UPPER SAN JACINTO RIVER BASIN REGIONAL SEDIMENTATION STUDY

Technical Memorandum 3

Annual Sediment Supply and Storage

Prepared for:
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December 2023

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1 Introduction

The next step of the Upper San Jacinto River Basin (USJRB) Regional Sedimentation Study (Study) was to perform detailed field sampling and analysis to quantify annual sediment supply and storage in the selected “calibration” watersheds within the USJRB. As discussed in Technical Memorandum (TM) 2, three calibration watersheds were selected to represent the clusters, or groups, of Hydrologic Unit Code 10-digit (HUC 10) watersheds contained within the USJRB. This memorandum (TM 3) details sampling efforts, analysis results, and conclusions regarding sediment supply and storage in these watersheds, as well as additional field sampling conducted in Lake Houston to determine the origin of sediments deposited in the lake. In subsequent Study tasks, results will ultimately be extrapolated to other watersheds with similar characteristics and used to calculate watershed sediment budgets for the entire USJRB.

2 Watershed Sampling and Assessment Background

The project team performed multiple sampling events and analyses as part of efforts to quantify the annual sediment budget for the USJRB. The field data collection efforts occurred within the Winters Bayou-East Fork San Jacinto River, Peach Creek-Caney Creek, and Walnut Creek-Spring Creek HUC 10 watersheds, as identified calibration watersheds in TM 2. The locations of these watersheds are shown in Figure 1.

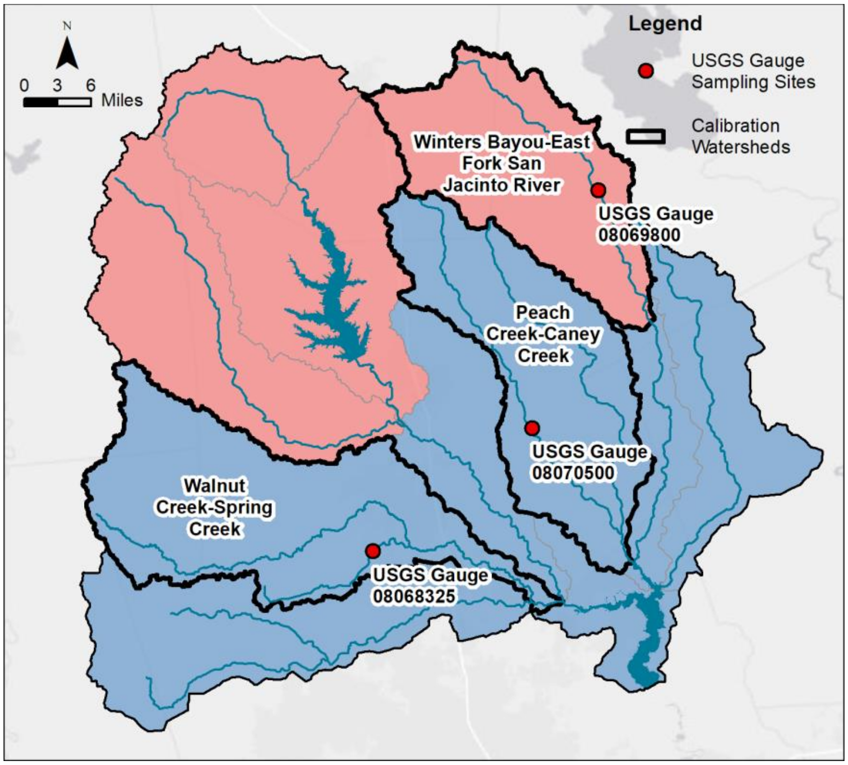


Figure 1. Calibration Watersheds and Corresponding USGS Gauge Sampling Sites

Project team scientists performed a Bank Assessment for Non-point Source Consequences of Sediment (BANCS) model field assessment and dendrogeomorphic sampling of exposed tree/shrub roots. The BANCS assessment is discussed in Section 3, and details of the dendrogeomorphic study are provided in Section 4.

In addition, a total of nine sediment samples were collected for laboratory isotope analysis (“sediment fingerprinting”). Each of the collected samples was tested to determine concentrations of specific isotopes in the soils. The concentrations of the isotopes provide a “fingerprint” in the samples that can be used to determine where the sediment originated. Watershed sediment fingerprinting analysis is discussed in Section 5.

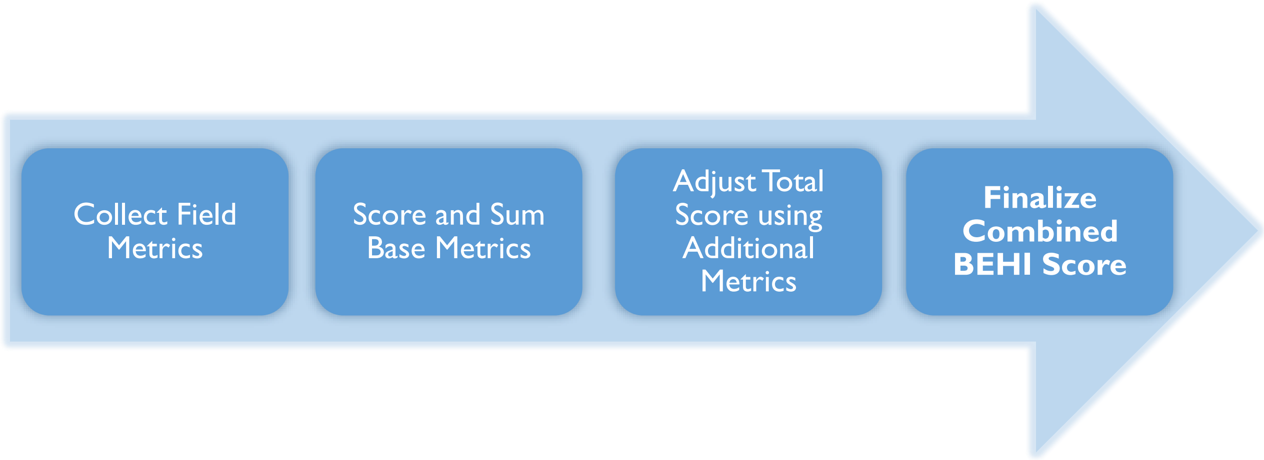
Sediment samples were also collected for laboratory particle size analysis to aid in additional sediment characterization. Sediment particle size sampling and analysis is discussed in Section 6. Similar isotope and particle size sampling conducted in Lake Houston is summarized in Section 7. Section 8 contains watershed sediment budget results, and Section 9 presents the major conclusions from these analyses.

3 BANCS Model Field Assessment

The BANCS assessment was conducted using the methods described by the U.S. Environmental Protection Agency in the *Watershed Assessment of River Stability and Sediment Supply* (WARSSS) manual (Rosgen, 2006). The BANCS assessment methodology utilizes both the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) analysis to estimate annual erosion rates generated from streambanks.

BEHI

The BEHI methodology uses field data to determine expected erosion rates at a specific streambank. The process by which BEHI scores are determined is summarized in Figure 2.



Collect Field Metrics

Score and Sum Base Metrics

Adjust Total Score using Additional Metrics

Finalize Combined BEHI Score

Figure 2. BEHI Process

The initial BEHI inputs are obtained in the field by observing and measuring the following physical metrics:

- **Study Bank Height / Bankfull Height** (Study bank height divided by bankfull height or depth. The bankfull height is the height at which flow would start to overtop the banks and begin to cause flooding, assuming there is an active floodplain).
- **Root Depth / Study Bank Height** (Average vegetation rooting depth divided by study bank height).
- **Percent Root Density** (Estimated proportion of the bank covered and protected by plant roots).
- **Bank Angle** (in degrees).
- **Percent Surface Protection** (Proportion of total bank covered by vegetation, rock, logs, etc.).

The numeric values of the metrics are then converted to a BEHI rating. The ratings range from very low to extreme and each has a corresponding numeric value ranging from 0 to 10. The numerical values for the first five metrics are then combined into an aggregate score.

Finally, the score is then adjusted according to the following two additional metrics:

- **Bank Material** (values ranging from -10 to +10 points based on composition of bank materials)
- **Stratification** (values of 5 to 10 points added for unstable layers observed in bankfull region).

Score adjustments, if warranted based on the two additional metrics, are applied to the previously aggregated score yield to develop a final combined BEHI score for the streambank.

NBS

The second step of the BANCS assessment is to predict NBS, which quantifies the amount of energy distributed to a streambank in the near-bank region that can accelerate erosion. The NBS process is summarized in Figure 3.

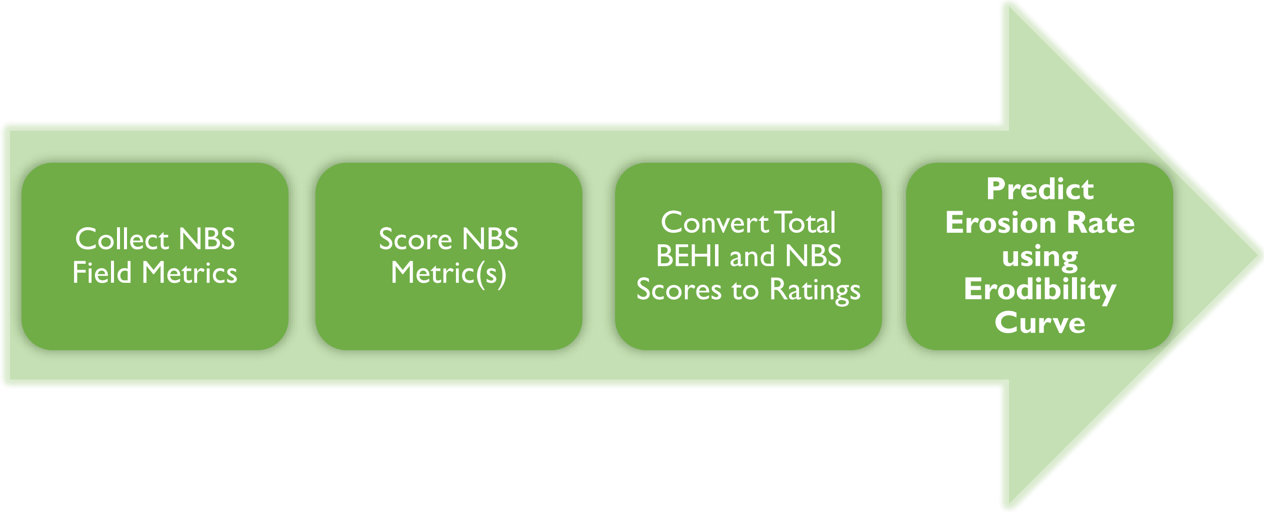


Figure 3. NBS Process and BANCS Erosion Rate Predictions

NBS scores are based upon one of seven methods, as determined by measurements of channel pattern, dimension, or profile, that best represent site conditions:

1. **Channel Pattern** (used in channels that exhibit transverse bars, split flow or central bars).
2. **Radius of Curvature / Bankfull Width** (radius of the channel bend divided by bankfull width)
3. **Pool Slope / Average Channel Slope** (average pool slopes divided by the average reach slope)
4. **Pool Slope / Riffle Slope** (average pool slope divided by the average slope of riffles)
5. **Near-Bank Maximum Depth / Mean Bankfull Depth** (maximum depth along the study bank divided by average bankfull depth).
6. **Near-Bank Shear Stress / Bankfull Shear Stress** (values calculated from geomorphic survey of channel dimensions and profile).
7. **Velocity Gradient or Profiles** (detailed measurement across the entire channel at high flow).

In this Study, Method 5 (Near-Bank Maximum Depth / Mean Bankfull Depth) was determined to be most representative and applied at all bank locations. Similar to the BEHI process, field measurements are used to compute the relevant NBS metric, which is then converted to a qualitative rating ranging from very low to extreme. However, in contrast to the BEHI process, in which several metrics are computed, the NBS scoring and rating was based on a single metric. Streambank erosion (in units of feet per year) is then predicted using empirically derived streambank erodibility curves, with curve selection base on the combined BEHI/NBS ratings. Utilizing the length and height of streambanks, the estimated erosion in feet per year can ultimately be converted to an estimated erosion rate for all streambanks analyzed.

3.1 Field Assessment Summary

Project team scientists performed a BANCS field assessment within the three calibration watersheds of the USJRB. In each of the watersheds, three sampling locations (reaches) were identified, for a total of nine sampling reaches. Consideration in choosing the field sampling reaches was given to site access, right-of-entry or permission from private landowners, and if the location was wadeable under baseflow conditions. The sampling locations were centered around the respective USGS gage locations (see Figure 1) that were utilized for bedload sampling in a separate Study task, as summarized in Table 1.

Table 1. Calibration Watersheds and USGS Stream Gauges

HUC 10 Watershed	USGS Stream Gauge
Peach Creek-Caney Creek	08070500 – Caney Creek near Splendora, TX
Winters Bayou-East Fork San Jacinto River	08069800 – East Fork San Jacinto River at SH150
Walnut Creek-Spring Creek	08068325 – Willow Creek near Tomball, TX

For simplicity, subsequent discussion and tables will identify locations based on the more concise tributary name (i.e., "Caney Creek," "East Fork San Jacinto," or "Willow Creek"). However, results should also be understood to represent the larger HUC 10 watershed containing each tributary.

At each gage location, the sampling reach began upstream of the bridge where the gage was located. The other six sampling reaches were located at more distal road crossings, where there was suitable access to the channel, both upstream and downstream of each gage location. To avoid any possible hydraulic influence of the bridge structures, sampling of the streambanks began at a distance greater than 500 feet (ft) from the bridge at each sampling reach location. The sampling reach locations in each watershed and the total length of streambanks assessed are provided in Table 2. Inset maps showing reach locations can be found in Appendix A.

Table 2. BANCS Sampling Locations for Reaches within the Three Calibration Watersheds

Creek / River	Reach Location	Length of Streambanks (ft)
Caney Creek	Near USGS gage 08070500	1,706
Caney Creek	Milmac Road	1,869
Caney Creek	Sycamore Lane	2,300
East Fork San Jacinto	Near USGS gage 08069800	1,740
East Fork San Jacinto	Farm to Market Road (945N)	243
East Fork San Jacinto	Lower Vann Road	1,387
Willow Creek	Near USGS gage 08068325	1,431
Willow Creek	Tuwa Road	1,553
Willow Creek	Gosling Road	1,770

In the Caney Creek watershed, a total of 5,875 feet of streambanks were sampled. In the East Fork of the San Jacinto a total of 3,370 feet of streambanks were sampled and in Willow Creek a total of 4,754 feet of streambanks were sampled. In total 13,999 linear feet of streambanks were sampled within the three watersheds. On the East Fork of the San Jacinto at 945N, the water level in most of the river reaches both upstream and downstream of the road crossing was too deep to wade safely during two separate site visits.

Within each BANCS field assessment location, individual bank segment (bank ID) lengths were identified that exhibited the same or similar geomorphic features, such as bank angle, bank height and vegetation density and types. A total of 128 distinct bank segments were identified and utilized in the BANCS analysis in the three watersheds.

To estimate NBS, the project team utilized method 5, which obtains an NBS rating using the ratio of near-bank maximum depth to bankfull mean depth (Rosgen, 2001). The bankfull height (or depth) used to obtain an NBS rating for each bank segment was estimated using the Harris County regional hydraulic relationships based upon the Final Report, *Fluvial Geomorphological Conditions of Harris County, Texas* (AMEC 2011). Due to channel incision in these tributaries, the “bankfull” discharge does not reach the top of the incised streambanks, and the bankfull height is typically less than the total bank height. As a result, the observed bank heights are commonly higher than the bankfull height that would be expected based on the hydraulic relationships, resulting in ratios greater than 1.0 in the majority of assessed streambanks.

3.2 Data Analysis and Results

The field-collected BEHI and NBS values within the three watersheds were further aggregated using the BEHI and NBS processes discussed previously. Streambank erosion was then predicted for each of the 128 individual bank segments. The erosion rate in feet per year (ft/yr) was derived from an erodibility curve based upon the BEHI and NBS ratings obtained from the field measurements. BANCS summary tables and mapping for individual bank segments are provided in Appendix B and Appendix A, respectively.

The predicted erosion rate in ft/yr was multiplied by the height and length of each individual bank segment, and an assumed, average soil density of 1.3 grams per cubic centimeter for loamy soils (Rai, et al., 2017) was applied to estimate erosion in tons per year (ton/yr). Erosion estimates were then divided by streambank length to compute average mass erosion rates in tons per year per foot (ton/yr/ft). These rates normalize erosion to facilitate comparison and will be used in future analyses to extrapolate results to other watersheds.

Table 3 below provides a summary of the average predicted erosion rates and predicted erosion volumes utilizing the BANCS methodology for the reaches sampled in the three calibration watersheds.

Table 3. BANCS Summary for Reaches within the Three Calibration Watersheds

Tributary	Total Length of Streambanks (ft)	Average Predicted Erosion Rate (ft/yr)	Total Predicted Erosion Rate (ton/yr)	Average Mass Erosion Rate (ton/yr/ft)
Caney Creek	5,875	0.18	483	0.08
East Fork San Jacinto	3,370	0.41	534	0.16
Willow Creek	4,754	0.61	1,540	0.32

The results in Table 3 indicate that a total of approximately 2,560 tons of sediment are produced annually from the 13,999 linear feet of streambanks sampled.

4 Dendrogeomorphic Field Sampling

Dendrogeomorphic techniques provide another estimate of streambank erosion by estimating the time and exposure of living tree and shrub roots. During the field sampling, project team scientists performed a dendrogeomorphic study to estimate streambank erosion rates within the nine sampling reaches previously identified. The study provides an estimate of streambank erosion rates by measuring the exposed distance of a root from the intact soil of the streambank, sampling the living root, and determining the age of the sample by ring counting. The erosion rate was then calculated by dividing the exposed distance from the streambank by the age of the sample.

4.1 Field Sampling Methods

In each of the nine sampling reaches, scientists observed and recorded the locations of exposed roots growing from trees and shrubs along the streambanks. The criteria for the suitability of roots were that the root was both exposed and alive, as dead roots would require cross-dating to estimate the age of death. Roots that were not anchored into the soil of the bank at both ends were not sampled, as these were assumed to be dead.

At each tree or shrub location, roots meeting the above criteria and furthest out from the streambank were first measured and recorded for an eroded distance. Where multiple roots were in the same location, the smallest (assumed to be the youngest) roots were sampled. Table 3 below provides a summary of the number of individual trees/shrubs and samples collected within each of the three calibration watersheds.

Table 4. Dendrogeomorphic Sampling Summary for Reaches within the Calibration Watersheds

Tributary	Total Number of Trees/Shrubs Sampled	Total Number of Root Samples
Caney Creek	19	52
East Fork San Jacinto	9	22
Willow Creek	11	28

A total of 102 individual root samples were collected and analyzed from 39 individual trees/shrubs. Based on the total linear feet of streambanks assessed, the number of trees or shrubs with exposed roots was considered relatively low. Many portions of the reaches were devoid of trees and shrubs along the streambanks or in the near bank region. Reasons for the relatively low number of trees/shrubs may be attributed to stream type. In the East Fork of the San Jacinto and two of the three reaches along Willow Creek, scientists observed relatively deep and narrow channels with high-angle streambanks. Coupled with the sandy composition of the soils, it may be difficult for woody vegetation to establish for long periods of time before becoming undermined and eroding into the active channel. At these locations, multiple fallen trees were observed. Secondly, stream type observed for all reaches along Caney Creek and Willow Creek upstream of Gosling Road is highly susceptible to disturbance and shifts in both lateral and vertical stability. Mapping of the individual trees/shrubs sampled in the nine sampling reaches during the dendrogeomorphic study is provided in Appendix C.

4.2 Data Analysis and Results

Once all the samples were collected, the age of each sample was determined by ring counting. Each sample was cut to a thickness of approximately 30 microns (0.03 millimeters) with a sliding microtome, stained, and viewed under a high magnification stereomicroscope. For each sample, individual rings were counted and recorded and then quality checked by a second scientist to minimize error. To estimate the uncertainty of age in the samples, the lower and upper possible ages were recorded. The upper limit age range of all the samples collected was between one and six years. The young age of the root samples may further indicate that woody vegetation does not provide a significant controlling influence on streambank stability for the stream types sampled and/or that anthropogenic impacts (i.e., impacts originating from human activity) play a more significant role on channel stability.

For each root sample, a representative erosion rate was identified using the method described by Vandekerckhove et al. (2001). The rate of erosion was calculated as:

$$E_m = {}^{L}\!/_{T_m}$$

where E_m is the calculated erosion rate, L is measured distance from the exposed root to the bank surface, and T_m is the measured age of the sample.

At each individual tree or shrub, a single root sample or multiple root samples may have been collected. Therefore, where multiple samples were collected from a single tree/shrub, the sample with the maximum eroded distance and lowest (youngest) age was used to determine the predicted erosion rate. To determine a mass erosion rate in ton/yr/ft, the bank length and bank height from the corresponding BANCS reach where the root was sampled were utilized. Due to differing bank heights, the ratios between mass erosion rate (ton/yr/ft) and predicted erosion rate (ft/yr) vary across the three tributaries. Table 5 below provides a summary of the average predicted erosion rates utilizing dendrogeomorphic techniques for the reaches sampled in the three calibration watersheds.

