West Fork San Jacinto Watershed, TX
Base Level Engineering (BLE) Results

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APPROVALS

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Table of Contents

Executive Summary

FEMA Region VI contracted Compass to complete a Base Level Engineering (BLE) analysis for the HUC-8 watershed West Fork San Jacinto River (WFSJR) in Southeast Texas, to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory-quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development in support of hydrologic and hydraulic analysis as well as mapping activities were leveraged from various local, State, and Federal partners. Details regarding the different datasets used are provided below in Section 1.1.

Flood discharges for this study were calculated the United States Geological Survey (USGS) regression equations that were adjusted to account for Harvey-adjusted flood frequency analyses (explained in further detail below). Regression equations were obtained from the USGS Scientific Investigations Report (SIR) 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach* (2009).

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 4.1 was used to compute water surface elevations on a stream by stream basis. All hydraulic models were computed using 1-D steady state analysis.

In August 2017, the West Fork San Jacinto River watershed experienced record rainfall and flooding from Hurricane Harvey. At the time, Compass was nearly complete with the BLE analysis on the WFSJR under Task Order HSFE60-16-J-0228. The historic scale of the storm and the anticipated level of reconstruction in its aftermath precipitated a need to provide advisory data to the communities most impacted. Per Task Order HSFE60-17-J-0003, FEMA contracted Compass to reanalyze the BLE models for the watershed to account for observed Hurricane Harvey data. Updated flood frequency analyses[1] that incorporated peak Harvey discharges on six USGS gages in the East and West Fork San Jacinto River watersheds were utilized to determine appropriate factors to apply to the USGS regression equations. The BLE models were updated with the Harvey-adjusted peak discharges; a summary of peak discharges is tabulated in Appendix A. In addition, roughness coefficients were revised to calibrate the BLE models to observed Harvey streamflow and high-water data points. The streamflow and n-value adjustments were applied throughout the watershed. A memorandum detailing the methodology behind the adjustments is provided in Appendix C.

The stream mile network that was validated for these watersheds was compiled using FEMA's Community Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risks. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-1 lists the stream miles associated with this validation analysis.

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[1] FEMA (Federal Emergency Management Agency) 2017, *Hurricane Harvey: Precipitation and Streamflow Analysis*.

Table ES-1: Summary of Stream Miles

Source	West Fork San Jacinto Stream Miles
CNMS	448.89
Total	**448.49**

The full inventory of Zone A studies in the watershed were classified in CNMS. Total miles validated in CNMS are summarized in Table ES-2 and illustrated in Figure ES-1 below.

Table ES-2: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	167.94
UNVERIFIED	BEING STUDIED	280.94

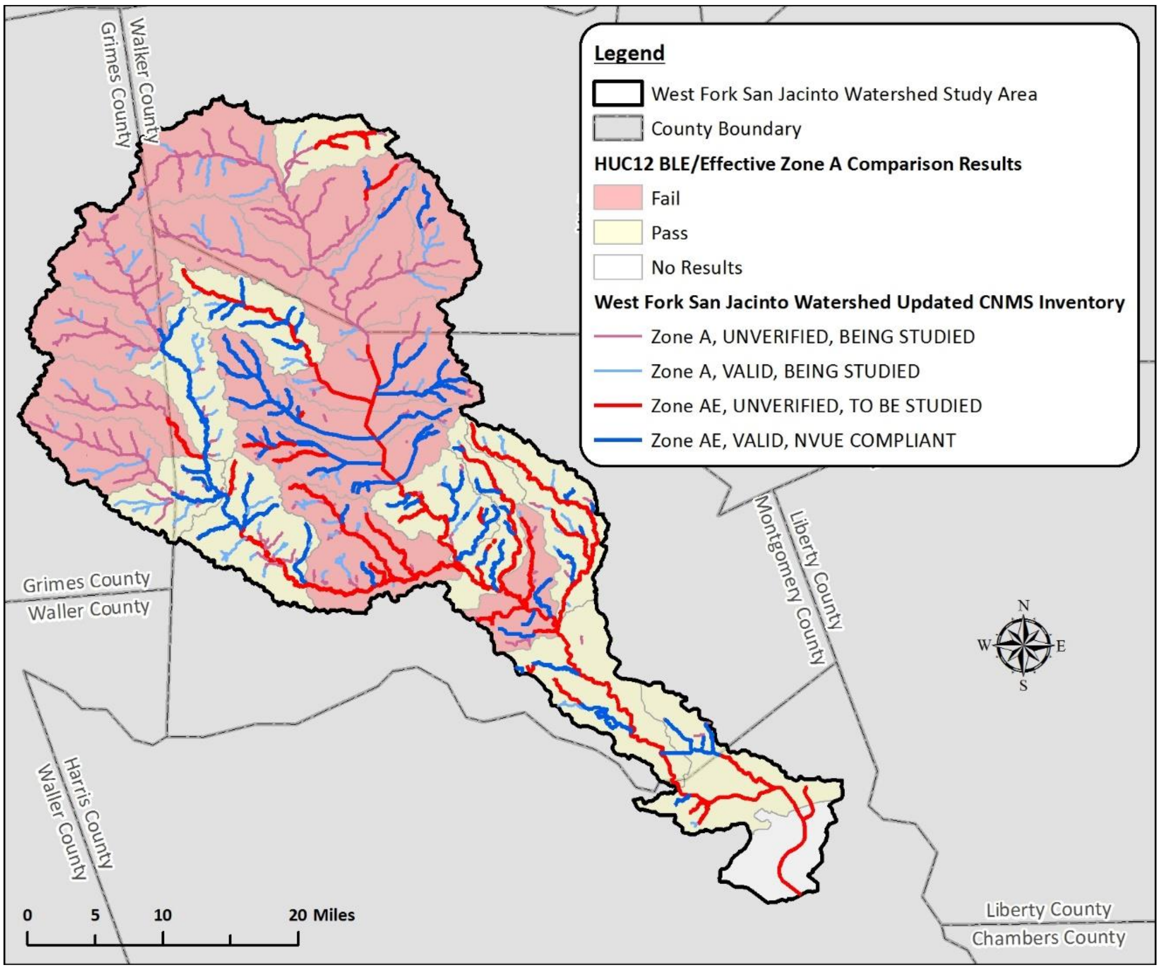

Figure ES-1: West Fork San Jacinto River Watershed CNMS Validation Results

An overall risk for each HUC-12 watershed was calculated using the National Flood Risk Percentages Dataset and its proportional area. The weighted risk was multiplied by the percentage of points in the watershed that failed the CNMS comparison to effective to determine the priority score. Figure ES-2 below shows the range of the West Fork San Jacinto HUC-8 priority scores which can be used to initiate discussions during the Discovery phase.

Little Caney Creek-West Fork San Jacinto River HUC-12 was determined to have the highest priority score and the most need while Caney Creek HUC-12 had the lowest score.

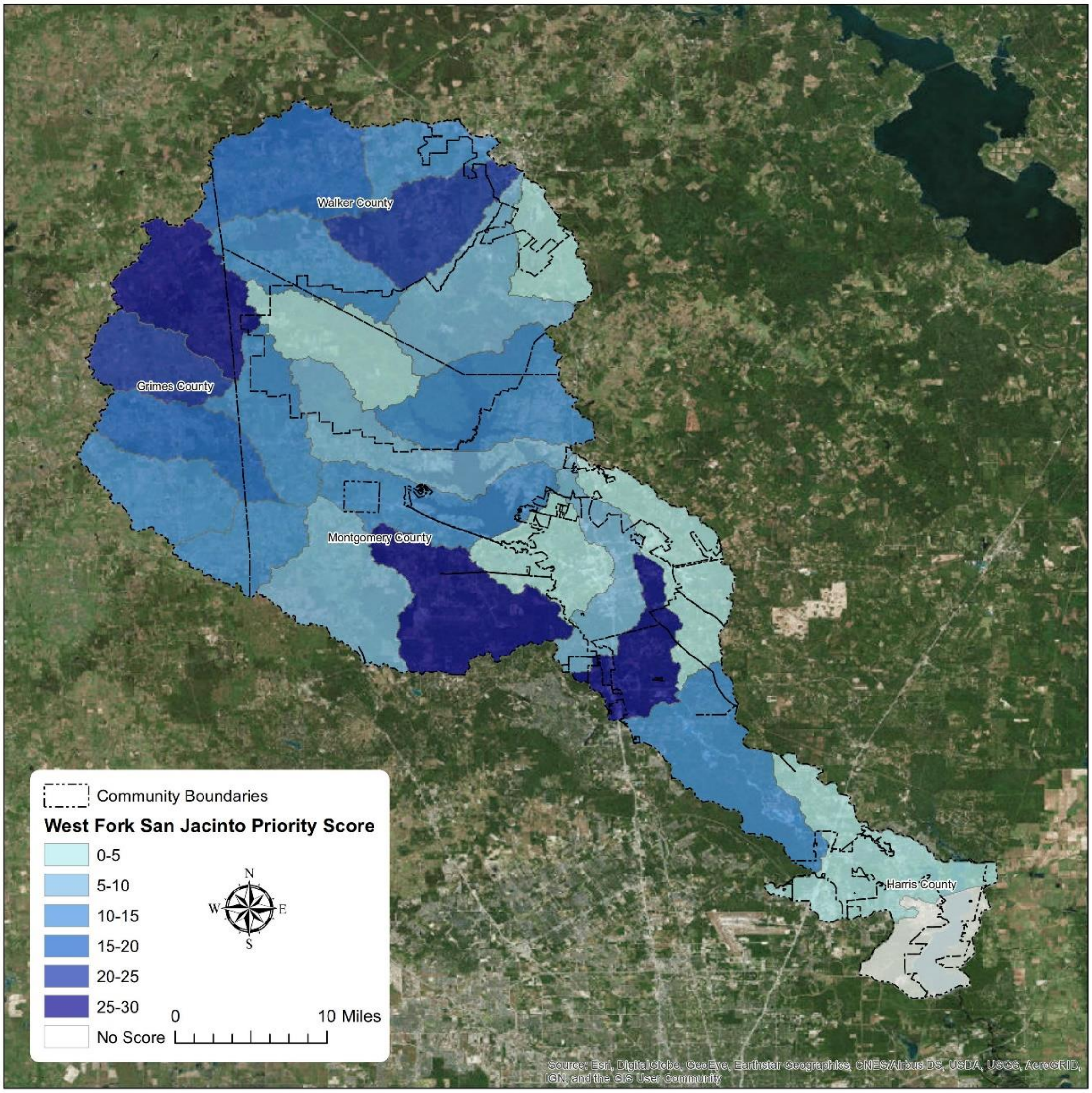

Figure ES-2: Ranking of West Fork San Jacinto River Watershed HUC-12s

Base Level Engineering (BLE) Methodology

Recent innovations and efficiencies in floodplain mapping have allowed the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop a process called Base Level Engineering (BLE), which can be used to address current program challenges, including the validation of Zone A studies and the availability of flood risk data in the early stages of a Flood Risk Project. The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals. The cost for developing the data and estimates resulting from the BLE process are lower than standard flood production costs. The BLE results may be used for eventual production of regulatory and non-regulatory products.

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every five years, FEMA must evaluate whether the information on Flood Insurance Rate Maps (FIRMs) reflects the current risks in flood-prone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the Coordinated Needs Management Strategy (CNMS) Technical Reference. The CNMS Validation Checklist provides a series of critical and secondary checks to determine the validity of flood hazard areas studied by detailed methods (e.g., Zone AE, AH, or AO). While the critical and secondary elements in CNMS provide a comprehensive method of evaluating the validity of Zone AE studies, a cost-effective approach for evaluating Zone A studies has been lacking.

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the early stages of a Flood Risk Project. FEMA Program Standard SID #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses should be shared and results should be discussed with stakeholders.

An important goal of the BLE process is the scalability of the results. Scalability means that the results of a BLE analysis can not only be used for CNMS evaluations of Zone A studies, but can also be leveraged throughout the Risk MAP program. The data resulting from a BLE analysis can be updated as needed and used for the eventual production of regulatory and non-regulatory products, outreach and risk communication, and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

FEMA Region VI contracted Compass to complete a BLE analysis for the West Fork San Jacinto Watershed in Southeast Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Montgomery, Harris, Walker, and Grimes Counties, and include the following communities: the Cities of Conroe, Cut and Shoot, Houston, Humble, Huntsville, Montgomery, Oak Ridge North, Panorama Village, Shenandoah, and Willis; and the Towns of Chateau Woods, Dobbin, Kennan, Kingwood, Moonshine Hill, Richards, Shiro, Tamina, and Woodloch. The study area consists of five HUC-10 basins: West Fork San Jacinto River, WFSJR-Conroe Lake, Caney Creek-Lake Creek, Crystal Creek-WFSJR, and Frontal Lake Houston. Figure 1 shows the orientation of the WFSJR HUC-10 basins with respect to the counties.

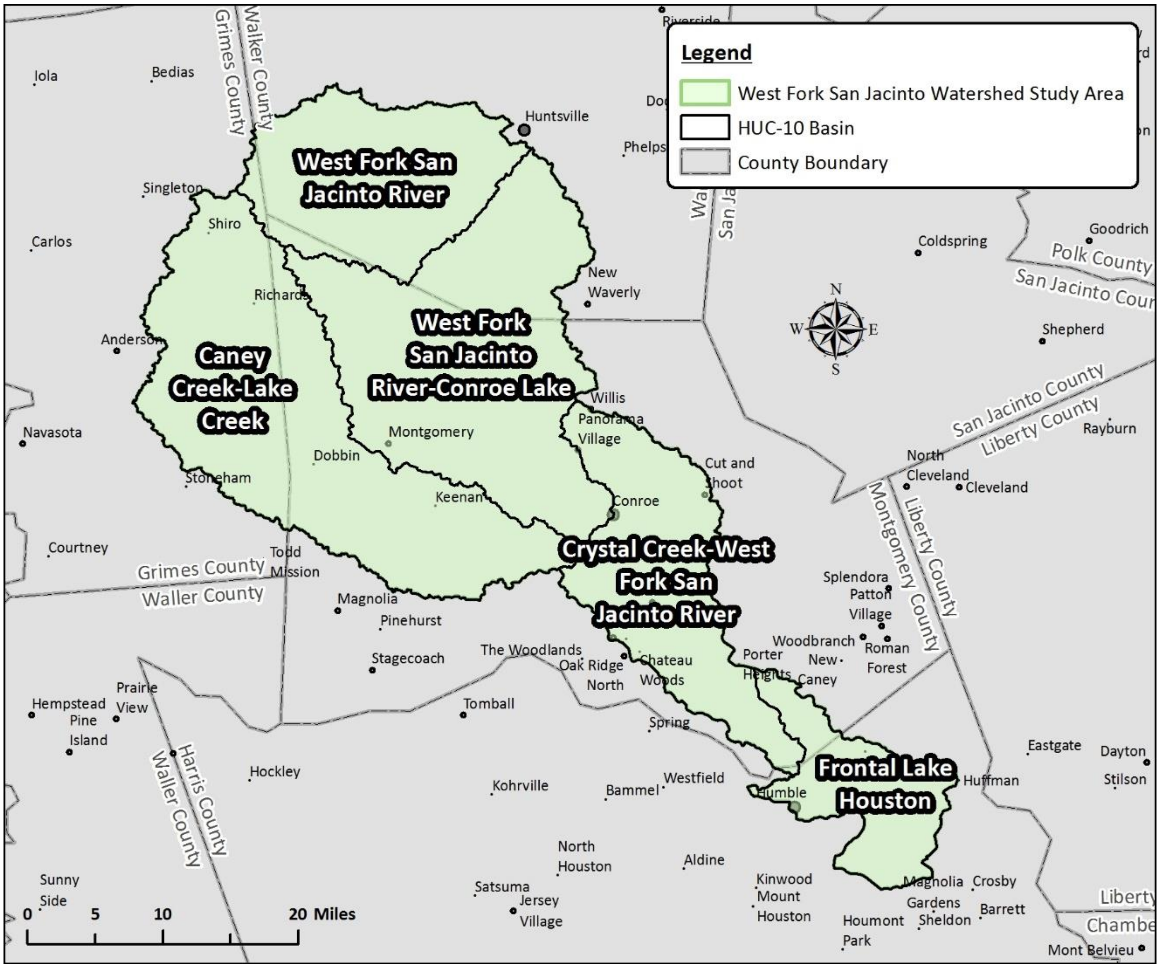

Figure 1: West Fork San Jacinto Watershed HUC-10 Basins

Compass studied approximately 1,332 miles of stream reaches within the West Fork San Jacinto Watershed with a minimum drainage area tolerance of one square mile. The selection and extent of stream reaches studied were based upon the number of stream miles with a minimum drainage area of one square mile and not the number of effective Zone A stream miles. Study reaches were extended above this threshold as appropriate to ensure all effective Zone A flood areas received an updated analysis. Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. The following sections summarize the BLE process and discuss the results along with their recommended use.

1.1 Topographic Data

Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. Topographic data was obtained from the Houston-Galveston Area Council (H-GAC), Texas Natural Resources Information System (TNRIS), and the United States Geological Survey (USGS).

All available metadata, survey reports, and other leverage documentation are available with the source dataset. Figure 2 shows the extents of the source Digital Terrain Model (DTM) data used for the West Fork San Jacinto Watershed.

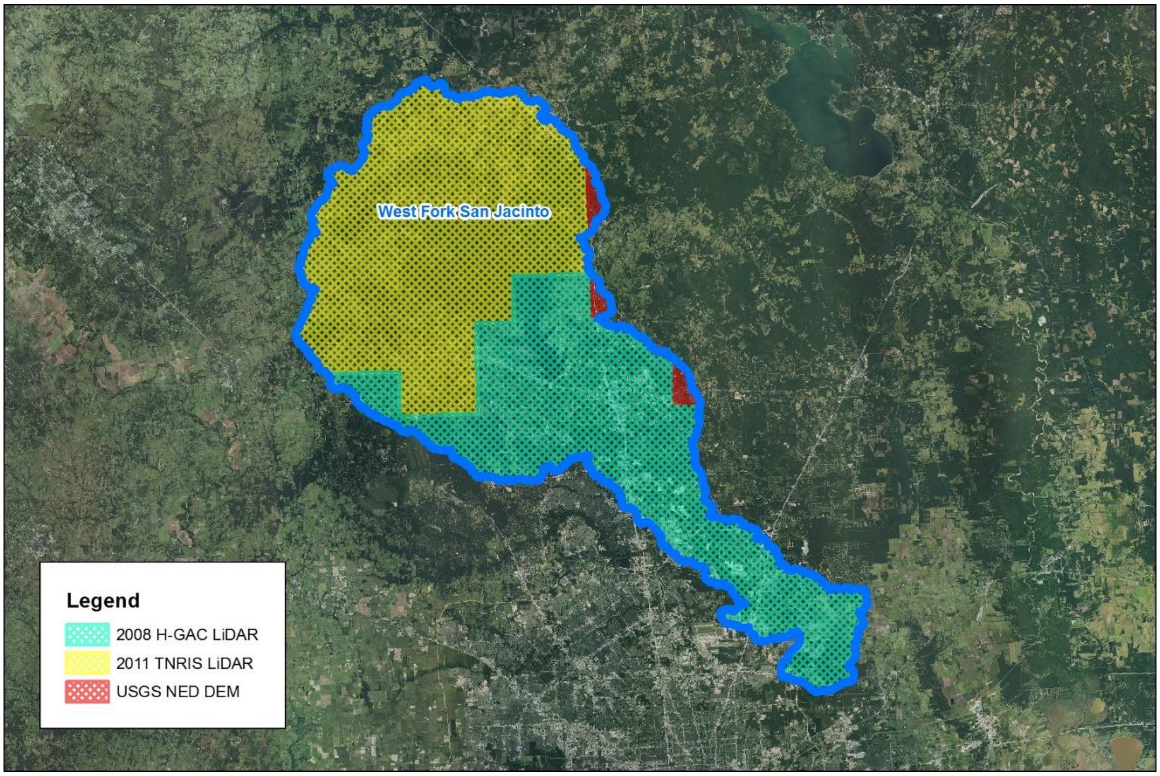

Figure 2: Extent of LiDAR Data for West Fork San Jacinto Watershed

1.1.1 Source Terrain Data

1.1.1.1 H-GAC 2008 LiDAR

The H-GAC 2008 LiDAR was acquired by Merrick & Company. The data density is 1 PPSM with a 1 Meter NPS. The data was compiled to meet 18.5-cm vertical accuracy at 95 percent confidence level which meets project accuracy specifications of the NSSDA. This data was available as LiDAR point clouds in the American Society of Photogrammetry and Remote Sensing (ASPRS) common LiDAR Data Exchange Format (LAS 1.2).

1.1.1.2 2011 TNRIS LiDAR

The TNRIS LiDAR data was acquired in 2011 by Aerometric. The data density is 4 PPSM with a 0.5 Meter NPS. The data was compiled to meet 18.5-cm vertical accuracy at 95 percent confidence level which meets project accuracy specifications of the NSSDA. This data was available as LiDAR point clouds in the American Society of Photogrammetry and Remote Sensing (ASPRS) common LiDAR Data Exchange Format (LAS 1.2).

1.1.1.3 USGS NED DEM

The National Elevation Dataset (NED), a product of the USGS, is a seamless gridded dataset representing the best available raster elevation data available to the USGS for the conterminous United States, Alaska, Hawaii, and territorial islands. The NED is derived from diverse source data that are processed to a common coordinate system and unit of vertical measure. The NED serves the West Fork San Jacinto Watershed topographic data development by filling in as best available data where there are gaps in the data sets listed above. This dataset was only used for a very small area in comparison to the overall HUC-8 watershed.

1.1.1.4 Terrain Data Processing

The LiDAR data were processed in Environmental System Research Institute (ESRI) ArcGIS software to create a composite Digital Terrain Model (DTM) dataset for the project area. The outputs from the processing described above were used during the hydrology, hydraulics, and floodplain mapping processes.

The Watershed Information System (WISE) software platform was utilized in order to create a digital surface model for each watershed's project area. This module allows source data from a variety of sources to be prioritized based on level of accuracy or preference of the user.

For the West Fork San Jacinto Watershed, the 2011 TNRIS LiDAR was first priority, and the H-GAC 2008 LiDAR was second highest priority. Lastly the USGS NED DEM data was used as the third data source for areas where LiDAR did not exist.

The DEMs created from the LiDAR datasets mentioned above were compiled in order of vertical accuracy into a mosaic dataset using ArcMap. From this mosaic, a tile index was created for the project area and the mosaic was clipped into 50,000-foot tiles, converted to asciis and imported into WISE Terrain Analyst (WTA). Visual inspection of the 10-foot DEMs was performed to ensure no voids and/or artifacts were present in the DEM. The DEM surface model was affirmed to be suitable for hydraulic takeoffs and supporting other hydraulic analyses.

Stream centerlines were manually digitized using the 10-foot DEMs as a source for horizontal alignment and vertical elevation. These stream centerlines are created for use in the hydraulic analysis, hydro-enforcement of the 50-foot DEMs, and visual reference on the FIRM products. Several routines were then used to take localized elevations from the source topographic data and apply them to the streams. This gave the stream vertices elevation information along the Z axis. The resulting elevations ensure that the streams are lower in elevation than any overbank sumps. A separate routine was then used to ensure that the elevations of these vertices descend in height down to an outfall. The final streams file is then “burned” into the 50-foot DEMs to force flow through structures while preventing it from jumping out of the channel banks.

After the DEM was imported, an additional 50-foot DEM was created from the same mosaic and tile index used for the 10-foot DEM. This 50-foot DEM was used for hydro enforcement of the project areas. Proprietary software was used to identify natural sinks, peaks and flat areas in the 50-foot DEM surface. Elevations of the cells in the DEM were algorithmically calculated and the best path to route flow was determined without filling sinks in the DEM. Once all calculations were completed, the flow was checked confirming that all drainage flows downstream correctly and is routed to outside of the HUC-8 basin.

In addition to the quantitative assessment of the source digital terrain, a qualitative visual inspection of the composite DEM was performed using a hillshade derived from the 10-foot DEM. The visual inspection indicated that no unusual or non-terrestrial features were observed in the composite DEM, assuring the surface files used for hydrologic and hydraulic analyses and floodplain mapping activities are sufficient for BLE analysis.

1.2 Hydrology

Flood discharges for this study were calculated using the United States Geological Survey (USGS) regression equations that were adjusted to account for Harvey-adjusted flood frequency analyses (see Section 1.2.1). Regression equations were obtained from the USGS Scientific Investigations Report (SIR) 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach* (2009).

The Watershed Information System (WISE) software was used to delineate drainage basins in shapefile format using the 50-foot DEM. WISE was also used to calculate the main-channel slope for each basin. The basin shapefile attribution was automated by WISE with drainage area, main-channel slope, and precipitation.

Table 1 shows the published equations used in this study. In these equations, Q_i represents peak streamflow for i-recurrence interval (annual chance exceedance (a.c.e.)) in cubic feet per second (cfs), P represents mean annual precipitation in inches, S represents dimensionless main-channel slope, Ω represents the OmegaEM parameter, and A represents cumulative drainage area in square miles.

