SJRA
SAN JACINTO RIVER AUTHORITY

UPPER SAN JACINTO RIVER BASIN REGIONAL SEDIMENTATION STUDY

Technical Memorandum 2

Watershed Characterization

Prepared for:

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1 Watershed Characterization Study Approach

As a part of the Upper San Jacinto River Basin (USJRB) Regional Sedimentation Study (Study), the watersheds within the Study area were screened to define watersheds that have similitude in parameters that can be used to characterize the condition and physical setting of each watershed within the USJRB. This watershed characterization forms an important foundation to complete the analysis of sediment budgets, storage, and transport and the planning of sediment management strategies.

The Study team calculated the watershed characteristic factors using geospatial data related to the topographical, land cover, soils, hydrological, and meteorological components based on the eleven Hydrologic Unit Code 10-digit (HUC 10) watersheds contained within the USJRB. The team then applied these results to develop watershed "clusters," or "bins," with shared characteristics by using Geospatial Information System (GIS) Spatial Cluster Analysis tools. Figure 1 provides a schematic showing examples of data that were analyzed to develop the watershed clusters for future analysis.

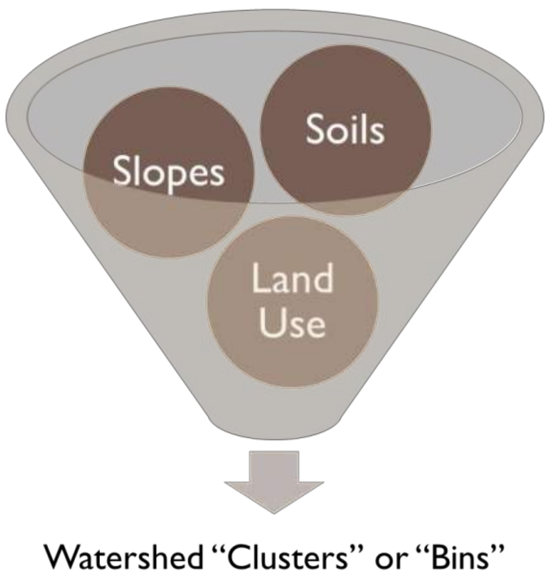


Figure 1. Study Approach for Watershed Grouping

After grouping watersheds into clusters (or bins) based on shared characteristics, coordinating discussions with stakeholders, and evaluating known problem areas, the San Jacinto River Authority (SJRA) and the consultant selected 1 – 2 representative areas from each cluster to serve as calibration watersheds. Site access and data availability were also key considerations in selecting representative watersheds. The purpose of the watershed clustering was not to identify locations of sediment erosion or deposition, but rather to identify which watersheds have shared attributes. The calibration watersheds will form the basis of extrapolating sediment loading and storage estimates to other watersheds that were found to have similar characteristics. Figure 2 shows the Study procedure for watershed characterization.

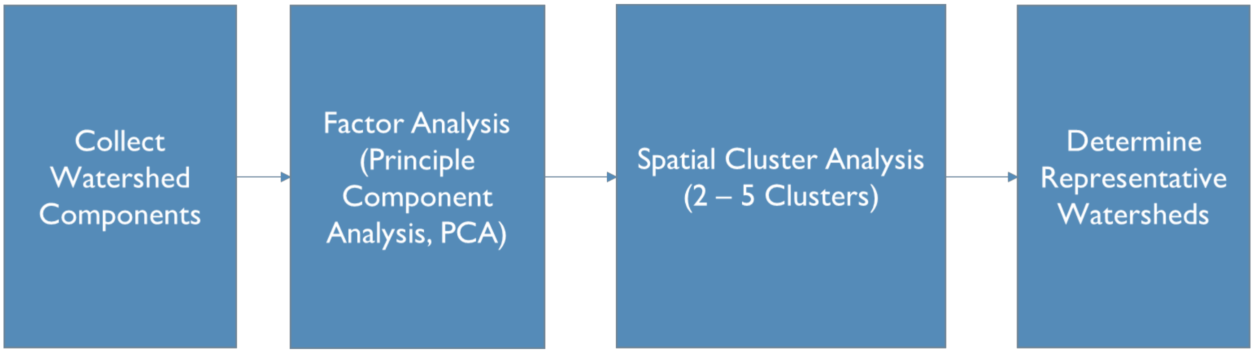


Figure 2. Study Procedure for Watershed Characterization

For this Study to support regional sediment management strategies in line with the Texas Water Development Board (TWBD) Flood Infrastructure Fund program requirements, the Study team chose to complete the watershed characterization on the HUC 10 watershed division level. The USJRB is made up of eleven HUC 10 watersheds, as shown in Figure 3. This technical memorandum summarizes the methodology and results of the characterization and clustering of the HUC 10 watersheds, and the selection of the calibration watersheds.

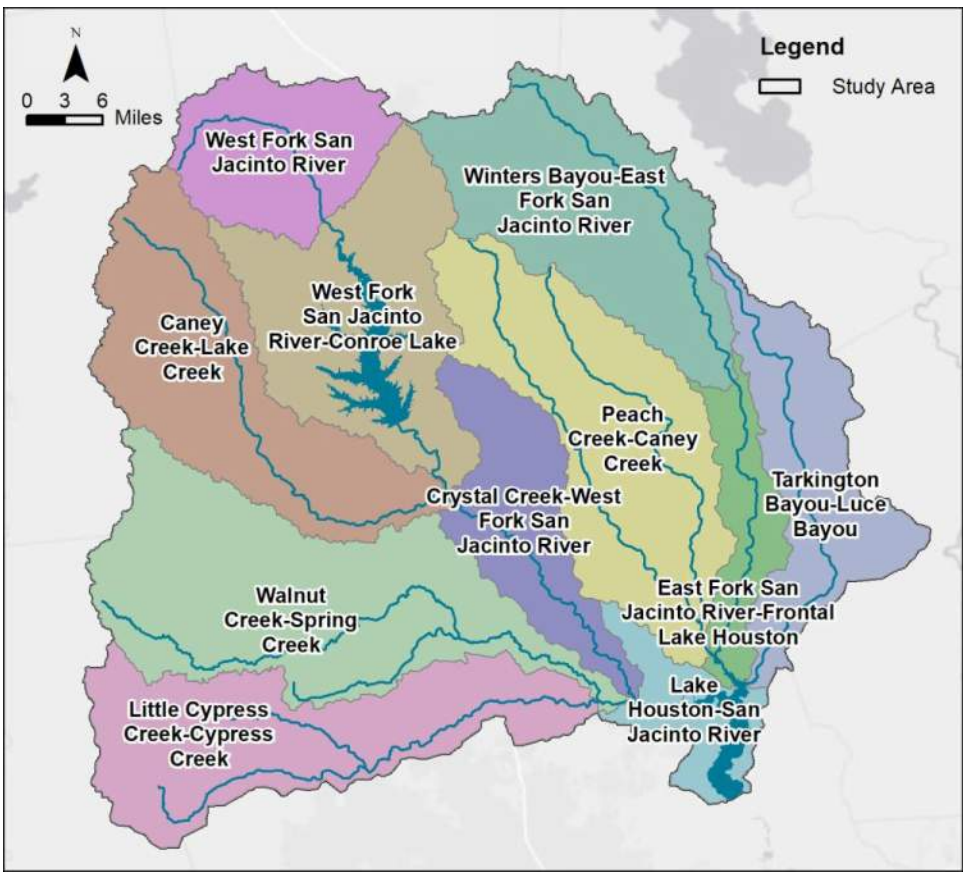


Figure 3. HUC 10 Watersheds in the USJRB

2 Multivariate Statistical Analysis

The watersheds in the USJRB are described by many different factors, including topographical, hydrological, and meteorological among others. Statistical analyses, including a principal component analysis (PCA) and spatial clustering, were performed to streamline the factors describing watersheds and to group the USJRB watersheds into clusters of similar watersheds.

2.1 Principal Components Analysis

Factor analysis is a technique that is used to reduce a large number of variables into fewer numbers of factors. Factor analysis involves techniques to help produce a smaller number of linear combinations of variables so that the reduced variables account for and explain most of the variance in the underlying data. Several methods are available, but PCA is used most commonly. PCA is an effective screening tool that can be used to determine the minimum number of factors that will account for the maximum variance in the data. In this Study, IBM SPSS Statistics software was applied to conduct PCA on the watershed data to better understand inherent relationships between the data and to ultimately screen which data would best inform subsequent watershed clustering analysis. PCA was employed in this study to examine the relationships between various parameters and to streamline the data for input into the clustering analysis.

2.2 Spatial Cluster Analysis

Cluster analysis is the statistical grouping of a set of objects into a “cluster” that contains objects more similar to each other than objects in other clusters. Spatial clustering tools perform cluster analysis on geospatial elements to identify the locations of statistically significant zones of shared characteristics. The Multivariate Clustering tool in ArcGIS Pro finds natural clusters of disparate variables based solely on data values. Given a number of clusters, the tool will create a solution where all the features within each cluster are as similar as possible, and all the clusters themselves are as unique as possible. Figure 4 shows an example of how ArcGIS Pro’s Multivariate Clustering tool can be applied to group geospatial data into four clusters with shared characteristics.

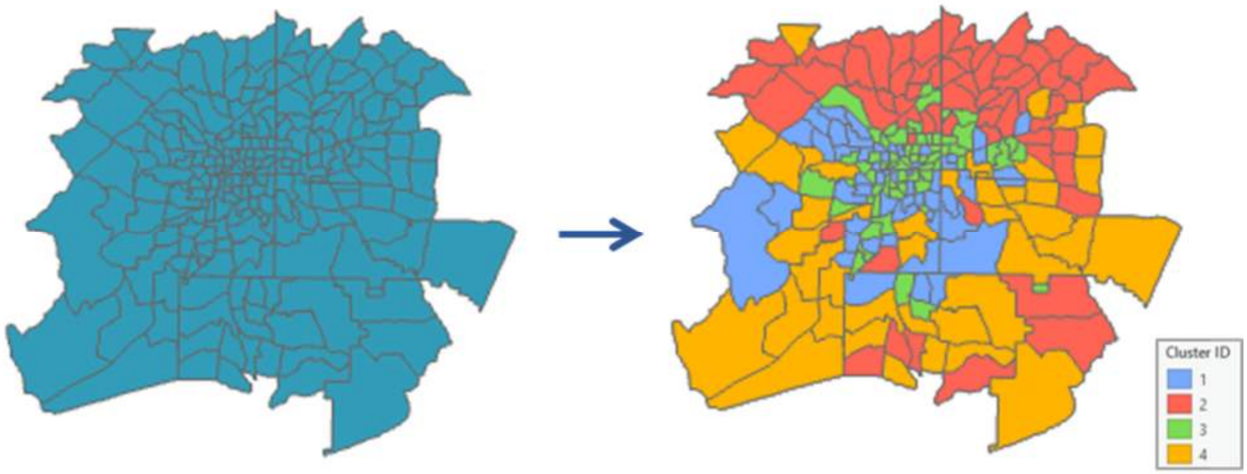


Figure 4. Example of Multivariate Clustering in ArcGIS Pro
(Source: ESRI, 2022)

The success of clustering in describing the data can vary depending on the number of clusters created. A Pseudo F-statistic value, which is a ratio of between-cluster variance to within-cluster variance, can be used to distinguish the effectiveness of different numbers of clusters in describing the data. Figure 5 represents an example of the variance of the Pseudo F-statistic across different numbers of clusters. The highest peak on the graph indicates the “optimal” number of clusters. In this example, the optimum number is four clusters.