Table 5. Dendrogeomorphic Erosion Rate Summary for Reaches in the Calibration Watersheds

Tributary	Total Number of Samples	Average Predicted Erosion Rate (ft/yr)	Average Mass Erosion Rate (ton/yr/ft)
Caney Creek	52	0.70	0.43
East Fork San Jacinto	22	0.60	0.26
Willow Creek	28	1.20	0.84

5 Sediment Fingerprinting

Additional samples were collected in the calibration watersheds for measurement of two specific isotopes, lead-210 (Pb-210) and cesium-137 (Cs-137). Such analysis provides a way to “fingerprint” sediments because upland sediment sources are expected to have different concentrations of these isotopes than streambank sediments. By analyzing sediment samples in sedimentation areas, such as lakes and reservoirs, the relative sources of sedimentation can be ascribed.

Pb-210, a heavy radioactive isotope of lead, originates primarily from the decay of radon 222. Radon 222 can originate from various sources, including coal burning. The presence of Pb-210 in sediment is associated with deposition that occurred within the past 125 years (He and Walling, 1996).

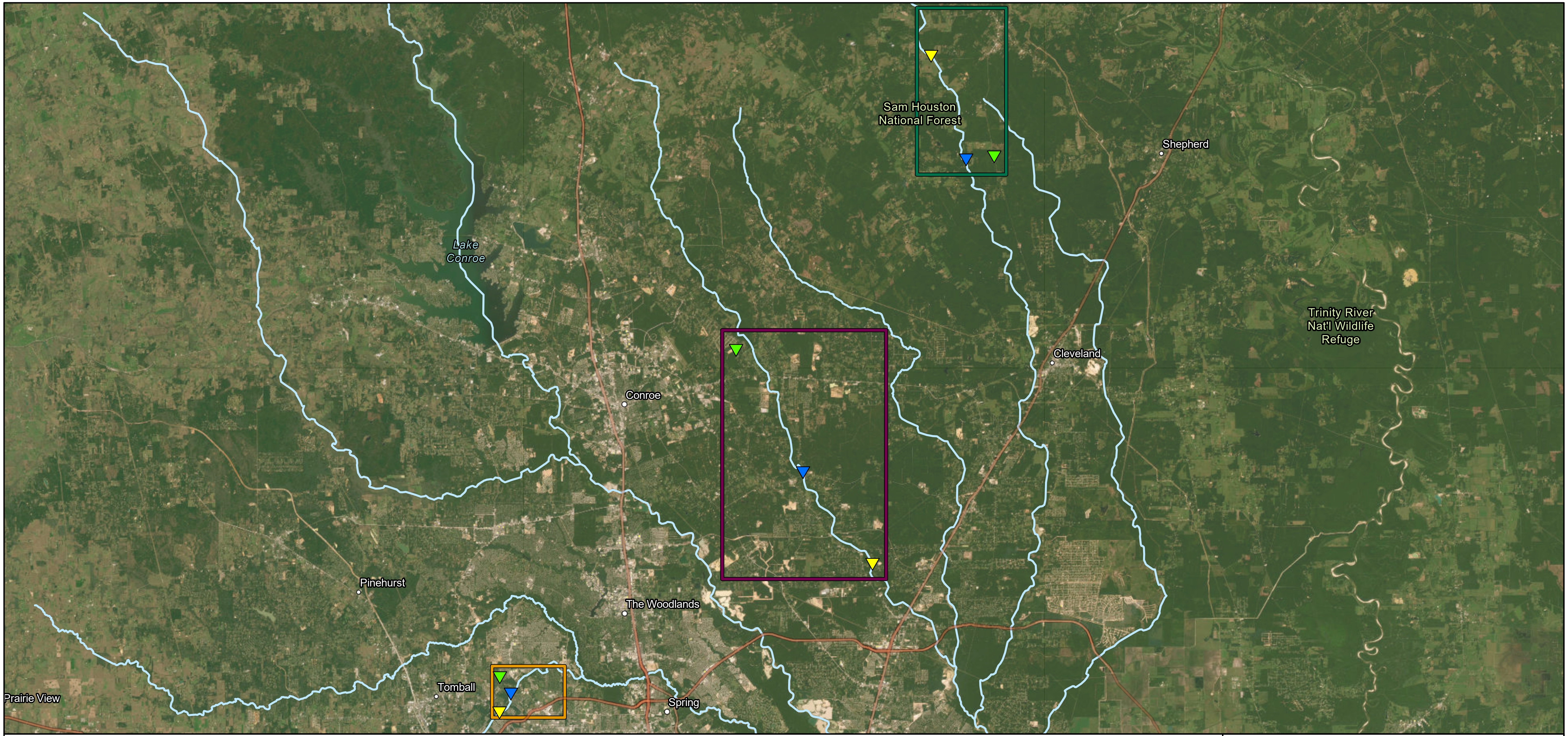
In North America, atmospheric deposition of Cs-137, a common radioactive byproduct from the fission (i.e., splitting) of uranium-235, is attributed to nuclear weapons tests in 1954 – 1955 and atmospheric nuclear weapons tests commonly attributed to 1963 (Foucher et al., 2021). The presence of Cs-137 in sediment is associated with deposition that occurred within the past 70 years (Walling and He, 1997).

During the field investigations, a total of nine sediment samples for isotope analysis (sediment fingerprinting) were collected within the three calibration watersheds. In each watershed, a sample was collected at representative upland, floodplain and streambank locations and analyzed to determine concentrations of Cs-137 and Pb-210 in the soil.

5.1 Field Assessment Methods

Sample locations were in close proximity to locations where BANCS and dendrogeomorphic sampling occurred. An overview map of the nine sediment samples collected for isotope analysis is shown in Figure 4, and more detailed mapping of sample locations for isotope analysis is provided on the figures prepared for the dendrogeomorphic study in Appendix C. At each sampling location, the immediate surface was cleared from detritus (e.g., leaf litter), and the soil sample was collected to a depth of approximately 6 inches.

Streambank sediment samples were taken from areas where the streambank soils were exposed with very little, if any, vegetation or roots present. Floodplain (storage) sample locations were chosen where scientists observed a high concentration of depositional sediments in the overbank areas adjacent to the active channel, but at an elevation above the banks and not subject to frequent inundation.



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Upper San Jacinto River Sedimentation Study

Figure 4. Isotope Sediment Sampling Locations

0 3 6 12 18 24
Miles

Sources:
Earthstar Geographics, Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS

— Streams

Isotope Sample Locations
▽ Floodplain
▽ Streambank
▽ Upland

Creek Regions
▭ Caney Creek
▭ East Fork
▭ Willow Creek

N

Upland sites for sediment sample collection were first shortlisted by finding locations which drain to the sampled stream channels but are outside of the 100-year floodplain based on current Federal Emergency Management Association (FEMA) floodplain mapping. The locations of the upland sampling sites were further screened utilizing aerial imagery available from Google Earth and the Texas Natural Resources Information System (TNRIS). For all three watershed areas, imagery from Google Earth dating back to 1939 – 1944 was screened to look for upland areas near the channels that have remained undisturbed since the earliest imagery date. Based on the screening process, forested locations within all three watersheds were chosen to sample upland soils, as open or agricultural sites were assumed to have been previously disturbed.

5.2 Data Analysis and Results

Each of the collected samples was sent to a laboratory for gamma spectroscopy analysis to determine concentrations of Cs-137 and Pb-210 in the soil samples. Results, in units of picocuries per gram (pCi/g), are summarized in Figure 5 and Figure 6.

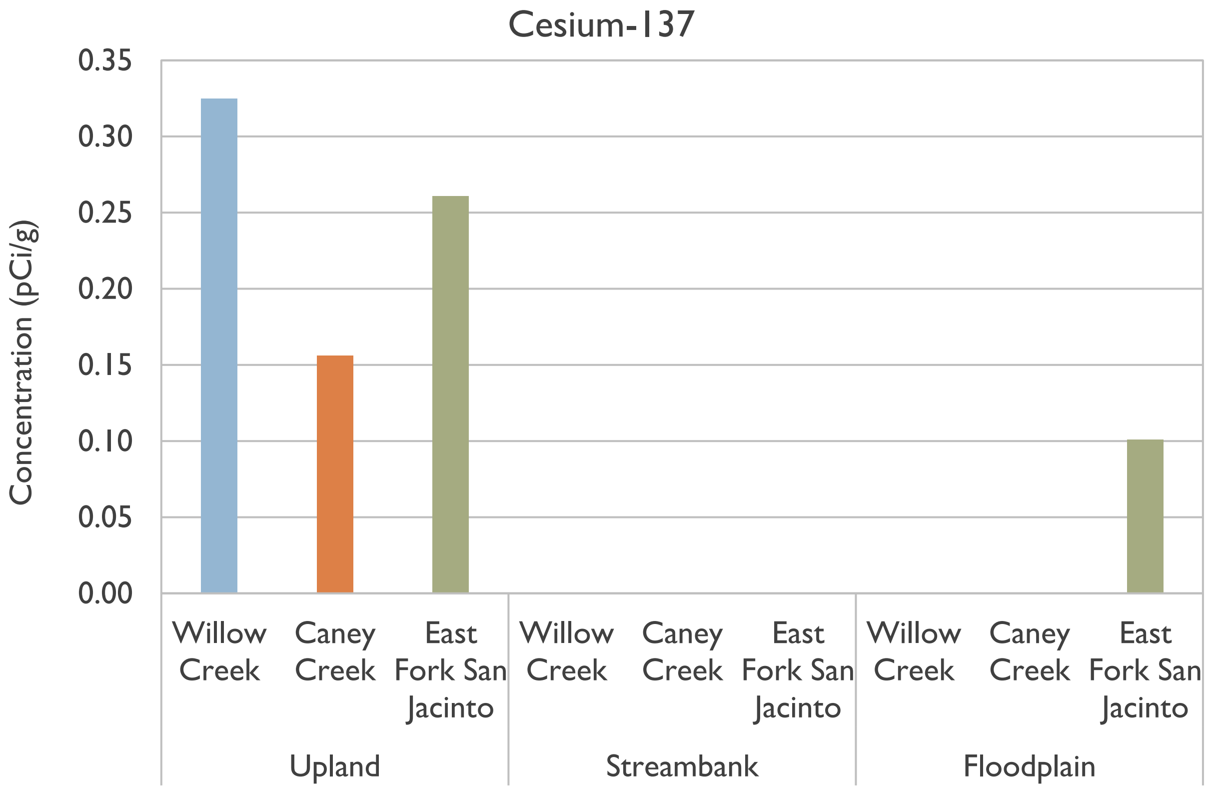

Figure 5. Cs-137 Concentrations for Watershed Samples

Upland surface sediment samples included detection of both Cs-137 and Pb-210, which is expected, since it is assumed those sediments have been relatively undisturbed for the past 125 years and would have been affected by atmospheric deposition of these radionucleotides.

The streambank samples at all three streams include Pb-210 but did not have detectable concentrations of Cs-137, which means that the sediments that make up the current streambanks may have been deposited after the late 1800s but before 1954-63. This result may be an indicator of prior anthropogenic impacts, where upland sediments were washed into floodplains, likely as a result of poor land use practices in the late 1800s and early 1900s, and streams then cut through the newly deposited, unconsolidated sediments. The current streambanks are composed of these relatively recent, unconsolidated sediments.

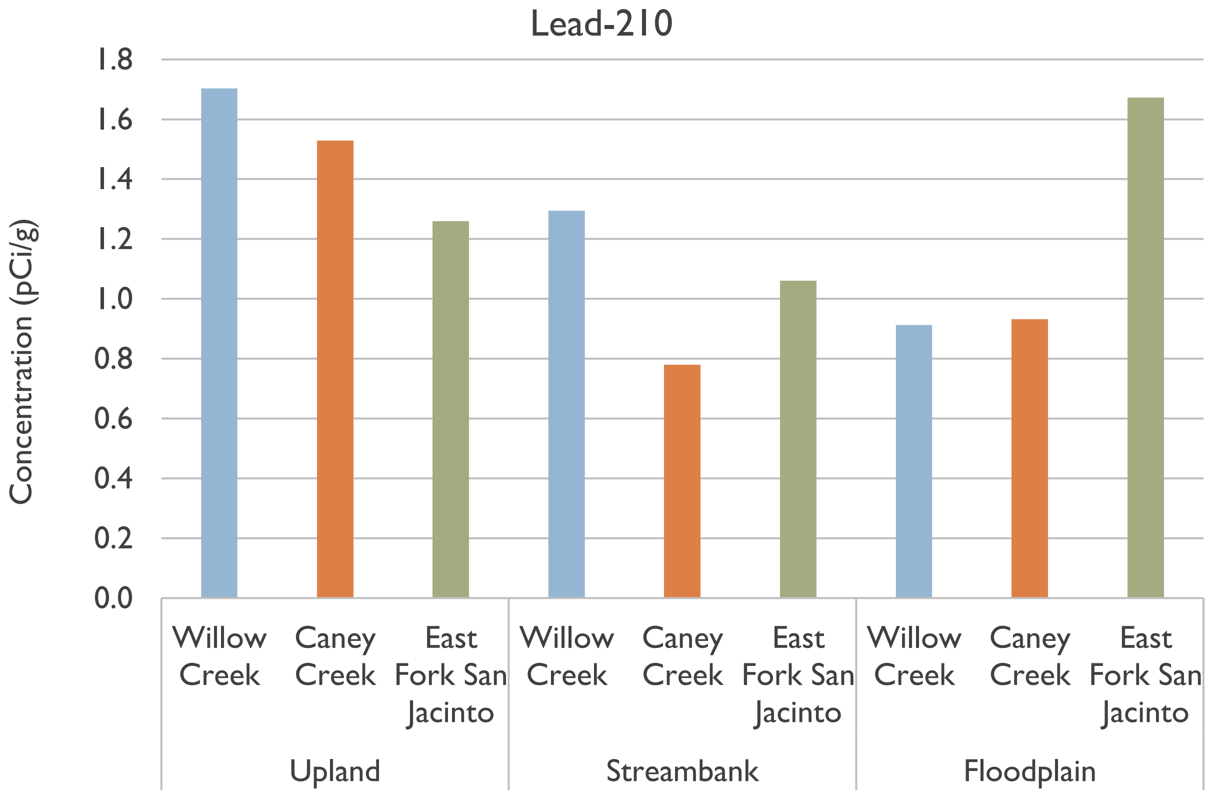

Figure 6. Pb-210 Concentrations for Watershed Samples

At both Caney Creek and Willow Creek, floodplain surface sediments had concentrations of Pb-210 generally comparable to the streambank samples. At both Caney Creek and Willow Creek, no detectable concentrations of Cs-137 were found in floodplain surface sediments. These results indicate that floodplain deposition at both Caney Creek and Willow Creek can be attributed entirely to sediments originating from streambank erosion, as streambank samples at these locations also had no detectable Cs-137.

In contrast, at East Fork San Jacinto, the floodplain surface concentration of Pb-210 was higher than at the upland and streambank sampling locations. Cs-137 was detectable in East Fork San Jacinto floodplain surface sediments, but at a lower concentration relative to the upland sediments. This suggests that floodplain deposition at the East Fork San Jacinto River location was a blend of both upland sediment and streambank erosion. The relatively higher concentration of Pb-210 is attributed to the relatively higher proportion of fine-grained sediments in this sample, as discussed in Sections 6 and 7.

6 Sediment Particle Size Sampling

Concurrent with the watershed sampling and assessment tasks described in prior sections, project team scientists collected sediment samples for particle size analysis.

6.1 Sampling Approach

Samples were collected at three distinct location types within each calibration watershed: streambank, floodplain, and point bars. The streambank samples were collected at the same locations as those for isotope analysis. Floodplain samples were collected at overbank sites that are inundated only during extreme stormflow conditions. Bar samples were collected from areas of visible sediment deposition within the stream channels. All samples were catalogued, bagged, and sent to a geotechnical laboratory for analysis.

6.2 Data Analysis and Results

All samples were analyzed by the geotechnical laboratory for particle size distribution using ASTM Method D422. Sample particle size distributions are summarized in Figure 7.

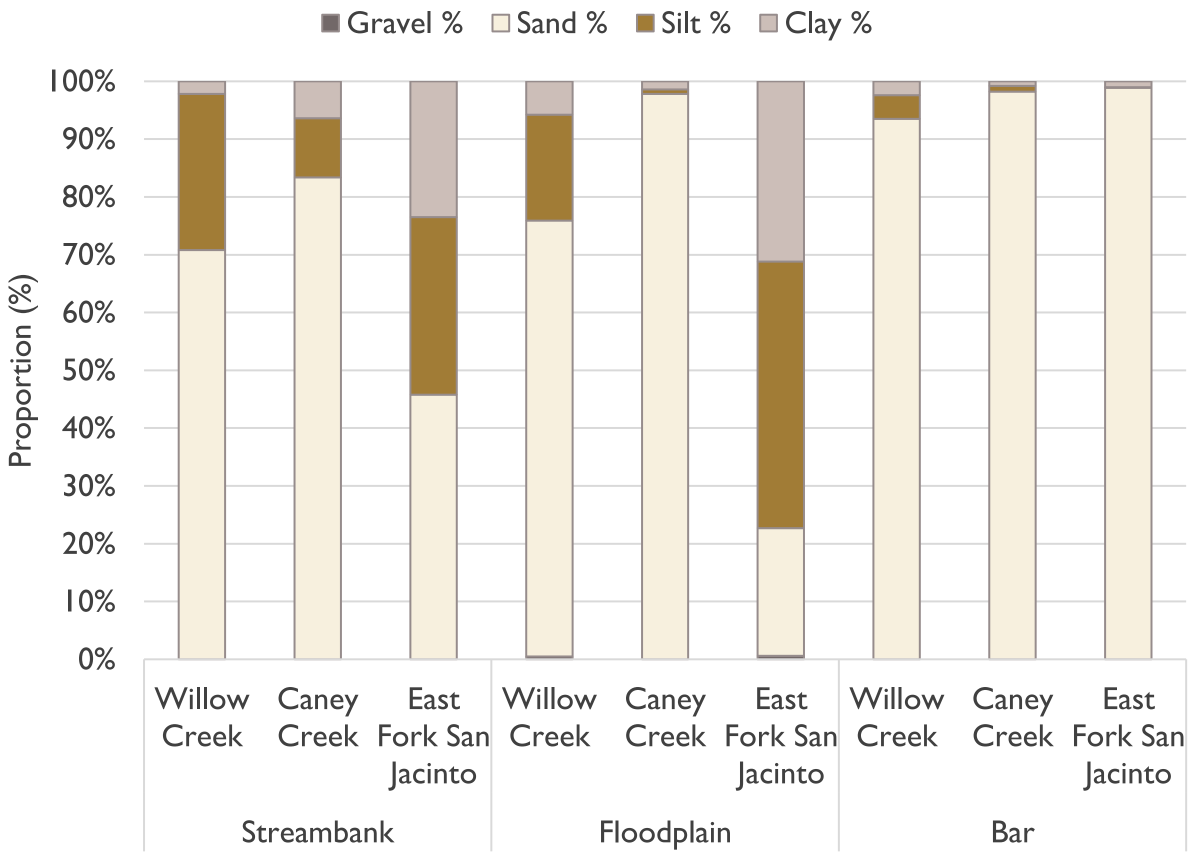

Figure 7. Particle Size Distributions for Watershed Samples

As can be seen in the figure, sand was the most dominant component in the majority of the samples, and it exceeded 70% in seven of the nine sampled locations. Only the streambank and floodplain samples from the East Fork San Jacinto River had more than 50% fine-grained (i.e., silt and clay) composition. All samples contained less than 1% gravel, and it is believed that the trace gravel that was measured originated from anthropogenic sources (e.g., road shoulders, rip rap or other stabilization backfill, etc.).

At all three streambank sites, samples were composed of varying proportions of sand, silt, and clay, with sand the most prevalent component. Floodplain proportions were more variable, but bore a resemblance to the corresponding streambank samples. In contrast, all bar samples had sand proportions exceeding 93%.

These results, when evaluated in tandem with the isotope results shown in Figure 5 and Figure 6, suggest that the Willow Creek and Caney Creek floodplain sediments originate predominantly – and perhaps entirely – from streambank sources. The floodplain sample at the East Fork San Jacinto River likely contains sediments from both streambank and upland sources. The bar deposition results demonstrate the relative tendency of sand to settle out during typical flow conditions. Sand is mobilized only under stormflow conditions and then settles as floodwaters recede and stream velocities decrease. In contrast, baseflows in these streams apparently have sufficient velocity to keep the majority of silt and clay sediments in suspension for downstream transport. Sediment bedload (i.e., sand) transport is discussed in greater detail in TM 4 – Sediment Transport Modeling.

7 Lake Houston Sampling

Lake Houston is a reservoir situated on the San Jacinto River, located northeast of downtown Houston, Texas (Figure 8). The Lake Houston Dam was constructed by the City of Houston in 1953 – 1954 to provide potable water supply to the greater Houston area. It currently serves as the sole water source for the City of Houston's Northeast Water Purification Plant (NEWPP). Along with the Trinity River, it is also one of two water sources for the City of Houston's East Water Purification Plant and the SJRA's Highlands Division, which supplies raw water for industrial and other uses, via Coastal Water Authority (CWA) canals.