Table 1: Summary of Regression Equations in Texas (SIR 2009-5087)

Recurrence Interval	Equation
$Q_{10\%}$	$P^{1.203} \times S^{0.403} \times 10^{[0.918\Omega + 13.62 - 11.97A\hat{}(-0.0289)]}$
$Q_{4\%}$	$P^{1.140} \times S^{0.446} \times 10^{[0.945\Omega + 11.79 - 9.819A\hat{}(-0.0374)]}$
$Q_{2\%}$	$P^{1.105} \times S^{0.476} \times 10^{[0.961\Omega + 11.17 - 8.997A\hat{}(-0.0424)]}$
$Q_{1\%}$	$P^{1.071} \times S^{0.507} \times 10^{[0.969\Omega + 10.82 - 8.448A\hat{}(-0.0467)]}$
$Q_{0.2\%}$	$P^{0.988} \times S^{0.569} \times 10^{[0.976\Omega + 10.40 - 7.605A\hat{}(-0.0554)]}$
Variables: Q_i, peak flow for i recurrence interval (a.c.e.), in cubic feet per second; P, mean annual precipitation, in inches; S, Main-channel slope (dimensionless); Ω, OmegaEM parameter; A, cumulative drainage area, in square miles	

Discharges for the 1-percent plus and 1-percent minus a.c.e. were calculated as $Q_{1\%+/-} = Q_{1\%} \pm 10^{1.6*0.30}$, where 0.30 is the mean residual standard error for the $Q_{1\%}$ equation.

The mean annual precipitation values were determined based on a shapefile coverage obtained from the Texas Water Development Board (TWDB) and available for download at the following location: http://www.twdb.texas.gov/mapping/gisdata/doc/Precipitation_Shapefile.zip

The annual precipitation values reflect data for the climatological period 1981-2010 as recorded by the Natural Resources Conservation Service (NRCS).

Main-channel slope was calculated in WISE. An automated routine determined the longest flowpath from upstream of a reach to the outlet of the sub-basin of interest. Two points along the channel, one at 10 percent and the other at 85 percent of the channel length, determined the endpoints of the segment used in the main-channel slope calculation. The elevations for those endpoints were based on the 10-foot DEM developed from the LiDAR.

From USGS SIR 2009-5087, the OmegaEM parameter is a generalized terrain and climate index that expresses relative differences in peak-streamflow potential. A shapefile was developed and populated with OmegaEM values based on Figure 2 in SIR 2009-5087. This shapefile was used, along with a python script in ArcCatalog, to determine OmegaEM values on a sub-basin basis. For sub-basins spanning more than one OmegaEM grid, the sub-basin's centroid determined its OmegaEM parameter.

Automated basin delineations were performed in WISE. Basin break points were set by the user with a sub-basin target size of one square mile. This criterion was adjusted for the main stem of the West Fork San Jacinto River to avoid excessive and unnecessary discharge breaks. Break points were also set immediately upstream of stream confluences. Cumulative drainage area was determined based on these automated delineations performed by WISE in combination with a stream connectivity routine that defined the stream reach segments with upstream and downstream neighbors.

The sub-basin shapefile was attributed with the computed discharges, and those discharges were incorporated into the HEC-RAS models using an automated routine in WISE. Discharges, as well as water surface elevation results, were associated with the hydraulic cross sections prior to generation of floodplain boundaries and grid mapping. Those results are available in GIS format as part of this BLE submittal package.

1.2.1 Special Considerations: Harvey Advisory Data

In August 2017, the West Fork San Jacinto River watershed experienced record rainfall and flooding from Hurricane Harvey. Per Task Order HSFE60-17-J-0003, FEMA contracted Compass to reanalyze the WFSJR BLE models to account for observed Hurricane Harvey data.

FEMA performed pre- and post-Harvey flood frequency analyses (FFAs)[2] on 46 USGS stream gages in the Harvey-affected counties. Of the analyzed gages, six were in the East and West Fork San Jacinto River watersheds (see Figure 3). The results of the FFAs for these six gages are shown on Table 2. The analysis indicates substantial increases in peak discharge for all storm events of interest (i.e., 10%, 4%, 2%, 1%, and 0.2% annual exceedance probabilities), and the percent increases are greater in the larger storm events.

[2] FEMA (Federal Emergency Management Agency) 2017, *Hurricane Harvey: Precipitation and Streamflow Analysis*.

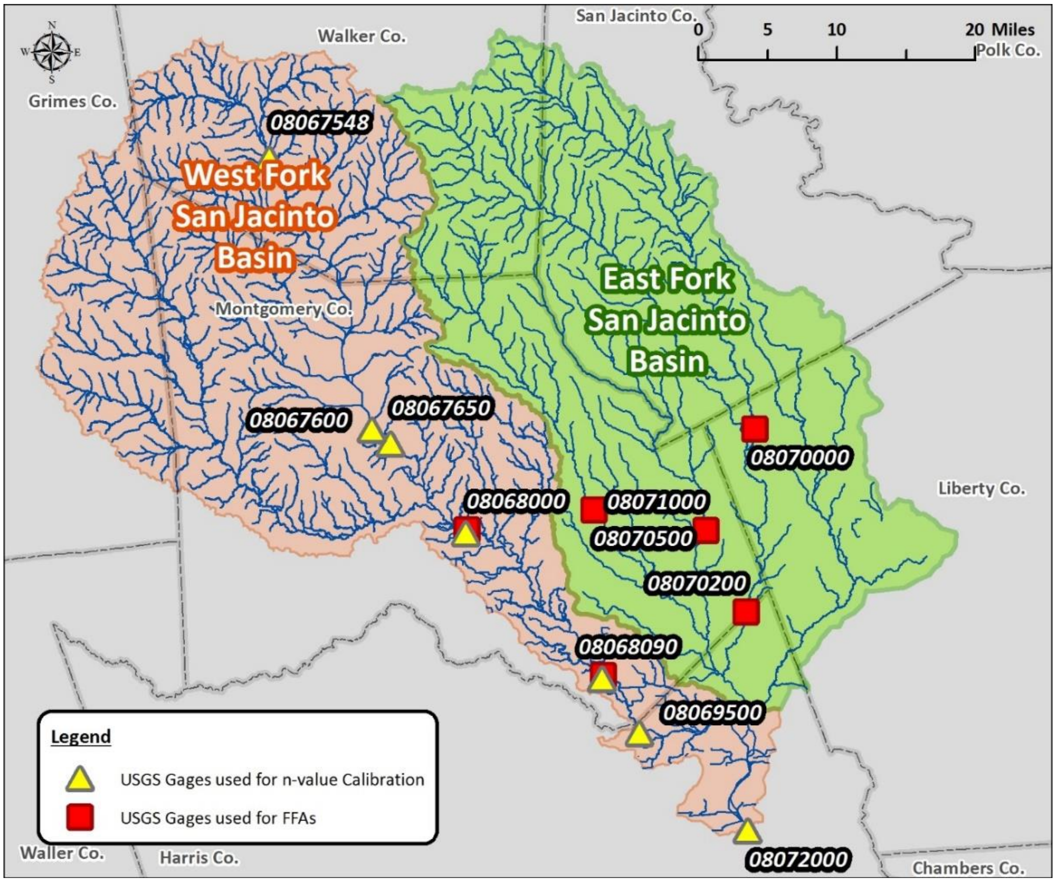

Figure 3: Locations of USGS Gages Utilized in n-value Calibration and Flood Frequency Analyses

Table 2: Post-Harvey Flood Frequency Analyses on Gages in the East and West Fork San Jacinto River Watersheds[3]

Station ID	Station Name	Drainage Area (mi^2)	Post-Harvey Peak Discharge (cfs) for Selected AEPs *(Percent Change from Pre-Harvey)*				
			10%	4%	2%	1%	0.2%
08068000	W Fork San Jacinto River near Conroe	828	31,400 *(6.7%)*	53,800 *(9.3%)*	78,100 *(12.3%)*	111,000 *(14.6%)*	238,000 *(19.7%)*
08068090	W Fork San Jacinto River above Lake Houston near Porter	962	39,900 *(6.3%)*	64,800 *(9.3%)*	89,400 *(11.4%)*	120,000 *(13.3%)*	224,000 *(18.8%)*
08070000	E Fork San Jacinto River near Cleveland	325	22,900 *(5.7%)*	40,200 *(8.7%)*	58,300 *(10.5%)*	82,000 *(12.3%)*	166,000 *(16.3%)*
08070200	E Fork San Jacinto River near New Caney	388	21,000 *(6.7%)*	38,000 *(11.1%)*	57,000 *(14.6%)*	83,100 *(17.8%)*	186,000 *(25.3%)*
08070500	Caney Creek near Splendora	105	10,100 *(5.7%)*	17,100 *(6.4%)*	24,500 *(7.3%)*	34,300 *(8.2%)*	70,400 *(9.7%)*
08071000	Peach Creek at Splendora	117	9,300 *(8.4%)*	17,000 *(11.2%)*	25,200 *(13.5%)*	36,100 *(15.5%)*	75,500 *(19.7%)*

[3] FEMA 2017, *Hurricane Harvey: Precipitation and Streamflow Analysis*.

The discharges obtained in the gage analyses (pre- and post-Harvey) were compared to those calculated from the 2009 regression equations used in the BLE models. Discharge versus cumulative drainage area data points were plotted on a log-log scale for the six gages and all WFSJR sub-basins (see Figure 4). Power trendlines were fitted to the gage data and the 2009 regression model data points. The resulting trendline equations and R^2 values for the 1% AEP are displayed on Figure 4. When compared to the gage analyses, the 2009 regression models under-predict streamflow.

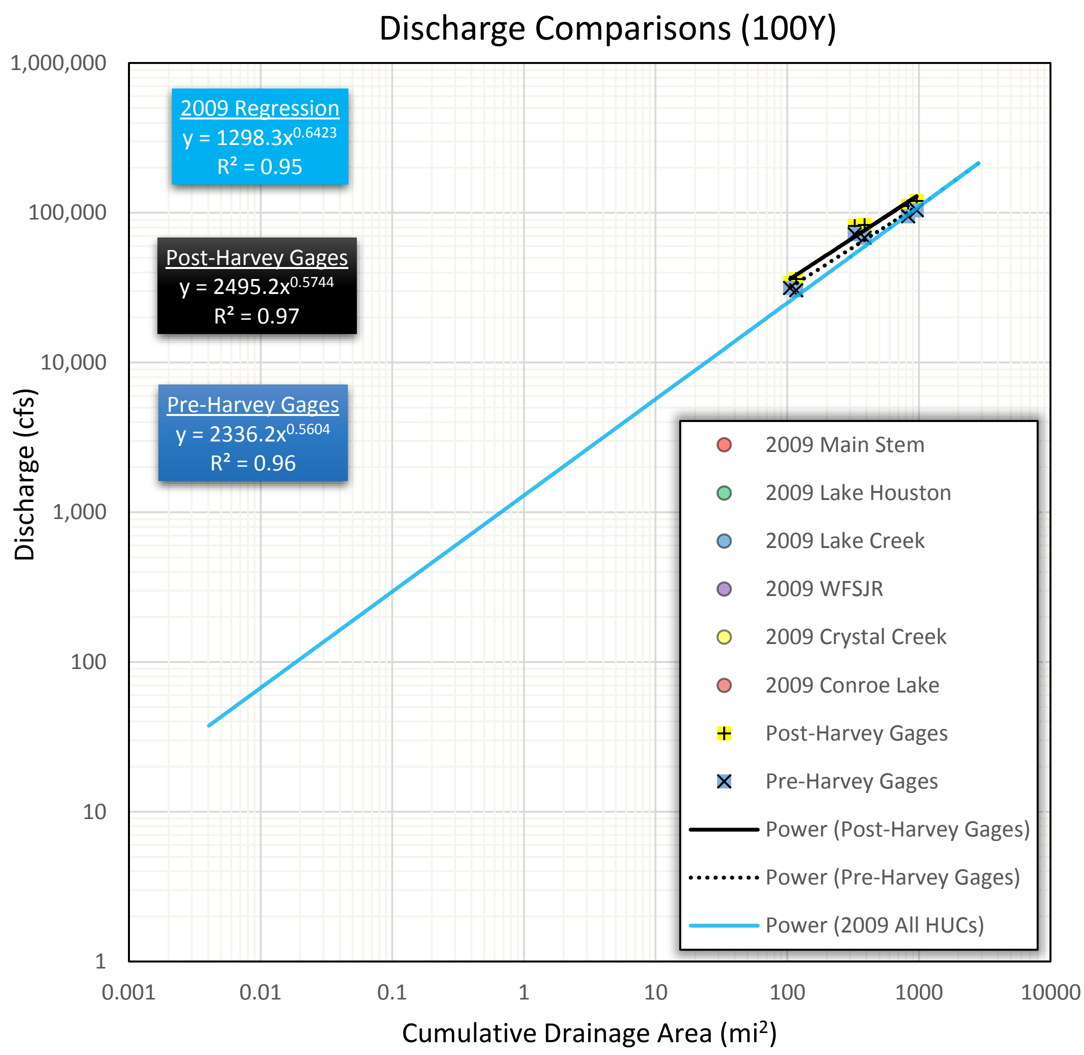

Figure 4: Comparison of Q_{100} values calculated from the regression models and the gage analyses

For each storm recurrence interval, a constant "α" was computed from the trendline equations to adjust the 2009 regression model streamflow predictions to the post-Harvey flood frequency analyses. α was computed as $\alpha = y_{\text{Post-Harvey FFA}} / y_{\text{2009 Regression}}$, where y represents the respective power trendline equations. The α-factors were applied as a constant multiplier to the 2009 regression equations (Table 1) to obtain the adjusted flows. The computed α-factors are given in Table 3. The α-factor for the 10-year storm event is less than one, so no adjustment was used for the 10-year. The BLE models were updated with the modified discharges; a summary of peak discharges is tabulated in Appendix A. The hydrologic adjustments described here are discussed further in the attached memorandum (Appendix C).

Table 3: Computed α-factors for BLE on the East and West Fork San Jacinto Watersheds

10%	4%	2%	1%	0.2%
0.86 (no adjustment)	1.02	1.15	1.30	1.72

1.3 Hydraulics

The hydraulic approach for this BLE analysis of the West Fork San Jacinto Watershed consisted of using the terrain model described in Section 1.1 in combination with the hydrologic outputs from Section 1.2 to establish water surface elevations using 1-D steady state analysis. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 4.1 was chosen as the computer model to compute water surface elevations on a stream by stream basis. The WISE software was used to establish model stream orientation, generate initial hydraulic cross section layout and stationing, assign n-values to cross sections, and develop all input files for the HEC-RAS program. ESRI's ArcMap program was used to review and refine cross-section layout orientation.

First pass cross-section layout was performed using an automated routine in WISE based on the cumulative drainage area at the cross section location. A first draft model was created based on this initial cross-section layout, and draft boundaries were developed. At this stage, a second pass inspection for cross-section placement occurred. Significant refinement occurred during this step. To improve the hydraulic models, additional cross-sections were added as needed to better define the BLE floodplain boundary. Cross-sections were extended in locations where overtopping occurred. Orientation of cross-sections was refined to improve on the perpendicular orientation to flow. Additional cross-sections were added at floodplain constrictions and at downstream portions of tributaries to ensure a proper tie-in with receiving streams. Cross-sections were adjusted to remove sections that intersected hydraulic crossings in the floodplain. For some of the largest studied streams, cross-sections were laid out manually in order to have more reasonable spacing and better capture the constrictions in the floodplain.

Cross-sections were not drawn on top of roadways or railroads but were placed at the upstream and downstream face of major roads and railroads. Ineffective flow stations were placed in the hydraulic models as appropriate to account for flow constrictions and other locations deemed by the engineer to be ineffective at conveying flow downstream.

Cross-sections were drawn on dam tops for significant dams with well-defined spillways in order to better represent ponded water upstream of the structures. In so doing, it was assumed that the vast majority of the flow during a flood event would pass the spillway and that the hydraulic model would reasonably estimate flow across the spillway as represented in the hydraulic cross-section. The elevations used in the modeling were checked against effective Zone A boundaries, and the results were deemed reasonable.

The relationship between cumulative drainage area and assigned channel geometry is shown in Table 4. These default values for dimensions and spacing were subject to change based on engineering judgment.

Table 4: Cross-Section Default Parameters

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
1.0	500	4	3.5	0.5
2.0	500	6	5	0.5
4.0	500	11	10	0.5
8.0	500	18	17	0.5
10.0	500	20	19	0.5
15.0	600	26	25	0.5
20.0	600	32	31	0.5
25.0	600	38	36	0.5
30.0	600	43	41	0.5
40.0	600	52	50	0.5
50.0	600	60	57	1
75.0	750	68	65	1
100.0	750	76	73	1
150.0	1000	91	88	1
250.0	1000	122	119	2
500.0	1500	198	195	2
1000.0	2500	351	346	3
2000.0	4000	657	652	3
5000.0	4000	1575	1565	3

In typical BLE projects, Manning's roughness coefficients (n-values) are determined using the 2011 National Land Cover Data (NLCD) dataset in combination with n-values from Chow (1959) and Calenda et al. (2005). The association between the n-values and the NLCD Classification is shown in Table 5. Manning's n-value takeoffs are performed by WISE (default values taken from the "Normal" column). N-values within channel banks are constrained by the automated routine to a range of 0.030 to 0.070. Then, overbank and channel n-values are manually adjusted in certain locations based on engineering judgment. Under the current BLE task order, the n-value assignments were modified in a calibration process detailed in Section 1.3.1.

Table 5: Manning's "n" Roughness Based on 2011 NLCD Classification (Moore, 2011)

NLCD Classification	Minimum	Normal	Maximum	Source
Open Water	0.025	0.03	0.033	Chow 1959
Developed, Open Space	0.01	0.013	0.016	Calenda et al. 2005
Developed, Low Intensity	0.038	0.05	0.063	Calenda et al. 2005
Developed, Medium Intensity	0.056	0.075	0.094	Calenda et al. 2005
Developed, High Intensity	0.075	0.1	0.125	Calenda et al. 2005
Barren Land	0.025	0.03	0.035	Chow 1959
Deciduous Forest	0.1	0.12	0.16	Chow 1959
Evergreen Forest	0.1	0.12	0.16	Chow 1959
Mixed Forest	0.1	0.12	0.16	Chow 1959
Scrub/Shrub	0.035	0.05	0.07	Chow 1959
Grassland/Herbaceous	0.025	0.03	0.035	Chow 1959
Pasture/Hay	0.03	0.04	0.05	Chow 1959
Cultivated Crops	0.025	0.035	0.045	Chow 1959
Woody Wetlands	0.08	0.1	0.12	Chow 1959

NLCD Classification	Minimum	Normal	Maximum	Source
Emergent Herbaceous Wetland	0.075	0.1	0.15	Chow 1959

The boundary condition used for the majority of the study streams was normal depth with a default value of 0.005 ft/ft. For streams with large drainage areas (generally greater than 8 square miles), the normal depth slope was calculated based on the channel inverts of the downstream cross sections.

In cases where streams tie in to a lake, a normal depth slope was calculated based on the channel inverts of the downstream cross sections (typically between 0.0001 and 0.001 ft/ft). Several HUC-10s within this watershed are located in urban areas with storm drain systems, which are unaccounted for in the BLE models. Simplifications of these systems may considerably affect perceived risk.

1.3.1 Special Considerations: Harvey Advisory Data

Per Task Order HSFE60-17-J-0003, FEMA contracted Compass to reanalyze the WFSJR BLE models to account for observed Hurricane Harvey data. A limited number of gages operate within the WFSJR watershed, with most located on the mainstem of the West Fork San Jacinto River. High water marks were also recorded by USGS following the storm event; however, only 36 points were collected within the WFSJR watershed, with 20 points applicable for calibration on the West Fork San Jacinto Mainstem.

To verify the hydraulic methodology of the BLE process in the WFSJR watershed, the peak recorded USGS gage flows on the West Fork San Jacinto River during Harvey were input into the existing hydraulic model. There are four USGS gages (08067548, 08067650, 08068000, 08068090) on the West Fork San Jacinto River that record streamflow; all were utilized in the hydraulic calibration (see Figure 3). Additionally, the flow published by the San Jacinto River Authority at the Lake Conroe Dam was used. Flow was estimated at four other locations: at the headwaters (approximately 23 miles upstream of the first USGS gage) and at three locations downstream of the Grand Parkway where significant hydrologic changes were expected due to incoming streams.

Each of the gages used to define the streamflow during Hurricane Harvey also records water surface elevation. In addition to these gages, two USGS gages that record only stream stage and multiple high water marks recorded by the USGS following Hurricane Harvey were used for the hydraulic calibration.

Using the initial model created for the West Fork San Jacinto River and the Harvey flows, the computed water surface elevation was an average of 3.6 feet below the recorded water surface elevations. The modeled water surface was higher than recorded through the Lake Houston region, and lower everywhere else. No comparison points were available through the Lake Conroe region.

During the initial model creation the manning’s n-values were based on the NLCD (2011), using values that had been incorporated in previous studies (see Section 1.3). These values were investigated in the calibration process. Several iterations of universal adjustments and channel- and bank-specific adjustments were tested. It was concluded that within the WFSJR watershed, all overbank values should be increased by 0.05 with a minimum value of 0.11, and all channel values should be increased by 0.02 with a minimum value of 0.06. Through large reservoirs and lakes, the channel n-value should be set to 0.015.

After making these adjustments to the initial West Fork San Jacinto model the modeled water surface averaged 0.3 feet below the recorded water surface elevations, which was deemed an allowable variance.

It was also noted during the iteration process that the NLCD frequently contains erroneous land use values. The WFSJR watershed is primarily undeveloped with dense wooded areas, but many of these areas were represented as 'Developed – Low Intensity', 'Developed – Green Space', or 'Grassland'. In future BLE efforts, the NLCD layer should be juxtaposed with recent aerial maps and the preliminary hydraulic layout to check for conflicts.

The n-value calibration process is detailed further in the attached memorandum (Appendix C).

1.4 Quality Control

Following the initial BLE analysis in each watershed, the flood hazard area delineations created by the BLE process were reviewed for areas where the results were not ideal.

QC results indicated that some of the models should be extended to cover the scope of effective flood hazard data. Those streams were extended farther upstream to match the extents of the SFHA data.

Typical manual editing resulting from reasonability checks included adding cross-sections, adjusting orientation of cross-sections, trimming cross-sections and reduction of the default "V" angle of cross-sections. Examples of default "V" angled cross-sections are shown in Figure 5. It is estimated that 75 percent of cross-sections were adjusted in some work areas while other areas did not require as much editing. Other examples of manual editing included the addition of cross-sections at confluence areas (see Figure 6 below), modifications to improve perpendicular orientation at the channel, adjustment of discharge breaks to better represent flow addition points, revisions to dam spillways and dam tops, additional cross-sections bounding major hydraulic structures, and revisions to n-values.

A major component of the QC process was an automated check that identified locations where the 1-percent a.c.e profile was crossed by any other frequency profile. Significant effort was made to reasonably resolve all of these instances. Another automated check identified locations where there was a drawdown of greater than 0.5 foot on the 1-percent a.c.e. water surface profile. This check is particularly useful for identifying errors in the model such as a channel that is too wide, a poorly placed cross-section, or a need for additional cross-sections. Again, significant effort was made to reasonably resolve these drawdown situations.

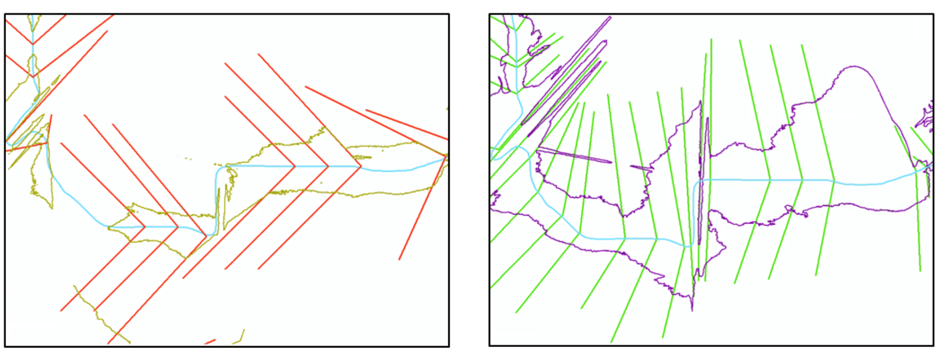

Figure 5: Default "V" angle cross-sections automated by WISE (left). Manually edited cross-sections to more accurately capture terrain (right). Resulting flood boundaries shown in gold (left) or purple (right) for clarity.

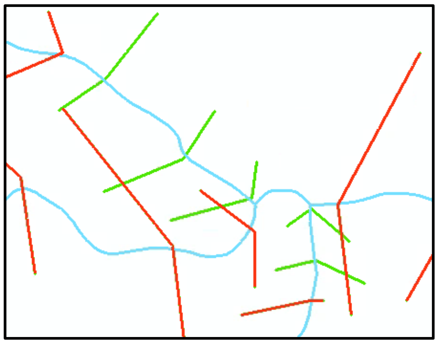

Figure 6: Manually added cross-sections (green) to improve accuracy of tie-ins at confluences.

1.5 One-percent Special Flood Hazard Area Delineation

The 1-percent and 0.2-percent boundaries were mapped using a routine that develops water surface elevation grids based on the 10-foot cell size DEM developed from the LiDAR dataset used for this project (see Section 1.1). This product was converted to a polygon for cleaning. The cleaning routine involved manual inspection of the polygons to identify and remove areas of disconnected flooding. In general, areas with a size of less than 5,000 square feet were removed and all others were investigated to determine whether they should be considered as potentially part of the SFHA. This investigation was aided by the ground DEM and aerial imagery. Manual adjustments to the polygons were made to account for spillways on dams which could not be accurately modeled using HEC-RAS as well as disconnected areas along the flooding source that should reasonably be connected.

Following the removal of disconnected flooding areas and other boundary adjustments, the small islands in the floodplain were filled. Islands with a size between roughly 5,000 and 30,000 square feet were inspected and, in general, islands that were less than 10,000 square feet were filled.

Once the island filling process was complete, the water surface raster mapping routine was run and set to conform to the polygon boundary. This ensures that the water surface raster and the floodplain boundary are consistent with each other. The depth raster product was created at the end of the process by performing a raster subtraction with the water surface elevation raster and the ground DEM.

