (sq. mi.)	Area (Ac.)	AMC II	AMC I	Adjusted CN	% Imperv.	Lag time (min.)
NOL_1360	0.2081	133.2	70	50	58	11.5	22.4
NOL_1370	0.5342	341.9	81	64	71	5.8	28.1
NOL_1380	0.8459	541.4	74	55	63	3.4	50.1
NOL_1390	0.5542	354.7	78	59	67	5.0	40.2
NOL_1400	1.3365	855.4	82	65	72	18.6	66.2
NOL_1410	0.1847	118.2	81	65	72	14.1	29.7
NOL_1420	0.2299	147.2	74	55	63	4.3	34.9
NOL_1430	0.3851	246.5	75	56	63	1.9	37.4
NOL_1440	0.6824	436.7	78	60	67	6.1	50.5
NOL_1450	0.8242	527.5	81	65	72	8.7	54.1
NOL_1460	0.0904	57.9	71	50	58	1.2	27.5
NOL_1470	0.4147	265.4	81	65	71	8.3	40.9
NOL_1480	0.9353	598.6	79	62	69	8.9	55.9
NOL_1490	0.5159	330.2	82	66	73	21.6	32.3
NOL_1500	0.6657	426.0	79	61	68	7.0	39.0
NOL_1510	0.6101	390.5	80	63	70	31.8	39.5
NOL_1520	0.2228	142.6	78	60	67	20.8	28.8
NOL_1530	0.5208	333.3	82	66	72	19.1	35.3
NOL_1540	0.5866	375.4	80	63	70	16.9	35.2
NOL_1550	0.3704	237.1	80	63	70	26.4	34.3
NOL_1560	0.6036	386.3	81	63	70	12.6	42.4
NOL_1570	0.4238	271.2	80	62	69	19.4	23.8
NOL_1580	0.4835	309.4	78	60	67	25.5	25.5
NOL_1590	0.1606	102.8	82	65	72	24.4	22.2
NOL_1600	0.4144	265.2	77	59	66	40.0	35.3
NOL_1610	0.3395	217.3	80	63	70	43.3	27.2
NOL_1620	0.1923	123.1	81	64	70	49.5	20.9
NOL_1630	0.3945	252.5	75	55	63	44.2	26.4
NOL_1640	0.2542	162.7	80	63	70	62.1	24.2
NOL_1650	0.2234	143.0	74	54	62	51.2	21.0
NOL_1660	0.3861	247.1	76	57	64	29.9	31.0
NOL_1670	0.4964	317.7	74	55	62	22.2	37.3
NOL_1680	0.3741	239.4	69	48	56	9.2	45
NOLV_TRIB1_10	0.5887	376.8	77	59	66	3.7	35.4
NOLV_TRIB1_20	0.5979	382.7	78	61	68	38.0	34.8
NOLV_TRIB1_30	0.1624	103.9	75	56	64	35.0	19.0
NOLV_TRIB2_10	0.8837	565.6	84	69	75	47.7	53.2
NOLV_TRIB2_20	0.5220	334.1	81	63	70	31.4	32.6
SNOL_010	0.3418	218.8	82	66	72	33.9	30.6

Name	Area (sq. mi.)	Area (Ac.)	AMC II	AMC I	Adjusted CN	% Imperv.	Lag time (min.)
SNOL_020	0.4122	263.8	81	64	71	33.7	44.2
SNOL_030	0.2708	173.3	82	66	73	47.1	18.6
SNOL_040	0.2389	152.9	83	67	73	46.8	24.0
SNOL_050	0.5190	332.2	81	65	72	47.4	28.5
SNOL_060	0.3441	220.2	81	64	71	51.8	20.7
SNOL_070	0.2092	133.9	81	64	71	45.8	16.8
SNOL_080	0.3946	252.6	82	66	73	54.3	29.8
SNOL_090	0.3267	209.1	81	64	71	44.7	24.3
SNOL_100	0.2844	182.0	79	61	68	47.0	24.6
SNOL_110	0.2858	182.9	79	62	69	47.8	23.1
SNOL_120	0.2509	160.6	79	62	69	25.1	27.3

Routing Data Summary

Modified Puls Data

RLNOL_030

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
10.27	150
16.42	300
20.11	400
23.61	500
26.8	600
32.92	800
38.1	1000
61.79	2000
79.85	3000
95.46	4000
110.51	5000
125.5	6000
154.65	8000
182.35	10000
269.78	15000
357.63	20000
543.78	30000
712.56	40000

RLNOL_060

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.15	150
7.85	300
9.44	400
10.99	500
12.53	600
16.18	800
19.59	1000
36.41	2000
46.81	3000
55.07	4000
62.75	5000
70.42	6000
85.66	8000
100.56	10000
145.77	15000
199.01	20000
309.79	30000
412	40000

RLNOL_070

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
9.66	150
13.13	300
15.22	400
17.32	500
19.59	600
23.73	800
27.26	1000
47.24	2000
65.12	3000
76.32	4000
87.04	5000
96.76	6000
116.56	8000
135.09	10000
175.32	15000
218.15	20000
290.18	30000
358.44	40000

RLNOL_080

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.56	150
9.2	300
11.27	400
13.45	500
15.24	600
18.72	800
22.47	1000
41.22	2000
69.5	3000
84.15	4000
100.84	5000
115.04	6000
142.66	8000
170.27	10000
225.06	15000
282.63	20000
391.83	30000
483.21	40000

RLNOL_100

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
1.23	100
2.29	200
3.28	300
4.2	400
5.92	600
7.11	800
8.5	1000
15.87	2000
29.17	4000
39.17	6000

RLNOL_110

Routing Steps 6

Storage (ac-ft)	Discharge (cfs)
8.54	100
14.63	200
19.31	300
23.63	400
30.77	600
36.19	800
41.82	1000
70.42	2000
119.68	4000
161.5	6000

RLNOL_120

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
3.3	100
5.67	200
7.83	300
10.05	400
15.12	600
21.13	800
26.01	1000
40.29	2000
66.41	4000
88.81	6000

RLNOL_130

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
1.9	100
3.11	200
4.13	300
5.16	400
7.17	600
9.09	800
10.91	1000
21.11	2000
37.69	4000
51.69	6000

RLNOL_140

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
7.67	150
11.72	300
14.09	400
16.3	500
18.43	600
22.5	800
26.57	1000
43.55	2000
58.26	3000
73.25	4000
90.14	5000
108.79	6000
148.78	8000
201.73	10000
323.12	15000
427.32	20000
711.59	30000
1022.21	40000

RLNOL_160

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
1.59	100
2.53	200
3.37	300
4.16	400
4.91	500
5.81	600
6.72	700
7.8	800
8.85	900
9.93	1000
15.31	1500
21.04	2000
30.31	3000
41.75	4000
59.67	6000
74.29	8000
88.86	10000
102.77	12000

RLNOL_170

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
1.3	100
2.84	200
4.19	300
5.61	400
6.46	500
7.55	600
9.19	700
10.11	800
10.95	900
11.76	1000
16.01	1500
20.27	2000
28.2	3000
36.6	4000
51.3	6000
64.52	8000
74.81	10000
84.96	12000

RLNOL_180

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
2.86	100
4.74	200
6.46	300
8.12	400
9.92	500
11.54	600
13.28	700
14.89	800
16.55	900
18.45	1000
27.93	1500
38.36	2000
57.73	3000
78.59	4000
112.88	6000
145.45	8000
175.27	10000
204.22	12000

RLNOL_200

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
2.06	100
3.34	200
4.47	300
5.47	400
6.43	500
7.38	600
8.32	700
9.25	800
10.17	900
11.1	1000
16.33	1500
20.97	2000
28.52	3000
36.88	4000
62.27	6000
101.65	8000
133.14	10000
160.34	12000

RLNOL_210

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
1.86	100
2.94	200
3.87	300
4.69	400
5.45	500
6.16	600
6.83	700
7.48	800
8.11	900
8.72	1000
11.66	1500
14.26	2000
19.49	3000
27.61	4000
40.23	6000
54.96	8000
70.76	10000
91.08	12000

RLNOL_220

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
2.28	100
3.45	200
4.44	300
5.32	400
6.18	500
7.01	600
7.93	700
8.8	800
9.64	900
10.49	1000
14.66	1500
18.83	2000
27.12	3000
39.15	4000
105.63	6000
154.49	8000
195.71	10000
236.87	12000

RLNOL_230

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
1.68	100
2.66	200
3.62	300
4.42	400
5.18	500
5.93	600
6.74	700
7.5	800
8.21	900
8.9	1000
12.16	1500
15.27	2000
21.1	3000
26.84	4000
43.25	6000
60.27	8000
72.25	10000
88.36	12000

RLNOL_240

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
1.66	100
2.71	200
3.6	300
4.42	400
5.27	500
6.15	600
6.9	700
7.57	800
8.16	900
8.73	1000
11.33	1500
13.67	2000
17.86	3000
21.64	4000
28.52	6000
35.12	8000
41.59	10000
47.86	12000

RLNOL_250

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
3.79	100
6.32	200
7.76	300
9.04	400
10.23	500
12.43	600
14.45	700
23.36	800
31.15	900
38.67	1000
47	1500
57.14	2000
85	3000
108.44	4000
168.36	6000
245.88	8000
382.87	10000
511.59	12000

RLNOL_260

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
3.78	100
5.83	200
7.11	300
8.29	400
9.4	500
11.44	600
13.3	700
21.89	800
29.86	900
37.82	1000
47.05	1500
58.84	2000
81.17	3000
107.12	4000
174.98	6000
228.37	8000
340	10000
402.28	12000

RLNOL_280

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
7.38	100
11.66	200
14.11	300
16.35	400
18.49	500
22.49	600
26.54	700
44.32	800
60.6	900
81.42	1000
108.13	1500
132.16	2000
184.58	3000
232.46	4000
338.68	6000
429.87	8000
611.23	10000
788.21	12000

RNNOL_210

Routing Steps 6

Storage (ac-ft)	Discharge (cfs)
8.08	100
13.41	200
18.07	300
22.09	400
25.73	500
29.29	600
32.85	700
36.1	800
39.26	900
42.6	1000
78.95	1500
116.58	2000
153.14	3000
184.53	4000
215.65	6000
272.21	8000
325.43	10000

RNNOL_250

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
3.99	100
6.35	200
8.51	300
10.42	400
12.18	500
13.81	600
15.44	700
17.11	800
18.7	900
20.26	1000
35.53	1500
50.71	2000
66.96	3000
82.67	4000
97.31	6000
125.69	8000
154.51	10000
217.48	16000

RNNOL_270

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
2.49	100
4.14	200
5.76	300
7.16	400
8.34	500
9.45	600
10.53	700
11.55	800
12.58	900
13.55	1000
22.13	1500
29.96	2000
38.74	3000
47.85	4000
59.36	6000
83.23	8000
107.44	10000
208.83	20000

RNNOL_290

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
4.54	100
7.23	200
9.57	300
11.72	400
13.78	500
15.79	600
17.66	700
19.45	800
21.25	900
23	1000
39.88	1500
59.59	2000
77.95	3000
96.99	4000
116.64	6000
157.34	8000
194.94	10000
393.82	25000

RNOLVT1_20

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
0	0
7.76	100
13.89	200
19.05	300
24.23	400
30.33	500
37.17	600
44.95	700
53.65	800
63.8	900
75.57	1000
177.49	2000
214.09	3000

RNOLVT1_30

Routing Steps 7

Storage (ac-ft)	Discharge (cfs)
0	0
20.55	100
24.19	200
27.21	300
30.21	400
33.17	500
36.44	600
39.97	700
43.3	800
46.75	900
50.29	1000
82.82	2000
113	3000

RNOLVT2_20

Routing Steps 6

Storage (ac-ft)	Discharge (cfs)
0	0
6.76	100
12.35	200
17.56	300
22.6	400
28.05	500
33	600
38.55	700
43.6	800
48.79	900
54.54	1000
124.96	2000
168.06	3000

RNOL_0020

Routing Steps 5

Storage (ac-ft)	Discharge (cfs)
7.75	8.6
10	17.2
11.88	25.8
13.63	34.4
15.23	43
18.8	64.5
23.42	100
47.45	172
55.64	344
66.36	645
73.23	860
84.5	1290
94.29	1720
111.84	2580
128.88	3440

RNOL_0050

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
377.1	191.4
583.05	382.8
757.15	574.2
914.13	765.6
1059.63	957
1356.46	1435.5
1484.77	1914
2613.83	3828
5446.7	7656
10826.6	14355
14732.95	19140
21984.07	28710
29154.77	38280
41249.16	57420
52499.62	76560

RNOL_0080

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
0.3	10
0.9	50
1.3	100
2.1	200
2.8	300
3.9	500
6.4	1000
11	2000
25.2	5000

RNOL_0090

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
0.4	10
1.2	50
2	100
3.3	200
4.5	300
6.8	500
11.9	1000
20.5	2000
47	5000

RNOL_0100

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
7.16	191.4
12.05	382.8
16.38	574.2
20.5	765.6
24.61	957
35.48	1435.5
47.13	1914
88.71	3828
173.17	7656
288.5	14355
355.82	19140
464.52	28710
565.44	38280
740.78	57420
903.72	76560

RNOL_0160

Routing Steps 5

Storage (ac-ft)	Discharge (cfs)
0	0
12.8	50
16.6	100
22.9	200
28.1	300
37.2	500
55.6	1000
85.3	2000
155.5	5000
248.9	10000
326.5	15000

RNOL_0170

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
11.1	50
12.2	100
14.2	200
15.8	300
18.7	500
24.8	1000
34.9	2000
59.3	5000
92	10000
121.4	15000

RNOL_0190

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
13.7	50
15.1	100
17.3	200
19.1	300
22.3	500
29	1000
40.3	2000
68.5	5000
109.1	10000
153.2	15000

RNOL_0200

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
1.48	191.4
2.34	382.8
3.04	574.2
3.69	765.6
4.28	957
5.65	1435.5
6.91	1914
11.56	3828
27.85	7656
53.16	14355
72.71	19140
112.39	28710
139.1	38280
178.66	57420
217.98	76560

RNOL_0220

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
0.56	10
1.56	50
2.45	100
4.04	200
5.43	300
8.04	500
15.07	1000
36.15	2000
85.97	5000

RNOL_0230

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
3.97	191.4
6.29	382.8
8.28	574.2
10.06	765.6
11.73	957
15.54	1435.5
18.93	1914
32.74	3828
88.56	7656
161.43	14355
219.82	19140
300.84	28710
377.42	38280
509.67	57420
624.9	76560

RNOL_0250

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
4.39	191.4
6.87	382.8
8.95	574.2
10.85	765.6
12.61	957
16.59	1435.5
20.28	1914
33.63	3828
64.4	7656
143.7	14355
191.92	19140
278.7	28710
353.19	38280
479.22	57420
594.73	76560

RNOL_0280

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
0.6	10
1.8	50
3.2	100
5.5	200
7.4	300
11.2	500
22.9	1000
50.2	2000
123.4	5000

RNOL_0290

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
1.47	191.4
2.39	382.8
3.23	574.2
4	765.6
4.72	957
6.37	1435.5
7.85	1914
13.14	3828
25.51	7656
54.07	14355
84.83	19140
118.74	28710
149.21	38280
199.57	57420
240.28	76560

RNOL_0300

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
8.62	191.4
13.54	382.8
17.81	574.2
21.75	765.6
25.46	957
34.21	1435.5
42.33	1914
74.67	3828
175.51	7656
406.35	14355
573.3	19140
825.22	28710
984.84	38280
1217.05	57420
1469.2	76560

RNOL_0340

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
0.6	10
1.7	50
2.6	100
4.2	200
5.5	300
8.1	500
14.2	1000
34.4	2000
86	5000

RNOL_0350

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
0.4	10
1.2	50
1.9	100
3.3	200
4.7	300
7.8	500
15.9	1000
31.3	2000
73	5000

RNOL_0360

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
8.51	191.4
12.94	382.8
16.6	574.2
19.94	765.6
23.08	957
30.24	1435.5
36.91	1914
62.37	3828
134.46	7656
298.4	14355
423.99	19140
635.8	28710
843.61	38280
1141.66	57420
1472.77	76560

RNOL_0390

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
0.9	10
2.4	50
3.7	100
5.9	200
7.8	300
11.7	500
20.8	1000
38.4	2000
81.7	5000

RNOL_0400

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
0.4	10
1.1	50
1.9	100
3.1	200
4.2	300
6.3	500
12.2	1000
23.3	2000
63.9	5000

RNOL_0410

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
6.14	191.4
8.55	382.8
10.52	574.2
12.37	765.6
14.25	957
18.43	1435.5
22.14	1914
35.49	3828
63.85	7656
128.43	14355
208.06	19140
291.07	28710
382.53	38280
502.82	57420
605.81	76560

RNOL_0430

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
11.21	191.4
16.98	382.8
22.3	574.2
27.5	765.6
32.54	957
44.4	1435.5
55.86	1914
102.97	3828
211.92	7656
368.45	14355
473.94	19140
670.72	28710
831.43	38280
1137.25	57420
1389.24	76560

RNOL_0490

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
0	0
2.5	50
4	100
6.6	200
8.9	300
13	500
22.3	1000
39.9	2000
84.3	5000
152.8	10000

RNOL_0510

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
1.3	50
2.1	100
3.7	200
5.1	300
8	500
14.5	1000
26	2000
54.4	5000
94.3	10000

RNOL_0530

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
0.6	10
1.6	50
2.6	100
4.1	200
5.5	300
7.9	500
13.7	1000
26.1	2000
74.2	5000

RNOL_0540

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
0.6	10
1.6	50
2.6	100
4.1	200
5.5	300
7.9	500
13.7	1000
26.1	2000
74.2	5000

RNOL_0550

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
0	0
3	50
4.8	100
8.3	200
11.3	300
17.3	500
32.5	1000
64.6	2000
146.7	5000
274.1	10000

RNOL_0560

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
0	0
2.4	50
3.9	100
6.5	200
9.6	300
15.8	500
29.6	1000
59.3	2000
134.1	5000
237.1	10000

RNOL_0570

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
10.32	191.4
15.88	382.8
21.1	574.2
25.82	765.6
30.58	957
41.81	1435.5
52.8	1914
106.58	3828
246.75	7656
439.32	14355
549.72	19140
743.74	28710
896.85	38280
1206.48	57420
1458.37	76560

RNOL_0590

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
0.5	10
1.3	50
2	100
3.2	200
4.2	300
5.9	500
9.9	1000
17.6	2000
42	5000

RNOL_0600

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
7.07	191.4
10.64	382.8
13.72	574.2
16.48	765.6
19.06	957
25.22	1435.5
31.89	1914
60.75	3828
121.45	7656
253.99	14355
354.86	19140
484.2	28710
649.37	38280
910.24	57420
1103.18	76560

RNOL_0640

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.58	191.4
8.44	382.8
10.72	574.2
12.77	765.6
14.69	957
19.28	1435.5
24.18	1914
45.08	3828
98.79	7656
190.02	14355
248.71	19140
363.59	28710
465.07	38280
641.12	57420
797.74	76560

RNOL_0670

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
1.4	50
2.4	100
4.2	200
5.9	300
9.4	500
17.5	1000
31.2	2000
71.2	5000
141.4	10000
206.1	15000

RNOL_0680

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
0	0
1.3	50
2	100
3.1	200
4.1	300
5.8	500
9.6	1000
16.8	2000
46.4	5000
100.5	10000
157.1	15000

RNOL_0700

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
2.7	50
4.3	100
7	200
9.3	300
14.2	500
26.2	1000
48.1	2000
99.7	5000
169.9	10000
232.8	15000

RNOL_0720

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
0	0
2.8	50
4.8	100
7.9	200
10.6	300
16.1	500
29.6	1000
49.5	2000
95.7	5000
157	10000
210.6	15000

RNOL_0730

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.39	191.4
8.72	382.8
11.77	574.2
14.35	765.6
17.03	957
22.82	1435.5
28.04	1914
48.11	3828
115.9	7656
241.44	14355
312.52	19140
444.67	28710
560.27	38280
770.68	57420
1037.76	76560

RNOL_0780

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.54	191.4
8.63	382.8
11.21	574.2
13.5	765.6
15.63	957
20.49	1435.5
24.92	1914
39.65	3828
82.19	7656
186.17	14355
247.63	19140
360.44	28710
489.86	38280
682.38	57420
1035.4	76560

RNOL_0830

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
8.21	191.4
12.84	382.8
16.79	574.2
20.29	765.6
23.59	957
31.74	1435.5
40.36	1914
73.57	3828
144.5	7656
300.79	14355
400.81	19140
671.97	28710
1051.84	38280
1369.17	57420
2162.35	76560

RNOL_0850

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
6.85	191.4
10.5	382.8
13.62	574.2
16.71	765.6
19.24	957
24.79	1435.5
29.94	1914
51.84	3828
113.21	7656
204.64	14355
260.93	19140
378	28710
557.34	38280
783	57420
1026.53	76560

RNOL_0910

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
11.25	191.4
16.75	382.8
21.37	574.2
25.97	765.6
30.15	957
39.5	1435.5
48.99	1914
81.36	3828
156.36	7656
297.88	14355
455.7	19140
785.38	28710
1238.23	38280
1708.21	57420
2243.05	76560

RNOL_0920

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
9.71	191.4
14.92	382.8
19.07	574.2
22.82	765.6
26.27	957
34.04	1435.5
41.66	1914
64.08	3828
121.03	7656
270.34	14355
363.13	19140
506.19	28710
653.06	38280
859.11	57420
1061.56	76560

RNOL_0940

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
2.39	191.4
3.36	382.8
4.13	574.2
4.81	765.6
5.42	957
6.77	1435.5
8.42	1914
12.43	3828
25.46	7656
45.74	14355
60.04	19140
92.91	28710
120.89	38280
168.56	57420
211.32	76560

RNOL_0950

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
8.18	191.4
12.66	382.8
16.91	574.2
20.98	765.6
24.51	957
31.78	1435.5
39.52	1914
68.3	3828
168.44	7656
314.12	14355
408.19	19140
544.93	28710
683.07	38280
900.25	57420
1101.68	76560

RNOL_0970

Routing Steps 5

Storage (ac-ft)	Discharge (cfs)
15.23	191.4
23.51	382.8
30.64	574.2
37.04	765.6
43.01	957
57.3	1435.5
71.05	1914
124	3828
256.81	7656
529.11	14355
712.69	19140
999.81	28710
1245.9	38280
1693.01	57420
2092.01	76560

RNOL_0980

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
9.04	191.4
13.68	382.8
17.52	574.2
21.12	765.6
24.53	957
32.04	1435.5
39.09	1914
64.75	3828
115.79	7656
242.95	14355
347.46	19140
529.02	28710
691.18	38280
974.49	57420
1221.43	76560

RNOL_1100

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
8.72	191.4
13.58	382.8
17.64	574.2
21.38	765.6
24.91	957
33.08	1435.5
40.27	1914
64.83	3828
129.31	7656
257.52	14355
362.19	19140
524.93	28710
661.35	38280
913.06	57420
1177.93	76560

RNOL_1120

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
8.04	191.4
11.85	382.8
15.27	574.2
18.18	765.6
20.9	957
27.29	1435.5
33.42	1914
57.64	3828
109.44	7656
192.44	14355
241.85	19140
363.6	28710
483.24	38280
730.13	57420
880.87	76560
981.45	81000

RNOL_1180

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
7.5	100
12.37	200
14.75	300
16.52	400
18.4	500
20.13	600
21.78	700
23.47	800
25.06	900
26.55	1000
46.16	2000
82.31	3000
101.91	4000
130.17	5000
152.06	6000

RNOL_1190

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.85	191.4
9.29	382.8
12.2	574.2
14.82	765.6
17.27	957
22.79	1435.5
27.65	1914
43.52	3828
75.22	7656
178.27	14355
242.25	19140
346.46	28710
446.23	38280
633.54	57420
802.36	76560
838.26	81000

RNOL_1210

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
8.71	191.4
13.53	382.8
17.42	574.2
20.83	765.6
23.95	957
30.93	1435.5
37.42	1914
59.94	3828
128.16	7656
277.21	14355
395.05	19140
619.03	28710
814.59	38280
1155.22	57420
1477.19	76560
1546.65	81000

RNOL_1220

Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
13.32	191.4
21.4	382.8
27.88	574.2
33.59	765.6
38.86	957
50.76	1435.5
61.12	1914
95.39	3828
177.69	7656
347.09	14355
469.59	19140
713.09	28710
945.2	38280
1343.44	57420
1708.38	76560
1789.22	81000

RNOL_1230

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
9.47	191.4
14.95	382.8
19.45	574.2
23.52	765.6
27.37	957
36.9	1435.5
44.8	1914
71.27	3828
134.73	7656
261.94	14355
344.49	19140
519.79	28710
642.83	38280
870.78	57420
1071.64	76560
1115.54	81000

RNOL_1310
Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.11	191.4
7.93	382.8
10.38	574.2
12.57	765.6
14.59	957
19.11	1435.5
23.07	1914
36.68	3828
74.49	7656
146.81	14355
190.87	19140
278.64	28710
362.85	38280
502.25	57420
615.32	76560
640.14	81000

RNOL_1330
Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.93	191.4
9.05	382.8
11.6	574.2
13.9	765.6
16.06	957
20.99	1435.5
25.46	1914
40.56	3828
75.65	7656
167.53	14355
231.94	19140
352.67	28710
476.14	38280
686.75	57420
801.72	76560
837.02	81000

RNOL_1360
Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
8.71	191.4
13.64	382.8
17.82	574.2
21.61	765.6
25.07	957
33.04	1435.5
40.11	1914
64.22	3828
133.23	7656
274.35	14355
362.81	19140
516.57	28710
654.03	38280
908.03	57420
1109.79	76560
1157.61	81000

RNOL_1380
Routing Steps 5

Storage (ac-ft)	Discharge (cfs)
15.92	191.4
24.7	382.8
32.02	574.2
38.62	765.6
44.43	957
57.84	1435.5
69.72	1914
111.64	3828
204.09	7656
379.28	14355
513.27	19140
789.46	28710
1017.93	38280
1412.11	57420
1745.71	76560
1818.99	81000

RNOL_1390
Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
5.32	191.4
8.23	382.8
10.61	574.2
12.79	765.6
14.89	957
19.69	1435.5
24.21	1914
40.88	3828
81.79	7656
150.99	14355
199.57	19140
304.83	28710
397.47	38280
580.26	57420
768.4	76560
805.93	81000

RNOL_1420
Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
3.18	191.4
5.1	382.8
6.68	574.2
8.08	765.6
9.39	957
12.32	1435.5
14.94	1914
24.02	3828
48.55	7656
95.03	14355
129.37	19140
193.59	28710
252.71	38280
421.92	57420
570.6	76560
595.92	81000

RNOL_1430
Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
13.71	191.4
21.83	382.8
28.44	574.2
34.25	765.6
39.59	957
51.34	1435.5
61.69	1914
100.35	3828
203.92	7656
428.54	14355
602.1	19140
939.53	28710
1271.73	38280
2292.46	57420
2859.77	76560
2941.24	81000

RNOL_1480
Routing Steps 4

Storage (ac-ft)	Discharge (cfs)
17.28	191.4
25.25	382.8
31.8	574.2
37.51	765.6
42.72	957
54.89	1435.5
66.54	1914
117.44	3828
234.65	7656
447.08	14355
605.64	19140
932.62	28710
1229.25	38280
1949.45	57420
2368.04	76560
2473.67	81000

RNOL_1500	
Routing Steps	3
Storage (ac-ft)	Discharge (cfs)
8.41	191.4
13.09	382.8
17.03	574.2
20.51	765.6
23.76	957
31.23	1435.5
37.61	1914
59.51	3828
118.25	7656
218.45	14355
287.08	19140
435.9	28710
580.12	38280
872.99	57420
1232.83	76560
1370.57	81000

RNOL_1510	
Routing Steps	4
Storage (ac-ft)	Discharge (cfs)
13.81	191.4
19.93	382.8
24.84	574.2
29.16	765.6
33.08	957
41.9	1435.5
49.87	1914
79.91	3828
156.85	7656
293.2	14355
386.75	19140
579.62	28710
775.52	38280
1169.81	57420
1578.01	76560
1891.31	81000

RNOL_1520	
Routing Steps	3
Storage (ac-ft)	Discharge (cfs)
8.31	191.4
12.46	382.8
15.96	574.2
19.01	765.6
21.78	957
27.93	1435.5
33.45	1914
52.24	3828
93.49	7656
163.42	14355
208.92	19140
294.59	28710
375.3	38280
530.3	57420
686.66	76560
724.41	81000

RNOL_1600	
Routing Steps	3
Storage (ac-ft)	Discharge (cfs)
9.56	191.4
14.97	382.8
19.36	574.2
23.16	765.6
26.68	957
34.82	1435.5
42.27	1914
69.9	3828
131.45	7656
224.21	14355
298.26	19140
394.06	28710
536.97	38280
746.39	57420
957.16	76560
1002.87	81000

RNOL_1620	
Routing Steps	1
Storage (ac-ft)	Discharge (cfs)
4.13	191.4
5.97	382.8
7.46	574.2
8.76	765.6
10	957
12.71	1435.5
15.08	1914
23.4	3828
39.76	7656
73.55	14355
106.68	19140
149.54	28710
239.12	38280
292.73	57420
364.52	76560
379.96	81000

RNOL_1640	
Routing Steps	1
Storage (ac-ft)	Discharge (cfs)
2.97	191.4
4.58	382.8
5.99	574.2
7.24	765.6
8.42	957
11.15	1435.5
13.79	1914
23.7	3828
40.57	7656
66.52	14355
83.92	19140
117.77	28710
170.18	38280
269.69	57420
342.42	76560
359.59	81000

RNOL_1650	
Routing Steps	1
Storage (ac-ft)	Discharge (cfs)
3.09	191.4
5.07	382.8
7.08	574.2
8.59	765.6
10.04	957
13.41	1435.5
16.5	1914
26.14	3828
47.43	7656
81.28	14355
112.96	19140
191.07	28710
263.75	38280
421.5	57420
573.41	76560
601.66	81000

RNOL_1660	
Routing Steps	3
Storage (ac-ft)	Discharge (cfs)
7.81	191.4
12.65	382.8
16.51	574.2
19.94	765.6
23.13	957
30.24	1435.5
36.77	1914
61.11	3828
113.96	7656
212.18	14355
294.25	19140
461.55	28710
613.37	38280
768.84	57420
911.58	76560
940.58	81000

RNOL_1670

Routing Steps 5

Storage (ac-ft)	Discharge (cfs)
14.71	191.4
22.89	382.8
29.97	574.2
36.49	765.6
42.52	957
56.14	1435.5
68.78	1914
112.34	3828
194.03	7656
355.08	14355
501.42	19140
833.03	28710
1105.14	38280
1534.6	57420
1869.51	76560
1954.82	81000

RNOL_1680

Routing Steps 6

Storage (ac-ft)	Discharge (cfs)
18.82	191.4
31.33	382.8
41.99	574.2
51.64	765.6
60.54	957
81.42	1435.5
99.97	1914
163.78	3828
291.29	7656
486.76	14355
633.26	19140
969.74	28710
1385.67	38280
2049.69	57420
2694	76560
2820.73	81000

RSNOL_020

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
8.64	100
11.28	200
13.57	300
15.63	400
19.13	600
21.8	800
24.47	1000
39.35	2000
49.91	3000
56.33	4000
73.41	6000
106.12	8000

RSNOL_030

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
2.69	100
4.79	200
6.57	300
8.04	400
10.79	600
13.25	800
15.56	1000
25.86	2000
37.33	3000
47.7	4000
72.35	6000
100.45	8000
111.07	100003

RSNOL_050

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
1.96	100
3.35	200
4.78	300
6.24	400
9.02	600
11.77	800
14.58	1000
29.26	2000
42.63	3000
54.14	4000
75.02	6000
93.58	8000
109.94	10000

RSNOL_060

Routing Steps 1

Storage (ac-ft)	Discharge (cfs)
0.69	100
1.12	200
1.48	300
1.81	400
2.37	600
2.88	800
3.36	1000
8.08	2000
14.57	3000
22.1	4000
30.9	6000
39.6	8000
48.5	10000

RSNOL_070

Routing Steps 3

Storage (ac-ft)	Discharge (cfs)
3.1	100
5.3	200
7.29	300
9.31	400
13.74	600
17.43	800
21.14	1000
36.13	2000
50.71	3000
63.93	4000
88.71	6000
111.07	8000
133.9	10000

RSNOL_100

Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
1.89	100
3.39	200
4.94	300
6.25	400
8.67	600
10.82	800
12.88	1000
22.28	2000
31.18	3000
39.76	4000
56.57	6000
72.63	8000
88.37	10000
104.63	12000

RSNOL_110

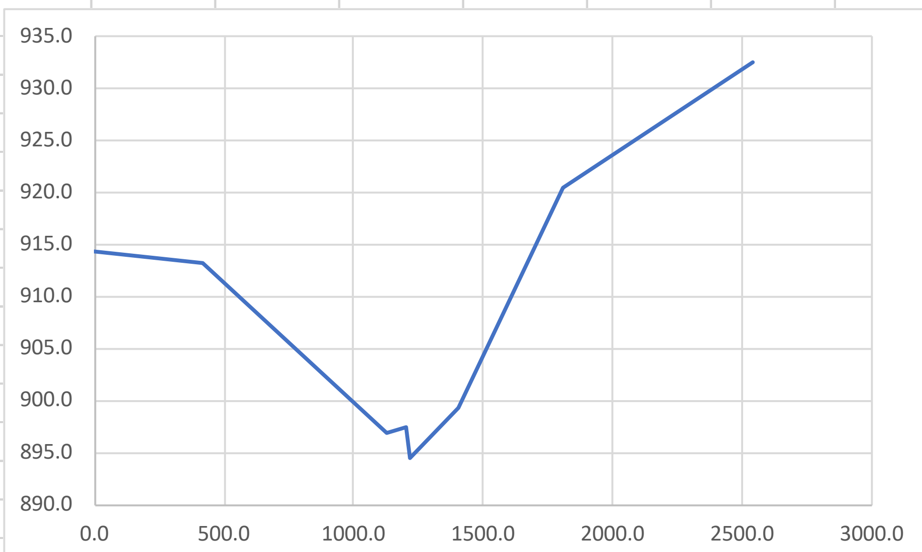
Routing Steps 2

Storage (ac-ft)	Discharge (cfs)
1.04	100
2.52	200
3.39	300
4.2	400
5.78	600
7.4	800
8.99	1000
16.3	2000
23.21	3000
29.78	4000
41.3	6000
55.06	8000
70.05	10000
87.52	12000

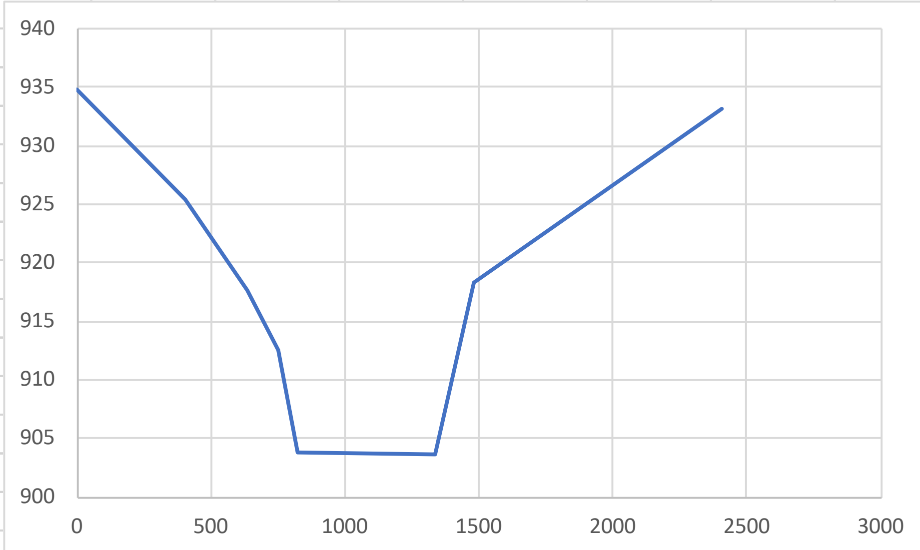
Muskingum-Cunge Data:

RLNOL_050

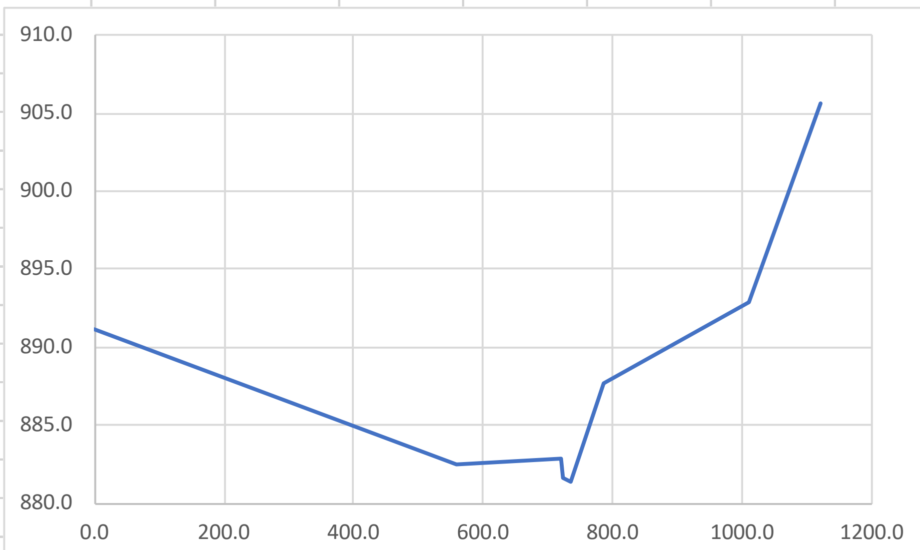
Length (ft)	3150
Slope (ft/ft)	0.008
Left n	0.06
Chan n	0.045
Right n	0.06
Sta.	Elev.
0.0	914.4
419.8	913.2
1130.6	896.9
1205.5	897.5
1217.5	894.5
1406.5	899.3
1805.3	920.4
2537.0	932.6



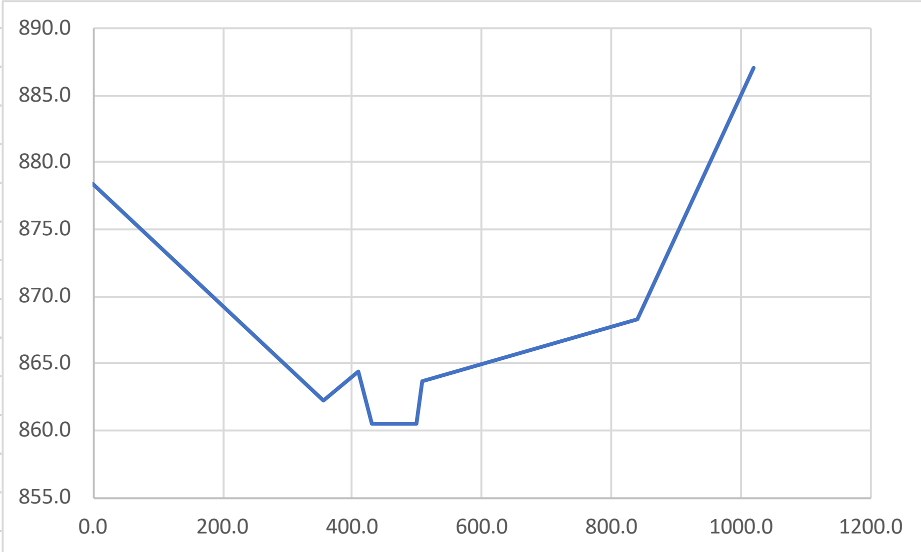
RNNOL_030	
Length (ft)	1828
Slope (ft/ft)	0.001
Left n	0.1
Chan n	0.06
Right n	0.09
Sta.	Elev.
0	934.8
404.6	925.4
638.3	917.6
749.2	912.5
821.1	903.8
1334.8	903.6
1478.5	918.4
2403.7	933.1



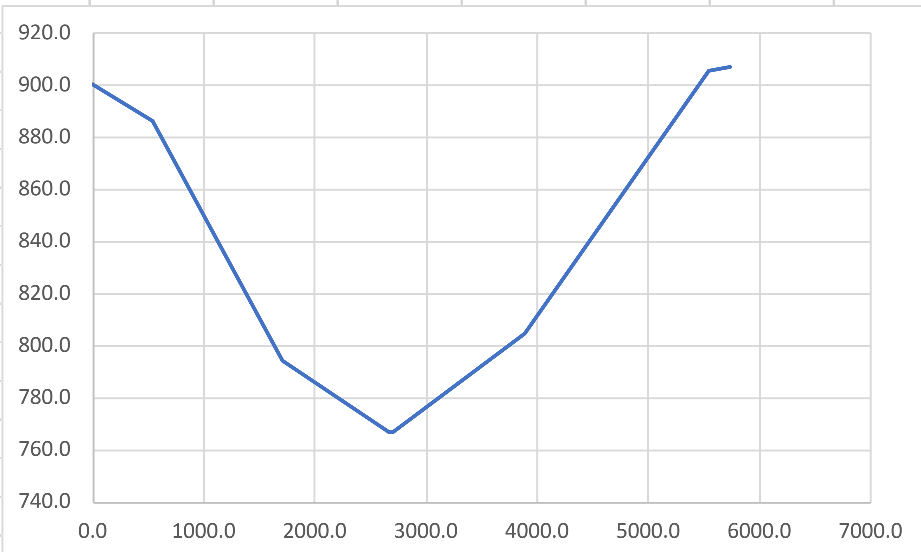
RNNOL_050	
Length (ft)	2663
Slope (ft/ft)	0.009
Left n	0.09
Chan n	0.06
Right n	0.09
Sta.	Elev.
0.0	891.1
559.9	882.4
718.6	882.8
721.5	881.6
733.5	881.4
784.4	887.7
1009.0	892.9
1119.9	905.7



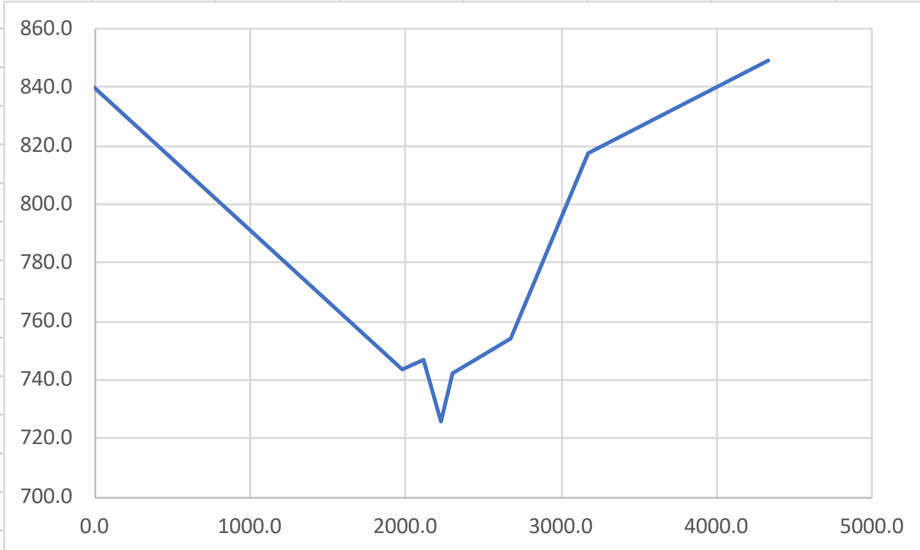
RNNOL_070	
Length (ft)	8327
Slope (ft/ft)	0.005
Left n	0.09
Chan n	0.06
Right n	0.09
Sta.	Elev.
0.0	878.4
356.6	862.2
407.6	864.4
428.6	860.5
497.5	860.5
506.5	863.7
839.1	868.3
1018.9	887.1



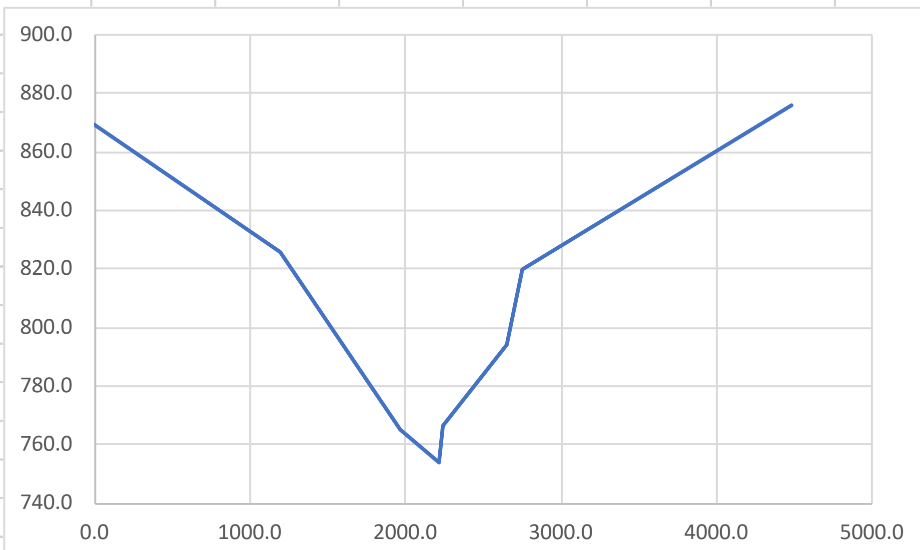
RNNOL_110	
Length (ft)	8128
Slope (ft/ft)	0.009
Left n	0.09
Chan n	0.06
Right n	0.08
Sta.	Elev.
0.0	900.2
530.9	886.6
1700.8	794.1
2663.6	766.6
2696.6	767.1
3890.5	805.0
5543.3	905.3
5735.2	906.9



RNNOL_130	
Length (ft)	10617
Slope (ft/ft)	0.003
Left n	0.08
Chan n	0.06
Right n	0.08
Sta.	Elev.
0.0	840.1
1976.9	743.7
2111.9	746.6
2225.9	725.5
2300.9	742.0
2678.9	754.1
3176.9	817.4
4334.9	849.0

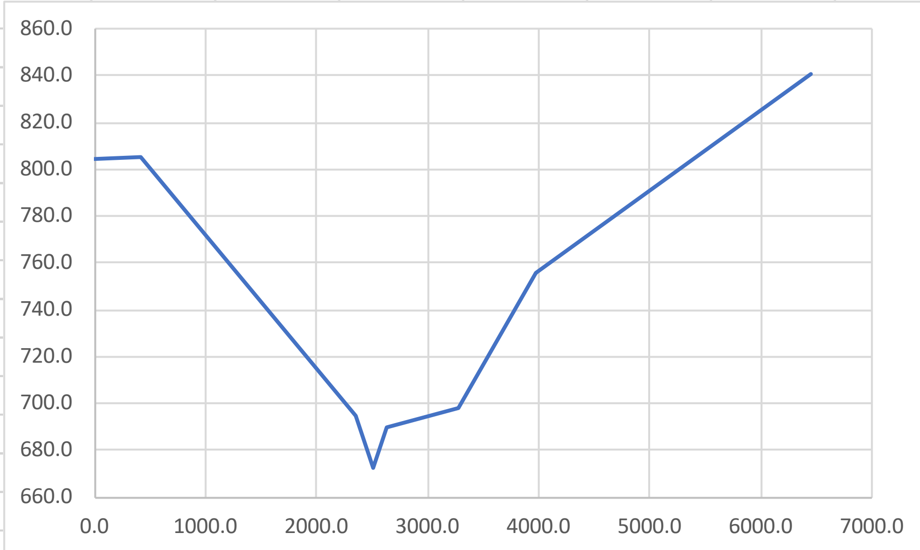


RNNOL_160	
Length (ft)	13534
Slope (ft/ft)	0.005
Left n	0.06
Chan n	0.055
Right n	0.06
Sta.	Elev.
0.0	869.4
1193.7	826.0
1961.4	765.3
2213.4	753.8
2234.4	766.2
2648.2	794.1
2750.2	820.1
4483.7	875.7



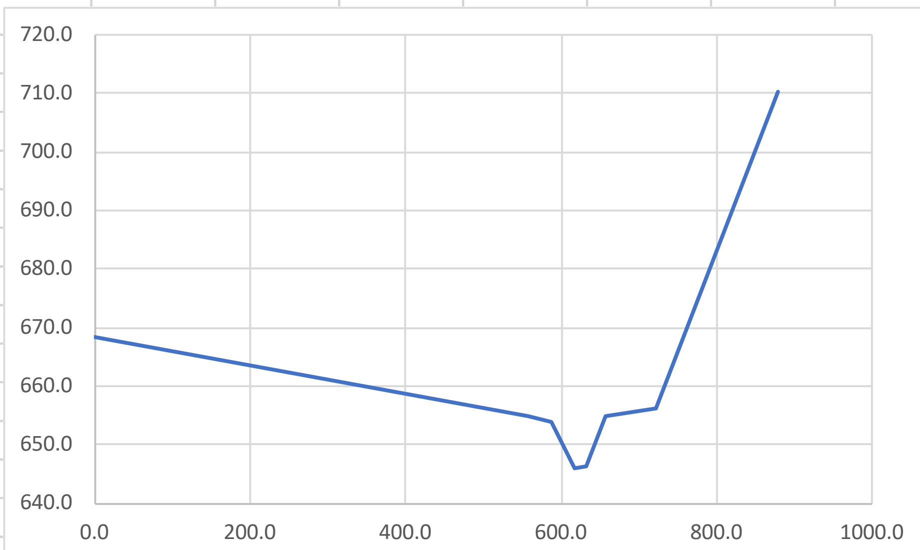
RNNOL_190

Length (ft)	6023
Slope (ft/ft)	0.006
Left n	0.08
Chan n	0.06
Right n	0.09
Sta.	Elev.
0.0	804.3
419.8	805.0
2345.0	694.3
2509.9	672.3
2626.8	690.0
3277.6	698.1
3970.3	755.5
6450.2	840.8



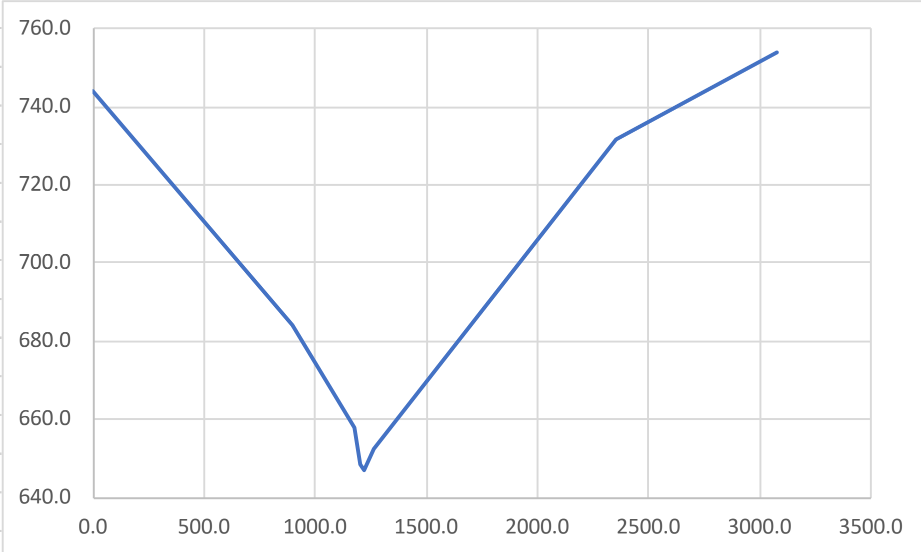
RNNOL_200

Length (ft)	6800
Slope (ft/ft)	0.004
Left n	0.1
Chan n	0.06
Right n	0.1
Sta.	Elev.
0.0	668.5
556.6	654.8
586.6	654.0
616.5	646.0
631.4	646.3
658.4	655.0
721.2	656.3
879.8	710.3



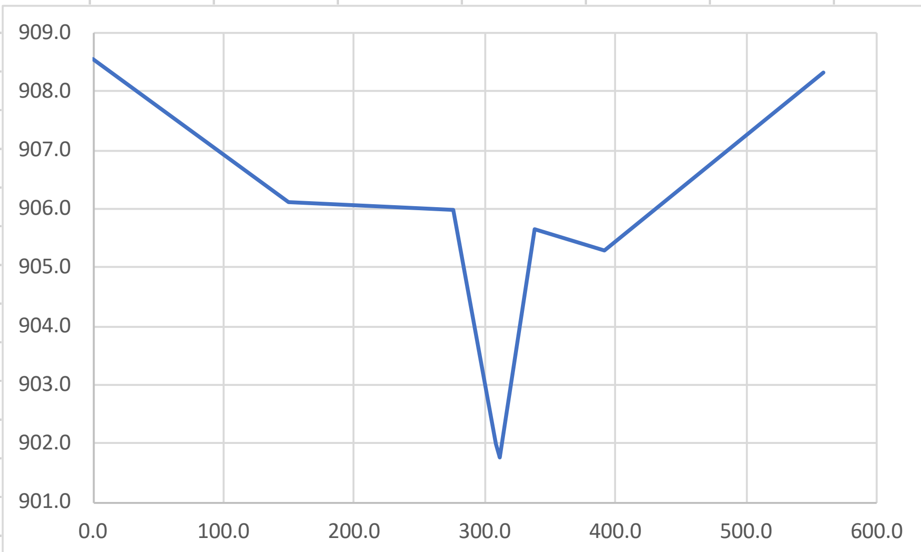
RNNOL_240

Length (ft)	8967
Slope (ft/ft)	0.008
Left n	0.08
Chan n	0.06
Right n	0.08
Sta.	Elev.
0.0	744.2
896.2	683.9
1172.0	657.9
1199.0	648.6
1223.0	646.9
1264.9	652.6
2356.0	731.5
3072.4	753.9

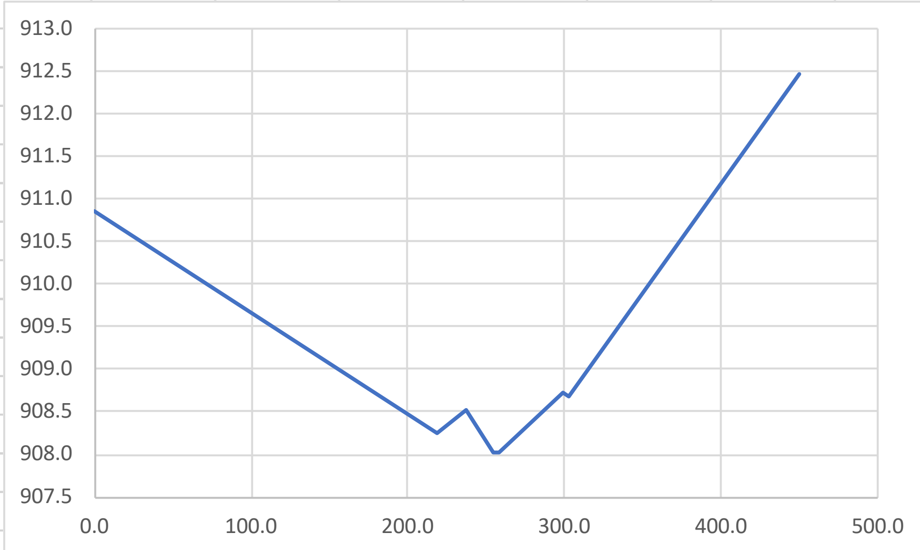


RNOL_0120

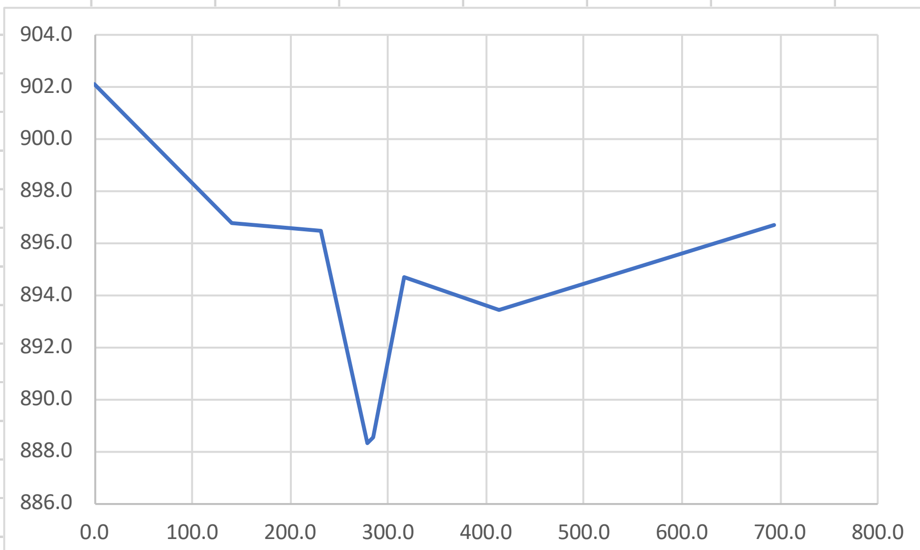
Length (ft)	2860
Slope (ft/ft)	0.009
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	908.6
149.5	906.1
275.0	906.0
307.9	902.0
310.9	901.8
337.8	905.7
391.6	905.3
559.0	908.3



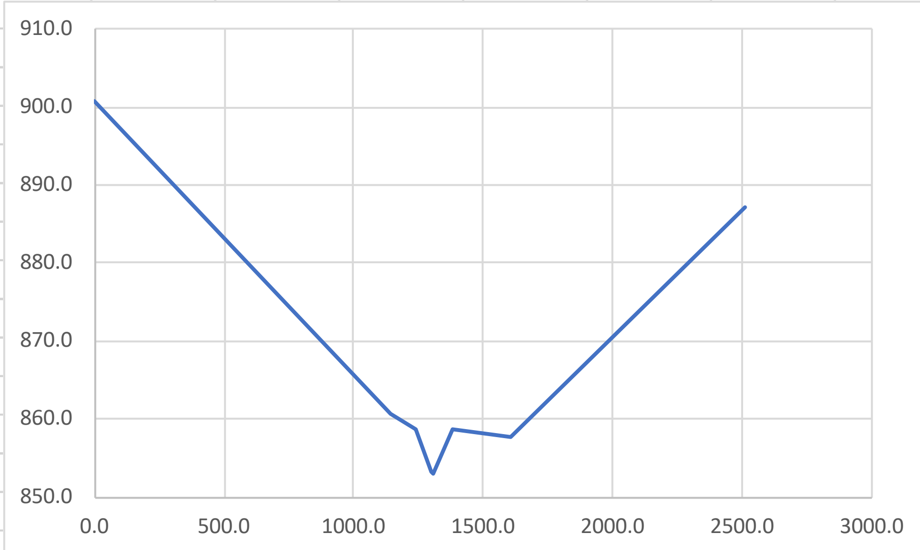
RNOL_0140	
Length (ft)	2360
Slope (ft/ft)	0.006
Left n	0.1
Chan n	0.013
Right n	0.1
Sta.	Elev.
0.0	910.9
218.6	908.2
236.6	908.5
254.6	908.0
257.6	908.0
299.5	908.7
302.5	908.7
449.3	912.5



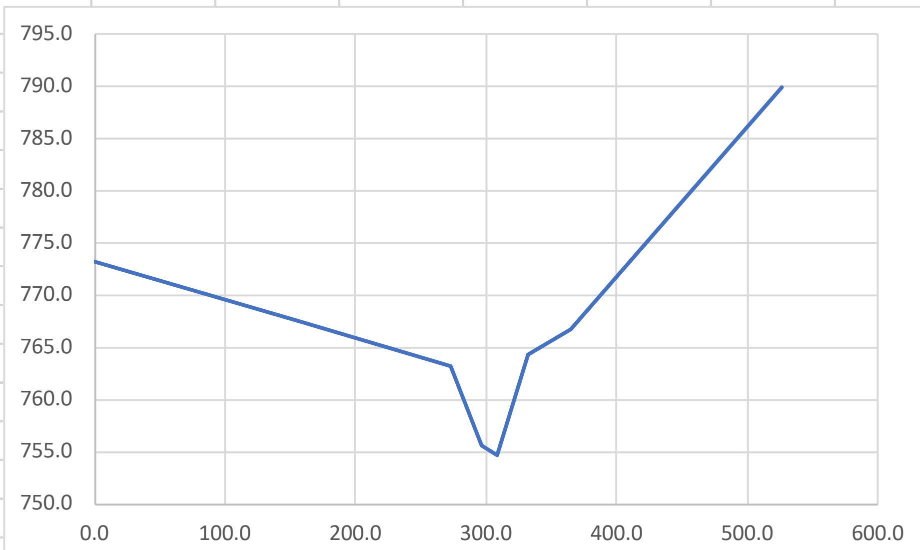
RNOL_0150	
Length (ft)	1120
Slope (ft/ft)	0.005
Left n	0.06
Chan n	0.013
Right n	0.06
Sta.	Elev.
0.0	902.1
140.5	896.8
230.2	896.5
278.0	888.3
284.0	888.5
316.8	894.7
412.5	893.4
693.5	896.7



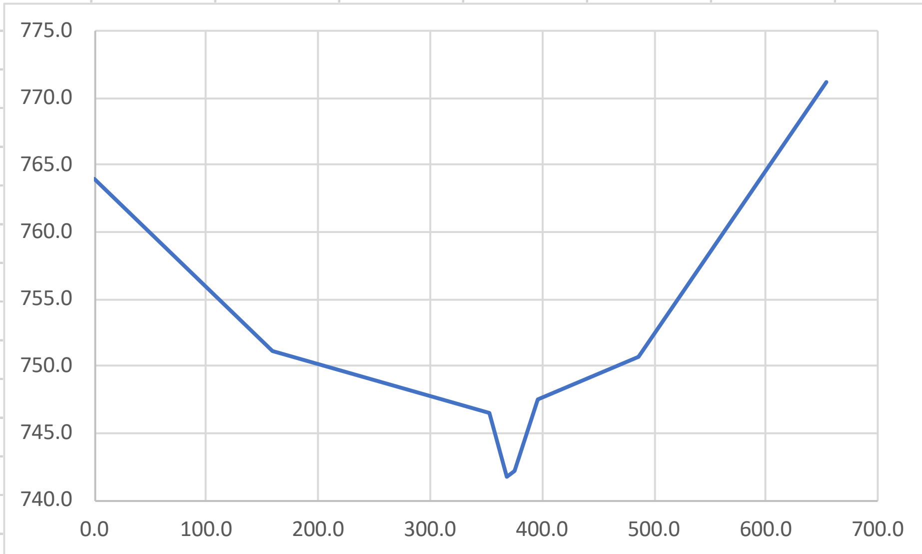
RNOL_0270	
Length (ft)	3550
Slope (ft/ft)	0.006
Left n	0.1
Chan n	0.05
Right n	0.1
Sta.	Elev.
0.0	900.7
1139.1	860.7
1241.0	858.6
1298.0	853.2
1304.0	853.0
1378.9	858.7
1606.7	857.7
2509.0	887.0



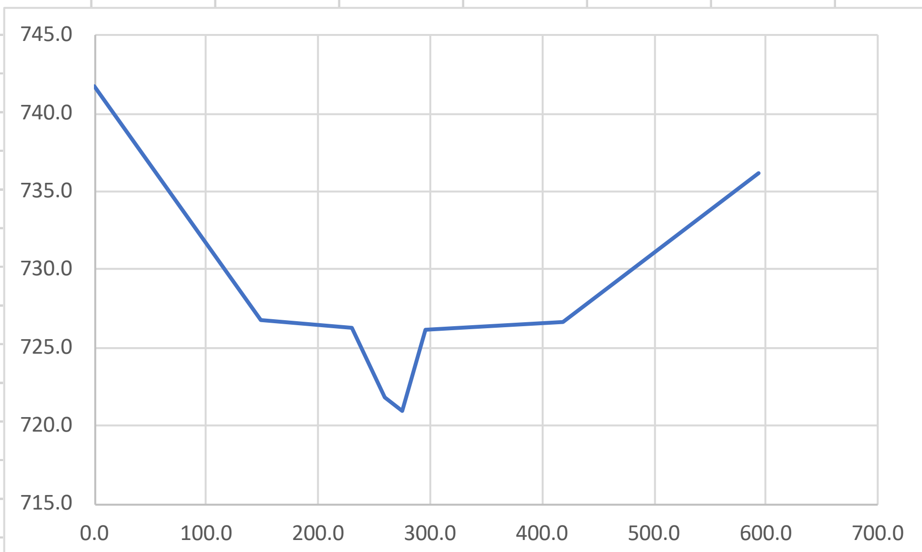
RNOL_0620	
Length (ft)	3153
Slope (ft/ft)	0.01
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	773.2
152.5	767.6
272.1	763.3
296.0	755.6
307.9	754.7
331.9	764.2
364.7	766.8
526.2	790.0



RNOL_0630	
Length (ft)	3414
Slope (ft/ft)	0.007
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	764.0
158.8	751.1
353.5	746.6
368.5	741.7
374.5	742.1
395.4	747.5
485.3	750.7
653.0	771.3

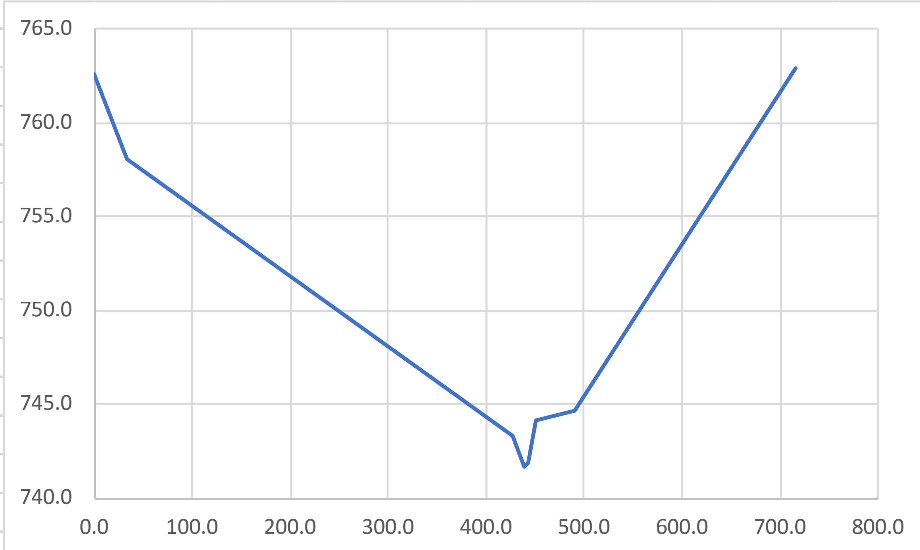


RNOL_0770	
Length (ft)	2330
Slope (ft/ft)	0.007
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	741.8
149.3	726.8
229.9	726.3
259.7	721.8
274.7	720.9
295.6	726.1
418.0	726.6
594.1	736.2



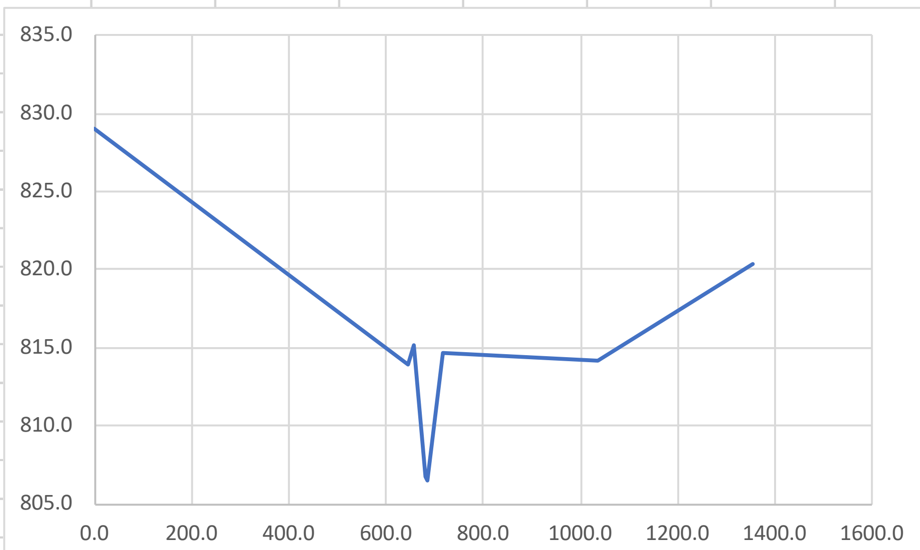
RNOL_0820

Length (ft)	4000
Slope (ft/ft)	0.007
Left n	0.05
Chan n	0.01
Right n	0.05
Sta.	Elev.
0.0	762.6
32.9	758.1
427.7	743.3
439.6	741.7
442.6	741.8
451.6	744.1
490.5	744.7
714.8	762.9

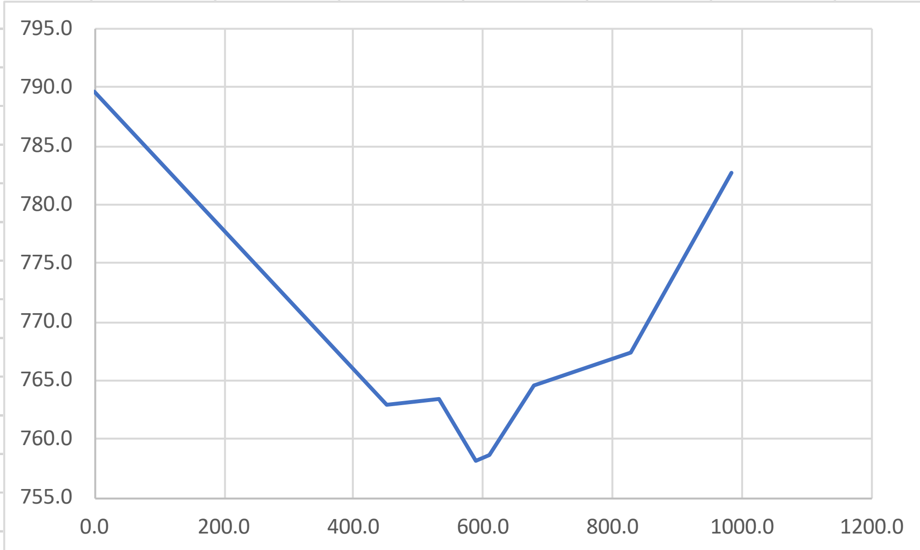


RNOL_0870

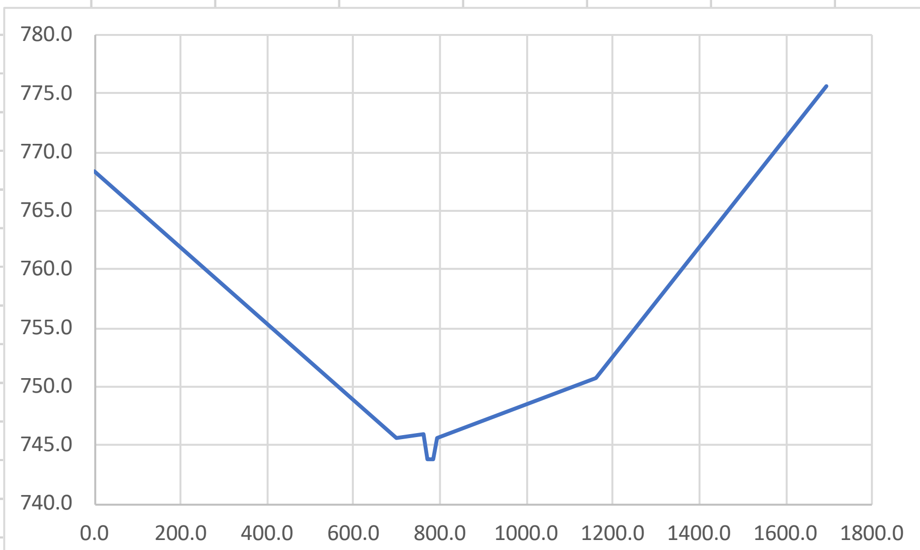
Length (ft)	6790
Slope (ft/ft)	0.007
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	829.0
643.5	813.9
658.5	815.2
682.4	806.8
685.4	806.5
718.3	814.7
1035.5	814.2
1353.1	820.4



RNOL_0890	
Length (ft)	4090
Slope (ft/ft)	0.007
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	789.6
452.2	762.9
533.0	763.4
586.9	758.2
607.9	758.6
676.7	764.6
826.5	767.3
982.2	782.7

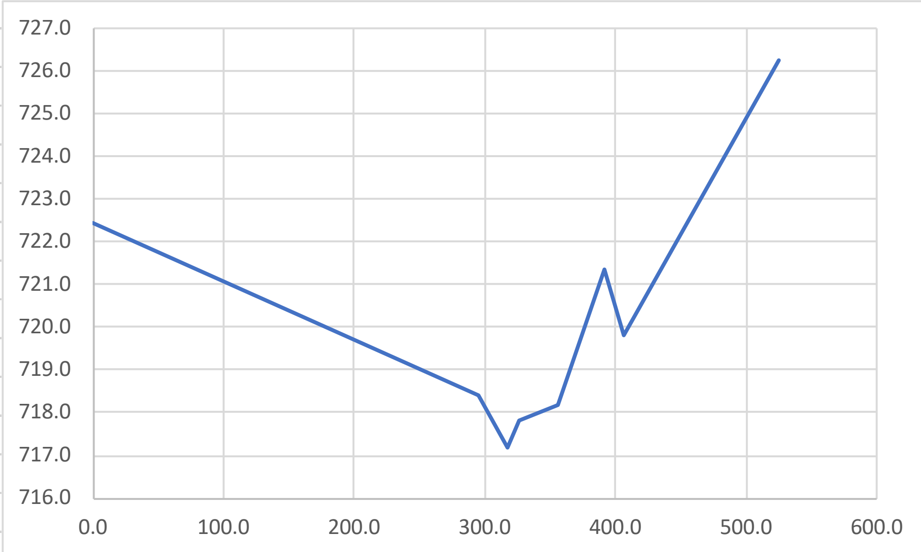


RNOL_1000	
Length (ft)	5145
Slope (ft/ft)	0.007
Left n	0.1
Chan n	0.05
Right n	0.1
Sta.	Elev.
0.0	768.5
698.0	745.6
760.9	745.9
769.9	743.9
784.9	743.8
793.9	745.7
1159.4	750.8
1692.6	775.6



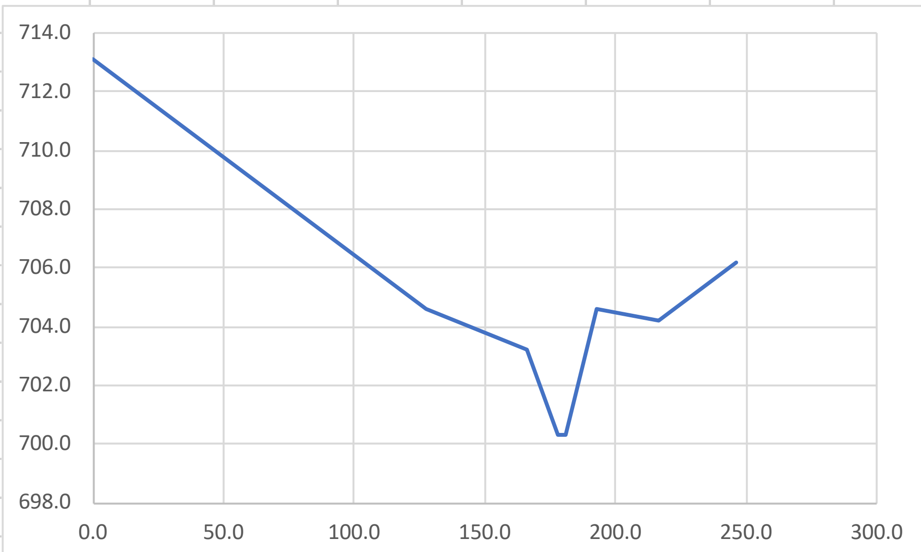
RNOL_1030

Length (ft)	2275
Slope (ft/ft)	0.007
Left n	0.1
Chan n	0.05
Right n	0.1
Sta.	Elev.
0.0	722.5
295.6	718.4
316.5	717.2
325.4	717.8
355.3	718.2
391.1	721.4
406.0	719.8
525.5	726.3

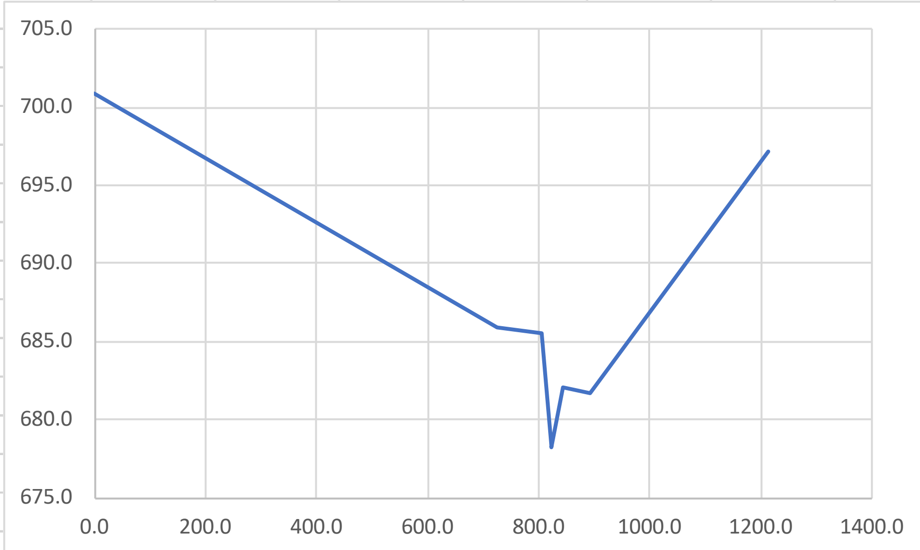


RNOL_1050

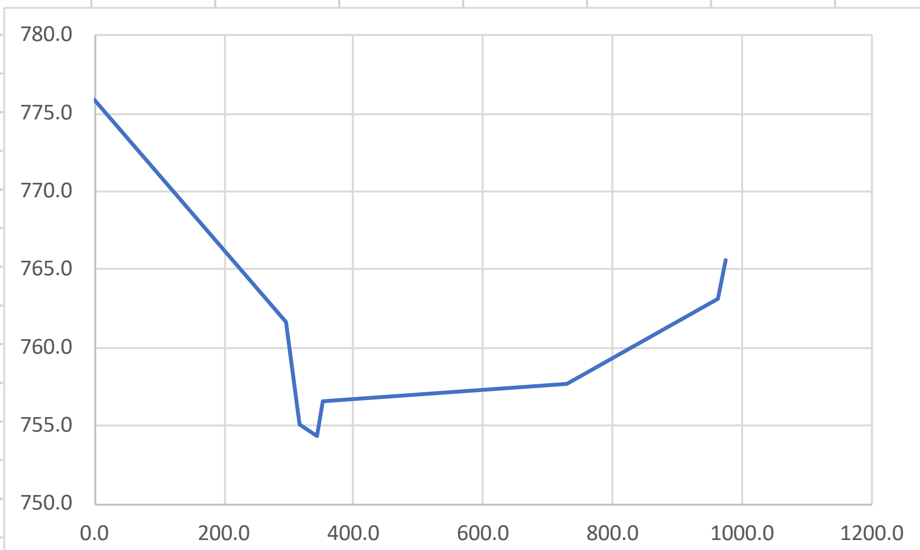
Length (ft)	3059
Slope (ft/ft)	0.007
Left n	0.1
Chan n	0.05
Right n	0.1
Sta.	Elev.
0.0	713.1
127.7	704.6
166.3	703.2
178.1	700.3
181.1	700.3
193.0	704.6
216.7	704.2
246.4	706.2



RNOL_1070	
Length (ft)	2802
Slope (ft/ft)	0.006
Left n	0.1
Chan n	0.05
Right n	0.1
Sta.	Elev.
0.0	700.9
725.2	685.9
806.1	685.5
821.1	678.4
824.1	678.3
845.0	682.1
893.0	681.7
1213.6	697.1

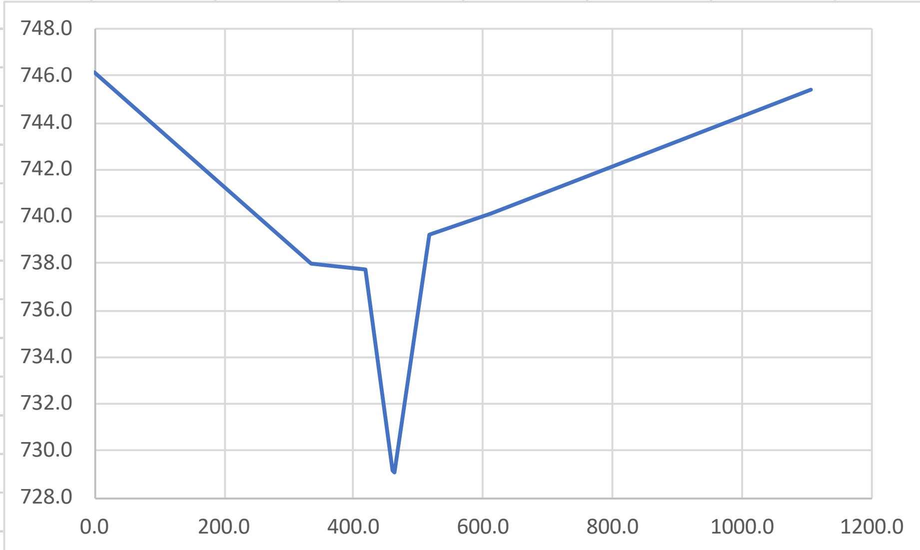


RNOL_1150	
Length (ft)	5967
Slope (ft/ft)	0.007
Left n	0.06
Chan n	0.055
Right n	0.06
Sta.	Elev.
0.0	775.9
296.6	761.6
317.5	755.1
344.5	754.3
353.5	756.6
727.9	757.7
961.5	763.2
973.5	765.6



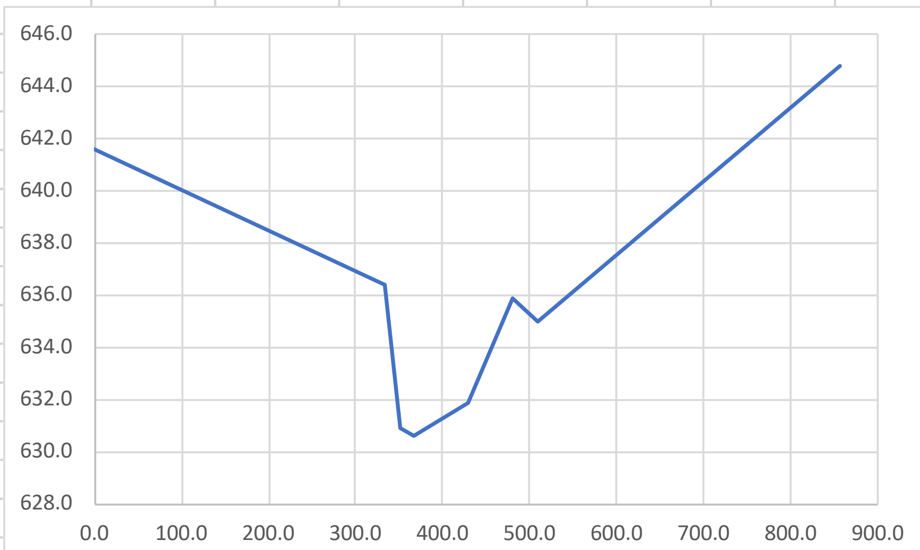
RNOL_1160

Length (ft)	5967
Slope (ft/ft)	0.003
Left n	0.06
Chan n	0.055
Right n	0.06
Sta.	Elev.
0.0	746.1
335.3	738.0
419.2	737.8
461.1	729.2
464.1	729.1
518.0	739.2
613.8	740.1
1104.8	745.4



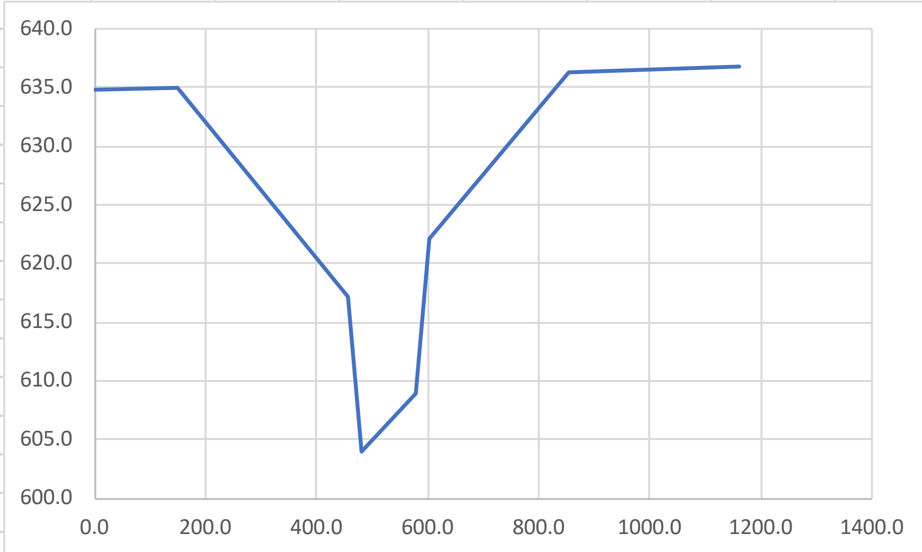
RNOL_1270

Length (ft)	3770
Slope (ft/ft)	0.015
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	641.6
332.9	636.4
350.9	630.9
365.9	630.6
428.9	631.9
479.7	635.9
509.5	635.0
855.7	644.8



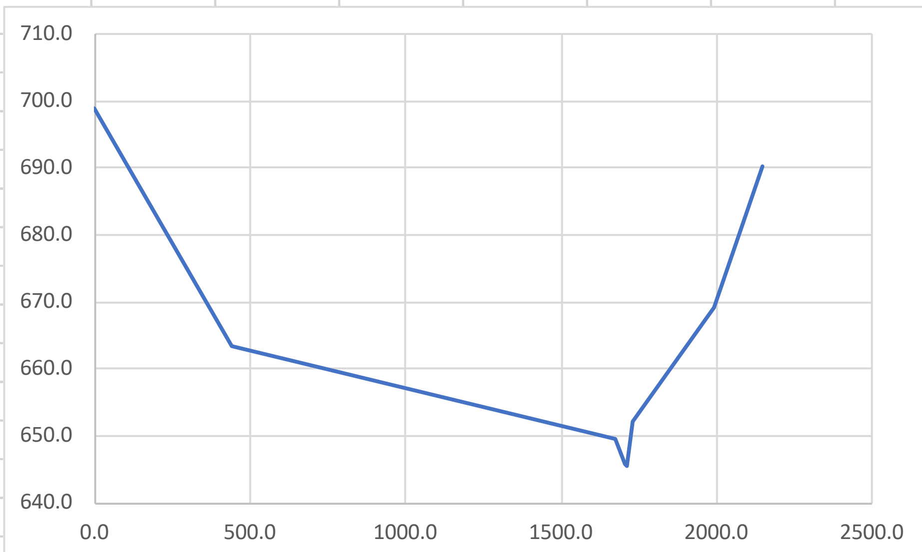
RNOL_1300

Length (ft)	1338
Slope (ft/ft)	0.014
Left n	0.06
Chan n	0.05
Right n	0.06
Sta.	Elev.
0.0	634.8
149.6	634.9
457.9	617.2
481.8	603.9
577.6	609.0
601.5	622.1
852.9	636.4
1161.2	636.8

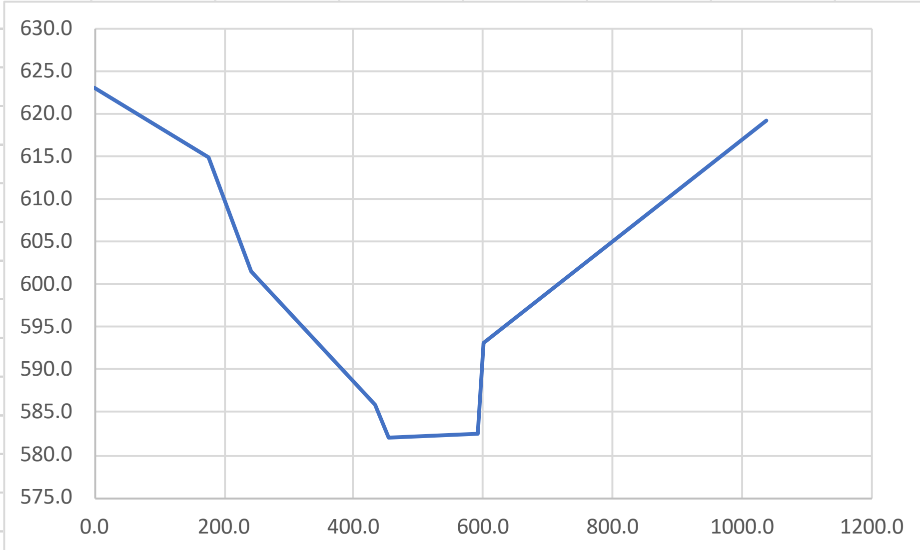


RNOL_1350

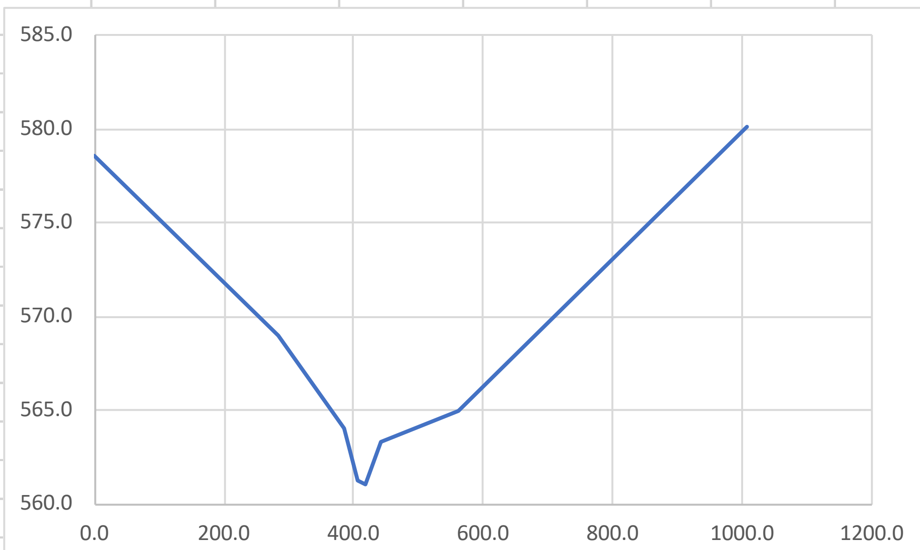
Length (ft)	6395
Slope (ft/ft)	0.014
Left n	0.1
Chan n	0.05
Right n	0.1
Sta.	Elev.
0.0	698.9
440.5	663.4
1672.3	649.4
1702.3	645.8
1711.3	645.5
1729.3	652.2
1993.1	669.2
2146.0	690.2