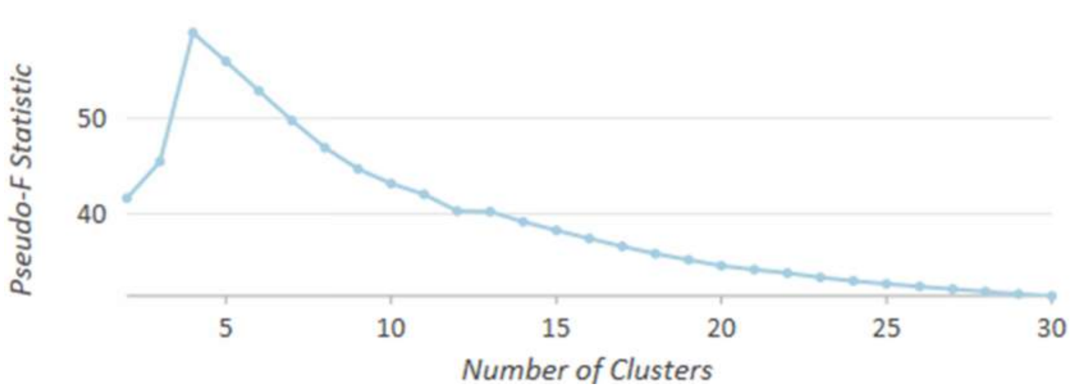


Figure 5. Example of Optimized Pseudo F-statistic Chart
(Source: ESRI, 2022)

KIT used the Multivariate Clustering Tool in ArcGIS Pro 3.0 to group the watersheds of the USJRB based on similar watershed characteristics and quantify the effectiveness of the clustering analysis.

3 Watershed Characteristics

This section provides an overview of USJRB watershed data characterization analysis efforts. As discussed, the objective of watershed clustering is not to predict sedimentation, but rather to identify watersheds with similar characteristics to facilitate data extrapolation in subsequent analyses.

3.1 Determination of Watershed Characteristics

As described in Technical Memorandum (TM) 1, the project team collected topographical, geologic, hydrologic, and other data describing the USJRB from publicly available databases including U.S. Geological Survey (USGS), Houston-Galveston Area Council (H-GAC), U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), ArcGIS Living Atlas, and National Oceanic and Atmospheric Administration (NOAA). More detailed descriptions of the collected data can also be found in TM 1. Additional watershed characterization factors were calculated from the raw data to further describe the watersheds within the Study Area. Thirty-two watershed characteristics factors related to topography, land cover, soil, hydrology, sedimentation, and meteorology components were selected for preliminary screening analysis. Table 1 summarizes the watershed characteristic factors and the corresponding data sources. Many of these parameters were introduced and discussed in TM 1 – Data Inventory.

Table 1. Watershed Characteristic Factors and Raw Data

Characteristic Categories	Watershed Characteristic Factors	Raw Data
Topographical	• Watershed area (square miles [mi^2]) • Watershed perimeter (miles [mi]) • Reach length (mi) • Straight line length (mi) • Reach relief (feet [ft]) • Stream slope (%) • Watershed slope (%) • Longest flow path (mi) • Watershed width (mi) • Length to width ratio (unitless)	• HUC 10 Watershed Boundaries • Streams (National Hydrologic Dataset) • USGS NAD 88 Digital Elevation Model (DEM) (90m)
Land cover	• Change in total developed area (%) • Change in total forested area (%) • Change in total pasture/ag/shrub area (%) • Change in total wetlands area (%) • Total developed area 2020 (%) • Total forested area 2020 (%) • Total pasture/ag/shrub area 2020 (%) • Total wetlands area 2020 (%)	• H-GAC 2008 and 2020 Land Covers (30m)
Soil and Hydrological	• Hydrologic soil group A area (%) • Hydrologic soil group B area (%) • Hydrologic soil group C area (%) • Hydrologic soil group D area (%) • Average soil erodibility (unitless)	• USDA NRCS SSURGO (Soil Survey Geographic Database) (30m)

Characteristic Categories	Watershed Characteristic Factors	Raw Data
SPARROW Sedimentation	• Total accumulated yield (metric tons per square kilometer [Mt/km²]) • Accumulated yield from urban land (Mt/km²) • Accumulated yield from agricultural land (Mt/km²) • Accumulated yield from forest land (Mt/km²) • Accumulated yield from shrub, scrub, grass, and barren land (Mt/km²) • Accumulated yield from alluvial deposits (Mt/km²) • Accumulated yield from channel sources (Mt/km²)	• USGS SPARROW Model Results
Meteorological	• Annual average precipitation (inch) • Rainfall intensity (inch)	• NOAA Daily Precipitation Data (2008–2021) • NOAA Atlas 14

3.2 Topographical Components

The topographical parameters listed in Table 1 were derived from the USGS DEM and the National Hydrologic Dataset. The ten topographical features of interest selected and calculated for this Study include watershed area, watershed perimeter, reach length, straight line length, reach relief, stream slope, watershed slope, longest flow path, watershed width, and length to width ratio. The topographical watershed characteristics are shown in Figure 6.

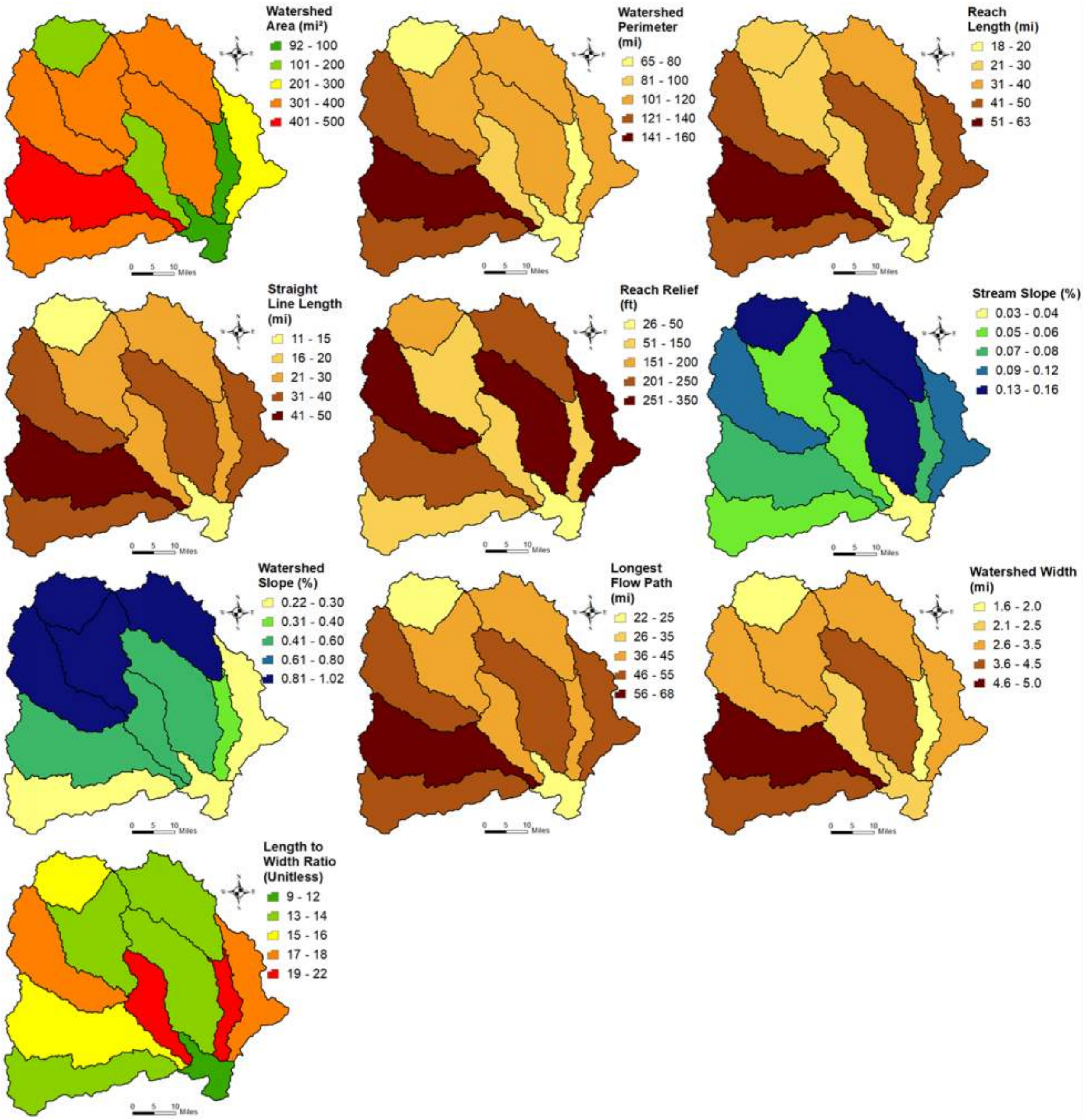


Figure 6. Topographical Watershed Characteristics

Some of the lesser-known parameters are defined as follows:

- Reach length – the overall length of the stream's flow path
- Straight line length – the "as-the-crow-flies" distance between the most upstream and downstream points of the stream
- Reach relief – the elevation difference between the most upstream and downstream points of the stream
- Stream slope – the reach relief divided by the reach length

- Watershed slope – the average slope of the land surface within a given watershed
- Longest flow path – the longest distance that precipitation in the watershed could theoretically travel
- Watershed width – watershed area divided by longest flow path
- Length to width ratio – Longest flow path divided by watershed width

Several of these parameters were derived primarily to assist in the computation of slopes and the unitless length to width ratio. In general, these parameters describe the size and shape of the watershed and its dominant stream.

As shown in the figure, watershed slope had a strong northwest to southeast gradient, but other parameters were more variable spatially. It was observed that a majority of these factors (e.g., watershed perimeter, reach length, etc.) were strongly correlated with one another and were primarily a function of watershed area. To reduce the dominant influence of the strongly correlated topographical components in PCA and cluster analysis, several of these factors were screened out in favor of predominantly dimensionless components. Ultimately, only watershed area, stream slope, watershed slope, and length to width ratio were included in the final cluster analysis.

3.2.1 Land Cover Components

Land use, particularly the increase in impervious area associated with development, influences the magnitude and location of run-off and non-point sediment sources. H-GAC land cover data from 2008 and 2020 was used to analyze the land use changes in the USJRB over the past decade. The 2008 and 2020 land covers were classified into ten and fifteen major land cover classes, respectively, based on the National Land Cover Data (NLCD) land cover classification schemes.

To facilitate comparison of the land cover datasets with different numbers of land cover classifications, the land cover classes were normalized into the following broad categories, as detailed in TM 1:

- Developed
- Forested
- Pasture / Agricultural / Shrub
- Wetlands
- Other (open water, barren, etc.)

In this Study, the total developed area, total forested area, total pasture/agricultural/shrub area, and total wetlands area were used to characterize the most recent land cover and the trends of land cover change over time in the USJRB. The percent areas of the broad land use categories were calculated from the most recent 2020 dataset, as shown in Figure 7, and the percent change in land cover (as a percentage of the total watershed area) from 2008 to 2020 are shown in Figure 8. For example, a 25% increase in developed land cover in a HUC-10 watershed means that an additional 25% of that entire watershed was developed in this period, with a corresponding 25% decrease in other land uses. These percentages were computed relative to the entire watershed area to facilitate direct comparison between values.