Challenges

Challenges encountered during BLE analyses vary based on available data on which to run the analysis. The West Fork San Jacinto Watershed presented challenges as summarized in the following paragraphs.

The West Fork San Jacinto Watershed is located in Southeast Texas, an area known for flat terrain. In some of the wide and flat floodplains, small tributaries run parallel to large streams. Parallel streams with shared floodplains were modeled by moving the combined discharge upstream to the cross-section that begins the shared floodplain.

A significant effort was made to improve water surface elevation tie-ins at stream confluences. Cross-sections were manually added on the downstream end of nearly every stream, some of which traverse the receiving stream, so that the water surface elevation of the tributary would be lower than that of the receiving stream.

There are a significant number of small-sized dams on the tributaries throughout the watershed. Discharges calculated with the regression equations do not take into account the impact of these structures. There may be need for further investigation when upgrading these models for detailed studies.

There is a noticeable inconsistency in the mapping of Conroe Lake HUC-10 in the area where the studied reach moves in and out of the different topography sources.

As noted in Section 1.4 above, multiple streamlines did not extend far enough to fully capture effective flood hazard data. The streamlines generated in the development of the one-square mile basins were extended in order to more closely match the effective areas and CNMS streams.

Finally, there are a few containment issues in the Crystal Creek and Frontal Lake Houston HUC-10 basins. Significant effort was made to contain the flooding events, but this was not always achieved due to particularly wide, flat floodplains.

Results and Recommendations

The BLE results for this study produced a SFHA that compares reasonably well with the effective SFHA. These boundaries provide an additional estimated SFHA in areas that do not currently have an SFHA mapped. These results provide context for flood risk communication as part of the Discovery process, and should be verified through community work map meetings before being applied to a regulatory product.

A map showing the BLE results is included as Appendix B.

3.1 CNMS Validation of Effective Zone A SFHA

The inventory of Zone A studies (448.89 miles) in the West Fork San Jacinto watershed were classified in CNMS with validation status of “UNVERIFIED” (280.94 miles) or “VALID” (167.94 miles), and with status type of “BEING STUDIED” (448.49 miles). The following is a summary of the results of the CNMS validation assessment for the effective Zone A studies in the study area. Initial Assessment checks A1-A3 were evaluated for the CNMS inventory of Zone A studies.

INITIAL ASSESSMENT A1 – SIGNIFICANT TOPOGRAPHY UPDATE CHECK

This check involves determining whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. For the study area in West Fork San Jacinto Watershed TX, the effective Zone A topographic data leveraged a variety of sources, but was primarily based upon United States Interagency Elevation Inventory. The topography listed in Section 1.1 above represents a significant improvement from the effective Zone A topographic source, and thus fails this assessment (see Table 6).

INITIAL ASSESSMENT A2 – CHECK FOR SIGNIFICANT HYDROLOGY CHANGES

This check involves first determining whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent annual chance flow.

The hydrology methods for the effective Zone A study areas located in Grimes, Walker, and Harris Counties in TX are unknown due to the lack of effective data. It is known that the study analyses for these counties were performed prior to the most recent publication SIR 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment-Based, PRESS-Minimized, Residual-Adjusted Approach* (2009).

Montgomery County effective Zone As were developed using the publication WRIR 96-4307, *Regional Equations for Estimation of Peak-Streamflow Frequency for Natural Basins in Texas* (1997).

For the Zone A streams in Grimes, Walker, and Harris counties, the A2 check would pass due to the hydrology methods being unknown. However, for the Zone A streams in Montgomery County where it is known that regression equations were used to develop the hydrology, the A2 check will fail due to the publication of an updated regression report in 2009 (see Table 6).

INITIAL ASSESSMENT A3 – CHECK FOR SIGNIFICANT DEVELOPMENT

This check involves using the National Urban Change Indicator (NUCI) dataset to assess increased urbanization in the watershed of the Zone A study. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15% or more, and has increased by 50% or more since the effective analysis, the study would fail this check. Although the NUCI data provide year-to-year changes in urbanization, the NLCD also is needed to establish a baseline of urban land cover for this analysis. The check for significant development in this watershed was completed by evaluating percentage of urban change at the HUC-12 level. Of the 29 HUC-12 polygons within the study area, 0 show a percentage of 15% or more urban area, and thus none have applicable significant development. This check passes the assessment. All of the initial assessment results are shown in Table 6.

Table 6: Zone A Initial Assessment Results

Assessment Check	Pass / Fail	Notes
A1 – Topography	Fail	Topographic described in Section 1.1 is significantly better than effective topographic source.
A2 – Hydrology	Fail	Newer Regression Equations published in 2009 are available for studies located in Grimes, Walker, Harris, and Montgomery TX. Methods for Grimes, Walker, and Harris were unknown, but Montgomery streams failed where it is known that regression equations were used to develop the hydrology.
A3 – Development	Pass	None of the HUC-12s fail.

VALIDATION CHECK A4 – CHECK OF STUDIES BACKED BY TECHNICAL DATA

Zone A studies that pass all initial assessment checks described above may be categorized as "Valid" in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If the effective Zone A study passes all initial assessment checks, but is not supported by modeling, or if the original engineering method used is unsupported or undocumented, a comparison of the BLE results and effective Zone A's is performed. Streams located in Grimes, Walker, Harris, and Montgomery Counties have been marked as Pass in the A4 check due to sufficient evidence in the FIS report and on FEMA's Mapping Information Platform (MIP) detailing study methods.

VALIDATION CHECK A5 – COMPARISON OF BLE AND EFFECTIVE ZONE A

The BLE /effective Zone A comparison method leverages the existing Floodplain Boundary Standard (FBS) certification procedures described in FEMA SID 113, but with a slight modification. This modified FBS comparison approach uses the 1-percent plus and 1-percent minus flood profiles and horizontal and vertical tolerances described in FEMA's Automated Engineering guidance document dated May 2016. For the comparison of BLE and effective Zone A in the Texas study area, the following vertical and horizontal tolerances were used to conduct the modified FBS procedure. One point was placed every 200 feet along the floodplain boundaries for comparison.

Vertical Tolerance: +/- 10 feet (one-half contour interval of assumed effective topographic source).
Horizontal Tolerance: +/- 75 feet (standard horizontal tolerance for BLE comparison testing).

Of the 438 modeled BLE streams in the study area, 168 were found to correspond (within the tolerance limits) with effective Zone A flood zones. Comparison results for these streams were grouped at the HUC-12 level and are summarized in Table 7 to better understand the general health of the HUC-12 watershed, but the validation check was performed at the stream level. Streams where the percentage of passing FBS sample points is greater than or equal to 85% are marked as "Pass", otherwise marked as "Fail".

Table 7: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	**Watershed Number**						
West Fork San Jacinto	All Streams	21401	4518	16883	78.9%	Fail	
Bens Branch-Frontal Lake Houston	120401010501	82	2	80	97.6%	Pass	2.4
Caney Creek	120401010203	259	5	254	98.1%	Pass	1.5
Crystal Creek	120401010403	584	28	556	95.2%	Pass	4.3
East Sandy Creek	120401010201	583	101	482	82.7%	Fail	4.3
Flagtail Creek-Lake Creek	120401010301	2047	645	1402	68.5%	Fail	25.2
Garretts Creek	120401010302	980	292	688	70.2%	Fail	24.4
Haynie Creek-Little Caney Creek	120401010304	1067	226	841	78.8%	Fail	18.6
Hostetter Creek-Conroe Lake	120401010204	823	247	576	70.0%	Fail	13.0
Kidhaw Branch-Lake Creek	120401010303	592	75	517	87.3%	Pass	12.0
Landrum Creek-Lake Creek	120401010307	586	47	539	92.0%	Pass	7.2
Little Caney Creek-West Fork San Jacinto River	120401010402	30	6	24	80.0%	Fail	29.3
Little Lake Creek-Conroe Lake	120401010205	76	12	64	84.2%	Fail	9.7
McDonald Creek-West Fork San Jacinto River	120401010202	2376	617	1759	74.0%	Fail	9.7
McGary Creek	120401010102	774	107	667	86.2%	Pass	12.4
Mound Creek-Lake Creek	120401010308	771	229	542	70.3%	Fail	26.3
Robinson Creek-West Fork San Jancinto River	120401010104	2133	563	1570	73.6%	Fail	23.1
Rocky Creek-West Fork San Jacinto River	120401010101	3074	612	2462	80.1%	Fail	17.9
Sand Creek-Caney Creek	120401010305	1505	264	1241	82.5%	Fail	14.0
Stewarts Creek-West Fork San Jacinto River	120401010401	51	3	48	94.1%	Pass	5.3
Town Creek-Conroe Lake	120401010206	168	40	128	76.2%	Fail	13.9
Town of Dobbin-Lake Creek	120401010306	776	105	671	86.5%	Pass	11.4
West Sandy Creek	120401010103	1598	260	1338	83.7%	Fail	13.0

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
White Oak Creek-West Fork San Jacinto River	120401010404	165	19	146	88.5%	Pass	10.9
White Oak Creek-West Fork San Jacinto River	120401010207	301	13	288	95.7%	Pass	4.3

VALIDATION RESULTS

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the West Fork San Jacinto Watershed has been updated as summarized in Table 8 and illustrated in Figure 7 below.

Table 8: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	167.94
UNVERIFIED	BEING STUDIED	280.94

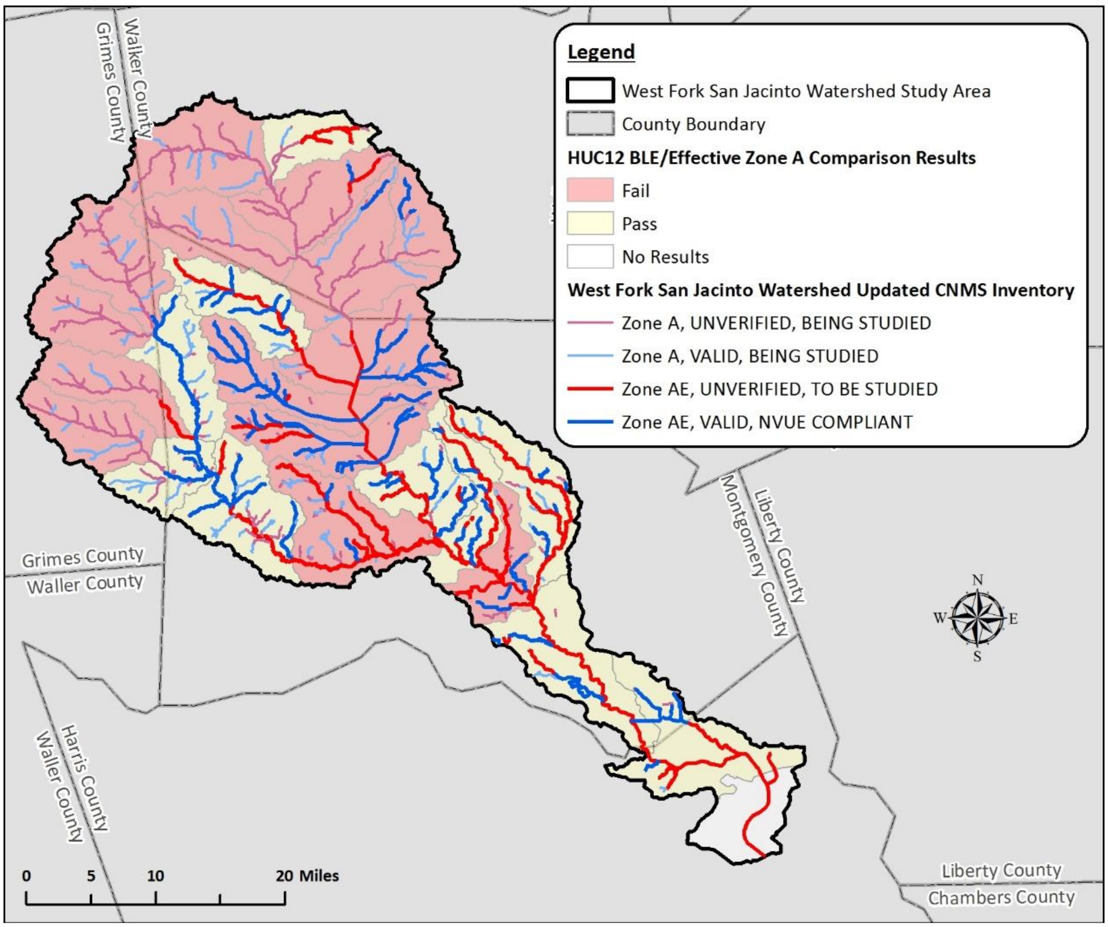

Figure 7: West Fork San Jacinto River Watershed CNMS Validation Results

An overall risk for each HUC-12 watershed was calculated using the National Flood Risk Percentages Dataset and its proportional area. The weighted risk was multiplied by the percentage of points in the watershed that failed the CNMS comparison to effective to determine the priority score. Figure 8 below shows the range of the HUC-12 priority scores which can be used to initiate discussions during the Discovery phase.

Little Caney Creek-West Fork San Jacinto River HUC-12 was determined to have the highest priority score and the most need while Caney Creek HUC-12 had the lowest score.

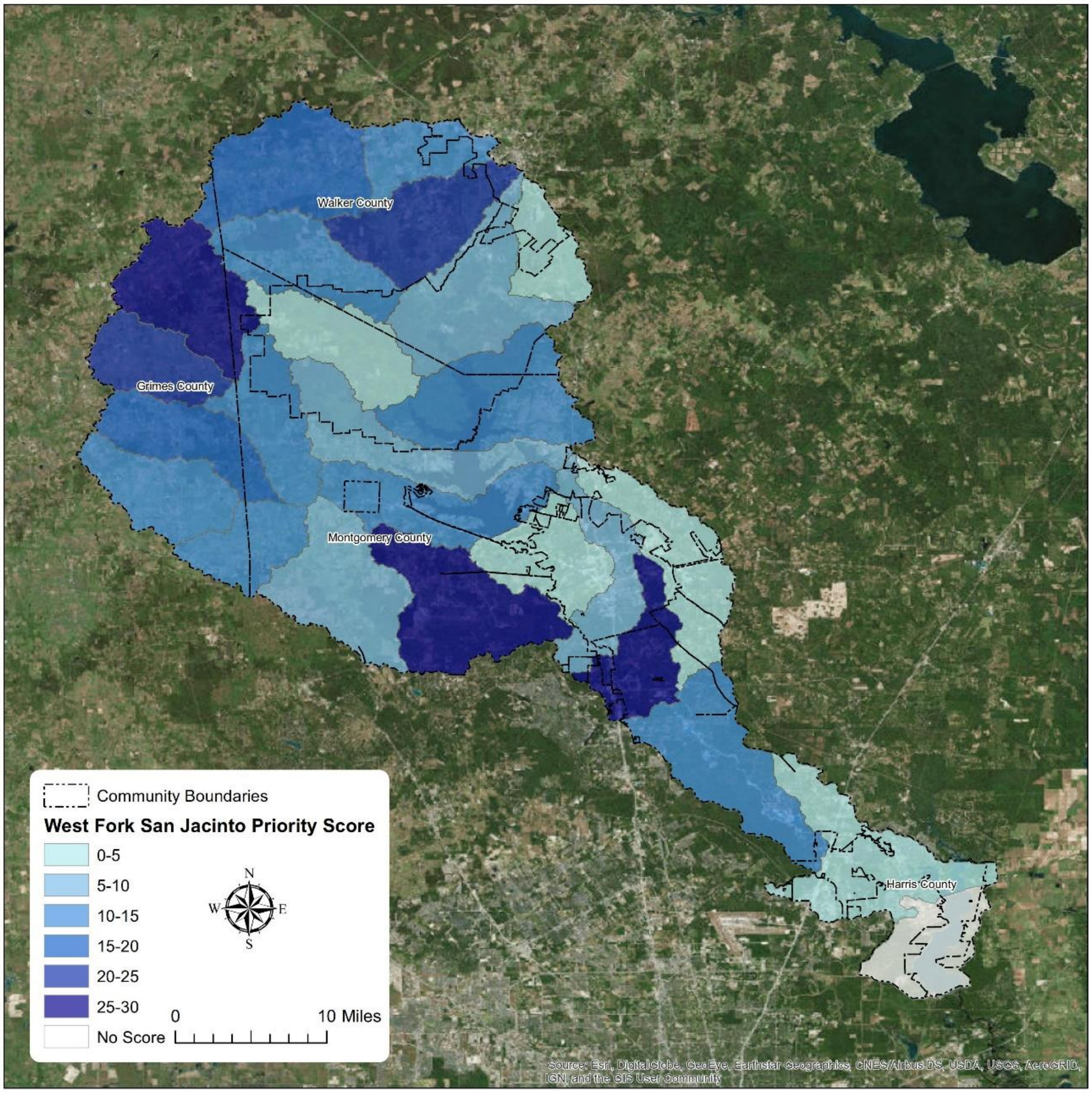

Figure 8: Ranking of West Fork San Jacinto River Watershed HUC-12s

3.2 Flood Risk Analysis

An advanced flood risk analysis was performed using the updated 1-percent-annual-chance grid (known as 'refined' grid) created for this project. The loss analysis uses 2010 census data and the subsequent results are stored in the L_RA_Results table.

Hazus version 4.0 was used for the loss analysis.

The losses are reported via census blocks. It is important to note that Hazus version 4.0 uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by other bodies of water, wetlands, or forests) from the Census blocks, changing their shape and reducing their size in these areas. For more information on dasymetric data visit FEMA's Media Library for the Hazus-MH Data Inventories: Dasymetric vs. Homogenous, or Hazus 3.0 Dasymetric Data Overview.

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Appendix A Summary of Peak Qs

Table A-1: Summary of Hydrology

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
ALLIGATOR BRANCH	0.52	2,087	691	6,303
ALLIGATOR BRANCH	2.24	3,595	1,190	10,857
ALLIGATOR CREEK	0.30	657	218	1,984
ALLIGATOR CREEK	1.07	1,781	590	5,379
ALLIGATOR CREEK	3.42	4,398	1,456	13,282
ALLIGATOR CREEK	4.40	5,247	1,737	15,846
ALLIGATOR CREEK	5.38	5,467	1,810	16,510
ALLIGATOR CREEK	5.58	5,863	1,941	17,706
ANTHONY BRANCH	0.59	1,229	407	3,712
ANTHONY BRANCH	1.37	1,811	600	5,469
ANTHONY BRANCH	1.94	2,235	740	6,750
ANTHONY BRANCH	3.43	3,731	1,235	11,267
ANTHONY BRANCH	3.72	3,778	1,251	11,409
ATKINS CREEK	0.60	1,152	381	3,479
ATKINS CREEK	1.22	2,079	688	6,278
BASE CREEK	1.00	1,915	634	5,783
BASE CREEK	1.99	3,419	1,132	10,325
BASE CREEK	2.40	3,290	1,089	9,936
BAY BRANCH	0.39	814	270	2,458
BAY BRANCH	0.62	1,050	348	3,171
BAY BRANCH	2.00	2,913	965	8,797
BAY BRANCH	3.47	4,358	1,443	13,161
BAY BRANCH TRIBUTARY NO 1	0.54	1,135	376	3,428
BAY BRANCH TRIBUTARY NO 1	1.06	1,694	561	5,116
BAY BRANCH TRIBUTARY NO 1	1.23	1,899	629	5,735
BAY BRANCH TRIBUTARY NO 2	0.61	1,187	393	3,585
BAY BRANCH TRIBUTARY NO 2	0.81	1,535	508	4,636
BELL CREEK	0.20	577	191	1,743
BELL CREEK	1.00	1,895	627	5,723
BELL CREEK	1.48	2,232	739	6,741
BELL CREEK	3.98	5,633	1,865	17,011
BELL CREEK	6.15	6,871	2,275	20,750
BELL CREEK	7.15	6,676	2,211	20,161
BELL CREEK	8.15	7,630	2,527	23,042
BELL CREEK	8.41	6,183	2,047	18,672
BENS BRANCH	0.24	203	67	613
BENS BRANCH	3.71	2,996	992	9,048

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
BENS BRANCH	4.92	3,150	1,043	9,513
BENS BRANCH	5.30	3,559	1,178	10,748
BENS BRANCH	6.34	3,816	1,264	11,524
BENS BRANCH	6.62	4,155	1,376	12,548
BENS BRANCH	8.47	5,066	1,678	15,299
BENS BRANCH	9.75	5,322	1,762	16,072
BENS BRANCH	10.44	5,057	1,675	15,272
BENS BRANCH TRIBUTARY NO 1	0.96	833	276	2,516
BENS BRANCH TRIBUTARY NO 2	2.16	1,400	464	4,228
BENS BRANCH TRIBUTARY NO 2	2.89	1,940	642	5,859
BIG CHINQUAPIN CREEK	0.35	954	316	2,881
BIG CHINQUAPIN CREEK	1.00	2,395	793	7,233
BIG CHINQUAPIN CREEK	1.95	3,190	1,056	9,634
BIG CHINQUAPIN CREEK	2.55	3,626	1,201	10,950
BIG CHINQUAPIN CREEK	5.37	6,668	2,208	20,137
BLACK BRANCH	0.46	3,172	1,050	9,579
BLACKS BRANCH	0.81	1,333	441	4,026
BLACKS BRANCH	1.54	2,786	923	8,414
BLACKS BRANCH	2.43	2,618	867	7,906
BLACKS BRANCH	2.85	2,545	843	7,686
BROWN BRANCH	0.55	1,647	545	4,974
BROWN BRANCH	1.18	2,275	753	6,870
BROWN BRANCH	1.84	2,796	926	8,444
BROWN BRANCH	2.31	3,214	1,064	9,706
BUMS CREEK	0.63	1,442	477	4,355
BUMS CREEK	2.30	2,772	918	8,371
CANEY CREEK	1.00	1,547	512	4,672
CANEY CREEK	1.24	1,752	580	5,291
CANEY CREEK	2.70	3,283	1,087	9,915
CANEY CREEK	2.95	3,545	1,174	10,706
CANEY CREEK	6.65	6,256	2,072	18,893
CANEY CREEK	8.35	7,561	2,504	22,834
CANEY CREEK	9.67	8,155	2,700	24,628
CANEY CREEK	12.70	10,378	3,436	31,341
CANEY CREEK	13.57	10,806	3,578	32,634
CANEY CREEK	14.63	10,483	3,471	31,658
CANEY CREEK	16.97	12,013	3,978	36,279
CANEY CREEK	17.92	12,034	3,985	36,342
CANEY CREEK	21.46	13,062	4,325	39,447
CANEY CREEK	25.14	15,012	4,971	45,336

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CANEY CREEK	26.13	15,464	5,121	46,701
CANEY CREEK	31.62	16,535	5,475	49,935
CANEY CREEK	32.45	17,003	5,630	51,348
CANEY CREEK	37.00	18,524	6,134	55,942
CANEY CREEK	38.44	19,752	6,541	59,650
CANEY CREEK	39.44	19,254	6,376	58,146
CANEY CREEK	40.44	20,237	6,701	61,115
CANEY CREEK	41.05	18,318	6,066	55,319
CANEY CREEK	48.85	23,111	7,653	69,794
CANEY CREEK	52.61	21,717	7,191	65,584
CANEY CREEK	53.35	21,421	7,093	64,690
CANEY CREEK	57.16	23,959	7,934	72,355
CANEY CREEK	58.10	23,902	7,915	72,183
CANEY CREEK	58.72	22,205	7,353	67,058
CANEY CREEK NORTH	0.61	1,060	351	3,201
CANEY CREEK NORTH	1.07	1,782	590	5,382
CANEY CREEK NORTH	1.98	2,781	921	8,398
CANEY CREEK NORTH	2.75	2,986	989	9,018
CANEY CREEK NORTH	4.52	4,347	1,439	13,128
CANEY CREEK NORTH	4.63	4,952	1,640	14,955
CANEY CREEK NORTH	6.93	6,387	2,115	19,288
CANEY CREEK NORTH	8.26	7,218	2,390	21,798
CANEY CREEK NORTH	12.46	9,542	3,160	28,816
CANEY CREEK NORTH	13.67	10,498	3,476	31,703
CANEY CREEK NORTH	15.37	11,449	3,791	34,575
CANEY CREEK NORTH	16.32	12,156	4,025	36,711
CANEY CREEK NORTH	16.45	11,037	3,655	33,331
CANEY CREEK NORTH	18.42	12,347	4,088	37,287
CANEY CREEK NORTH	19.36	11,825	3,916	35,711
CANEY CREEK NORTH	21.69	13,186	4,366	39,821
CANEY CREEK NORTH	22.75	13,785	4,565	41,630
CANEY CREEK NORTH	26.51	15,404	5,101	46,519
CANEY CREEK NORTH	28.60	14,586	4,830	44,049
CANEY CREEK NORTH	30.91	15,363	5,087	46,396
CANEY CREEK NORTH	33.39	14,944	4,948	45,130
CANEY CREEK NORTH	35.27	15,685	5,194	47,368
CANEY CREEK NORTH	36.11	17,295	5,727	52,230
CANEY CREEK NORTH	36.32	15,915	5,270	48,063
CANEY CREEK NORTH	40.68	17,222	5,703	52,010
CANEY CREEK NORTH	41.28	18,646	6,174	56,310

