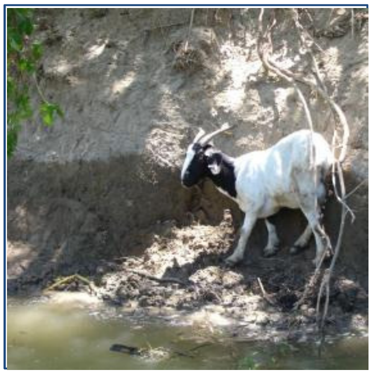
RPS Espey

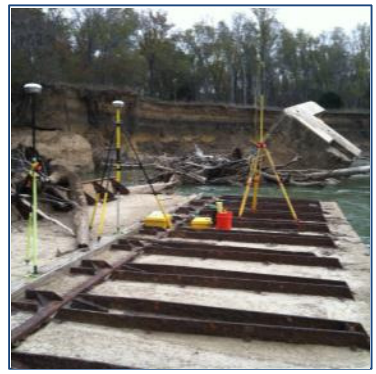
Trinity River Long-Term Study

Master Report - Objectives, Progress and Summary

through November 2013, Revision 03b

Date Submitted: November 27, 2013 (revised December 04, 2013)
Client: Trinity River Authority
Project Number: 13016








Trinity River Long-Term Study
Master Report – Objectives, Progress and Summary
through November 27, 2013

Prepared in collaboration with:
Webster Mangham
Manager Special Studies and Assessments
Trinity River Authority of Texas
5300 South Collins St.
Arlington, TX 76018

Prepared by:
Tim Osting
RPS Espey
4801 Southwest Parkway
Parkway 2, Suite 150
Austin, Texas 78735

T (512) 326-5659
F (512) 326-5723

www.rpsgroup.com

Project No. 13016

Table of Contents

List of Figures

List of Tables

P:\Active\13016.00_TRA_LT_Yr2\00_Reporting\20131204_TRA_LongTerm_V03b.docx

Document Revision History

V01 – December 21, 2011

V02 – April 5, 2013 (rev June 10, 2013)

V03b – November 27, 2013 (rev December 4, 2013)

1.0 Long Term Study Plan

December 2011

The Trinity River is a major natural resource for 52% of all Texans, spanning the state north to south and making a connection between the Dallas /Fort Worth (DFW) metroplex and Houston, two major population hubs in Texas. Although abundant water quality data exist, only limited quantitative data exist to assess the current geomorphic structure and stability of the river.

Multiple factors influence the health and value of the Trinity River as a resource, including human factors, climate, landscape and geology. Current and historical human factors (including water use and management) exert a degree of influence that is currently unknown relative to degree of influence of historical climate patterns and basin geology. After three years of empirical reconnaissance efforts leading to this study plan, it is evident that the river channel and floodplain within upper-basin urbanized areas exhibit characteristics that are in contrast to channel and floodplain characteristics of middle-basin agricultural/forested areas.

1.1 Mission Statement

First and foremost, the goal of the Trinity River Authority's (TRA) Trinity River Long-Term Study (TRLTS) is to create an extensive interdisciplinary repository and base of knowledge founded on empirical data. This repository is envisioned as not only a reliable dataset, but also as a continually-updated and synthesized river status report. Part of that repository will be knowledge regarding historical and active processes shaping the Trinity River.

A driving force behind the TRLTS is the use of observed, quantitative data to derive findings. The study will identify indicators of status and health that can then be monitored for change at a decadal scale. As changes are observed and measured, the primary factors or processes will be identified.

In general, studies will be arranged in the following sequence:

1. Identify a baseline current condition for health of the river today (2012-2015);
2. Identify indicators to monitor;
3. Conduct monitoring studies to identify changes through time (next 20 to 40 years);
4. Quantify primary influences or causes of observed changes; and
5. Reassess indicators and study methodology periodically.

1.2 Starting point

The TRLTS faces two main challenges: existing data gaps, and logistics.

Although significant water quality data exists throughout the Trinity River basin, the passing of Texas State Senate Bill 3 (SB3) in 2007, designed to "set aside" instream water for environmental uses, highlighted large data gaps in geomorphologic and biological data as basin workgroups analyzed existing scientific information. A previous piece of legislation, Texas State Senate Bill 2 (SB2), passed in 2001, was intended to develop a multidisciplinary scientific methodology for river studies to be carried out by a multi-agency partnership, the Texas Instream Flow Program (TIFP). Due to river basin prioritization at the State level, SB3 flow numbers were adopted by the Texas Commission on Environmental Quality (TCEQ) in 2011, prior to the SB2 TIFP study beginning. While the SB2 and SB3 environmental flow processes are parallel to some concepts of the TRLTS, the TRLTS focuses on identifying influences on river characteristics rather than focusing more narrowly on how flow regime influences the river.

Access to the main stem of the Trinity River is difficult at best with only one public boat ramp along 246 river miles between Dallas and Lake Livingston. The ability to launch a boat and navigate to remote river reaches requires significant time, planning, coordination and expense. Limited access points, along with unfavorable historical water quality conditions, steep banks and extensive private land ownership have contributed to the lack of historical data and field studies. Based upon longitudinal studies completed by TRA between 2009 and 2011, logistical and access issues are being mitigated.

Multiple entities and programs are interested in assessing the current and future health of the Trinity River system (Table 1). Because of both the geographical and political complexity of the Trinity River basin, it is important to coordinate data collection efforts and study planning with these entities, as well as research institutions and universities, to ensure that data are collected efficiently and can serve diverse research goals whenever possible. Additionally, university and research institutions working on the Trinity River main stem should be identified.

Table 1. List of Major Basin Entities.

Abbreviation	Name
TRA	Trinity River Authority of Texas
TRWD	Tarrant Regional Water District
NTMWD	North Texas Municipal Water District
COD	City of Dallas
COFW	City of Fort Worth
COH	City of Houston
CRP	Texas Clean Rivers Program
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
TPWD	Texas Parks and Wildlife
RWPG	SB1 Regional Water Planning Groups (primarily C and H)
TIFP	SB2 Texas Instream Flow Program
EFAG	SB3 Environmental Flows Advisory Group
BBASC	SB3 Trinity-San Jacinto Bay-Basin Area Stakeholder Committee
BBEST	SB3 Trinity-San Jacinto Bay-Basin Expert Science Team

1.3 Geographic Scope

The TRLTS begins at river mile (RM) 512 at the most downstream low water check dam in Fort Worth (near Handley-Ederville Road) and extends downstream to RM 0 at the mouth at Trinity Bay near Anahuac, TX.

The entire study area has been segmented based on a longitudinal field survey of the entire river (2011 – 2013) in combination with other scientific methodologies (planform analyzed with historical satellite imagery, historical cross section data, historical photographs, levee locations, floodplain connectivity, and etcetera) (TRA and RPS Espey 2012). The refined 2012 Study Areas and Segments are presented in Figure 1.

Segmentation can change in light of new or additional information, and it is the intention that segmentation will not be based on access alone. The typical segmentation scales and nomenclature are used for this study as follows:

1. Study Area (> 40 river miles)
2. Segments (5-80 river miles)
3. Reaches (<3 river miles)
4. Sites (<2500 feet)
5. Point (<75 feet)

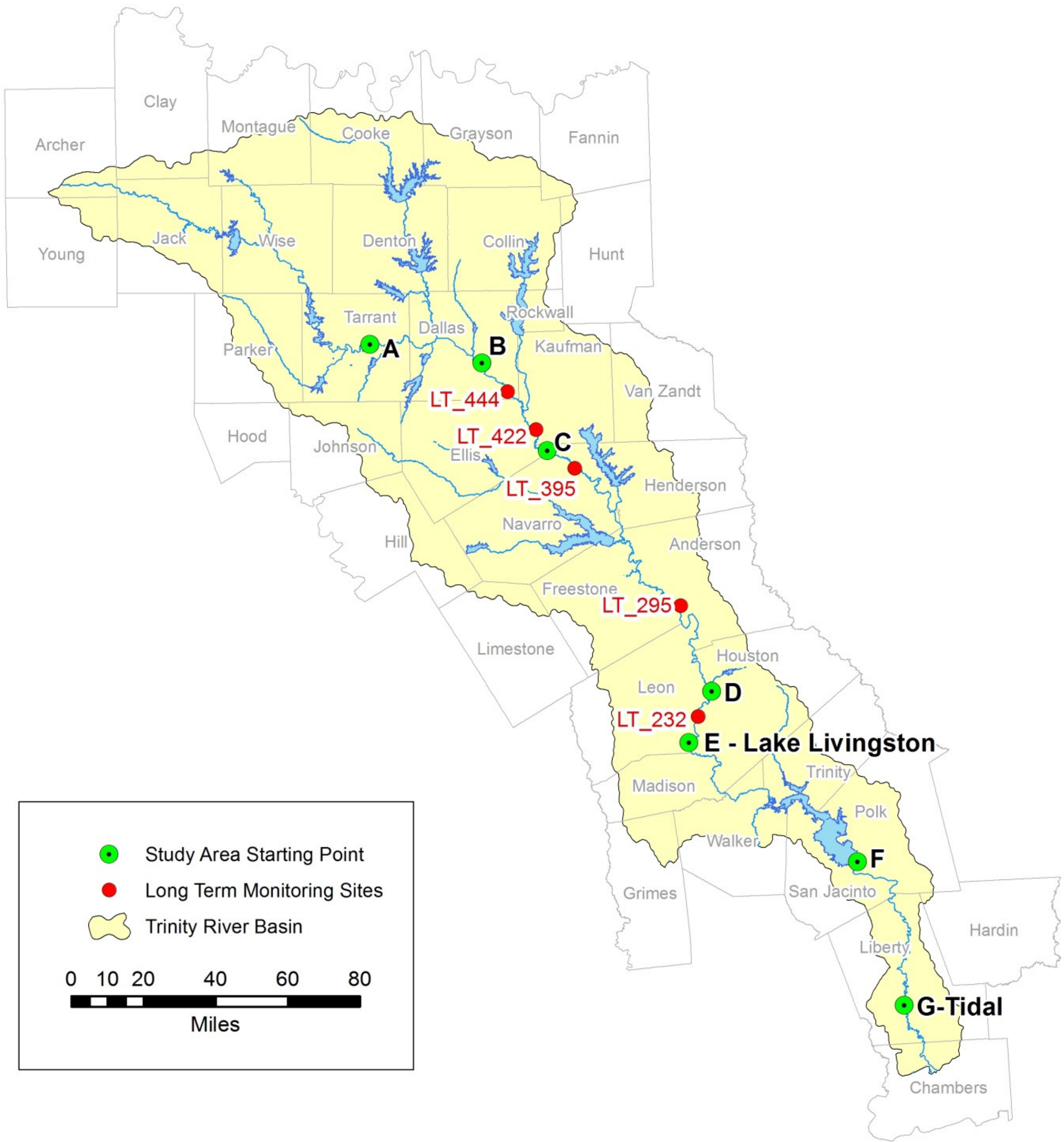


Figure 1. Basin map and area segmentation

1.4 Long Term Monitoring Plan

This monitoring effort is designed to proceed in step-wise fashion through four steps: indicator identification, baseline monitoring, long-term monitoring and trend assessment. The overall approach for this study is to work within major focus disciplines or focus classes. For each discipline, the study will establish baseline conditions, identify indicators for baseline conditions, monitor indicators over the long-term for trends, then determine what influences are driving the trends.

An initial set of indicators is assumed based upon similar studies conducted in other regions, upon experience in the Trinity River basin and in Texas and upon multiple reconnaissance studies conducted between 2009 and 2011.

As baseline studies are completed, indicators may change. At the end of the baseline study timeline, a set of indicators will be used to monitor river condition and health. As the studies progress into the long-term monitoring stage and more is learned about active processes and influences, additional questions will arise and be addressed through additional study initiatives and adaptive monitoring techniques.

Overarching objectives include creation of a long-term high quality dataset that covers, but is not limited to, the biology, hydrology, geology, geomorphology, geography, water quality and riparian attributes of the Trinity River basin. The Trinity River Long-Term Plan has potential to become a clearing house for all Trinity River scientific projects, studies and endeavors in the basin.

1.4.1 Monitoring objectives

A set of focus disciplines or focus classes have been identified to guide the study through its 20 to 40 year life-cycle. At this initial stage of the study, these classes are perceived to improve organization, planning and interpretation of study activities. The initial focus classes are:

- Biology – instream
- Biology – riparian
- Habitat
- Hydrology and Hydraulics (H&H)
- Physical processes
- Water quality
- Economics and Recreation

1. Identify indicators for health and status of Trinity River

The main objective during the first four years (2012 through 2015) of the study is to identify indicators appropriate for long-term monitoring. Example indicators for each focus class are provided (Table 2) and are anticipated to change as initial baseline studies are completed.

Table 2. EXAMPLE indicators by focus class

Indicator Focus Class	Example Indicators, or Potential Indicators
Biology - instream	Fish species diversity by segment Mussel species density by segment Benthic species diversity by segment
Biology - riparian	Riparian species density by segment
Habitat	Percent run/riffle/pool by segment Large woody debris piles per river mile by segment
H&H (Hydrology)	Long-term baseflow percent exceedence by area Short-term baseflow percent exceedence by area Long-term high flow pulse level and occurrences per year by area Long-term overbank flow level and occurrences per year by area Drought condition per Drought Monitor by area
H&H (Hydraulics)	Water surface slope by reach Mean baseflow wetted width by reach Mean baseflow cross-sectional area by reach
Physical Processes	Long-term annual sediment load by area Long-term coefficient variation on annual sediment load by area Short-term annual sediment load by area Reach length Mean bank angle by reach Channel migration (feet) by study site
Water quality	Long-term average DO by area Long-term average nutrient indicator by area Short-term average DO by area
Economics and Recreation	Number of public access points by reach Number of landowners with river access by reach

2. Understand the current 2012-2015 status (baseline condition) of the Trinity River

Baseline conditions should be evaluated and should result in identification of indicators (e.g., Table 2). The indicator data should be representative of the current baseline and future data should eventually convey a bigger picture of river health and status.

3. Understand what historical factors have shaped the baseline condition

Many factors are known to contribute to the current form, function, health and status of the Trinity River. These factors are both man-made and natural, and include channel straightening, levee construction, flood control, reservoirs, instream navigation structures, climate and urbanizing watersheds. Localized influence of structural factors may be relatively straight-forward to assess (e.g., scour near a bridge crossing); however, long-term changes to habitats, channel cross-section, species diversity and etc., in expansive areas distant from structural factors are more difficult to assess.

Historical factors likely caused an initial rapid adjustment to many indicators, with influence tapering off as time progresses. Hypotheses should be developed to identify how indicators have changed through time leading up to the current indicator value.

4. Understand what processes are currently active in the river, including localized effects of urban and rural riparian activities

As baseline conditions are identified and quantified, second-stage follow-up studies should focus on identifying what processes are driving and influencing the river's current health and status. With current status and indicators in hand, hypotheses should be made to guide and test in the follow-up studies.

5. Understand, after 20 years, what changes have occurred to the Trinity River since 2015 baseline

A main difficulty of short-term studies is identifying current status. This is the case because a status assessment often is a comparison to an earlier condition. The main purpose of this study is to identify – and quantify – changes through time.

6. Understand, after 20 years (approx. 2031), what have been the most influential factors of change (e.g., climate, flow patterns, structures, land use, water quality, etc.)

Given the difficulty of simply identifying current status and then systematically monitoring and observing changes, even more difficult is assessing what factors are most influential in observed changes. Dissecting the factors that influence change is important for project planning and for locating structures within the river system, and is the very essence of some existing programs (e.g., SB2 and SB3 with interest in the influence of flow regime and water management on changes).

7. Understand, after 40 years (approx. 2051), what have been the most influential factors of change, and whether those factors are different than previous 20 years

At the end of 20 years, hypotheses can be formed about what changes would be expected in subsequent years through to year 40. Monitoring should continue through the end of year 40. At that time, the format, function and continued viability of the TRLTS should be re-assessed.

1.5 Milestone checkpoints

This project is initiated, maintained, fostered and monitored by the Trinity River Authority (TRA). When feasible, the TRA will coordinate, cooperate, accumulate, assimilate and commandeer external resources as deemed necessary for completion of tasks.

At the end of every fiscal year, the intent is to assess status relative to completion of studies. The studies and timeline for studies are identified in this Long-Term Monitoring Plan document. The beginning year for this long-term study is 2012.

<u>Major milestone checkpoints</u>

1 year – FY2012 - Complete long-term plan and timeline development; begin baseline studies; confirm segmentation; identify study sites
Coordinate with other entities and discuss long-term plan and objectives
Focus is on biological data collection
Quantify and articulate long-term routine sampling program

2 years – FY2013 - Complete biological and riparian baseline sampling; complete establishment of study sites

3 years – FY2014 - Complete sediment and water quality baseline sampling

4 years – FY2015 - Complete additional baseline sampling

5-years – FY2016 - Complete all baseline sampling; revise long-term plan; begin long-term trend monitoring

10-years – FY2021 - First major summary to assess trends; revise long-term plan as necessary; continue long-term trend sampling

20-years – FY2031 - Second major summary to assess trends; revise long-term plan as necessary; continue long-term trend sampling

30-years – FY2041 - Third major summary to assess trends; revise long-term plan as necessary; continue long-term trend sampling

40-years – FY2051 - Fourth major summary to assess trends; revise long-term plan as necessary; continue long-term trend sampling

As of April 2013, these completed tasks are supportive of the Study Plan:

- 2010 Reconnaissance project – Longitudinal survey and data collection
- 2011 Reconnaissance Field Survey (TRA and RPS Espey 2012) – 300 mile longitudinal survey of meso-habitat, depth, cross-sections; DFW to Lake Livingston headwaters
- Cross-section study site selection – 2012 - Identification of long-term cross-section study sites, and preliminary biological sampling sites (the subject of this report)
- TPWD Supplemental Biological Sampling – Summer 2012 - Longitudinal baseline sampling of fish and macroinvertebrates in the mainstem between Trinity Falls in Ellis and Kaufman Counties and Lake Livingston in Madison and Houston Counties (TRA and TPWD 2014).
- TRA Biological Sampling – Summer/Fall 2012 - Additional baseline sampling of fish and macroinvertebrates in the mainstem in the Dallas-Fort Worth area
- 2013 Reconnaissance Field Survey – 116 mile longitudinal survey of meso-habitat, depth, cross-sections; Lake Livingston dam to Trinity Bay
- 2013 Coordinate and support TIFP SB2 Stakeholder meetings
- 2013 Coordinate with TIFP, identify SB2 study sites, and initiate SB2 field efforts
- 2013 LT295 (Oakwood) - HEC-RAS water level and sediment modeling
- 2013 LT295 (Oakwood) - Map-based riparian inundation assessment
- 2013 LT444 (Lock 3) - riparian vegetation field data collection
- 2013 LT444 (Lock 3) - baseline cross-section field data collection following breach of Lock 3

1.6 Current status – November 2013 Revision 03

This “Master Report” dated April 2013 was the first accumulation of several reports and it is the intent that this report be a long-term repository for work completed and synthesized within the Trinity River. The current November 2013 revision 03 represents continuation of this intent, with 2013 activities being added. The TRLTS was initially conceptualized in December 2011 (EC 2011) and included a version of Table 3. The 2011 Longitudinal Reconnaissance Study is summarized in TRA and RPS Espey (2012). The first year of monitoring studies is summarized in RPS Espey (2012).

The following baseline assessment tasks are recommended in support of the 2014 Long-term Study (Table 3):

- Continue participation with TIFP on SB2 initiatives within the Trinity River Basin
- Baseline water quality diurnal study (one-month continuous sonde deployments)
- Baseline riparian assessment
- Historical timeline of each study area and segment
- Data processing for 2013 longitudinal survey from LLP to Trinity Bay
- Complete LT295 benchmark installation and riparian vegetation survey
- Complete LT444 field effort, data processing and RAS modeling
- Develop data structure to archive past and future long-term data

Table 3. << UPDATED NOV 2013 >> Proposed – Detailed study sequence by study sites and reaches (EC 2011)

River Area	Fiscal Year	UPDATED Schedule outlook	Study	Focus area
ALL AREAS – A, B, C, D, F				
All	2012	**This report**	Establish statement of study goals	All
A-D	2012	**Completion 2013**	Continue data processing of 2011 survey	All
A-D	2012	**Complete**	Reach Re-segmentation	All
A-G	2012	**Complete**	Updated / New River Miles	All
B-D	2012	**4 sites identified**	Identify long-term study sites	All
C, D	2012	**Initiated**	TIFP coordination	All
	2012	**Initiated**	Landowner coordination	All
B-D	2012	**4 sites measured 2012**	Cross-sectional measurements and elevation reference	Physical Processes
B-D	2012	**6 sites sampled 2012 (with TIFP)**	Baseline biological sampling – Fish, Mussels, Invasives	Biological – instream
	2013	Baseline	1-month diurnal sonde data DO/Temp	Water Quality
F, G	2013	**Survey complete, Processing initiated**	Reconnaissance downstream of Livingston	Habitat
	2013	Near-term	Historical timeline for each segment	Physical Processes
C	2013	**Initiated 2012**	1D hydraulic model for pulse inundation	H&H
C, D	2013	**Initiated 2013**	Baseline riparian study	Biological – riparian
	2014	**Initiated 2013**	Riparian inundation study	Biological - riparian
C		**Initiated 2013**	Sediment load and transport	Physical Processes
		Baseline	Large Woody Debris study	Physical Processes
	2014	**Initiated 2013 (LT444)**	Impact of lock and dam bank failure	Physical Processes
		Mid-Term	Recreation uses	Rec. and Eco.
		Mid-Term	Economic value	Rec. and Eco.
	2014	**SB2 initiated 2013**	Fish HSC development	Biological - instream
	2014	Mid-term	2D hydraulic models for habitat	H&H
	2015	Mid-term	Instream habitat models	Habitat
	2015	Mid-term	Determine WQ goal values and assess	Water quality
		Initiated 2012	Baseline biological sampling – Tribs	Biological - instream
	2015	Baseline	High base flow habitat study for tribs and riffles	Habitat
		Long-term	Repeated area-wide recon – high base	Habitat
		Long-term	Repeated area-wide recon – low base	Habitat
		Long-term	Long-term cross-section monitoring	Physical Processes

2.0 Field Data Collection Methods

This section generally describes field data that has been measured and methods used to conduct measurements.

2.1 Site Access

Multiple jon boats and kayaks were launched at public and private launch points on or near Long-Term Monitoring (LTM) sites. Launch points included sand bars, river banks and bridge crossings. TRA and Texas Water Development Board field safety protocols were used.

2.2 Accuracy Goals

Successful long-term monitoring depends heavily on repeatability. Particularly important in assessment of geometric changes in cross-sections are positional accuracy and repeatability of measuring known locations. English units (e.g., feet, cfs, miles, etc.) are used for this assessment for consistency available flow data. Geographic coordinate projection is Texas State Plane (4202, 4203) NAD83 and elevation datum is NAVD88 GEOID03. For data collection efforts spanning multiple zones, WGS84 is the preferred horizontal coordinate system.

The overall goal of this long-term monitoring study was to detect morphological changes in the river due to deposition or erosion at magnitudes (of change) of between 3 and 6 inches. While that goal is easily attainable for relative accuracy for any single-day data collection event, the goal for absolute accuracy may be somewhat larger, closer to 1 foot. The absolute accuracy goal is in consideration of using GPS equipment for expedient survey of many locations throughout a site, in lieu of installing additional benchmarks (ideally, 2 benchmarks per cross-section are required for optimum accuracy).

Typically, the relative accuracy of any single-day GPS data collection event is high (less than one inch precision); however, the absolute accuracy is more difficult to quantify and may be less accurate (less than one foot). Positional shifts are difficult to assess and correct when compiling multiple datasets from multi-day field data collection events (Osting 2007). To maximize both precision and accuracy, state-of-the-art survey technologies and techniques were incorporated into study methods to help achieve accuracy goals, and established national reference points were surveyed where available.

As this study progresses, the installation and incorporation of additional fixed benchmark locations at each cross-section will contribute considerably to achieving the data accuracy goals. The next phase of work will further evaluate data collected during the 2012 survey to estimate level of accuracy, and to evaluate an appropriate balance between level of accuracy and level of field effort.

2.2.1 Survey Reference Marks

One temporary benchmark was installed at each LTM site to provide a more permanent reference point for each site. Benchmark installation consisted of cementing rebar with a survey cap flush with ground elevation (Figure 2) on a high point of a cross section, thus reducing potential disturbance. In future monitoring data collection efforts a second temporary benchmark will be installed on the opposite bank of the river, repair to any disturbed temporary benchmark will be conducted, and a pair of benchmarks will be installed on every cross-section.

Figure 2. Typical survey reference mark

Additional elevation reference points were used within each study site. These include railroad spikes or nails driven into trees and existing fence posts.

2.2.2 Trimble RTK GPS Surveying

A Trimble RTK GPS Surveying system was used to collect cross section data points, temporary benchmark points and established National Geodetic Survey (NGS) reference cap points. This system utilized the deployment of an on-site base-station at each LTM site which allowed for RTK surveying to be conducted with a rover receiver. The base station was deployed on temporary benchmarks when terrain or access allowed.

The Trimble RTK GPS Surveying system was also used to tie each LTM site survey to established NGS reference caps. All data collected with the Trimble RTK GPS Surveying system was post processed using the Trimble Business Center software.

2.3 Cross-Section Field Data Methods

2.3.1 Trimble VX Spatial Station and Laser Scanner

A Trimble VX Spatial Station (VX) was used to collect cross sectional data and water surface elevation data at each LTM site along with a traditional Auto-Level. The VX has several different operation settings which were utilized during data collection efforts. The total station setting (accuracy of 0.08”; prism rod, to 0.156; direct reflection”) in conjunction with a prism rod, or direct reflection (if terrain was not accessible) was used to collect cross section data for some of the cross sections at each LTM site. This method collected all cross section data at wadeable cross sections. At non-wadeable cross sections this method only collected the above water portion of the cross section and a Sontek M9 Echosounder was used to collect the submerged portion of the cross section. The prism rod was used to collect water surface elevation data which was used to determine water surface slope and water surface profiles.

The VX robotic scan (accuracy of 0.5”) setting was used to collected data along several large bank areas at selected LTM sites (Figure 3). Georeferenced digital photos were collected simultaneous by the instrument during the automated scans and utilized during post processing. Photogrammetry is possible and will be conducted on selected scans to improve the data coverage.

2.3.2 Traditional Auto-Level Survey

A traditional auto level (accuracy of 0.7mm per 1km level loop) with survey rod was used to collect cross sectional data and water surface elevations at each LTM. This method collected all cross sectional data at wadeable cross sections. At non-wadeable cross sections this method only collected the above water portion of the cross section and a Sontek M9 Echosounder was used to collect the submerged portion of the cross section. The water surface elevation data was used to determine water surface slope and water surface profiles. Selected reference points along each auto-level cross-section were also measured with either the VX or RTK GPS.