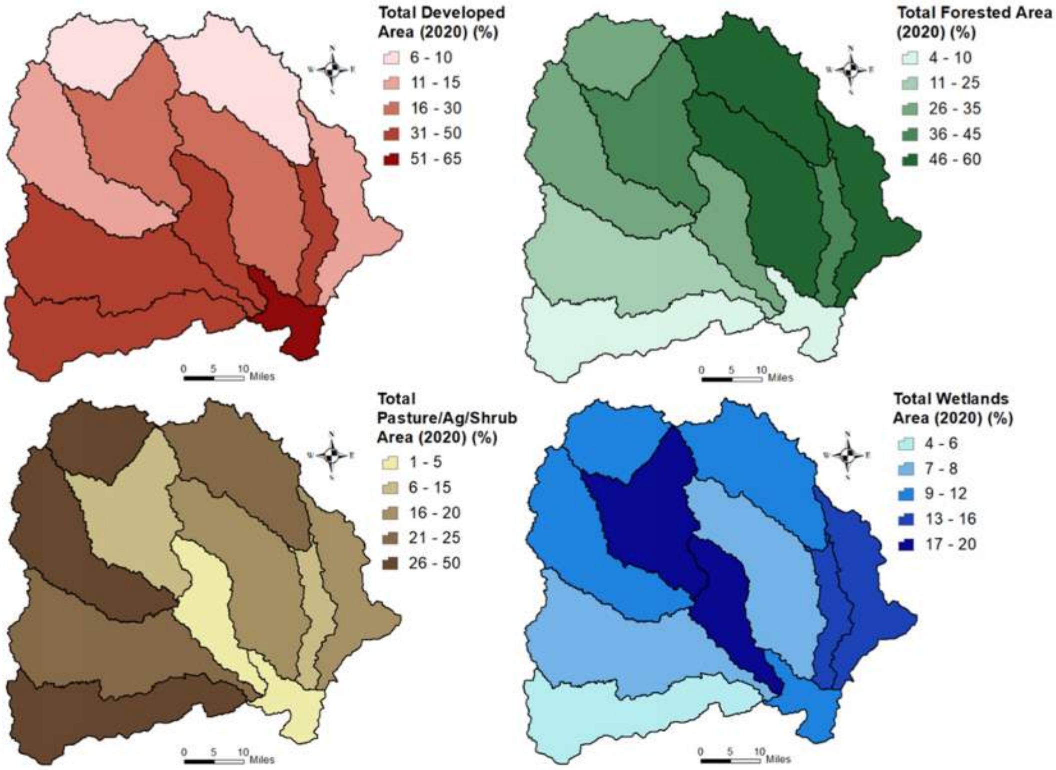


Figure 7. Land Cover Watershed Characteristics

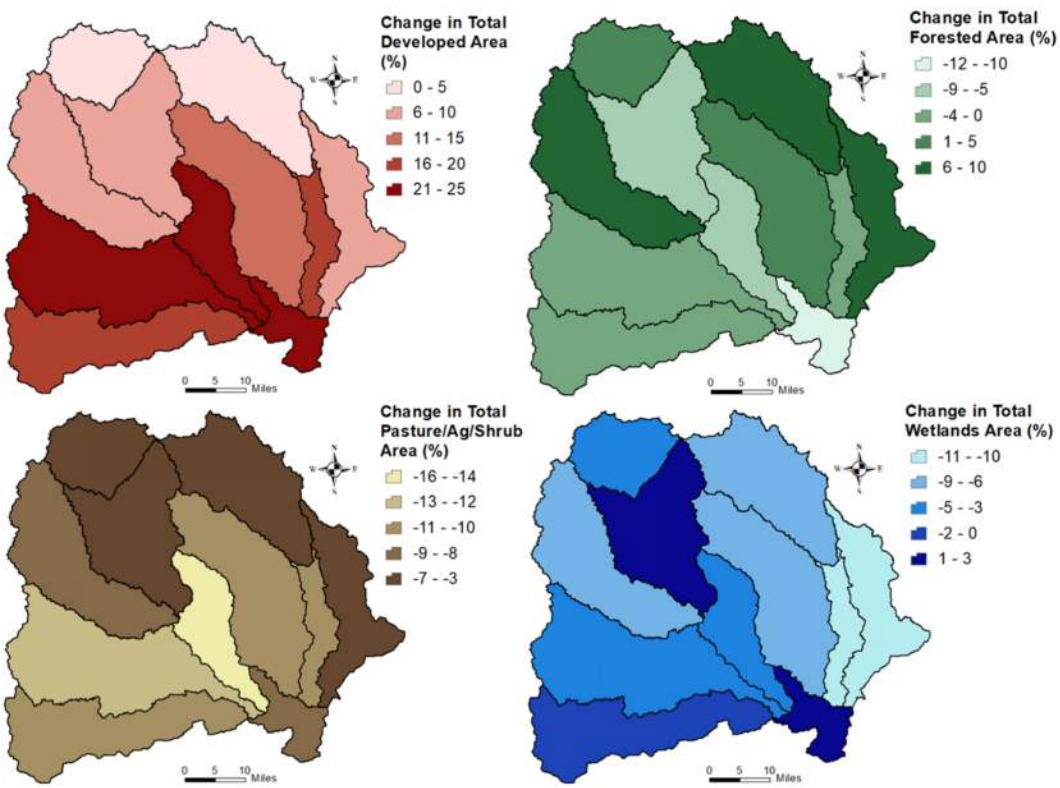


Figure 8. Land Cover Change (2008 – 2020) Watershed Characteristics

As discussed in TM 1, the 2020 USJRB-wide land cover percentages were 27% developed area, 34% forested area, 25% pasture/agricultural/shrub area, 10% wetland area, and 4% other. As shown in Figure 7, the southern portion of the USJRB is more densely developed, and there is a general trend in forested cover when moving southwest to northeast through the USJRB. Pasture, agricultural, and shrub areas are more heavily concentrated on the western side of the USJRB. The West Fork San Jacinto River-Conroe Lake ("Middle West Fork"), Crystal Creek-West Fork San Jacinto River ("Lower West Fork"), East Fork San Jacinto River-Frontal Lake Houston ("Lower East Fork"), and Tarkington Bayou-Luce Bayou ("Luce Bayou") watersheds have the greatest percentages of wetland areas.

TM 1 also documented the increase in developed area and decrease in forested and pasture / agricultural / shrub areas over time. Figure 8 summarizes the spatial patterns in this overall trend. Increases in total developed area in the past decade have been most significant in the southern portion of the USJRB. Specifically, the highest increases in percent developed area occurred in the Walnut Creek-Spring Creek ("Spring Creek"), Lower West Fork, and Lake Houston-San Jacinto River watersheds.

3.2.2 Soil and Hydrological Components

The characteristics of soils are also an important influence on the magnitude and location of run-off and non-point sediment sources. The hydrologic soil group is a factor that the USDA NRCS uses to classify the precipitation infiltration rates and runoff potential of a soil's dominant component. Soils are grouped in four groups based on their infiltration rate ranging from high rates in the well-drained sands in Group A to very slow infiltration rates in the clayey, shallow soils of Group D. The hydrologic soil group makeup for the USJRB is 24% Group A, 26% Group B, 20% Group C, and 29% Group D, with the remainder unclassified.

Figure 9 summarizes the hydrologic soil groups on a percent-area basis for each of the eleven HUC 10 watersheds. Upper watersheds are Groups A and D dominant, while higher proportions of Group B soils can be found in the central USJRB. The Little Cypress Creek-Cypress Creek ("Cypress Creek") watershed is unique in having predominantly Group C soils. Additional details on hydrologic soil groups can be found in TM 1.

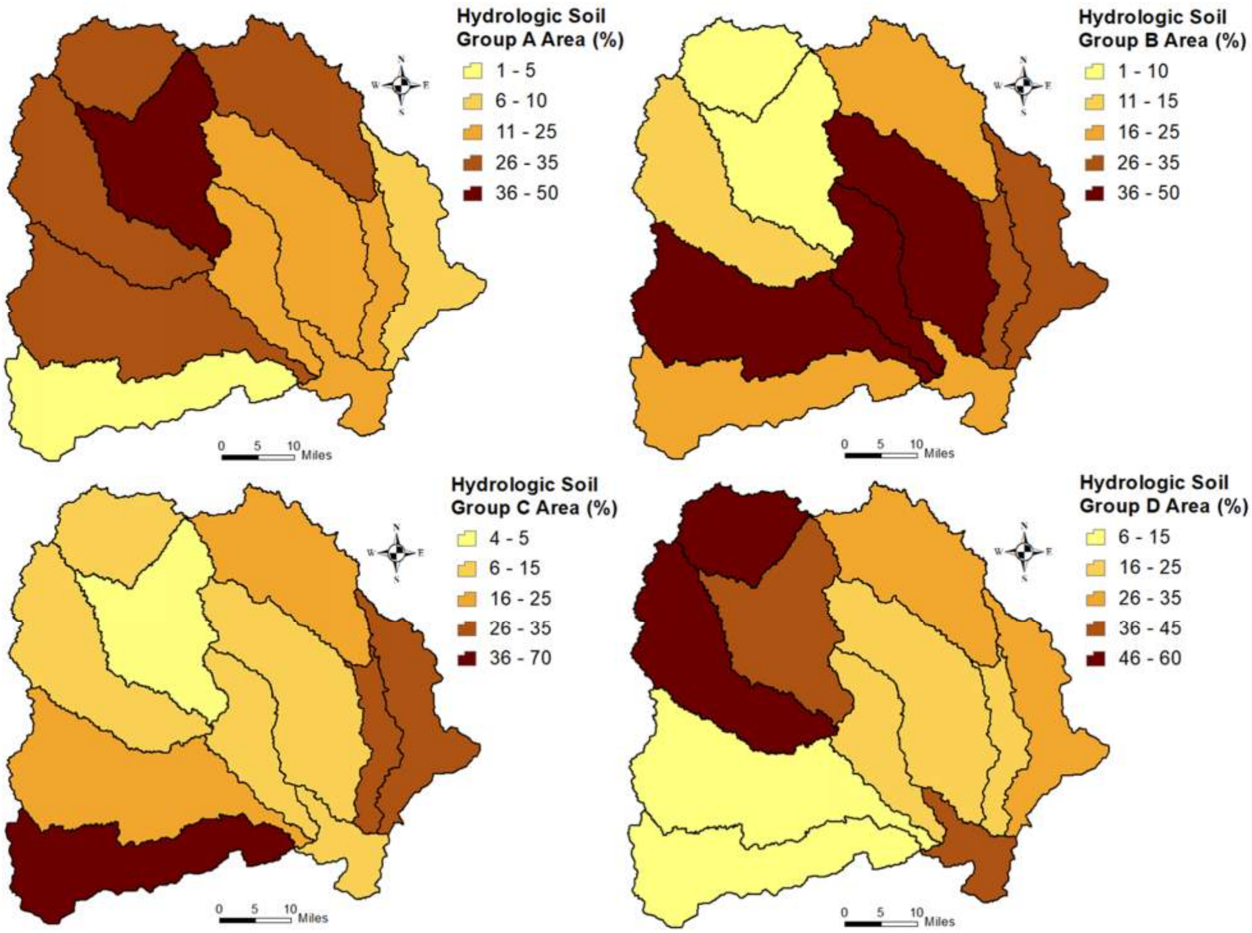


Figure 9. Hydrologic Soil Group Watershed Characteristics

The soil erodibility, also known as the “K factor,” is one of the six inputs to the USDA NRCS Revised Universal Soil Loss Equation (RUSLE). The K factor quantifies the susceptibility of soil particles to detachment and transport. While the K factor is sometimes presented in units of mass per unit area per depth of rainfall (e.g., tons per hectare per millimeter), it is frequently presented as a dimensionless quantity. Soils with high clay content are resistant to detachment and have low K values, typically about 0.05 to 0.15. Although coarse-textured soils (e.g., sandy soils) are easily detached, they also have relatively low K values, about 0.05 to 0.2, because the coarse particles settle easily and are therefore not readily transported. Medium textured soils (e.g., silt loam), have moderate K values, about 0.25 to 0.4, because they are moderately susceptible to detachment and transport. Soils having a high silt content have the highest erodibility. They are easily detached and readily transported in runoff. Silty soils typically have K values greater than 0.4. As seen in Figure 10, the northern portion of the USJRB has soils of moderate K values, and silt soils with high erodibility are concentrated in the southeast portion. The area below Spring Creek has moderate soil erodibility, but has an appreciable amount of unavailable K factor data.

