Appendix F

2012

US Army Corps of Engineers Galveston District

NOISE STUDY

for the proposed

CAPERS RIDGE PUMP STATION

Liberty County, Texas

COASTAL WATER AUTHORITY

Houston, Texas

AECOM

WCW INTERNATIONAL, INC.

performed by

QUADRANT CONSULTANTS INC.

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October 16, 2012

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NOISE STUDY
for
PROPOSED CAPERS RIDGE PUMP STATION

1 Introduction

Quadrant Consultants Inc. was retained by WCW International, under contract to AECOM, to perform a study of the potential noise impacts of the proposed Capers Ridge Pump Station for the Coastal Water Authority.

1.1 Background

The Coastal Water Authority (CWA), a special district established by the Texas Legislature with a board appointed by the Governor of Texas and City of Houston, provides untreated water to the Houston metropolitan area, including nearby cities and industries along the Houston Ship Channel. CWA obtains water as permitted by Texas from the San Jacinto and Trinity Rivers and conveys it in canals and pipelines to water treatment plants in Harris County. Most of the water consumed in the Houston metropolitan area is provided by the CWA.

CWA currently has one pump station on the Trinity River (the Trinity River Pump Station) about five miles north of Winfree in Liberty County (Figure 1 and Figure 2). The proposed Capers Ridge Pump Station will be built at Caper's Ridge, about 10 miles north of Dayton in Liberty County (Figure 3 and Figure 4). The new station will be configured similarly to the Trinity River Pump Station. AECOM and its subconsultant WCW International are assisting CWA to plan the proposed Capers Ridge Pump Station.

1.2 The Problem

Questions were raised by resource agencies during the permitting process for the Capers Ridge Pump Station about potential noise impacts from the pumps to wildlife in the area. The Trinity River and its surrounding riparian forest provide fishing and nesting habitat for bald eagles (*Haliaeetus leucocephalus*) and other raptors, and many species of wildlife can be found at the pump station site. While the bald eagle is no longer an endangered species on the federal list, it is still protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act, and it is still on the Texas list of threatened species. Habitat is not directly protected, but habitat protection can be made a condition of a permit.

Noise events can affect birds by repelling or startling them, causing them to leave their nests or roosting areas and thus rendering otherwise favorable bird habitat unusable. Birds are likely to avoid very loud constant noise (*i.e.*, over 90 dB) or be startled by sudden, distinct noise events (*i.e.*, about 30 dB over background level). However, birds would typically ignore a constant noise source that is a small amount (*i.e.*, about 10 dB) over the background level.

This study considers the potential noise impacts of operating pumps at the proposed Capers Ridge Pump Station and how it may affect bald eagles and other wildlife species near the pump station.

1.3 Objectives

This study has two objectives:

- Measure noise levels and sonic characteristics around the Trinity River Pump Station during normal operation to determine potential noise impacts at varying distances and angles from the pumps; and

Figure 1: Topographic Map of Trinity River Pump Station Vicinity

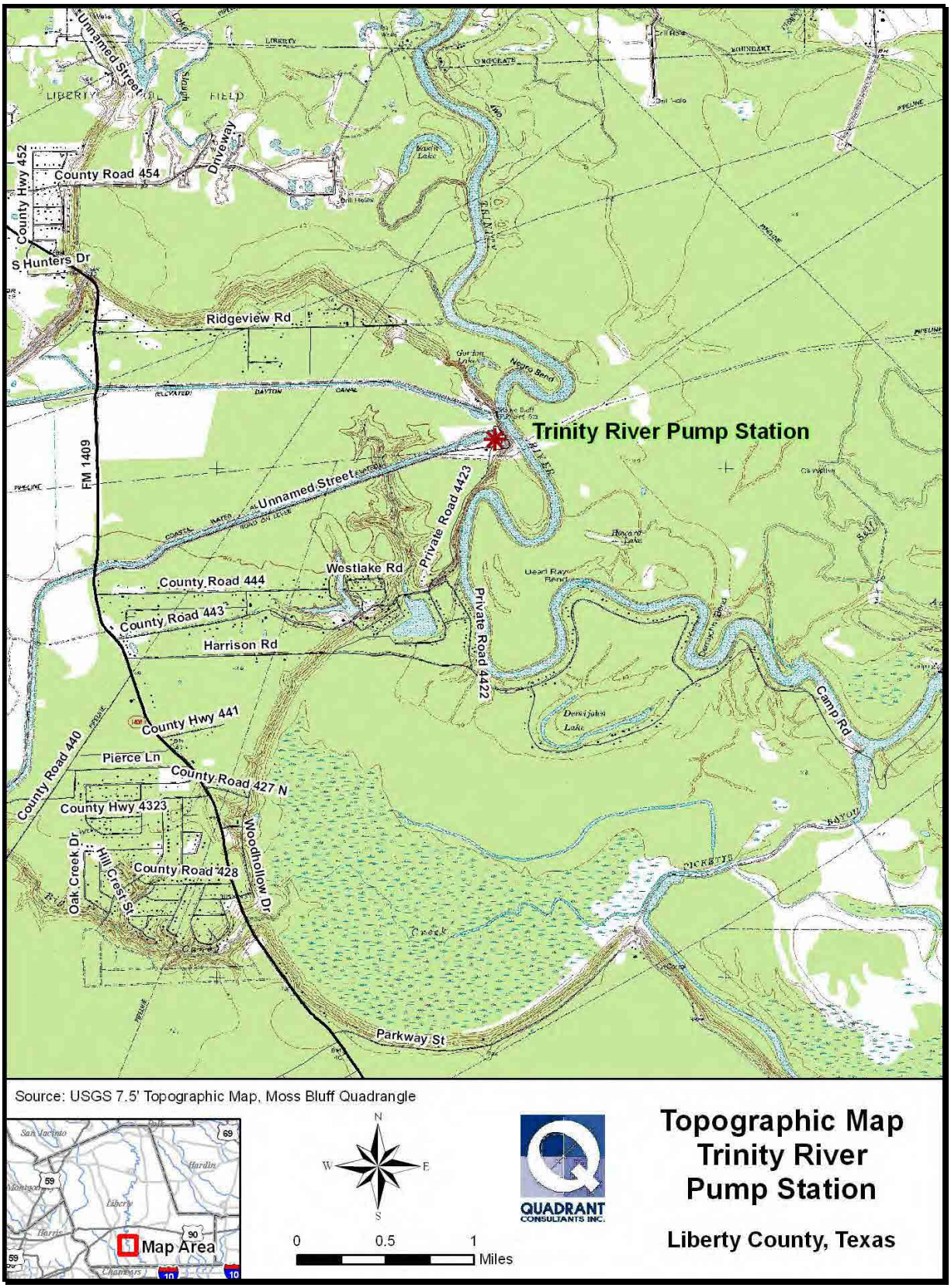


Figure 2: Aerial Photograph of Trinity River Pump Station

Figure 3: Topographic Map of Capers Ridge Pump Station Vicinity

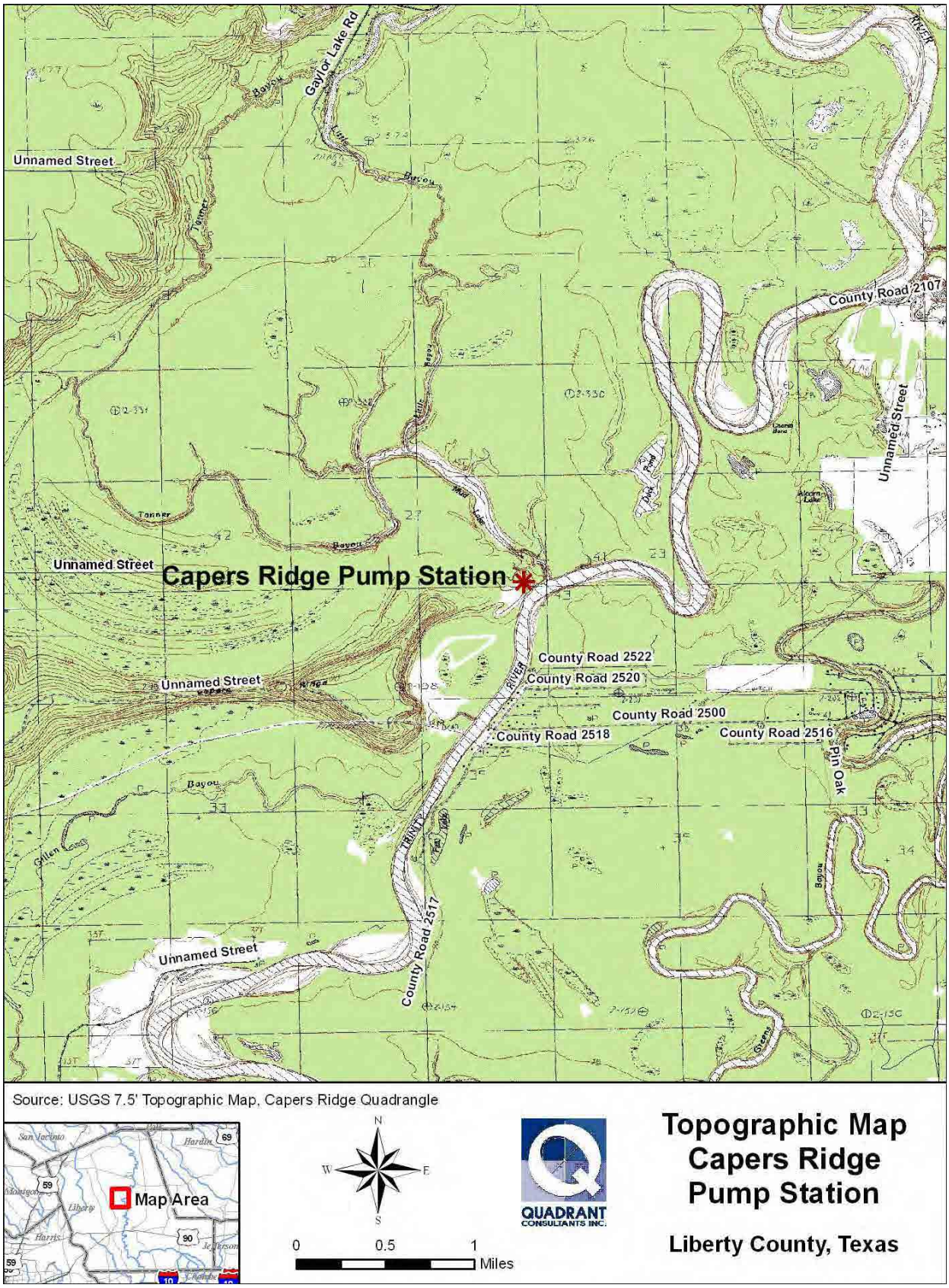
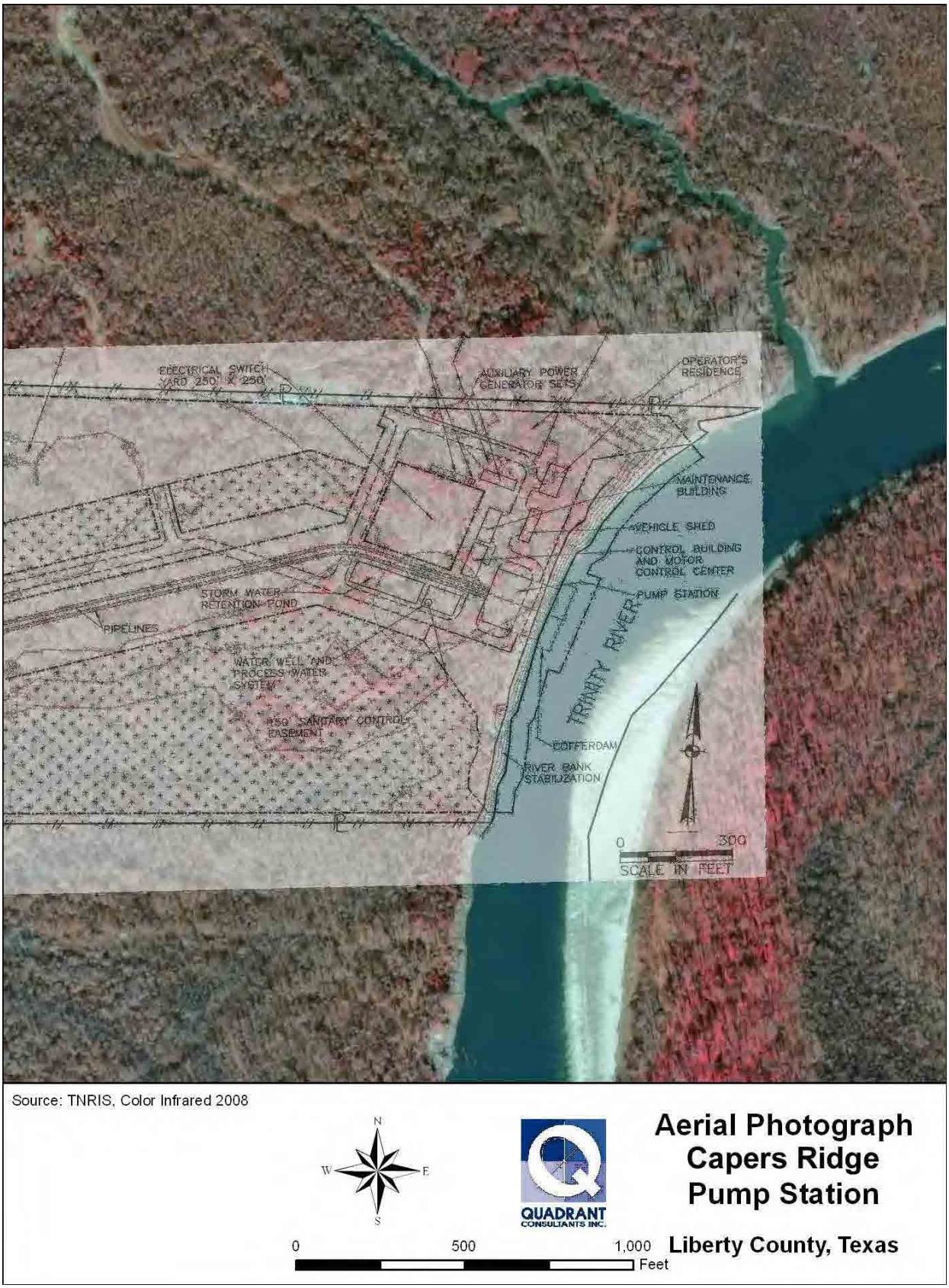


Figure 4: Aerial Photograph and Plan of Capers Ridge Pump Station



- Apply the noise results for the Trinity River Pump Station to estimate future potential noise impacts due to the proposed Capers Ridge Pump Station.

2 Methods

2.1 Noise Monitoring

Since the Capers Ridge pump station is not yet operating, noise monitoring was conducted at the existing Trinity River Pump Station, and results were then used to estimate future noise levels at the proposed Capers Ridge Pump Station.

Noise monitoring was performed from 10:00 to 11:00 AM on March 24, 2009, during normal pumping operation. Quadrant staff used three Larson-Davis Model 820 Type 1 SLM noise meters, mounted on tripods at about 4½ feet height above ground and calibrated to 114 dB before the monitoring. Each of the three meters was run simultaneously for 15 minutes, then moved to a second location and run for 15 more minutes, then moved to a third location and run for 15 more minutes, resulting in nine monitoring locations over three sequential 15-minute periods. At each location, Quadrant staff recorded instantaneous noise level every three minutes, single-event level minimum and maximum over the 15-minute period, and equivalent integrated noise level (L_{eq}) over the 15-minute period.

The layout of the noise monitoring sites is shown in Figure 5. Station B1 is the closest to the pumps, at about 20 feet distance, and Station C3 is the farthest, at 367 feet. Stations A1, A2 and A3 are on a sight line with the pumps, as are Stations B1, B2 and B3. Station C1 is at the top of the slope above the pumps and about 30 feet higher than the pumps, but still on a sight line with the pumps, while Stations C2 and C3 are not on the sight line; they are behind Station C1 at the same elevation, and the slope blocks the sight line.

2.2 Noise Assessment

Noise contours were estimated from integrated noise levels (L_{eq}) at the nine monitoring points at the Trinity River Pump Station. Contours were drawn between pairs of points spanning the contour interval, using the station topography shown on plan sheets provided by the Coastal Water Authority to guide contour line placement. Since the proposed layout of the Capers Ridge Pump Station is very similar to that of the Trinity River Pump Station, these contour lines for the Trinity River Pump Station were copied onto the proposed layout of the Capers Ridge Pump Station and rotated to match the orientation of the pumps at that station.

3 Results

The Trinity River Pump Station was operating normally on the morning of March 24, 2009, according to Mr. Wilson Fregia, the station superintendent. Pumps 2, 3, 8 and 10 were operating at full power, and noise levels were typical for normal operation. The weather was overcast, with winds from the south at five to 15 miles per hour, gusting to 25 miles per hour.

The results of the noise monitoring are shown in Table 1. The integrated noise level at 23 feet from the pumps was 66.2 dBA. As distance from the pumps increases, noise levels drop. The lowest noise level recorded, 47.1 dBA at Station C3, is probably close to the background noise level. Background noise is always present and in this case includes the noise produced by wind moving through tree leaves, water running in streams and canals, bird calls and barking dogs. We

Figure 5: Noise Measurements and Contours at Trinity River Pump Station

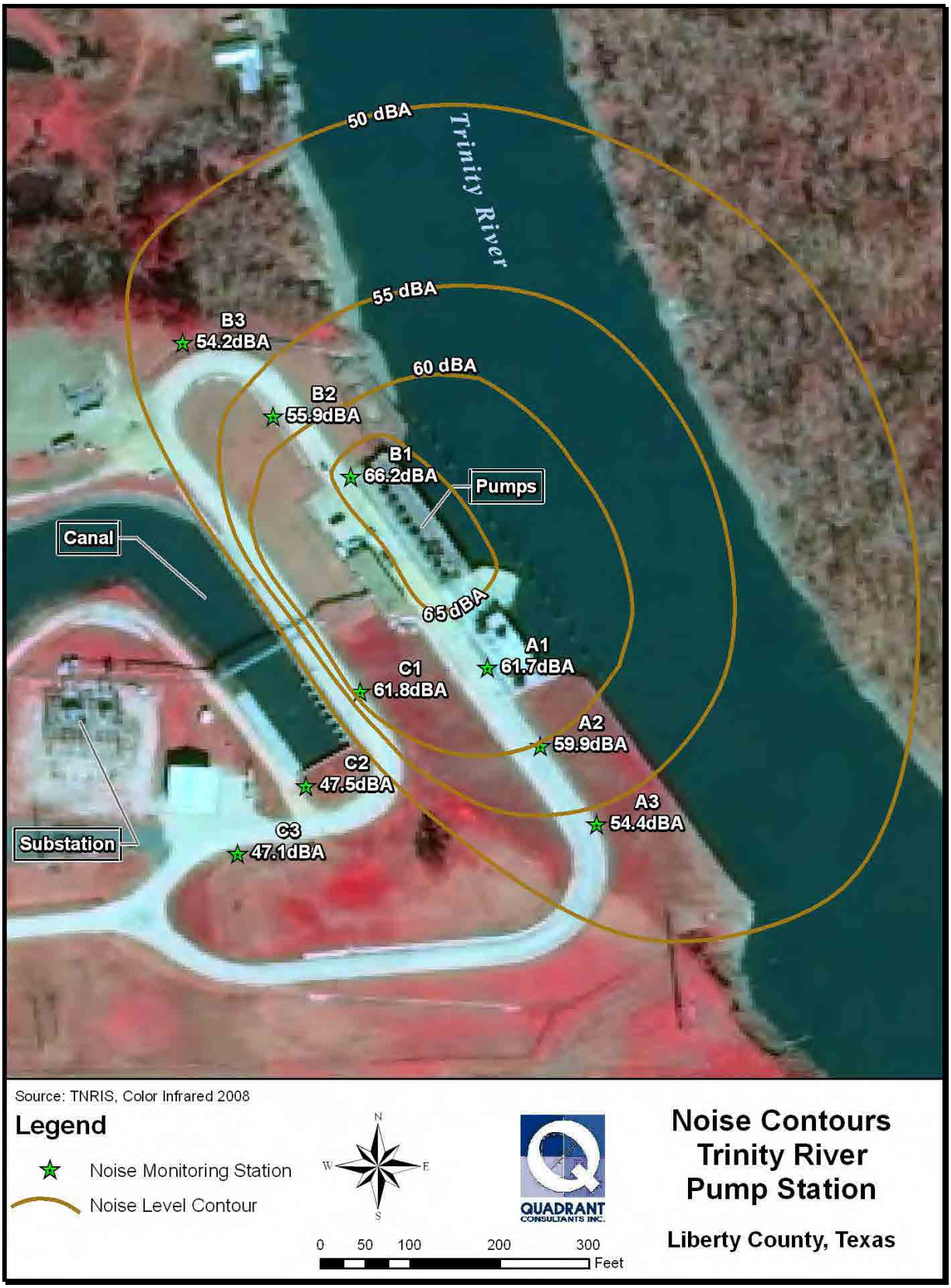


Figure 6: Noise Contours at Proposed Capers Ridge Pump Station

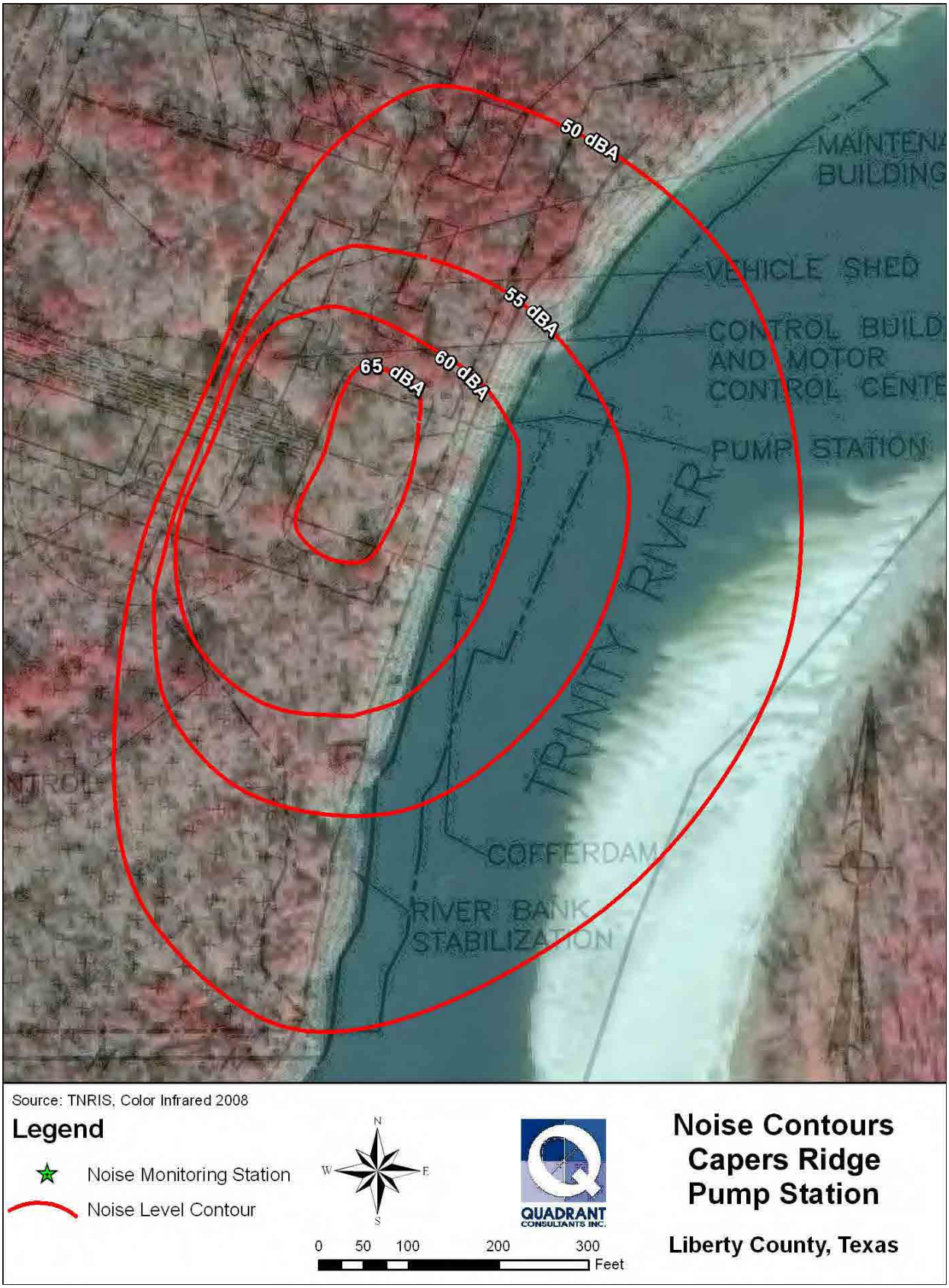


Table 1: Noise Monitoring Results at Trinity River Pump Station

Monitor Station	*Distance from Closest Operating Pump (feet)*	*Elevation (MSL, feet)*	*Integrated Noise Level (L_{eq}, dBA)*	*Maximum Sound Level (dBA)*	*Minimum Sound Level (dBA)*
A1	113	25	61.7	*	*
A2	214	25	59.9	67.1	58.4
A3	318	25	54.4	72.1	51.6
B1	23	25	66.2	70.1	62.1
B2	121	30	55.9	61.7	52.0
B3	241	55	54.2	65.6	48.9
C1	150	55	61.8	**	56.1
C2	268	55	47.5	68.8	43.7
C3	367	55	47.1	61.8	41.3

* Readings were not taken.

** L_{max} measurement was spoiled by a sneeze by the operator. This does not affect the L_{eq} or L_{min} levels.

noted that noise at stations near the pumps was dominated by pump noise, while wind noise and other background noise dominated at Station C3.

The single-event noise level at Station A1, the station closest to the pumps, ranged from 62.1 dBA to 70.1 dBA, or only about 4 dBA on either side of the integrated noise level. This noise variation is very small and is barely perceptible to humans and probably most wildlife.