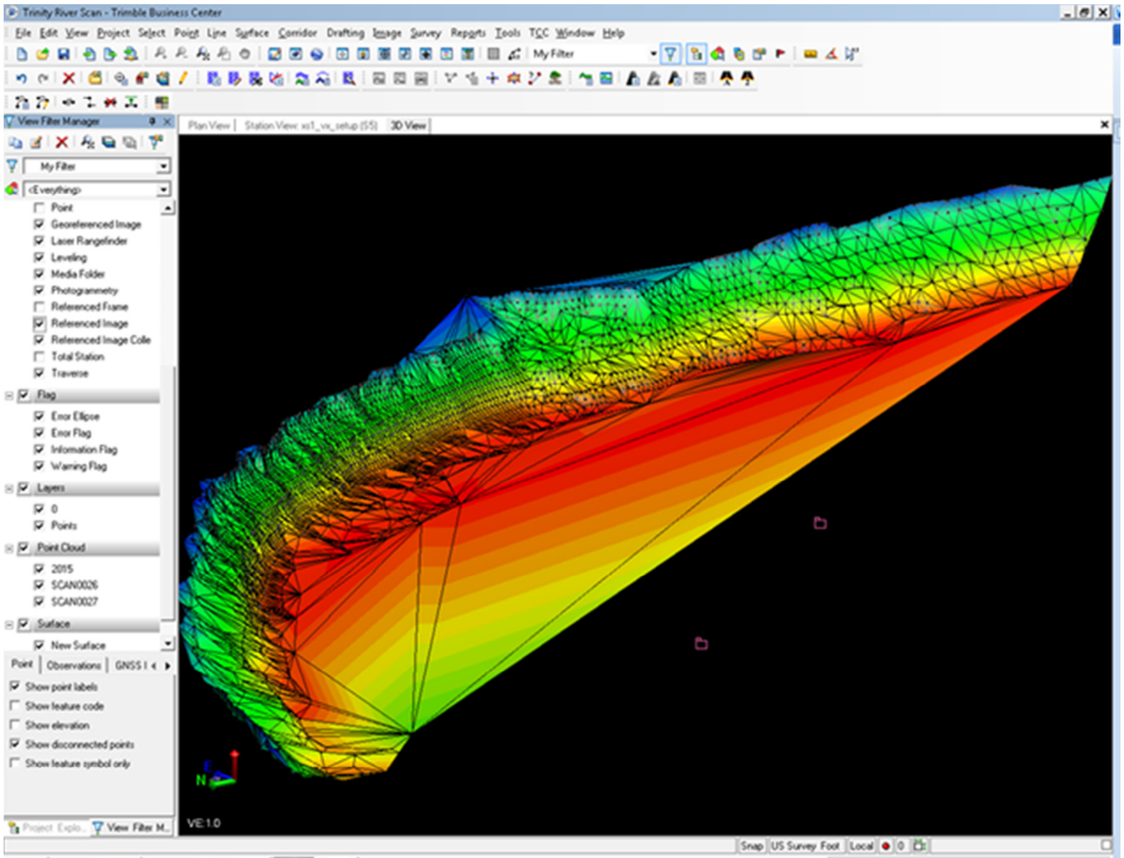


Figure 3. Sample TIN isometric view from robotic total station scan of cut bank

2.3.3 Sontek M9 Echosounding and Flow Measurement

A Sontek M9 Acoustic Doppler Profiler (ADCP) was used to collect flow measurements at each LTM site on the same day as cross sectional survey was conducted. The M9 unit was also used to collect submerged portions of cross-sections as well as additional bathymetry within the LTM site. A longitudinal bathymetry profile was collected at selected LTM sites. This profile collected data from the most upstream cross section through the most downstream cross section following the centerline of the stream (unless debris prevented this course).

Data collected with the M9 unit was post processed using Sontek's RiverSurveyor Live software.

2.4 Sediment and Erosion Monitoring Methods

2.4.1 Erosion Pins

Erosion pins were installed at selected cross sections (Figure 4). These installations consisted of driving rebar laterally into the river bank. At least one erosion pin was installed at every LTM site. The erosion pins were installed at locations and elevations which were accessible and had the highest erosion/deposition potential.

Figure 4. Installing erosion pin

2.4.2 Erosion Chains

Erosion chains were installed at selected cross sections in gravel areas on point bars or in riffle areas. At least one erosion chain was installed at each LTM sites. The erosion chains were installed at locations and elevations which were accessible, had erosion/deposition potential, and were frequently inundated (e.g., gravel bar).

2.4.3 Sediment Samples

Sediment samples were collected at selected cross sections. Typically 5 samples were collected along a sampled cross section: right bank (out of water), left bank (out of water), left channel (in channel; submerged), middle channel (in channel; submerged), right channel (in channel; submerged). Additional sediment samples were taken if significant substrate changes were observed.

2.5 Water Quality Monitoring

Water quality point measurements were collected at selected locations throughout all the LTM sites using a YSI multi parameter sonde. Limited continuous water quality data was collected as well. Typical calibration protocols were followed.

2.6 Water level and slope data

Water level data is available at USGS gage locations but water level changes at these locations may not be the same as water level changes at each LTM site. During the each LTM site survey while the survey crew was on site, water level change was monitored using a temporary staff gauge. Additionally, pressure transducers (PTs) were installed to measure water level at 5 to 15 minute increments.

3.0 Priority Areas and Monitoring Site Selection

3.1 Background and Motivation

The long-term goal of this cross-section monitoring project is to develop quantitative data sets to assess status of large and small-scale physical processes active on the Trinity River, considering short-term and long-term influences (for example abandoned lock and dam structures).

Building on work completed in 2011 involving reconnaissance and field survey of river habitat and geometry encompassing nearly 300 river miles (TRA and RPS Espey 2012), the current phase of the project has identified long-term study sites and has initiated monitoring of channel geometry and patterns of erosion and deposition. Initial field data measurements were conducted and a plan is presented in this document to guide future long-term monitoring efforts. Over the next 20 years, the cross-sections will be periodically measured to identify physical processes influencing changes to cross-section shape, erosion and deposition patterns, and channel planform.

3.2 Area Prioritization

The Trinity River Long-term Study has three primary objectives that will be used to inform study site selection:

- To understand the current status of the Trinity River, using the 2011 to 2015 period as baseline
- To understand what processes are active in the river at broad scale, and what localized effects are active resulting from urban, rural and riparian activities
- To understand through time (e.g., after 20 years), what have been the most influential factors of change (e.g., climate, flow patterns, structures, land use, water quality, etc.).

To balance research needs with available resources, the following is a priority list of study areas (see Figure 1). The prioritization is based upon an extensive longitudinal survey of the Trinity River completed in summer 2011 and winter 2013.

1. <u>Study Area C – Middle Trinity</u> – Two main factors contribute to the high priority placed on this study area. (1) This area encompasses a large geographic area exhibiting limited influence (when compared to other study areas) from external factors (primary influence

is increased baseflow from upstream sources). (2) There is current interest in this area by other programs (TIFP), to the level of initiating related studies.

2. Study Area A – Urban area – This highly-influenced study area spanning the Fort Worth and Dallas metroplex receives four large discharges and exhibits a range of in-channel conditions from lightly impacted to highly modified for flood control. Because of the wide range of influences; the opportunities for recreation and public visibility; the potential for future influences; and the proximity to less-influenced headwater streams, this study area is a good candidate for long-term study.
3. Study Area D – Coastal Plain – Like study area C, study area D is comparatively lightly influenced. The single segment identified within this area is highly homogeneous along its length based upon instream mesohabitat, bank materials and intact riparian areas. Area D exhibits a predominance of pool mesohabitats in contrast to Area C which is predominantly run mesohabitat.
4. Study Area B – Locks and Flood Control – This study area is highly influenced by a number of factors including five relic, non-functioning lock and dam structures and flood control bypass channels. The river channel in this area is complex and its current condition represents continued adjustment in response to 100-year old in-channel grade control structures, 40 to 50 year old flood control activities, and recent high flow flood events (e.g., Tropical Storm Hermine in 2010, larger flows in 2007 and highest-recorded flows in 1991).
5. Study Areas F and G - downstream of Lake Livingston – This area was not covered in the 2011 study, but field work was completed in March of 2013. Field data processing and data analysis is currently underway. This section of river is almost entirely run or pool habitat and, interestingly, one single riffle mesohabitat was identified along the entire 117-mile study area.

3.3 Long-Term Site Selection

In 2012, four sites were selected using analysis completed in 2011 (TRA and RPS Espey 2012), using available geo-spatial data (e.g., aerial imagery) and using the 2011 survey data (e.g., meso-habitat characterizations, cross-section data and field observations). A fifth long-term site was added in 2013 to monitor channel evolution in response to the erosion breaching of Lock 3 (near RM 444 just downstream of Malloy Bridge Road in southeast Dallas County) sometime between July 2011 and April 2012 (Figure 5).

Figure 5. Photograph showing breached Lock 3. Top image taken in July 2011 and bottom image taken in November 2013.

Following the 2011 reconnaissance survey, Reaches C1, C2 and C3 were identified as focus areas for future study and for monitoring of long-term cross-section geometry. Study Area C, the Middle Trinity, was identified because of limited influence by external factors (in comparison to heavily modified areas upstream and downstream) and because of current interest from the Texas Instream Flow Program (TIFP). A concurrent TIFP biological sampling project was centered in Study Area C, with an additional upstream site in B4 and additional downstream site in D1. While Study Areas B and D were lower priority based upon the 2011 survey (TRA and RPS Espey 2012), having cross-section data coincident with biological sampling data is beneficial; therefore, Reaches B4 and D1 were also identified as focus areas for monitoring long-term cross-section geometry.

A timeline of aerial imagery available through Google Earth, Bing and Texas Natural Resources Information System (TNRIS) was used to identify areas within reaches B4, C1, C2, C3 and D1 that exhibited relatively intact riparian areas. The length of intact riparian should encompass over a mile within an identified long-term study site, as well as additional mileage upstream of the study site.

After identifying reaches with intact riparian areas, a one-mile (give or take) long sub-reach was chosen that contained a range of mesohabitats including riffle, run and pool. The target cross-section was a straight run that appeared stable based upon available historical aerial photos between 1995 and 2011.

Choosing a reach with a straight run allows for monitoring of aggradation and degradation and widening. Each site reach was selected based upon proximity of the straight run mesohabitat to other types of mesohabitat. Riffle areas were selected since these are grade control and substrate size can be monitored. Meander bend areas were selected so migration can be monitored through time.

Descriptions of each site, along with data, are provided in Appendix A – SITE DESCRIPTIONS AND DATA. The location of each site is shown on Figure 1.

4.0 Data analyses and findings

This section provides a brief overview of observations, data analysis, and findings. Detailed information and write-ups for each analysis or modeling project is included in the respective appendix.

4.1 2011 –Trinity River Reconnaissance Survey

The 2011 Trinity River Reconnaissance Survey (TRRS) (TRA and RPS Espey 2012) was conceptualized and planned using baseline knowledge from the 2009 and 2010 studies. Covering nearly 300 river miles, the 2011 TRRS represents the most comprehensive and systematic longitudinal survey completed on the river in over 50 years. The objective was to collect quantitative datasets characteristic of the Trinity River and to begin the establishment of a field program to monitor river status and changes over the long term.

This project was funded through the TRA by the Texas Commission on Environmental Quality (TCEQ) Clean Rivers Program (CRP). Espey Consultants, Inc. (RPS Espey) was hired to assist TRA with this project. state agency personnel participated in data collection activities in select areas. Texas Water Development Board (TWDB) staff collected cross-section and longitudinal depth lines totaling 153 river miles, thus allowing TRA and RPS Espey to collect additional habitat-specific data within those miles. Texas Commission on Environmental Quality (TCEQ) staff participated in mesohabitat data collection in 59 river miles and also conducted a limited number of seine and backpack electroshocking activities; these represent the first fish samples collected on the main stem Trinity River in many years.

Project goals for low base-flow conditions were as follows:

- Determine the relative abundance of instream mesohabitats (e.g. riffles, runs, pools, and etc.) on the Trinity River at a coarse scale (Figure 6);
- Identify potential reaches for future, detailed biological, geomorphological, water quality, habitat, and flow studies, and
- Identify representative channel locations to be used for long-term channel monitoring.

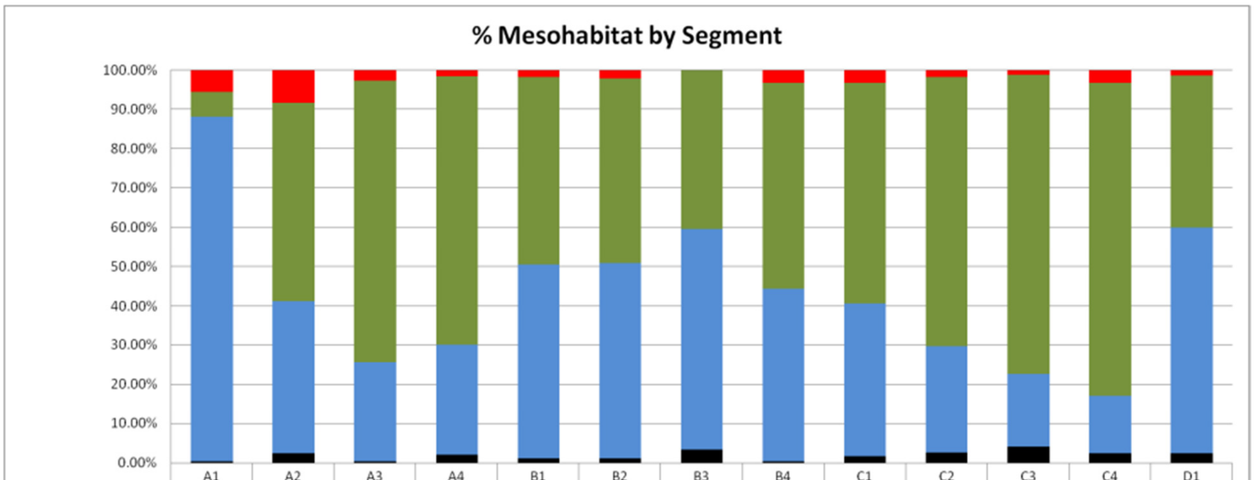
Trinity River flows during summer 2011 were near the lowest that have been experienced in recent history, though flows remained considerably higher compared to historical (i.e., pre-1960) low flows. Summer 2011 flow conditions were as low as could be anticipated under current water use patterns (i.e. reservoir release, return flow and diversion).

The systematic data collected June through August 2011 includes:

- Georeferenced photographs taken at every river mile (as designated in Trinity River Miles – 1997) (Trinity River Authority, 1997);
- Additional georeferenced photographs throughout each reach;
- Georeferenced mesohabitat classification throughout each reach;
- Cross-sections every two 1997 RM (below and between vegetation lines);
- Continuous longitudinal depth profile throughout each reach;
- Flow measurements within each reach;
- Localized bank stability assessments;
- Measurement of mesohabitat characteristics (water quality, water surface slope, velocity, cross-sections and sediment samples) in selected reaches (B2, B3, B4); and
- Preliminary fish data collection by electroshock and seine.

Based on the results of this study, a new RM system was created and a segmentation was created to identify four Areas (see Areas A,B,C,D in Figure 1) with distinct, characteristics comprised of 13 segments in total.

The 2011 survey report and data archive (TRA and RPS Espey 2012) is available upon request to TRA.



	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1
Flow Mean	4	147	368	605	588	669		703	719	626	588	687	595
Percent_Riffle	5.60%	8.40%	2.60%	1.46%	1.69%	2.13%	0.00%	3.11%	3.16%	1.71%	1.09%	3.21%	1.21%
Percent_Run	6.28%	50.50%	71.73%	68.56%	47.88%	46.96%	40.51%	52.63%	56.25%	68.56%	76.22%	79.79%	38.82%
Percent_Pool	87.82%	38.76%	25.37%	27.90%	49.27%	49.83%	56.17%	43.81%	38.84%	27.21%	18.64%	14.52%	57.56%
Percent_Bifurcated	0.30%	2.33%	0.30%	2.08%	1.17%	1.08%	3.31%	0.44%	1.74%	2.52%	4.06%	2.48%	2.41%
Length (RM)	8.5	22.4	14.1	6.9	16.1	10.7	7.6	14.7	29.4	64.8	35.8	36.4	23.3

Figure 6 - 2011 recon survey - percent of mesohabitat (by length) for each segment

4.2 2013 – Lower Trinity River Reconnaissance Survey

A reconnaissance data collection trip was completed in March 2013 between Lake Livingston Dam (RM116) and Trinity Bay (RM 0), covering approximately 116 river miles. Methods were similar to those used for the 2011 Trinity River Reconnaissance Survey (see Section 4.1 above).

Data processing and summary of the 2013 Lower Trinity River Reconnaissance Survey are anticipated to be completed in 2014.

4.3 Annual cross-section monitoring assessment

4.3.1 2012 – Long-term site identification and Year 1 Cross-Section monitoring

In 2012, work focused on establishing baseline information on morphology, particularly cross-section shape. Site selection is described above in Section 3.3.

Activities during 2012 during numerous field trips included:

- Installation of on-site survey reference points
- Cross-section surveys using RTK GPS, traditional leveling and echosounding
- Flow and velocity measurements
- Bathymetry surveys
- Bank profile survey using an robotic laser scanner
- Water quality measurements
- Bed sediment sampling – 5 samples along a cross-section
- Installation of erosion pins
- Installation of scour chains
- Water surface slope, profile and water level measurements.

Two separate one week field efforts were conducted in July 2012 and October 2012. Four long-term monitoring sites were established, each having three cross-sections. Measurements on over 50% of the cross-sections were repeated following a 7,000 cfs pulse event occurring in September 2012. Additional site visits (four half-day visits following biological sampling in the vicinity) were completed to tie on-site benchmark elevations to regional elevation benchmarks.

Additional HEC-RAS modeling was conducted to estimate water level and stable sediment grain sizes for a range of pulse events in each of the cross-sections. The predicted water level can be used in future work to compare to observed vegetation lines and top of bank elevations. The stable grain sizes can be compared in future work to sediment samples collected during the field efforts.

Work in 2012 quantified change in cross-section geometry at several locations following a rainfall-induced flow pulse. A range of changes were observed, including mass failure sloughing, silt and clay deposition, clay erosion and sand migration. These observed changes will lead to a greater understanding of processes active in this Trinity River system. The intent is to use quantitative data to understand what processes have greatest influence on the channel morphology: natural variation; increased base flows; continued response to historical channel modification; continued response to riparian modification; or other processes.

Discharge was measured on-site during each site visit using the Sontek M9 ADCP. The USGS flow gages at Trinity River Oakwood and Trinity River Crocket were monitored during this study. Between monitoring trips in July 2012 and October 2012, rainfall events produced pulses between 6,000 and 12,000 cfs that passed the LTM study sites (Figure 7). Data collection events occurring before and after the events allow for comparison of changes in cross-sections.

Although the two Long-Term sampling trips were only 3 months apart, preliminary analysis of a portion of the data indicates river channel activity at LTM cross sections including localized changes in depth of up to 3 feet and changes in thalweg location up to 20 feet. The erosion pins proved valuable in quantifying change in cross-section in response to a particular pulse event occurring between trip 1 and trip 2. A small amount of scour was observed at LTM sites 422 and 395 based on erosion pins.

Specifically at LTM 395, the most significant amount of erosion occurred at the downstream cross section (XS3) where the right bank erosion pin was exposed approximately 8” indicating scour. The XS3 left bank erosion pin was buried approximately 3” under clay indicating deposition, and was directly upstream of a new bank slump.

Descriptions of each site, along with data, are provided in Appendix A – SITE DESCRIPTIONS AND DATA. The location of each site is shown on Figure 1.

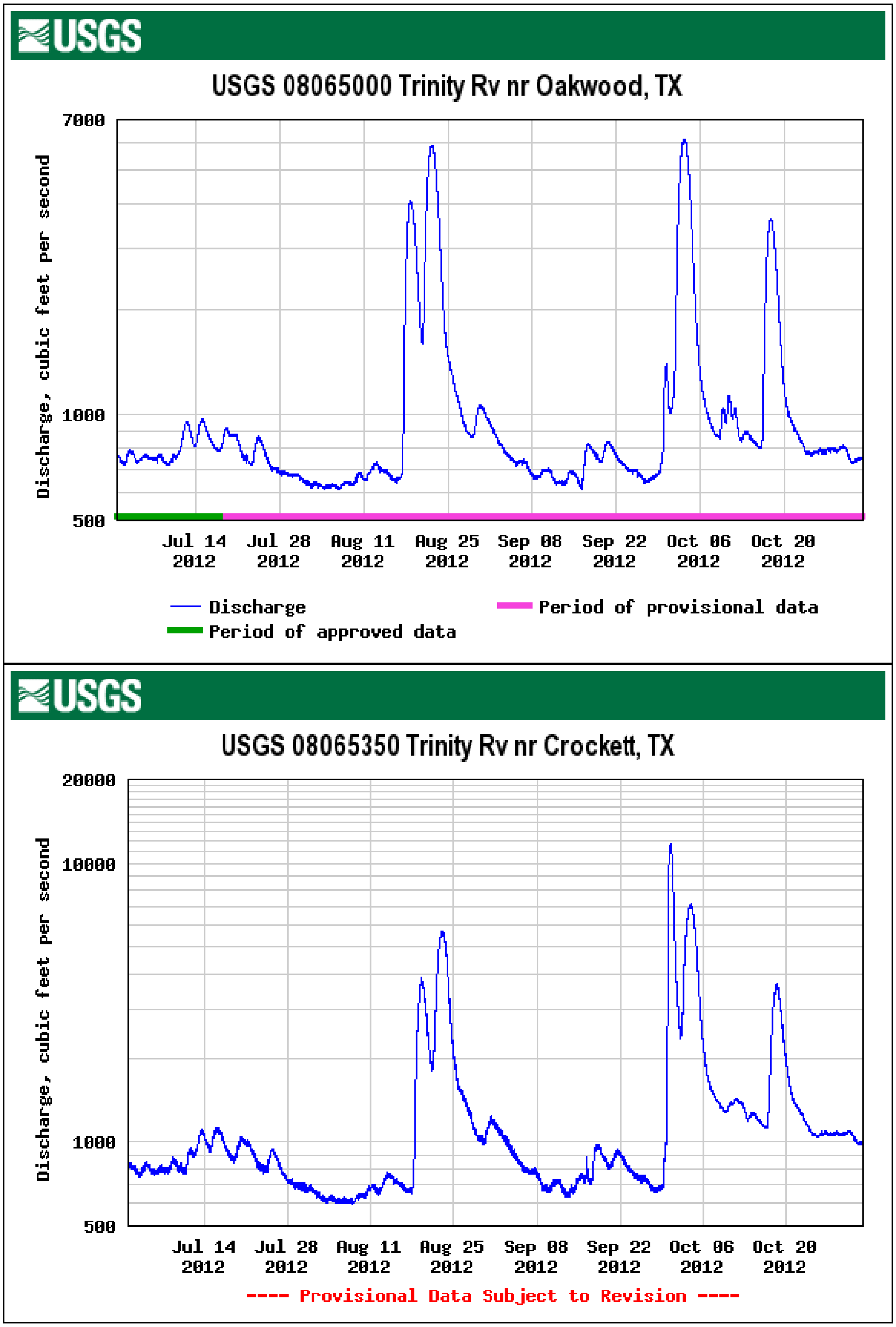


Figure 7. USGS hydrographs for Trinity River near Oakwood and Trinity River near Crockett

4.3.2 LT444 – Long Term site installation

A field effort was initiated in 2013 in response to the erosion undermining and breaching of the lock structure near river mile 444. The purpose of the field effort was to measure cross-sections to establish a baseline condition for future monitoring of river changes. Following the structural failure of the left portion of Lock 3, the local grade control was removed resulting in a stream base level reduced by 5ft to 7ft. This is anticipated to have an impact on the local bank and channel erosion processes.

Activities in 2013 for two field trips included:

- Installation of 5 on-site survey reference points
- Cross-section surveys using RTK GPS, traditional leveling and echosounding
- Flow and velocity measurements
- Bathymetry surveys
- Bank profile survey using an robotic laser scanner
- Installation of erosion pins
- Water surface slope, profile and water level measurements.

Data will be processed during 2014. A description of the site is provided in Appendix A – SITE DESCRIPTIONS AND DATA. The site location is shown on Figure 1.

4.4 Biological monitoring

4.4.1 2012 – TRA biological baseline sampling – DFW-area portions of the Trinity River

Instream biological, habitat, flow and water quality data was by TRA, BIO-WEST and RPS under TRA contract at two sites on the Trinity River within Area A (between Fort Worth and Dallas). Biological data recorded consists of fish, invertebrate and mussel sampling. Fish abundance was recorded for multiple shocking and seine hauls at each site across a range of habitats. Habitat characteristics (velocity, depth, substrate and water quality) were recorded inside each sample area. Flow measurements were collected along with point water quality field parameters (temperature, DO, conductivity, pH).

Data is currently being processed by TRA. This section will be updated when data QA/QC and analysis is complete.

4.4.2 2012 – SB2 biological baseline sampling

In 2012, the SB2 TIFP agencies and TRA conducted fish, mussel and invert data collection efforts on the middle Trinity.

Instream biological, habitat, flow and water quality data was collected under TWDB/TPWD contract with TRA at six sites on the Trinity River within Area B, C and D. The focus is on Middle Trinity Area C, with one upstream and one downstream bracket site in each of Areas B and D.

Biological data recorded consists of fish, invertebrate and mussel sampling. Fish abundance was recorded for multiple shocking and seine hauls at each site across a range of habitats. Habitat characteristics (velocity, depth, substrate and water quality) were recorded inside each sample area. Flow measurements were collected along with point water quality field parameters (temperature, DO, conductivity, pH).

The following sites were sampled in 2012:

- 080423 - Segment B4 – RM423 – (State Highway 34) Area near “upper falls” bifurcated riffle area, downstream of SH34 and USGS Rosser gage.
- 080409 – Segment C1 – RM409 – (FM85/FM1129) Area immediately downstream of “Trinity Falls”, a significant grade control.
- 080354 – Segment C2 - RM354 – (US287) Site near highway 287, upstream of confluence outfalls from Richland-Chambers and Cedar Creek Reservoirs.
- 080295 – Segment C3 - RM295 – (US79/US84) Site near confluence of Keechi Creek.
- 080242 – Segment D1 - RM242 – (State Highway 7) Downstream of Lock #6; coupled with a site at RM 245 upstream of the lock near Hurricane Shoals.
- 080214 – Segment E - RM 212 – (State Highway 21) In the headwaters of Lake Livingston.

Data was processed by TRA and TIFP (TRA and TPWD 2014) and this section will be updated when the report is finalized.

4.4.3 2013 - SB2 coordination, site Identification and biological sampling

Initial Senate Bill 2 (SB2) stakeholder meetings have been conducted by Texas Instream Flow Program (TIFP) agencies (TCEQ, TWDB, TPWD) and cooperators (TRA) in 2013. A Study Design document is in-progress, and will be taken to stakeholders in 2014. A meeting in June 2013 with TIFP and TRA (and consultants) was held to coordinate field efforts and identify SB2 study sites and study elements (

Table 4). Study elements include field studies and analysis, and also include hydraulic parameters (flow, velocity, depth, water surface profiles) as necessary to facilitate modeling and analysis.

In 2013 substrate mapping field data was completed for 3 sites (080423, 080354, 080295).

Table 4. SB2 study sites and elements

TRA Reach	SB2 site	River miles	Nearby landmark	SB2 Study Elements			
				Riparian	Mussel	Macro-invertebrate	Fish
B4	080423	424.5-422	SH34 – Grass Farm		X	X	X
C2	080354	346.5-342	US287	X	X	X	X
C3	080295	297-291 (HSI 296-293)	US79/US84 - Oakwood	X	X	X	X
D1	080242	242 (TBD)	SH 7 – Lock 6, Crockett	X (evaluate LT232 as riparian)	X	X	X

4.5 Water surface profile and sediment modeling

4.5.1 Four long-term sites

A HEC-RAS hydraulic model was developed in 2012 to determine computed water surface elevations for each of the long-term study sites.