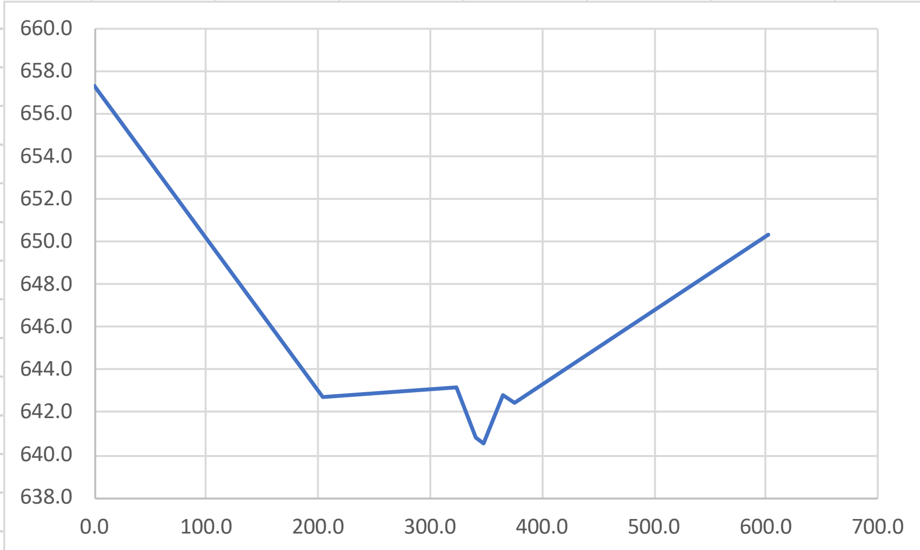
RNOL_1410	
Length (ft)	2985
Slope (ft/ft)	0.01
Left n	0.05
Chan n	0.045
Right n	0.05
Sta.	Elev.
0.0	623.1
176.6	615.0
242.4	601.6
433.9	585.9
454.9	582.0
592.5	582.5
601.5	593.3
1035.4	619.3



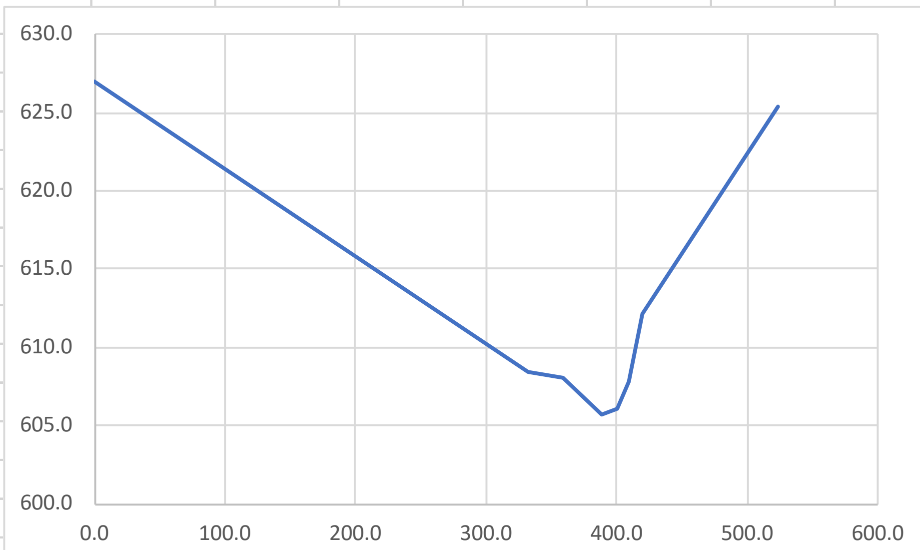
RNOL_1460	
Length (ft)	2265
Slope (ft/ft)	0.01
Left n	0.1
Chan n	0.05
Right n	0.1
Sta.	Elev.
0.0	578.6
283.0	568.9
384.8	564.0
405.8	561.3
417.8	561.1
441.7	563.4
561.5	565.0
1007.2	580.1



RNOL_1540	
Length (ft)	4550
Slope (ft/ft)	0.008
Left n	0.06
Chan n	0.045
Right n	0.06
Sta.	Elev.
0.0	657.4
203.7	642.8
323.5	643.2
341.5	640.8
347.5	640.6
365.4	642.8
374.4	642.4
602.1	650.3

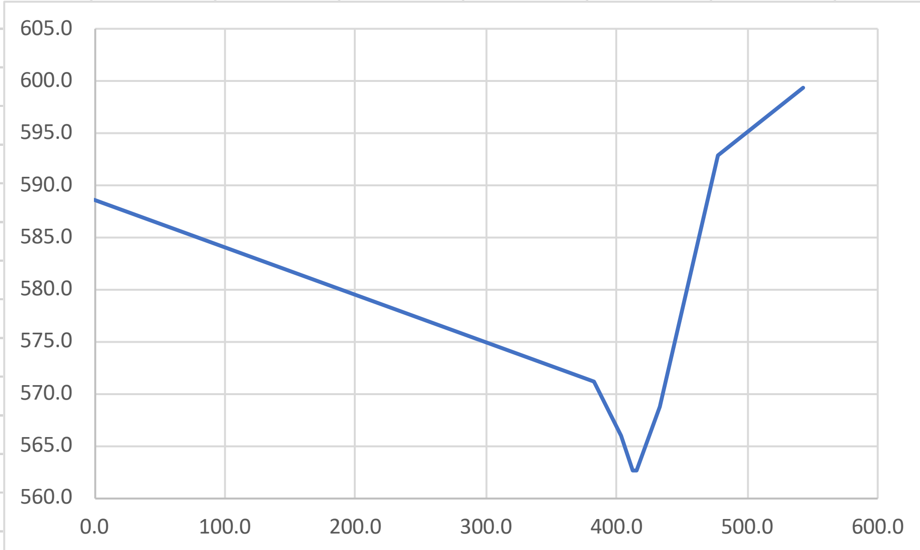


RNOL_1550	
Length (ft)	3710
Slope (ft/ft)	0.01
Left n	0.06
Chan n	0.045
Right n	0.06
Sta.	Elev.
0.0	626.9
332.1	608.4
359.0	608.0
388.9	605.7
400.9	606.1
409.8	607.9
418.8	612.2
523.5	625.4



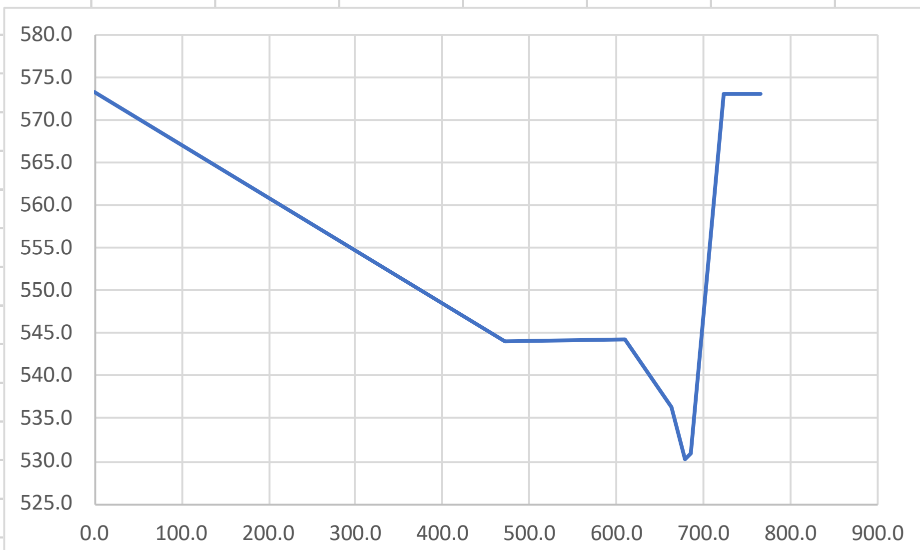
RNOL_1570

Length (ft)	3320
Slope (ft/ft)	0.009
Left n	0.06
Chan n	0.045
Right n	0.06
Sta.	Elev.
0.0	588.6
382.0	571.1
402.9	566.0
411.9	562.5
414.9	562.7
432.8	568.7
477.5	592.9
543.2	599.5

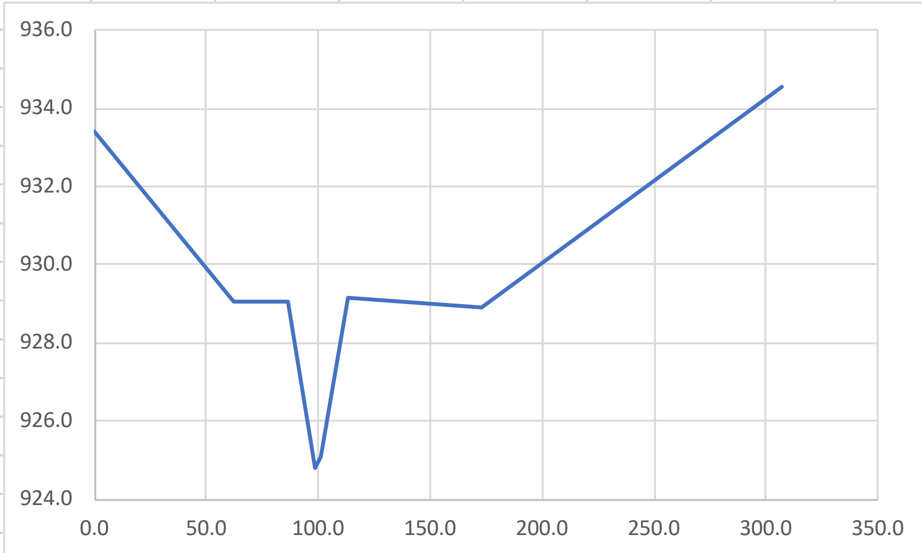


RNOL_1590

Length (ft)	2800
Slope (ft/ft)	0.012
Left n	0.06
Chan n	0.045
Right n	0.06
Sta.	Elev.
0.0	573.3
472.3	544.0
609.8	544.2
663.6	536.3
678.5	530.3
684.5	531.0
723.4	573.0
765.2	573.2



RSNOL_090	
Length (ft)	3889
Slope (ft/ft)	0.009
Left n	0.06
Chan n	0.045
Right n	0.06
Sta.	Elev.
0.0	933.4
62.5	929.1
86.3	929.0
98.2	924.8
101.2	925.1
113.1	929.1
172.7	928.9
306.6	934.5



Reservoir Routing:

NRCS Site 1	
Elevation (ft)	Storage (ac-ft)
868.21	0
872.21	10
876.21	42
880.21	118
882.61	199
884.21	254
885.91	325
888.21	470
892.21	807
896.21	1282
900.21	1903
904.21	2696
906.61	3260
908.21	3692
912.21	4980
914.00	5700

NRCS Site 2	
Elevation (ft)	Storage (ac-ft)
790.61	1
794.61	5
798.61	14
802.61	34
806.61	90
809.61	149
810.61	173
814.61	290
818.61	453
822.61	675
826.61	952
830.61	1295
834.61	1713
837.61	2077
838.61	2208
842.61	2803
846.61	3520

NRCS Site 3	
Elevation (ft)	Storage (ac-ft)
688.21	1
692.21	4
696.21	14
700.21	38
704.21	86
708.21	166
712.21	296
716.21	516
720.21	890
724.21	1470
728.21	2248
732.21	3168
734.21	3690
736.21	4270
740.21	5584
744.21	7054

NRCS Site 5A	
Elevation (ft)	Storage (ac-ft)
830.21	0
834.21	2
838.21	22
842.01	69
842.21	81
846.21	207
850.21	435
853.21	690
854.21	802
858.21	1347
860.00	1650

NRCS Site 7	
Elevation (ft)	Storage (ac-ft)
770.21	0
774.21	4
778.21	24
782.21	74
785.51	146
786.21	166
790.21	313
794.21	528
795.81	640
798.21	822
802.21	1211

NRCS Site 8	
Elevation (ft)	Storage (ac-ft)
722.21	0
725.21	1
730.21	5
734.21	18
738.21	43
742.21	81
744.61	114
746.61	139
750.11	226
750.21	230
754.21	365
758.21	550
762.21	795
766.21	1104
768.01	1263
770.21	1487
774.21	1953

NRCS Site 9	
Elevation (ft)	Storage (ac-ft)
705.21	0
709.21	1
713.21	4
717.21	19
721.21	53
723.81	86
725.21	111
729.21	204
733.21	341
737.21	531
741.21	784
745.21	1106
745.41	1158
749.21	1506
751.00	1670

NRCS Site 10	
Elevation (ft)	Storage (ac-ft)
657.50	0
658.00	5
662.00	38
666.00	100
669.30	195
670.00	213
674.00	372
678.00	572
682.00	851
685.10	1135
686.00	1217
690.00	1667

NRCS Site 11	
Elevation (ft)	Storage (ac-ft)
668.21	1
672.21	5
676.21	17
680.21	47
682.51	79
684.21	102
688.21	196
692.21	342
696.21	556
700.21	849
701.01	935
704.21	1223
706.00	1420
707.00	1520

NRCS Site 12	
Elevation (ft)	Storage (ac-ft)
640	0
640.21	0.4
644.21	4
648.21	25
651.51	67
652.21	80
656.21	179
660.21	347
664.21	603
665.91	741
668.21	945
670.91	1229
672.00	1380

NRCS Site 13	
Elevation (ft)	Storage (ac-ft)
612.21	0.2
616.21	1
620.21	3
624.21	7
628.21	18
632.21	42
636.21	83
640.21	145
644.21	236
648.21	371
651.31	513
652.21	556
655.01	721

NRCS Site 14	
Elevation (ft)	Storage (ac-ft)
668.21	0
672.21	2
676.21	12
680.21	37
683.41	75
684.21	86
688.21	161
692.21	261
696.21	384
699.01	485
702	600

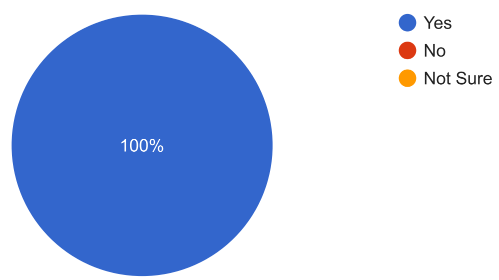
NRCS Site 15	
Elevation (ft)	Storage (ac-ft)
601.10	0
605.10	3
609.10	16
613.10	46
618.10	110
620.20	149
622.00	182
624.00	223
626.00	269
628.00	322
630.00	382
632.00	451
634.00	529
636.00	615
638.00	711
640.00	816
641.10	878
642.00	929

Nolan Creek Partners Flood Response Strategies Questionnaire

5 responses

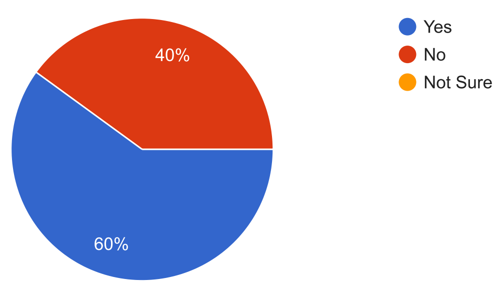
1. Does your local government entity have a designated Emergency Management Coordinator?

5 responses



2. Do you have a written flood management protocol or response plan?

5 responses



3. Where is this kept? Please indicate if it is part of another document or plan, or if it is stand-alone.

4 responses

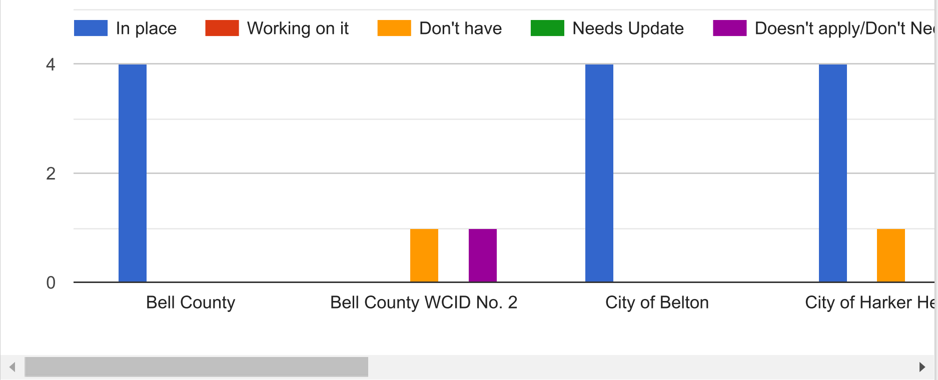
We fall under Bell County Response Plan

Part of an emergency response plan.

Stand alone

In the Emergency Mangement Folder and on FD drives

4. Please indicate the status of interlocal agreements your community has that cover flood response with each of the entities



5. Which department in your organization takes the lead in a flood event response?

5 responses

Chief of Police

Fire Department/EMC

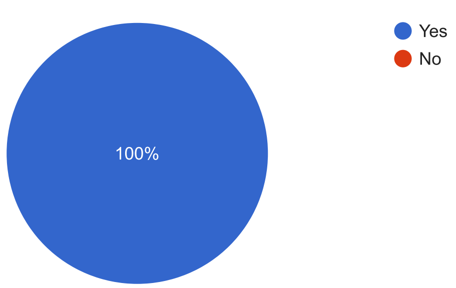
Fire Department then PD and PW

Fire Chief is EMC; PD; PW Depts

Belton Fire Department

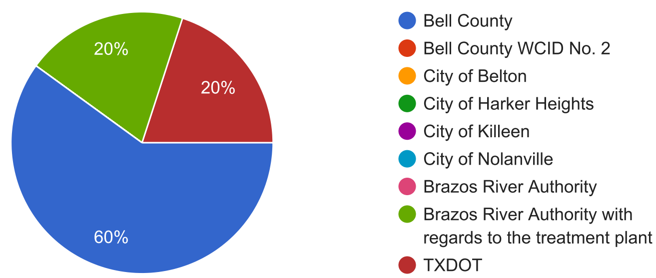
6. Are there known areas where you set out barricades?

5 responses



7. During a flood event, what other entities are you in frequent (more than 1x per day) in contact with?

5 responses



8. Please list the specific communities/entities/departments you are in most frequent contact with during a flood event.

5 responses

CBCFR, Public Works Local, Police Department

City of Harker Heights Police, Public Works and City Administration. Bell County EMC

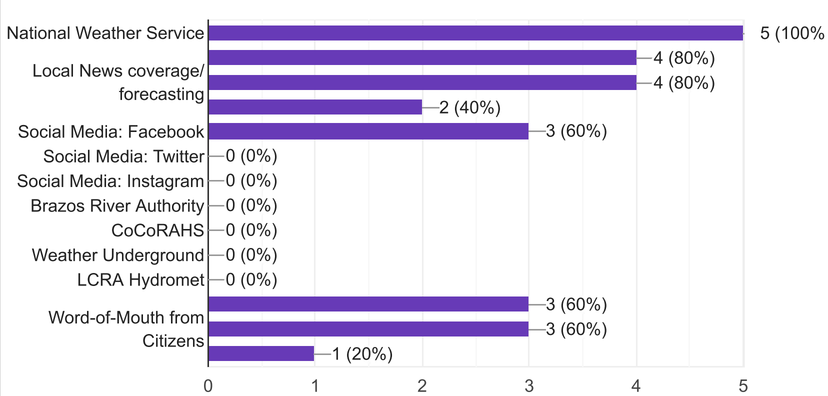
City of Belton: Fire, Police, Public Works, City Manager's office

Belton FD, PD, PW; TXDOT; Bell County; 911 Center

Belton PD, Belton PW, Bell County EMC, Harker Heights FD, NWS

9. What information sources are you watching in making decisions about when to start a protocol or elevate your community's response? (Check all that apply)

5 responses



10. Please elaborate on the information sources available to you, and which are most timely and influential in your decision-making process.

5 responses

Site Observations

We receive data from the State Operation Center (SOC) regarding weather briefings that come directly from the National Weather Service.

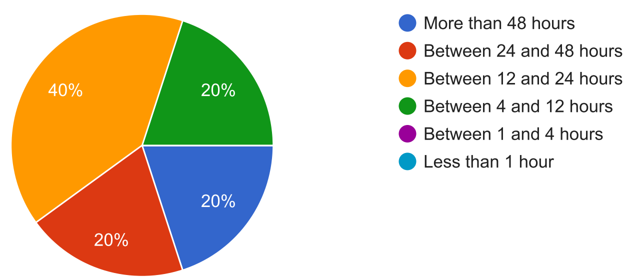
USGS is most accurate; visual inspections are best

Driving around, PD, FD, and PW patrols

Our flood protocol is initiated by considering information from all sources

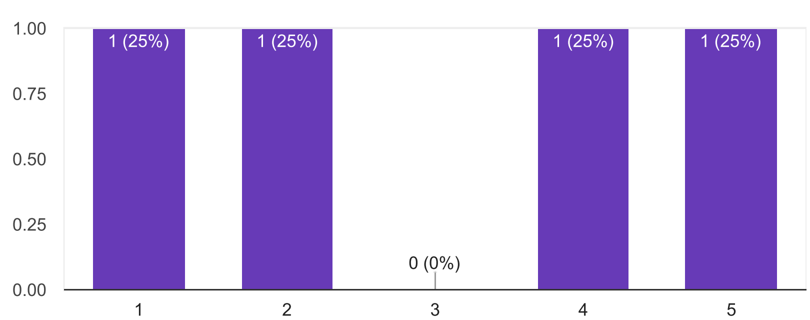
11. How much lead time does the information you monitor provide you in making decisions about response?

5 responses



12. Is this enough time?

4 responses



13. Please elaborate on the lead time that monitored information provides, and include your perceptions of when the information is adequate or not adequate in making response decisions.

5 responses

We are not linked in to rain gauge data.

The lead-time information from the SOC typically provides extensive detail as to the type of rain and or associated events that could occur in the severe weather time-frame. This in-turn provides us with the data to make decisions on pre-staging assets or equipment as well as to let our residents know of what to expect.

USGS is real time, I look at forecast and upstream gages to determine what is coming

Monitor flood gauges in Nolan Creek as water approaches from the west.

We begin to monitor severe weather as soon as NWS begins to indicate the time period weather is predicted to impact our area

14. In the coordination with other entities, what would improve the communication?

5 responses

Not sure

I would say we have good relationships with all entities that we work with and work well.

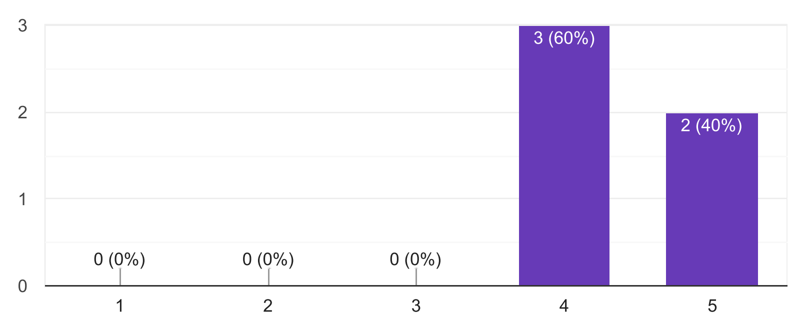
We need interlocal agreements with all entities to help with response to flooding for Public Works.

Working well.

Direct phone calls, Text messaging

15. During the last flood response, did your community have adequate equipment?

5 responses



16. What equipment would assist your community in providing a better response? Please indicate if you already have it, but need more or updated, or if you don't have it.

5 responses

Permanent barricades, monitors that link to Code Red messaging

An enhanced system as to the water levels and notifications for water levels. Specifically a text, email or other digital alerts to water levels.

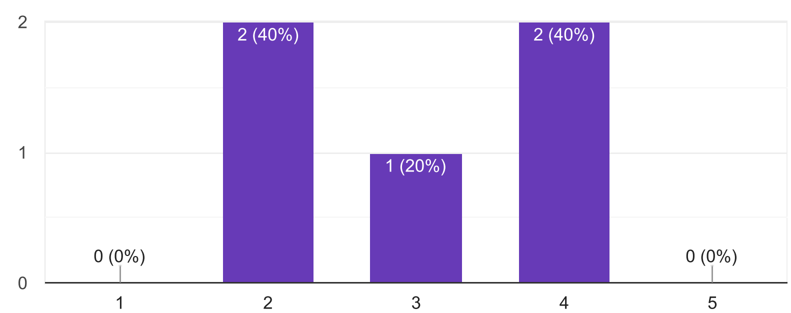
Better flood monitoring gauges, better prediction using the gauges given forecasted rain, flood spread at certain water levels in creek

OK

A better equipped rescue boat which can be easily deployed and specific to swift water conditions

17. Please evaluate the following statement: We have adequate staffing in a flood event.

5 responses



Anything else you would like to elaborate on, share, mark for future discussions, etc.?

2 responses

Code Red Usage

N/A

APPENDIX B:

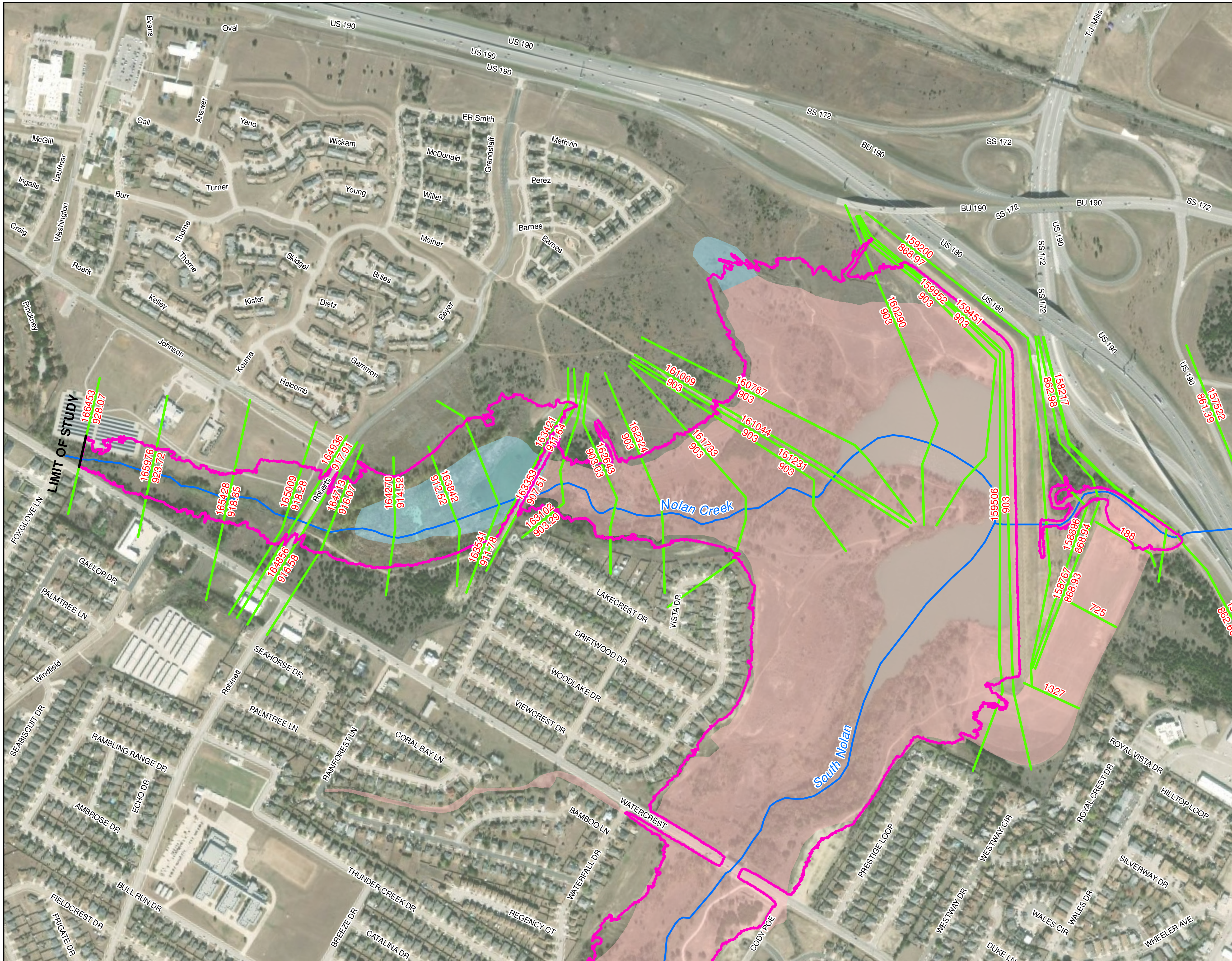
HYDROLOGIC AND HYDRAULIC RESULTS

River	Junction	Station	Key Location	Drainage Area (sq. mi.)	2-YR (CFS)	5-YR (CFS)	10-YR (CFS)	25-YR (CFS)	50-YR (CFS)	100-YR (CFS)	250-YR (CFS)	500-YR (CFS)
Little Nolan	JLNOL_020	32767		0.42	290	430	540	690	820	960	1180	1380
	JLNOL_010_020	30535	Trimmier Rd.	0.64	470	700	870	1110	1320	1550	1920	2230
	JLNOL_030	29778		0.80	460	700	890	1180	1430	1710	2120	2490
	JLNOL_030_050	28170		1.52	840	1330	1680	2270	2790	3350	4200	4940
	JLNOL_060	26465	W.S. Young Dr.	1.95	1010	1610	2040	2780	3470	4220	5330	6290
	JLNOL_070	22921		2.22	1070	1670	2120	2870	3660	4480	5720	6760
	JLNOL_080	20236		2.45	1100	1720	2170	2850	3720	4610	5950	7130
	JLNOL_080_130	17890	Little Nolan Rd.	4.21	1890	3090	3950	5120	6600	8080	10310	12330
	JLNOL_140	14565	Scott and White Dr.	5.02	2090	3410	4390	5680	7090	8770	10990	13250
	JLNOL_140_240	12239	Confluence with Trimmier Road Ditch	9.16	4930	7250	8910	11170	13360	16180	20170	24120
	JLNOL_250	10296	Martin Luther King Jr. Dr. (FM 2410)	9.76	5280	7620	9460	11850	13850	16600	20740	24780
	JLNOL_260	8105		10.24	5220	7520	9290	11770	13710	16250	20280	24100
	JLNOL_270	7037	Veterans Memorial Blvd.	10.60	5330	7660	9470	12010	13990	16460	20530	24410
	JLNOL_280	3266	Confluence with Nolan Creek	11.05	5230	7590	9430	12080	14130	16670	20700	24520
	JNOL_0010	166453	Watecrest Rd.	0.39	410	600	740	940	1110	1310	1600	1860
	JNOL_0020	164936		0.86	360	560	720	1240	1670	2170	2850	3400
	JNOL_0030	161231		1.10	510	800	1020	1420	1930	2500	3330	4030
	CONDUIT	159200	NRCS Dam 1 Outflow	5.34	90	90	100	100	100	110	110	320
		158217	Interstate 14		270	380	460	570	670	790	960	1120
	JNOL_0050	156437		5.99	590	820	990	1240	1460	1710	2090	2420
	JNOL_0050_0090	153772		7.21	1550	2230	2750	3500	4130	4850	5960	6930
	JNOL_0100	152278		7.41	1520	2210	2740	3490	4130	4860	5970	6950
	JNOL_0100_0190	150516		11.37	4080	6120	7720	9960	11870	14030	17450	20410
	JNOL_0200	149777	Ft. Hood St.	11.61	4130	6190	7800	10100	12020	14200	17630	20630
	JNOL_0200_0220	149516		12.35	4620	6930	8750	11360	13520	16010	19840	23210
	JNOL_0230	148517	Houston St.	12.53	4590	6830	8670	11270	13430	15820	19690	23240
	JNOL_0240	147580		12.83	4710	7010	8920	11590	13840	16310	20280	23930
	JNOL_0250	146267	2nd St.	13.11	4770	7090	8890	11580	13830	16430	20400	24110
	JNOL_0250_0280	145671		14.14	5310	7870	9870	12920	15450	18340	22750	26990
	JNOL_0290	144848	S.10th St.	14.72	5570	8220	10260	13430	15980	18950	23740	28120
	JNOL_0300	142645	Veterans Memorial Blvd.	15.06	5480	7960	9780	12600	15030	17760	22560	26770
	JNOL_0310	141241		15.47	5610	8120	9960	12840	15310	18090	23020	27380
	JNOL_0310_0350	140779	S. 28th St.	17.22	6380	9220	11170	14380	17180	20270	25910	30970
	JNOL_0360	138260		17.59	6380	9140	11090	14200	16870	19990	25370	30320
	JNOL_0370_0400	136326		18.85	6740	9580	11570	14770	17540	20810	26500	31740
	JNOL_0410	135718	N. 38th St. (FM 2410)	18.93	6730	9550	11550	14660	17340	20700	26340	31540
	JNOL_0420	135117		19.34	6840	9680	11690	14810	17510	20930	26650	31920
	JNOL_0430	132560		19.68	6720	9620	11630	14750	17370	20660	26280	31600
	JNOL_0430_0560	130431	S. Twin Creek Dr.	25.52	7800	11340	13760	17330	20190	23950	30650	36910
	JNOL_0570	127585		25.74	7550	11180	13620	17280	20210	23850	30560	36680
	JNOL_0590_0570	126018		26.47	7580	11240	13700	17410	20370	24000	30780	36970
	JNOL_LNOL	124805	Confluence with Little Nolan Creek	37.51	11330	17180	21300	27450	32410	38020	48000	57370
	JNOL_0600	123341		37.71	11170	16900	21180	27300	32180	37810	47750	57060
	JNOL_0600_0630	122020		38.72	11240	17000	21340	27520	32420	38090	48030	57430
	JNOL_0640	120890		38.82	11170	16910	21220	27390	32340	38010	47940	57270
	JNOL_0640_0720	120131		41.51	11210	16960	21310	27530	32520	38210	48120	57560
	JNOL_0730	118485		41.92	11110	16870	21190	27400	32480	38180	48070	57490

	JNOL_0730_0770	117353		44.93	11080	16810	21110	27300	32370	38040	47840	57190
	JNOL_0780	116069		45.09	11020	16710	21000	27200	32230	37890	47760	57070
	JNOL_0790_0820	114365	FM 3219	46.97	11110	16860	21190	27470	32570	38280	48240	57600
	JNOL_0830	111816	Railroad	47.37	11010	16710	20820	27010	31790	37390	48070	57350
	JNOL_0840	110770		48.30	11050	16780	20930	27170	31960	37590	48480	57860
	JNOL_0850	109873		49.01	11020	16730	20880	27100	31800	37370	48410	57780
	JNOL_DAM09_0850	107827	Railroad	52.59	10980	16650	20770	26950	31650	37160	48080	57500
	JNOL_0910	106089	Interstate 14	52.89	10920	16370	20480	26500	31060	36360	47490	57080
	JNOL_0920	103507		53.68	10860	16280	20440	26430	31030	36310	47390	57020
	JNOL_0940	100661		54.91	10890	16310	20480	26490	31090	36390	47450	57110
	JNOL_0950	98337	Old Nolanville Rd.	55.13	10820	16210	20410	26400	31030	36300	47270	56980
Nolan Creek	JNOL_0960	97083		55.47	10820	16220	20420	26420	31060	36320	47310	57010
	JNOL_NOLVT2	96478	Confluence with Nolanville West Trib.	56.88	10900	16330	20560	26590	31240	36510	47710	57570
	JNOL_0970	93791		57.48	10770	16120	20350	26390	31130	36380	47150	57230
	JNOL_NOLVT1	90370	Confluence with Nolanville Trib.	58.83	10850	16180	20420	26480	31250	36490	47320	57520
	JNOL_0980	88384	Levi Crossing Rd.	59.30	10800	16070	20260	26340	31170	36400	46980	57300
	JNOL_0980_1080	86580		63.10	10780	16020	20170	26230	31060	36240	47530	58370
	JNOL_1090	85231		64.03	10790	16040	20190	26260	31110	36290	47590	58430
	JNOL_1100	83316		64.43	10750	15930	20070	26160	31060	36230	47350	58290
	JNOL_1110	82079		64.80	10750	15930	20070	26170	31080	36250	47370	58310
	JNOL_1120	81673		65.03	10720	15900	19980	26090	31000	36170	47010	58100
	JNOL_1120_1180	80081		67.91	10780	15940	19990	26090	31020	36150	46880	58240
	JNOL_1190	78813	Interstate 14	68.02	10740	15890	19930	26030	30950	36090	46690	58030
	JNOL_1200	78052		68.38	10740	15890	19940	26040	30970	36110	46700	58060
	JNOL_1210	77123		69.24	10690	15790	19770	25860	30850	35990	46350	57700
	JNOL_1220	71634		70.20	10640	15710	19660	25710	30720	35880	46060	57360
	JNOL_1230	67324	Paddy Hamilton Rd.	70.60	10600	15660	19590	25600	30670	35830	45940	57210
	JNOL_1230_1270	65097		72.46	10620	15670	19590	25600	30670	35830	45890	57130
	JNOL_1270_1300	64546		73.71	10650	15710	19620	25630	30700	35850	45880	57090
	JNOL_1310	63569		73.98	10630	15680	19600	25590	30660	35810	45810	57030
	JNOL_1320	62278		74.80	10640	15700	19620	25620	30700	35860	45860	57080
	JNOL_1330	60607		74.99	10610	15650	19570	25540	30600	35780	45690	56880
	JNOL_1330_1350	60085	FM 39	76.34	10640	15680	19590	25560	30630	35810	45690	56920
	JNOL_1360	57354		76.54	10580	15620	19530	25480	30540	35740	45570	56710
	JNOL_1370	55877	Backstrom's Crossing Rd.	77.08	10590	15630	19540	25490	30560	35770	45600	56750
	J_NOL_NNOL	54341	Confluence with North Nolan	99.06	10660	15680	19590	25570	30720	35980	45570	56550
	JNOL_1380	52392		99.91	10620	15620	19510	25430	30610	35920	45460	56350
	JNOL_1390	49370		100.46	10610	15610	19500	25400	30580	35900	45410	56250
	JNOL_1390_1410	47367		101.98	10640	15650	19540	25450	30630	35960	45620	56550
	JNOL_1420	46904		102.21	10630	15630	19520	25420	30590	35940	45470	56340
	JNOL_1430	42737		102.60	10540	15490	19360	25180	30260	35670	44420	54580
	JNOL_1430_1470	41359	Wheat Rd.	104.61	10570	15550	19440	25290	30390	35830	44600	54760
	JNOL_1480	37535		105.54	10510	15460	19330	25110	30210	35670	44320	54140
	JNOL_1490	36358		106.06	10520	15480	19360	25150	30250	35720	44380	54190
	JNOL_1500	34375	N. Loop 121	106.72	10510	15470	19350	25130	30230	35710	44370	54120
	JNOL_1510	29318	Martin Luther King Jr. Ave.	107.33	10480	15460	19330	25110	30190	35670	44340	54010
	JNOL_1520	26691		107.56	10480	15450	19330	25100	30190	35670	44350	53980
	JNOL_1520_1590	25224		110.71	10520	15560	19480	25320	30460	35990	44720	54330
	JNOL_1600	23064	W. 2nd Ave.	111.12	10510	15540	19490	25320	30430	35970	44730	54320

	JNOL_1610	21088	W. Central Ave.	111.46	10510	15550	19510	25350	30460	36000	44770	54360
	JNOL_1620	20397	Main St.	111.65	10510	15540	19500	25350	30390	35940	44780	54380
	JNOL_1630	19918	Penelope St.	112.05	10510	15550	19520	25380	30420	35980	44830	54420
	JNOL_1640	19288		112.30	10510	15560	19520	25390	30420	35980	44840	54400
	JNOL_1650	18039	Interstate 35	112.52	10510	15550	19500	25350	30400	35950	44800	54310
	JNOL_1660	14760	E. Central Ave.	112.91	10490	15520	19450	25310	30370	35900	44820	54320
	JNOL_1670	9267		113.41	10470	15460	19360	25180	30280	35800	44790	54220
	Nolan_Out	3927	Confluence with Leon River	113.78	10430	15420	19300	25060	30070	35550	44650	53950
Nolanville Trib	JNOLVT1_10	8731	FM 439	0.59	180	370	530	760	960	1180	1530	1840
	JNOLVT1_20	3975	Interstate 14	1.19	410	670	910	1260	1540	1850	2290	2660
	JNOLVT1_30	1155	Confluence with Nolan Creek	1.35	410	700	940	1310	1600	1920	2400	2810
North Nolan	JNNOL_190	21046		15.42	370	690	950	1330	1660	2040	2620	3130
	JNNOL_200	18850		16.77	650	1280	1780	2540	3200	3890	4890	5740
	JNNOL_210	13140		17.66	770	1510	2110	3000	3790	4680	6060	7170
	JNNOL_210_240	8859		20.17	1310	2590	3620	5150	6490	8020	10420	12430
	JNNOL_250	7329		20.34	1310	2600	3620	5160	6500	8040	10490	12540
	JNNOL_260	6295	FM 439	20.97	1380	2740	3820	5470	6890	8530	11150	13410
	JNNOL_270	5152		21.13	1380	2760	3840	5470	6890	8530	11140	13450
	JNNOL_280	4500	Railroad	21.69	1420	2850	3960	5660	7150	8850	11610	14070
	JNNOL_290	2038	Confluence with Nolan Creek	21.98	1420	2850	3990	5690	7180	8930	11770	14320
Nolanville West Trib	JNOLVT2_10	6959	FM 439	0.88	560	830	1030	1310	1560	1830	2250	2620
	JNOLVT2_20	2242	Interstate 14	1.41	620	930	1160	1410	1650	1930	2410	3050
Old Florence Ditch	JLNOL_090	14237		0.41	360	540	680	870	1030	1220	1510	1760
	JLNOL_100	10420	Trimmier Rd.	0.69	530	810	1020	1330	1580	1870	2320	2710
	JLNOL_110	6703	W.S. Young Dr.	1.32	800	1310	1670	2180	2610	3090	3870	4550
	JLNOL_120	3035	E Elms Rd.	1.43	750	1290	1670	2210	2650	3150	3920	4650
	JLNOL_130	988	Cunningham Rd.	1.75	800	1370	1810	2420	2940	3490	4360	5210
Shaw Branch	JNOL_1160	9514	FM 439	2.07	590	1120	1590	2210	2760	3440	4370	5220
	JNOL_1170	6174	NRCS Dam 11	2.55	680	1260	1810	2510	3150	3940	5000	5990
	CONDUIT	3883	NRCS Dam 11 Outflow		50	50	60	60	60	60	60	60
	JNOL_1180	3273	Paddy Hamilton Rd.	2.88	250	360	450	580	700	830	1040	1220
South Nolan	JSNOL_010	17354		0.34	250	390	500	650	780	920	1150	1340
	JSNOL_020	15824	W. Stan Schlueter Loop	0.75	460	720	920	1220	1470	1760	2190	2560
	JSNOL_030	13531		1.02	540	850	1090	1450	1770	2110	2620	3050
	JSNOL_040	12028		1.26	710	1060	1350	1790	2200	2650	3330	3910
	JSNOL_050	10697		1.78	1130	1670	2090	2710	3270	3930	4950	5850
	JSNOL_060	9583	Robinette Rd.	2.13	1400	2050	2550	3240	3860	4590	5890	6990
	JSNOL_070	7138		2.34	1460	2140	2650	3400	4060	4830	6140	7330
	JSNOL_080_090	5974		3.06	2040	2990	3700	4730	5640	6690	8420	10010
	JSNOL_100	5119		3.34	2160	3190	3930	5050	6030	7170	9010	10690
	JSNOL_110	3565	Watercrest Dr.	3.63	2290	3380	4160	5370	6410	7590	9510	11240
	JSNOL_120	1551	NRCS Dam 1	3.88	2400	3580	4400	5700	6820	8070	10090	11910
Trimmier Road Ditch		23088			150	210	260	330	390	460	560	660
		22834	Clairidge Ave.		170	240	300	380	450	530	650	750
		22383	Caprock Dr.		170	250	310	390	470	550	670	780
	JLNOL_150	21651	W. Elms Rd.	0.20	250	360	450	570	670	790	970	1120
	JLNOL_160	19845	Old FM 440	0.64	560	830	1030	1330	1580	1870	2300	2680
	JLNOL_170	18019	S. Ft. Hood St. (SH 195)	0.98	800	1170	1470	1890	2240	2650	3270	3810
	JLNOL_180	15039	Florence Rd.	1.30	1000	1440	1800	2290	2730	3230	3970	4600

	JLNOL_190	13100		1.75	1320	1930	2400	3070	3640	4320	5330	6170
	JLNOL_200	11260	Trimmier Rd.	2.35	1770	2600	3240	4120	4860	5660	6900	7990
	JLNOL_210	8745		2.81	2050	3010	3710	4700	5580	6530	7850	9080
	JLNOL_220	6457	Interstate 14	3.20	2290	3340	4050	4790	5530	6430	8010	9390
	JLNOL_230	3229	Illinois Ave.	3.85	2770	4020	4860	5840	6500	7360	9110	10790
	JLNOL_240	969	Confluence with Little Nolan Creek	4.14	2960	4300	5210	6310	7100	7950	9610	11380



Nolan Creek Watershed Flood Protection Planning Study

CTCOG central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 1 of 31

Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

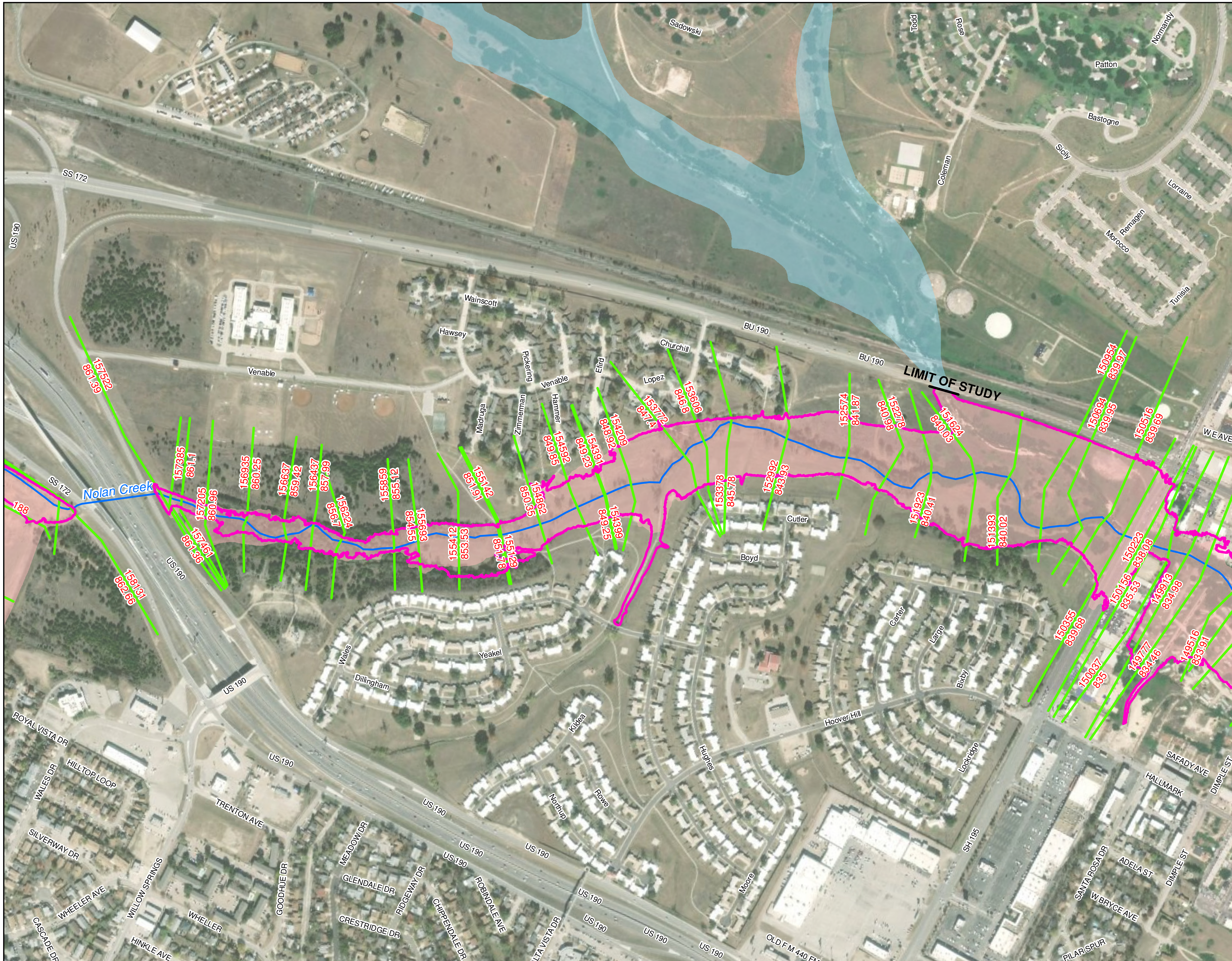
FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

0 300 600 1,200 Feet



Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 2 of 31

Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

A

AE

SCHEIBE CONSULTING LLC

N

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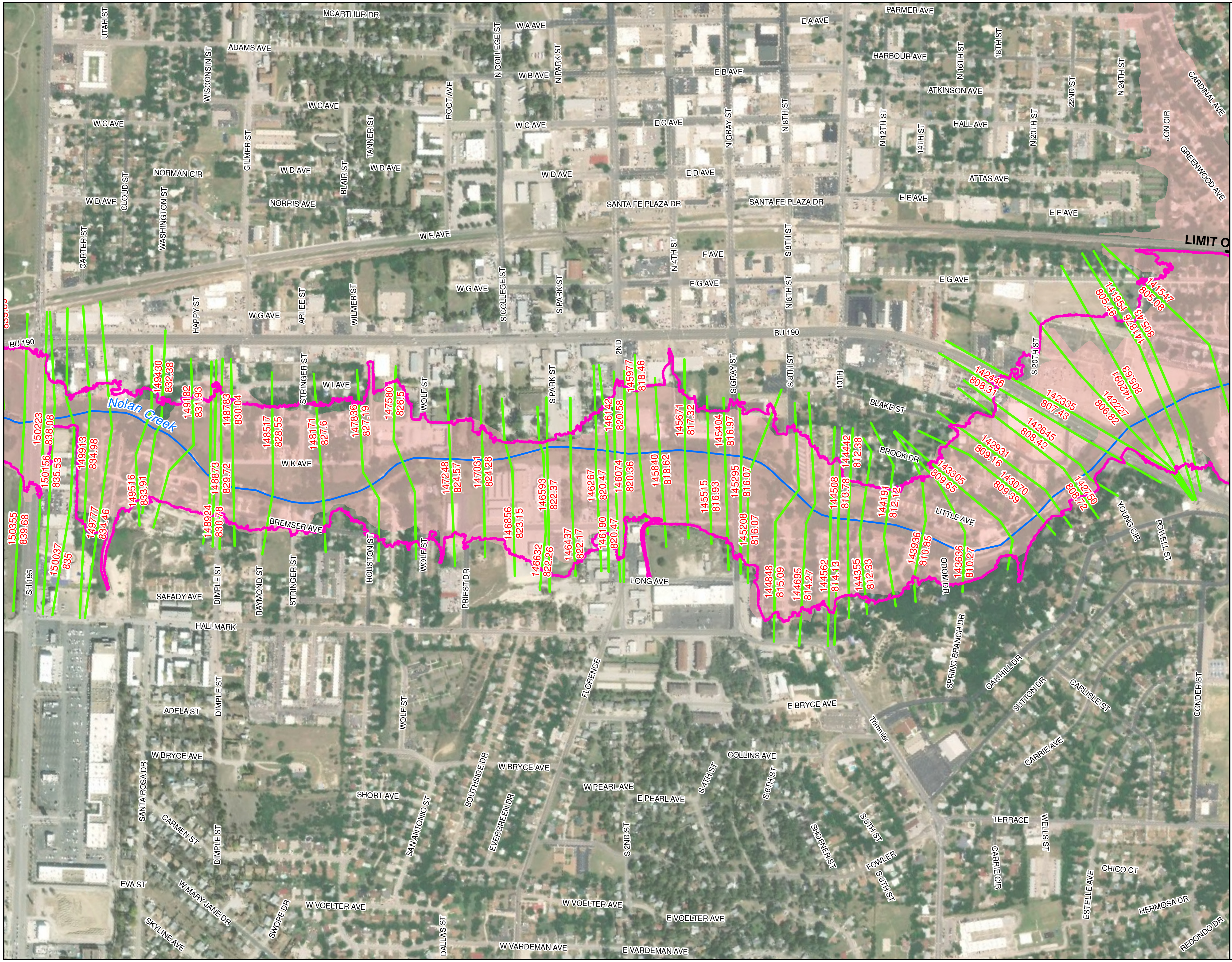

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 3 of 31

Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

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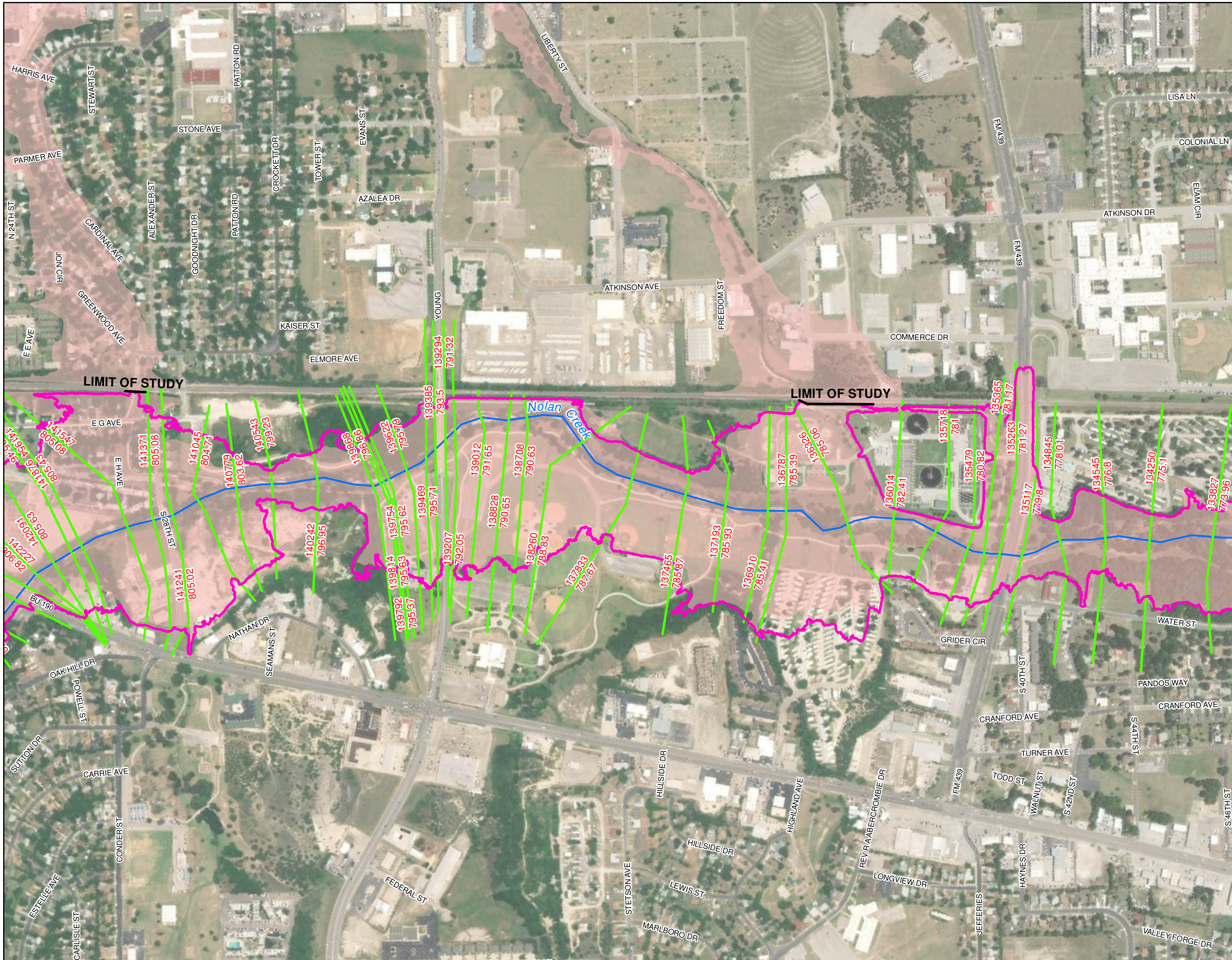

Nolan Creek Watershed Flood Protection Planning Study

CTCOG
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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 4 of 31

Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain
Cross-section Cutlines
Study Streams

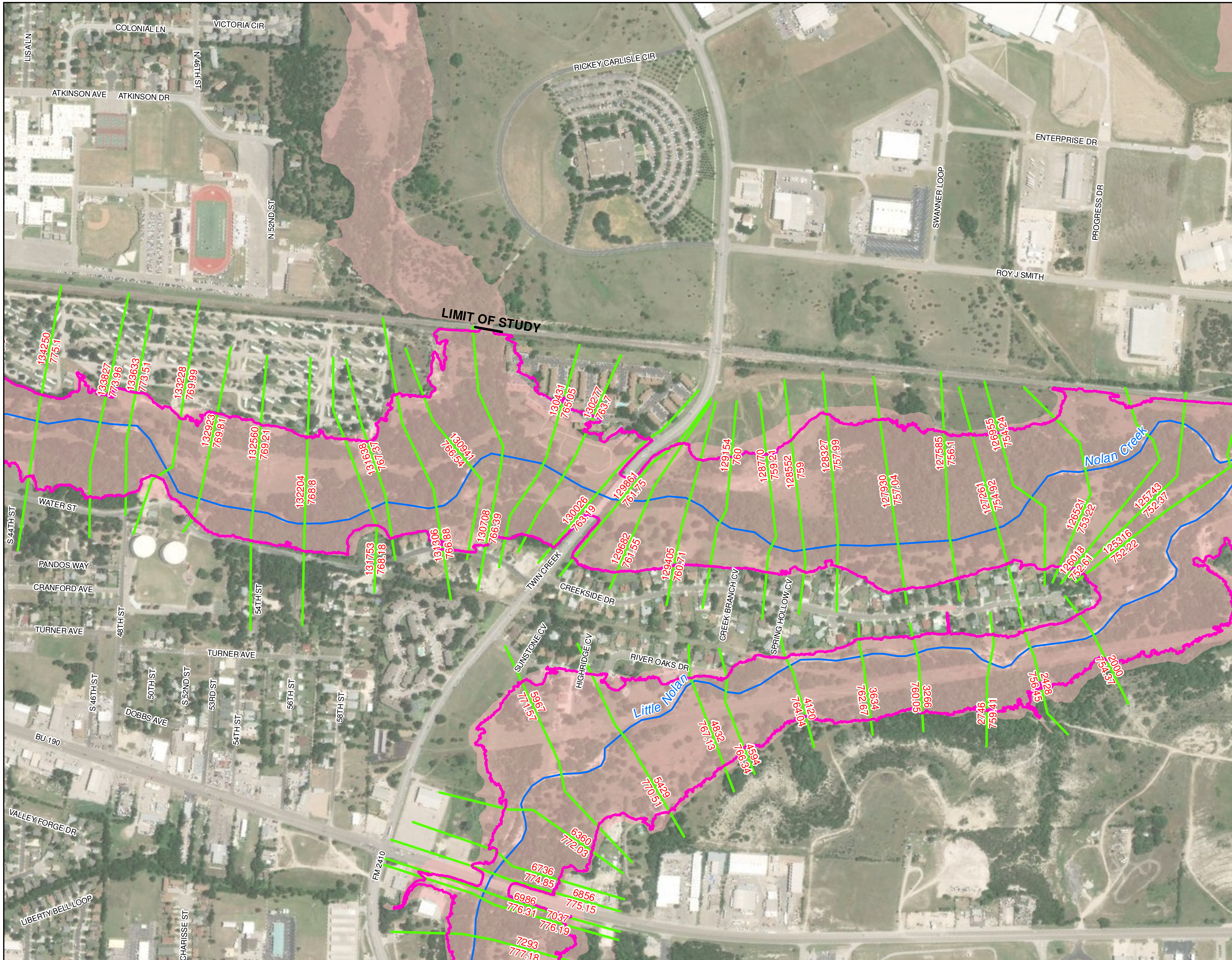
FEMA Flood Zone

A
AE

SCHEIBE CONSULTING LLC

N

0 300 600 1,200 Feet



Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 5 of 31

Nolan Creek
Little Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

0 300 600 1,200 Feet

Nolan Creek Watershed Flood Protection Planning Study

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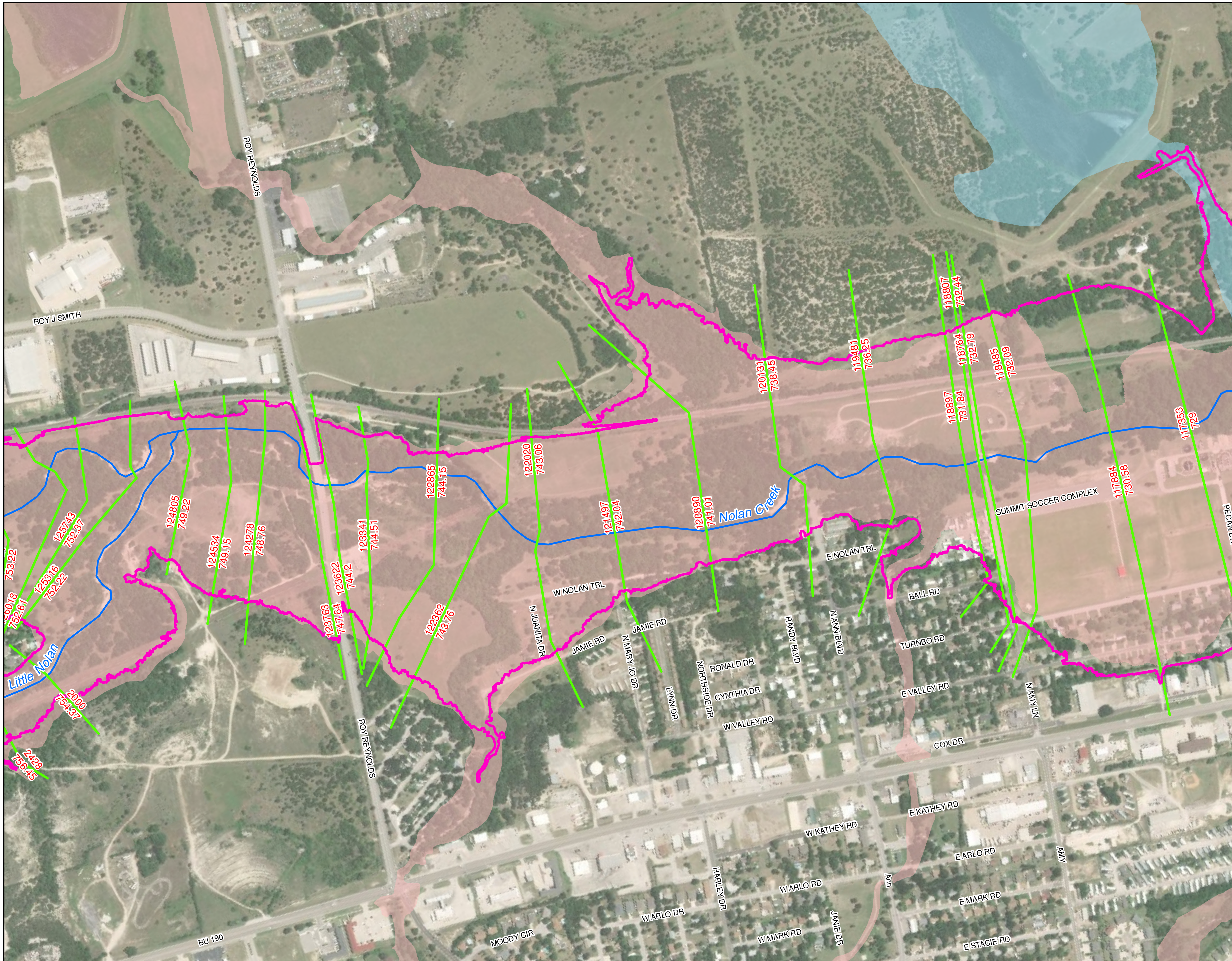
Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 6 of 31

Nolan Creek



KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

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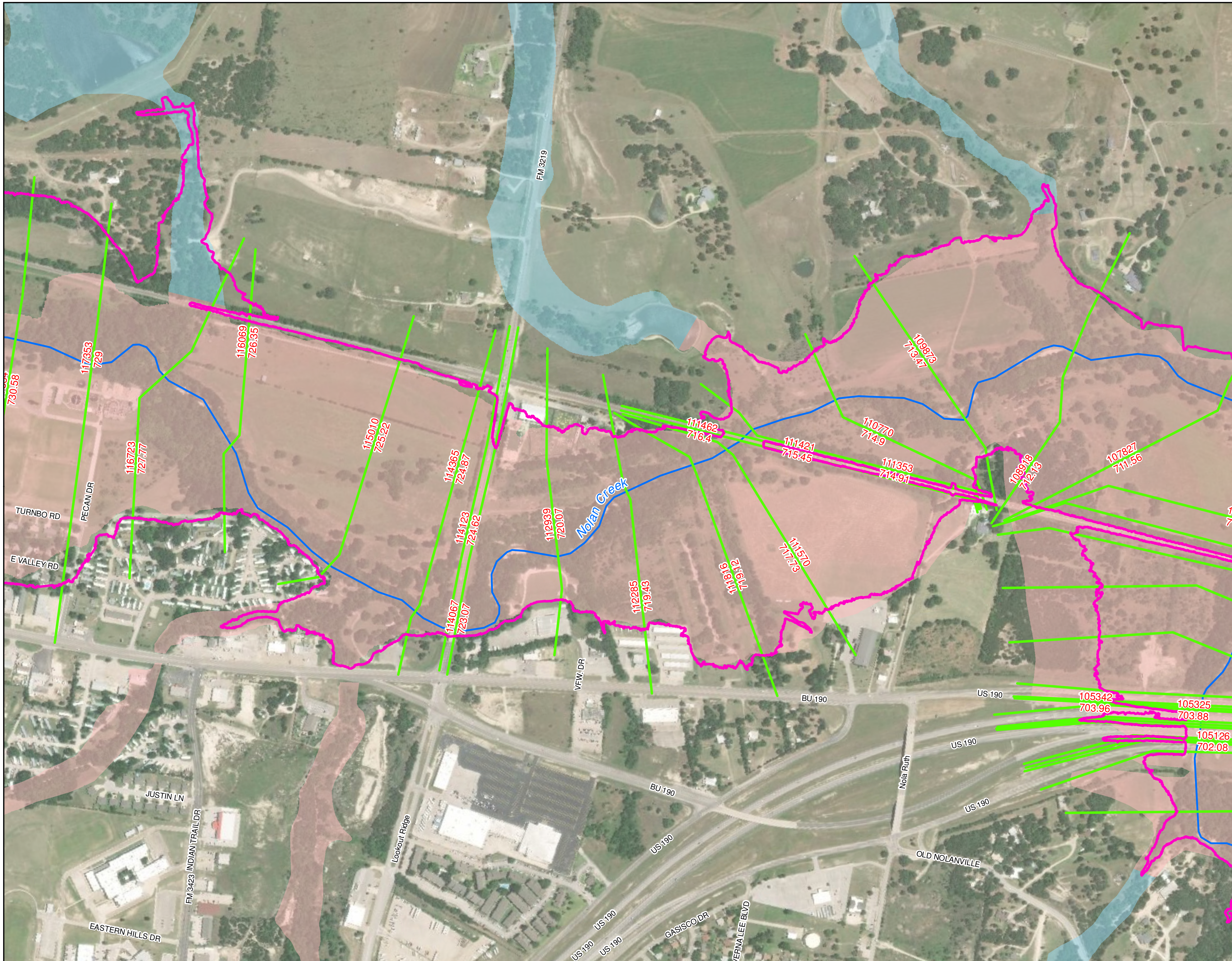

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 7 of 31

Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

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Nolan Creek Watershed Flood Protection Planning Study

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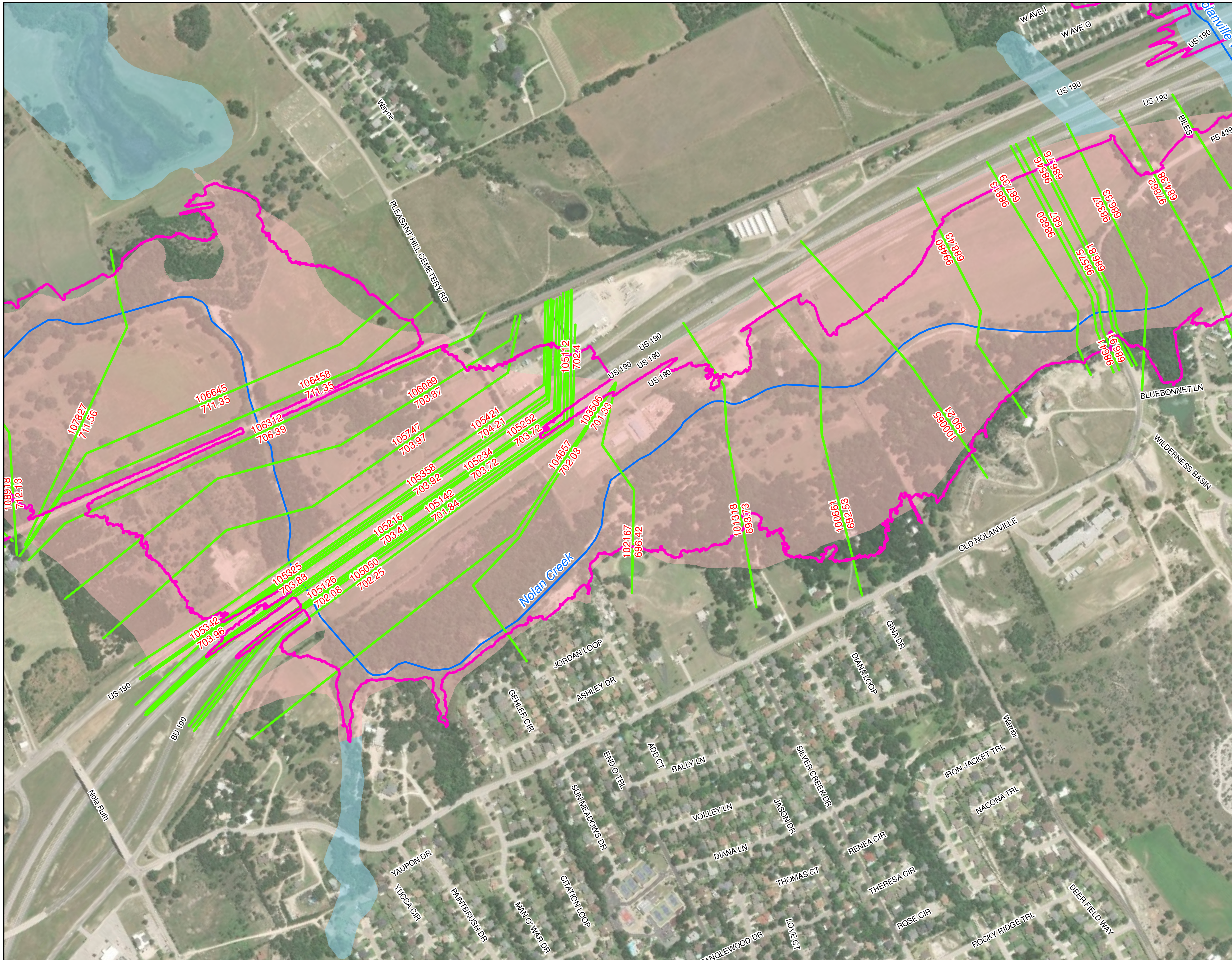
Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 8 of 31

Nolan Creek



KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

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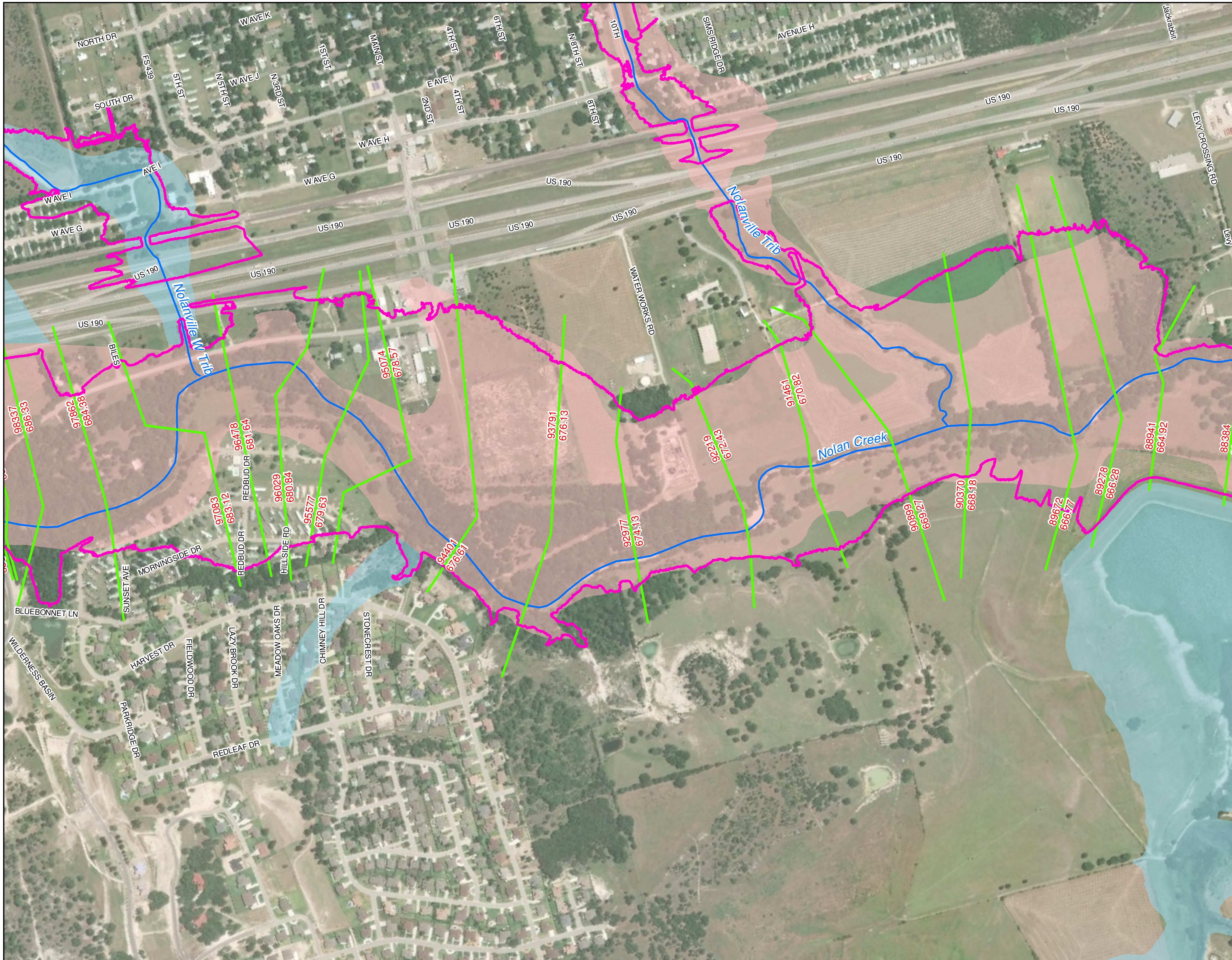

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 9 of 31

Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

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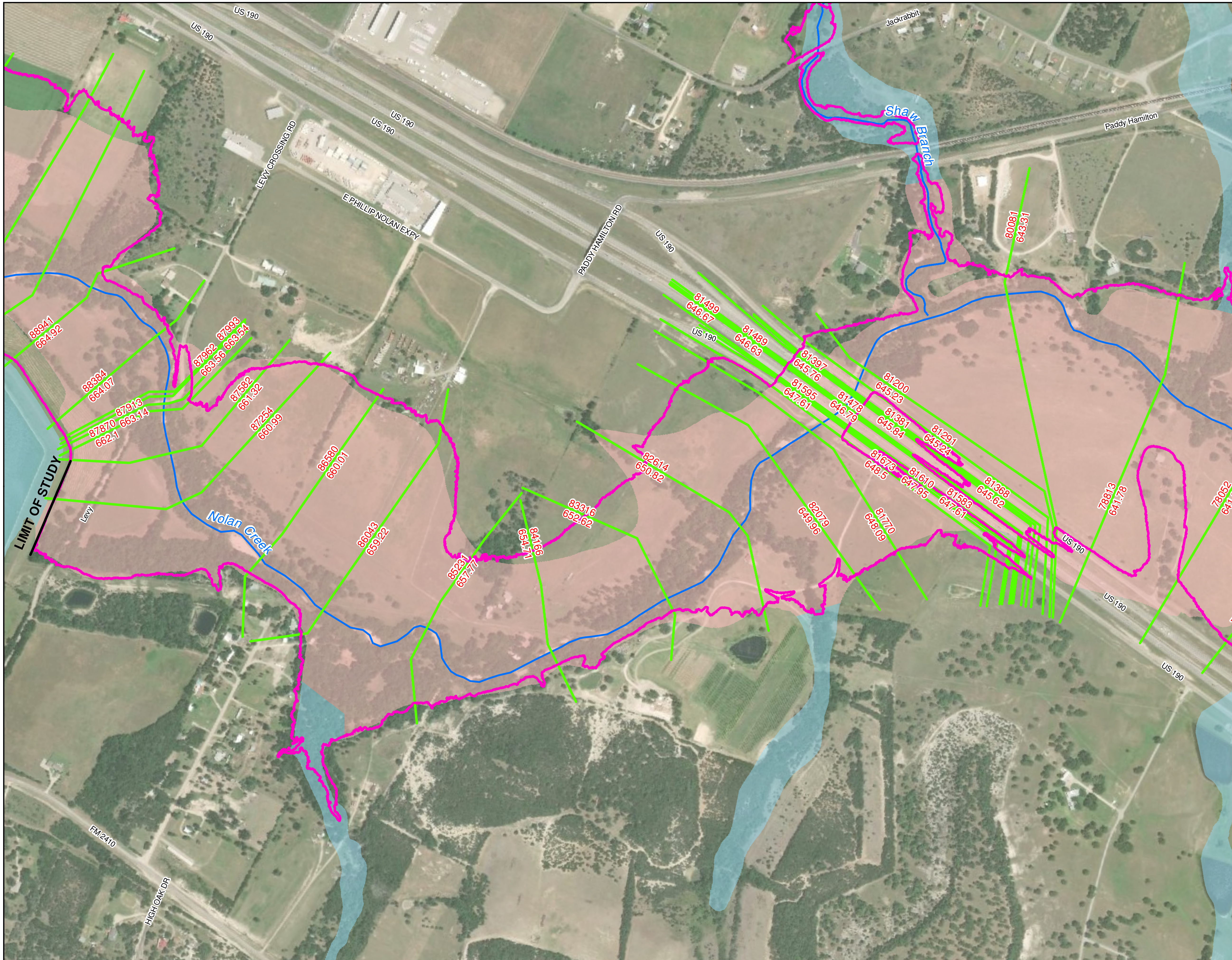

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 10 of 31

Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

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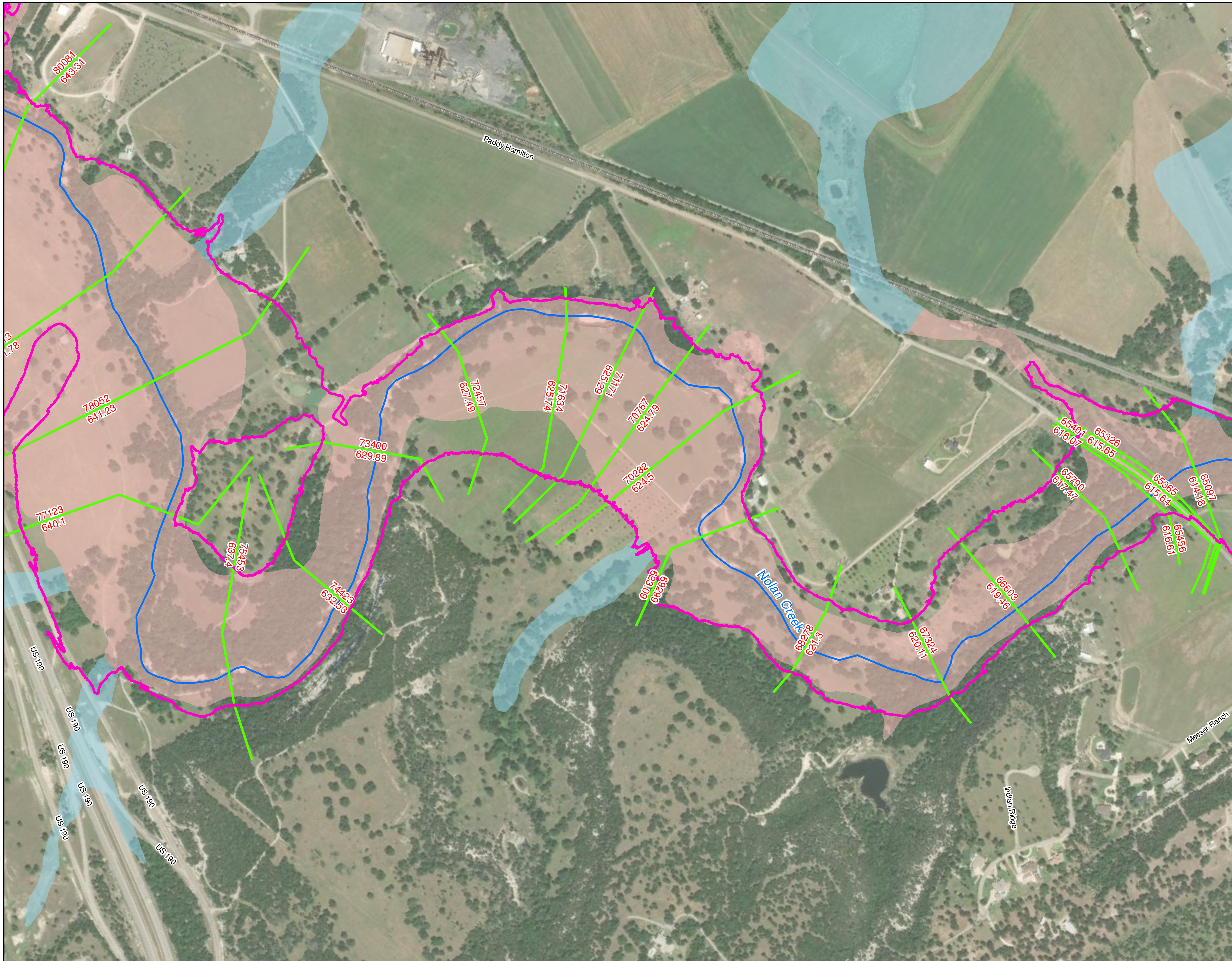

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 11 of 31

Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

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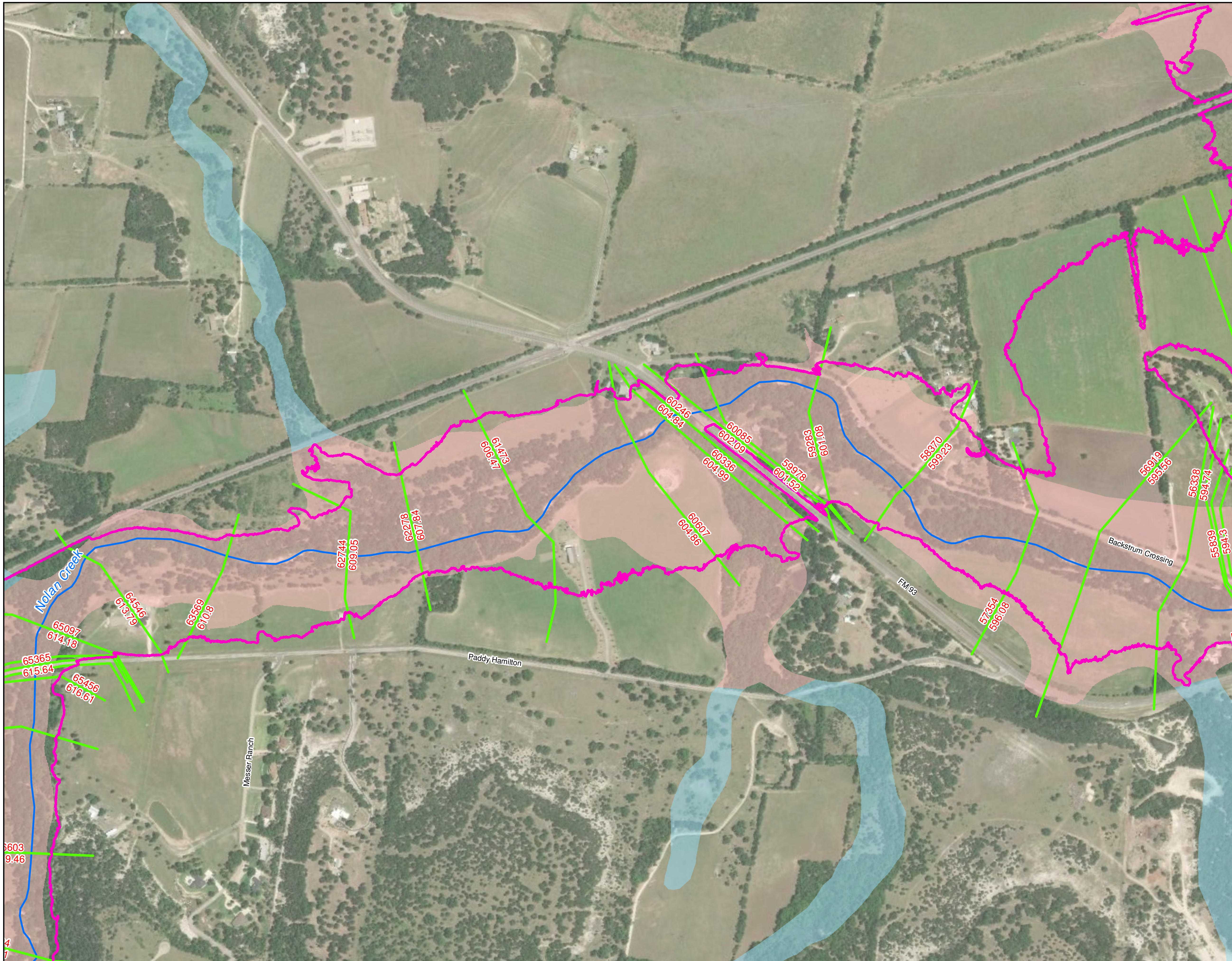

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 12 of 31

Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain
Cross-section Cutlines
Study Streams