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CANEY CREEK NORTH	42.16	16,422	5,438	49,594
CANEY CREEK NORTH	44.57	17,057	5,648	51,511
CANEY CREEK NORTH	45.21	17,139	5,675	51,759
CANEY CREEK NORTH	45.90	17,261	5,716	52,127
CANEY CREEK NORTH	46.74	17,479	5,788	52,786
CANEY CREEK NORTH	47.71	19,218	6,364	58,037
CANEY CREEK NORTH	48.70	17,579	5,821	53,088
CANEY CREEK NORTH	49.05	18,854	6,243	56,938
CANEY CREEK NORTH TRIB NO 1	0.36	835	276	2,522
CANEY CREEK NORTH TRIB NO 1	1.00	2,168	718	6,547
CANEY CREEK NORTH TRIB NO 1	1.09	2,002	663	6,046
CANEY CREEK NORTH TRIB NO 2	0.50	1,083	359	3,271
CANEY CREEK NORTH TRIB NO 2	1.36	2,233	739	6,744
CANEY CREEK NORTH TRIB NO 2	1.65	2,172	719	6,559
CANEY CREEK NORTH TRIB NO 3	0.30	943	312	2,848
CANEY CREEK NORTH TRIB NO 3	1.00	1,905	631	5,753
CANEY CREEK NORTH TRIB NO 3	1.20	1,957	648	5,910
CANEY CREEK NORTH TRIB NO 4	0.48	1,964	650	5,931
CANEY CREEK NORTH TRIB NO 4	0.94	850	281	2,567
CANEY CREEK NORTH TRIB NO 4_1	0.47	1,024	339	3,092
CANEY CREEK NORTH TRIB NO 5	0.24	524	174	1,582
CANEY CREEK NORTH TRIB NO 5	1.43	2,175	720	6,568
CANEY CREEK NORTH TRIB NO 5	1.90	2,748	910	8,299
CANEY CREEK NORTH TRIB NO 6	0.17	533	176	1,610
CANEY CREEK NORTH TRIB NO 6	1.33	2,337	774	7,058
CANEY CREEK NORTH TRIB NO 6	1.87	2,673	885	8,072
CANEY CREEK NORTH TRIB NO 6	3.07	4,183	1,385	12,632
CANEY CREEK NORTH TRIB NO 6	3.76	4,178	1,383	12,617
CANEY CREEK NORTH TRIB NO 6_1	0.18	607	201	1,833
CANEY CREEK NORTH TRIB NO 6_1	0.93	1,651	547	4,986
CANEY CREEK NORTH TRIB NO 7	0.52	1,101	365	3,325
CANEY CREEK NORTH TRIB NO 7	0.74	1,370	454	4,137
CANEY CREEK TRIBUTARY NO 2	0.64	1,178	390	3,558
CANEY CREEK TRIBUTARY NO 2	1.59	2,357	780	7,118
CANEY CREEK TRIBUTARY NO 2	2.59	3,531	1,169	10,663
CANEY CREEK TRIBUTARY NO 2	2.90	3,985	1,320	12,035
CANEY CREEK TRIBUTARY NO 2	2.99	3,699	1,225	11,171
CARTERS SLOUGH	0.87	1,153	382	3,482
CARTERS SLOUGH	2.54	2,668	883	8,057
CARTERS SLOUGH	3.44	2,688	890	8,118

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CARTERS SLOUGH	4.34	3,277	1,085	9,896
CARWILE CREEK	0.22	593	196	1,791
CARWILE CREEK	0.90	1,817	602	5,487
CARWILE CREEK	1.08	1,606	532	4,850
CARWILE CREEK	1.92	2,847	943	8,598
CARWILE CREEK	2.19	4,281	1,418	12,928
CASIDY BRANCH	1.51	2,244	743	6,777
CASIDY BRANCH	1.92	2,488	824	7,514
CASIDY BRANCH	2.16	2,656	879	8,021
CASIDY BRANCH	3.73	4,120	1,364	12,442
CASIDY BRANCH	6.72	6,798	2,251	20,530
CCLC 007	0.71	1,539	510	4,648
CCLC 007	0.84	1,564	518	4,723
CCLC 010	0.35	1,052	348	3,177
CCLC 010	0.53	1,473	488	4,448
CCLC 010	0.70	1,764	584	5,327
CCLC 010	1.95	3,383	1,120	10,216
CCLC 011	0.62	1,517	502	4,581
CCLC 012	0.79	1,624	538	4,904
CCLC 012	1.62	3,253	1,077	9,824
CCLC 013	0.79	1,790	593	5,406
CCLC 015	0.06	170	56	513
CCLC 015	0.13	415	137	1,253
CCLC 015	0.38	1,013	335	3,059
CCLC 015	0.81	1,616	535	4,880
CCLC 015	1.36	2,323	769	7,015
CCLC 016	0.66	1,609	533	4,859
CCLC 020	0.64	1,546	512	4,669
CCLC 020	1.09	1,899	629	5,735
CCLC 022	0.83	1,435	475	4,334
CCLC 022	2.35	3,030	1,003	9,150
CCLC 022	2.86	3,593	1,190	10,851
CCLC 023	0.53	1,271	421	3,838
CCLC 024	1.01	2,113	700	6,381
CCLC 024	1.97	3,415	1,131	10,313
CCLC 024	3.26	4,299	1,424	12,983
CCLC 024	6.36	7,029	2,328	21,227
CCLC 024	7.78	7,877	2,608	23,788
CCLC 025	0.93	2,061	682	6,224
CCLC 026	0.90	1,781	590	5,379

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CCLC 026	2.42	4,046	1,340	12,219
CCLC 027	1.05	2,066	684	6,239
CCLC 027	1.43	2,730	904	8,244
CCLC 028	1.03	1,920	636	5,798
CCLC 028	1.16	1,603	531	4,841
CCLC 030	1.26	2,555	846	7,716
CCLC 030	2.22	3,579	1,185	10,808
CCLC 030	3.14	4,294	1,422	12,968
CCLC 030	4.11	4,980	1,649	15,039
CCLC 031	0.83	1,645	545	4,968
CCLC 033	0.32	917	304	2,769
CCLC 033	0.77	1,758	582	5,309
CCLC 034	0.73	1,461	484	4,412
CCLC 035	0.98	1,798	595	5,430
CCLC 036	0.69	1,372	454	4,143
CCLC 036	3.01	3,565	1,180	10,766
CCLC 037	1.11	1,812	600	5,472
CCLC 037	2.17	2,761	914	8,338
CCLC 039	0.55	975	323	2,944
CCLC 040	1.02	2,005	664	6,055
CCLC 040	1.19	2,081	689	6,285
CCLC 041	0.56	1,320	437	3,986
CCLC 041	1.00	1,684	558	5,086
CCLC 041	1.09	1,776	588	5,363
CCLC 042	1.15	1,868	619	5,641
CCLC 042	1.71	2,705	896	8,169
CCLC 044	0.47	871	288	2,630
CCLC 044	2.04	2,837	939	8,568
CCLC 044	2.69	2,828	936	8,540
CCLC 045	0.57	1,058	350	3,195
CCLC 047	0.96	1,715	568	5,179
CCLC 049	0.22	559	185	1,688
CCLC 049	0.72	1,414	468	4,270
CCLC 050	0.87	1,533	508	4,630
CCLC 051	0.76	1,453	481	4,388
CCLC 058	1.43	3,055	1,012	9,226
CCLC 058	2.19	3,012	997	9,096
CCLC 058	2.93	3,552	1,176	10,727
CCLC 063	1.02	1,517	502	4,581
CCLC 063	1.68	1,990	659	6,010

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CCLC 064	0.63	1,374	455	4,149
CCLC 064	1.07	1,698	562	5,128
CCLC 064	2.05	3,032	1,004	9,156
CCLC 064	2.29	2,926	969	8,836
CCLC 065	0.87	1,258	417	3,799
CCLC 066	0.44	948	314	2,863
CCLC 066	0.73	1,485	492	4,485
CCLC 066	2.36	3,583	1,186	10,820
CCLC 066	3.05	4,235	1,402	12,789
CCLC 066	4.01	4,723	1,564	14,263
CCLC 067	0.25	517	171	1,561
CCLC 068	0.53	1,218	403	3,678
CCLC 068	1.52	2,484	823	7,502
CCLC 069	0.97	1,840	609	5,557
CCLC 070	0.63	1,169	387	3,530
CCLC 070	5.19	5,637	1,867	17,023
CCLC 070	5.99	5,820	1,927	17,576
CCLC 070	6.74	6,401	2,120	19,331
CCLC 070	7.47	6,685	2,214	20,188
CCLC 071	0.84	1,368	453	4,131
CCLC 071	4.43	5,057	1,675	15,272
CCLC 072	0.56	905	300	2,733
CCLC 072	2.76	3,455	1,144	10,434
CCLC 072	3.34	3,663	1,213	11,062
CCLC 073	1.15	1,842	610	5,563
CCLC 073	1.98	2,614	866	7,894
CCLC 074	1.28	2,389	791	7,215
CCLC 074	1.50	2,144	710	6,475
CCLC 075	1.00	1,658	549	5,007
CCLC 075	1.34	1,828	605	5,520
CCLC 075	3.02	3,917	1,297	11,829
CCLC 076	1.14	2,015	667	6,085
CCLC 076	1.35	3,917	1,297	11,829
CCLC 078	0.88	1,797	595	5,427
CCLC 078	2.62	3,936	1,303	11,887
CCLC 079	0.87	1,459	483	4,406
CCLC 080	0.99	1,654	548	4,995
CCLC 084	1.32	2,178	721	6,577
CCLC 084	1.58	2,432	805	7,345
CCLC 086	1.01	1,989	659	6,007

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CCLC 086	1.43	2,170	719	6,553
CCLC 086	3.30	4,313	1,428	13,025
CCLC 087	0.61	1,287	426	3,887
CCLC 087	1.06	1,798	595	5,430
CCLC 088	0.74	1,453	481	4,388
CCLC 088	1.03	1,827	605	5,517
CCLC 089	0.68	1,125	373	3,397
CCLC 089	1.48	2,045	677	6,176
CCLC 091	0.52	991	328	2,993
CCLC 091	6.04	5,756	1,906	17,383
CCLC 092	0.53	1,248	413	3,769
CCLC 092	1.34	2,126	704	6,420
CCLC 092	2.69	3,270	1,083	9,875
CCLC 092	5.27	5,225	1,730	15,779
CCLC 093	0.73	1,340	444	4,047
CCLC 094	0.57	654	217	1,975
CCLC 094	1.96	2,097	694	6,333
CCLC 095	0.91	1,277	423	3,856
CCLC 096	0.76	1,284	425	3,878
CCLC 097	1.00	1,664	551	5,025
CCLC 097	1.30	1,843	610	5,566
CCLC 098	0.57	1,171	388	3,536
CCLC 098	1.10	1,936	641	5,847
CCLC 099	1.04	1,694	561	5,116
CCLC 099	2.13	2,768	917	8,359
CCLC 099	2.27	2,691	891	8,127
CCLC 100	1,399	463	4,225	1,399
CCLC 101	0.65	1,177	390	3,554
CCLC 105	0.66	1,083	359	3,271
CCLC 105	3.82	2,825	935	8,531
CCLC 106	1.27	2,050	679	6,191
CCLC 106	2.24	2,696	893	8,142
CCLC 106	2.90	2,302	762	6,952
CCLC 107	0.81	1,474	488	4,451
CCLC 110	1.01	1,685	558	5,089
CCLC 110	1.90	2,522	835	7,616
CCLC 110	2.89	3,440	1,139	10,389
CCLC 110	3.18	3,718	1,231	11,228
CCLC 112	0.64	1,382	458	4,174
CCLC 113	0.55	1,049	347	3,168

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CCLC 114	0.60	1,369	453	4,134
CCLC 114	1.29	2,668	883	8,057
CCLC 114	2.23	2,846	942	8,595
CCLC 115	0.16	2,439	808	7,366
CCLC 115	1.80	2,439	808	7,366
CCLC 116	1.20	2,254	746	6,807
CCLC 116	1.62	2,373	786	7,166
CCLC 117	0.51	970	321	2,929
CCLC 117	1.10	1,842	610	5,563
CCLC 118	1.02	1,937	641	5,850
CCLC 118	1.52	2,254	746	6,807
CCLC 120	0.83	1,559	516	4,708
CCLC 121	0.85	1,476	489	4,457
CCLC 124	0.62	1,121	371	3,385
CCLC 124	0.71	1,251	414	3,778
CCLC 124	3.44	4,038	1,337	12,195
CCLC 125	0.70	1,407	466	4,249
CCLC 125	2.66	3,364	1,114	10,159
CCLC 126	1.02	1,739	576	5,252
CCLC 126	1.71	2,467	817	7,450
CCLC 127	0.18	411	136	1,241
CCLC 127	0.32	688	228	2,078
CCLC 127	1.00	1,645	545	4,968
CCLC 127	1.51	2,337	774	7,058
CCLC 128	0.61	1,492	494	4,506
CCLC 128	0.94	2,094	693	6,324
CCLC 135	1.00	1,850	613	5,587
CCLC 135	1.71	2,709	897	8,181
CCLC 145	0.53	1,091	361	3,295
CHAMBERS CREEK	0.15	670	222	2,023
CHAMBERS CREEK	1.03	2,334	773	7,049
CHAMBERS CREEK	1.51	2,666	883	8,051
CLEAR BRANCH	0.85	2,035	674	6,146
CLEAR BRANCH	1.14	2,142	709	6,469
CLEAR BRANCH	2.94	4,141	1,371	12,506
CLEAR BRANCH	5.40	5,993	1,984	18,099
Conroe Lake 001	0.83	1,504	498	4,542
Conroe Lake 001	1.01	1,871	620	5,650
Conroe Lake 001	1.25	2,018	668	6,094
Conroe Lake 003	0.65	1,723	571	5,203

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
Conroe Lake 003	0.83	2,009	665	6,067
Conroe Lake 005	0.57	1,632	540	4,929
Conroe Lake 005	0.74	1,895	627	5,723
Conroe Lake 007	0.45	1,188	393	3,588
Conroe Lake 007	0.89	2,057	681	6,212
Conroe Lake 008	0.56	1,738	576	5,249
Conroe Lake 008	1.00	2,239	741	6,762
Conroe Lake 008	1.44	2,594	859	7,834
Conroe Lake 011	0.29	982	325	2,966
Conroe Lake 011	0.81	1,808	599	5,460
Conroe Lake 015	0.60	995	329	3,005
Conroe Lake 026	0.26	898	297	2,712
Conroe Lake 026	0.58	1,403	465	4,237
Conroe Lake 030	0.12	441	146	1,332
Conroe Lake 032	0.75	1,394	462	4,210
Conroe Lake 034	0.22	829	275	2,504
Conroe Lake 034	0.46	1,417	469	4,279
Conroe Lake 035	0.12	520	172	1,570
Conroe Lake 035	0.49	1,216	403	3,672
Conroe Lake 037	0.49	1,151	381	3,476
Conroe Lake 037	0.64	1,357	449	4,098
Conroe Lake 038	0.53	1,360	450	4,107
Conroe Lake 038	1.02	2,107	698	6,363
Conroe Lake 038	1.12	2,048	678	6,185
Conroe Lake 040	0.51	1,409	467	4,255
Conroe Lake 040	0.88	1,789	592	5,403
Conroe Lake 042	0.59	1,713	567	5,173
Conroe Lake 042	1.13	2,241	742	6,768
Conroe Lake 042	1.66	2,357	780	7,118
Conroe Lake 045	0.61	1,452	481	4,385
Conroe Lake 046	0.71	1,477	489	4,460
Conroe Lake 049	1.03	2,699	894	8,151
Conroe Lake 049	1.63	3,192	1,057	9,640
Conroe Lake 049	2.44	3,871	1,282	11,690
Conroe Lake 049	3.00	4,731	1,567	14,287
Conroe Lake 050	0.53	1,227	406	3,705
Conroe Lake 050	0.66	1,427	473	4,309
Conroe Lake 053	0.54	1,365	452	4,122
Conroe Lake 053	0.78	1,646	545	4,971
Conroe Lake 056	0.18	724	240	2,186

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
Conroe Lake 056	0.63	1,580	523	4,772
Conroe Lake 057	0.59	1,422	471	4,294
Conroe Lake 058	0.51	1,832	607	5,533
Conroe Lake 059	0.56	1,089	361	3,289
Conroe Lake 061	1.03	2,061	682	6,224
Conroe Lake 061	1.08	1,998	662	6,034
Conroe Lake 063	1.05	2,657	880	8,024
Conroe Lake 063	1.34	3,626	1,201	10,950
Conroe Lake 064	0.45	1,143	378	3,452
Conroe Lake 064	0.62	1,459	483	4,406
Conroe Lake 065	0.64	1,500	497	4,530
Conroe Lake 065	2.28	3,416	1,131	10,316
Conroe Lake 066	0.57	1,242	411	3,751
Conroe Lake 066	0.93	1,742	577	5,261
Conroe Lake 067	0.48	1,253	415	3,784
Conroe Lake 067	1.01	2,120	702	6,402
Conroe Lake 067	1.12	1,950	646	5,889
Conroe Lake 068	0.59	1,413	468	4,267
Conroe Lake 068	0.84	1,708	566	5,158
Conroe Lake 069	0.50	1,208	400	3,648
Conroe Lake 069	0.69	1,296	429	3,914
Conroe Lake 071	0.19	537	178	1,622
Conroe Lake 071	0.90	1,651	547	4,986
Conroe Lake 072	0.59	1,359	450	4,104
Conroe Lake 072	2.45	3,117	1,032	9,413
Conroe Lake 073	1.04	2,170	719	6,553
Conroe Lake 073	1.59	2,380	788	7,187
Conroe Lake 077	0.15	499	165	1,507
Conroe Lake 077	1.01	1,634	541	4,935
Conroe Lake 077	1.97	2,334	773	7,049
Conroe Lake 077	2.37	2,587	857	7,813
Conroe Lake 077	3.52	3,478	1,152	10,503
Conroe Lake 082	0.52	936	310	2,827
Conroe Lake 082	0.96	1,487	492	4,491
Conroe Lake 084	0.52	1,019	337	3,077
Conroe Lake 084	0.61	1,092	362	3,298
Conroe Lake 084	1.42	2,350	778	7,097
Conroe Lake 085	0.60	1,290	427	3,896
Conroe Lake 085	0.76	1,529	506	4,618
Conroe Lake 086	0.54	1,000	331	3,020

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
Conroe Lake 088	0.60	1,274	422	3,847
Conroe Lake 088	0.79	1,489	493	4,497
Conroe Lake 089	0.54	1,083	359	3,271
Conroe Lake 091	0.57	1,383	458	4,177
Conroe Lake 091	1.00	1,772	587	5,351
Conroe Lake 091	1.40	2,388	791	7,212
Conroe Lake 092	0.53	1,356	449	4,095
Conroe Lake 092	1.00	1,975	654	5,964
Conroe Lake 092	1.19	1,866	618	5,635
Conroe Lake 098	0.72	1,435	475	4,334
Conroe Lake 098	1.00	1,999	662	6,037
Conroe Lake 098	1.87	2,855	945	8,622
Conroe Lake 099	0.50	974	323	2,941
Conroe Lake 099	0.77	1,340	444	4,047
Conroe Lake 102	0.65	1,275	422	3,850
Conroe Lake 102	1.07	1,756	581	5,303
Conroe Lake 102	1.09	1,869	619	5,644
Conroe Lake 104	0.19	629	208	1,900
Conroe Lake 104	0.74	1,357	449	4,098
Conroe Lake 107	0.21	750	248	2,265
Conroe Lake 107	1.00	1,684	558	5,086
Conroe Lake 107	1.17	1,697	562	5,125
Conroe Lake 110	0.72	1,333	441	4,026
Conroe Lake 110	1.01	1,788	592	5,400
Conroe Lake 110	1.10	1,765	584	5,330
Conroe Lake 115	0.17	463	153	1,398
Conroe Lake 115	0.52	1,317	436	3,977
Conroe Lake 117	1.06	1,946	644	5,877
Conroe Lake 117	1.92	3,095	1,025	9,347
Conroe Lake 118	0.14	332	110	1,003
Conroe Lake 118	0.27	611	202	1,845
Conroe Lake 119	1.18	1,934	640	5,841
CRYSTAL CREEK	1.10	2,059	682	6,218
CRYSTAL CREEK	1.94	3,115	1,031	9,407
CRYSTAL CREEK	2.93	4,217	1,396	12,735
CRYSTAL CREEK	3.72	4,607	1,526	13,913
CRYSTAL CREEK	6.37	6,491	2,149	19,603
CRYSTAL CREEK	6.93	6,751	2,235	20,388
CRYSTAL CREEK	9.06	8,064	2,670	24,353
CRYSTAL CREEK	9.94	8,479	2,808	25,606

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CRYSTAL CREEK	12.33	10,106	3,346	30,520
CRYSTAL CREEK	13.29	10,288	3,407	31,069
CRYSTAL CREEK	16.39	11,396	3,774	34,415
CRYSTAL CREEK	16.79	11,284	3,736	34,077
CRYSTAL CREEK	19.28	12,240	4,053	36,964
CRYSTAL CREEK	19.48	12,164	4,028	36,735
CRYSTAL CREEK	22.52	13,354	4,422	40,328
CRYSTAL CREEK	23.52	13,702	4,537	41,379
CRYSTAL CREEK	23.89	13,731	4,547	41,467
CRYSTAL CREEK	24.77	13,979	4,629	42,216
CRYSTAL CREEK	25.75	14,255	4,720	43,049
CRYSTAL CREEK	25.84	14,227	4,711	42,965
CRYSTAL CREEK	26.22	14,347	4,751	43,327
CRYSTAL CREEK	36.52	18,320	6,066	55,326
CRYSTAL CREEK	37.23	18,279	6,053	55,202
CRYSTAL CREEK	37.62	18,387	6,089	55,528
CRYSTAL CREEK	43.15	20,305	6,724	61,320
CRYSTAL CREEK	43.86	20,465	6,777	61,803
CRYSTAL CREEK	44.66	20,554	6,806	62,072
CRYSTAL CREEK	47.43	21,485	7,114	64,884
Crystal Creek 001	1.07	1,255	416	3,790
Crystal Creek 001	1.49	1,494	495	4,512
Crystal Creek 002	2.20	1,911	633	5,771
Crystal Creek 002	3.05	2,399	794	7,245
Crystal Creek 002	4.77	3,155	1,045	9,528
Crystal Creek 002	5.59	3,852	1,276	11,633
Crystal Creek 003	0.91	566	187	1,709
Crystal Creek 006	0.21	231	76	698
Crystal Creek 007	2.50	1,543	511	4,660
Crystal Creek 007	2.90	2,770	917	8,365
Crystal Creek 008	1.12	1,266	419	3,823
Crystal Creek 008	1.17	1,619	536	4,889
Crystal Creek 008	2.10	2,673	885	8,072
Crystal Creek 008	2.15	2,730	904	8,244
Crystal Creek 009	0.84	1,074	356	3,243
Crystal Creek 010	0.47	511	169	1,543
Crystal Creek 012	0.59	785	260	2,371
Crystal Creek 012	0.65	813	269	2,455
Crystal Creek 013	1.45	2,691	891	8,127
Crystal Creek 013	1.65	2,674	885	8,075

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
Crystal Creek 015	0.28	585	194	1,767
Crystal Creek 024	1.00	1,486	492	4,488
Crystal Creek 024	1.39	1,942	643	5,865
Crystal Creek 027	0.57	1,170	387	3,533
Crystal Creek 033	0.73	1,227	406	3,705
Crystal Creek 037	1.08	1,650	546	4,983
Crystal Creek 037	1.72	2,722	901	8,220
Crystal Creek 038	1.06	1,702	564	5,140
Crystal Creek 038	2.02	2,610	864	7,882
Crystal Creek 038	2.71	3,167	1,049	9,564
Crystal Creek 039	0.84	1,669	553	5,040
Crystal Creek 040	1.02	1,706	565	5,152
Crystal Creek 040	1.08	1,624	538	4,904
Crystal Creek 043	0.70	1,333	441	4,026
Crystal Creek 046	1.02	1,700	563	5,134
Crystal Creek 046	1.71	1,958	648	5,913
Crystal Creek 050	1.00	1,693	561	5,113
Crystal Creek 053	1.19	1,537	509	4,642
Crystal Creek 053	1.69	2,025	671	6,115
Crystal Creek 054	0.26	233	77	704
Crystal Creek 054	1.38	673	223	2,032
Crystal Creek 054	2.32	1,700	563	5,134
Crystal Creek 054	2.83	2,909	963	8,785
Crystal Creek 055	0.19	207	69	625
Crystal Creek 056	1.46	1,418	470	4,282
Crystal Creek 056	2.46	1,840	609	5,557
Crystal Creek 056	3.13	2,214	733	6,686
Crystal Creek 060	0.16	326	108	985
CRYSTAL CREEK TRIBUTARY NO 1	1.25	1,630	540	4,923
CRYSTAL CREEK TRIBUTARY NO 1	2.14	2,636	873	7,961
CRYSTAL CREEK TRIBUTARY NO 1	3.11	3,565	1,180	10,766
CRYSTAL CREEK TRIBUTARY NO 1	3.82	4,087	1,353	12,343
CRYSTAL CREEK TRIBUTARY NO 1	4.43	4,594	1,521	13,874
CRYSTAL CREEK TRIBUTARY NO 10	1.50	1,526	505	4,608
CRYSTAL CREEK TRIBUTARY NO 10	1.96	1,832	607	5,533
CRYSTAL CREEK TRIBUTARY NO 2	0.63	1,145	379	3,458
CRYSTAL CREEK TRIBUTARY NO 3	0.77	1,100	364	3,322
CRYSTAL CREEK TRIBUTARY NO 3	2.58	3,072	1,017	9,277
CRYSTAL CREEK TRIBUTARY NO 3	2.73	3,202	1,060	9,670
CRYSTAL CREEK TRIBUTARY NO 3_1	1.64	2,291	759	6,919