Likewise, pump noise variability is small at all stations except C2 and C3, where noise levels were near the low background level and would be disproportionately affected by the same variations in noise. It appears that the pump noise levels are very constant and produce no sudden noise event (except possibly during startup and shutdown, which were not measured).

The data show that pump noise is the dominant source of noise within 500 feet of the pumps and where there is a sight line to the pumps. Where there is no sight line, or beyond 500 feet, the pump noise recedes to or below the background level.

Figure 5 shows approximate noise contours around the pumps, drawn from the integrated noise levels at the nine monitoring stations. The 50 dBA contour is close to the background level, and sites inside this contour are exposed to some amount of pump noise. The presence of a slope to the west of the pumps limits the pump noise exposure of the areas beyond the slope because they are not on a sight line with the pumps.

Noise contours for the proposed Capers Ridge Pump Station (Figure 6) were developed by taking the same noise contours developed for the Trinity River Pump Station (shown on Figure 5), rotating and placing them onto the layout for the Capers Ridge Pump Station.

4 Conclusions

This study shows that pump noise will not affect wildlife beyond 500 feet from the proposed Capers Ridge Pump Station. This conclusion is based on the following findings:

1. At 500 feet distance, pump noise is essentially the same intensity as background noise.
2. Pump noise variability is within 10 dBA, which is relatively constant, and pumps in normal operation do not cause sudden noise events that would startle wildlife.

Furthermore, it is unlikely that the pump station will affect most wildlife even 100 feet from the pumps. At 100 feet distance, pump noise is about 10 dBA louder than background noise, a relatively small increment. Many birds and other kinds of wildlife would habituate to the constant drone of the pumps and use the pump station area whenever human activity is at a low level.

Appendix G

2012

US Army Corps of Engineers Galveston District

October 2, 2009

Victoria A. Foss, P.E.
Civil/Environmental Engineer
Texas Water Engineering, PLLC
16 Pecan Gorge Ct.
Sugar Land, TX 77479

Dear Ms. Foss:

This letter report was requested to provide a summary of the results to date in regard to an investigation of a historic-period homestead reported by family landowners and confirmed by archeological field investigations within a proposed revised alignment segment of the Luce Bayou Diversion Project corridor. The following points regarding the history of the resident Huffman/May family were conveyed to Mr. Jeff Eversberg of AECOM at a September 1, 2009 meeting with family members.

- Ms. [Robin] May gave an overview of the family history. The Huffman/May family has owned the subject property since 1839. Ancestors of the May family, including Sara Huffman and Sam May (pictured below, Figure 1) received the land at the conclusion of the Texas Revolution.
- A large live oak tree exists near the center of the May property. The tree was planted in 1839 by Sara Huffman and is now of considerable size. According to Ms. May, the tree has been registered with the Texas Big Tree Registry and the Texas Family Land Heritage Program. The tree is pending measurement for documentation with the Texas Big Tree Registry.

Figure 1. Sara Huffman and Sam May (reputed date, 1839)

Dr. Moore, Mr. Ferguson, and Ms. Denman from Moore Archeological Consulting, Inc., met with Ms. Robin May and her father, Mr. Buddy May, on Wednesday September 9th, 2009, at the home of the latter at 2400 Wolf Road, adjacent to the proposed revised alignment segment passing through the May property. We received an oral historical summary similar to that presented to Mr. Eversburg, as well as a tour of the alignment and the traditional homestead site location and features (i.e., the large oak and sycamore trees whose positions are clues to the location of the former home site).

Ms. May also promised to provide us with copies of the documentation submitted to secure the listing on the Texas Family Land Heritage Program, a project of the Texas Department of Agriculture created to recognize family farmers and ranchers who have owned their land for 100 years or more, and kept it in agricultural production during that time. (I confirmed by later telephone discussion with a Department of Agriculture program administrator that listing with the Family Land Heritage Program confers no historical or other protective covenants to the listed property.) To date, however, a family medical emergency has precluded Ms. May from providing any of the promised written documentation. She has, however, provided scans of a few more historic photographs associated with the homestead site.

The relevant portion of the proposed alignment revision is situated on the Huffman USGS quadrangle map (Figure 2.) The large tree is visible on the project aerial photograph (Figure 3). A structure is depicted at or near the traditional family location on the 1920 edition of the Huffman Quadrangle (Figure 4). This structure had disappeared, however, by the time the 1960 edition of the same map was drafted (Figure 5). We can therefore conclude that the structure was constructed some time before 1920, and demolished some time before 1960. The date of construction can be refined to an extent by historic family photographs provided by Ms. May. One photograph, dated to Christmas Day, 1909, includes the corner of the house structure (Figure 6) in the periphery of the picture. The large tree visible in the background is also believed to be the large oak that survives to the present.

Figure 6. Family photograph with home visible in the background.

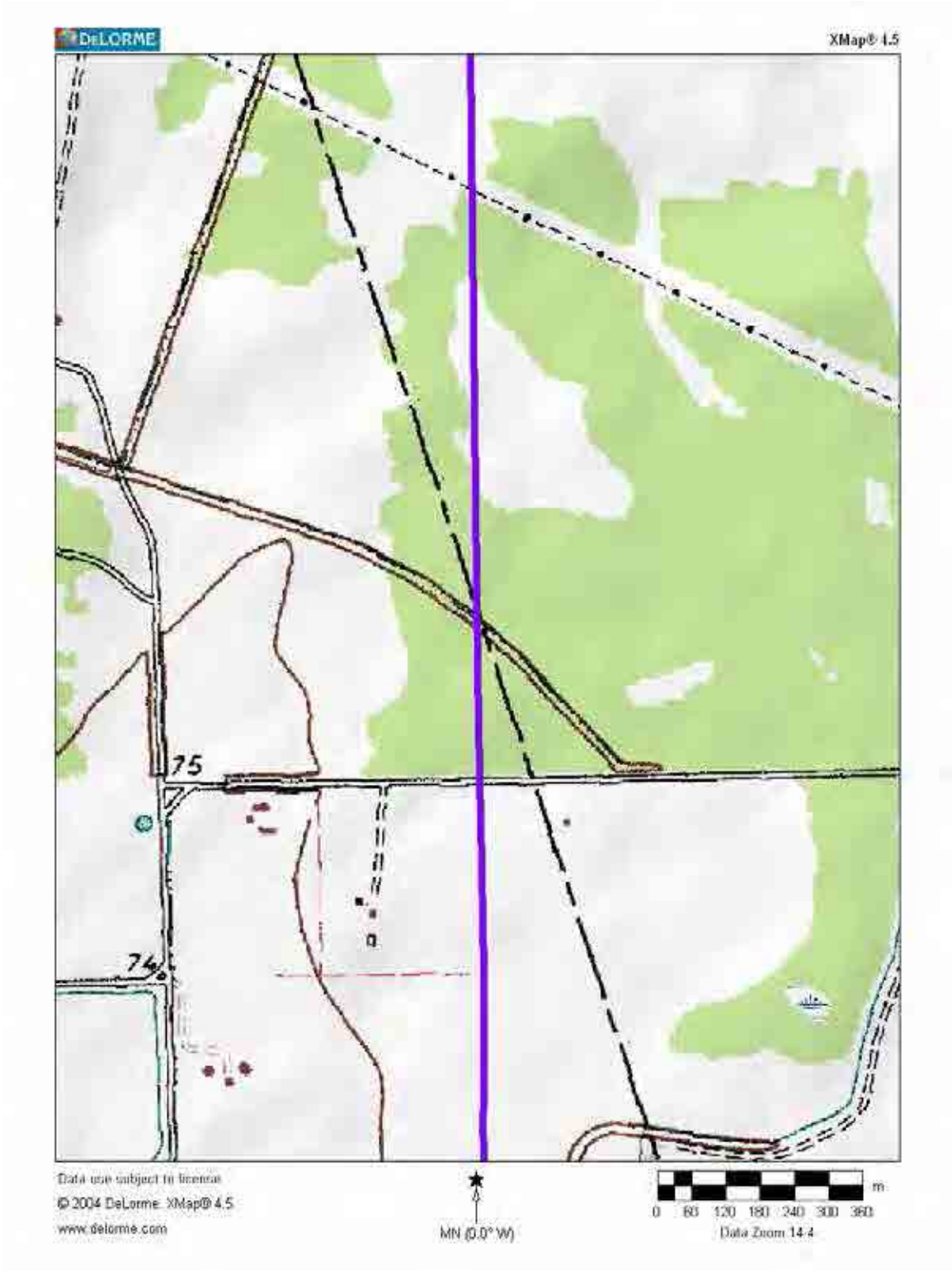


Figure 2. Proposed Revised Parcel 47.5 Alignment Center Line at the May Property as Depicted on the Current Edition of the Huffman, Texas, USGS Quadrangle Map.

Figure 3. Project Aerial phototgraph of the Revised Parcel 47.5 Alignment at the May Property.

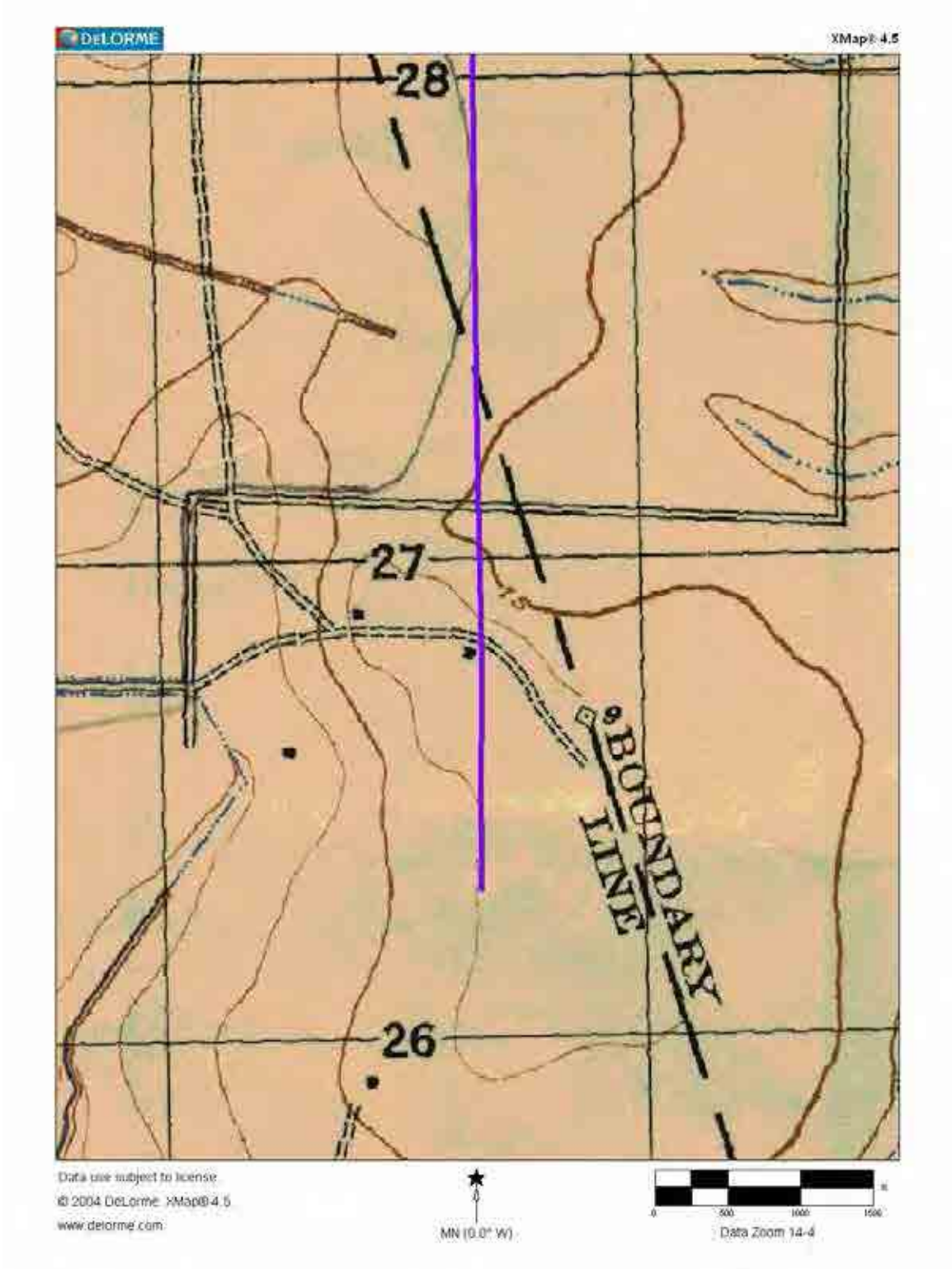


Figure 4. Proposed Revised Parcel 47.5 Alignment Center Line at the May Property as Depicted on the 1920 Edition of the Huffman, Texas, USGS Quadrangle Map. A structure is illustrated by a black square adjacent to the west side of the alignment center line (purple line).

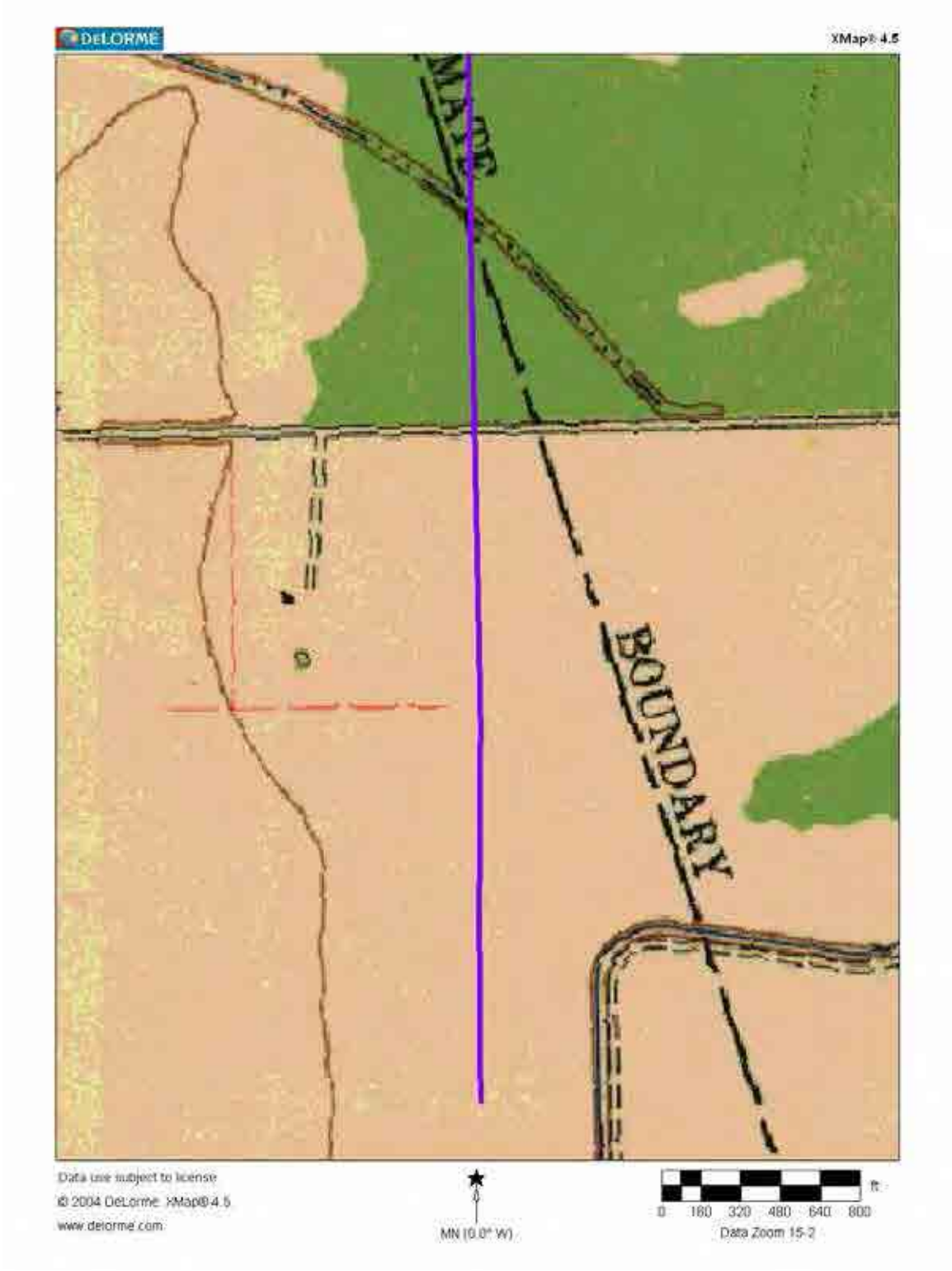


Figure 5. Proposed Revised Parcel 47.5 Alignment Center Line at the May Property as Depicted on the 1960 Edition of the Huffman, Texas, USGS Quadrangle Map. The structure present on the 1920 edition has vanished.

The Moore Archeological Consulting, Inc. crew returned to begin survey-level archeological investigations of the purported homestead site in earnest on September the 17th and 18th 2009. Intensive shovel testing within the proposed corridor quickly confirmed that historic-period deposit and artifacts were, indeed, present within the corridor, and that they were concentrated more or less in the area suggested by May family tradition (Figure 7). This location was thus designated Temporary Site No. 32 (for the overall project survey).

The locus of the TS 32 artifact concentration coincides closely with both the May family traditional location for the homestead structure and with the building location shown on the 1920 quadrangle map, and the site is clearly within the archeological APE of the proposed Parcel 47.5 alignment revision. Soil and artifact orientation observations during intensive shovel testing indicated that the site area had not been significantly disturbed to any depth (see Attachment 1) and artifact yield were consistent with a domestic site (residence; see Attachment 2).

The archeological results, while productive, differed in one important respect from the May family tradition as related to us and to Mr. Eversberg. We failed to find any dateable materials that would suggest an occupation in the corridor dating back as far as the the third quarter of the 19th Century, much less to the time the land was awarded in to the Huffman family in 1839. Domestic occupation within the alignment during that period should have left ample, temporally diagnostic evidence in the form of artifacts such as hand-blown or three-piece mold bottles, hand-painted and transfer–printed soft paste whitewear ceramics, and many other characteristic items found on such sites.

I do not doubt that there were one or more habitation sites on the original Huffman land grant that dated to the Republic of Texas period through the latter part of the 19th Century, and it is possible that the May family still owns one of these older sites. There is no direct archeological evidence to indicate that any such sites are situated within the portion of the proposed alignment currently owned by the May family.

Though we believe that TS 32 does not represent an early historic-period Anglo occupation, the archeological site does exhibit good archeological context and produces artifacts in large numbers and reasonable diversity. The site provides an archeological window to a late 19th to early 20th Century agricultural homestead class that has seen little systematic archeological investigation, and whose potential to yield new information may increase with the passage of time.

Moore Archeological Consulting, Inc., therefore recommends that the Clients avoid impact to Site TS 32 by adjusting the proposed alignment of the project, or by abandoning altogether the proposed Parcel 47.5 revision of the diversion route.

Sincerely,

Roger G. Moore, Ph.D.,President
Moore Archeological Consulting, Inc.

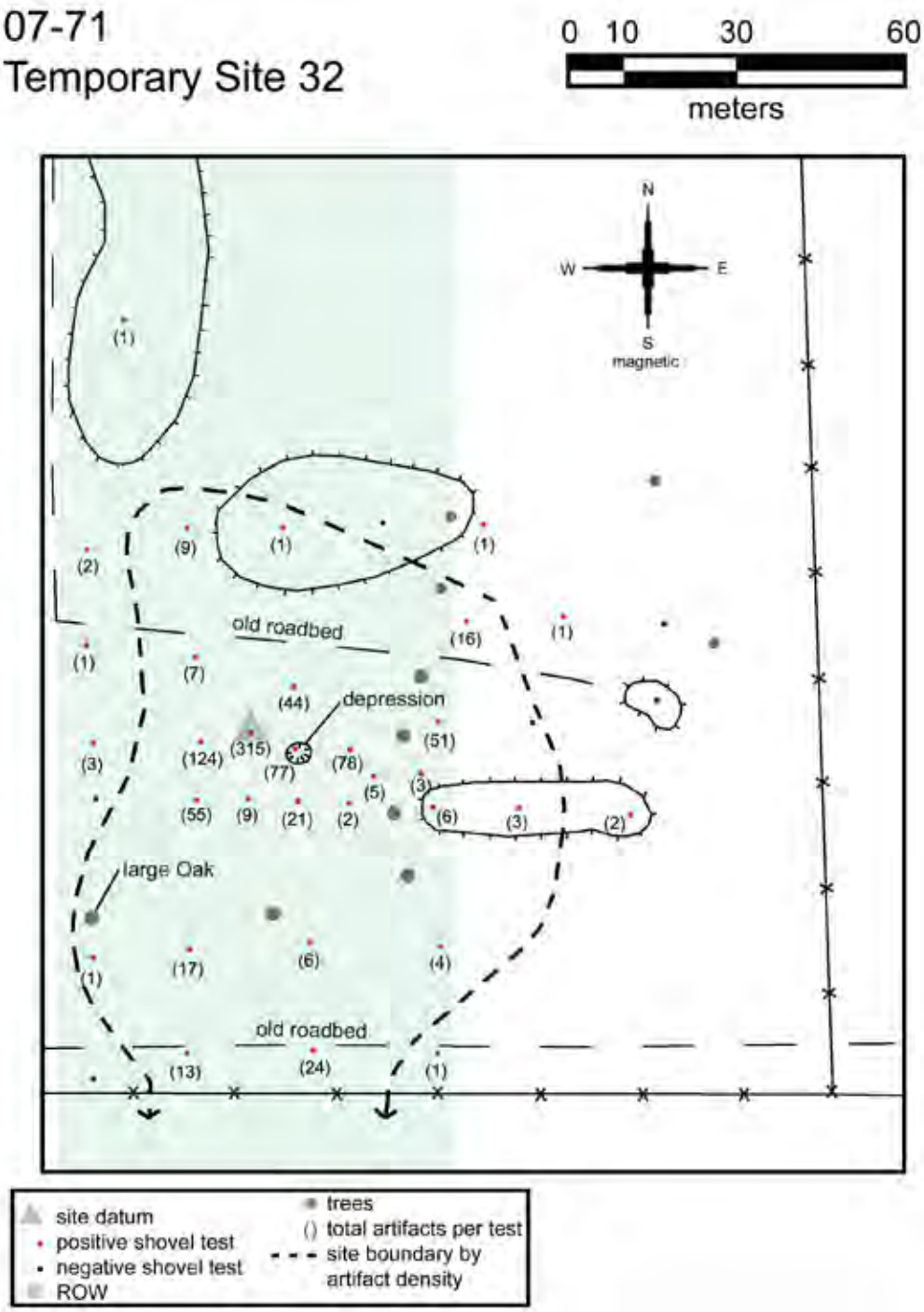


Figure 7. Site Map of Temporary Site 32 illustrating ROW Corridor relative to shovel test locations and artifact numbers, and natural (trees) and cultural (fence lines, roadbeds, possible well or cistern depression) features, and tentative site boundaries.

Attachment 1: May Family Archeological Investigation Field Notes [Randy Ferguson, Field Director]

On Wednesday September 9th, 2009 Roger Sarah and myself went to the May family home to meet with Mr. May and his daughter Robin to discuss the possibility of a family Oak Tree and home site on their property which a realignment of the Luce Bayou Diversion Project would affect. The May's gave us some information and family photos from the early 1900's that showed the Oak and a couple of Sycamore Trees in association with a wood frame home. The May's then took us out to the location of the trees on their property and showed us the vantagepoint from which they believed the photos were taken. The spot looked convincing enough for us to go ahead with some shovel testing around the general area to try and assess whether there was a home site there, how old it might be, and whether there were any intact remnants of it left.

The home site area is now use for cattle grazing. There are a few round bale hay feeders scattered across the lot. These feeders have been in place for so long that the elevation of the ground beneath them is a good deal higher than the surrounding area. The vegetation includes quite a few very mature trees, most of which could date back to the time of occupation or earlier. There is the one large 17' circumference Oak, 2 or 3 large Sycamore Trees, the same number of old Pecan Trees, and quite a few younger trees of the same species. The surface of the ground is fairly flat excepting for a couple of old roadbeds to the north and south of the proposed home site. There are also a couple of low mounded areas to the north of the home site that follow the old roadbed.

On September the 17th and 18th 2009, Roger, Rebecca, Sarah, Rachel, & myself [Ferguson] returned to the May family tract and did some shovel testing and site delineation in the site we had looked at with the Mays in the previous week. We excavated a total of 38 shovel tests, 6 of which were negative. The area was thus designated as Temporary Site (TS) 32. The artifacts seemed to come from generally levels 1-3 (0-30 cm. below surface). There was one test, #486, that had artifacts down to level 8 (80 cm). And #490, next to a suspicious looking depression, had artifacts down to level 6 (60 cm). The depression, we determined later, was previously an intentionally excavated, large hole (perhaps a well or cistern), as a probe in its center produced an abundance of modern glass and ceramics. It is evident from shovel test 515 that the soils around the home site are probably intact as we found an intact wagon wheel rim in level 1 (o – 10 cm) that was still as perfectly round as the day it was built. If the land had been plowed over, the rim would no doubt have been affected in some manner. We did not locate any well-defined features during the shovel testing that would indicate an exact location of the house site. But with sheer numbers of artifacts per shovel test, I think we have a pretty good idea of where the focus of activity was during the heyday of the home site. Shovel test 521 is located about 10m west of the possible well/cistern/privy pit, and contained a total of 315 artifacts.

The other high-count tests within 20m of test 315 included total artifact numbers of 124, 77, 78, 55, 51, & 44 respectively. The artifact counts per test tail off significantly after this 20m radius. The old roadbed that led to the house runs about 25m north of the

highest count shovel test and the artifact counts subside substantially north of this. The artifacts do pick up again about 40m south of STP 521 but the counts are not nearly as high.

The artifacts recovered from the site include a general mix of things found at old home sites like an abundance of rusted iron, the majority of which could not be identified, window and bottle glass, ceramics including white ware and stone ware, low fired brick fragments, mortar, buttons, bone and much more. Most of the artifacts, at this stage, seem to point to a time period of occupation around the turn of the 19th century or later.