FEMA Flood Zone

A
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SCHEIBE CONSULTING LLC

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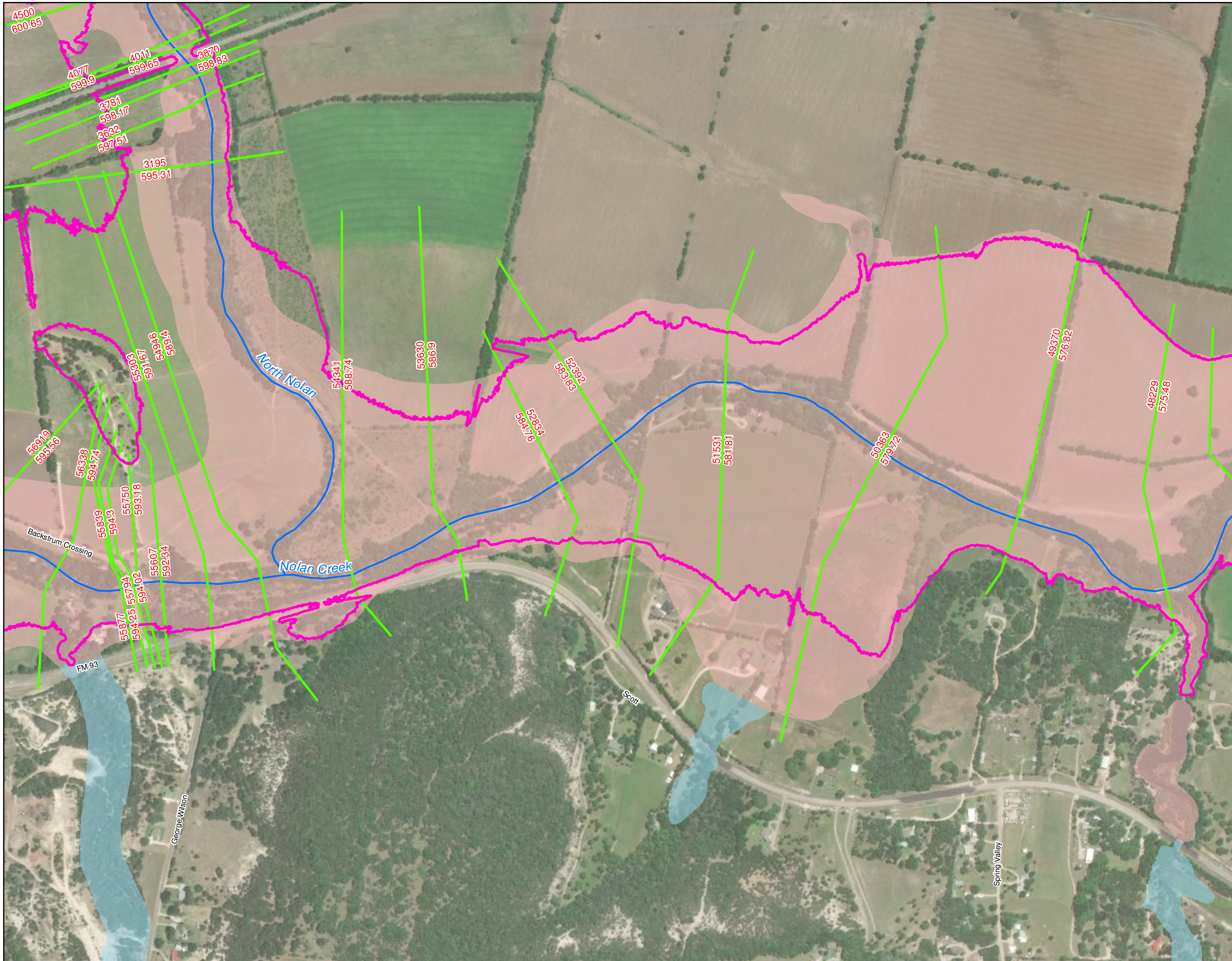

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 13 of 31

Nolan Creek
North Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

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SCHEIBE CONSULTING LLC

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Nolan Creek Watershed Flood Protection Planning Study

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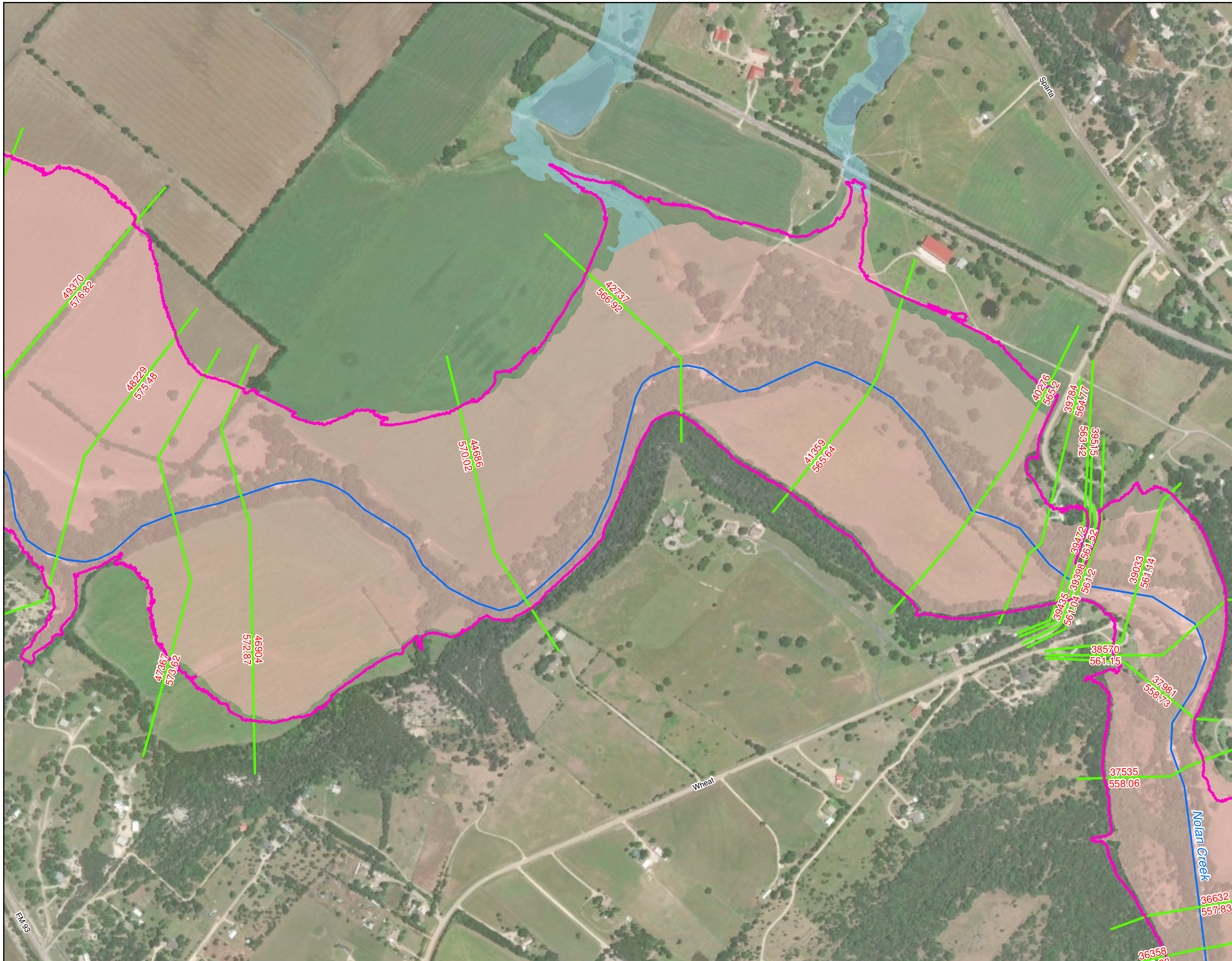
Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 14 of 31

Nolan Creek



KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

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SCHEIBE CONSULTING LLC

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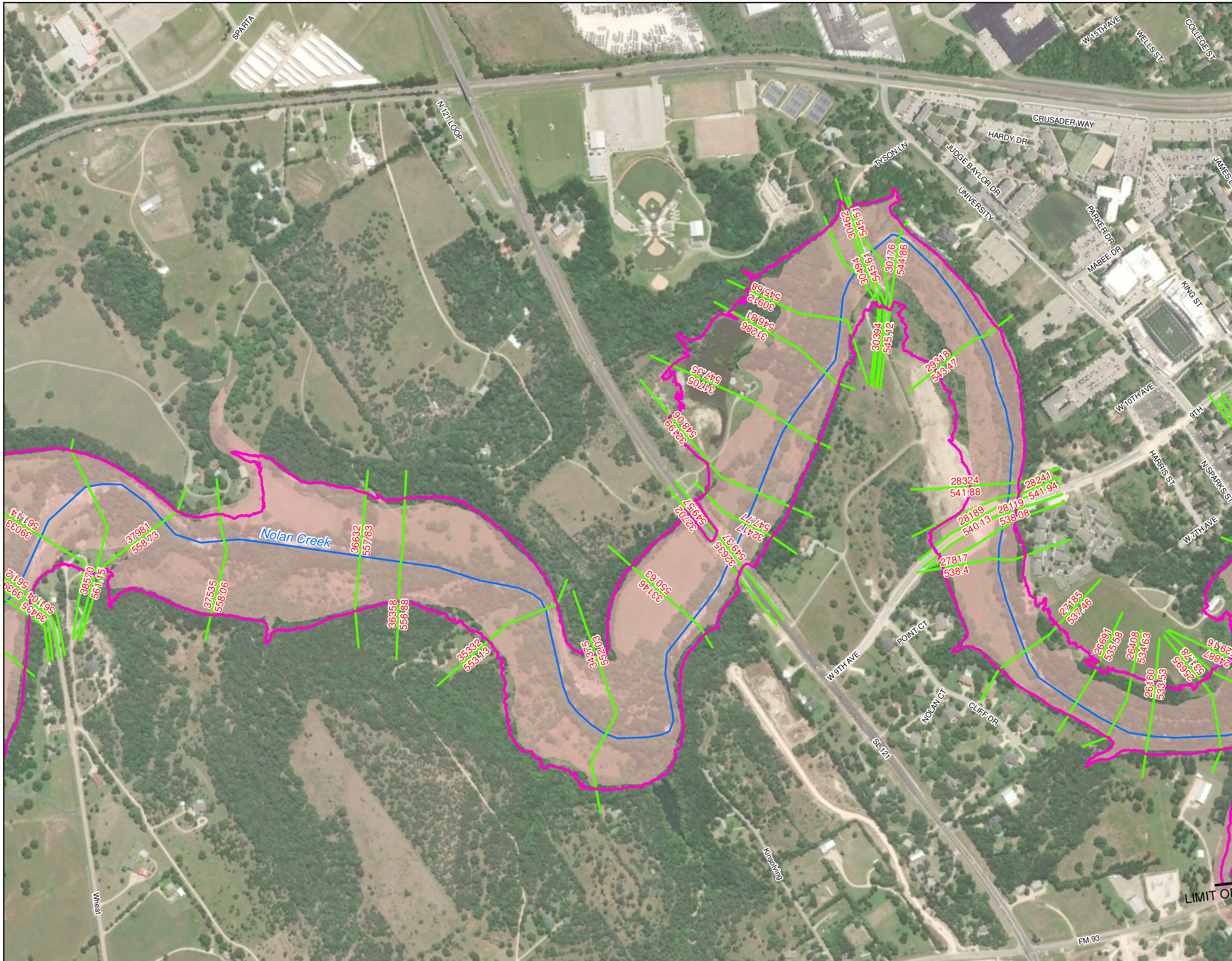

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 15 of 31

Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain
Cross-section Cutlines
Study Streams

FEMA Flood Zone

A
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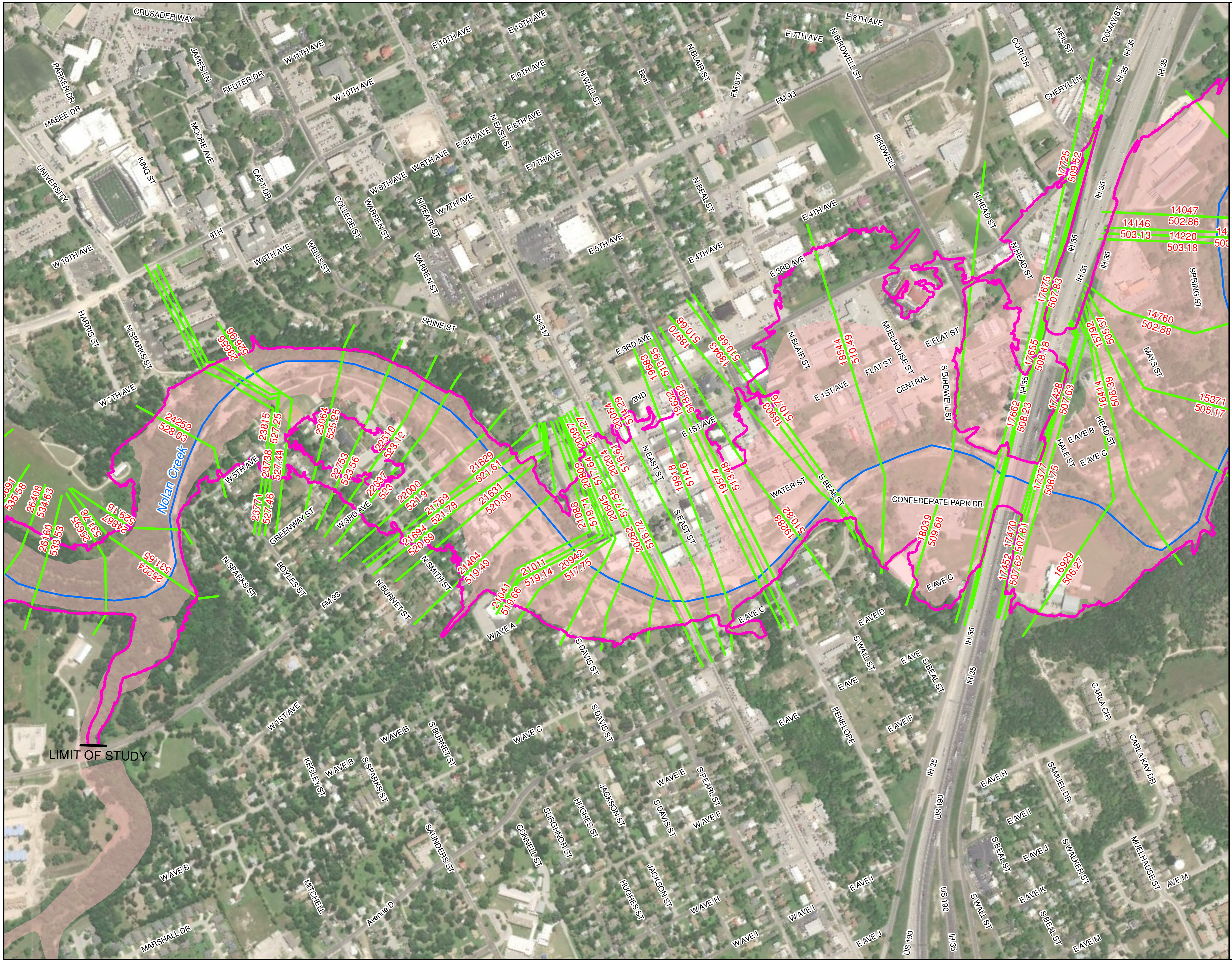

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 16 of 31

Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

A

AE

SCHEIBE CONSULTING LLC

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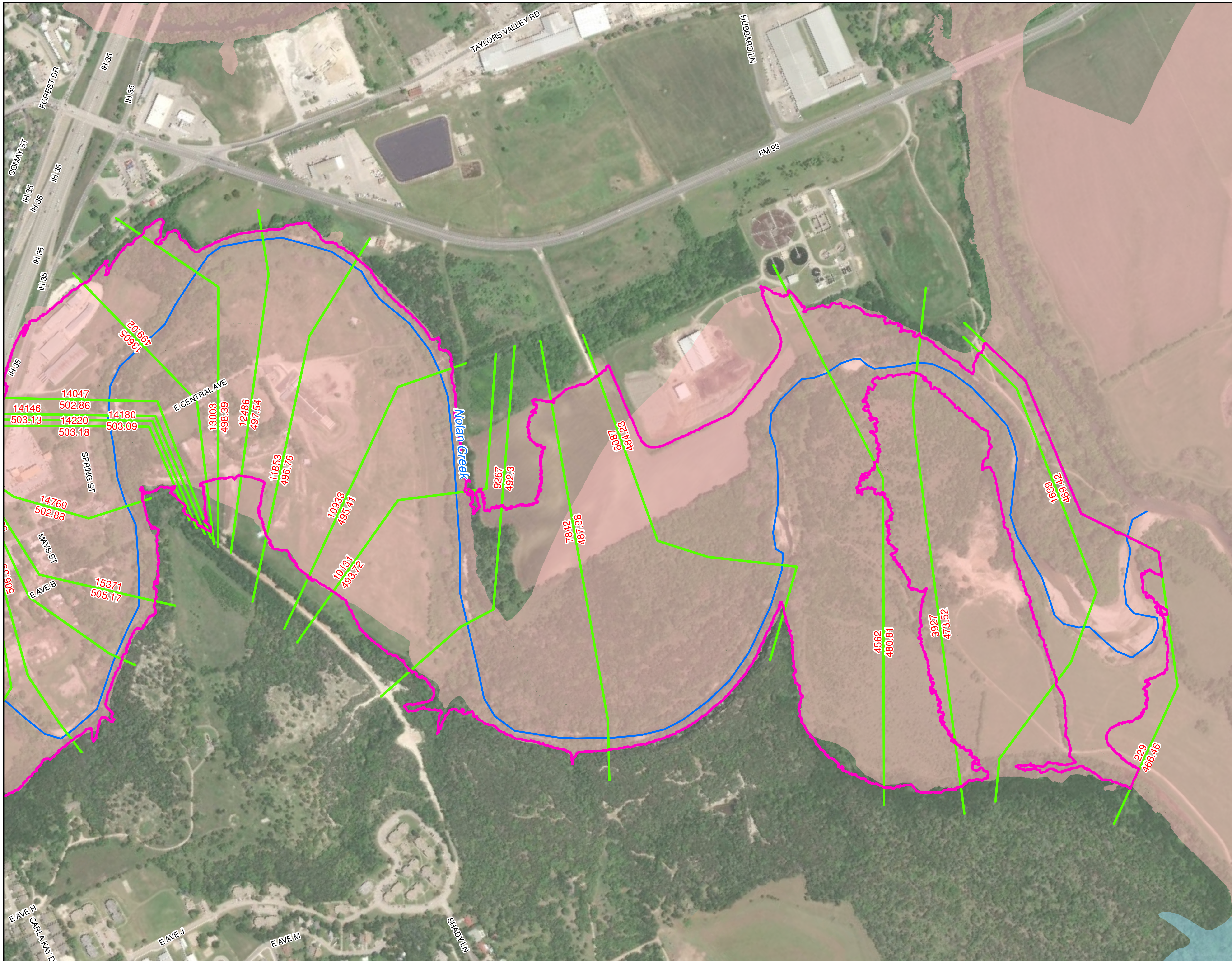

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 17 of 31

Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

A

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SCHEIBE CONSULTING LLC

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0 300 600 1,200 Feet

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 18 of 31

Nolanville Tributary

KEY TO FEATURES

FPP Study 100yr Floodplain

Study Streams

FEMA Flood Zone

A

AE

SCHEIBE CONSULTING LLC

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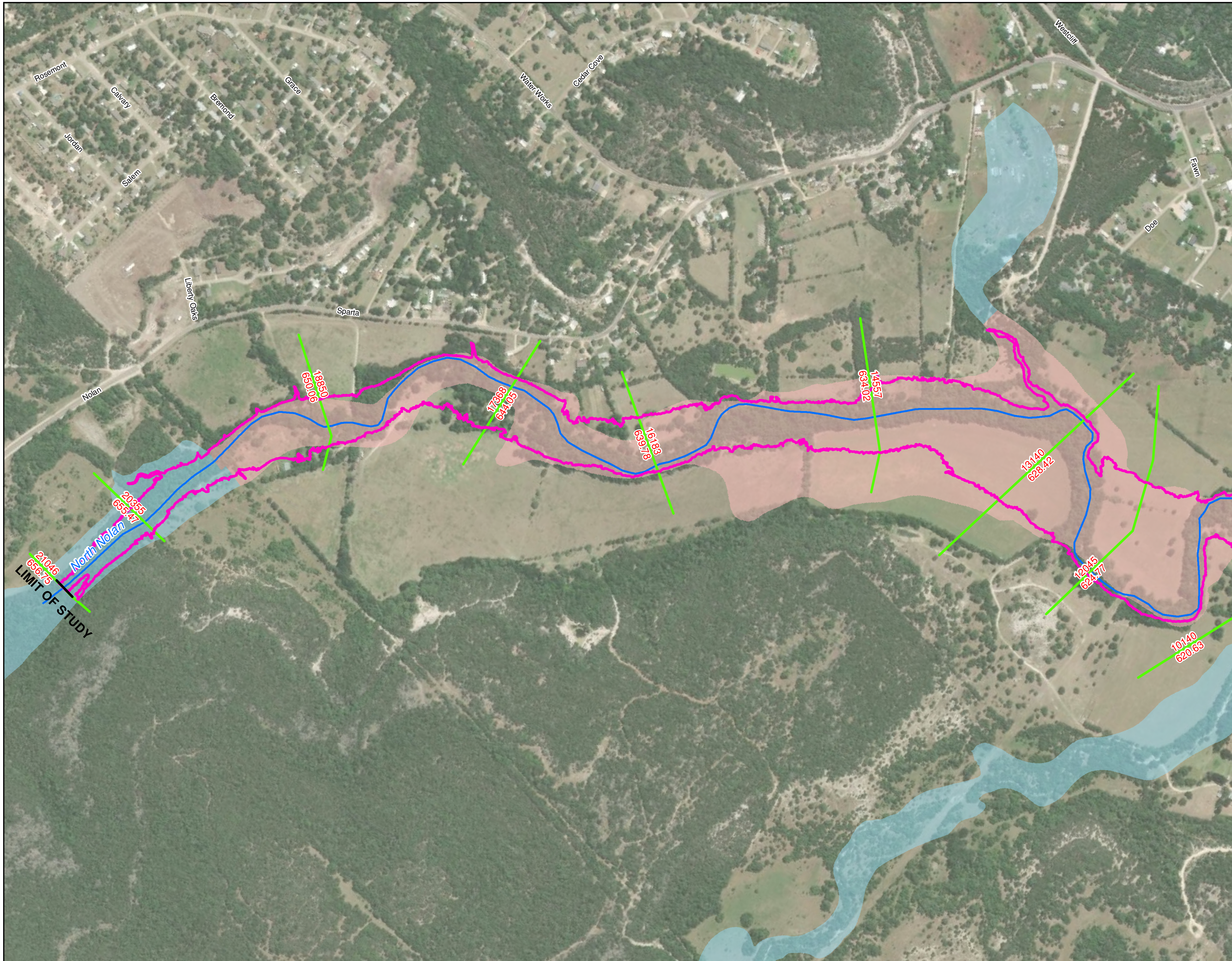

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 19 of 31

North Nolan Creek

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

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SCHEIBE CONSULTING LLC

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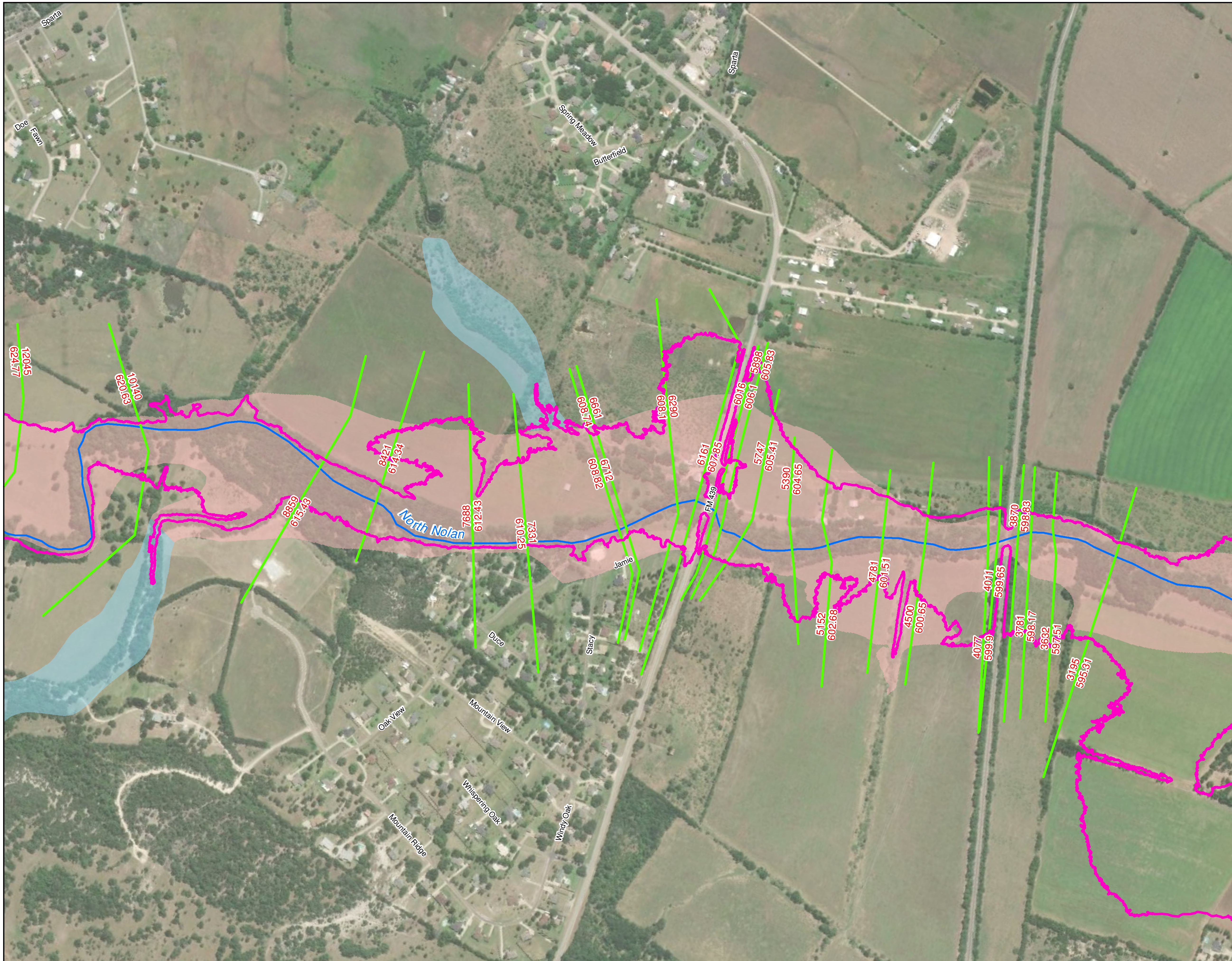
Feet



Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 20 of 31

North Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

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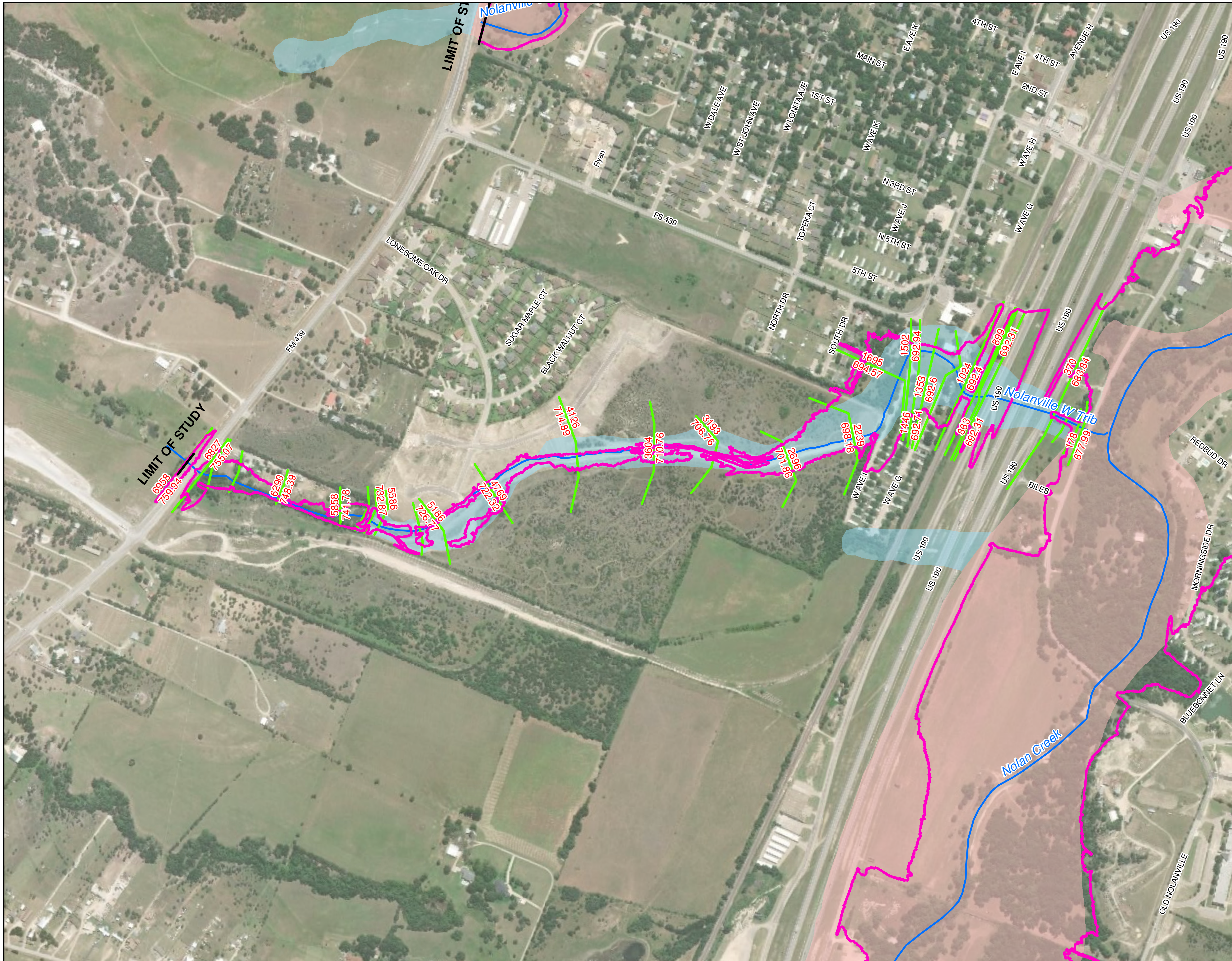

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 21 of 31

Nolanville West Tributary

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

A

AE

SCHEIBE CONSULTING LLC

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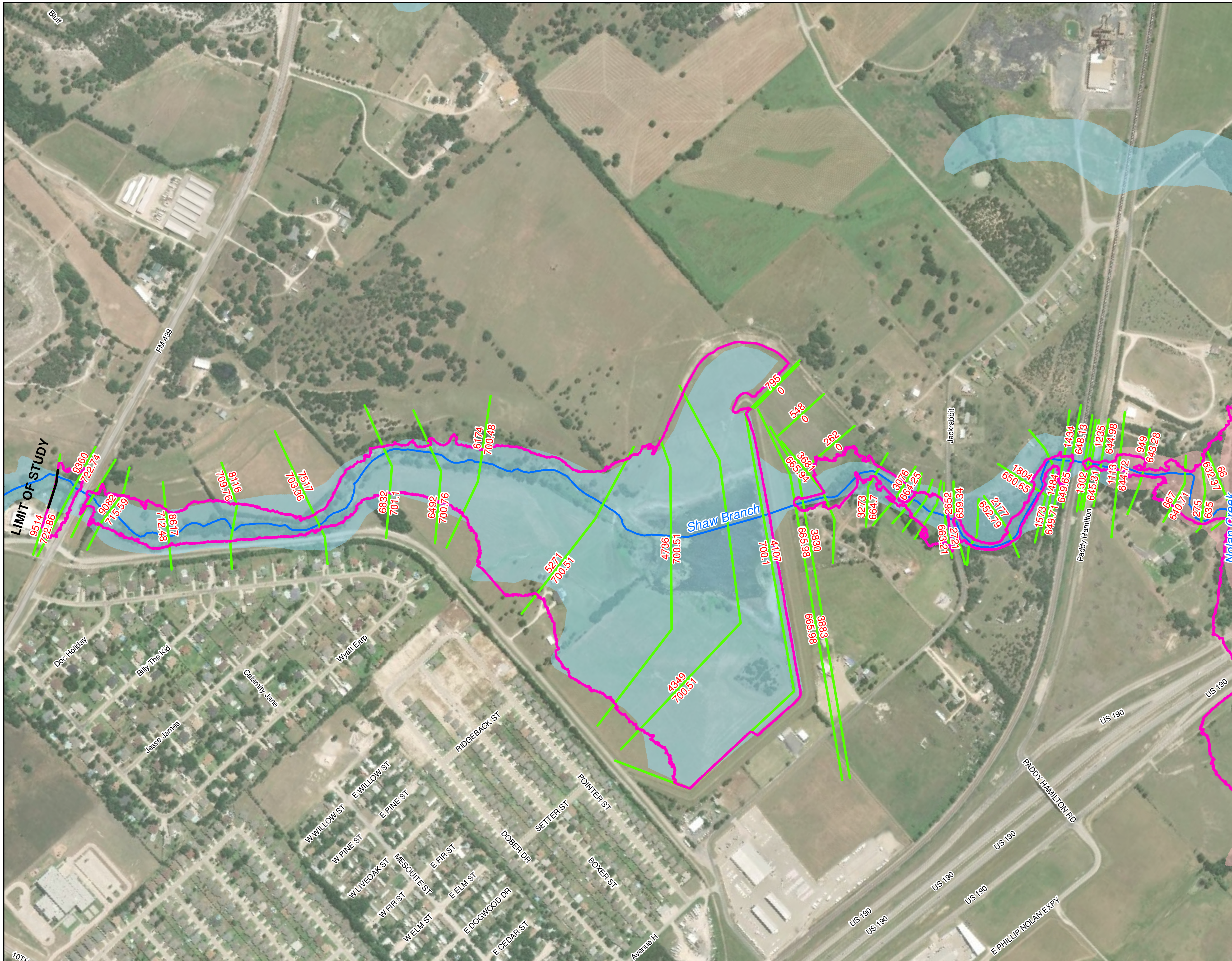
0 300 600 1,200 Feet



Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 22 of 31

Shaw Branch

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

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AE

SCHEIBE CONSULTING LLC

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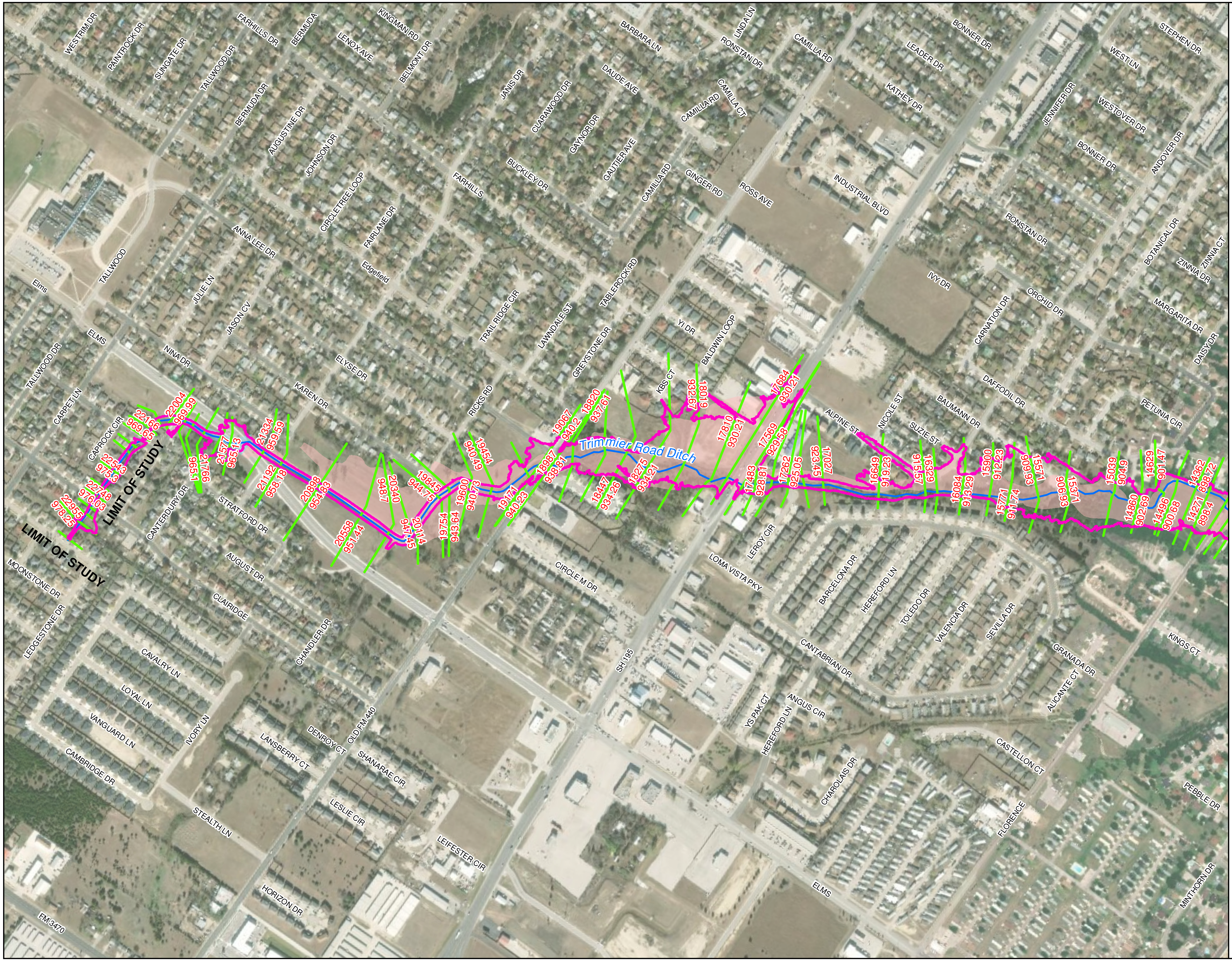

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 23 of 31

Trimmier Road Ditch

KEY TO FEATURES

FPP Study 100yr Floodplain

Cross-section Cutlines

Study Streams

FEMA Flood Zone

A

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SCHEIBE CONSULTING LLC

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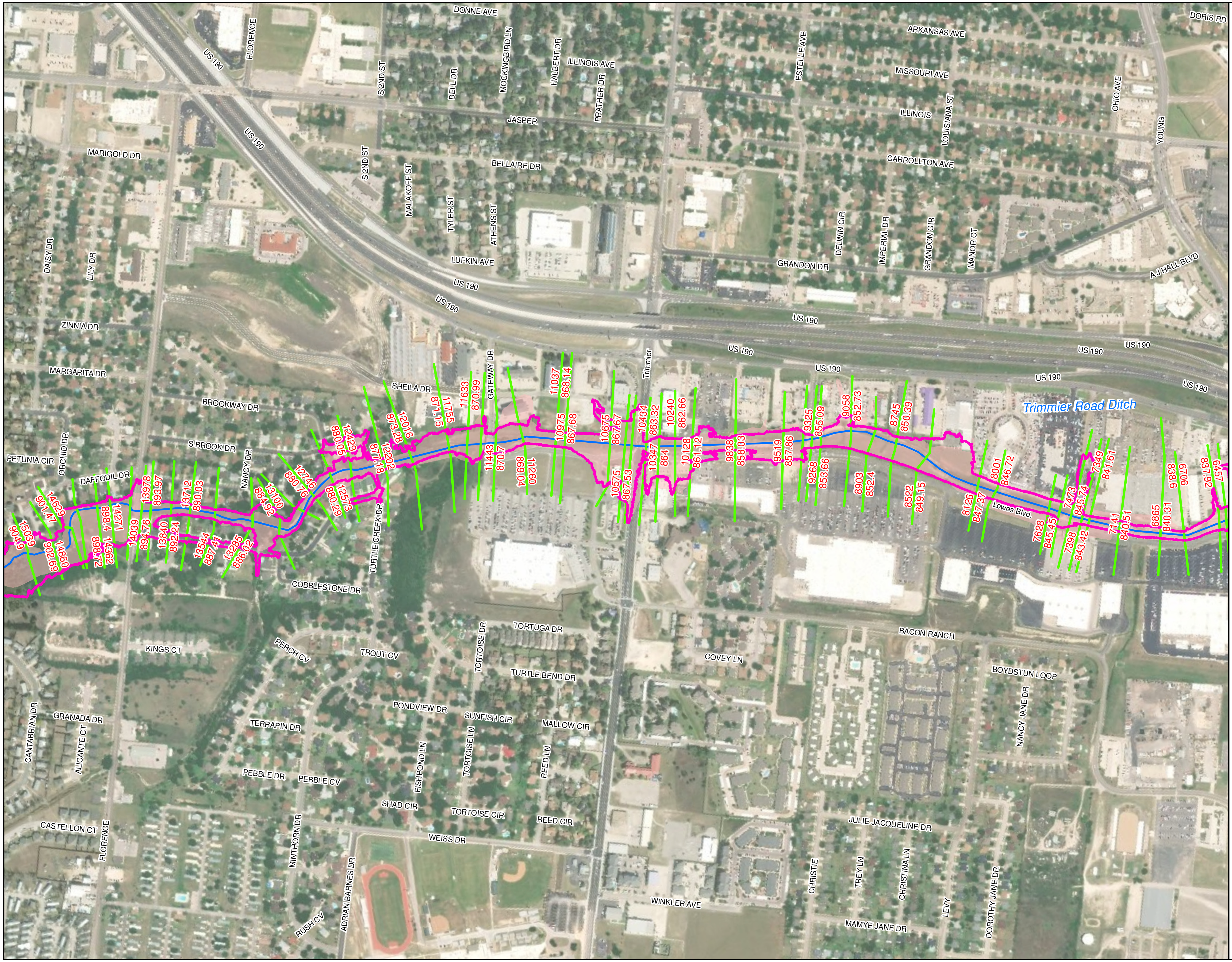

Nolan Creek Watershed Flood Protection Planning Study

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Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 24 of 31

Trimmier Road Ditch

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

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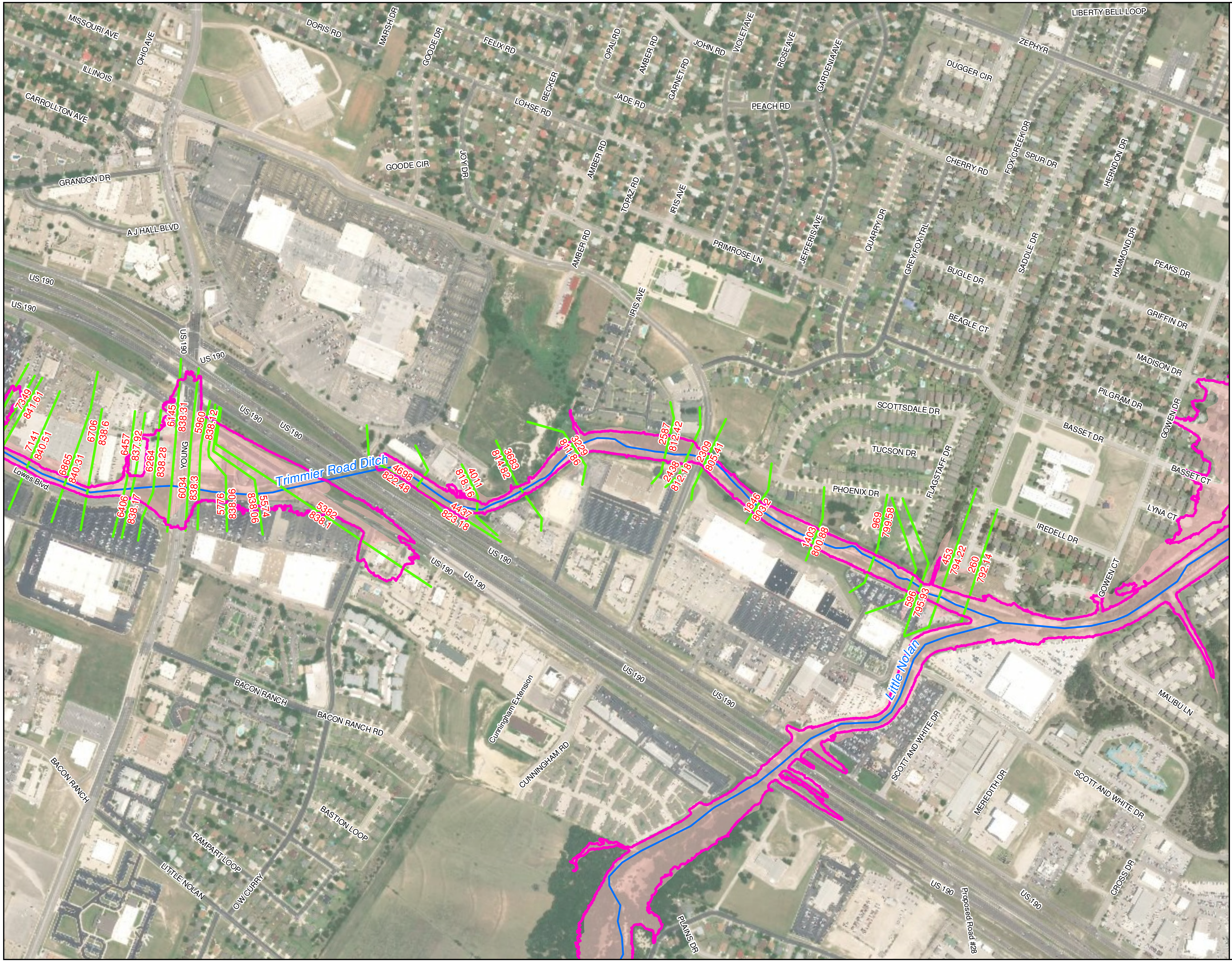

Nolan Creek Watershed Flood Protection Planning Study

CTCOG
central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 25 of 31

Trimmier Road Ditch

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEATURE Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

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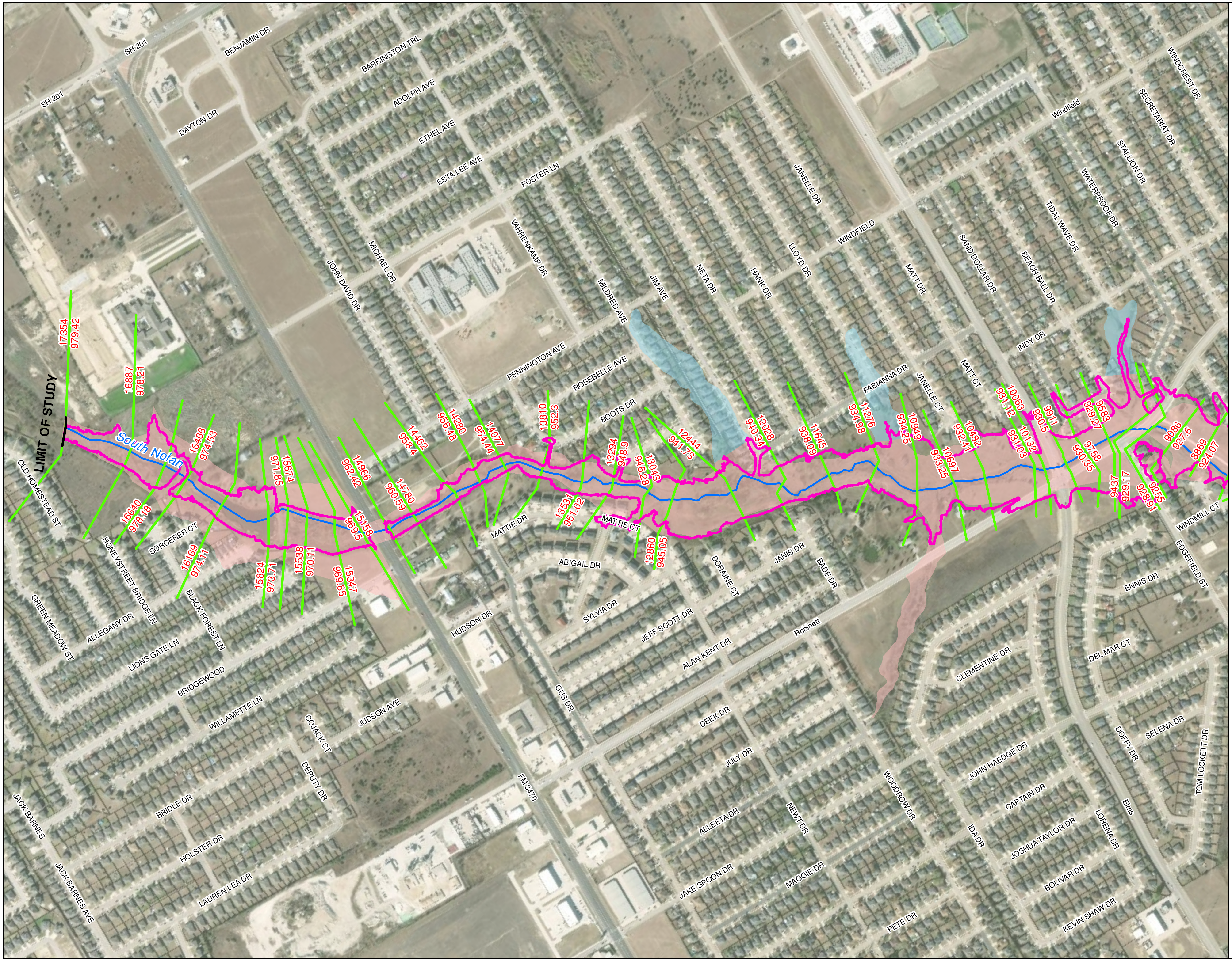

Nolan Creek Watershed Flood Protection Planning Study

CTCOG
central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 26 of 31

South Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

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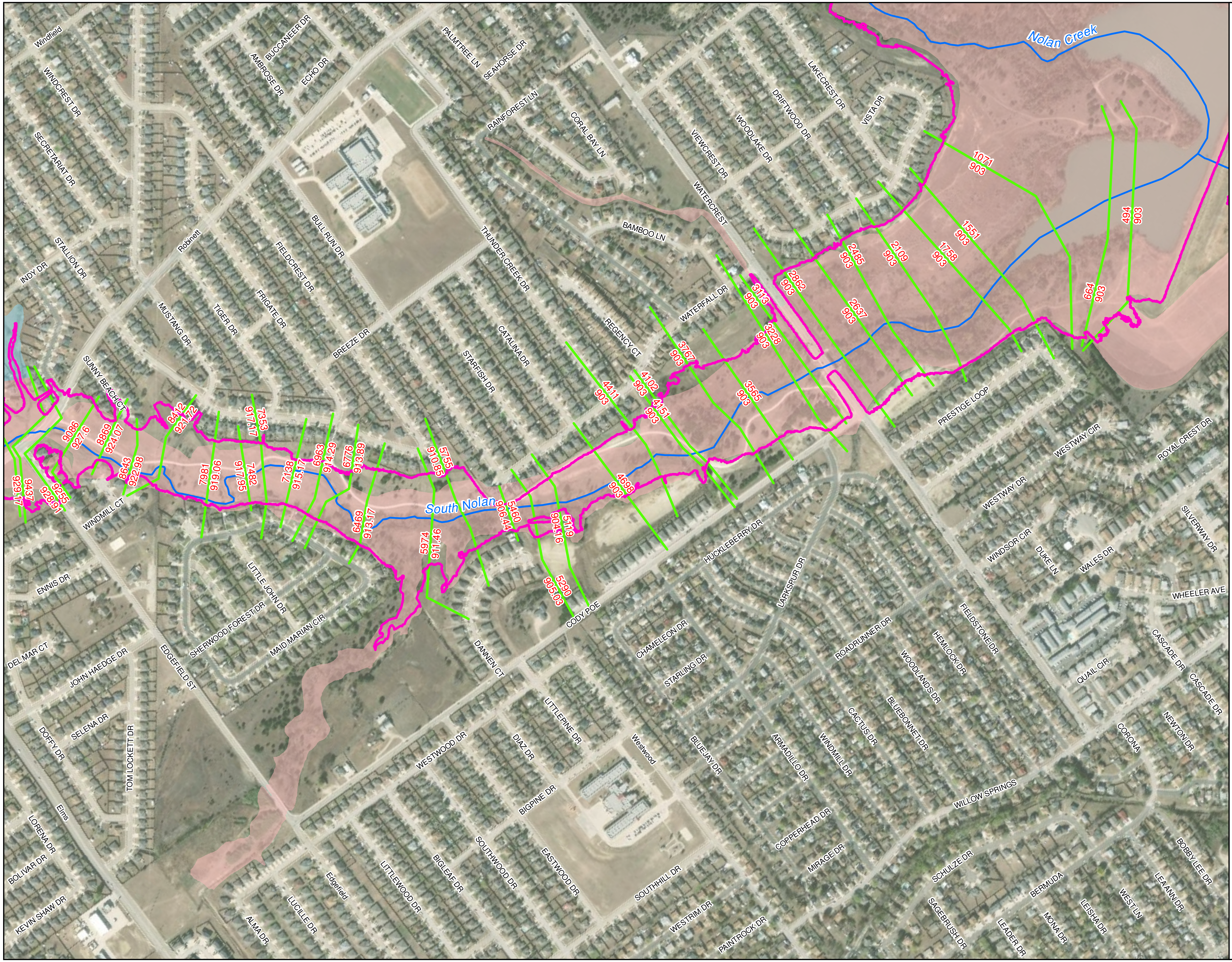

Nolan Creek Watershed Flood Protection Planning Study

CTCOG
central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 27 of 31

South Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

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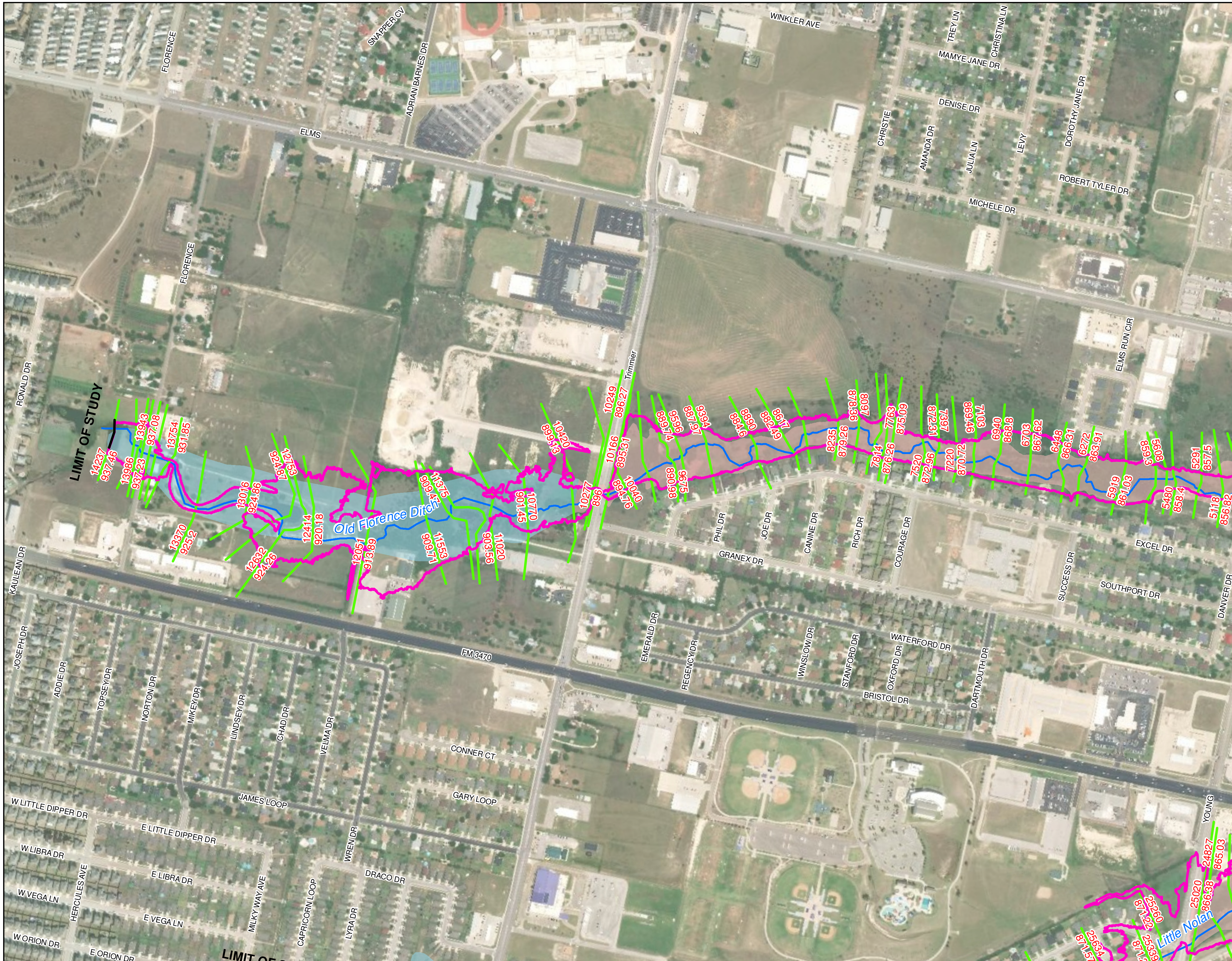
Feet



Nolan Creek Watershed Flood Protection Planning Study

CTCOG
central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 28 of 31

Old Florence Ditch

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

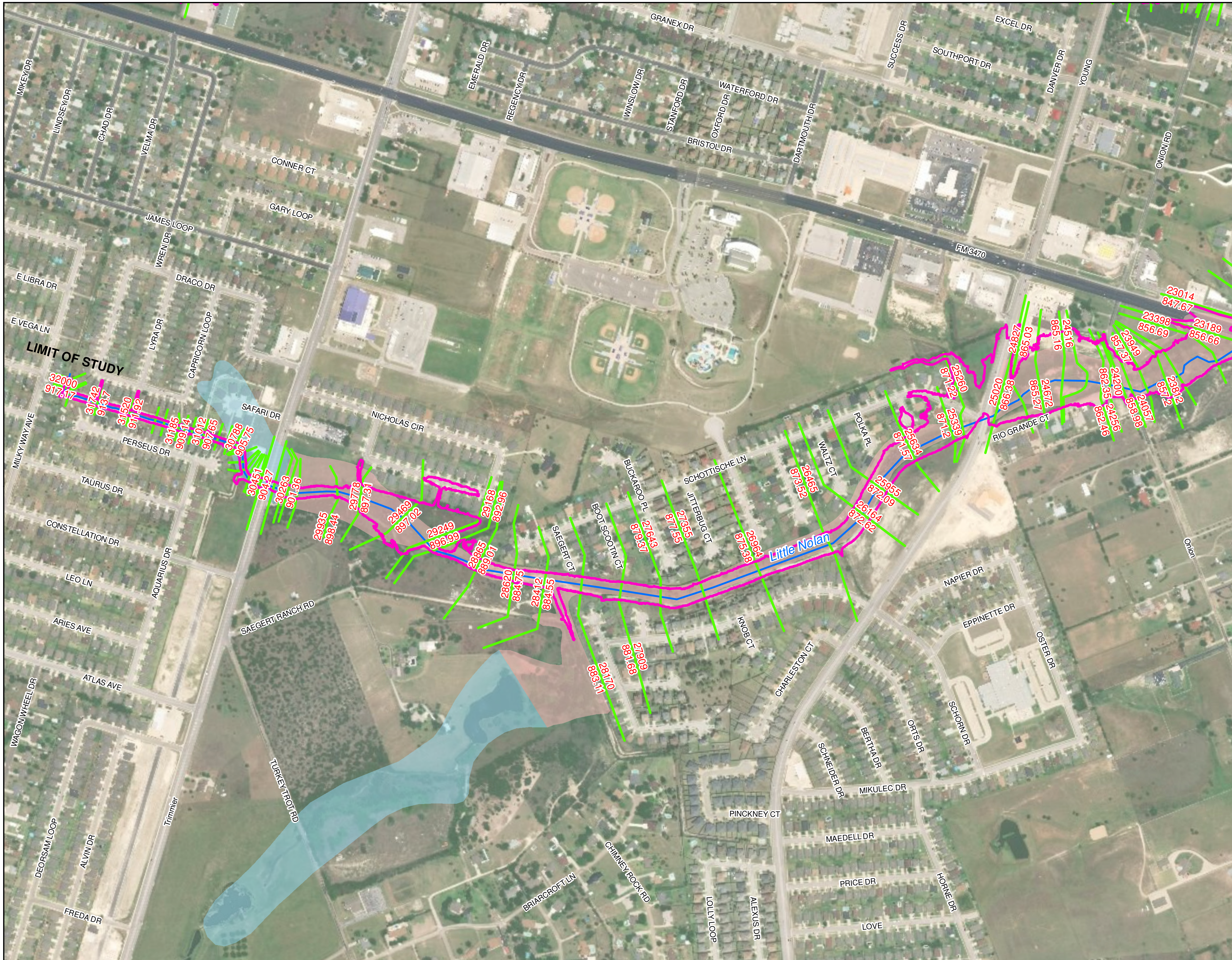
FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

0 300 600 1,200 Feet



Nolan Creek Watershed Flood Protection Planning Study

CTCOG
central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 29 of 31

Little Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

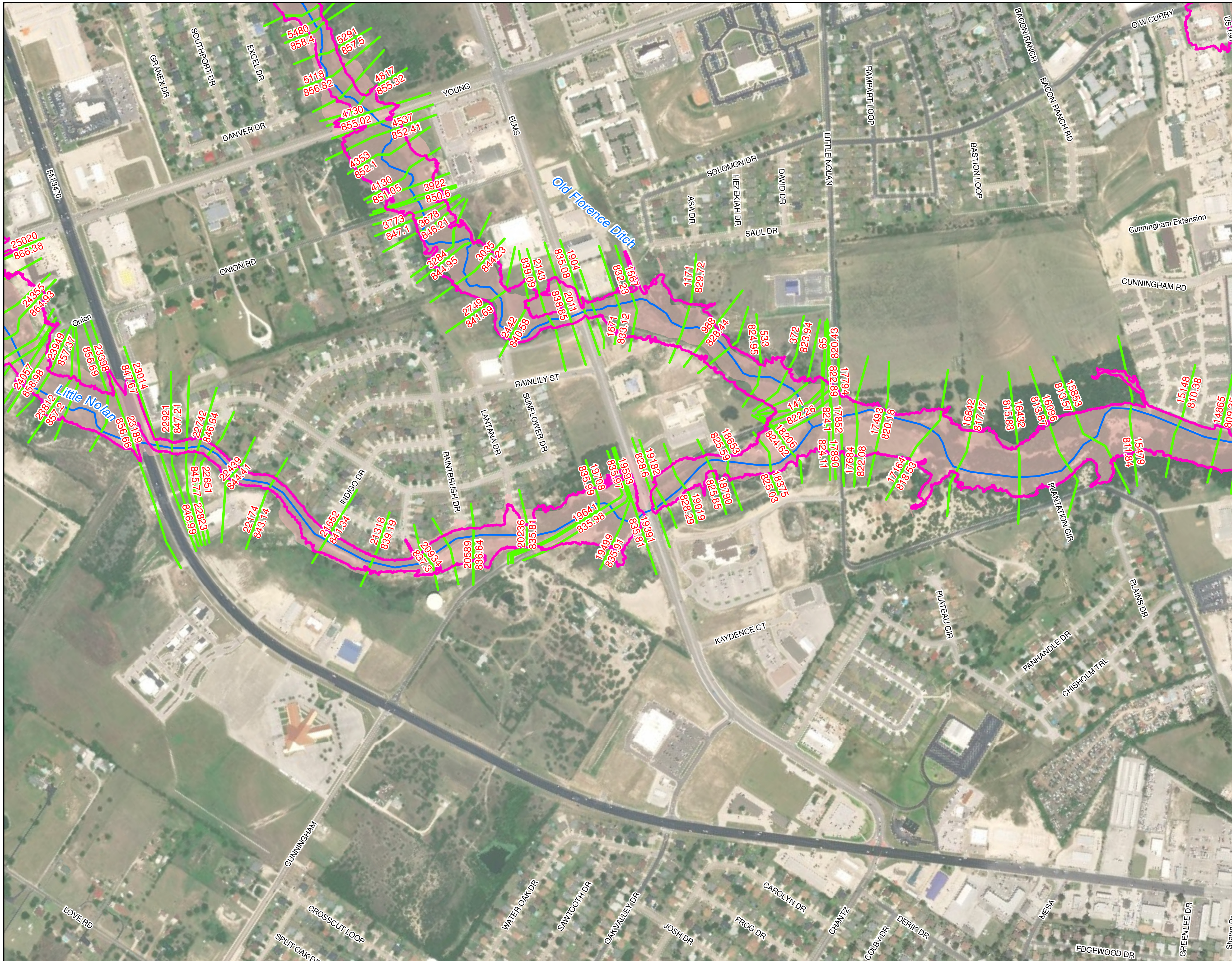
FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

N

0 300 600 1,200 Feet



Nolan Creek Watershed Flood Protection Planning Study

CTCOG
central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 30 of 31

Little Nolan Creek Old Florence Ditch

KEY TO FEATURES

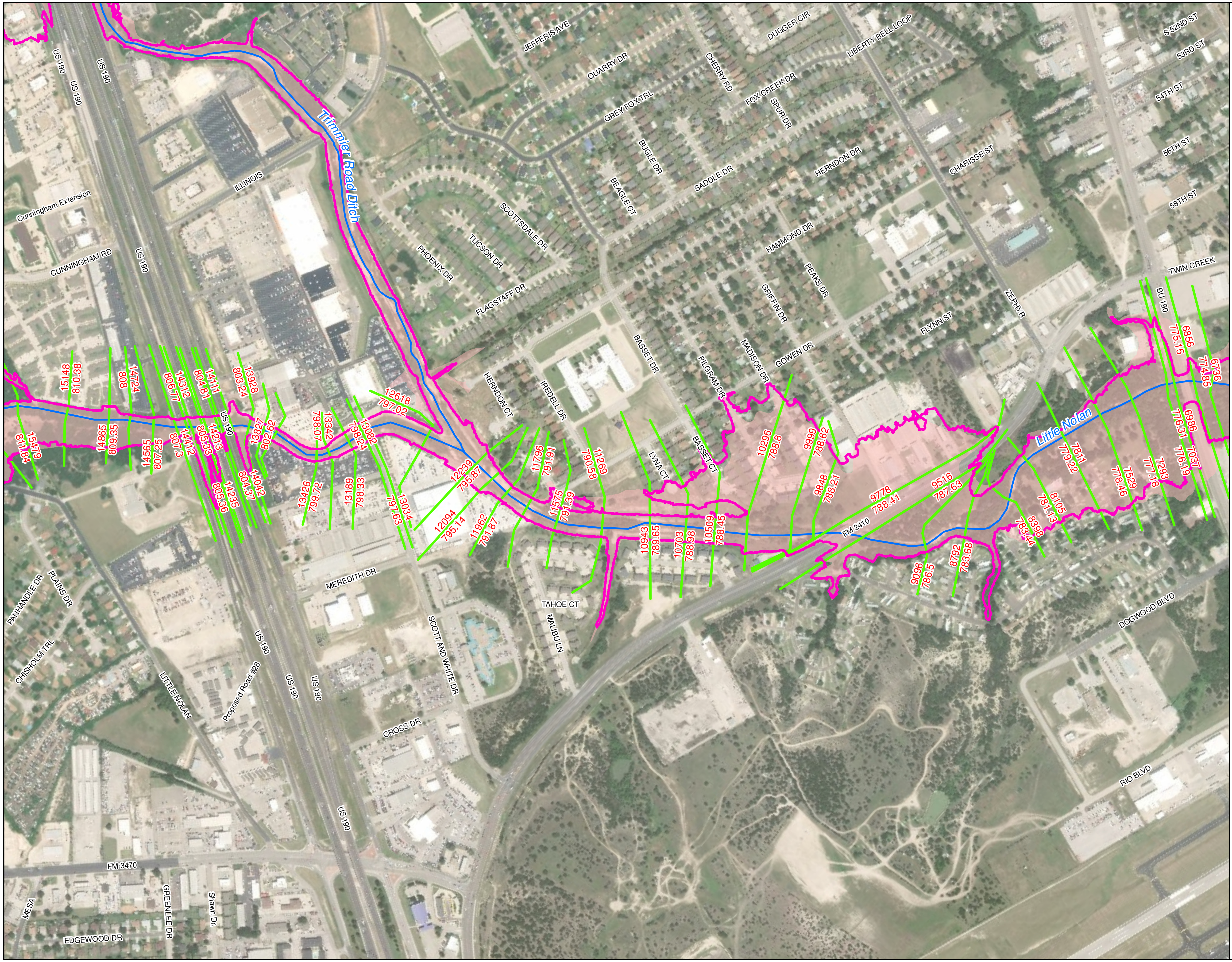
- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

0 300 600 1,200 Feet



Nolan Creek Watershed Flood Protection Planning Study

CTCOG
central texas council of governments

Appendix B: Existing 100-yr Water Surface Elev. and Floodplain Map 31 of 31

Little Nolan Creek

KEY TO FEATURES

- FPP Study 100yr Floodplain
- Cross-section Cutlines
- Study Streams

FEMA Flood Zone

- A
- AE

SCHEIBE CONSULTING LLC

0 300 600 1,200
Feet

APPENDIX C:

ALTERNATIVE ANALYSIS DETAILS

Alternative 1 – Removal of Low Water Crossing at East Central Avenue

The goal of this alternative is to reduce nuisance flooding between Interstate 35 and East Central Ave. related to debris build up at the East Central Ave. low water culvert crossing. The crossing currently consists of five 10 ft. X 4 ft. boxes with concrete wingwalls and deck and is shown in the photo below. Hydraulic analysis of the removal of this structure shows no negative downstream impacts. If debris does regularly build up at this cross and cause potential flooding, then removal of the structure would be a favorable alternative. An opinion of probable cost was not developed for this alternative as it is assumed that removal of the structure could likely be completed by city maintenance crews at low cost. Due to the likely low cost and positive benefits related to this alternative, Belton has assigned a high priority to Alternative 1.

Alternative 2 – Increase Capacity of Interstate 35 Frontage Road Bridges

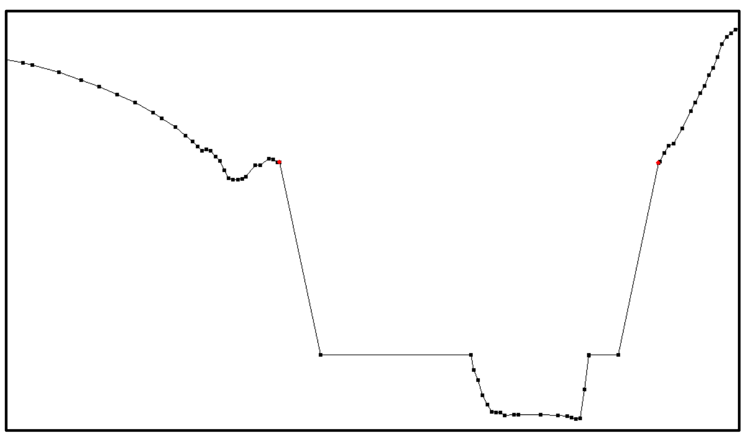
The goal of this alternative is to reduce flooding upstream of Interstate 35 by increasing conveyance capacity through the Interstate 35 frontage road bridges. The current northbound frontage road bridge can be seen in the photo below. Note the how much lower the frontage road is than the main lanes. During major flood events such as Hermine in 2010, flood waters overtop both frontage roads posing a danger to traffic and potentially obstructing flow. For the hydraulic analysis, the frontage roads were modified in the model to have a similar dimension to the higher and longer main lane bridge. The increase bridges openings resulted in a 1-foot decrease in flood elevations upstream of Interstate 35. However, no structures benefitted from the decrease, as the impacts did not reach very far upstream. Although no opinion of probable cost was determined, It is assumed that the cost of raising both frontage road bridges would be very high and produce little flood reduction benefit. Also, since TxDOT just recently completed improvements to this section of Interstate 35, they are not likely to invest any more funds in improvements in the near future. Due to the very low potential cost-benefit associated with this alternative and low likelihood of TxDOT funding, Belton has assigned a low priority to Alternative 2.

Alternative 3 – Channel Improvement from Penelope Street to Interstate 35

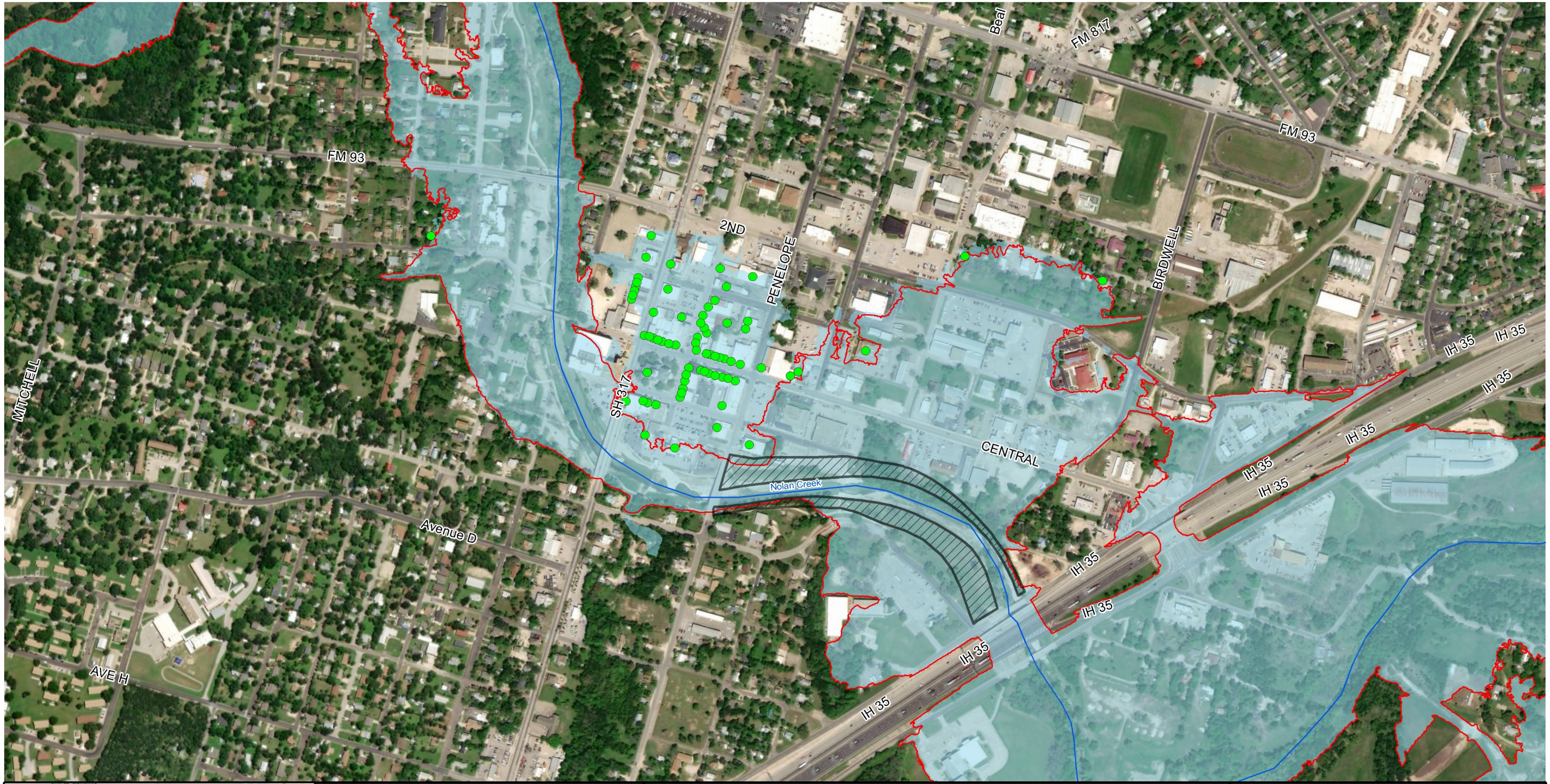
The goal of this alternative is to reduce flooding in downtown Belton downstream of Main St by adding a benched channel improvement between Penelope St. and Interstate 35. The typical dimensions of the benched cut include a 200 ft. bottom width with 3 to 1 side slopes. A typical section downstream of Penelope St. is shown below. Care was taken to avoid any existing structures and no additional improvements were made to existing bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 3.3 ft. reduction in 100-yr flood elevations in the downtown Belton area removing 71 structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $1,852,000 and will result in removal of $14,711,744 of structures from the 100-yr floodplain. The cost-benefit ratio for this project is high and has a positive impact on the downtown Belton area, which is vital to Belton's economy. Due to the positive cost-benefit ratio and high level of positive impact of this alternative, it was given a high priority by the City of Belton.

Typical Section of Channel Modification



Alternative 3 Opinon of Probable cost				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
6.09	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 15,225
24	EA	Tree Removal	$ 800.00	$ 19,200
130,010	CY	Excavation - (CHANNEL)	$ 7.43	$ 965,974
314	CY	Fill - On-site borrow	$ 6.00	$ 1,884
2,100	SY	Removing Conc (Sidewalks)	$ 11.16	$ 23,436
100	SY	Conc Sidewalks (4")	$ 50.11	$ 5,011
1	LS	Cofferdams and Dewatering	$ 25,000.00	$ 25,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
29,476	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 44,213
		SUBTOTAL*		$ 1,124,944
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 57,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 169,000
1	AC	Land Acquisition	$ 130,242	$ 130,242
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 1,481,186
		25% CONTENGENCIES		$ 370,296
		GRAND TOTAL		$ 1,852,000



Legend

- Stream CL
- Structures Removed from 100-yr Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	124	$39,195,996
Preliminary 100-YR Floodplain	195	$53,907,740
Structures Removed From 100-YR Floodplain	71	$14,711,744

N

0 500 1,000 1,500 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 3 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL IMPROVEMENT FROM PENELOPE STREET TO INTERSTATE 35

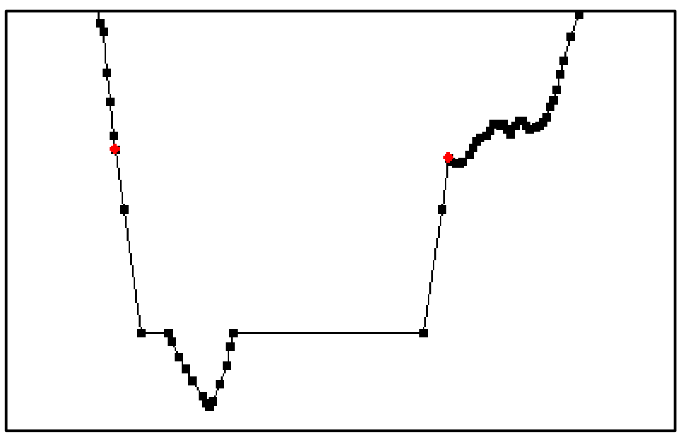
Note: The increase in discharge due to channel modifications resulted in a 0.7% increase in water surface elevations. No detention basin was recommended

Alternative 4 – Channel Improvement from Second Street to Main Street

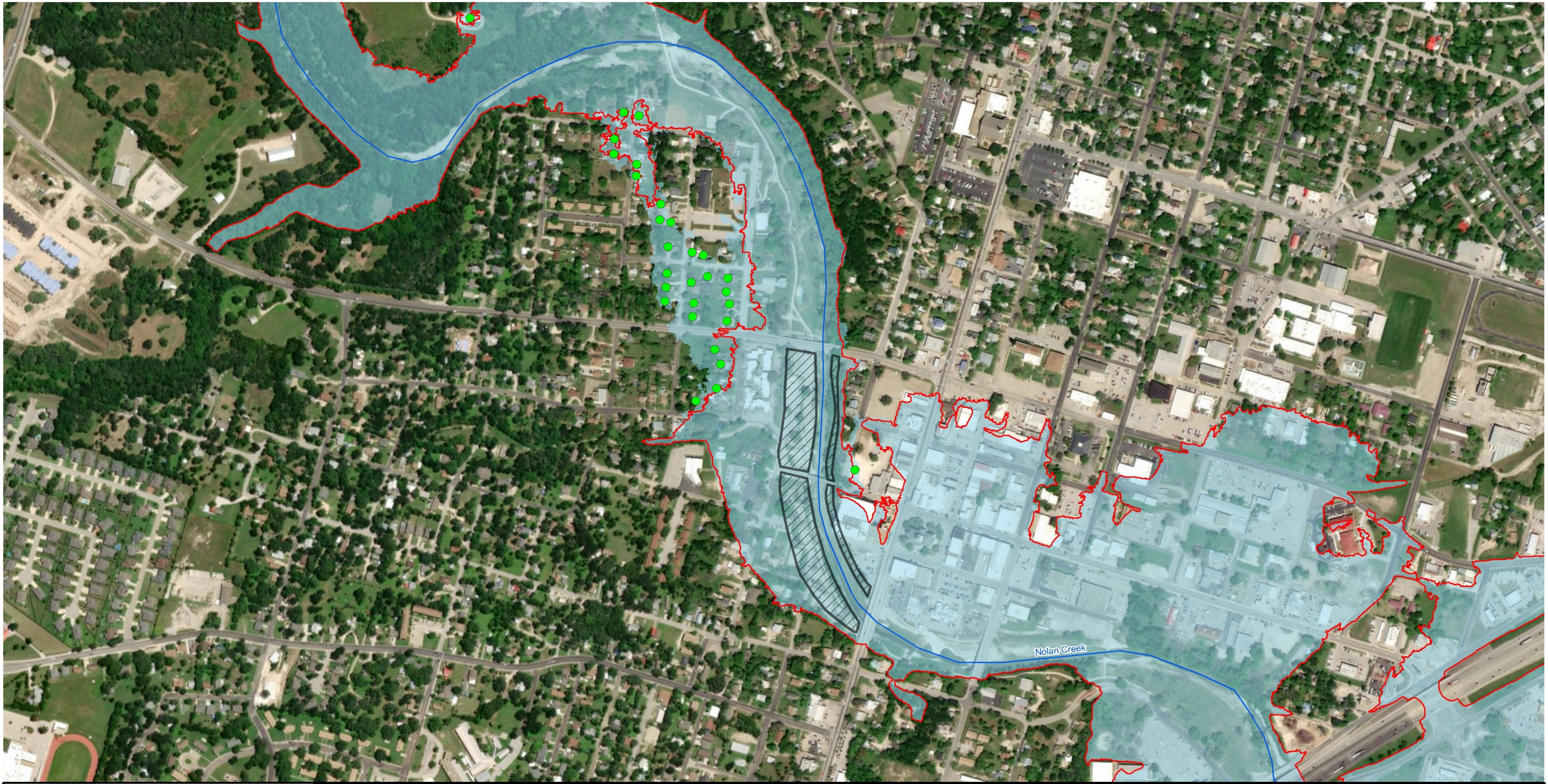
The goal of this alternative is to reduce flooding in Belton upstream of Main St. by adding a benched channel improvement between Main St. and Second St. The typical dimensions of the benched cut include a 240 ft. bottom width with 3 to 1 side slopes. A typical section upstream of Central Ave. is shown below. Care was taken to avoid any existing structures and no additional improvements were made to existing bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 3.2 ft. reduction in 100-yr flood elevations just upstream of Second St. removing 30 structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $2,467,000 and will result in removal of $3,139,203 of structures from the 100-yr floodplain. The cost-benefit ratio for this project is good but has a high impact on the historic Yettie Polk Park, which is a focal point of recreation in Belton. Due to the high level of negative impact and moderate cost-benefit ratio of this alternative, it was given a low priority by the City of Belton.

Typical Section of Channel Modification



Alternative 4 Opinon of Probable cost				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
3.68	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 9,200
12	EA	Tree Removal	$ 800.00	$ 9,600
107,595	CY	Excavation - (CHANNEL)	$ 7.43	$ 799,431
762	CY	Fill - On-site borrow	$ 6.00	$ 4,572
11,160	SY	Removing Conc (Sidewalks)	$ 11.16	$ 124,546
11,000	SY	Conc Sidewalks (4")	$ 50.11	$ 551,210
1	LS	Cofferdams and Dewatering	$ 25,000	$ 25,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
17,811	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 26,717
		SUBTOTAL*		$ 1,575,275
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 79,000
		Engineering Design (approx. 15% of construction subtotal)	$ -	$ 237,000
1	AC	Land Acquisition	$ 81,556	$ 81,556
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 1,972,831
		25% CONTENGENCIES		$ 493,208
		GRAND TOTAL		$ 2,467,000



Legend

- Stream CL
- Structures Removed from 100-yr Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	165	$50,768,537
Preliminary 100-YR Floodplain	195	$53,907,740
Structures Removed From 100-YR Floodplain	30	$3,139,203

N

0 500 1,000 1,500 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 4 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL IMPROVEMENT FROM 2ND STREET STREET TO MAIN STREET

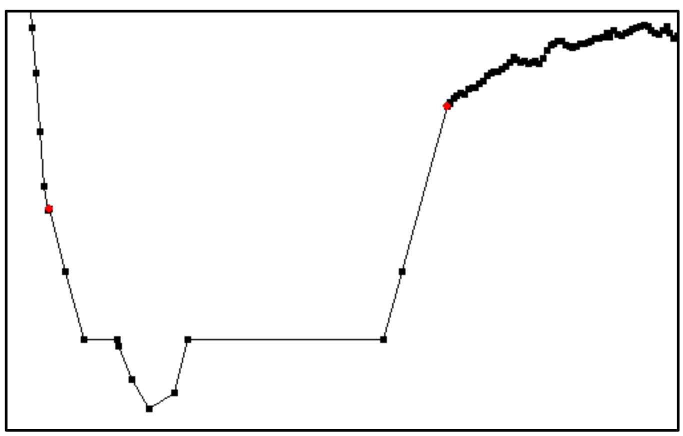
Note: The increase in discharge due to channel modifications resulted in a 0.7% increase in water surface elevations. No detention basin was recommended

Alternative 5 – Channel Improvement
Upstream of Second Street

The goal of this alternative is to reduce flooding in Belton upstream of Second St. by adding a benched channel improvement beginning from upstream of Baxter's Crossing down to Second St. The typical dimensions of the benched cut include a 240 ft. bottom width with 3 to 1 side slopes. A typical section upstream of Second St. is shown below. Care was taken to avoid any existing structures and no additional improvements were made to existing bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 6.4 ft. reduction in 100-yr flood elevations upstream of Second St. removing 21 structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $5,163,000 and will result in removal of $752,101 of structures from the 100-yr floodplain. Although the cost-benefit ratio for this alternative is low, it is located in a reach with fewer physical constraints for construction. Due to the low cost-benefit ratio but more favorable location, it was given a medium priority by the City of Belton.