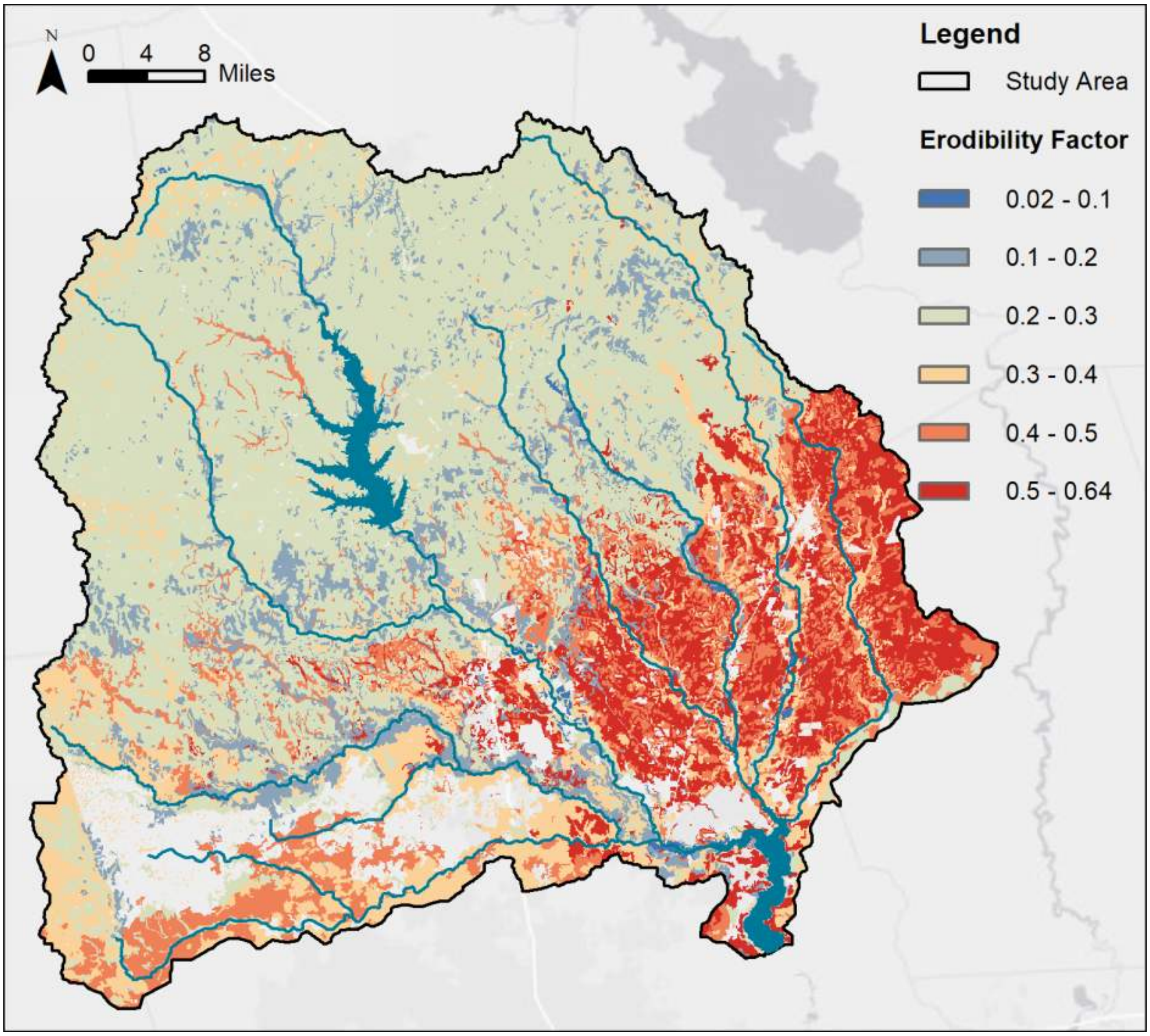


Figure 10. USDA NRCS SSURGO Soil Erodibility (K Factor) in USJRB

The characterization of the average soil erodibility is shown in Figure 11 and confirms the patterns discussed earlier. The ranges of soil erodibility in upper watersheds and lower west watersheds are between 0.24 and 0.35, representing moderate K values. The ranges of soil erodibility in the southeastern watersheds are between 0.36 and 0.47 as a result of high silt content, with the East Fork San Jacinto River – Frontal Lake Houston and Tarkington Bayou – Luce Bayou watersheds averaging the highest erodibility of those within the USJRB.

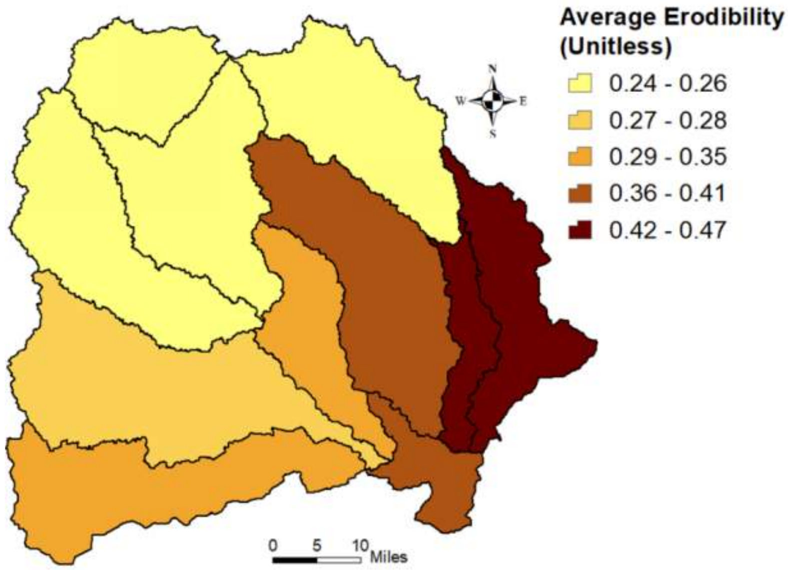


Figure 11. Soil Erodibility Watershed Characteristics

The hydrologic soil group and soil erodibility were chosen to characterize the soil and hydrological factors of the USJRB watersheds in subsequent PCA and spatial cluster analysis.

3.2.3 SPARROW Sedimentation Components

As described in TM 1, the USGS developed the Spatially Referenced Regression on Watershed Attributes (SPARROW) models to estimate the annual loads of contaminants like suspended sediment to the waters of the United States. The results of these models include estimates of catchment-level incremental and accumulated contaminant loads and yields (i.e., loads normalized by contributing area) for suspended sediment from the following sources: urban land; agricultural land; forested land; shrub, scrub, grass, and barren land; alluvial deposits; and channel sources.

For this Study, SPARROW results were extracted on a HUC 10 watershed-basis by extracting the accumulated load and yield values from the most downstream catchment within each watershed. Given that the model results are cumulative, downstream watersheds also include the loads from upstream watersheds. For example, suspended sediment predictions for the Lower West Fork include contributions from three upstream watersheds.

Figure 12 shows the SPARROW annual accumulated yield predictions for each HUC-10 watershed on a metric ton per square kilometer (Mt/km^2) basis. As shown in Figure 12, the highest accumulated yield was predicted in the Peach Creek-Caney Creek ("Caney Creek") watershed. The lowest accumulated yield was predicted in the Middle West Fork watershed, likely as a result of sediment capture in Lake Conroe.

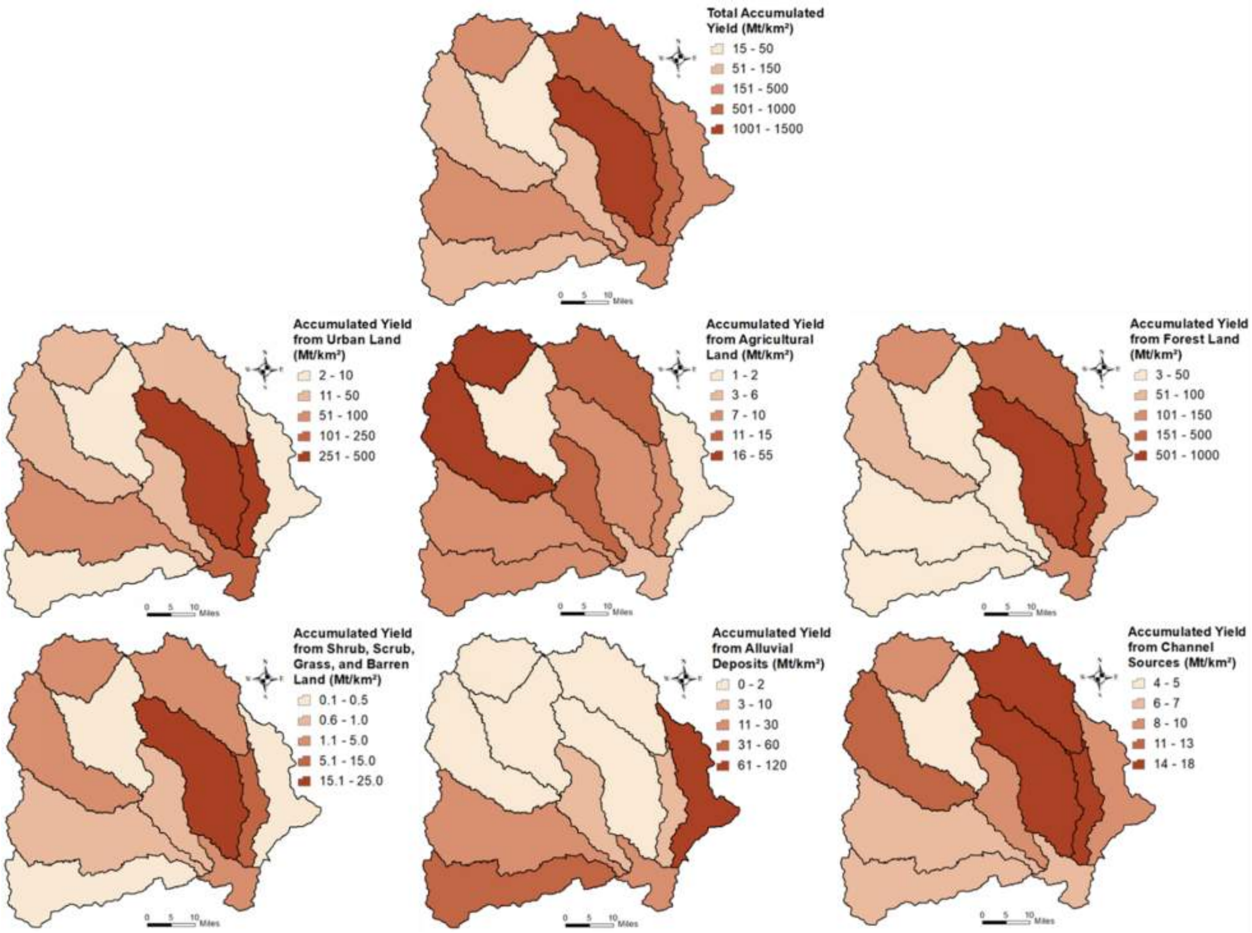


Figure 12. SPARROW Model Accumulated Sediment Yield Watershed Characteristics

Given that the SPARROW results effectively represent an output resulting from many of the other underlying watershed factors (e.g., land use, soils, slopes, etc.), they were ultimately omitted from the PCA and cluster analysis. However, these values will be revisited in subsequent Study tasks, particularly with respect to the development of watershed sediment budgets.