Steady-state models of water surface elevation have been used to predict pulse flow event water levels. Detailed information is included in APPENDIX B - Water Surface Profile Modeling.

4.5.2 LT295 near USGS Oakwood

In 2013, the preliminary model was updated at LT295 to investigate:

- inundation of vegetation and riparian areas by a suite of pulses
- transport initiation of sediment grain sizes at particular pulse flow levels.

Detailed information is included in APPENDIX C – 2013 – LT295 Inundation, riparian and sediment modeling. Flood flows lower than 21,000 cfs are generally between the banks. Higher flows spread out into the flood plain.

The riparian investigation was initiated to evaluate the types and acreage of riparian habitat inundated across a range of pulse flows. The first test case was conducted near the LT295 site and is based upon readily available riparian information combined with the HEC-RAS models and inundation maps.

Sediment shear stress modeling indicate that sand is continuously being transported. Gravel transport occurs in typical reaches of Area C between flows 2,500 and 30,000 cfs. Maximum sediment transport capacity occurs at 10,000 cfs. Cohesive sediments are predicted to erode for flows between 5,000 cfs and 13,000 cfs.

5.0 Next Steps and Recommendations for Continued Work

The long-term sequence of study topics is presented in Section 1.6, Table 3.

This section identifies specific planned activities or specific recommendations based upon the results of earlier activities.

5.1 Annual cross-section monitoring

5.1.1 Monitoring sites and data recommendations

To continue this channel morphology monitoring program the following steps are recommended:

- Develop a data archive framework for past and future long-term data
- Complete data processing for longitudinal survey between Lake Livingston and Trinity Bay
- Assess level of survey accuracy in relation to anticipated long-term channel movement and monitoring cycle
- Install headpins and tailpins on opposing banks for all cross-sections at existing LTM sites, specifically LT295
- Continue cross-section monitoring at existing sites, particularly LT444
    - Monitor on a regular cycle (cycle to be refined based upon accuracy assessment, assume a 5-year cycle)
    - Monitoring events should encompass both hydrologically stable periods and should also be triggered by significant flood events
- Add additional LTM sites to encompass a broader range of observed conditions:
    - the “backwards” site at mile 309 would make a great comparison to the natural WMA site at LTM 295
    - Add cross-sections upstream in segment A1, A2, A4

At the end of baseline sampling, a set of easily-understood indicators should be chosen. These indicators should communicate levels of change observed through this field work, and should also communicate which are the most influential active processes affecting change.

5.2 Water surface profile modeling

The recommended next steps for the water surface profile modeling include:

- HEC-RAS model for LT444; evaluate existing models accumulated from USACE
- Continue model sediment evaluation
    - At LT295, incorporate erosion pin data and resurvey of XS1 and XS2; compare channel migration data in light of (a) recent pulse flows and (b) sediment transport capacity predictions
- Incorporate additional calibration data and refine pulse flow water level predictions
- Conduct riparian vegetation survey at LT295
- The predicted water level should be used to photographically compare to observed vegetation lines and top of bank elevations.
- Extend and connect HEC-RAS model between multiple long-term sites
- Improve the water surface profile models at LT422 and LT395 to take advantage of 2012 data for pulses, erosion pins and repeat cross-section measurements.
- Initiate water quality functions in HEC-RAS; develop an unsteady RAS model as first step

6.0 References

[EC] Espey Consultants, Inc. 2011. Trinity River Long-Term Study – DRAFT Study Plan Document 2012. Submitted to TRA December 21, 2011.

Osting, T. and B. Hodges. 2007. Estimating uncertainty of 2D hydraulic models used for aquatic habitat modeling studies. University of Texas Center for Research in Water Resources Online Report 07-03. http://www.crwr.utexas.edu/reports/2007/rpt07-3.shtml

[TRA and RPS Espey] Trinity River Authority of Texas and RPS Espey. 2012. Trinity River Reconnaissance Survey 2011 – DRAFT Data Review, Summary and Analysis. Internal project report, March 30, 2012.

[TRA and TPWD] Trinity River Authority of Texas and Texas Parks and Wildlife Department. 2014. Supplemental Biological Data Collection, Middle Trinity River Priority Instream Flow Study, Draft Report. Prepared under Texas Water Development Board (TWDB) interlocal contract 1148321527. October 11, 2013.

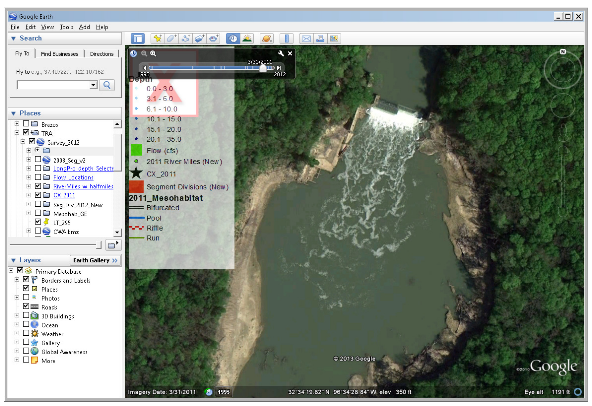
7.0 Appendix A – SITE DESCRIPTIONS AND DATA

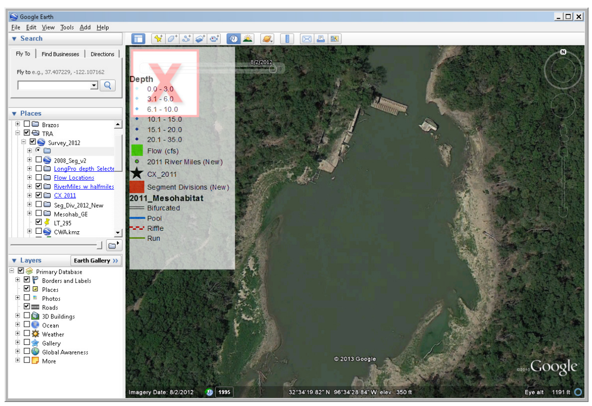
7.1 B1/B2 – LT444

This area is located at the boundary between segment B1 and B2, approximately 2 miles downstream of Malloy Bridge Road, approximately 32 river miles upstream of Trinity Falls, and in the immediate vicinity of a lock and dam structure (Lock 3) that failed between July 2011 and April 2012.

Prior to the failure, the lock served as a local grade control with water surface drop of 5 ft to 7 ft. A long term monitoring effort is being conducted at this site to quantify geomorphic response to the change in grade control. Five permanent benchmarks have been installed for each of five cross-sections.

Data processing is in-progress and this information will be updated when data is available.





03/31/2011 08/02/2012 (breach is apparent 04/04/2012)

Lock 3 historical aerial imagery

Looking upstream at left bank, from below USACE Lock 3; July 2011.

Benchmarks

Point	Easting	Northing	Elevation	Notes
				XS1
				XS2
				XS3
				XS4
				Lock Eye Bolt
				Lock Bolt 5 (from right)
				Lock Bolt 7 (from right)
				Lock Bolt 11 (from right)
				XS5

Erosion pins and chains

Point	Easting	Northing	Elevation	Notes
				XS3 LB erosion pin
				XS3 RB erosion pin

Locations for sediment and water quality data

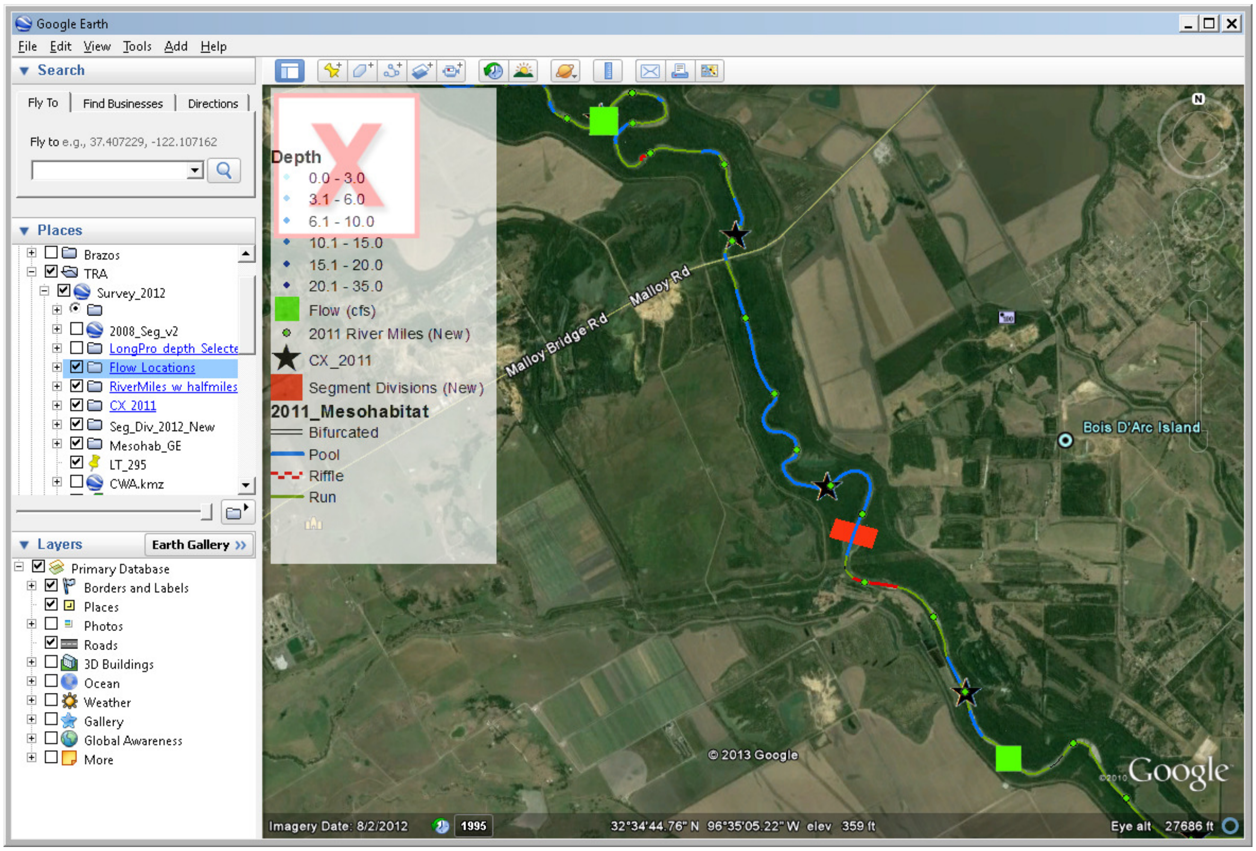
(none at this time)

Water quality location description

(none at this time)

Water quality summary statistics

(none at this time)



Mesohabitat (2011) in the vicinity of LT444

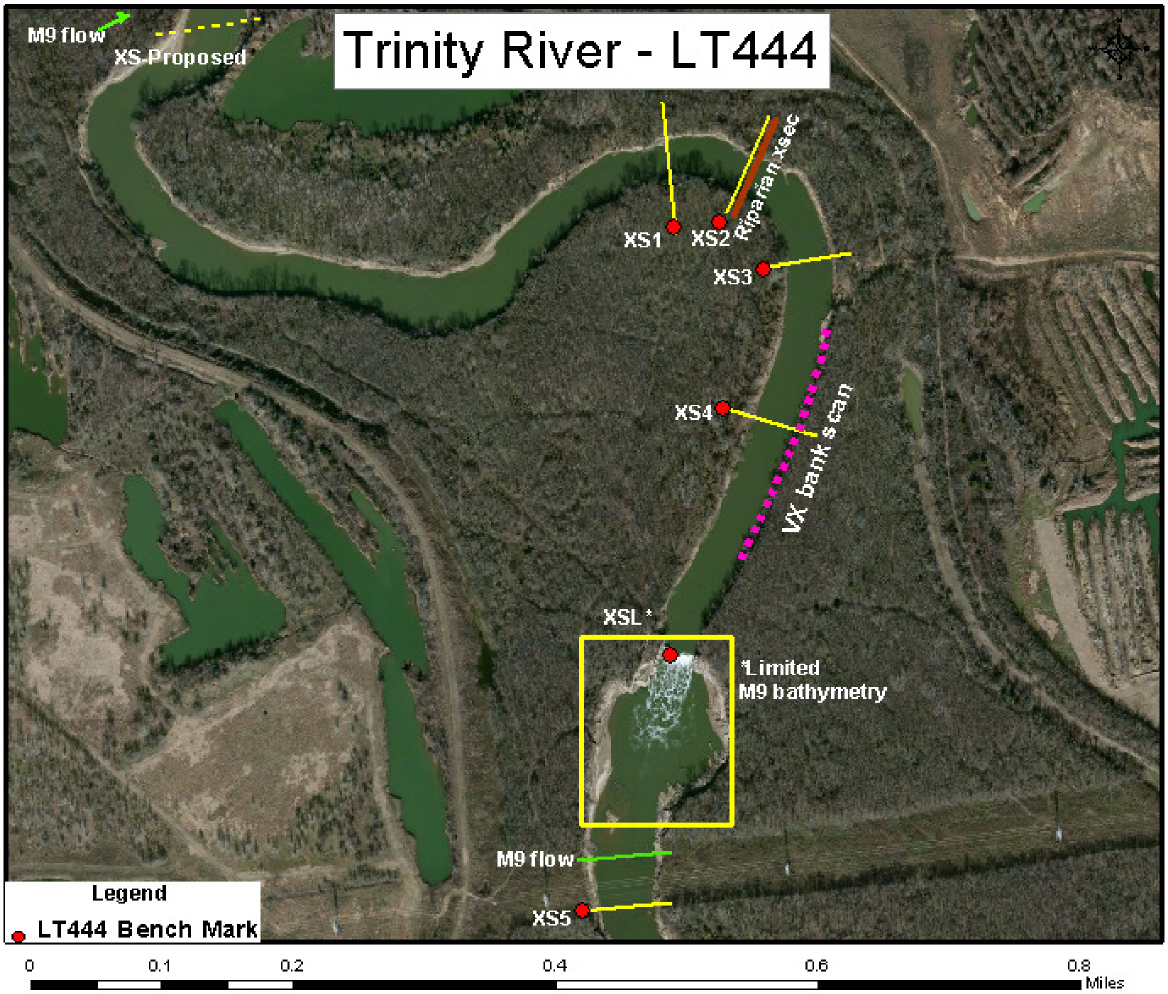


Figure 8. B1/B2 - LT444 – Lock3 site with approximated Nov 2013 field work locations

7.2 B4 – LT422

This area is located approximately 10 river miles upstream of Trinity Falls and approximately five miles downstream of the most downstream lock and dam structure (Lock 5).

An existing hard-substrate riffle provides stable grade control at the downstream end of the site (Figure 9). There are no apparent levees adjacent to the site on the right (south) bank and the riparian area on both sides of the site exhibit a range of vegetation age classes. The left bank and both banks for the next 10 miles downstream of the site incorporate levees and channel modification (straightening) for flood control.

Benchmarks

Point	Easting	Northing	Elevation	Notes
LT422 Benchmark	2601959.071	6841716.768	330.06	LT422_XS1

Erosion pins and chains

Point	Easting	Northing	Elevation	Notes
xs_02_eropin01LB	2603744.405	6840770.901	306.455	LT422_XS3; all these pins are close or on XS3
xs_02_erochain01	2603732.896	6840755.303	299.131	LT422_XS3; all these pins are close or on XS3
xs_02_erochn02	2603649.649	6840739.995	299.257	LT422_XS3; all these pins are close or on XS3
xs_02_eropin02rb	2603608.81	6840619.825	318.601	LT422_XS3; all these pins are close or on XS3

Locations for sediment and water quality data

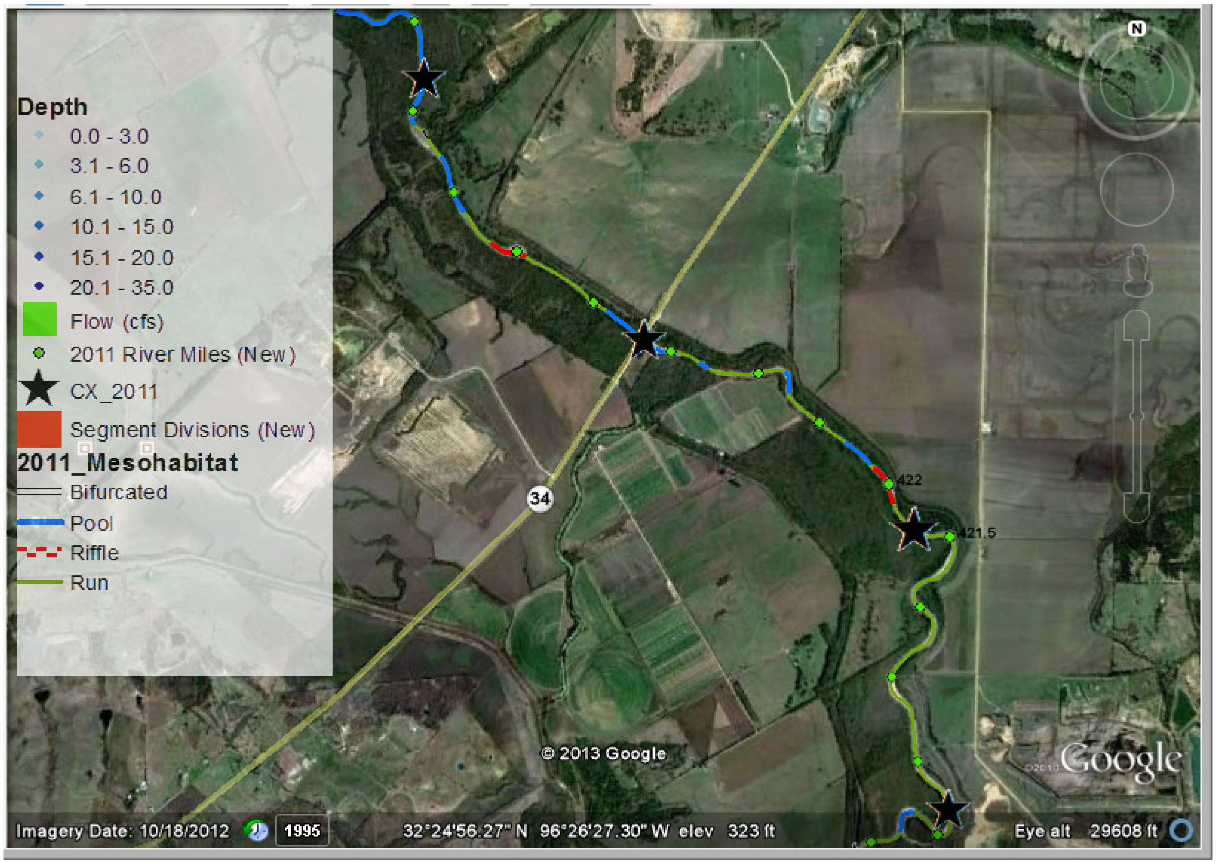
Site	Cross Section	Data Collected	Notes
LT422	XS1	Water Quality	
LT422	XS3	Sediment	

Water quality location description

Site	Date	Approximate location
LT422	July 9, 2012	Run, 100 feet downstream of cross-section 1

Water quality summary statistics

	Temp_ C	SpCond_ mS/cm	Cond_ uS/cm	pH_	ODOsat_ %	ODO_ mg/L
LT422						
min	26.1	0.011	11.0	7.9	88.9	6.6
average	31.0	0.832	927.2	8.1	98.2	7.3
max	31.3	0.842	938.0	8.2	119.3	9.0



Mesohabitat in vicinity of site

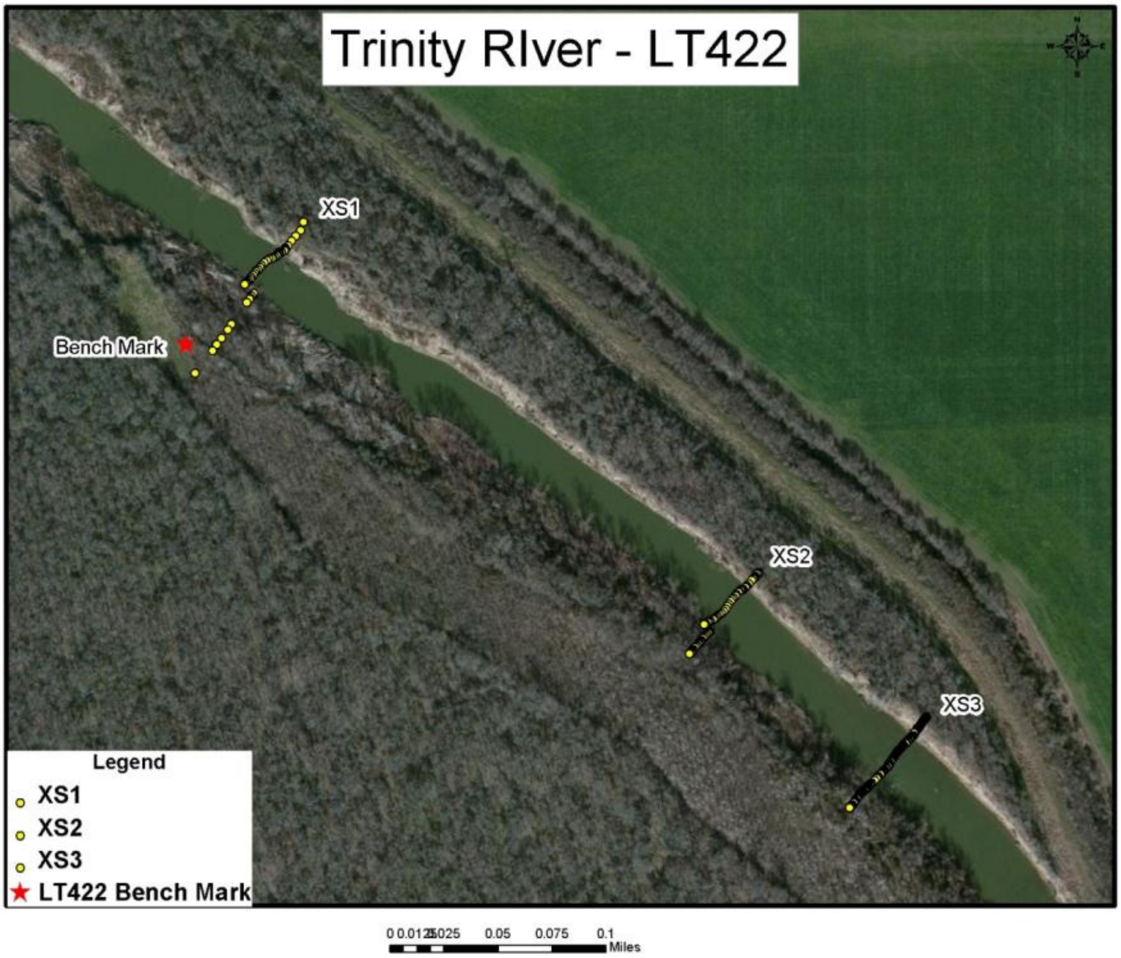
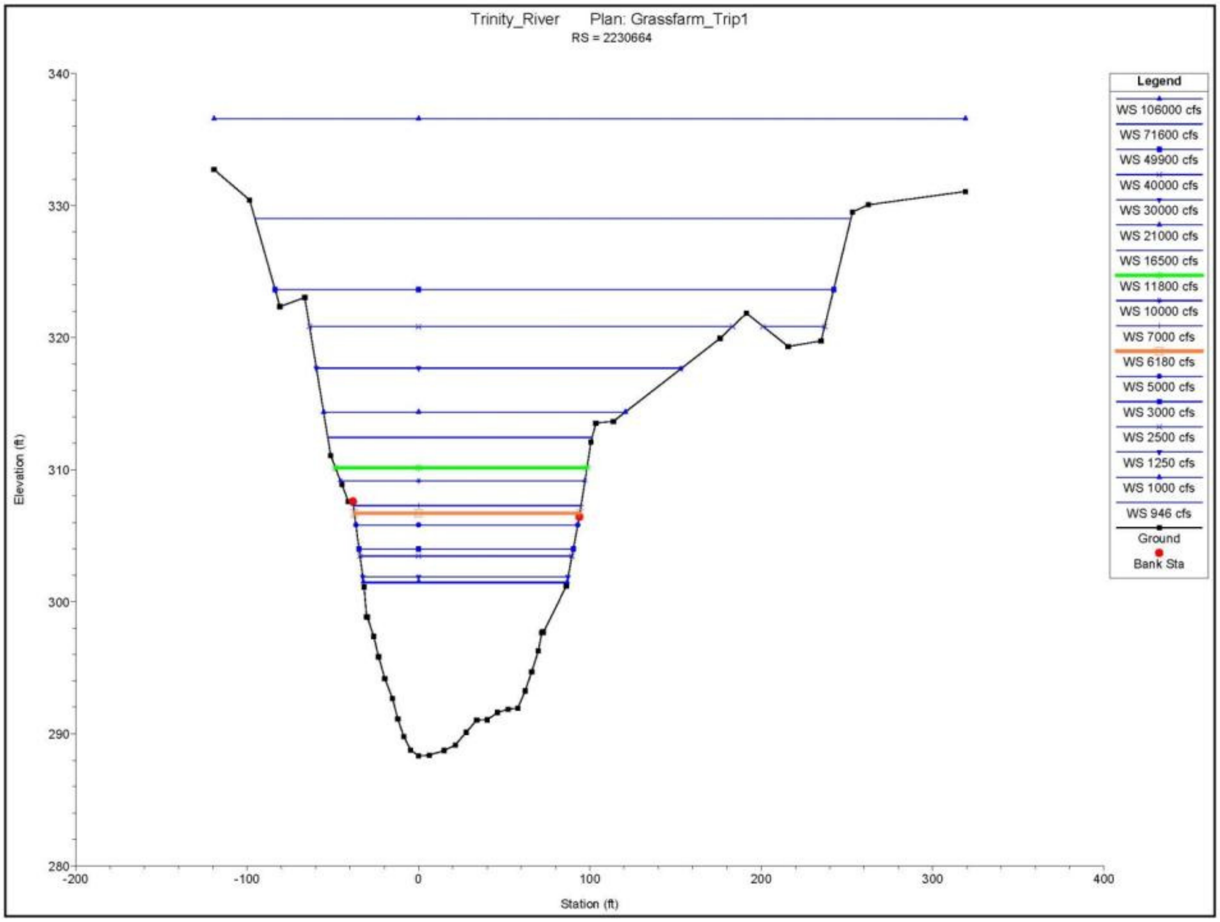
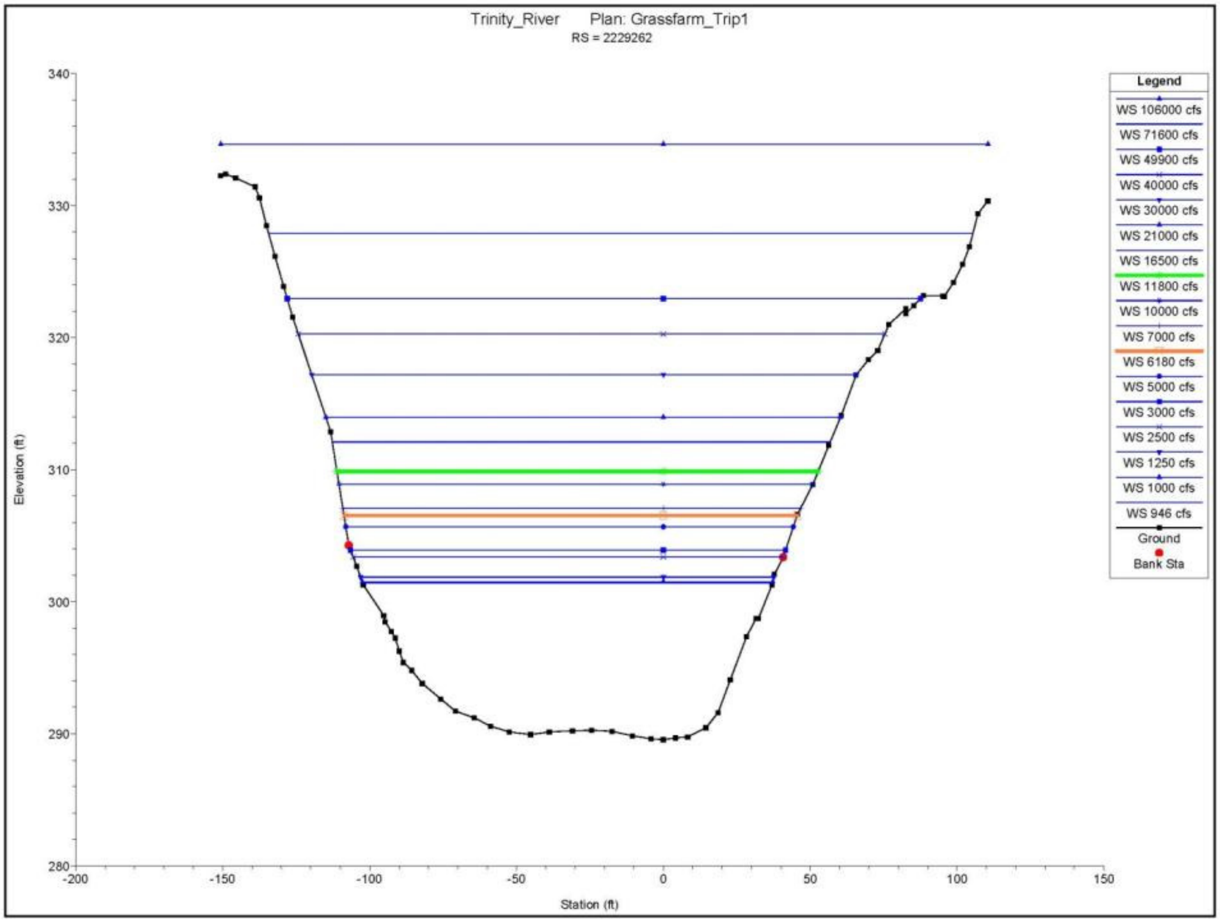