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
CRYSTAL CREEK TRIBUTARY NO 4	0.80	1,301	431	3,929
CRYSTAL CREEK TRIBUTARY NO 4	1.52	2,496	827	7,538
CRYSTAL CREEK TRIBUTARY NO 5	0.63	1,060	351	3,201
CRYSTAL CREEK TRIBUTARY NO 6	0.65	1,304	432	3,938
CRYSTAL CREEK TRIBUTARY NO 6	2.10	2,989	990	9,027
CRYSTAL CREEK TRIBUTARY NO 6_2	0.59	976	323	2,947
CRYSTAL CREEK TRIBUTARY NO 7	1.05	1,795	594	5,421
CRYSTAL CREEK TRIBUTARY NO 7	1.69	2,248	744	6,789
CRYSTAL CREEK TRIBUTARY NO 8	1.03	1,906	631	5,756
CRYSTAL CREEK TRIBUTARY NO 8	1.95	2,893	958	8,737
CRYSTAL CREEK TRIBUTARY NO 9	0.53	1,175	389	3,548
DEER LAKE BRANCH	1.22	2,480	821	7,489
DEER LAKE BRANCH	1.76	3,123	1,034	9,431
DEER LAKE BRANCH	1.87	3,318	1,099	10,020
DUNKS DITCH	0.75	478	158	1,444
EAST SANDY CREEK	1.00	2,033	673	6,140
EAST SANDY CREEK	1.22	2,393	792	7,227
EAST SANDY CREEK	4.12	5,253	1,739	15,864
EAST SANDY CREEK	4.46	5,515	1,826	16,655
EAST SANDY CREEK	5.44	6,466	2,141	19,527
EAST SANDY CREEK	6.44	6,886	2,280	20,795
EAST SANDY CREEK	6.86	5,719	1,894	17,271
EAST SANDY CREEK	23.19	17,596	5,827	53,139
EAST SANDY CREEK	23.84	16,874	5,588	50,959
EAST SANDY CREEK	29.76	18,963	6,279	57,267
EAST SANDY CREEK	36.13	21,754	7,203	65,696
EAST SANDY CREEK	37.18	21,727	7,194	65,614
EAST SANDY CREEK	37.73	21,795	7,217	65,820
EAST SANDY CREEK	38.47	22,270	7,374	67,254
EAST SANDY CREEK	39.38	20,552	6,805	62,066
EAST SANDY CREEK	40.01	20,592	6,819	62,187
EAST SANDY CREEK	45.11	22,729	7,526	68,640
EAST SANDY CREEK	45.94	23,219	7,689	70,120
EAST SANDY CREEK	46.75	22,291	7,381	67,318
EAST SANDY CREEK	47.71	24,034	7,958	72,582
EGYPT CREEK	0.18	376	125	1,136
EGYPT CREEK	0.68	1,504	498	4,542
EGYPT CREEK	2.08	3,320	1,099	10,026
ERA BRANCH	0.43	1,164	385	3,515
ERA BRANCH	1.26	2,314	766	6,988

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
ERA BRANCH	1.51	2,405	796	7,263
FISH CREEK	0.91	1,477	489	4,460
FISH CREEK	1.32	1,695	561	5,119
FISH CREEK	2.18	2,426	803	7,326
FISH CREEK	2.72	3,336	1,105	10,075
FISH CREEK	3.72	3,900	1,291	11,778
FISH CREEK	4.72	4,594	1,521	13,874
FISH CREEK	5.72	5,184	1,717	15,655
FISH CREEK	6.69	5,591	1,851	16,885
FLAGTAIL CREEK	1.02	2,027	671	6,121
FLAGTAIL CREEK	1.72	2,534	839	7,653
FLAGTAIL CREEK	2.30	3,307	1,095	9,987
FLAGTAIL CREEK	6.37	5,113	1,693	15,441
FLAGTAIL CREEK	7.19	4,662	1,544	14,079
FLAGTAIL CREEK	8.03	5,559	1,841	16,788
FLAGTAIL CREEK	9.00	6,477	2,145	19,560
FLAGTAIL CREEK	9.74	5,448	1,804	16,453
FLAGTAIL CREEK	10.71	5,883	1,948	17,766
FLAGTAIL CREEK	11.61	7,110	2,354	21,472
FLH 10	0.99	467	155	1,410
FLH 10	1.25	554	183	1,673
FLH 10	1.97	645	214	1,948
FLH 12	0.27	96	32	290
FLOYDS CREEK	0.36	813	269	2,455
FLOYDS CREEK	1.01	1,638	542	4,947
FLOYDS CREEK	1.34	1,944	644	5,871
G103 15 00	0.46	302	100	912
G103 15 00	0.79	286	95	864
G103 15 00	0.96	512	170	1,546
G103 15 00	3.53	788	261	2,380
G103 15 00	4.28	949	314	2,866
G103 24 02	0.58	423	140	1,277
G103 24 03	0.72	486	161	1,468
G103 24 03	1.54	772	256	2,331
G103 24 03	1.78	872	289	2,633
G103 33 01	1.18	1,738	576	5,249
G103 33 01	1.46	1,990	659	6,010
G103 36 00	1.00	1162	385	3509
G103 36 00	2.21	2123	703	6411
G103 36 00	3.42	2769	917	8362

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
G103 36 00	3.66	2876	952	8685
G103 37 00	1.06	339	112	1,024
G103 37 00	1.72	921	305	2,781
G103 37 00	4.09	2,691	891	8,127
G103 37 02	1.34	1,494	495	4,512
G103 38 00	0.38	30	10	91
G103 38 00	1.02	541	179	1,634
G103 38 00	3.44	2,638	874	7,967
G103 38 00	3.74	2,724	902	8,226
G103 38 02	0.78	503	167	1,519
G103 38 02	1.18	871	288	2,630
G103 52 99	0.90	415	137	1,253
G103 52 99	2.19	820	272	2,476
GARRETTS CREEK	1.00	1,710	566	5,164
GARRETTS CREEK	1.29	2,090	692	6,312
GARRETTS CREEK	4.42	5,088	1,685	15,366
GARRETTS CREEK	7.46	6,951	2,302	20,992
GARRETTS CREEK	8.93	7,491	2,481	22,622
GARRETTS CREEK	9.67	8,533	2,826	25,769
GARRETTS CREEK	10.66	8,280	2,742	25,005
GARRETTS CREEK	10.80	7,775	2,575	23,480
GARRETTS CREEK	12.71	9,334	3,091	28,188
GARRETTS CREEK	20.57	14,469	4,791	43,696
GARRETTS CREEK	21.31	14,630	4,844	44,182
GARRETTS CREEK	21.91	14,567	4,824	43,992
GARRETTS CREEK	26.82	16,888	5,592	51,001
GARRETTS CREEK	27.07	15,726	5,207	47,492
GARRETTS CREEK	29.58	18,599	6,159	56,168
GARRETTS CREEK	30.57	18,613	6,163	56,210
GARRETTS CREEK	30.79	16,093	5,329	48,600
GETER CREEK	1.04	1,886	625	5,696
GETER CREEK	1.91	2,808	930	8,480
GETER CREEK	2.81	3,455	1,144	10,434
GETER CREEK	3.78	3,908	1,294	11,802
GRAND LAKE CREEK	1.03	1,724	571	5,206
GRAND LAKE CREEK	1.47	1,724	571	5,206
GRAND LAKE CREEK	2.47	2,436	807	7,357
GRAND LAKE CREEK	3.47	3,377	1,118	10,198
GRAND LAKE CREEK	3.95	4,823	1,597	14,565
GREEN BRANCH	0.22	573	190	1,730

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
GREEN BRANCH	1.20	2,215	733	6,689
GREEN BRANCH	1.39	2,041	676	6,164
GUM BRANCH	1.01	2,643	875	7,982
GUM BRANCH	2.00	3,402	1,127	10,274
GUM BRANCH	2.96	3,957	1,310	11,950
GUM BRANCH	3.95	4,167	1,380	12,584
GUM BRANCH	4.78	4,971	1,646	15,012
GUM BRANCH	5.49	4,326	1,432	13,064
GUM BRANCH	6.48	5,577	1,847	16,842
GUM BRANCH	6.70	5,732	1,898	17,310
GUM BRANCH	16.04	11,028	3,652	33,304
GUM BRANCH	16.92	10,253	3,395	30,964
HARPERS HORSEPEN BRANCH	0.45	893	296	2,697
HAYNIE CREEK	0.94	1,515	502	4,575
HAYNIE CREEK	2.56	3,194	1,058	9,646
HAYNIE CREEK	3.38	4,252	1,408	12,841
HAYNIE CREEK	4.33	4,264	1,412	12,877
HOSTETTER CREEK	1.02	2,053	680	6,200
HOSTETTER CREEK	1.85	2,540	841	7,671
HOSTETTER CREEK	3.13	3,804	1,260	11,488
HOSTETTER CREEK	3.99	4,926	1,631	14,876
HOSTETTER CREEK	5.13	5,937	1,966	17,929
HOSTETTER CREEK	5.43	5,795	1,919	17,501
HOSTETTER CREEK	6.42	6,395	2,118	19,313
HOSTETTER CREEK	7.31	6,573	2,177	19,850
HOSTETTER CREEK	7.90	7,267	2,406	21,946
HOSTETTER CREEK	8.35	7,310	2,421	22,076
JOHNS CREEK	1.30	2,279	755	6,882
JOHNS CREEK	1.95	2,854	945	8,619
JOHNS CREEK	2.52	2,673	885	8,072
JORDAN GULLY	0.47	338	112	1,021
JORDAN GULLY	1.16	1,076	356	3,249
JORDAN GULLY	2.16	1,760	583	5,315
JORDAN GULLY	2.96	3,359	1,112	10,144
KELLY BRANCH	0.22	614	203	1,854
KELLY BRANCH	1.08	1,760	583	5,315
KELLY BRANCH	2.01	2,257	747	6,816
KELLY BRANCH	2.45	2,872	951	8,673
KIDHAW BRANCH	0.76	1,403	465	4,237
KIDHAW BRANCH	1.03	1,720	570	5,194

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
KIDHAW BRANCH	2.00	3,233	1,071	9,764
KIDHAW BRANCH	2.13	2,757	913	8,326
KIDHAW BRANCH	3.91	4,781	1,583	14,438
KIDHAW BRANCH TRIBUTARY NO 1	0.80	1,567	519	4,732
KIDHAW BRANCH TRIBUTARY NO 2	0.87	1,736	575	5,243
LAKE CREEK	0.99	1,583	524	4,781
LAKE CREEK	3.12	3,797	1,257	11,467
LAKE CREEK	9.88	9,244	3,061	27,916
LAKE CREEK	10.76	9,629	3,188	29,079
LAKE CREEK	10.90	9,607	3,181	29,013
LAKE CREEK	12.22	10,275	3,402	31,030
LAKE CREEK	13.42	10,741	3,557	32,437
LAKE CREEK	15.18	10,871	3,600	32,830
LAKE CREEK	15.89	11,275	3,734	34,050
LAKE CREEK	20.14	13,094	4,336	39,543
LAKE CREEK	23.17	13,979	4,629	42,216
LAKE CREEK	34.80	18,975	6,283	57,304
LAKE CREEK	38.39	19,928	6,599	60,182
LAKE CREEK	39.26	20,046	6,638	60,538
LAKE CREEK	39.59	19,798	6,556	59,789
LAKE CREEK	42.79	20,944	6,935	63,250
LAKE CREEK	43.79	21,203	7,021	64,032
LAKE CREEK	44.55	21,069	6,977	63,627
LAKE CREEK	47.13	20,721	6,861	62,576
LAKE CREEK	47.18	20,488	6,784	61,873
LAKE CREEK	51.12	21,554	7,137	65,092
LAKE CREEK	52.62	22,175	7,343	66,967
LAKE CREEK	53.45	22,474	7,442	67,870
LAKE CREEK	84.87	31,333	10,375	94,624
LAKE CREEK	89.77	31,431	10,408	94,920
LAKE CREEK	91.45	31,684	10,492	95,684
LAKE CREEK	98.88	32,877	10,887	99,287
LAKE CREEK	99.52	32,204	10,664	97,255
LAKE CREEK	103.46	33,519	11,099	101,226
LAKE CREEK	107.05	33,414	11,064	100,909
LAKE CREEK	107.20	33,836	11,204	102,183
LAKE CREEK	111.72	33,628	11,135	101,555
LAKE CREEK	115.78	34,000	11,258	102,678
LAKE CREEK	116.88	34,220	11,331	103,343
LAKE CREEK	155.05	41,224	13,651	124,494

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
LAKE CREEK	155.17	41,228	13,652	124,507
LAKE CREEK	157.61	41,613	13,779	125,669
LAKE CREEK	157.79	41,462	13,729	125,213
LAKE CREEK	158.12	41,444	13,723	125,159
LAKE CREEK	158.55	41,088	13,606	124,084
LAKE CREEK	159.26	40,812	13,514	123,250
LAKE CREEK	218.05	51,190	16,951	154,591
LAKE CREEK	222.04	51,849	17,169	156,581
LAKE CREEK	223.49	51,977	17,211	156,968
LAKE CREEK	224.02	51,587	17,082	155,790
LAKE CREEK	229.31	53,391	17,679	161,238
LAKE CREEK	241.17	54,865	18,168	165,690
LAKE CREEK	246.22	55,440	18,358	167,426
LAKE CREEK	249.79	55,310	18,315	167,034
LAKE CREEK	252.57	55,292	18,309	166,979
LAKE CREEK	254.55	55,397	18,344	167,296
LAKE CREEK	260.54	55,432	18,355	167,402
LAKE CREEK	263.01	54,790	18,143	165,463
LAKE CREEK	267.14	55,188	18,274	166,665
LAKE CREEK	274.52	56,042	18,557	169,244
LAKE CREEK	274.79	55,784	18,472	168,465
LAKE CREEK	281.74	55,948	18,526	168,960
LAKE CREEK	288.02	57,948	19,188	175,000
LAKE CREEK	290.24	58,140	19,252	175,580
LAKE CREEK	290.60	58,123	19,246	175,529
LAKE CREEK	292.23	58,236	19,284	175,870
LAKE CREEK	314.53	61,068	20,222	184,422
LAKE CREEK	315.51	61,121	20,239	184,582
LAKE CREEK	323.88	61,872	20,488	186,850
LAKE CREEK	325.81	61,848	20,480	186,778
LAKE CREEK	326.41	61,545	20,379	185,863
LAKE CREEK	327.89	61,074	20,224	184,441
LAKE CREEK	329.60	60,948	20,182	184,060
LAKE CREEK TRIBUTARY NO 1	0.66	1,152	381	3,479
LAKE CREEK TRIBUTARY NO 1	1.60	2,304	763	6,958
LAKE CREEK TRIBUTARY NO 10	0.55	1,499	496	4,527
LAKE CREEK TRIBUTARY NO 10	0.74	1,920	636	5,798
LAKE CREEK TRIBUTARY NO 10	2.32	3,361	1,113	10,150
LAKE CREEK TRIBUTARY NO 10	4.13	5,001	1,656	15,103
LAKE CREEK TRIBUTARY NO 10	4.82	4,761	1,577	14,378

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
LAKE CREEK TRIBUTARY NO 10 1	0.41	1,113	369	3,361
LAKE CREEK TRIBUTARY NO 10 1	0.66	1,613	534	4,871
LAKE CREEK TRIBUTARY NO 11	1.04	2,020	669	6,100
LAKE CREEK TRIBUTARY NO 11	2.00	2,653	878	8,012
LAKE CREEK TRIBUTARY NO 11	3.00	3,504	1,160	10,582
LAKE CREEK TRIBUTARY NO 11 2	1.72	3,025	1,002	9,135
LAKE CREEK TRIBUTARY NO 11 2	2.50	3,960	1,311	11,959
LAKE CREEK TRIBUTARY NO 12	0.69	1,528	506	4,614
LAKE CREEK TRIBUTARY NO 12	1.42	2,642	875	7,979
LAKE CREEK TRIBUTARY NO 12	2.17	3,407	1,128	10,289
LAKE CREEK TRIBUTARY NO 13 A	0.89	1,487	492	4,491
LAKE CREEK TRIBUTARY NO 13 A	1.01	1,717	569	5,185
LAKE CREEK TRIBUTARY NO 13 A	1.21	1,918	635	5,792
LAKE CREEK TRIBUTARY NO 14	0.53	1,201	398	3,627
LAKE CREEK TRIBUTARY NO 14	1.01	1,730	573	5,225
LAKE CREEK TRIBUTARY NO 15	0.88	1,820	603	5,496
LAKE CREEK TRIBUTARY NO 15	1.48	2,900	960	8,758
LAKE CREEK TRIBUTARY NO 15	1.86	2,968	983	8,963
LAKE CREEK TRIBUTARY NO 16	1.01	2,334	773	7,049
LAKE CREEK TRIBUTARY NO 16	1.60	3,303	1,094	9,975
LAKE CREEK TRIBUTARY NO 16	2.44	4,646	1,538	14,031
LAKE CREEK TRIBUTARY NO 17	0.48	914	303	2,760
LAKE CREEK TRIBUTARY NO 17	1.08	1,859	616	5,614
LAKE CREEK TRIBUTARY NO 17	2.03	2,846	942	8,595
LAKE CREEK TRIBUTARY NO 17	2.45	3,333	1,104	10,065
LAKE CREEK TRIBUTARY NO 18	1.09	2,302	762	6,952
LAKE CREEK TRIBUTARY NO 18	1.90	2,672	885	8,069
LAKE CREEK TRIBUTARY NO 18	3.79	3,959	1,311	11,956
LAKE CREEK TRIBUTARY NO 18	4.33	4,502	1,491	13,596
LAKE CREEK TRIBUTARY NO 18 5	0.65	1,400	464	4,228
LAKE CREEK TRIBUTARY NO 18 5	1.07	2,224	736	6,716
LAKE CREEK TRIBUTARY NO 2	1.02	1,749	579	5,282
LAKE CREEK TRIBUTARY NO 2	1.44	1,876	621	5,665
LAKE CREEK TRIBUTARY NO 20	0.98	1,781	590	5,379
LAKE CREEK TRIBUTARY NO 21	1.00	1,764	584	5,327
LAKE CREEK TRIBUTARY NO 21	1.48	2,176	721	6,571
LAKE CREEK TRIBUTARY NO 21	2.84	3,618	1,198	10,926
LAKE CREEK TRIBUTARY NO 21 1	0.92	1,643	544	4,962
LAKE CREEK TRIBUTARY NO 22	1.05	1,752	580	5,290
LAKE CREEK TRIBUTARY NO 22	1.51	1,783	590	5,384

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
LAKE CREEK TRIBUTARY NO 27	0.64	1,304	432	3,938
LAKE CREEK TRIBUTARY NO 27	1.34	2,278	754	6,879
LAKE CREEK TRIBUTARY NO 28	1.03	2,223	736	6,713
LAKE CREEK TRIBUTARY NO 28	1.59	3,028	1,003	9,144
LAKE CREEK TRIBUTARY NO 28	2.59	4,038	1,337	12,195
LAKE CREEK TRIBUTARY NO 28	3.18	4,048	1,340	12,225
LAKE CREEK TRIBUTARY NO 29	1.04	2,146	711	6,481
LAKE CREEK TRIBUTARY NO 29	2.05	3,189	1,056	9,631
LAKE CREEK TRIBUTARY NO 29	2.85	3,532	1,170	10,666
LAKE CREEK TRIBUTARY NO 3	1.05	1,973	653	5,958
LAKE CREEK TRIBUTARY NO 3	2.01	3,543	1,173	10,700
LAKE CREEK TRIBUTARY NO 3	2.83	3,871	1,282	11,690
LAKE CREEK TRIBUTARY NO 3	3.83	4,971	1,646	15,012
LAKE CREEK TRIBUTARY NO 3	4.04	4,524	1,498	13,662
LAKE CREEK TRIBUTARY NO 4	1.27	2,652	878	8,009
LAKE CREEK TRIBUTARY NO 4	2.09	3,276	1,085	9,893
LAKE CREEK TRIBUTARY NO 4	3.68	4,533	1,501	13,689
LAKE CREEK TRIBUTARY NO 4	4.68	5,561	1,841	16,794
LAKE CREEK TRIBUTARY NO 4	5.23	5,729	1,897	17,301
LAKE CREEK TRIBUTARY NO 5	0.62	1,565	518	4,726
LAKE CREEK TRIBUTARY NO 5	1.02	2,348	777	7,091
LAKE CREEK TRIBUTARY NO 5	1.45	2,678	887	8,087
LAKE CREEK TRIBUTARY NO 5	2.23	3,346	1,108	10,105
LAKE CREEK TRIBUTARY NO 5	2.86	3,923	1,299	11,847
LAKE CREEK TRIBUTARY NO 5	3.05	3,959	1,311	11,956
LAKE CREEK TRIBUTARY NO 6	0.28	797	264	2,407
LAKE CREEK TRIBUTARY NO 6	1.22	1,955	647	5,904
LAKE CREEK TRIBUTARY NO 7	0.11	237	78	716
LAKE CREEK TRIBUTARY NO 7	1.03	1,992	660	6,016
LAKE CREEK TRIBUTARY NO 7	1.43	1,928	638	5,822
LAKE CREEK TRIBUTARY NO 8	1.00	1,578	523	4,765
LAKE CREEK TRIBUTARY NO 8	1.35	1,788	592	5,400
LAKE CREEK TRIBUTARY NO 8	2.82	3,409	1,129	10,295
LAKE CREEK TRIBUTARY NO 8	4.30	4,571	1,514	13,804
LAKE CREEK TRIBUTARY NO 8	6.24	5,972	1,978	18,035
LAKE CREEK TRIBUTARY NO 8 1	0.78	1,764	584	5,327
LAKE CREEK TRIBUTARY NO 8 2	0.51	941	312	2,842
LAKE CREEK TRIBUTARY NO 8 2	1.12	2,150	712	6,493
LAKE CREEK TRIBUTARY NO 8 4	0.91	1,517	502	4,581
LANDRUM CREEK	0.55	1,180	391	3,564

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
LANDRUM CREEK	0.85	1,440	477	4,349
LANDRUM CREEK	3.41	4,014	1,329	12,122
LANDRUM CREEK	5.74	5,766	1,909	17,413
LANDRUM CREEK	5.84	6,858	2,271	20,711
LANDRUM CREEK	8.06	6,858	2,271	20,711
LANDRUM CREEK	10.87	8,282	2,742	25,011
LEE BRANCH	2.15	3,467	1,148	10,470
LEE BRANCH	4.53	5,710	1,891	17,244
LEE BRANCH	5.61	6,798	2,251	20,530
LEE BRANCH	6.04	6,803	2,253	20,545
LEWIS CREEK	0.21	637	211	1,922
LEWIS CREEK	1.09	2,110	699	6,373
LEWIS CREEK	1.52	2,449	811	7,395
LEWIS CREEK	2.44	2,768	917	8,360
LEWIS CREEK	5.53	5,462	1,808	16,494
LEWIS CREEK	6.33	5,325	1,763	16,082
LEWIS CREEK	7.31	5,412	1,792	16,345
LEWIS CREEK	8.12	5,794	1,918	17,497
LEWIS CREEK	9.00	5,493	1,819	16,587
LEWIS CREEK	9.19	5,078	1,681	15,335
LITTLE CANEY CREEK	4.88	4,501	1,490	13,593
LITTLE CANEY CREEK	6.09	5,993	1,984	18,099
LITTLE CANEY CREEK	10.69	9,187	3,042	27,744
LITTLE CANEY CREEK	11.55	9,744	3,227	29,426
LITTLE CANEY CREEK	12.36	9,660	3,199	29,173
LITTLE CANEY CREEK	13.24	10,144	3,359	30,634
LITTLE CANEY CREEK	13.68	10,329	3,420	31,193
LITTLE CANEY CREEK	18.40	11,920	3,947	35,998
LITTLE CANEY CREEK	19.26	12,786	4,234	38,613
LITTLE CANEY CREEK	24.00	12,715	4,210	38,399
LITTLE CANEY CREEK	24.05	13,666	4,525	41,271
LITTLE CANEY CREEK	26.75	14,599	4,834	44,088
LITTLE CANEY CREEK	27.38	13,862	4,590	41,863
LITTLE CANEY CREEK	29.83	13,423	4,445	40,537
LITTLE CANEY CREEK	30.56	14,847	4,916	44,837
LITTLE CANEY CREEK	32.92	15,144	5,015	45,734
LITTLE CANEY CREEK	33.79	14,678	4,860	44,327
LITTLE CANEY CREEK	34.53	13,935	4,614	42,083
LITTLE CANEY CREEK	35.51	15,365	5,088	46,402
LITTLE CANEY CREEK	35.76	13,540	4,484	40,890