Typical Section of Channel Modification



Alternative 5 Opinon of Probable cost				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
13.2	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 33,000
30	EA	Tree Removal	$ 800.00	$ 24,000
395,802	CY	Excavation - (CHANNEL)	$ 7.43	$ 2,940,809
379	CY	Fill - On-site borrow	$ 6.00	$ 2,274
3,459	SY	Removing Conc (Sidewalks)	$ 11.16	$ 38,602
3,459	SY	Conc Sidewalks (4")	$ 50.11	$ 173,330
1	LS	Cofferdams and Dewatering	$ 25,000.00	$ 25,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
63,888	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 95,832
		SUBTOTAL*		$ 3,357,848
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 168,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 504,000
1	AC	Land Acquisition	$ 100,457	$ 100,457
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 4,130,305
		25% CONTENGENCIES		$ 1,032,576
		GRAND TOTAL		$ 5,163,000

Legend

- Stream CL
- Structures Removed from 100-yr Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	174	$53,155,639
Preliminary 100-YR Floodplain	195	$53,907,740
Structures Removed From 100-YR Floodplain	21	$752,101

N

0 500 1,000 1,500 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 5 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL IMPROVEMENT UPSTREAM OF 2ND STREET

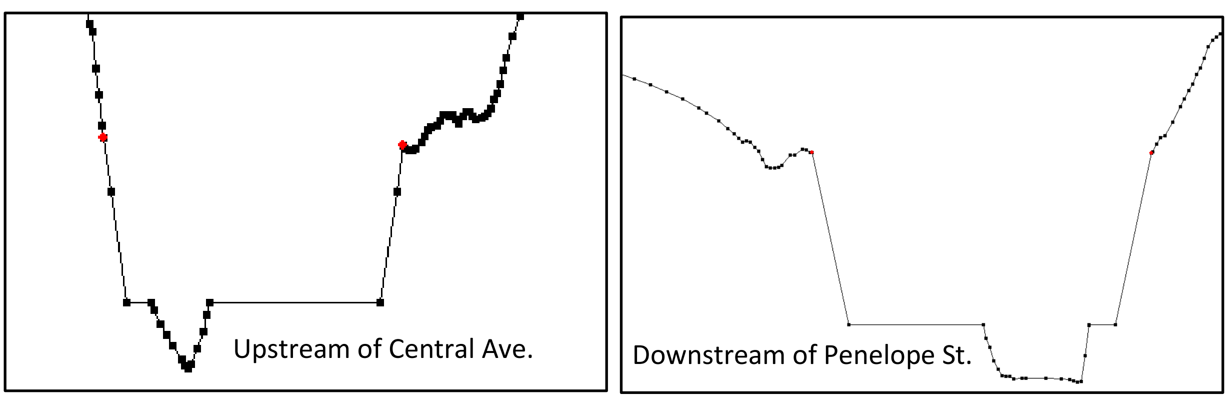
Note: The increase in discharge due to channel modifications resulted in a 0.7% increase in water surface elevations. No detention basin was recommended

Alternative 6 – Channel Improvement
Second Street to Main Street and Penelope St. to Interstate 35

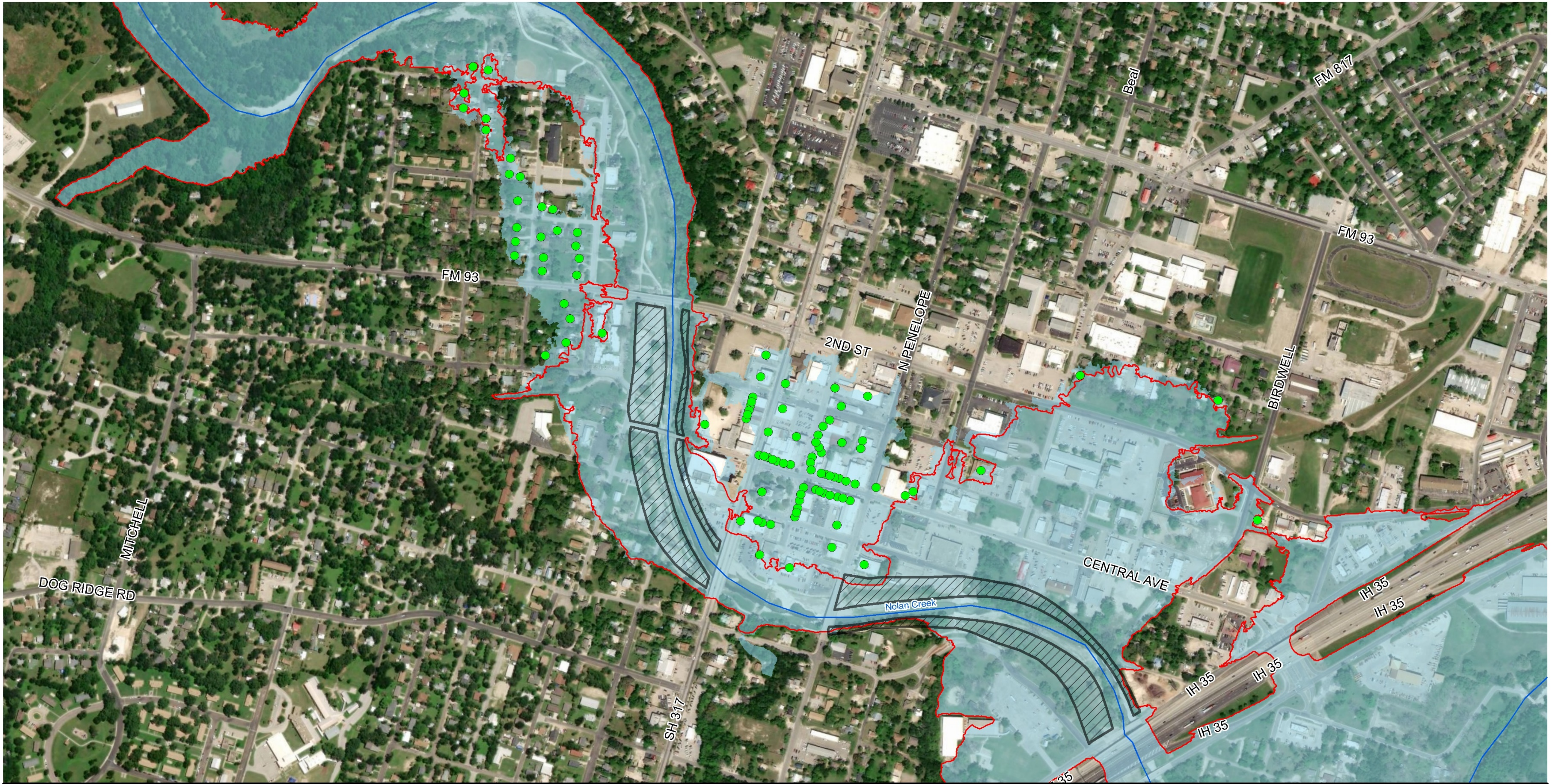
The goal of this alternative is to reduce flooding in downtown Belton from Second St. to Interstate 35 by adding a benched channel improvement from Second St. to Main St. and Penelope St. to Interstate 35. This alternative is a combination of the benched cuts described for Alternatives 3 and 4. Care was taken to avoid any existing structures and no additional improvements were made to existing bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 3.8 ft. reduction in 100-yr flood elevations upstream of Second St. and 3.2 ft. in downtown Belton removing 105 structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $4,242,000 and will result in removal of $19,509,422 of structures from the 100-yr floodplain. The cost-benefit ratio for this alternative is very high. However, like Alternative 4 it has a high and unacceptable impact on Yettie Polk Park. Due to the negative impact tot Yettie Polk Park related to this alternative, it was given a low priority by the City of Belton. It should be noted that combining Alternatives 3 and 5 would likely have a similar level of benefits as combining Alternatives 3 and 4 and would not impact Yettie Polk Park.

Typical Sections of Channel Modification



Alternative 6 Opinon of Probable cost				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
10	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 24,425
36	EA	Tree Removal	$ 800.00	$ 28,800
237,605	CY	Excavation - (CHANNEL)	$ 7.43	$ 1,765,405
1,076	CY	Fill - On-site borrow	$ 6.00	$ 6,456
13,260	SY	Removing Conc (Sidewalks)	$ 11.16	$ 147,982
11,100	SY	Conc Sidewalks (4")	$ 50.11	$ 556,221
1	LS	Cofferdams and Dewatering	$ 25,000.00	$ 25,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
47,287	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 70,930
		SUBTOTAL*		$ 2,650,219
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 133,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 398,000
1	AC	Land Acquisition	$ 211,798	$ 211,798
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 3,393,017
		25% CONTENGENCIES		$ 848,254
		GRAND TOTAL		$ 4,242,000



Legend

- Stream CL
- Structures Removed from 100-yr Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplains
- Preliminary 100-YR Floodplains

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	93	$34,,572,950
Preliminary 100-YR Floodplain	195	$53,907,740
Structures Removed From 100-YR Floodplain	102	$19,334,790

N

0 500 1,000 1,500 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 6 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

COMBNATION OF ALTERNATIVES 3 AND 4
CHANNEL IMPROVEMENTS

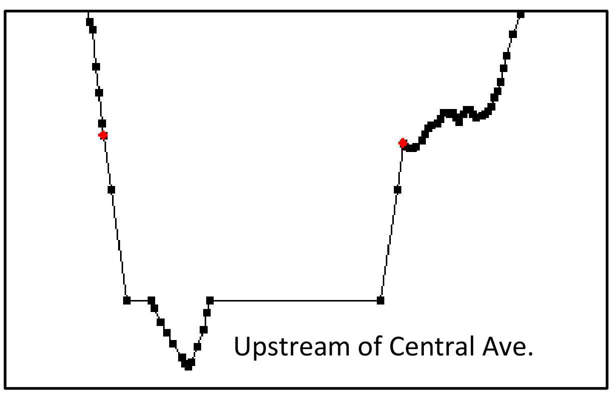
Note: The increase in discharge due to channel modifications resulted in a 0.7% increase in water surface elevations. No detention basin was recommended

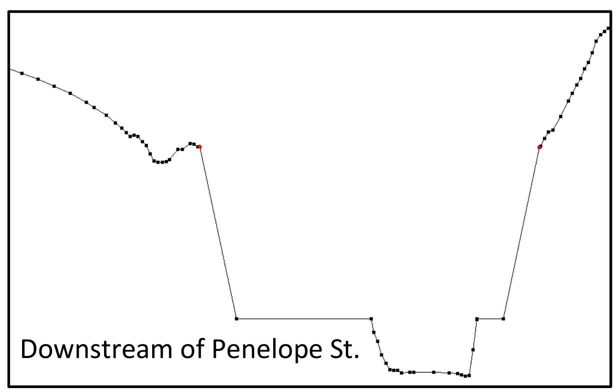
Alternative 7 – Channel Improvement
Baxter Crossing to Main Street and Penelope St. to Interstate 35

The goal of this alternative is to reduce flooding in downtown Belton from upstream of Second St. to Interstate 35 by adding a benched channel improvement from upstream of Baxter's Crossing to Main St. and Penelope St. to Interstate 35. This alternative is a combination of the benched cuts described for Alternatives 3, 4, and 5. Typical sections are shown below. Care was taken to avoid any existing structures and no additional improvements were made to existing bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 7.4 ft. reduction in 100-yr flood elevations upstream of Second St. and 3.2 ft. in downtown Belton removing 112 structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

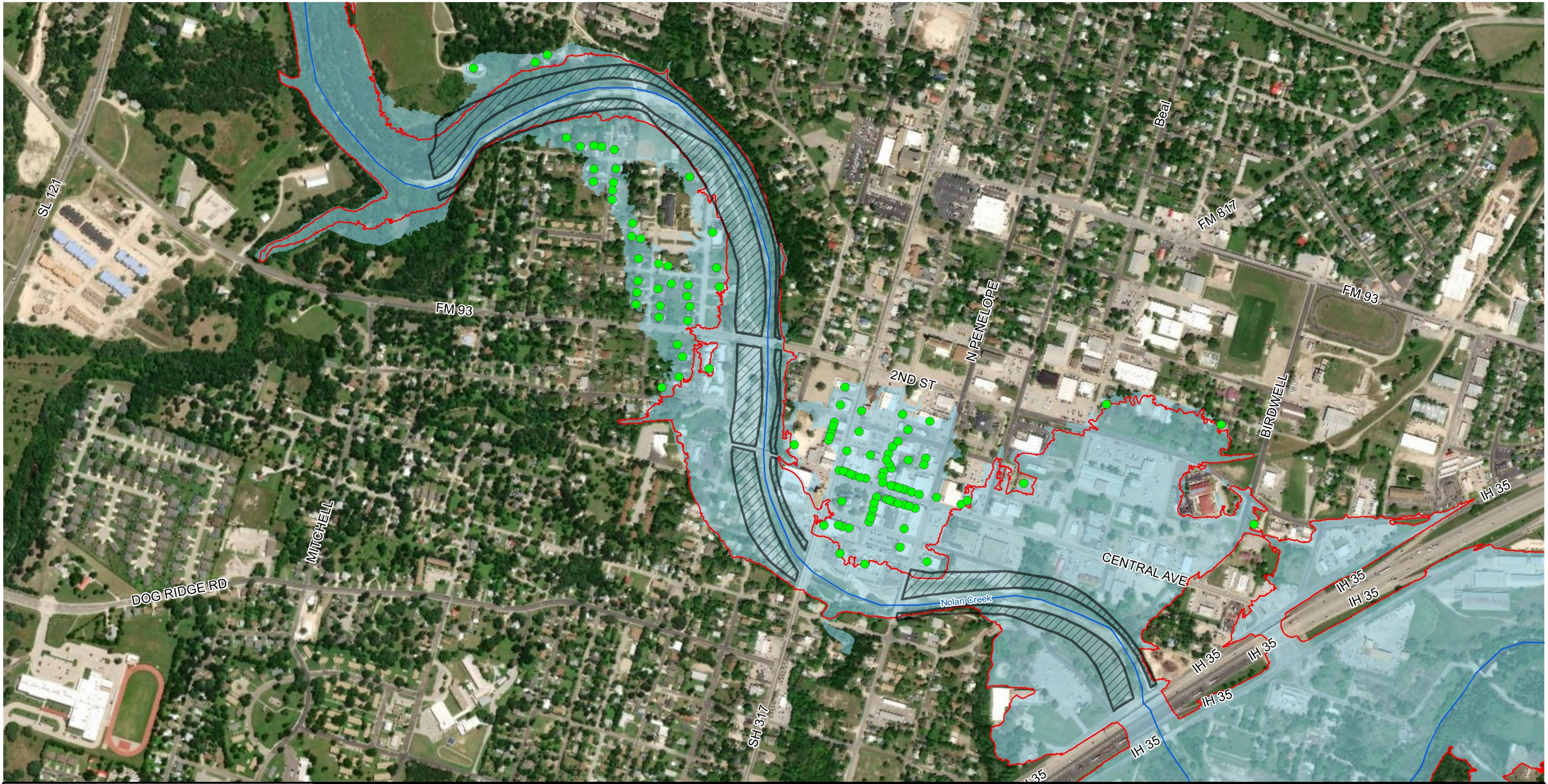
A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $9,328,000 and will result in removal of $19,509,422 of structures from the 100-yr floodplain. The cost-benefit ratio for this alternative is high. However, like Alternative 4 it has a high and unacceptable impact on Yettie Polk Park. Due to the negative impact tot Yettie Polk Park related to this alternative, it was given a low priority by the City of Belton.

Typical Section of Channel Modification





ALT7 - Channel Modifications				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
23	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 57,425
66	EA	Tree Removal	$ 800.00	$ 52,800
633,407	CY	Excavation - (CHANNEL)	$ 7.43	$ 4,706,214
1,455	CY	Fill - On-site borrow	$ 6.00	$ 8,730
16,719	SY	Removing Conc (Sidewalks)	$ 11.16	$ 186,584
14,559	SY	Conc Sidewalks (4")	$ 50.11	$ 729,551
1	LS	Cofferdams and Dewatering	$ 25,000.00	$ 25,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
111,175	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 166,762
		SUBTOTAL*		$ 5,958,067
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 298,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 894,000
1	AC	Land Acquisition	$ 312,255	$ 312,255
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 7,462,322
		25% CONTENGENCIES		$ 1,865,580
		GRAND TOTAL		$ 9,328,000



Legend

- Stream CL
- Structures Removed from 100-yr Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplains
- Preliminary 100-YR Floodplains

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	82	$34,265,066
Preliminary 100-YR Floodplain	195	$53,907,740
Structures Removed From 100-YR Floodplain	113	$19,642,674

N

0 600 1,200 1,800 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 7 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

COMBINATION OF ALTERNATIVES 3, 4, AND 5 CHANNEL IMPROVEMENTS

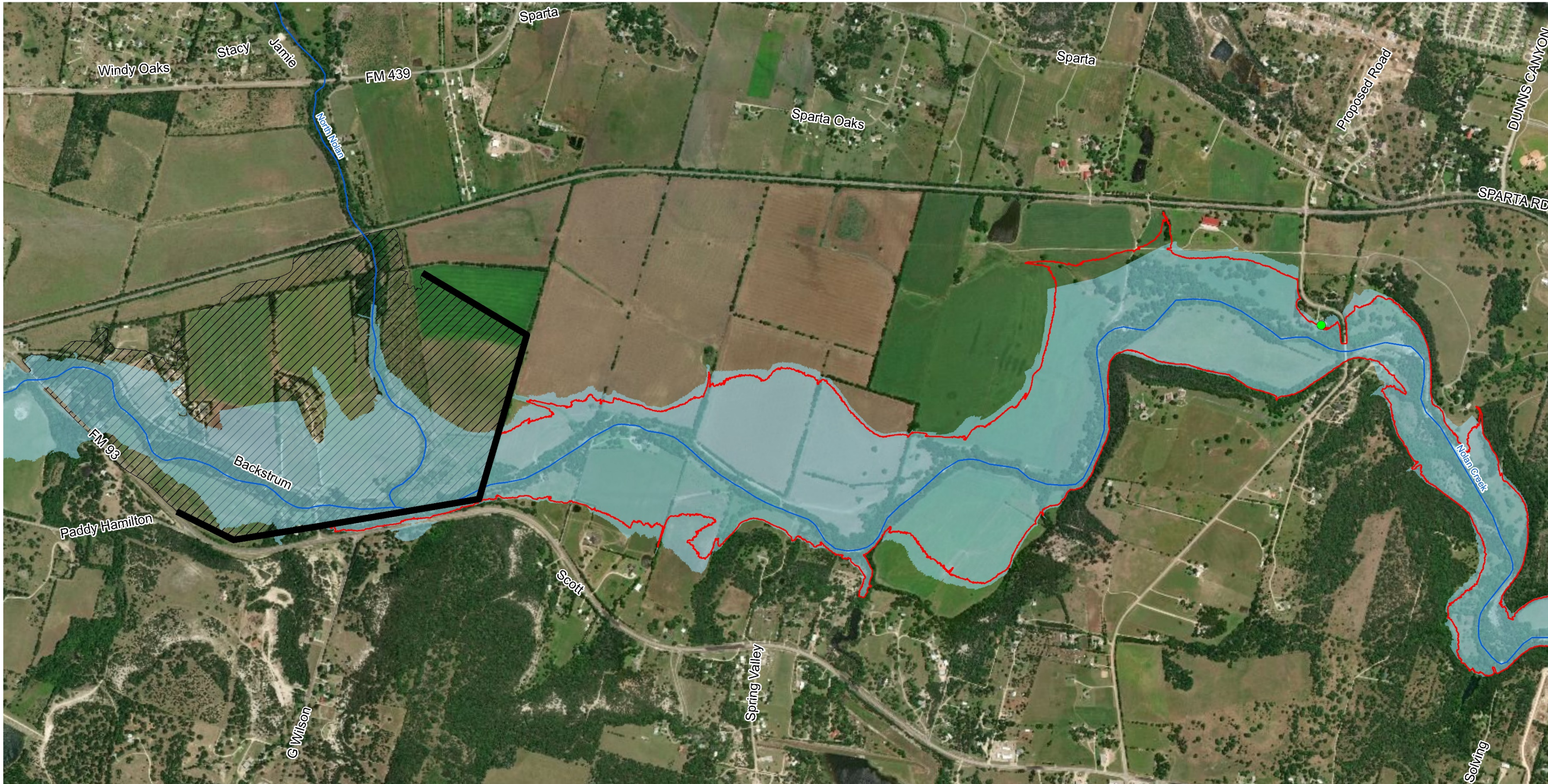
Note: The increase in discharge due to channel modifications resulted in a 0.7% increase in water surface elevations. No detention basin was recommended

Alternative 8 – Proposed Detention Basin
Nolan/North Nolan Confluence

The goal of this alternative is to reduce flooding downstream of the confluence with North Nolan Creek and especially through the City of Belton. This alternative consists of a 3,580 acre-foot at-grade, in-line regional detention pond located just downstream of the confluence of Nolan Creek and North Nolan Creek. The conceptual configuration of the berm structure consists of ten 12 ft. X 12 ft. box culverts, a 150 ft. long emergency spillway, and a 2050 ft. long dam top. The placement of the berm structure is conceptual and subject to negotiation with property owners for construction and inundation easements. Care was taken to avoid any existing structures by the dam structure or corresponding flood pool elevation. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in the removal of 139 structures from the existing 100-yr floodplain mostly in downtown Belton. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $7,892,000 and will result in removal of $23,497,053 of structures from the 100-yr floodplain.

ALT8- Proposed Detention Basin (Nolan/North Nolan Detention)				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
64	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 192,000
30	EA	Tree Removal	$ 400	$ 12,000
356,496	CY	Embankment (95% Proctor) - Select Fill	$ 6.00	$ 2,138,976
1,850	LF	10 - Conc Box Culv (12FT x 12FT)	$ 700	$ 1,295,000
1	EA	1 Set - Wingwalls (HW = 12FT)	$ 150,000	$ 150,000
1,874	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ 4,123
1,562	CY	RipRap (Stone Common) (Dry) (12 in)	$ 60.00	$ 93,720
74,700	SY	Soil Retention Blankets (CL 1) (TY A)	$ 1.27	$ 94,869
20,000	SY	Broadcast Re-seeding	$ 0.30	$ 6,000
1	LS	Temporary Erosion Control	$ 20,000	$ 20,000
1	LS	Land Acquisition (Homeowners/agriculture)	$ 1,254,004	$ 1,254,004
		SUBTOTAL		$ 5,260,692
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 789,104
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 263,035
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 6,312,830
		25% CONTENGENCIES		$ 1,578,208
		CONSTRUCTION TOTAL		$ 7,892,000



Legend

- Proposed Dam
- Stream CL
- Structures Removed from 100-YR Floodplain
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain
- Proposed Detention Footprint

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	54	$30,321,246
Preliminary 100-YR Floodplain	193	$53,818,299
Structures Removed From 100-YR Floodplain	139	$23,497,053

N

0 1,200 2,400 3,600 Feet

SCHEIBE CONSULTING LLC

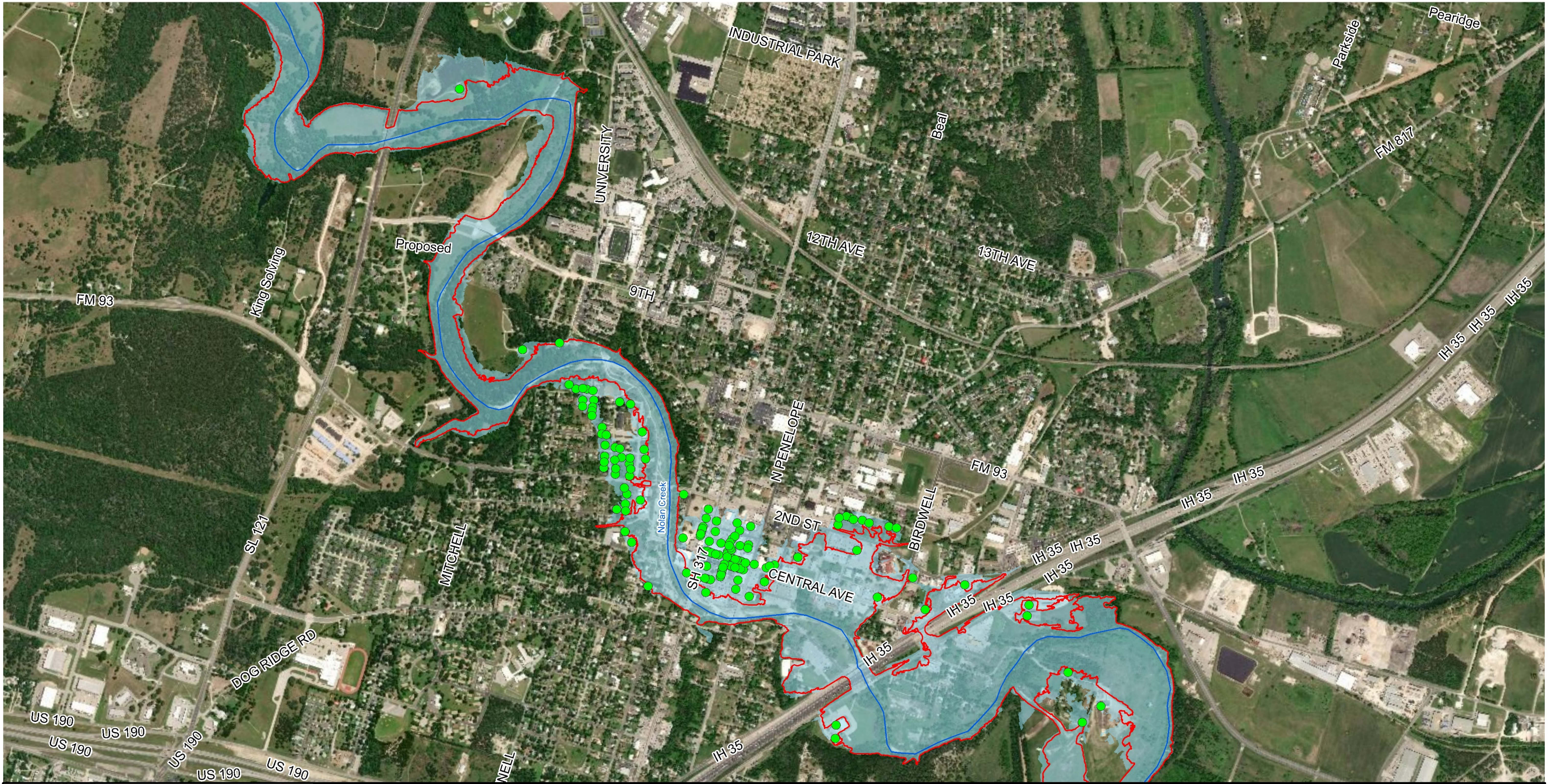
ALTERNATIVE 8 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION AT
NOLAN/NORTH NOLAN CONFLUENCE

MAP 1 OF 2

Note: Storage analysis is preliminary and subject to change in final design



Legend

- Proposed Dam
- Stream CL
- Structures Removed from 100-YR Floodplain
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain
- Proposed Detention Footprint

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	54	$30,321,246
Preliminary 100-YR Floodplain	193	$53,818,299
Structures Removed From 100-YR Floodplain	139	$23,497,053

N

0 1,200 2,400 3,600 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 8 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION AT
NOLAN/NORTH NOLAN CONFLUENCE

MAP 2 OF 2

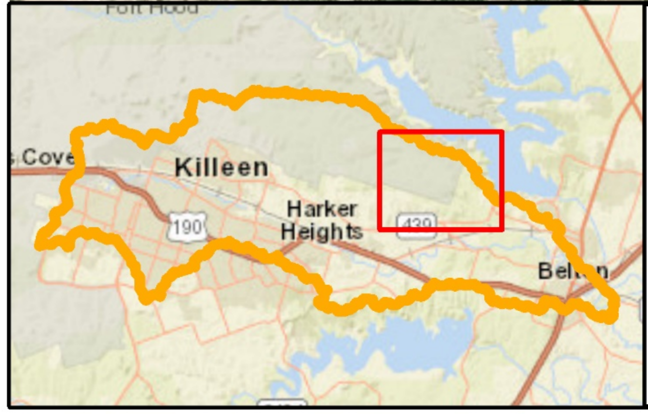
Note: Storage analysis is preliminary and subject to change in final design

Alternative 9 – Proposed Diversion Structure
Flood Diversion to Lake Belton

The goal of this alternative is to reduce flooding is to reduce downstream flooding while producing the added benefit of additional water supply to Lake Belton. The diversion alternative consists of small detention/diversion structure connected to a 60” diameter tunnel from North Nolan Creek to an outfall at Lake Belton. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in reducing the 100-yr flow on North Nolan Creek down to the existing 10-yr flow and removing five structures from the existing 100-yr floodplain along North Nolan Creek. Potential flood reduction benefits downstream of North Nolan Creek through the City of Belton as well potential water supply benefits to Lake Belton are possible and will need to be quantified as part of future efforts. The total value (from appraisal district data) of structures removed from the North Nolan floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $12,435,000 and will result in removal of only $135,000 of structures from the North Nolan 100-yr floodplain, but additional flood damage reduction benefits could occur through the City of Belton as well as benefits derived from additional water supply to Lake Belton. Due to the potential for additional benefits and for a regional flood reduction impact, Alternative 9 was given a medium priority.

Alt 9 - Proposed Diversion Structure				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
15	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 45,000
133,907	CY	Excavation	$ 7.50	$ 1,004,300
7,407	CY	Embankment (95% Proctor) - Select Fill	$ 6.00	$ 44,444
7,000	LF	60" O.D. Tunnel and Airshafts	$ 750	$ 5,250,000
7,500	LF	48" carrier RCP	$ 200	$ 1,500,000
1	EA	Concrete Inlet Structure	$ 50,000	$ 50,000
278	SY	Concrete Diversion Weir (160'x2')(LxH) "Saddle" Apron at North Nolan Tributary	$ 35.00	$ 9,722
1	LS	Cofferdams and Dewatering	$ 10,000	$ 10,000
1	EA	Concrete Outlet Works	$ 75,000.00	$ 75,000
1	LS	Temporary & Permanent Erosion Control	$ 20,000	$ 20,000
1	LS	Land Acquisition (15 ac)	$ 281,250	$ 281,250
		SUBTOTAL		$ 8,289,717
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 1,243,458
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 414,486
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 9,947,660
		25% CONTINGENCIES		$ 2,486,915
		CONSTRUCTION TOTAL		$ 12,435,000



Legend

- Diversion Conveyance
- Structures Removed from Floodplain
- Proposed Diversion Storage
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Count	Cost
Proposed 100-YR Floodplain	0	$0
Preliminary 100-YR Floodplain	5	$135,000
Structures Removed From 100-YR Floodplain	5	$135,000

N

0 1,000 2,000 4,000 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 9 - NORTH NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

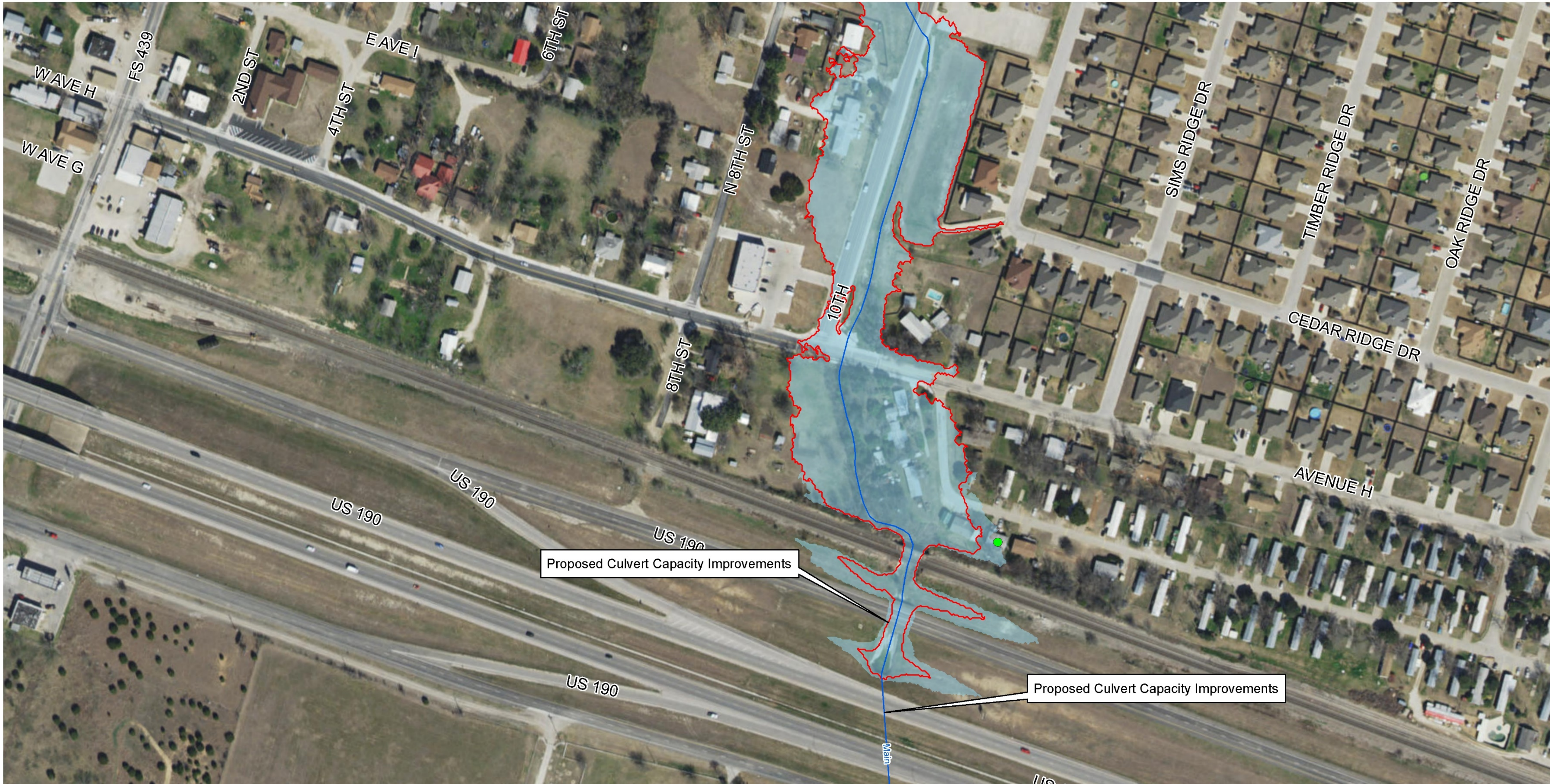
FLOOD DIVERSION TO LAKE BELTON

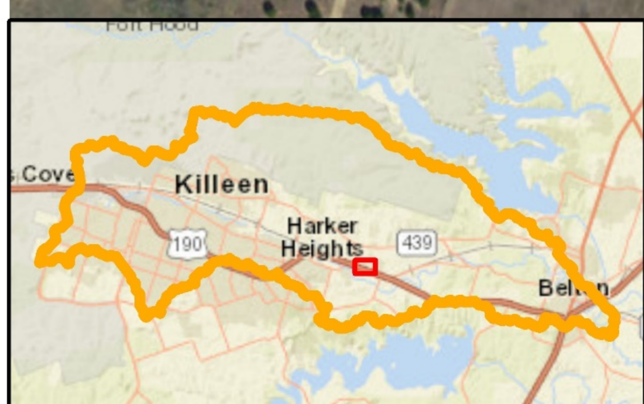
Alternative 10 – Culvert Capacity Improvements
I-14 WB Service Road and Main Lanes

The goal of this alternative is to reduce flooding in along Nolanville Tributary between the railroad and 10th Street. Based on existing conditions analysis it was note that the culvert capacity under I-14 causes a constriction of flow and backwater effect upstream of the culvert. This alternative consists of adding an additional 7 ft. x 7 ft. box under I-14 main lanes and an additional 10 ft. X 8 ft. box under the westbound service road to reduce the upstream water surface elevation. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 1.5 ft. reduction in 100-yr flood elevations upstream of the railroad but removes only 1 structure from the existing 100-yr floodplain. The total value (from appraisal district data) of the structure removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $460,000 and will result in removal of $55,000 of structures from the 100-yr floodplain. This alternative has a low benefit cost ratio and only impacts one residential structure. A buyout of affected structures may be a more cost-effective option to this alternative. However, if reducing flood elevations is desired, capacity under I-14 must be increased. Since this alternative is needed as a starting point to reduce flood elevations on Nolanville Tributary, it was given a medium priority despite the low cost-benefit ratio.

Alt 10 - Culvert Capacity Improvements: Nolanville Tributary (I-14 WB Serv & Main Lanes)				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
1.50	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 3,750
185	CY	Excavation	$ 7.43	$ 1,376
65	LF	Install Additional 10'x8' RCB	$ 525.00	$ 34,125
320	LF	Install Additional 7'x7' RCB	$ 500.00	$ 160,000
2	LS	Concrete Apron and Headwall	$ 25,000.00	$ 50,000
600	SY	HMAC Pavement Repair	$ 45.00	$ 27,000
1	LS	Traffic Control	$ 30,000.00	$ 30,000
600	LF	MBGR, Transition, & Pavement Markings	$ 37.50	$ 22,500
2	LS	Temporary Erosion Controls	$ 5,000.00	$ 10,000
7,260	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 10,890
		SUBTOTAL		$ 349,641
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 18,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 53,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 367,641
		25% CONTENGENCIES		$ 91,910
		GRAND TOTAL		$ 460,000





Legend

- Streams
- Structures Removed
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Count	Cost
Proposed 100-YR Floodplain	7	$385,000
Preliminary 100-YR Floodplain	8	$440,000
Structures Removed From 100-YR Floodplain	1	$55,000

N

0 100 200 400
Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 10 - NOLANVILLE TRIBUTARY

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

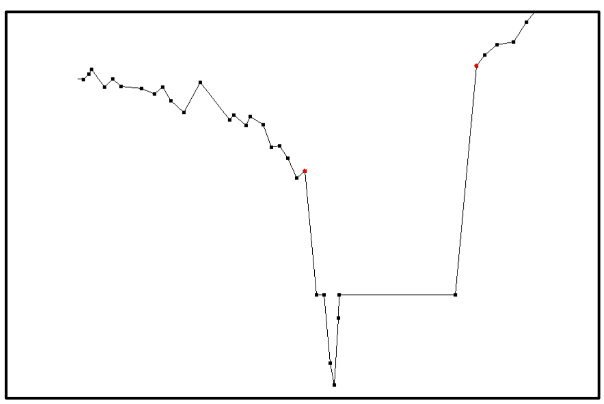
CULVERT CAPACITY IMPROVEMENTS I-14
WB SERVICE ROAD & MAINLANES

Alternative 11 –Culvert Conveyance Improvements at I-14/Frontage and Avenue H plus Channel Improvements

The goal of this alternative is to reduce flooding along Nolanville Tributary between the railroad and 10th Street. This alternative includes the improvements described under Alternative 10 plus capacity improvements at Avenue H and channel improvements between the railroad and Avenue H. These additional improvements include upgrading Avenue H to a bridge structure with additional flow capacity and adding a benched channel modification between the railroad and Avenue H consisting of a 100 ft. bottom width and 3 to 1 side slopes. A typical section of the channel modification is shown below. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 2 ft. reduction in 100-yr flood elevations upstream of the railroad but removes only three structures from the existing 100-yr floodplain. The total value (from appraisal district data) of the structure removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided for the three project components and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $922,000 and will result in removal of $165,000 of structures from the 100-yr floodplain. This alternative has a very low benefit cost ratio and only impacts three residential structures. A buyout of affected structures would be a more cost-effective option to this alternative. Due to the very low cost-benefit ratio associated with this alternative, Alternative 11 was given a low priority.

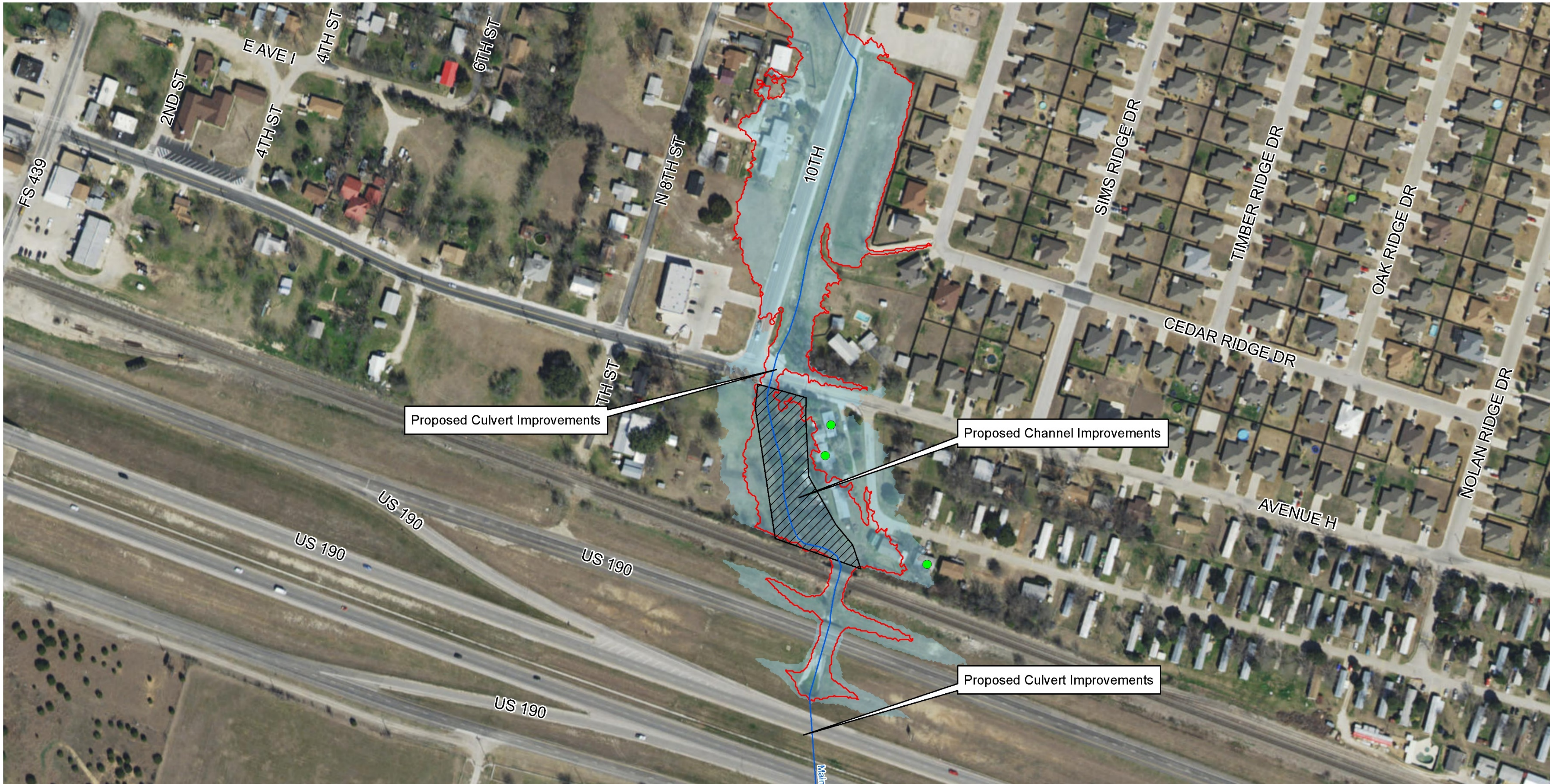
Typical Section of Channel Modification

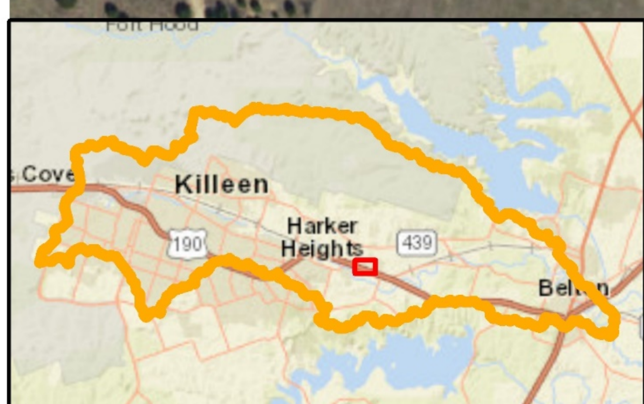


Alt11A - Culvert Capacity Improvements: Nolanville Tributary (I-14 WB Serv & Main Lanes)				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
1.50	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 3,750
185	CY	Excavation	$ 7.43	$ 1,376
65	LF	Install Additional 10'x8' RCB	$ 525.00	$ 34,125
320	LF	Install Additional 7'x7' RCB	$ 500.00	$ 160,000
2	LS	Concrete Apron and Headwall	$ 25,000.00	$ 50,000
600	SY	HMAC Pavement Repair	$ 45.00	$ 27,000
1	LS	Traffic Control	$ 30,000.00	$ 30,000
600	LF	MBGR, Transition, & Pavement Markings	$ 37.50	$ 22,500
2	LS	Temporary Erosion Controls	$ 5,000.00	$ 10,000
7,260	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 10,890
		SUBTOTAL		$ 349,641
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 18,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 53,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 367,641
		25% CONTENGENCIES		$ 91,910
		TOTAL		$ 460,000

Alt 11B - Culvert Capacity Improvements: Nolanville Tributary (Ave. H)				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
1.50	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 3,750
1.00	LS	Demolition/Removal of Existing Structure	$ 20,000.00	$ 20,000
185	CY	Excavation	$ 7.50	$ 1,388
1	LS	Utility Adjustments (Sewer/Water/Temporary Electric)	$ 50,000.00	$ 50,000
100	LF	Drill Shafts	$ 120.00	$ 12,000
17	CY	Columns	$ 1,200.00	$ 20,933
52.33	CY	Abutments	$ 800.00	$ 41,867
2,100	SF	Concrete Slab	$ 15.00	$ 31,500
480	LF	Slab Beam (XSB12-18)	$ 155.00	$ 74,400
150	SY	HMAC Pavement Repair	$ 45.00	$ 6,750
1	LS	Traffic Control	$ 12,000.00	$ 12,000
250	LF	MBGR, Transition, & Pavement Markings	$ 37.50	$ 9,375
2	LS	Temporary Erosion Controls	$ 5,000.00	$ 10,000
7,260	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 10,890
		SUBTOTAL		$ 304,853
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 16,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 46,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 320,853
		25% CONTENGENCIES		$ 80,213
		TOTAL		$ 402,000

Alt11C - Channel Improvements: Nolanville Tributary (Ave. H to Railroad)				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
1.31	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 3,271
2,700	CY	Excavation - (CHANNEL)	$ 8.00	$ 21,600
1	LS	Cofferdams and Dewatering	$ 3,500	$ 3,500
1	LS	Temporary Erosion Controls	$ 6,850	$ 6,850
6,333	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 9,500
		SUBTOTAL		$ 44,721
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 3,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 7,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 47,721
		25% CONTENGENCIES		$ 11,930
		TOTAL		$ 60,000
			GRAND TOTAL ALT 11	**$ 922,000**





Legend

- Streams
- Structures Removed
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Count	Cost
Proposed 100-YR Floodplain	5	$275,000
Preliminary 100-YR Floodplain	8	$440,000
Structures Removed From 100-YR Floodplain	3	$165,000

N

0 100 200 400 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 11 - NOLANVILLE TRIBUTARY

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

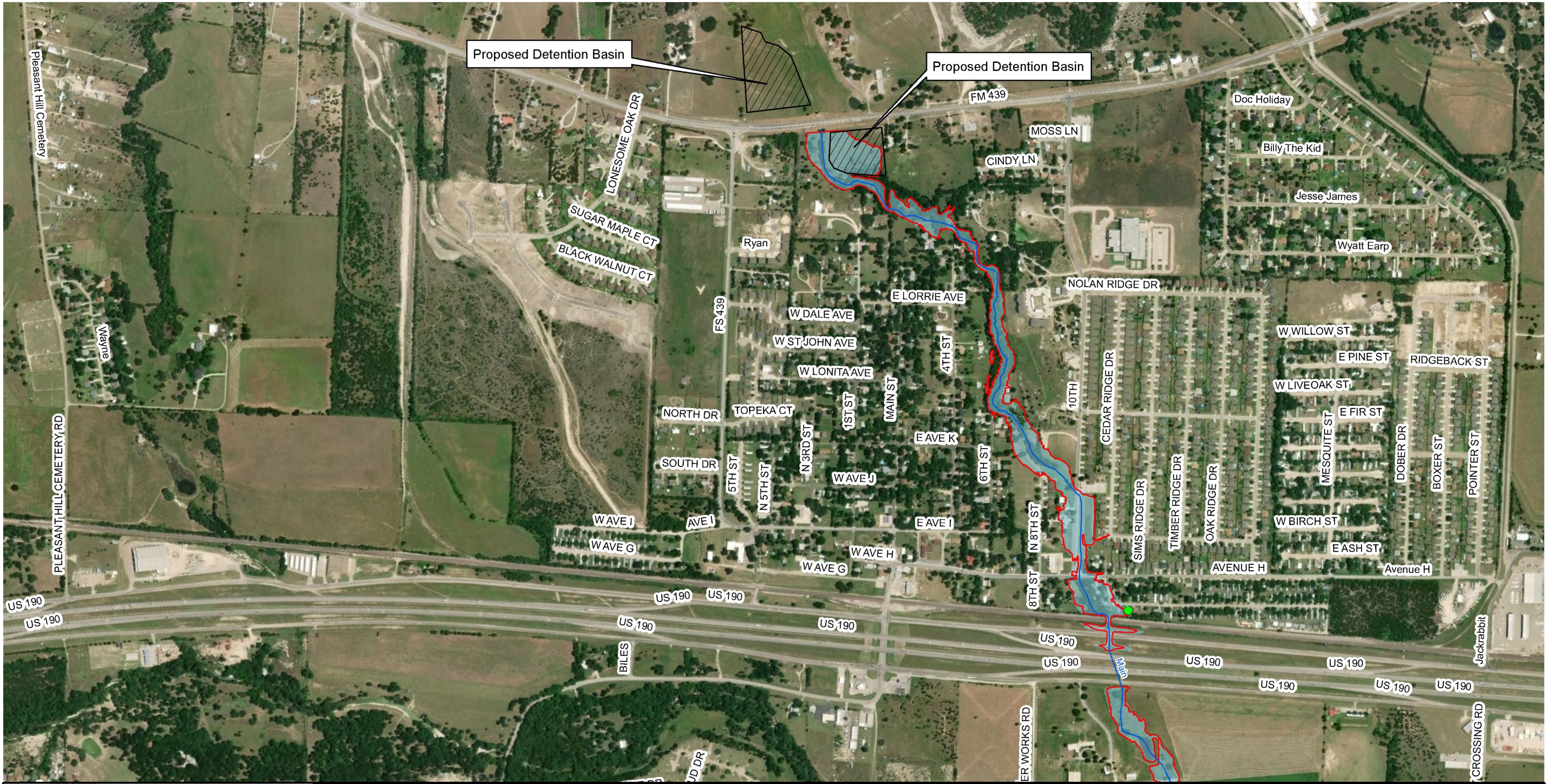
CULVERT CONVEYANCE IMPROVEMENTS AT I-14/FRONTAGE AND AVENUE H PLUS CHANNEL IMPROVEMENTS

Alternative 12 – Proposed Detention Basin FM 439 Area

The goal of this alternative is to reduce flooding along Nolanville Tributary between the railroad and 10th Street by maximizing upstream detention. This alternative consists of two offline detention facilities comprising a total of 66 acre-feet of storage just upstream and downstream of FM 439. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 1 ft. reduction in 100-yr flood elevations between the railroad and Avenue H removing only 1 structure from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $1,383,000 and will result in removal of $55,000 of structures from the 100-yr floodplain. This alternative has a very low benefit cost ratio and only impacts one residential structure. A buyout of affected structures would be a more cost-effective option to this alternative. Due to the very low cost-benefit ratio associated with this alternative, Alternative 12 was given a low priority.

Alt 12 - Proposed Detention Basin (FM 439 area)				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
11	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 33,000
15	EA	Tree Removal	$ 400	$ 6,000
31,074	CY	Embankment (95% Proctor) - Select Fill	$ 6.00	$ 186,444
600	LF	Box Culvert Outfall Structure	$ 400	$ 240,000
1	EA	1 Set - Wingwalls (HW = 12FT)	$ 150,000	$ 150,000
4,431	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ 9,747
877	CY	RipRap (Stone Common) (Dry) (12 in)	$ 60.00	$ 52,635
4,431	SY	Soil Retention Blankets (CL 1) (TY A)	$ 1.27	$ 5,627
13,291.67	SY	Broadcast Re-seeding	$ 0.30	$ 3,988
1	LS	Temporary Erosion Control	$ 20,000	$ 20,000
1	LS	Land Acquisition (11 ac in 3 properties)	$ 200,625	$ 200,625
		SUBTOTAL		$ 908,066
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 136,210
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 45,403
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 1,089,679
		25% CONTENGENCIES		$ 272,420
		GRAND TOTAL		$ 1,363,000



Legend

- Streams
- Structures Removed from Floodplain
- Offline Detention Basins
- Reduced 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Count	Cost
Proposed 100-YR Floodplain	7	$385,000
Preliminary 100-YR Floodplain	8	$440,000
Structures Removed From 100-YR Floodplain	1	$55,000

N

0 400 800 1,600 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 12 - NOLANVILLE TRIBUTARY

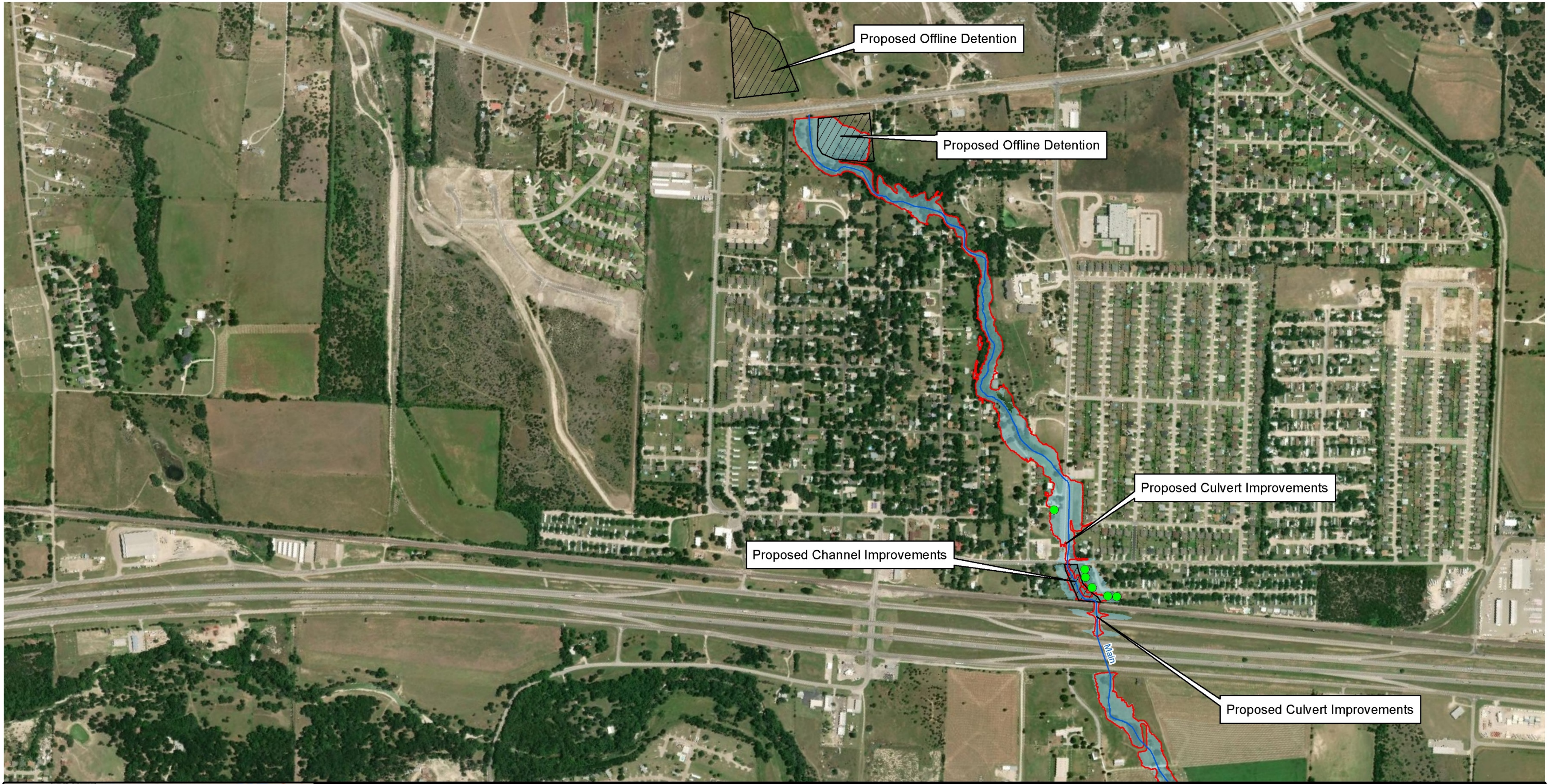
CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

DETENTION BASINS AT FM 439

Alternative 13 – Culvert Conveyance Improvements at Avenue H and I-14 Plus Channel Improvements and Detention

The goal of this alternative is to reduce flooding along Nolanville Tributary between the railroad and 10th Street by combining the detention and improvements described in Alternatives 11 and 12. Descriptions of the improvements are provided in the respective Alternative write-ups. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 2.8 ft. reduction in 100-yr flood elevations between the railroad and Avenue H removing six structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is provided with Alternatives 11 and 12 and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project (i.e. sum of alternatives 11 and 12) is $1,765,000 and will result in removal of $330,000 of structures from the 100-yr floodplain. This alternative has a very low benefit cost ratio and only impacts one residential structure. A buyout of affected structures would be a more cost-effective option to this alternative. Due to the very low cost-benefit ratio associated with this alternative, Alternative 13 was given a low priority.



Legend

- Streams
- Structures Removed from Floodplain
- Offline Detention Ponds
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Count	Cost
Reduced 100-YR Floodplain	2	$110,000
Preliminary 100-YR Floodplain	8	$495,000
Structures Removed From 100-YR Floodplain	6	$330,000

N

0 400 800 1,600 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 13 - NOLANVILLE TRIBUTARY

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

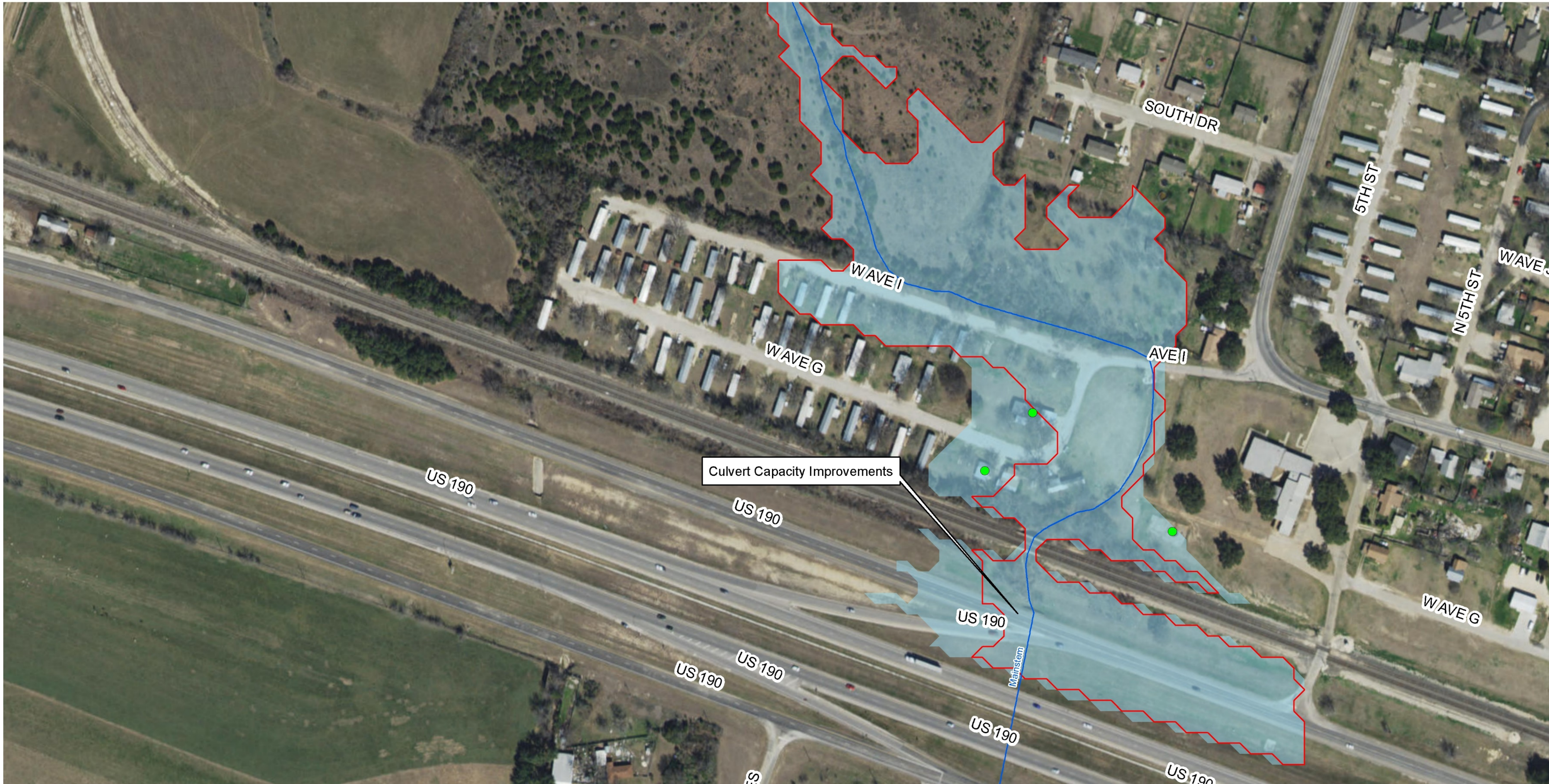
CULVERT CONVEYANCE IMPROVEMENTS AT AVENUE H & I-14 PLUS CHANNEL IMPROVEMENTS & DETENTION IMPROVEMENTS

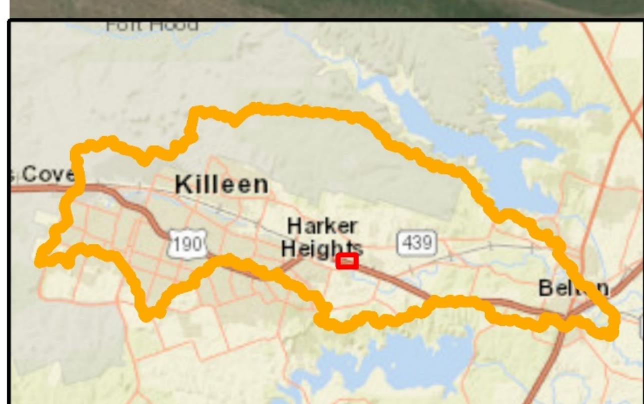
Alternative 14 – Culvert Capacity Improvements I-14 Main Lanes

The goal of this alternative is to reduce flooding in along Nolanville West Tributary between the railroad and Avenue I near Mac's Crossing Mobile Home Park. Based on existing conditions analysis it was note that the culvert capacity under I-14 causes a constriction of flow and backwater effect upstream of the culvert. This alternative consists of adding an additional 6 ft. x 6 ft. box under I-14 main lanes to reduce the upstream water surface elevation. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 2 ft. reduction in 100-yr flood elevations upstream of the railroad and removes three structures from the existing 100-yr floodplain. The total value (from appraisal district data) of the structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $722,000 and will result in removal of $165,000 of structures from the 100-yr floodplain. This alternative has a low benefit cost ratio and only impacts three residential structures. A buyout of affected structures may be a more cost-effective option to this alternative. However, if reducing flood elevations is desired, capacity under I-14 must be increased. Since this alternative is needed as a starting point to reduce flood elevations on Nolanville West Tributary, it was given a medium priority despite the low cost-benefit ratio.

ALT 14 - Culvert Capacity Improvements: Nolanville West Tributary (I-14)				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
0.50	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 1,250
1,574	CY	Excavation/Haul Off	$ 16.00	$ 25,185
425	LF	Install Additional 6'x6' RCB	$ 915.00	$ 388,875
1	LS	Concrete Apron and Headwall	$ 32,000.00	$ 32,000
1,111	SY	HMAC Pavement Repair	$ 45.00	$ 50,000
1	LS	Traffic Control	$ 25,000.00	$ 25,000
480	LF	MBGR, Transition, & Pavement Markings	$ 37.50	$ 18,000
1	LS	Temporary Erosion Controls	$ 5,000.00	$ 5,000
2,420	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 3,630
		SUBTOTAL		$ 548,940
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 28,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 83,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 576,940
		25% CONTENGENCIES		$ 144,235
		GRAND TOTAL		$ 722,000





Legend

- Streams
- Structures Removed
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Cost
Reduced 100-YR Floodplain	6	$330,000
Preliminary 100-YR Floodplain	9	$495,000
Structures Removed From 100-YR Floodplain	3	$165,000

N

0 100 200 400 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 14 - NOLANVILLE WEST TRIBUTARY

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

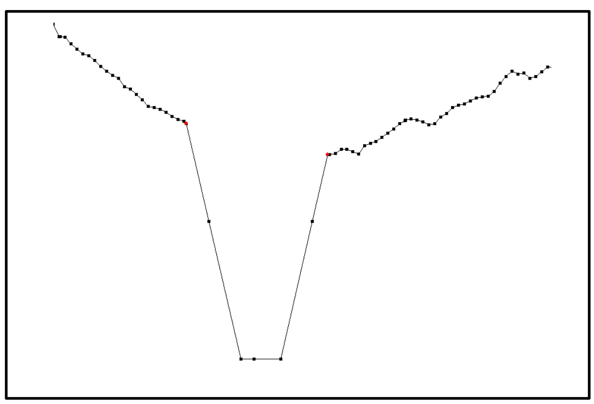
CAPACITY IMPROVEMENTS AT I-14

Alternative 15 – Culvert Capacity Improvements I-14 Main Lanes and Channel Modification from Railroad to Ave. I

The goal of this alternative is to reduce flooding in Nolanville between the railroad and Avenue I near Mac's Crossing Mobile Home Park. This alternative includes the culvert improvements described under Alternative 14 plus channel improvements between the railroad and Avenue I. These additional channel improvements include adding a channel modification between the railroad and Avenue I consisting of a 20 ft. bottom width and 3 to 1 side slopes. A typical section of the channel modification is shown below. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 2.2 ft. reduction in 100-yr flood elevations upstream of the railroad and removes three structures from the existing 100-yr floodplain. The total value (from appraisal district data) of the structure removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

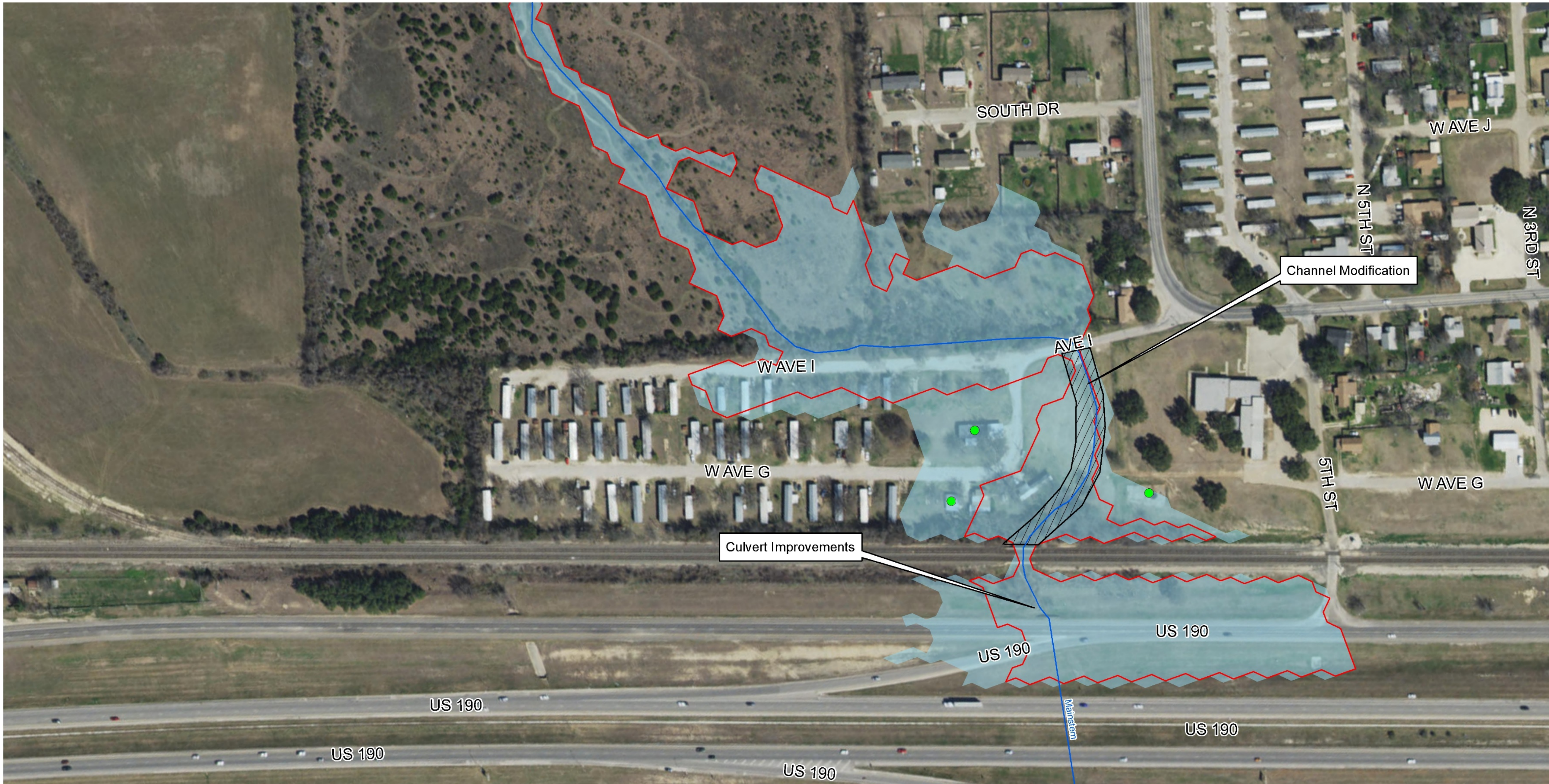
A detailed opinion of probable cost is also provided for the two project components and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $794,000 and will result in removal of $165,000 of structures from the 100-yr floodplain. This alternative has a low benefit cost ratio and only impacts three residential structures. A buyout of affected structures may be a more cost-effective option to this alternative. Due to the very low cost-benefit ratio associated with this alternative, Alternative 15 was given a low priority.

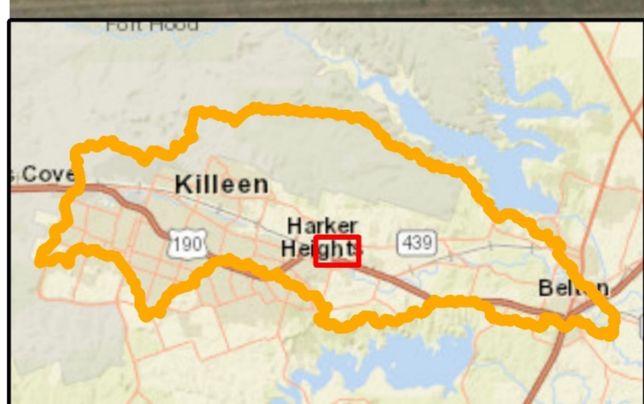
Typical Section of Channel Modification



Alt 15A - Culvert Capacity Improvements: Nolanville West Tributary (I-14)				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
0.50	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 1,250
1,574	CY	Excavation/Haul Off	$ 16.00	$ 25,185
425	LF	Install Additional 6'x6' RCB	$ 915.00	$ 388,875
1	LS	Concrete Apron and Headwall	$ 32,000.00	$ 32,000
1,111	SY	HMAC Pavement Repair	$ 45.00	$ 50,000
1	LS	Traffic Control	$ 25,000.00	$ 25,000
480	LF	MBGR, Transition, & Pavement Markings	$ 37.50	$ 18,000
1	LS	Temporary Erosion Controls	$ 5,000.00	$ 5,000
2,420	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 3,630
		SUBTOTAL		$ 548,940
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 28,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 83,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 576,940
		25% CONTENGENCIES		$ 144,235
		TOTAL		$ 722,000

Alt 15B - Channel Improvements: Nolanville West Tributary (Ave. I to RR)				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
1.41	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 3,530
1,735	CY	Excavation/Haul Off - (CHANNEL)	$ 16.00	$ 27,758
1	LS	Cofferdams and Dewatering	$ 7,500	$ 7,500
1	LS	Temporary Erosion Controls	$ 5,500	$ 5,500
6,833	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 10,250
		SUBTOTAL		$ 54,538
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 3,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 9,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 57,538
		25% CONTENGENCIES		$ 14,384
		TOTAL		$ 72,000
			GRAND TOTAL ALT 15	$ 794,000





Legend

- Streams
- Structures Removed From Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Count	Cost
Proposed 100-YR Floodplain	6	$330,000
Preliminary 100-YR Floodplain	9	$495,000
Structures Removed From 100-YR Floodplain	3	$165,000

N

0 100 200 400 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 15 - NOLANVILLE WEST TRIBUTARY

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

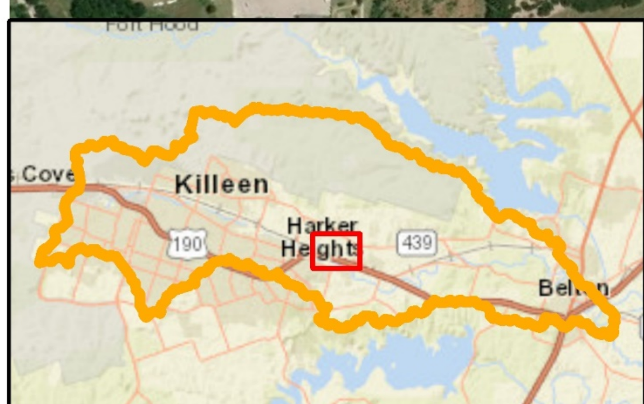
CULVERT CAPACITY IMPROVEMENTS AT I-14 & CHANNEL MODIFICATION ALTERNATIVE FROM RAILROAD TO AVE. I

Alternative 16 – Proposed Detention Basins
Near FM 439 and North of Mac’s Crossing

The goal of this alternative is to reduce flooding in Nolanville between the railroad and Avenue I near Mac’s Crossing Mobile Home Park by maximizing upstream detention. This alternative consists of three offline detention facilities comprising a total of 198 acre-feet of storage just near FM 439 and just upstream of Mac’s Crossing. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 2 ft. reduction in 100-yr flood elevations between the railroad and Avenue I removing 5 structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $4,281,000 and will result in removal of $275,000 of structures from the 100-yr floodplain. This alternative has a low benefit cost ratio and only impacts five residential structures. A buyout of affected structures may be a more cost-effective option to this alternative. Due to the very low cost-benefit ratio associated with this alternative, Alternative 15 was given a low priority.

Alt 16 - Proposed Detention Basins (FM 439 area and north of Mac's)				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
27	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 81,267
15	EA	Tree Removal	$ 400	$ 6,000
100,378	CY	Embankment (95% Proctor) - Select Fill	$ 6.00	$ 602,268
600	LF	Box Culvert Outfall Structure	$ 400	$ 240,000
3	EA	1 Set - Wingwalls (HW = 8FT)	$ 75,000	$ 225,000
66,250	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ 145,749
13,117	CY	RipRap (Stone Common) (Dry) (12 in)	$ 60.00	$ 787,044
66,250	SY	Soil Retention Blankets (CL 1) (TY A)	$ 1.27	$ 84,137
198,748.55	SY	Broadcast Re-seeding	$ 0.30	$ 59,625
3	LS	Temporary Erosion Control	$ 20,000	$ 60,000
1	LS	Land Acquisition (30 ac in 3 properties)	$ 562,500	$ 562,500
		SUBTOTAL		$ 2,853,590
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 428,039
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 142,680
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 3,424,308
		25% CONTENGENCIES		$ 856,077
		CONSTRUCTION TOTAL		$ 4,281,000



Legend

- Streams
- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain
- Proposed Detention Footprint

Structure Count

Flood Event	Count	Cost
Proposed 100-YR Floodplain	4	$220,000
Preliminary 100-YR Floodplain	9	$495,000
Structures Removed From 100-YR Floodplain	5	$275,000

N

0 400 800 1,600 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

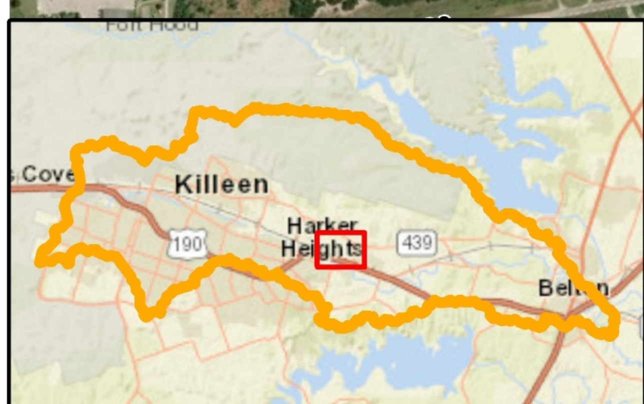
ALTERNATIVE 16 - NOLANVILLE WEST TRIBUTARY

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

198 AF DETENTION (3 SITES COMBINED)

Alternative 17 – Culvert Conveyance Improvements at I-14 Plus Channel Improvements and Detention

The goal of this alternative is to reduce flooding in Nolanville between the railroad and Avenue I near Mac's Crossing Mobile Home Park by combining the detention and improvements described in Alternatives 15 and 16. Descriptions of the improvements are provided in the respective Alternative write-ups. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 4.4 ft. reduction in 100-yr flood elevations between the railroad and Avenue I removing nine structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below. A detailed opinion of probable cost is provided with Alternatives 15 and 16 and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project (i.e. sum of alternatives 11 and 12) is $5,075,000 and will result in removal of $495,000 of structures from the 100-yr floodplain.



Legend

- Streams
- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain
- Proposed Detention Footprint

Structure Count

Flood Event	Count	Cost
Proposed 100-YR Floodplain	0	$0
Preliminary 100-YR Floodplain	9	$495,000
Structures Removed From 100-YR Floodplain	9	$495,000

N

0 400 800 1,600 Feet

SCHEIBE CONSULTING LLC

MOODY ENGINEERING INC

ALTERNATIVE 17 - NOLANVILLE WEST TRIBUTARY

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

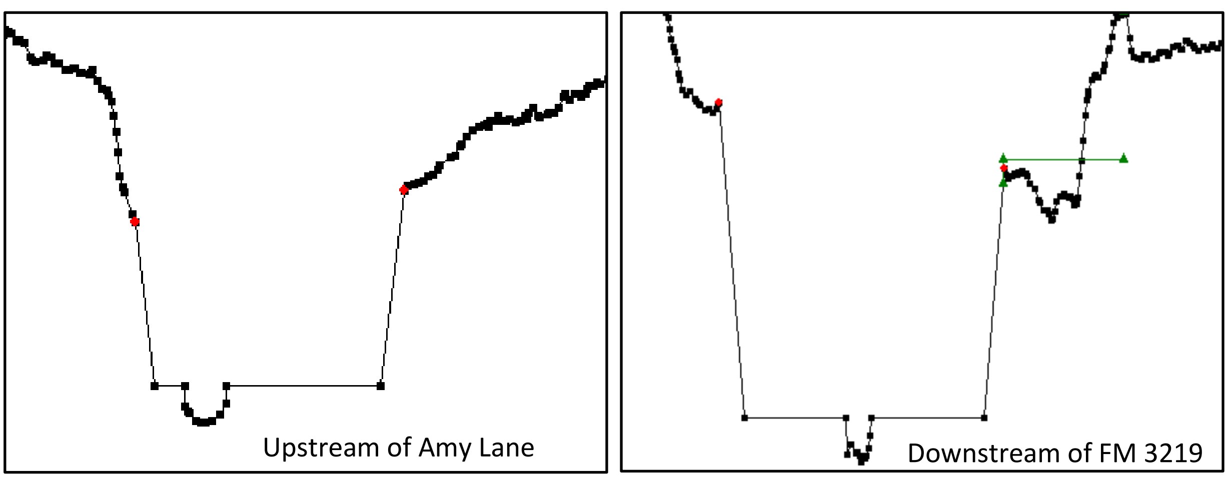
CHANNEL IMPROVEMENTS CULVERT CAPACITY IMPROVEMENTS AT I-14 198 AF DETENTION (3 SITES COMBINED)

Alternative 18 – Channel Modification
Harker Heights

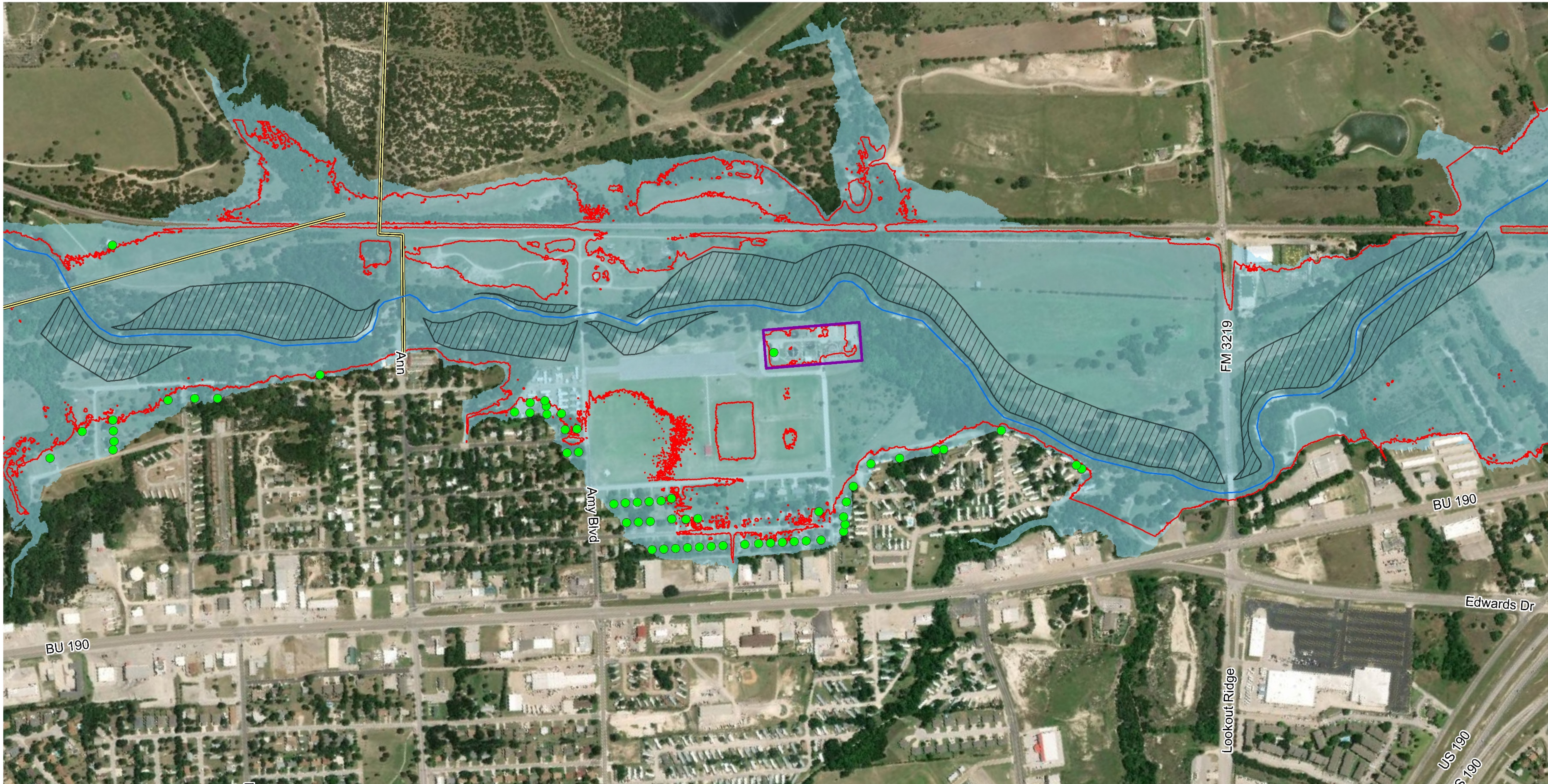
The goal of this alternative is to reduce flooding along Nolan Creek through Harker Heights by adding a benched channel improvement from approximately 1,250 feet downstream of Roy Reynolds Dr. to the railroad crossing downstream of FM 3219. The typical dimensions of the benched cut include a 300 ft. bottom width with 3 to 1 side slopes upstream of FM 3219 and 400 ft bottom width with 3 to 1 side slopes downstream of FM 3219. Typical sections are shown below. Care was taken to avoid any existing structures, including an existing gas transmission line, and no additional improvements were made to existing bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 4.4 ft. reduction in 100-yr flood elevations downstream of Amy Lane removing 65 structures from the existing 100-yr floodplain. Additional benefits include protection of a wastewater treatment plant with a berm structure to prevent flooding and potential water quality issues associated with flooding of a wastewater treatment plant. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

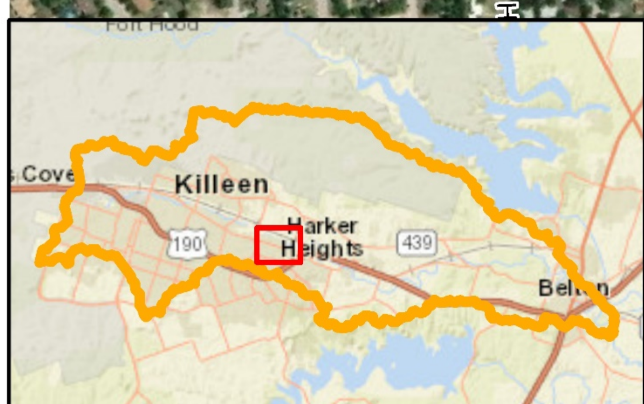
A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $12,490,000 and will result in removal of $2,515,400 of structures from the 100-yr floodplain. While this alternative has a low benefit-cost ratio it removes many structures from the 100-yr floodplain and protects the wastewater treatment plant, which is a significant benefit to the City of Harker Heights. Due to the additional benefits to the wastewater treatment plant, Harker Heights has assigned a medium priority to this alternative.

Typical Section of Channel Modification



ALT18 - Channel Modifications: Harker Heights				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
7.00	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 17,500
200	EA	Tree Removal	$ 800.00	$ 160,000
980,972	CY	Excavation - (CHANNEL)	$ 8.00	$ 7,847,776
1	CY	Fill - On-site borrow	$ 6.00	$ 6.00
1	LS	Cofferdams and Dewatering	$ 25,000.00	$ 25,000
1	LS	Temporary Erosion Controls	$ 75,000	$ 75,000
33,880	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 50,820
		SUBTOTAL*		$ 8,176,102
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 409,000
1	LS	Engineering Design (approx. 15% of construction subtotal)		$ 1,226,415
45	AC	Land Acquisition	$ 4,000	$ 180,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 9,991,517
		25% CONTENGENCIES		$ 2,497,879
		GRAND TOTAL		$ 12,490,000





Legend

- Streams
- Structures Removed
- Power/Gas Lines
- WWTP Proposed Berm
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	43	$696,600
Preliminary 100-YR Floodplain	108	$3,212,000
Structures Removed From 100-YR Floodplain	65	$2,515,400

N

0 300 600 1,200 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 18 - NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL MODIFICATION ALTERNATIVE ALONG NOLAN CREEK DOWNSTREAM OF ROY REYNOLDS DR. TO BURLINGTON NORTHERN SANTA FE RAILROAD

Note: The decrease (about 100 cfs) in discharge due to channel modifications did not results in increased downstream water surface elevations. No detention basin was recommended.

Alternative 19 – Proposed Detention Basin Between Twin Creek Dr. and Roy Reynolds Dr.

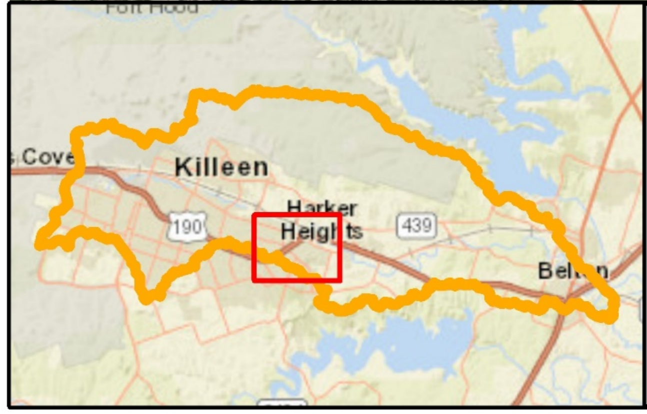
The goal of this alternative is to reduce flooding along Nolan Creek through communities downstream of Killeen. This alternative consists of a regional detention pond located at the confluence of Nolan and Little Nolan Creeks just upstream of Roy Reynolds Drive. Care was taken to avoid any existing structures and existing railroad embankment. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. Two options were analyzed reflecting storages of 3630 acre-feet (Option A) and 5670 acre-feet (Option B). Option A consists of a dam structure consisting of 17-10 X 10 box culverts, a 500 ft. emergency spillway, a 1242 ft. dam top, and a storage area excavated below the minimum dam top of dam elevation at a 3 to 1 side slope to the minimum channel elevation. Option B consists of a dam structure consisting of 13-10 X 10 box culverts, a 500 ft. emergency spillway, a 1242 ft. dam top, and a storage area excavated to the max extents possible within the proposed easement.

Option A resulted in an average 0.6 ft. reduction in 100-yr flood elevations removing 120 structures from the existing 100-yr floodplain as far downstream as downtown Belton. Option B resulted in an average 1.4 ft. reduction in 100-yr flood elevations as far downstream as downtown Belton removing 173 structures from the existing 100-yr floodplain as far downstream as downtown Belton. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents for each option are provided in the maps below. Additional benefits associated with this alternative are recreational and water quality related. The proposed regional pond and surrounding easement can be used as a regional park with the installation of parking areas, trails, and other amenities to make the location accessible. Water quality goals related to reducing total suspended solids and related pollutants can be included in the final design of the structure. A detailed opinion of probable cost is provided for each option and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency.

The total opinion of probable cost for Option A is $27,607,000 and will result in removal of $21,114,100 of structures from the 100-yr floodplain. The total opinion of probable cost for Option B is $39,380,000 and will result in removal of $23,913,100 of structures from the 100-yr floodplain. While flood reduction benefits alone do not produce a high benefit-cost ratio, the additional benefits described above combined with the regional flood reduction impact to multiple communities make Alternative 19 a very high priority to all stakeholder communities.