3.2.4 Meteorological Components

Rainfall and its associated runoff can carry sediments and other pollutants into waterways. Meteorological characteristic factors for the USJRB were calculated from NOAA daily precipitation data and NOAA Atlas 14 precipitation intensity estimates.

Fourteen years (2008–2021) of daily precipitation data were collected from sixteen NOAA gauge stations in the vicinity of the USJRB to calculate annual average precipitation. For rainfall intensity, 1-year return interval, 30-min rainfall point precipitation estimates were obtained from NOAA Atlas 14 at the centroid of each watershed. This return interval and duration was selected based on its consistency with input for the rainfall-runoff erosivity factor (R factor) used in USDA NRCS RUSLE computations. It is understood that higher magnitude storm events would lead to greater erosion. The selected storm magnitude is simply a comparative benchmark value. Figure 13 shows contours computed from annual average precipitation data and the resulting meteorological characterization of the HUC 10 watersheds in the USJRB, specifically the annual average watershed precipitation and the 1-year, 30-minute rainfall intensity at the centroid of each watershed.

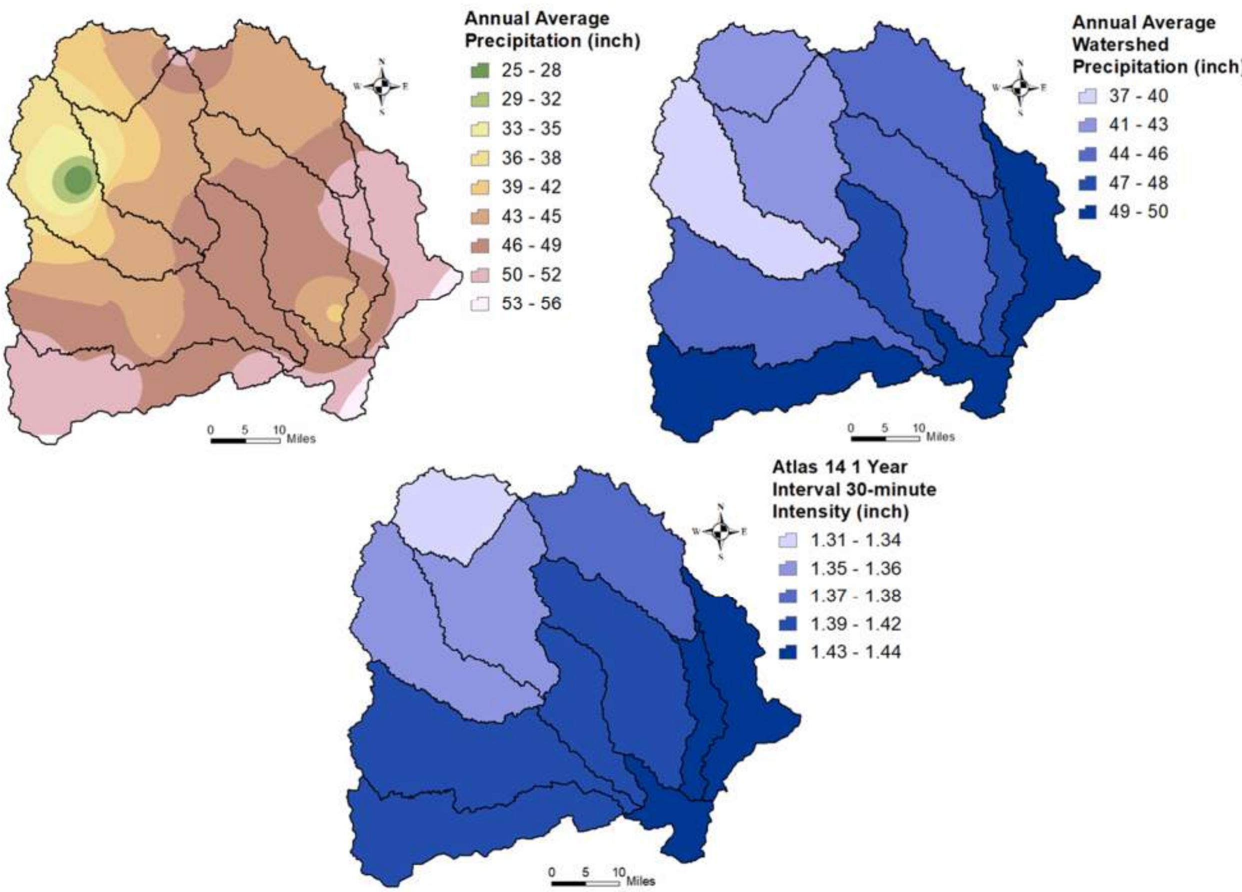


Figure 13. Meteorological Watershed Characteristics

Both the average precipitation and rainfall intensity increase from the northwest to southeast watersheds within the Study area. The watersheds closest to the Gulf of Mexico have both the highest annual average precipitation and the highest rainfall intensity.

4 Watershed Characterization Analyses

This section provides the results of watershed characterization analyses. Section 4.1 presents the results of PCA that was conducted to identify relationships between parameters and to streamline the dataset for input into clustering analysis. Section 4.2 includes the results of watershed clustering analysis conducted to group the USJRB watersheds into clusters with shared characteristics.

4.1 Factor Analysis – Principal Component Analysis (PCA)

Before conducting the cluster analysis, PCA was performed to deepen the understanding of the characteristics of the USJRB watersheds, including how parameters were spatially correlated and their ability to describe the variance of the overall dataset. The PCA, originally conducted with all thirty-two factors, was conducted iteratively to shortlist the watershed characteristics. Over time, factors were removed from the analysis due to redundancy (e.g., several of the topographical factors) or their dependence on other considered factors (e.g., SPARROW results). Table 2 lists the fifteen watershed characterization factors that were retained following PCA.

Table 2. Selected Watershed Characteristic Factors

Watershed Data Type	Factor #	Watershed Characteristic Factors
Topographical	F1	Watershed area (mi^2)
	F2	Stream slope (%)
	F3	Watershed slope (%)
	F4	Length to width ratio (unitless)
Land Cover	F5	Total developed area 2020 (%)
	F6	Total forested area 2020 (%)
	F7	Total pasture/ag/shrub area 2020 (%)
	F8	Total wetlands area 2020 (%)
Soil and Hydrological	F9	Hydrologic soil group A area (%)
	F10	Hydrologic soil group B area (%)
	F11	Hydrologic soil group C area (%)
	F12	Hydrologic soil group D area (%)
	F13	Average soil erodibility (unitless)
Meteorological	F14	Annual average precipitation (inch)
	F15	Rainfall intensity (inch)

As the duplicative factors were removed, the analysis was repeated until the common characteristics of the factors appeared more clearly. In PCA, individual factors are combined into mathematically independent components that explain the variance of the underlying data. In this analysis, a factor was considered to be significant if the absolute value of its weight was greater than 0.5 (on a scale of 0 – 1) in at least one of the resulting components. It was eventually determined that four components comprising fifteen individual factors meaningfully explained 88% of the variance in the underlying data, with additional components and factors contributing diminishing returns. These fifteen factors were therefore carried forward into the GIS cluster analysis.

As discussed, retained topographical data included the watershed area, stream and watershed slopes, and length to width ratio, while other factors were excluded due to redundancy and/or insignificance. The four major land cover types (developed, forested, pasture/agricultural/shrub, and wetlands) based on 2020 land cover data were also retained. Among the soils data, the four hydrologic soil groups (A, B, C, and D) and soil erodibility were retained. Finally, average annual precipitation and rainfall intensity were also retained for use in cluster analysis.

4.2 Spatial Cluster Analysis

The purpose of the GIS-based cluster analysis was to group the eleven HUC 10 watersheds into 2 – 5 clusters, or bins, of watersheds with shared characteristics. Using ArcGIS Pro's Multivariate Clustering tool, the fifteen retained factors were used to develop clusters of watersheds with a high degree of similitude. Figure 14 shows the resulting clustering of the eleven HUC 10 watersheds into two clusters.

The resultant F statistic output consistently indicated that two clusters was the most efficient way to group the watersheds based on the input factors. In essence, the differences between the two clusters were much higher than the differences within each cluster, such that the addition of one or more additional clusters did not add appreciable explanatory value. Cluster 1 (blue) included the seven watersheds in the lower portion of the USJRB closer to Lake Houston. The second cluster (red) included four watersheds in the upper portion of the USJRB, at higher elevations and furthest from Lake Houston.

Although the watersheds within these clusters have somewhat different characteristics, those differences are generally smaller than the differences between the two clusters. It is understood that watersheds within a given cluster will differ in terms of soil erosion, sediment transport, and net sediment contributions, and there are appreciable differences in individual parameters. However, the goal of this analysis was to identify distinct groups of watersheds to assist in the selection of representative calibration watersheds for more targeted field data collection in future Study tasks. The analysis indicated that the relatively steeper, less developed, and more forested watersheds in the upper portion of the USJRB differed substantially from the watersheds in the lower portion of the basin.