Attachment 2: May Family Archeological Investigation Preliminary Artifact Analysis [Kelly Schexnayder, Laboratory Director]

The artifact assemblage recovered from Temporary Site (TS) 32, the May Family homestead, consisted primarily of building materials, with very few personal items. The artifacts present in the shovel tests were: brick fragments (handmade), wire, fencing staples, nails (mostly round), curved glass, flat glass, crude whiteware, porcelain, nonhuman bone, modern ammunition cartridges, and charcoal (minimal). A few of the glass fragments exhibited mold seams and one brown bottle base was embossed, dating them to the early to mid twentieth century. The combination of handmade brick and round nails also indicates the assemblage to be from this period. Other than this the assemblage did not contain diagnostics. With a few exceptions, most of the artifacts came from the top forty centimeters. There was no presence of modern trash.

An Archaeological Cultural Resources Survey and Historic Evaluation of the Luce Bayou Interbasin Transfer Project, Harris and Liberty Counties, Texas

Texas Antiquities Permit 5082
U.S. Army Corps of Engineers Permit No. SWG-2009-00188

by
John R. Ferguson
Roger G. Moore
and
David Driver

Moore Archeological Consulting, Inc.
Report of Investigations Number 553

August 2012

An Archaeological Cultural Resources Survey and Historic Evaluation of the Luce Bayou Interbasin Transfer Project, Harris and Liberty Counties, Texas

Texas Antiquities Permit 5082
U.S. Army Corps of Engineers Permit No. SWG-2009-00188
MAC Project Number 07-71

by
John R. Ferguson
Roger G. Moore
and
David Driver

with contributions by
Terri Meyers

Prepared for
DESCO, LP
and
AECOM
Houston, Texas

Moore Archeological Consulting, Inc.
Houston, Texas
Report of Investigations Number 553

August 2012

ABSTRACT

Moore Archeological Consulting, Inc. (MAC) conducted a three-phase cultural resource investigation of the Capers Ridge Pump Station location and diversion alignment for the Luce Bayou Interbasin Transfer Project (LBITP) in Harris and Liberty Counties, Texas. This work began as a reconnaissance-level pedestrian cultural resource survey investigation of the Pump Station location and the LBITP diversion alignment in Harris and Liberty Counties, Texas. The pedestrian cultural resource survey was performed between January 5, 2009 and April 2010. Initial reporting and consultation with the US Army Corps of Engineers (USACE), Galveston District, resulted in the decision to expand the survey into a full-scale 100 percent pedestrian cultural resource survey of the entire project area. A second fieldwork phase was conducted to fully delineate by shovel testing all the sites identified in the initial survey and fill in any gaps left by the reconnaissance-level pedestrian survey. The results of this second field phase were integrated into the initial report draft and presented for review to the Corps of Engineers, Galveston District, and to the Archeology Division of the Texas Historical Commission (THC). After this consultation with the THC, mechanical trenching was conducted in some portions of the LBITP alignment during December 2011, as specified by the Archeology Division reviewers.

The ultimately 100 percent intensive-level pedestrian survey of the LBITP area included both surface and subsurface (shovel test and backhoe trenching) examination. A total of 1,046 shovel tests and 44 backhoe trenches were excavated. The investigations relocated one previously recorded site, 41LB42, and identified 26 new archeological sites (41HR1073-1076 and 41LB97-118). Four locations where shovel testing produced only a single prehistoric artifact were determined to be isolated finds (IF 1-4) and were not designated as archeological sites. A total of 1,568 artifacts were recovered during these investigations.

Of the 26 newly discovered locations, three are historic and 23 are prehistoric. 41HR1073 and 41HR1076 appear to be historic farmsteads that date to the early 20th century, while 41HR1075 contained artifacts associated with late 19th century occupations. All three appear to have potential subsurface features that may be partially filled cisterns, etc. However, the late period of occupation for these three historic sites do not appear to demonstrate potential for future study, and are thus not recommended for further investigations. Further, 41HR1076 is a historic farmstead located on the May family property and the LBITP will avoid this property entirely. Once the current report is finalized, the diagnostic and non-redundant artifacts recovered from the three historic sites will be curated at Texas Archeological Research Laboratory (TARL). No potentially historic structures were observed within or near the survey alignment.

Sixteen of the prehistoric sites, 41HR1074, 41LB98, 41LB100, 41LB101, 41LB102, 41LB105, 41LB106, 41LB107, 41LB108, 41LB109, 41LB110, 41LB111, 41LB113, 41LB114, 41LB115, and 41LB116, each appear to contain deposits of very limited artifact density and diversity, and are not recommended for further investigations. At one of these sites, 41LB105, only the portion of the site that was located within the APE was delineated and assessed for NRHP eligibility. Should impacts be planned for the portion of 41LB105 located outside the current APE boundary, additional investigations should be conducted to determine the NRHP eligibility for the additional site area.

One newly discovered site, 41LB118, was identified in an area that no longer is part of the LBITP ROW. This site was not fully delineated since it is no longer in the APE of the proposed project. The level of investigations conducted at this site was insufficient to assess it for NRHP eligibility. Consequently, additional delineation and assessment of site eligibility should be conducted if future impacts are proposed for the site.

Six of the newly discovered prehistoric sites, 41LB97, 41LB99, 41LB103, 41LB104, 41LB112, and 41LB117, appear to potentially contain intact cultural deposits that exhibit low-moderate artifact densities and diversity. Each of these six sites warrant further investigations to determine their potential significance for future research. These sites should be avoided, or if this is impossible, additional investigations will be necessary to determine eligibility prior to the initiation of construction.

The previously identified prehistoric site, 41LB42, was greatly expanded in size by the current investigations, and areas of denser and more diverse artifact concentrations within the site were identified that warrant further investigations. Another previously identified prehistoric site, 41LB43, could not be relocated at the published coordinates. This site was either originally plotted incorrectly or has eroded away. If misplotted, the site may lie outside the surveyed alignment or could be represented by one of the newly discovered sites 41LB100 or 41LB101 (which are located more than 200 m to the east of the site's reported UTMs). Once the current report is finalized, the artifacts recovered from 41LB42 and the 23 newly discovered prehistoric sites will be curated at TARL.

In the event that additional archeological deposits or features should be encountered during construction, work should cease in the immediate vicinity and the Archeology Division of the Texas Historical Commission contacted for further consultation.

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INTRODUCTION

Moore Archeological Consulting, Inc. (MAC) conducted a three-stage cultural resource investigation of the Capers Ridge Pump Station location and diversion alignment for the Luce Bayou Interbasin Transfer Project (LBITP) in Harris and Liberty Counties, Texas. This work began as a reconnaissance-level pedestrian cultural resource survey investigation of the Pump Station location and the LBITP diversion alignment in Harris and Liberty Counties, Texas. The pedestrian cultural resource survey was performed between January 5, 2009 and April 2010. Initial reporting and consultation with the US Army Corps of Engineers (USACE), Galveston District, resulted in the decision to expand the survey into a full-scale 100 percent pedestrian cultural resource survey of the entire project area. A second fieldwork phase was conducted to fully delineate by shovel testing all the sites identified in the initial survey and fill in any gaps left by the reconnaissance-level pedestrian survey. The results of this second field phase were integrated into the initial report draft and presented for review to the Corps of Engineers, Galveston District, and to the Archeology Division of the Texas Historical Commission (THC). After this consultation with the Texas Historic Commission, mechanical trenching was conducted in some portions of the LBITP alignment during December 2011, as specified by the Archeology Division reviewers.

The project area is depicted on the Huffman, Plum Grove, Simmons Bottom, and Capers Ridge, Texas 7.5-minute USGS topographic quadrangle maps (Figures 1 and 1A through 1D). An AECOM map illustrating the location of the LBITP parcels is also provided in Appendix 1 (Figure 1-1). The initial objective of the investigation was to identify subdivisions of the project alignment into areas of high and low probability of the occurrence of cultural resources sites, as well as incorporate data on known cultural resource sites and surveys. The investigations (MAC Report of Investigations No. 553) were conducted at the request of DESCO, LP, WCW International, Inc., AECOM, and the Coastal Water Authority, under Texas Antiquities Permit Number 5082. The LBITP is also subject to permitting under Section 404 of the Clean Water Act and there is a USACE, Galveston District, Permit SWG-2009-00188 established for this project.

The Luce Bayou Project has a long and complex history. The concept of diversion of Trinity River water into Luce Bayou to supply the City of Houston and its industries was expressed in a Houston Chronicle newspaper article as early as March 22, 1938. The project first moved toward realization in the late 1970s and early 1980s, with some studies (including archeological investigations) conducted prior to a long hiatus in the project. Archeological investigations[1] during this period included an intensive pedestrian survey of the Capers Ridge Pump Station tract and of the diversion alignment (Chaffin-Lohse 1978) and National Register of Historic Places (NRHP) eligibility testing at historic site 41LB41 within the Capers Ridge Pump Station tract (Heartfield Prince and Greene 1982).

The current diversion alignment departs significantly from the 1978 survey alignment, while the Capers Ridge Pump Station tract remains the same. Site 41LB41 was the only cultural resource identified within the Capers Ridge Pump Station property in 1978. Testing conducted in 1982 revealed that 41LB41 was not eligible for NRHP or State Archeological Landmarks (SAL) designation (Heartfield Prince and Greene 1982:8-1). This site is therefore given no further consideration in this study. Only two small prehistoric sites (41LB42, 41LB43) on Capers Ridge Pump Station property of the six sites identified in the 1978 survey are proximal to the current alignment. Avoidance of these sites was recommended in the 1978 report. The current

[1] Roger Moore served as a field technician on the 1978 survey and was director of the 1982 site testing project.

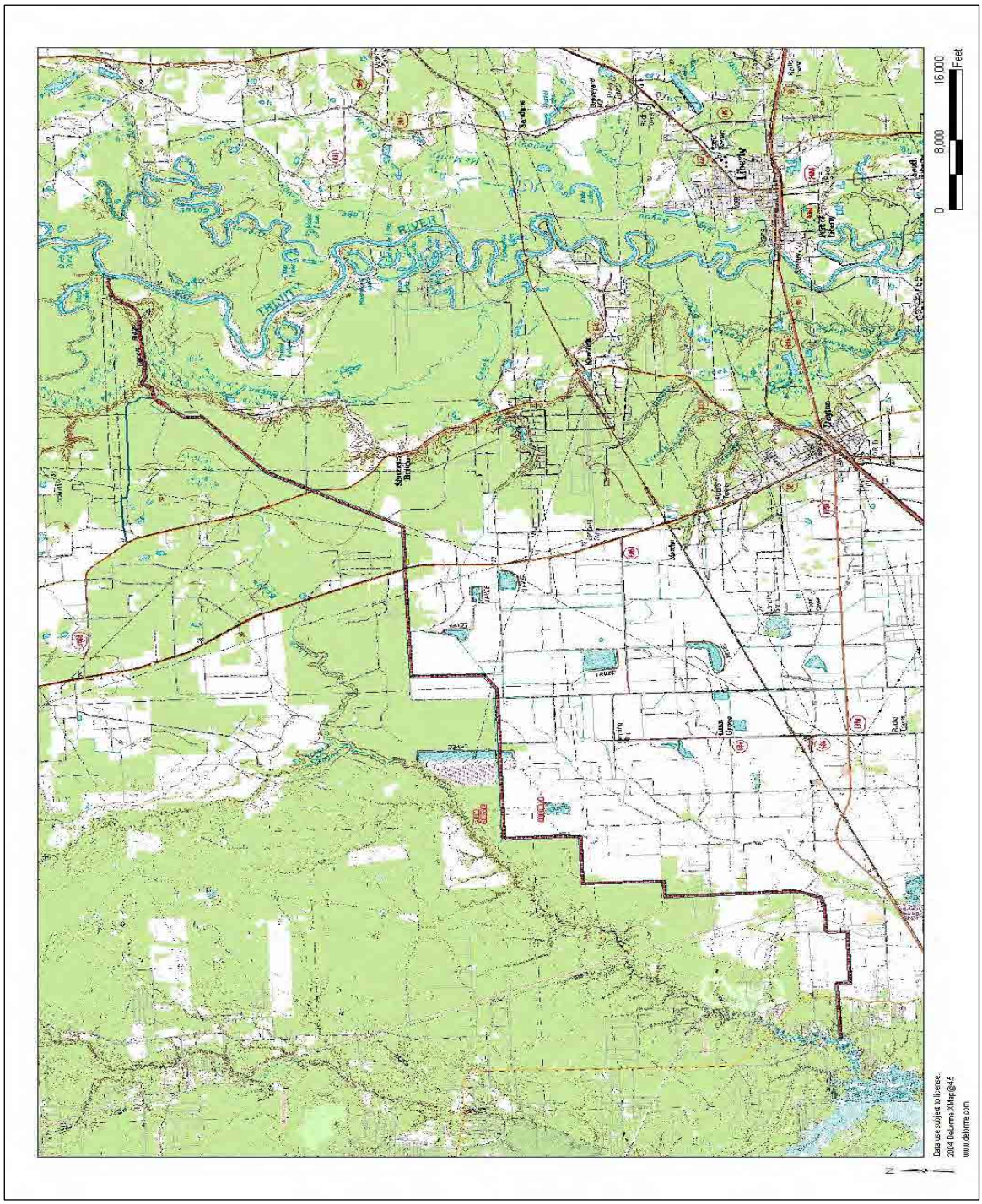
archeological investigations included efforts to relocate, delineate, and re-evaluated these two sites.

Reviewers and other readers will note that our level of effort in the current volume far exceeds that normally expected under what began as a reconnaissance-level Antiquities Permit investigation. The tight project schedule combined with an unexpectedly high number of sites found, time-limited access, and availability of logistical resources made it both possible and justifiable to continue the work, first through delineation of essentially all of the sites found during the reconnaissance, and second, to fill in gaps in shovel testing along the alignment in any land parcel where ROE was granted and shovel testing was allowed. In the final phase of survey investigations, a series of mechanical trenches were excavated in both site and intersite areas along the Capers Ridge portion of the alignment as requested by the Archeology Division reviewers. Each transition from one level of survey intensity to a higher one was accompanied by consultation with the USACE archeologist for the Galveston District and did not proceed without his consent.

It was never our intent to preclude the USACE or the Archeology Division of the THC from its proper role in reviewing and amending, where necessary, the scope of work for this project, which now clearly qualifies for a 100 percent intensive pedestrian survey. The Survey Scope and Research Design for the current report evolved with the USACE and THC reviewers' analysis of the currently available survey data at each earlier stage of the investigation, all of which was collected by customary methods and principles as presented in the State Survey Standards. Only now, with the current report, are we presenting this data as sufficient for completion of a 100 percent intensive survey, since we have now completed all the work specified for such an investigation by the project reviewers.

The anticipated – and achieved - benefit of the approach taken with this report is that it allowed the Coastal Water Authority to complete a 100 percent survey that provides a completed field investigation that is reasonably expected to be acceptable to the reviewers on the first round of review (at draft submission) ***since the methodology for each step of the investigation has been defined in direct consultation with the USACE archeologist and/or the THC Archeology Division reviewer and based on the results of the preceding step***. This approach also allowed us to carry on with the analysis and assessment of significance for each of the already-discovered sites concurrently with the review of the Draft Reconnaissance Permit thereby expediting the transition to the subsequent Testing Permit phase of the investigation, which appears to be necessary for some of the sites identified along the LBITP alignment.

The ultimately 100 percent intensive-level pedestrian survey of the LBITP area included both surface and subsurface (shovel test and backhoe trenching) examination. A total of 1,046 shovel tests (Figure 2) and 44 backhoe trenches (Figure 3) were excavated, resulting in the discovery of 26 new archeological sites (41HR1073-1076 and 41LB97-118), and the identification of four isolated find locations (IF 1-4). The locations of the two previously identified sites, 41LB42 and 41LB43, were revisited, and resulted in the significant expansion of 41LB42. 41LB43 could not be relocated. The field investigations were conducted by project archeologist Randy Ferguson and field technicians Richard Alba, Sarah Blake, Rebecca Carroll, Eleanor Dahlin, Rachael Going, Sally Morehead, and Lisa Rodriguez. Roger Moore served as the project's principal investigator.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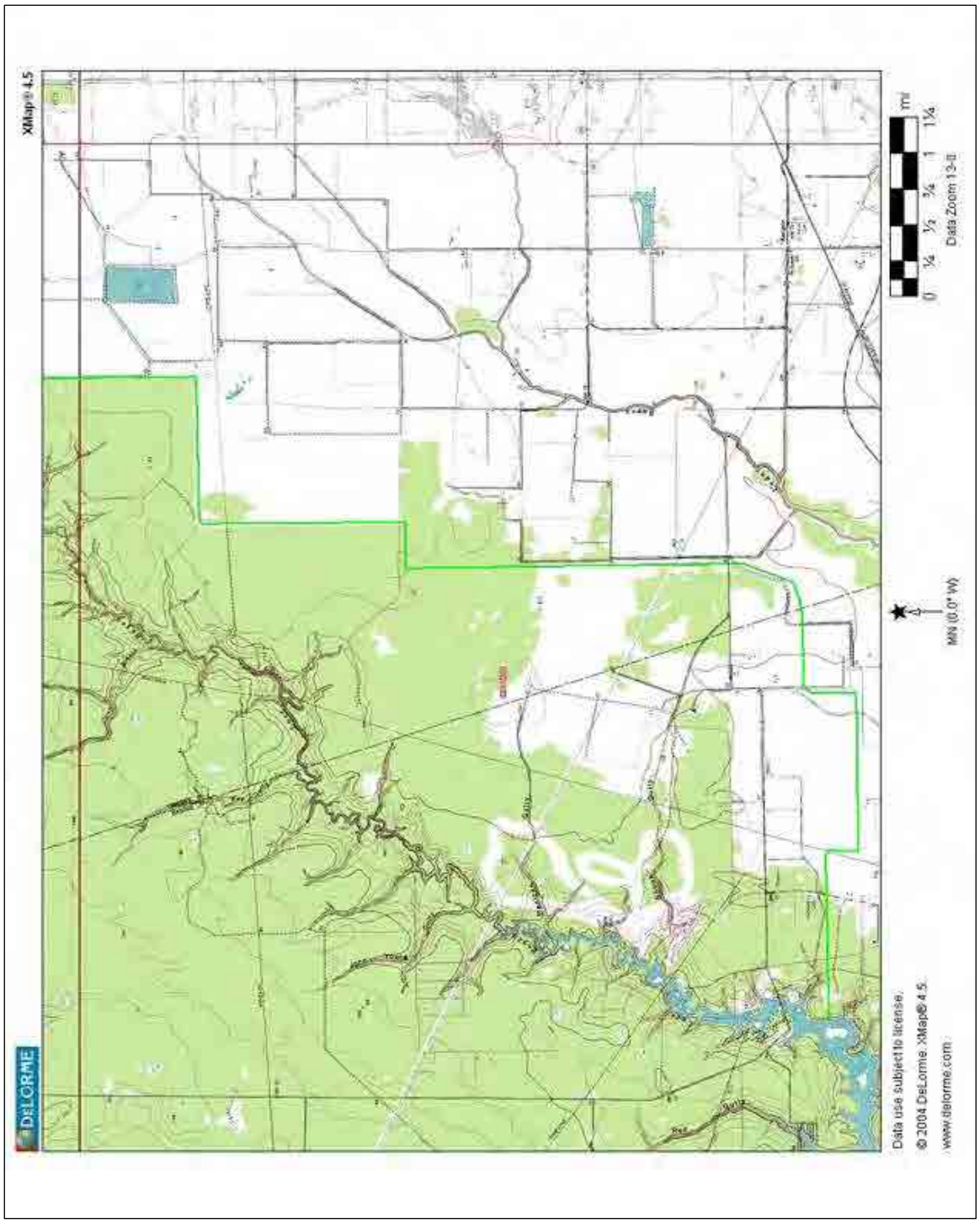
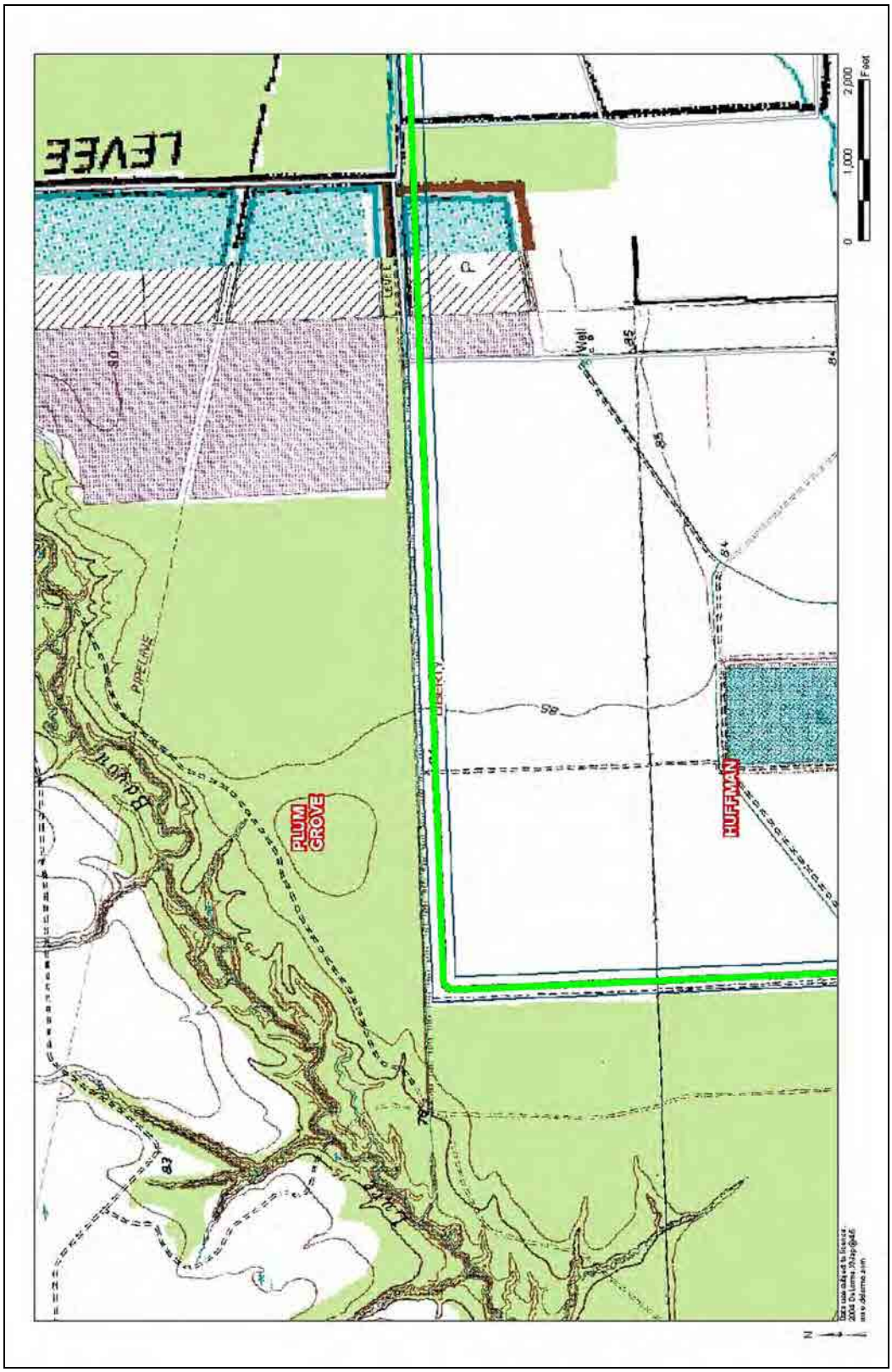


Figure 1A. Map of the project alignment on the Huffman USGS Quad.