ALT19A - Proposed Detention Basin (Upstream of Roy Reynolds)				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
138	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 414,000
1,500	EA	Tree Removal	$ 400	$ 600,000
2,922,827	CY	Excavation (Special)	$ 4.00	$ 11,691,308
274,552	CY	Embankment (95% Proctor) - Select Fill	$ 4.00	$ 1,098,208
4,420	LF	17 - Conc Box Culv (10FT x 10FT)	$ 1,000.00	$ 4,420,000
2	EA	Conc. Headwall (HW=10 FT)	$ 120,000	$ 240,000
853	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ 1,877
853	CY	RipRap (Stone Common) (Dry) (12 in)	$ 30.00	$ 25,600
667,184	SY	Broadcast Re-seeding	$ 0.20	$ 133,437
1	LS	Temporary Erosion Control	$ 40,000	$ 40,000
1	LS	Land Acquisition	$ 540,000	$ 540,000
		SUBTOTAL		$ 19,204,430
1	LS	Engineering Design (approx. 10% of construction subtotal)	$ -	$ 1,920,443
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 960,222
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 22,085,095
		25% CONTENGENCIES		$ 5,521,274
		CONSTRUCTION TOTAL		$ 27,607,000

ALT19B - Proposed Detention Basin (Upstream of Roy Reynolds)				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
138	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 414,000
1,500	EA	Tree Removal	$ 400	$ 600,000
5,116,957	CY	Excavation (Special)	$ 4.00	$ 20,467,828
274,552	CY	Embankment (95% Proctor) - Select Fill	$ 4.00	$ 1,098,208
3,380	LF	13 - Conc Box Culv (10FT x 10FT)	$ 1,000.00	$ 3,380,000
260	LF	1 - Conc Box Culv (5FT x 5FT)	$ 582.00	$ 151,320
2	EA	Conc. Headwall (HW=10 FT) (Upstream & Downstream Side)	$ 120,000	$ 240,000
853	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ 1,877
853	CY	RipRap (Stone Common) (Dry) (30 in)	$ 65.00	$ 55,466
667,184	SY	Broadcast Re-seeding	$ 0.20	$ 133,437
1	LS	Temporary Erosion Control	$ 40,000	$ 40,000
1	LS	Land Acquisition	$ 812,000	$ 812,000
		SUBTOTAL		$ 27,394,137
1	LS	Engineering Design (approx. 10% of construction subtotal)	$ -	$ 2,739,414
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 1,369,707
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 31,503,257
		25% CONTENGENCIES		$ 7,875,814
		CONSTRUCTION TOTAL		$ 39,380,000



Legend

- Stream CL
- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	378	$45,501,000
Preliminary 100-YR Floodplain	498	$66,615,100
Structures Removed From 100-YR Floodplain	120	$21,114,100

N

0 1,000 2,000 4,000 Feet

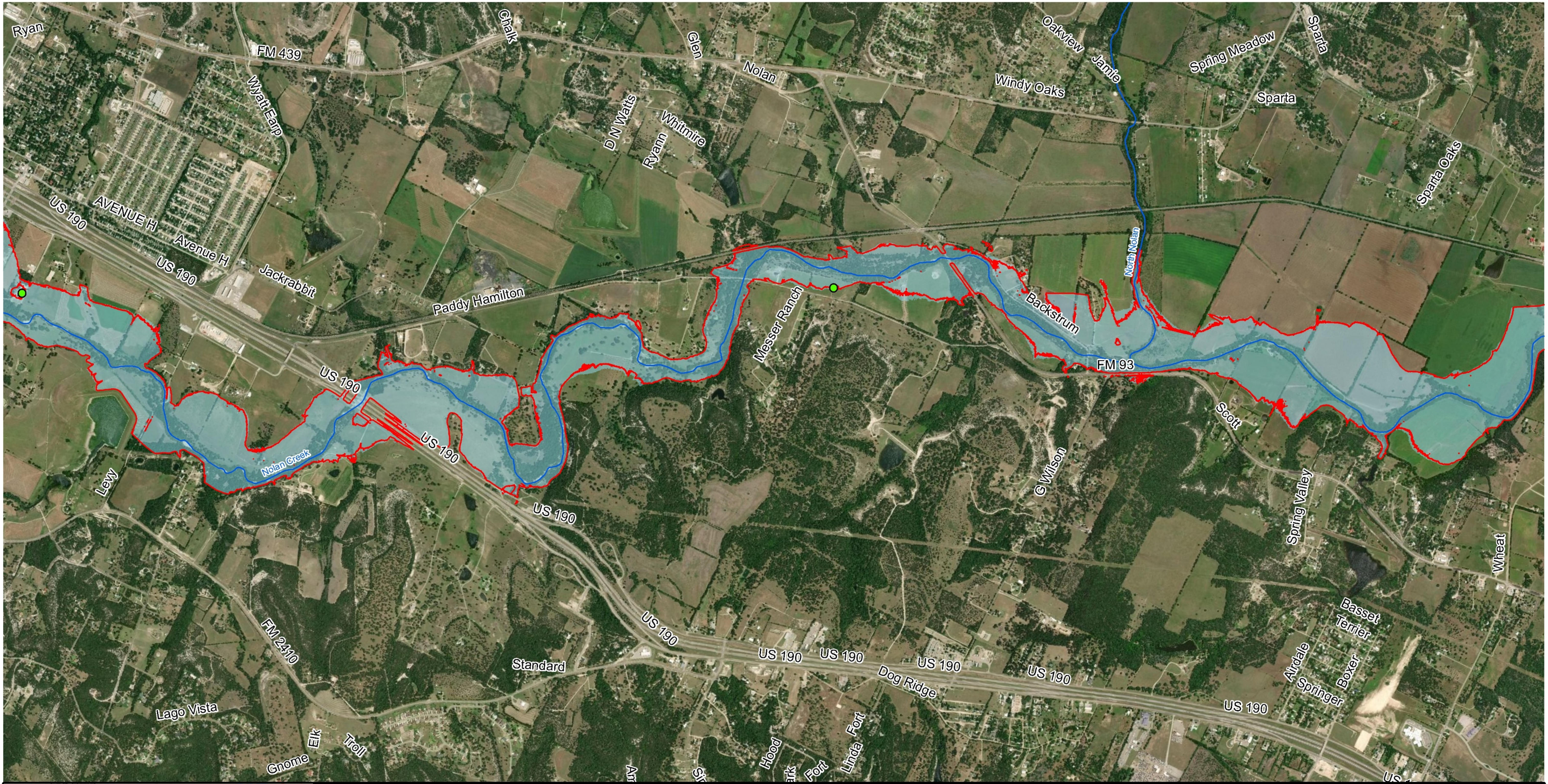
SCHEIBE CONSULTING LLC

ALTERNATIVE 19A - NOLAN CREEK
MAP 1 OF 3

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION BASIN LOCATED BETWEEN SOUTH TWIN CREEK DR AND NORTH ROY REYNOLDS DR

Note: Storage analysis is preliminary & subject to change in final design.



Legend

- Stream CL
- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	378	$45,501,000
Preliminary 100-YR Floodplain	498	$66,615,100
Structures Removed From 100-YR Floodplain	120	$21,114,100

N

0 1,000 2,000 4,000
Feet

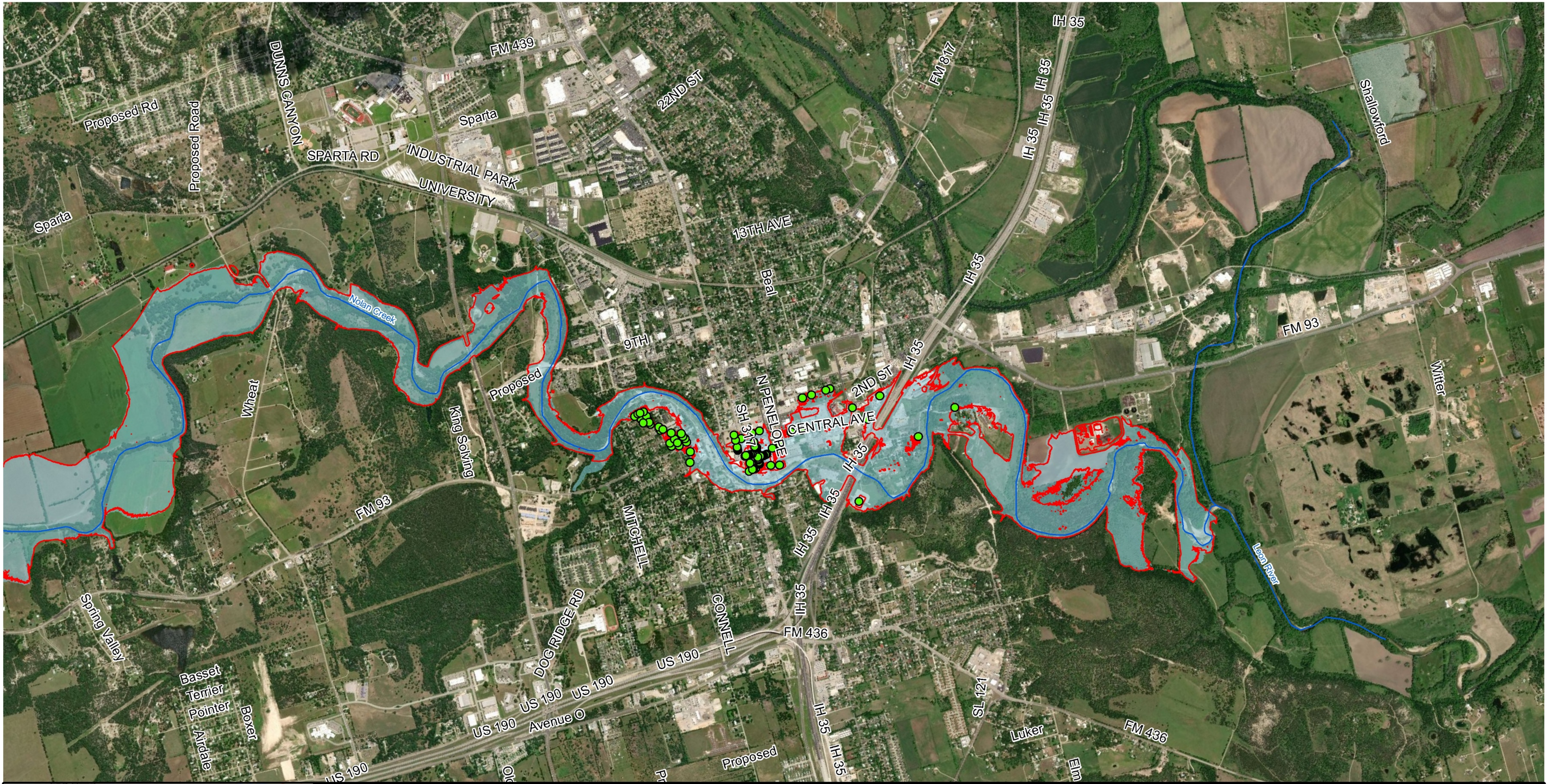
SCHEIBE CONSULTING LLC

ALTERNATIVE 19A - NOLAN CREEK
MAP 2 OF 3

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION BASIN LOCATED BETWEEN SOUTH TWIN CREEK DR AND NORTH ROY REYNOLDS DR

Note: Storage analysis is preliminary & subject to change in final design.



Legend

- Stream CL
- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	378	$45,501,000
Preliminary 100-YR Floodplain	498	$66,615,100
Structures Removed From 100-YR Floodplain	120	$21,114,100

N

0 1,000 2,000 4,000 Feet

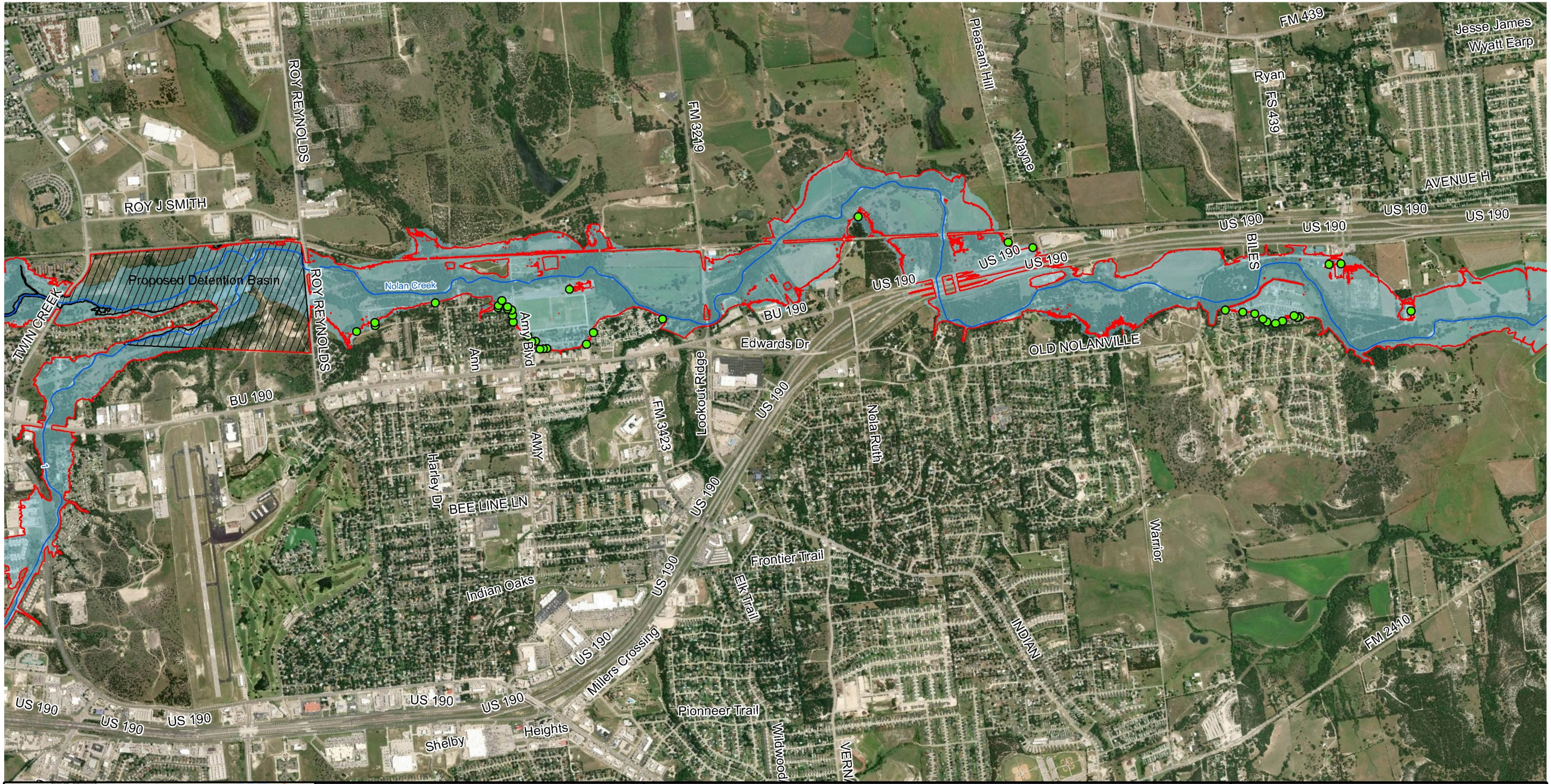
SCHEIBE CONSULTING LLC

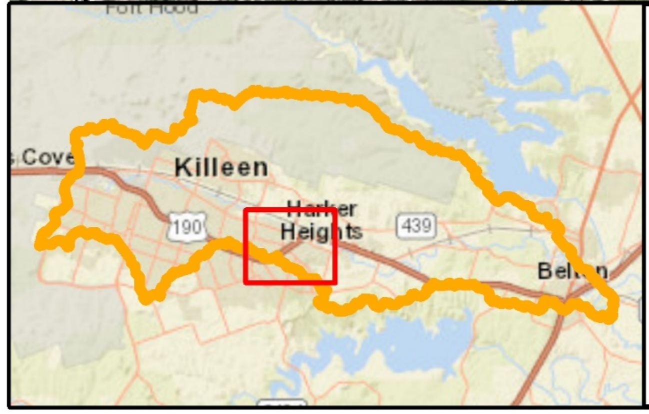
ALTERNATIVE 19A - NOLAN CREEK MAP 3 OF 3

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION BASIN LOCATED BETWEEN SOUTH TWIN CREEK DR AND NORTH ROY REYNOLDS DR

Note: Storage analysis is preliminary & subject to change in final design.





Legend

- Structures Removed From Floodplain
- Stream CL
- Proposed 100-YR Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	325	$42,702,000
Preliminary 100-YR Floodplain	500	$66,615,100
Structures Removed From 100-YR Floodplain	173	$23,913,100

N

0 1,000 2,000 4,000 Feet

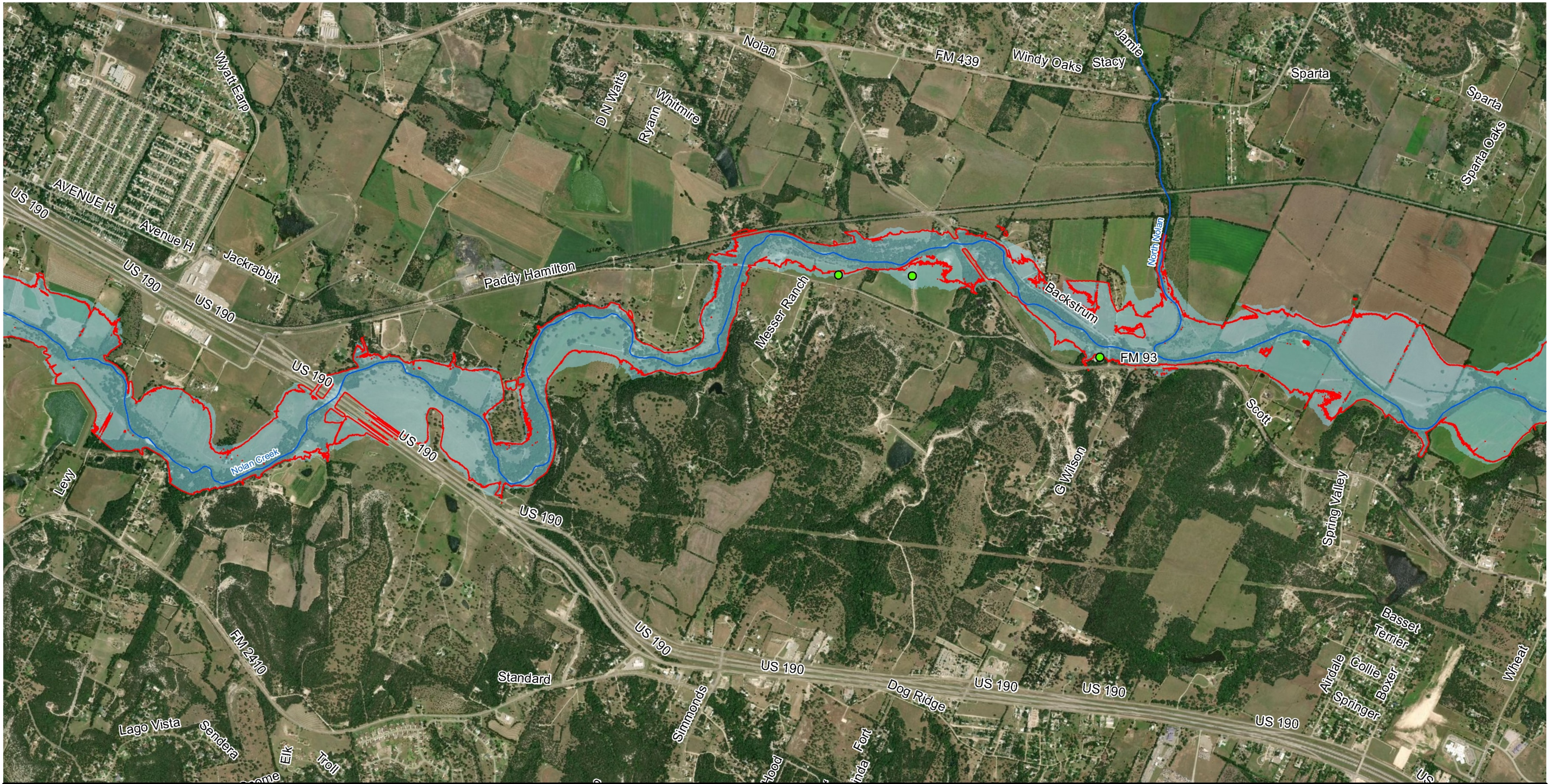
SCHEIBE CONSULTING LLC

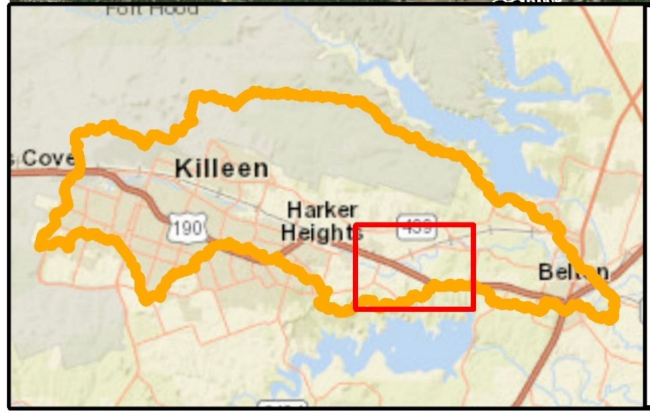
ALTERNATIVE 19B - NOLAN CREEK
MAP 1 OF 3

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION BASIN LOCATED BETWEEN SOUTH TWIN CREEK DR AND NORTH ROY REYNOLDS DR

Note: Storage analysis is preliminary & subject to change in final design.





Legend

- Structures Removed From Floodplain
- Stream CL
- Proposed 100-YR Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	325	$42,702,000
Preliminary 100-YR Floodplain	500	$66,615,100
Structures Removed From 100-YR Floodplain	173	$23,913,100

N

0 1,000 2,000 4,000 Feet

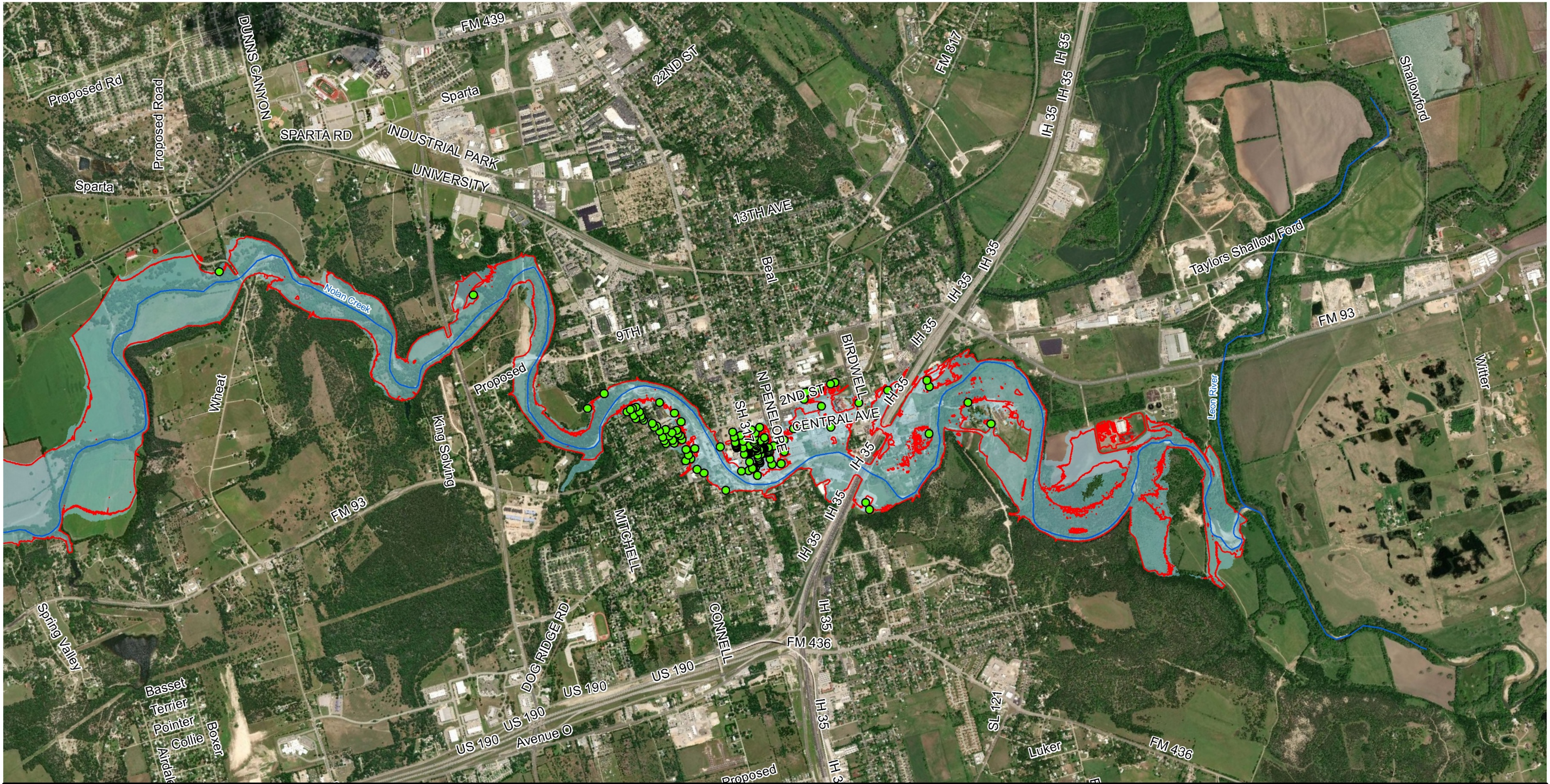
SCHEIBE CONSULTING LLC

ALTERNATIVE 19B - NOLAN CREEK
MAP 2 OF 3

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION BASIN LOCATED BETWEEN SOUTH TWIN CREEK DR AND NORTH ROY REYNOLDS DR

Note: Storage analysis is preliminary & subject to change in final design.



Legend

- Structures Removed From Floodplain
- Stream CL
- Proposed 100-YR Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	325	$42,702,000
Preliminary 100-YR Floodplain	500	$66,615,100
Structures Removed From 100-YR Floodplain	173	$23,913,100

N

0 1,000 2,000 4,000 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 19B - NOLAN CREEK MAP 3 OF 3

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

REGIONAL DETENTION BASIN LOCATED BETWEEN SOUTH TWIN CREEK DR AND NORTH ROY REYNOLDS DR

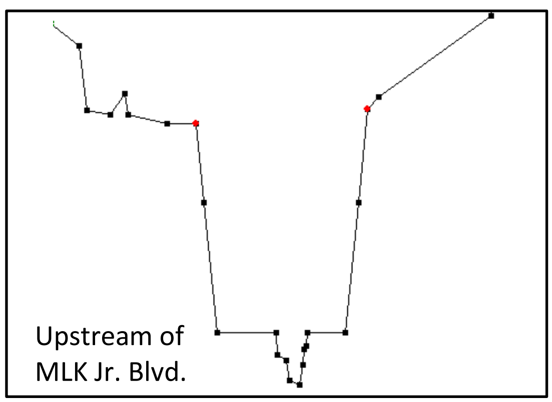
Note: Storage analysis is preliminary & subject to change in final design.

Alternative 20 – Channel Modifications at Martin Luther King Jr Blvd.

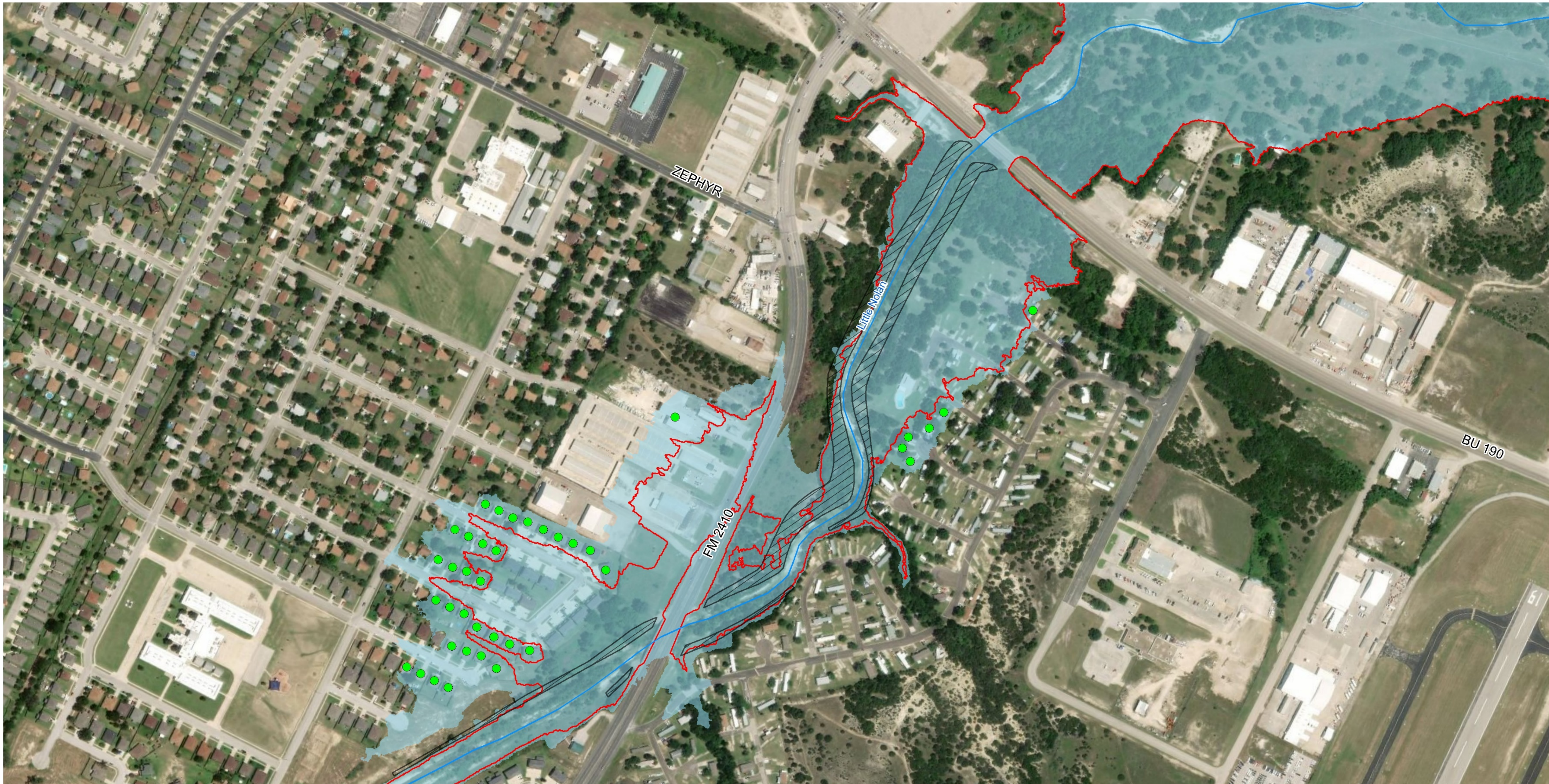
The goal of this alternative is to reduce flooding in Killeen along Little Nolan Creek upstream of MLK Jr. by adding a benched channel improvement upstream and downstream of the road. The typical dimensions of the benched cut include a 150 ft. bottom width with 3 to 1 side slopes. A typical section upstream of MLK Jr. Blvd. is shown below. Care was taken to avoid any existing structures and no additional improvements were made to existing bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 3.5 ft. reduction upstream and 7.6 ft. reduction downstream of MLK in 100-yr flood elevations removing 39 structures from the existing 100-yr floodplain. An additional benefit of this alternative would be to improve water quality by remediating old leaky clay wastewater lines located along the right bank downstream of MLK. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

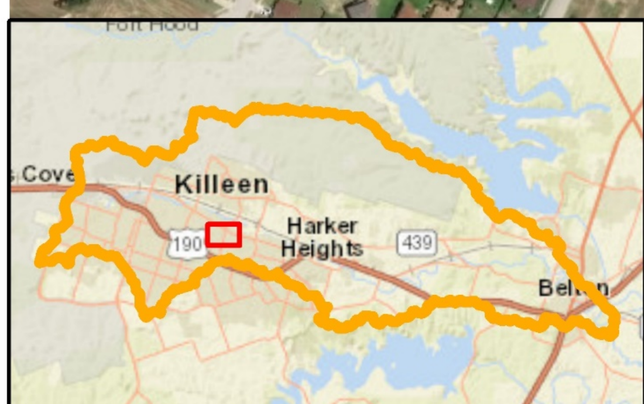
A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $1,979,000 and will result in removal of $4,323,350 of structures from the 100-yr floodplain. This alternative has high benefit to cost ratio and can potentially provide additional water quality related benefits. Due to the high flood reduction impact and additional benefits, Killeen has assigned a high priority to Alternative 20.

Typical Section of Channel Modification



ALT20 - Channel Modifications: Little Nolan				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
7.72	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 19,300
55	EA	Tree Removal	$ 800.00	$ 44,000
139,740	CY	Excavation - (CHANNEL)	$ 8.00	$ 1,117,920
1	CY	Fill - On-site borrow	$ 6.00	$ 6.00
1	LS	Cofferdams and Dewatering	$ 25,000.00	$ 25,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
37,365	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 56,047
		SUBTOTAL*		$ 1,287,273
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 65,000
1	LS	Engineering Design (approx. 15% of construction subtotal)		$ 193,091
1	AC	Land Acquisition	$ 37,600	$ 37,600
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 1,582,964
		25% CONTENGENCIES		$ 395,741
		GRAND TOTAL		$ 1,979,000





Legend

- Stream CL
- Structures Removed from Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	21	$3,984,340
Preliminary 100-YR Floodplain	60	$8,307,690
Structures Removed From 100-YR Floodplain	39	$4,323,350

N

0 250 500 1,000 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 20 - LITTLE NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL MODIFICATION ALTERNATIVES AT MARTIN LUTHER KING JR BLVD

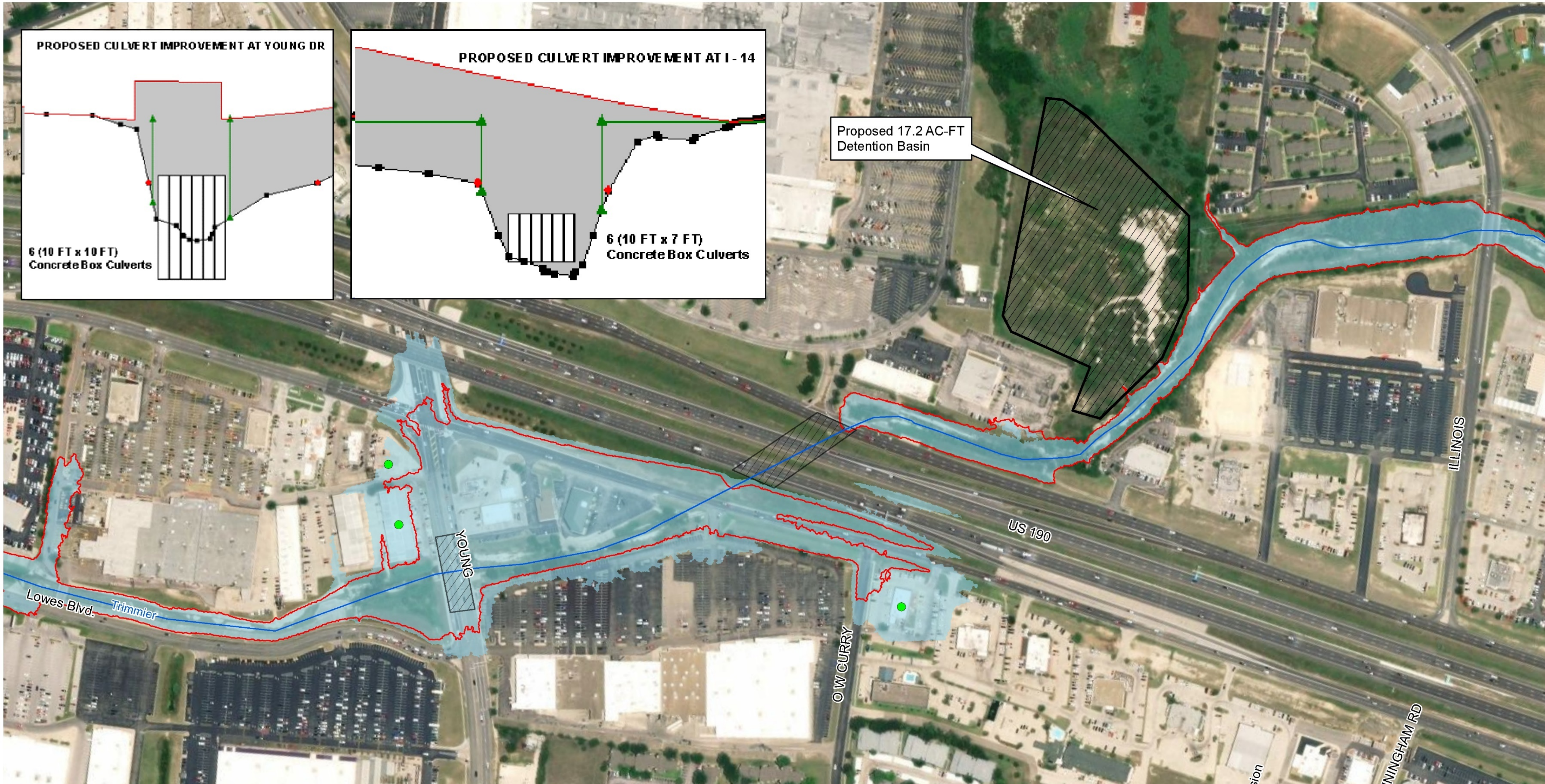
Alternative 21 – Culvert Improvements at I-14 and W.S. Young Drive

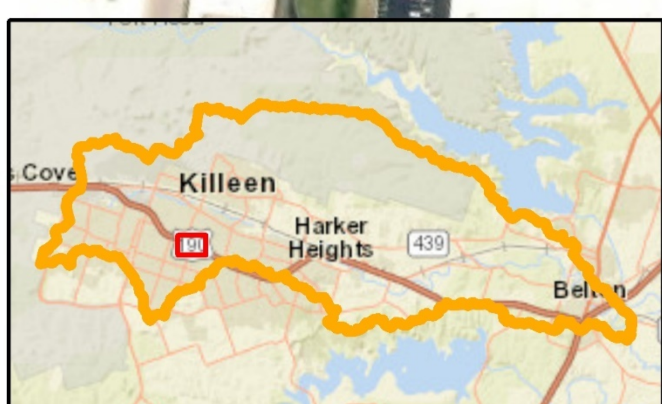
The goal of this alternative is to reduce flooding upstream of I-14 in Killeen that affects commercial properties between W.S. Young Dr. and I-14 along Trimmier Road Ditch. This alternative consists of two culvert improvement options. Option A consists of adding 2-10 X 7 boxes at I-14 and replacing the existing culverts at W.S. Young with 6-10 X 10 boxes. Option B consists of adding 4-10 X 7 boxes at I-14 and replacing the existing culverts at W.S. Young with 6-10 X 10 boxes. Opening the culverts with these options results in an increase in flow impacting downstream infrastructure. To mitigate for this impact both options will require detention potentially located in the open parcel on the left overbank downstream of I-14. Respective required detention volumes are provided on the attached figures. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. Option 1 resulted in a maximum 3.9 ft. reduction in 100-yr flood elevations upstream of I-14 and Option 2 resulted in a maximum 9.1 ft. 100-yr flood elevation reduction removing 3 and 7 commercial structures respectively from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the maps below.

A detailed opinion of probable cost for each option is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for Option A is $9,108,000 and will result in removal of $632,900 of structures from the 100-yr floodplain. The total opinion of probable cost for Option B is $16,844,000 and will result in removal of $1,558,320 of structures from the 100-yr floodplain. The cost-benefit ratio for this alternative is low due to the high cost of adding additional boxes under I-14. Cost savings could be possible if this alternative was coupled with future TxDOT improvements for I-14 main lanes. However, due to the high cost, low benefit, and low likelihood of funding, of this alternative, it was given a low priority by the City of Killeen.

ALT21A - Culvert Improvements				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
2.00	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 5,000
1,275	LF	2 - Conc Box Culv (10FT x 7FT)	$ 982.00	$ 1,252,050
4	EA	Wingwall (FW - 0) (HW = 7 FT)	$ 14,233	$ 56,932
1275	LF	Jack Bor Tun Box Culverts	$ 3,000	$ 3,825,000
540	LF	Remove STR (BOX CULVERT)	$ 31.00	$ 16,740
7,093	CY	Excavation - (ROADWAY)	$ 6.00	$ 42,558
540	LF	6 - Conc Box Culv (10FT x 10FT)	$ 836.00	$ 451,440
4	EA	Wingwall (FW - 0) (HW = 10 FT)	$ 17,250	$ 69,000
693	TON	D-GR HMA TY-C	$ 60.00	$ 41,580
2,128	SY	Removing Stab Base & Asph Pav (2' - 6")	$ 2.27	$ 4,831
27,749	CY	Excavation (Special)	$ 6.00	$ 166,494
9,240	CY	Embankment (95% Proctor) - Select Fill	$ 4.00	$ 36,960
1	LS	Traffic Control	$ 48,000.00	$ 48,000
1	LS	Minor Utility Adjustments	$ 15,000.00	$ 15,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
9,680	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 14,520
		SUBTOTAL		$ 6,071,105
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 304,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 911,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 7,286,105
		25% CONTENGENCIES		$ 1,821,526
		GRAND TOTAL		$ 9,108,000

ALT21B - Culvert Improvements				
Qnty	Unit	Item Description	Unit Price	Amount
2.00	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 5,000
2,550	LF	4 - Conc Box Culv (10FT x 7FT)	$ 982.00	$ 2,504,100
4	EA	Wingwall (FW - 0) (HW = 7 FT)	$ 14,233	$ 56,932
2550	LF	Jack Bor Tun Box Culverts	$ 3,000	$ 7,650,000
360	LF	Remove STR (BOX CULVERT)	$ 31.00	$ 11,160
7,093	CY	Excavation - (ROADWAY)	$ 6.00	$ 42,558
540	LF	6 - Conc Box Culv (10FT x 10FT)	$ 836.00	$ 451,440
4	EA	Wingwall (FW - 0) (HW = 10 FT)	$ 17,250	$ 69,000
693	TON	D-GR HMA TY-C	$ 60.00	$ 41,580
2,128	SY	Removing Stab Base & Asph Pav (2' - 6")	$ 2.27	$ 4,831
39,365	CY	Excavation (Special)	$ 6.00	$ 236,190
13,109	CY	Embankment (95% Proctor) - Select Fill	$ 4.00	$ 52,436
1	LS	Traffic Control	$ 48,000.00	$ 48,000
1	LS	Minor Utility Adjustments	$ 15,000.00	$ 15,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
9,680	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 14,520
		SUBTOTAL		$ 11,227,747
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 562,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 1,685,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 13,474,747
		25% CONTENGENCIES		$ 3,368,687
		GRAND TOTAL		$ 16,844,000





Legend

- Structures Removed from Floodplain
- Stream CL
- Proposed Culvert Improvements
- Proposed Detention Basin
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	17	$2,085,180
Preliminary 100-YR Floodplain	20	$2,718,080
Structures Removed From 100-YR Floodplain	3	$632,900

N

0 150 300 600 Feet

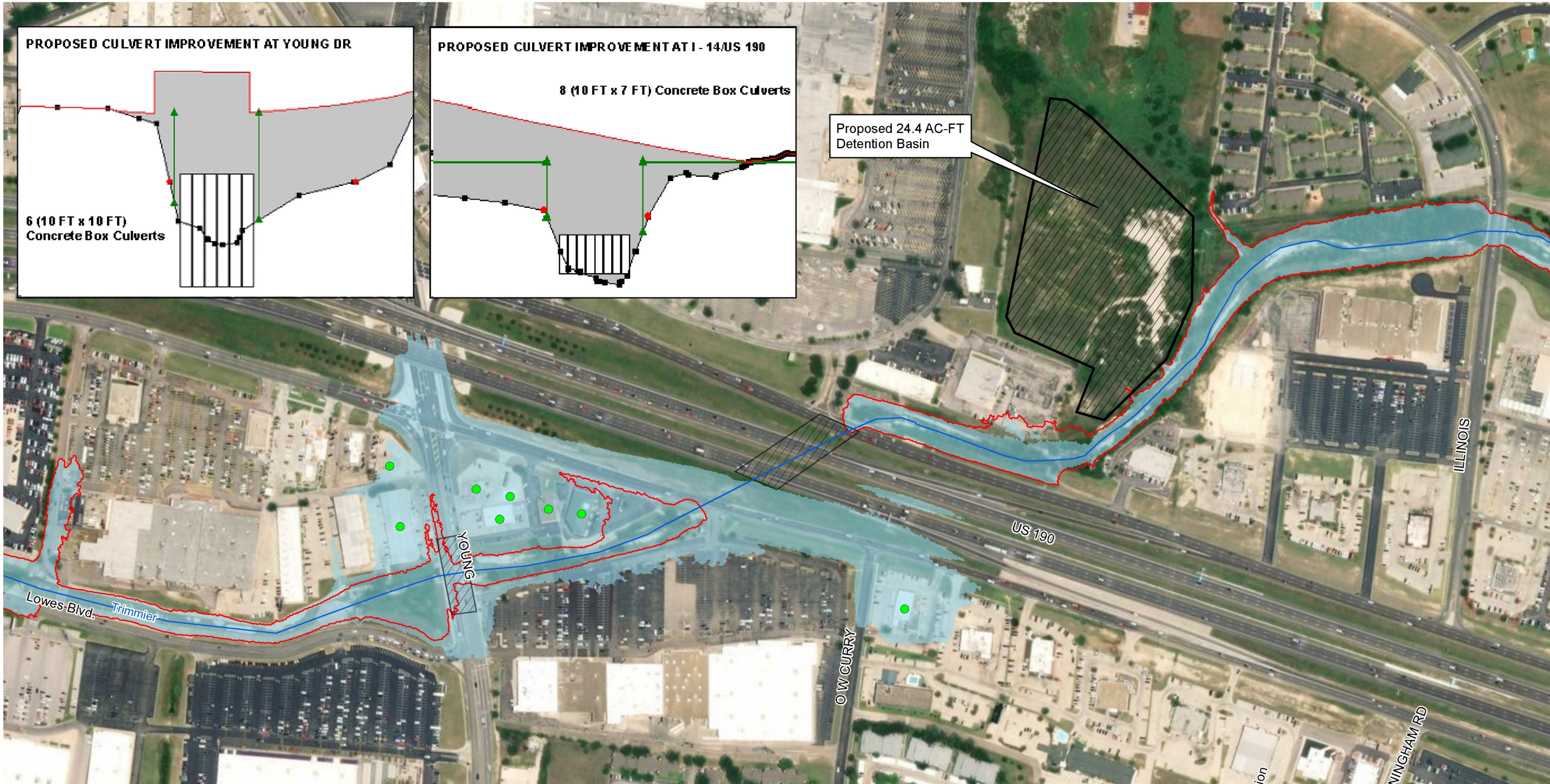
SCHEIBE CONSULTING LLC

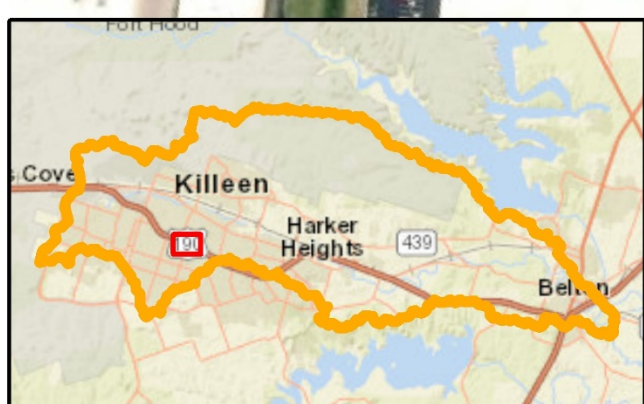
ALTERNATIVE 21A - TRIMMIER ROAD DITCH

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CULVERT IMPROVEMENTS AT INTERSTATE 14/ US 190 AND SOUTH YOUNG DR - OPTION A

Note: Storage analysis is preliminary and subject to change in final design





Legend

- Stream CL
- Structures Removed from Floodplain
- Proposed Culvert Improvements
- Proposed Detention Basin
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	12	$1,159,760
Preliminary 100-YR Floodplain	20	$2,718,080
Structures Removed From 100-YR Floodplain	8	$1,558,320

N

0 150 300 600 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 21B - TRIMMIER ROAD DITCH

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CULVERT IMPROVEMENTS AT INTERSTATE 14/ US 190 AND SOUTH YOUNG DR - OPTION B

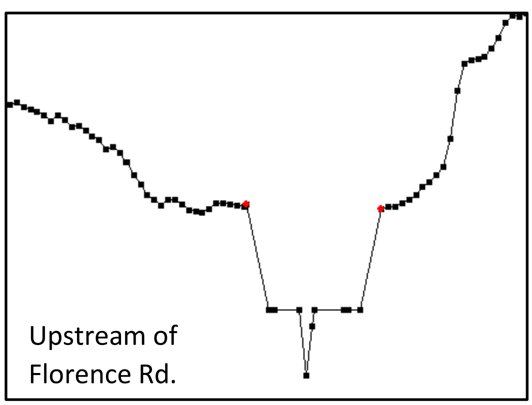
Note: Storage analysis is preliminary and subject to change in final design

Alternative 22 – Detention and Channel Improvement Upstream of Florence Rd.

The goal of this alternative is to reduce residential flooding along Trimmier Road Ditch upstream of Florence Rd. in Killeen. Two options were evaluated to reduce flooding to the residential structures. Option A consists of benched cuts with a 40 ft. bottom width and 3 to 1 side slopes combined with a small 2 acre-foot detention pond located upstream of SH 195 to mitigate for increase downstream flows. A typical section of the Option A benched cut is shown below. Option B consists of a larger 28.6 acre-foot detention structure upstream of SH 195 with no additional channel modifications. Care was taken to avoid any existing structures and no additional improvements were made to existing culverts or bridges. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. Option A resulted in a maximum 2 ft. reduction in 100-yr flood elevations upstream of Florence Rd. and Option B resulted in a maximum 1 ft. reduction upstream of Florence Rd. with an additional 5.7 ft. reduction just upstream of I-14. Option A removes 6 residential structures, while Option B removes 13 total structures including 7 commercial structures upstream of I-14 from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the maps below.

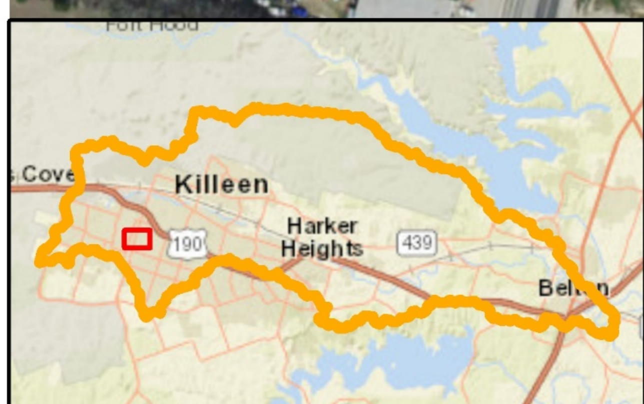
A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for Option A is $442,000 and will result in removal of $550,000 of structures from the 100-yr floodplain. The total opinion of probable cost for Option B is $2,069,000 and will result in removal of $1,633,000 of structures from the 100-yr floodplain. The cost-benefit ratio is better for Option A than Option B. However, Option B provides significantly more benefits further downstream. It is likely a combination of channel improvements with a larger amount of detention could results in a more favorable benefit-cost ratio than is provided by Option A. Due to the potential for high benefits a with a combination of these options, this alternative was given a medium priority by the City of Killeen.

Typical Section of Option A Channel Modification



ALT 22A - Proposed Detention Basin (Upstream of Roy Reynolds)				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
3	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 8,400
84	EA	Tree Removal	$ 400	$ 33,600
17,784	CY	Excavation (Special)	$ 8.00	$ 142,270
14	CY	Embankment (95% Proctor) - Select Fill	$ 6.00	$ 81
144	LF	2 - 24" RCP (CL IV)	$ 80.10	$ 11,514
2	EA	WINGWALL (PW - 1) (HW=10 FT)	$ 2,600	$ 5,200
1	LS	RCP End Treatment (Estimated)	$ 2,500	$ 2,500
-	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ -
-	CY	RipRap (Stone Common) (Dry) (12 in)	$ 30.00	$ -
9,326	SY	Soil Retention Blankets (CL 1) (TY A)	$ 1.27	$ 11,844
13,552	SY	Broadcast Re-seeding	$ 0.30	$ 4,066
1	LS	Temporary Erosion Control	$ 20,000	$ 20,000
1	LS	Land Acquisition	$ 66,000	$ 66,000
1	EA	Flap Gate (Approx. 50% installation cost)	$ 1,800	$ 1,800
		SUBTOTAL		$ 307,276
1	LS	Engineering Design (approx. 10% of construction subtotal)	$ -	$ 30,728
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 15,364
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 353,367
		25% CONTENGENCIES		$ 88,342
		CONSTRUCTION TOTAL		$ 442,000

ALT 22B - Proposed Detention Basin (Upstream of Roy Reynolds)				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
11	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 33,900
339	EA	Tree Removal	$ 400	$ 135,600
135,584	CY	Excavation (Special)	$ 6.00	$ 813,503
702	CY	Embankment (95% Proctor) - Select Fill	$ 4.00	$ 2,807
221	LF	2 - 24" RCP (CL IV)	$ 80.10	$ 17,682
4	EA	WINGWALL (PW - 1) (HW=10 FT)	$ 5,200	$ 20,800
1	LS	RCP End Treatment (Estimated)	$ 2,500	$ 2,500
-	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ -
-	CY	RipRap (Stone Common) (Dry) (12 in)	$ 30.00	$ -
18,007	SY	Soil Retention Blankets (CL 1) (TY A)	$ 1.27	$ 22,869
53,240	SY	Broadcast Re-seeding	$ 0.30	$ 15,972
1	LS	Temporary Erosion Control	$ 20,000	$ 20,000
1	LS	Land Acquisition	$ 43,200	$ 350,000
2	EA	Flap Gate (Approx. 50% installation cost)	$ 1,800	$ 3,600
		SUBTOTAL		$ 1,439,233
1	LS	Engineering Design (approx. 10% of construction subtotal)	$ -	$ 143,923
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 71,962
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 1,655,118
		25% CONTENGENCIES		$ 413,779
		CONSTRUCTION TOTAL		$ 2,069,000



Legend

- Stream CL
- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Proposed Channel Modifications
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	9	$1,649,000
Preliminary 100-YR Floodplain	15	$2,199,000
Structures Removed From 100-YR Floodplain	6	$550,000

N

0 100 200 400 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 22A - TRIMMIER ROAD DITCH

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL MOD & DETENTION ALTERNATIVE 1 LOCATED BETWEEN OLD FM 440 RD & FLORENCE RD.

Note: Storage analysis is preliminary & subject to change in final design.

Legend

- Stream CL
- Structures Removed From Floodplain
- Proposed 100-yr Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	2	$566,000
Preliminary 100-YR Floodplain	15	$2,199,000
Structures Removed From 100-YR Floodplain	13	$1,633,000

N

0 250 500 1,000 Feet

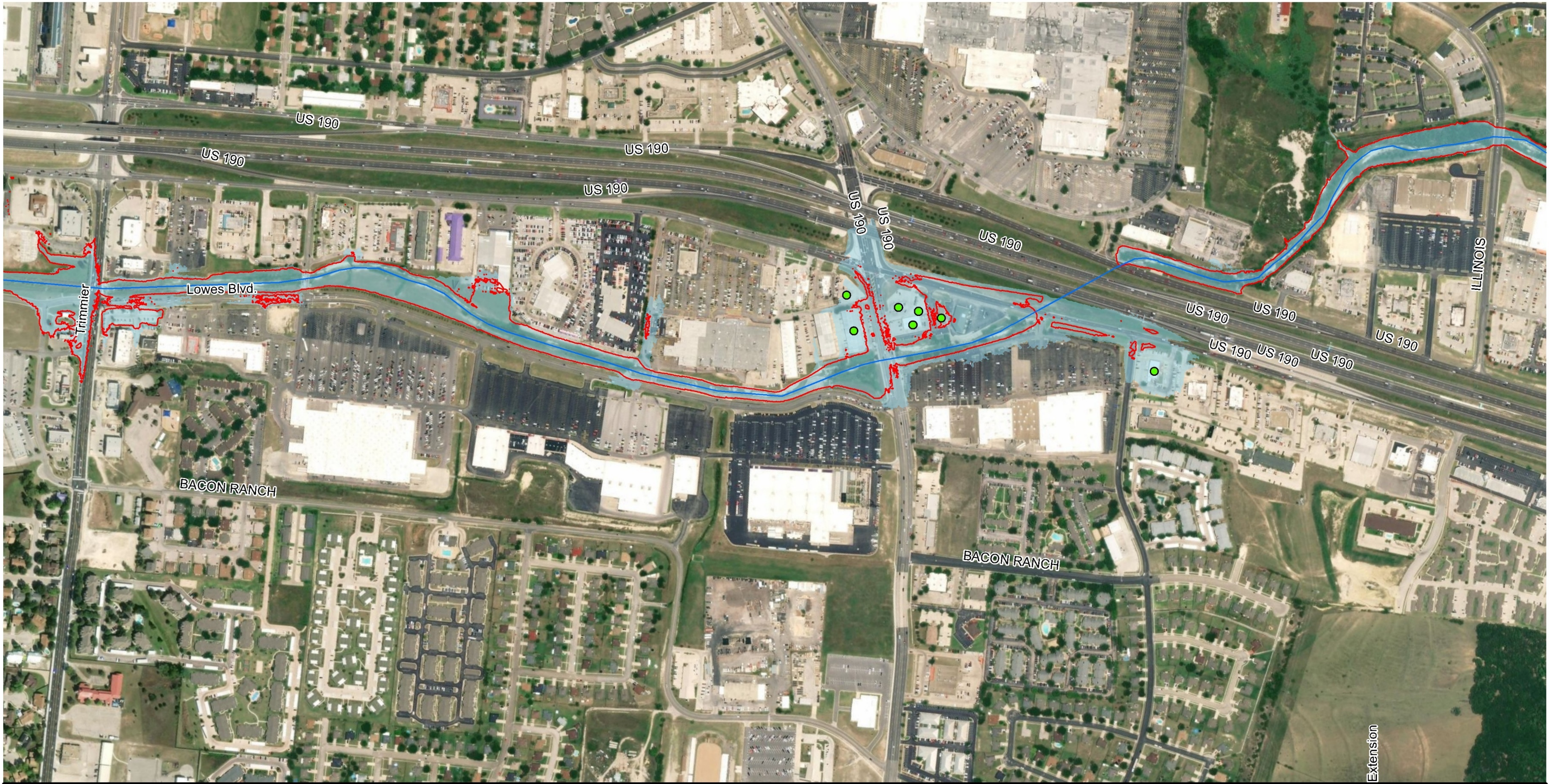
SCHEIBE CONSULTING LLC

ALTERNATIVE 22B - TRIMMIER ROAD DITCH MAP 1 OF 2

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

DUAL-CHAMBER LATERAL DETENTION BASIN LOCATED BETWEEN OLD FM 440 RD & S. FORT HOOD ST.

Note: Storage analysis is preliminary & subject to change in final design.



Legend

- Stream CL
- Structures Removed From Floodplain
- Proposed 100-yr Floodplain
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	2	$566,000
Preliminary 100-YR Floodplain	15	$2,199,000
Structures Removed From 100-YR Floodplain	13	$1,633,000

N

0 250 500 1,000 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 22B - TRIMMIER ROAD DITCH MAP 2 OF 2

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

DUAL-CHAMBER LATERAL DETENTION BASIN LOCATED BETWEEN OLD FM 440 RD & S. FORT HOOD ST.

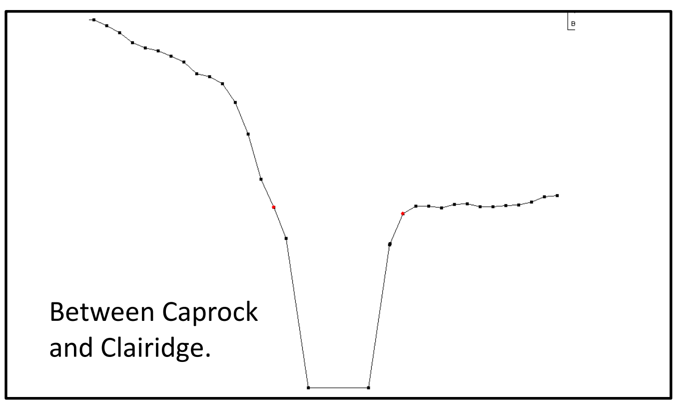
Note: Storage analysis is preliminary & subject to change in final design.

Alternative 23 – Culvert and Channel Modifications near Clairidge Ave. and Caprock Dr.

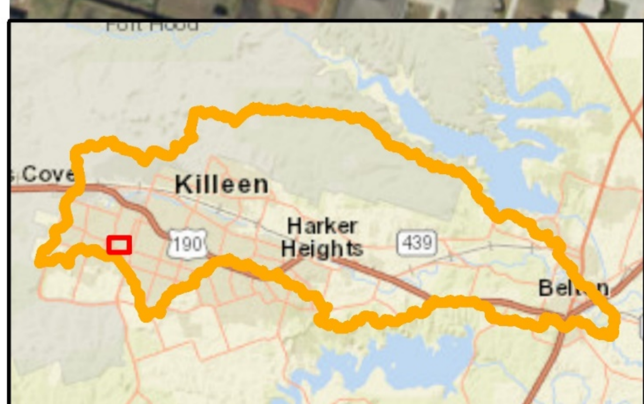
The goal of this alternative is to reduce flooding and overflow from just upstream of Clairidge Dr. down to Caprock Dr. along the upper portion of Trimmier Road Ditch in Killeen by adding channel improvement to the affected reach and increasing culvert capacity at Clairidge Dr. and Caprock Dr. Existing conditions modeling shows the potential for a lateral overflow along the left bank that would allow flood water to impact homes along Granite Dr. in the 100-yr event. This alternative combines a larger trapezoidal channel (14 ft. bottom width and 1 to 1 side slopes) combined with upgrading existing culverts with 3-6 X 5 boxes at Clairidge and 2 – 7 X 5 boxes at Caprock. A typical channel section is shown below. Care was taken to avoid any existing structures and to stay within the existing drainage easement. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 3 ft. reduction in 100-yr flood elevations and prevents the existing conditions 100-yr overflow from occurring. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $556,000 and will result in removal of at least $196,000 of structures from the 100-yr floodplain. The City of Killeen recently funded drainage improvements associated with Elms Rd. extension just downstream of this project area. Due to the recent investment in drainage improvements combined with the low benefit-cost ratio, Killeen has assigned a low priority for this alternative.

Typical Section of Channel Modification



ALT 23 - Culvert Improvements/Channel Modifications				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
0.08	AC	Site Preparation (Clearing & Grubbing)	$ 2,500	$ 198
2,156	CY	Excavation - (CHANNEL)	$ 6.00	$ 12,936
358	LF	Remove STR (BOX CULVERT)	$ 31	$ 11,059
208	LF	Conc Box Culv (6FT x 5FT)	$ 317.00	$ 65,936
4	EA	Wingwall (PW - 1) (HW = 5 FT)	$ 7,903	$ 31,612
150	LF	Conc Box Culv (7FT x 5FT)	$ 624	$ 93,600
4	EA	Wingwall (PW - 1) (HW = 5 FT)	$ 7,903	$ 31,612
100	SY	Removing Conc (Sidewalks)	$ 11.16	$ 1,116
100	SY	Conc Sidewalks (4")	$ 50.11	$ 5,011
43	TON	D-GR HMA TY-C	$ 60.00	$ 2,580
132	SY	Removing Stab Base & Asph Pav (2' - 6")	$ 2.27	$ 300
1	LS	Cofferdams and Dewatering	$ 25,000	$ 25,000
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
382	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 574
1	LS	Traffic Control	$ 48,000.00	$ 48,000
1	LS	Minor Utility Adjustments	$ 15,000.00	$ 15,000
		SUBTOTAL		$ 369,532
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 19,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 56,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 444,532
		25% CONTENGENCIES		$ 111,133
		GRAND TOTAL		$ 556,000



Legend

- Stream CL
- Structures Removed from Floodplain
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	18	$2,522,080
Preliminary 100-YR Floodplain	20	$2,718,080
Structures Removed From 100-YR Floodplain	2	$196,000

N

0 75 150 300 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 23 - TRIMMIER ROAD DITCH

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CULVERT IMPROVEMENTS AT CLAIRIDGE AVE.
AND CAPROCK DR. AND CHANNEL
MODIFICATIONS ALONG TRIMMER RD DITCH

Note: The increase in discharge due to culvert improvements result in a negligible increase in downstream water surface elevations
All channel modifications are contained within the limits of the existing channel

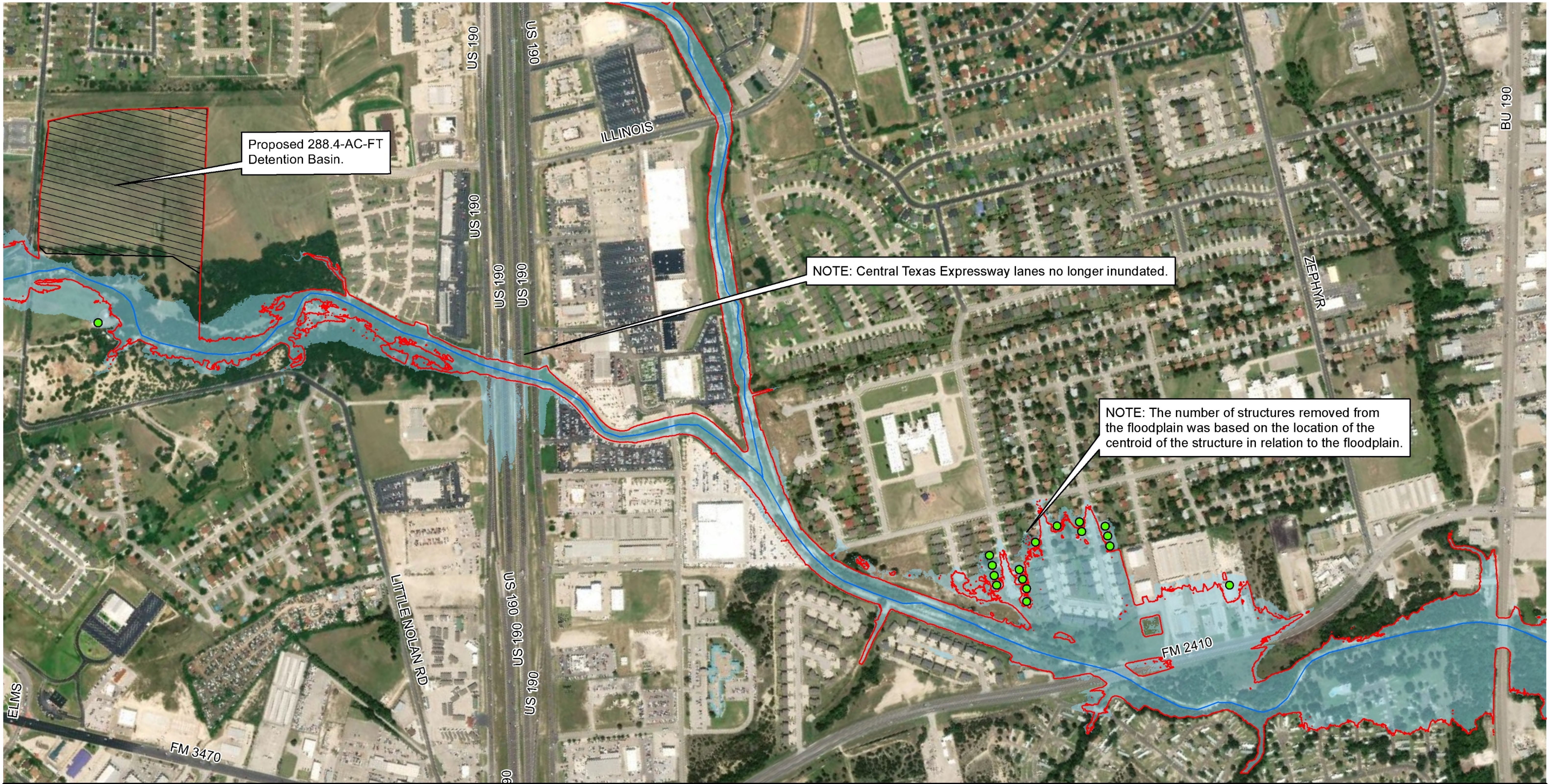
Alternative 24 – Proposed Offline Detention Basin Downstream of Little Nolan Rd.

The goal of this alternative is to reduce flooding at I-14 and MLK Jr. Blvd. along Little Nolan Creek by construction of an offline detention pond downstream of Little Nolan Rd. This alternative consists of two options that reflect different amounts of storage. Option A is a 288.4 acre-foot pond that reduces the existing 100-yr flow to the existing 10-yr flow. Option B is a 486.5 acre-foot pond that reduces the existing 100-yr flow to the existing 5-yr flow. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. Option A resulted in a maximum 3.1 ft. reduction in 100-yr flood elevations upstream of MLK Jr. Blvd. and option B resulted in a maximum 3.7 ft. reduction in 100-yr flood elevations. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for Option A is $5,040,000 and will result in removal of $1,671,000 of structures from the 100-yr floodplain. The total opinion of probable cost for Option A is $7,710,000 and will result in removal of $1,724,000 of structures from the 100-yr floodplain. These options will also alleviate flooding impacting the I-14 bridges. The structures removed are in the same area upstream of MLK Jr. Blvd. benefitted by Alternative 20. However, this alternative produces lower benefits for a higher cost than the benefits produced by Alternative 20. Also, there is less opportunity for dual benefits of the detention location as a recreational park area due to lack of access and location. Due to the lower benefits and higher cost of these options and lack of additional benefits, Killeen has ranked this alternative as low priority.

ALT 24A - 10 yr Dam				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
22	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 66,000
484	EA	Tree Removal	$ 400	$ 193,600
726,709	CY	Excavation (Special)	$ 4.00	$ 2,906,836
57	CY	Embankment (95% Proctor) - Select Fill	$ 6.00	$ 342
144	LF	2 - 24" RCP (CL IV)	$ 80.10	$ 11,514
2	EA	WINGWALL (PW - 1) (HW=10 FT)	$ 2,600	$ 5,200
1	LS	RCP End Treatment (Estimated)	$ 2,500	$ 2,500
-	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ -
-	CY	RipRap (Stone Common) (Dry) (12 in)	$ 30.00	$ -
6,333	SY	Soil Retention Blankets (CL 1) (TY A)	$ 1.27	$ 8,043
106,480	SY	Broadcast Re-seeding	$ 0.30	$ 31,944
1	LS	Temporary Erosion Control	$ 20,000	$ 20,000
1	LS	Land Acquisition	$ 256,000	$ 256,000
2	EA	Flap Gate (Approx. 50% installation cost)	$ 1,800	$ 3,600
		SUBTOTAL		$ 3,505,579
1	LS	Engineering Design (approx. 10% of construction subtotal)	$ -	$ 350,558
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 175,279
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 4,031,416
		25% CONTENGENCIES		$ 1,007,854
		CONSTRUCTION TOTAL		$ 5,040,000

ALT 24B - 5 yr Dam				
Quantity	**Unit**	**Item Description**	**Unit Price**	**Amount**
31	AC	Site Preparation (Clearing & Grubbing)	$ 3,000	$ 91,800
936	EA	Tree Removal	$ 400	$ 374,544
1,110,934	CY	Excavation (Special)	$ 4.00	$ 4,443,735
69	CY	Embankment (95% Proctor) - Select Fill	$ 6.00	$ 414
144	LF	2 - 24" RCP (CL IV)	$ 80.10	$ 11,514
2	EA	WINGWALL (PW - 1) (HW=10 FT)	$ 2,600	$ 5,200
1	LS	RCP End Treatment (Estimated)	$ 2,500	$ 2,500
-	SY	Geotextile Fabric (Est. installation cost at $.21 per SF)	$ 2.20	$ -
-	CY	RipRap (Stone Common) (Dry) (12 in)	$ 30.00	$ -
7,500	SY	Soil Retention Blankets (CL 1) (TY A)	$ 1.27	$ 9,525
148,100	SY	Broadcast Re-seeding	$ 0.30	$ 44,430
1	LS	Temporary Erosion Control	$ 20,000	$ 20,000
1	LS	Land Acquisition	$ 356,000	$ 356,000
2	EA	Flap Gate (Approx. 50% installation cost)	$ 1,800	$ 3,600
		SUBTOTAL		$ 5,363,262
1	LS	Engineering Design (approx. 10% of construction subtotal)	$ -	$ 536,326
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)	$ -	$ 268,163
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 6,167,752
		25% CONTENGENCIES		$ 1,541,938
		CONSTRUCTION TOTAL		$ 7,710,000



Legend

- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Stream CL
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	39	$5,151,000
Preliminary 100-YR Floodplain	56	$6,822,000
Structures Removed From 100-YR Floodplain	17	$1,671,000

N

0 300 600 1,200 Feet

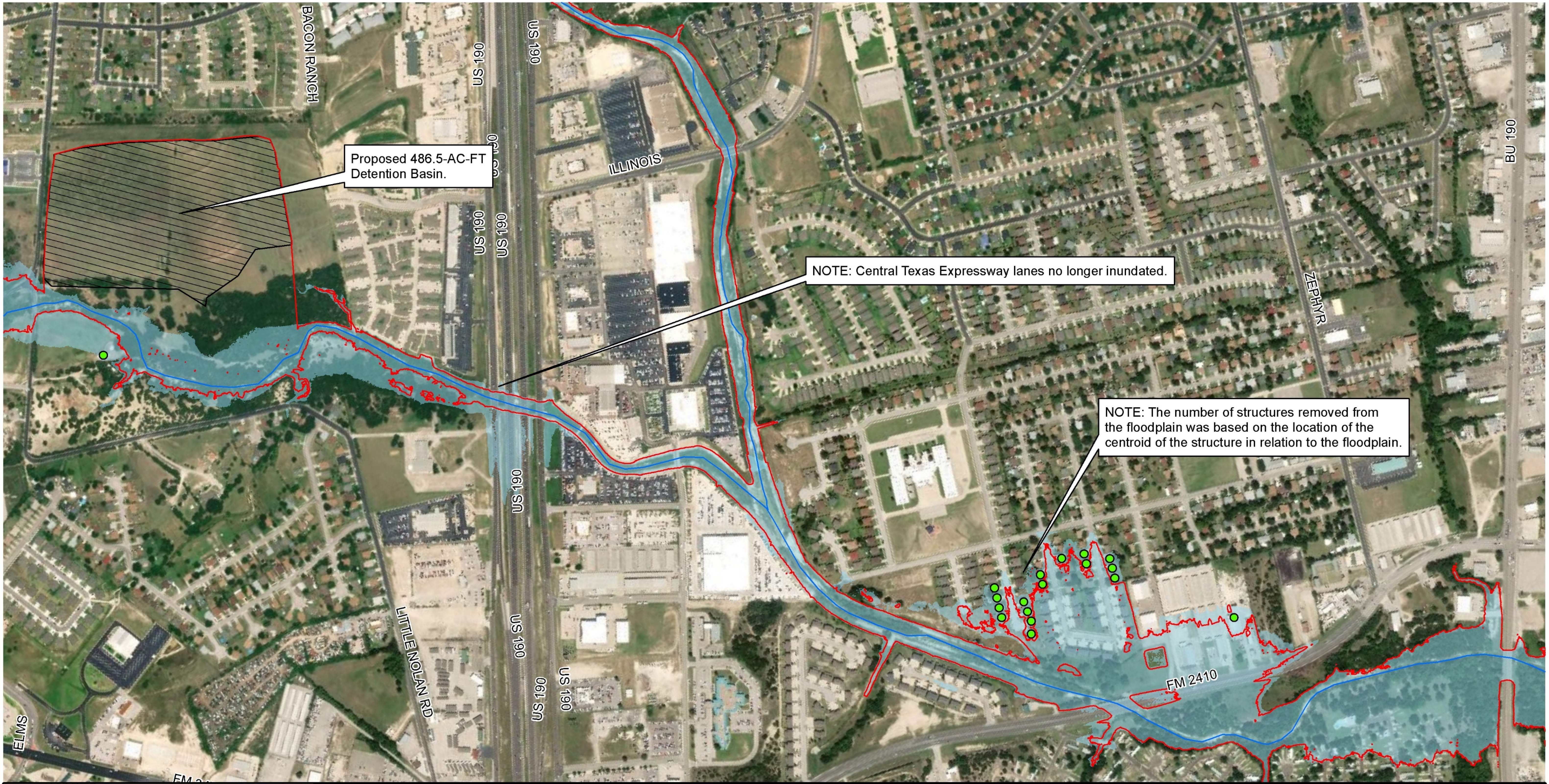
SCHEIBE CONSULTING LLC

ALTERNATIVE 24A - LITTLE NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

LATERAL DETENTION BASIN (10YR OUTFLOW POND) LOCATED BETWEEN LITTLE NOLAN RD & CENTRAL TEXAS EXPRESSWAY.

Note: Storage analysis is preliminary & subject to change in final design.



Legend

- Structures Removed From Floodplain
- Proposed 100-YR Floodplain
- Stream CL
- Proposed Detention Basin
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	38	$5,098,000
Preliminary 100-YR Floodplain	56	$6,822,000
Structures Removed From 100-YR Floodplain	18	$1,724,000

N

0 300 600 1,200 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 24B - LITTLE NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

LATERAL DETENTION BASIN (5YR OUTFLOW POND) LOCATED BETWEEN LITTLE NOLAN RD & CENTRAL TEXAS EXPRESSWAY.

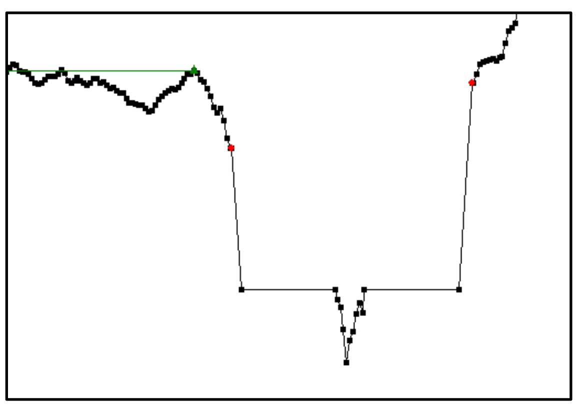
Note: Storage analysis is preliminary & subject to change in final design.

Alternative 25 – Channel Modifications
Old Florence Ditch Upstream of Trimmier Rd.

The goal of this alternative is to reduce flooding along Old Florence Ditch upstream of Trimmier Rd. associated with the presence of existing stock pond along the main channel. There are two options associated with this alternative reflecting a benched channel modification and possible removal of one of the stock pond dams. Option A consists of a bench cut with a 200 ft. bottom width and 3 to 1 side slopes. Option B consists of the same channel cut plus removal of the stock pond just upstream of Trimmier Rd. A typical section of the benched cut is shown below. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. Option A resulted in a maximum 2.4 ft. reduction in 100-yr flood elevations upstream of Trimmier Rd. and Option B resulted in 3.4 ft. reduction. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

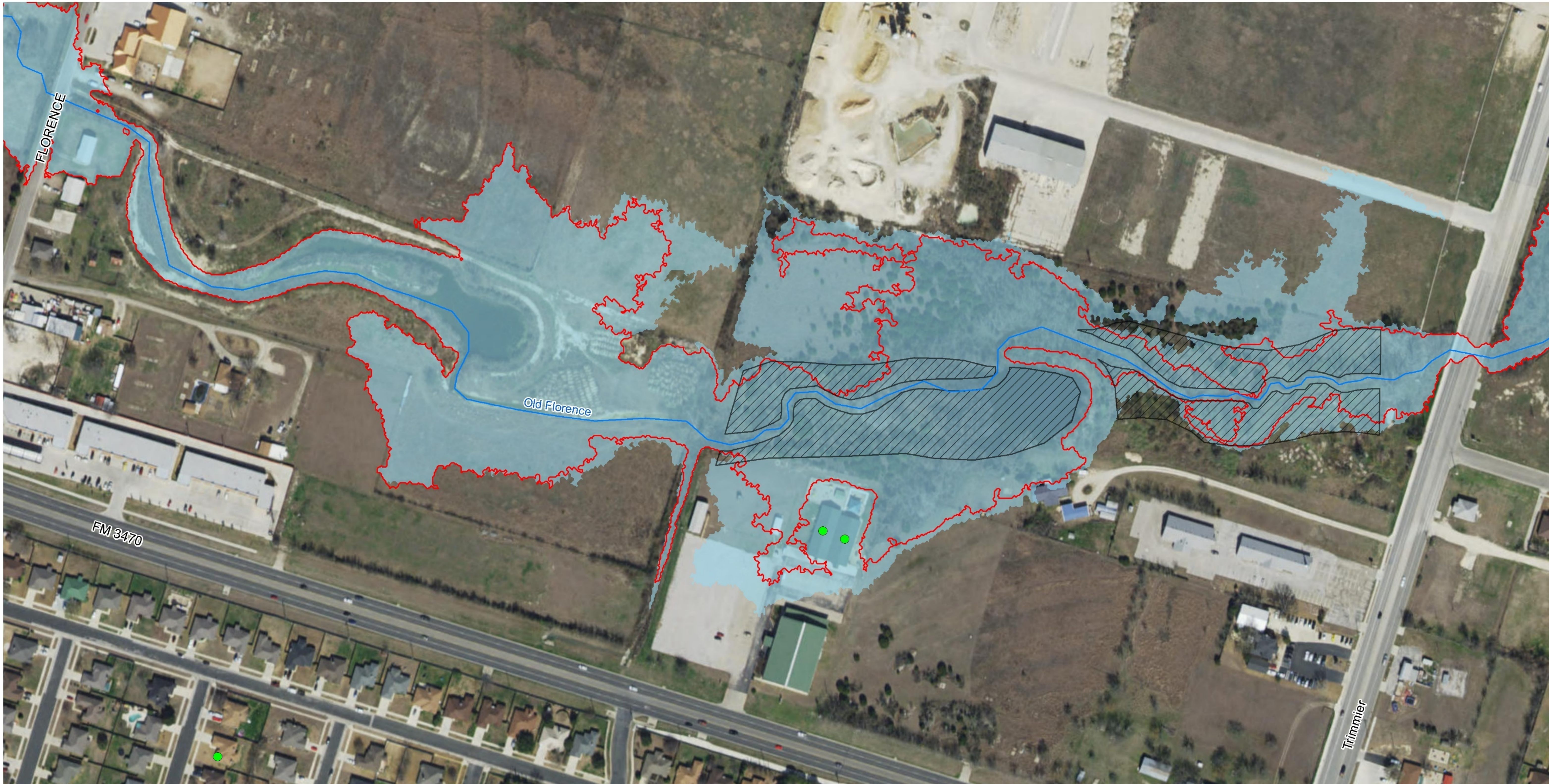
A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for Option A is $505,000 and will result in removal of $420,600 of structures from the 100-yr floodplain. The total opinion of probable cost for Option B is $617,000 and will also result in removal of $420,600 of structures from the 100-yr floodplain. The wooded area upstream of the stock pond dam contains some of the last remaining “old growth” trees left in the Killeen area, which would be a significant environmental constraint associated with this alternative as they would have to be removed as part of the channel modification. Also, the two structures removed by the alternative are recent construction and were built according to the current Killeen floodplain development ordinance (i.e. raised or floodproofed). Due to the environmental impact and lack of benefits associated with this alternative, Killeen has assigned it a low priority.

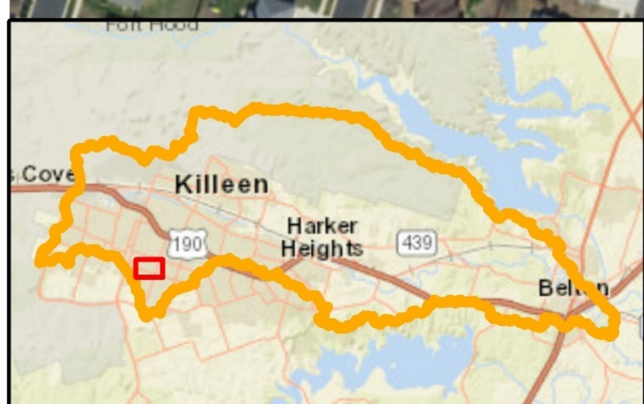
Typical Section of Channel Modification



ALT 25A - Channel Modifications: Old Florence				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
7.12	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 17,800
53	EA	Tree Removal	$ 800.00	$ 42,400
13,273	CY	Excavation - (CHANNEL)	$ 7.43	$ 98,618
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
34,461	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 51,691
		SUBTOTAL*		$ 235,510
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 12,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 36,000
1	LS	Land Acquisition		$ 120,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 403,510
		25% CONTENGENCIES		$ 100,877
		GRAND TOTAL		$ 505,000

ALT 25B - Channel Modifications: Old Florence				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
7.12	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 17,800
68	EA	Tree Removal	$ 800.00	$ 54,400
21,673	CY	Excavation - (CHANNEL)	$ 7.43	$ 161,030
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
34,461	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 51,691
		SUBTOTAL*		$ 309,922
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 16,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 47,000
1	LS	Land Acquisition		$ 120,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 492,922
		25% CONTENGENCIES		$ 123,230
		GRAND TOTAL		$ 617,000





Legend

- Stream CL
- Structures Removed from Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	1	$16,000
Preliminary 100-YR Floodplain	3	$436,600
Structures Removed From 100-YR Floodplain	2	$420,600

N

0 100 200 400 Feet

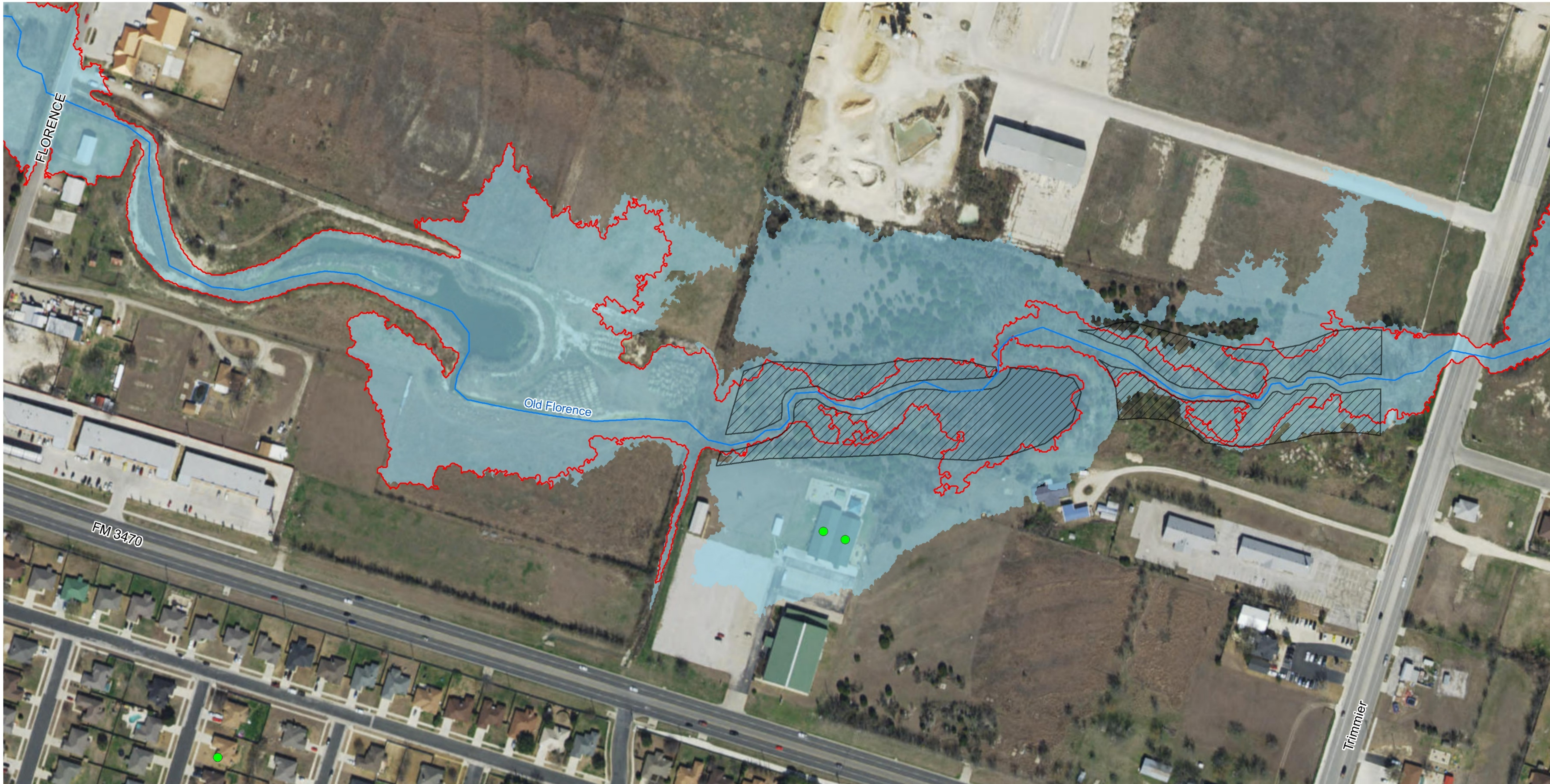
SCHEIBE CONSULTING LLC

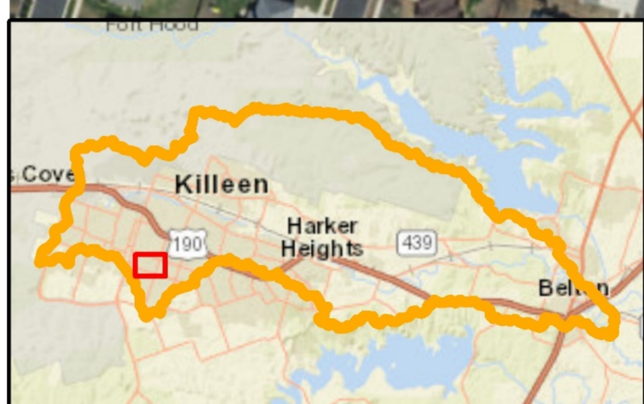
ALTERNATIVE 25A - OLD FLORENCE DITCH

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL MODIFICATION ALONG OLD FLORENCE DITCH UPSTREAM OF TRIMMIER RD. OPTION 1

Note: The increase in discharge due to channel modifications resulted in a 0.01 ft. increase in downstream water surface elevations. No detention basin was recommended.