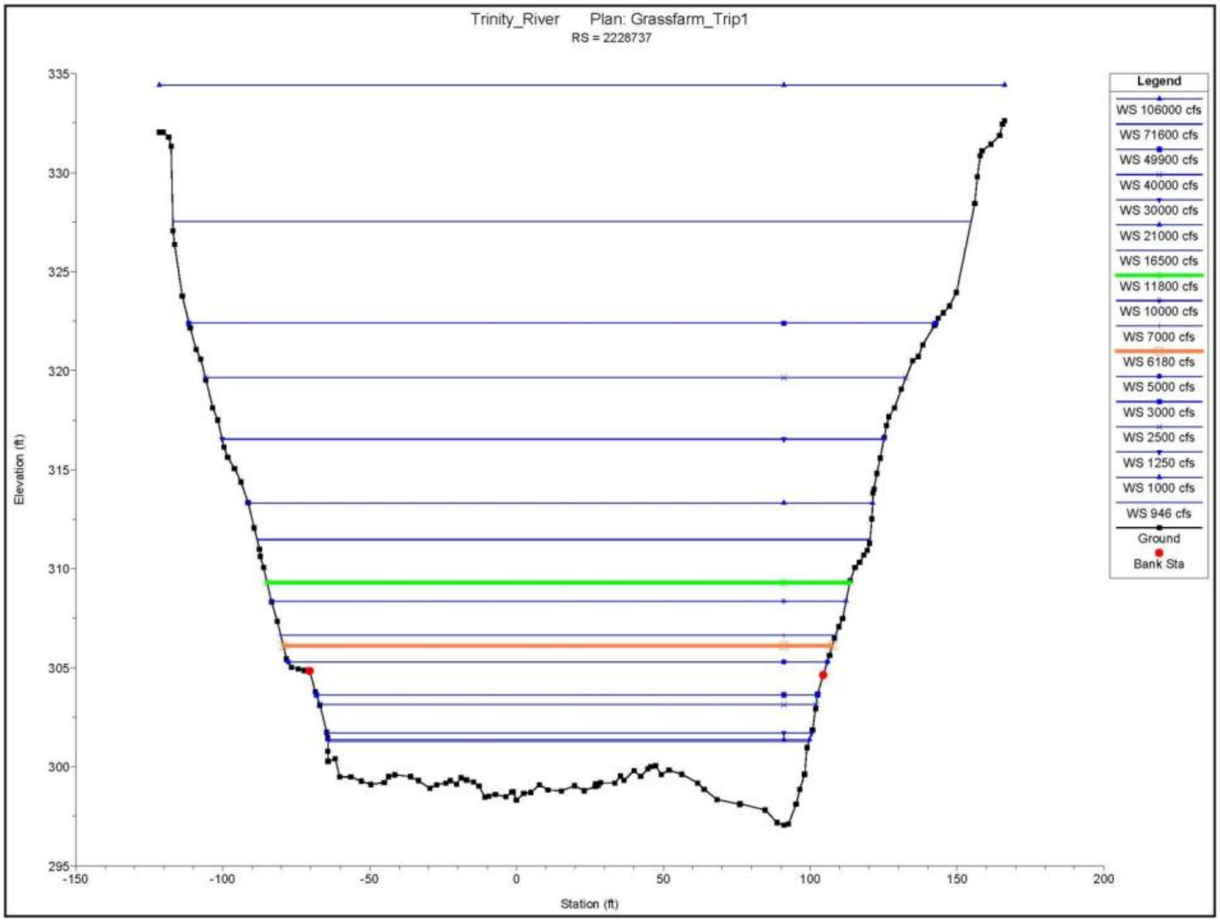
Figure 9. B4 - LT422 - Grass Farm site



HEC-RAS cross-section of XS1



HEC-RAS cross-section of XS2



HEC-RAS cross-section of XS3

7.3 C1 – LT395

This site is located in an area with largely intact riparian zone on both banks (Figure 10). A riffle is located upstream just below a bend. The riffle transitions to a long shallow run or bifurcated riffle with a pool located downstream. The upstream meander bend exhibits significant cut on the outside edge with a deposition bar on the inside edge.

Alternate sites identified during the site selection process are:

Backup1
409
Upstream of FM85
Riparian area adequate on both sides, a little sparse on right bank
Looks like a good site; we have access
Too close to falls?
Riffle and bifurcated nearby

Backup2
407.5 to 407
Downstream of FM85
Riparian area appears mostly intact both sides
Possible LWD source upstream from cleared, eroding bend
Bifurcated near 407.5
Run near 407.25 appears stable (looking at GE historical photos)
Intensive mesohab at 406.75

Benchmarks

Point	Easting	Northing	Elevation	Notes
LT395 Benchmark	2658987.01	6784181.77	295.2	LT2395_XS2

Erosion pins and chains

Point	Easting	Northing	Elevation	Notes
xs1_lb_eropin	2658724.715	6784581.438	280.029	LT395_XS1
xs1_rb_ero chn	2658653.621	6784469.465	269.941	LT395_XS1
xs1_rb_ero pin	2658617.515	6784415.218	280.528	LT395_XS1
xs4_lb_eropin	2658995.564	6783115.314	278.196	LT395_XS4
xs4_lb_7	2658855.352	6783058.099	278.621	LT395_XS4

Locations for sediment and water quality data

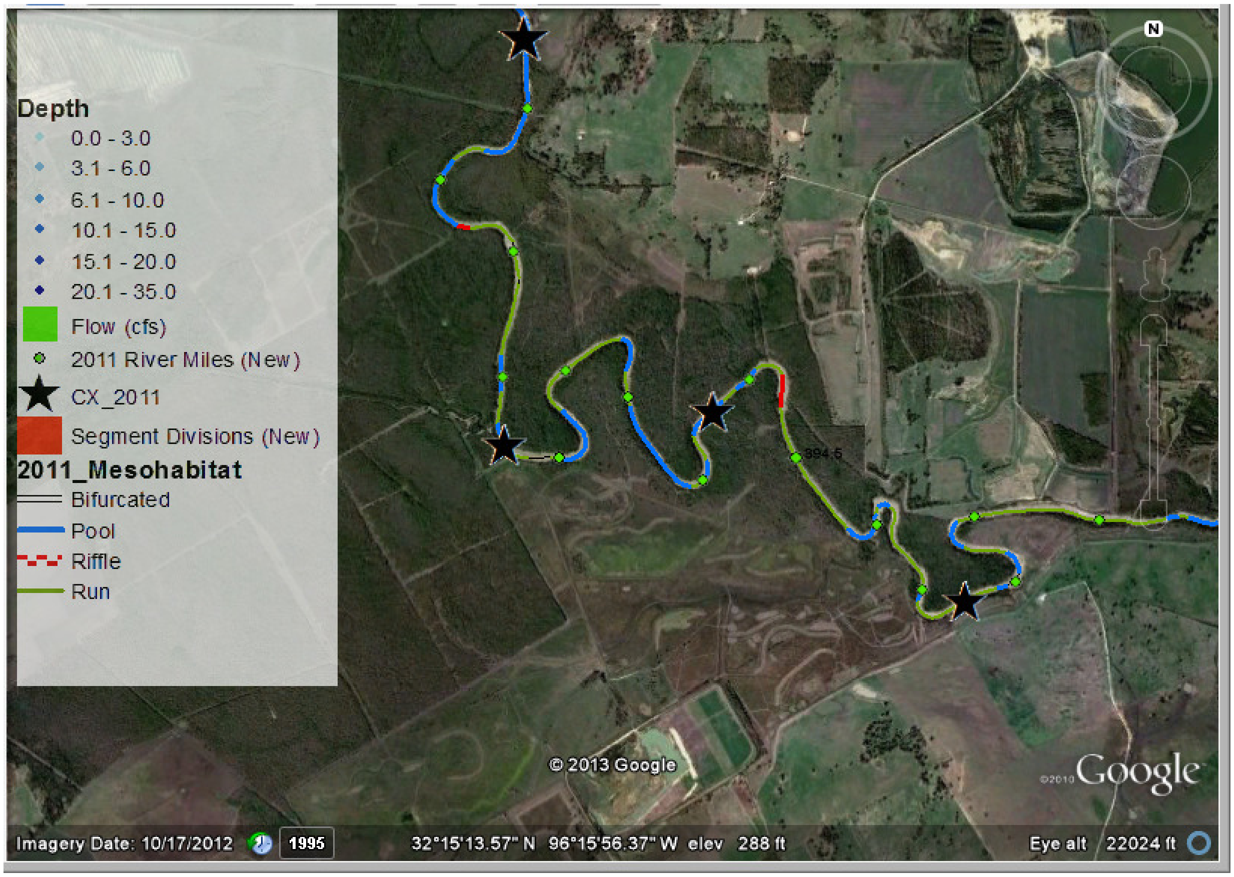
Site	Cross Section	Data Collected	Notes
LT395	XS2	Sediment	
LT395	XS3	Water Quality	

Water quality location description

Site	Date	Approximate location
LT395	July 10, 2012	Run, 25 feet downstream of cross-section 3

Water quality summary statistics

	Temp_ C	SpCond_ mS/cm	Cond_ uS/cm	pH_	ODOsat_ %	ODO_ mg/L
LT395						
min	30.0	0.016	17.0	8.1	86.4	6.5
average	30.6	0.820	907.4	8.1	87.3	6.5
max	30.7	0.824	914.0	8.1	93.4	7.0



Mesohabitat in vicinity of site

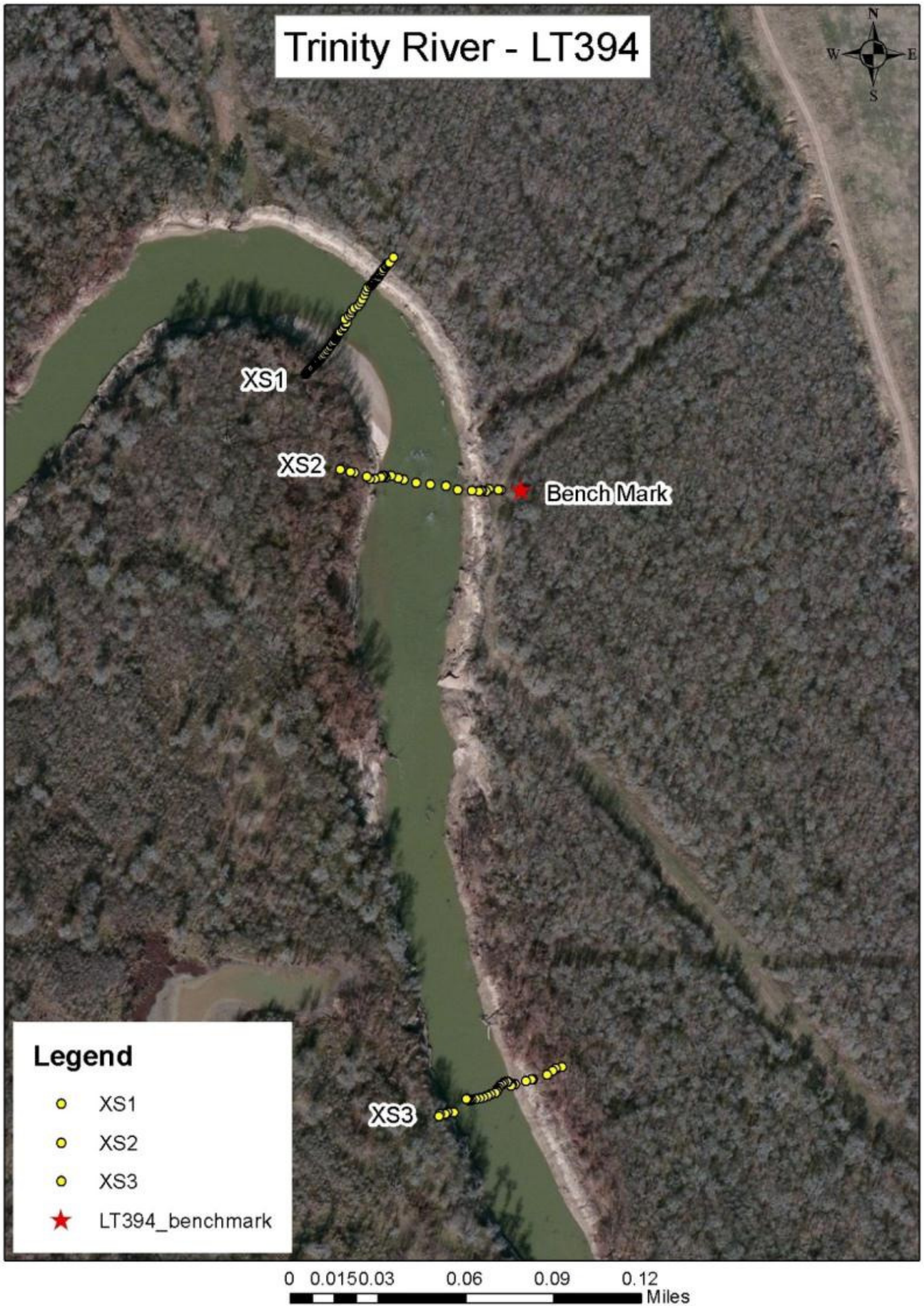
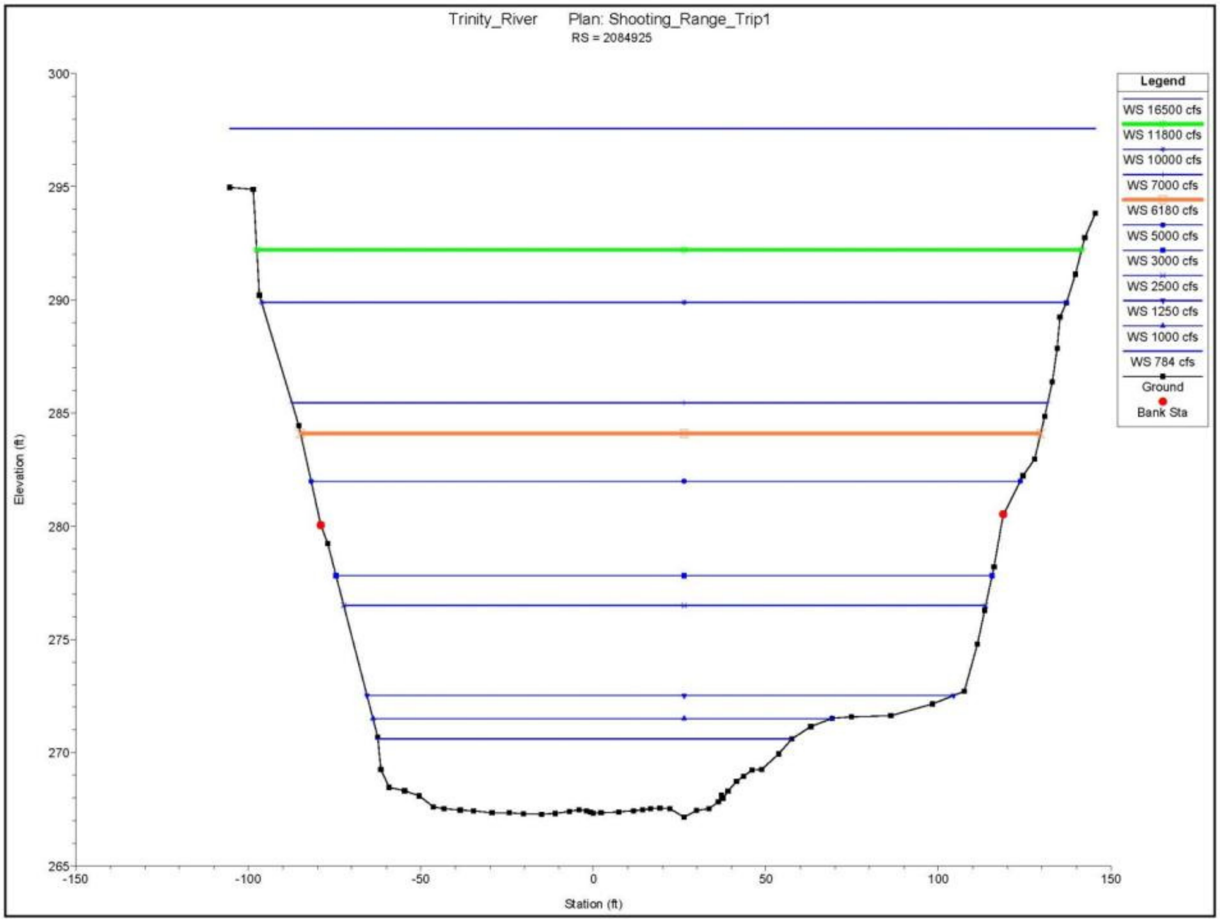
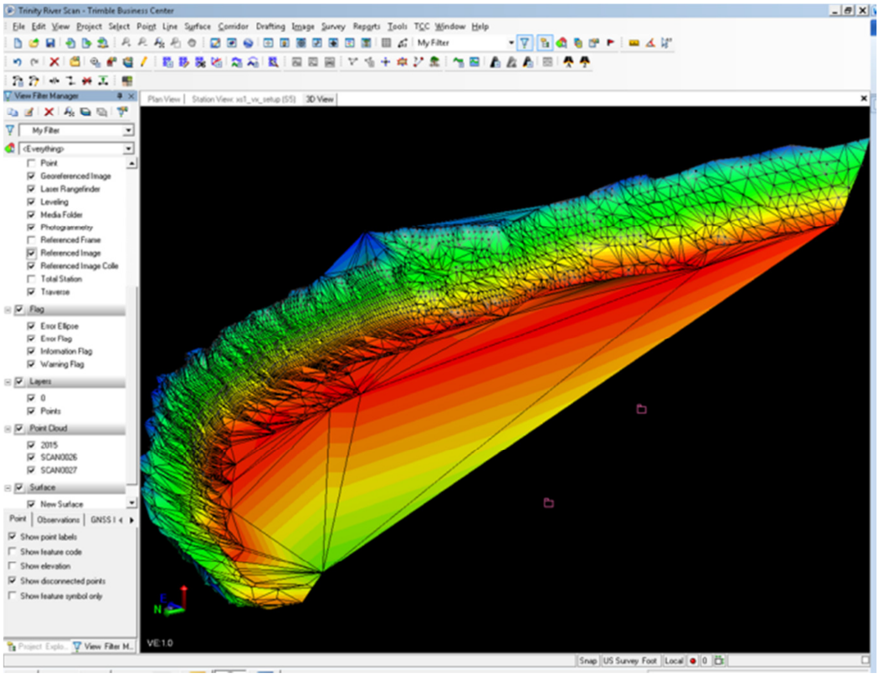


Figure 10. C1 - LT395 - Shooting Range Site

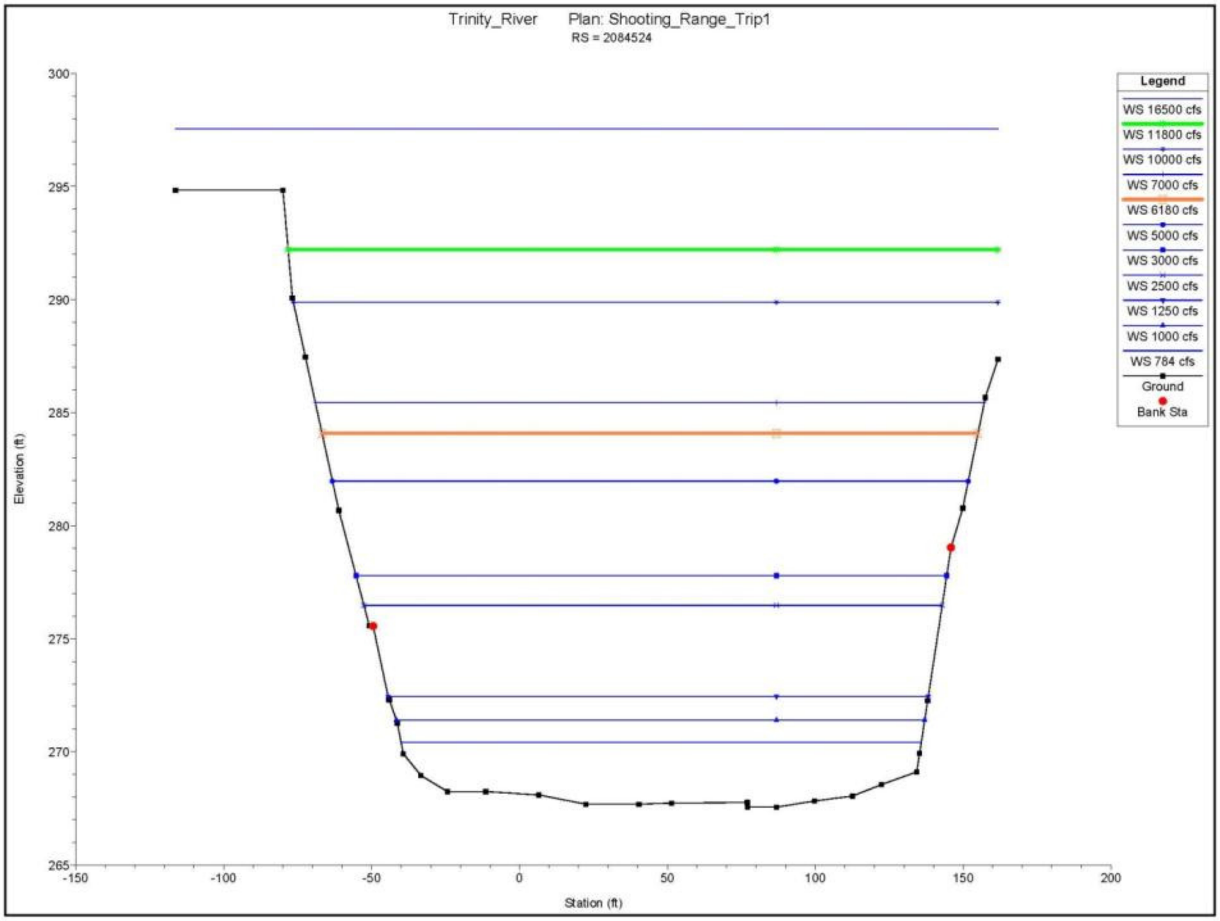


HEC-RAS cross-section of XS1

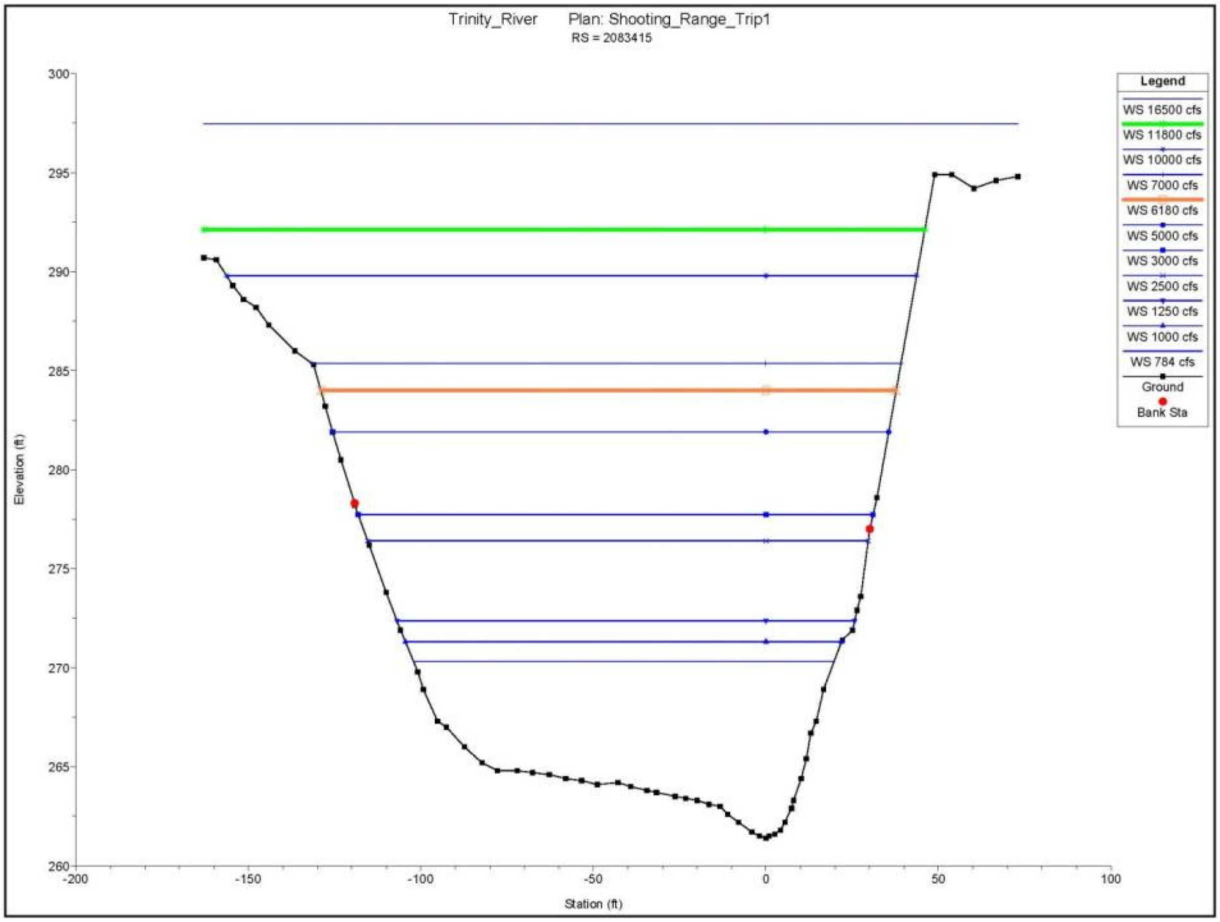
Looking downstream at XS1 and XS2 (boat is on right bank between XS1 and XS2)