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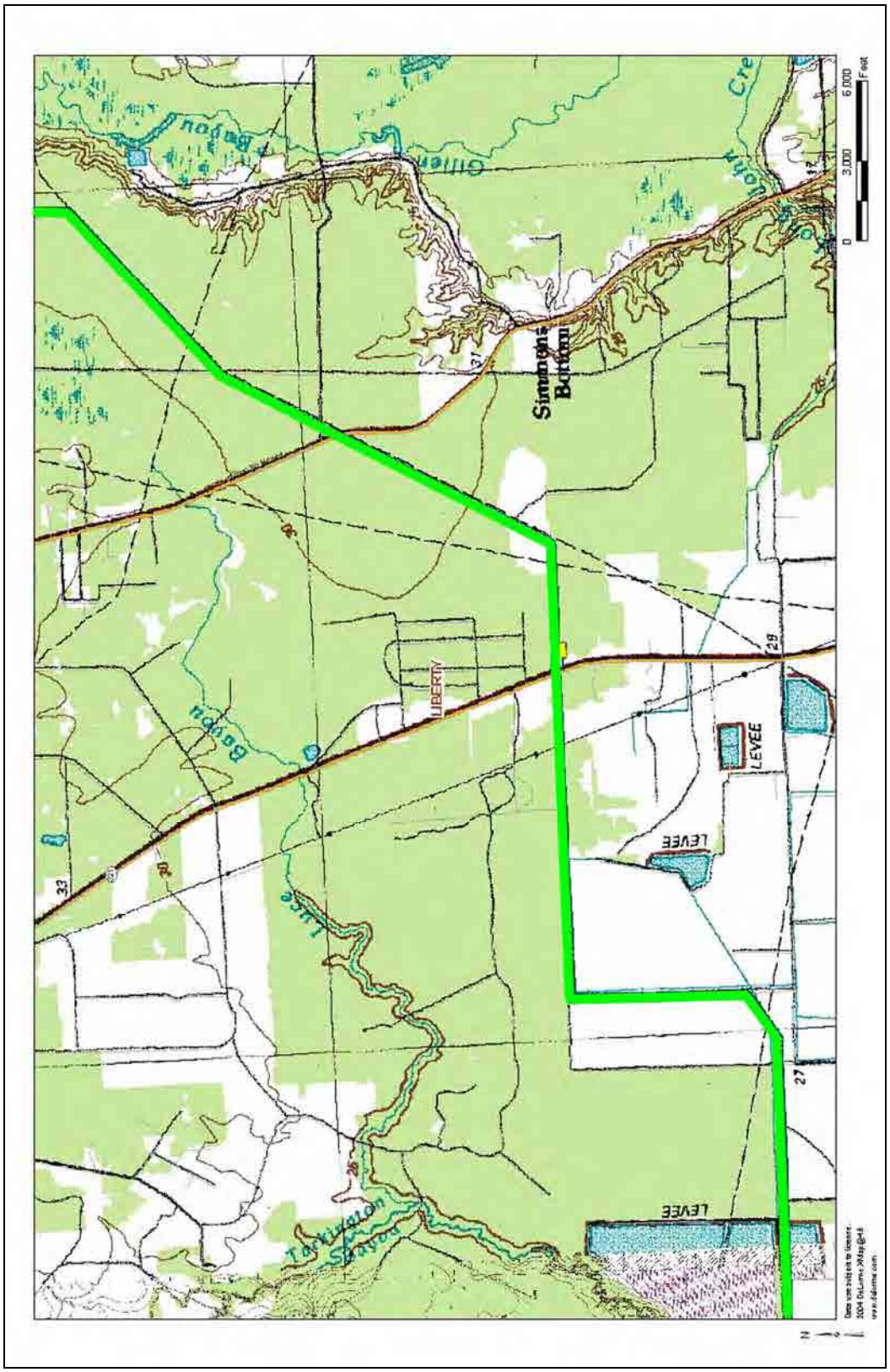

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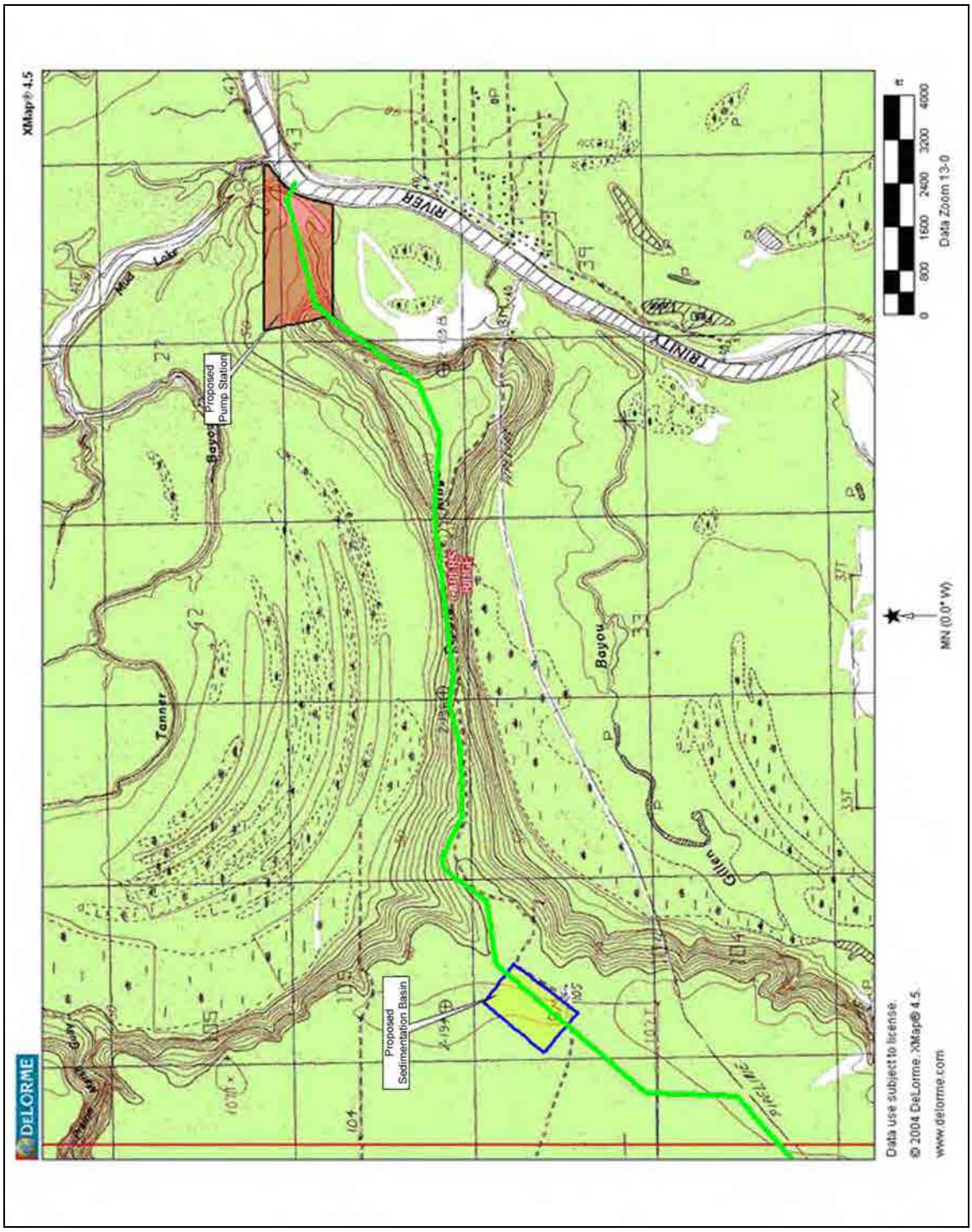

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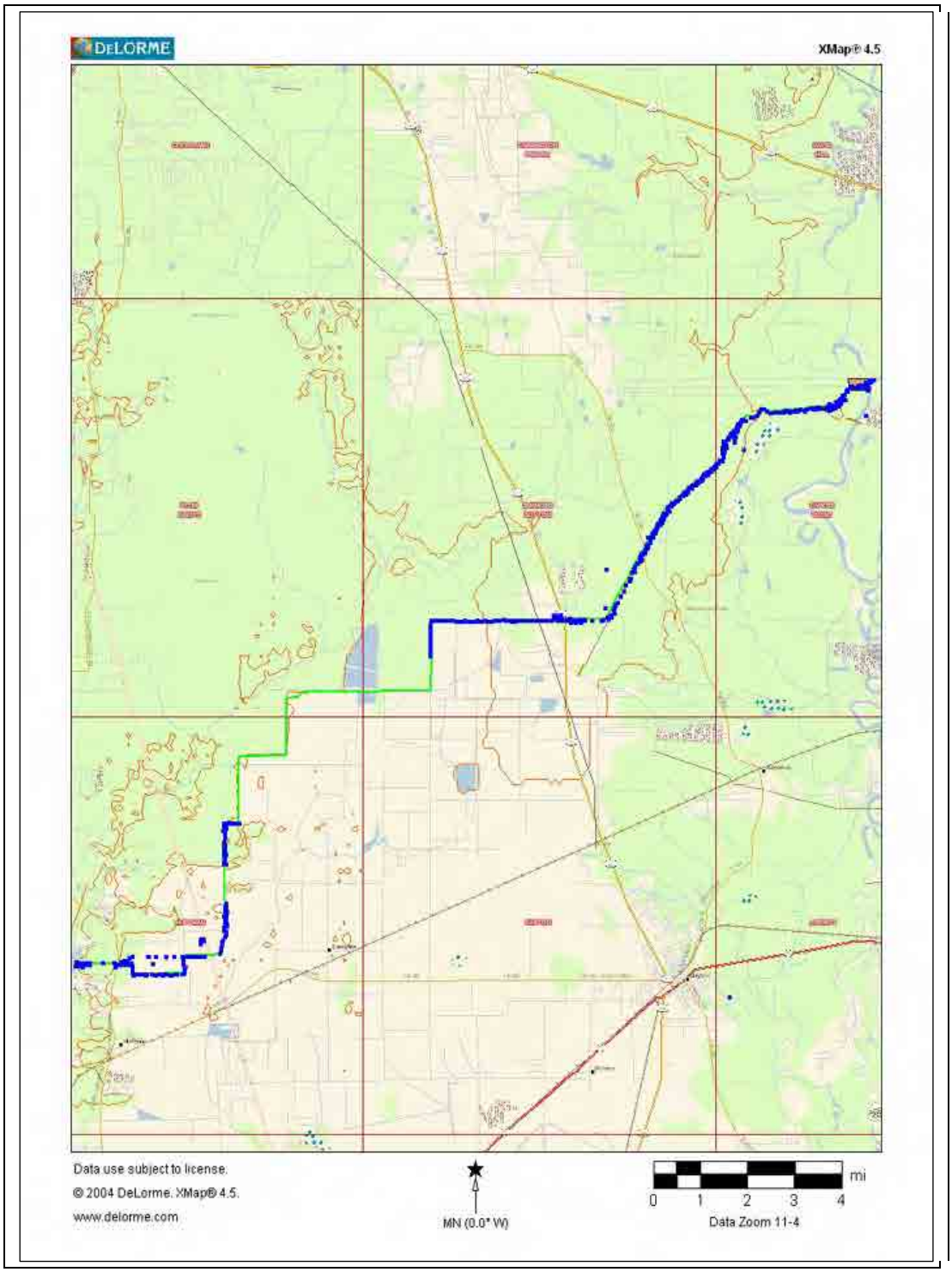

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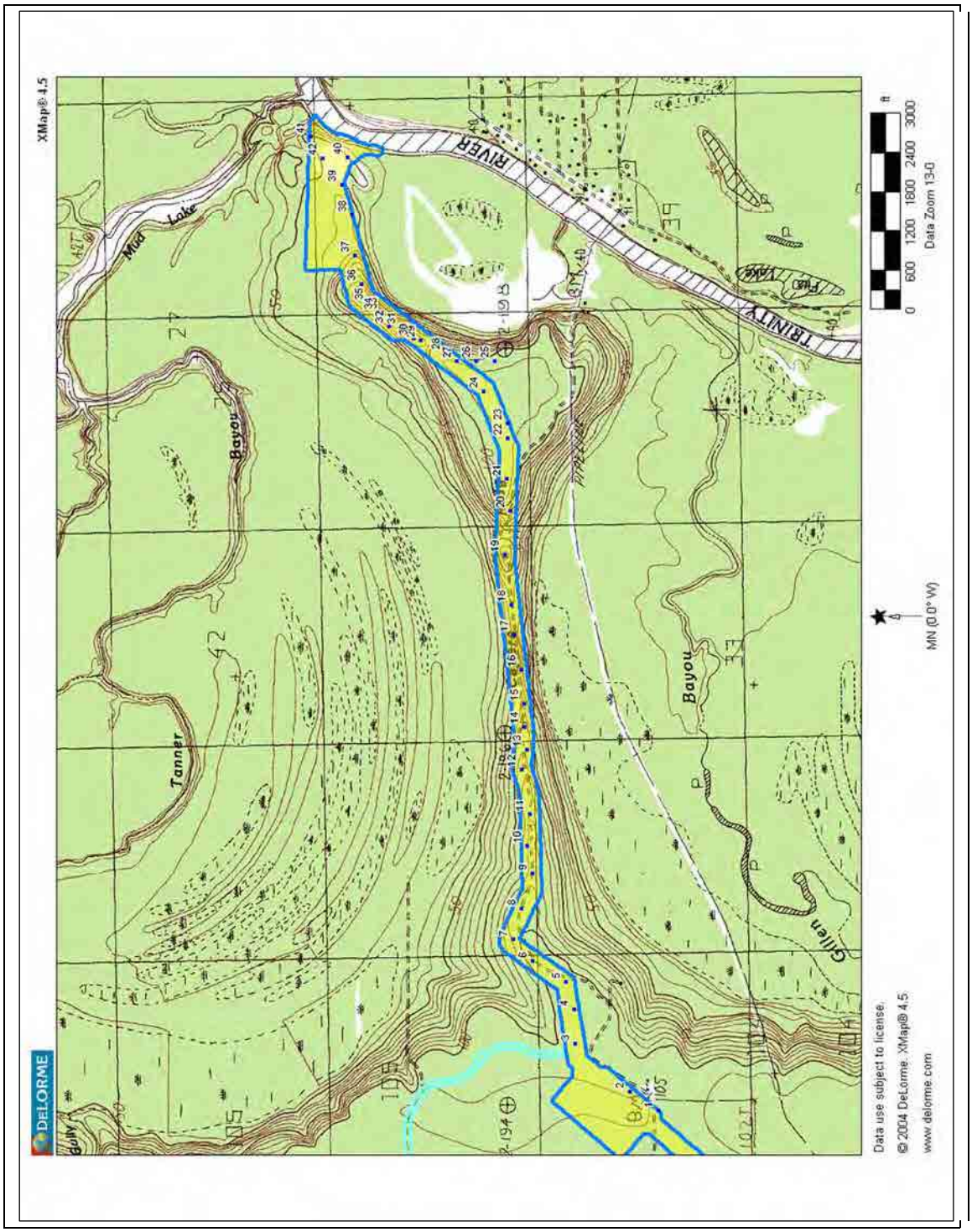

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ENVIRONMENTAL BACKGROUND

Soils and Geology

The Harris and Liberty County areas are located within the West Gulf Coastal Plain physiographic province (Hunt 1974). In the Southeast Texas region, the surface topography of the plain is characterized by relatively flat topography that dips slightly toward the Gulf of Mexico. Geologically, the project area lies atop the Lissie Formation, a surface outcrop that extends from just east of the Mississippi River in Louisiana, to Kingsville, Texas (Bureau of Economic Geology 1982). The formation was deposited during a series of glacial and interglacial events during the Middle to Late Pleistocene. Extensive riverine downcutting and erosion of the formation occurred during the periods of lower sea levels associated with the Wisconsin glaciation. During the Holocene, after sea levels rose once more, the resulting river valleys filled with alluvial soils, creating broad, level floodplains.

The project area is depicted on sheet 26 of the ***Soil Survey of Harris County*** (Wheeler 1976), and on sheets 22, 25, 26, 28, 29, 33, 39, of the ***Soil Survey of Liberty County*** (Griffith 1996). The soil types identified in the Harris County portion of the project area include Aldine very fine sandy loam (Am), Atasco fine sandy loam, 1 to 4 percent slopes (AtB), Bernard clay loam (Bd), Lake Charles clay, 0 to 1 percent slopes (LcA), and Midland silty clay loam (Md). The soil types identified in the Liberty County portion of the project area include Aldine silt loam, 0-2 percent slopes (AdA), Aldine-Aris complex (Ae), Anahuac-Aris complex (An), Aris silt loam (Ar), Beaumont clay (Ba), Bernard clay loam (Be), Bernard-Morey complex (Bm), Bienville loamy fine sand, 0 to 2 percent slopes (BnB), Fausse clay, frequently flooded (Fa), Guyton-Aldine complex (Gy), Kemah-Aris complex (Km), Lake Charles clay, 0 to 1 percent slopes (LaA), Mocarey-Yeaton complex (My), Spurger fine sandy loam, 0 to 2 percent slopes (SrB), Verland clay loam (Ve), Waller loam (Wa), Woodville fine sandy loam, 1 to 3 percent slopes (WvB), and Woodville fines slandy loam, 5 to 8 percent slopes (WvD).

Climate

The modern climate of Harris County is moderated by winds from the Gulf of Mexico, resulting in mild winters and relatively cool summer nights (Wheeler 1976:2, 66). Summer temperatures average 92°F (33°C), while winter temperatures average 64°F (18°C). Annual precipitation averages 46 inches (117 cm). In Liberty County, the summers are hot and humid, while the winters are warm and only occasionally interrupted by cold air from the north (Griffith 1996:2). Summer temperatures average 82°F (28°C), while winter temperatures average 52°F (11°C). Annual precipitation averages 53.6 inches (136 cm).

Hydrology

The LBITP traverses the upland areas between the Trinity River on its east end and Lake Houston downstream of Luce Bayou (within the San Jacinto River watershed) on its west end. In addition, a portion of the project alignment roughly parallels Cedar Bayou at a distance of 700 to 2500 m. While there are a limited number of small unnamed drainages for Cedar Bayou, few of these drainages extend very far into the uplands.

Flora and Fauna

Harris and Liberty Counties lie within the Austroriparian biotic province (Blair 1950:98-101). Not determined by a marked physiographic break, the western boundary of this province is loosely identified by the distribution of pine and hardwood forests on the eastern Gulf coastal plain. The county is situated within the pine-oak subdivision of the Austroriparian province (Tharp 1939). Blair (1950) lists the dominant floral species of the pine-oak forest subdivision as loblolly pine (Pinus taeda), yellow pine (***Pinus echinata***), red oak (***Quercus rubra***), post oak

(***Quercus stellata***), and blackjack oak (***Quercus marilandica***). Hardwood forests are found on lowlands within the Austroriparian and are characterized by such trees as sweetgum (***Liquidambar styraciflua***), magnolia (***Magnolia grandiflora***), tupelo (***Nyssa sylvatica***), water oak (***Quercus nigra***), and other species of oaks, elms, and ashes, as well as the highly diagnostic Spanish moss (***Tillandisia usneiodes***) and palmetto (***Sabal glabra***).

Blair (1950) and Gadus and Howard (1990) identify the following mammals as common within the Austroriparian province: white-tailed deer (***Odocoileus virginianus***), muskrat (***Ondatra zibethicus***), raccoon (***Procyon lotor***), coyote (***Canis latrans***), opossum (***Didelphis virginiana***), eastern mole (***Scalopus aquaticus)***, eastern pipistrelle bat (***Pipistrellus subflavus***), eastern red bat (***Lasiurus borealis***), fox squirrel (***Sciurus niger***), eastern gray squirrel (***Sciurus carolinensis***), southern flying squirrel (***Glaucomys volans***), pocket gopher (***Geomys breviceps***), slender harvest mouse (***Reithrodonomys fulvescens***), white-footed mouse (***Peromyscus leucopus***), marsh rice rat (***Oryzomys palustris***), cotton rat (***Sigmodon hispidus***), packrat (***Neotoma floridana***), eastern cottontail (***Sylvilagus floridanus***), and swamp rabbit (***Sylvilagus aquaticus***). Bison (***Bison bison***) may have been present on nearby grasslands at various times in the past (Gadus and Howard 1990:15). Common turtles include eastern box turtle (***Terrapene carolina***) and ***Terrapene ornata***, as well as snapping turtle (***Chelydra serpentinia***), mud turtle (***Kinosteron*** spp.), river cooter (***Chrysemys concinna***) and diamondback terrapin (***Malaclemys terrapin***). Common lizards include green anole lizard (***Anolis carolinensis***), eastern fence lizard (***Sceloporus undulates***), skink (***Leiolopisma laterale***), broad-headed skink (***Eumeces laticeps***), six-lined racerunner (***Cnemidophorus sexlineatus***), and eastern glass lizard (***Ophiosaurus ventralis***). Snakes and amphibians are also present in considerable numbers and diversity.

CULTURAL BACKGROUND

Southeast Texas Culture History

The LBITP area is located within the southeast Texas archaeological region (Patterson 1995; Story et al. 1990). The culture history of the region extends back at least 12,000 years into the past. A number of researchers have compiled chronological frameworks to describe the cultural histories of the area (Aten 1983; Ensor 1991; Patterson 1995; Shafer et al. 1975; Story et al. 1990). The majority of these divide human occupation into four broad stages, Paleoindian, Archaic/Lithic, Ceramic/Late Prehistoric, and Historic. The stages are based on a proposed sequence of economic strategies as they are revealed through the archaeological and/or historical record. These proposed shifts in dominant lifeways consider cultural, economic, and technological factors to provide a heuristic model useful for attempting to understand ancient and early historic populations. While the dates assigned to the period interfaces are based on "absolute" dating methods, they of course represent a generalized time range for the implied cultural evolution. The dates provided in the following discussion will be drawn from Ensor (1991) and are presented in Table 1.

The earliest period of occupation in southeast Texas is identified as the Paleoindian stage. Based on the earliest securely dated appearance of populations in the New World, this stage begins around 11,000-10,000 B.C., and lasts for approximately 4,000 years. During this time, it is proposed that populations continued with a highly nomadic hunting tradition brought with them from the Old World. Traditional models emphasize the heavy reliance that these groups placed on the hunting of the large mammals of the Pleistocene. Plant foods and small game undoubtedly supplanted this diet, and may have played a more important role than previously thought (Black and McGraw 1985; Patterson 1995). Artifact types associated with this phase include various fluted and non-fluted lanceolate projectile points, such as Clovis and Folsom. In general, due to a paucity of well-stratified older sites, the Paleoindian stage remains poorly defined in southeast Texas.

Table 1. Archeological Chronology for Southeast Texas (after Ensor 1991).

Time Period	Dates
Paleoindian	10,000-8000 B.C.
Early Archaic	8000-5000 B.C.
Middle Archaic	5000-1000 B.C.
Late Archaic	1000 B.C.-A.D. 400
Early Ceramic	A.D. 400-800
Late Ceramic	A.D. 800-1750
Historic	post A.D. 1750

By 8000 B.C., the Late Wisconsin glaciation had ended, increasing climatic aridity and creating extensive changes in the environment. As a result, the majority of Pleistocene megafauna became extinct. This required drastic changes in the dominant subsistence strategies of the affected populations. By 8000 B.C., the start of the Early Archaic stage, the remaining southeast Texas populations had adapted to the environmental changes by shifting to a lifeway dominated by seasonal scheduling. This type of subsistence economy specializes in a regionally circumscribed and repetitive exploitation of specific floral and faunal resources. By remaining in familiar territory, the nomadic populations were able to better exploit the various resources available within their local environment.

However, research has suggested that human population densities remained low in the area, and may have even decreased significantly during this time (Moore and Moore 1991). Eventually, the stabilization of the climate by around 1000 B.C., the start of the Late Archaic, appears to have led to increasing populations. This rise in regional population may have been further facilitated by the development of long-distance trade, technological innovations, and changing social relations (Patterson 1995).

The final prehistoric period in southeast Texas is marked by the emergence of ceramics. Ceramic artifacts appear in the archaeological record of the Galveston Bay area by approximately A.D. 100, and by A.D 500, had been adopted by a number of inland populations (Pertulla et al. 1995). A plain, sand-tempered type of ceramic identified as Goose Creek became prevalent during the period, although a number of decorated varieties and tempering materials were also present (Patterson 1995; Pertulla et al. 1995). The appearance of Caddoan pottery in southeast Texas around A.D. 1000-1300 has been used to suggest the presence of extended trade networks or migration during this time (Aten 1983). The period has also been associated with the introduction of the bow and arrow around A.D. 600 (Aten 1983).

Historic Overview

European contact in the area began in the early 16th century with the ill-fated Narváez expedition that, in 1528, deposited Cabeza de Vaca onto the Texas coastline, possibly on Galveston Island. More long-term contacts resulting from permanent European settlement did not directly impact aboriginal lifeways in southeast Texas until the early 18th century (Patterson 1995). However, European diseases introduced by explorers and early traders had begun to affect Native American populations in Texas by the 16th century (Ewers 1974). Throughout the eighteenth and nineteenth centuries, epidemic diseases, the mission system, and the fur trade seriously reduced, and in some cases exterminated, the indigenous populations residing in the region.

A detailed historic context for the project, as well as site specific research on historic sites 41HR1075 and 41HR1076, all authored by historian Terri Meyers of Preservation Central. Inc., of Austin, Texas, is presented as Appendix 3.

PREVIOUS ARCHEOLOGICAL INVESTIGATIONS

Prior to beginning field investigations, Moore Archeological Consulting, Inc., performed a background investigation of archeological and historical literature relevant to the project area. Literature examined for this project includes site inventory records on file at TARL, previous archeological investigative reports on file at the THC and Moore Archeological Consulting, Inc. and other published literature pertinent to the current project. The archival background search determined that there are three previously recorded archeological sites, 41LB41-41LB43, located within the project area. All three of these sites were recorded during a 1978 study for a previously proposed water diversion project described below.

The first iteration of the Luce Bayou diversion project necessitated an approximately 13 mile long pedestrian archeological survey between the Trinity River and Luce Bayou that was conducted in 1978 by archeologists subcontracted by Brown and Root, Inc., on behalf of the City of Houston (Chaffin-Lohse 1978). The easternmost approximately 4.6 mile long section of this earlier project occupies the same route as the current project alignment. This section included some of the current approximate 90-acre Capers Ridge Pump Station property and the traverse of the proposed pipeline across the top of Capers Ridge. The survey identified six archeological sites, three of which were located within the route of the current proposed project. These included 41LB41, a historic occupation and midden site, and two prehistoric sites, 41LB42 and 41LB43. All three of these sites were judged to be potentially significant, and it was recommended that the two prehistoric sites be avoided. Testing excavations conducted in 1982 at the historic site, 41LB41, determined that the site was not eligible for NRHP or SAL designation (Moore and Heartfield 1982). This site is therefore excluded from further discussion in this investigation.

A second archeological survey project intersected a portion of the current alignment in 2006 and 2007. Conducted by HRA Gray and Pape, LLC, for the proposed ENSTOR Houston Hub Storage Project, archeologists conducted an intensive pedestrian survey of a total of approximately 960 acres, of which only the northernmost extent intersected with the current project (Fugate and Scott 2008). The investigations documented extensive past and current agriculture disturbances throughout the survey area. No historic or prehistoric cultural resources were identified.

The west end of the current water transfer project terminates at Luce Bayou, upstream from its confluence with the Lake Houston Reservoir. This reservoir is fed primarily by the San Jacinto River watershed. Two previous surveys have been carried out in proximity to the western end of the current project. A cultural resources survey was conducted by Moore Archeological Consulting, Inc. in 1988 near the end of the West Fork of the San Jacinto River for the proposed West Lake Houston Parkway (Moore and Pettus 1988). The survey identified two prehistoric sites, 41HR615 and 41HR616, both of which were judged to be potentially significant. While 41HR615 was determined to be outside of the project's construction APE, site 41HR616 was recommended for significance testing. Test excavations were conducted in 1988 (Moore 1989), and indicated the site had intact stratified deposits. The site was recommended as potentially eligible for nomination to the NRHP.

In 2008, Moore Archeological Consulting, Inc. conducted a reconnaissance level survey as part of a predictive model for Lake Houston Park, which is situated between the confluences of Caney Creek and the East Fork San Jacinto River, in Harris and Montgomery Counties (Moore and Driver 2009). The reconnaissance examined a total of 193 testing localities (ca. 200 acres) within the approximately 5,000 acre park, and identified 39 new prehistoric archeological sites.