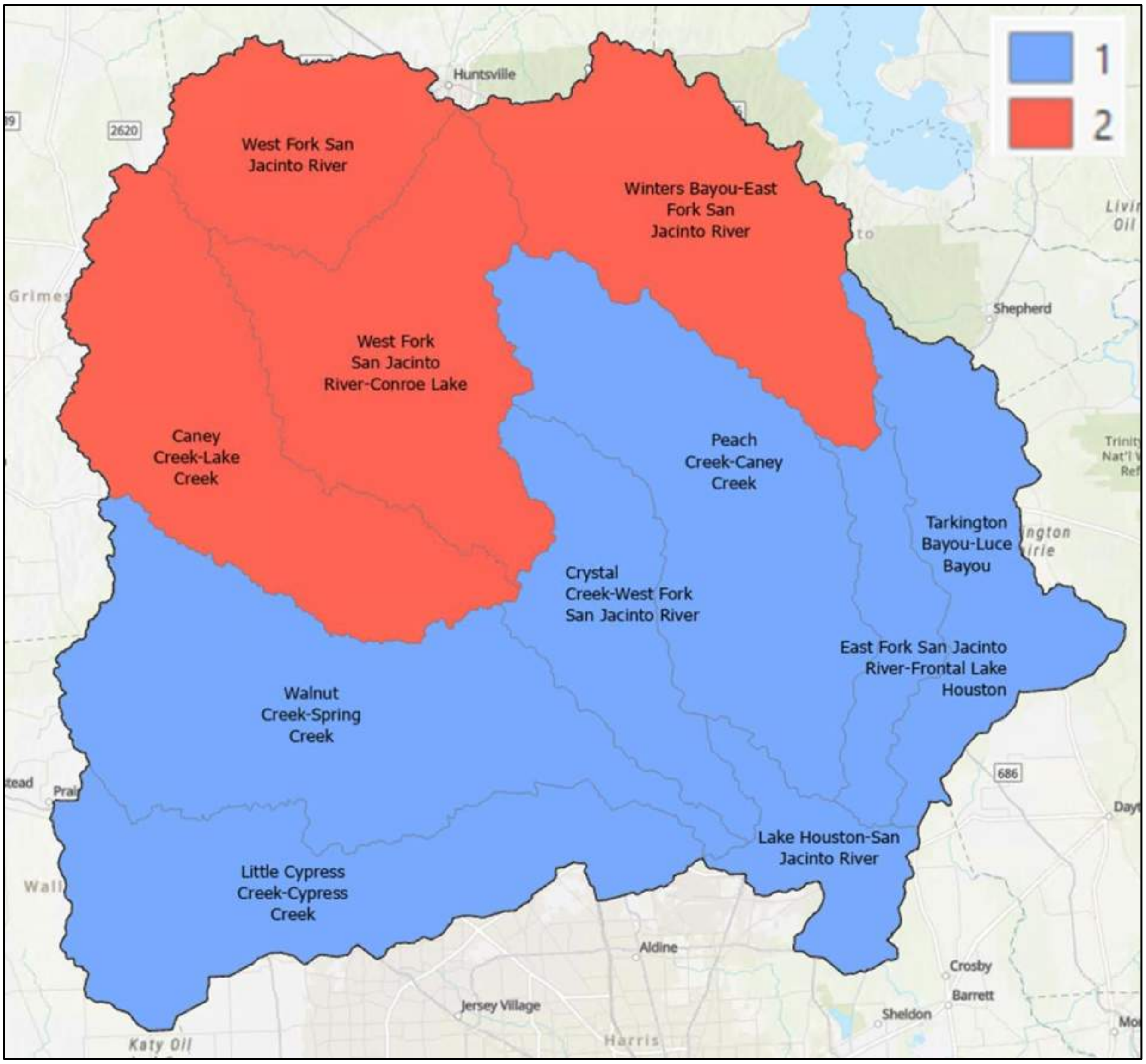


Figure 14. Spatial Clustering Analysis – 2 Clusters

Table 3 provides a summary of the average values for each factor for each of the two watershed clusters. The filled and empty circles indicate whether the cluster's average value is higher (●) or lower (○) versus the other cluster. It can be seen in the table that the seven watersheds in Cluster 1 (blue) are characterized by slightly higher length to width ratios, higher developed area, higher group B and group C soils, high soil erodibility, and higher precipitation and rainfall intensity. Conversely, the four watersheds in Cluster 2 are characterized by higher average watershed areas, higher slopes, higher forested and pasture / agriculture / shrub land cover, slightly higher wetlands land cover, and higher proportions of group A and group D soils. These findings are consistent with observations of the individual datasets presented in Section 3.

Table 3. Average Factor Values by Clusters

#	Watershed Characteristic Factors	Cluster 1		Cluster 2	
-	Watershed Count	7		4	
F1	Watershed area (mi²)	○	243	●	284
F2	Stream slope (%)	○	0.08	●	0.11
F3	Watershed slope (%)	○	0.42	●	0.95
F4	Length to width ratio (unitless)	●	16	○	15
F5	Total developed area 2020 (%)	●	39	○	12
F6	Total forested area 2020 (%)	○	28	●	41
F7	Total pasture/ag/shrub area 2020 (%)	○	16	●	33
F8	Total wetlands area 2020 (%)	○	10.6	●	11.2
F9	Hydrologic soil group A area (%)	○	19	●	34
F10	Hydrologic soil group B area (%)	●	33	○	11
F11	Hydrologic soil group C area (%)	●	27	○	9
F12	Hydrologic soil group D area (%)	○	22	●	46
F13	Average soil erodibility (unitless)	●	0.38	○	0.25
F14	Annual average precipitation (inch)	●	48	○	42
F15	Rainfall intensity (inch)	●	1.4	○	1.3

In subsequent Study tasks, field sampling will be conducted within three of the HUC 10 watersheds, and the goal of the cluster analysis was to facilitate extrapolation of the collected data to similar watersheds across the USJRB.

5 Selection of Calibration Watersheds and Associated Sampling Sites

The selection of calibration watersheds was necessary in order to streamline data collection, assessment, and modeling efforts. The findings made on the calibration watersheds form the basis of extrapolating sediment loading and storage estimates to other watersheds with similar characteristics. Three calibration watersheds were selected with an objective of one from the smaller, upper watershed cluster (Cluster 2, red) and two from the larger, lower watershed cluster (Cluster 1, blue). This distribution was considered optimal to obtain more proportional representation of the USJRB with the sampling sites while acknowledging that the general understanding is that sedimentation is generally more problematic in the lower basin.

Three sampling sites within each calibration watershed will be identified for dendrochronology samples and Bank Erosion Hazard Index (BEHI) development. In addition, sediment bedload data will be collected at 1 to 2 locations in order to conduct sediment transport modeling. Sediment bedload sampling will need to be conducted at USGS flow gauge sites in order to develop sediment bedload rating curves. For consistent field efforts and to collect comparable data through all the Study's sampling efforts, three USGS gauges from different watersheds were selected as sampling sites. Bedload sampling will be conducted at a subset of the calibration sites, and dendrochronology and BEHI data will be collected at three points/reaches along the stream in the vicinity of the USGS gauge site.

The sediment transport modeling conducted during this Study requires flow duration curves and sediment rating curves. The former requires an extended history of flow data which can be found for USGS gauge sites within the USJRB. The selected sites need to be representative of the characteristics of their watershed cluster to facilitate extrapolation of results to remainder of the watersheds within the Basin. The USGS currently has 52 gauge sites within the USJRB, as shown in Figure 15, eighteen (18) within the upper watershed cluster and 34 within the lower cluster. Potential sampling sites were shortlisted based on the following criteria:

- Available Data Record – The gauge stage and streamflow data need to be of an adequate length to establish a flow-duration curve.
- Accessible and Wadable – The stream upstream and downstream of the gauge site needs to be wadable in order to sample sediments for the sediment rating curves.
- Representativeness – The stream near the gauge site and the contributing drainage area should be sufficiently representative of the watershed cluster being represented.

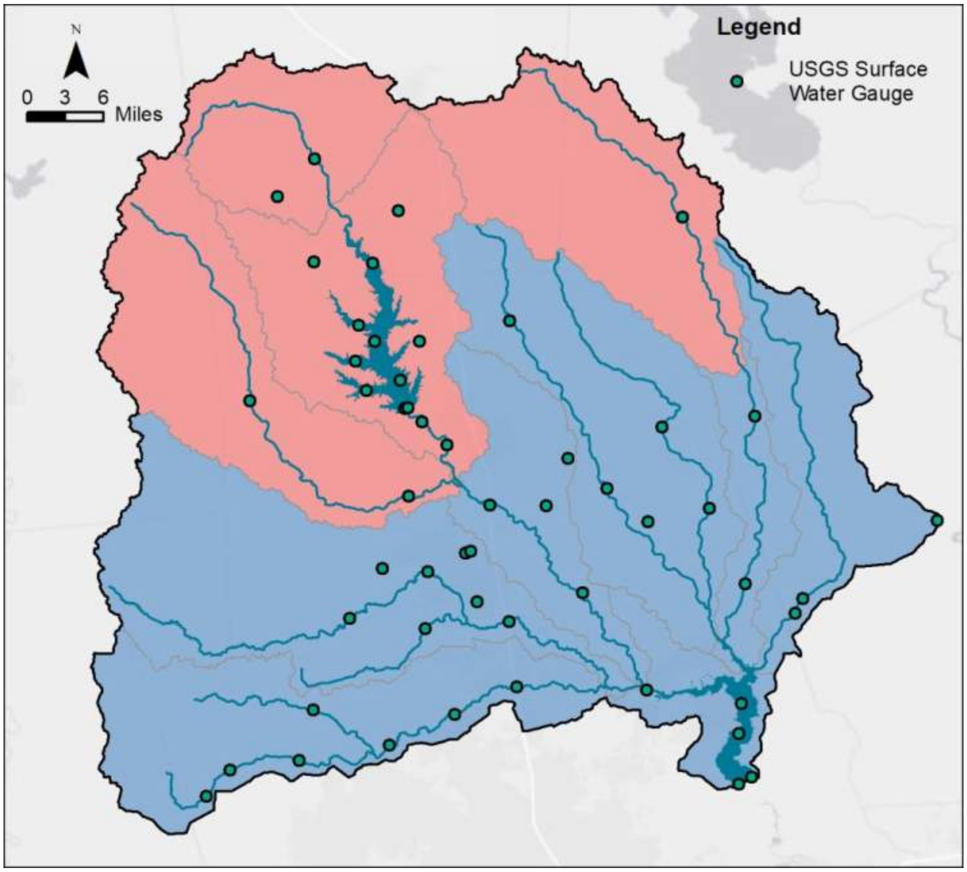


Figure 15. USGS Gauges within the USJRB

5.1 USGS Gauge Site Shortlisting

This section details the shortlisting process for the selection of the sampling gauge sites within the calibration watersheds. Data records, access, and environmental characteristics were considered when selecting sites, one within the smaller, upper watershed cluster and two from the larger, lower cluster, to conduct sampling.

A flow-duration curve requires an extended history of flow data in order to capture short-term seasonal changes and long-term climatic changes such as wet or drought years. Eleven (11) of the 52 USGS gauges in the USJRB are within the Lake Conroe, Lake Houston, and Lewis Creek Reservoirs and only collect water quality data. Of the remaining 41 gauges, twelve (12) began collecting data in 2022 and have not yet captured a full year of streamflow data; these new gauges were not considered as sampling sites for this study due to the limited data record.

As shown in Figure 16, there are 29 gauge sites within the USJRB that have flow data records greater than 3 years. Six gauges with data records greater than 3 years are located within the upper watershed cluster; the two directly downstream of Lake Conroe are well established, and the four located on the streams are more modern with data collection dates starting between 2009 and 2019. There are 23 gauges with data records greater than 3 years within the lower watershed cluster, and only one of the gauges has a data collection start date post-2000.