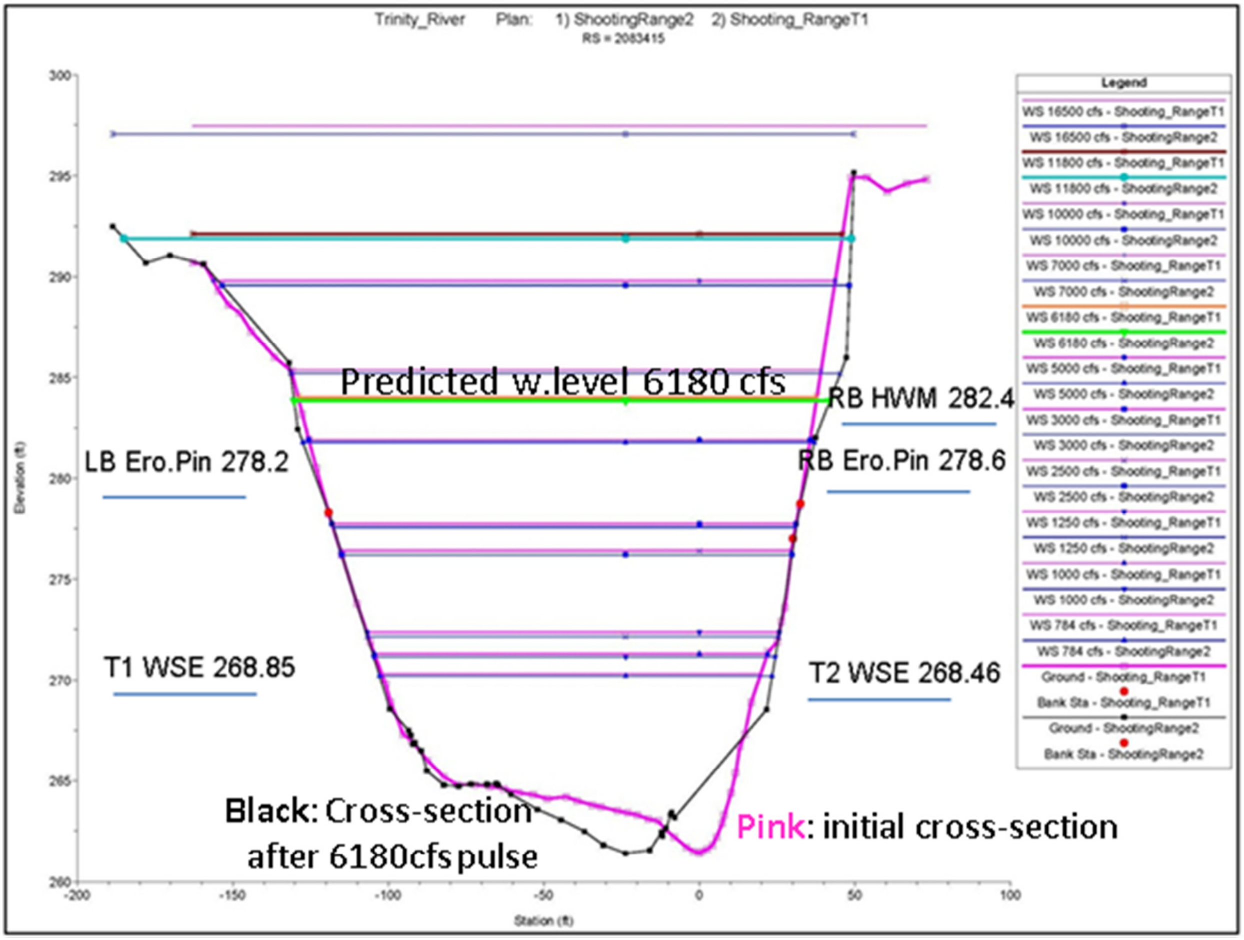
DTM of laser scan of left cut bank from XS1, of XS1 and XS2



HEC-RAS cross-section of XS2



HEC-RAS cross-section of XS3



HEC-RAS cross-section of XS3 before (pink) and after (black) a 6180cfs pulse

	
XS3 Left bank erosion pin after pulse	XS3 Right bank erosion pin after pulse

7.4 C3 – LT295

This site is located near the confluence with Keechi Creek. The upstream end is within the Big Lake Bottom WMP. Riparian areas are intact on both banks, with large tracts of adjacent forest (Figure 11). Near the channel condition of willows indicates recent channel change; willows on a lower terrace near the upstream cross-section lean over toward side channels indicating historical widening. The downstream end of the site is a large riffle a shale outcrop.

Alternate sites considered in this reach:

309.5 to 308.5

Several "backwards runs" with in-channel bars (309.5), stable straight run (308.5)

297.5

Good area but no bifurcated or riffles

Benchmarks

Point	Easting	Northing	Elevation	Notes
LT295 Benchmark	2810892.108	6579111.166	212.999	LT295_XS1

Erosion pins and chains

Point	Easting	Northing	Elevation	Notes
lt295_xs1_lb_ero	2810949.651	6579108.434	195.759	LT295_XS1
lt295_xs1_rb_ero	2811121.9	6579081.213	195.117	LT295_XS1
lt295_xs2_lb_pin	2811691.542	6581768.908	187.648	LT295_XS2
lt295_xs3_lb_rb_ero	2812279.165	6581730.363	191.033	LT295_XS3

Locations for sediment and water quality samples

Site	Cross Section	Data Collected	Notes
LT295	XS1	Sediment	
LT295	XS3	Water Quality	

Water quality location description

Site	Date	Approximate location
LT295	July 11, 2012	Run/Pool, 200 feet upstream of Keechi Creek confluence, 500 feet upstream of cross-section 3

Water quality summary statistics

	Temp_ C	SpCond_ mS/cm	Cond_ uS/cm	pH_	ODOsat_ %	ODO_ mg/L
LT295						
min	30.5	0.843	932.0	8.1	91.1	6.8
average	30.7	0.845	936.4	8.2	93.8	7.0
max	30.8	0.846	940.0	8.2	95.7	7.1

Mesohabitat in vicinity of site

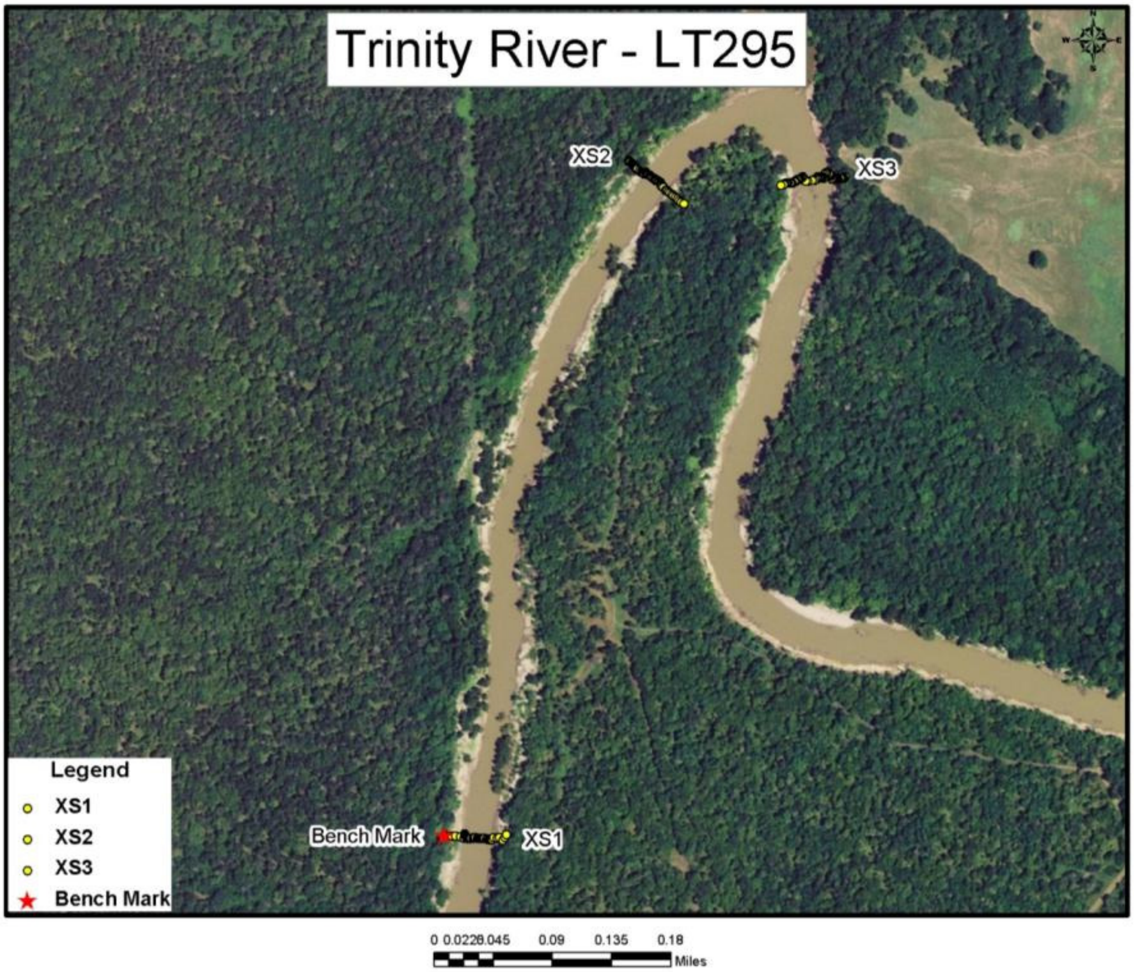


Figure 11. C3-LT295 - Keechi Creek Site

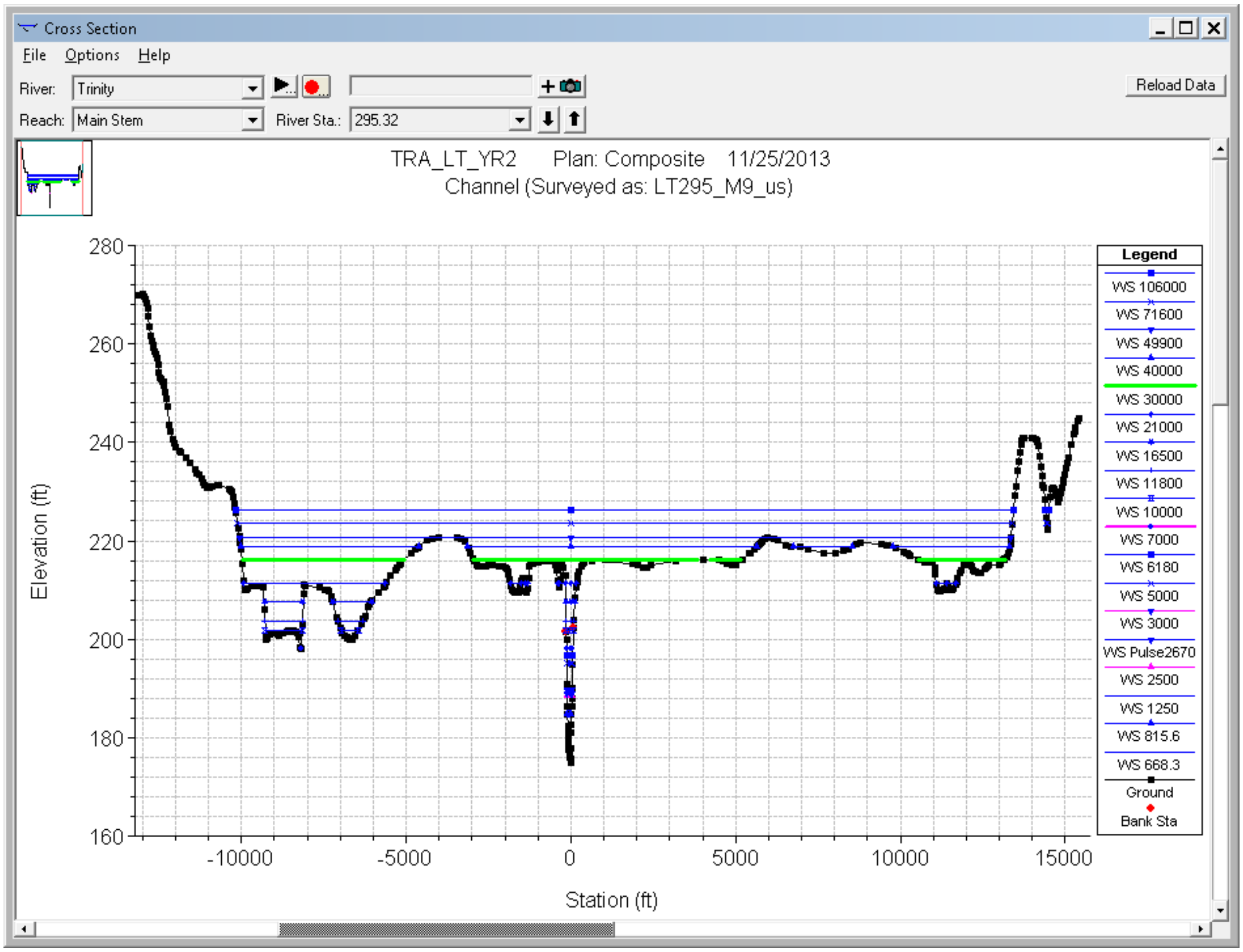


Figure 12. LT295 XS1 - Upstream benchmark cross-section floodplain

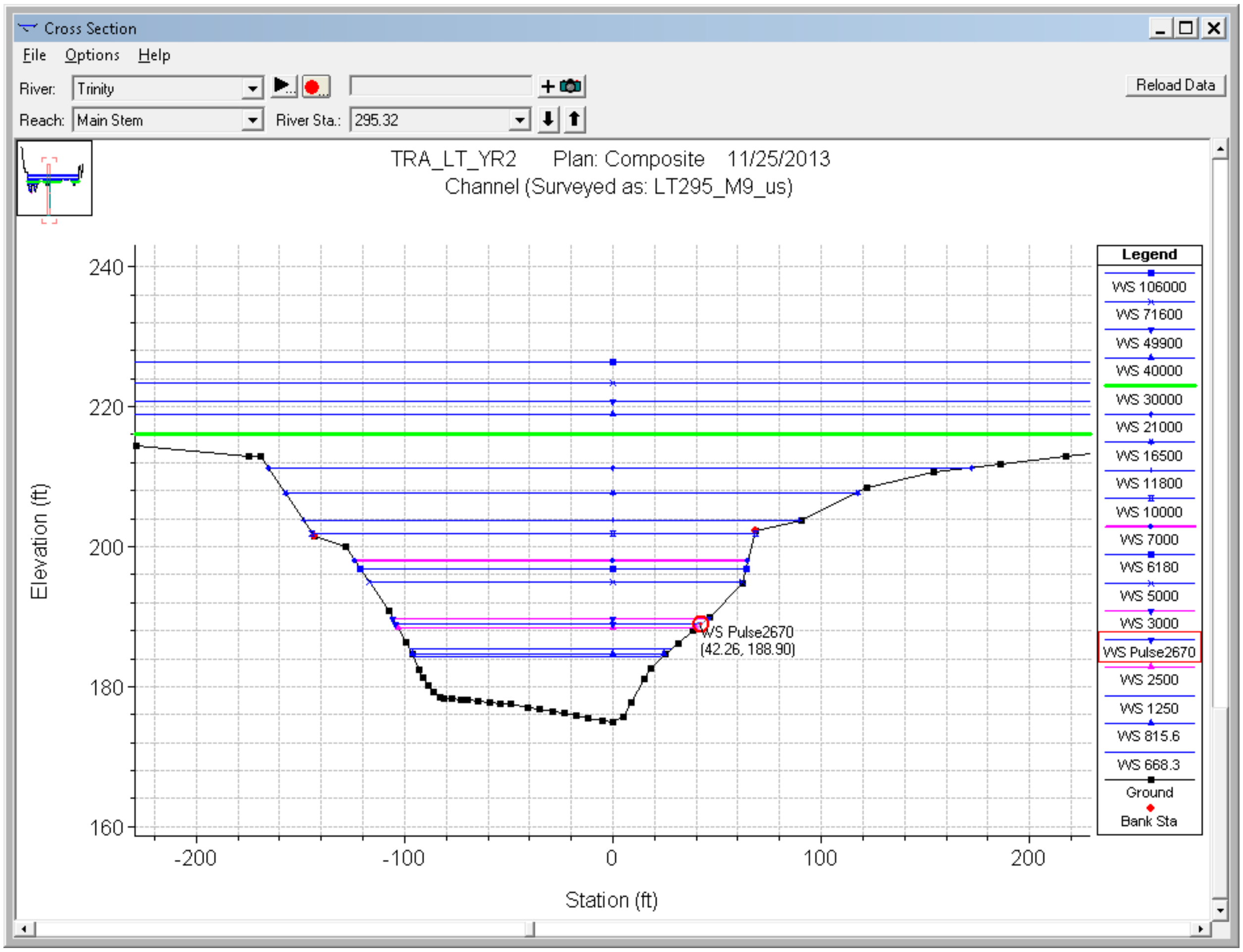


Figure 13. LT295 XS1 - Upstream benchmark cross-section near-channel

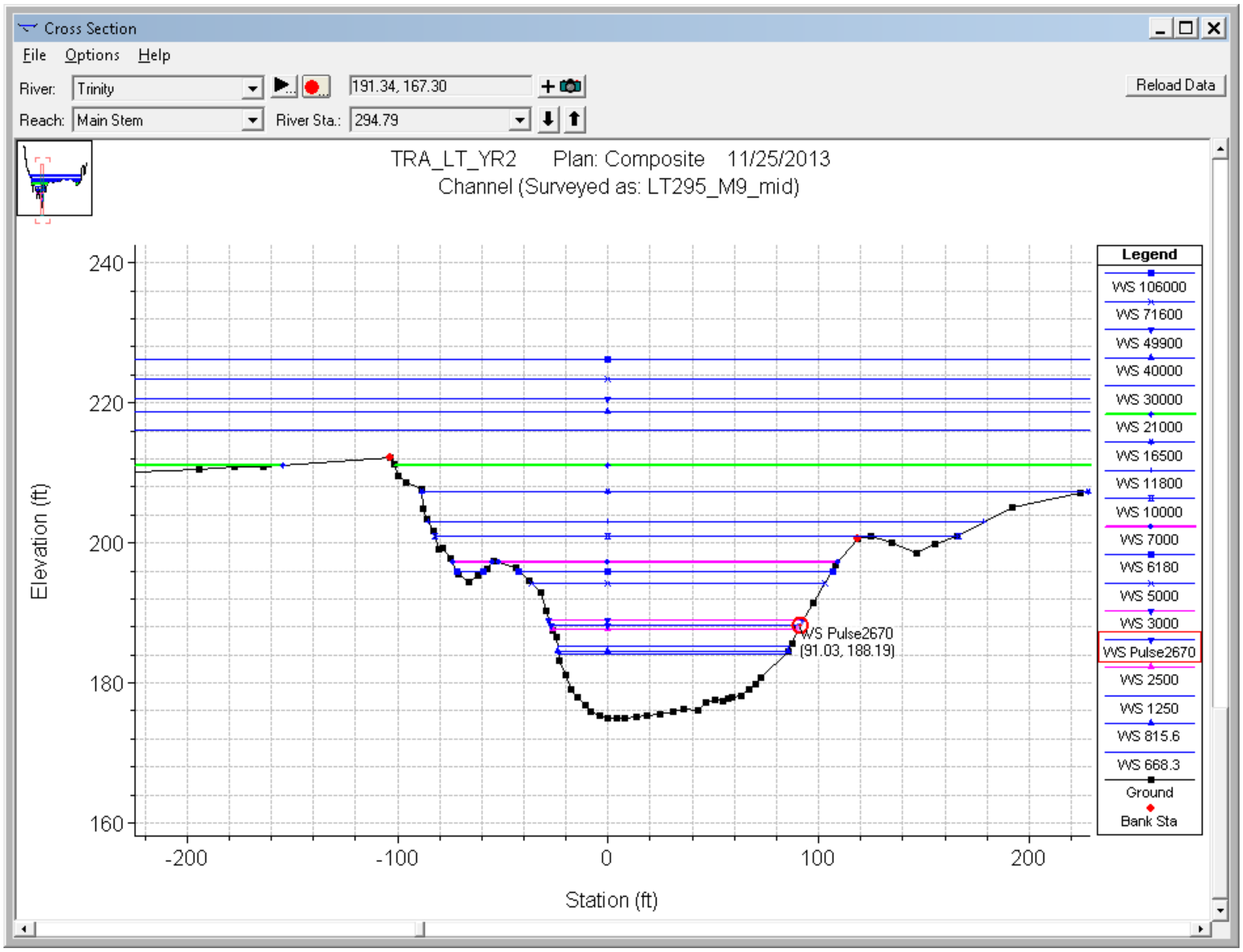


Figure 14. LT295 XS2 - Middle cross-section near-channel

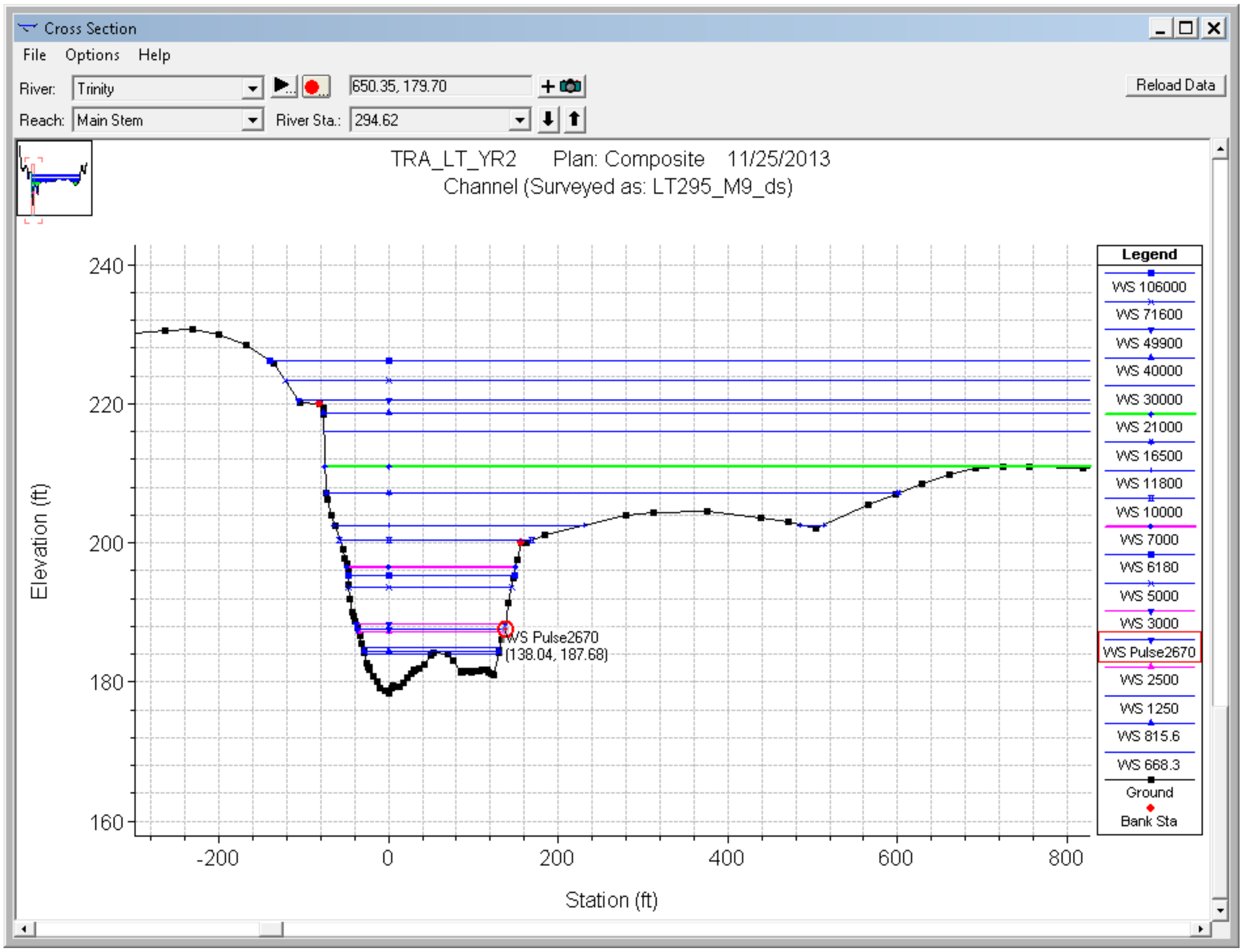


Figure 15. LT295 XS3 - Downstream riffle cross-section near-channel

7.5 D1 – LT232

This is a long site and incorporates a bifurcated riffle at the upstream end transitioning to a long run. The bifurcated riffle was the location of a 2011 mesohabitat survey and temporary benchmark that was located (Figure 16). This site is indicative of this Study Area D between Lock 6 at Crockett and the headwaters of Lake Livingston.