Lake Houston is relatively wide and shallow, with a maximum depth of less than 40 ft and an average depth of 12 ft. The main body of the lake has two major vehicular crossings: Farm-to-Market (FM) 1960, a roadway crossing the lake's northern portion, and a Union-Pacific Railroad (UPRR) bridge crossing roughly at the lake's midpoint (see Figure 9). The majority of FM 1960, including the portion in the center of the lake, was constructed on natural ground and/or fill. It includes two bridges on opposite sides of the lake spanning the historical riverbeds of the San Jacinto's two major branches: West Fork San Jacinto River and East Fork San Jacinto River.

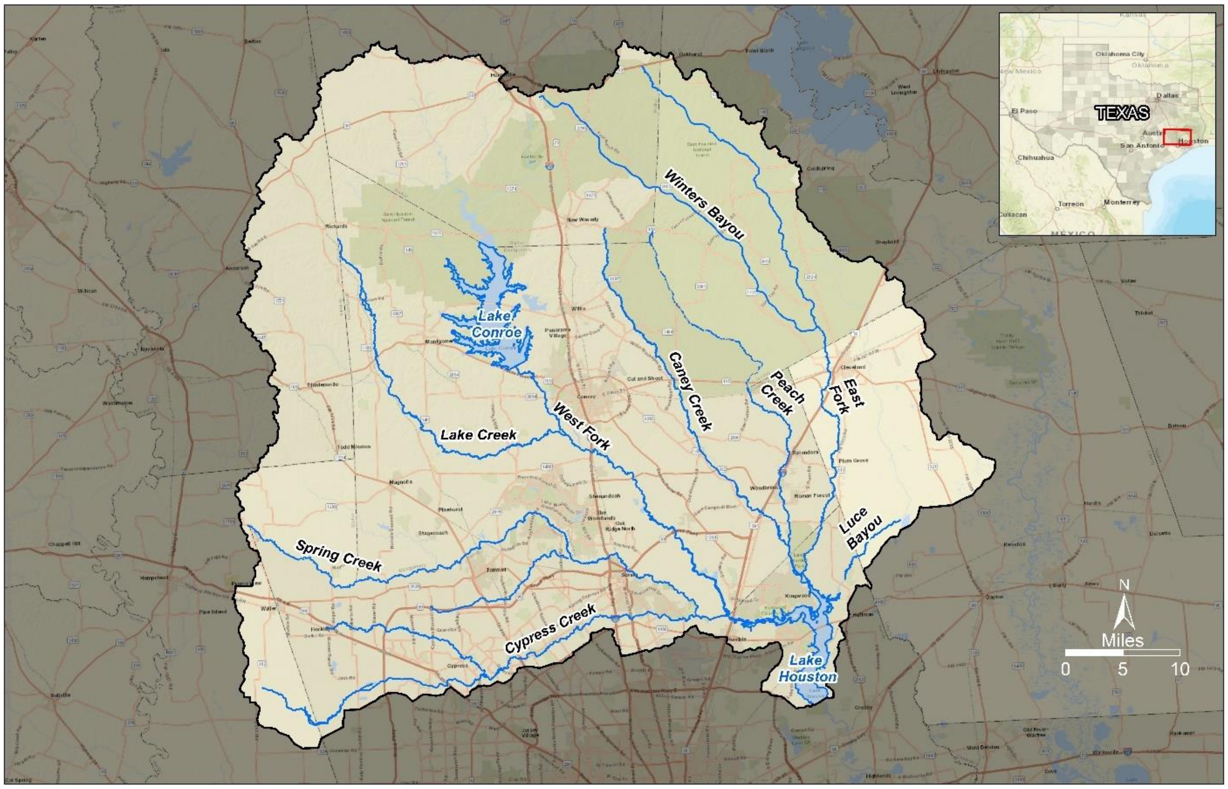

Figure 8. Lake Houston Location within the USJRB

As shown in Figure 9, Lake Houston has seven major tributaries entering via three major inlets. Arrow thicknesses in this figure are roughly proportional to annual average inflows/outflows. The west inlet receives inflows from Cypress Creek, Spring Creek, and the West Fork of the San Jacinto. Together, these three tributaries contribute approximately 63% of the major tributary inflows to Lake Houston, with approximately half of this total originating in the West Fork of the San Jacinto. The north inlet receives inflows from Caney Creek, Peach Creek, and the East Fork of the San Jacinto. The north inlet tributaries together contribute approximately 28% of the total inflow, half of which is supplied by the East Fork of the San Jacinto. The east inlet receives Luce Bayou inflows (9% of total Lake Houston tributary inflow). Based on the inlet locations in the upper reaches of the lake, all major inflows to Lake Houston pass beneath one of the two FM 1960 bridges.

As shown in the figure, the vast majority of flows entering Lake Houston leave the lake by flowing over the Lake Houston Dam to the Lower San Jacinto River. Although the dam has gates that can be used to adjust lake water levels, the majority of outflow is via the uncontrolled spillway. For the purposes of this Study, the USJRB refers to the entire basin above the Lake Houston Dam, as shown in Figure 8.

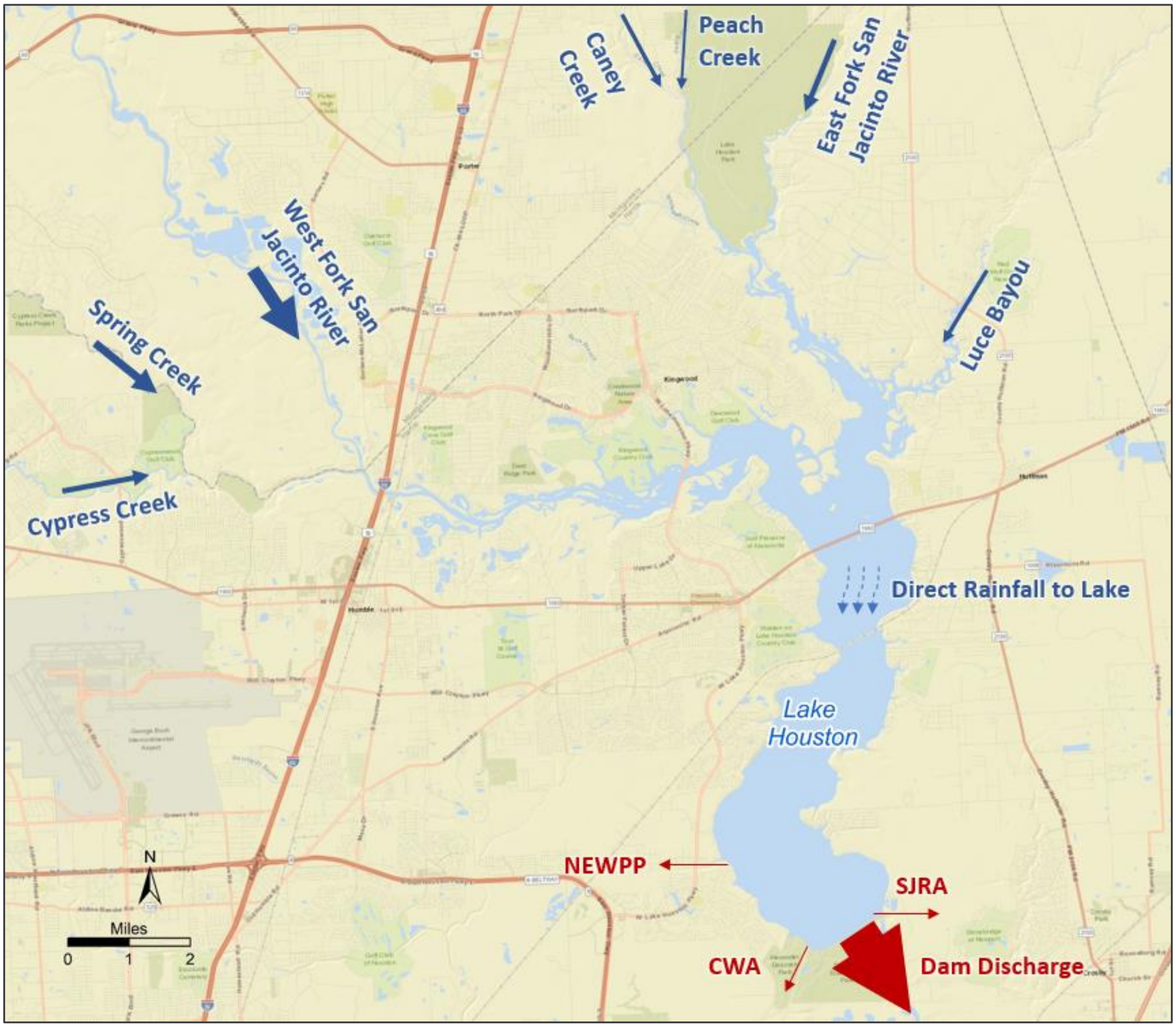

Figure 9. Lake Houston Tributaries and Withdrawals

As part of this Study, lakebed sediment samples were collected in Lake Houston for comparison with the results of the watershed sampling described in prior sections of this memorandum. This comparison will assist in determining the origin of Lake Houston sediments and depositional patterns within the lake.

7.1 Volumetric Surveys

The original volume of Lake Houston was estimated to be 158,600 acre-feet (ac-ft) of storage at the conservation pool elevation of 42.38 feet above mean sea level. Several estimates and volumetric surveys have been conducted since that time, most recently by the Texas Water Development Board in 2018 (TWDB, 2019). Figure 10 shows estimated Lake Houston volumes over time and its capacity relative to the original volume. As shown in the figure, the lake's volume has decreased by approximately 14% due to sedimentation over 64 years. This corresponds to approximately 397,000 ton/yr (350 ac-ft/year) of sediment, on average, being deposited in Lake Houston.

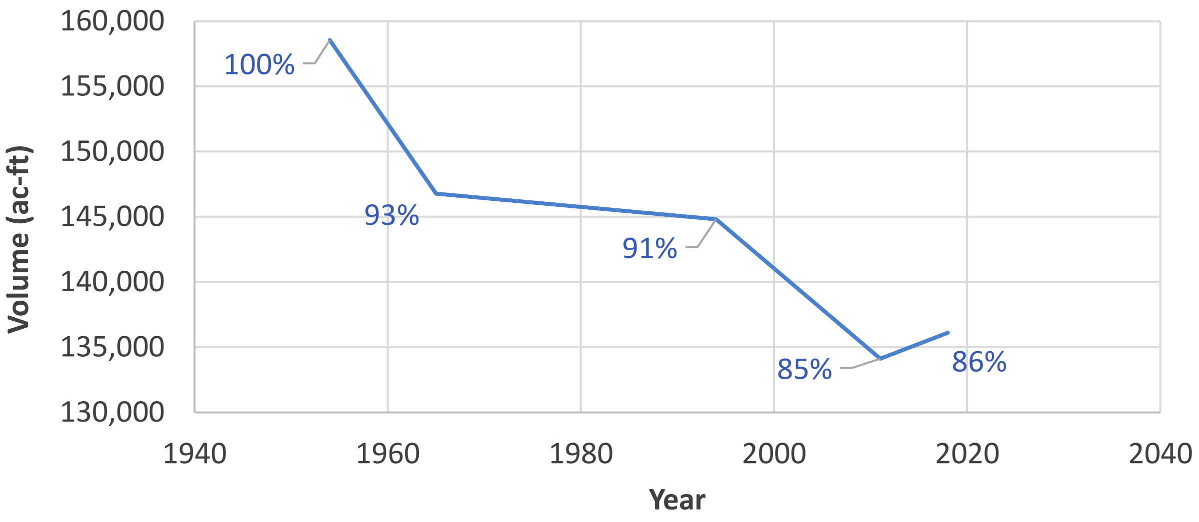

Figure 10. Lake Houston Volume Estimates over Time

The data in Figure 10 show an apparent increase in volume between 2011 and 2018. Although some areas of the lake experienced scouring of sediments during Hurricane Harvey in 2017, there are other areas that experienced significant deposition during that event. It is therefore believed that this apparent increase in volume is a result of a data limitation. The greater Houston area experienced extreme drought in 2011, resulting in unusually low water levels in Lake Houston during the time that volumetric survey was conducted. This resulted in a more limited spatial coverage during data collection (i.e., depth sounding), resulting in increased extrapolation of data to shallow, near-shore areas. Due to the improved data coverage in 2018, the estimated volume from this survey was used to compute the historic sedimentation rate.

7.2 Hydraulic Modeling

Prior to sample site selection, the project team performed hydraulic modeling of the San Jacinto River to evaluate the hydraulic influence of the Lake Houston Dam. Under baseflow conditions, the hydraulic influence of the dam extends far upstream into the relatively narrow west, north, and east inlets of the lake. Under baseflow conditions, the dam's hydraulic influence within the west inlet extends westward past the US-59/I-69 expressway, ending upstream of the confluence of Spring Creek and the West Fork San Jacinto River.

In the north inlet, the dam's hydraulic influence extends northward past the confluence of Caney Creek and the East Fork of the San Jacinto River. It terminates just upstream of the Caney Creek/Peach Creek confluence on the Caney Creek branch of the inlet. On the East Fork branch, it terminates at a nondescript but comparably distal location upstream of the main body of the lake. In the east inlet, the influence under baseflow conditions terminates in Luce Bayou a few thousand feet upstream of FM 2100 / Humble-Crosby Rd. Given that none of the calibration watersheds drain to the east inlet, it is not discussed further herein.

Under stormflow conditions, the increased tributary water levels are able to overcome the dam’s influence, pushing its area of influence further downstream in all three inlets. In this Study, the project team applied the existing 1-dimensional hydraulic model used in the San Jacinto Regional Watershed Master Drainage Plan (Harris County Flood Control District [HCFCD], et al., 2020) to evaluate the dam’s hydraulic influence under stormflow conditions. This model was developed using updated National Oceanic and Atmospheric Administration (NOAA) Atlas 14 point precipitation frequency estimates. Specifically, the team modeled 1% (“100-year”) and 50% (“2-year”) stormflow conditions. The 1% event is the standard benchmark for flood mapping, and the 50% storm was the lowest intensity event included in the model. For each scenario, the team examined the simulated Lake Houston water levels and found the location where the slope of the hydraulic grade line (i.e., the water surface) approaches zero. At such locations, the water velocity drops considerably, resulting in likely sediment deposition zones.

The approximate locations of the likely depositional zones identified by the modeling for the west inlet and north inlet are shown in Figure 11 and Figure 12, respectively. In both inlets, the identified depositional zone is located where the inlets enter the main body of the lake. These are also known locations of sediment deposition. The location identified for the west inlet includes an area of deltaic islands and the West Fork mouth bar, which was recently removed via dredging efforts conducted by the City of Houston. The north inlet location similarly corresponds with deltaic islands where the inlet enters the main body of the lake and where the East Fork mouth bar formed over time.

Figure 11. Lake Houston West Inlet Depositional Zone

Figure 12. Lake Houston North Inlet Depositional Zone

7.3 Sample Collection

Based on the hydraulic modeling results, prior knowledge of the lake, and other considerations, six locations were identified for sample collection, as shown in Figure 13:

- Spring Creek above West Fork Confluence (Spring Creek ab WF) – Selected to obtain a sample containing only Spring Creek and Cypress Creek sediments, with no West Fork contribution.
- West Fork above Spring Creek Confluence (West Fork ab SC) – Selected to obtain a sample containing only West Fork San Jacinto sediments.
- West Fork Arm near River Grove Park (West Fork nr RGP) – Known depositional area during Hurricane Harvey (2017) that was subsequently dredged by the U.S. Army Corps of Engineers.
- West Fork Mouth Bar – Selected based on hydraulic modeling and the location of the former West Fork mouth bar.
- East Fork Mouth Bar – Selected based on hydraulic modeling and deltaic islands.
- Lower Lake Houston (Jack's Ditch) – Lower lake location near the intake for City of Houston's NEWPP selected to evaluate longitudinal sediment trends within the lake.

In May 2023, the project team visited each of the six locations by boat and collected lakebed sediment samples using an Ekman dredge. This device obtains a surficial sediment sample using a spring-loaded claw or scoop, and the device is then retrieved to extract the sample. Samples were catalogued and placed in plastic containers for subsequent processing. After settling, excess water was decanted from the samples, which were then measured and bagged for laboratory analysis. Due to the sandy sediments and stream currents at the West Fork and Spring Creek locations above their confluence, limited sample volume could be obtained. Thus, for these two locations, only laboratory isotope analysis was conducted. Both isotope and particle size analyses were conducted on the other four samples.

Figure 13. Lake Houston Sediment Sampling Locations

7.4 Data Analysis and Results

The same laboratories and analysis methods used for the watershed sample analysis were employed for the Lake Houston samples to ensure consistency and comparability of the results. Figure 14 shows the results of Cs-137 results from the Lake Houston samples alongside the same watershed sample results previously shown in Figure 5. As can be seen in the figure, Cs-137 concentrations were detectable in four of the six samples, and concentrations were consistently lower than those of the upland samples. These results suggest that Lake Houston lakebed sediments are predominantly from streambank sources, with some contribution from upland sources. Notably, the two most upstream samples along the West Fork Arm of Lake Houston had Cs-137 concentrations below the detectable limit, suggesting these samples may have been almost entirely streambank in origin.

One exception is the relatively higher concentration of Cs-137 at the East Fork Mouth Bar location. Similar to the East Fork San Jacinto floodplain sample discussed in Section 0, it is likely that this location receives a blend of upland and streambank sediments.

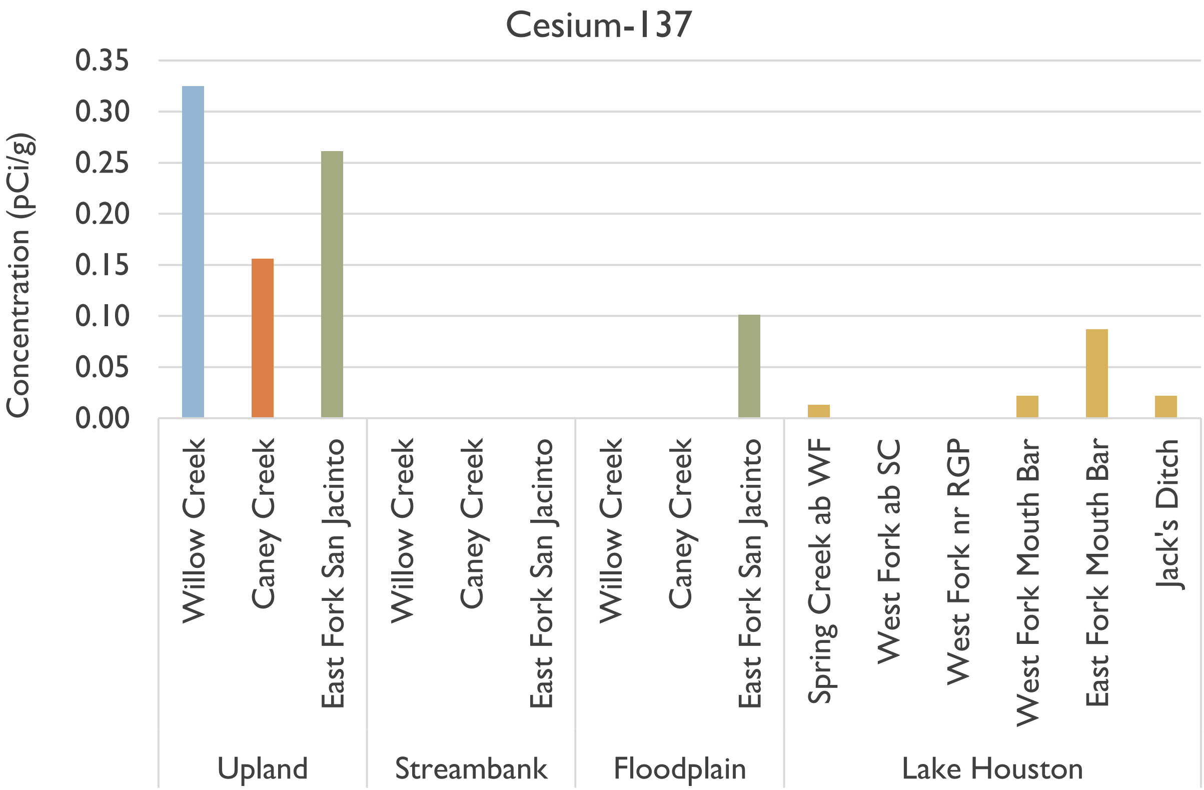

Figure 14. Cs-137 Concentrations for Watershed and Lake Houston Samples

Figure 15 presents the results of Pb-210 analysis for the Lake Houston samples alongside the watershed sample results previously presented in Figure 6. As can be seen in the figure, the four samples from the west inlet (Spring Creek ab WF, West Fork ab SC, West Fork nr RGP, West Fork Mouth Bar) all had relatively low Pb-210 concentrations, while the East Fork Mouth Bar and Jack's Ditch (i.e., lower Lake Houston) samples had the highest reported concentrations of all samples collected in this study.

Although there is less contrast between the upland and streambank samples in the Pb-210 data versus the Cs-137 data, the streambank samples have generally lower Pb-210 concentrations relative to the upland samples in the same watershed. Thus, consistent with the Cs-137 results, the four west inlet samples are likely predominantly from streambank sources. In contrast, the East Fork Mouth Bar and Jack's Ditch samples have elevated Pb-210 concentrations that are higher than the upland sample concentrations.