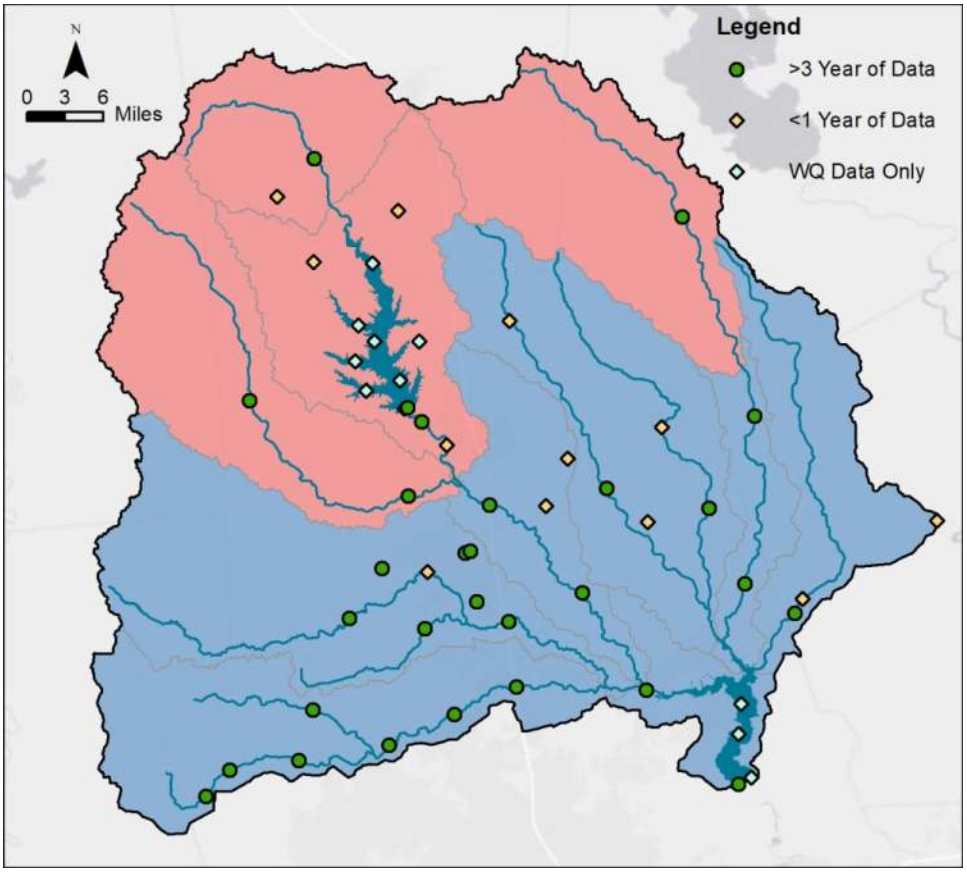


Figure 16. USGS Gauges Flow Data Records Lengths in the USJRB

Sediment bedload sampling occurs within the stream during rain events that cause at or near bankfull discharge at the representative USGS gauge. Accessible, wadable streams are desirable for bedload sampling efforts to avoid the procurement of expensive crane-mounted equipment and an at-moments-notice coordination of a transport and public safety team. A combination of in-person site visits by Study team members and desktop assessments using Google Earth and USGS Gauge data were conducted to review the accessibility and stream depths of the gauge sites. These accessibility concerns disqualified high-flow streams such as the lower portion of Cypress Creek and the West Fork of the San Jacinto River. However, these streams are known to be problematic contributors of sediment. In addition to ensuring that one of the selected sampling streams is an adequate proxy for these sediment-problematic streams, physical investigatory efforts, detailed in Section 5.3, will be employed to identify areas of sediment deposition or erosion in the West Fork and Cypress Creek watersheds.

Sediment erosion and deposition varies significantly across the USJRB, and selecting calibration watersheds that captured the full spectrum of sediment conditions was an important consideration during the gauge site shortlisting. During field and Google Earth exploration of potential sampling sites, it was observed anecdotally that there appeared to be a correlation between level of development and both streambank erosion and in-channel sediment deposition. Development can exacerbate sediment issues by increasing runoff and stream shear stresses through increases in impervious area, decreases in infiltration, and reduction of vegetation that slows runoff and stabilizes soil and stream banks. Development also frequently results in exposed soils during construction activities that can contribute to sediment loads if not properly mitigated. Forested areas dominate the northeastern portions of the USJRB and are likely to safeguard the more eastern streams from sediment-related problems. Tributaries known to contain high concentrations of suspended solids, such as Cypress Creek, are within the more developed southwestern portions of the watershed.

As shown in Figure 17, there is a strong correlation between development and average tributary suspended solids concentrations in USJRB tributaries. Note that the developed drainage area percentages are for the entirety of each tributary's drainage area, while total suspended solids (TSS) data are collected from sampling sites within the watersheds. Thus, although the TSS data are from the most downstream site with sufficient data, the level of development within the gauge's drainage area may differ slightly from the watershed as a whole. Regardless of precise values, the correlation between development and suspended solids concentrations is readily visible. It was therefore considered desirable to select sampling sites spanning a relatively broad range of the USJRB development spectrum to ensure broad coverage of watershed conditions, while simultaneously ensuring that sites remained sufficiently representative of the overall watersheds and watershed clusters.

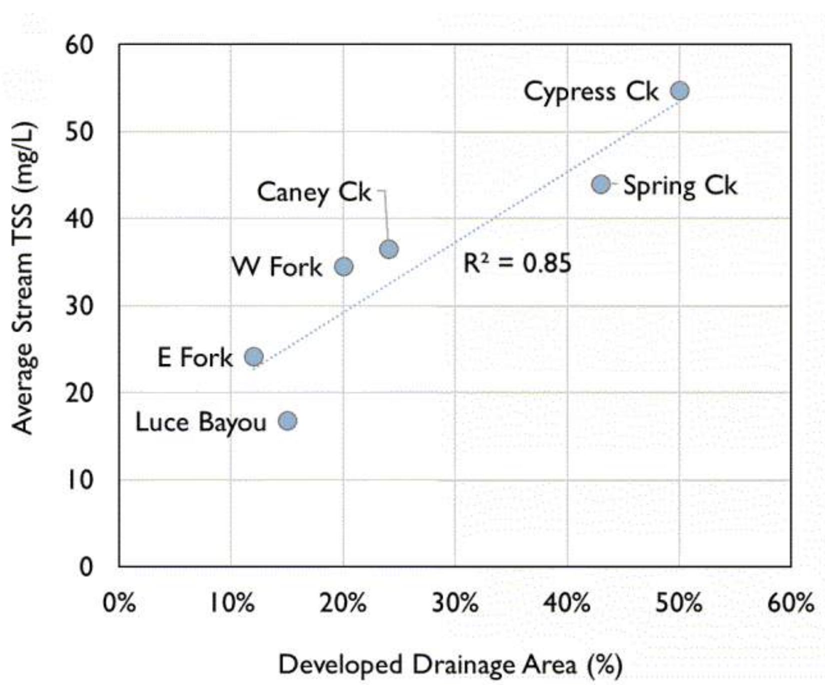


Figure 17. Developed Drainage Area Percentage and Stream TSS Correlation

5.2 Calibration Watershed and Sampling Site Selections

The result of the iterative and collaboration shortlisting process was the selection of the Walnut Creek-Spring Creek ("Spring Creek"), Peach Creek-Caney Creek ("Caney Creek"), and Winters Bayou-East Fork San Jacinto River ("Upper East Fork") watersheds as the calibration watersheds for this Study. Within these watersheds, the Willow Creek Gauge near Tomball (USGS Gauge 08068325), the Caney Creek Gauge near Splendora (USGS Gauge 08070500), and the East Fork Gauge near Coldspring (USGS Gauge 08069800) were the USGS gauge sites selected to serve as the locations for field data collection efforts later in this Study. Calibration watersheds and selected USGS gauge sites are shown in Figure 18.

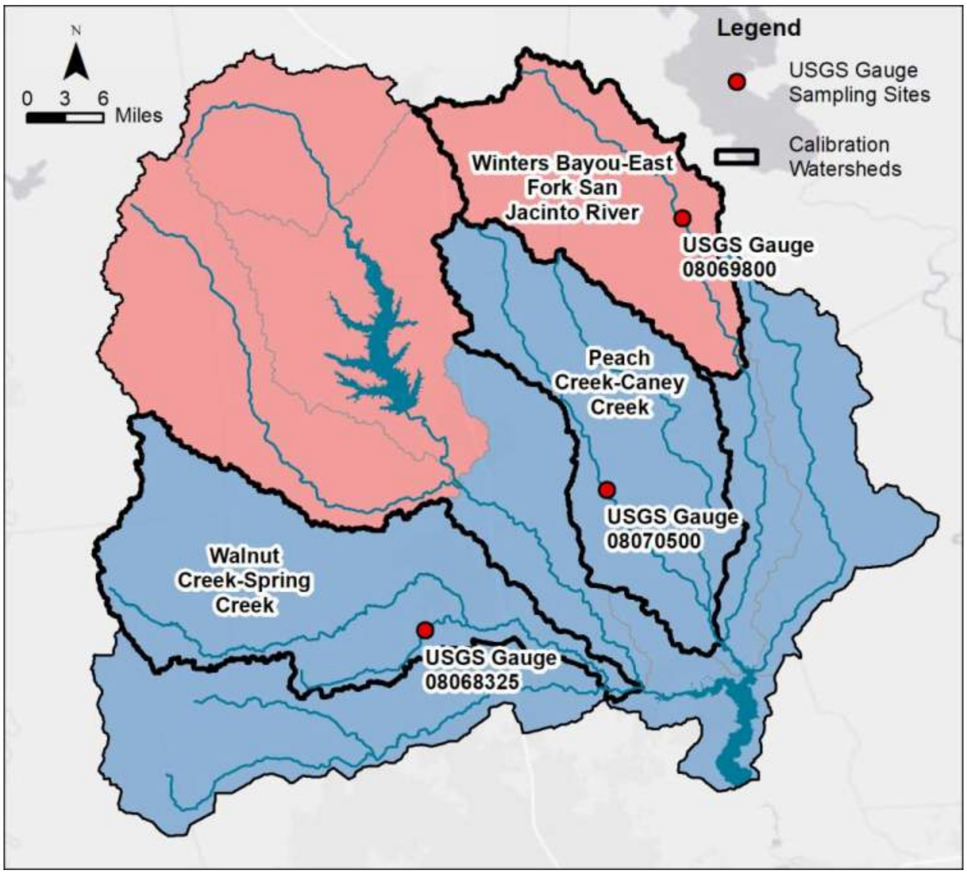


Figure 18. Calibration Watersheds and Corresponding USGS Gauge Sampling Sites

5.2.1 Willow Creek

The Walnut Creek-Spring Creek watershed is in the more developed southwestern portion of the USJRB within the lower watershed cluster. The watershed had a 21% increase in developed area between 2008 and 2020 and as of 2020 now has 50% developed land cover. The Willow Creek gauge is off of Kuykendahl Road approximately 1.7 miles northwest of the intersection of Kuykendahl and State Highway 99. Discharge data has been collected at this gauge beginning in April of 1991. Approximately 41 square miles of land drains to the Willow Creek gauge. Figure 19 shows an aerial image of the Willow Creek gauge location.

Figure 19. Aerial Imagery of the Willow Creek Gauge Area from February 2019 (Source: Google Earth, 2022)

5.2.2 Caney Creek

The Peach Creek-Caney Creek watershed and Caney Creek gauge are both located on the eastern side of the USJRB just north of the Lake Houston-San Jacinto watershed and are also a part of the lower watershed cluster. This watershed has seen moderate development, with an increase in developed land cover from 11% in 2008 to 24% in 2020, but is still predominantly made up of forested land (48%). The Caney Creek gauge began collecting an ample history of daily discharge data beginning in 1944. It is located at a bridge of Farm to Market (FM) 2090, close the intersection of FM 2090 and Crockett Martin Road. The contributing area draining to the Caney Creek Gauge is approximately 105 square miles. Figure 20 shows an aerial image of the Caney Creek gauge location.

Figure 20. Aerial Imagery of the Caney Creek Gauge Area from March 2022 (Source: Google Earth, 2022)

5.2.3 East Fork

The final calibration watershed, the Winters Bayou-East Fork San Jacinto River watershed, is located on the far northeast side of the USJRB in the upper watershed cluster. This portion of the watershed has been minimally developed and the majority of the land cover is classified as forest. The East Fork Gauge captures drainage from an area of approximately 92 square miles. This gauge is located at a bridge on FM 150 near its intersection with Happy Trails Rd, approximately 4 miles west of Coldspring. The East Fork gauge is the newest of the selected sampling gauges, with a record of discharge data beginning in June of 2019. Figure 21 shows an aerial image of the East Fork gauge location. This imagery pre-dates gauge installation.