Alternate sites considered in this reach:

239
Pool straightaway; riffle is upstream around bend
243.5
Pool stable; no riffles
Too close to SH7 and lock 6?

Benchmarks

Point	Easting	Northing	Elevation	Notes
LT232 Benchmark	2835190.436	6415223.924	175.389	LT232_XS3

Erosion pins and chains

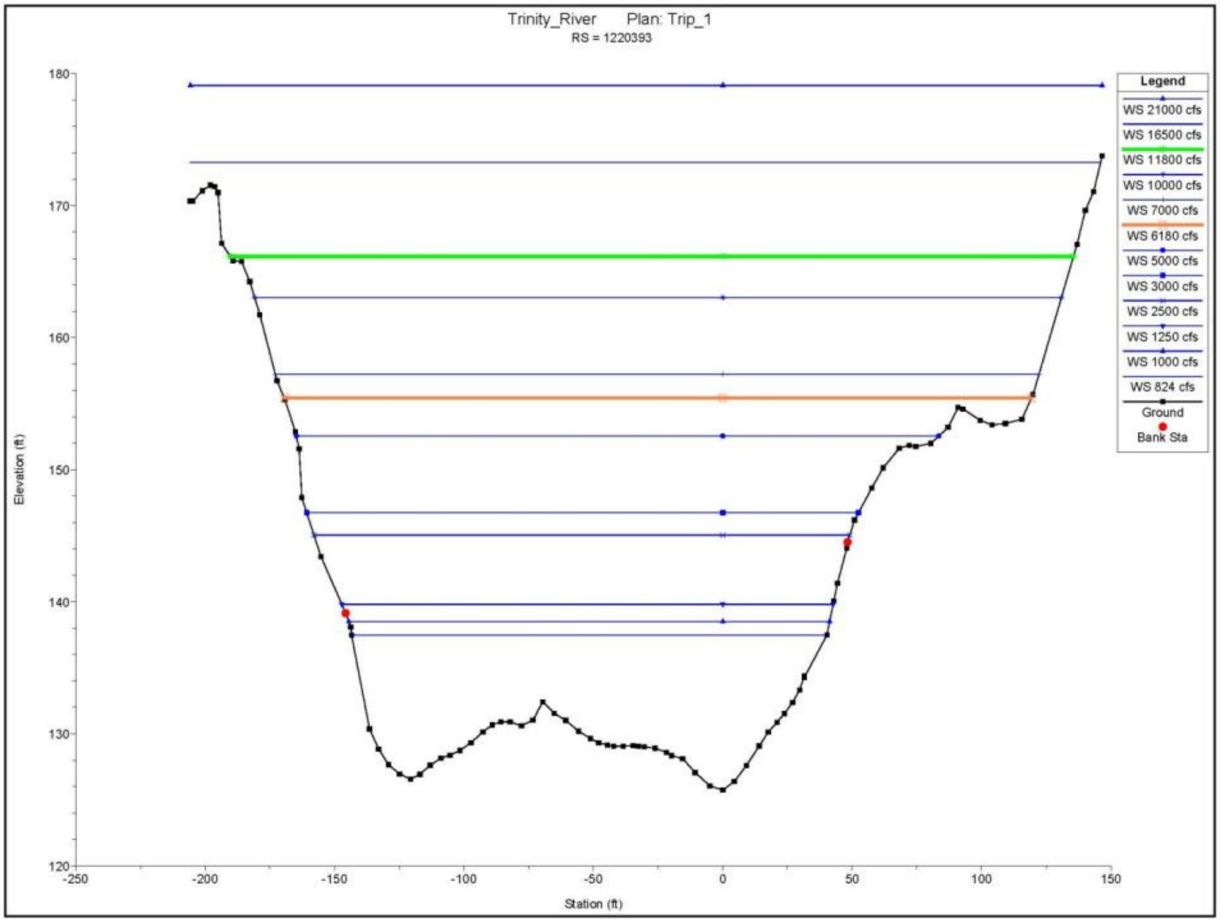
Point	Easting	Northing	Elevation	Notes
xs3_ep_lb	2836007.045	6415055.383	141.968	LT232XS3
xs3_ep_rb	2835808.314	6415040.212	143.448	LT232_XS3

Locations for sediment and water quality samples

Site	Cross Section	Data Collected	Notes
LT232	XS1	Sediment	

Mesohabitat in vicinity of site

Figure 16. D1 - LT232 - CR232 site



HEC-RAS cross-section of XS3

8.0 APPENDIX B - Water Surface Profile Modeling

8.1 Purpose

A hydraulic model is developed in this analysis to determine the computed water surface elevations along the studied segments. This preliminary model is developed to allow for the next phase of this project to investigate:

- inundation of vegetation and riparian areas by a suite of pulses
- impact of sediment transport on channel conveyance and its subsequent effect on cross section geometry.

8.2 HEC-RAS Model Description

Version 4.1.0 of the HEC-RAS computer program developed by the Hydrologic Engineering Center of the USACE is used in this analysis to estimate computed water surface elevations for the studied river segments. The model algorithms used in this assessment are one-dimensional steady-state equations capable of predicting water level based upon downstream boundary conditions, upstream flow input and either normal or critical flow.

Future modeling for dynamic (time-varying) flow conditions will facilitate dynamic sediment modeling.

8.3 Model Inputs

The hydraulic analysis methodology incorporates field data collected during this study. This hydraulic analysis includes modeling for four different segments of the Trinity River, LT422, LT395, LT295, and LT232 as introduced in **Appendix A – SITE DESCRIPTIONS AND DATA**.

Cross sections and stream centerline were entered manually into HEC-RAS. The numbering of river stations is based on the river foot distance along the Trinity River from its confluence terminus at the Gulf of Mexico to the studied cross section location (per 2012 River Miles in TRA and RPS Espey 2012). Downstream reach locations are determined using geographically referenced data. The Manning's n values used in this analysis are 0.03 for the channel and 0.04 for the overbanks.

Computed water surface elevations are computed for a range of flow rate scenarios encompassing observed low-flow conditions, typical pulse flows and large floods.
Flow rates and water surface elevations collected at each studied segment during the reconnaissance trips was used as a rough, initial calibration to determine appropriate downstream boundary condition. The normal depth downstream boundary condition was adjusted such that the observed water surface elevation matches the computed water surface elevation for one cross section from each segment, generally the downstream cross-section. Additional calibration is recommended to match water surface profile measurements at all cross-sections for the observed flow rates.

Table 5. Measured flow rates (Trip 1) used for calibration

Studied Segment	Measured Flow Rate (cfs)
LT422	946
LT395	784
LT295	816
LT232	824

Using the same downstream slope boundary condition, water level was predicted at each of the study segments for pulse and flood flow rates (Table 6). These chosen flow rates were based available flow statistic studies, historical high flows, recent high pulse flows and the Senate Bill 3 (SB3) environmental flow rules for the Trinity River at Oakwood.

8.4 Model Results

The following Figure 17 is for LT422 cross section 3 (RAS station 2230664) and indicates predicted water level for all modeled pulse flow rates. The measured water surface elevation (WSE) from the first trip and estimated high water mark (HWM) from the second trip are included on the figure. Note that the HWM is higher than the HEC-RAS predicted water level for the Oakwood 6,180 cfs flow. Measurement of additional time series water level data that includes multiple pulse peak flows is recommended for each site, along with refinement of the model boundary conditions.

Table 6. Modeled pulse flow rates

Flow Rate (cfs)	Note
1,000	
1,250	1965-2011 HEFR Jan-Jun Wet baseflow
2,500	TCEQ SB3 Oakwood Summer/Fall pulse
3,000	TCEQ SB3 Oakwood Winter pulse
5,000	
6,180	Oakwood pulse 10/03/2012
7,000	TCEQ SB3 Oakwood Spring pulse (and Crocket pulse 10/03/2012)
10,000	
11,800	Crockett pulse 09/30/2012
16,500	1965-2011 HEFR Jan-Jun 1/season
21,000	1965-2011 HEFR Jul-Dec 1/season
30,000	
40,000	
49,900	Oakwood flood peak 10/31/2010
71,600	Oakwood flood peak 07/10/2007
106,000	Oakwood maximum flood peak 12/24/1991 (also 107,000cfs 05/07/1990)

Figure 18 is for LT395 cross section 3 (RAS station 2084524) and shows geometric transformation between Trip 1 and Trip 2. A flow pulse occurred between the trips (Figure 7). The measured water surface elevation (WSE) from the first trip and estimated high water mark (HWM) from the second trip are included on the figure. The measured WSE from both trips are lower than predicted WSE at the flow rates observed during the field effort. The observed HWM is consistent with the predicted water level for the 6,180 cfs Oakwood pulse peak. Additional water level data would confirm that correct assumptions are used for model boundary conditions for both low and pulse flows.

The electronic archive transmitted with this report includes figure images for all cross-sections. Each cross-section figure indicates predicted water surface level at each of the modeled flows.

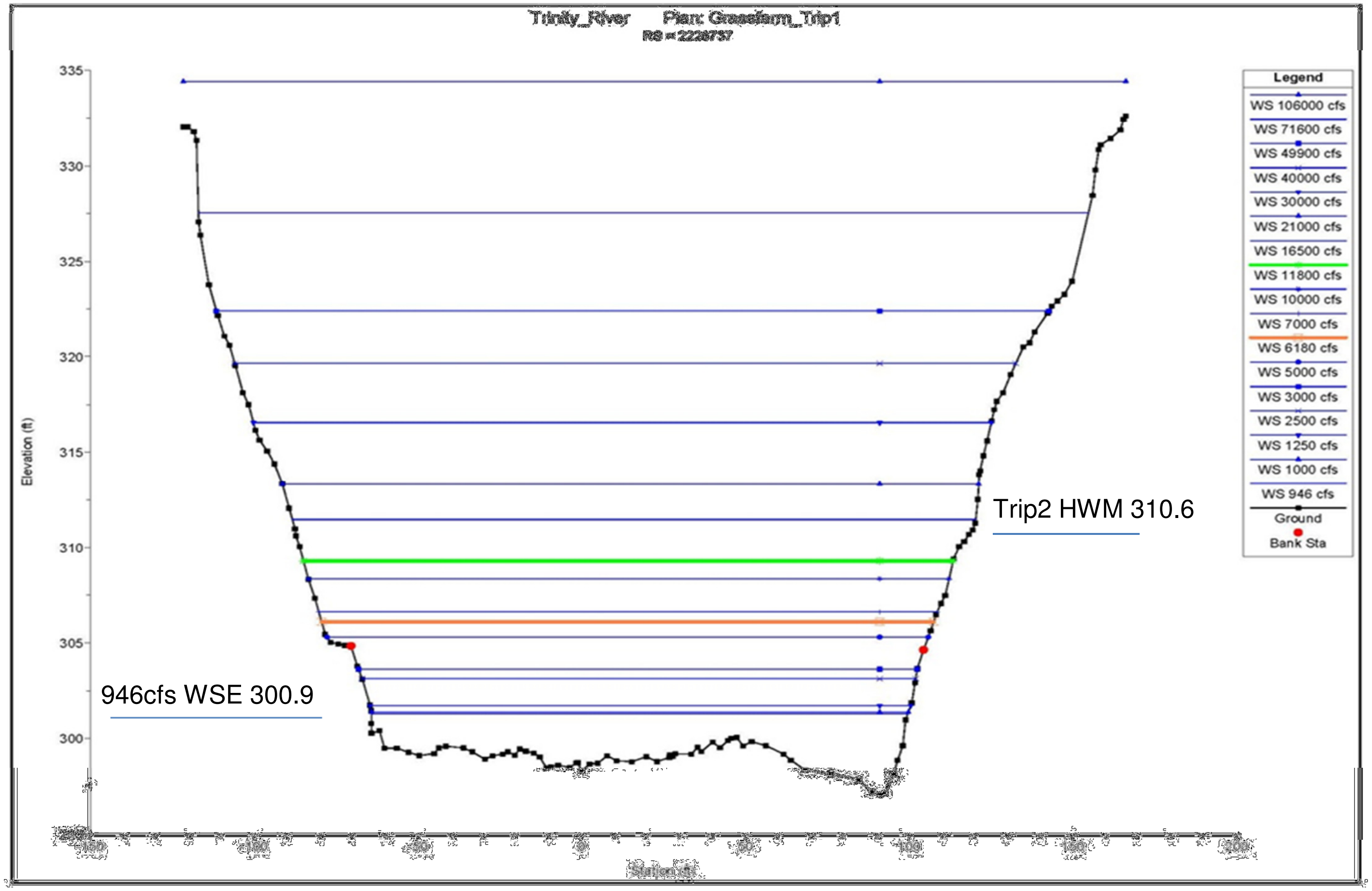


Figure 17. Model output – LT422 XSEC3 - Trip 1 with predicted water levels

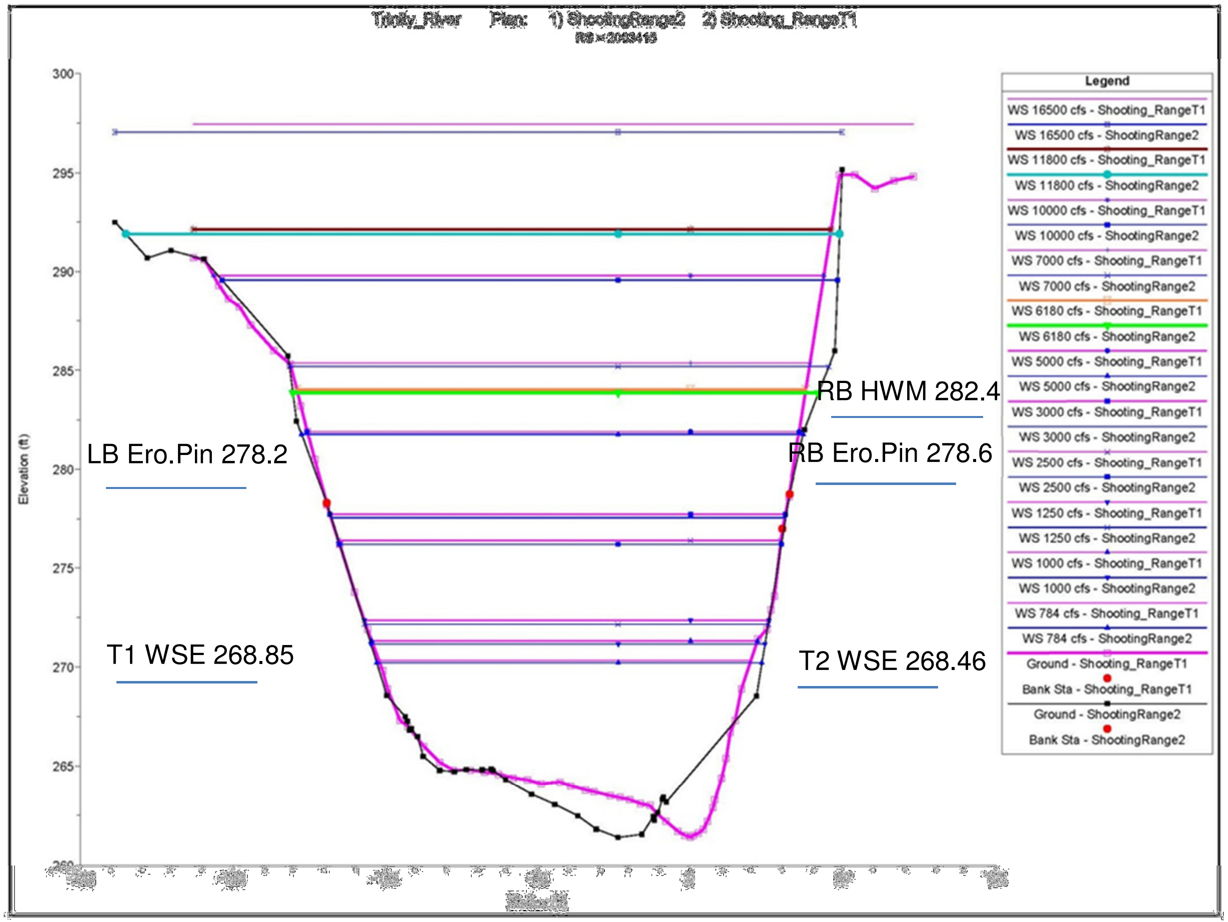


Figure 18. Model output – LT395 XSEC3 – Comparison of Trip 1 and Trip 2

8.5 Recommended Future Model Work

The following items are recommended to complete preliminary modeling work initiated in 2012:

- Finalize calibration by refining flow rating curves or including additional downstream cross-sections.
  - Install PTs for extended period (2 months) at each site's downstream cross-section; monitor water elevation for duration sufficient to capture a range of pulse flows
- Incorporate Trip 2 cross-sections
- Compare Trip 2 results for pulse inundations to Trip 1 results
- Future modeling for dynamic (time-varying) flow conditions, to support dynamic sediment or water quality conditions
- Identify what flow rates produce a computed water surface elevation that meets the following vertically significant thresholds
  - Inundates top of first terrace
  - Inundates top of erosion pins
  - Inundates top of vegetation
  - Begins to inundation of riparian area
  - Reaches top of bank
- Compare flow areas at select cross sections for Trips 1 and 2 in order to determine impact to channel conveyance.

8.6 Potential Future Model Work on Sediment Transport and Water Quality

The HEC-RAS model includes algorithms to evaluate sediment movement and water quality. Future work could utilize this model, or similar models, to evaluate the following concepts:

- Stable Channel Design calculation - generalized incipient motion calculation to estimate at a cross-section, what grain size is mobilized at a given flow.
- Compare Stable Channel Design calculation to existing grain size analysis field data
- Sediment transport capacity (tons per year)
- Sediment time series modeling to predict aggradation and degradation (with calibration to known events)
- Additional sediment sampling and grain size analysis
- Water temperature related to aquatic habitat goals
- Range of dissolved oxygen related to aquatic habitat goals

9.0 APPENDIX C – 2013 – LT295 Inundation, riparian and sediment modeling

9.1 Overview

One focus for 2013 was accumulation of information at one long-term study site to determine potential utility and preliminary findings based upon long-term monitoring data. Site LT295 was chosen as the focus site because of (1) proximity to long-term water level data at the USGS Trinity River near Oakwood gauge, (2) proximity to the state natural areas with good riparian edge habitats, (3) coincidence with one of the SB2 chosen instream flow study sites and (4) proximity to a SB3 environmental flows Oakwood measurement point .

The main tasks for this work were to:

- develop a calibrated HEC-RAS water surface profile model based upon data
- identify water levels associated with pulse events
- identify inundation extents (water edge) associated with pulse events
- identify extent of inundated riparian habitats
- identify transport of sediment grain sizes associated with pulse events

9.2 HEC-RAS water surface profile modeling

9.2.1 Data sources

The primary existing data used to develop the HEC-RAS water surface profile models are

- 2011 longitudinal survey, M9 cross-sections and water surface profiles (TRA and RPS Espey 2012)
- 2012 Long-Term monitoring cross-section surveys and water surface profiles (Appendix B)
- 2013 PT data and water surface profiles (TRA)
- 10 meter Digital Elevation Model (DEM) from public sources (TNRIS)
- USGS gauge height and discharge data from the Trinity River near Oakwood gauge. Gauge datum was adjusted from reported NGVD29 to NAVD88 by adding 0.06 feet.

Additional data collected during 2013 was also used in development of the models.

- Pressure Transducer (PT) data on water levels collected in 2013 (TRA)
- Water surface profile data collected in 2013 (TRA).

Water surface profiles were adjusted to water surface elevation based upon a tie to the elevation of the established benchmark, or based upon the water surface elevation of the USGS gauge. The water surface elevations were used to determine the elevation of cross-sections where depth echosoundings were collected in the field.

9.2.2 Model development

The 2012 HEC-RAS model for LT295 was modified by extending the boundaries upstream to RM 297.04 (location of a 2011 M9 cross-section) and downstream past the USGS Oakwood gauge to RM289.04 (location of a 2011 M9 cross-section). In addition to the two 2011 cross-sections at the boundaries, three additional 2011 cross-sections were incorporated into the model.

High-flow flood events inundate significant portions of the floodplain, beyond the extent of 2011 and 2012 near-channel surveys. To ensure water surface profiles for high-flow events would be suitably captured in this modeling analysis, publicly-available topography data (10 meter DEMs) was used for flood plain areas. The elevation datum for DEMs is NAVD88.

Cross-section locations for the HEC-RAS model were developed (Figure 19). Elevations across each section were assigned by combining floodplain geospatial elevation data with low-flow on-site survey data (Table 7 and Figure 20).

A downstream water level boundary condition was used to develop backwater water surface profiles. The discharge versus water level rating curve at the USGS Trinity River near Oakwood gauge was translated to the downstream-most cross-section (289.04) and adjusted so water levels at cross-section 291.16 (nearest to the gauge) matched the reported gauge levels.

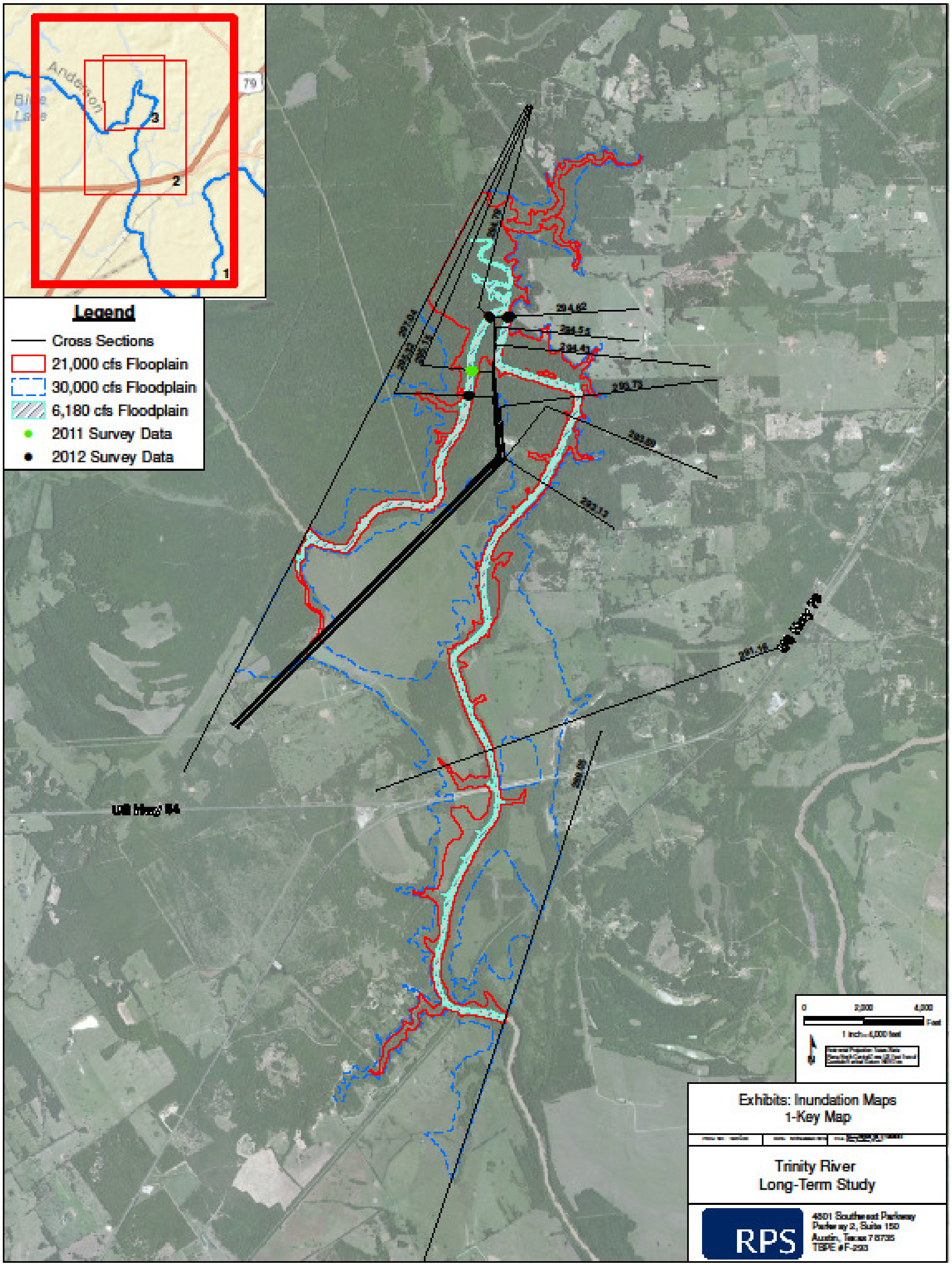


Figure 19. LT295 HEC-RAS cross-section locations

Table 7. LT295 HEC-RAS cross-section elevation data sources

River Mile	Overbank data	In-channel data	Notes
289.04	10m DEM	2011 M9 xsec + 2011 WSP	Downstream boundary condition from adjusted Oakwood rating curve
291.16	10m DEM	2011 M9 xsec + 2013 WSP	Just upstream of USGS Oakwood gage
293.13	10m DEM	2011 M9 xsec + 2013 WSP	
293.59	10m DEM	Inferred in-channel to match observed WSP	
293.73	10m DEM	Inferred in-channel to match observed WSP	Riffle downstream from LT295
293.905*	*interpolated 293.73-294.43 to match water surface profile		
294.08*			
294.255*			
294.43	10m DEM	Inferred in-channel to match observed WSP	
294.55	10m DEM	2012 VX survey + M9 + WSP	LT295 XS3 - The main riffle
294.79	10m DEM	2012 VX survey + M9 + WSP	LT295 XS2
295.15	10m DEM	2011 M9 xsec + 2013 WSP	
295.32	10m DEM	2012 level survey + M9 + WSP	LT295 XS1 - Onsite benchmark
297.04	10m DEM	2011 M9 xsec + 2013 WSP	

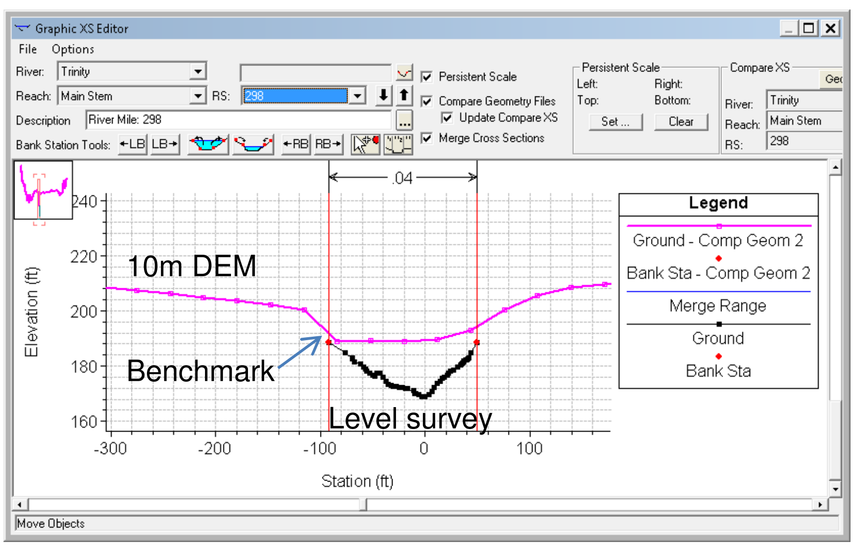


Figure 20. LT295 XS1 - Merging DEM and survey cross-sections

9.2.3 Calibration

The LT295 HECRAS model was calibrated based upon available water surface profile observation data at 668cfs and 2670cfs. Model predictions were calibrated by adjusting roughness factors and by inferring cross-section bathymetry where data was sparse (see below). Mannings roughness factors used are:

- n=0.08 - Overbank flood plain areas
- n=0.20 – Near-bank riparian area
- n=0.038 – in-channel areas between the banks

In areas without measured in-channel cross-section information, interpreted cross-sections were added. These additions were included to promote model prediction of observed water surface profiles, and observed field conditions. Specifically, cross-sections between river miles 294.43 and 293.73 were added to represent the observed riffle located downstream of the riffle at LT295_XS3.

Additional subsequent PT data will allow for further future calibration at higher level pulses (5,750cfs and 18,750cfs), once instrumentation is retrieved and downloaded.

9.2.4 HEC-RAS Water Surface Profile Results

A series of steady-state flow rates were modeled as part of this project, ranging from low-flow (668 cfs) to highest recorded flow (106,000 cfs at Oakwood) (Table 8).

Model water level predictions for 668.3cfs compare well with observations from Trip 3 (08/01/2013) (Figure 21). Similarly, model predictions for the 2,690cfs pulse compare well with pulse peak water levels exhibited in PT data (08/17/2013) (Figure 21).