Because the survey was limited to a reconnaissance-level examination of areas within the project property, it was recognized that the data generated for any newly discovered sites would be minimal (consisting of a single positive shovel test), and would thus be too cursory to generate sufficient information to fully delineate site boundaries, nor would the survey provide sufficient information to determine the eligibility of any of these sites for nomination as a State Archeological Monument or for inclusion on the NRHP. The results of the study indicated that the park is potentially a very important preserve for prehistoric cultural resource sites, and that the predictive model was quite successful in identifying areas that will probably yield sites dating from prehistoric times. However, additional evaluations of each of the newly identified archeological sites will be required in order to determine their research potential and significance. That work will most likely be driven by park development, as intensive surveys are necessary to evaluate the tracts scheduled to be disturbed. Most sites within this nature reserve will probably be preserved indefinitely.

FIELD METHODS AND RESULTS

The methods employed during the fieldwork phase of the LBITP varied along the alignment from section to section and through the year of field work as information was gathered and data collected and analyzed. The particular set of field methods used when in a given area depended on factors such as intactness of soils, right of entry (ROE) status for a given parcel, and probability that a given area would hold intact cultural deposits. The length of time of the investigations influenced the methodology because at the initial stages, Moore Archeological Consulting, Inc. was conducting a reconnaissance-level investigation in accordance with the scope of work. After some investigations had been conducted, and data collected and reviewed, it seemed prudent to conduct an approximation of an intensive-level survey of the alignment for specific areas to provide time and cost effective services to our client, the Coastal Water Authority. Successive agency reviews of the results of this increasingly more intense survey have culminated in this 100 percent intensive survey report.

1. The general methodology for intensive survey within undisturbed areas included the excavation of two lines of shovel tests, each at 100 meter (m) intervals, on either side of the centerline of the alignment. The shovel tests would be staggered to limit the gap between shovel tests to approximately 50 m along the alignment. In certain cases, for example in areas of extensive pimple mounds, the distance between tests was modified so that every mound within the alignment was tested.

2. In areas of active or past farming practices, or other type of disturbance, in areas with remnant dikes, ditches, and terracing from rice farming, typical field methodology involved single transects with tests every 100 m or greater, depending on site-specific conditions. Often, the footprint of the farm fields was very obvious from a review of aerial photography. In these areas and instances a less extensive number of shovel tests were performed. In general, again, in areas of obvious prior disturbance based on historic or current aerial photographs and field observations, a single transect with shovel tests at 100 m intervals or greater was performed.

3. In some rare cases, ROE to a specific parcel was not granted by the landowner. However, it was generally more common that landowners restricted access to their properties, especially in cases of active farming operations. At the time of the survey, there were many parcels in active rice farming and the owners asked that no excavations be performed. There were also properties where there were no obvious intact soils anywhere in the proposed LBITP ROW. In those instances, the investigation was limited to photo-documentation of existing conditions.

4. Reconnaissance level survey in undisturbed areas included at most, a single line of shovel tests at 100 m intervals.

5. After the completion of the shovel testing program, consultation with the THC determined that mechanical trenching needed to be included at several of the identified sites and along the Capers Ridge portion of the alignment to achieve 100 percent intensive survey. A total of 44 trenches were excavated, 25 within established site boundaries, and 19 within intersite areas along the ridge (Figure 3). Trench placement in areas between sites varied due to topography, but tended to occur at intervals ranging from 150-200 m.

All but one of the archeological sites (41LB118) located during the survey were provisionally delineated with shovel tests in cardinal directions from the original positive test.

Sometimes the shovel tests took the direction of the obvious landform instead of cardinal directions. The site boundaries were located using a combination of positive and negative shovel test orientations, and landforms. All newly discovered sites were recorded on State of Texas Archaeological Site Forms, and update forms were completed for the two previously identified sites.

All shovel tests were recorded on shovel test forms so that all pertinent data are included and summarized. The backhoe trenches were recorded on trench forms, and for each trench, a side wall was cleaned and the profile was drawn and photographed. Photographs were taken throughout the survey area and recorded on photograph logs. A set of daily field notes was kept throughout the project.

Summary of Investigations by Parcel

The following section provides a detailed methodological description for each parcel. A summary of the field results by parcel is provided in Appendix 1. An AECOM map illustrating the location of the LBITP parcels is also provided in Appendix 1 as Figure 1-1.

Parcel 1 Reconnaissance- and Intensive-Level Survey. Parcel 1 is the Capers Ridge Pump Station property. This property was among the first to be surveyed and was therefore surveyed at a reconnaissance level of investigation. Located, delineated, and recorded prehistoric sites 41LB98, 41LB104, 41LB105, 41LB108, 41LB109, and 41LB110 are on this parcel. Historic site 41LB41 is located in this parcel but was deemed not significant based on prior testing. Two potential prehistoric sites were identified, but after additional delineation efforts, were determined to be isolated finds (IF) 2 and 4. Backhoe trenches (BHT) 33-42 were excavated within this parcel. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 2 Intensive Survey Approximate 50 m Shovel Tests. Parcel 2 is a small, linear strip of land located between Parcels 1 and 4. Delineation of previously identified sites from Parcel 1 and 4 through the boundary of Parcel 2 has been completed. Prehistoric site 41LB99 was located, delineated, and recorded within this parcel. BHTs 31 and 32 were excavated within this parcel. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 3 No Survey Necessary. Parcel 3 is a narrow strip of land adjacent to Parcels 1 and 4. Field investigations conducted included limited evaluation of a new road and entry gate; no additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 4 and Parcel 4.5 Reconnaissance- and Intensive-Level Survey Completed. Parcel 4 is an approximate 3,000-acre property although the LBITP generally is contained in a 100 m ROW along Capers Ridge and within the proposed 20-acre sedimentation basin. Reconnaissance level surveys were performed and a number of sites were identified. Delineation of the identified sites has been performed and the number of shovel tests conducted exceeded those needed for an intensive survey. Prehistoric temporary sites 41LB97, 41LB100, 41LB101, 41LB102, 41LB103, 41LB106, 41LB107, 41LB112, 41LB113, 41LB114, as well as 41LB42 were located within Parcel 4. Two potential prehistoric sites were identified, but after additional delineation efforts, were determined to be isolated finds, IF 1 and 3. In addition, 41LB118 was identified in an area that no longer is part of the LBITP ROW. This site was not fully delineated since it is no longer

in the APE of the proposed project. BHTs 1-30 were excavated within this parcel. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 5 No Survey Conducted. Parcel 5 is not within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 6 Reconnaissance- and Intensive-Level Survey. Parcel 6 consists of a wooded property that contains sandy mounds. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 7 Reconnaissance- and Intensive-Level Survey. Parcel 7 consists of a wooded property that contains sandy mounds. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 8 Reconnaissance- and Intensive-Level Survey. Parcel 8 consists of a wooded property that contains sandy mounds. Reconnaissance level surveys were performed and two sites, prehistoric sites 41LB111 and 41LB115 were identified. Delineation of these identified sites has been completed. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 9 Reconnaissance- and Intensive-Level Survey. Parcel 9 consists of a wooded property that contains sandy mounds. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 10 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 10 consists of an open field and pine plantation farming. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 11 No Survey Conducted. Parcel 11 is minimally within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 12 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 12 consists of pine plantation farming. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 13 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 13 consists of pine plantation farming. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 14 Reconnaissance- and Intensive-Level Survey. Parcel 14 consists of a wooded property that contains sandy mounds that were all shovel-tested. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 15 Reconnaissance- and Intensive-Level Survey. Parcel 15 consists of a wooded property that contains sandy mounds that were all shovel-tested. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 16 Reconnaissance- and Intensive-Level Survey. Parcel 16 consists of a wooded property that contains sandy mounds that were all shovel-tested. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 17 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 17 consists of a disturbed property that contains a cell tower. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 17.5 No Survey Conducted. Parcel 17.5 is not within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 18 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 18 is fairly disturbed and no sites were located on this property. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 19 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 19 is partially wooded and partially an open, former farm field; no sites were located on this property. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcels 20 and 21 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcels 20 and 21 consist of an open, former farm field; no sites were located on these properties. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 22 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 22 is an open field with remnant sandy mounds. All sandy mound areas in LBITP alignment were tested and no sites were located on this property. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 23.2 and 23.4 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcels 23.2 and 23.4 consists of farm fields containing areas of disturbance. Along the northern portion of Parcel 23.2, there were intact areas that required shovel testing along the northern portion of the parcel. No sites were located on these properties and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcels 23.6 No Survey Conducted. Parcel 23.6 is a former farm field that is owned by ENSTOR Hub and Storage. Previous archeological investigations were conducted by others in the area and no additional investigations appeared warranted at that time. In addition, the LBITP alignment was changed to avoid Parcel 23.6 and the parcel is no longer within the LBITP ROW. No surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 24 No Survey Conducted. Parcel 24 is not within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 25 No Survey Conducted. Parcel 25 is not within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcels 25.2, 25.4 and 25.6 Active Farming with Photo-Documentation. These parcels consist of active rice farming operations and the property owner requested no shovel testing or other disturbance. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 26 Visual Survey Conducted. Parcel 26 is an active agricultural field, visual surveys conducted. No other investigations appear warranted, subject to review and concurrence.

Parcel 27 Reconnaissance- and Intensive-Level Survey Completed. Parcel 27 is a wooded property that appears relatively undisturbed. Reconnaissance investigations conducted, no sites identified and no additional investigations appear warranted, subject to review and concurrence.

Parcels 28-32 Active Farming with Photo-Documentation. These parcels consist of an agricultural reservoir, dike or berm, and drainage ditch used for agricultural production on the surrounding rice fields. The property owner requested no shovel testing or other disturbance. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcels 33 Active Farming with Photo-Documentation. Parcel 33 consists of an agricultural field. The property owner requested no shovel testing or other disturbance. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 34-37 No Survey Conducted. Parcels 34-37 are not within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 37.5 Active Farming with Photo-Documentation. Parcel 37.5 consists of an agricultural field. The property owner requested no shovel testing or other disturbance. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 38 and Parcel 39 No Survey Conducted. Parcel 38 and Parcel 29 are not within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 39.4 Intensive Level Survey Completed. Parcel 39.4 consists of an agricultural field with a potential historic barn structure. The existing structure was not within the LBITP ROW and no additional investigations appear warranted, subject to review and concurrence.

Parcel 39.6 and Parcel 39.8 Active Farming with Photo-Documentation. Parcel 39.6 and 39.8 consist of active agricultural fields. The property owner requested no shovel testing or other disturbance. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 40 No Survey Conducted. Parcel 40 is not within the LBITP ROW, no surveys were performed and none appear warranted, subject to review and concurrence.

Parcel 40.5 Active Farming with Photo-Documentation. Parcel 40.5 consists of an agricultural field. The property owner requested no shovel testing or other disturbance. No additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 41 Reconnaissance- and Intensive-Level Survey Completed. Parcel 41 is wooded with a few sandy mounds, although the property is disturbed throughout. A reconnaissance level survey was conducted; no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 42 Reconnaissance- and Intensive-Level Survey Completed. Parcel 42 is wooded and undisturbed with sandy mounds present throughout. Located, delineated, and recorded prehistoric site 41LB117 on sandy mounds within this property at a level of investigation that approached an intensive survey methodology in specific areas. BHTs 43 and 44 were excavated

in this parcel at 41LB117. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 43A Reconnaissance- and Intensive-Level Survey Recommended, Additional Investigations Recommended. Parcel 43A is a cleared field that is the north half of Parcel 43. No ROE for the northern half of this property is available from the property owner. After ROE is obtained or after the property is acquired, additional investigations appear warranted, subject to review and concurrence.

Parcel 43B Reconnaissance- and Intensive-Level Survey Completed. Parcel 43B is a wooded undisturbed area that is the south half of Parcel 43 with ROE from the property owner. Located, delineated, and recorded prehistoric site 41LB116. No additional survey-level investigations appear warranted, subject to review and concurrence.

Parcel 44 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 44 consists of fallow farm fields. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 44.5 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 44.5 is a narrow easement located between Parcel 44 and Parcel 45 and consists of a fallow field. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 45 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 45 is a fallow field. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 46 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 46 is a fallow field. No sites were located on this property and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 46.5 Reconnaissance- and Intensive-Level Survey Completed. Parcel 46.5 is a fallow field, a reconnaissance survey was conducted, no sites identified; no additional investigations appear warranted, subject to review and concurrence.

Parcel 47 Intensive Survey Conducted. Parcel 47 is a fallow field that is not within the LBITP ROW. Located, delineated, and recorded historic site 41HR1076, a historic farmstead identified as the property of the May family (see site description for discussion). No additional survey-level investigations appear warranted since the LBITP avoids this property in entirety.

Parcel 47.5 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 47.5 is a fallow field. Reconnaissance investigation completed, the May family farmstead, historic site 41HR1076, delineation completed. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 48 and Parcel 49 Intensive Level Survey Completed: Single Transect Approximate 100 m Shovel Tests. Parcel 48 and Parcel 49 are fallow fields. No sites were identified and no additional investigations appear warranted at this time, subject to review and concurrence.

Parcel 50 Intensive Level Survey Completed: Transect Approximate 100 m Shovel Tests. Parcel 50 is a fallow field. No sites were identified and no additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 51 Intensive Level Survey, Survey Completed. Parcel 51 is wooded with a few sandy mounds. Located, delineated, and recorded historic site 41HR1075. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcel 52 Reconnaissance- and Intensive-Level Survey Conducted. Parcel 52 is a fallow farm field that is naturalizing with returning forest growth; there are sandy mounds near FM 2100. Prehistoric site 41HR1074 was located on a sandy mound and delineated. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Parcels 53 and 54 Reconnaissance- and Intensive-Level Survey Completed. Parcels 53 and 54 are wooded areas with uplands. Located, delineated, and recorded historic site 41HR1073. No additional survey-level investigations appear warranted at this time, subject to review and concurrence.

Summary of Recommendations

To summarize, additional survey-level investigations are recommended only for Parcel 43A (North) after ROE is obtained or the property is acquired. A parcel location map is located in Appendix 1 as Figure 1-1.

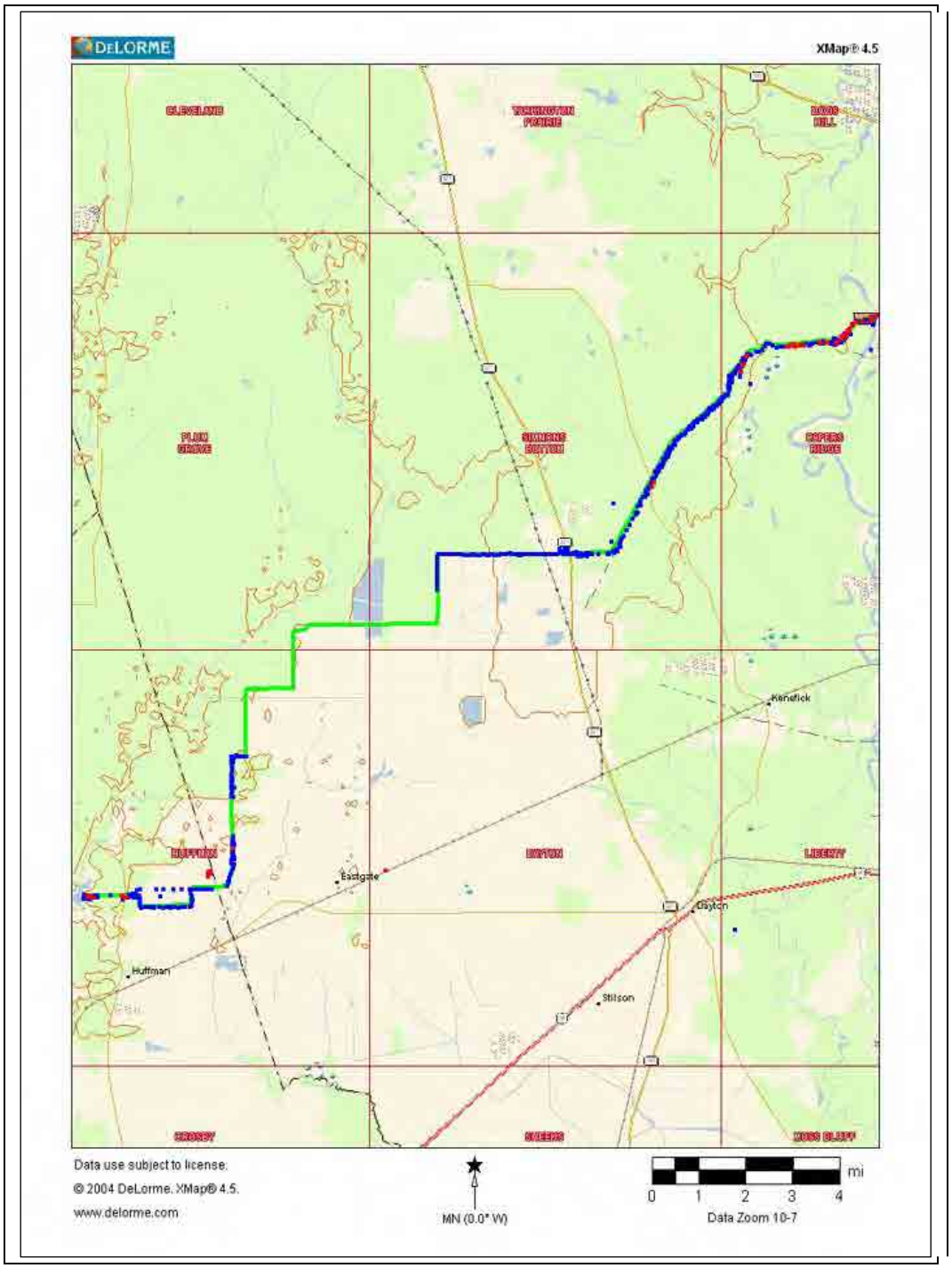


Figure 4. Map of the project area showing locations of positive (red) and negative (blue) shovel tests.

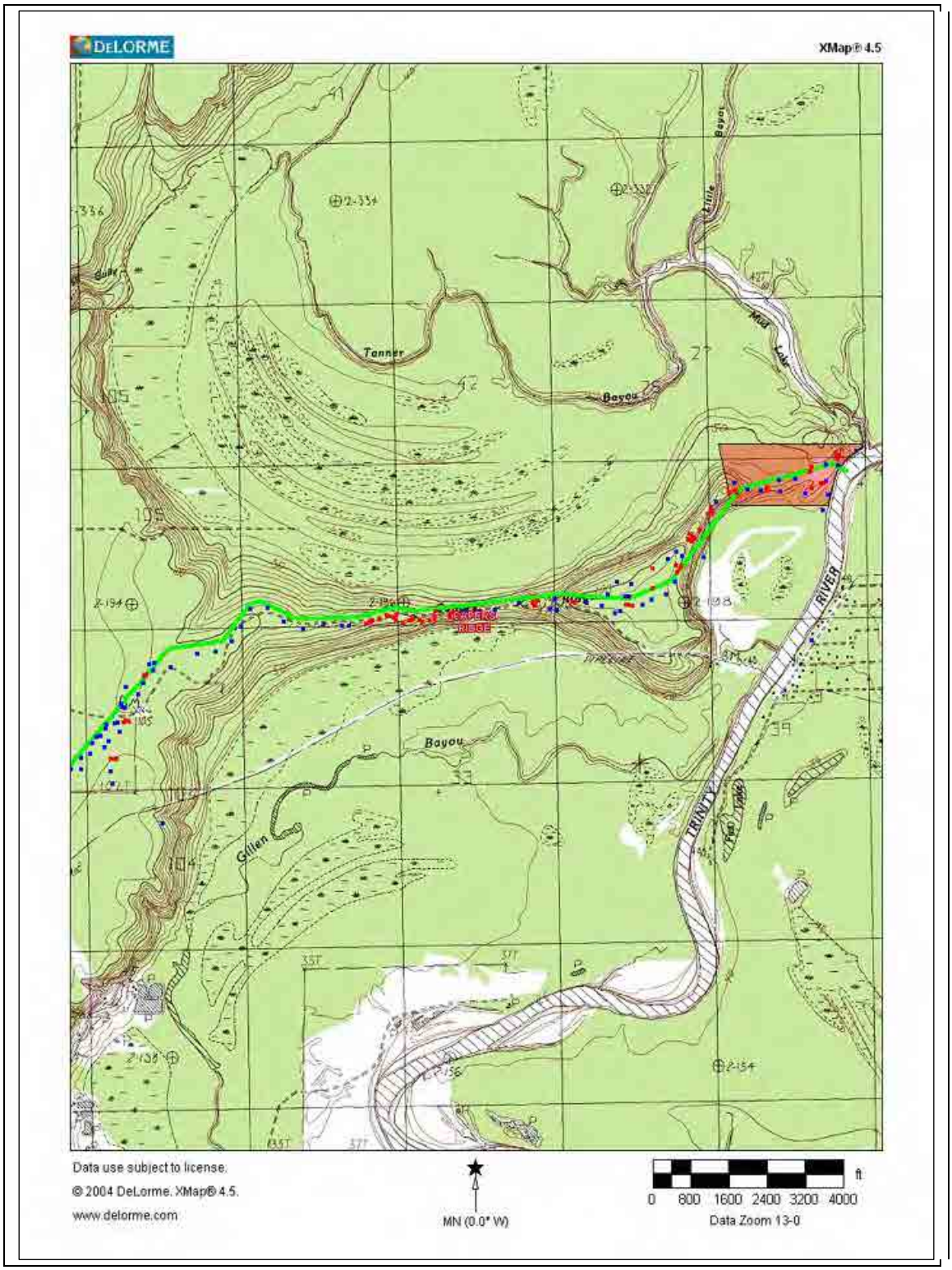


Figure 5. Example map of the eastern terminus of the project area showing locations of positive (red) and negative (blue) shovel tests.

Site Descriptions

41LB42 (Prehistoric) Parcel 4

Site 41LB42 is a previously recorded site atop Capers Ridge that was revisited and expanded during the current survey (Figure 6). The site consists of a series of prehistoric buried campsites connected by a more or less continuous buried lithic scatter. Site dimensions are 600 m E/W by 40-60 m N/S. There are prehistoric sites to the east and west of 41LB42 along the ridge. 41LB100 is located approximately 40-50 m to the west of the westernmost end of 41LB42, and 41LB102 is about 400 m to the east of the easternmost end of the site. The topography at this site consists of a general E/W trending ridgeline that slopes to the north and south into old meander scars of the Trinity River that contain seasonally inundated wetlands. There is a well-maintained dirt road running along the apex of the ridge. The area is heavily wooded with oak, elm, magnolia, yaupon, and pine. The landform at 41LB42 consists mainly of the ridge feature, which is 40-60 ft higher than the meander scar areas to the north and south. There are also high and low points along the ridge itself. Many of the high points contain deep sandy soils where there are concentrations of artifacts.

The site was identified and horizontally defined by 103 shovel tests, 60 of which were positive for cultural materials. In addition, a total of five backhoe trenches (BHTs 13-17) were excavated within the site (Figures 7-11). Four of these trenches, BHTs 13-16, produced cultural materials. A basin-shaped hearth (Feature 1) was revealed in the east profile of BHT 13. The hearth measured 1.25 m in diameter and had a maximum thickness of 40 cm. The upper limit of the feature was located at a depth of 45 cm below the modern ground surface. All of the cultural materials recovered from this trench were associated with Feature 1, and was recovered from on, immediately above, its uppermost interface (Level 5), or from the base of the feature fill (Level 8). Although the feature fill was dark in color, no charcoal fragments were visible. BHT 15 revealed two features in its north profile. Feature 2 had a basin-shaped profile with almost vertical sides that extended down 40 cm from the top of Zone 2, and measured 45 cm in diameter. The feature fill contained a light scatter of charcoal flecks, but no artifacts. Feature 3 was irregular in shape, and also contained charcoal flecks but no artifacts. The shape of this feature suggests it may be the remains of a burned tree root rather than a cultural feature. The east profile of BHT 16 contained a faint, lenticular charcoal stain at a depth of 150 cmbs. No artifacts were associated with the stain, and it is unclear whether it represents a cultural feature.

The general character of this site is one of greater artifact concentration and diversity in certain areas with thin lithic scatters in between. This ridge has no doubt not only been an attractive place to live but also a convenient route for transportation given its high elevation. There is evident modern bioturbation occurring along the ridge including moderate slope wash, root activity, and animal burrowing that are common in SE Texas wherever sandy sites are found. A combination of natural bioturbation and human movement along the ridge through time may account for the lithic scatter between the artifact concentration areas. The areas in the site that contain artifact concentration have potential for intact features.

The shovel testing produced a total of 395 artifacts (Table 2). The artifacts were recovered from Levels 1-12 (0-120 cmbs), with relatively consistent numbers of artifacts in Levels 2-10 (20-100 cmbs). The artifacts included 191 pieces of lithic debitage (111 chert, 38 quartzite, 42 silicified wood), one chert ***Perdiz*** arrow point (Figure 12), one quartzite ***Gary*** dart point (Figure 13), one chert biface fragment, one utilized flake of silicified wood, 126 Goose Creek sherds (119 plain, 7 incised), 39 faunal bone fragments (unidentifiable mammal, some with evidence of light burning), and 35 pieces of burned clay. The presence of the pottery sherds in Levels 1-10, and 12 (0-120 cmbs), and the arrow and dart points, both of which were found in

Level 3 (20-30 cmbs; and both in association with pottery), indicate the site dates to the Early and Late Ceramic periods.

In summary, 41LB42 is a large prehistoric occupation site that dates to the Early and Late Ceramic periods. The cultural deposits extend from Levels 1-12 (0-120 cmbs), and the artifact assemblage exhibits medium artifact density and diversity. In terms of the horizontal distribution of artifacts, the site contains areas with greater artifact concentration and diversity, with thin lithic scatters in between. Based on the results of backhoe trenching, the site has a high potential for containing preserved subsurface cultural features. We recommend that further investigations be conducted at the site in order to determine its significance and potential eligibility for the National Register of Historic Places. Once the current report is finalized, the artifacts recovered from 41LB42 will be curated at TARL.

Table 2. Artifacts recovered from 41LB42.