Similar to the elevated concentration in the East Fork San Jacinto floodplain sediments, the elevated concentrations at these two locations are attributed to their relatively high fine-grain (i.e., silt and clay) sediment composition, as some isotopes are known to bind more readily with fine-grained soils. While the precise upland contribution cannot be directly determined from the isotope concentrations, it is likely that these locations receive a considerably higher proportion of upland sediments than the west inlet locations.

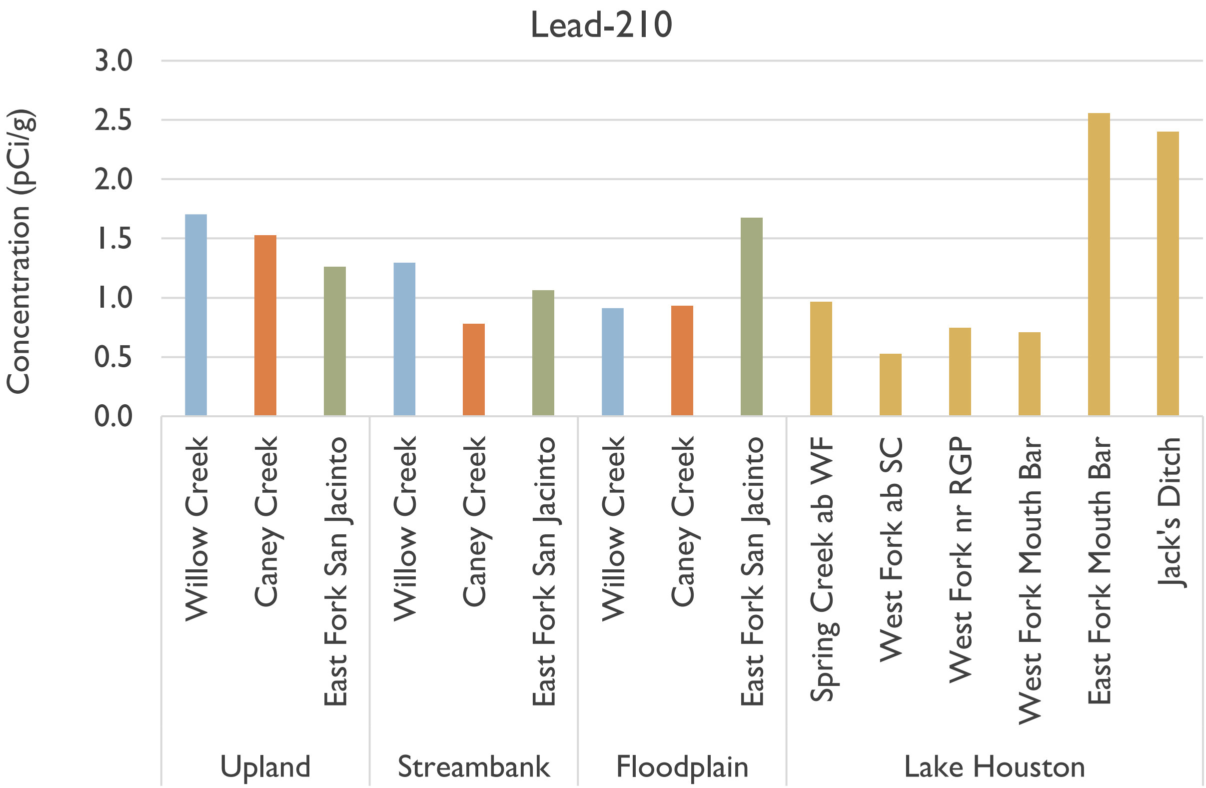

Figure 15. Pb-210 Concentrations for Watershed and Lake Houston Samples

Figure 16 contains particle size distributions for four Lake Houston lakebed sediment samples. These proportions are shown alongside the watershed sample results (previously presented in Figure 7) to facilitate comparison. Due to sandy sediment composition and stream currents at the Spring Creek ab WF and West Fork ab SC locations, insufficient sample was collected for particle size analysis. However, these samples were anecdotally observed to be predominantly sand, with sand concentrations likely exceeding 80% of the overall sediment sample mass.

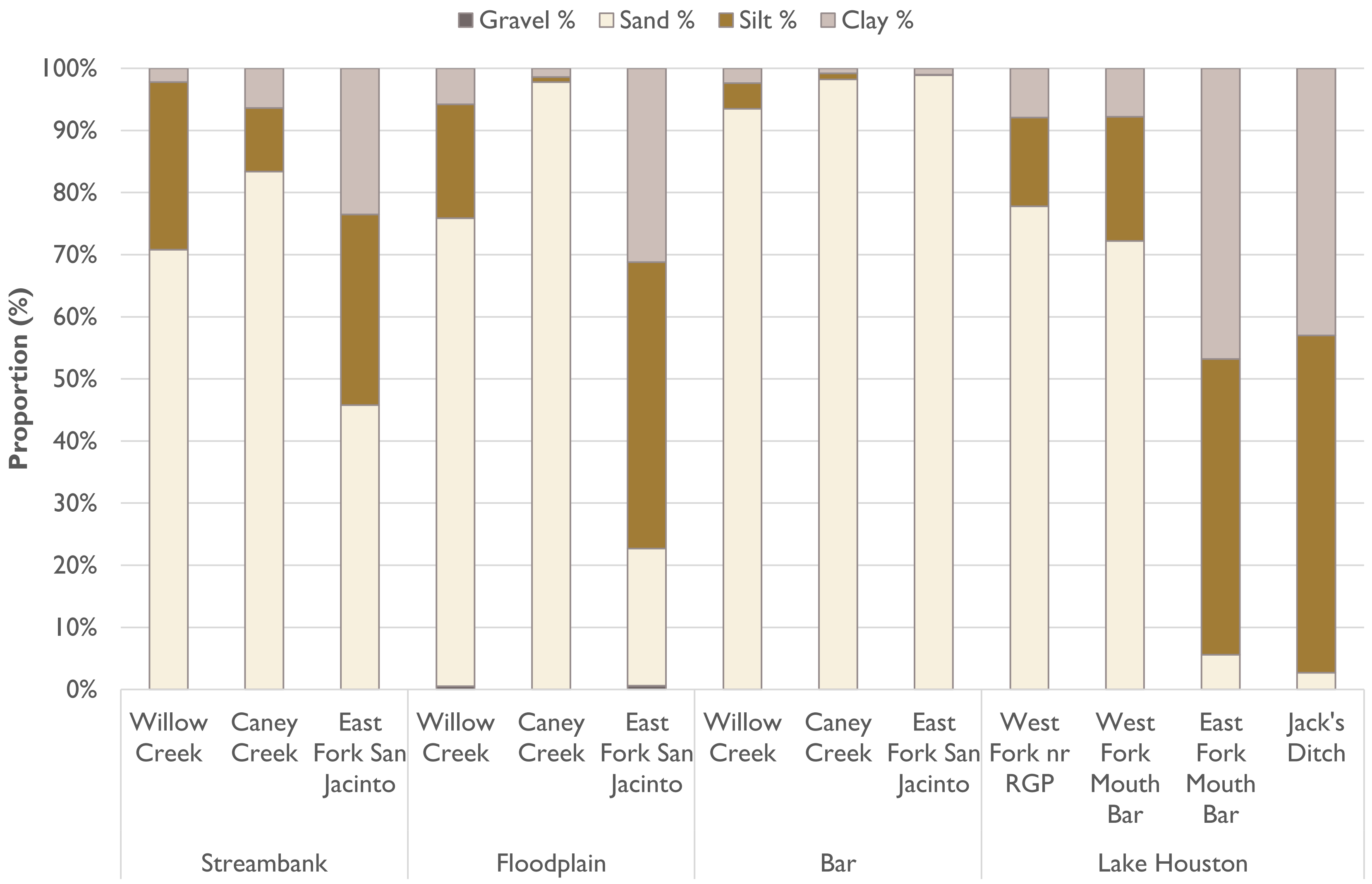

Figure 16. Particle Size Distributions for Watershed and Lake Houston Samples

The two west inlet samples were predominantly (greater than 70%) sand. These proportions, when considered in tandem with the isotope results, indicate that the west inlet (i.e., West Fork Arm) samples likely originated primarily from eroding streambanks. In contrast, the relatively high proportions of fines in the East Fork Mouth Bar and Jack's Ditch samples indicate appreciable upland sediment contribution, consistent with the Pb-210 data.

Despite the relative similarities in the Pb-210 concentrations and particle size distributions between the East Fork Mouth Bar and Jack's Ditch locations, these results do not indicate that Jack's Ditch sediments originate primarily from the north inlet. Rather, these similarities indicate that similar types of predominantly fine sediments are deposited at these locations, with sand sediments settling out upstream of these locations. Prior modeling work (Coastal Water Authority, 2022) indicated that Jack's Ditch receives blended flows from all three inlets under most flow conditions. During extreme rainfall events (greater than 6 inches of rainfall), it receives inflow from only the west inlet.

8 Sediment Budget Development

The data presented in this memorandum were analyzed in conjunction with sediment transport modeling results and suspended solids regression analysis to establish high-level sediment "budgets" for the calibration watershed gauge drainage areas. The sediment transport modeling work and its findings are detailed in TM 4, and regression analysis results are presented in TM 5. In TM 5, net sediment export was computed for each of the eleven HUC-10 watersheds based on the results of regression analysis and volumetric surveys for Lake Conroe and Lake Houston.

For this analysis, sediment load estimates from the HUC-10 regression analysis were downscaled to the drainage areas of the three calibration watershed gauges, shown in Figure 17. First, the HUC-10 watershed sediment export was divided by the total watershed area (in square miles [mi^2]) to obtain an annual sediment yield in units of tons per year per square mile (ton/yr/mi^2). This yield was multiplied by the area of the gauge's drainage area to compute the net sediment export from each of these smaller areas, as follows:

$$W_{gauge} = \frac{W_{HUC-10}}{A_{HUC-10}} \cdot A_{gauge} = Y_{HUC-10} \cdot A_{gauge}$$

where W_{gauge} is the net sediment export from the gauged area, W_{HUC-10} is the net sediment export from the HUC-10 watershed, A_{HUC-10} is the area of the HUC-10 watershed, A_{gauge} is the gauge's drainage area, and Y_{HUC-10} is the sediment yield from the HUC-10 watershed.

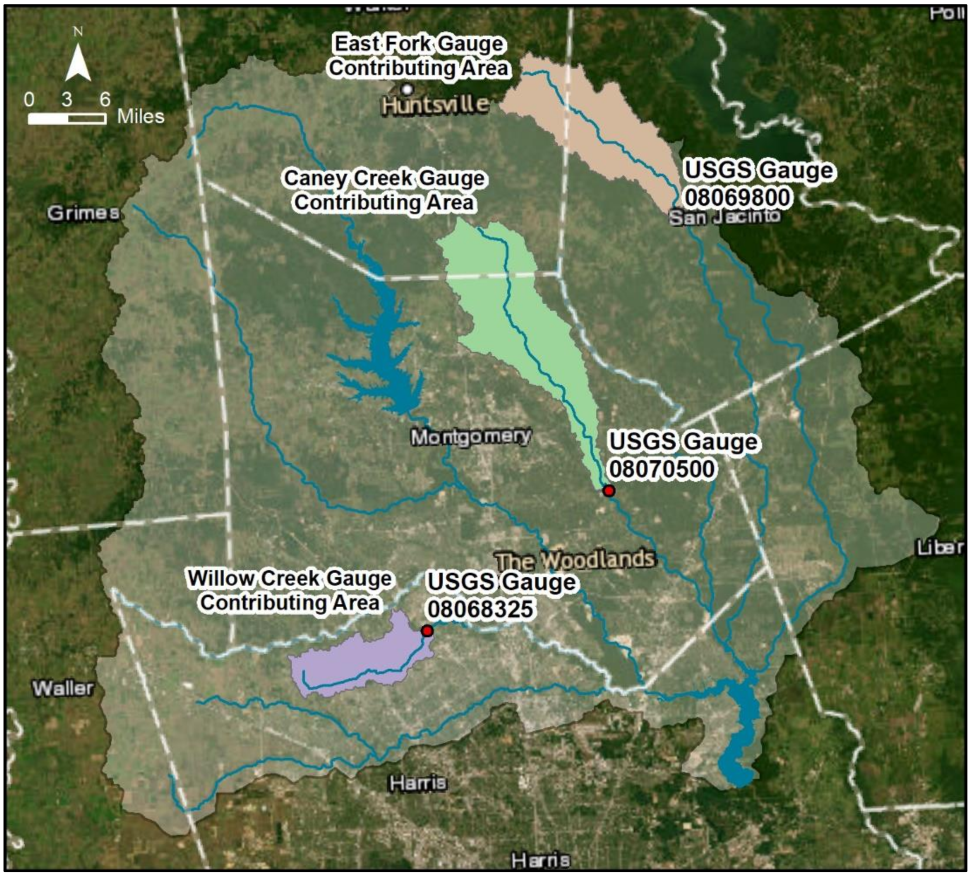

Figure 17. Delineated Contributing Areas for Study Sampling Gauges

As shown in Table 6, the Willow Creek Gauge drainage area has the highest sediment export despite being the smallest of the three due to its appreciably higher sediment yield.

Table 6. Net Sediment Export from Calibration Watershed Gauge Drainage Areas

Tributary	Drainage Area (mi²)	Sediment Yield (ton/yr/mi²)	Net Sediment Export (ton/yr)
Caney Creek	105	192	**20,200**
East Fork San Jacinto	92	158	**14,500**
Willow Creek	41	570	**23,400**

Next, the results of the BANCS models (see Section 3) were applied to estimate streambank erosion within the calibration watershed gauge areas. The average mass erosion rates first presented in Table 3 were multiplied by the length of each calibration stream above the sampled stream gauge, as follows:

$$W_{streambank} = L_{stream} \cdot R_{mass\ erosion}$$

Where $W_{streambank}$ is the calculated streambank erosion, L_{stream} is the length of the stream, and $R_{mass\ erosion}$ is the average mass erosion rate. All three streams have intermittent portions that only convey flows following rainfall. Two streambank erosion calculations were performed: 1) using only the perennial (continuously flowing) stream length, and 2) using the total stream length, including both perennial and intermittent segments. Estimated streambank erosion for the three calibration watershed gauge areas is presented in Table 7.

Table 7 also provides a calculated streambank contribution to the net sediment export from each watershed gauge area. These values were calculated by dividing the streambank erosion by the net sediment export from Table 6, as follows:

$$C_{streambank} = {W_{streambank}}\Big/{W_{gauge}}$$

Where $C_{streambank}$ is the calculated streambank erosion contribution (%), $W_{streambank}$ is the calculated streambank erosion, and W_{gauge} is net sediment export from the gauged area.

Due to it's relatively low mass erosion rate and the relatively small proportion of intermittent stream channel, Caney Creek had the narrowest range of calculated streambank contribution (44 – 57%). In contrast, Willow Creek's intermittent stream length was greater than its perennial length, resulting in a relative wide range of calculated streambank contribution (42 – 97%). It is possible that the actual contributions from the intermittent portions of these streams is lower than computed, which would cause the upper end of the calculated range to be biased high. Regardless, these results indicate a significant contribution to the overall sediment loading to these reaches. For comparison, the overall USJRB calculations presented in TM 5 indicate that streambank erosion accounts for more than half of all sediment loading in the basin.

Table 7. Calibration Watersheds Streambank Erosion

Tributary	Mass Erosion Rate (ton/yr/ft)	Perennial Stream Length (miles)	Perennial Streambank Erosion (ton/yr)	Total Stream Length (miles)	Total Streambank Erosion (ton/yr)	Calculated Streambank Contribution (%)
Caney Creek	0.08	21.1	8,900	27.2	11,500	**44 – 57%**
East Fork San Jacinto	0.16	16.1	13,600	20.2	17,100	**94 – 100%**
Willow Creek	0.32	5.8	9,800	13.5	22,700	**42 – 97%**

Further, the sediment fingerprinting results presented in Section 0 indicate that streambanks are the predominant source of *sand* loading to these channels, with upland sand contributions negligible to nonexistent. Thus, regardless of its overall sediment contribution, streambank erosion is likely the primary source of sand sediments, which collect in stream channels and lakes, reducing their conveyance capacity and volumes, respectively.

The calculated streambank contribution range for the East Fork San Jacinto River (94 – 100%) is considerably higher. These results seem qualitatively inconsistent with the floodplain isotope and grain size data presented in Section 5, which suggested meaningful contributions from upland sediments for this stream. This discrepancy could result from one or both of two possibilities. First, it is possible that the calculated mass erosion rate for this stream is not representative of the entire stream length, causing the calculated streambank erosion to be biased high. Second, a significant portion of streambank sediments may settle out of suspension between the sampling locations and the downstream gauge where regression analysis was performed. Regardless, adjustment may be required when extrapolating these results to other watersheds.

Given the tendency for sand sediments to settle within stream channels, additional calculations were performed related to sand loading and transport. For each stream in Table 8, the calculated streambank erosion was multiplied by its sand content to compute the estimated sand loading from the streambanks, as follows:

$$W_{streambank\ sand} = F_{sand} \cdot W_{streambank}$$

Where $W_{streambank\ sand}$ is the calculated streambank sand loading, F_{sand} is the fraction of streambank sediments composed of sand, and $W_{streambank}$ is the calculated streambank erosion. Note that the values in this and other tables were rounded following calculations for clarity, and recalculation (i.e., multiplying) using the numbers listed in the table may therefore yield slightly different results.

Table 8. Calibration Watershed Gauge Areas Streambank Sand Loading

Tributary	Sand Content (%)	Streambank Erosion (ton/yr)	Streambank Sand Loading (ton/yr)
Caney Creek	83%	8,900 – 11,500	7,400 – 9,600
East Fork San Jacinto	46%	13,600 – 17,100	6,200 – 7,800
Willow Creek	71%	9,800 – 22,700	6,900 – 16,100

Sediment bedload transport modeling results from TM 4 for Caney Creek and Willow Creek are also provided for comparison in Table 9. Sediment transport modeling was performed at six or more stream channel cross sections for these two streams, with considerable variability in predicted bedload transport.

For example, the predicted transport in Willow Creek varied by more than two orders of magnitude as a function of channel geometry. The full range of predicted values is shown in the table, along with the average simulated bedload transport for each stream. Note that these values represent only the transport within the channel, omitting overbank transport that could occur under extreme flow conditions.

The previously calculated streambank sand loading was compared against the average predicted bedload transport to evaluate how much of the streambank sand loading is captured as storage either within the channel or in overbank (i.e., floodplain) areas. Storage was calculated as follows:

$$S_{sand} = {(W_{streambank\ sand} - W_{bedload})}/{W_{streambank\ sand}}$$

Where S_{sand} is the calculated streambank sand storage (%), $W_{streambank\ sand}$ is the calculated streambank sand erosion/loading, and $W_{bedload}$ is the average predicted bedload transport from sediment transport modeling. Calculated sand storage is also shown in Table 9.

Table 9. Calibration Watershed Gauge Areas Sand Storage

Tributary	Streambank Sand Loading (ton/yr)	Bedload Transport Range (ton/yr)	Average Bedload Transport (ton/yr)	Calculated Storage (%)
Caney Creek	7,400 – 9,600	730 – 3,100	2,060	**72 – 78%**
East Fork San Jacinto	6,200 – 7,800	N/A	N/A	N/A
Willow Creek	6,900 – 16,100	120 – 14,200	8,885	**0 – 45%**

For Caney Creek, the modeled bedload transport is less than the annual streambank sand load, resulting in an apparent storage of 72 – 78% of the sand load in point bars, along streambanks, and in the floodplain. Thus, approximately 22 – 28%, on average, of the Caney Creek sand load is transported downstream into Lake Houston.

In contrast, the potential downstream transport at Willow Creek is considerably higher, such that 0 – 45% of the sand load is captured as storage. The wide range of values is the result of the relatively long intermittent length for this stream. Regardless, the Willow Creek channel geometries and streamflow appear to convey more sediment (55 – 100%) downstream into Spring Creek and ultimately into Lake Houston. These results are consistent with the Lake Houston sediment sampling, which found relatively high sand content in the West Fork Arm of the lake.

A few important caveats should be considered when interpreting these results. Calculations were based on average sediment bedload transport, but predicted values varied considerably across different channel cross sections. Streams are highly dynamic systems, and transport is not uniform across multiple locations and not static with respect to time. In reality, sand is likely to be transported in plugs from one low-transport-capacity channel section to another during extreme flow conditions and then settle as storage during lower flow conditions. It is possible that a given calendar year may not have sufficient flow to mobilize large point bars, which remain in channels as storage until a more extreme rainfall occurs. Further, while the measured bedload for these channels was predominantly sand, bedload transport is not the only way sand can be transported downstream. It is possible for sand, particularly very fine sand, to become resuspended during high streamflow.