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
LITTLE CHINQUAPIN CREEK	1.99	3,706	1,227	11,192
LITTLE CHINQUAPIN CREEK	2.77	4,307	1,426	13,007
LITTLE LAKE CREEK	0.27	696	230	2,102
LITTLE LAKE CREEK	1.01	1,778	589	5,369
LITTLE LAKE CREEK	1.33	2,050	679	6,191
LITTLE LAKE CREEK	3.13	3,705	1,227	11,189
LITTLE LAKE CREEK	4.12	4,180	1,384	12,623
LITTLE LAKE CREEK	4.47	4,277	1,416	12,916
LITTLE LAKE CREEK	5.17	5,080	1,682	15,341
LITTLE LAKE CREEK	7.06	6,456	2,138	19,497
LITTLE LAKE CREEK	8.52	6,812	2,256	20,572
LITTLE LAKE CREEK	13.21	9,985	3,306	30,154
LITTLE LAKE CREEK	14.04	9,901	3,279	29,901
LITTLE LAKE CREEK	14.71	10,114	3,349	30,544
LITTLE LAKE CREEK	20.13	13,222	4,378	39,930
LITTLE LAKE CREEK	20.87	12,138	4,019	36,656
LITTLE LAKE CREEK	21.13	11,211	3,712	33,857
LITTLE LAKE CREEK	22.93	13,575	4,495	40,996
LITTLE LAKE CREEK	23.84	12,285	4,068	37,100
LITTLE LAKE CREEK	24.23	12,154	4,025	36,704
LITTLE LAKE CREEK	25.21	12,202	4,040	36,849
LITTLE LAKE CREEK	26.12	11,778	3,900	35,569
LITTLE LAKE CREEK	26.84	12,683	4,200	38,302
LITTLE LAKE CREEK	27.78	12,843	4,253	38,785
LITTLE LAKE CREEK	28.18	12,017	3,979	36,291
LITTLE LAKE CREEK	28.99	12,230	4,050	36,934
LITTLE LAKE CREEK	30.54	12,397	4,105	37,438
LITTLE LAKE CREEK	31.25	12,038	3,986	36,354
LITTLE LAKE CREEK TRIB NO 1	0.68	1,450	480	4,379
LITTLE LAKE CREEK TRIB NO 1	0.78	186	62	562
LITTLE LAKE CREEK TRIB NO 2	0.65	1,044	346	3,153
LITTLE LAKE CREEK TRIB NO 3	0.13	389	129	1,175
LITTLE LAKE CREEK TRIB NO 3	1.01	1,684	558	5,086
LITTLE LAKE CREEK TRIB NO 3	1.60	1,937	641	5,850
LITTLE LAKE CREEK TRIB NO 4	1.30	2,379	788	7,184
LITTLE LAKE CREEK TRIB NO 5	0.32	770	255	2,325
LITTLE LAKE CREEK TRIB NO 5	1.10	2,146	711	6,481
LITTLE LAKE CREEK TRIB NO 5	1.49	2,215	733	6,689
LITTLE LAKE CREEK TRIB NO 5	3.62	4,568	1,513	13,795
LITTLE LAKE CREEK TRIB NO 5	4.46	5,170	1,712	15,613

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
LITTLE LAKE CREEK TRIB NO 5	5.17	5,759	1,907	17,392
LITTLE LAKE CREEK TRIB NO 5_1	0.25	943	312	2,848
LITTLE LAKE CREEK TRIB NO 5_1	1.30	2,375	786	7,172
LITTLE LAKE CREEK TRIB NO 6	1.25	2,110	699	6,372
LITTLE LAKE CREEK TRIB NO 7	0.13	467	155	1,410
LITTLE LAKE CREEK TRIB NO 7	0.32	828	274	2,501
LIVE BRANCH	0.10	420	139	1,268
LIVE BRANCH	0.53	1,439	476	4,346
LIVE BRANCH	1.99	3,441	1,139	10,392
LIVE OAK BRANCH	0.12	374	124	1,129
LIVE OAK BRANCH	0.32	783	259	2,365
LIVE OAK BRANCH	1.06	2,051	679	6,194
LIVE OAK BRANCH	2.04	3,264	1,081	9,857
LIVE OAK BRANCH	2.91	3,819	1,265	11,533
LOWER TRIB TO WF OF WHT OAK CRK	0.22	520	172	1,570
LOWER TRIB TO WF OF WHT OAK CRK	0.52	1,361	451	4,110
LUCAS BRANCH	0.72	1,814	601	5,478
MAPLE BRANCH	0.65	1,456	482	4,397
MAPLE BRANCH	1.04	2,133	706	6,442
MAPLE BRANCH	1.33	2,449	811	7,396
MAPLE BRANCH	2.41	3,702	1,226	11,180
MAPLE BRANCH	3.06	4,388	1,453	13,252
MAPLE BRANCH	3.74	4,872	1,613	14,713
MAPLE BRANCH	4.43	5,486	1,817	16,567
MARTIN CREEK	1.00	2,509	831	7,577
MARTIN CREEK	1.91	3,448	1,142	10,413
MARTIN CREEK	4.01	5,529	1,831	16,697
MARTIN CREEK	5.72	6,871	2,275	20,750
MARTIN CREEK TRIBUTARY NO 1	0.58	1,058	350	3,195
MARTIN CREEK TRIBUTARY NO 1	1.01	1,884	624	5,690
MARTIN CREEK TRIBUTARY NO 1	1.49	2,480	821	7,489
MARTIN CREEK TRIBUTARY NO 2	0.87	1,404	465	4,240
MARTIN CREEK TRIBUTARY NO 2	1.47	2,404	796	7,260
MARTIN CREEK TRIBUTARY NO 2_1	0.44	857	284	2,588
MARTIN CREEK TRIBUTARY NO 2_1	0.55	1,061	351	3,204
MCDONALD CREEK	0.25	655	217	1,978
MCDONALD CREEK	1.04	2,122	703	6,408
MCDONALD CREEK	1.99	3,524	1,167	10,642
MCDONALD CREEK	2.99	4,645	1,538	14,028
MCDONALD CREEK	3.96	5,532	1,832	16,706

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
MCDONALD CREEK	4.94	6,273	2,077	18,944
MCDONALD CREEK	5.58	7,021	2,325	21,203
MCDONALD CREEK	6.54	7,554	2,501	22,813
MCDONALD CREEK	7.54	7,930	2,626	23,948
MCDONALD CREEK	8.54	8,761	2,901	26,458
MCDONALD CREEK	9.30	9,218	3,052	27,838
MCDONALD CREEK	10.29	9,018	2,986	27,234
MCDONALD CREEK	11.13	9,490	3,142	28,659
MCGARY CREEK	1.78	3,410	1,129	10,298
MCGARY CREEK	2.18	3,409	1,129	10,295
MCGARY CREEK	4.71	6,037	1,999	18,231
MCGARY CREEK	6.46	6,553	2,170	19,790
MCGARY CREEK	6.48	6,911	2,288	20,871
MCGARY CREEK	6.74	6,933	2,296	20,937
MCGARY CREEK	7.85	7,531	2,494	22,743
MCGARY CREEK	11.54	9,989	3,308	30,166
MCGARY CREEK	13.38	10,261	3,398	30,988
MCGARY CREEK	14.97	10,888	3,605	32,881
MCGARY CREEK	15.88	11,770	3,897	35,545
MCGARY CREEK	20.52	13,181	4,365	39,806
MCGARY CREEK	21.83	12,024	3,982	36,312
MCGARY CREEK	23.27	13,783	4,564	41,624
MCGARY CREEK	23.74	13,293	4,402	40,144
MCGARY CREEK	24.08	14,097	4,668	42,572
MCGARY CREEK	24.35	13,099	4,337	39,558
MCGARY CREEK	25.51	13,555	4,488	40,935
MILL BRANCH	1.42	2,334	773	7,049
MILL BRANCH	3.59	4,620	1,530	13,952
MILL BRANCH	4.23	4,965	1,644	14,994
MOCK BRANCH	0.75	1,222	405	3,690
MOCK BRANCH	1.70	2,214	733	6,686
MOCK BRANCH	3.11	2,900	960	8,758
MOCK BRANCH	4.62	3,972	1,315	11,995
MOUND CREEK	0.69	1122	372	3388
MOUND CREEK	2.03	2348	777	7091
MOUND CREEK	2.90	2941	974	8882
MOUND CREEK	7.32	7219	2390	21801
MOUND CREEK	8.28	7316	2423	22094
MOUND CREEK	10.26	8239	2728	24881
MOUND CREEK	11.80	9433	3124	28487

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
MOUND CREEK	14.58	10616	3515	32060
MOUND CREEK	16.78	10971	3633	33132
MOUND CREEK	17.70	11246	3724	33962
MOUND CREEK	18.53	11686	3870	35291
MOUND CREEK	19.43	11409	3778	34455
MOUND CREEK	20.27	11954	3958	36101
MOUND CREEK	20.82	11532	3819	34826
MOUND CREEK TRIBUTARY NO 1	0.61	1,264	419	3,817
MOUND CREEK TRIBUTARY NO 1	1.05	1,862	617	5,623
MOUND CREEK TRIBUTARY NO 1	1.24	9,433	3,124	28,487
MOUND CREEK TRIBUTARY NO 2	0.58	1,209	400	3,651
MOUND CREEK TRIBUTARY NO 2	1.05	2,097	694	6,333
MOUND CREEK TRIBUTARY NO 2	1.17	1,985	657	5,995
MOUND CREEK TRIBUTARY NO 3	1.24	2,510	831	7,580
MOUND CREEK TRIBUTARY NO 3	1.97	3,790	1,255	11,446
MOUND CREEK TRIBUTARY NO 5	1.35	2,471	818	7,462
MOUND CREEK TRIBUTARY NO 5	2.12	2,909	963	8,785
MOUND CREEK TRIBUTARY NO 5	3.00	3,353	1,110	10,126
MOUND CREEK TRIBUTARY NO 5	3.51	3,631	1,202	10,965
NEELY SPRING BRANCH	0.35	515	171	1,555
NEELY SPRING BRANCH	2.01	2,352	779	7,103
NEELY SPRING BRANCH	3.08	3,101	1,027	9,365
NORTH FORK STEWARTS CREEK	0.43	1,017	337	3,071
PERSIMMON CREEK	4.33	5,443	1,802	16,438
PERSIMMON CREEK	5.31	6,019	1,993	18,177
PERSIMMON CREEK	6.05	6,652	2,203	20,089
PLUM CREEK	0.69	1,525	505	4,605
PLUM CREEK	0.90	1,837	608	5,548
PLUM CREEK	2.28	3,626	1,201	10,950
PLUM CREEK	3.28	5,073	1,680	15,320
PLUM CREEK	3.72	4,661	1,543	14,076
PLUM CREEK	5.36	5,980	1,980	18,059
PLUM CREEK	5.87	6,166	2,042	18,621
POLE CREEK	0.13	339	112	1,024
POLE CREEK	1.18	1,697	562	5,125
POLE CREEK	2.10	2,922	968	8,824
POLE CREEK	3.07	3,375	1,118	10,192
POLE CREEK	3.83	3,688	1,221	11,138
POLECAT BRANCH	0.50	1,156	383	3,491
POLECAT BRANCH	0.75	1,431	474	4,322

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
POSSUM BRANCH	0.99	1,359	450	4,104
PRAIRIE BRANCH	0.88	2,375	786	7,172
PRAIRIE BRANCH	1.43	2,746	909	8,293
PRAIRIE BRANCH	2.17	3,569	1,182	10,778
PRAIRIE BRANCH	3.15	4,053	1,342	12,240
PRAIRIE BRANCH	3.91	5,333	1,766	16,105
PRAIRIE BRANCH	5.35	6,171	2,043	18,636
PRAIRIE BRANCH	5.69	6,781	2,245	20,478
PRAIRIE BRANCH	8.88	8,679	2,874	26,210
PRAIRIE BRANCH	9.28	8,871	2,937	26,790
PRAIRIE BRANCH	15.48	13,307	4,406	40,186
ROBINSON BRANCH	1.84	2,495	826	7,535
ROBINSON BRANCH	2.33	2,643	875	7,982
ROBINSON CREEK	0.18	696	230	2,102
ROBINSON CREEK	1.46	3,323	1,100	10,035
ROBINSON CREEK	3.56	5,789	1,917	17,483
ROBINSON CREEK	4.83	6,487	2,148	19,590
ROBINSON CREEK	8.30	10,537	3,489	31,821
ROBINSON CREEK	9.38	9,190	3,043	27,753
ROBINSON CREEK	10.94	10,490	3,474	31,679
ROBINSON CREEK	11.94	10,451	3,461	31,562
ROBINSON CREEK	12.70	10,336	3,423	31,214
ROBINSON CREEK	13.85	11,201	3,709	33,826
ROBINSON CREEK	16.11	12,214	4,044	36,886
ROBINSON CREEK	16.58	12,073	3,998	36,460
ROBINSON CREEK	18.37	12,463	4,127	37,638
ROBINSON CREEK	19.47	12,254	4,058	37,006
ROBINSON CREEK	19.87	12,120	4,013	36,602
ROCKY CREEK	2.84	4,493	1,488	13,569
ROCKY CREEK	4.34	5,690	1,884	17,184
ROCKY CREEK	5.30	5,671	1,878	17,126
ROCKY CREEK	5.48	5,071	1,679	15,314
ROCKY CREEK	8.00	6,877	2,277	20,768
ROCKY CREEK	9.06	7,450	2,467	22,499
ROCKY CREEK	11.51	8,473	2,806	25,588
ROGERS GULLY	1.00	424	140	1,280
ROGERS GULLY	1.20	566	187	1,709
ROGERS GULLY	2.24	1,722	570	5,200
ROGERS GULLY	2.42	690	228	2,084
ROGERS GULLY	4.30	1,972	653	5,955

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
ROGERS GULLY	5.19	2,318	768	7,000
ROGERS GULLY	5.82	2,421	802	7,311
SAND BRANCH (Frontal Lake Houston)	0.59	716	237	2,162
SAND BRANCH (Frontal Lake Houston)	1.60	1,668	552	5,037
SAND BRANCH (Conroe Lake)	0.68	1,611	533	4,865
SAND BRANCH (Conroe Lake)	0.95	1,912	633	5,774
SAND BRANCH (Conroe Lake)	1.18	2,101	696	6,345
SAND BRANCH (WFSJR)	0.48	1,240	411	3,745
SAND BRANCH (WFSJR)	0.73	1,624	538	4,904
SAND BRANCH (WFSJR)	1.57	2,816	932	8,504
SAND BRANCH (WFSJR)	2.17	3,077	1,019	9,292
SAND BRANCH (WFSJR)	2.95	3,908	1,294	11,802
SAND BRANCH NO 2	0.12	408	135	1,232
SAND BRANCH NO 2	1.00	2,071	686	6,254
SAND BRANCH NO 2	1.86	2,526	836	7,628
SAND BRANCH NO 3	0.14	577	191	1,743
SAND BRANCH NO 3	1.19	2,328	771	7,030
SAND BRANCH NO 3	2.10	2,718	900	8,208
SAND BRANCH NO 3	3.82	3,575	1,184	10,796
SAND CREEK (Conroe Lake)	2.04	2,570	851	7,761
SAND CREEK (Conroe Lake)	2.15	2,514	832	7,592
SAND CREEK (CCLC)	0.53	1,153	382	3,482
SAND CREEK (CCLC)	1.29	2,205	730	6,659
SAND CREEK (CCLC)	2.16	3,007	996	9,081
SAND CREEK (CCLC)	2.33	2,765	916	8,350
SAND CREEK (CCLC)	3.31	3,445	1,141	10,404
SAND CREEK (CCLC)	4.31	4,670	1,546	14,103
SAND CREEK (CCLC)	5.26	5,521	1,828	16,673
SANDY BRANCH	1.06	1,609	533	4,859
SANDY BRANCH	1.90	2,713	898	8,193
SANDY BRANCH	2.76	3,306	1,095	9,984
SANDY BRANCH	3.20	3,611	1,196	10,905
SCOTT BRANCH 01	1.29	2,690	891	8,124
SHEPARD BRANCH	0.14	520	172	1,570
SHEPARD BRANCH	1.35	2,769	917	8,362
SHEPARD BRANCH	2.14	3,231	1,070	9,757
SHEPARD BRANCH	2.44	3,335	1,104	10,072
SILVERDALE CREEK	1.00	1,513	501	4,569
SILVERDALE CREEK	1.99	2,679	887	8,090
SILVERDALE CREEK	2.86	3,561	1,179	10,754

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
SILVERDALE CREEK	3.71	3,747	1,241	11,316
SMITH BRANCH	0.53	1,421	471	4,291
SMITH BRANCH	1.45	3,091	1,024	9,335
SMITH BRANCH	2.02	3,757	1,244	11,346
SMITH BRANCH	2.96	4,814	1,594	14,538
SMITH BRANCH	3.88	4,437	1,469	13,400
SMITH BRANCH	4.83	4,934	1,634	14,900
SMITH BRANCH	5.45	5,288	1,751	15,970
SPRING BRANCH NO 2	0.57	1,483	491	4,479
SPRING BRANCH NO 2	2.06	3,306	1,095	9,984
STEWART CREEK NORTH	0.20	562	186	1,697
STEWART CREEK NORTH	0.73	1,668	552	5,037
STEWART CREEK NORTH	1.98	3,207	1,062	9,685
STEWART CREEK NORTH	2.97	4,245	1,406	12,820
STEWART CREEK NORTH	3.95	5,039	1,669	15,218
STEWART CREEK NORTH	4.95	5,326	1,764	16,084
STEWART CREEK NORTH	5.62	5,363	1,776	16,196
STEWART CREEK NORTH	16.72	10,023	3,319	30,269
STEWART CREEK NORTH	17.46	9,706	3,214	29,312
STEWART CREEK NORTH	23.68	12,351	4,090	37,299
STEWART CREEK NORTH	24.26	12,507	4,141	37,771
STEWART CREEK NORTH	24.92	12,370	4,096	37,357
STEWART CREEK NORTH	25.91	12,913	4,276	38,997
STEWART CREEK NORTH	26.57	11,327	3,751	34,207
STEWART CREEK NORTH	27.22	11,619	3,847	35,089
STEWART CREEK NORTH TRIB NO 2	0.71	1,785	591	5,391
STEWART CREEK NORTH TRIB NO 2	0.94	1,758	582	5,309
STEWART CREEK NORTH TRIB NO 2	1.01	1,589	526	4,799
STEWARTS CREEK	1.08	2,145	710	6,478
STEWARTS CREEK	1.96	3,133	1,037	9,462
STEWARTS CREEK	2.93	4,017	1,330	12,131
STEWARTS CREEK	3.75	4,003	1,326	12,089
STEWARTS CREEK	4.75	5,441	1,802	16,432
STEWARTS CREEK	5.38	5,559	1,841	16,788
STEWARTS CREEK	6.34	6,439	2,132	19,445
STEWARTS CREEK	7.20	6,569	2,175	19,838
STEWARTS CREEK	7.48	6,785	2,247	20,490
STEWARTS CREEK	10.25	8,782	2,908	26,521
STEWARTS CREEK	12.08	9,386	3,108	28,345
STEWARTS CREEK	12.95	10,312	3,415	31,142

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
STEWARTS CREEK	13.29	10,416	3,449	31,456
STEWARTS CREEK	13.95	10,175	3,369	30,728
STEWARTS CREEK	14.84	10,641	3,524	32,135
STEWARTS CREEK	16.60	10,696	3,542	32,301
STEWARTS CREEK	17.00	11,244	3,723	33,956
STEWARTS CREEK	17.97	11,220	3,715	33,884
STEWARTS CREEK	18.97	11,605	3,843	35,047
STEWARTS CREEK	19.27	12,865	4,260	38,852
STEWARTS CREEK	22.99	14,235	4,714	42,989
STEWARTS CREEK TRIBUTARY NO 1	1.00	1,503	498	4,539
STEWARTS CREEK TRIBUTARY NO 1	1.97	2,445	810	7,384
STEWARTS CREEK TRIBUTARY NO 1	2.11	2,287	757	6,907
STOWE BRANCH	0.69	1,152	381	3,479
STOWE BRANCH	0.71	1,045	346	3,156
TOWN CREEK	0.44	1,145	379	3,458
TOWN CREEK	1.01	2,250	745	6,795
TOWN CREEK	1.32	2,176	721	6,571
TOWN CREEK	3.69	4,281	1,418	12,928
TOWN CREEK	5.43	5,825	1,929	17,591
TOWN CREEK	7.47	6,288	2,082	18,989
TOWN CREEK	7.76	7,570	2,507	22,861
TOWN CREEK	9.27	7,968	2,638	24,063
TOWN CREEK	10.19	7,186	2,380	21,701
TOWN CREEK TRIBUTARY NO 1	0.16	359	119	1,084
TOWN CREEK TRIBUTARY NO 1	0.71	1,110	368	3,352
TOWN CREEK TRIBUTARY NO 1	1.05	1,594	528	4,814
TOWN CREEK TRIBUTARY NO 2	0.11	426	141	1,286
TOWN CREEK TRIBUTARY NO 2	1.02	2,102	696	6,348
TOWN CREEK TRIBUTARY NO 2	1.19	2,415	800	7,293
TRADE CTR DITCH_COLLEGE PK DITCH	0.67	1,066	353	3,219
TRADE CTR DITCH_COLLEGE PK DITCH	1.66	1,892	627	5,714
TRADE CTR DITCH_COLLEGE PK DITCH	2.04	3,030	1,003	9,150
TRADE CTR DITCH_COLLEGE PK DITCH	3.01	3,328	1,102	10,050
TRADE CTR DITCH_COLLEGE PK DITCH	4.00	2,887	956	8,719
TRADE CTR DITCH_COLLEGE PK DITCH	4.62	2,969	983	8,966
TRIBUTARY 4	0.47	1,216	403	3,672
TRIBUTARY 4	1.66	3,097	1,026	9,353
TRIBUTARY 4	2.98	4,597	1,522	13,883
TRIBUTARY 5	0.55	1,032	342	3,117
TRIBUTARY 5	1.57	2,259	748	6,822

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
TRIBUTARY 6	2.09	2,984	988	9,012
TRIBUTARY 6	2.23	3,276	1,085	9,893
TRIBUTARY 6	3.19	3,923	1,299	11,847
TRIBUTARY 6	3.37	4,116	1,363	12,430
TxDOT DITCH NO 4	0.95	1,902	630	5,744
TxDOT DITCH NO 4	1.87	2,389	791	7,215
UNNAMED TRIB TO WOODSONS GULLY	1.00	1,470	487	4,439
UNNAMED TRIB TO WOODSONS GULLY	1.53	2,149	712	6,490
WEIRS CREEK	0.20	744	246	2,247
WEIRS CREEK	1.58	3,926	1,300	11,856
WEIRS CREEK	1.67	4,316	1,429	13,034
WEIRS CREEK	2.52	4,628	1,532	13,976
WEIRS CREEK	2.72	4,047	1,340	12,222
WEIRS CREEK	3.36	4,781	1,583	14,438
WEIRS CREEK	5.54	6,891	2,282	20,810
WEIRS CREEK	8.17	7,882	2,610	23,803
WEIRS CREEK	10.21	8,090	2,679	24,431
WEIRS CREEK	12.67	9,711	3,216	29,327
WEIRS CREEK	14.62	10,503	3,478	31,719
WEIRS CREEK	15.37	10,089	3,341	30,468
WEIRS CREEK	16.06	9,190	3,043	27,753
WEIRS CREEK TRIBUTARY NO 1	0.16	580	192	1,752
WEIRS CREEK TRIBUTARY NO 1	0.72	1,849	612	5,584
WEIRS CREEK TRIBUTARY NO 1	0.88	1,879	622	5,674
WEIRS CREEK TRIBUTARY NO 1	2.08	3,312	1,097	10,002
WEIRS CREEK TRIBUTARY NO 2	0.54	1,282	425	3,872
WEIRS CREEK TRIBUTARY NO 2	1.02	1,983	657	5,989
WEIRS CREEK TRIBUTARY NO 2	1.15	1,834	607	5,539
WEIRS CREEK TRIBUTARY NO 3	0.65	1,227	406	3,705
WEIRS CREEK TRIBUTARY NO 3	1.04	1,851	613	5,590
WEIRS CREEK TRIBUTARY NO 3	1.87	2,846	942	8,595
WELCH BRANCH	1.69	2,408	797	7,272
WELCH BRANCH	2.32	2,928	970	8,842
WELCH BRANCH	2.47	3,021	1,000	9,123
WEST BRANCH ALLIGATOR CREEK	0.16	447	148	1,350
WEST BRANCH ALLIGATOR CREEK	0.58	1,238	410	3,739
WEST BRANCH ALLIGATOR CREEK	1.40	2,542	842	7,677
WEST CEDAR CREEK	0.67	1,351	447	4,080
WEST CEDAR CREEK	1.01	1,668	552	5,037

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
WEST CEDAR CREEK	1.41	1,992	660	6,016
WEST FORK OF CRYSTAL CREEK	1.01	1,218	403	3,678
WEST FORK OF CRYSTAL CREEK	1.98	2,090	692	6,312
WEST FORK OF CRYSTAL CREEK	2.88	2,607	863	7,873
WEST FORK OF CRYSTAL CREEK	3.36	3,286	1,088	9,924
WEST FORK OF CRYSTAL CREEK	5.42	4,850	1,606	14,647
WEST FORK OF CRYSTAL CREEK	6.97	5,889	1,950	17,784
WEST FORK OF CRYSTAL CREEK	7.70	6,304	2,087	19,038
WEST FORK OF CRYSTAL CREEK	8.27	6,323	2,094	19,095
WEST FORK OF CRYSTAL CREEK	9.27	6,960	2,305	21,019
WEST FORK OF CRYSTAL CREEK	9.39	7,006	2,320	21,158
WEST FORK OF WHITE OAK CREEK N	1.14	2,917	966	8,809
WEST FORK OF WHITE OAK CREEK N	1.60	3,348	1,109	10,111
WEST FORK OF WHITE OAK CREEK N	2.52	4,629	1,533	13,979
WEST FORK OF WHITE OAK CREEK N	3.34	5,730	1,897	17,304
WEST FORK OF WHITE OAK CREEK N	4.06	6,375	2,111	19,252
WEST FORK W BR ALLIGATOR CRK	0.20	560	185	1,691
WEST FORK W BR ALLIGATOR CRK	0.74	1,990	659	6,010
WEST GUM BRANCH	1.77	2,824	935	8,528
WEST ROCKY BRANCH	1.33	1,856	615	5,605
WEST ROCKY BRANCH	2.14	2,687	890	8,115
WEST ROCKY BRANCH	2.25	2,582	855	7,798
WEST ROCKY CREEK	1.40	2,029	672	6,127
WEST ROCKY CREEK	1.97	2,516	833	7,598
WEST ROCKY CREEK	2.39	2,703	895	8,163
WEST ROCKY CREEK	2.81	3,215	1,065	9,709
WEST ROCKY CREEK	3.09	3,098	1,026	9,356
WEST SANDY CREEK	1.00	1,684	558	5,086
WEST SANDY CREEK	1.07	1,654	548	4,995
WEST SANDY CREEK	1.96	2,665	882	8,048
WEST SANDY CREEK	2.94	3,931	1,302	11,871
WEST SANDY CREEK	3.48	4,371	1,447	13,200
WEST SANDY CREEK	6.70	6,085	2,015	18,376
WEST SANDY CREEK	9.04	7,010	2,321	21,170
WEST SANDY CREEK	9.83	7,826	2,591	23,634
WEST SANDY CREEK	10.56	8,280	2,742	25,005
WEST SANDY CREEK	12.83	8,886	2,942	26,835
WEST SANDY CREEK	19.21	12,871	4,262	38,870
WEST SANDY CREEK	19.63	12,810	4,242	38,686
WEST SANDY CREEK	21.84	13,745	4,551	41,509