STP/BHT	Level	Artifact Class	Count	Comments
21	7	Tertiary flake	1	chert
21	8	Tertiary flake	3	1 silicified wood, 2 quartzite
21	9	Tertiary flake	1	chert
22	3	Tertiary flake	2	chert
22	4	Tertiary flake	1	chert
23	1	Tertiary flake	1	chert
23	4	Tertiary flake	1	chert
23	4	Debris	1	chert
23	5	Native American ceramic- undecorated	4	
23	5	Secondary flake	2	chert
23	5	Tertiary flake	2	chert
23	5	Flake fragment	4	chert
23	6	Secondary flake	1	chert
23	6	Debris	1	chert
23	6	Tertiary flake	3	chert
23	7	Flake fragment	1	chert
23	7	Tertiary flake	1	chert
23	8	Tertiary flake	1	chert
23	9	Tertiary flake	1	chert
23	10	Tertiary flake	1	chert
23	12	Debris	1	chert
24	2	Secondary flake	1	chert
611	3	Flake fragment	1	chert
611	4	Secondary flake	1	biface thinning, silicified wood
615	5	Native American ceramic- undecorated	1	
615	6	Debris	1	pot lidded, chert
615	7	Tertiary flake	1	chert
615	10	Tertiary flake	1	silicified wood
619	5	Secondary flake	1	silicified wood
620	4	Native American ceramic- undecorated	7	retrofit
620	6	Native American ceramic- undecorated	3	two retrofit
621	8	Secondary flake	1	chert
622	9	Secondary flake	1	quartzite
622	11	Tertiary flake	1	chert

623	5	Tertiary flake	1	chert
624	8	Tertiary flake	1	chert
625	7	Tertiary flake	1	biface thinning, silicified wood
625	7	Tertiary flake	2	1 chert, 1 quartzite
626	2	Tertiary flake	1	pot lidded, chert
626	3	Debris	1	chert
627	3	Dart point	1	Gary, quartzite
628	3	Tertiary flake	1	chert
631	2	Debris	1	chert
631	3	Native American ceramic- undecorated	3	2 retrofit
631	6	Debris	1	chert
638	3	Secondary flake	1	chert
638	3	Debris	1	chert
638	4	Tertiary flake	1	chert
638	5	Tertiary flake	1	chert
638	5	Secondary flake	1	silicified wood
639	4	Debris	1	chert
639	6	Native American ceramic- decorated	1	very large notched rim sherd
639	6	Native American ceramic- undecorated	1	
639	7	Secondary flake	3	chert
639	7	Tertiary flake	2	quartzite
639	7	Native American ceramic- undecorated	2	one with asphaltum
639	8	Bone- nonhuman, unmodified	3	tiny fragments
641	2	Native American ceramic- decorated	4	incised
641	2	Native American ceramic- undecorated	3	
641	2	Tertiary flake	1	chert
641	3	Native American ceramic- decorated	1	incised
641	3	Flake fragment	1	quartzite
641	3	Tertiary flake	1	quartzite
641	5	Secondary flake	2	chert, quartzite
641	5	Tertiary flake	1	chert
642	2	Tertiary flake	1	silicified wood
645	7	Native American ceramic- undecorated	1	
645	7	Secondary flake	1	chert
811	3	Debris	1	silicified wood
811	8	Tertiary Flake	1	silicified wood
811	8	Tertiary Flake	1	chert
811	10	Tertiary Flake	1	chert
811	11	Debris	1	silicified wood
812	3	Tertiary Flake	1	quartzite
812	7	Native American ceramic- undecorated	3	
812	8	Native American ceramic- undecorated	7	
812	8	Flake Fragment	1	quartzite
812	9	Native American ceramic- undecorated	3	
812	9	Debris	1	silicified wood
812	10	Native American ceramic- undecorated	3	
813	2	Secondary Flake	1	chert
813	3	Debris	1	silicified wood
813	3	Flake Fragment	1	quartzite

813	5	Native American ceramic- undecorated	3	
813	10	Secondary Flake	1	quartzite
814	3	Native American ceramic- undecorated	3	
814	4	Debris	1	quartzite
814	5	Native American ceramic- undecorated	1	
814	7	Native American ceramic- undecorated	1	
814	7	Secondary Flake	1	silicified wood
814	8	Native American ceramic- undecorated	3	
814	9	Native American ceramic- undecorated	2	
815	1	Tertiary Flake	1	chert
817	3	Secondary Flake	1	chert
817	3	Flake Fragment	1	chert
818	5	Native American ceramic- undecorated	1	
818	8	Tertiary Flake	1	chert
819	1	Tertiary Flake	1	silicified wood
819	1	Flake Fragment	1	silicified wood
819	6	Tertiary Flake	1	silicified wood
819	7	Debris	1	chert
819	8	Bone- nonhuman, unmodified	3	
819	8	Tertiary Flake	1	chert
819	10	Bone- nonhuman, unmodified	6	
819	10	Native American ceramic- undecorated	1	
819	12	Native American ceramic- undecorated	1	
819	12	Flake Fragment	1	chert
822	1	Flake Fragment	1	quartzite
822	3	Debris	1	quartzite
824	1	Secondary Flake	1	silicified wood
824	4	Native American ceramic- undecorated	3	
824	5	Biface	1	broken
824	5	Native American ceramic- undecorated	5	
825	2	Tertiary Flake	1	chert
826	2	Tertiary Flake	1	chert
826	3	Native American ceramic- undecorated	1	
826	3	Secondary Flake	3	silicified wood
826	3	Flake Fragment	1	silicified wood
826	3	Tertiary Flake	1	chert
826	4	Native American ceramic- decorated	1	Incised
826	4	Native American ceramic- undecorated	1	
826	5	Native American ceramic- undecorated	4	
826	6	Native American ceramic- undecorated	7	
826	6	Primary flake	1	silicified wood
826	6	Debris	1	silicified wood
826	7	Native American ceramic- undecorated	10	
826	7	Tertiary Flake	2	chert
826	7	Secondary Flake	2	quartzite
826	8	Secondary Flake	1	quartzite
826	8	Native American ceramic- undecorated	1	
826	9	Native American ceramic- undecorated	3	1- rim sherd
826	10	Primary flake	1	silicified wood

827	5	Primary flake	1	silicified wood
827	5	Debris	1	silicified wood
830	3	Secondary Flake	1	chert
834	3	Native American ceramic- undecorated	1	
835	2	Native American ceramic- undecorated	2	
836	4	Secondary Flake	1	chert
836	4	Native American ceramic- undecorated	1	
836	5	Flake Fragment	1	chert
836	6	Native American ceramic- undecorated	1	
836	6	Tertiary Flake	1	chert
836	6	Secondary Flake	1	chert
836	9	Native American ceramic- undecorated	1	
836	9	Tertiary Flake	1	chert
837	2	Native American ceramic- undecorated	2	
838	2	Secondary Flake	1	chert
838	4	Tertiary Flake	1	silicified wood
838	4	Tertiary Flake	1	chert
838	6	Secondary Flake	1	quartzite
838	6	Secondary Flake	1	silicified wood
838	10	Native American ceramic- undecorated	1	
838	10	Tertiary Flake	2	silicified wood
840	2	Primary flake	1	silicified wood
843	2	Tertiary Flake	1	chert
846	2	Tertiary Flake	1	chert
846	3	Secondary Flake	1	chert
846	3	Tertiary Flake	1	silicified wood
846	3	Tertiary Flake	1	chert
846	4	Native American ceramic- undecorated	3	quartzite
850	3	Secondary Flake	1	quartzite
850	5	Secondary Flake	2	silicified wood
850	5	Utilized debitage	1	silicified wood
850	6	Tertiary Flake	1	quartzite
850	8	Secondary Flake	1	quartzite
853	11	Bone- nonhuman, unmodified	5	
854	4	Secondary Flake	1	quartzite
855	1	Secondary Flake	1	chert
855	3	Secondary Flake	1	chert
855	4	Secondary Flake	2	quartzite
858	1	Tertiary Flake	1	quartzite
859	3	Flake Fragment	2	chert
861	8	Native American ceramic- undecorated	1	
861	8	Bone- nonhuman, unmodified	1	
861	9	Bone- nonhuman, unmodified	1	
861	9	Native American ceramic- undecorated	4	
861	9	Tertiary Flake	1	quartzite
861	10	Native American ceramic- undecorated	5	
864	2	Tertiary Flake	1	chert
867	2	Flake Fragment	1	chert
868	4	Secondary Flake	1	quartzite

870	3	Tertiary Flake	1	silicified wood
870	4	Debris	1	chert
870	4	Miscellaneous burned clay	2	
870	5	Miscellaneous burned clay	1	
870	5	Secondary Flake	1	chert
870	6	Tertiary Flake	1	quartzite
870	6	Flake Fragment	1	chert
870	7	Tertiary Flake	1	chert
870	8	Miscellaneous burned clay	25	
870	9	Miscellaneous burned clay	7	
870	9	Tertiary Flake	1	chert
870	9	Flake Fragment	1	chert
870	9	Flake Fragment	1	quartzite
870	12	Flake Fragment	1	quartzite
872	3	Primary flake	1	chert
872	3	Flake Fragment	1	chert
883	2	Tertiary Flake	4	chert
883	3	Flake Fragment	2	chert
883	4	Tertiary Flake	1	quartzite
883	4	Debris	1	quartzite
884	3	Secondary Flake	1	chert
884	8	Secondary Flake	1	quartzite
885	2	Native American ceramic- undecorated	1	
885	2	Tertiary Flake	1	quartzite
946	3	Arrow point	1	Perdiz; chert
946	4	Secondary Flake	1	chert
946	5	Primary flake	1	chert
946	8	Debris	1	silicified wood
946	8	Native American ceramic- undecorated	1	
946	8	Tertiary Flake	1	chert
946	9	Debris	1	silicified wood
946	10	Bone- nonhuman, unmodified	3	
947	6	Secondary Flake	1	chert
947	6	Secondary Flake	1	silicified wood
947	7	Tertiary Flake	1	silicified wood
947	8	Tertiary Flake	1	silicified wood
947	8	Debris	1	silicified wood
947	9	Tertiary Flake	1	silicified wood
947	10	Tertiary Flake	1	quartzite
BHT 13	5	Bone- nonhuman, unmodified	7	Feature 1
BHT 13	5	Tertiary Flake	1	chert, Feature 1
BHT 13	5	Flake Fragment	4	1 quartzite, 3 chert, Feature 1
BHT 13	5	Bone- nonhuman, unmodified	7	Feature 1
BHT 13	8	Tertiary Flake	1	chert, Feature 1
BHT 14	2	Secondary Flake	1	chert
BHT 15	1	Native American ceramic- undecorated	2	
BHT 16	4	Bone- nonhuman, mammal	3	
BHT 16	10	Native American ceramic- undecorated	1	rim
		Total	395	

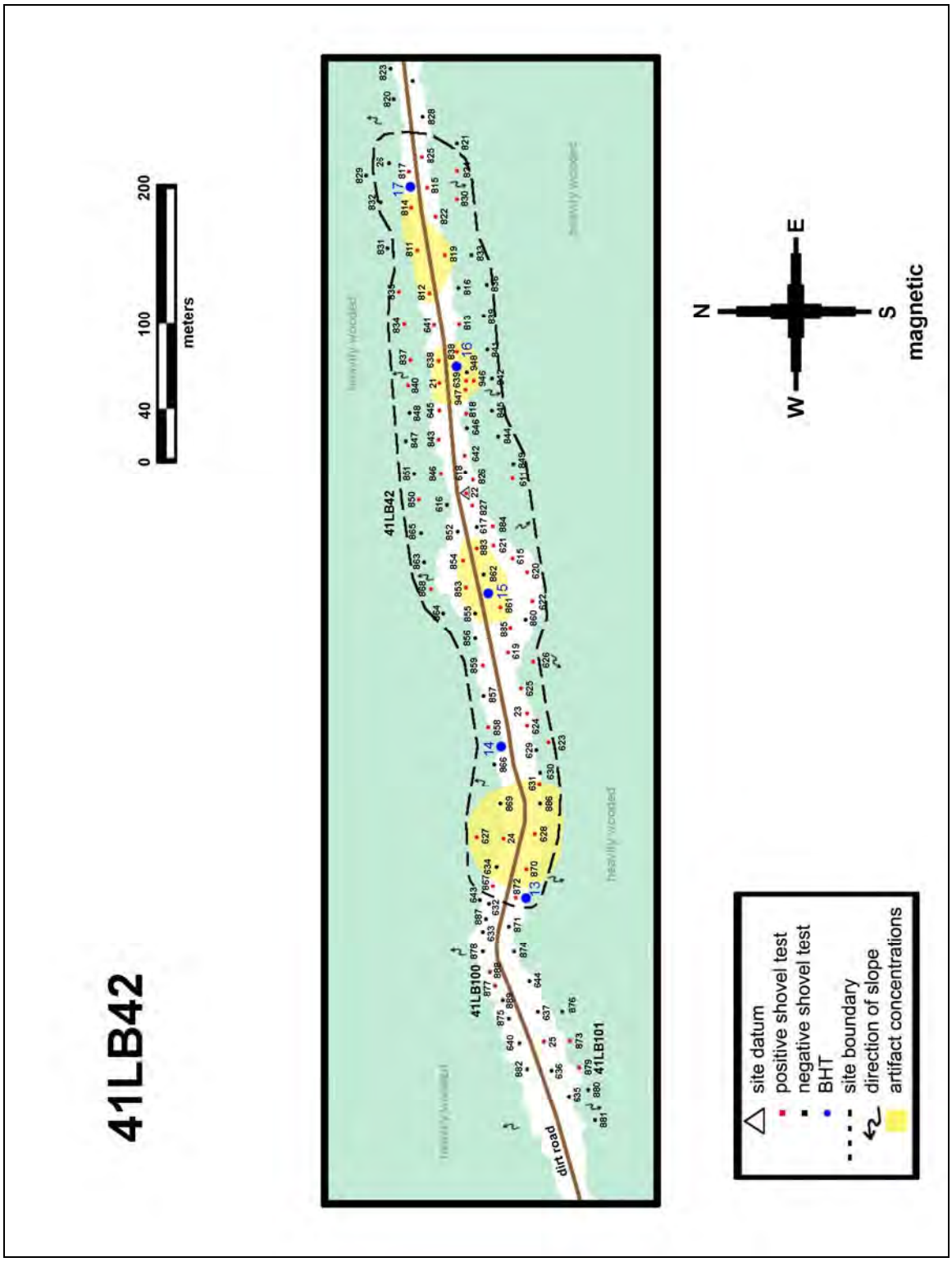
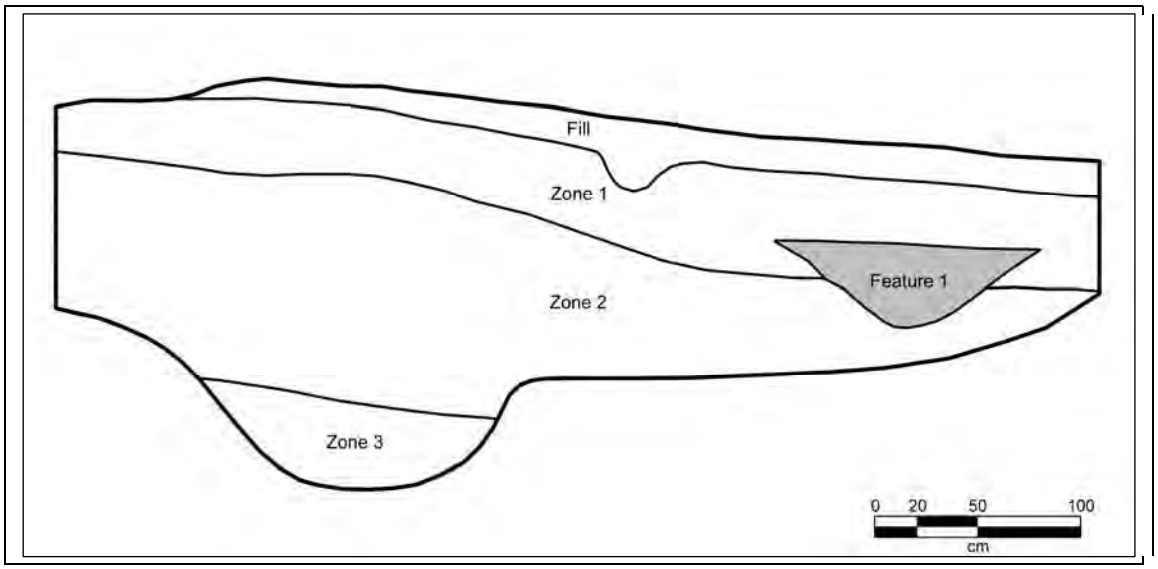
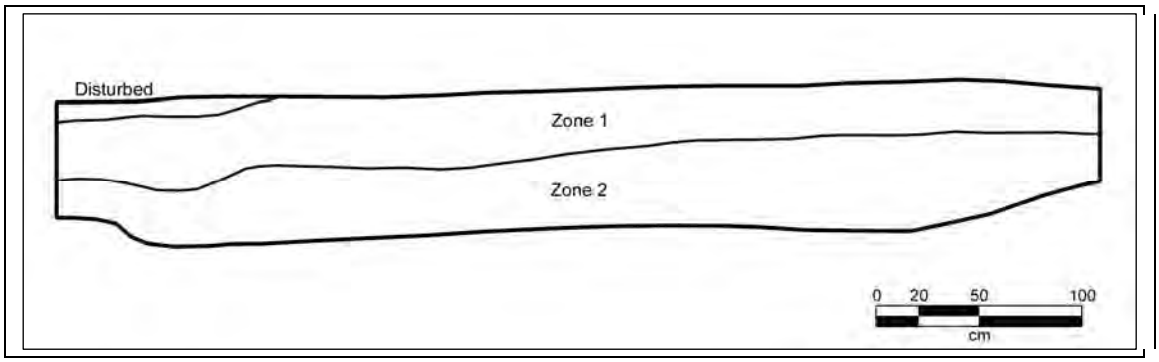


Figure 6. Map of 41LB42.



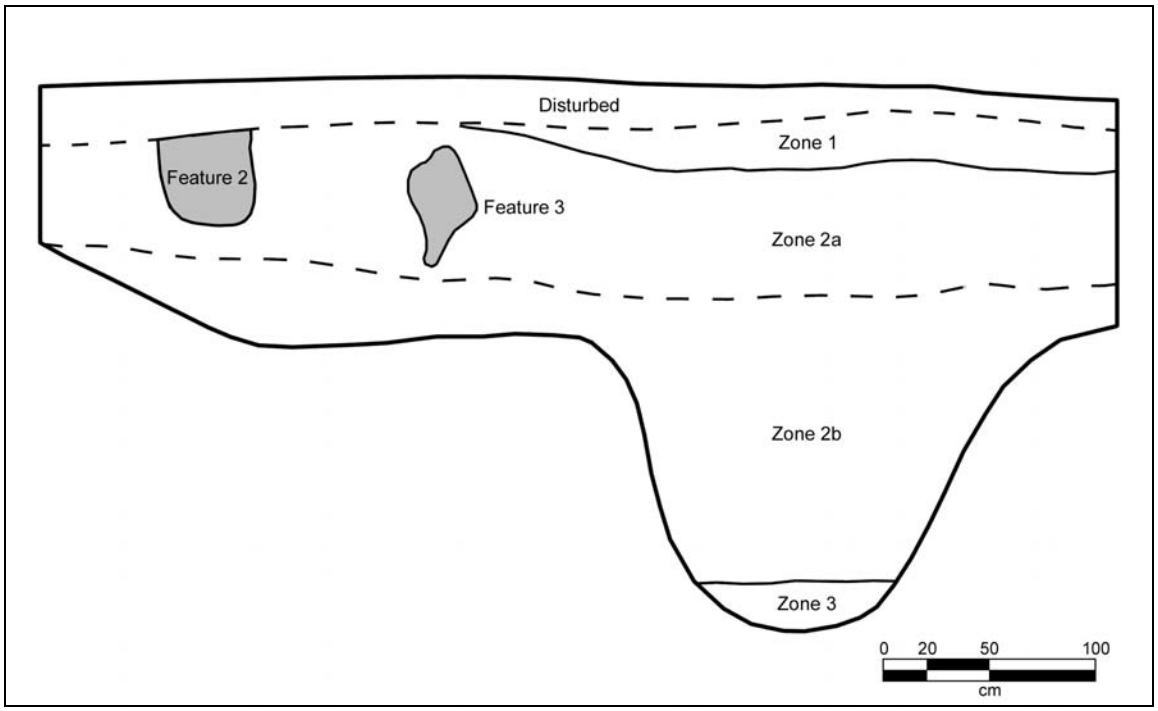
Fill	Contains a mix of brown, dark brown, pale brown, and orange sand and sandy clay
Zone 1	10YR4/3 brown fine sandy loam. Moist and friable with few roots and rootlets. Clear, smooth boundary with few iron concretions. Contains the upper portion of the Feature 1 hearth with fill of 10YR2/2 very dark brown fine sandy loam. Contained chert flakes, bone, and fired clay fragments located in and above the hearth
Zone 2	10YR6/3 Pale brown fine sand with many 10YR5/3 brown sandy lamilae throughout. Hearth's lower portion extends into this zone.
Zone 3	10YR4/2 Dark gray brown sandy clay with 7.5YR5/8 strong brown mottles, moist and firm

Figure 7. East profile of BHT 13, 41LB42.



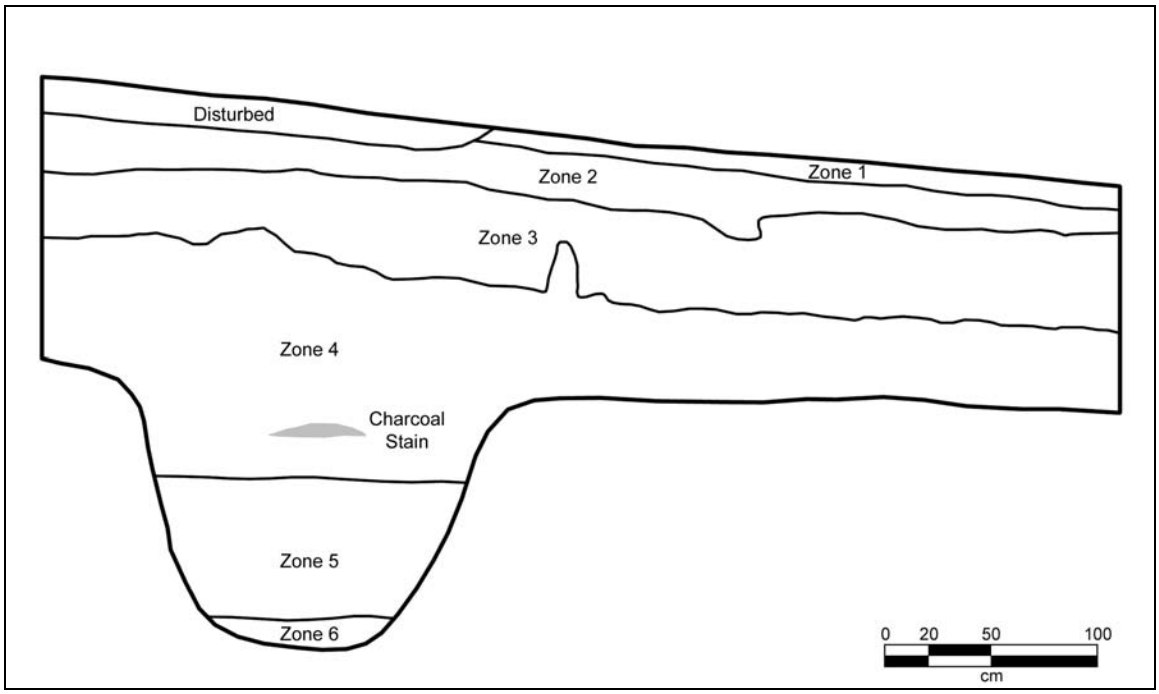
Zone 1	10YR3/3 Dark brown fine sandy loam, moist and friable with many roots and rootlets and some disturbance. Had a clear, wavy boundary and contains some lithic debitage.
Zone 2	5YR4/8 Yellowish red clay, moist and firm.

Figure 8. South profile of BHT 14, 41LB42.



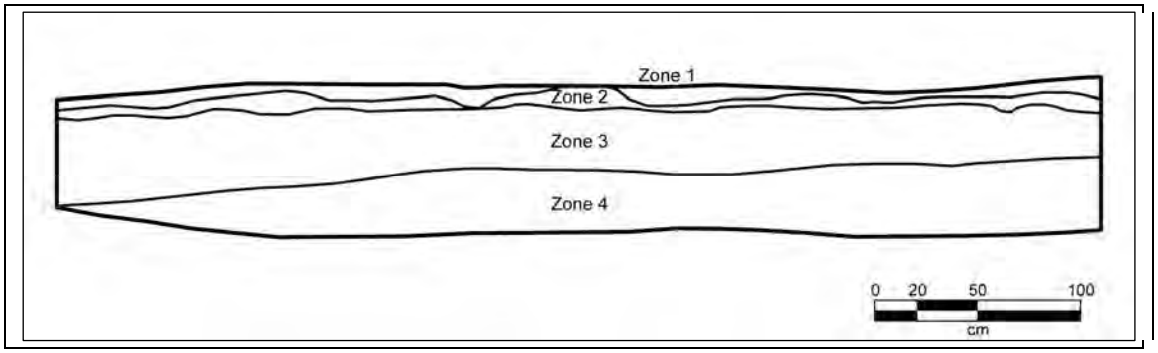
Disturbed	Zone of yellowish brown and pale brown sand disturbed by heavy machinery during sand mining.
Zone 1	10YR5/4 Yellow brown fine sand, moist and friable. Truncated and incomplete across profile. Wavy, clear boundary.
Zone 2a	10YR6/3 Pale brown fine sand.
Feature 2	10YR5/4 Yellow brown fine sand, and 10YR6/3 pale brown fine sand. Had a few charcoal flecks. Screened some soil with no artifacts.
Feature 3	Mottled mix of 10YR2/2 very dark brown and 10YR4/3 brown sandy loam. Had common charcoal flecks. Screened some soil with no artifacts.
Zone 2b	10YR6/3 Pale brown fine sand with many lamilae of 10YR4/4 dark yellow brown clayey sand.
Zone 3	7.5YR5/6 Strong brown clay with 10YR4/4 dark yellow brown mottles, moist and firm.