Legend

- Stream CL
- Structures Removed from Floodplain
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	1	$16,000
Preliminary 100-YR Floodplain	3	$436,600
Structures Removed From 100-YR Floodplain	2	$420,600

N

0 100 200 400 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 25B - OLD FLORENCE DITCH

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CHANNEL MODIFICATION AND DAM REMOVAL ALONG OLD FLORENCE DITCH UPSTREAM OF TRIMMIER RD. OPTION 2

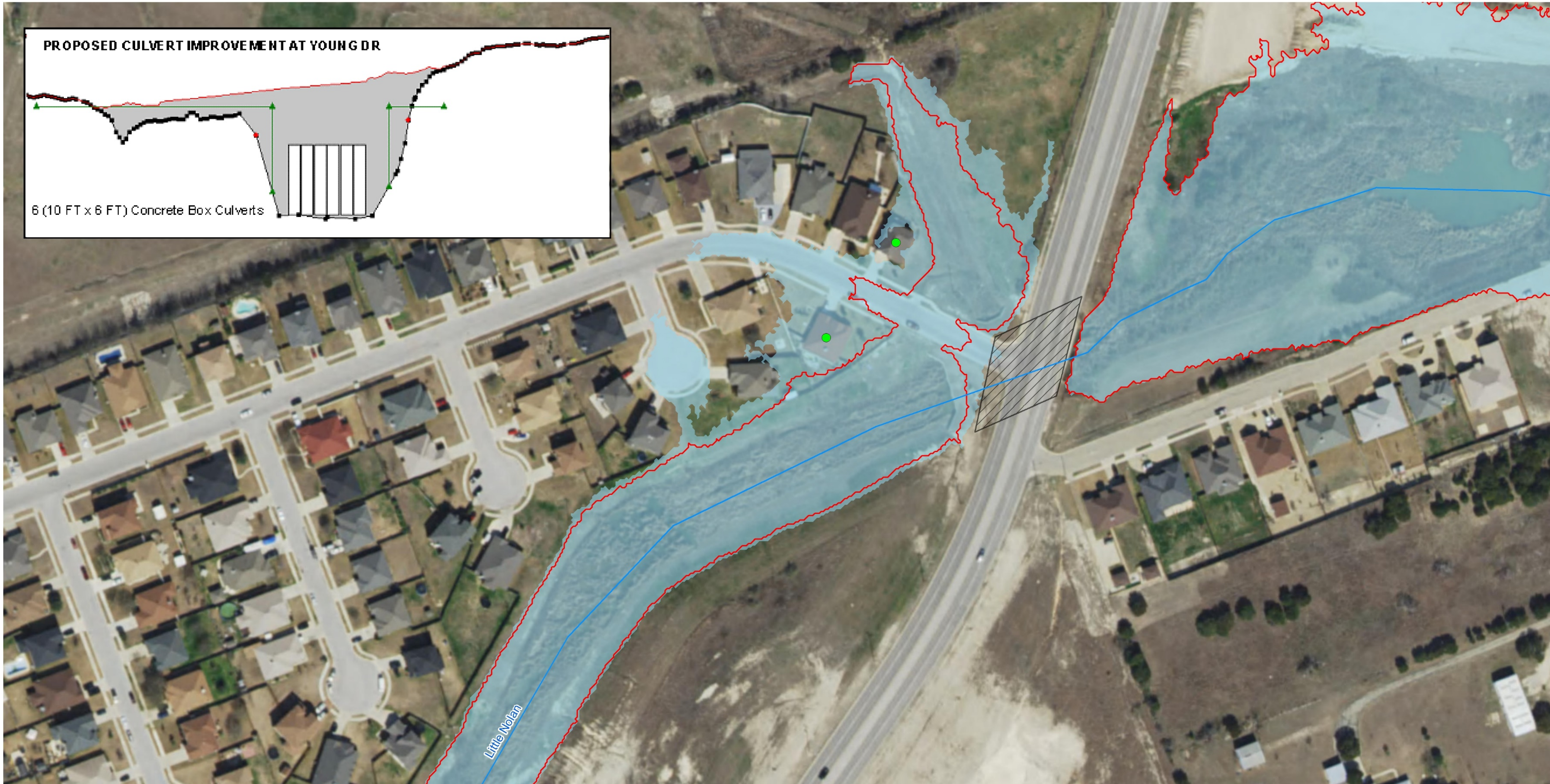
Note: The increase in discharge due to channel modifications resulted in a 0.02 ft. increase in downstream water surface elevations. No detention basin was recommended.

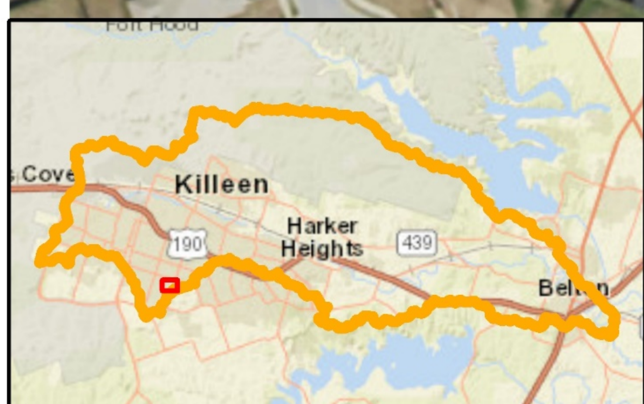
Alternative 26 – Culvert Improvements
South W.S. Young Drive

The goal of this alternative is to reduce flooding in Killeen upstream of W.S. Young Dr. along Little Nolan Creek. This alternative consists of replacing the existing corrugated arch culverts at W.S. Young with a more efficient culvert group comprised of 6-10 X 6 box culverts. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 1.7 ft. reduction in 100-yr flood elevations upstream of upstream of W.S. Young Dr. removing 2 structures from the existing 100-yr floodplain. The total value (from appraisal district data) of structures removed from the floodplain and reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $1,528,000 and will result in removal of $252,880 of structures from the 100-yr floodplain. This alternative resulted in a low cost-benefit ratio. Only two houses are impacted by the existing 100-yr flooding and have already been elevated according to the current City of Killeen floodplain ordinance. Due to the lack of benefit related to this alternative, Killeen has assigned it a low priority.

ALT26 - Culvert Improvement				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
0.50	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 1,250
1,303	SY	Removing Stab Base & Asph Pav (2' - 6")	$ 2.27	$ 2,958
526	LF	Remove STR (BOX CULVERT)	$ 30.89	$ 16,248
425	TON	D-GR HMA TY-C	$ 60.00	$ 25,500
1,170	LF	Conc Box Culv (10FT x 6FT)	$ 624.00	$ 730,080
2	EA	Wingwall (PW - 1) (HW = 6 FT)	$ 20,000	$ 40,000
216	SY	Removing Conc (Sidewalks)	$ 11.16	$ 2,411
216	SY	Conc Sidewalks (4")	$ 50.11	$ 10,824
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
2,420	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 3,630
1	LS	Traffic Control	$ 48,000.00	$ 48,000
1	LS	Reconstruction of Railing	$ 10,000.00	$ 10,000
889	SY	Base (8" Thick)	$ 12.00	$ 10,667
889	SY	HMAC (Type D, 2" Thick)	$ 9.00	$ 8,000
1	LS	Minor Utility Adjustments	$ 15,000.00	$ 15,000
		SUBTOTAL		$ 949,567
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 48,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 143,000
1	AC	Land Acquisition	$ 81,556	$ 81,556
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 1,222,123
		25% CONTENGENCIES		$ 305,531
		GRAND TOTAL		$ 1,528,000





Legend

- Stream CL
- Structures Removed from Floodplain
- Proposed Culvert Improvement
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

Flood Event	Structures Impacted	Value of Structures
Proposed 100-YR Floodplain	58	$8,054,810
Preliminary 100-YR Floodplain	60	$8,307,690
Structures Removed From 100-YR Floodplain	2	$252,880

N

0 75 150 300
Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 26 - LITTLE NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
NOLAN CREEK FPP STUDY

CULVERT IMPROVEMENTS AT SOUTH W. S. YOUNG DRIVE

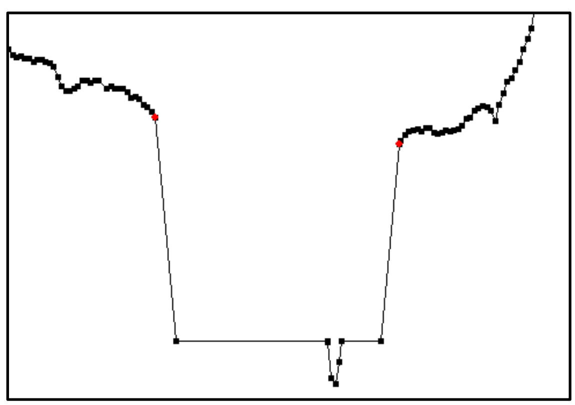
Note: The increase in discharge due to proposed culvert improvements result in negligible increase in downstream water surface elevations.

Alternative 27 – Channel Modification
South Nolan Creek Downstream of Robinett Rd.

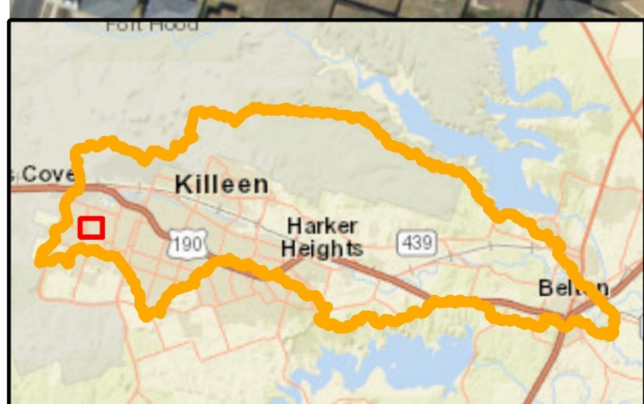
The goal of this alternative is to reduce flooding in Killeen with a channel modification along South Nolan Creek downstream of Robinett Rd. This alternative consists of a benched cut with a 150 - 200 bottom width depending on location and 3 to 1 side slopes   A typical section of the cut is shown below. Care was taken to avoid any existing structures as the existing channel alignment runs close to several residential structures on the right bank. Utility conflicts were not analyzed as part of this alternative and will need to be addressed during a future design phase. This alternative resulted in a maximum 2.9 ft. reduction in 100-yr flood elevations downstream of Robinett Rd. and moves the 100-yr floodplain boundary away from many residential structures. The reduced 100-yr flooding extents are provided in the map below.

A detailed opinion of probable cost is also provided and includes typical construction component costs, engineering fee, land acquisition cost, and a 25% contingency. The total opinion of probable cost for this project is $565,000. Benefits for this project are not associate with homes being removed from the floodplain as the existing floodplain comes close to but does not impact any residential structures. The project benefit is related to mitigating for severe erosion that is currently occurring along the right bank downstream of Robinett Rd. endangering private property and some residential structures. The reduction of the 100-yr floodplain is a secondary benefit. Due to the potential for this alternative to correct current erosion issues and produce a significant reduction in 100-yr flood elevations, Killeen has assigned a high priority to this alternative.

Typical Section of Channel Modification



ALT27 - Channel Modifications: South Nolan				
Qnty	**Unit**	**Item Description**	**Unit Price**	**Amount**
7.09	AC	Site Preparation (Clearing & Grubbing)	$ 2,500.00	$ 17,725
25	EA	Tree Removal	$ 800.00	$ 20,000
25,314	CY	Excavation - (CHANNEL)	$ 7.43	$ 188,083
1,200	SY	Removing Conc (Sidewalks)	$ 11.16	$ 13,392
1,200	SY	Conc Sidewalks (4")	$ 50.11	$ 60,132
1	LS	Temporary Erosion Controls	$ 25,000	$ 25,000
34,316	SY	Permanent Erosion Control & Re-Vegetation	$ 1.50	$ 51,473
		SUBTOTAL*		$ 375,805
1	LS	Total Mobilization Payment (approx. 5% of construction subtotal)		$ 19,000
1	LS	Engineering Design (approx. 15% of construction subtotal)	$ -	$ 57,000
**Assumed no Utility Conflicts*				
		CONSTRUCTION SUBTOTAL		$ 451,805
		25% CONTENGENCIES		$ 112,951
		GRAND TOTAL		$ 565,000



Legend

- Stream CL
- Proposed Channel Modifications
- Proposed 100-YR Floodplain
- Preliminary 100-YR Floodplain

Structure Count

No structures are inundated on the 100-yr floodplain for South Nolan

N

0 100 200 400 Feet

SCHEIBE CONSULTING LLC

ALTERNATIVE 27 - SOUTH NOLAN CREEK

CENTRAL TEXAS COUNCIL OF GOVERNMENTS NOLAN CREEK FPP STUDY

CHANNEL MODIFICATION ALTERNATIVE ALONG SOUTH NOLAN CREEK DOWNSTREAM OF ROBINETT RD.

Note: The increase in discharge due to channel modifications resulted in a 0.02 ft. increase in downstream water surface elevations. No detention basin was recommended.

APPENDIX D:

FLOOD EARLY WARNING SYSTEM REPORT

Nolan Creek Flood Alert System:

Operational Assessment and Recommendations

April 2019

A report prepared for:

Scheibe Consulting, LLC

And

Central Texas Council of Governments

Prepared by:

June Wolfe III, Ph.D.

Texas A&M AgriLife Research
Blackland Research and Extension Center
720 East Blackland Road
Temple, Texas 76502

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1 Executive Summary

In 2017 the Central Texas Council of Governments received a grant from the Texas Water Development Board to prepare a Flood Protection Plan for Nolan Creek. This report describes a sub-task of the planning process, an assessment of the current Nolan Creek flood alert system, operated by the City of Belton, supporting recommendations from the 2019 State Flood Assessment which includes evaluating non-structural community approaches to reducing local flood risk.

Nolan Creek has a long history of flash flooding with associated loss of life and property. Following a significant storm event in 2010, the City of Belton saw the need to extend warning times for flash floods and committed resources toward the installation and continuous operation of a flood alert system consisting of gauging stations along the main channel of Nolan Creek. Two of 5 gauging stations were funded by the upstream communities of Killeen and Harker Heights; however, long-term operation and maintenance of the system has been supported by the City of Belton. While the Nolan Creek Flood Alert System was designed for, and is specific to, Belton's needs and interests, upstream communities also use the system and receive benefit.

Texas A&M AgriLife Research – Temple determined the management and documentation, data collection and processing, risk assessment and forecasting, information communication and distribution, preparedness and response, and usage of The Nolan Creek flood alert system through personal interviews, phone conversations, and email queries. Findings indicate Belton believes the flood alert system is adequate for making flood-related response decisions in some parts of Belton but sees the need to upgrade the system to expand coverage and to have a more robust and reliable system. Officials from upstream communities in the watershed expressed varying degrees of knowledge about the current system, moderate use, and interest in expanding system coverage.

Texas A&M AgriLife Research – Temple developed flood alert system recommendations for the watershed as a whole, based on evaluation interviews, consultation with other Texas flood alert system managers, opinions of flood warning professionals, and a review of flood warning related literature. As each community in the Nolan Creek Watershed has unique problems and needs associated with reducing flood-risk, flood alert system recommendations are made relative to the operation of a regional or shared system. Major recommendations include an overarching management entity to oversee and coordinate shared flood alert system components, formally defined goals, operational documentation, an expanded data-gathering network, data collection and analysis, threat risk interpretations, forecasting, user-specific data presentations, and community-wide response planning. The intent is not to address unique community needs, but to describe important flood alert systems components that local communities may wish to consider to implement and share.

Definitions:

For consistency and ease of reading, the following term definitions are used in this report.

<u>ALERT:</u> Automated Local Evaluation in Real Time – a transmission protocol for the operation of remote field sensors communicating environmental data to a central computer in real time. It was developed in the 1970's by the National Weather Service and is used by numerous federal, state, and local agencies. ALERT-based hardware and software systems have become standard for real time environmental data collection due to their accuracy, reliability, and low cost.

<u>Base Station:</u> Location where data is received from remote field station sensors, processed, and provided to primary users and the public.

<u>Gauge:</u> See sensor.

<u>Nolan Creek flood alert system:</u> the local stream gauge network managed and operated by the City of Belton.

<u>Primary Users:</u> Government officials who monitor flood alert system data and rely on it as a basis for alerting the public and making critical decisions. Primary users of the current Nolan Creek flood alert system are Belton city officials.

<u>Sensor (or Gauge):</u> Electronic device that measures specific information such as rainfall amount, water level or stage, battery voltage, etc.

<u>Station or Gauge Station:</u> The physical location and collection platform with multiple environmental sensors and a transmitter.

2 Background

2.1 Nolan Creek Watershed

The Nolan Creek Watershed encompasses approximately 135 square miles and contains three officially named streams; North Nolan Creek, South Nolan Creek, and Nolan Creek (Figure 2.1) collectively classified by the United States Geological Survey as Stream Segment 1218. Stream flow travels east starting in Killeen and drops approximately 400 feet over its 29 mile course before joining the Leon River east of Belton. A large portion of the watershed is heavily urbanized. Portions of the Fort Hood military reservation and the cities of Killeen, Harker Heights, Nolanville, and Belton are contained within its boundaries. Due to the watershed's drainage pattern, urbanization, and the naturally impervious nature of its soils, runoff from large storm events has the potential to cause flash flooding at numerous locations across the area.

Nolan Creek is located in the middle of Texas's "Flash Flood Alley," a swath of land running north to south along the eastern edge of the Balcones Escarpment from San Antonio to Dallas (Figure 2.2). The incidence of flash flooding is greater in this area of Texas than any other region of the United States due to the impervious nature of its soils and a characteristically steep topography of narrow stream channels. When combined with high precipitation rates, the discharge per unit drainage area is some of the highest in the world (Owen, 2016). Rainfall distribution and intensity, topography, land use, vegetation, and soil properties all influence timing and location of flash flooding. Urbanized areas are particularly prone to flash flooding due to impervious surfaces which prevent water infiltration and increase runoff rates.

Flooding is defined as any high flow, overflow, or inundation by water which causes or threatens damage to property or threatens lives. Flash flooding is a sub-type defined as flooding that begins within 3 to 6 hours of heavy rainfall (NOAA, 2012). Because flash flooding occurs rapidly, it often catches people off-guard. At home or businesses, quickly rising waters may trap people or cause property damage before preventative actions may be taken. Situations may become dangerous when people encounter high, fast-moving water while driving. There is a long history of flash flooding in the Nolan Creek Watershed.

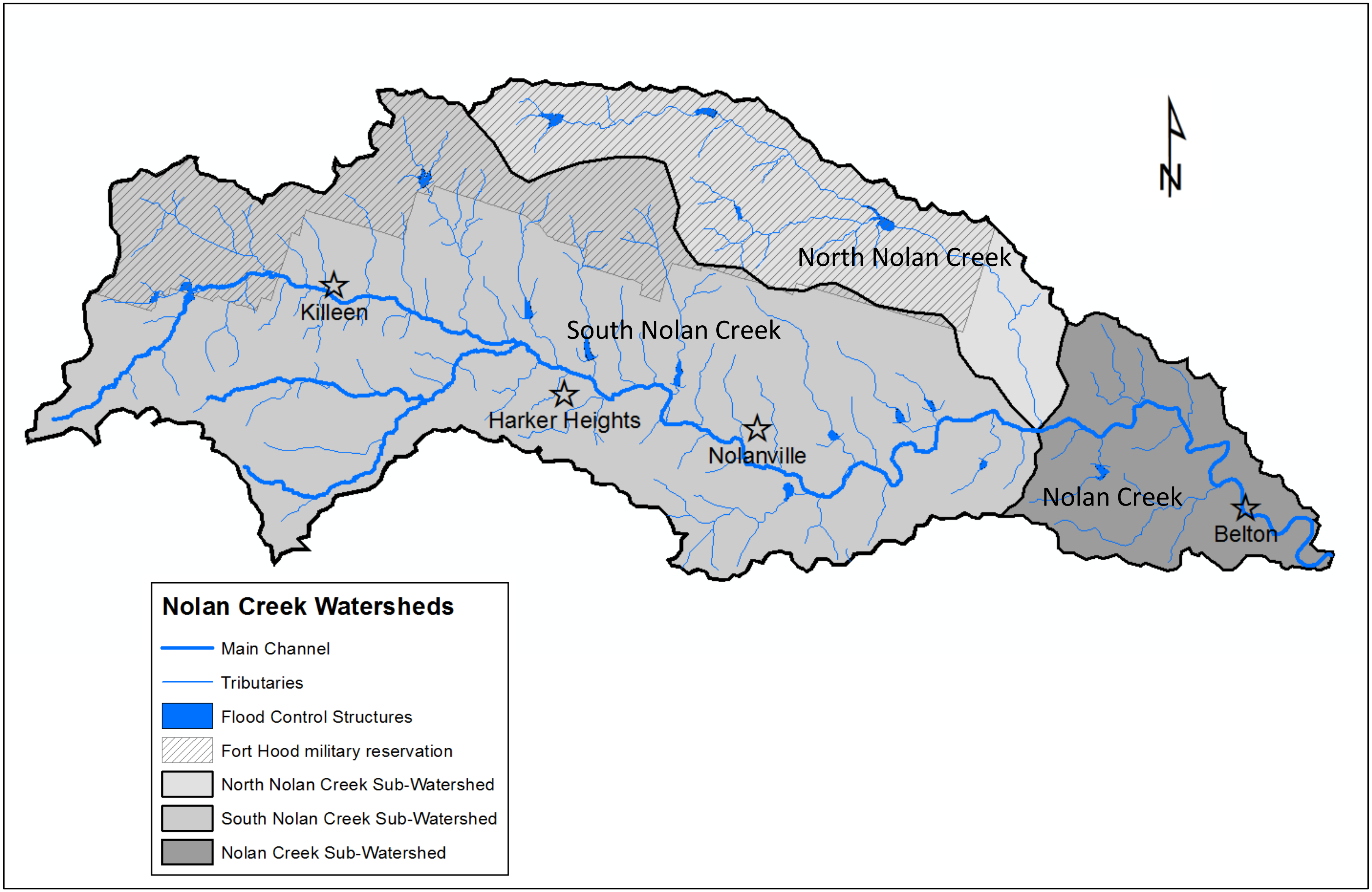


Figure 2.1 Map of Nolan Creek and Sub-Watersheds

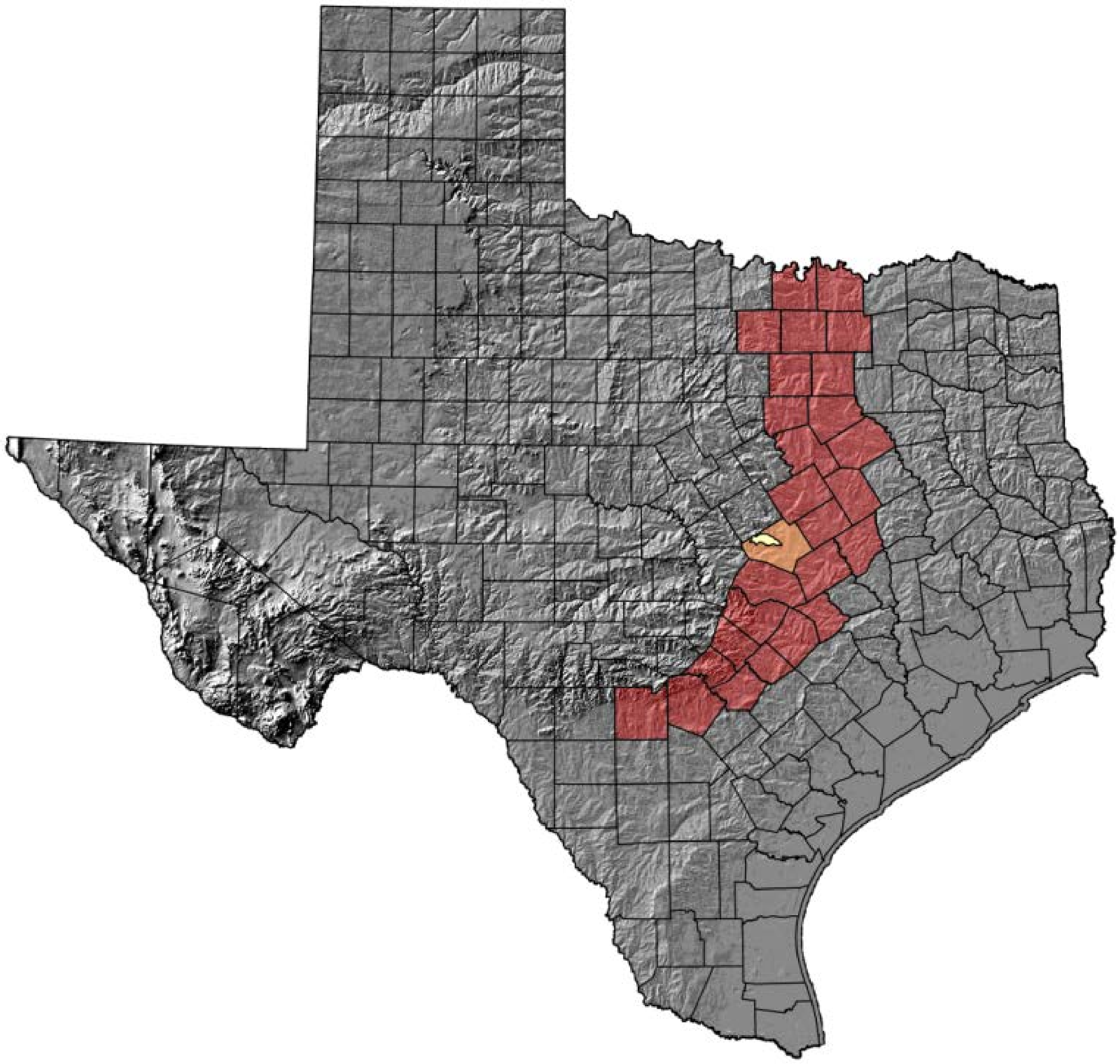


Figure 2.2 Texas "Flash Flood Alley"

Bell County (orange) and the Nolan Creek Watershed (yellow) are highlighted near the center.

2.2 Nolan Creek Flood History

More than a dozen noteworthy Nolan Creek floods have been described in various accounts reaching back as far as 1853 (Table 2.1). Scattered records indicate that at least 20 people, and possibly more, have died in Nolan Creek flooding events and at least $36 million dollars in estimated property damage has occurred (adjusted for inflation - 2017). The most notable event on record was the flood of 1913 in which 5 members of the Polk family and 6 unknown persons perished in Belton. The Polk home (Figure 2.3) was located on the banks of Nolan Creek near present day Yettie Polk Park and destroyed "when a thirty-foot wall of water washed down the creek" (Limmer, 1988). Prior to the 1950's most flood-related fatalities were attributed to persons trapped in flooded structures, falling from bridge collapses, or entering flood waters on foot. Since the 1950's, 4 of 6 fatalities have occurred when motorists crossed flooded roads.

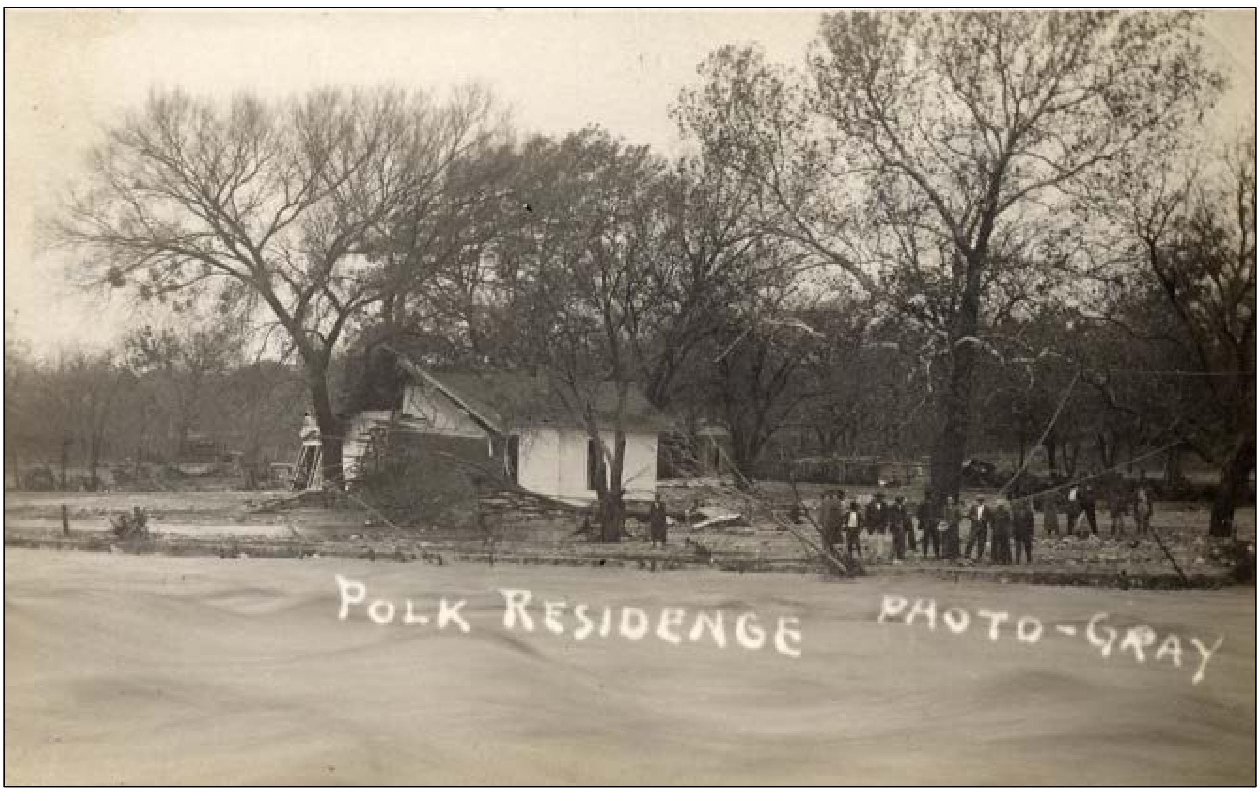


Figure 2.3 Polk Residence after 1913 Nolan Creek flood
Photo courtesy of Bell County Museum

More recently, rainfall from storms generated by Tropical Storm Hermine in 2010 caused flash flooding of downtown Belton (Figure 2.4) in which numerous people and businesses were affected. This event spurred the City of Belton to take the initiative to design, install, and operate a local flood alert system to augment regional National Weather Service announcements.

Today, Belton maintains a stream gauging station network along the main channel of South Nolan Creek and Nolan Creek. Precipitation and water levels are monitored by a centralized receiving base station during inclement weather conditions in order to assist city officials with making flood-related response decisions. Public notices are made when gauge station data reports upstream water levels exceeding established threshold limits.

Figure 2.4 Flooding in the Nolan Creek Watershed
View of Central Avenue looking east from North Wall Street

Table 2.1 Noteworthy Nolan Creek flooding events

Date	Max Rainfall (inches)	Fatalities	Event Description	Source
3 Apr 1853	-	0	Many cows and horses drowned, 9 houses destroyed, other buildings damaged	Nanny's Scrapbook
30 Jun 1899	9	0	Many houses and household effects washed away, crops destroyed	Nanny's Scrapbook
02 Dec 1913	-	11	Eleven deaths in Belton: 5 members of Polk family and 5 unknown campers washed away, one unknown person lost when bridge collapsed, entire downtown Belton inundated, 3 bridges washed out, estimated $40k in damages	Story of Bell Co., Vol. 1
15 Sep 1921	-	0	Water covering Central Avenue and Avenue A in downtown Belton but little damage, estimated $5thousand in damages	Story of Bell Co., Vol. 1
24 Apr 1957	6.59	3	Three deaths in Killeen, $1.25-$2M in total damages with $400k to city facilities	Killeen Daily Herald
16-17 May 1965	10	0	Estimated $1.2 million in damage to property and crops.	USGS report
30-31 Oct 1974	5	0	Several cars and mobile homes swept away.	Killeen Daily Herald
29 Dec 1997	-	2	Two deaths, teenagers car swept into Nolan Creek, estimated $275k property damage	Killeen Daily Herald
24 May 2007	-	3	Three deaths in Killeen, 2 children in car, 1 adult in culvert, numerous high water rescues in Killeen, Nolanville and Harker Heights, estimated $3.7 million in damages	Temple Daily Telegram
08 Sep 2010	11.32	0	Tropical Storm Hermine, 40 evacuations in Belton, Central Avenue businesses flooded in Belton, 289 total structures affected in some way. Of that figure, 29 residences were destroyed, 45 sustained major damage, 56 had minimal damage and 149 were affected, Estimated $3million in damages	Temple Daily Telegram
17 Jun 2015	2.75	1	One death in Nolanville, child caught in flooded drainage culvert	News 10 Television
24 Oct 2015	6.8	0	Residences on east side of Belton evacuated	Temple Daily Telegram
11 Apr 2017	8.6	0	Flow over I35 Service Road in Belton	Central Texas News 25

2.3 Nolan Creek Flood Alert System evaluation objectives and approach

Texas A&M AgriLife Research – Temple conducted an evaluation of the current Nolan Creek flood alert system, operated by the City of Belton, as part of a grant from the Texas Water Development Board. The grant was issued to the Central Texas Council of Governments to prepare a Flood Protection Plan for the Nolan Creek Watershed. The flood alert system assessment addresses one of several components, the need to better understand non-structural approaches to reducing flood risk in Texas, as described in the 2019 State Flood Assessment report (Lake et al., 2019). The state's report is based on a survey of numerous professionals in flood-related positions and was commissioned to better understand flood planning, mitigation needs, and associated costs for communities across Texas.

Objectives for this Nolan Creek flood alert system assessment included:

1. *Determine current system management and staff organization*
2. *Determine current system operational documentation*
3. *Determine current data collection, transmission, and storage methods*
4. *Determine current data interpretation and threat recognition definitions*
5. *Determine current system primary users and message interface content*
6. *Determine current emergency response procedures and documentation*
7. *Determine current system maintenance and review procedures*
8. *Determine upstream community usage of and interest in current system*
9. *Recommend future system improvements relative to the watershed as a whole*

This assessment was carried out through personal interviews, phone conversations, and email queries with city officials, equipment vendors, software vendors, and service providers to determine and document the Nolan Creek flood alert system's history, current configuration, operational outputs, usage levels, and user interest in system improvements, upgrades, and/or expansions. Field trips to Nolan Creek stream gauge stations were conducted to examine stream gauge location, equipment types and configuration, and site conditions.

Belton city officials responsible for Nolan Creek flood alert system operation (i.e., City Manager, Director of Information Technology, Director of Public Works, Police Chief, Fire Chief, and Public Information Officer) were interviewed to determine how the system is managed, configured, operated, and documented. This information was used to prepare the current system description in Section 2.4. See the References and Resources section for names and contact information of Belton city officials who were interviewed for this report.

Officials from the City of Killeen, the City of Harker Heights, the City of Nolanville, and Water Control and Improvement District #6 (WCID#6) were interviewed regarding their usage, understanding, and interest in the current system operated by Belton. WCID#6 was included because several PL566 flood control structures under their jurisdiction are upstream of Killeen. In addition to information specific to the current Nolan Creek flood alert system, officials were asked about problematic flood-prone areas in their jurisdictions that would benefit from additional gauging stations, flashing lights, automated crossing arms, and other high-water related monitoring tools. See the References and Resources Section for names and contact information of upstream community officials who were interviewed for this report.

Additional officials from Bell County (County Engineer) and the Brazos River Authority (Watershed Planner) were interviewed to determine their involvement and/or interest in the current system. See the References and Resources for names and contact information of additional Bell County and Brazos River Authority officials who were interviewed for this report.

Published articles and flood alert system manuals were used to provide basic information on flood alert system design and operation. Several Texas flood alert system managers (i.e., Harris County Flood Control District, the City of Austin, the City of Fort Worth, and Hays County) were interviewed to determine how their systems are configured and managed for comparison. Numerous flood equipment hardware and software vendors were also interviewed and several professional meetings and workshops were attended to learn about the most current advances in flood alert system hardware and software as well as to better understand how modern flood alert systems are organized, managed, and operated. See the References and Resources for names and contact information of flood warning professionals consulted in the preparation of this report.

Recommendations were developed through consideration of published technical descriptions of effective flood alert systems, recommendations by Texas flood alert system managers and flood warning professionals, the current Nolan Creek flood alert system configuration, and multiple needs and interests of the communities within the Nolan Creek Watershed, as a whole.

2.4 Nolan Creek Flood Alert System description and use

2.4.1 Management and documentation

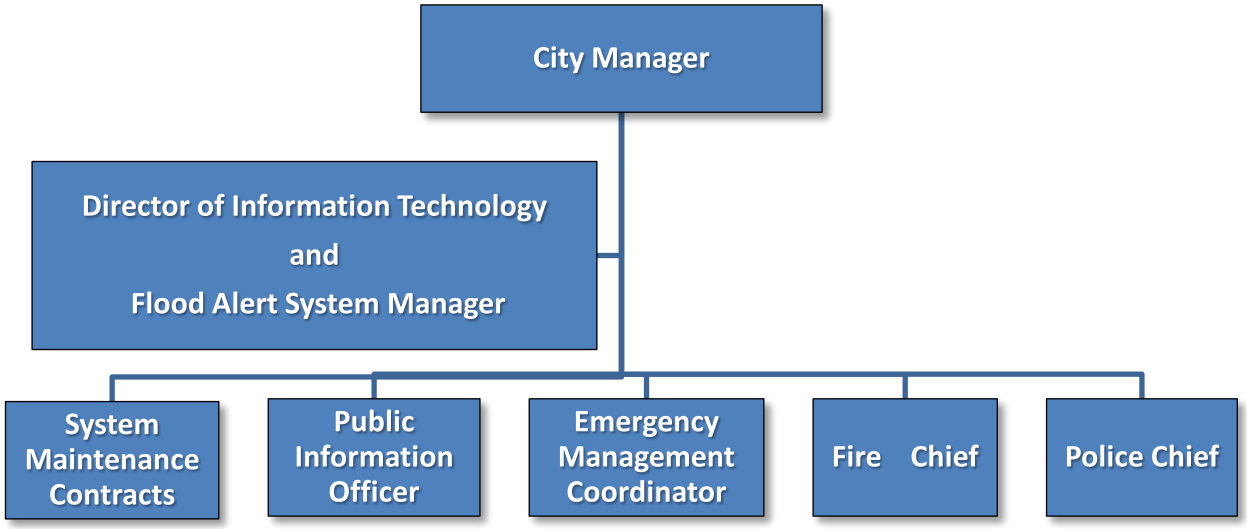
The City of Belton operates the Nolan Creek flood alert system which is overseen by its Director of Information Technology. This position is responsible for overall system management including remote gauge station network operation and maintenance, base station and reporting software configuration and maintenance, flood notification list maintenance, and coordination among city staff involved with the system (Appendix A).

The flood alert system consists of 5 stream gauges that are used to augment federally-provided flood-related weather announcements and make high-water response decisions. Belton's flood alert system goal is defined in a city document entitled Emergency Notification Procedure for Flash Flood Conditions document (Appendix B) which states:

> *"This Emergency Notification System is a tool to help City Staff notify citizens of potentially dangerous or life threatening flash flood conditions along Nolan Creek within the Belton."*

On-duty personnel (i.e., police and fire officials) alert key city officials to begin monitoring rainfall and Nolan Creek water levels using the city's gauging station network when National Weather Service issues public watches and warnings that indicate weather conditions are favorable for flooding events. Flood alert system staff includes the City Manager, Director of Information Technology, Fire Chief, Police Chief, Public Works Director, and the Public Information Officer.

Written documentation of the flood alert system's management scheme and operational procedures is spread across three documents: a job description listing the duties of the Director of Information Technology (Appendix A), personnel notification lists described in the Emergency Notification Procedures for Flash Flood Conditions (Appendix B), and an inter-local agreement among Belton, Killeen, and Harker Heights that describes each party's responsibilities and ownership of gauging station equipment (Appendix C). Figure 2.5 depicts Belton's management hierarchy and system responsibilities, determined from these documents.



RESPONSIBILITIES

City Manager
Oversees all city departments, functions, and inter-local agreements

Director of Information Technology
Manages Flood Alert System
Staff coordination
Data collection
Local stream gauge network operation and maintenance
Base station operation and maintenance
Stream gauge data (i.e., MySQL database)
DataWise software configuration

System Maintenance Contractors
High Sierra Electronics – Field gauge station maintenance and repair
DataWise LTD – Monitoring base station data backup and software support

Bell County Emergency Management Coordinator
Provides radio telemetry repeater support for stream gauge network

Public Information Officer
Generates and maintains web content for Nolan Creek parks and flood descriptions
Maintains hyperlinks to offsite server delivering local stream gauge network data

Police and Fire Chiefs
Monitor National Weather Service flood watch and warning announcements
Make field observations for developing and improving flood alarm thresholds
Follow and update, when appropriate, flood preparedness and response plans
Conduct post event reviews of flood effects and responses

Figure 2.5 Belton Flood Alert System management hierarchy chart and responsibilities

2.4.2 Data collection and processing

High Sierra Electronics was selected as the vendor of choice for stream gauging and communications hardware. Site-specific variations of High Sierra Electronics' Packaged Pressure Transducer Station (Model 3466-00) were purchased and installed shortly after the 2010 Tropical Storm Hermine event. Three packaged gauge stations were purchased by Belton and two were purchased by the upstream communities of Killeen and Harker Heights through cooperative agreements. Today all field gauge station equipment is managed, and maintained by the City of Belton. Killeen and Harker Heights provide liability insurance and select equipment replacement in the event of damage or destruction of gauging stations within their jurisdictions (See Appendix C for details).

Each field gauge station consists of an equipment shelter (standpipe or box-type), rain gauge, water level sensor (either pressure or radar type), electronic datalogger/transmitter, antenna, cables, various mounting hardware, and a solar power system (Table 2.2). Appendix G contains High Sierra Electronics, Inc. specification sheets for each piece of equipment. This hardware uses the ALERT transmission protocol to relay environmental information from the field stations to the receiving base station (Appendix H). ALERT is an "event-based" protocol which only transmits data when a preset condition or threshold is detected by gauge sensors.

Rainfall data is transmitted with each tip of a tipping bucket rain gauge (See Appendix I for tipping bucket rain gauge description). Stream level changes, detected by pressure transducers or radar transducers (See Appendix I for transducer details), of 0.83 inches, in either rise or fall, initiate a water level transmission. During baseflow (i.e., periods of no rainfall and low water levels) the gauge stations transmit battery voltage every 12 hours to verify operation.

Event transmission settings are user-configurable and are the original values implemented by High Sierra Electronics during system installation. This level of data transmission efficiently delivers all site-specific rainfall, stream level, and station health (i.e., battery voltage) information while conserving station power, which operates on a solar/battery configuration.

Table 2.2 List of High Sierra Electronics Stream Monitoring Equipment.

Part Num.	Description	Function
7000-00	Standpipe Assembly	Houses datalogger and communication equipment
2400-00	12" Tipping Bucket Rain Gauge	Measures rainfall amount and intensity
6640	Submersible Pressure Transducer	Measures water surface level, above sensor – Channel mounted, upward looking. Instrument range is 0-20 ft.
6753	Radar Level Sensor	Measured water surface level, below the sensor – Bridge mounted, downward-looking
3206-20	Datalogger/transmitter	Dual function datalogger for managing sensors and transmitting data
1000-02,03	ALERT Encoder, Decoder	Converts datalogger signal to radio transmission protocol
5307	Solar power system	Solar panel, battery, cables, voltage regulators, etc. to provide remote power for electronic components
3300	ALERT Repeater	Relays radio transmission data from remote field gauges to receiving Base Station
4500	Base Station Receiver	Converts radio signal to computer input
Macintosh	Base Station (computer)	Runs DataWise environmental monitoring software, stores system data in relational database, and provides connection to internet

Note: Actual part number may differ slightly and support equipment (cabling, hardware, etc.) is not included.

A map of stream gauge station locations is shown in Figure 2.6. The most upstream station is located at Roy Reynolds Road at the Killeen-Harker Heights city limit. This is approximately 3.3 channel miles above the second station located at I-14 (US190). The third station, near the middle of the watershed, is located at Paddy Hamilton Road approximately 8.0 channel miles downstream of the I-14 station. Approximately 4.9 channel miles downstream from the Paddy Hamilton Station is the Wheat Road Station. The most downstream gauge is located on the Main Street Bridge in downtown Belton, approximately 3.6 channel miles from the Wheat Road Station. Appendix E contains detailed descriptions and photos of the Nolan Creek gauge stations.

Field equipment maintenance is accomplished through a contract with High Sierra Electronics. Service is scheduled twice annually based on the nature of historic weather patterns for the area. Two rainy seasons, which occur in the spring and fall, are typical. In early spring and fall of each year, gauge stations receive a standard check of all sensors, datalogging equipment and radio systems. Water level sensors (i.e., pressure and radar transducers) are calibrated, if necessary. Appendix F contains an example report and checklist from one gauge station produced by High Sierra technicians during a 2018 maintenance visit.

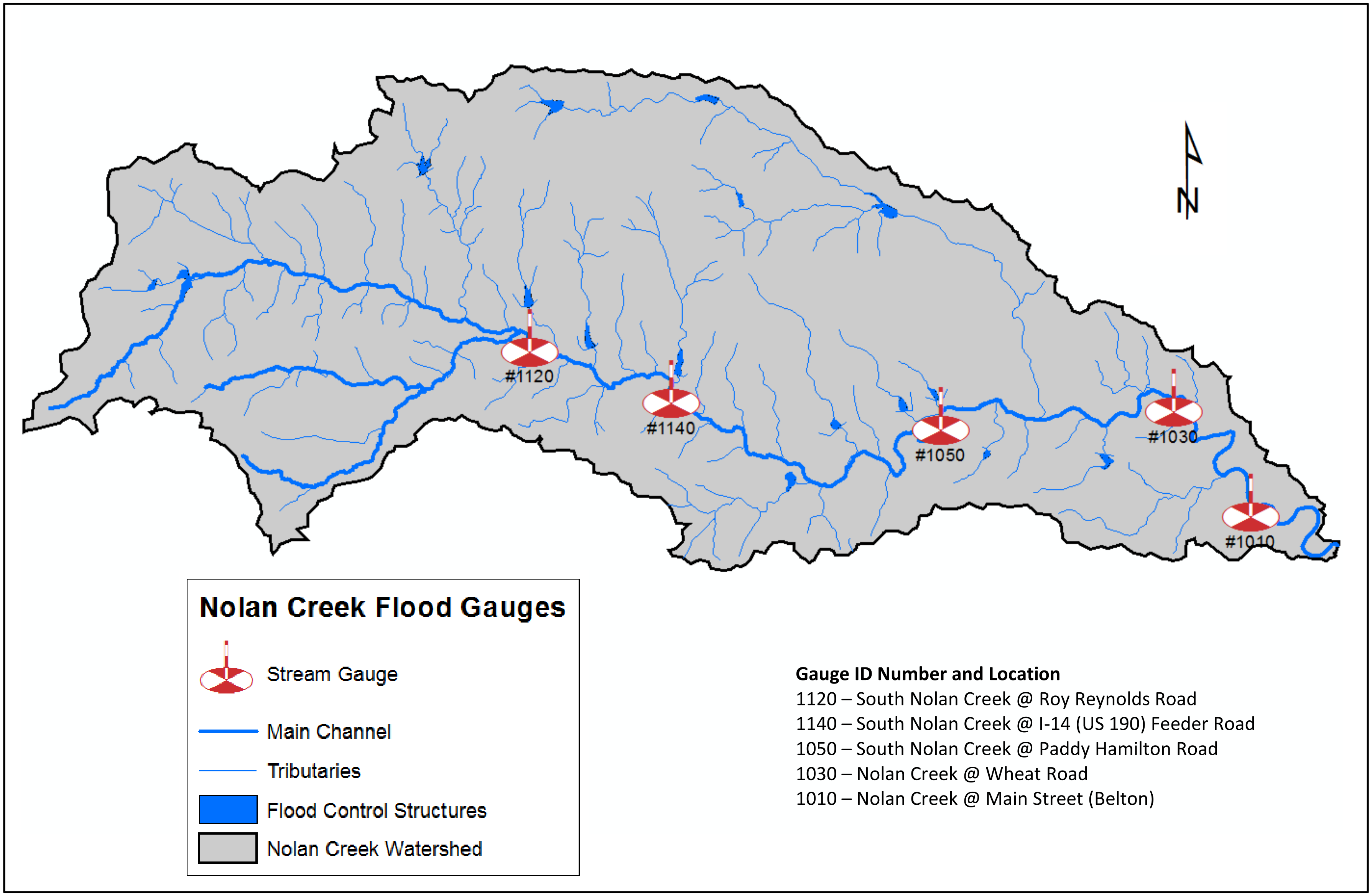


Figure 2.6 Map of Nolan Creek flood gauge locations

In order to preserve system integrity, the Director of Information Technology (i.e., system manager) augments scheduled contract maintenance visits with occasional field trips to examine gauge stations and make minor repairs when power issues or erroneous data transmissions are noted in the system output (e.g., non-reporting stations, low battery, low rainfall or water level values during large storm events, etc.). High Sierra Electronics gauging station hardware has performed well. In its ~6 year operational history, two pressure transducers (i.e., water level sensors) have failed; one due to freezing when water surface level at the exact location of the pressure transducer diaphragm caused physical damage and one due to salt/sediment build up in the pressure transducer diaphragm cavity.

Telemetry data is relayed from individual gauge stations through a county-wide repeater operating in the hydrologic data radio band at 169.425 MHz. The repeater is managed by the Bell County Emergency Center located near Belton. Field gauge station signals are relayed by the repeater to a receiver connected to the system's base station located at Belton City Hall.

The base station receiving field data consists of a dedicated Macintosh computer running DataWise software produced by DataWise Environmental Monitoring, Inc. (Auburn, CA). This environmental monitoring software collects, stores, and displays received data in multiple formats suitable for a variety of applications. See https://datawise.software/ for more detail. Belton maintains an annual contract with DataWise Environmental Monitoring, Inc. to support the software and provide data-hosting services for backup and display of flood alert system gauge station data (see Section 2.4.4.). Data received from the remote field gauge stations are stored in a MySQL database residing on the local Macintosh computer. DataWise software configuration and maintenance is accomplished through a direct user interface managed by the Belton Director of Information Technology. Automated threshold conditions are programmed in the software to inform the system manager of failing field equipment and send alarm messages, via email, to system primary user lists.

2.4.3 Risk Assessment and forecasting

Belton's flood risk assessment consists of four emergency response stages to Nolan Creek flood conditions which are described in Belton's Emergency Notification Procedure for Flash Floods document (Appendix B). Through high-water and flood event observations and flood alert system gauge response experience, flood alert system "alert" and "alarm" conditions have been established for 2 of the 5 gauge locations. This gives Belton city officials sufficient information to activate their flash flood response plan, direct emergency personnel, and notify the public.

A stage reading of 15 feet at the Paddy Hamilton station (Gauge #1050) indicates downstream flooding in Belton is possible and that the on-line gauge information should be continuously monitored and personnel notifications issued. When the Paddy Hamilton station (Gauge #1050) reports a stage reading of 18 feet, flooding downstream in Belton is imminent. Public warnings are issued and additional emergency personnel are activated. When the Main Street station (Gauge #1010) reports a stage reading of 15 feet, a public warning is issued and evacuation of specific low-lying areas is ordered.

Analysis of historic flood alert system data for flood forecasting purposes in the form of lead times associated with flood alert and alarm thresholds are not documented. However conversations with flood alert system management staff indicates that observed flood flow peaks require approximately 30 to 45 minutes to travel from Paddy Hamilton to Main Street gauges.

2.4.4 Data distribution and communication

Primary users (i.e., Belton city officials involved with flood alert system activities) receive automated messaging in the form of text or email messages generated by DataWise software running on the system's base station. This information is relayed to the public through the CodeRED system, public service announcements (i.e., radio and television), and by emergency response personnel in the field during flood events.

The City of Belton cooperates with Bell County and the Central Texas Council of Governments to provide public service messages regarding a variety of situations, including flood-related warnings, through the "CodeRED" service. CodeRED is an emergency notification product produced by OnSolve (Ormond Beach, Florida) that is used by numerous city and county governments across North America for community messaging. Registration is required to receive flood-related messages and may be accomplished through the Belton web site (http://www.beltontexas.gov/services/codered.php) or by phone. Residents who sign up for local CodeRED services receive flood alerts, warnings, and evacuation notices via phone calls, text messages, emails, and/or other social media messages.

Nolan Creek flood alert system stream gage data is available to its primary users (i.e., Belton city officials) and the public through Belton's internet web services. Hyperlinks located on Belton's Emergency Preparedness (Figure 2.7) and Nolan Creek (Figure 2.8) web pages connect users to a hosted data server https://mobileweatherdata.com/Beltonpwd/ that delivers gauge station information collected by DataWise software running on the base station located in Belton.

The DataWise interface is compatible with most computer browsers and mobile devices. Stream condition data can be displayed in many user-selectable forms (see https://datawise.software/). The Belton flood alert system stream gauge information includes rainfall, water level, and battery voltage for each monitoring location. User selected data (Figure 2.9) of interest is summarized in list, overview, and map formats. The list form displays all stream gauges in the network by ID number and location description with the selected variable of interest's value, time of last reading, and time since last reading (Figure 2.10). Overview gives an indication of data received, by percent (Figure 2.11), and map view displays the currently selected variable value on a map at the gauge location (Figure 2.12).

Selecting a particular stream gauge from either the summary list or map view displays the site data in tabular, glance, or chart formats (Figure 2.13, Figure 2.14, and Figure 2.15). Time intervals ranging from one hour to 30 days for variables of interest can be requested by the user. (Note: all historic data collected by the system is stored in a MySQL database residing on the local base station computer however, only the most recent 30 days are accessible through the public web interface. Older data is available upon request from Belton officials. Data may be displayed in either graphical or table form on the public web site.).

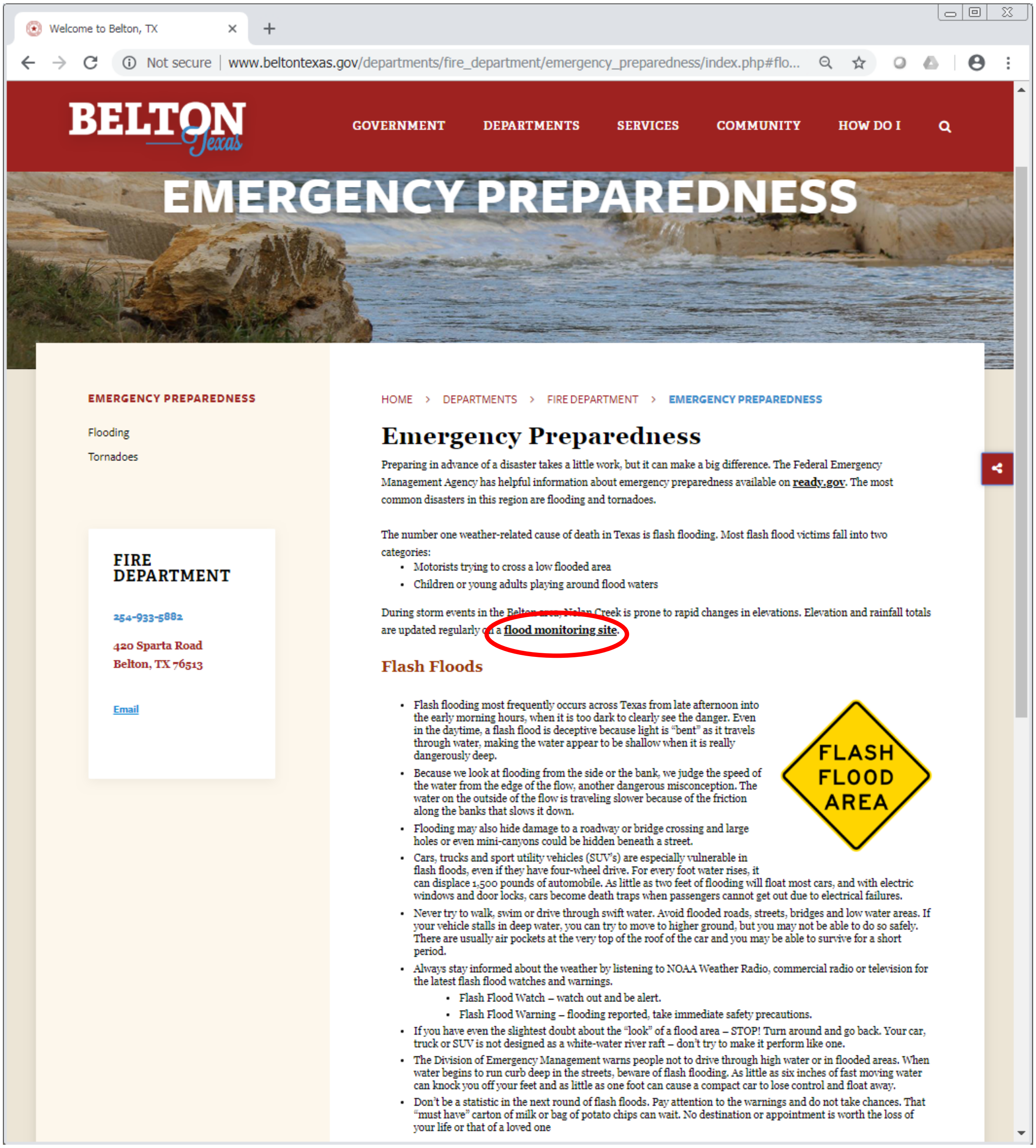


Figure 2.7 Screenshot of Belton Emergency Preparedness web page
See: http://www.beltontexas.gov/departments/fire_department/emergency_preparedness/index.php#flooding
Red oval indicates hypertext link to flood alert system gauge monitoring interface.

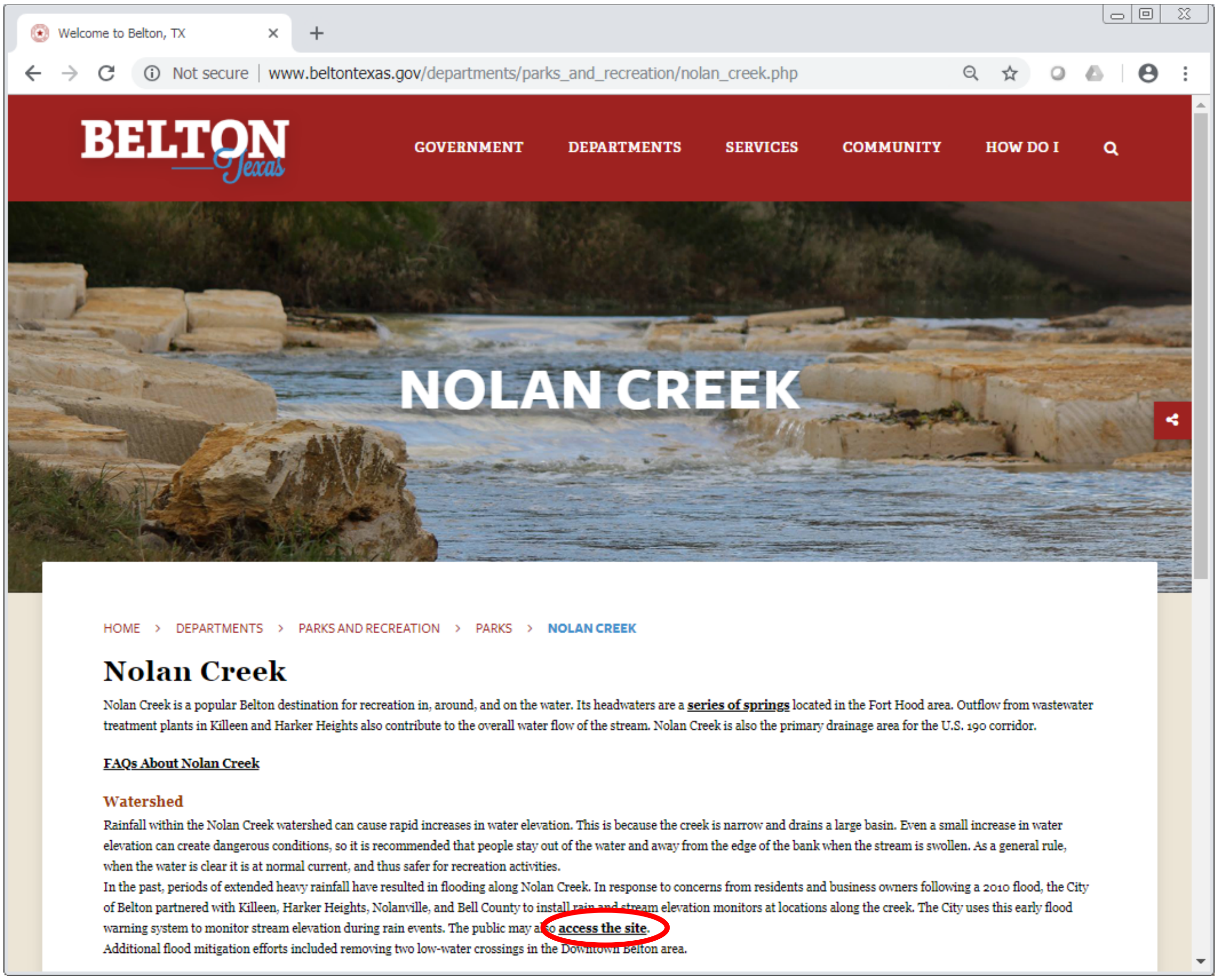


Figure 2.8 Screenshot of Belton Nolan Creek web page
See: http://www.beltontexas.gov/departments/parks_and_recreation/nolan_creek.php
Red oval indicates hypertext link to flood alert system gauge monitoring interface.

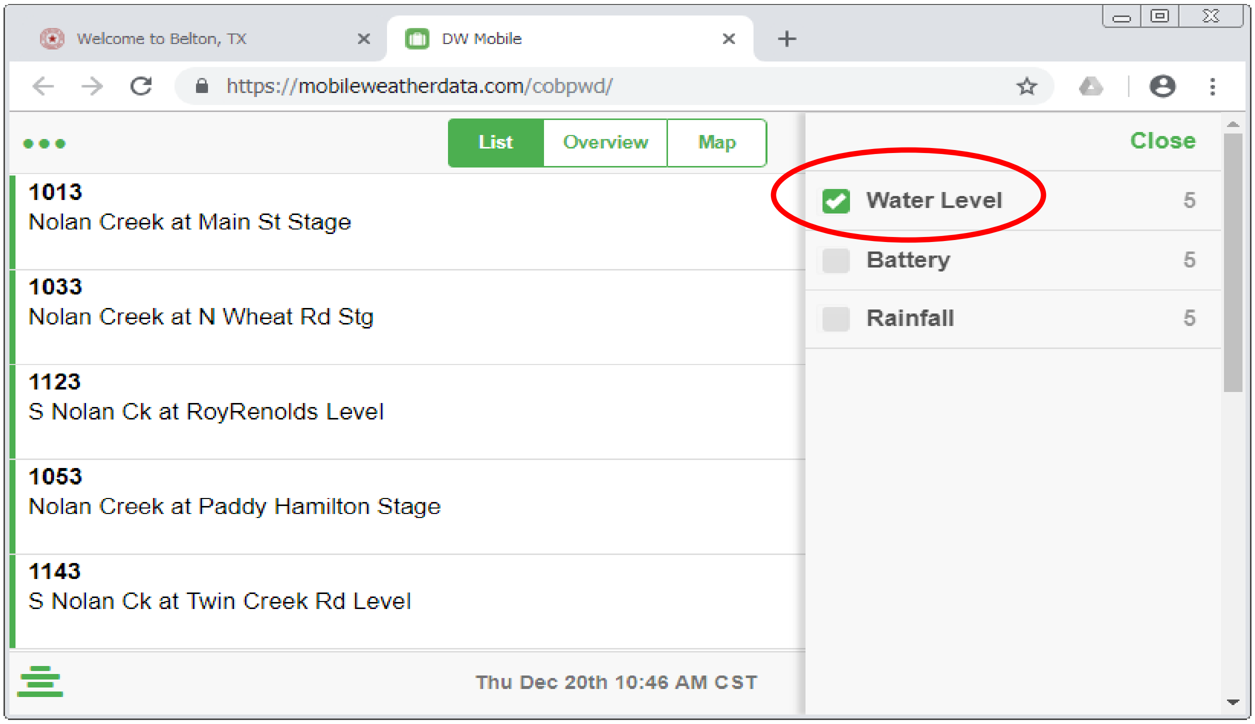


Figure 2.9 Screenshot of Nolan Creek flood alert system variable selection menu
User may select variables of interest to be displayed, water level in this case (red oval).

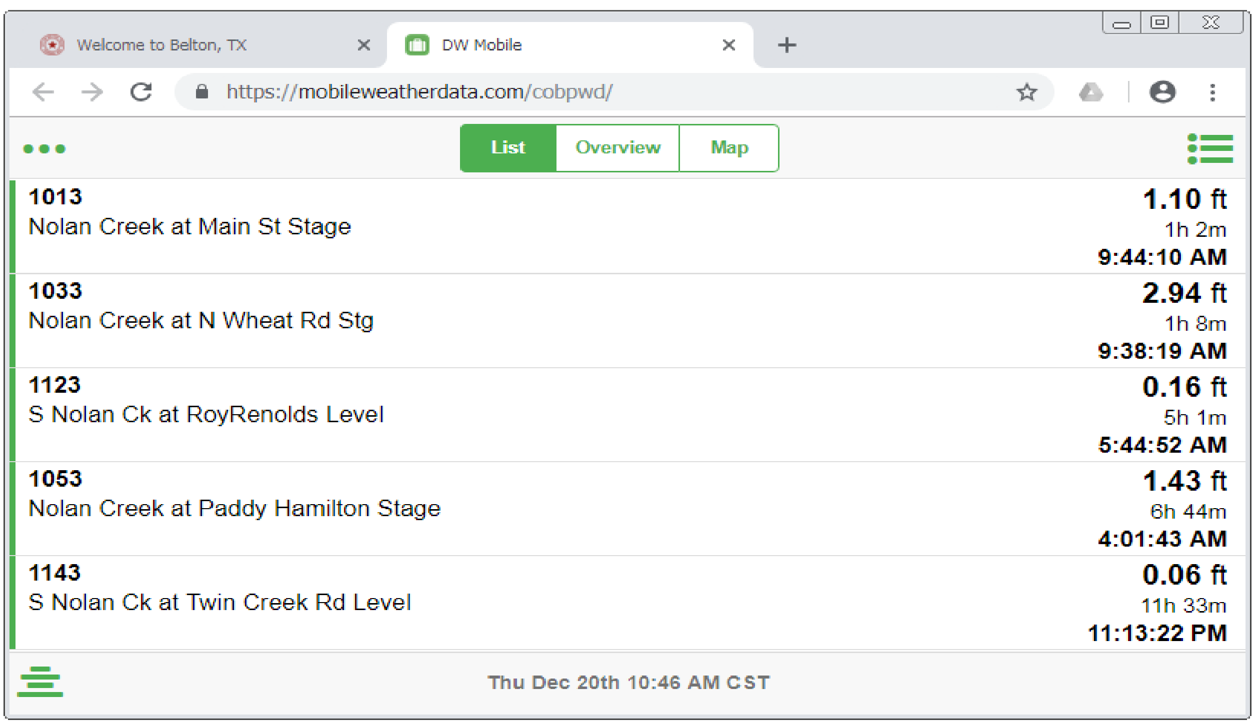


Figure 2.10 Screenshot of Nolan Creek flood alert system gauges in List format
With data selection menu closed, last reading and times are displayed

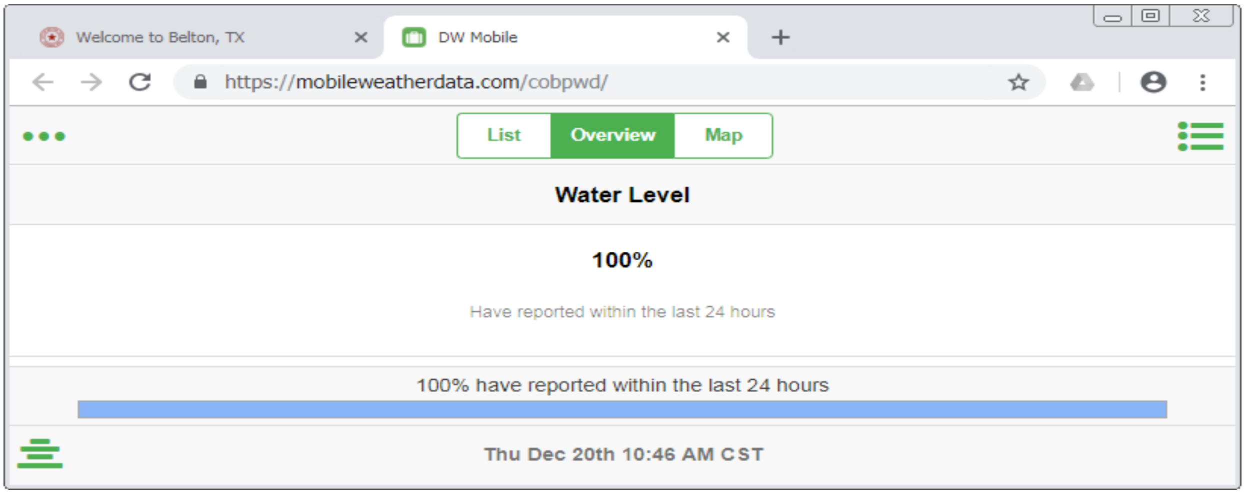


Figure 2.11 Screenshot of Nolan Creek flood alert system web interface in Overview format
Percentage of stations reporting within the past 24 hours gives indication of operational condition or health.

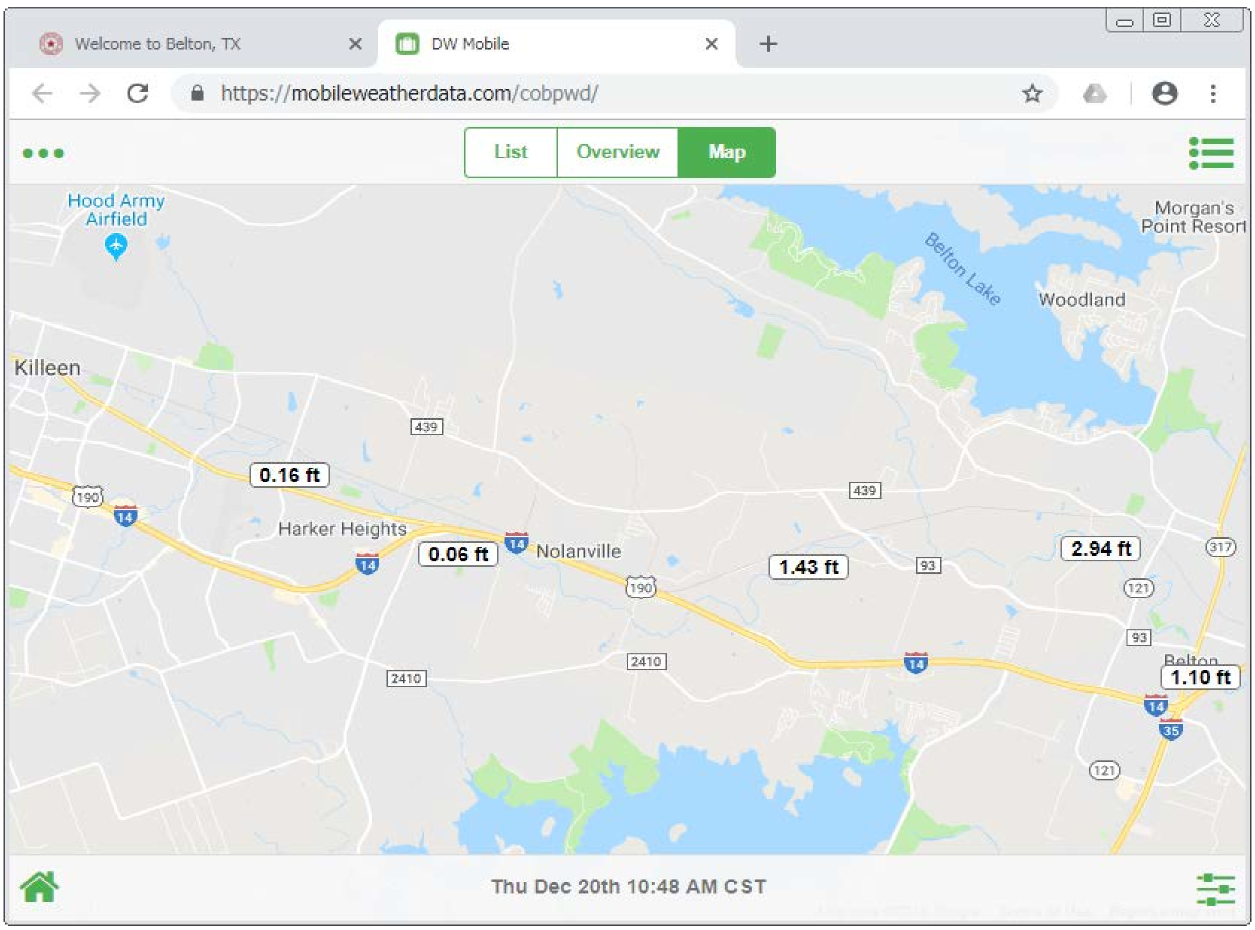


Figure 2.12 Screenshot of Nolan Creek flood alert system web interface Map format
Individual flood alert system gauges locations appear as water level values over map. Clicking on an individual value allows user to review data from the site in detail (See Figure 2.13, Figure 2.14, and Figure 2.15).

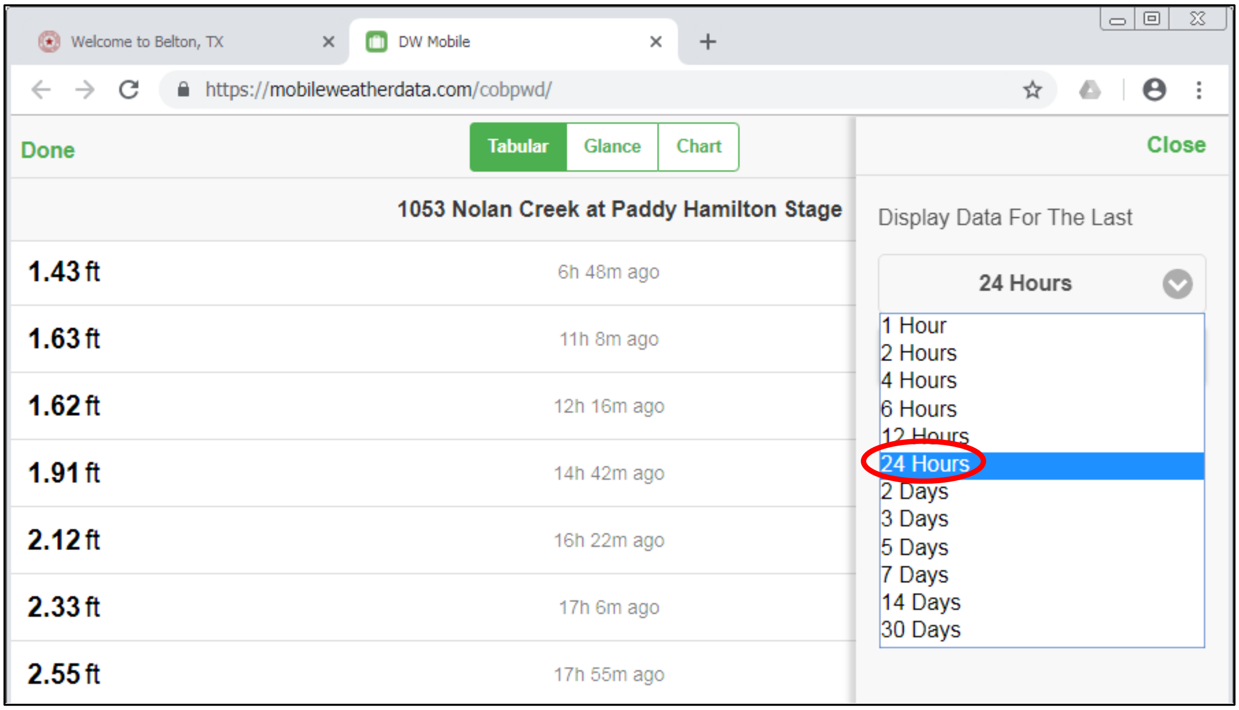


Figure 2.13 Screenshot of Nolan Creek web interface for individual gauge in Tabular format
Time interval for data display is user-selected, 24 hours in this case (red oval).

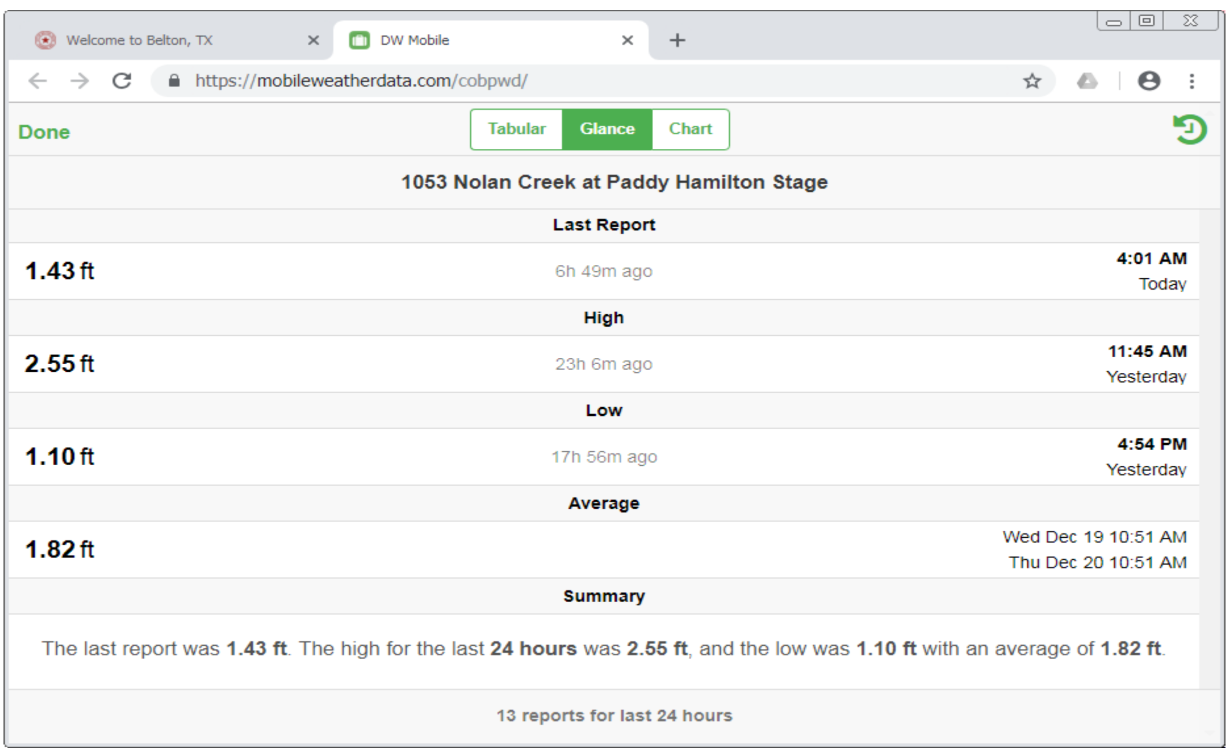


Figure 2.14 Screenshot of Nolan Creek flood alert system individual gauge Glance format
Shows a summary of the last, high, low, and average values for the selected variable

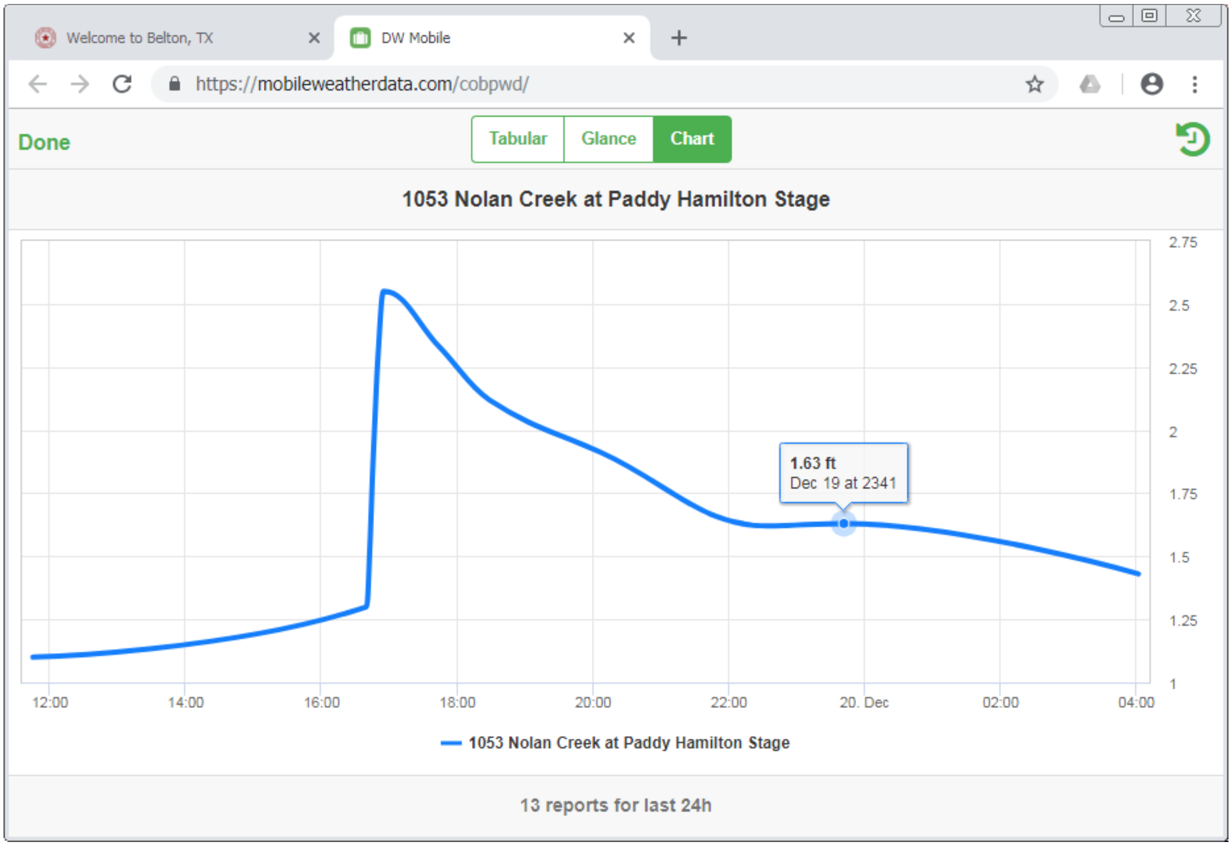


Figure 2.15 Screenshot of Nolan Creek flood alert system individual gauge Chart format
Time series data are plotted for the user-selected variable over the time interval of interest. Hovering over the plot line will highlight time and value of an individual measurement.

2.4.5 Preparedness and response

Belton's Emergency Preparedness web page contains basic information addressing the most common disasters which occur in this area; floods and tornados. The page also carries a link to the Nolan Creek flood alert system gauge network interface. See the following link:

http://www.beltontexas.gov/departments/fire_department/emergency_preparedness/index.php

Flood preparedness and response planning are described on Belton's public website and in the Flash Flood Emergency Notification Procedure document (Appendix B). The document states that it is reviewed and revised following major flood events.

2.4.6 Use by Belton, upstream communities, and other entities

Belton uses the current flood alert system to help City Staff notify citizens of potentially dangerous or life threatening flash flood conditions along Nolan Creek within Belton. Findings indicate Belton believes the flood alert system is adequate for making flood-related response decisions in some parts of Belton but sees the need to upgrade the system to expand coverage and to have a more robust and reliable system. Gauge station data is evaluated by software and used to notify Belton primary users when pre-programmed thresholds for management and alarm conditions are exceeded. Data is published in real-time for primary users and public users through Belton's web-site. Message distribution lists can be programmed into an alert module for participating Inter-Local Agreement parties, if requested (Appendix C). Belton does not currently plan to upgrade or expand the system beyond the current configuration.

Killeen's Environmental Services Director and Emergency Response Coordinator use the Nolan Creek flood alert system to augment other data sources that are monitored during inclement weather to judge flooding magnitude and coordinate response. Information from the Nolan Creek Flood Alert System, 5 City of Killeen rain gauges, the CoCoRaHS (Community Collaborative Rain, Hail, and Snow) network, and visually confirmed high-water and flooding reports by public officials are used to gauge storm gravity. The Nolan Creek flood alert system rain gauges are monitored through the Belton public web-interface and used to judge storm intensity and travel direction. The Roy Reynolds gauge station is monitored to determine peak stage time and estimate how fast water is leaving the city. Fort Hood officials and Bell County Water Conservation and Improvement District #6 (WCID#6) officials notify Killeen when visually determined water levels in PL566 flood control structures upstream of city areas approach capacity. Three of these structures are managed by WCID#6 and 1 is managed by Fort Hood. Killeen officials (i.e., Environmental Services Director or Emergency Response Coordinator) call Belton's Director of Public Works to relay pertinent information when flooding appears eminent. There is interest in formalizing these procedures and improving coordination among collaborating parties. There is also interest in installing and operating gauge stations for forecasting and automated flashing lights and/or crossing arms. Appendix K contains a list of 50 prioritized locations that flooded during the 2010 Tropical Storm Hermine event. Interest was expressed in monitoring water levels of the PL566 flood control structures managed by WCID#6 which are directly above portions of the Killeen area. Interest was also expressed interested in developing a regional flood alert system.Bell County Water Conservation and Improvement District #6 does not use the current Nolan Creek flood alert system. The majority of its board members did not see a need to add field gauging stations to the PL566 flood control structures they manage since observational monitoring has shown that since built, the structures have operated as intended during large storm runoff events and have not exceeded their capacity. One board member thought automated monitoring might be useful but also noted that operational maintenance costs would be problematic.

Harker Heights Emergency Coordinators actively use the current Nolan Creek flood alert system to monitor the two most upstream gauges during inclement weather. Officials begin watching the Roy Reynolds (Gauge #1120) and I-14 (Gauge #1140) station data, using the Belton public web-interface, when the National Weather service issues flood watch notices. When the Roy Reynolds gauge station exceeds 7.0 feet, officials begin continuous monitoring. When the Roy Reynolds gauge station exceeds 9.0 feet, they consider issuing evacuation notices, if rainfall is heavy. Public officials would like better developed stage information for the system, in particular, tying gauge values to benchmarked landscape elevations. They would also like automated notifications from the system, routed through the Bell County Emergency Communications center, when these water level conditions are reached. Two areas that flood during major events were of particular interest. North Anne Boulevard near the Nolan Creek main channel floods during large storm events. Adding a gauge here would provide water level information for properties north of Veterans Boulevard (old HWY 190), many of which flooded during the 2010 Tropical Storm Hermine event. Also, FM3219 where it crosses Nolan Creek floods during large storm events and threatens motorists. The Texas Department of Transportation (TXDOT) operates a high-water sensor with flashing light at this location. It would be useful if this sensor were added to the network so when activated, Harker Heights emergency crews would receive notification (NOTE: in the past, TXDOT notified Harker Heights officials through a text message mechanism but this was no longer working at the time of this report). City officials expressed interest in developing a regional flood alert system.

Nolanville officials do not use the current Nolan Creek flood alert system but are concerned about two locations that flood during extreme weather events: Levi Crossing, a low water concrete ford, and 10th Street at Avenue H where the housing area known as "Pecan Village" is located. City officials expressed interest in learning more about the current system and perhaps adding additional gauges for their problematic areas. The city has applied for flood improvement grants to fund these kinds of efforts.

The Bell County Engineer's Office does not use the current Nolan Creek flood alert system but maintains an Agreement for Right of Entry and Use of County Road Right-Of-Way for an Early Warning Flood Warning System with the City of Belton (Appendix D).

The Brazos River Authority (BRA) does not use the current Nolan Creek flood alert system but was interested regarding collected data and how it is used by local authorities. BRA operates a web site which collects and distributes streamflow, precipitation, and reservoir level data from multiple sources throughout the Brazos River Basin, which encompasses the Nolan Creek Watershed. The public interface is well designed and easy to understand. (See: https://www.brazosbasinnow.org/home.php). Although BRC's public information is not intended for flood warning purposes, there was interest in possibly including data gathered by the Nolan Creek flood alert system gauges.

3 Recommendations

3.1 General comments

There is no centralized management or coordination among communities within the Nolan Creek Watershed regarding current Nolan Creek flood alert system operation, or usage, beyond the 2012 Inter-Local Agreement among Belton, Killeen, and Harker Heights describing field gauge station ownership and operation (Appendix C).

The Nolan Creek flood alert system meets Belton's current specific needs; monitoring upstream conditions in order to notify its citizens regarding imminent flood conditions. Belton is commended for taking the initiative and committing resources to operate and maintain a functioning flood alert system. The Cities of Killeen and Harker Heights are commended for assisting Belton with equipment purchases and maintaining inter-local agreements with Belton to operate gauging station within their jurisdictions.

Belton is satisfied with the current configuration of the Nolan Creek flood alert system and has no plans for change. Upstream communities considering a flood alert system have different monitoring needs due to their physical position in the watershed and land use (i.e., urbanized area). Recommendations are therefore generalized for application toward a regionally shared flood alert system.

Elements making up an effective flood alert system, and what it can deliver, are described in the following sections to assist each community with means to consider its specific needs towards flood alert system design and operation. First, basic flood alert system concepts are described and then addressed separately. Recommendations for flood alert system sub-components are made toward the watershed as a whole (i.e., not specific to any single city or community).