Overall, these results suggest that sand sediments are stored in meaningful quantities within these stream channels. Anecdotally, sand deposits are readily visible at the Willow Creek gage site and in point bars in all sampled streams, indicating that not all streambank sand is transported downstream. It is likely that some fraction of the sand load settles out as flows recede following rain events and is retained within the watersheds either within the channel or in the floodplain. The portion that settles within the channel can be considered temporary storage, remaining in place until flows are sufficiently high to remobilize the sediments (i.e., sand) for further downstream transport.

In contrast, the sampling data indicate the fine-grained sediments do not settle in significant quantities within the stream channels. Such sediments are instead carried downstream to Lake Conroe and/or Lake Houston, where they either settle out or pass through the lakes, depending on their size and the hydrologic conditions.

9 Sediment Transport Summary and Conclusions

9.1 Additional Potential Sediment Sources

Overall, these data indicate that the fate and transport of USJRB sediments vary based on particle size. Specifically, the sand found within channels, in floodplains, and in Lake Houston originates predominately from streambank sources, as floodwaters scour the banks and transport the sand downstream. As discussed in TM 5, field reconnaissance along the West Fork San Jacinto River did not identify any active discharges or sediment loading from aggregate production operations (APOs). However, there have been several purported breaches of APO berms along the West Fork San Jacinto River in the past (e.g., Reduce Flooding, 2018), including as recently as April 2023 (Reduce Flooding, 2023). Given that many APO facilities are located adjacent to the river, they are also susceptible to streambank erosion, particularly where operations commenced before the Texas Commission on Environmental Quality (TCEQ) developed best management practices (BMPs) for sand mining in the basin (TCEQ, 2021). These BMPs include vegetative controls and other methods to stabilize streambanks and mitigate erosion.

Also, anecdotal public comments to the project team have attributed localized sedimentation to construction associated with land development. Although proper construction BMPs, such as silt fences, are capable of capturing and retaining sediments onsite, improperly constructed or maintained BMPs can allow erosion and washoff of disturbed soils to leave the site. Sand is not readily transported by overland sheet flow, but construction near waterbodies could contribute sand loading to stream channels and lakes. Although these contributions are likely lower in magnitude than those from streambank erosion overall, they can have substantial localized impacts and make their way downstream to lakes, as documented in the public comments received.

9.2 Summary and Conclusions

Based on the results of these analyses, sediment transport modeling work discussed in greater detail in TM 4, and field reconnaissance efforts described in subsequent memoranda, a number of generalizations can be made. Sediment can originate from a number of sources, including both point and non-point, from both upland and streambank sources. However, results from this Study indicate that a majority of the sand sediments in the USJRB likely originate from streambanks. Public comments received by the project team also cite APOs along stream channels as a potential source of sediments. In particular, berms located adjacent to river channels are vulnerable to breaches during high streamflow conditions.

The root causes of sand sedimentation in the USJRB include sandy, unconsolidated streambanks and likely an imbalance between the energy of the streams and the sizes of the stream channels. This is particularly apparent in the more developed western half of the USJRB, where relatively higher streamflow, streambank erosion, and channel incising have been observed. Incised channels are characterized by high, steep streambanks, which prevent high-energy flows from escaping the channel and dissipating in the floodplain and which are likely to be further eroded until the energy balance is restored.

A comparison of calculations based on field data and sediment transport modeling showed that streambank erosion rates can exceed the stream’s transport capacity, resulting in appreciable storage of sand sediments within the stream channels. Once sand enters a stream channel, particles have a tendency to settle readily, and they experience bulk transport only during sufficiently high flows to resuspend and/or mobilize the particles downstream. Sand can settle within stream channels, forming point bars and streambed deposits that are remobilized under higher magnitude stormflow conditions. Sand can also be deposited in floodplains when flows overtop a channel’s banks.

The majority of the sand that makes its way downstream to Lake Houston settles out within the lake’s upper extents in the relatively narrow arms in the west and north inlets where the tributaries enter the lake. In particular, the western inlet (i.e., the West Fork arm of Lake Houston) has a predominantly sand lakebed extending downstream into the wider main body of Lake Houston. The majority of sand entering Lake

Houston settles upstream of Farm-to-Market 1960 (FM 1960) crossing in the northern portion of the lake's main body.

Fine-grained sediments (i.e., silt and clay) behave differently than sand. Fines originate from both upland and streambank sources. As discussed, anecdotal comments from the public to the project team have attributed localized sedimentation to construction associated with land development. Additional sources of fines within the USJRB likely include wash-off of undisturbed soils, wash-off of dust from impermeable surfaces, and streambank erosion. Fine-grained sediments tend not to settle in stream channels, where velocities are sufficiently high to keep them in suspension. Some fine-grained sediments entering Lake Houston are carried over the Lake Houston Dam and out of the USJRB into the Lower San Jacinto River, particularly under stormflow conditions. However, fines also settle within the lake, particularly under lower flow conditions that increase the travel time through the lake. Lower Lake Houston sediments are composed predominantly of silt and clay.

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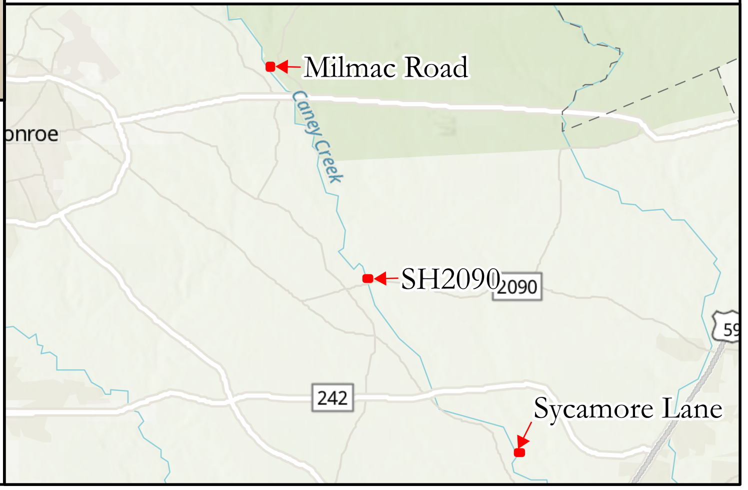
APPENDIX A

BANCS Erosion Rate Mapping

Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS



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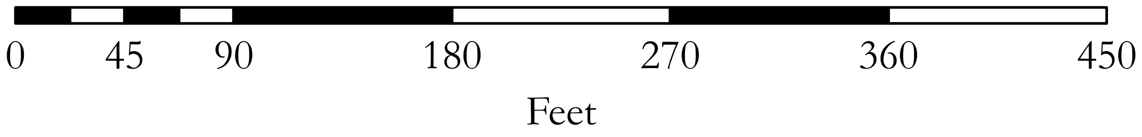
Upper San Jacinto River Sedimentation Study

Caney Creek at Milmac Road : Bank Data



Erosion Rate (ft/yr)	Category
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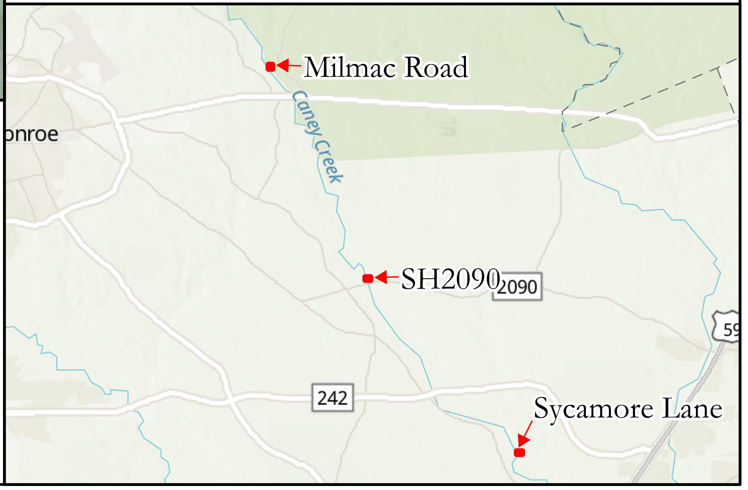
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS



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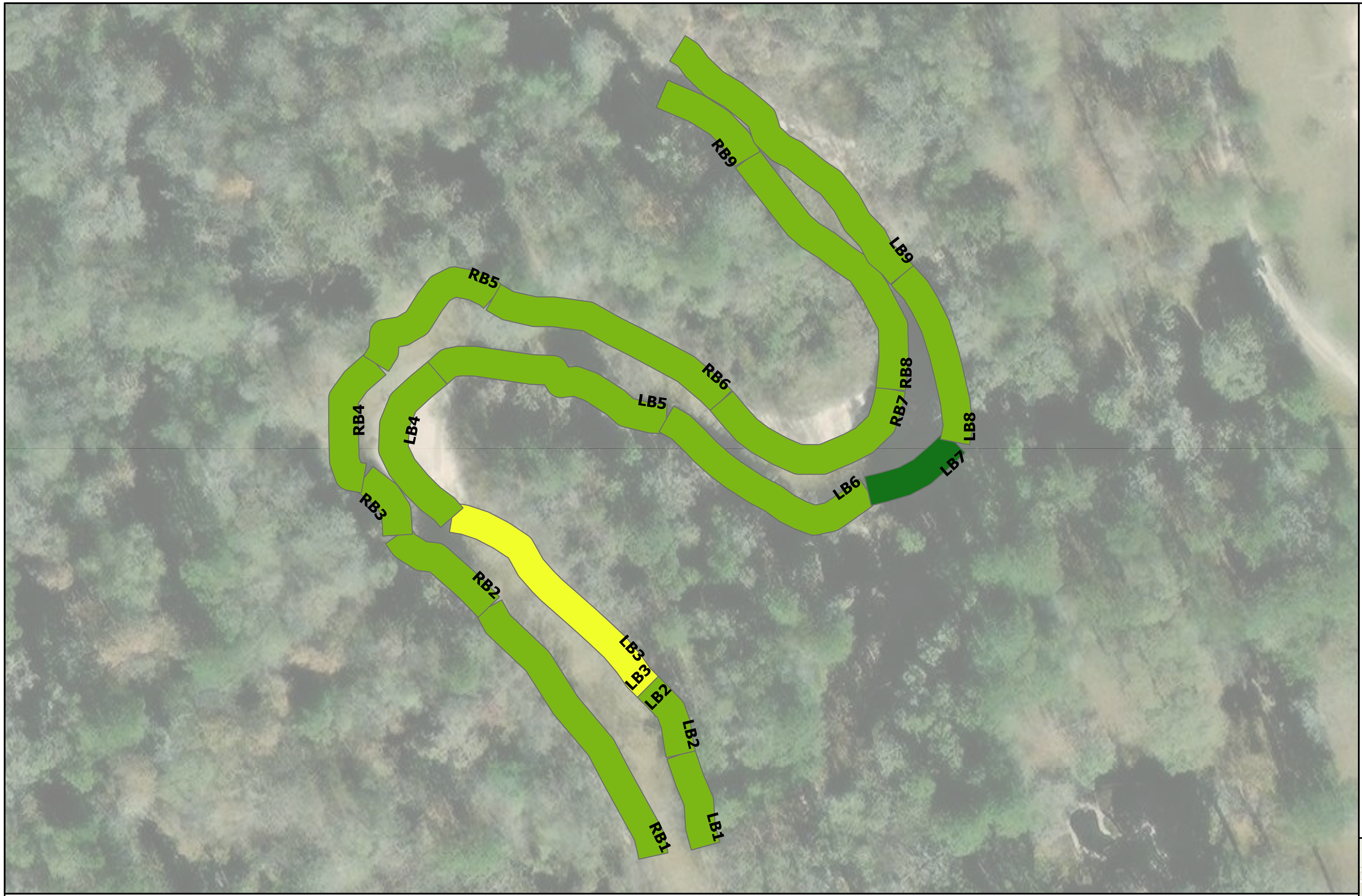
Upper San Jacinto River Sedimentation Study

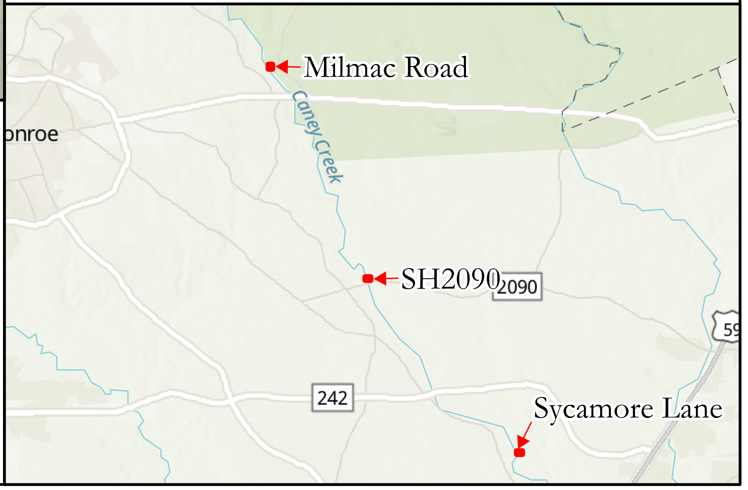
Caney Creek at SH2090 : Bank Data

0 45 90 180 270 360 450
Feet



Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS



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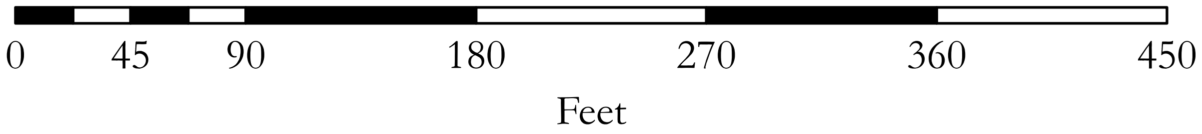
Upper San Jacinto River Sedimentation Study

Caney Creek at Sycamore Lane : Bank Data



Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

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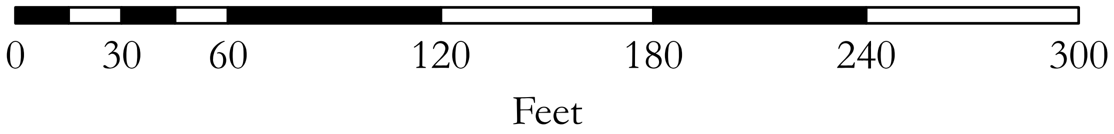
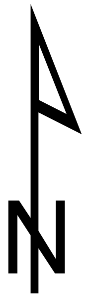
Upper San Jacinto River Sedimentation Study

East Fork at Farm to Market Road 945 : Bank Data





Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

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Upper San Jacinto River Sedimentation Study

East Fork at SH150 : Bank Data

0 37.5 75 150 225 300 375
Feet

N

Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

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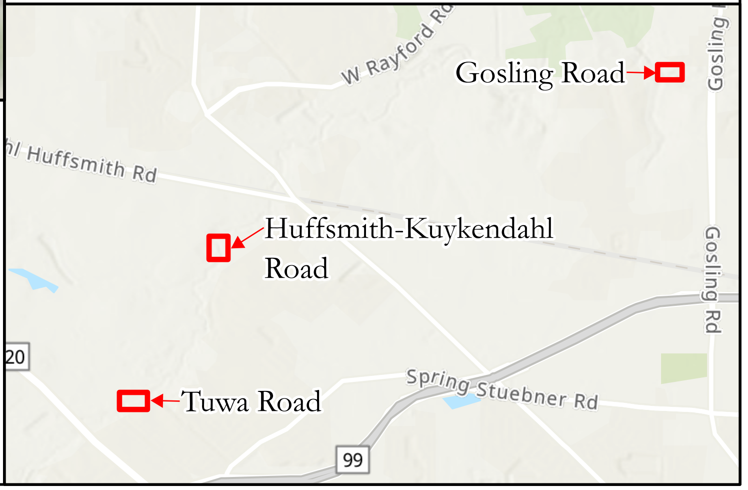
Upper San Jacinto River Sedimentation Study

East Fork at Lower Vann Road : Bank Data

0 45 90 180 270 360 450
Feet

Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, FEMA, Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



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Upper San Jacinto River Sedimentation Study

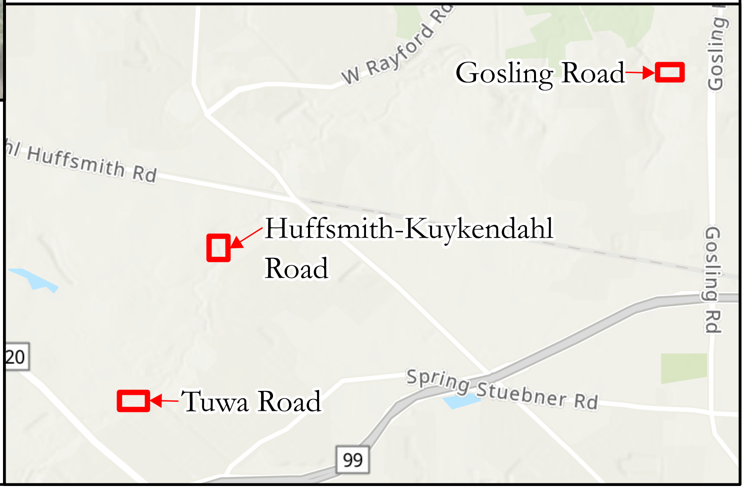
Willow Creek at Tuwa Road : Bank Data

0 50 100 200 300 400 500
Feet

N

Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



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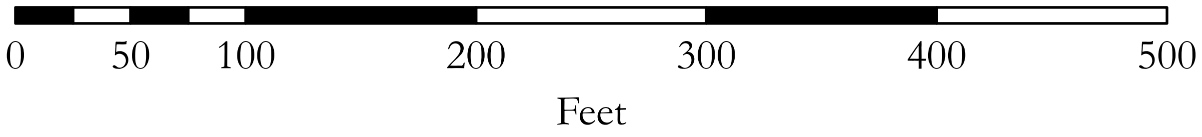
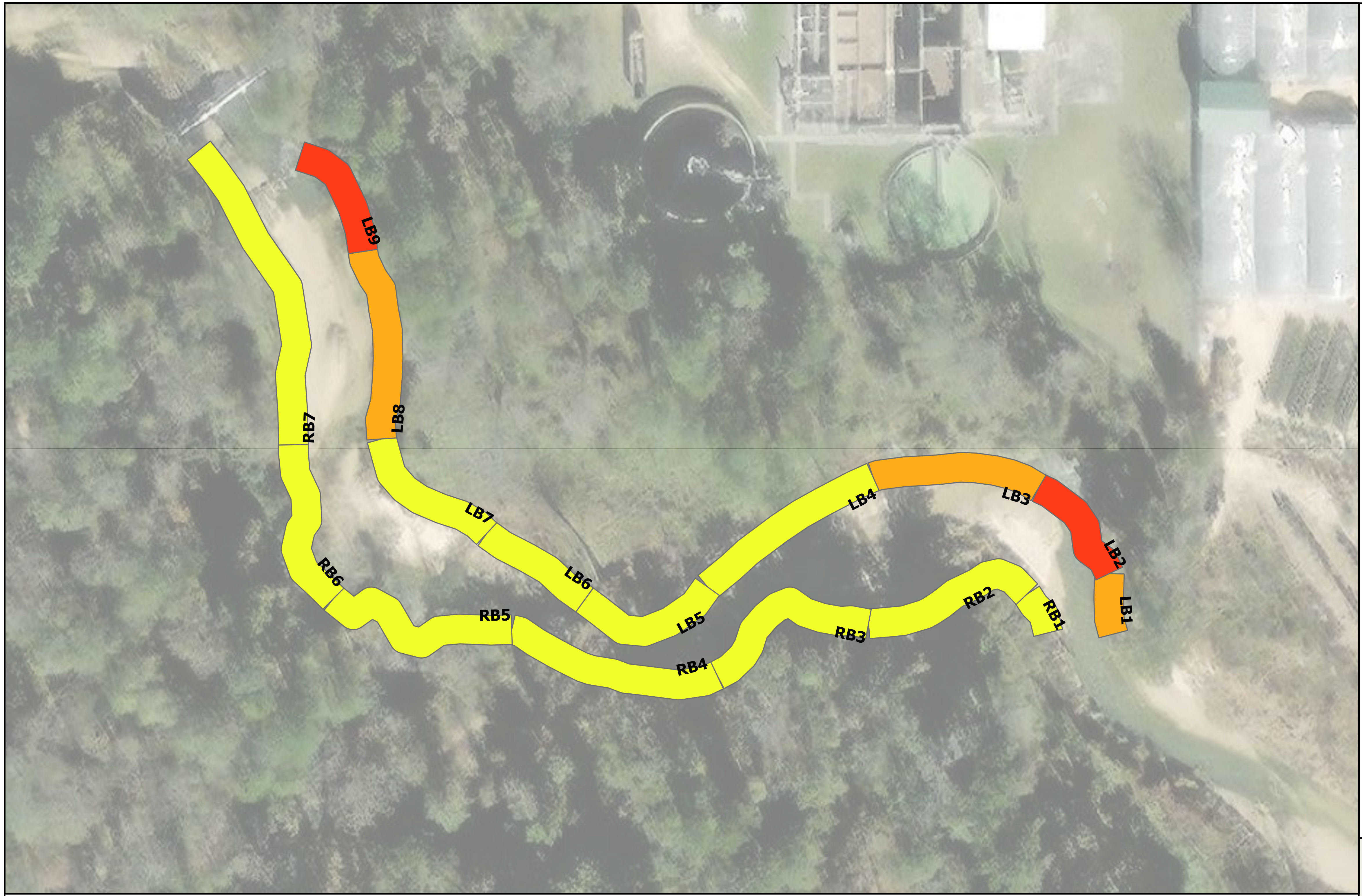
Upper San Jacinto River Sedimentation Study