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
WEST SANDY CREEK	24.04	14,736	4,880	44,502
WEST SANDY CREEK	24.69	15,040	4,980	45,420
WEST SANDY CREEK	31.64	17,761	5,881	53,637
WEST SANDY CREEK	33.06	18,071	5,984	54,574
WEST SANDY CREEK	35.34	18,777	6,218	56,706
WEST SANDY CREEK	35.55	17,449	5,778	52,695
WEST SANDY CREEK	36.41	16,349	5,414	49,373
WEST SANDY CREEK	37.08	16,506	5,466	49,847
WEST SANDY CREEK	38.07	17,780	5,888	53,695
WEST SANDY CREEK	39.66	17,689	5,857	53,420
WEST SANDY CREEK	41.07	17,689	5,857	53,420
WEST SANDY CREEK	42.93	19,280	6,384	58,225
WF OF CRYSTAL CREEK TRIB NO 1	1.04	891	295	2,691
WF OF CRYSTAL CREEK TRIB NO 1	1.31	1,101	365	3,325
WF OF CRYSTAL CREEK TRIB NO 2	1.01	737	244	2,226
WF OF CRYSTAL CREEK TRIB NO 2	1.58	1,594	528	4,814
WF OF SAN JAC RIVER TRIB NO 1	0.54	1,242	411	3,751
WF OF SAN JAC RIVER TRIB NO 1	1.05	1,535	508	4,636
WF OF SAN JAC RIVER TRIB NO 1	1.14	1,799	596	5,433
WF OF SAN JAC RIVER TRIB NO 1_1	0.70	1,264	419	3,817
WFSJ Main	1.00	1,559	516	4,708
WFSJ Main	1.92	1,936	641	5,847
WFSJ Main	4.18	3,571	1,182	10,784
WFSJ Main	7.70	5,208	1,725	15,728
WFSJ Main	14.00	8,113	2,686	24,501
WFSJ Main	21.22	9,788	3,241	29,559
WFSJ Main	26.02	11,387	3,771	34,388
WFSJ Main	36.39	14,651	4,851	44,245
WFSJ Main	47.96	18,203	6,028	54,972
WFSJ Main	51.46	19,718	6,529	59,547
WFSJ Main	57.62	19,803	6,557	59,804
WFSJ Main	83.99	25,779	8,536	77,851
WFSJ Main	88.83	26,749	8,857	80,781
WFSJ Main	95.85	27,999	9,271	84,556
WFSJ Main	103.05	27,982	9,266	84,504
WFSJ Main	108.62	28,938	9,582	87,391
WFSJ Main	129.09	33,164	10,982	100,154
WFSJ Main	174.86	39,967	13,234	120,698
WFSJ Main	186.64	41,746	13,823	126,071
WFSJ Main	191.27	39,615	13,118	119,635

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
WFSJ Main	239.19	47,062	15,584	142,125
WFSJ Main	248.26	46,303	15,332	139,833
WFSJ Main	253.67	45,622	15,107	137,776
WFSJ Main	258.61	45,212	14,971	136,538
WFSJ Main	264.74	44,136	14,615	133,289
WFSJ Main	281.66	46,024	15,240	138,990
WFSJ Main	285.24	46,203	15,299	139,531
WFSJ Main	302.50	48,379	16,020	146,102
WFSJ Main	353.38	50,975	16,879	153,942
WFSJ Main	366.64	51,302	16,988	154,930
WFSJ Main	406.96	53,508	17,718	161,592
WFSJ Main	436.55	54,575	18,071	164,814
WFSJ Main	449.89	55,794	18,475	168,495
WFSJ Main	456.13	55,294	18,310	166,985
WFSJ Main	464.30	71,335	23,621	215,428
WFSJ Main	473.55	71,966	23,830	217,334
WFSJ Main	487.76	72,071	23,865	217,651
WFSJ Main	819.58	96,651	32,004	291,881
WFSJ Main	829.30	99,766	33,036	301,289
WFSJ Main	852.60	101,721	33,683	307,193
WFSJ Main	864.39	102,972	34,097	310,970
WFSJ Main	870.89	102,982	34,101	311,001
WFSJ Main	878.04	104,184	34,499	314,631
WFSJ Main	925.55	107,785	35,691	325,505
WFSJ Main	930.87	108,153	35,813	326,617
WFSJ Main	939.03	111,260	36,842	336,000
WFSJ Main	948.15	108,992	36,091	329,151
WFSJ Main	957.25	112,784	37,346	340,602
WFSJ Main	972.38	115,083	38,108	347,545
WFSJ Main	982.48	114,211	37,819	344,912
WFSJ Main	996.29	114,558	37,934	345,960
WFSJ Main	1763.46	143,468	47,507	433,266
WFSJ Main	1774.05	158,548	52,500	478,807
WFSJ Main	1782.96	158,978	52,643	480,106
WFSJ Main	1787.27	158,420	52,458	478,421
WFSJ Main	1797.69	157,788	52,249	476,512
WFSJ Main	1802.77	157,081	52,014	474,377
WFSJ Main	2801.54	202,251	66,972	610,788
WFSJ Main	2807.04	215,023	71,201	649,359
WFSJ Main	2816.60	213,749	70,779	645,512

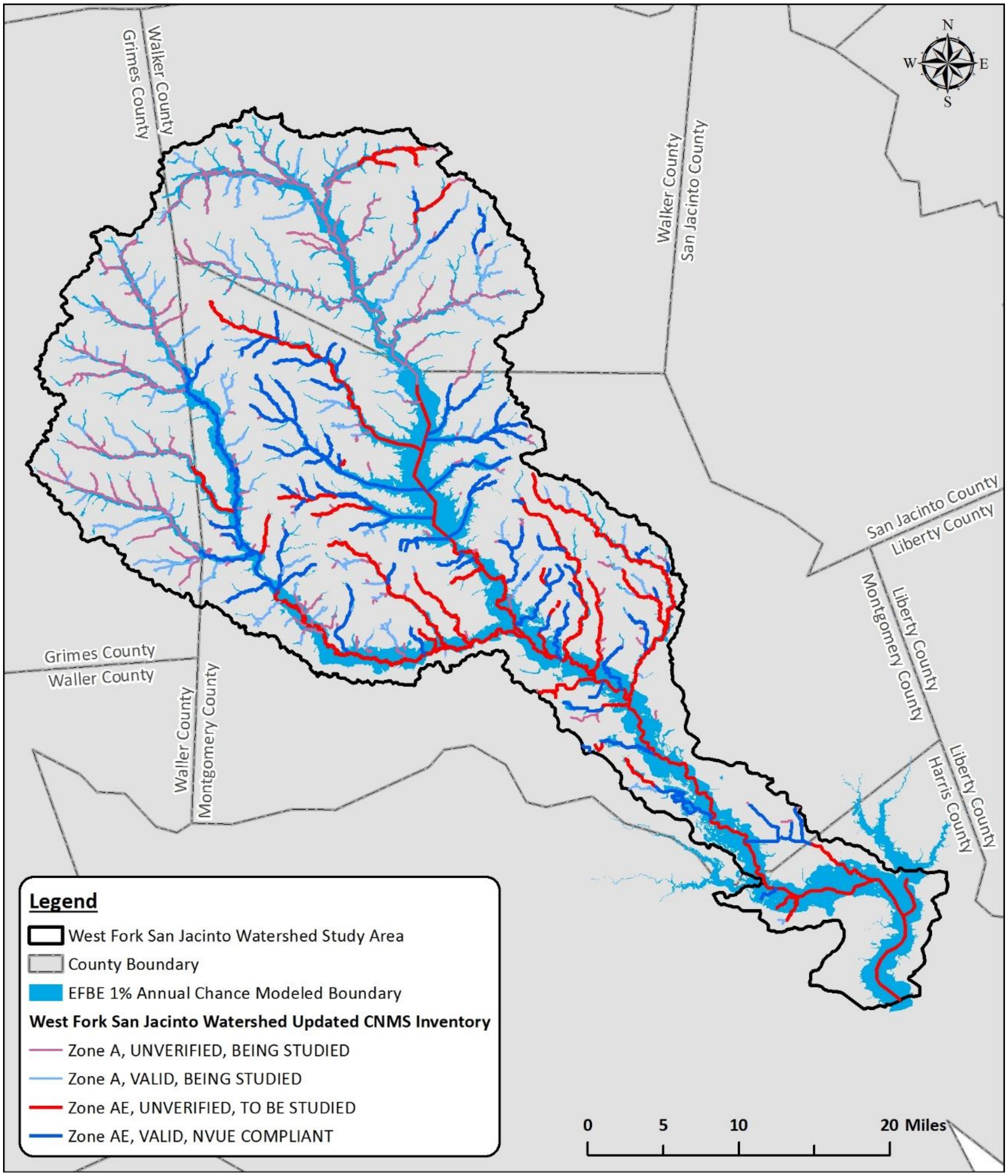
Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
WFSJ Main	2824.37	211,413	70,005	638,457
WFSJ Main	2834.22	209,877	69,497	633,818
WFSJ Main	2839.48	212,435	70,344	641,543
WFSJ Main	2840.05	211,599	70,067	639,019
WFSJR 001	1.01	1,724	571	5,206
WFSJR 002	1.28	3,242	1,074	9,791
WFSJR 003	1.27	2,435	806	7,354
WFSJR 003	1.42	2,458	814	7,423
WFSJR 004	0.75	1,632	540	4,929
WFSJR 005	0.65	2,649	877	8,000
WFSJR 006	2.19	3,406	1,128	10,286
WFSJR 007	0.67	2,178	721	6,577
WFSJR 009	1.30	2,155	714	6,508
WFSJR 012	0.74	1,713	567	5,173
WFSJR 016	0.60	1,526	505	4,608
WFSJR 016	1.11	2,100	695	6,342
WFSJR 017	1.96	2,984	988	9,012
WFSJR 018	1.13	2,465	816	7,444
WFSJR 018	1.76	3,197	1,059	9,655
WFSJR 019	0.54	1,079	357	3,259
WFSJR 021	0.57	1,325	439	4,001
WFSJR 022	0.74	1,577	522	4,762
WFSJR 023	0.52	1,212	401	3,660
WFSJR 023	0.62	1,346	446	4,065
WFSJR 024	0.55	1,907	631	5,759
WFSJR 026	1.01	2,621	868	7,915
WFSJR 028	0.63	1,619	536	4,889
WFSJR 028	0.97	1,853	614	5,596
WFSJR 030	0.86	2,006	664	6,058
WFSJR 030	1.56	2,474	819	7,471
WFSJR 033	1.64	2,974	985	8,981
WFSJR 033	2.80	4,458	1,476	13,463
WFSJR 033	3.95	5,733	1,898	17,313
WFSJR 033	4.78	5,983	1,981	18,068
WFSJR 034	0.39	1,095	363	3,307
WFSJR 034	1.05	2,129	705	6,429
WFSJR 037	0.73	1,543	511	4,660
WFSJR 038	0.55	1,179	390	3,561
WFSJR 038	1.02	1,546	512	4,669
WFSJR 039	0.85	1,464	485	4,421

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
WFSJR 041	0.53	1,334	442	4,029
WFSJR 041	0.74	1,291	427	3,899
WFSJR 042	0.97	1,586	525	4,790
WFSJR 043	0.42	1,037	343	3,132
WFSJR 045	0.80	1,108	367	3,346
WFSJR 046	0.57	731	242	2,208
WFSJR 046	1.49	1,758	582	5,309
WFSJR 048	0.51	1,023	339	3,089
WFSJR 048	1.03	1,711	567	5,167
WFSJR 050	1.11	1,268	420	3,829
WFSJR 050	2.06	1,993	660	6,019
WFSJR 051	0.03	94	31	284
WFSJR 053	0.72	1,654	548	4,995
WFSJR 055	0.43	897	297	2,709
WFSJR 055	0.81	1,374	455	4,149
WFSJR 055	1.96	2,348	777	7,091
WFSJR 056	0.58	1,113	369	3,361
WFSJR 057	0.54	879	291	2,655
WFSJR 057	0.68	1,050	348	3,171
WFSJR 058	1.07	1,643	544	4,962
WFSJR 058	1.47	1,892	627	5,714
WFSJR 059	1.29	1,993	660	6,019
WFSJR 060	0.11	246	81	743
WFSJR 061	0.37	699	231	2,111
WFSJR 063	0.24	482	160	1,456
WFSJR 064	0.93	1,463	484	4,418
WFSJR 065	1.92	2,248	744	6,789
WFSJR 066	0.47	780	258	2,356
WFSJR 066	0.72	1,157	383	3,494
WFSJR 068	0.75	1,128	374	3,407
WFSJR 071	1.02	1,850	613	5,587
WFSJR 071	1.08	1,940	642	5,859
WFSJR 075	1.37	1,802	597	5,442
WFSJR 075	1.71	2,267	751	6,846
WFSJR 075	2.04	2,436	807	7,357
WFSJR 075	2.26	2,542	842	7,677
WFSJR 076	1.04	1,593	527	4,811
WFSJR 078	0.61	1,209	400	3,651
WFSJR 078	1.21	2,002	663	6,046
WFSJR 079	0.29	387	128	1,169

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
WFSJR 079	0.55	723	239	2,183
WFSJR 080	0.53	836	277	2,525
WFSJR 080	1.05	1,431	474	4,322
WFSJR 082	0.51	1,141	378	3,446
WFSJR 082	0.97	1,508	499	4,554
WFSJR 084	0.23	645	214	1,948
WFSJR 084	0.65	1,296	429	3,914
WFSJR 085	0.43	1,114	369	3,364
WFSJR 085	0.97	1,925	637	5,813
WFSJR 086	0.47	1,227	406	3,705
WFSJR 086	0.80	2,003	663	6,049
WFSJR 087	0.31	915	303	2,763
WFSJR 087	0.52	1,182	391	3,570
WFSJR 087	0.56	1,304	432	3,938
WFSJR 089	0.62	1,434	475	4,331
WFSJR 090	0.60	1,624	538	4,904
WFSJR 090	0.70	1,660	550	5,013
WFSJR 092	0.99	2,245	743	6,780
WFSJR 094	1.12	2,376	787	7,175
WFSJR 097	0.51	1,222	405	3,690
WFSJR 097	0.77	1,583	524	4,781
WHITE OAK CREEK	0.65	1,459	483	4,406
WHITE OAK CREEK	1.19	2,370	785	7,157
WHITE OAK CREEK	2.26	3,654	1,210	11,035
WHITE OAK CREEK	3.42	5,041	1,669	15,224
WHITE OAK CREEK	4.76	6,208	2,056	18,748
WHITE OAK CREEK	6.03	6,673	2,210	20,152
WHITE OAK CREEK	6.88	7,371	2,441	22,260
WHITE OAK CREEK	6.99	7,470	2,474	22,559
WHITE OAK CREEK NORTH	0.22	698	231	2,108
WHITE OAK CREEK NORTH	1.03	2,479	821	7,486
WHITE OAK CREEK NORTH	1.75	3,375	1,118	10,192
WHITE OAK CREEK NORTH	6.40	8,819	2,920	26,633
WHITE OAK CREEK NORTH	7.88	9,441	3,126	28,511
WHITE OAK CREEK NORTH	8.37	9,975	3,303	30,124
WHITE OAK CREEK NORTH	8.54	10,011	3,315	30,233
WHITE OAK CREEK WEST	1.79	904	299	2,730
WHITE OAK CREEK WEST	1.96	1,374	455	4,149
WHITE OAK CREEK WEST	4.08	2,590	858	7,822
WHITE OAK CREEK WEST	5.02	3,164	1,048	9,555

Stream Name	Drainage Area (sq. mi.)	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
WHITE OAK CREEK WEST	5.53	2,335	773	7,052
WHITE OAK CREEK WEST	7.07	4,065	1,346	12,276
WHITE OAK CREEK WEST TRIB NO 1	0.77	933	309	2,818
WOODSONS GULLY	0.53	592	196	1,788
WOODSONS GULLY	1.58	1,092	362	3,298
WOODSONS GULLY	2.10	1,167	386	3,524
WOODSONS GULLY	3.75	1,923	637	5,807
WOODSONS GULLY	4.28	2,703	895	8,163
WOODSONS GULLY	4.61	2,019	669	6,097
WOODSONS GULLY	5.53	2,613	865	7,891
WOODSONS GULLY	6.51	3,082	1,021	9,307
WOODSONS GULLY	6.89	3,312	1,097	10,002

Appendix B BLE Map



Appendix C BLE WFSJR Harvey Hydrology & Hydraulics Memo

Date: 12/27/2017

To: Alan Johnson

Larry Voice

From: Sam Hinojosa, PE, CFM

Subject: BLE West Fork San Jacinto River Watershed Harvey Hydrology & Hydraulics Update

Summary

The intent of this memo is to summarize the findings and proposed updates to the Base Level Engineering (BLE) hydrology and hydraulics for the West Fork San Jacinto River (WFSJR) watershed as a result of the recent major storm event Hurricane Harvey. The implementation of the proposed updates to the WFSJR basin are also recommended for the East Fork San Jacinto River (EFSJR) watershed. However, the BLE hydrology and hydraulic results for the EFSJR basin will need to be compared to the respective gages and high water marks in the EFSJR watershed before finalizing the datasets.

Major findings related to the incorporation of post-Harvey flood frequency analyses include:

- The 1996 regression model predict lower 100-year streamflow values than those of the 2009 regression model for 95% of the basins studied (**Figure 1**). The 2009 regression equations are recommended for use because they provide streamflow estimates closer to the Flood Insurance Study (FIS) discharges for the WFSJR and Lake Creek (**Figure 2**).

- Both the 1996 and 2009 regression models predict lower 100-year streamflow values than the post-Harvey flood frequency analyses on gages located in the East and West Fork San Jacinto River watersheds (**Figure 2**). Therefore, a frequency adjustment factor is recommended for the 2009 regression equations.

- For each storm recurrence interval and regression model, a constant "α" was computed from the trendline equations to adjust the 1996 and 2009 regression model streamflow predictions to the post-Harvey flood frequency analyses. The α-factors were applied as a constant multiplier to the regression equations to obtain the adjusted flows (**Figure 3**). The computed α-factors are given in **Table 1**. The factors for the 10-year storm event are less than one, so no adjustment is recommended for the 10-year.

Table 1. Computed α-factors for the WFSJR Watershed

	10-year	25-year	50-year	100-year	500-year
α_{1996}	0.52	1.77	2.00	2.24	2.35
α_{2009}	0.86	1.02	1.15	1.30	1.72

- The adjusted 2009 model Q_{100} flows were applied to six representative streams—the main stem of the WFSJR and one from each HUC. On average, water surface elevations increased by approximately 1 foot in the streams studied (**Figure 4**). There is a positive correlation between the magnitude of the increase and the flow in the stream as seen in **Table 2**.

Table 2. Average Increase in WSEL by Flow Range

Q_{100} Range (cfs)	Average ΔWSEL (ft)
0 – 8,000	0.57
8,000 – 16,000	0.89
16,000 – 32,000	1.27
32,000 +	1.58

Major findings of BLE model calibration to recorded flows and stages from Harvey:

- Manning's roughness coefficients assigned by the GIS tool, which utilizes the 2011 NLCD land cover data, appear to be low when the recorded Harvey USGS gage flows are input into the models and the water surface elevations are compared to the USGS gage elevations (**Figures 5** and **6**).

- An overbank adjustment of +0.05 with a minimum final value of 0.11 is recommended for the West Fork San Jacinto River. This alters the range of manning's values from 0.05 – 0.12 to 0.11 – 0.17. The channel adjustment of +0.02 with a minimum final value of 0.06 is recommended. This will alter the range of manning's values from 0.03 – 0.07 to 0.06 – 0.9. The exception to the adjustment of roughness coefficients within the channel is through large reservoirs or lakes. The manning's n-value was set to 0.015 through Lake Houston and Lake Conroe. Increasing the n-values results in profiles more representative of the gage elevations recorded during Harvey (**Figure 5**).

- In cursory review of the West Fork San Jacinto values assigned, it was found that the NLCD raster may assign inaccurate land use values in various locations, which leads to low manning's values reported using the GIS tool and subsequently used in the hydraulic models (**Figure 7).** During review of the model building process, the n-values assigned using the GIS tool should be reviewed.

- By adjusting the n-value as proposed, the water surface elevation increases on average of 1.5 – 2.0 feet. The increase is dependent on the flow in the stream (**Figure 8**).

Suggested Adjustments Based On Findings

1. The Manning's roughness coefficients for the West Fork San Jacinto River should be increased by 0.02 in the channel and 0.05 in the overbanks, with minimum values of 0.06 and 0.11, respectively. The following table details the adjustments that are suggested. The values should be tested on the East Fork San Jacinto River to see if increases are warranted.

Table 3. Roughness Value Adjustments

Channel		Overbank		Large Lake/Reservoir	
Original Assigned Value	Suggested Value	Original Assigned Value	Suggested Value	Original Assigned Value	Suggested Value
0.03	0.06	0.05	0.11	0.03	0.015
0.04	0.06	0.075	0.125		
0.05	0.07	0.1	0.15		
0.06	0.08	0.12	0.17		
0.07	0.09				

2. Polygons created by the manning's roughness assignment tool should be viewed in conjunction with aerial imagery during model building to verify appropriate land use values are present in the NLCD dataset.

3. The flows calculated from the 2009 regression equations should be adjusted by the following factors in **Table 4**.

Table 4. Recommended Flow Adjustments for BLE on the WFJSR and EFSJR Watersheds

	10-year	25-year	50-year	100-year	500-year
α_{2009}	None	1.02	1.15	1.30	1.72

Supporting Figures

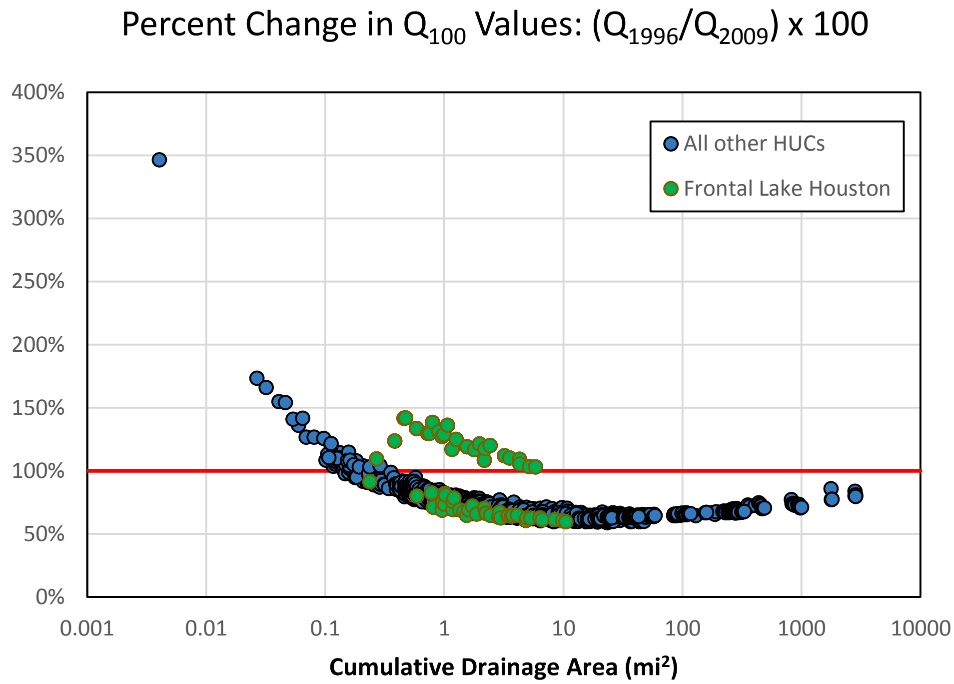


Figure 1. A comparison of Q_{100} values calculated with the 1996 and 2009 regression models for the WFSJR watershed. Frontal Lake Houston basins are plotted in green; all other HUCs within the watershed are blue. 2009 regression flows are higher than 1996 regression flows for 95% of the basins. However, 1996 regression flows are higher in basins with small cumulative drainage area (< 0.1 square miles) or those with an Ω value of -0.167 (i.e., Frontal Lake Houston).