3.2 Flood alert system concepts

A flood alert system is best described as a "system of systems" integrating a wide range of specialties (engineering, clerical, information, etc.), personnel (managers, technicians, etc.) and infrastructure (sensors, radios, computers, software, etc.) in sophisticated ways to extend warning lead times for areas subject to flood risk (NOAA, 2010). Because all organizations are unique and all flood alert systems are unique, no single management structure will apply to all. However, all flood alert systems, regardless of their size, share certain common features (Ford, 2001). These include means to manage and document the system, collect and process environmental data, assess high-water risks, develop forecasting solutions, communicate and distribute flood-related information, and maintain preparedness and response plans for emergency officials (Figure 3.1). Several manuals describing the basic organizational and technical requirements of flood alert systems have been produced by government agencies and are readily available online for flood alert system manager reference (NOAA, 2010; 2012).

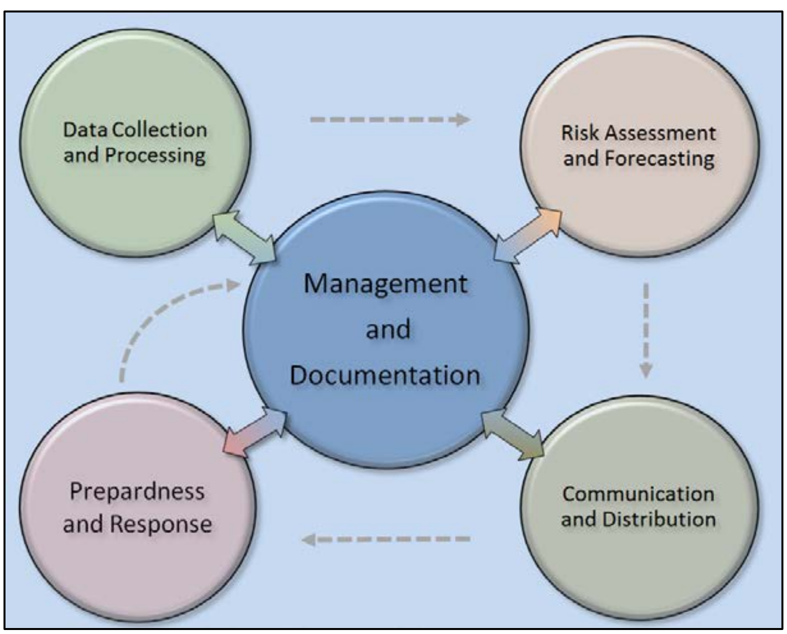


Figure 3.1 Flood alert system common features
Large arrows indicate flow of information and responsibility among different sub-systems or departments. Dotted arrows indicate general flow of information from environmental sensors through the various sub-systems which in turn influences system organization, management and planning activities.

3.2.1 Management and Documentation

Effective flood alert systems have a proactive, knowledgeable team consisting of, at minimum, a system manager, a data specialist, and technical support staff (NOAA, 2012). As noted by numerous sources (i.e., published guides and interviews with flood alert system managers), the most critical element of an effective flood alert system are a designated manager who oversees and coordinates persons responsible for the various sub-systems and tasks. Training and education of flood alert system team members is also critical. A list of professional organizations and Texas flood alert system managers who sponsor training activities for advancing flood-related technology and flood warning system operation is presented in Table 3.1.

Descriptions of each person's role and duties in the organization must be clearly defined and standard operating procedures must be established and maintained. As the organizational structure of a local flood alert system is developed, it is important to document how the system is organized and operated so that policies and operational procedures do not rely on institutional or staff memory. The following documentation is considered essential:

1. *System management hierarchy describing who is in charge and their responsibilities*
2. *System organizational policies and standard operating procedures*
3. *Technical manuals for all instrumentation, hardware, and software*
4. *Memorandums of Agreement between flood alert system owners and cooperating entities describing each participating party's responsibilities and limitations*
5. *Licenses issued by the Federal Communications Commission for locations using radio equipment*
6. *Preparedness and response plans integrating data collection with elements of education, public information, response and recovery procedures*

Recommendations

The most difficult task regarding a regional flood alert system for the Nolan Creek Watershed will be to determine how the system is managed among stakeholders. System components could be owned and operated by a watershed coalition, or partially shared or completely separate. If a shared solution is chosen, all participating communities will need to take steps to agree upon a centralized management scheme and planning process for coordinating flood alert sub-systems.

How this is to be accomplished is not addressed in this report. Recommendations regarding the management and documentation of Nolan Creek flood alert system(s) include:

- Designate a centralized manager to oversee system coordination and serve as the point of contact among participating parties or sub-system personnel
- Provide staff training opportunities through participation in flood-warning organizations
- Document system organizational structure and operational procedures

Table 3.1 List of flood-related organizations and local flood alert systems

Organization	Description	Contact Information
National Hydrologic Warning Council	Non-profit organization dedicated to assisting emergency and environmental management officials by providing expert advice on the use of real-time, high quality hydrologic information from remote data systems, with the goals of protecting lives, property, and the environment.	http://www.hydrologicwarning.org 2480 W. 26th Ave., Suite 156-B Denver, Colorado 80211 (303) 455-6277
ALERT Users Group	Non-profit group developing and promoting use of the Automated Local Evaluation in Real Time (ALERT) communication protocol for transmitting field data to a central computer in real-time to reduce injuries, deaths, and property damage caused by floods. ALERT2 protocol now replaces ALERT.	https://www.alertsystems.org/ On-line only
Texas Floodplain Managers Association	An organization of Texas professionals involved in floodplain management, flood hazard mitigation, the National Flood Insurance Program (NFIP), flood education, flood preparedness, warning and disaster recovery.	https://www.tfma.org/ 1511 Main Street Cedar Park, Texas 78603 (512) 260-1366
National Oceanic and Atmospheric Administration - Weather Forecast Center	Federal agency providing weather, water, and climate data, forecasts and warnings for the protection of life and property and enhancement of the national economy.	https://www.weather.gov/fwd/ 3401 Northern Cross Blvd. Fort Worth, Texas 76137 (817) 429-2631
Harris County Flood Control District - Flood Alert Group	Large, stand-alone flood alert system department. Conducts management, sub-system coordination, technical field capabilities, research and development, information distribution, and flood education.	http://www.harriscountyfws.org 9900 Northwest Freeway Houston Texas 77092 (713) 684-4000
City of Austin – Watershed Protection Department	Small, stand-alone department. Management, technical, multi-departmental with emphasis on data collection, forecast modeling, and information distribution. Partners with other agencies to collect and deliver flood-related data to public.	http://www.austintexas.gov/department/flood-safety 505 Barton Springs Road Austin, Texas 78704 (512) 974-2843
Hays County – Office of Emergency Management	Small, multi-responsibility system operated through the Office of Emergency Management. Flood Alert System managed by single person using service provider maintenance and operational contracts. Contracts support field gauges and base station that collects, hosts, and display field gauge data.	http://novastar-main.co.hays.tx.us/WETMapV3/HaysCounty/public/ WETMap.html 712 S. Stagecoach Trail San Marcos, Texas 78666 (512) 393-7779

3.2.2 Data collection and processing

Too often a monitoring network of stream gauging stations and a receiving base station has been identified as a complete flood alert system; however this represents only the data collection portion. (NOTE: modern flood alert system software may overlap, augment, or even replace some flood alert system components or sub-systems. Automated software routines can collect, process, display, and deliver relevant data to targeted audiences through online communications).

Local flood alert system stream gauge stations are typically comprised of an equipment shelter, a rain sensor, a water level sensor, a datalogger, a data encoder, a transmitter, and a battery/solar panel power system. Water level is usually measured with either a submersible pressure transducer or a radar transducer (i.e., sensors). Pressure transducers are less costly but more fragile and require significantly more maintenance than radar transducers. See Appendix I for detailed descriptions on their function and maintenance requirements. Water level transducers must be surveyed and benchmarked to an established engineering datum in order to maintain long-term system integrity and develop stage-impact relationships for data interpretation. See Appendix J for detailed descriptions regarding stage, elevation, and benchmarks. Transducer measurements are processed by an encoder - an electronic device which converts sensor data into a communication format (e.g. ALERT) that can be sent by radio and interpreted as measurements by computers at the receiving location. Data from local monitoring networks typically depend upon wireless communications such as UHF/VHF radio or GOES satellites for data transmission. Figure 3.2 shows the conceptual flow of data from a remote sensor to a base station.

Communication between gauge stations and the receiving location is usually one-way; however, two-way communication facilitates software updates, system fault diagnosis, and remote control of warning lights and automated crossing arms. With two-way communications, these tasks may be carried out without physically visiting remote sites. New ALERT2 protocol, which replaces ALERT, includes 2-way communication capability. See Appendix H for details regarding ALERT protocols.

Modern flood software allows the importation and assessment of numerous data types and sources in addition to local gauging stations. The US Geological Survey (USGS) provides reliable and timely stream flow information needed to understand the Nation's water resources.

Likewise, the National Weather Service provides weather forecasts and warnings for the protection of life and property and enhancement of the national economy.

Once data is gathered from various remote sources it must be processed (i.e., evaluated relative to management conditions and high-water warning thresholds, etc.). Pre-programmed conditions may be automatically evaluated by software and pre-defined messages may be automatically sent to system managers, emergency response personnel, and other designated users. Most modern flood-related software utilizes a relational database for data storage purposes. Data organized in this fashion can be quickly accessed and updated.

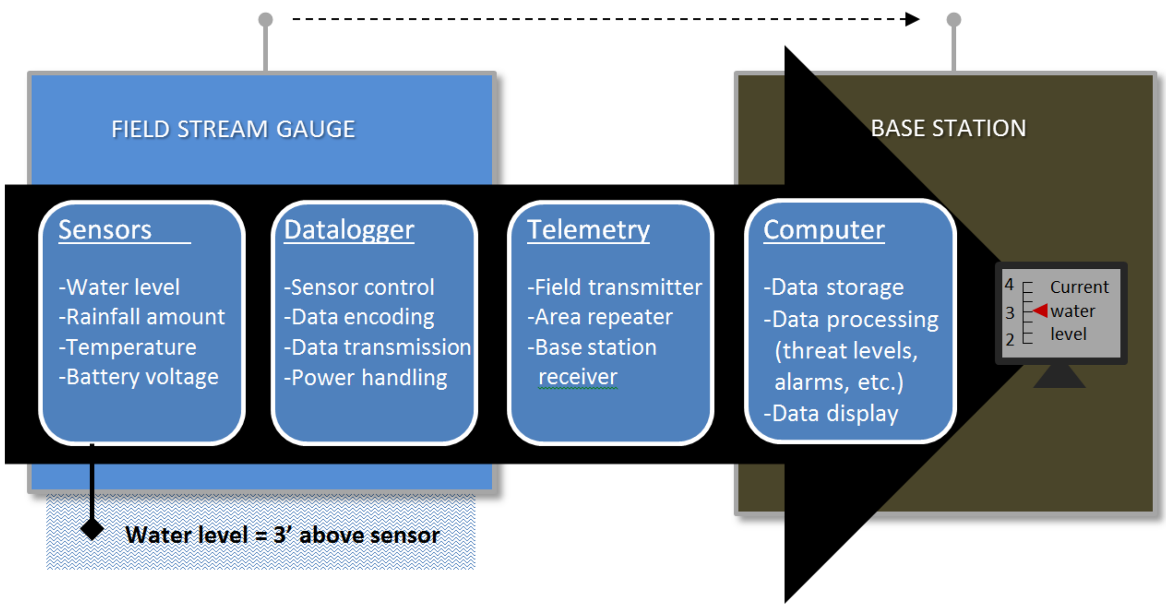


Figure 3.2 Data flow from field stream gauge network to base station at receiving center

Flood alert system maintenance is a daily occurrence. Gauge station networks, computer systems, and output messages must be continually monitored and evaluated to insure that the system is functioning properly and ready to provide rainfall and water level information for assessing high-water events. Field gauge stations must receive regular maintenance. Most manufacturers and flood alert system managers recommend at least quarterly servicing of field equipment to clean and calibrate sensors and check telemetry and power systems. Many system maintenance processes can be carried out through vendor contracts, however maintaining a knowledgeable technical staff allows for quick response to failing equipment and can verify vendor services.

Recommendations

Three general solutions are available to expand the current gauge station network for use by upstream cities. The first is to add field equipment compatible with the system currently operated by Belton and configure Belton's base station software to forward collected data, through internet connections, to a watershed-inclusive network. Second, each city could install field gauge stations and operate independent base stations using Belton's area-wide repeater network. A third possibility is for each city to install and operate completely separate gauge station networks but this is not recommended as the communities are physically connected by Nolan Creek and are already sharing instrumentation costs.

If the City of Belton, or upstream communities, or a watershed-wide coalition continues to operate stream field gauges, replaces damaged or aging equipment, or pursues additional gauge station installation, the following is recommended:

- Survey all field gauges and benchmark to an established engineering datum to maintain system integrity and facilitate water level data interpretation; consider the North American Vertical Datum 88, used by the Federal Emergency Management Agency for flood inundation mapping
- If/when adding field gauge stations or replacing failed or aging equipment, use ALERT2 transmission protocol hardware in lieu of older ALERT protocol hardware
- If/when adding field gauge stations or replacing failed or aging equipment, use non-contact water level sensors (i.e., radar transducers) for water level determination, where possible
- Aggregate data from multiple sources, including federal agencies, other local authorities, and the local gauge stations to provide more information to primary users and the public
- Conduct system maintenance daily through automated system messaging and observation
- If contracting system maintenance, service system components quarterly, or at manufacture recommended specifications, and following significant flood events
- Consider maintaining a technical staff to support timely repairs and general maintenance of remote field gauge stations, other system hardware, and software

3.2.3 Risk Assessment and forecasting

Once collected, rainfall and water level data must be assessed for risk before it can be effectively interpreted in order to make decisions regarding dangerous high-water conditions. A clear understanding of a stream gauge's reported stage value is critical. See Appendix J for details.

Perhaps the best way to establish tangible stream stage values is to define gauge-specific "stage-impact" relationships. Stage information may be displayed numerically in table form (Figure 3.3) or graphically in a chart (Figure 3.4). Either method enables users to quickly and easily apply meaning to a reported stage value by linking it to the surrounding landscape. Flood alert system operators can analyze historic data to define stage-impact relationships for each gauge in their system to establish normal, watch, alarm, and warning stream conditions. This is helpful not only for primary users but non-technical and first time users. Most flood system software has provisions for entering, managing, and displaying stage-impact information (Figure 3.3).

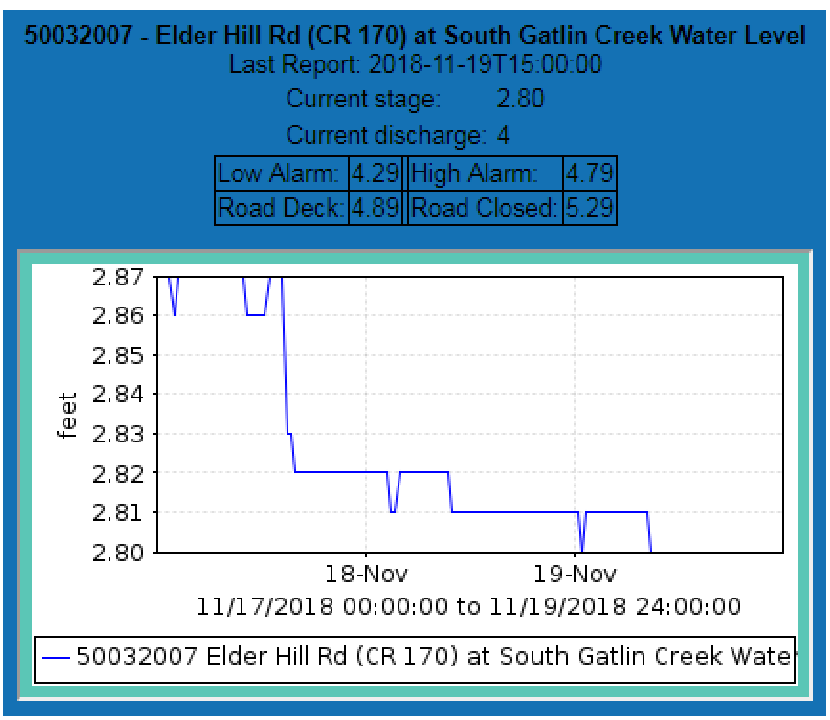


Figure 3.3 Example of a Stage-Impact table
The table above the graph defines stage levels for alarm conditions (Low and High), a physical landmark (Road deck) and an emergency response action (Road closed) allowing anyone to easily interpret the graphed data. In this case, the current level of 2.8 feet is below any impact levels.

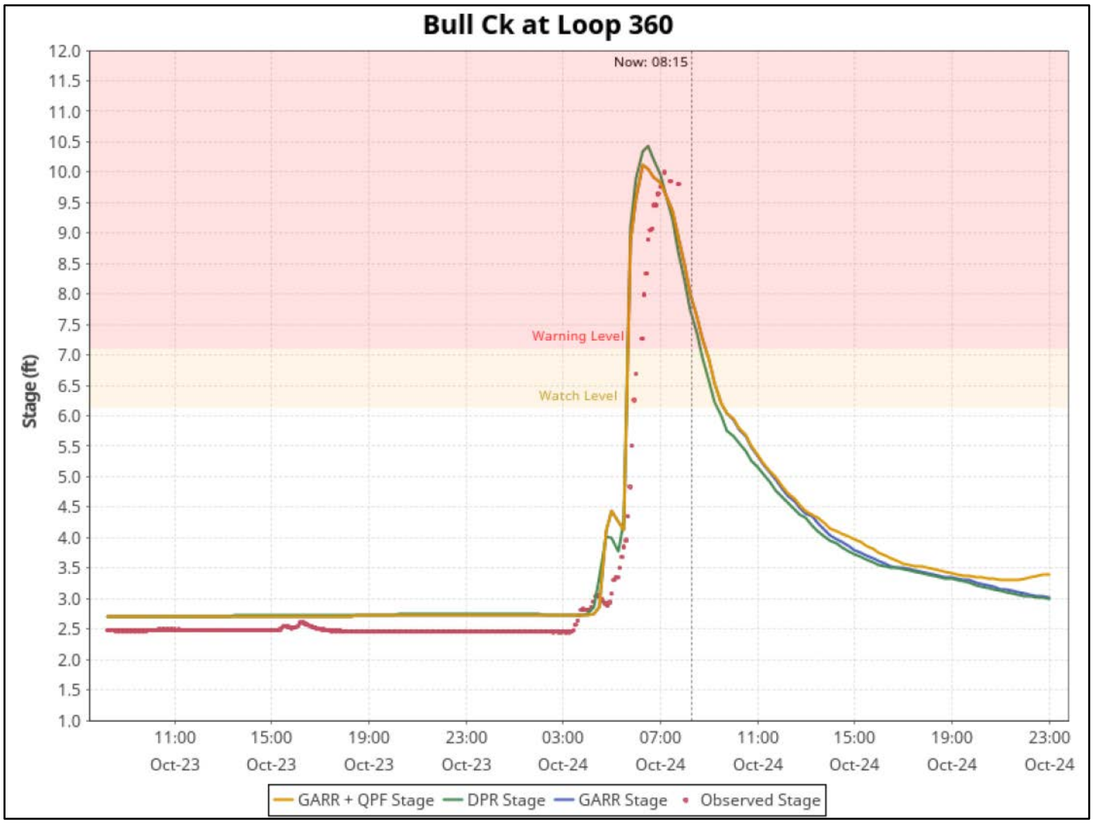


Figure 3.4 Example of graphical thresholds and real-time flood forecasting model output
Flood thresholds indicated by horizontal color bars. Forecasting values are compared to observed values in relation to watch/warning thresholds. Dashed vertical line indicates current time with historic data to the left and forecasted data to the right. Example comes from the City of Austin which uses Vieux and Associates, Inc. FloodVieux product.

Stage-impact relationship development relies on a site elevation survey to establish landscape reference points, or benchmarks, relative to a defined datum - a fixed starting point of a scale or operation. Local benchmarks tied to the datum will insure that long-term gauge accuracy is maintained. Field technicians may reference benchmarks when servicing and calibrating water level sensors to insure correct vertical replacement of the sensor during maintenance activities. See Appendix J for more information regarding survey levels. (NOTE: Some basic stage-impact relationships for Belton's current flood alert system gauge station network are provided in Appendix J. These may be used as a starting point for developing more detailed relationships or extending system use.)

Real-time gauge inundation mapping represents a relatively straight-forward method of visualizing stage-impact relationships. It combines real-time stream level data with pre-processed Geographic Information System (GIS) models to produce visual representations of flooding, displayed over a landscape map. A hydraulic model is developed for a specific stream segment and used to determine incremental flood elevations. The resulting flood inundation map "library" represents a set of maps showing flood inundation from near-bankfull river levels to record flooding levels (Figure 3.5). Field gauge water level sensors and flood inundation maps must be linked through a common engineering datum such as North American Vertical Datum 1988 (NAVD88) that is used by the Federal Emergency Management Agency (FEMA) for local flood inundation mapping. Real-time reporting, through a well-structured web-interface, facilitates useful information distribution to multiple audiences. The accuracy of this approach expands with increased gauge density, and the result is a real-time inundation boundary that emergency responders can use to aid with evacuations, road-closures, and regional resource allocations during an emergency. Flood data presented in this format (i.e., map) is easily interpreted by non-technical users and may be suitable for public distribution.

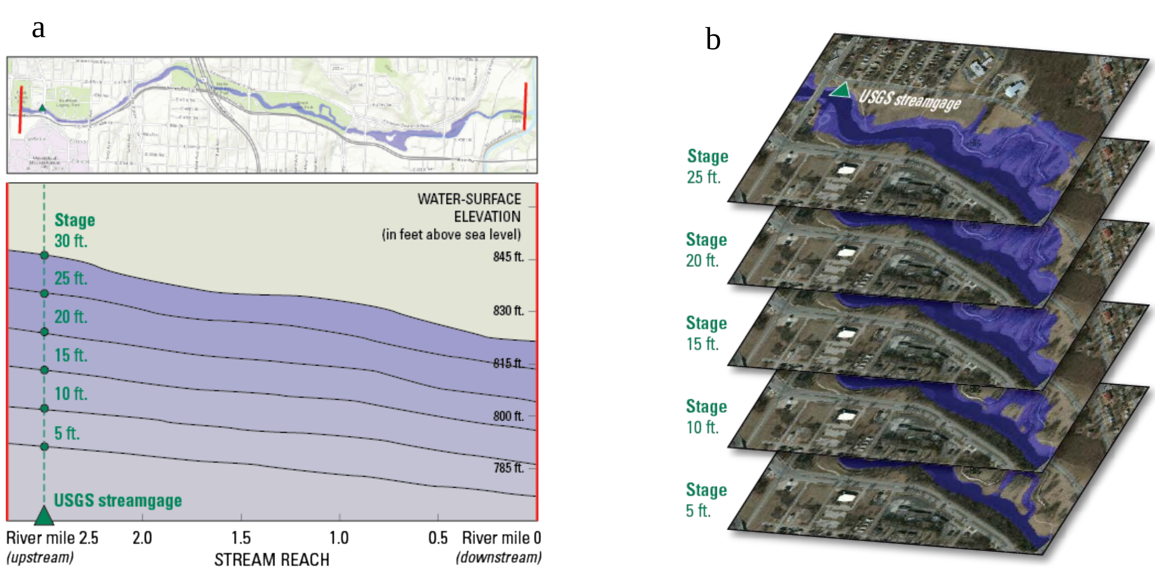


Figure 3.5. Real-time inundation mapping.
Field stream gauge water surface elevation data (a) is referenced to a flood inundation map library (b) yielding a visual representation of flooding. Figures from US Geological Survey (https://www.usgs.gov/mission-areas/water-resources/science/flood-inundation-mapping-science?qt-science_center_objects=0#qt-science_center_objects).

The most basic function of a flood alert system is to increase watch and warning lead times for locations subject to flood risk. Two basic flood forecasting methods exist; simple threshold forecasting and real-time integrated hydrological-hydraulic forecasting. Each method has strengths and weaknesses related to cost and effectiveness.

Simple threshold forecasting compares precipitation and/or water level rise rates to calculated values to determine when predefined flood thresholds will be reached at specific points in the landscape. This requires analysis of historic data to determine rainfall and stream rise rate responses for gauged points in the watershed. Results may be presented as either numerical thresholds (e.g. >2 feet of stream level rise per hour) or probability values (e.g. 40% chance of exceeding flood threshold). Figure 3.5 shows a numeric threshold in graphical form. Real-time gauge data can be compared with the curve to guide action decisions (i.e., issue alerts, warnings, evacuation orders, etc.). This type of forecasting is less costly to develop and easy to apply but is not as sensitive as real-time computer simulation modeling.

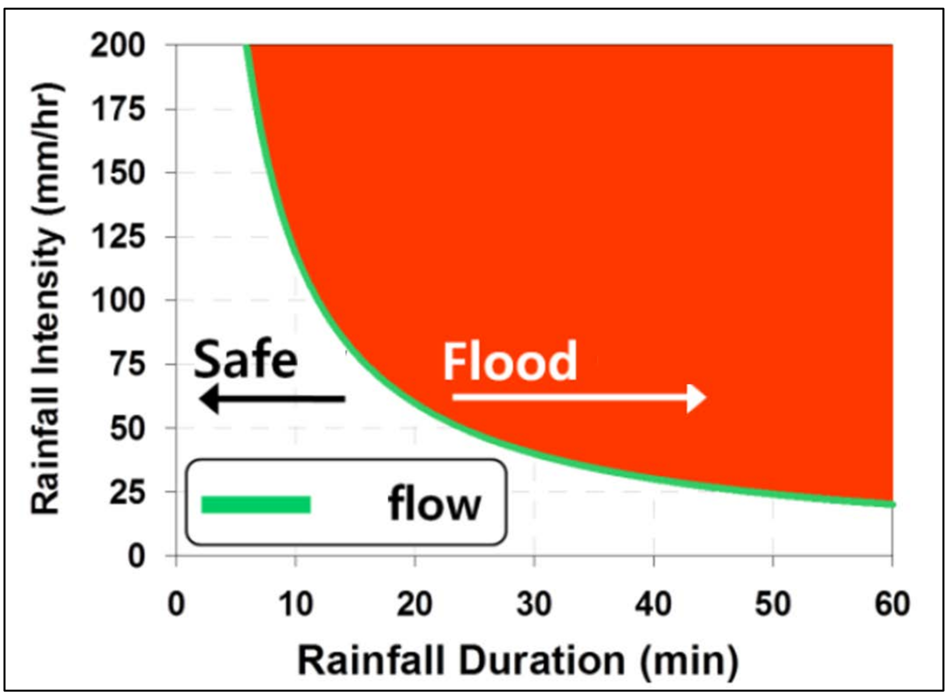


Figure 3.6 Flood forecast nomograph based on historic data
Current rainfall duration and intensity data is compared to isoflow curve to determine if action is necessary. Curve, generated from historic data, is location and threshold specific. Modified from Yoon et al. (2012).

Integrated hydrological-hydraulic forecasting involves real-time integration of data gathering and computer modeling. This is a much more sophisticated and complex methodology combining real-time measurements with on-the-fly runoff and flow routing calculations to predict future stream levels and velocities at specific points in the landscape. This requires the importation, management, and assessment of high resolution spatial and temporal weather data from multiple sources including: rain gauges, weather radars, and stream flow gauges. Additional static and dynamic physical data are required to describe watershed topography, land use, vegetation types and amounts, and soil characteristics (Jain et al., 2017). This level of forecasting requires significant expenditure of time and resources but provides a high level of flood risk reduction through timely flood warnings at very fine time intervals and spatial scales. Figure 3.4 illustrates a typical user interface for a real-time integrated hydrologic/hydraulic model product.

Liability must be considered before providing public flood forecasts. It is difficult to explain the inherent uncertainty in flood forecasting to non-technical audiences. Flood prediction uncertainty is due to the high variability in calculating stormwater runoff. Antecedent soil moisture conditions, routing calculations, and flood inundation estimates greatly affect forecast results and can lead to false alarms and missed predictions. Even with the best modeling available, random events, such as temporary damming from flood debris, cannot be predicted. Flood forecast information generated by a local flood alert system may best be reserved for internal management and emergency responder use. In Texas, some systems do provide forecasts to the public (e.g., City of Austin) while others provide only real-time conditions (e.g., Harris County Flood Control District and Hays County Office of Emergency Management).

Recommendations

If the City of Belton or upstream communities or a watershed coalition seek to improve their flood risk assessment, real-time inundation mapping, or forecast model development, the following solutions are recommended:

- Develop stage-impact tables, based on surveyed benchmarks, for all gauge stations to facilitate water level data understanding and linking to flood inundation maps for real-time evaluation

- Collect and archive flood alert system gauge data to develop relationships between rainfall rates and stream level rise for specific gauging stations to facilitate simple threshold forecasting
- Collect and archive flood alert system data to determine travel times for peak flows among gauging stations to facilitate simple threshold forecasting
- Conduct additional studies to determine if and where real-time forecasting is necessary
- Consider liability risks before providing flood forecast information to the public

3.2.4 Communication and distribution of information

Field data, once collected and interpreted, must be communicated to different audiences in different forms, for different purposes. Modern flood alert system software is typically configurable to send pre-defined notifications to specified user lists. Automated messages are useful for informing flood system managers of failing equipment and are critical for alerting emergency response teams of developing weather and high-water situations.

During periods of baseflow stream conditions (no rainfall or normal rainfall), field gauging stations are typically programmed to report only once or twice a day, indicating that the station has power and is functioning properly. When a station fails to report, automated messages generated by system software can be sent to a distribution list informing managers of the problem. Communications of this type support timely deployment of field technicians to repair non-responsive equipment and can also serve as system maintenance records.

Developing weather and stream condition information must be conveyed to officials and the public prior to, during, and immediately following a flood. Automated messages are critical for alerting emergency response teams of developing weather and high-water situations. Once aware of developing conditions, primary users may utilize online services to closely monitor the local stream gauge sensor network for decision making and forecasting.

Modern online services have become one of the most common forms of information transfer. Internet servers can instantly provide a wealth of information to users across a variety of computing platforms and mobile devices. A very complete list of vendors specializing in flood warning-related hardware and software is maintained by the Alert Users Group and available at: https://www.alertsystems.org/index.php/vendors

Among those most noted for flood warning system software and hosting services are:

- **DataWise Environmental Monitoring, Inc.** : Forecasting & ALERT software
- **HydroLynx Systems, Inc.** : Complete/partial hardware and software systems
- **OneRain, Inc.** System integration, maintenance, real-time data analysis

The Harris County Flood Control District in Texas uses OneRain, Inc.'s "Contrail" software product to integrate all of its local flood alert system operations including personnel management, data aggregation from multiple sources, gauge maintenance records, stream level and rainfall data analysis, data storage and handling, and most important data display. Displays or "dashboards" are highly configurable and may be designed for different users and applications.

The public interface, like most flood-warning system software, provides gauge station mapping and status display (Figure 3.6). Additional data for individual gauges, such as channel cross section images and flood threshold levels, are available so non-primary users can make decisions regarding high water conditions (Figure 3.7). Maintenance dashboards assist flood alert system technicians and managers determine when gauge station servicing is necessary (Figure 3.8).

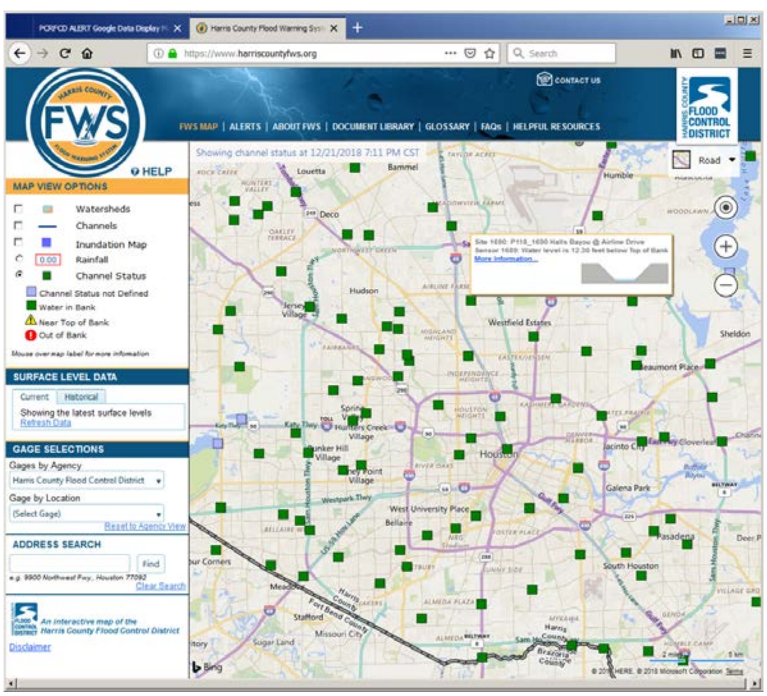


Figure 3.7 Screenshot of Harris County Flood Control District flood alert system interface
Contrail software by OneRain, Inc. is used to generate this output.

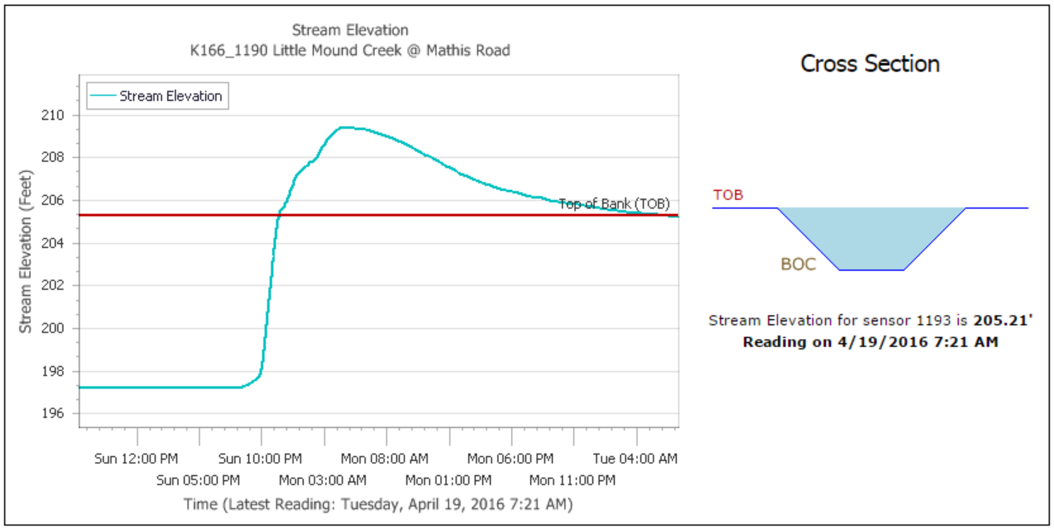


Figure 3.8 Screenshot of Harris County Flood Control District individual stream gauge
Red line indicates top of bank and flood threshold allowing users to interpret stream elevation values.

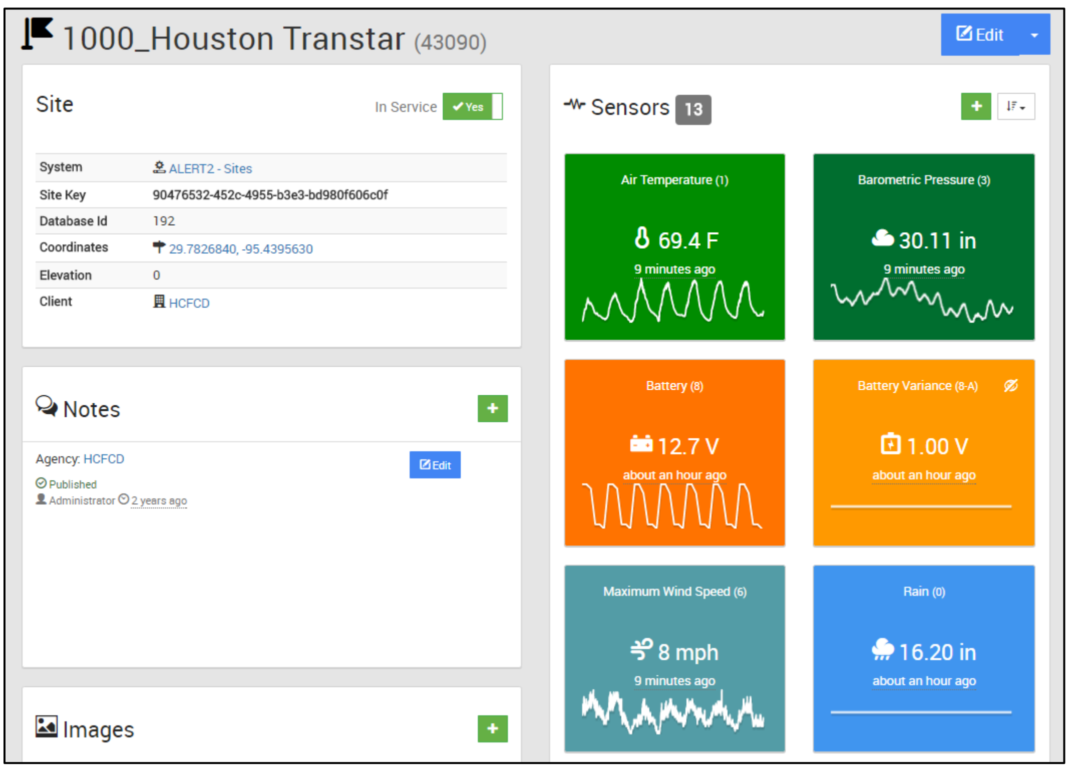


Figure 3.9 Screenshot of Harris County Flood Control District maintenance dashboard
Contrail software by OneRain, Inc. is used to produce this output.

Hays County, Texas Emergency Services Department uses HydroLynx Systems, Inc. software to manage and display data from its local flood alert system stream gauge network (Figure 3.9). The public user interface is well-designed and easy to use. Stream gauge stage readings are automatically updated every few minutes and displayed in color representing road crossing conditions (open = green, at risk = yellow, and red = closed). Clicking on a particular gauge will deliver additional information about the site in the form of a time-series chart consisting of stream level data and a stage-impact table describing flood risk alarm levels and landmarks (i.e., road deck). This presentation is useful and intuitive to non-technical public users and those with no experience or knowledge of the area.

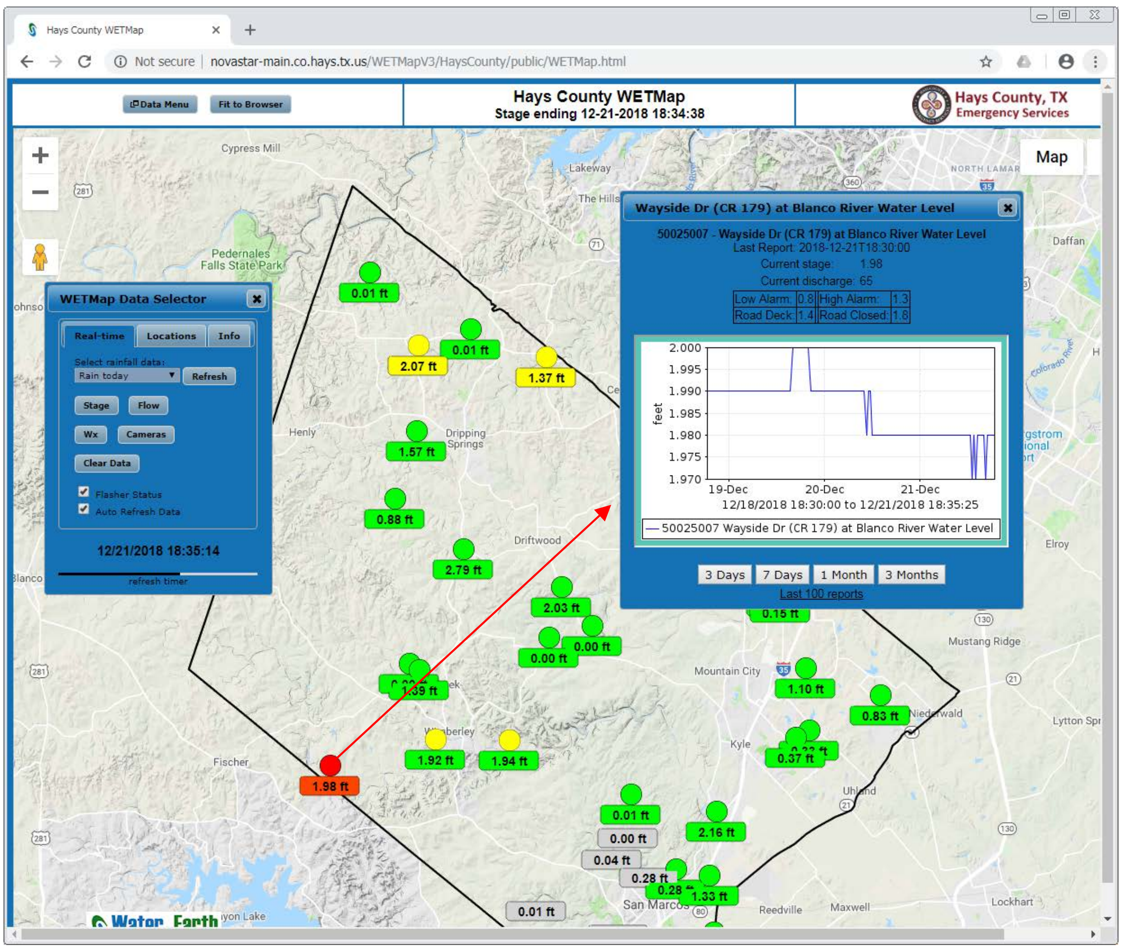


Figure 3.10 Screen shot of Hays County, Texas flood alert system public web interface
HydroLynx software is used to generate this output. Clicking on a particular gauge opens an additional window with graphical data and stage-impact information.

The Pima County Flood Control District in Arizona uses software produced by DataWise, Inc. to collect and distribute information from its flood alert system stream gauge network and multiple agencies. The public website provides users access to multiple data types (current and historic) displayed over an adjustable map. As with other flood system software, additional information about specific gauges in the network can be accessed by clicking on a gauge of interest. Rating tables and stage-impact information facilitate user decision making (Figure 3.10).

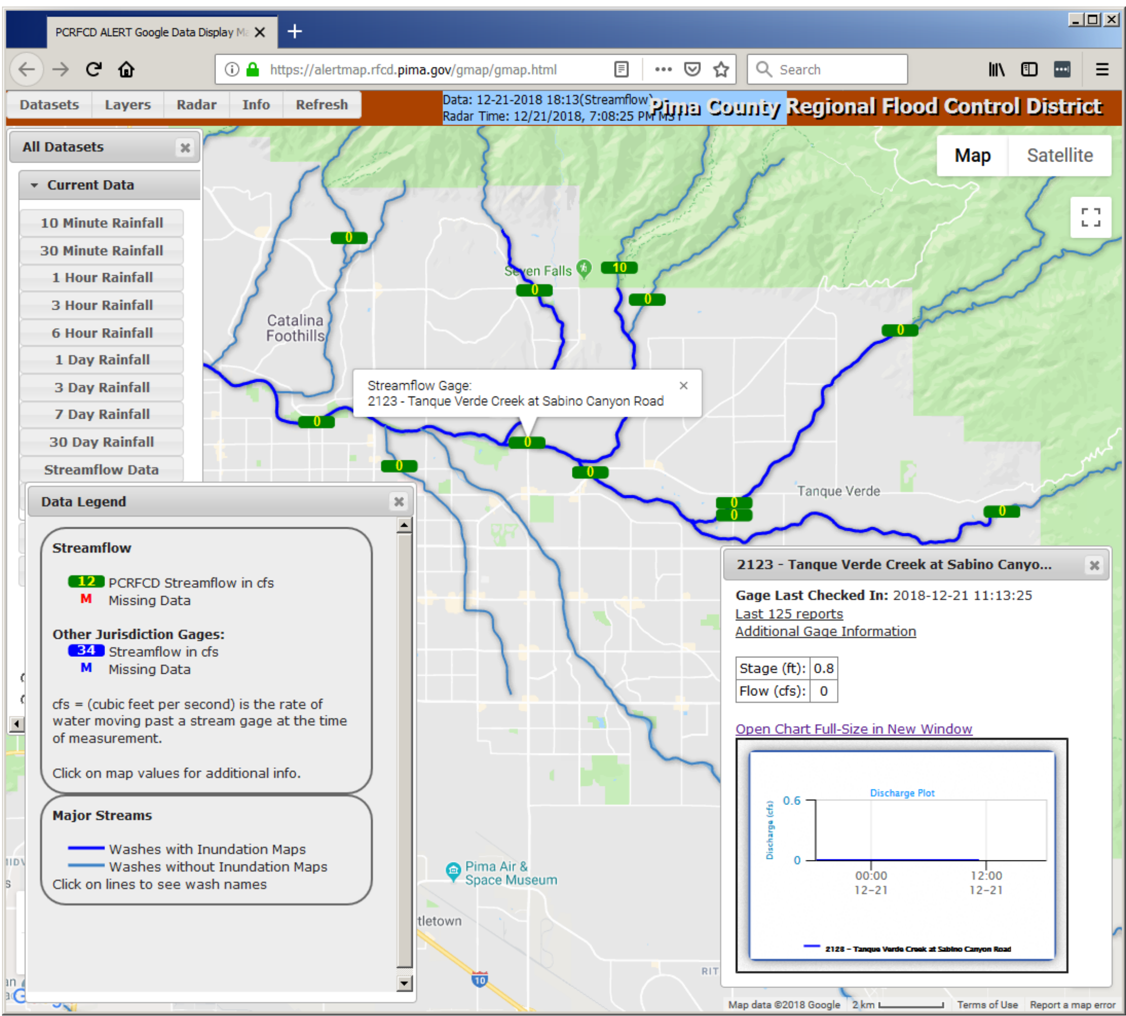


Figure 3.11 Screenshot of Pima County, AZ flood alert system public interface
DataWise software is used to generate this public output. Clicking on a particular gauge opens a window with graphical data and stage information table.

Recommendations

If the City of Belton, upstream communities, or a watershed coalition seeks to update or operate information communication and distribution flood alert system software, the following solutions are recommended:

- Consider the use of a software package that combines multiple flood alert system components to centralize management efforts (i.e., maintenance, data collection, messaging, etc.)
- Add stage-impact information (i.e., landmarks, alarm thresholds), based on surveyed benchmarks, to public gauge descriptions to facilitate water level data interpretation
- Develop primary user lists for management notifications and flood alert notifications
- If making flood gauge information public, make system data easy to find by ensuring hyperlink visibility from the home page to flood alert system-related information page(s)
- If making flood gauge information public, provide a dedicated page describing the system, goals, stream gauge network, data interpretations, usage, and cautions
- If making flood gauge information public, provide informative public web page(s) which describes the system and how to interpret gauge data, thresholds, and warning messages
- If making flood gauge information public, exclude non-flood data from public displays (i.e., system health, statistics, battery voltage, etc.)

3.2.5 Preparedness and Response

For flood alert system managers and staff, the best way to prepare for high-water events is to remain current with flood-warning related technology and flood alert system operational procedures through education, training, and involvement with professional flood safety organizations and other flood alert system managers (See Section 3.2.1).

Preparation for flood events through community education is perhaps one of the best ways to protect against flood-related incidents. Communities may include flood-related mail flyers with utility bills, make educational presentations at community celebrations, events, and school programs, and broadcast flood education messages through public service announcements; for example, the familiar “Turn Around, Don’t Drown” slogan created and used by the National

Weather Service. Due to the prevalence of modern internet services, knowledge and education regarding local flood alert systems can be effectively delivered through public web sites. Regardless of the message vehicle, flood alert system goals and flood gauge information should be clearly explained.

Typical flood alert system message types include early watches and alerts, imminent warnings, and evacuation notices. *Flood Watches* should be issued when conditions are favorable for flooding. It does not mean flooding will occur, but it is possible. *Flood Warnings* should be issued when flooding is imminent or occurring. Message content must be worded appropriately to obtain maximum response and should include information regarding actions to be taken, areas to be avoided, location of safe areas, location of reception centers, and ways of obtaining emergency assistance.

Effective use of flood alert system information requires a response plan that includes written procedures to help to reduce loss of life and property. Authorities must establish operational procedures for police, fire, utility repair, rescue, medical, and other services prior to and during floods. The plan should include elements of warning dissemination, evacuation and rescue, and review following significant flood events for updating purposes.

Recommendations

Recommendations related to preparedness and planning are the same for any and all entities operating a local flood alert system in the Nolan Creek Watershed and include:

- Conduct regular and seasonal public educational campaigns regarding high water awareness
- Maintain a well-documented, clear internet presentation of local flood alert system procedures
- Develop clear messages regarding areas to avoid, actions to take, and how to get help
- Provide a mechanism for response plan review and updating

3.3 Summary of recommendations

The most difficult task regarding a regional flood alert system for the Nolan Creek Watershed will be to determine how the system is managed among stakeholders. Elements of the system could be owned and operated by a watershed coalition, or partially shared, or completely separate. If a shared solution is chosen, all participating communities will need to take steps to agree upon a centralized management scheme and planning process for coordinating flood alert sub-systems. How this is to be accomplished is not addressed in this report. Recommendations regarding the management and documentation of Nolan Creek flood alert system(s), either separate or shared, include:

- Designate a centralized manager to oversee system coordination and serve as the point of contact among participating parties or sub-system personnel
- Provide staff training opportunities through participation in flood-warning organizations
- Document system organizational structure and operational procedures

If the City of Belton or upstream communities or a watershed coalition continues to operate a flood alert system, replaces damaged or aging equipment, or pursues the installation and operation of additional gauge stations, the following solutions are recommended:

- Survey all field gauges and benchmark to an established engineering datum to maintain system integrity and facilitate water level data interpretation; consider the North American Vertical Datum 88, used by the Federal Emergency Management Agency for flood inundation mapping
- If/when adding field gauge stations or replacing failed or aging equipment, use ALERT2 transmission protocol hardware in lieu of older ALERT protocol hardware
- If/when adding field gauge stations or replacing failed or aging equipment, use non-contact water level sensors (i.e., radar transducers) for water level determination, where possible
- Aggregate data from multiple sources, including federal agencies, other local authorities, and the local gauge stations to provide more information to primary users and the public
- Conduct system maintenance daily through automated system messaging and observation
- If contracting system maintenance, service system components quarterly, or at manufacture recommended specifications, and following significant flood events

- Consider maintaining a technical staff to support timely repairs and general maintenance of remote field gauge stations, other system hardware, and software

If the City of Belton or upstream communities or a watershed coalition seek to improve their flood risk assessment, real-time inundation mapping, or forecast model development, the following solutions are recommended:

- Develop stage-impact tables, based on surveyed benchmarks, for all gauge stations to facilitate water level data understanding and linking to flood inundation maps for real-time evaluation
- Collect and archive flood alert system gauge data to develop relationships between rainfall rates and stream level rise for specific gauging stations to facilitate simple threshold forecasting
- Collect and archive flood alert system data to determine travel times for peak flows among gauging stations to facilitate simple threshold forecasting
- Conduct additional studies to determine if and where real-time forecasting is necessary
- Consider liability risks before providing flood forecast information to the public

If the City of Belton or upstream communities or a watershed coalition seek to update or operate information communication and distribution flood alert system software, the following solutions are recommended:

- Consider the use of a software package that combines multiple flood alert system components to centralize management efforts (i.e., maintenance, data collection, messaging, etc.)
- Add stage-impact information (i.e., landmarks, alarm thresholds), based on surveyed benchmarks, to public gauge descriptions to facilitate water level data interpretation
- Develop primary user lists for management notifications and flood alert notifications
- If making flood gauge information public, make system data easy to find by ensuring hyperlink visibility from the home page to flood alert system-related information page(s)
- If making flood gauge information public, provide a dedicated page describing the system, goals, stream gauge network, data interpretations, usage, and cautions
- If making flood gauge information public, provide informative public web page(s) which describes the system and how to interpret gauge data, thresholds, and warning messages
- If making flood gauge information public, exclude non-flood data from public displays (i.e., system health, statistics, battery voltage, etc.)

Recommendations related to preparedness and planning are the same for any entity operating a local flood alert system in the Nolan Creek Watershed and include:

- Conduct regular and seasonal public educational campaigns regarding high water awareness
- Maintain a well-documented, clear internet presentation of local flood alert system procedures
- Develop clear messages regarding areas to avoid, actions to take, and how to get help
- Provide a mechanism for response plan review and updating

4 References and resources

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NOAA (2012) NOAA's National Weather Service Flood Warning Systems Manual. Version 1.0. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service. Washington D. C. 81 pg. http://www.nws.noaa.gov/os/water/resources/Flood_Warning-Systems_Manual.pdf

Owen, T. (2011) A history of Nolan Creek flooding. Presentation delivered to the Belton Nolan Creek Workshop. 16 August. Belton, TX

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Persons interviewed in the preparation of this report:

Nolan Creek flood alert system description

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1. Sam Listi – City Manager
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(254) 933-5818, slisti@beltontexas.gov

2. Chris Brown – Director of Information Technology and
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(254) 933-5878, cbrown@beltontexas.gov

3. Angellia Points – Director of Public Works and City Engineer
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4. Bruce Prichard - Fire Chief
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5. Paul Romer – Public Information Officer
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6. Kristina Ramirez – Director of Environmental Services
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7. Joseph Molis – Director of Planning and Development
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8. Glenn Gallenstine – Deputy Fire Chief
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City of Nolanville

9. Kara Escajeda - City Manager
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Additional local authorities

10. Glen Grandy – President -Water Conservation and Improvement District #6
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11. Bryan Neaves – County Engineer, Bell County Engineer's Office
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12. Aaron Abel – Water Services Manager, Water Brazos River Authority
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Flood alert system equipment and software vendors and service providers

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14. James Logan – Chief Executive Officer, OneRain
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15. Donald Colton – Chief Executive Officer, DataWise Environmental Monitoring, Inc.
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16. Baxter Vieux – Principal, Vieux & Associates, Inc.
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(405) 325-1818, baxter.vieux@vieuxinc.com

17. David Haynes – President, Automated Flood Warning System Designs, Inc.
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20. Jeffery Linder – Director of Hydrologic Operations, Harris County Flood Control District
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21. Mark Moore – Lead Hydrologic Technician, Harris County Flood Control District
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22. Scott Prinsen – Program Manager, Flood Early Warning System, City of Austin Watershed Protection Department, 505 Barton Springs Road, Austin, Texas 78704
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23. Ranjan Muttiah –Director of Stormwater Management Division and Engineer, City of Fort Worth, 1000 Throckmorton Street, Fort Worth, TX 76102
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24. Justin McInnis – Assistant Director and Assistant EMC, Hays County Office of Emergency Management, 2171 Yarrington Road, Suite 300, Kyle, TX 78640
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25. Gregory Waller – Service Coordination Hydrologist, National Weather Service, West Gulf Coast Rover Forecast Center, 3401 Northern Cross Blvd. Fort Worth, TX 76137
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greg.waller@noaa.gov

Appendix A – Flood alert system documentation (Belton)

City of Belton

Nolan Creek Flood Alert System

Management Documentation

City of Belton
JOB DESCRIPTION

Job Title: **Director of Information Technology** **FSLA Status:** **Exempt**
Reports to: **Assistant City Manager** **Revision Date:** **10/14/2016**

JOB SUMMARY

Under the general direction of the Assistant City Manager, the Director of Information Technology directs and manages City-wide information technology/systems and telecommunications systems and activities. Evaluate the IT Department and its operations to ensure effective support for organizational objectives and efficient and effective implementation of initiatives. Lead and develop technology strategic plans and implementation strategies. Provide leadership to the City Manager's Office, City Council, and Department Directors in integrating and aligning technology with organizational goals and objectives. Supervises assigned department staff.

ESSENTIAL JOB FUNCTIONS [*Related to the Nolan Creek Flood Monitoring System*]

2. Management of Hardware/Software/Information Systems

- Manage Nolan Creek Flood Monitoring System.

3. Acquisition/Deployment

- Ensure regular maintenance of the Nolan Creek Flood Monitoring System and coordinate with Bell County, Cities, and vendors, as needed.

5. Other Duties

- Be present for Emergency Management operations and monitor data from Nolan Creek Flood Monitoring System.

Appendix B – Emergency plan for flash flood conditions (Belton)

City of Belton

Emergency Operations Plan

for Flash Flood Conditions

Code RED Emergency Notification System

City of Belton, Texas
Emergency Notification Procedure for Flash Flood Conditions
Revised 04/05/2017

This Emergency Notification System is a tool to help City Staff notify citizens of potentially dangerous or life threatening flash flood conditions along Nolan Creek within the City of Belton. The following Protocol will assist authorized personnel in the decision-making process to activate the Code RED Emergency Notification System.

Note: BPD Communications personnel are trained in Code RED activations and can initiate activation at the direction of City Management, Fire Command, or Police Command. In addition, Code RED manuals are located in the EOC, the BPD communications office, and in both fire stations.

I. Stage 1 -Flash Flood WATCH (Flash Flooding possible)

When the National Weather Service (NWS) issues a flash flood watch for Belton or immediate surrounding areas of Belton. When water levels begin to significantly rise at either the Paddy Hamilton or Main Street Bridge sites, Central Fire Station personnel will begin monitor rising water levels from both sites hourly. *Monitoring will remain in effect until the NWS flash flood watch expires or water levels begin to recede.*

Personnel notifications (or Stage 1

1. Central Station Officer (933-5828)
2. BPD Communications (933-5840)

ll. Stage 2 -ALERT Conditions (flooding likely to cause road closures)

When water levels at Paddy Hamilton site reach fifteen feet (15')the Fire OIC, on-duty Police Supervisor, or other authorized person will request BPD Communications to notify the Fire Chief/EMC and Assistant Fire Chief/Assistant EMC, City Manager, Police Chief or his designee, and Public Works Director (or designee) and Public Information Officer. The on-duty Fire OIC, on-duty Police Supervisor, or other authorized person will request BPD Communications to send out a "Watch" message to the Nolan Creek Early Notification Flood Area Contact List.

Personnel notifications (or Stage 2 byBPD Communications:

1. Fire Chief, Assistant Fire Chief, Central Fire Station Officer (933-5828)
2. Police Chief
3. PW Director
4. Public Information Officer (PIO)
5. City Manager (CM)

III. Stage 3 - ALARM Conditions (Flooding imminent/NWS Flash Flood Warning)

At the discretion of the EMC or designee, under one of these conditions, BPD Communications will activate the Code RED Emergency Notification System by contacting those projected to be impacted. BPD staff will make direct contact with residents in the Shirttail Bend area to alert them of imminent flooding conditions.

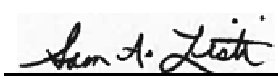
- Nolan Creek Early Flood Monitor at Paddy Hamilton reaches eighteen feet (18')
- Water level breeches IH 35 south bound Frontage Road Bridge.
- Nolan Creek Early Flood Monitor at Main Street reaches fifteen feet (15')
- Other conditions which may result in imminent danger to life or property

Personnel notifications for Stage 3 by BPD Communications:

1. Fire Chief/EMC, Assistant Fire Chief/Assistant EMC
2. Police Chief
3. PW Director
4. PIO
5. City Manager
6. IT Director

IV. Stage 4 (Imminent danger to life & property)

- Emergency Operations Center (EOC) activated by Fire Chief/EMC or designee
- EMC, in coordination with CM, opens EOC, with designated personnel on site (CM, Fire Chief, Police Chief, PW Director, IT Director, PIO and Mayor).



Sam A. Listi
City Manager

Distribution List:
Mayor/City Council
Fire Chief/EMC
Asst. Fire Chief/Assistant EMC
Police Chief
Public Works Director
Public Information Officer
Information Technology Director

Appendix C – Gauge station Inter-Local Agreements

Inter-local Agreements for Belton, Killeen, and Harker Heights

To operate stream Gaging Station along Nolan Creek

INTERLOCAL AGREEMENT FOR NOLAN CREEK EARLY FLOOD WARNING SYSTEM AMONG THE CITIES OF KILLEEN, HARKER HEIGHTS, AND BELTON, TEXAS

1.1 This agreement is made and entered into by the Cities of Killeen, Harker Heights, and Belton, Texas, to be effective as of the 27 day of December, 2012. (The entities are sometimes referred to herein singularly as a "Party" and together as the "Parties".)

1.2 Pursuant to the Interlocal Cooperation Act, Texas Government Code Chapter 791, as amended (the "Act"), cities, counties, special districts and other legally constituted political subdivisions of the State of Texas are authorized to enter into interlocal contracts and agreements with each other regarding governmental functions and services as set forth in the Act.

1.3 The natural resources and functions of Nolan Creek help maintain the integrity of natural systems and provide multiple benefits such as the storage and conveyance of flood waters, recreation, the recharging of ground water, the maintenance of surface water quality, and the provision of habitats for fish and wildlife.

1.4 The periodic flows of Nolan Creek cause extensive damage to property and loss of life.

1.5 The Parties are experiencing population growth and continued development within the floodplains of Nolan Creek.

1.6 The actions of upstream and downstream communities along Nolan Creek directly affect each other such that individual local goals for flood protection and abatement, drainage, transportation, greenway establishment and protection, and development can be better achieved through cooperative management and planning.

1.7 Building consensus among all affected stakeholders, however diverse, best provides an opportunity to establish mutually supportive partnerships and offers the benefits of commitment to basic goals and objectives and more meaningful implementation.

1.8 There does not presently exist a regional entity that can comprehensively address the management needs described above.

1.9 In consideration of the premises and mutual covenants contained, and subject to the conditions herein set forth, the Parties hereto covenant, agree, and bind themselves as follows:

Purpose

2.1 An Early Flood Warning System has been established by Belton along a portion of Nolan Creek. To further protect life, private property, and public facilities and infrastructure, the extension of the warning system is needed along Nolan Creek.

2.2 The Cities of Killeen, Harker Heights, and Belton are municipalities situated along Nolan Creek. A partnership among the Cities will help monitor creek levels within the Nolan Creek watershed in order to accomplish the stated purpose of protection to life and property.

Responsibilities for Equipment, Services, Payment Terms, and Ownership

3.1 Belton has purchased the wireless infrastructure, server and software for the Flood Monitoring system and agrees to allow the other Parties to utilize this infrastructure during the term of this Interlocal Agreement.

3.2 Belton agrees to host, manage, and provide routine maintenance for wireless infrastructure, server and software. Each Party agrees to provide liability insurance for equipment in its city and provide routine maintenance, including battery replacement, as needed. In the event of destruction of a Flood Warning station, the City in which it is located agrees to replace the Flood Warning station within 60 days.

3.3 Belton agrees to purchase and install three Flood Warning stations at mutually agreed locations to be determined by the Parties. Killeen and Harker Heights will reimburse Belton for the cost to purchase the Flood Warning stations located in their City, once installation and configuration has been completed. Each Flood Warning station is estimated to cost $5,000.00.

3.4 Belton agrees to house and publish data collected from site stations in real time. Belton agrees to provide initial training at set up, and as needed upon request by a party.

3.5 Distribution lists provided by the Parties will be programmed into an alert module for monitoring purposes. However, each Party is independently responsible for monitoring its equipment.

3.6 Each Party, regardless of who purchased the equipment, retains full ownership of the equipment located within their City.

3.7 Each party paying for the performance of governmental services or functions must make those payments from current revenues available to the paying party.

Term of Contract

4.1 The Agreement shall be for a period of one year. The term of this Agreement shall be automatically renewed each year unless terminated by written notice to the other Parties given thirty days before the expiration of the Agreement.

4.2 Notice shall be given to the Parties at the following addresses:

City of Belton P.O. Box 120 Belton, Tx 76513	City of Killeen P.O. Box 1329 Killeen, Tx 76540	City of Harker Heights P.O. Box 2518 Harker Heights, Tx 76548

Miscellaneous

5.1 This contract is executed in duplicate originals.

5.2 In case any one or more of the provisions contained in this agreement shall for any reason be held to be invalid, illegal, or unenforceable in any respect, such invalidity, illegality, or unenforceability shall not affect any other provision hereof and this agreement shall be construed as if such invalid, illegal, or unenforceable provision had never been contained herein.

5.3 This agreement contains the complete agreement between the Parties and cannot be varied except by the written agreement of the Parties. The Parties agree that there are no oral agreements, understanding, representations or warranties which are not expressly set forth herein.

5.4 Any notice or communication required or permitted hereunder shall be deemed to be delivered, whether actually received or not, when deposited in the United States mail, postage fully prepaid, registered or certified mail, and addressed to the intended recipient at the address on the signature page of this contract. Any address for notice may be changed by written notice delivered as provided herein.

CITY OF KILLEEN, TEXAS

Glen Morrison, City Manager

ATTEST:

CITY OF BELTON, TEXAS

Sam A. Listi, City Manager

ATTEST:

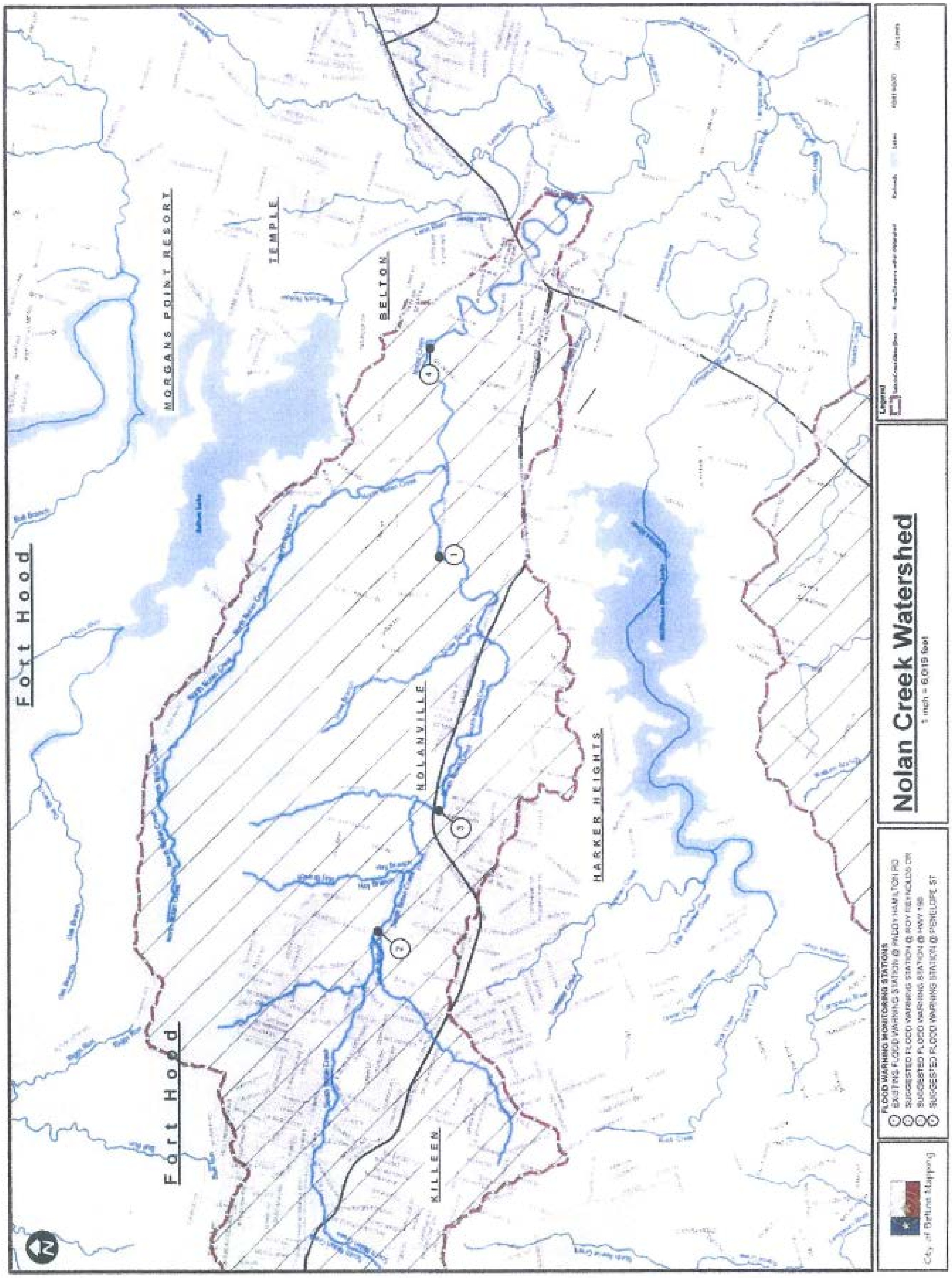
Connie Torres, City Clerk

CITY OF HARKER HEIGHTS, TEXAS

Steve Carpenter, City Manager

ATTEST:

CITY OF HARKER HEIGHTS TEXAS


Nolan Creek Watershed
1 inch = 6,019 feet
Fort Hood
Fort Hood
MORGANS POINT RESORT
TEMPLE
BELTON
NOLANVILLE
HARKER HEIGHTS
KILLEEN
FLOOD WARNING MONITORING STATIONS
EXISTING FLOOD WARNING STATION @ PADDY HAMILTON RD
SUGGESTED FLOOD WARNING STATION @ ROY REYNOLDS DR
SUGGESTED FLOOD WARNING STATION @ HWY 190
SUGGESTED FLOOD WARNING STATION @ PENELOPE ST
City of Belton Mapping
Legend

Appendix D – Gauge station Right-Of-Way Agreement

Right-of-Way Agreement

between

Bell County, Texas

and

the City of Belton

AGREEMENT FOR RIGHT OF ENTRY AND USE OF COUNTY ROAD RIGHT-OF-WAY FOR AN EARLY WARNING FLOOD WARNING SYSTEM

THIS AGREEMENT IS MADE by and between Bell County, Texas and the City of Belton, Texas, hereinafter referred to as "COB."

WITNESSETH

WHEREAS, An Early Flood Warning System has been established by COB along portions of Nolan Creek through an Interlocal Agreement with the Cities of Killeen and Harker Heights; and

WHEREAS, Bell County is a corporate and political body created and operating pursuant to the Article IX, Section 1, and Article XI, Section 1 of the Constitution of Texas; Texas Local Government Code Chapter 70: and the applicable, general laws of the State of Texas; and

WHEREAS, Pursuant to the Interlocal Cooperation Act, Texas Government Code Chapter 791, as amended (the "Act"), cities, counties, special districts and other legally constituted political subdivisions of the State of Texas are authorized to enter into interlocal contracts and agreements with each other regarding governmental functions and services as set forth in the Act; and

WHEREAS, COB and Bell County finds it necessary to enter certain public Right-of-Way ("ROW") under the control and jurisdiction of Bell County; and

WHEREAS, Bell County has determined that such entry is in the public interest and will not damage the County Road facility, impair safety, impede maintenance, or in any way restrict the operation of the County Road facility;

NOW, THEREFORE, in consideration of the premises and of the mutual covenants and agreements of the parties hereto, to be by them respectively kept and performed as set forth, it is hereby agreed as follows:

AGREEMENT

Article 1. Notice to Bell County

A. COB shall notify the Bell County Engineer prior to installation of said flood monitoring devices. The Bell County Engineer shall approve the installation in writing or via email, prior to the installation.

B. COB shall notify the Bell County Engineer of any modifications, alterations, or any deviations from the original design and installation to be made in writing or via email. All changes shall be approved, in writing or email, by the Bell County Engineer prior to changes being made.

C. Right of entry shall be limited to site investigations associated with installation, monitoring, and maintenance of automatic flood monitoring devices located at the Nolan Creek bridge on Paddy Hamilton Road and at the Nolan Creek bridge on Wheat Road.

Article 2. Investigations, Maintenance, and Responsibilities

A. At all times when on Bell County ROW, COB staff, its contractors, and their respective employees, agents, and representatives shall wear protective clothing including but not limited to protective head gear such as hard hats, protective footwear such as steel-toed shoes, and reflective vests visible to the traveling public.

B. All site investigations/maintenance shall be conducted in accordance with all applicable federal, state, and local regulations and policies.

C. Pursuant to §203.031 of the Transportation Code, entry onto the ROW of any controlled access facility shall be allowed only from the outer edge of the ROW by way of frontage roads, nearby or adjacent public roads or streets, or trails along or near the highway ROW that connect to an intersecting road.

D. COB shall notify the Bell County Engineer at least 48 working hours in advance before performing any task that will result in disturbing the pavement.

E. COB shall notify the Bell County Engineer at least 48 working hours in advance before installing any equipment, structure, or other object intended to remain in place for more than 48 hours.

F. COB shall notify the Bell County Engineer at least 48 working hours in advance before closing one or more traffic lanes or otherwise interfering with the flow of traffic in any way unless it is deemed as an emergency and vital to the safety of the public.

G. If, during a site investigation, Bell County must perform or authorize a contractor to perform routine or special maintenance, COB will cooperate with Bell County maintenance requirements.

H. The Bell County Engineer and COB's authorized representatives are authorized to communicate directly with one another to coordinate, clarify, or otherwise discuss site investigation/maintenance activities.

I. If it becomes necessary for COB to curtail the use/maintenance of the flood monitoring devices because of damages due to flooding, accident, or other catastrophic event, COB shall not resume use/maintenance until notified by Bell County to do so.

Article 3. Concluding Investigation/Maintenance Activities

A. COB shall notify the Bell County Engineer when investigation/maintenance activities have been completed.

B. COB shall restore the ROW to its original condition at the conclusion of the investigation/maintenance. Bell County Engineer will inspect the ROW after any such restoration and determine that the original condition has been restored. If the ROW is found not to have been restored to its original condition, Bell County will repair the damage at COB's expense.

Article 4. General Terms and Conditions

A. Bell County's authorization to allow COB a right-of-entry onto the ROW identified in this Agreement does not in any way impair or relinquish Bell County's right to use such land for ROW purposes when it is required for construction or reconstruction of the traffic facility for which it was acquired, nor shall use of the land for other than highway purposes under this agreement ever be construed as abandonment of the ROW by Bell County.

B. Bell County will notify COB of any utility installations owned by third parties known to be located on the ROW. COB shall provide adequate notice of the investigation/maintenance to all utility owners identified by either Bell County or COB who are potentially impacted by the investigation/maintenance.

C. Each party reserves the right to terminate this agreement at any time after notifying the other party in writing at least thirty (30) days in advance of the intended termination and establishing the conditions of termination.

IN WITNESS WHEREOF, Bell County and COB have executed duplicate counterparts to effectuate this agreement.

BELL COUNTY, TEXAS

By ______________________ Date April 29, 2013

Bryan Neaves, P.E.
Bell County Engineer

Address: 206 N. Main Street, Belton, Texas 76513

ATTEST:

Tanja Poboril
____

TANJA POBORIL
NOTARY PUBLIC
STATE OF TEXAS
My Commission Expires 12-17-2016
NOTARY PUBLIC STATE OF TEXAS

CITY OF BELTON

By *Sam A. Listi* Date *4/10/13*

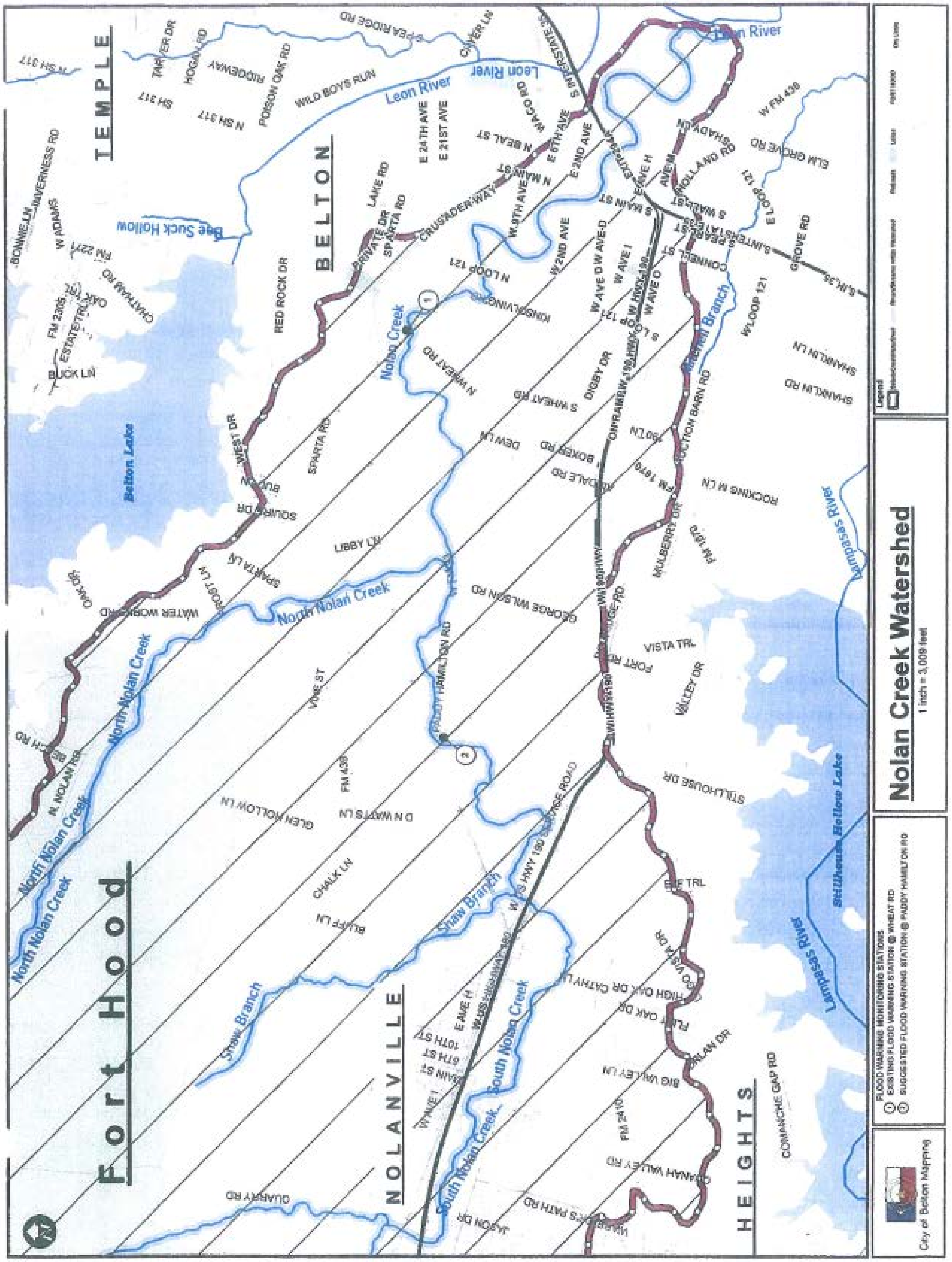
Sam Listi, City Manager
City of Belton

Address: 333 Water Street, P.O. Box 120, Belton, TX 76513

ATTEST:

Connie Torres

Connie Torres, City Clerk



Nolan Creek Watershed
1 inch = 3,009 feet
Fort Hood
NOLANVILLE
BELTON
TEMPLE
HEIGHTS
Belton Lake
Stillhouse Hollow Lake
Leon River
Lampasas River
North Nolan Creek
South Nolan Creek
Nolan Creek
Shaw Branch
Mitchell Branch
FLOOD WARNING MONITORING STATIONS
EXISTING FLOOD WARNING STATION @ WHEAT RD
SUGGESTED FLOOD WARNING STATION @ PADDY HAMILTON RD
City of Belton Mapping

Appendix E – Gauge station descriptions

Nolan Creek Flood Alert System

Stream Gaging Station Descriptions

Gauge Station #1120 @ Roy Reynolds Road:

This monitoring station is located furthest upstream from Belton on the northwest corner of the Nolan Creek at Roy Reynolds Road Bridge. Roy Reynolds Road also marks the city limits between the communities of Killeen (upstream) and Harker Heights (downstream). This station is ~3.3 channel miles above the next station at I-14 (US109). The gage has a standpipe equipment shelter with rain gauge and uses a pressure transducer to determine water surface elevation. The pressure transducer conduit is mounted directly on the concrete bridge skirt and is anchored to the bank with a steel post. Under base flow conditions, the pressure transducer location is *at or near* the water surface elevation. This site uses a directional Yagi antenna to reach the flood alert system repeater at the Bell County Emergency 911 Center in Belton. The channel bottom at this location consists of shifting limestone cobble and gravel.

Gauge Station #1140 @ I-14:

This monitoring station is located between the city limits of Harker Heights (upstream) and Nolanville (downstream) on the southwest corner of east bound Feeder Road Bridge of I-14 (i.e., US 190). The station is ~3.3 miles downstream of the Roy Reynolds station and ~8.0 miles upstream of the Paddy Hamilton station. The gauge has a standpipe equipment shelter with rain gauge and a pressure transducer for measuring water surface elevation. The pressure transducer conduit is mounted on the bridge skirt with the pressure transducer located at the lowest level where the skirt ends. Under base flow conditions, the pressure transducer location is ~ 1.4 feet *above* the water surface elevation. The channel bottom consists of fine clay over a hard limestone base.

Gauge Station #1050 @ Paddy Hamilton Road:

This monitoring station is located between Nolanville and Belton on the northeast corner of the Nolan Creek – Paddy Hamilton Road Bridge and is the approximate mid-point gauge in the Belton flood alert system. This station is ~8.0 miles downstream of the I-14 station and ~ 5.9 miles upstream from the Wheat Road station. The gauge has a standpipe equipment shelter with rain gauge and a pressure transducer for measuring water surface elevation. The pressure transducer conduit is mounted on the bridge skirt with the pressure transducer located at in the stream channel. Under base flow conditions the pressure transducer is located ~1.1 feet *below* the water surface. The channel bottom consists of large limestone boulders, remnant bridge pilings on a hard limestone bottom. Some shifting cobble and gravel are present.

Gauge Station #1030 @ Wheat Road:

This monitoring station is located on the northeast corner of the Nolan Creek – Wheat Road Bridge west of Belton. This station is ~5.9 miles downstream of the Paddy Hamilton station and ~ 3.6 miles upstream from the Main Street station in Belton. The gauge has a standpipe equipment shelter with rain gauge and a pressure transducer for measuring water surface elevation. The pressure transducer conduit is mounted on the bridge skirt and extends along the natural bank to a pool near the water's edge. Under base flow conditions the on-line gauge information reports 2.82 feet of depth above the pressure transducer's diaphragm, indicating it is 2.82 feet *below* the water surface; however this could not be physically verified by AgriLife when visiting the site (i.e., the sensor off-set value is unknown). The channel bottom is a hard limestone base with loose limestone cobble and gravel near mid-channel. Channel banks are predominantly clay.

Gauge Station #1010 @ Main Street (HWY 317): is the flood alert system furthest downstream gauge and is located ~3.6 miles downstream of the Wheat Road station in downtown Belton on the east side of the Nolan Creek – Main Street Bridge. This gauge has a different configuration from upstream gauges. It consists of an equipment shelter with rain gauge and supporting hardware mounted above the mid-channel on the Main Street Bridge. It uses a radar-type transducer to determine water surface elevation. Under base flow conditions the radar transducer reports a stream stage of ~0.9 feet. The channel bottom at this location consists of shifting limestone cobble and gravel over a hard limestone base.

Appendix F – Gauge station maintenance report

Nolan Creek Flood Alert System

Belton - Contract Maintenance

High Sierra Electronics, Inc.

Example Field Service Report

HIGH SIERRA ELECTRONICS, INC.
environmental monitoring solutions

155 Springhill Drive, Suite 106
Grass Valley, California 95945
530.273.2080
Fax: 530.273.2089
www.highsierraelectronics.com

ISO 9001:2008

Belton Maintenance Summary

Date: August 7, 2018 **Field Technician:** Brendon Drew, Matt Harris

Sites Maintained

Nolan Creek @

- Penelope (1010)
- Wheat Road (1030)
- Paddy Hamilton Road (1050)
- Roy Reynolds (1120)
- US 190 Feeder (1140)

Summary

Most sites were found to be in satisfactory condition. Any minor issues were corrected onsite.

System Wide Action Items Performed

- Battery Voltage with and without load
- Replace batteries if needed
- Solar Panel regulated and unregulated voltages if battery low
- Short Circuit Current if battery low
- Tipping Bucket and Funnel clean out
- Radio Output and Reflected Power
- Pressure Transducer test and calibrations

Site Specific Action Items Performed

- 1010 / Nolan Creek @ Penelope: The tipping bucket funnel was extremely clogged. Has been cleaned to improve performance.
- 1050 / Nolan Creek @ Paddy Hamilton Road: The tipping bucket had leaves and berries blocking the rain count. The bucket has been cleaned. The LB closer to the standpipe is damaged. Site pressure transducer conduit was clogged with mud and flushed fully.
- 120 / Nolan Creek @ Roy Reynolds: Tipping bucket platform was loose causing bucket to be slightly off level. Issue corrected and tested.
- 1140 / Nolan @ US 190 Feeder: pressure transducer required calibration, was off by 20 counts (.2 feet).

Recommendations

- Continue with biannual service program

HIGH SIERRA ELECTRONICS, INC.
environmental monitoring solutions

City of Belton
Nolan Creek @ Penelope
Master Gauging Station
Maintenance Report
8/6/2018

Station Information	
Customer:	City of Belton
Site Name:	Nolan Creek @ Penelope
Master Site ID #:	1010
Technician 1:	Brendon Drew
Technician 2:	Matt Harris
Date:	8/6/2018
Arrival Time:	10:00:00 AM
Departure Time:	10:45:00 AM
Air Temperature:	Extremely Hot 90-105 deg
Weather Conditions:	Sunny

Radio & Communications	
Frequency:	169.425 MHz
Power Amp Present:	No
Output Power:	4.80 Watts
Reflected Power:	0.00 Watts

Controller Set Up	
5 Volt Referene Reading:	4.99
Programming Verification:	Yes
Test Button Verification:	Yes
ALERT Tx & Rx Verification:	Yes
System Alarm Verification:	N/A
Replaced PT Desiccant:	Yes
Programming Screen Capture:	Yes
Program File Saved:	Yes

Site Inspections Check List	
Clean Solar Panel & Verify Best Exposure:	Yes
Clean & Level Tipping Bucket:	Yes
Remove Debris from Funnel & Screens:	Yes
Replaced Sensor Keypad:	N/A
Secured Radar Cabinet:	Yes
Directional or Omni Antenna:	Omni
Directional Antenna Azimuth:	n/a
Inspect all Cables & Connectors:	Yes
Note Changes/Damage to Site/Equipment:	Yes
Take Photos of Site:	Yes

Photo

Master Electronics Tests		
Controller Battery Replaced:	No	
Battery ID: 1015	**Old Battery Test:**	**New Battery Test:**
Battery Voltage w/o Load:	13.69 Volts	
Battery Voltage w/ Load:	13.61 Volts	
Controller Idle Current:	0.03 mA	
Controller Transmit Current:	1.10 A	
Solar Panel & Regulator	**Voltage:**	**Short Circuit Current:**
Solar Panel Voltage:	19.46 Volts	0.23 A
Regulated Voltage:	13.70 Volts	

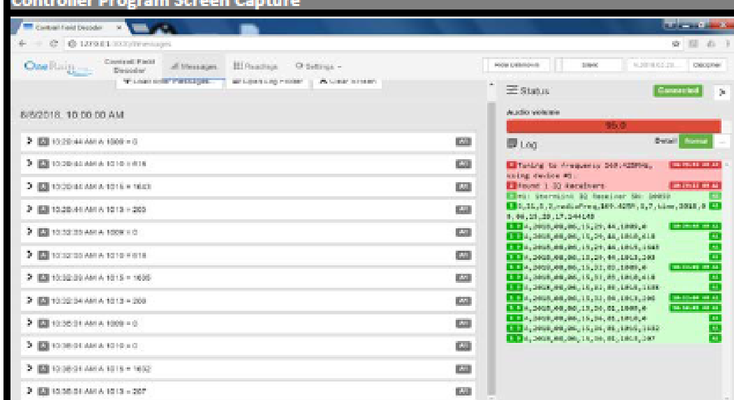
Rain Gauge		
Precip ID: 1010	**Current Rain Count:**	**Reset Rain Count:**
	618 cnts	
Tipping Bucket Verification:	Pass	

Radar Sensor Setup		
Radar ID: 1013 Current Reading:		
Radar Range:	**High Threshold:**	**Low Threshold:**
	N/a	N/a
Key Pad Checklist		
001 Media Type: Liquid		Yes
002 Tank Shape: Flat Ceiling		Yes
003 Medium property: DC>10		Yes
004 Process Condition: Standard		Yes
005 Empty Calibration: 50.00 ft		
006 Full Calibration (Span): 40.95 ft		
Base Station Multiplier: 0.02		
Base Station Offset: TBD		

Additional Notes

SWR 1.03 The tipping bucket funnel was extremely clogged. Has been cleaned to improve performance.