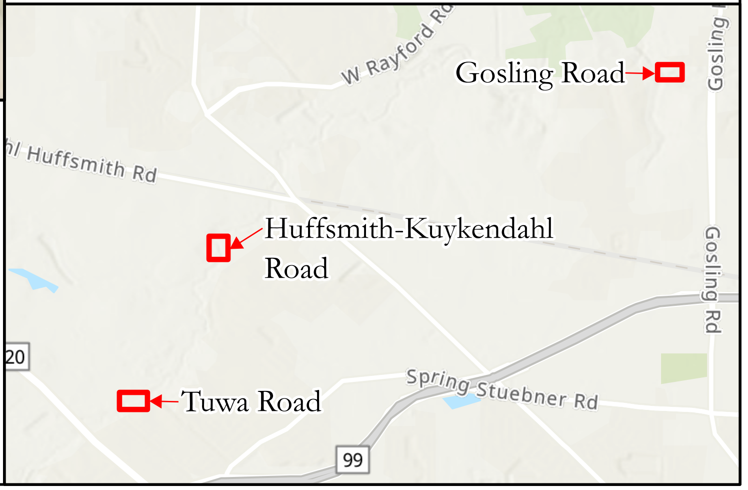
Willow Creek at Huffsmith-Kuykendahl Road : Bank Data





Erosion Rate (ft/yr)	Category
🟩 0.030 - 0.070	1
🟩 0.071 - 0.13	2
🟨 0.14 - 0.64	3
🟧 0.65 - 1.3	4
🟥 Greater than 1.3	5

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



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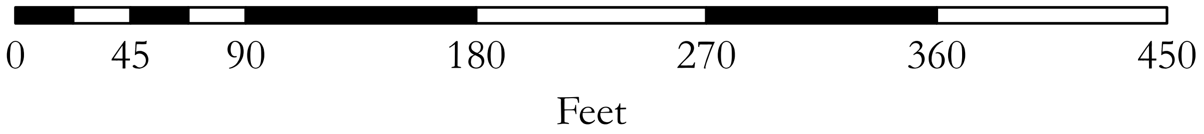
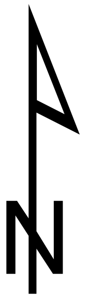
Upper San Jacinto River Sedimentation Study

Willow Creek at Gosling Road : Bank Data





APPENDIX B

BANCS Summary Tables

Caney Creek BANCS Summary Table

Stream Channel Type: C5 (All Sections)

Watershed Average Erosion Rate
0.18 ft/yr, 242.9 cuft/yr, 0.08 ton/yr/ft

Stream	Bank Location	Length of bank (ft)	Study Bank Height (ft)	BEHI Rating	NBS Rating	Predicted Erosion Rate (ft/yr)	Predicted Erosion Volume (cuft/yr)	Predicted Erosion Rate (tons/ft/yr)	Predicted Erosion Rate (tons/yr)
Caney Creek at SH2090	LB1	77	7	Moderate	Moderate	0.30	161.7	0.09	6.6
Caney Creek at SH2090	LB2	128	10	Moderate	Low	0.13	160.0	0.05	6.5
Caney Creek at SH2090	LB3	115	8	Low	Low	0.03	27.6	0.01	1.1
Caney Creek at SH2090	LB4	188	12	Moderate	Low	0.13	282.0	0.06	11.4
Caney Creek at SH2090	LB5	152	11	Moderate	High	0.80	1337.6	0.36	54.3
Caney Creek at SH2090	LB6	40	10.5	Low	Moderate	0.07	29.4	0.03	1.2
Caney Creek at SH2090	LB7	145	8	Moderate	Low	0.13	145.0	0.04	5.9
Caney Creek at SH2090	RB1	99	16.5	Very High	Moderate	0.64	1045.4	0.43	42.4
Caney Creek at SH2090	RB2	102	16.5	Moderate	Low	0.13	210.4	0.08	8.5
Caney Creek at SH2090	RB3	58	17.5	Moderate	Very Low	0.09	91.4	0.06	3.7
Caney Creek at SH2090	RB4	72	13.5	Moderate	Low	0.13	121.5	0.07	4.9
Caney Creek at SH2090	RB5	94	13.5	Moderate	Low	0.13	158.6	0.07	6.4
Caney Creek at SH2090	RB5	234	9	Moderate	Low	0.13	263.3	0.05	10.7
Caney Creek at SH2090	RB7	29	7	Low	Low	0.03	6.1	0.01	0.2
Caney Creek at SH2090	RB8	79	11	Moderate	High	0.80	695.2	0.36	28.2
Caney Creek at SH2090	RB9	94	16.5	Moderate	Moderate	0.30	465.3	0.20	18.9
Caney Creek at Milmac Road	LB1	89	10	Moderate	Low	0.13	111.3	0.05	4.5
Caney Creek at Milmac Road	LB2	172	12	Moderate	Low	0.13	258.0	0.06	10.5
Caney Creek at Milmac Road	LB3	76	12	Moderate	Moderate	0.30	273.6	0.15	11.1
Caney Creek at Milmac Road	LB4	139	8	Moderate	Low	0.13	139.0	0.04	5.6
Caney Creek at Milmac Road	LB5	254	8	Moderate	Low	0.13	254.0	0.04	10.3
Caney Creek at Milmac Road	LB6	49	8	Moderate	Low	0.13	49.0	0.04	2.0
Caney Creek at Milmac Road	LB7	210	10	Moderate	Low	0.13	262.5	0.05	10.7
Caney Creek at Milmac Road	RB1	88	10	Moderate	Low	0.13	110.0	0.05	4.5
Caney Creek at Milmac Road	RB2	55	12	Moderate	Low	0.13	82.5	0.06	3.3
Caney Creek at Milmac Road	RB3	204	9	High	Low	0.40	734.4	0.15	29.8
Caney Creek at Milmac Road	RB4	136	10	Moderate	Low	0.13	170.0	0.05	6.9
Caney Creek at Milmac Road	RB5	200	9	Moderate	Low	0.13	225.0	0.05	9.1
Caney Creek at Milmac Road	RB6	42	9	Moderate	Low	0.13	47.3	0.05	1.9
Caney Creek at Milmac Road	RB7	106	8.5	Moderate	Low	0.13	112.6	0.04	4.6
Caney Creek at Milmac Road	RB8	49	5.7	High	Low	0.40	111.7	0.09	4.5

Caney Creek BANCS Summary Table

Stream Channel Type: C5 (All Sections)

Watershed Average Erosion Rate
0.18 ft/yr, 242.9 cuft/yr, 0.08 ton/yr/ft

Stream	Bank Location	Length of bank (ft)	Study Bank Height (ft)	BEHI Rating	NBS Rating	Predicted Erosion Rate (ft/yr)	Predicted Erosion Volume (cuft/yr)	Predicted Erosion Rate (tons/ft/yr)	Predicted Erosion Rate (tons/yr)
Caney Creek at Sycamore Lane	LB1	65	13.3	Moderate	Low	0.125	108.1	0.07	4.4
Caney Creek at Sycamore Lane	LB2	53	13.3	Moderate	Low	0.125	88.1	0.07	3.6
Caney Creek at Sycamore Lane	LB3	179	13	High	Low	0.400	930.8	0.21	37.8
Caney Creek at Sycamore Lane	LB4	124	13	Moderate	Low	0.125	201.5	0.07	8.2
Caney Creek at Sycamore Lane	LB5	169	11	Moderate	Low	0.125	232.4	0.06	9.4
Caney Creek at Sycamore Lane	LB6	164	11	Moderate	Low	0.125	225.5	0.06	9.2
Caney Creek at Sycamore Lane	LB7	69	11	Low	Low	0.030	22.8	0.01	0.9
Caney Creek at Sycamore Lane	LB8	122	11	Moderate	Low	0.125	167.8	0.06	6.8
Caney Creek at Sycamore Lane	LB9	220	8	Moderate	Low	0.125	220.0	0.04	8.9
Caney Creek at Sycamore Lane	RB1	204	10.5	Moderate	Low	0.125	267.8	0.05	10.9
Caney Creek at Sycamore Lane	RB2	80	13	Moderate	Low	0.125	130.0	0.07	5.3
Caney Creek at Sycamore Lane	RB3	48	13	Moderate	Low	0.125	78.0	0.07	3.2
Caney Creek at Sycamore Lane	RB4	95	17	Moderate	Low	0.125	201.9	0.09	8.2
Caney Creek at Sycamore Lane	RB5	112	10	Moderate	Low	0.125	140.0	0.05	5.7
Caney Creek at Sycamore Lane	RB6	173	10	Moderate	Low	0.125	216.3	0.05	8.8
Caney Creek at Sycamore Lane	RB7	154	10	Moderate	Low	0.125	192.5	0.05	7.8
Caney Creek at Sycamore Lane	RB8	194	10	Moderate	Low	0.125	242.5	0.05	9.8
Caney Creek at Sycamore Lane	RB9	75	10	Moderate	Low	0.125	93.8	0.05	3.8

Bank Total (tons/yr) **483.2**

East Fork BANCS Summary Table

Stream Channel Type: E5 (All Sections)

Watershed Average Erosion Rate
0.41 ft/yr, 426.3 cuft/yr, 0.17 ton/yr/ft

Stream	Bank Location	Length of bank (ft)	Study Bank Height (ft)	BEHI Rating	NBS Rating	Predicted Erosion Rate (ft/yr)	Predicted Erosion Volume (cuft/yr)	Predicted Erosion Rate (tons/ft/yr)	Predicted Erosion Rate (tons/yr)
East Fork at SH150	LB1	54.0	9.25	High	Low	0.40	199.8	0.15	8.1
East Fork at SH150	LB10	103.0	9	Very High	Low	0.40	370.8	0.15	15.1
East Fork at SH150	LB2	36.0	10.5	High	Low	0.40	151.2	0.17	6.1
East Fork at SH150	LB3	99.0	12	High	Moderate	0.64	760.3	0.31	30.9
East Fork at SH150	LB4	112.0	10.25	High	Low	0.40	459.2	0.17	18.6
East Fork at SH150	LB5	102.0	9	High	Low	0.40	367.2	0.15	14.9
East Fork at SH150	LB6	75.0	8.5	High	Low	0.40	255.0	0.14	10.4
East Fork at SH150	LB7	75.0	8.5	Very High	Low	0.40	255.0	0.14	10.4
East Fork at SH150	LB8	145.0	10	High	Low	0.40	580.0	0.16	23.5
East Fork at SH150	LB9	49.0	8.75	High	Low	0.40	171.5	0.14	7.0
East Fork at SH150	RB1	175.0	8.5	High	Low	0.40	595.0	0.14	24.2
East Fork at SH150	RB2	52.0	11.5	Very High	Low	0.40	239.2	0.19	9.7
East Fork at SH150	RB3	63.0	11	High	Low	0.40	277.2	0.18	11.3
East Fork at SH150	RB4	88.0	15	High	Low	0.40	528.0	0.24	21.4
East Fork at SH150	RB5	84.0	14	High	Low	0.40	470.4	0.23	19.1
East Fork at SH150	RB6	63.0	8	High	Low	0.40	201.6	0.13	8.2
East Fork at SH150	RB7	51.0	10	Very High	Low	0.40	204.0	0.16	8.3
East Fork at SH150	RB8	219.0	12	High	Low	0.40	1051.2	0.19	42.7
East Fork at SH150	RB9	95.0	10	High	Low	0.40	380.0	0.16	15.4
East Fork at Farm to Market Road	LB1	162.0	9.5	High	Low	0.40	615.6	0.15	25.0
East Fork at Farm to Market Road	LB2	81.0	13	High	Moderate	0.64	673.9	0.34	27.4
East Fork at Lower Vann Road	LB1	59.0	10	High	Low	0.40	236.0	0.16	9.6
East Fork at Lower Vann Road	LB2	67.0	11	Very High	Low	0.40	294.8	0.18	12.0
East Fork at Lower Vann Road	LB3	149.0	9.5	Moderate	Low	0.13	176.9	0.05	7.2
East Fork at Lower Vann Road	LB4	99.0	9	High	Low	0.40	356.4	0.15	14.5
East Fork at Lower Vann Road	LB5	50.0	7.5	High	Low	0.40	150.0	0.12	6.1
East Fork at Lower Vann Road	LB6	242.0	9.5	High	Low	0.40	919.6	0.15	37.3
East Fork at Lower Vann Road	LB7	65.0	6	High	Low	0.40	156.0	0.10	6.3
East Fork at Lower Vann Road	RB1	148.0	10.5	Very High	Low	0.40	621.6	0.17	25.2
East Fork at Lower Vann Road	RB2	195.0	8.5	High	Low	0.40	663.0	0.14	26.9
East Fork at Lower Vann Road	RB3	179.0	10.5	High	Low	0.40	751.8	0.17	30.5
East Fork at Lower Vann Road	RB4	134.0	9.5	High	Low	0.40	509.2	0.15	20.7

Bank Total (tons/yr) **533.8**

Willow Creek BANCS Summary Table

Stream Channel Type: C5 (Gosling),
E5 (Tuwa, Hufsmith-Kuykendahl)

Watershed Average Erosion Rate
0.61 ft/yr, 808.3 cuft/yr, 0.32 ton/yr/ft

Stream	Bank Location	Length of bank (ft)	Study Bank Height (ft)	BEHI Rating	NBS Rating	Predicted Erosion Rate (ft/yr)	Predicted Erosion Volume (cuft/yr)	Predicted Erosion Rate (tons/ft/yr)	Predicted Erosion Rate (tons/yr)
Willow Creek at Gosling Road	LB1	41	8	High	High	1.00	328.0	0.32	13.3
Willow Creek at Gosling Road	LB2	79	21	Extreme	High	2.50	4147.5	2.13	168.4
Willow Creek at Gosling Road	LB3	115	21	High	High	1.00	2415.0	0.85	98.0
Willow Creek at Gosling Road	LB4	135	10	High	Low	0.40	540.0	0.16	21.9
Willow Creek at Gosling Road	LB5	101	12	High	Moderate	0.64	775.7	0.31	31.5
Willow Creek at Gosling Road	LB6	80	12	High	Low	0.40	384.0	0.19	15.6
Willow Creek at Gosling Road	LB7	102	10.5	High	Moderate	0.64	685.4	0.27	27.8
Willow Creek at Gosling Road	LB8	130	16	Very High	High	1.00	2080.0	0.65	84.4
Willow Creek at Gosling Road	LB9	83	16	Extreme	High	2.50	3320.0	1.62	134.8
Willow Creek at Gosling Road	RB1	31	15	High	Low	0.40	186.0	0.24	7.6
Willow Creek at Gosling Road	RB2	120	15	High	Low	0.40	720.0	0.24	29.2
Willow Creek at Gosling Road	RB3	129	15	High	Moderate	0.64	1238.4	0.39	50.3
Willow Creek at Gosling Road	RB4	148	12	High	Low	0.40	710.4	0.19	28.8
Willow Creek at Gosling Road	RB5	142	15	Moderate	Moderate	0.30	639.0	0.18	25.9
Willow Creek at Gosling Road	RB6	117	12	High	Low	0.40	561.6	0.19	22.8
Willow Creek at Gosling Road	RB7	217	10	High	Low	0.40	868.0	0.16	35.2

Willow Creek BANCS Summary Table

Stream Channel Type: C5 (Gosling),
E5 (Tuwa, Hufsmith-Kuykendahl)

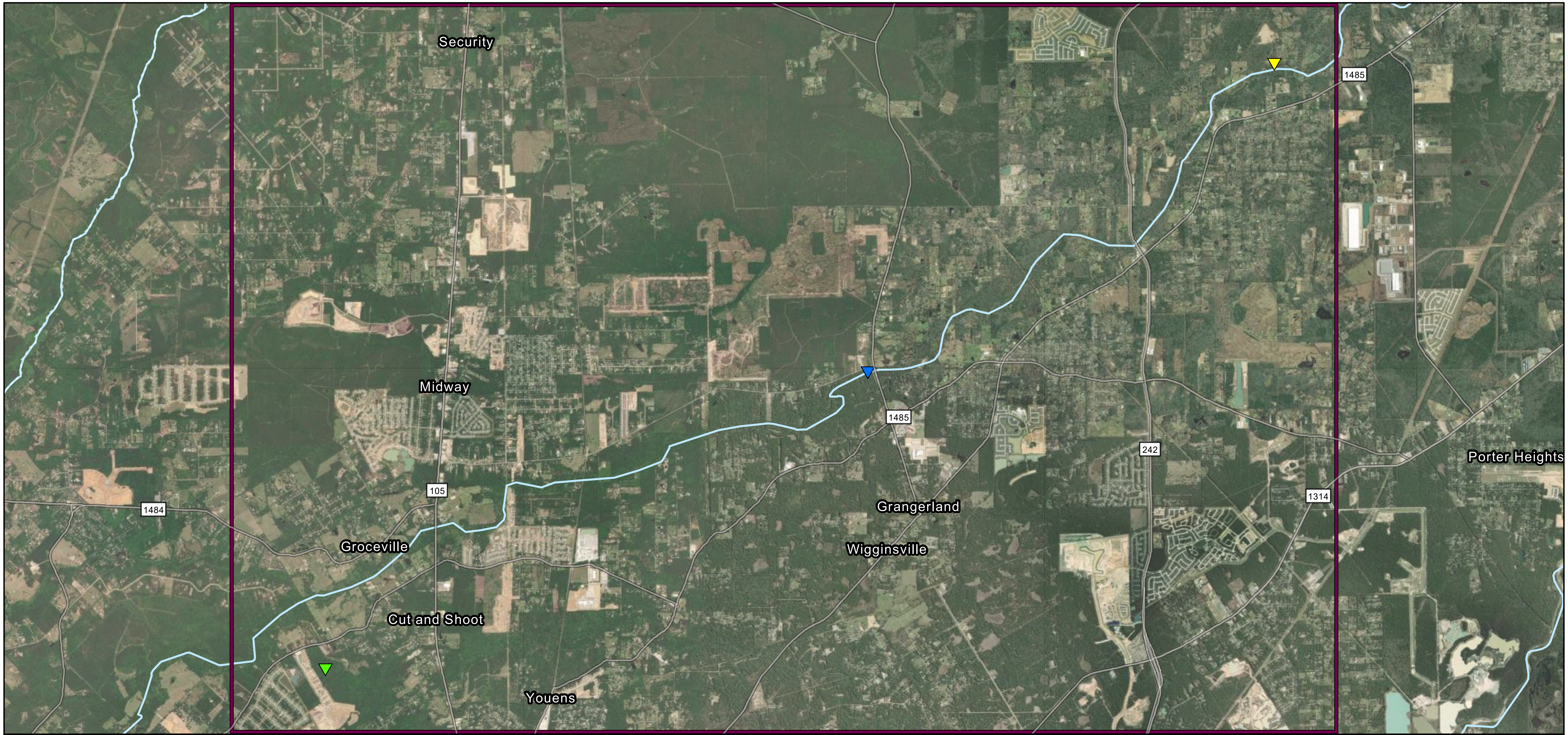
Watershed Average Erosion Rate
0.61 ft/yr, 808.3 cuft/yr, 0.32 ton/yr/ft