Figure 21. Aerial Imagery of the East Fork Gauge Area from April 2017
(Source: Google Earth, 2022)

5.2.4 Development in Calibration Watersheds

To confirm that the selected gauged portions of the calibration watersheds covered an adequate span of development conditions within the USJRB, the Study team examined development within the drainage areas of the selected gauges. This effort began with the delineation of drainage areas for the three selected USGS gauges, as shown in Figure 22. The percent area classified as developed was then calculated for each of the contributing drainage areas using the 2020 land cover data from the H-GAC.

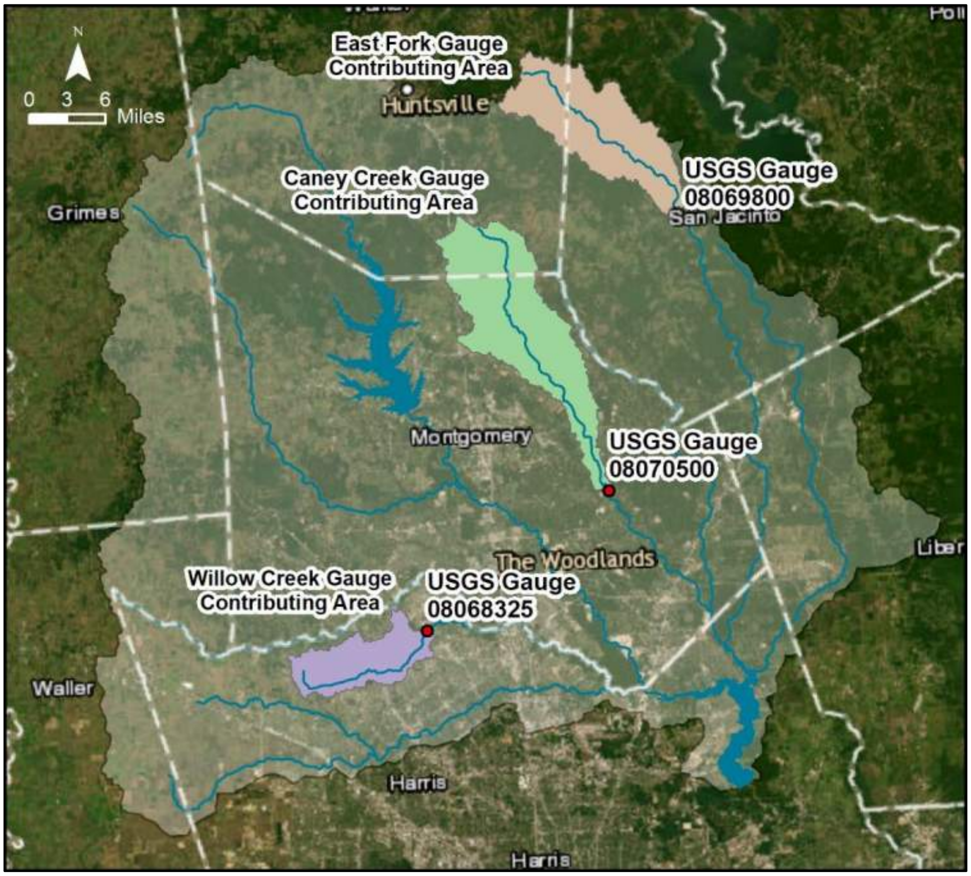


Figure 22. Delineated Contributing Areas for Study Sampling Gauges

The developed area percentages of the eleven HUC 10 watersheds and the three selected sampling gauge contributing areas (bold) are shown in Table 4 for comparison. The Willow Creek gauge represents the more highly developed end of the USJRB spectrum at 56% developed land cover. Its development is similar to the development in the Lake Houston-San Jacinto River and Little Cypress Creek-Cypress Creek watersheds, and the stream channel up- and downstream of the gauge shows similar destabilization that is seen in the sediment-problematic Cypress Creek and West Fork San Jacinto River. The East Fork gauge represents the mostly undeveloped areas that are in the north and east areas of the USJRB. The contributing area for the East Fork gauge is mostly forested area, with large vegetative buffers still in place to protect the stream banks. In the middle of the development spectrum is the Caney Creek gauge with 18% developed land cover in its contributing area. Thus, the selected USGS gauge sites are considered to be sufficiently representative of their respective watershed clusters while also spanning a wide spectrum of USJRB development conditions.

Table 4. Developed Land Cover in HUC-10 Watersheds and Selected Gauge Drainage Areas

HUC 10 Watershed	Developed Area (%)
Lake Houston-San Jacinto River	60
Willow Creek Gauge (08068325) Drainage Area	**56**
Little Cypress Creek-Cypress Creek	50
Crystal Creek-West Fork San Jacinto River	47
Walnut Creek-Spring Creek	43
East Fork San Jacinto River-Frontal Lake Houston	32
Peach Creek-Caney Creek	24
West Fork San Jacinto River-Conroe Lake	22
Caney Creek Gauge (08070500) Drainage Area	**18**
Tarkington Bayou-Luce Bayou	15
Caney Creek-Lake Creek	12
West Fork San Jacinto River	8
Winters Bayou-East Fork San Jacinto River	6
East Fork Gauge (08069800) Drainage Area	**5**

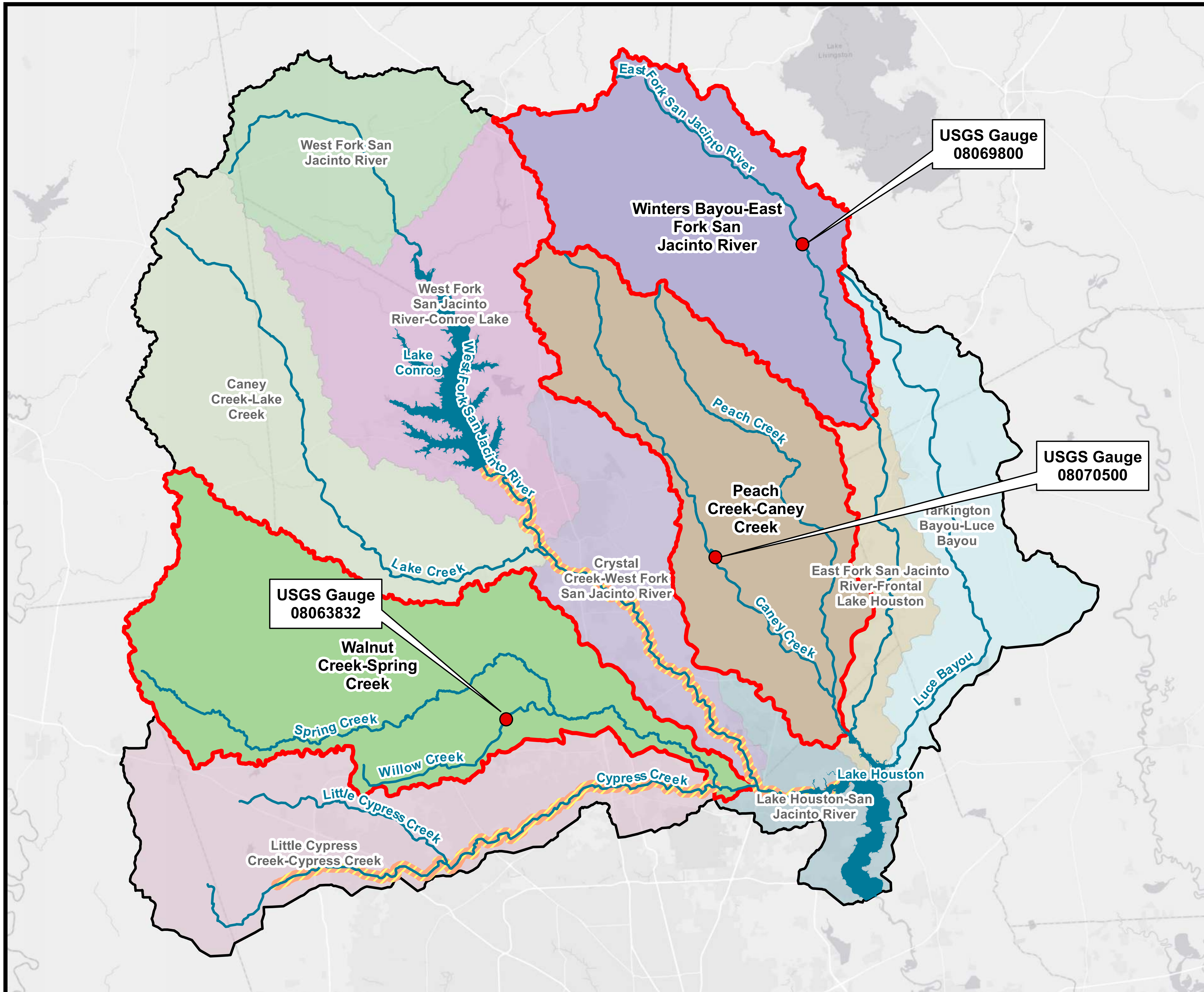
5.3 Field Reconnaissance

As discussed earlier, the need for wadable streams meant that the lower West Fork of the San Jacinto River and lower Cypress Creek could not readily be sampled in this Study. To investigate these areas further, the Study team agreed to conduct field reconnaissance along selected reaches of the lower West Fork of the San Jacinto River and, if time and accessibility permit, lower Cypress Creek. Locations of potential point-source sediment loading and/or streambank erosion will be flagged and photographed to create a database of problematic sites along the selected stream reaches. Unvegetated (or lightly vegetated) steep, sandy banks without trees to hold the banks in place are of specific interest. The streams will be accessed by foot, drone, or kayak depending on the nature of the density of vegetation and depth of the streams. Locations collected during this field reconnaissance will be used to further describe the sedimentation and erosion occurring within the West Fork and Cypress Creek stream channels and to identify areas where sediment management solutions could be applied.

6 Summary

A wide variety of topographical, soils, land cover, sediment modeling, and meteorological data were collected and analyzed to understand spatial trends in these parameters in the USJRB. Principal component analysis was performed to streamline the data for inclusion in subsequent spatial clustering analysis. Using GIS tools, the eleven USJRB HUC 10 watersheds were then grouped into spatial clusters containing watersheds with similar characteristics. Clustering analysis results indicated that the USJRB watersheds were optimally grouped into two distinct clusters, one including seven watersheds in the lower basin and a second cluster of four watersheds in the upper reaches of the USJRB.

Three calibration watersheds were selected to represent the clustered watersheds and the spectrum of development and sedimentation/erosion conditions across the USJRB. Two calibration watersheds were selected to represent the lower basin watershed cluster, and one calibration watershed was selected to represent the upper basin watershed cluster. In subsequent project tasks, field sampling will be conducted in stream reaches at or near the USGS gauge sites selected in each calibration watershed. Results will ultimately be extrapolated to other watersheds with similar characteristics and used to calculate watershed sediment budgets and conduct sediment transport modeling. The locations of the selected calibration watersheds, selected USGS gauge sites, and streams for potential field reconnaissance are shown in Figure 23.



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SJRA
SAN JACINTO RIVER AUTHORITY

Upper San Jacinto River Basin Regional Sedimentation Study

Figure 25.
Calibration Watersheds, Sampling Sites, and Field Reconnaissance Streams

Legend

- Study Area Boundary
- San Jacinto River Tributaries
- Reservoirs
- Calibration Watersheds
- USGS Gauge Sampling Sites
- Field Reconnaissance Streams

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7 References

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