Figure 9. North profile of BHT 15, 41LB42.



Zone 1	10YR4/2 Dark gray brown fine sandy loam. Moist and Friable, not continuous across profile. Smooth, clear boundary.
Zone 2	10YR5/3 Brown fine sand, moist and friable with a clear, wavy boundary.
Zone 3	10YR3/3 Dark brown fine sandy loam. Moist and friable. Clear, wavy boundary.
Zone 4	10YR5/3 Brown fine sand wit few 10YR3/3 dark brown fine sand lamilae to 173 cmbs.
Zone 5	10YR6/3 Pale brown fine sand, dry and soft. Abrupt, smooth boundary to 240 cmbs
Zone 6	10YR5/4 Yellow brown fine sandy clay loam moist and firm with 10YR5/8 yellow brown mottles (subsoil) to 253 cmbs.

Figure 10. East profile of BHT 16, 41LB42.



Zone 1	10YR3/3 Dark brown fine sandy loam, moist and friable, disturbed-bioturbation by hogs. Had a few iron concretions and a gradual smooth boundary.
Zone 2	10YR5/3 Brown fine sand, moist and firm. Few iron concretions and a gradual smooth boundary.
Zone 3	10YR3/2 Very dark gray brown clay, moist and firm. Few iron concretions and a gradual smooth boundary.
Zone 4	10YR5/1 Gray clay with many 10YR5/8 yellowish brown mottles, moist and firm.

Figure 11. South profile of BHT 17, 41LB42.

Figure 12. ***Perdiz*** arrow point recovered from STP 946, 41LB42.

Figure 13. ***Gary*** dart point recovered from STP 627, 41LB42.

41LB43 (Prehistoric) Parcel 4

Site 41LB43 is a previously recorded site atop Capers Ridge. A revisit of the site was made using the site digitization data UTM coordinates available from the Texas Archeological Sites Atlas. Three shovel tests, STPs 1031-1033, were placed at this location but failed to produce any cultural materials. It appears that the site was originally plotted incorrectly or has eroded away. If misplotted, the site may lie outside the surveyed alignment, or possibly, could be represented by one of the newly discovered sites 41LB100 or 41LB101, which are located more than 200 m to the east of 41LB43's reported UTMs.

41LB97 (prehistoric) Parcel 4

41LB97 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 20 shovel tests and a well-defined landform (Figure 14). This site sits on top of Capers Ridge about 30 m south of 41LB112, and is the southerly most site on a 1 km long string of sites on this N/S leg of Capers Ridge. The site measures 30-40 m E/W by 120 m N/S. Nine of the shovel tests were positive for cultural materials. We did not delineate the site any further to the east because the ridge quickly goes to a steep degree slope after walking in that direction from the top of the ridge. There is a modern circular hog trap in this site's perimeter. Two backhoe trenches (BHTs 25, 26) were excavated within the site (Figures 15, 16). A basin-shaped hearth, Feature 1, was identified in the south profile of BHT 25. The feature measured 40 cm in width and 35 cm in depth, and contained a significant amount of minute carbonized wood fragments. All six of the artifacts from BHT 25 were recovered from within the feature fill.

The topography at this site consists of a general N/S running ridgeline that slopes off to the east into an old meander scar of the Trinity River, containing seasonally inundated wetlands. The topography slopes off to the west into a large drainage that drains an area of wide upland at this end of Capers Ridge. There is a dirt road running along the apex of the ridge that crosses the site. The vegetation here includes pine, oak, yaupon, blackberry, and various grass species. The vegetation is somewhat thinned out due to a recent forest fire.

The shovel tests and backhoe trenches produced a total of 25 artifacts (Table 3). The artifacts were recovered from Levels 1-3 (0-30 cmbs), with the majority of the artifacts recovered from Level 1 (0-10 cmbs). The artifacts included 24 pieces of lithic debitage (20 chert, 4 silicified wood) and one chert dart preform (Figure 17). The presence of the dart preform and lack of pottery sherds suggest the site dates to the Archaic period.

In summary, 41LB97 is a large prehistoric occupation site that dates to the Archaic period. The cultural deposits extend from Levels 1-3 (0-30 cmbs), and the artifact assemblage exhibits low artifact density and medium artifact diversity. We recommend that further investigations be conducted at the site in order to determine its significance and potential eligibility for the National Register of Historic Places. Once the current report is finalized, the artifacts recovered from 41LB97 will be curated at TARL.

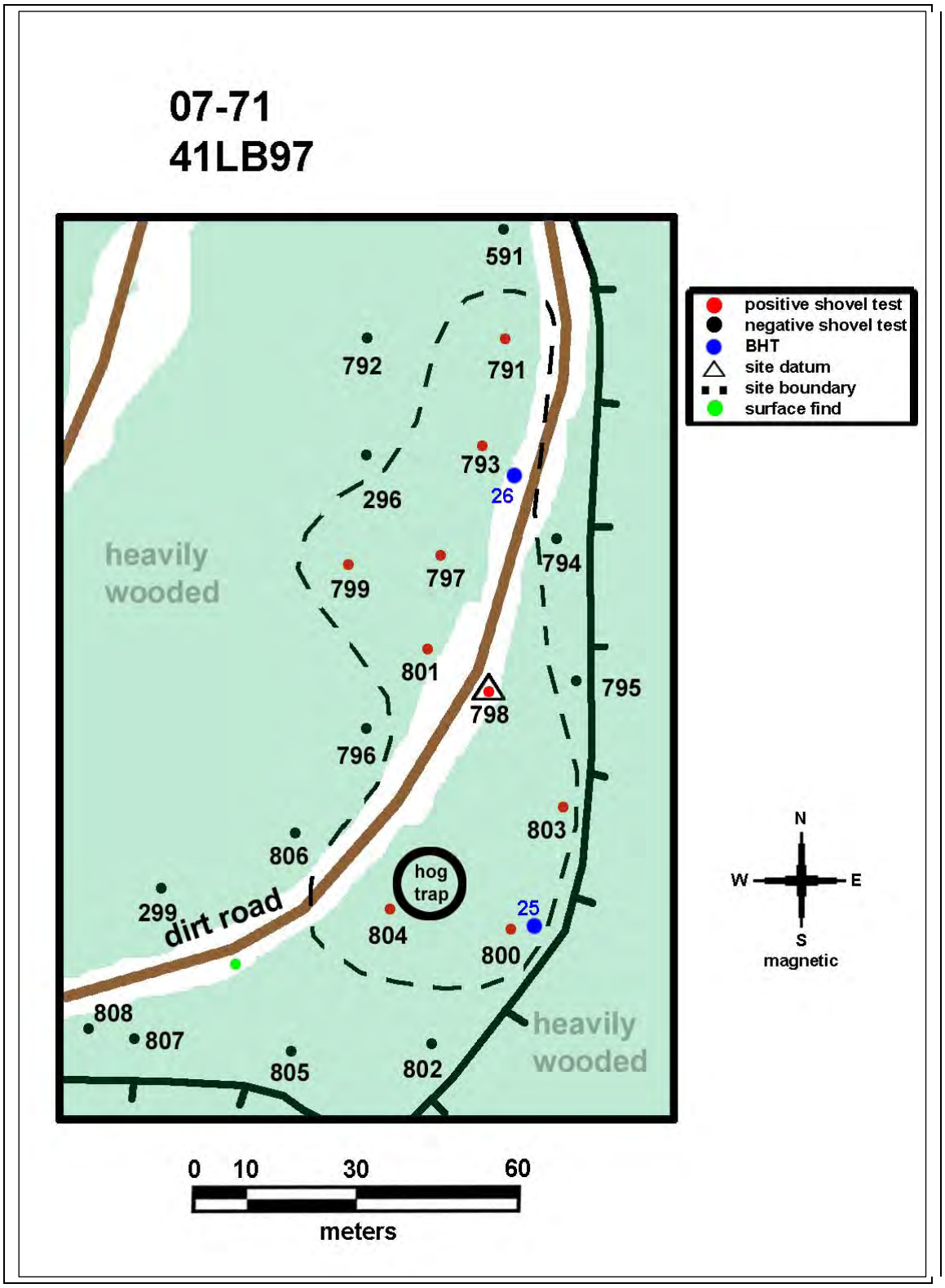
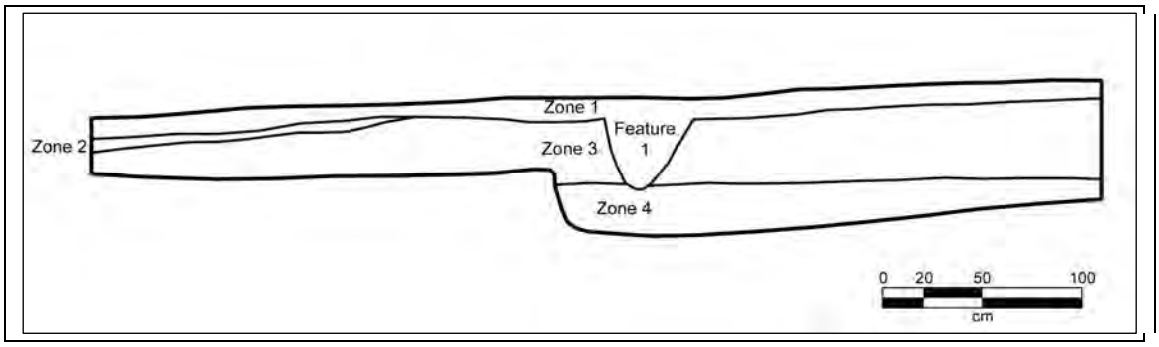
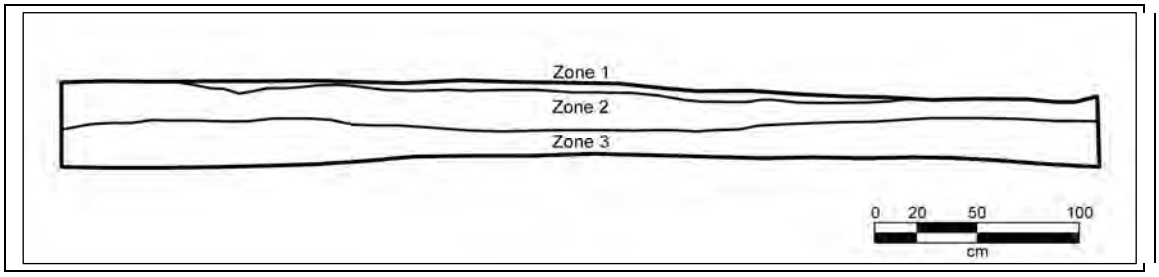


Figure 14. Map of 41LB97.



Zone 1	10YR3/3 Dark brown fine sandy loam. Moist and friable with few roots and rootlets. Clear, smooth boundary.
Feature 1	10YR3/3 Dark brown fine sandy loam. Hearth appears to have been excavated into clay extending through Zone 3 and into Zone 4. There are many charcoal fragments throughout.
Zone 2	10YR6/3 Pale brown fine sand. Moist and friable with few rootlets, not a continuous layer across profile. Clear smooth boundary.
Zone 3	2.5YR6/2 Light brown gray clay with many 7.5YR5/6 strong brown mottles. Moist and firm with few rootlets and a gradual smooth boundary. Subsoil.
Zone 4	2.5YR4/2 Dark gray brown clay. Moist and firm with few calcium carbonate concretions. Subsoil.

Figure 15. South profile of BHT 25, 41LB97.



Zone 1	10YR3/3 Dark brown fine sandy clay loam. Moist and friable with many roots and rootlets. Truncated, discontinuous across profile. Bioturbated, clear wavy boundary.
Zone 2	10YR6/3 Pale brown clay loam with few 10YR6/8 brown yellow mottles. Moist and friable with few roots and rootlets and few charcoal fragments. Bioturbated, partially truncated, with a clear wavy boundary.
Zone 3	10YR6/2 Light brown gray clay with many 5YR4/6 yellow red mottles. Moist and firm with few rootlets. Subsoil.

Figure 16. Northeast profile of BHT 26, 41LB97.

Table 3. Artifacts recovered from 41LB97.

STP/BHT	Level	Artifact Class	Count	Comments
791	3	Tertiary Flake	1	chert
793	2	Secondary Flake	1	silicified wood
793	2	Flake Fragment	1	silicified wood
793	2	Flake Fragment	1	chert
793	2	Flake Fragment	1	chert
793	2	Tertiary Flake	2	chert
797	1	Tertiary Flake	1	chert
797	1	Tertiary Flake	1	silicified wood
799	1	Flake Fragment	1	chert
800	1	Preform	1	chert
800	1	Secondary Flake	1	chert
800	1	Tertiary Flake	1	chert
800	1	Tertiary Flake	1	silicified wood
801	1	Tertiary Flake	1	chert
803	1	Tertiary Flake	1	chert
803	1	Tertiary Flake	2	chert
804	1	Tertiary Flake	1	chert
BHT 97	2	Secondary Flake	1	chert
BHT 97	3	Secondary Flake	2	chert
BHT 97	3	Tertiary Flake	1	chert
BHT 97	3	Flake Fragment	2	chert
		Total	25	

Figure 17. Dart point preform recovered from STP 800, 41LB97.

41LB98 (prehistoric) Parcel 1

41LB98 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 18 shovel tests and a well-defined landform (Figure 18). This site sits on top of Capers Ridge about 35 m north of 41LB104, and is the northern most site on a 1 km long string of sites on this N/S leg of Capers Ridge. The site measures 30 m E/W by 45 m N/S. Four of the shovel tests were positive for cultural materials. We did not delineate the site further to the east and west because the ridge quickly goes to a steep degree slope after walking in those directions from the top of the ridge. A single backhoe trench (BHT 35) was excavated within the site, but produced no cultural materials or features (Figure 19)

The topography at this site consists of a general N/S running ridgeline that slopes off to the east and west into old meander scars of the Trinity River that contain seasonally inundated wetlands. There is a dirt road running along the apex of the ridge that crosses the site. The vegetation here includes oak, pine, magnolia, yaupon, blackberry, and various grass species. The woods are thin in and around the site where there is a lot of downed timber from the recent hurricanes.

The shovel testing produced a total of 10 artifacts (Table 4). The artifacts were recovered from Levels 1-9 (0-90 cmbs), with the majority recovered from Level 2 (10-20 cmbs). The artifacts consisted of 10 pieces of lithic debitage (7 chert, 3 silicified wood). Though no chronologically diagnostic materials were recovered, the lack of pottery sherds suggests the site dates to the Archaic period.

In summary, 41LB98 represents a medium-sized prehistoric occupation site that exhibits low artifact density and low artifact diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB98 will be curated at TARL.

Table 4. Artifacts recovered from 41LB98.

STP	Level	Artifact Class	Count	Comments
894	2	Tertiary Flake	1	silicified wood
896	2	Secondary Flake	1	chert
899	1	Flake Fragment	1	chert
899	2	Flake Fragment	1	silicified wood
899	2	Secondary Flake	1	silicified wood
899	2	Tertiary Flake	1	chert
917	4	Flake Fragment	1	chert
917	6	Tertiary Flake	1	chert
917	7	Tertiary Flake	1	chert
917	9	Debris	1	chert
		Total	10	

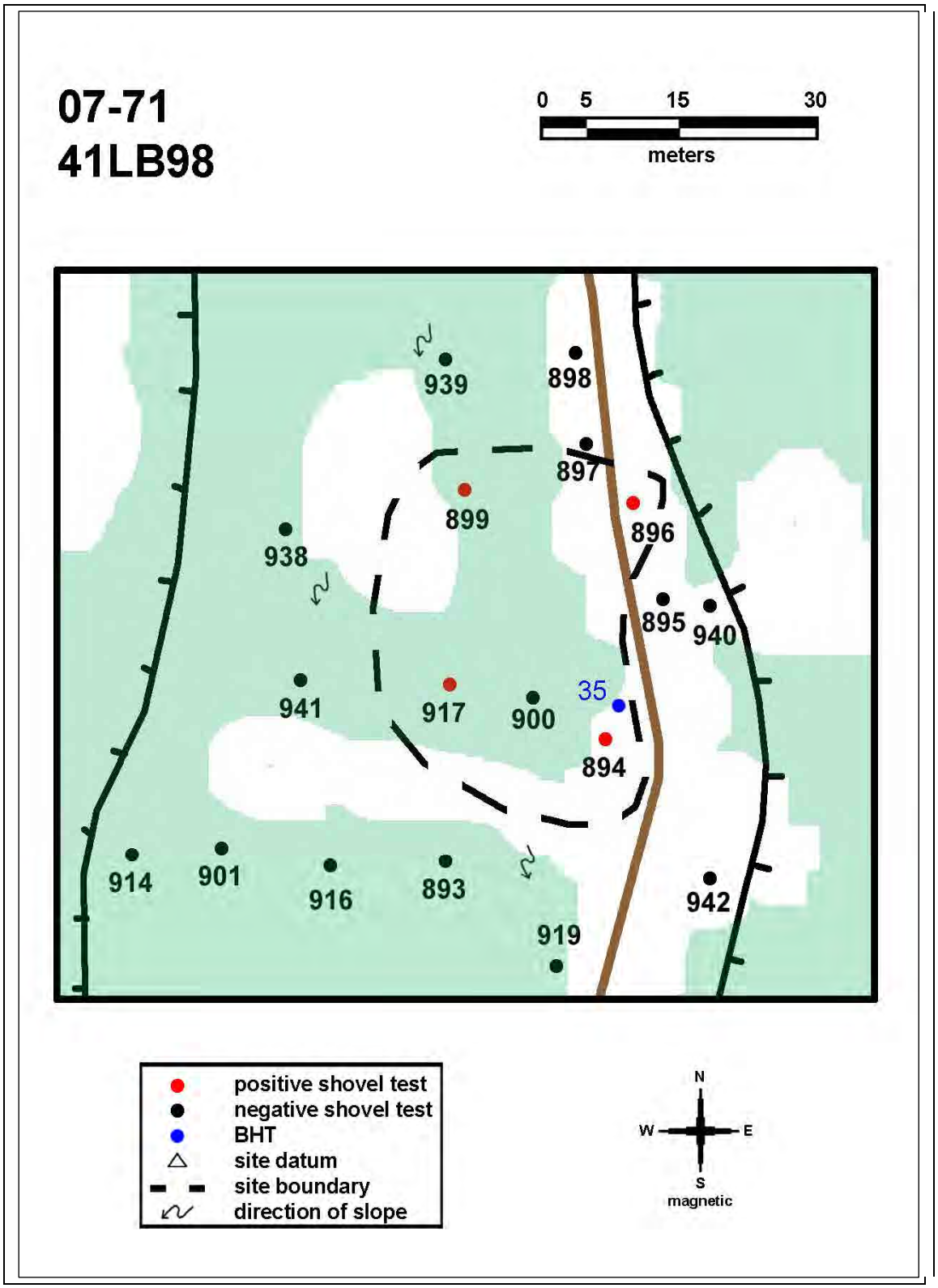
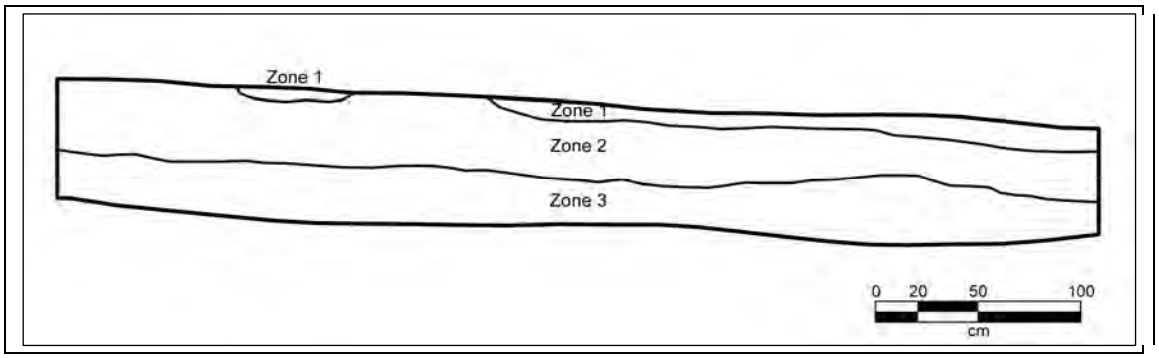


Figure 18. Map of 41LB98.



Zone 1	10YR3/3 Dark brown fine sandy loam. Moist and friable, bioturbated and truncated. Discontinuous across profile with many roots and rootlets and a clear, wavy boundary.
Zone 2	10YR5/4 Yellow brown fine sand. Moist and friable, bioturbated and partially truncated. Few roots and rootlets with some iron concretions and a clear, wavy boundary.
Zone 3	5YR3/4 Dark red brown clay. Moist and firm with a few roots and some iron concretions in the upper portion. Subsoil.

Figure 19. Southwest profile of BHT 35, 41LB98.

41LB99 (prehistoric) Parcel 2

41LB99 is a prehistoric buried campsite identified and horizontally defined on the basis of 18 shovel tests and a well-defined landform (Figure 20). This site sits on top of Capers Ridge about 45 m south of 41LB104, 40 m north of 41LB103, and is in the middle of a 1 km long string of sites on this N/S leg of Capers Ridge. The site measures 70 m E/W by 50 m N/S. Six of the shovel tests were positive for cultural materials.

The topography at this site consists of a general N/S running ridgeline that slopes off to the east and west into old meander scars of the Trinity River that contain seasonally inundated wetlands. There is a dirt road running along the apex of the ridge and across the ridge that both cross the site. The vegetation here includes oak, pine, magnolia, yaupon, blackberry, and various grass species. The woods are sparse in and around the site where there is a lot of downed timber from the recent hurricanes.

We did not delineate the site any further to the east and west because the ridge quickly goes to a steep degree slope after walking in those directions from the top of the ridge. Buried charcoal was common throughout the profile in the site but was not collected. There was also a light scatter of modern historic debris in Level 1. There is a modern deer camp just NE of this site with an old school bus for a cabin. Two backhoe trenches (BHT 31, 32) were excavated within the site, but produced no cultural materials or features (Figures 21, 22)

The shovel testing produced a total of 17 artifacts (Table 5). The artifacts were recovered from Levels 1-3 (0-30 cmbs). The artifacts consisted of 17 pieces of lithic debitage (5 chert, 3 quartzite, 9 silicified wood). Though no chronologically diagnostic materials were recovered, the lack of pottery sherds suggests the site dates to the Archaic period.

In summary, 41LB99 is a medium-sized prehistoric occupation site that dates to the Archaic period. The artifact assemblage exhibits medium artifact density and low artifact diversity. We recommend that further investigations be conducted at the site in order to determine its significance and potential eligibility for the National Register of Historic Places. Once the current report is finalized, the artifacts recovered from 41LB99 will be curated at TARL.

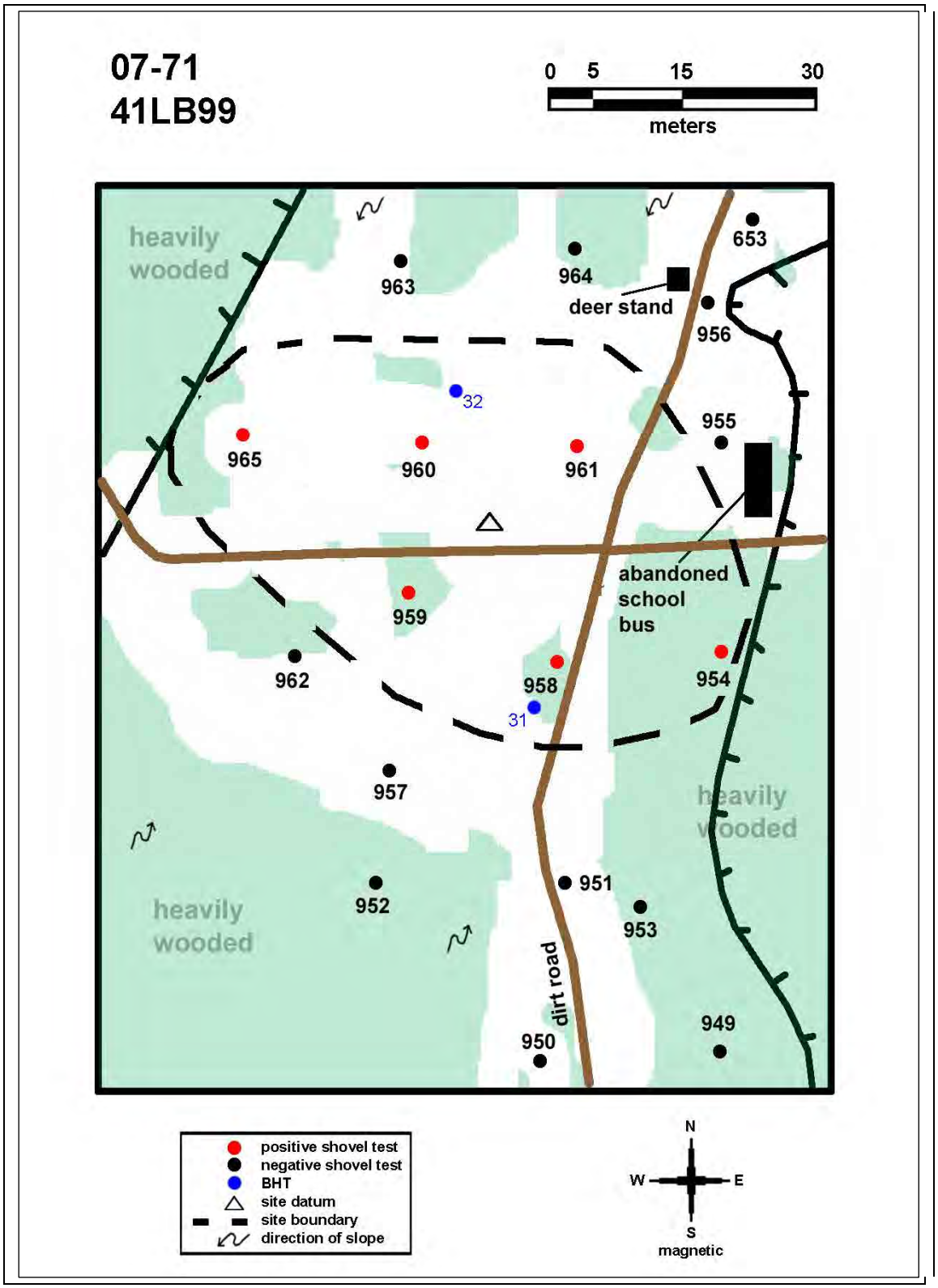
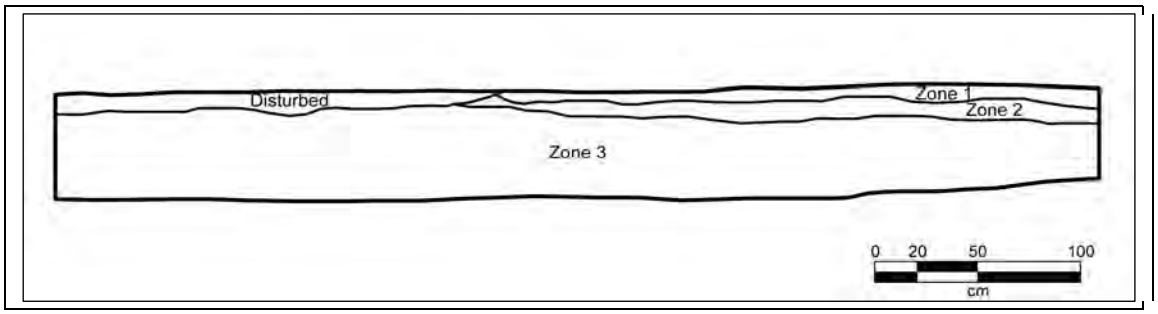
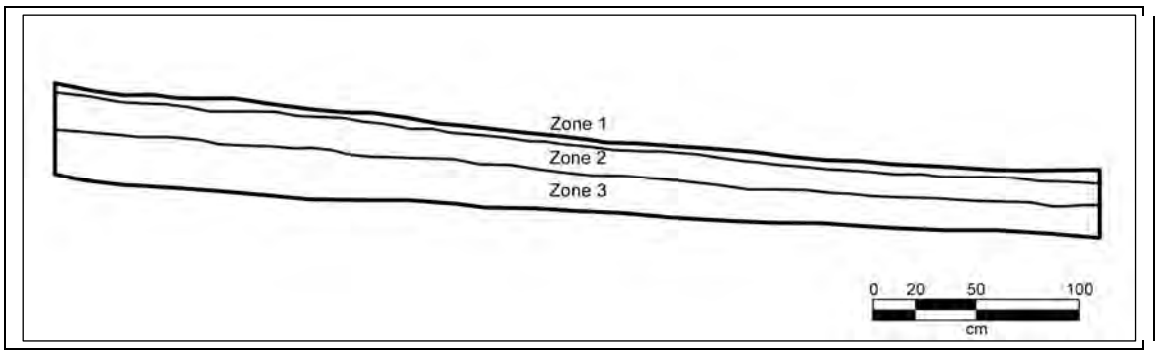


Figure 20. Map of 41LB99.