Stream	Bank Location	Length of bank (ft)	Study Bank Height (ft)	BEHI Rating	NBS Rating	Predicted Erosion Rate (ft/yr)	Predicted Erosion Volume (cuft/yr)	Predicted Erosion Rate (tons/ft/yr)	Predicted Erosion Rate (tons/yr)
Willow Creek at Hufsmith-Kuykendahl Road	LB1	28	4.8	Moderate	Low	0.13	16.8	0.02	0.7
Willow Creek at Hufsmith-Kuykendahl Road	LB2	67	9	High	Low	0.40	241.2	0.15	9.8
Willow Creek at Hufsmith-Kuykendahl Road	LB3	155	12	Very High	Low	0.40	744.0	0.19	30.2
Willow Creek at Hufsmith-Kuykendahl Road	LB4	77	12	Very High	Low	0.40	369.6	0.19	15.0
Willow Creek at Hufsmith-Kuykendahl Road	LB5	105	10	Very High	Low	0.40	420.0	0.16	17.1
Willow Creek at Hufsmith-Kuykendahl Road	LB6	74	7	High	Low	0.40	207.2	0.11	8.4
Willow Creek at Hufsmith-Kuykendahl Road	LB7	78	8	Very High	Low	0.40	249.6	0.13	10.1
Willow Creek at Hufsmith-Kuykendahl Road	LB8	92	8	High	Low	0.40	294.4	0.13	12.0
Willow Creek at Hufsmith-Kuykendahl Road	RB1	151	16	High	Low	0.40	966.4	0.26	39.2
Willow Creek at Hufsmith-Kuykendahl Road	RB2	66	14.5	High	Moderate	0.64	612.5	0.38	24.9
Willow Creek at Hufsmith-Kuykendahl Road	RB3	108	14.5	High	Low	0.40	626.4	0.24	25.4
Willow Creek at Hufsmith-Kuykendahl Road	RB4	91	8	High	Low	0.40	291.2	0.13	11.8
Willow Creek at Hufsmith-Kuykendahl Road	RB5	126	16.2	High	Low	0.40	816.5	0.26	33.1
Willow Creek at Hufsmith-Kuykendahl Road	RB6	77	15	High	Low	0.40	462.0	0.24	18.8
Willow Creek at Hufsmith-Kuykendahl Road	RB7	136	15	Extreme	High	2.50	5100.0	1.52	207.1
Willow Creek at Tuwa Road	LB1	115	9	High	Low	0.40	414.0	0.15	16.8
Willow Creek at Tuwa Road	LB2	46	9	High	Low	0.40	165.6	0.15	6.7
Willow Creek at Tuwa Road	LB3	61	9	High	Low	0.40	219.6	0.15	8.9
Willow Creek at Tuwa Road	LB4	52	10	Extreme	Low	1.30	676.0	0.53	27.4
Willow Creek at Tuwa Road	LB5	138	8	High	Low	0.40	441.6	0.13	17.9
Willow Creek at Tuwa Road	LB6	58	8	High	Low	0.40	185.6	0.13	7.5
Willow Creek at Tuwa Road	LB7	84	12	High	Low	0.40	403.2	0.19	16.4
Willow Creek at Tuwa Road	LB8	74	15	High	Low	0.40	444.0	0.24	18.0
Willow Creek at Tuwa Road	RB1	191	9	Moderate	Low	0.13	214.9	0.05	8.7
Willow Creek at Tuwa Road	RB2	45	9	High	Low	0.40	162.0	0.15	6.6
Willow Creek at Tuwa Road	RB3	58	7	Moderate	Low	0.13	50.8	0.04	2.1
Willow Creek at Tuwa Road	RB4	97	9	High	Low	0.40	349.2	0.15	14.2
Willow Creek at Tuwa Road	RB5	86	12	High	Low	0.40	412.8	0.19	16.8
Willow Creek at Tuwa Road	RB6	83	10.5	Moderate	Low	0.13	108.9	0.05	4.4
Willow Creek at Tuwa Road	RB7	150	10	Extreme	Low	1.30	1950.0	0.53	79.2
Willow Creek at Tuwa Road	RB8	215	9	High	Low	0.40	774.0	0.15	31.4

Bank Total (tons/yr) **1542.4**

APPENDIX C

Dendrogeomorphic and Soil Sample Data Mapping



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Upper San Jacinto River Sedimentation Study

Caney Creek Isotope Analysis Soil Sample Locations

0 0.5 1 2 3 4 5 6
Miles

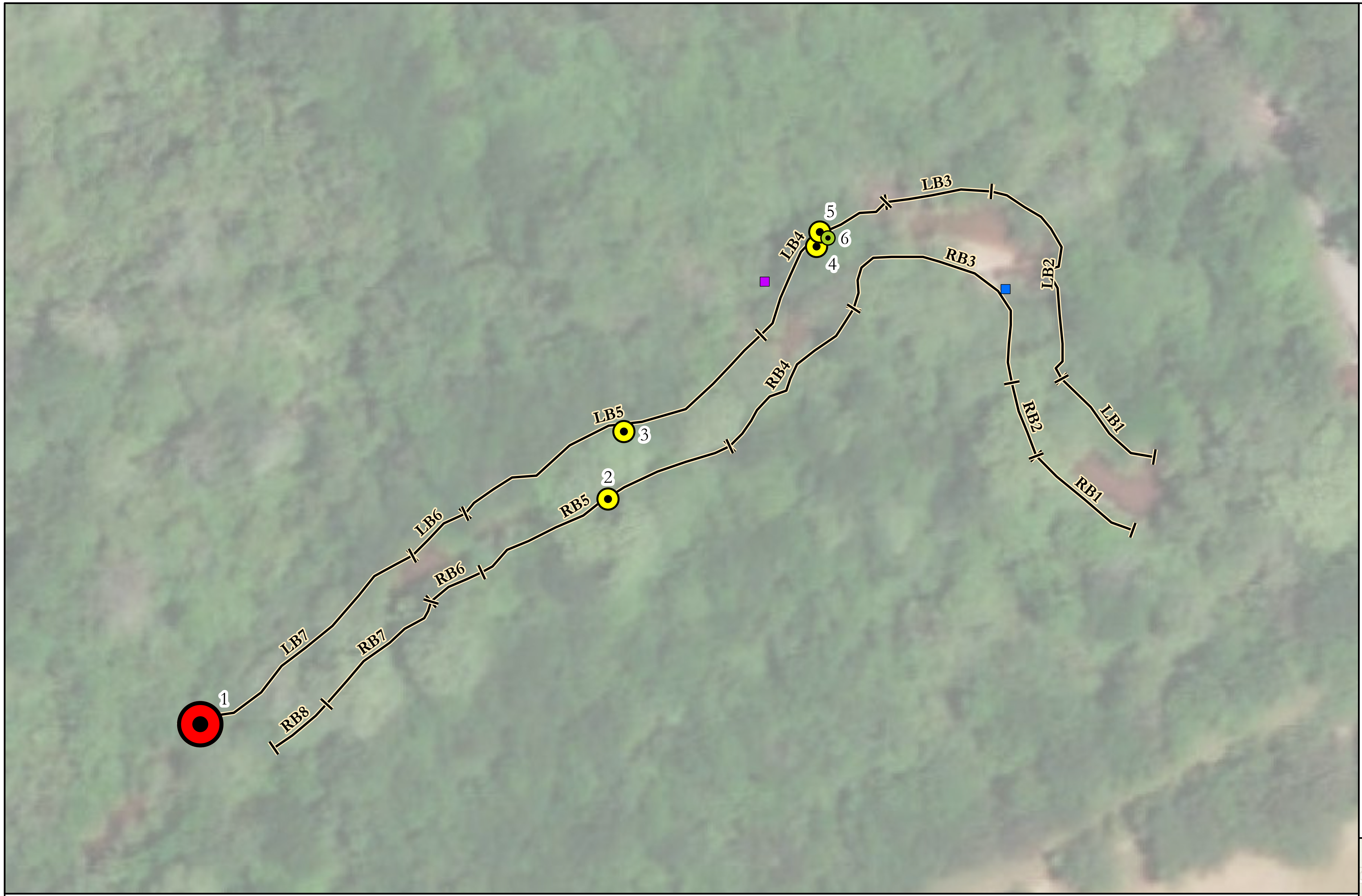
Sources:
Esri, NASA, NGA, USGS, Earthstar Geographics, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

— Streams

Isotope Sample Locations
- ▼ Floodplain
- ▼ Streambank
- ▼ Upland

Creek Regions
- ▭ Caney Creek

N



Tree Sample
Erosion Rate (ft/yr)

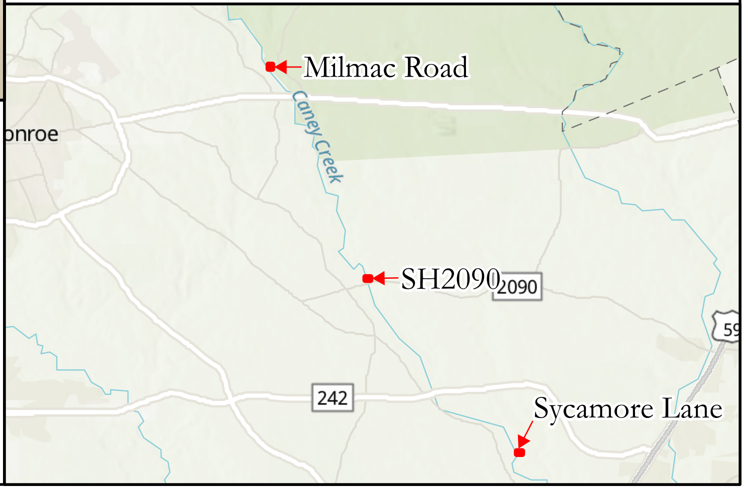
	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines
⊢⊣

Soil Sample Locations
Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS



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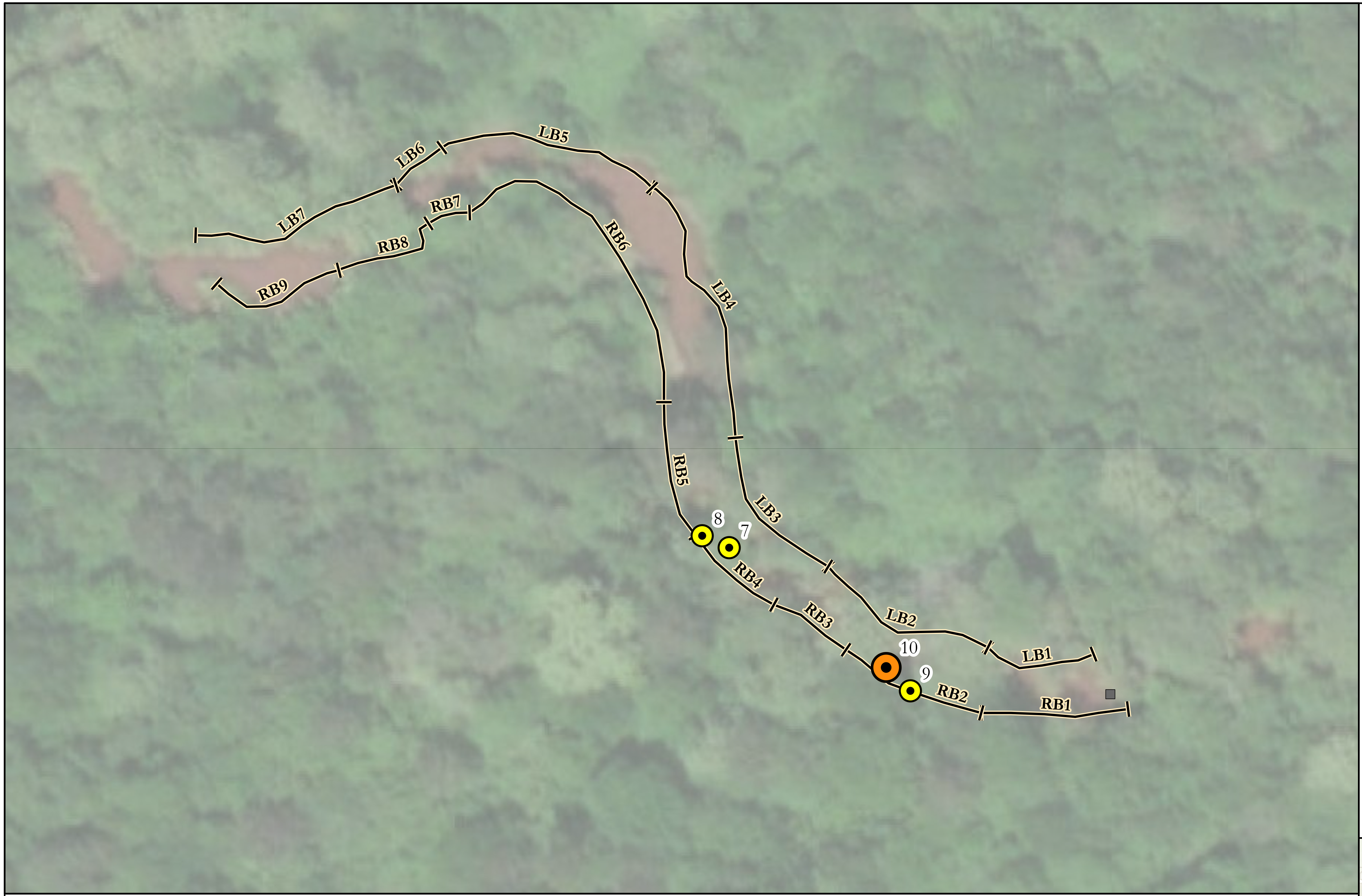
Upper San Jacinto River Sedimentation Study

Caney Creek at Milmac Road : Dendrogeomorphic and Soil Sample Data

0 45 90 180 270 360 450
Feet



Tree Sample
Erosion Rate (ft/yr)

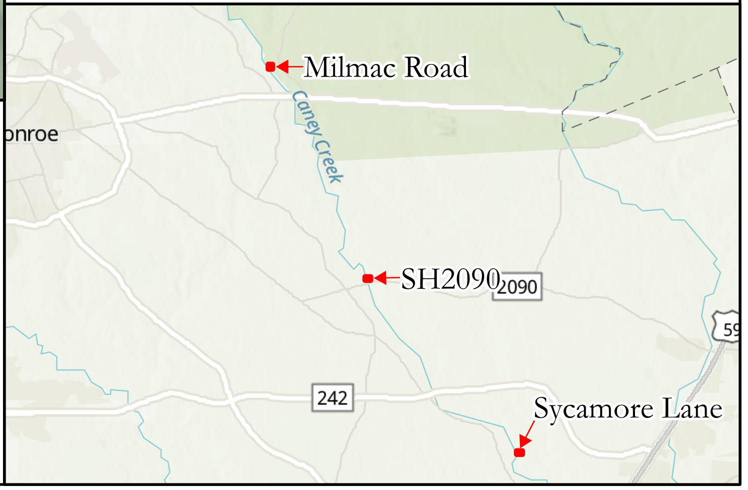
	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines
├─┤

Soil Sample Locations
Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS



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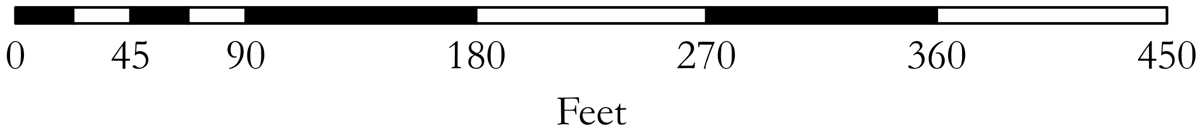
Upper San Jacinto River Sedimentation Study

Caney Creek at SH2090 : Dendrogeomorphic and Soil Sample Data



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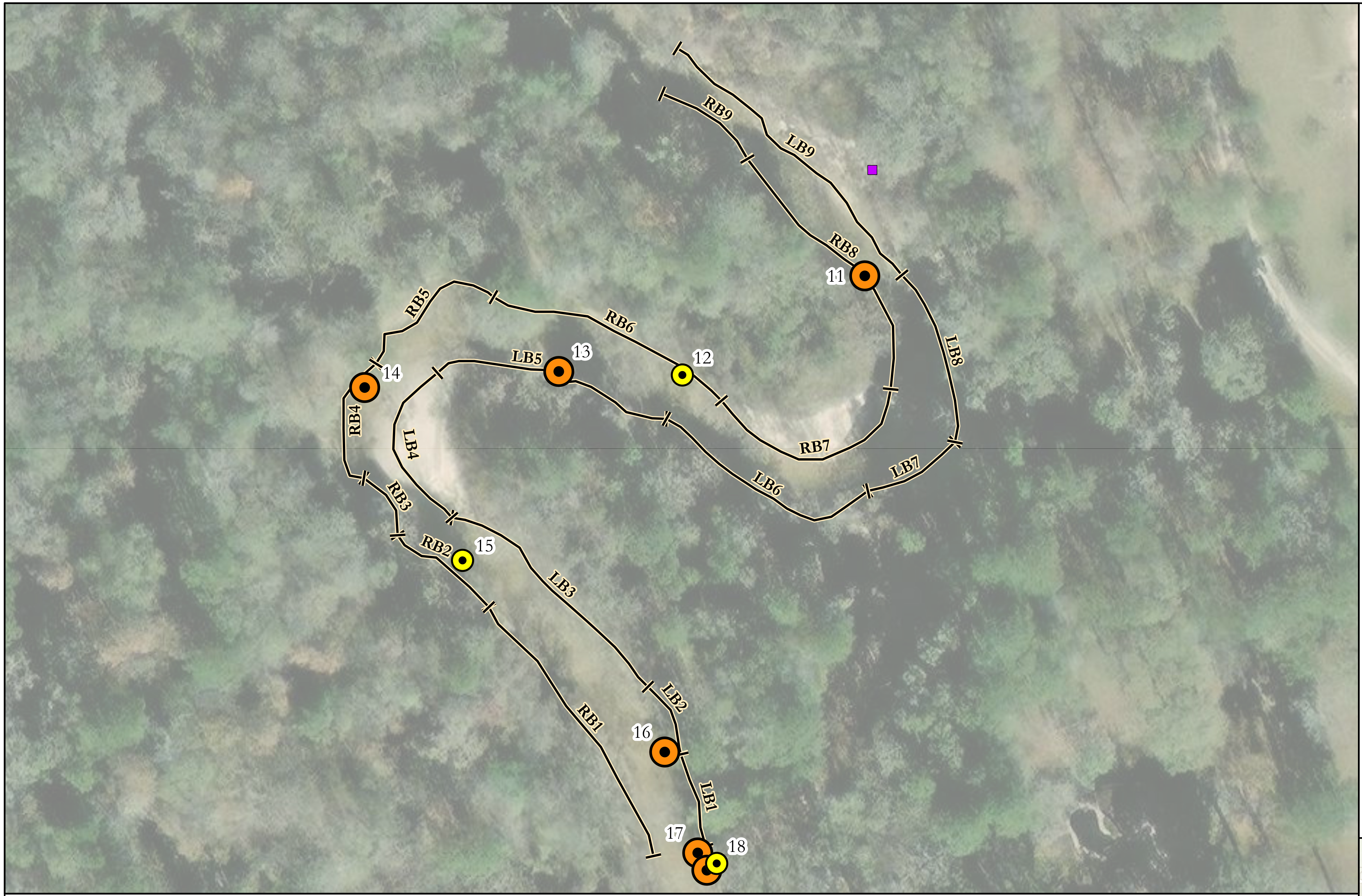


Tree Sample
Erosion Rate (ft/yr)

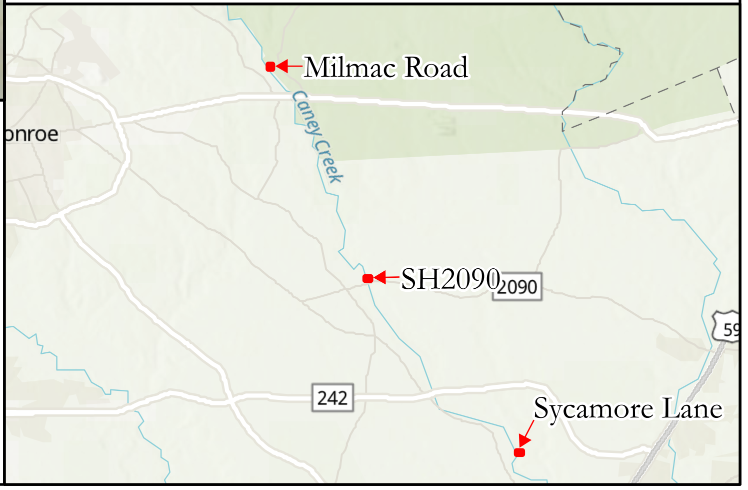
		Category
●	0 - 0.07	1
●	0.071 - 0.13	2
●	0.14 - 0.64	3
●	0.65 - 1.3	4
●	Greater than 1.3	5

Bank Lines
├┤

Soil Sample Locations
Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS



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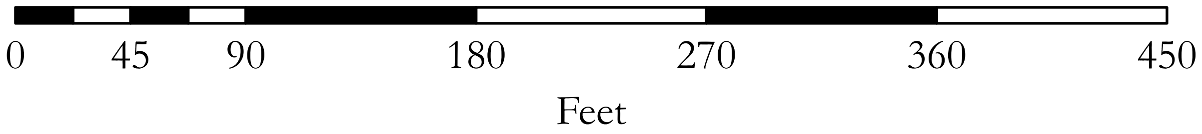
Upper San Jacinto River Sedimentation Study

Caney Creek at Sycamore Lane : Dendrogeomorphic and Soil Sample Data



N

Tree Sample
Erosion Rate (ft/yr)

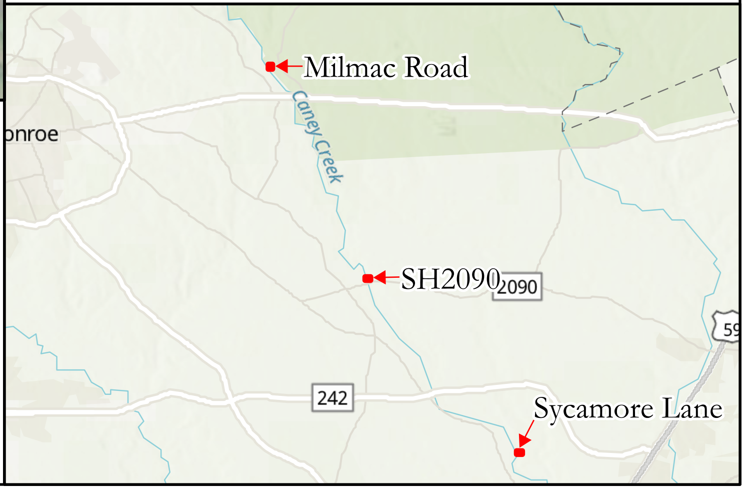
		Category
●	0 - 0.07	1
●	0.071 - 0.13	2
●	0.14 - 0.64	3
●	0.65 - 1.3	4
●	Greater than 1.3	5

Bank Lines

Soil Sample Locations
Sample Type
- Bar Sieve
- Floodplain
- Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, Maxar