Inundation at each of the 2012 LT295 cross-sections matches what has been observed for low-flow events. At LT295 XS1, the upstream cross-section where the benchmark is located, flows crest out of bank between 21,000 cfs and 30,000 cfs (Figure 22 and Figure 23). The August 2013 pulse observed in the PT data exhibited a crest just higher than the 2,500cfs SB3 pulse trigger flow and lower than the 3,000 cfs pulse trigger flow.

Table 8. LT295 - HEC-RAS modeled steady-state flows

Flow Rate (cfs)	Description
668	Observed WSP August 2013
815	Observed WSP September 2013
1,250	Typical recent high baseflow
2,500	SB3 Summer/Fall pulse trigger flow standard at USGS Oakwood
2,670	Observed peak from PT data August 2013
3,000	SB3 Winter pulse trigger flow standard at USGS Oakwood
5,000	
6,180	Oakwood pulse 10/03/2012
7,000	SB3 Spring pulse trigger flow standard at USGS Oakwood
10,000	
11,800	Crockett pulse 09/30/2012
16,500	Typical (1/season) recent Jan-Jun pulse
21,000	Typical (1/season) recent Jul-Dec pulse
30,000	
40,000	
49,900	Oakwood flood peak 10/31/2010
71,600	Oakwood flood peak 07/10/2007
106,000	Oakwood flood peak 12/24/1991 (maximum 107,000cfs 05/07/1990)

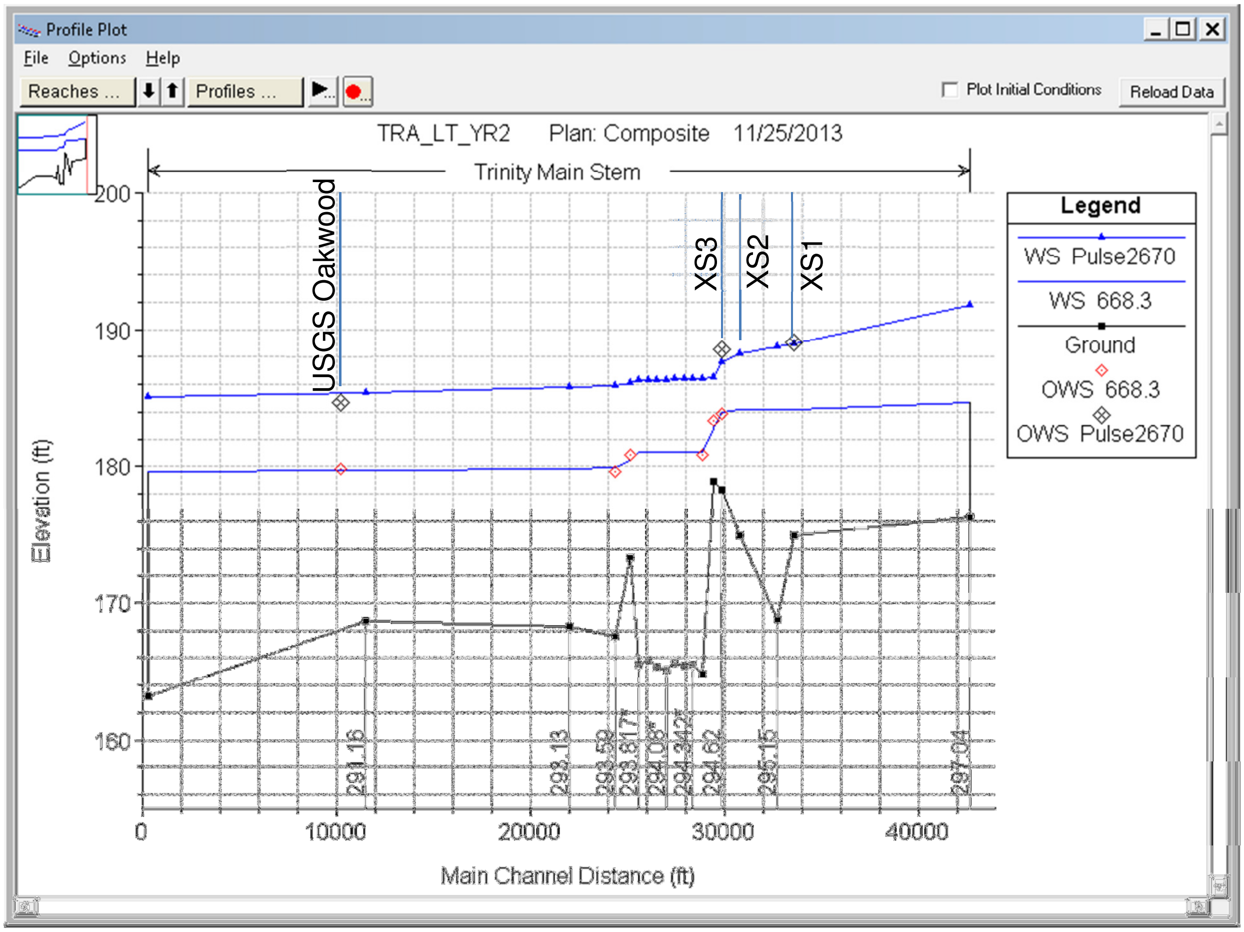


Figure 21. LT295 water surface profile calibration

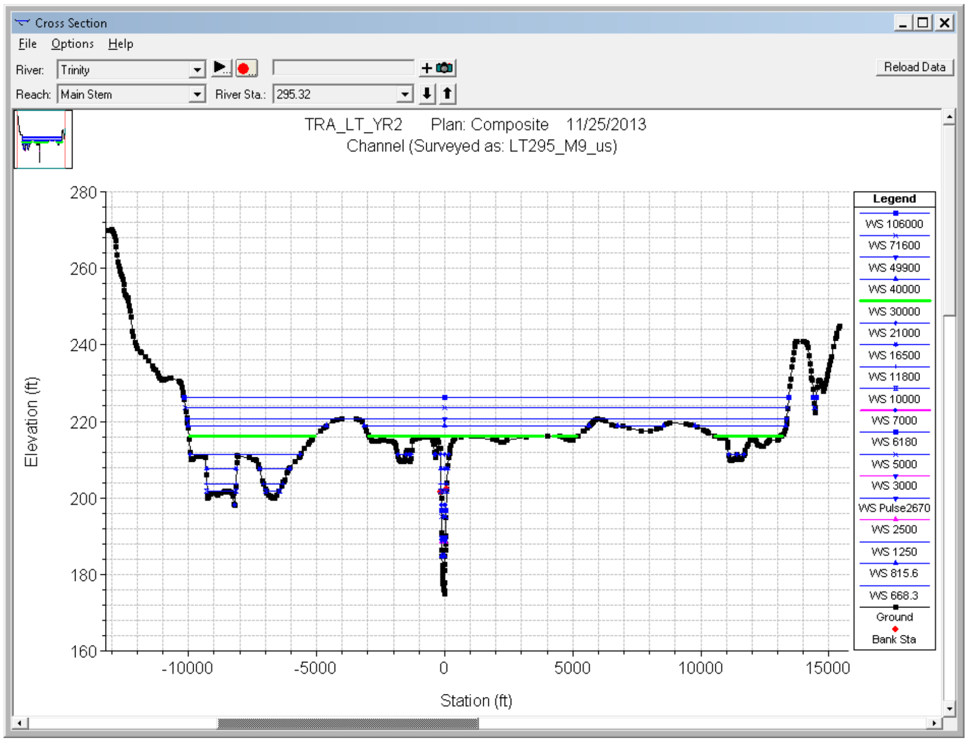


Figure 22. LT295 XS1 - Upstream benchmark cross-section floodplain

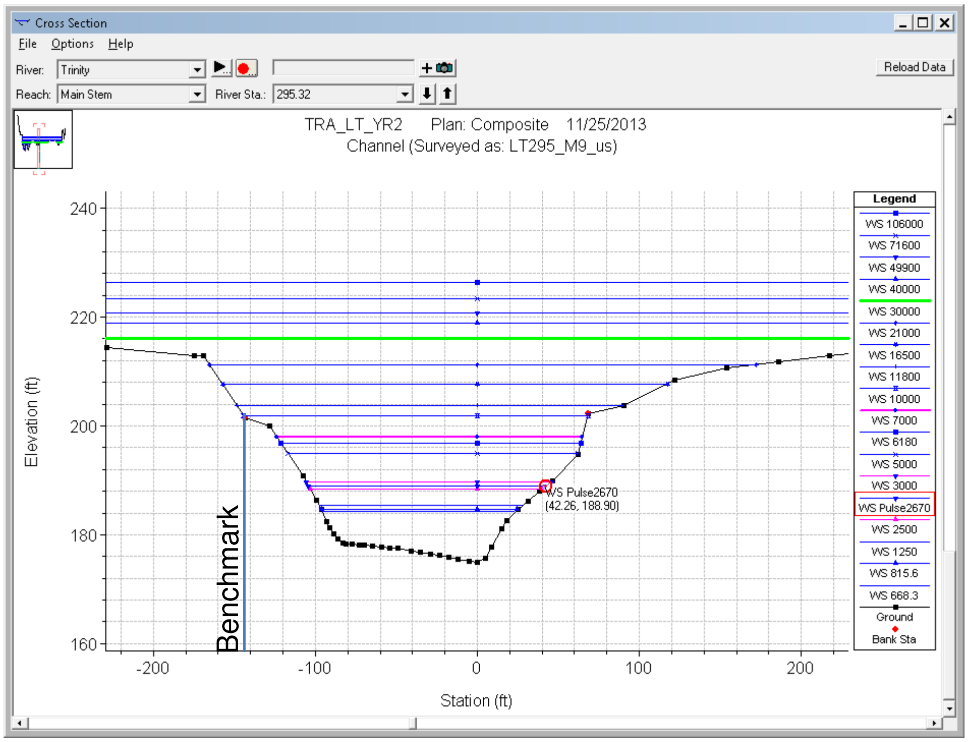


Figure 23. LT295 XS1 - Upstream benchmark cross-section near-channel

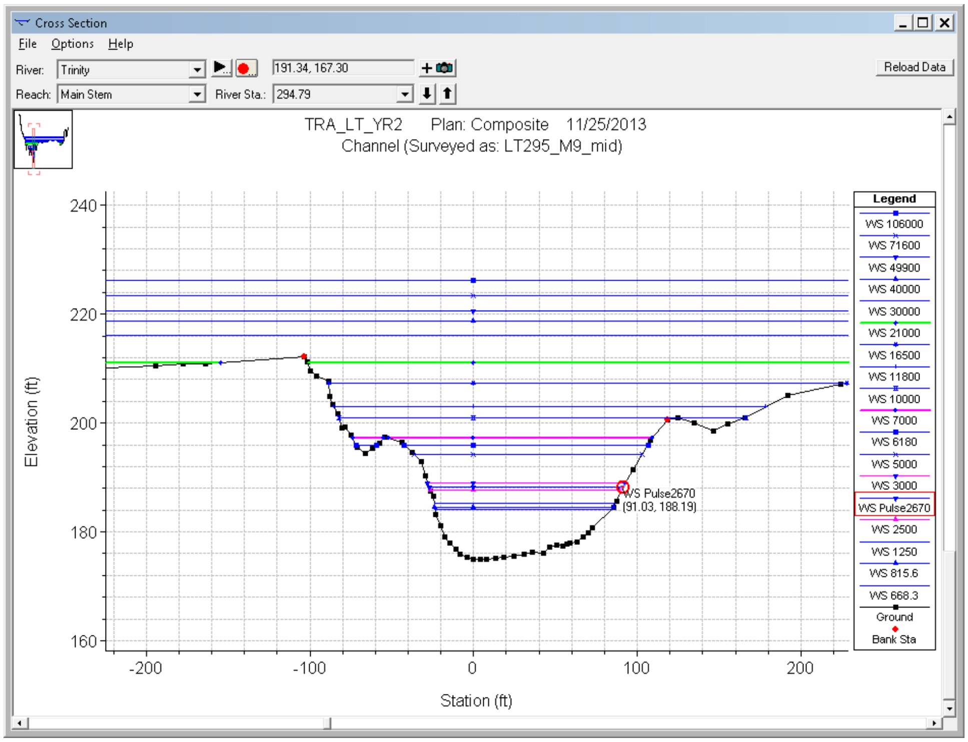


Figure 24. LT295 XS2 - Middle cross-section near-channel

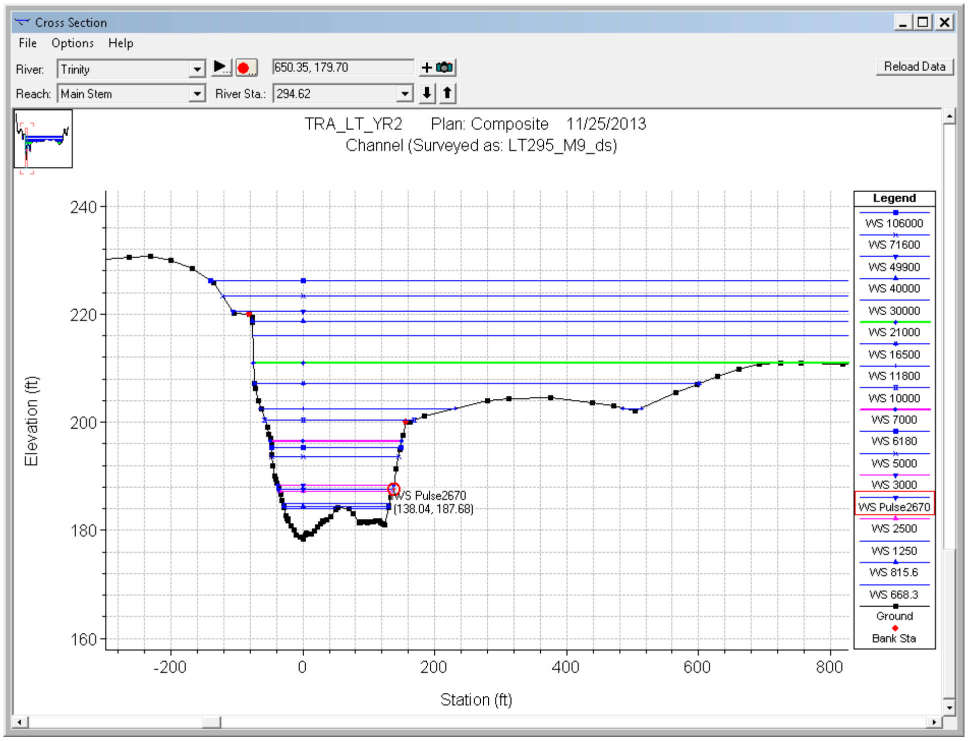


Figure 25. LT295 XS3 - Downstream riffle cross-section near-channel

9.3 Inundation mapping

Water edge inundation maps were created using the RAS Mapper function in HEC-RAS. The water surface elevation predictions for each modeled flow level were intersected with the 10 meter DEM topographic surface. This allowed mapping of the water edge of each flood event (Figure 19).

The spatial resolution of 10 meter DEM elevation data near the channel banks was too coarse to map water edges for flow levels less than 5,000 cfs.

Improved inundation mapping for flow levels lower than 30,000 cfs would be possible with higher-resolution topographic data between the banks (eg, LiDAR or photogrammetry).

9.4 Riparian area mapping

The Texas Parks and Wildlife Department (TPWD) provides a spatial GIS product called the Texas Ecological Systems Classification Project (TESCP). The TESCP data set is a combination of available land use, land cover, soils and vegetation type to identify different terrestrial habitats. The product is provided in a raster format with 10 meter grid resolution.

Figure 26 shows TESCP classifications within the area evaluated. This maximum evaluated spatial extent is coincident with the maximum inundation of the 106,000cfs flow event, and totals 7.06 square miles or 4,517 acres.

Spatial inconsistencies are evident in TESCP “open water” cells when compared to the inundated areas developed from HEC-RAS and the DEMs (Figure 27).

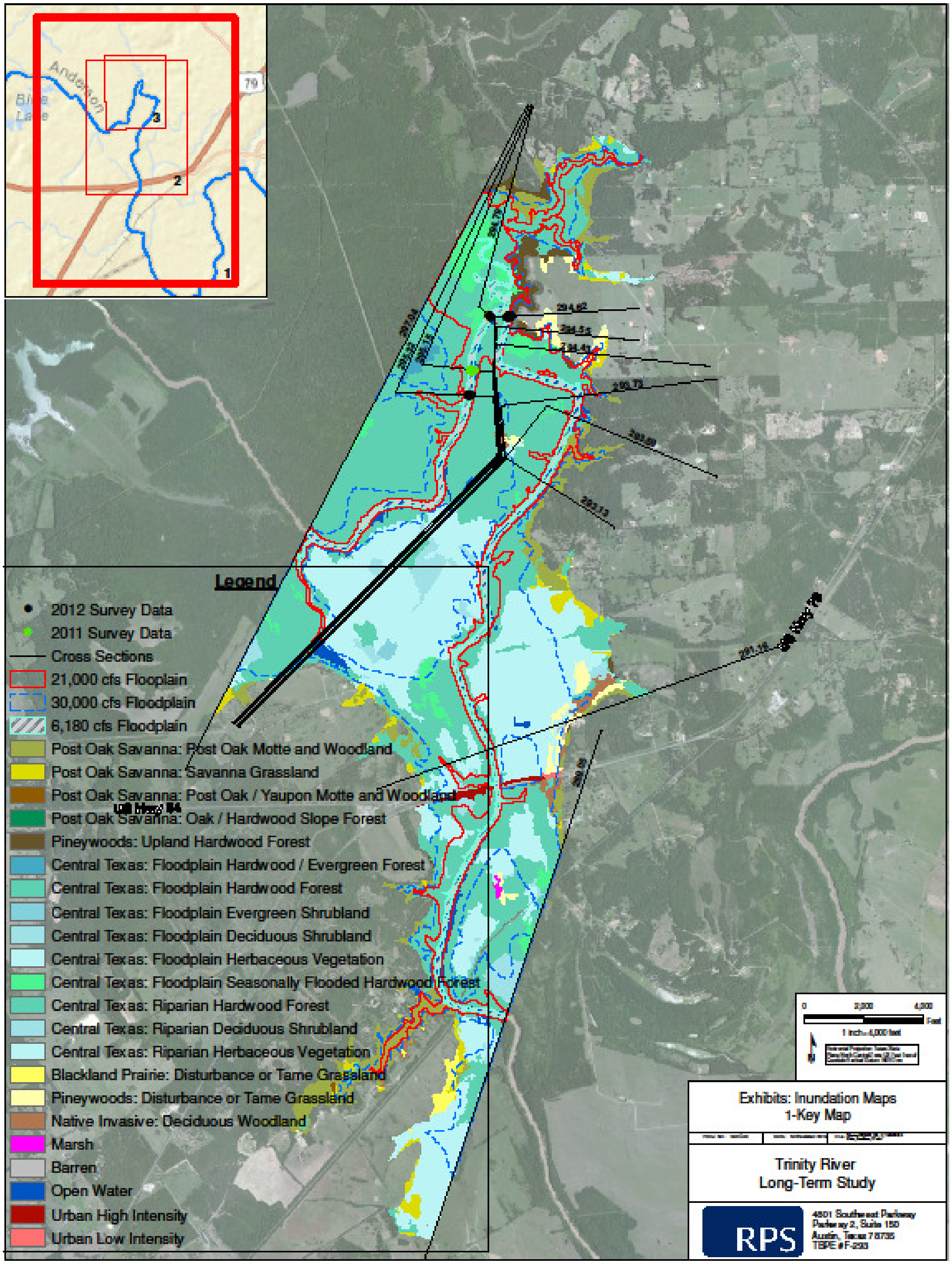


Figure 26. LT295 inundated TESCP area by Common Name class

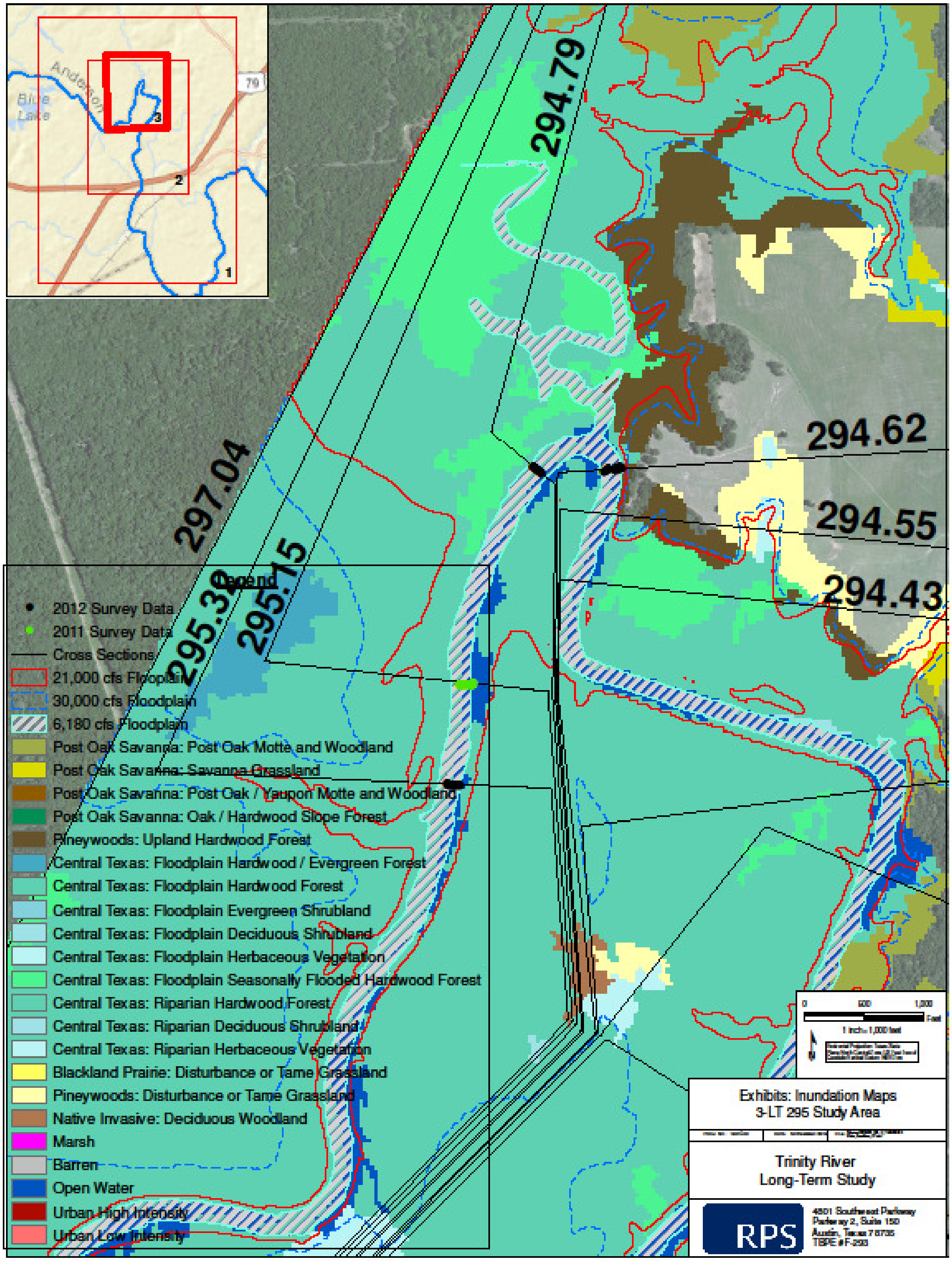


Figure 27. LT295 inundated TESCP area by Common Name class, near site

The HEC-RAS inundation water edge maps were used to determine area inundated of each TESCP classification. Over 75% of the area analyzed has Ecological classification as Southeastern Great Plains Floodplain Forest (Figure 28) and over 75% of area has Common Name classification of Central Texas: Floodplain Hardwood Forest and Central Texas: Floodplain Herbaceous Vegetation (Figure 29a). Of the common name classifications, approximately 60% of the acreage is represented by floodplain woody areas, with Central Texas: Floodplain Forest representing the majority (Figure 29b).

Inundated area varies with flow. As flow increases beyond 21,000cfs, the inundated area spreads out from the main channel into the flood plain. Areas classified as riparian or floodplain exhibit less than 25% inundation at 21,000cfs. As flow increases to 30,000 cfs, inundation also increases to 60%-70% for the same riparian-classified areas (Figure 30 and Figure 31). Inundation is reported in percent of maximum area inundated at 106,000 cfs.