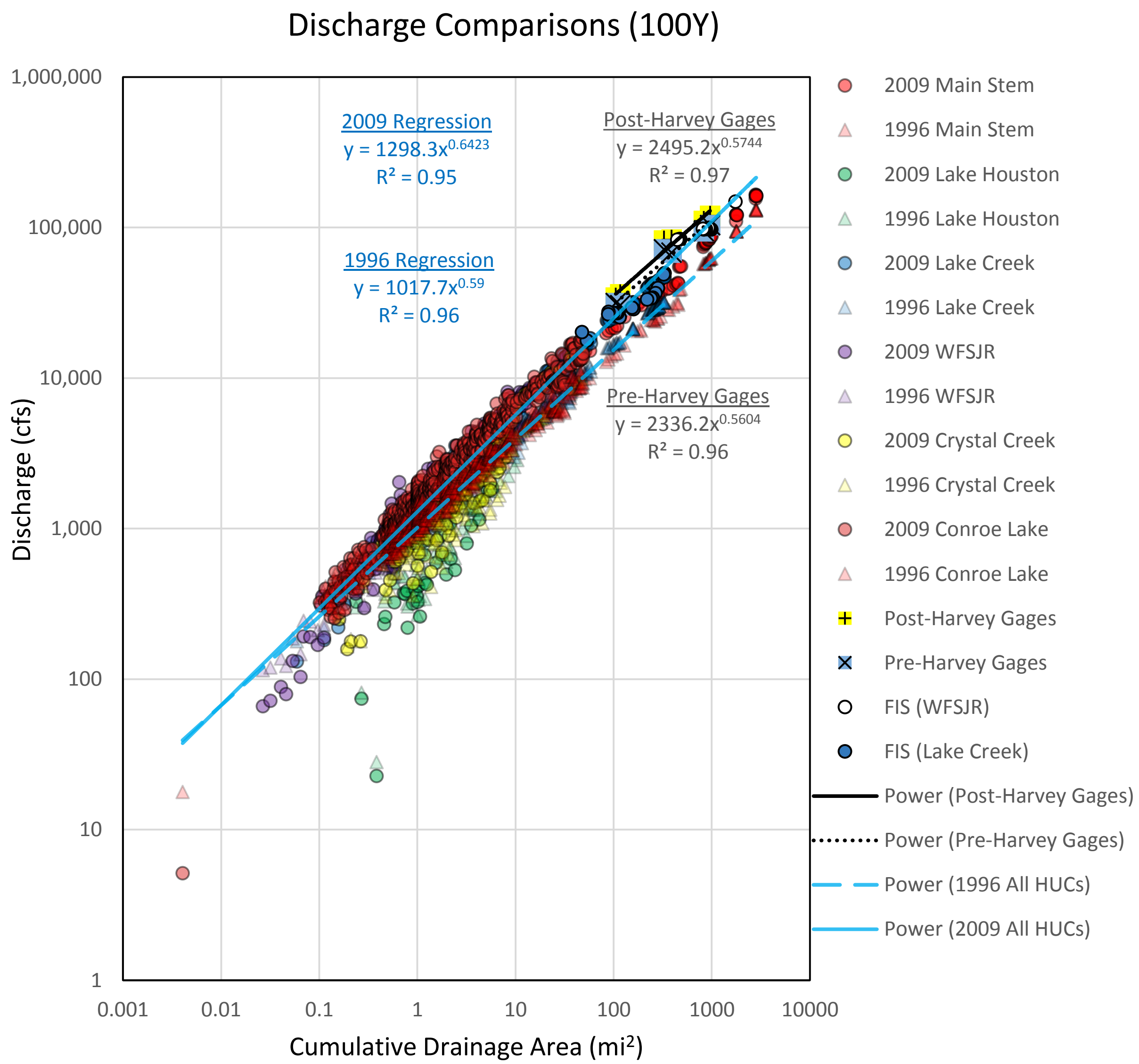


Figure 2. A comparison of Q_{100} values calculated from the regression models and the gage analyses. The HUCs are differentiated by color, as shown on the legend. The circles and triangles represent the 2009 and 1996 regression model streamflows, respectively. The solid blue power trendline is fitted to all 2009 data points, and the dashed blue power trendline is fitted to all 1996 data points. In general, both 2009 and 1996 regression models under-predict streamflow when compared to the gage analyses. The 2009 model streamflows are closer to the FIS discharges than the those of the 1996 model.

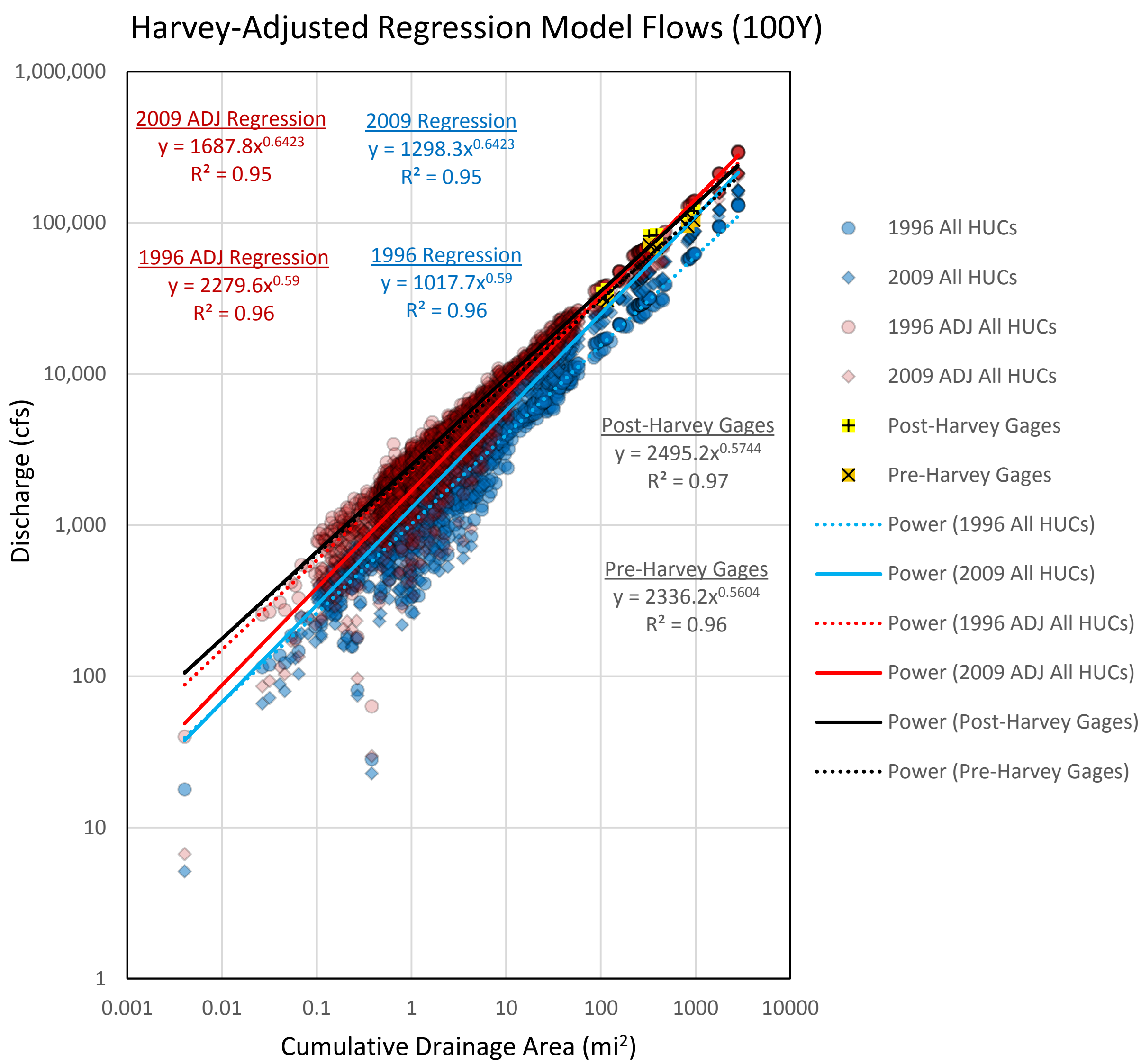


Figure 3. A comparison of Harvey-adjusted and non-adjusted regression model Q_{100} values. The solid black trendline is fitted to the post-Harvey gage analyses, representing the "target" trendline. The dotted blue trendline is fitted to the 1996 non-adjusted model. When flows are multiplied by the α-factor ($\alpha_{1996,\ 100Y}$ = 2.24), the trendline translates upward (represented by the dotted red line). The solid blue trendline represents the 2009 non-adjusted model. When multiplied by its α-factor ($\alpha_{2009,\ 100Y}$ = 1.30), the solid red trendline is the result.

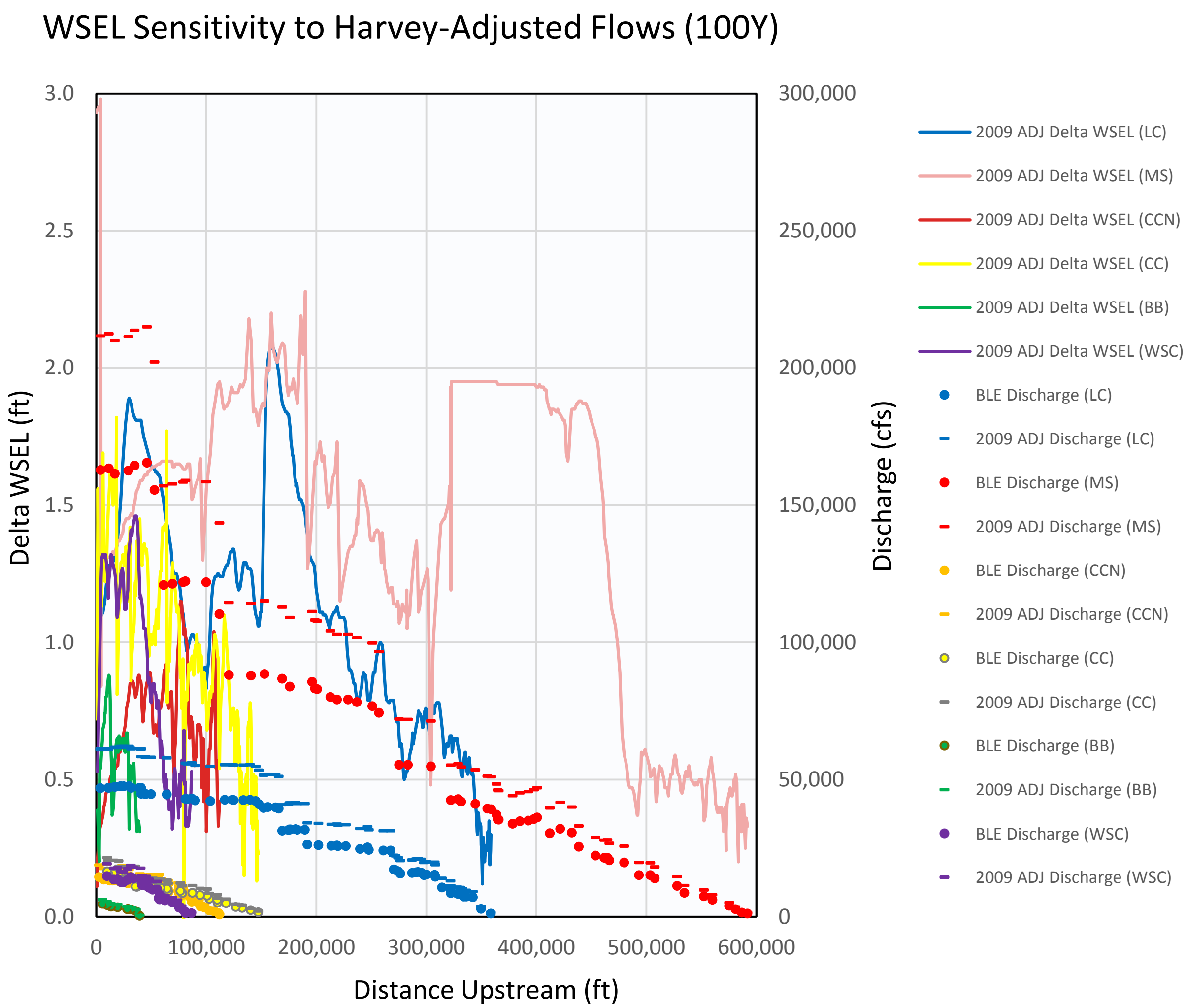
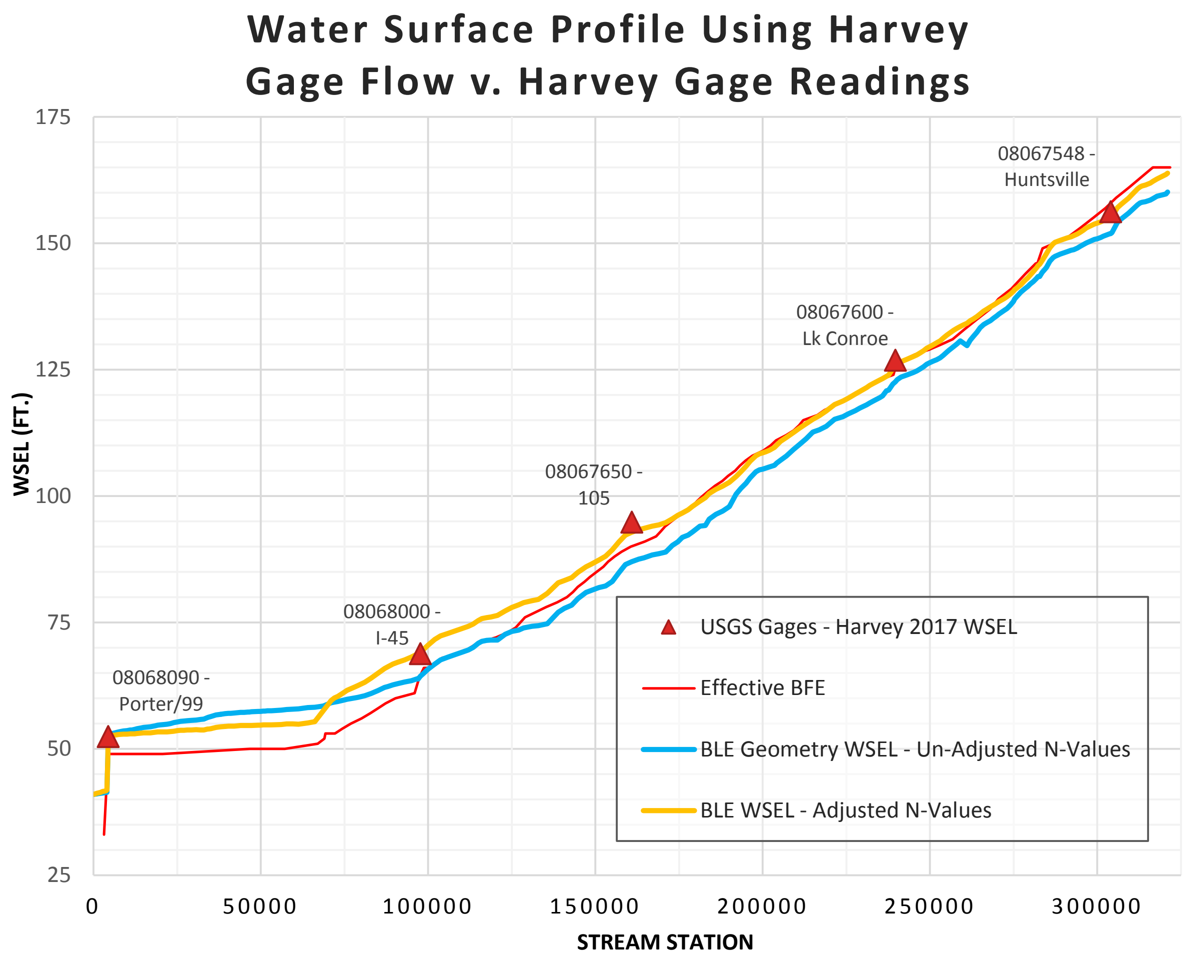


Figure 4. The sensitivity of water surface elevation to changes in Q_{100} for six streams in the WFSJR watershed. The streams studied were: the main stem of the WFSJR (MS), Caney Creek North (CCN), Crystal Creek (CC), Bens Branch (BB), Lake Creek (LC), and West Sandy Creek (WSC). The solid lines (color-differentiated by stream) represent the increase in water surface elevation from the original BLE model due to the adjusted 2009 streamflows. The adjusted 2009 hydraulic model shows that a 30% increase in flow ($\alpha_{2009,\ 100Y}$ = 1.30) results in an average water surface elevation rise of approximately 1 foot in the streams studied. There is a positive correlation between the magnitude of the increase and the amount of flow in the stream.



**Note: The 105 gage has been adjusted down from the published peak elevation of 162.18' to 156.30' (Δ 5.88') based upon surveyed high water marks and site visits during the storm event.*

Figure 5. A hydraulic model utilizing the geometry resulting from the standard BLE process and peak flows recorded by USGS gages during Hurricane Harvey resulted in lower water surfaces than those recorded by the gages. A hydraulic model utilizing the BLE geometry with adjusted manning's roughness coefficients and peak flows recorded by USGS gages during Hurricane Harvey resulted in similar water surfaces to those recorded by the gages.

USGS Gage	Gage Location	Gage Peak Water Surface	Original Geometry Peak WS	Adjusted Geometry Peak WS	Orig. Geom WS - Gage WS	Adj. Geom WS - Gage WS
08067548	Huntsville - At 1795	232.39	229.07	231.74	-3.32	-0.65
08067600	Lake Conroe Dam	206.23	211.74	211.74	5.51	5.51
08067650	SH 105	156.30	151.88	155.07	-4.42	-1.23
08068000	I-45	126.93	122.57	125.75	-4.36	-1.18
08068090	Porter - At Grand Pkwy	94.87	86.99	92.82	-7.88	-2.05
08069500	SH 59/69	68.87	64.37	69.15	-4.50	0.28
08072000	Outfall of Lake Houston	52.45	52.61	52.49	0.16	0.04

Figure 6. A tabular comparison of the modeled conditions as described in *Figure 5.* The larger discrepancy in water surface elevations between the modeled elevation and gage at the Grand Parkway is due to erroneous values in the NLCD dataset. Correcting these values then adjusting according to the recommendations provided in the executive summary raises the water surface elevation to within 0.5’ of the Grand Parkway gage reading during Harvey.

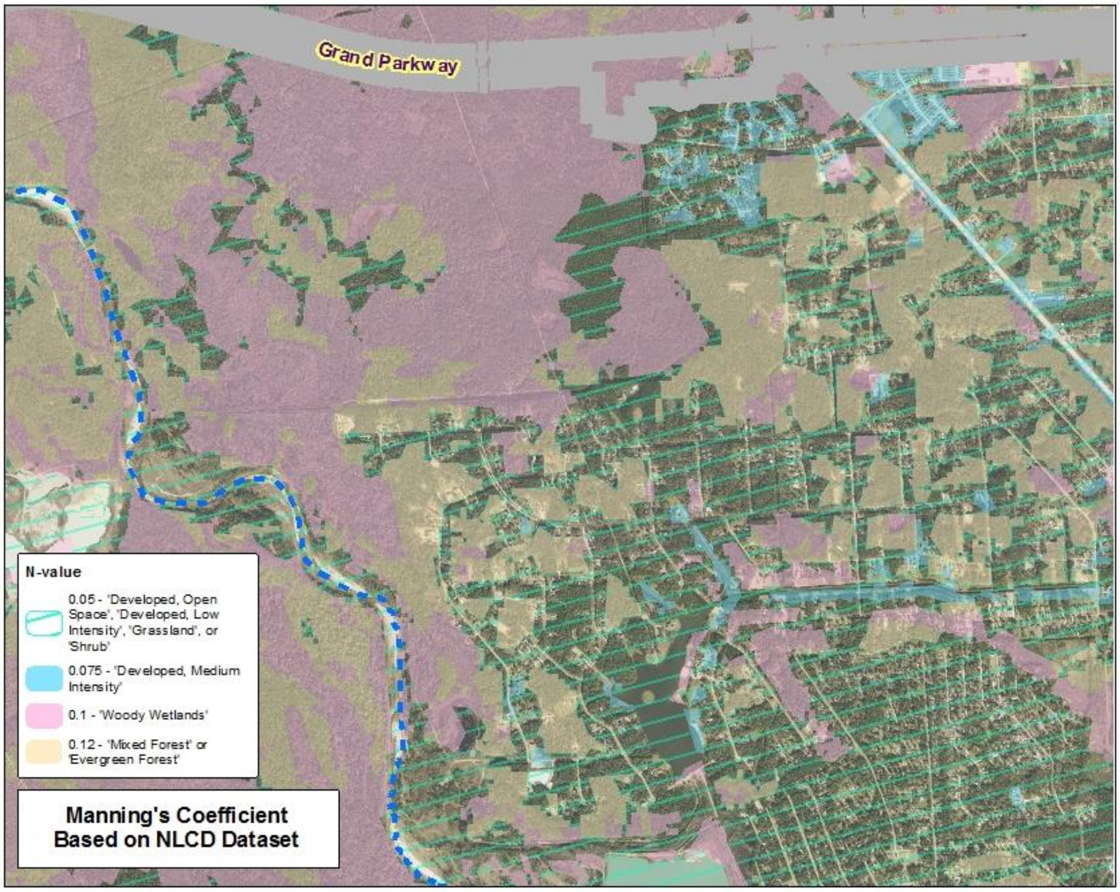


Figure 7. The graphic shows land use type which is erroneously reported in the NLCD. At this location the NLCD raster shows 'Developed – Open Space' in the majority of the area. The GIS tool initially assigns a manning's value of 0.013 to this, assumed to represent paving, which is then constrained to a minimum value of 0.05. As seen in the imagery, most of the area is either dense woods, which should be written as 0.12 according to the tool, or neighborhoods with dense tree cover, which should be written as 0.1 according to the tool. Correcting these values then adjusting according to the recommendations provided in the executive summary raises the water surface elevation to within 0.5' of the Grand Parkway gage reading during Harvey.

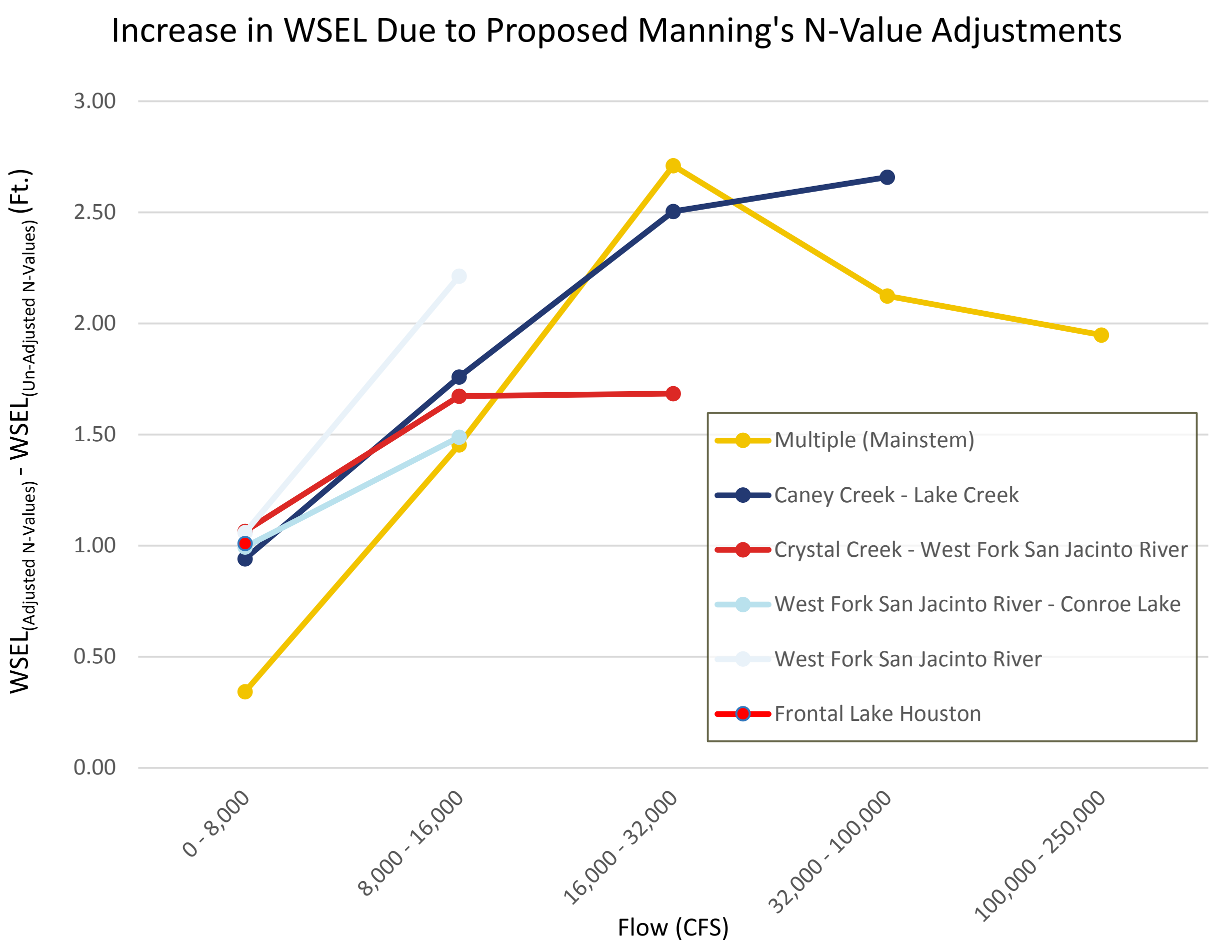


Figure 8. The change in water surface elevation based on the proposed manning's roughness adjustments was plotted for several streams. As the flow in the stream increases the effects of the proposed adjustments are increased. There is a fluctuation in the plotting of the WFSJ mainstem because n-values were lowered through lakes and reservoirs and the mainstem contains two large reservoirs; Lake Conroe and Lake Houston.