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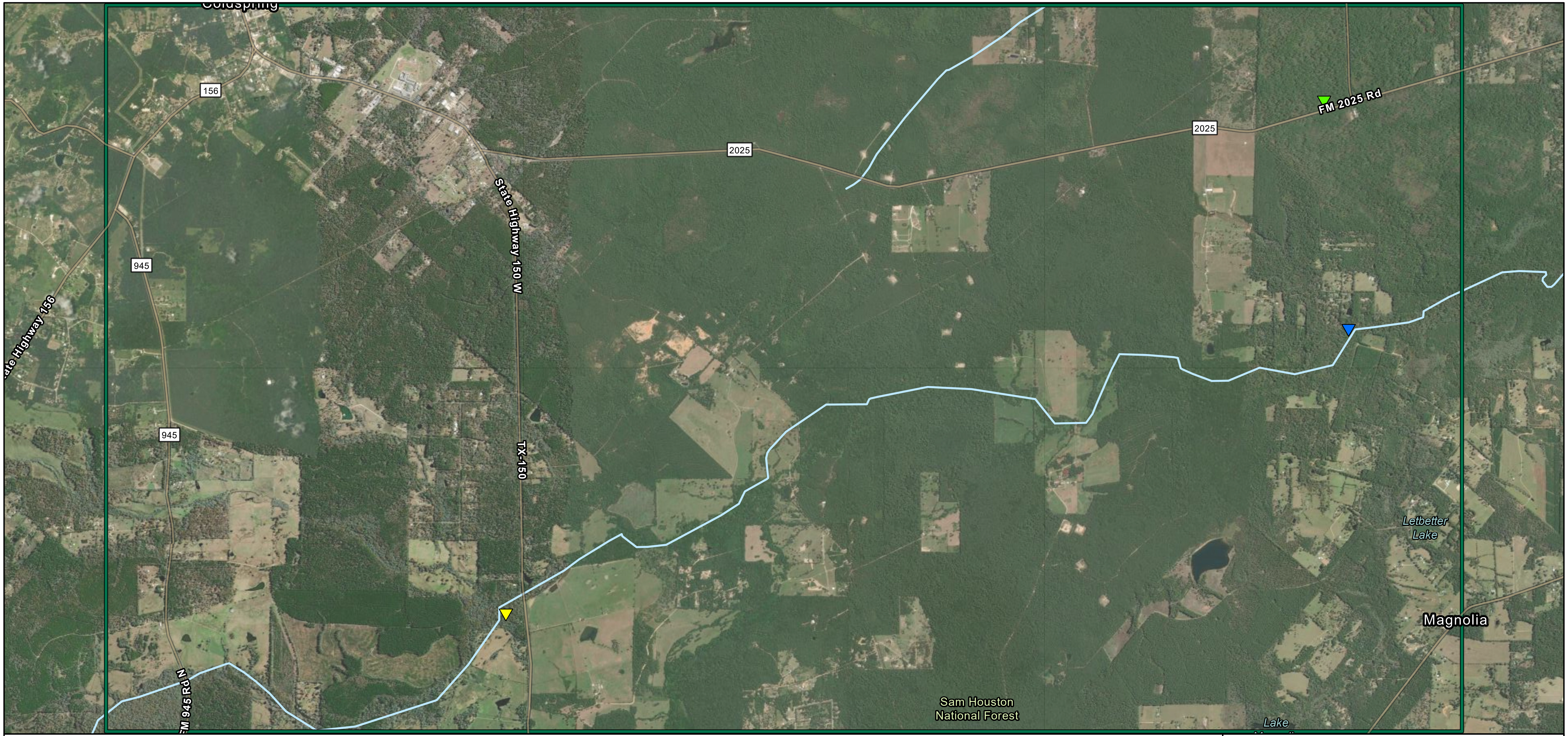
Upper San Jacinto River Sedimentation Study

Caney Creek at Upland Sample Location : Dendrogeomorphic and Soil Sample Data

0 300 600 1,200 1,800 2,400 3,000
Feet

N



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Upper San Jacinto River Sedimentation Study

East Fork Isotope Analysis Soil Sample Locations

0 0.5 1 2 3
Miles

Sources:
Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, Maxar, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

— Streams

Isotope Sample Locations

▽ Floodplain

▽ Streambank

▽ Upland

Creek Regions

▭ East Fork

N

Tree Sample

Erosion Rate (ft/yr)

	Erosion Rate (ft/yr)	Category
●	0 - 0.07	1
●	0.071 - 0.13	2
●	0.14 - 0.64	3
●	0.65 - 1.3	4
●	Greater than 1.3	5

Bank Lines

Soil Sample Locations

Sample Type

- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations

- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

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Upper San Jacinto River Sedimentation Study

East Fork at Farm to Market Road 945 : Dendrogeomorphic and Soil Sample Data

0 30 60 120 180 240 300

Feet

N

Tree Sample
Erosion Rate (ft/yr)

	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines
⊢⊣

Soil Sample Locations
Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

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Upper San Jacinto River Sedimentation Study

East Fork at SH150 : Dendrogeomorphic and Soil Sample Data

0 37.5 75 150 225 300 375
Feet

N

Tree Sample
Erosion Rate (ft/yr)

		Category
●	0 - 0.07	1
●	0.071 - 0.13	2
●	0.14 - 0.64	3
●	0.65 - 1.3	4
●	Greater than 1.3	5

Bank Lines
├─┤

Soil Sample Locations
Sample Type
- 🟦 Bar Sieve
- 🟪 Floodplain
- ■ Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA

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Upper San Jacinto River Sedimentation Study

East Fork at Lower Vann Road : Dendrogeomorphic and Soil Sample Data

0 45 90 180 270 360 450
Feet

N

Tree Sample
Erosion Rate (ft/yr)

	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines

⊢⊣

Soil Sample Locations

Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- ▭ Caney Creek
- ▭ East Fork
- ▭ Willow Creek

Sources:
Esri, CGIAR, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, METI/NASA, USGS, EPA, NPS, USDA, Maxar

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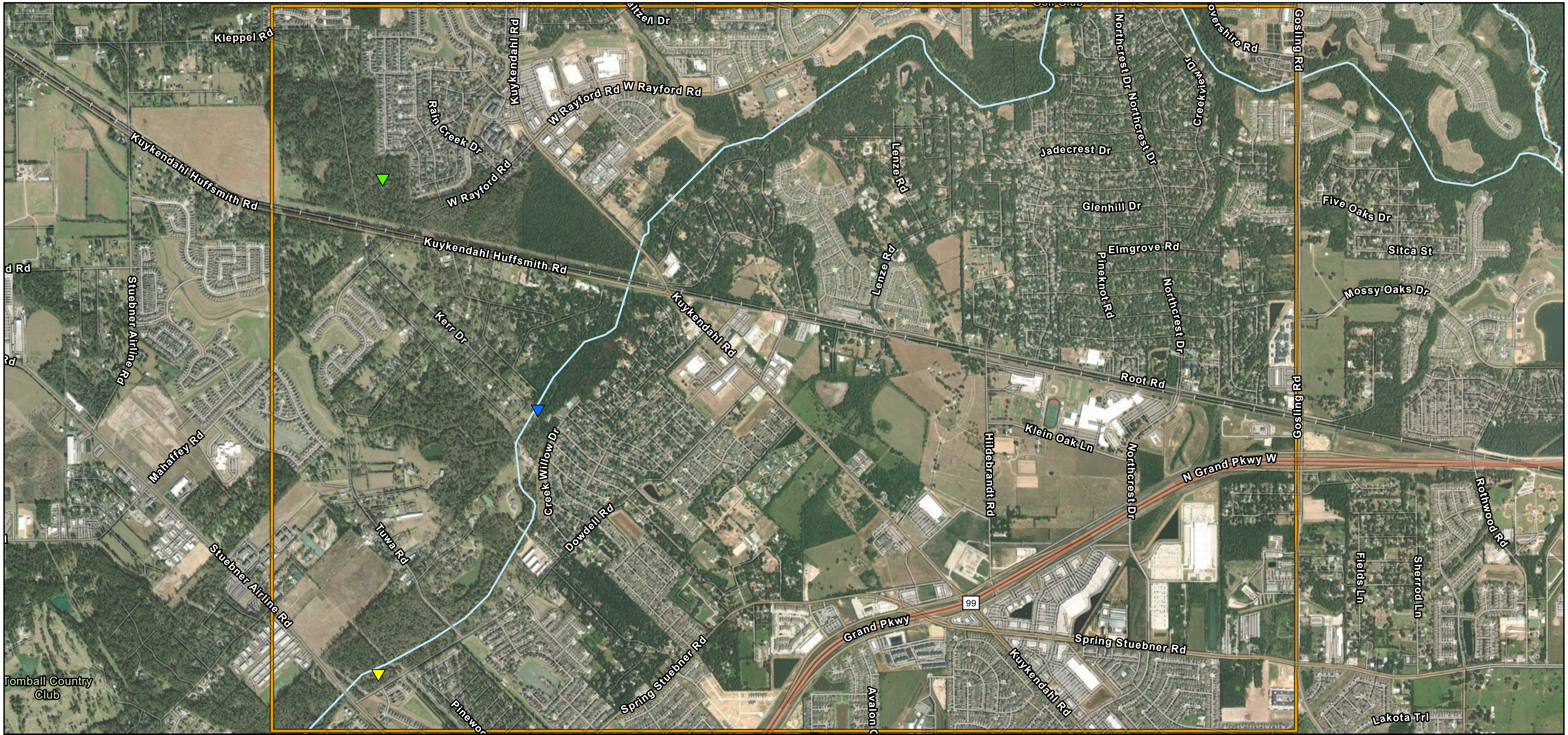
Upper San Jacinto River Sedimentation Study

East Fork at Upland Sample Location : Dendrogeomorphic and Soil Sample Data

0 180 360 720 1,080 1,440 1,800
Feet

N



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Upper San Jacinto River Sedimentation Study

Willow Creek Isotope Analysis Soil Sample Locations

0 0.5 1 2
Miles

Sources:
Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, US Census Bureau, USDA, Esri, NASA, NGA, USGS, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA, NPS, Maxar

— Streams

Isotope Sample Locations
- ▼ Floodplain
- ▼ Streambank
- ▼ Upland

Creek Regions
- ▭ Willow Creek

N

Tree Sample
Erosion Rate (ft/yr)

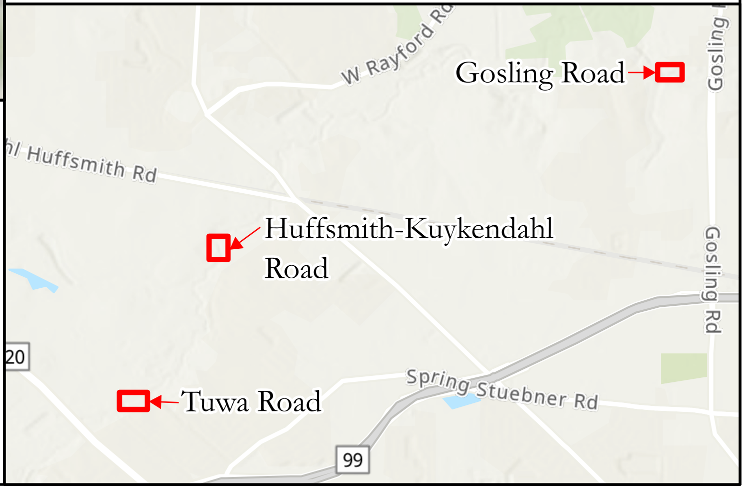
	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines
⊢⊣

Soil Sample Locations
Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



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Upper San Jacinto River Sedimentation Study

Willow Creek at Tuwa Road : Dendrogeomorphic and Soil Sample Data

0 50 100 200 300 400 500
Feet

N

Tree Sample
Erosion Rate (ft/yr)

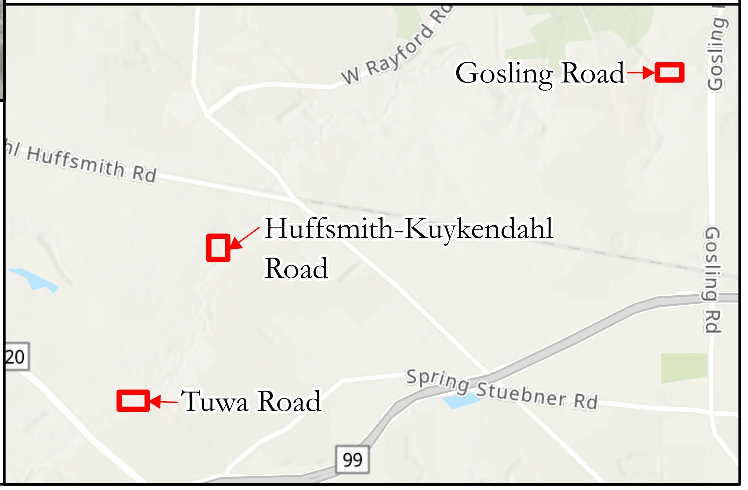
	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines
⊢⊣

Soil Sample Locations
Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



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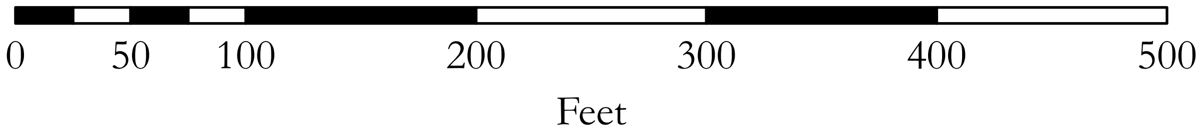
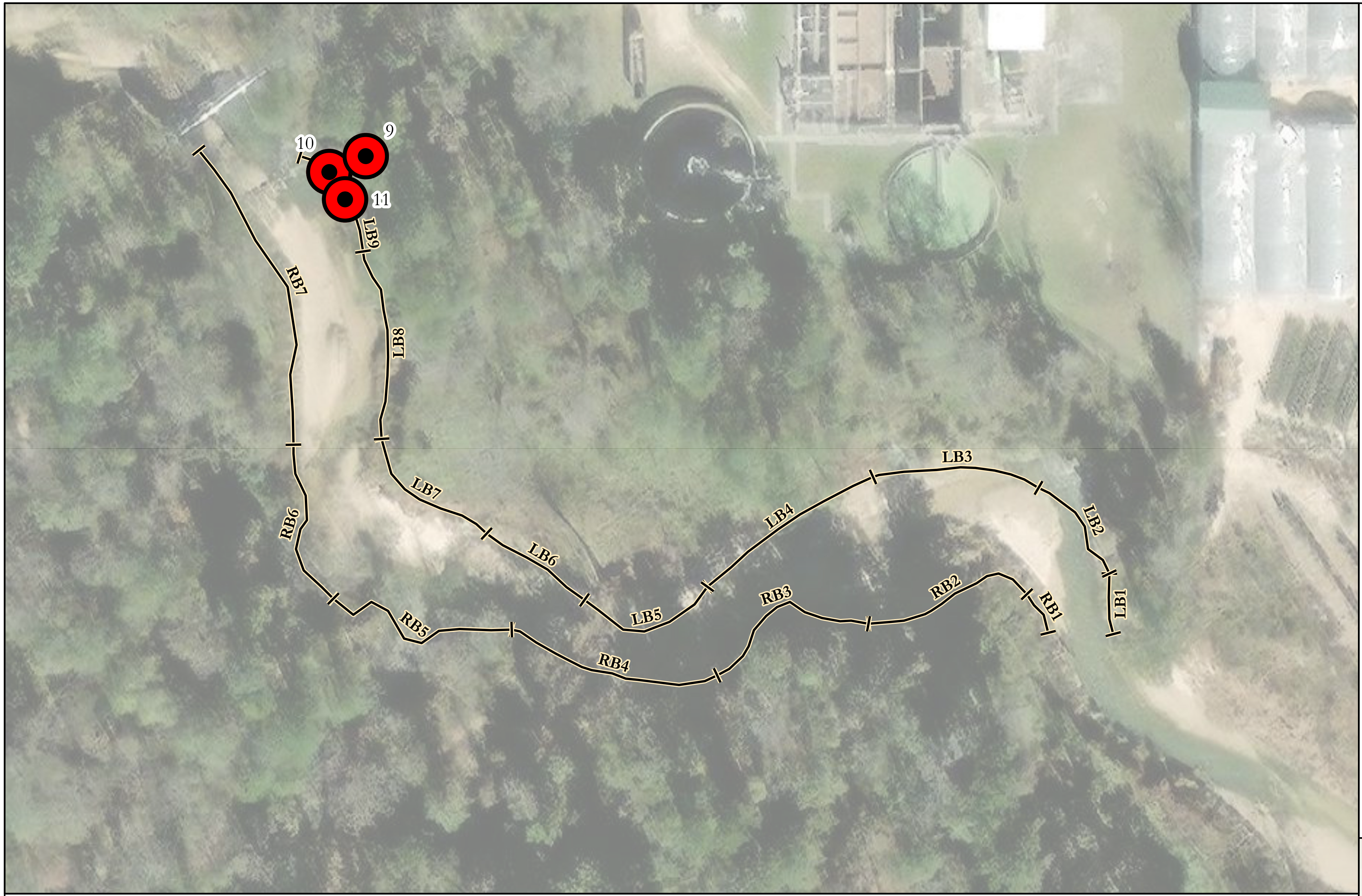
Upper San Jacinto River Sedimentation Study

Willow Creek at Huffsmith-Kuykendahl Road : Dendrogeomorphic and Soil Sample Data





Tree Sample

Erosion Rate (ft/yr)	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines

⊢⊣

Soil Sample Locations

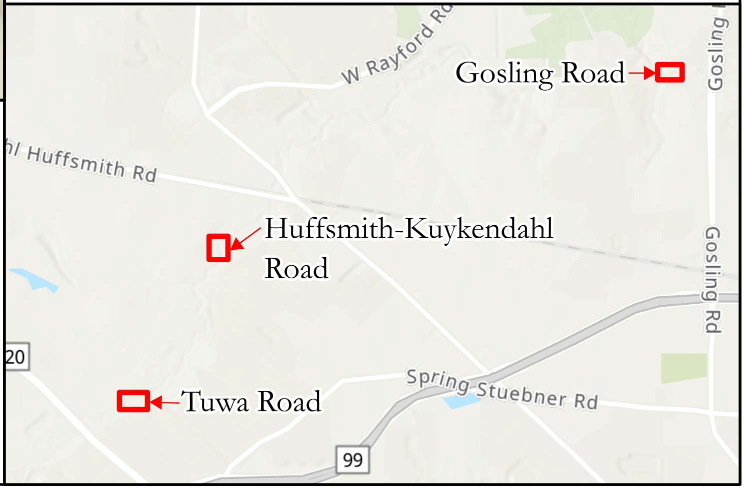
Sample Type

- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations

- Caney Creek
- East Fork
- Willow Creek

Sources:
Maxar, Microsoft, Esri, NASA, NGA, USGS, Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



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Upper San Jacinto River Sedimentation Study

Willow Creek at Gosling Road : Dendrogeomorphic and Soil Sample Data

0 45 90 180 270 360 450
Feet

Tree Sample
Erosion Rate (ft/yr)

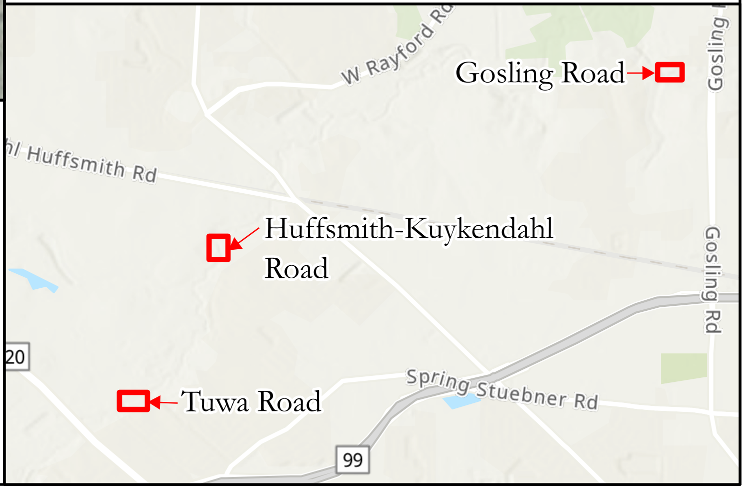
	Category
● 0 - 0.07	1
● 0.071 - 0.13	2
● 0.14 - 0.64	3
● 0.65 - 1.3	4
● Greater than 1.3	5

Bank Lines
⊢⊣

Soil Sample Locations
Sample Type
- ■ Bar Sieve
- ■ Floodplain
- ■ Stream Bank

Upland Sample Locations
- ⌐⌐ Caney Creek
- ⌐⌐ East Fork
- ⌐⌐ Willow Creek

Sources:
Esri, NASA, NGA, USGS, Baylor University, City of Houston, HPB, Montgomery County, TX GIS Office, Texas Parks & Wildlife, CONANP, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA, Maxar



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Upper San Jacinto River Sedimentation Study

Willow Creek at Upland Sample Location : Dendrogeomorphic and Soil Sample Data

0 305 610 1,220 1,830 2,440 3,050
Feet

N