Controller Program Screen Capture



Color Indicator for Test Values

Bad Poor Ok Good Ideal

HIGH SIERRA ELECTRONICS, INC.
environmental monitoring solutions

City of Belton
Nolan Creek @ Paddy Hamilton Road
Master Gauging Station
Maintenance Report
8/6/2018

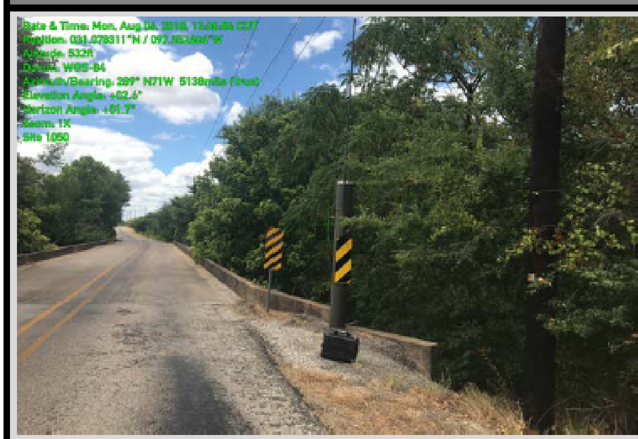
Station Information	
Customer:	City of Belton
Site Name:	olan Creek @ Paddy Hamilton Road
Master Site ID #:	1050
Technician 1:	Brendon Drew
Technician 2:	Matt Harris
Date:	8/6/2018
Arrival Time:	12:30:00 PM
Departure Time:	1:00:00 PM
Air Temperature:	Extremely Hot 90-105 deg
Weather Conditions:	Cloudy

Radio & Communications	
Frequency:	169.425 MHz
Power Amp Present:	No
Output Power:	6.00 Watts
Reflected Power:	0.20 Watts

Controller Set Up	
5 Volt Referene Reading:	5.01
Programming Verification:	Pass
Test Button Verification:	Pass
ALERT Tx & Rx Verification:	Pass
System Alarm Verification:	N/A
Replaced PT Desiccant:	Yes
Programming Screen Capture:	Yes
Program File Saved:	Yes

Site Inspections Check List	
Clean Solar Panel & Verify Best Exposure:	Yes
Clean & Level Tipping Bucket:	Yes
Remove Debris from Funnel & Screens:	Yes
Flush out Conduit:	Yes
Reposition PTs to Original Resting Position:	Yes
Directional or Omni Antenna:	Omni
Directional Antenna Azimuth:	
Inspect all Cables & Connectors:	Yes
Note Changes/Damage to Site/Equipment:	Yes
Take Photos of Site:	Yes

Photo



Master Electronics Tests		
Controller Battery Replaced:		
Battery ID: 1055	Old Battery Test:	New Battery Test:
Battery Voltage w/o Load:	13.40 Volts	
Battery Voltage w/ Load:	13.37 Volts	
Controller Idle Current:	0.03 mA	
Controller Transmit Current:	1.08 A	
Solar Panel & Regulator	Voltage:	Short Circuit Current:
Solar Panel Voltage:	13.45 Volts	
Regulated Voltage:	13.42 Volts	

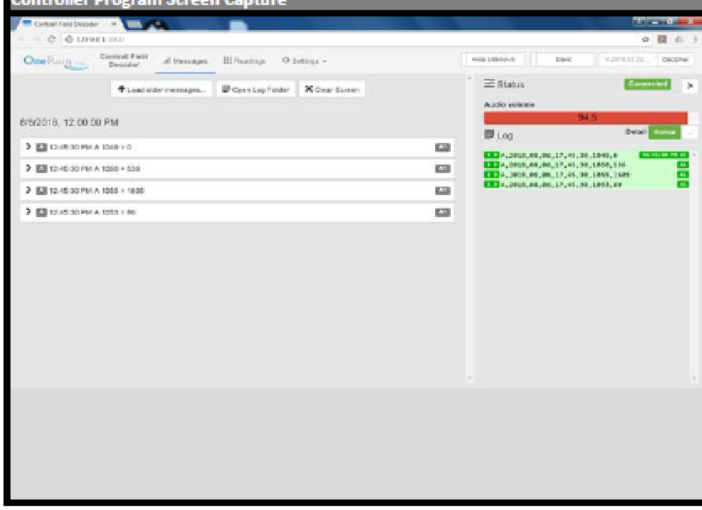
Rain Gauge		
Precip ID: 1050	Current Rain Count:	Reset Rain Count:
	536 cnts	0 cnts
Tipping Bucket Verification:	Pass	

Pressure Transducer(s)		
PT 01 ID: 1053 Current Reading:	Last Zero Offset Value:	New Zero Offset Value:
0.06 ft		
Analog 1	High Threshold:	Low Threshold:
PT 01 Calibration:	Druck Tester Reading:	Controller Reading:
PT Range:	1.00 ft	108 cnts
2047	10.00 ft	1007 cnts
	20.00 ft	2007 cnts

Additional Notes

The tipping bucket had leaves and berries blocking the rain count. The bucket has been cleaned. The lb closer to the standpipe is damaged. Site pt conduit was clogged with mud and flushed fully

Controller Program Screen Capture



Color Indicator for Test Values

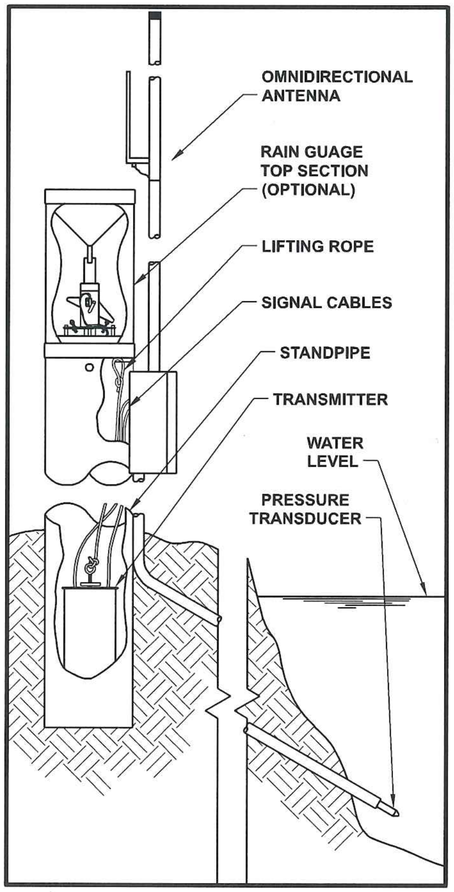
Bad Poor Ok Good Ideal

Appendix G – Gauge station hardware specification

MODEL 3466
Packaged Pressure Transducer Station

- Dam, Stream & Reservoir Management
- Automated Flow & Level Control Stations
- Emergency Management Planning

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS FAX: (530) 273-2089



DESCRIPTION:

The Model 3466-00 Packaged Pressure Transducer Station provides real-time data for monitoring water levels at dams, streams, reservoirs, lakes, waste treatment facilities, irrigation canals, or most anywhere hydrological data is needed with an accuracy of 0.1%. It provides all the necessary equipment to automate routine monitoring tasks. With a twelve-inch diameter, the easy maintenance Model 3466-00 is a practical choice whether you are at a rugged, space-confining site, or at a stream side.

An advantage of High Sierra's pressure transducer is that the signal conditioning for the sensor is mounted in a desiccant box; thus making it easy to access and allowing for the periodical recalibration of the transducer insuring the long-term accuracy and stability of data.

Recently a system operator with over 80 remote sites in a major metropolitan area told us when ordering three new stream gauge sites, "After observing the quality and stability of the pressure transducer data coming out of the 3206 I don't know why anyone would use anything else".

The Pressure Transducer Station includes a weatherproof Standpipe Assembly, ALERT/IFLOWS Data Transmitter w/battery, Pressure Transducer w/Desiccant Box, Spun Cap, Antenna, Antenna Mast & Cable. Also if you wish to monitor rainfall, you may add on an optional Model 2400-00 Rain Gauge Top Section.

An optional access door with key lock can be added on the standpipe to increase ease & efficiency, and decrease any maintenance time.

SPECIFICATIONS:

Standpipe assembly:

Height	10 feet
Diameter	12 inches
Shipping weight	60 Pounds

ORDERING GUIDE:

Model 3466-00	Pressure Transducer Station
Included are:	
Model 7000-00	Standpipe Assembly
Model 3206-00	ALERT/IFLOWS Data Transmitter
Model 6600-00	Pressure Transducer
Model 7100-00	Omni-Directional Antenna

OPTIONAL:

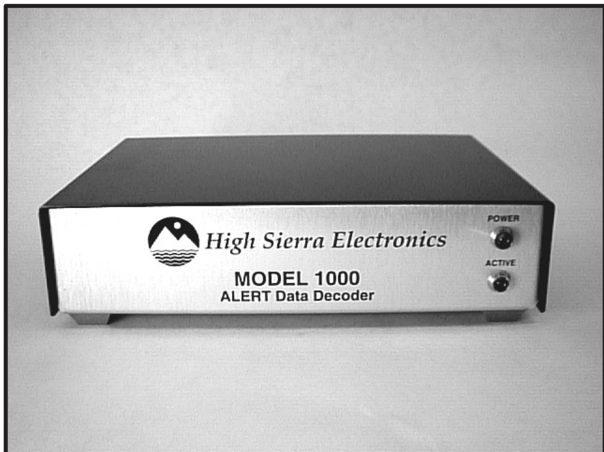
Model 8900-00	Radio Path Study
Model 7105-04	High Gain Directional Antenna
Model 3801-00	Power Amp, 25 Watts
Model 3206-20	Transmitter Data Logging Board
Model 2400-00	Rain Gauge Top Section
Model 7000-01	Standpipe Door (specify Position on Standpipe)
Model 7000-02	Extended Length of Standpipe (price per foot)
Model 7000-03	Door (field retro fit)
Model 7000-04	Mounting Bracket (to mount against walls, railings, etc.)
Model 7200-00	Antenna Lightning Protection

WEB SITE: www.highsierraelectronics.com *E-MAIL:* info@highsierraelectronics.com

MODEL 1000-03
ALERT / IFLOWS Decoder

- Two RS-232 Channels
- 12 V DC Powered
- Low Power Consumption
- Sensitive to Weak Messages

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS FAX: (530) 273-2089



DESCRIPTION:

The Model 1000-03 ALERT/IFLOWS Decoder decodes incoming data and provides an RS-232C output for computer input. Data is transferred out the serial port at the same time it is received at the audio input. An "active" light comes on when receiving data as visual feedback for verifying proper operation.

The Model 1000-03 is powered by 12 VDC. This facilitates it's use in the field while performing gauge maintenance and installation. (Note: the Model 5601-00, 7 Amp Hour Battery, is recommended for uninterrupted power.) The decoder comes with a 6 foot serial cable, (25-Pin Male to 9 pin Female), a 12 VDC charger (110 VAC), and a harness for optional battery back-up.

SPECIFICATIONS:

Inputs	1/8" Phone Jack Audio Input Connector
Outputs	RS-232C Format, 2 each 25-Pin Female Connectors
Data Format	ALERT/IFLOWS Binary Standard, A/I ASCII, A/I Wind, Enhanced IFLOWS Format
Temp Range	-30°C to +50°C
Operating Temp	-30°C to +50°C
Enclosure	Aluminum Box with External Connectors (Screw Terminals, 1/8"Phone Jack, RS-232C 25-Pin)
Power	12 VDC (300 mA Charger is Included) Active <220mA; Standby 13mA
Size	2.063" H x 8.375" L x 6.375" D
Weight	2 Pounds
Shipping Weight	3 Pounds

ORDERING GUIDE:

Model 1000-03	ALERT Decoder

OPTIONAL:

Model 1000-09	ALERT/IFLOWS Decoder with User Programmable Pass/Fail Capability; Includes Float Charger, Battery Cable & 9-Pin Serial Cable.
Model 5601-00	7 Amp Hour Battery

ACCURACY YOU CAN COUNT ON

WEB SITE: www.highsierraelectronics.com *E-MAIL:* info@highsierraelectronics.com

MODEL 2400
Tipping Bucket Rain Gauge

- One-Piece Machined Aluminum Bucket
- Accuracy of ±1.5% for 0 to 2 Inches per Hour
- Measures in 1mm and 0.01 In. Increments
- Set-And-Forget Operation

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS FAX: (530) 273-2089

2400-00, 2400-02

2400-03

DESCRIPTION:

The 2400-00 Tipping Bucket Rain Gauge provides state-of-the-art technology for ALERT flood warning. It consists of a 12″ diameter housing, a 12″ anodized funnel, a 12″ anodized debris screen, and a 4″ stainless steel screen. The Tipping Bucket Mechanism is mounted on an anodized aluminum base with an integrally mounted bulls-eye level that uses spring-tensioned adjusters for accurate, set-and-forget operation.

The gauge comes complete with 25′ signal cable and 5 Pin MS connector. Water is directed into the tipping bucket mechanism which is adjusted to tip when 1mm or 0.01 inch of rain is collected. As the bucket tips, it causes a magnet to pass over a sealed reed switch, closing the switch momentarily. The contact closure is then counted by the circuitry in the data collection equipment. Measurement accuracy is ±1.5% at a precipitation rate of 0 to 2 inches per hour and ±3% for above 2 inches to 6 inches per hour. Water is discharged through drain holes at the base of the gauge housing, these holes are protected by screens to prevent insect entry.

The Model 2400-00 is designed to fit on a standpipe assembly, but can easily be a "standalone" with the Roof Mount option.

SPECIFICATIONS:

Catch Bucket	Machined Aluminum
Sensor Type	Form A 2 Wire Switch
Sensor Housing . .	12″ Aluminum Cylinder
Materials	Anodized Aluminum
Event Resolution .	1mm or 0.01 Inch
Accuracy	±1.5% for 0 to 2 Inches per Hour ±3% for 2 to 6 Inches per Hour
Contact Closure . .	Normally Open - Momentary Contact Closure
Output	Pulse Count - Upward
Output Connector .	5 Pin MS Connector
Orifice Diameter . .	12 Inch, 2.5 Inch Lip above Screen
Operating Temp . .	0°C to 60°C, 32°F to 140°F
Signal Output . . .	Normally Open Contact Closure
Mounting.	Standpipe Assembly
Cable	Shielded
Cable Length. . . .	25 Foot
Size	12″ D x 22.5″ H
Weight	11 Pounds
Shipping Weight .	13 Pounds

ORDERING GUIDE:

Model 2400-00 . . .	Rain Gauge Top Section (Twist-lock)
Model 2400-15 . . .	Rain Gauge Top Section (Slotted)

OPTIONAL:

Model 2400-01 . . .	Rain Gauge Top Section without Spun Cap
Model 2400-02 . . .	Roof Mount Option
Model 2400-03 . . .	1 mm Tipping Bucket Mechanism w/25′ Cable Optional: (2400-10) 0.01 Inch Tipping Bucket Mechanism w/25′ Cable
Model 2400-04 . . .	Exchange - Form "C" - 3 Wire Reed Switch (Sierra Misco Type)
Model 2400-05 . . .	2 Wire Read Switch
Model 2400-06 . . .	Replacement Funnel w/3″ Lip
Model 2400-07 . . .	Altershield for Rain Gauge
Model 2400-08 . . .	Bracket for Altershield & 12″ Tube
Model 2400-09 . . .	Replacement Screen
Model 2400-10 . . .	Tipping bucket w/Base Plate, (.01″)
Model 2400-11 . . .	Top Section Retrofit Kit
Model 2400-16 . . .	Field Calibrator for Tipping Bucket

ACCURACY YOU CAN COUNT ON

WEB SITE: www.highsierraelectronics.com *E-MAIL:* info@highsierraelectronics.com

MODEL 3306
ALERT/IFLOWS Data Transmitter

- 6 Analog Inputs
- 5 Digital Inputs including SDI-12
- Switch Programmable OR Graphical User Interface
- Fuse Protection on Solar Panel, Battery, 12V Switched
- 64 Megabytes of Removable Memory

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS FAX: (530) 273-2089

DESCRIPTION:

The Model 3306 ALERT/IFLOWS Data Transmitter is a powerful and flexible addition to HSE's ALERT/IFLOWS family of products designed with the field technician in mind. The 3306 is housed in a 7” diameter aluminum canister for use in ALERT/IFLOWS standpipe applications. The 3306-16 is housed in a latching, hinged NEMA 4X enclosure. Sensor connections to both models are made via MS connectors.

The 3306-00 standard configuration accepts up to 6 Analog inputs (plus internal battery), up to 2 shaft encoders, up to 2 precipitation, SDI-12, wind speed, wind direction and peak gust. The 3306-16 accepts up to 8 analog inputs.

The basic programming mode allows the user to configure the unit simply by using rotary switches. Four switches are used to set the Station ID number and a fifth is used to select from factory-defined or user-defined preset sensor configurations for different station types. This allows for very quick set-up without the need for a laptop computer in the field.

Alternately, users can use HSE's Insight Software (a graphical user interface; GUI) for fast, easy set-up from either a desktop or laptop computer in the field. The user can program the following parameters independently for each sensor to be logged: ALERT/IFLOWS ID number, input number, multiplier and offset, sample interval, amount of change needed to generate an event, transmission hold-off time, amount of change needed to override transmission hold-off time, and a timed report interval.

The 3306 internal firmware is upgradable in the field. When new versions are released, they will be posted on our website for download. These versions are downloadable via the USB cable. The download process will take just a few seconds.

Data are logged on a Secured Data (SD) memory card and can be retrieved via the USB or serial port. The SD memory card can also be removed for later downloading and replaced with a spare card. The 3306 is supplied with a 64 Megabyte SD card and will support cards with up to 2 Gigabytes of memory.

Additional features include fuse protection on solar input, battery and 12V switched to avoid damage to the unit through shorting (these fuses automatically reset when they cool off). Reversing the battery terminals will cause no damage. A dedicated USB port for programming, data retrieval, and uploading of new firmware versions will be accessible at HSE’s website.

Available communication formats are ALERT/IFLOWS and SDI-12 Version 1.3. While the 3306 is supplied with a VHF or UHF data radio for ALERT/IFLOWS data transmission, other communication devices such as GPRS radio (or other radio modems) can utilize the serial port for two-way communications. Future development plans will enable the 3306 to act as a repeater and utilize 2-way interrogation and controller capabilities. Future support for ALERT2™ Protocol is also being developed.

MODEL 3306
Specifications

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS FAX: (530) 273-2089

SPECIFICATIONS:

Sensor Inputs .... 6 Analog 0-5V, Digital Inputs including SDI-12, up to 2 Up-Only Counters, up to 2 Shaft Encoders, Wind Run, ALERT Wind Format, Peak Wind Gust

Total Sensors................ 20

Real Time Clock .... Clock/Calendar with on-board Battery Back Up with Leap Year Correction

Programmable Parameters . . .

Contents	Field Size
Sensor ID	2 (Signed Int, Sign ingnored if next byte=0)
Sensor Type #	1 (See Below)
SDI-12 Address	1
Analog Warmup	1
Sample Interval	2 (0-65535 sec or [18 hrs, 12 min, 15 sec.])
Report Interval	4 (0-2,147,483,647 or > 1 year)
Hold Off	2 (0-65535 seconds)
Change to Tx	2
Override to Tx	2
Precision	1
Adder	4 (float)
Multiplier	4 (float)
Base Set	2
Log on Tx	1

Sensor Type Definition ...... SDI-12, Battery, Analog, Counters (e.g., Precip.), Shaft Encoders, Wind Run, ALERT Wind, Peak Gust.

Read Now .... Live sensor readings

Radio Range .... VHF 136 to 174 Mhz @ 5W UHF and other bands available.

Reporting Modes .... Each enabled sensor can be programmed to transmit on a user Timed-defined basis and/or on a user defined amount of change, also known as Event Mode.

Logging .... Each enabled sensor can log data on a user-defined time interval and can also be set to log data on Transmission.

Logging Medium .... Data are recorded on a removable SD Memory Card.

Logging Capacity........... The file format has a capacity of 512 files. The 3306 creates a file for each sensor each Month. To determine the capacity, devide 512 by the number of enabled sensors. This will give you the number of months of data storage capacity. For example, a site with 5 sensors can store 8.5 years of data [(512 files/5 sensors =102.4 months)/12=8.5333 years.] Logged data can be retrieved using the 3306 Windows GUI or via a HSE supplied supplication using a built-in or stand alone SD card reader.

Transmit Holdoff .... Holdoff time for all transmissions is 20 seconds so that a single 3306 Series Transmitter will transmit no more than every 20 seconds. The hardware circuit will disable the radio after 12 seconds on-time.

Low Battery Holdoff .... When the battery drops below 10.5V, RF Transmissions are disabled. Data Logging continues if transmissions stop due to low battery.

Environmental Monitoring Solutions

WEB SITE: www.highsierraelectronics.com *E-MAIL:* sales@highsierraelectronics.com

MODEL 3306
Specifications and Ordering Guide

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS FAX: (530) 273-2089

SPECIFICATIONS: (continued)

Programming	Rotary Switches or HSE Model 3306 Insight Software (Windows GUI)
Data Format	ALERT Binary Standard
Temperature Range	-50° C. to +70° C.
Operating Temp.	-40° C. to +60° C.
Radio Connector.	BNC
Lightning Protection	Standard on ALL inputs.
ID Number Range	0 to 8191, Switch selectable or GUI programmable.
RF Warm-up Time	Programmable, default 180 milliseconds
Power	12 to 18 VDC < 1mA, Solar Panel connection standard 3-PIN MS Connector
Battery	12 VDC, 12 Amp Hour
Warranty	3 Years from date of shipment

OPTIONS:

Model 3306-03	Connector Circuit Board
Model 3306-06	Transmitter w/ UHF Radio
Model 3306-08	Handar 585 Connector
Model 3306-20	Insight Software / Graphical User Interface
Model 3306-51	Adapter Cable for Sierra Misco Format to 3306 Shaft Encoder #1 (12′)
Model 3306-52	Optical Shaft Encoder to 3306 SDI-12 Cable (6′)
Model 3306-53	Handar to 3306 Shaft Encoder #2 (6′)
Model 3306-54	Optical Shaft Encoder to 3306 SDI-12 on Wind Connector
Model 3306-56	USB Cable
Model 3801-00	Power Amplifier

ORDERING GUIDE:

	3306-00	3306-16
Analog Inputs	**6**	**8**
Up Only Counting	**1**	**1**
Up/Down Counting	**1**	**1**
Input Connectors	**MS**	**MS**
Enclosure	**Aluminum Canister**	**NEMA 4X Enclosure**
Size	**7″ X 17″**	**12″ X 14″ X 5.5″**
Weight	**9 Pounds**	**15 Pounds**
Estimated Shipping Weight	**10 Pounds**	**20 Pounds**

Environmental Monitoring Solutions

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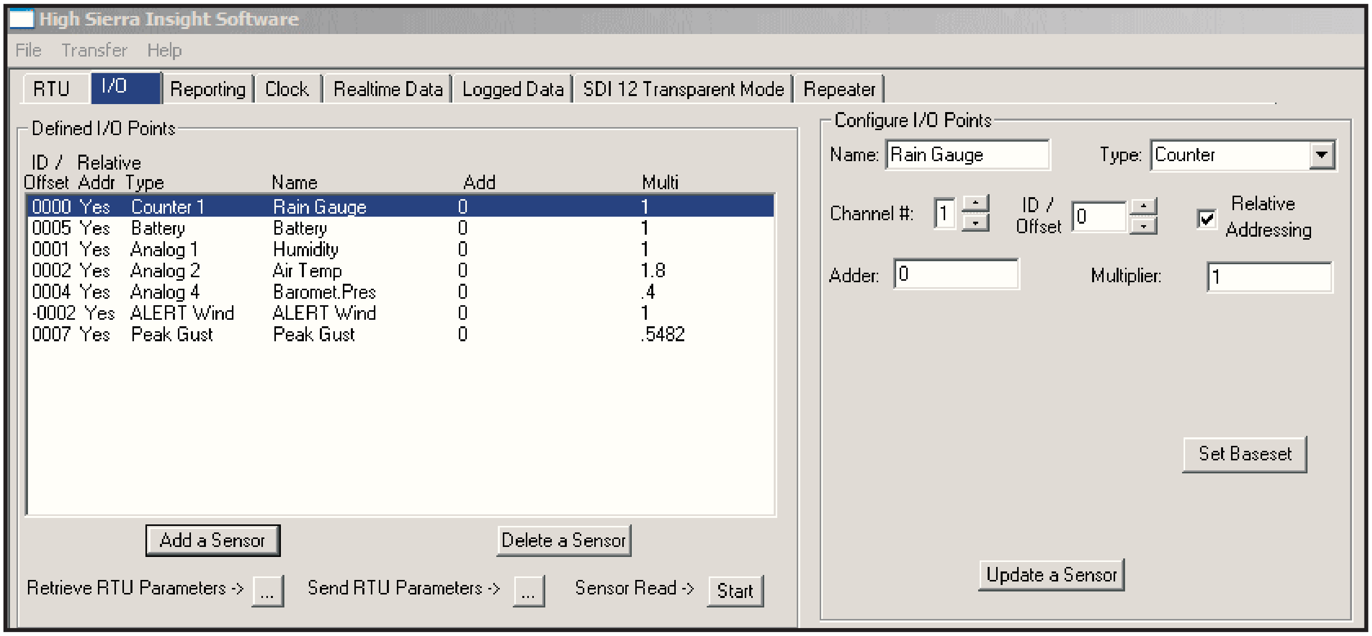
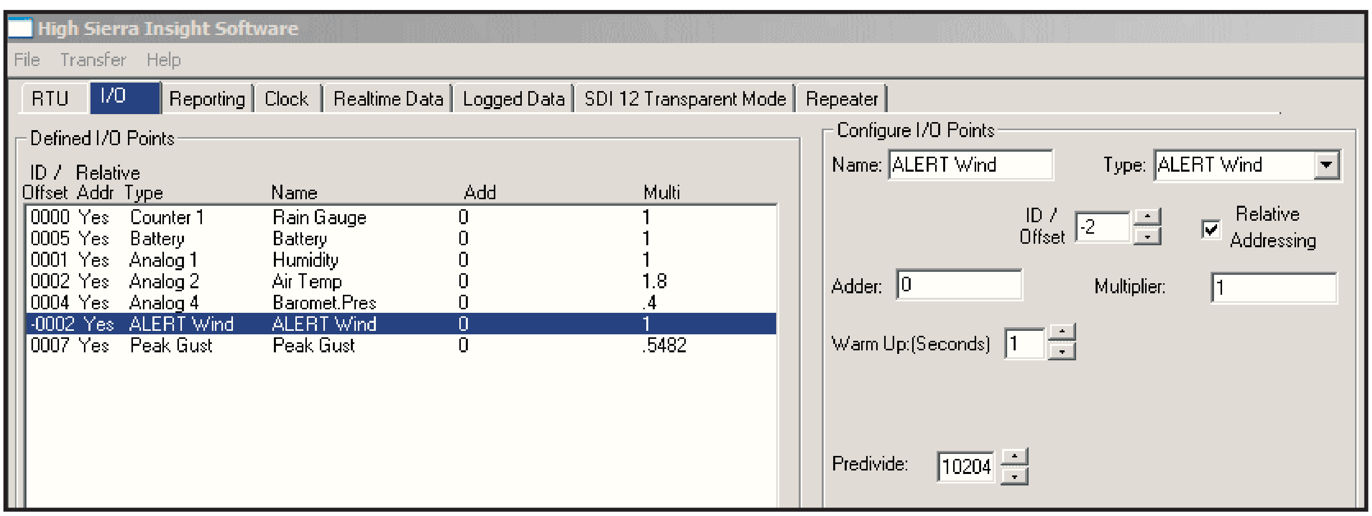
MODEL 3306
INSIGHT Software Screen Shots

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS FAX: (530) 273-2089





Environmental Monitoring Solutions

WEB SITE: www.highsierraelectronics.com *E-MAIL:* sales@highsierraelectronics.com

5300 SERIES
Solar Panels

- Long Outdoor Life
- Effective In Virtually Any Climate
- Mounts Easily
- Includes Mounting Bracket, Regulator, & Cable

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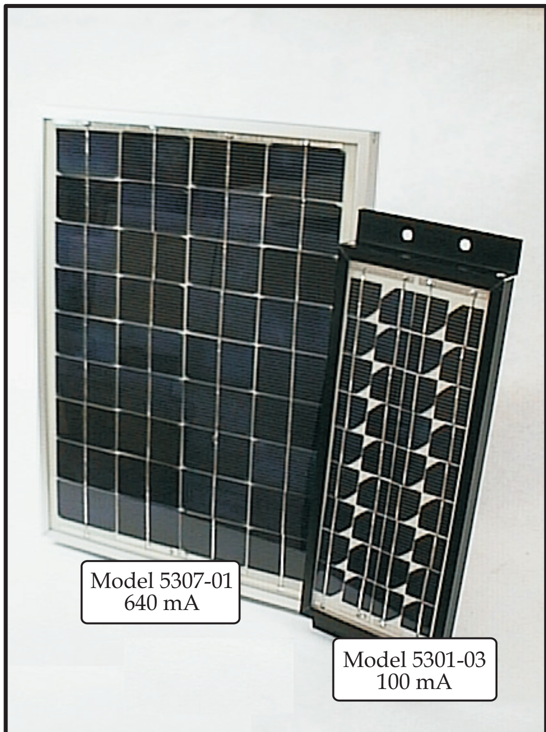

DESCRIPTION:

The 5300 Series of Solar Panels are used for maintaining a battery charge at sites that include control, telemetry, remote sensing, data collection, and other instrumentation systems. High Sierra Electronics uses photovoltaic and thin film technology for reliable, long-term operation. The modules generate direct current (DC) when exposed to sunlight or other sources of light.

When using photovoltaic panels, single crystal silicon cells are the most efficient. Polycrystalline (or multi-crystalline) cells are slightly less efficient than single crystal cells. Efficiency is also affected by cell coverage in the PV module. Square cells can be packed very closely, allowing most of the module surface to generate power. Modules made with round cells will have a lower cost, but the space between these cells is effectively wasted space, and causes the module to have less power output for any given area. Some cells are semi-round and will have an efficiency between round and square cells.

Thin-film modules are less fragile than crystalline modules and use much less silicone, but are about ½ as efficient as PV Modules. There is also a shorter panel life expectancy for thin-film panels.

High Sierra Electronics has many different solar panels in the 5300 Series. Each comes complete with mounting brackets, hardware, blocking diode function, and voltage regulator circuits engineered to efficiently charge 12 volt batteries in any climate without overcharging or discharging.

Providing virtually maintenance-free power to maintain batteries, the 5300 Series offers a durable system design for long outdoor life.

The module should be inspected a least twice a year for overall integrity.

SPECIFICATIONS:

DIMENSIONS:

Model 5301-03	13 x 6 x 1.3″
Model 5302-00	21.2 x 17.8 x 1.5″
Model 5305-01	24.9 x 20.8 x 2.2″
Model 5306-01	48.0 x 13.0 x 1.3″
Model 5307-01	13.8 x 11.2 x 1.4″

SHIPPING WEIGHT:

Model 5301-03	4 lbs
Model 5302-00	11 lbs
Model 5305-00	12 lbs
Model 5306-00	16 lbs
Model 5307-01	6 lbs

ORDERING GUIDE:

Model 5301-03	100 mA; 1.3 Watts regulated
Model 5302-00	1.2Amp; 20 Watts regulated
Model 5305-01	2.25 Amp; 37.0 Watts regulated
Model 5306-01	3.0 Amp; 50.0 Watts regulated
Model 5307-01	640 mA; 10.0 Watts regulated

All Models Include Regulator, Mounting Bracket & Hardware, Cable & Connector.

OPTIONAL:

Model 5310-00	Solar Panel Voltage Regulator, 3 Amps
Model 5100-00	Extra Signal Cable, 2-Conductor
Model 5507-00	Solar Panel Test Kit

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MODEL 5315-01
Solar Charger & Lamp Flasher

- Maximum Power Point Tracking
- 12 Amp Load Capacity
- Overload Protection
- Night Dimming
- RS-232 Data/Programming Port

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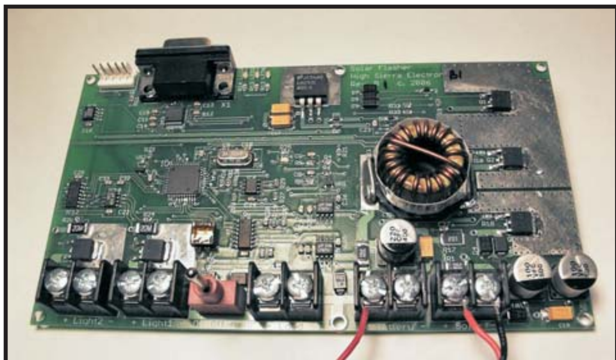

The Model 5315-01 12A MPPT Solar Charger & Lamp Flasher is designed for remote outdoor applications such as flood warning and traffic management systems. The unit monitors and optimizes battery charging from a solar panel using advanced real-time active Maximum Power Point Tracking (MPPT) to ensure that the solar array delivers peak power to the batteries regardless of solar exposure or ambient temperature. For a mostly discharged battery, Maximum Power Point Tracking results in approximately 33% improved charging efficiency compared to standard solar chargers. The unit includes integral protected beacon drivers to activate or flash lights in response to a contact closure or logical low. The beacon drivers incorporate a night dimming feature meeting Texas Department of Transportation TO-4051 Solar-Powered (Photovoltaic) Flasher Assembly specifications.

The Solar Flasher uses a three stage battery charge algorithm. In the bulk charging phase the MPPT charging algorithm measures the voltage and current input from the solar panel and controls the DC/DC converter voltage ratio to maximize power delivered to the battery. When the battery reaches the user -set maximum charging voltage, the charging algorithm enters the absorption phase and the battery voltage is held at the maximum charging voltage for one hour. The float phase then holds the battery at the user-set float voltage. If the battery voltage drops below the float voltage setting for more than one hour, the charge control will start a new bulk charging phase. The unit's internal temperature sensor reduces the maximum charging and float voltages by 30mV/ºC for every degree above 23ºC to protect the battery.

The charge controller microprocessor implements a simple user interface via RS-232 serial port. The user can display and set battery charging parameters and dimming levels using a simple terminal program such as Hyperterm for Windows or ZTerm for Macintosh. When not used for programming, the same RS-232 port provides output data such as battery charge state and battery temperature suitable for remote telemetry.

The microprocessor also controls lamp behavior. A contact closure on the load control terminals activates the lamp circuit, either activating both sets of terminals together, or alternating if flashing is set. The lamps can also be automatically dimmed (up to 75%) at night to conserve battery power. The solar panel acts as the ambient light detector to enable the night dimming. An ON/OFF/AUTO override switch is provided for local control. The light output circuit is protected via automatic over-current protection.

The charge controller enters sleep mode to save battery power if there is no solar power input and the Load Control is OFF, waking when Load control is activated or solar power is available.

Please See Next Page for Specifications...

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MODEL 5315-01
Solar Charger & Lamp Flasher

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SPECIFICATIONS:

Power Requirements	10 to 33 VDC, <1.5 mA Inactive
Solar Panel Sizing	12V @ 3A to 10A (50 to 170 Watt)
Maximum Charging Current	1A to 12A , Default =12A
Maximum Charging Voltage	13V to 15V, Default = 14.1V
Float Voltage	13V to 14V, Default = 13.7V
Load Activation	ON/AUTO/OFF Toggle Switch
Auto Load Activation	Contact Closure, or Logical Low (<1.5V to Ground)
Maximum Load Current	12A per Leg (Flashing), 12A Total (Non-Flashing)
Load Current Limiting	1A to 12A, Default = 4A
Low Voltage Load Disconnect	6V to 15V, Default = 10.8V
Rising Voltage Load Disconnect	6V to 15V, Default = 12.2 V
Dimming	0% to 75%, Default = 75% (Solar Panel Acts as Detector)
Dimming Type	100Hz Pulse Width Modulation
Flashing (if Activated)	Alternating: 1000mSec-1200mSec, Default = 1000
Firmware Upgrades	Bootloader (via RS-232 Port)
LED Indications	System Heartbeat, Load Activated, Override Switch On, Over-Current Protection
Size	6-1/16" X 3-3/8" X 1-3/4"
Mounting	Mounting Plate Provided
Terminals	Screw Terminal Block (12 AWG Max. Wire Size)
Protection	IP20 (Finger Protected)
Operating Temperature	-40^{o} C. to +50^{o} C. (-40^{o} F. to 122^{o} F.)

ORDERING GUIDE:

Model 3515-01	12A MPPT Solar Charger & Lamp Flasher

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SUBMERSIBLE PRESSURE TRANSDUCER – MODEL 664X-00

The Submersible Pressure Transducer – 664X Series provides high accuracy over a wide range of operating conditions, making it ideally suited to environmental monitoring applications such as surface water, streams, and reservoirs.

FEATURES:

- ±0.1% Accuracy
- Field Programmable
- Analog & RS485 Output
- Good Thermal Stability
- Polyurethane Submersible Cable

Description

The Submersible Pressure Transducer – 664X Series provides high accuracy over a wide range of operating conditions, making it ideally suited to environmental monitoring applications such as surface water, streams, and reservoirs.

The Submersible Pressure Transducers are built in the USA and feature a compensated temperature range of 14° to 178° F (-10° to 80° C), a durable stainless steel housing (titanium optional for severe applications, Model 6642-00), and a dual output (analog & RS-485). RS-485 permits you to calibrate your Submersible Pressure Transducers in the field.

The Submersible Pressure Transducers analog output is programmed at the factory for the desired measurement range. The Submersible Pressure Transducers are programmed via an Interface Converter, Model 6640-15, with a USB to RS-485 output. It is recommended that each technician with responsibility for maintaining sites equipped with a Submersible Pressure Transducer – 664X Series have a Model 6640-15 in their toolkit. The 6640-15 allows the technician to set zero and span/range settings for the Submersible Pressure Transducer.

An optional Submersible Pressure Transducer pressure calibrator, Model 5528, is also recommended for maintaining your sensors. This is a highly precise digital manometer with an integrated Max/Min function for calibrating and testing submersible pressure transducers.

Specifications

Operating Ranges

Relative	Infinite between 0 to 3 ft and 0 to 900 ft (0 to 0.9 m and 0 to 274.3 m) Water Column (WC)
Absolute	Infinite between 0 to 29.008 PSIA and 0 to 159.544 PSIA (0 to 2 bar to 0 to 11 bar)
Accuracy	±0.1% FS, includes hysteresis, linearity, and repeatability
Resolution	0.002% Full Scale
Compensated Temp Range	14° to 178° F (-10° to 80° C)
Temperature Effects	Total Error Band is ±0.25% 14° to 132° F (-10° to 55.56° C)
Output	4 to 20 mA + RS-485, or 0 to 5 VDC

Supply Voltage

Model 6640	13 to 28 VDC
Model 6641	11 to 28 VDC
Warm Up Time	1 second
Response Time	≤1 milliseconds
Overpressure	2 times the rating of the transducer
Barometric Compensation	Vented to the atmosphere
Signal Cable Length	12 ft (3.7 m) standard
Submersible Cable Length	35 ft (10.7 m) standard
Submersible Cable Weight	0.07 lbs/ft (0.1 kg/m)
Max Submersible Cable Length	250 ft (76.2 m)
Wetted Materials	Standard 316L Stainless Steel (Optional Titanium), Polyamide, Fluorocarbon
IP Rating	IP 68

Dimensions & Warranty

Model 6640-00	3.74×0.825 in (9.5×2.1 cm) (LxDia)
Model 6641-00	4.52×0.825 in (11.5×2.1 cm) (LxDia)
Desiccant Box	6x9x4 in (15.2×22.9×10.2 cm)
Weight	4.75 lbs (2.2 kg)
Shipping Weight	9 lbs (4.1 kg)
Sensor Warranty	2 year manufacturer warranty
Desiccant Box Warranty	3 Years from date of shipment

MODEL 6753
Radar Level Sensor

- Non-Contact
- Continuous Measurement
- Accurate, Reliable Operation
- Easy Installation

PHONE: (800) 275-2080 HIGH SIERRA ELECTRONICS, INC. FAX: (530) 273-2089

BENEFITS:

- Non-contact measurement means less likelyhood of losing your sensor to debris and silting conditions.
- HistoROM data management concept for fast and easy maintenance and diagnostics.
- Have the highest reliability even in the presence of obstructions in the water due to new Multi-Echo Tracking evaluation.
- Seamless integration into ALERT/ALERT2 management systems.

DESCRIPTION:

The Model 6753 Radar Level Sensor is a 'downward-looking' measuring system. It measures the distance from the transmitter to the water's surface. Radar impulses are emitted by an antenna, reflected off the water surface and received again by the radar system.

Traditionally, ultrasonic devices have been the preferred level measurement technique in many stream monitoring applications where budget restrictions are tight. And while ultrasonic level measurement indeed provides a low-cost solution, it can however, suffer from problems of echo loss and poor temperature compensation. The 6753 offers an accurate and reliable alternative to ultrasonics.

The Model 6753, has even more intelligent and reliable signal analysis with its Multi-Echo Tracking technology. All of the echo signals are marked and tracked, not only the level signal. Thanks to the new analysis, the level signal is also acquired if it is partly covered by baffles and/or debris. This guarantees safe and precise measurements at any time.

Model 6753's HistoROM data management function allows fast and easy maintenance and diagnostics. As well as continuously backing-up all relevant data, it allows you to replace your instrument module quickly and simply by installing it into the housing. The HistoROM function automatically uploads the configuration to the new module. HistoROM also offers intuitive and user-friendly menu guidance to cut the cost of training, maintenance, and operation.

The 6753 provides non-contact continuous measurement. The sensor has a measuring range of approximately 98 ft (30 m) and has a display for simple menu-guided operation. Configuration software is included with the sensor. NOTE: The 6753 can be freely mounted outdoors — operation is completely harmless to humans and animals.

WEB SITE: www.highsierraelectronics.com *E-MAIL:* sales@highsierraelectonics.com

Model 6753 Radar Level Sensor

SPECIFICATIONS:

Range	Approximately 98 feet (30 meters)
Accuracy	± 0.12 in (± 2 mm) to ± -0.03%
Signal Output	2-wire: 4-20mA HART
Beam Angle	10 Degrees
Power Requirements	10.4 to 35 V (For ambient temperatures $T_a \leq$ -4 °F (-20 °C) a minimum voltage of 15 V is required for the startup of the device at the MIN error current (3.6 mA). The startup current can be parametrized. If the device is operated with a fixed current I ≥ 5.5 mA (HART multi-drop mode), a voltage of U ≥ 10.4 V is sufficient throughout the entire range of ambient temperatures.
Operating Frequency	26 Ghz
Display Operation	SD02 4-line, push buttons + data backup function
Electrical Connection	Thread NPT 1/2
Process Connection	UNI slip on flange 3 in/DN80/80, PP max 4 bar abs/58 psia, suitable for NPS 3 in CI. 150/DN80 PN16/10K 80
Antenna	Horn 3 in (80 mm), PP cladded
Housing	GT20 Dual compartment, Aluminum, coated
Enclosure Rating	NEMA 4X/6P
Environmental Protection	IP 66/68
Operating Temperature	-40° to 176°F (-40° to 80°C)
Dimension	5.5 x 11 in (13.97 x 27.94 cm)
Weight	5.5 lbs (2.49 kg)
Shipping Weight	9 lbs (4.08 kg)
Approval	Non-Hazardous area

ORDERING GUIDE:

Model 6753-00	Radar Level Sensor; Default Range 0 to 40.95 ft (12.48 meters). Included 6725-03 Signal Converter/Power Supply and 6 ft. signal cable. Maximum Range 98 ft. (30 meters)

OPTIONS/SPARE PARTS:

Model 6753-03	Mounting Enclosure; (FMR Radar Sensor) (14 x 14 x 12 in), (35.56 x 35.56 x 30.48 cm) w/Hinged Cover & Key Lock. Powder coated white color.
Model 6753-04	Radar Water-Level Sensor Mounting Enclosure; 18 x 22 x 24 in (45.72 x 55.88 x 60.96 cm) Includes: Powder Coat White Finish w/Hinged Cover, Key Lock, & 8.5 ft (2.6 meters) Antenna Mast.
Model 6725-03	Signal Converter & Power Supply; Converts 12 V to 24 V & 4-20 mA to 0-5 V
Model 5101-00	Extra Signal Cable, 3 Conductor. In foot increments.

See www.highsierraelectronics.com for more specification and ordering information.

02-6753-00(B)

MODEL 7100
Omni-Directional Antenna

- 144 to 175 Mhz Range
- Easily Adjusted to Exact Operating Frequency
- Requires No Ground Plane or Radials

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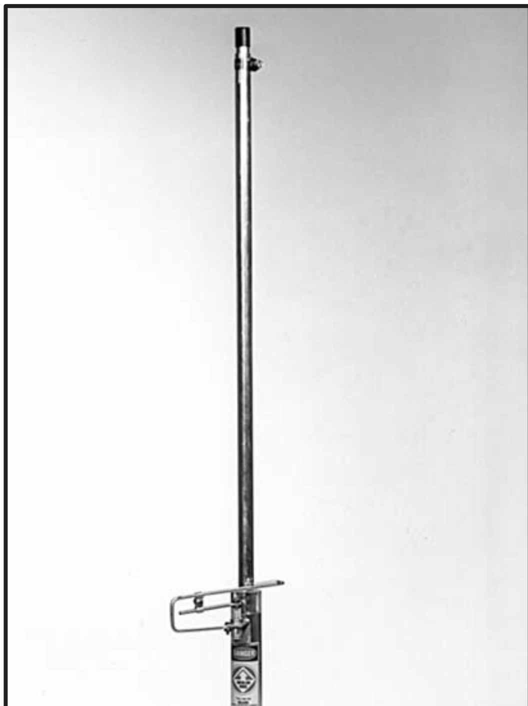

DESCRIPTION:

The Model 7100 Omni-Directional Antenna is a unity gain base matched 1/2 wave vertical antenna. It requires no ground plane radials for effective operation and easily adjusts to the exact operating frequency.

Typical applications for the Model 7100 include 7000 Series Standpipes, base stations and repeater sites where there are existing towers. It is made of seamless aluminum tubing and includes all stainless steel hardware for years of trouble-free service.

SPECIFICATIONS:

Size	.75 Inch diameter radiator 35 to 60 inch length
Connector	SO-239
Weight	1 pound
Shipping Weight	4 pounds

ORDERING GUIDE:

Model 7100	Unity Gain VHF Omni-Directional Antenna (specify frequency)

OPTIONAL:

Model 7150	Antenna Cable, 22 feet
Model 7200	Antenna Lightning Protection
Model 7150-02	Antenna Cable Set, using Lightning Protection, 23 feet
Model 7151	Foam Transmission Cable - ½ inch / 1 foot
Model 7151-1	N-Type connectors (for foam type transmission cable)
Model 7152	Foam Transmission Cable - 7/8 inch / 1 foot
Model 7152-1	N-Type Connectors (for foam type transmission cable)
Model 7153	RG8 Cable, 1 foot
Model 7150-02	Lightning Protection Antenna Cable Set
Model 7200	Antenna Lightning Protection

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MODEL 7200
Lightning Protection Device

- 1.5 to 1000 MHz Frequency Range
- Multi-Stroke Capability
- Low Strike Throughput Energy
- DC Blocked

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DESCRIPTION:

The Model 7200-00 Lightning Protection Device reduces the risk of system failure for equipment frequently exposed to lightning storms. Electrical surges due to lightning are common sources of sensor and data acquisition equipment failures. Although protection against a direct lightning strike can not be guaranteed, the Model 7200-00 minimizes the amount of energy that will get through to the equipment. It diverts the strike energy to the Earth through a deliberate and controlled path so that no damage will be incurred.

As a broadband VHF/UHF coaxial protector, the 7200-00 is designed for general radio use where transmitter combining is ***not*** done. It works on all equipment unlike DC continuity protectors which can not protect receivers, shunt fed cavities, etc. Other features include multi-strike capability and bulkhead mounting for antenna connections to the chassis.

The 7200-00 has an aluminum enclosure, UHF nickel shell (silver center) TFE or N silver shell and gold center pin. Its small size makes it ideal for mounting in ALERT standpipes and inside NEMA enclosures. Specify connector types when ordering.

SPECIFICATIONS:

Connectors.	Type “N” (Standard)
Size	1”D x 1.5”W x 2.75”H
Weight	5 ounces
Shipping weight	1 pound

ORDERING GUIDE:

Model 7200-00 . . . . . . Antenna Lightning Protection Device

OPTIONAL:

Model 8000-03 . . . . . . Telephone Modem Lightning Protection

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Appendix H – ALERT and ALERT 2 protocol descriptions

ALERT:

One of the oldest radio protocols designed for flood alert systems is the Automated Local Evaluation in Real Time (ALERT) data protocol. This legacy protocol conserves power as it is "event-based". Field stream gauge stations using the ALERT protocol only transmit data once or twice per day to verify the station healthy (i.e., powered). The stations also transmit when a rainfall or stream level conditions changes (i.e., increases or decreases by a user-defined amount).

Gauge transmissions are assigned unique 4-digit ID numbers defined by the ALERT protocol. The first 3 digits indicate gauge location and the last digit indicates sensor type (0=rainfall, 3=stage, 5=battery). Master site ID numbers for ALERT transducer network gauges is 4 digits ending in 0 (e.g., 1010 is the Main Street gauge station ID for Belton's flood alert system).

While sufficient for smaller flood alert system's, ALERT suffers from several limitations including a limited sensor ID pool, integer only data values between 0 and 2047 (i.e., limits stream level range of sensor), 300-baud transmission speed, and data loss due to message collisions.

User demand for higher quality data, faster transmission, less data loss, more sensor IDs and more complete data types has led the hydrologic community to design a better solution; ALERT2, which takes advantage of modern technology while maintaining backward compatibility with the legacy ALERT protocol.

ALERT2:

The new ALERT2 protocol has overcome many of ALERT's weaknesses, including carrying higher-resolution information (i.e., including engineering units) with much faster throughput, eliminating data loss due to message collisions, eliminating incorrect data reports, expanding the ID name space that had been exhausted in several regions, improving previously inefficient use of radio spectrum, and data encryption for security.

Also included is provision for 2-way communications which allow for system checks, updates, and remote control of attached equipment (i.e., warning lights, crossing arms, sampling hardware, etc.) without need to physically visit field gauge station locations.

A white paper describing the ALERT and ALERT2 protocols and their history can be found at: https://onerain.com/wp-content/uploads/2017/06/ alert2-transmission-protocol-overview-logan-gayl-thompson-v2.0.pdf.

Appendix I – Environmental sensor and hardware descriptions

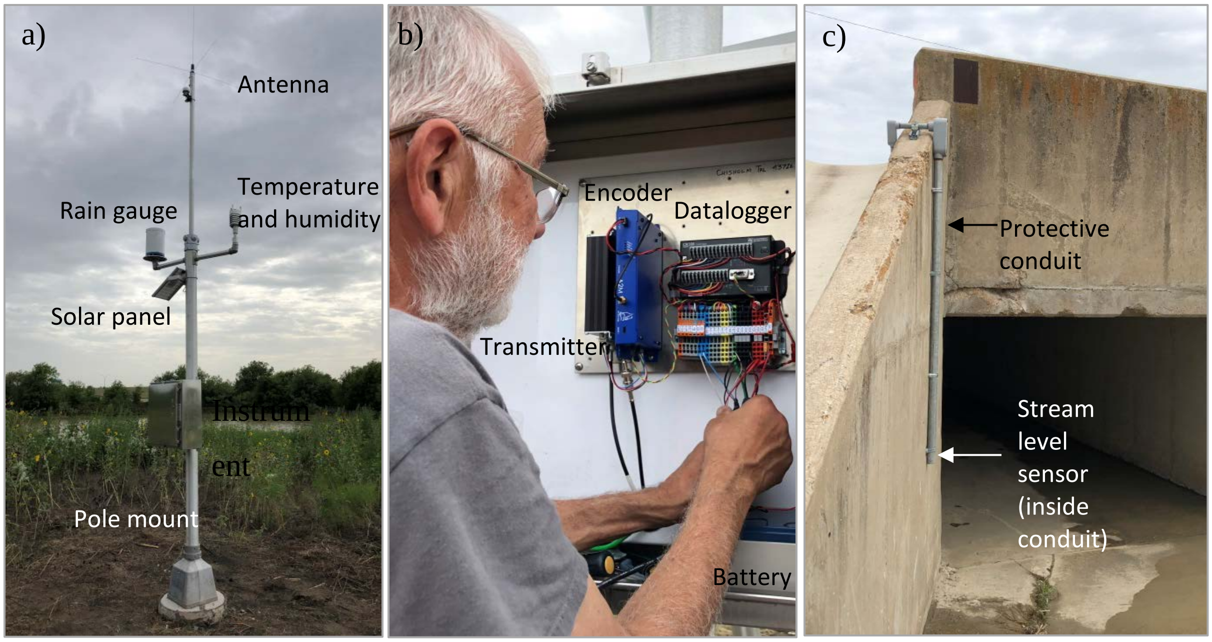
Field Gauging Stations:

Field gauging stations are comprised of hardware and electronic devices which measure environmental conditions, organize, store, and transmit data. Solar panels and batteries are used to provide power in remote locations. The figures show a complete flood monitoring gauge.

Dataloggers:

Electronic sensor measurements are collected, stored, and managed with a “datalogger”. This is an electronic device equipped with a microprocessor and internal memory for data storage. The datalogger manages attached sensors, stores electronic signals (i.e., measurements) gathered from the sensors, conducts mathematical operations (i.e., summing or averaging sensor readings), and handles communications (i.e., data transfer) through the data encoder and transmitter.

An electronic sensor used to measure environmental parameters such as rainfall and water level is known as a transducer – a device that converts a physical measurement to an electronic signal which can be transmitted and evaluated by computers. Numerous transducers are available for measuring environmental parameters such as rainfall, water level, temperature, and wind speed.



Field stream gauge for a local flood alert system
Gauging station includes pole mount with equipment cabinet, solar panel, rain gauge, temperature and humidity sensors, and antenna (a), instrument cabinet with transmitter, encoder, datalogger, and battery (b), pressure transducer (i.e., stream level sensor), and protective conduit mounted within channel (c).

Rain sensors:

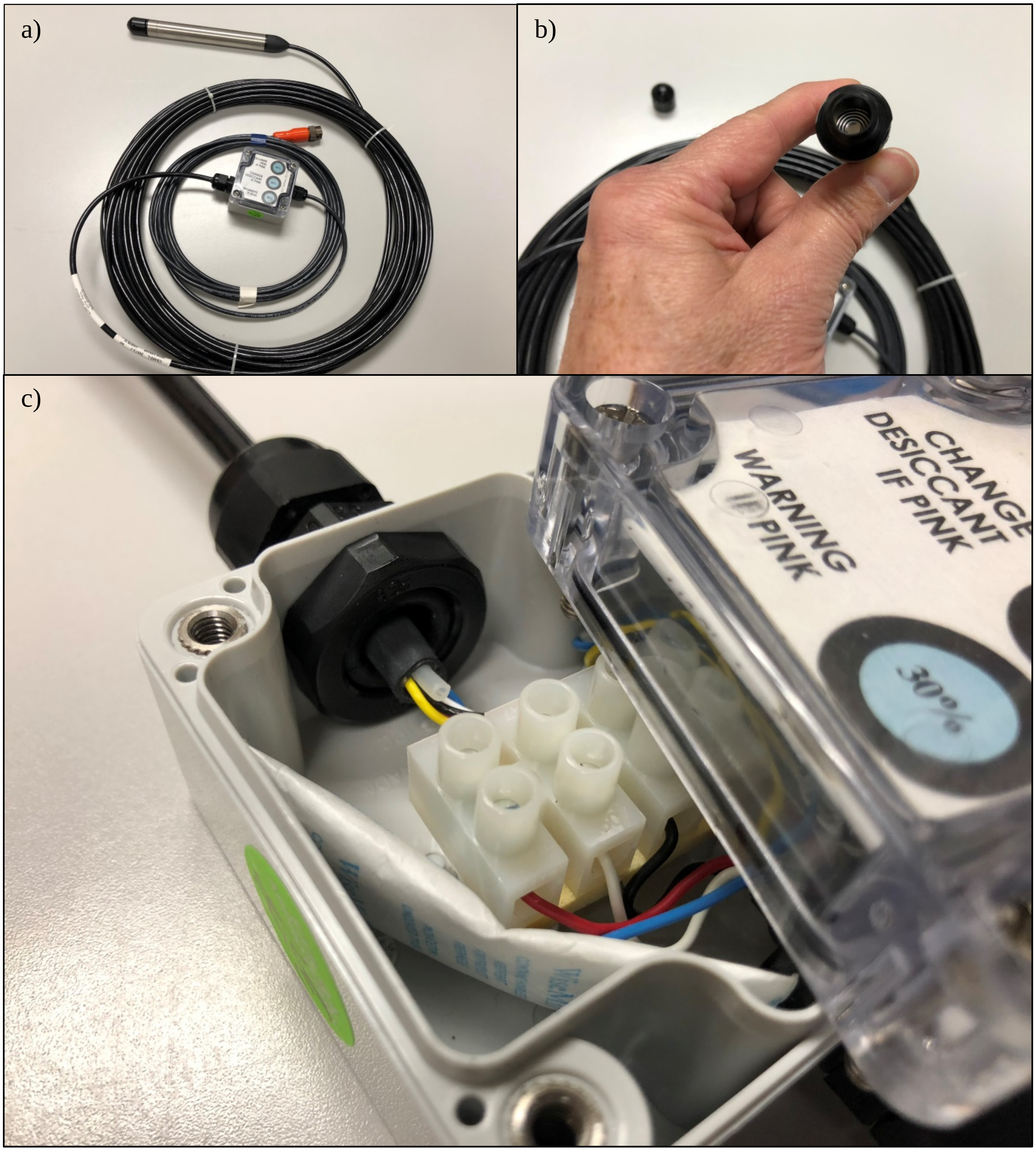
Tipping-bucket rain gauges are the most common type of rain sensor used in flood alert systems. A funnel catches rainfall and drains to one of two “buckets” mounted on a lever carefully balanced over a pivot point, much like a child’s “see-saw” (see figure below). As the top bucket fills to a calibrated amount (e.g., 1/100 inches of rain), the change in weight causes the lever to tip; the top bucket shifts to the bottom and empties while the empty bottom bucket moves to the top and the process repeats. As the lever tips back and forth, a magnet mounted on the lever passes by a magnetic switch with each tip. The number of times the switch closes (i.e., tips) is recorded by an electronic datalogger. Total tips indicate rainfall amounts (e.g., 100 tips at 1/100th of an inch per tip = 1 inch) while tips per unit time indicate rainfall rates (e.g., 100 tips per hour = 1 inch of rain per hour). Rainfall amounts and rates provide critical information necessary for monitoring developing weather conditions, forecasting flooding events, and issuing watches and warnings.

Close up of a tipping bucket rain gauge mechanism

Water level sensors:

Water level or height may be determined by many methods. Two of the most commonly employed in flood alert systems include pressure transducers and radar transducers. Pressure transducers are less expensive than radar transducer's but require more maintenance and are sensitive to environmental conditions.

Submersible pressure transducers convert pressure into an electrical signal through the physical deformation of a piezoelectric material (crystal or ceramic) bonded to a metal diaphragm. As the water level above a pressure transducer increases, the weight of the water column exerts pressure on its diaphragm which bends the piezoelectric material, changing its electrical resistance. The electrical signal is measured and recorded by a datalogger. Pressure transducers offer very high measurement precision, typically <1% of the instruments electrical range, but must be protected from environmental hazards and still be easily accessible for maintenance. For best results they should mounted so they maintain "hydraulic connectivity" (i.e., remain in constant contact with water) because a dry, *malfunctioning*, pressure transducer looks electrically identical to a dry, *functioning*, pressure transducer. Also, salt and/or sediment buildup on the diaphragm due to wet-dry cycling can cause measurement errors. Pressure transducers are sensitive to shock and may be damaged in turbulent flood waters. They must be mounted securely in a location protected from rocks and debris carried in the flow. Temperature affects all electrical circuitry and although most pressure transducers have built-in temperature compensation circuitry, they must be located so as to avoid highly fluctuating temperature extremes such as concrete surfaces in direct sunlight. Atmospheric variation (i.e., barometric pressure) also exerts pressure on a pressure transducer's diaphragm and requires compensation via a vent tube connecting the inside of the pressure transducer's diaphragm to the atmosphere. The vent tube is contained within the pressure transducer's power cable so care must be taken to avoid crimping or damaged to the cable which will affect the pressure transducer's output. See the figures on the next page for visual reference. Finally, pressure transducers commonly experience electrical drift as they age and must be tracked over time. For all of these reasons, pressure transducers require constant monitoring and regular servicing to insure proper function.



Vented pressure transducer
Transducer head, cable, desiccant box, and datalogger connection (orange) is seen in a). Close up of the transducer's metal diaphragm in seen b). Close up of the atmospheric vent tube extending from the cable inside the desiccant housing is seen in c). Desiccant in c) prevents moisture build-up inside vent tube.

Radar transducers, in contrast to pressure transducers, require less maintenance. They provide non-contact water level measurement by emitting a series of pulsed radio frequency waves that reflect off the target (i.e., the water surface) and echo back to a receiver. The distance between the target and receiver is calculated by evaluating the time interval between signal transmission and reception. Typical radar transducer accuracy is < 5% of the instrument's range and well within that required for flood warning applications. Maintenance is limited to regularly checking the instrument's power system (i.e., batteries and solar panels), external wiring condition, antenna horn condition, and most important, alignment. Radar transducer's have a relatively narrow transmittance beam and must be mounted so they are as perpendicular to the water surface as possible. The structure upon which they are mounted must be secure and immovable as it provides the reference distance from which to determine the water surface elevation. Bridges provide the most common mounting platform however overhanging pole-mounts are occasionally employed. Radar transducer interferences include misalignment, uneven water surface (due to turbulent flow, waves, etc.), floating debris, and damage from vandalism or animal activity (i.e., rodents, spiders, wasps, ants, etc.). Spiders and wasps commonly invade the space within the radar transducer's transmitter horn and affect water level measurements. Many designs have this orifice sealed with a plastic cover but others do not. The figure below shows two commercial radar transducer configurations.

Radar water level transducers
Two different models offered by OTT (left) and Campbell Scientific (right). Note plastic shield covering the transducer horn on the OTT model.

Appendix J – Stage and level descriptions

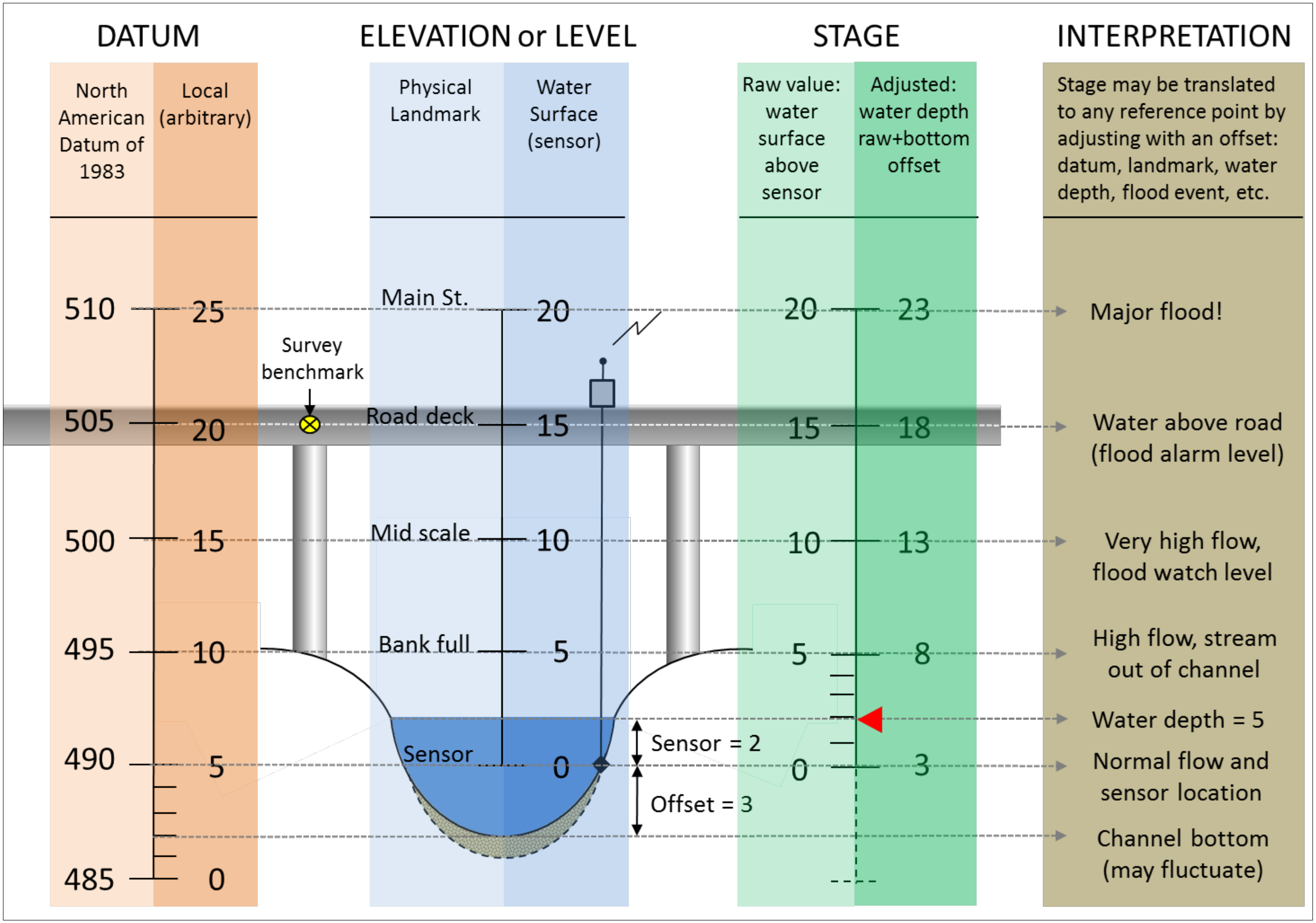
STAGE:

Stream gauge readings are commonly reported as “stage” values. Stream stage is defined as the height or elevation of the water surface above some arbitrary reference point. Interpreting a stage value requires the consideration of at least three distinct ideas: 1) water level, 2) elevation, and 3) a datum. Water level is the height or distance of the *water surface* above, or below, the *measurement point* (i.e., sensor location). Elevation is the height or distance to, *a fixed reference point*. A datum is the fixed reference point. The fixed reference point may be a local “arbitrary” datum or an established geo-referenced datum such as the North American Vertical Datum of 1988 (NAVD88), which is relative to Mean Sea Level (MSL). The combination of these concepts results in a “Stage” value which can be tied to landscape “benchmarks” and provide critical information regarding high water events (See figure on next page).

Arbitrary local datums are commonly applied to local flood alert system stream gauges to address scaling issues. From a conceptual perspective, it is desirable to present stream water level conditions during non-flooding, normal base-flow conditions, as low single digit values. If the local Nolan Creek flood alert system gauge stage values were defined on a georeferenced datum such as NAVD88, they would have values between 500 and 900 feet and would be difficult to interpret (i.e., large values representing low water depths is conceptually problematic).

Water level sensors may be programmed with an “offset” value to reflect actual water depth relative to a landscape benchmark. For example, in man-made channels such as a culvert, water level sensors for flood monitoring are often placed above the bottom to prevent damage. The pressure transducer is programmed with an offset (i.e., elevation or distance from pressure transducer to channel bottom). The sensor will report the offset value until the water surface level rises above the pressure transducer’s diaphragm. Water depths below the pressure transducer, when present, cannot be determined. In natural channels, the elevation of the bottom often changes due to scouring or deposition; because of this, monitoring agencies typically locate the zero point of local datums below the channel bottom to allow for fluctuation and prevent the need to re-survey after every event.

More detailed information regarding stream stages, levels, and datums may be found in USGS manuals by Sauer and Turnipseed (2010) and Kenney (2010).



Hypothetical stream cross-section, bridge, and sensor with stage interpretations.
Water depth is determined from raw sensor value (2) + bottom offset (3) = 5.

Basic stage-impact relationships for Nolan Creek flood alert system gauge locations were prepared by Texas A&M AgriLife Research – Temple for this report (see chart below). This information may be used as a starting point to augment current gauge station information. The addition of other stage values would allow alternative non-flood uses for field gauging station data, such as reporting recreational stream water levels for kayaking, fishing, etc.

LOCATION/SENSOR	STAGE (ft)	IMPACT
Gauge #1120 (Pressure transducer) Roy Reynolds Road Bridge	*21.4*	Road deck
	20.8	Standpipe equipment shelter base
	8.4	Bank full
	≤0.1	Base flow / PT elevation
Gauge #1140 (Pressure transducer) I-14 (US 190) Feeder Road Bridge	*22.2*	Road deck
	21.6	Standpipe base
	5.1	Bank full
	≤1.4	Base flow / PT elevation
Gauge #1050 (Pressure transducer) Paddy Hamilton Road Bridge	*25.4*	Road deck
	25.1	Standpipe equipment shelter base
	18.0	Alarm threshold (Belton)
	15.0	Alert threshold (Belton)
	12.7	Bank full
	≤1.1	Base flow / PT elevation
Gauge #1030 (Pressure transducer) Wheat Road Bridge	*30.2*	Road deck
	30.8	Standpipe equipment shelter base
	7.4	Bank full
	≤2.82	Base flow / PT elevation
Gauge #1010 (Radar transducer) Main Street Bridge	25.7	Road deck
	27.1	Radar shelter (bottom of box)
	15.0	Alarm threshold (Belton)
	12.1	Pavilion dance floor
	8.8	Bank full (sidewalk @ Main St. bridge)
	≤0.9	Base flow

Note: Italicized values exceed Pressure Transducer range (0-20 ft). Non-flood related information may also be developed such as minimal, optimal, and dangerous kayak conditions.

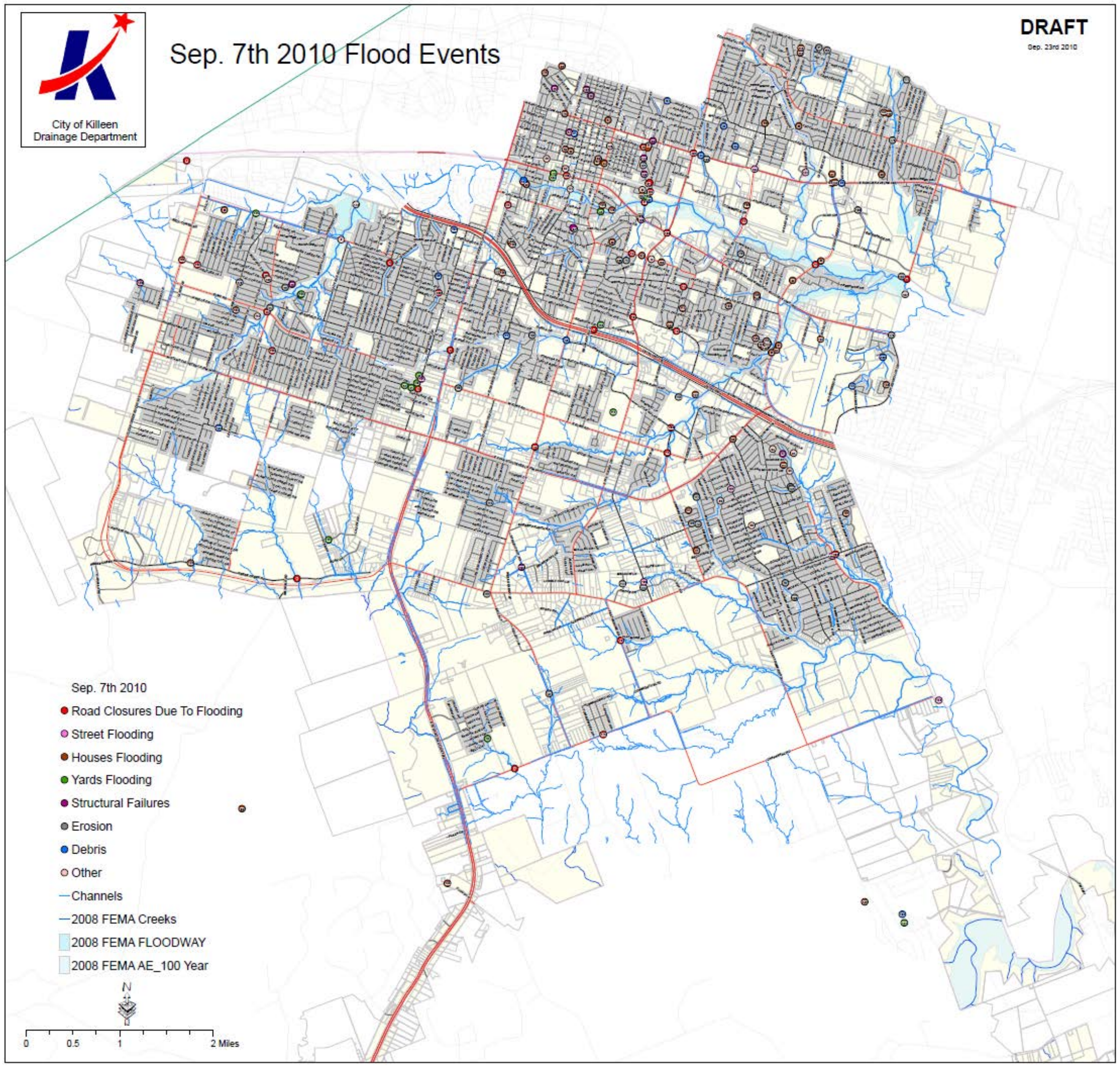
Appendix K – Locations for additional flood instrumentation

City of Killeen

City of Harker Heights

City of Nolanville

City of Killeen - Documented locations which flooded during the 7 September 2010 Tropical Storm Hermine event. Fifty locations of interest, prioritized 1, 2, or 3, that may benefit from additional flood-related instrumentation are shown in the following map and list.



Num	Map#	Priority	Location	Event Type	Need
1	43	1	505 Dimple Street	Houses Flooding	remote arm with flashers and signs (possible siren) duplicate
2	167	1	Roy Reynolds-Rancier Bell WC&ID6 Impoundment Site7	Other	remote arm with flashers and signs
3	172	1	South Nolan Creek and Second Street	Other	remote arm with flashers and signs (possible siren) duplicate
4	202	1	28th and Ave. G	Road Closures Due To Flooding	remote arm with flashers and signs (possible siren) duplicate
5	21	1	28th St between VMB and Greenwood	Road Closures Due To Flooding	remote arm with flashers and signs (possible siren)
6	12	1	38th St. below the overhead railroad track	Road Closures Due To Flooding	remote arm with flashers and signs
7	10	1	505 Dimple	Road Closures Due To Flooding	remote arm with flashers and signs (possible siren) duplicate
8	193	1	Greenwood and Alexander	Road Closures Due To Flooding	Need remote arm with Flashers and signage
9	1	1	Reese Creek Rd Near Maxdale Rd	Road Closures Due To Flooding	remote arm with flahsers and signage
10	8	1	Roy Reynolds south of railroad Near Roy J Smith	Road Closures Due To Flooding	Need remote arm with Flashers and signage
11	203	1	Stagecoach and Rosewood at creek crossing	Road Closures Due To Flooding	Need remote arm with Flashers and signage (duplicate entry?)
12	11	1	Twin Creek Rd and the railroad tracks	Road Closures Due To Flooding	Need remote arm with Flashers and signage
13	209	1	2nd St and SNC	Street Flooding	Need remote arm with Flashers and signage
14	214	1	4317 Water SNC	Street Flooding	Need remote arm with Flashers and signage
15	128	1	Chaparral Road and Harker Heights City Limit	Street Flooding	Need remote arm with Flashers and signage
16	131	1	Long Branch Park	Street Flooding	Currently a manual arm; Need remote arm with Flashers
17	129	1	Stagecoach Road and Rosewood	Street Flooding	Need remote arm with Flashers and signage
18	169	2	Stewart Ditch at 28th Street	Structural Failures	Currently a manual arm; Need remote arm with Flashers
19	188	2	Dimple Street at SNC	Debris	remote arm with flashers and signs (possible siren)
20	170	2	3816 Water Oak	Erosion	flashers and signage
21	171	2	3818 Water Oak	Erosion	flashers and signage
22	44	2	309 N 10th Street	Houses Flooding	flashers and signage
23	125	2	613 Little ave	Houses Flooding	flashers and signage possible siren
24	126	2	638 Little ave	Houses Flooding	flashers and signage possible siren
25	123	2	Reese Creek Rd	Houses Flooding	flashers and signs
26	173	2	SNCWatercrestFortHoodBellWC&ID6ImpoundmentSite1	Other	flashers and signs (txdot)
27	194	2	Clear Creek & Desert Willow	Road Closures Due To Flooding	Flashers and signage

28	204	2	Cunningham Road and Little Nolan Road	Road Closures Due To Flooding	Flashers and signage
			Willow & Heather	Due To Flooding	and signage
30	15	2	Elms Rd. and Cunningham	Road Closures Due To Flooding	Flashers and signage
31	24	2	Elms Rd. and Robinett Dr	Road Closures Due To Flooding	Flashers and signage
32	18	2	Featherline between Chaparral and Stagecoach	Road Closures Due To Flooding	Flashers and signage
33	13	2	Illinois Ave. between Grey Fox and Goode	Road Closures Due To Flooding	Flashers and signage
34	206	2	Leader near Meadow Drive	Road Closures Due To Flooding	Flashers and signage
35	23	2	W.S. Young between Elms and Stan Schlueter	Road Closures Due To Flooding	Flashers and signage
36	16	2	W.S. Young Dr. and Illinois Ave	Road Closures Due To Flooding	Flashers and signage
37	205	2	Chantz and Peppermill Hollow	Street Flooding	Flashers and signage
38	53	2	168 Laura Drive	Yards Flooding	Flashers and signage at creek crossing
39	153	3	4006 Pilgrim Units A,B,C,&D	Houses Flooding	Warning Siren with signage?
40	152	3	4007 Pilgrim Units A,B,C,&D	Houses Flooding	Warning Siren with signage?
41	156	3	4008 Pilgrim Units A,B,C,&D	Houses Flooding	Warning Siren with signage?
42	155	3	4010 Pilgrim Units A,B,C,&D	Houses Flooding	Warning Siren with signage?
43	154	3	4012 Pilgrim Units A,B,C,&D	Houses Flooding	Warning Siren with signage?
44	84	3	403 - 445 S Twin Creek Drive Apartment 1005	Houses Flooding	Warning Siren with signage?
45	157	3	4100 Pilgrim Units A,B,C,&D	Houses Flooding	Warning Siren with signage?
46	151	3	4102 Pilgrim Units A,B,C,&D	Houses Flooding	Warning Siren with signage?
47	6	3	Watercrest Dr at SNC	Other	warning siren & signage
48	210	3	10th and Littile	Street Flooding	Warning Siren?
49	211	3	Killeen St SNC	Street Flooding	Warning Siren?
50	174	3	609 Cardinal	Structural Failures	Warning Siren?

City of Harker Heights – Noted two locations of interest that may benefit from additional flood-related instrumentation.

Num	Location	Event type	Need
1	North Anne Street near Nolan Creek channel	Evacuation required during flooding	Stream level gauge to extend warning lead time
2	FM3219 where it crosses Nolan Creek	Road Closures Due To Flooding	Flashers and signage (txdot) – tie to current system

City of Nolanville – Noted two locations of interest that may benefit from additional flood-related instrumentation.

Num	Location	Event type	Need
1	10th Street & Avenue H – Pecan Village neighborhood	Evacuation required during flooding	Stream level gauge to extend warning lead time
2	Levi Crossing - Levi Road at Nolan Creek channel	Road Closures Due To Flooding	Stream level gauge to extend warning lead time

APPENDIX E:

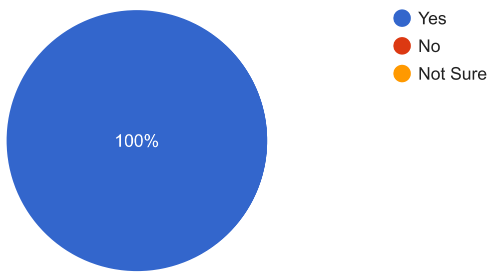
FLOOD EMERGENCY RESPONSE SURVEY RESULTS

Nolan Creek Partners Flood Response Strategies Questionnaire

5 responses

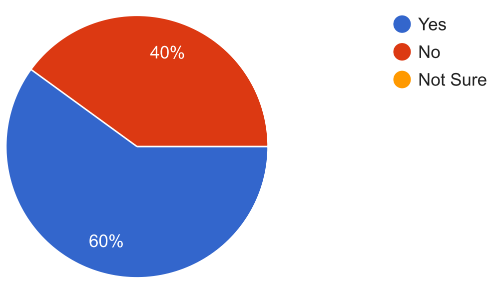
1. Does your local government entity have a designated Emergency Management Coordinator?

5 responses



2. Do you have a written flood management protocol or response plan?

5 responses



3. Where is this kept? Please indicate if it is part of another document or plan, or if it is stand-alone.

4 responses

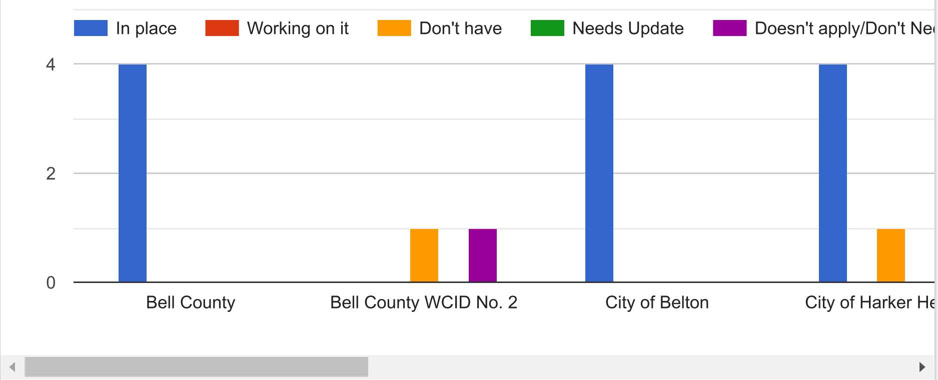
We fall under Bell County Response Plan

Part of an emergency response plan.

Stand alone

In the Emergency Mangement Folder and on FD drives

4. Please indicate the status of interlocal agreements your community has that cover flood response with each of the entities



5. Which department in your organization takes the lead in a flood event response?

5 responses

Chief of Police

Fire Department/EMC

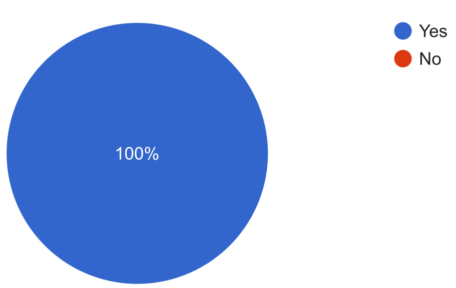
Fire Department then PD and PW

Fire Chief is EMC; PD; PW Depts

Belton Fire Department

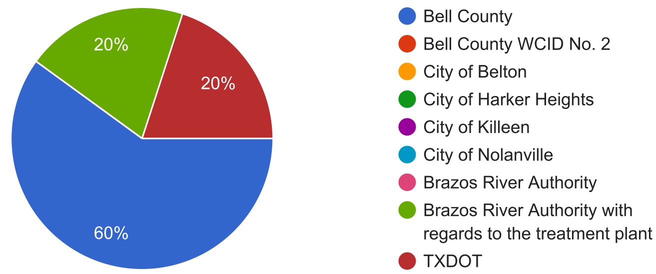
6. Are there known areas where you set out barricades?

5 responses



7. During a flood event, what other entities are you in frequent (more than 1x per day) in contact with?

5 responses



8. Please list the specific communities/entities/departments you are in most frequent contact with during a flood event.

5 responses

CBCFR, Public Works Local, Police Department

City of Harker Heights Police, Public Works and City Administration. Bell County EMC

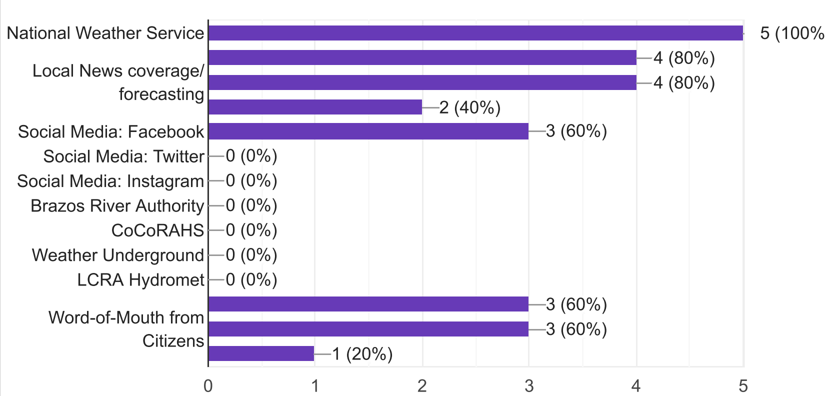
City of Belton: Fire, Police, Public Works, City Manager's office

Belton FD, PD, PW; TXDOT; Bell County; 911 Center

Belton PD, Belton PW, Bell County EMC, Harker Heights FD, NWS

9. What information sources are you watching in making decisions about when to start a protocol or elevate your community's response? (Check all that apply)

5 responses



10. Please elaborate on the information sources available to you, and which are most timely and influential in your decision-making process.

5 responses

Site Observations

We receive data from the State Operation Center (SOC) regarding weather briefings that come directly from the National Weather Service.

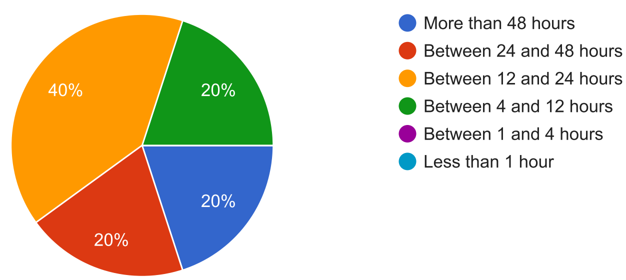
USGS is most accurate; visual inspections are best

Driving around, PD, FD, and PW patrols

Our flood protocol is initiated by considering information from all sources

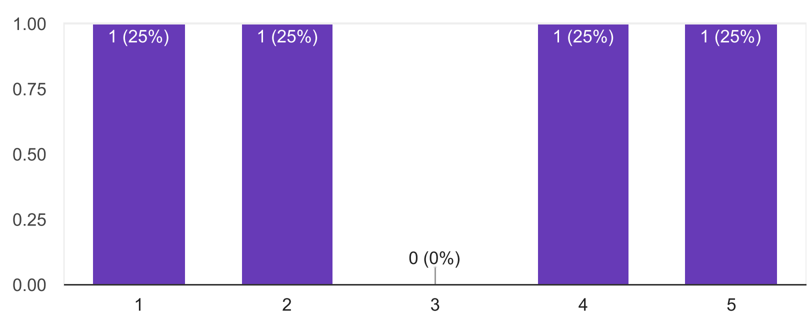
11. How much lead time does the information you monitor provide you in making decisions about response?

5 responses



12. Is this enough time?

4 responses



13. Please elaborate on the lead time that monitored information provides, and include your perceptions of when the information is adequate or not adequate in making response decisions.

5 responses

We are not linked in to rain gauge data.

The lead-time information from the SOC typically provides extensive detail as to the type of rain and or associated events that could occur in the severe weather time-frame. This in-turn provides us with the data to make decisions on pre-staging assets or equipment as well as to let our residents know of what to expect.

USGS is real time, I look at forecast and upstream gages to determine what is coming

Monitor flood gauges in Nolan Creek as water approaches from the west.

We begin to monitor severe weather as soon as NWS begins to indicate the time period weather is predicted to impact our area

14. In the coordination with other entities, what would improve the communication?

5 responses

Not sure

I would say we have good relationships with all entities that we work with and work well.

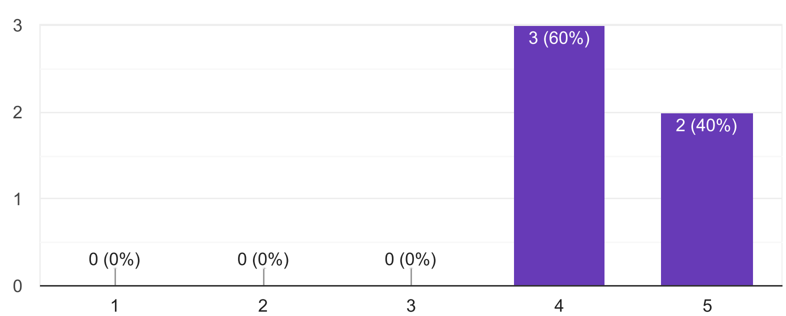
We need interlocal agreements with all entities to help with response to flooding for Public Works.

Working well.

Direct phone calls, Text messaging

15. During the last flood response, did your community have adequate equipment?

5 responses



16. What equipment would assist your community in providing a better response? Please indicate if you already have it, but need more or updated, or if you don't have it.

5 responses

Permanent barricades, monitors that link to Code Red messaging

An enhanced system as to the water levels and notifications for water levels. Specifically a text, email or other digital alerts to water levels.

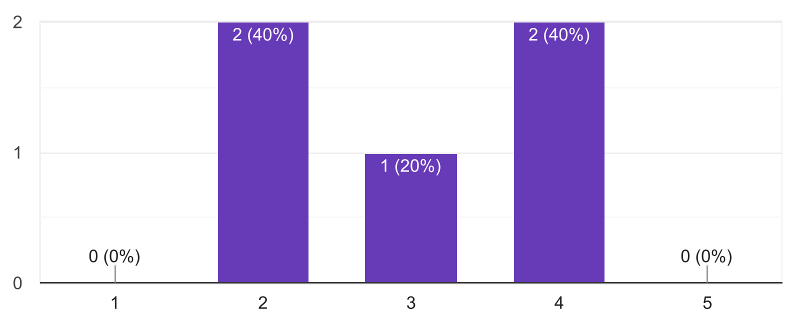
Better flood monitoring gauges, better prediction using the gauges given forecasted rain, flood spread at certain water levels in creek

OK

A better equipped rescue boat which can be easily deployed and specific to swift water conditions

17. Please evaluate the following statement: We have adequate staffing in a flood event.

5 responses



Anything else you would like to elaborate on, share, mark for future discussions, etc.?

2 responses

Code Red Usage

N/A

APPENDIX F:
DIGITAL DATA