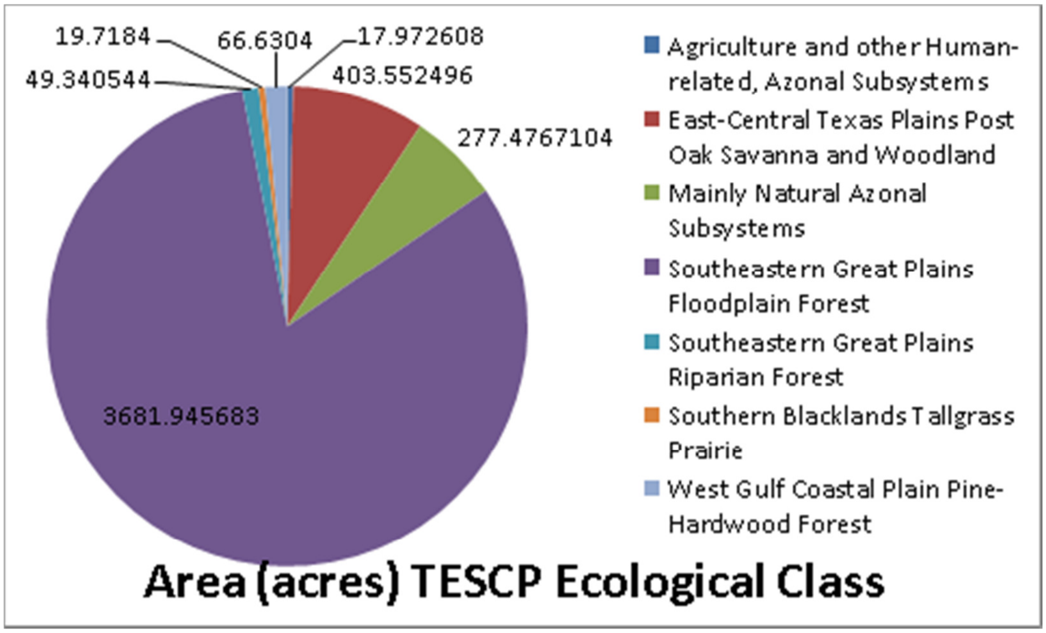


Figure 28. TESCP area of inundated Ecological Class

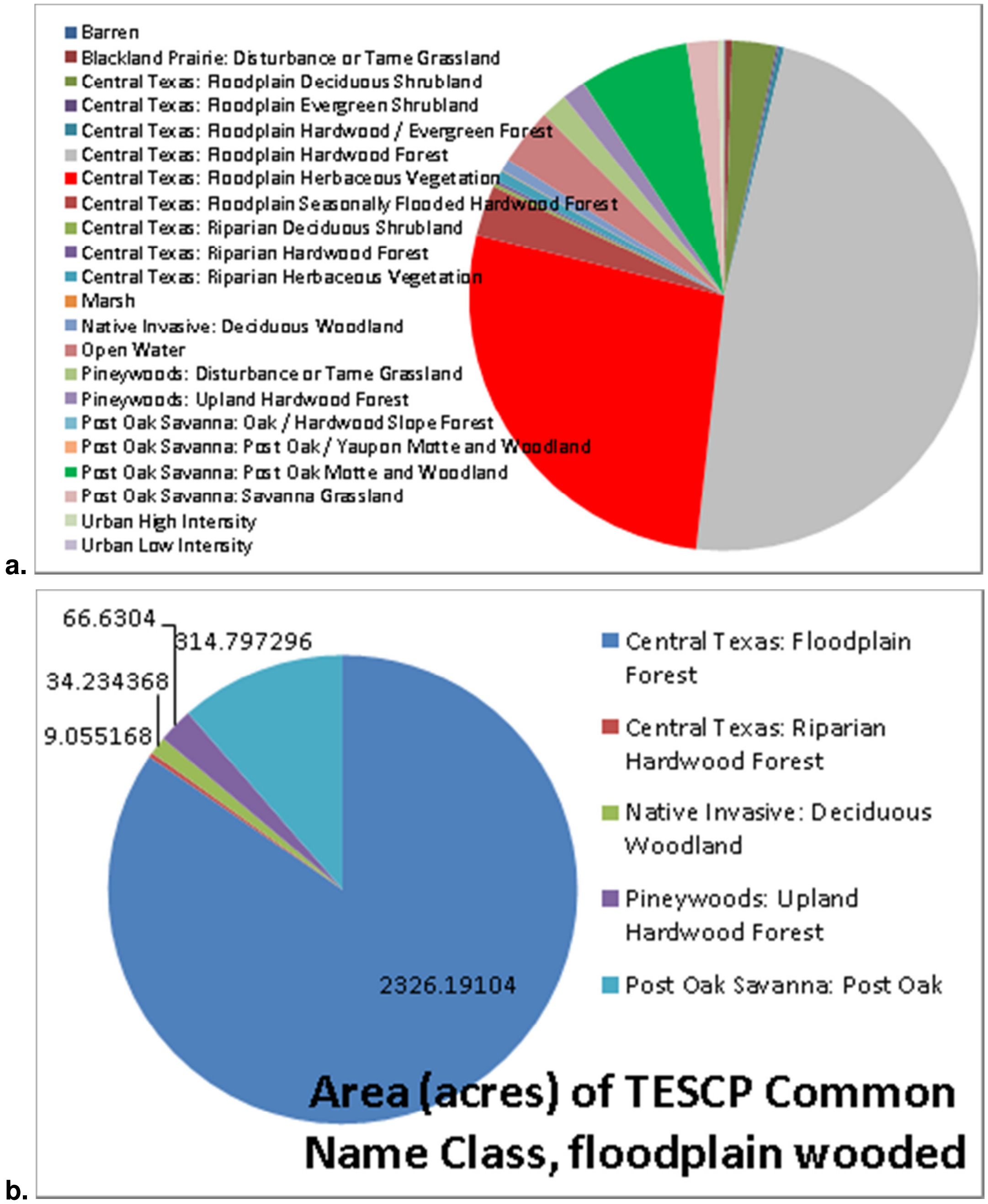


Figure 29. TESCP area of inundated Common Name classifications

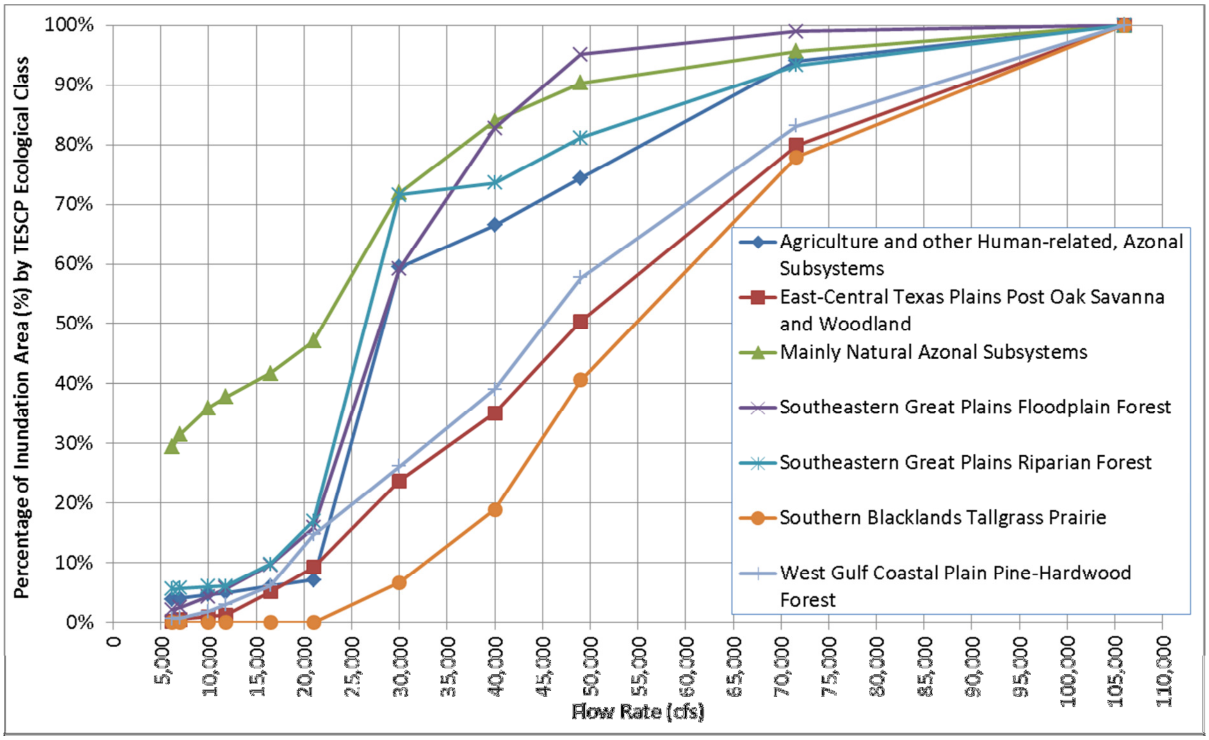


Figure 30. TESCP ecological classification area vs. pulse flow

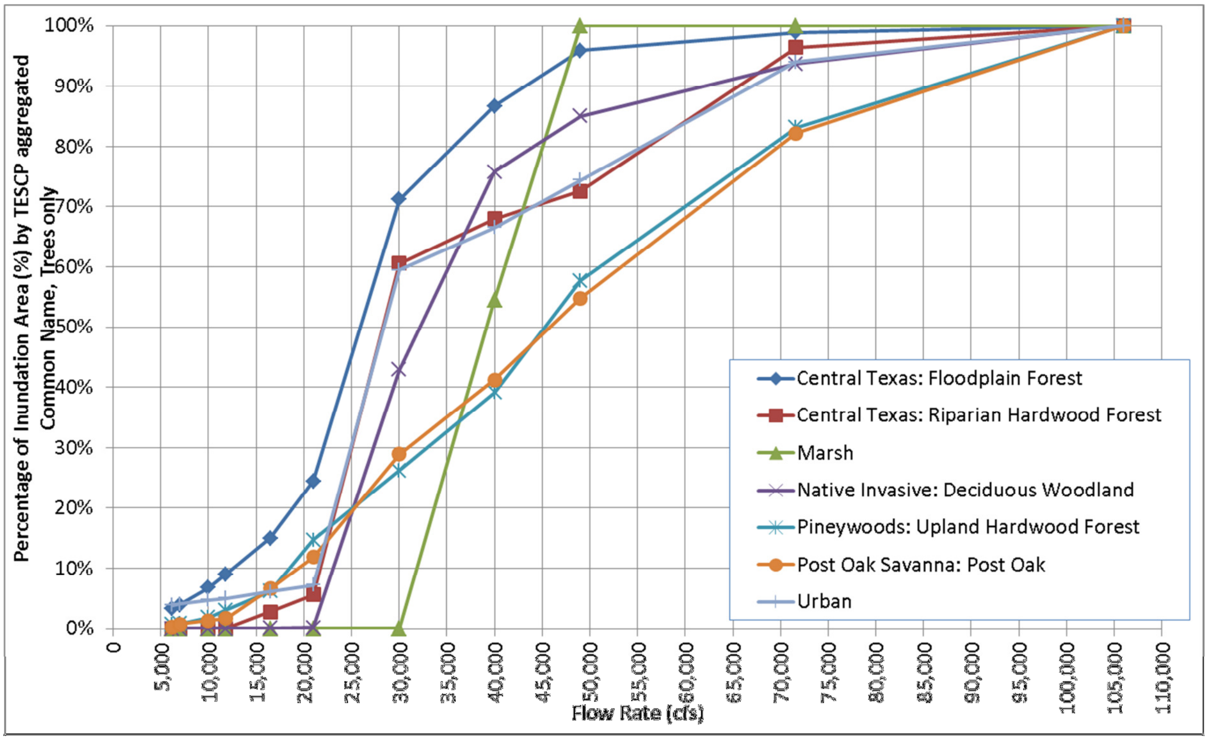


Figure 31. TESCP common name classification (trees only) area vs. pulse flow

9.5 Sediment assessment

Sediment samples were collected on-site at LT295 XS1 during the 2012 field efforts. As at all study sites, five sediment samples were collected and grain size analysis was performed. Two samples represent bank samples midway between top of bank and low-flow water edge. Three samples represent low-flow channel submerged substrates at the center of channel, midway between center and left water edge (L 3rd), and midway between center and right water edge (R 3rd). At LT295, the center of channel sample did not recover any loose sediment; the substrate was clean compacted clay. Sediment grain size analysis reveals bank and right channel substrates are primarily fine sand (>60% finer than 0.003 inch) (Figure 32). Submerged sediments near the left bank are primarily coarse sand (Figure 32).

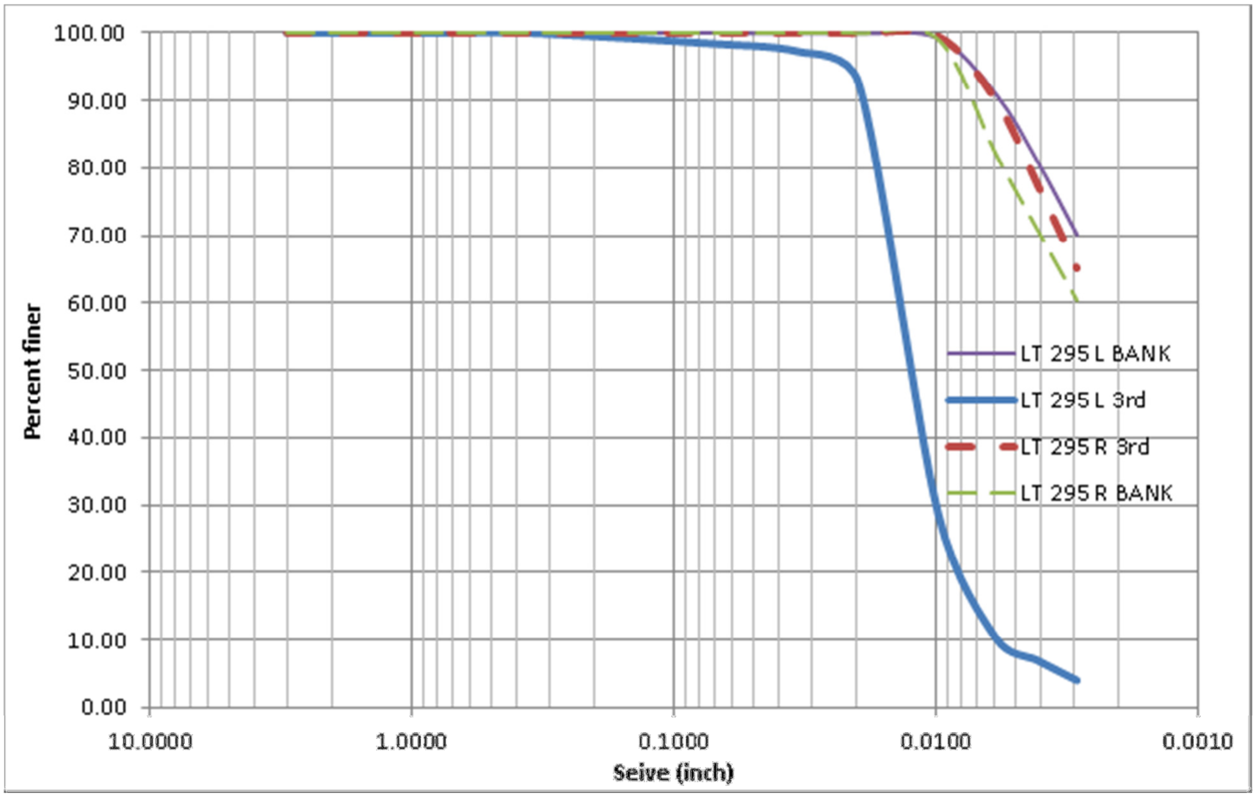


Figure 32. Grain size analysis of sediments at LT295_XS1 (no recovery at channel center)

Shear stress predictions can be used to investigate sediment mobilization. The shear stress necessary to cause incipient motion across a range of grain size classes was identified (Table 9). The HEC-RAS model was used to predict shear stress in the channel at each of the LT295 cross-sections (Table 10).

Table 9. Shear stress causing incipient motion

Shear stress (T) for transport of uniform sediments			
Sediment	**D(in)**	**T(lb/sf)**	**Note**
Cohesive compacted clay		**0.3**	*e=0.40*
Medium silt	0.001	0.001	
Fine sand	0.005	0.003	
coarse sand	0.02	0.006	
Fine gravel	0.16	0.06	
medium gravel	0.3	0.12	
coarse gravel	0.6	0.25	
very coarse gravel	1.3	0.54	
small cobble	2.5	1.1	
large cobble	5	2.3	

Analysis reveals that sand transport is predicted for all flow levels, including down to minimum flow modeled of 668 cfs (Table 10). Model predictions of all-sand transport are consistent with on-site sediment sample grain size analysis from bed material at LT295_XS1. At this cross-section, as in many other mid-channel areas of the Trinity River, the primary bed material was clean compacted clay. Ponar dredge samples at mid-channel returned empty or limited sample volumes comprised largely of organic material. As velocity and energy decreases away from channel center towards the banks, some deposition of sand-size particles is evident in the sediment field samples (Figure 32).

Modeling lower flow rates is recommended to see if sand had been transported at lower base flow levels historically encountered (e.g., SB3 base flows between 100 and 450 cfs). Different habitat may be expected if a lower flow regime allowed for sand to deposit and create different edge and channel habitats.

Table 10. Shear stress for LT295 cross-sections, in channel

	Channel shear stress (lb/sf) and transportable grain size					
	XS3-riffle		XS2		XS1-BM	
Flow (cfs)	Shear stress	Grain size	Shear stress	Grain size	Shear stress	Grain size
668.3	1.535	Sm cobble*	0.019	Coarse sand	0.017	Coarse sand
750	1.571	Sm cobble*	0.022	Coarse sand	0.020	Coarse sand
815.6	1.620	Sm cobble*	0.025	Coarse sand	0.022	Coarse sand
1,000	1.742	Sm cobble*	0.034	Coarse sand	0.030	Coarse sand
1,250	1.891	Sm cobble*	0.046	Coarse sand	0.040	Coarse sand
2,500	1.357	Sm cobble*	0.166	Med grvl	0.179	Med grvl
2,670	1.407	Sm cobble*	0.192	Med grvl	0.208	Med grvl
3,000	1.641	Sm cobble*	0.244	Coarse grvl	0.264	Coarse grvl
5,000	2.171	Cobble*	0.445	Coarse grvl*	0.502	Coarse grvl*
6,180	1.712	Sm cobble*	0.512	Coarse grvl*	0.628	Vry crs grvl*
7,000	1.221	Sm cobble*	0.537	Vry crs grvl*	0.709	Vry crs grvl*
10,000	0.525	Coarse grvl*	0.515	Coarse grvl*	0.902	Vry crs grvl*
11,800	0.411	Coarse grvl*	0.401	Coarse grvl*	0.557	Vry crs grvl*
16,500	0.322	Coarse grvl*	0.118	Med grvl	0.221	Med grvl
21,000	0.282	Coarse grvl	0.068	Fine grvl	0.163	Med grvl
30,000	0.290	Coarse grvl	0.033	Coarse sand	0.064	Fine grvl
40,000	0.150	Med grvl	0.026	Coarse sand	0.043	Coarse sand
49,900	0.122	Med grvl	0.025	Coarse sand	0.043	Coarse sand
71,600	0.082	Fine grvl	0.025	Coarse sand	0.033	Coarse sand
106,000	0.078	Fine grvl	0.028	Coarse sand	0.033	Coarse sand
	Note:	* - Erosion of compacted clay material				

Cross-sections LT295_XS2 and LT295_XS1 are typical of many pool and run reaches in Area C of the Trinity River. At cross-sections XS1 and XS2, shear stress sufficient for gravel transport is predicted between 2,500 cfs and 30,000 cfs, but no cobble transport is predicted (Table 10). Erosion of cohesive sediments (compacted clay) is predicted for flows between 5,000 cfs and 12,000 cfs (Table 10). Maximum shear is predicted at 7,000 cfs for XS2 and 10,000 cfs for XS1.

At the riffle cross-section immediately downstream of the confluence of Keechi (Town) Creek (LT295 XS3), it is not surprising that higher shear stresses are predicted than at XS1 and XS2 (Table 10). On-site, the observed bed material at XS3 ranges from coarse gravel to large cobble and this is consistent with the shear stress predictions between 0.29 lb/sf and 2.17 lb/sf for all flows below 30,000 cfs. These shear stress values are sufficient to mobilize coarse gravels and cobbles up to 5” diameter. Maximum shear of 2.17 lb/sf is predicted at 5,000 cfs.

For overbank areas, deposition of sands and fine gravel is expected for flow levels higher than 10,000 cfs (Table 11). Erosion of compacted clay material is not predicted at any flow level in the overbank areas. The topographically lower overbank level on the right of XS3 allows for inundation at flows between 5,000 cfs and 21,000 cfs, and shear stress is sufficient to transport gravel material (Table 11). Similarly, the topographically lower overbank level on the left banks of XS2 allows for inundation at flows between 5,000 cfs and 12,000 cfs with shear stress sufficient to transport gravels (Table 11).

These lower overbank areas are opportunity areas for seasonal riparian seedling development. A series of spring pulses can be envisioned with potential to (1) clean and lightly scour existing flood plain sediments (e.g., 6,000-10,000 cfs) to prepare a seed bed and deposit seeds, then (2) then inundate overbank areas (e.g., 21,000 cfs) depositing fertile fine material. The duration and timing of such pulses, as well as intermittent rain fall events, relative to seeding cycles would be important in determining viability of seedling establishment.

Table 11. Shear stress for LT295 cross-sections, overbank areas.

	Overbank channel shear stress (lb/sf)					
	XS3-riffle		XS2		XS1-BM	
Flow (cfs)	Left	Right	Left	Right	Left	Right
668.3						
750						
815.6						
1,000						
1,250						
2,500						
2,670						
3,000						
5,000		0.276	0.103			
6,180		0.312	0.165			
7,000		0.330	0.209			
10,000		0.256	0.120	0.030	0.056	
11,800		0.220	0.071	0.063	0.079	0.022
16,500	0.001	0.154	0.035	0.029	0.057	0.032
21,000	0.017	0.086	0.022	0.012	0.033	0.009
30,000	0.049	0.045	0.014	0.004	0.014	0.003
40,000	0.031	0.026	0.013	0.004	0.012	0.004
49,900	0.023	0.023	0.013	0.004	0.011	0.005
71,600	0.015	0.021	0.013	0.006	0.010	0.006
106,000	0.016	0.025	0.015	0.009	0.012	0.008
	Note:	* - Erosion of compacted clay material				

Bed load sediment transport capacity for cross-sections XS1 and XS2 was calculated using the Ackers-White equation (Figure 33). Transport occurs between 2,500 cfs and 30,000 cfs for the grain sizes appropriate to an Ackers-White analysis. Maximum transport is predicted at XS2, and for both XS1 and XS2 the maximum transport occurs at 10,000 cfs.

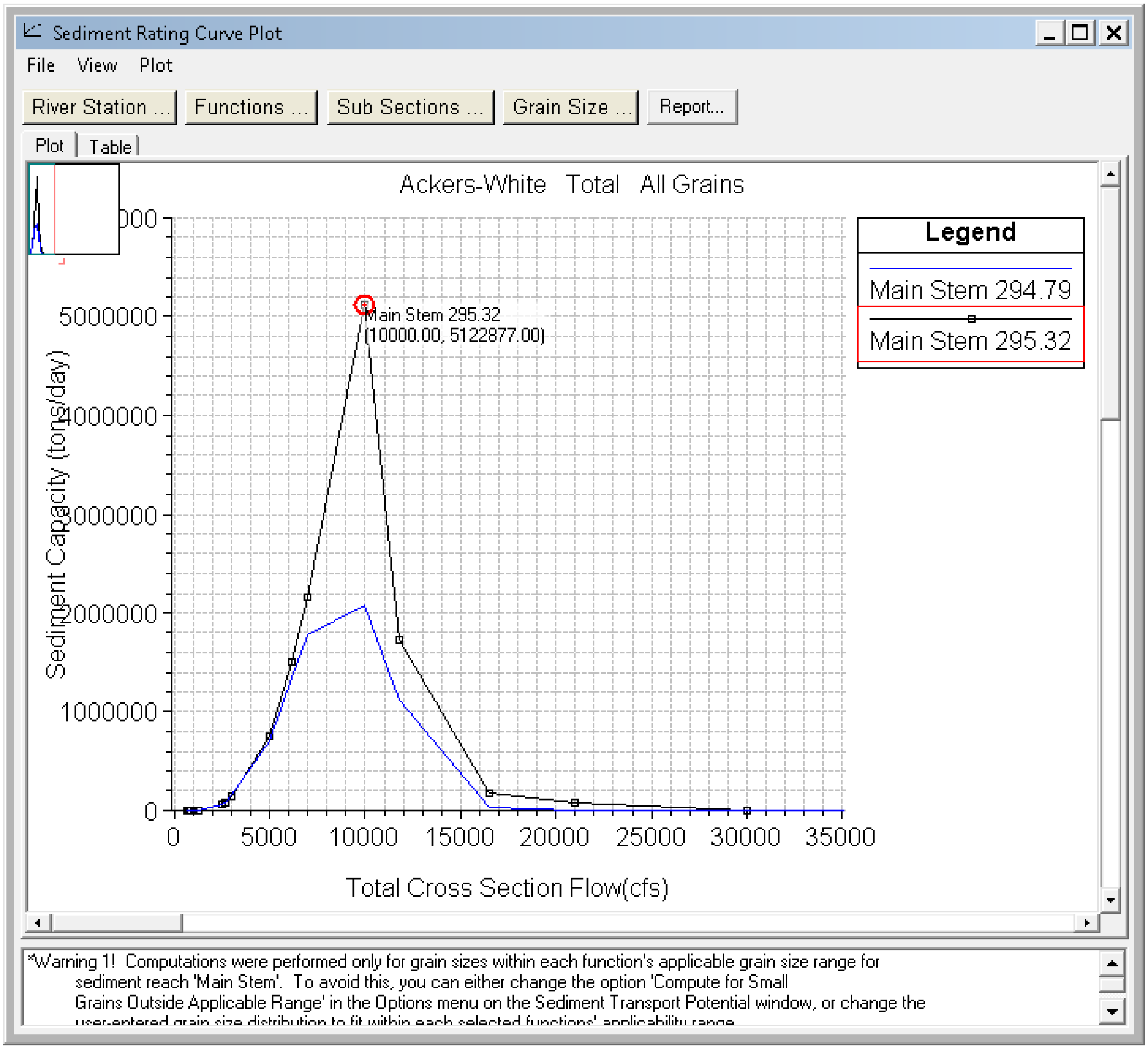


Figure 33. LT295 bed-load capacity

9.6 Discussion related to evaluating LT295 pulse flow levels

Adopted SB3 rules for the Trinity River environmental flows at the Oakwood measurement point include pulse trigger flow levels at 2500cfs (Summer/Fall), 3000cfs (Winter) and 7000cfs (Spring). A pertinent question is: “What is the value of a 2,500, 3,000 or 7,000cfs pulse trigger to (a) riparian areas, (b) sediment transport, and/or (c) instream aquatic habitat.”

(a) Riparian areas

Pulse flows between 5,000 and 21,000 cfs are confined to the near-banks of the river. The HEC-RAS inundation mapping exercise illustrated a need for better near-channel topography data (eg, LiDAR) to verify relation of our localized, site-specific data to regional data. To conduct a riparian analysis the 10m TESCP vegetation cover database combined with the 10m DEM topography were not found to have sufficient resolution for the near-channel SB3 pulse flows (lower than 21,000cfs) in this area of the Trinity basin.

The analysis did, however, tell us about higher seasonal flows, particularly that flows tend to spread out overbank at levels higher than 21,000 cfs. Hydrology analysis tells us that flows approach 21,000 cfs perhaps 2 times per year on average (Table 8). The TESCP shows us that areas classified as riparian and floodplain trees are mostly inundated for flows >30,000cfs.

With the TESCP, we have now plucked the low-hanging fruit and it does not offer much taste at SB3 pulse trigger levels. Additional site-specific riparian vegetation data is needed to better determine how intermediate flow levels (between 2,500cfs and 30,000cfs) inundate different near-channel components of the riparian community (specifically, what flows inundate willow then ash then sycamore then cottonwood then pecan then oak).

(b) Sediment

Flow levels between 7,000 and 10,000 cfs are important to the river as these flow levels represent the greatest sediment transport capacity.

Predicted gravel transport is initiated at flows as low as 2,500 cfs and tapers off at flows higher than 21,000 cfs, the level when flood waters begin to crest into overbank areas. A range of gravel size sediments are predicted to be transported these flow pulses, and would represent refreshment of substrates in riffle habitats potentially important for some lotic fish species and mussels.

(c) Instream aquatic habitat
The Long-Term Study is not focusing on low-flow instream aquatic habitat at this time. This is, however, a focus of the TIFP SB2 studies.

Sand is continually being transported at the flow levels currently exhibited. Different, more sandy, edge habitats may have existed under lower base flow levels considering lower shear stress (potentially low enough to deposit sand) would be expected at lower flow levels. Lower flow levels should be evaluated for sand transport.

9.7 LT295 Summary Findings

Current public datasets (10m DEM) are too coarse and not suitable for mapping inundation below 5,000cfs. Improved near-bank topography (e.g., LiDAR or photogrammetry) would significantly improve ability to predict flood surface profiles for flows lower than 30,000 cfs.

Inundation increases from near-bank flooding at 21,000 cfs to significant, expansive floodplain inundation at 30,000 cfs.

Sand transport is predicted at all flow levels modeled higher than 668 cfs.

Gravel transport is predicted between 2,500 cfs and 30,000 cfs. Maximum sediment transport capacity is estimated at 10,000 cfs.

Cohesive sediments are predicted to erode between flow levels of 5,000 cfs and 13,000 cfs.

9.8 Next steps

Continue calibration of LT295 HEC-RAS model using on-going PT data collected at higher pulse flow rates between October 2013 and date the PTs get pulled.

Recommend shear stress modeling lower flow levels (e.g., SB3 base flows between 100 and 450 cfs) to see if sand was transported at those flow levels.

Conduct a study to validate sediment transport grain size and flow level predictions.

Conduct a riparian cross-section vegetation survey at LT295 to determine distribution of riparian species relative to their proximity to the bank.

Recommend a field effort to photograph LT295 cross-sections showing inundation levels of relevant flow events. Elevation surveying would be performed to locate large signage/markers. The markers would provide a more definite visual representation of discharge levels to on-site scour, substrate and vegetation types.