Disturbed	Mixed sands disturbed by hogs.
Zone 1	10YR3/4 Dark yellow brown fine sandy clay loam. Moist and friable with few roots and rootlets. Biotrubated, discontinuous across profile with a clear, wavy boundary.
Zone 2	10YR5/4 Yellow brown fine sand. Moist and friable with few rootlets. Bioturbated, discontinuous across profile with a clear, wavy boundary.
Zone 3	10YR6/3 Pale brown clay with many 5YR4/6 yellow red mottles. Moist and firm, few roots, bioturbated at top. Subsoil.

Figure 21. South profile of BHT 31, 41LB99.



Zone 1	10YR3/2 Very dark gray brown fine sandy loam. Moist and friable with few roots and rootlets. Bioturbated with a clear, wavy boundary.
Zone 2	10YR5/4 Yellow brown fine sand. Moist and friable with few roots. Bioturbated with clear, wavy boundary.
Zone 3	2.5YR4/6 Red clay, moist and firm. Bioturbated at top. Subsoil.

Figure 22. West profile of BHT 32, 41LB99.

Table 5. Artifacts recovered from 41LB99.

STP	Level	Artifact Class	Count	Comments
954	2	Tertiary Flake	1	chert
958	1	Flake Fragment	1	silicified wood
958	2	Tertiary Flake	1	silicified wood
958	2	Tertiary Flake	1	chert
958	2	Flake Fragment	1	quartzite
958	3	Flake Fragment	1	quartzite
959	2	Tertiary Flake	1	silicified wood
959	2	Primary flake	1	quartzite
960	1	Primary flake	1	silicified wood
960	1	Flake Fragment	1	chert
960	2	Secondary Flake	2	silicified wood
961	1	Tertiary Flake	1	chert
961	1	Secondary Flake	1	silicified wood
961	2	Tertiary Flake	1	silicified wood
961	3	Flake Fragment	1	silicified wood
965	2	Tertiary Flake	1	chert
		Total	17	

41LB100 (prehistoric) Parcel 4

41LB100 is a prehistoric buried campsite identified and horizontally defined on the basis of 10 shovel tests and a well-defined landform (Figure 23). This site sits on top of Capers Ridge about 50 m west of the west end of 41LB42 and about 45 m east of 41LB101. This site is on the west end of a 1 km long E/W string of sites on this section of Capers Ridge. The site measures roughly 25 m in diameter. Two of the shovel tests were positive for cultural materials. A single backhoe trench (BHT 12) was excavated within the site, but produced no cultural materials or features (Figure 24).

The topography at this site consists of a general E/W running ridgeline that slopes off to the north and south into old meander scars of the Trinity River that contain seasonally inundated wetlands. There is a road running along the apex of the ridge, which is on the south side of the site. The area is heavily wooded with oak, elm, magnolia, yaupon, and pine.

We did not delineate the site any further to the north and south because the ridge quickly goes to a steep degree slope after walking in those directions from the top of the ridge. Buried charcoal was common throughout the profile in the site but not collected. The vegetation here includes oak, pine, magnolia, yaupon, blackberry, and various grass species.

The shovel testing produced a total of 10 artifacts (Table 6). The artifacts were recovered from Levels 1-8 (0-70 cmbs). The artifacts consisted of six pieces of lithic debitage (2 chert, 3 silicified wood), three pieces of burned clay, and one Goose Creek plain sherd. The presence of the pottery sherd indicates the site dates to the Early-Late Ceramic period.

In summary, 41LB100 represents a small prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB100 will be curated at TARL.

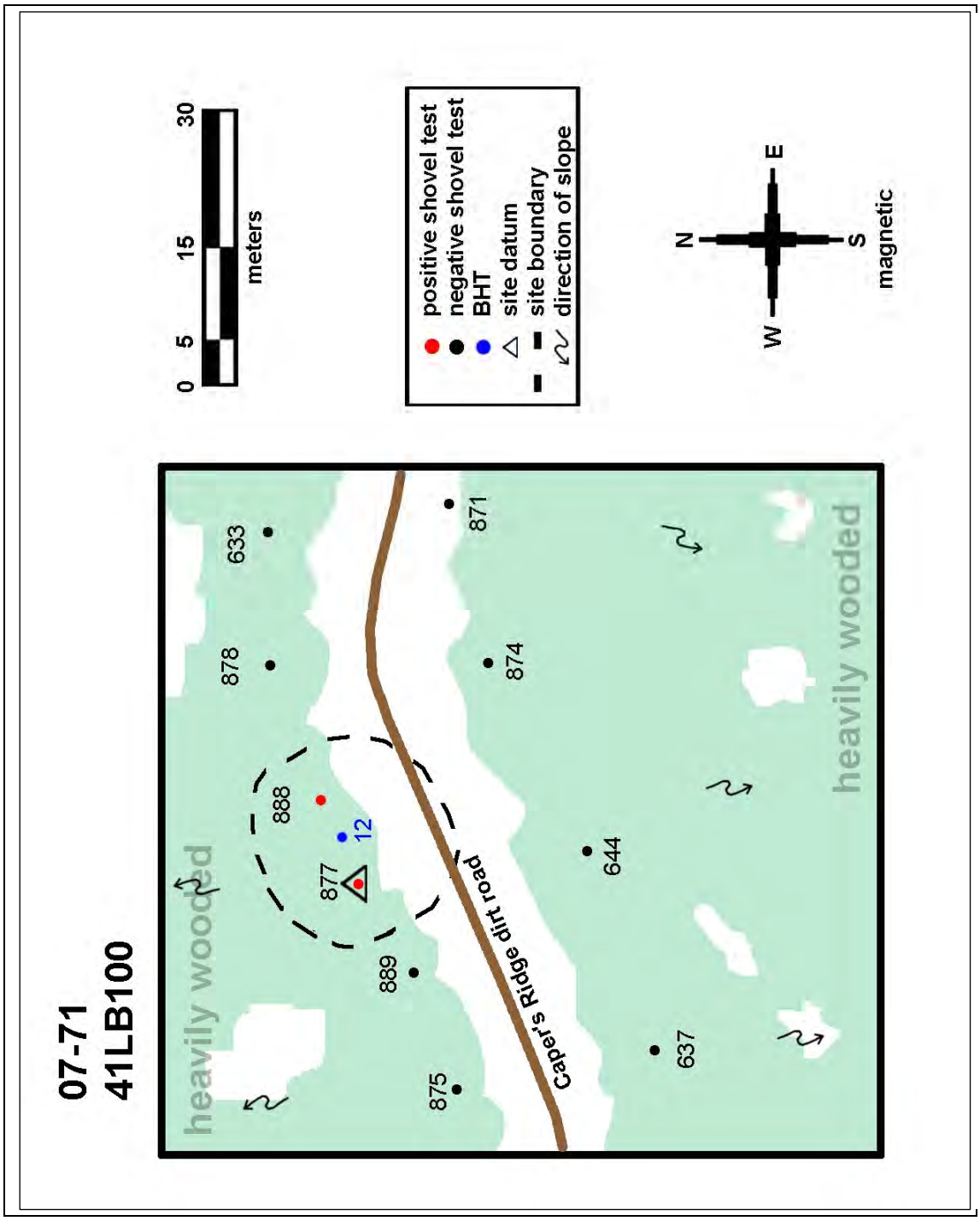
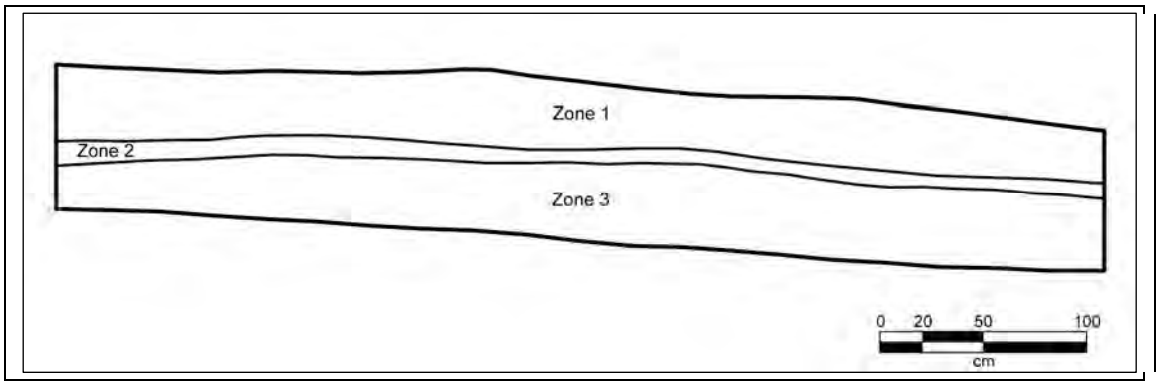


Figure 23. Map of 41LB100.



Zone 1	10YR4/2 Dark gray brown fine sandy loam, moist and friable. Smooth, clear boundary with many roots and rootlets and a few iron concretions.
Zone 2	10YR6/4 Light yellow brown fine clayey sand with many iron concretions and a smooth, clear boundary.
Zone 3	7.5YR5/6 Strong brown clay, moist and firm. Subsoil.

Figure 24. West profile of BHT 12, 41LB100.

Table 6. Artifacts recovered from 41LB100.

STP	Level	Artifact Class	Count	Comments
877	4	Flake Fragment	1	silicified wood
877	4	Tertiary Flake	1	chert
877	5	Flake Fragment	1	chert
877	6	Tertiary Flake	1	silicified wood
877	7	Secondary Flake	1	silicified wood
877	7	Miscellaneous burned clay	2	
877	8	Miscellaneous burned clay	1	
888	2	Native American ceramic- undecorated	1	
888	2	Tertiary Flake	1	silicified wood
		Total	10	

41LB101 (prehistoric) Parcel 4

41LB101 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 13 shovel tests and a well-defined landform (Figure 25). This site sits on top of Capers Ridge about 75 m west of the west end of 41LB42 and about 45 m west of 41LB100. This site is on the west end of a 1 km long E/W string of sites on this section of Capers Ridge. The site measures 35 m E/W by 55 m N/S. Three of the shovel tests were positive for cultural materials.

The topography at this site consists of a general E/W running ridgeline that slopes off to the north and south into old meander scars of the Trinity River that contain seasonally inundated wetlands. There is a road running along the apex of the ridge, which is on the north side of the site. The area is heavily wooded with oak, elm, magnolia, yaupon, and pine.

We did not delineate the site any further to the north and south because the ridge quickly goes to a steep degree slope after walking in those directions from the top of the ridge. Buried charcoal was evident throughout the profile in the site but not collected.

The shovel testing produced a total of five artifacts (Table 7). The artifacts were recovered from Levels 1-2, and 7 (0-20, 60-70 cmbs). The artifacts included 5 pieces of lithic debitage (4 chert, 1 silicified wood). Though no chronologically diagnostic materials were recovered, the lack of pottery sherds suggests the site dates to the Archaic period.

In summary, 41LB101 represents a medium-sized prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB101 will be curated at TARL.

Table 7. Artifacts recovered from 41LB101.

STP	Level	Artifact Class	Count	Comments
25	1	Flake fragment	1	chert
25	2	Flake fragment	2	chert
873	7	Secondary Flake	1	quartzite
879	2	Flake Fragment	1	chert
		Total	5	

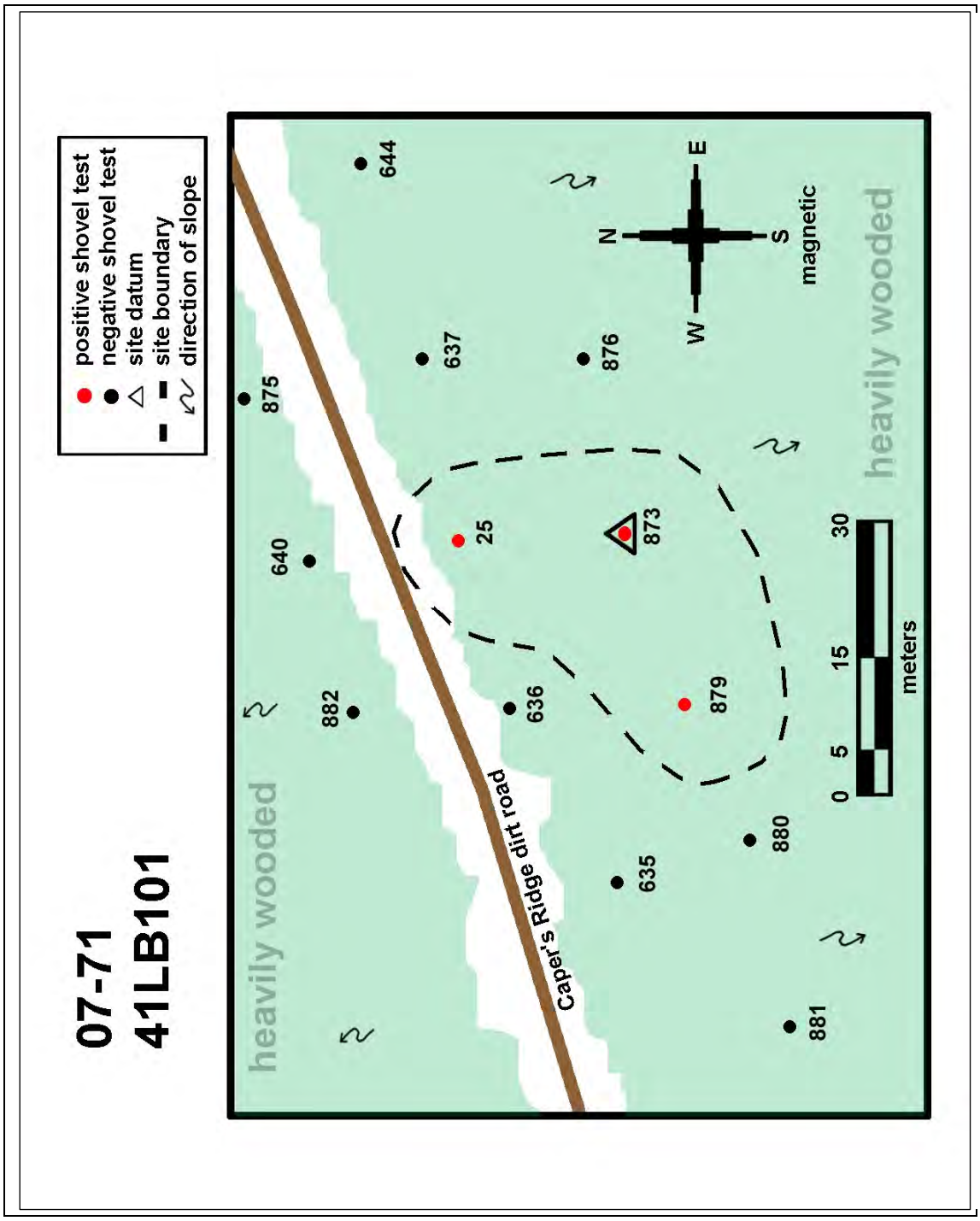


Figure 25. Map of 41LB101.

41LB102 (Prehistoric) Parcel 4

41LB102 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 8 shovel tests and a well-defined landform (Figure 26). Three of the shovel tests were positive for cultural materials. A single backhoe trench (BHT 19) was excavated within the site, but produced no cultural materials or features (Figure 27). The site is 275 m east of the east end of 41LB42 and about 600 m west of 41LB113. The site sits on a prominent high spot on this E/W stretch of Capers Ridge. The site measures 25 m E/W by 35 m N/S.

The topography at this site consists of a general E/W running ridgeline that slopes off to the north and south into old meander scars of the Trinity River that contain seasonally inundated wetlands. There is a road running along the apex of the ridge, which runs directly through the site. The area is heavily wooded with oak, elm, magnolia, yaupon, and pine. This particular site is on a prominent high point on the ridge.

The site produced one flake from two different shovel tests that were about 20 m apart from one another (Table 8). The artifacts are recovered from Levels 4 and 9 (30-40, 80-90 cmbs). This appears to be a very minimal occupation probably representing lithic scatter from more prominent sites up and down the ridgeline. We did not delineate the site any further to the north and south because the ridge quickly goes to a steep degree slope after walking in those directions from the top of the ridge.

In summary, 41LB102 represents a medium-sized prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB102 will be curated at TARL.

Table 8. Artifacts recovered from 41LB102.

STP	Level	Artifact Class	Count	Comments
42	4	Secondary flake	1	Chert
610	9	Tertiary flake	1	Chert
		Total	2	

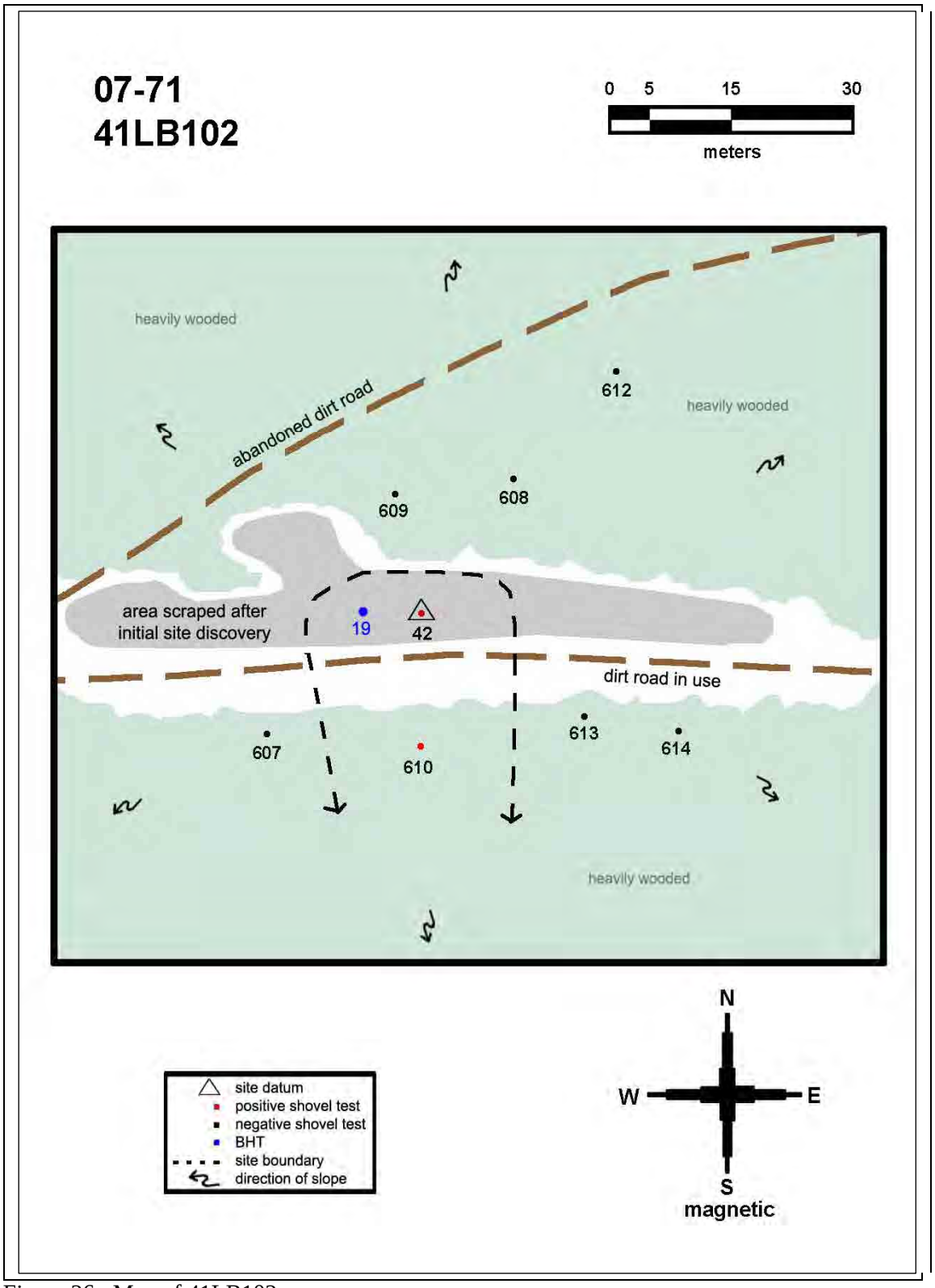
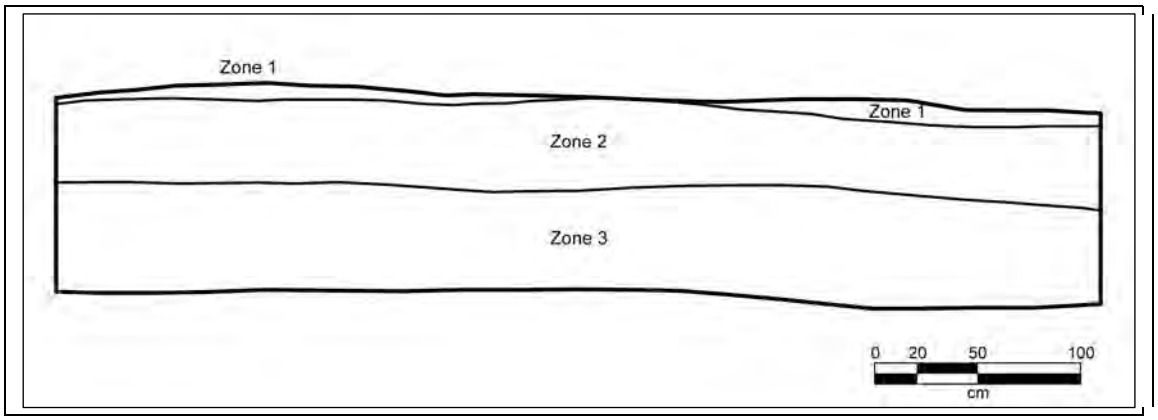


Figure 26. Map of 41LB102.



Zone 1	10YR3/3 Dark brown fine sandy loam with a few iron concretions, moist and friable. Truncated and non-continuous. Many roots and rootlets with a smooth clear boundary.
Zone 2	10YR6/4 Light yellow brown fine sand with many iron concretions, dry and soft. Smooth, clear boundary with few roots and rootlets.
Zone 3	10YR6/6 brownish yellow fine sandy clay, moist and firm with a few iron concretions, below dashed line clay is dry. Subsoil.

Figure 27. West profile of BHT 19, 41LB102.

41LB103 (prehistoric) Parcel 4

41LB103 is a prehistoric buried campsite identified and horizontally defined on the basis of 25 shovel tests on a well-defined landform (Figure 28). Eleven of the shovel tests were positive for cultural materials. Two backhoe trenches (BHT 29, 30) were excavated within the site, both produced cultural materials (Figures 29, 30). The site is 45 m south of 41LB99 and about 50 m north of 41LB112. This site is on a string of sites that runs for almost a kilometer on this stretch of Capers Ridge. The site measures 120 m SW/NE by 60 m SE/NW.

The topography at this site consists of a general N/S running ridgeline that slopes off to the east and west into old meander scars of the Trinity River that contain seasonally inundated wetlands. There are two dirt roads running along the ridge, which surround the site. The area is heavily wooded with oak, elm, holly, yaupon, and pine. This particular site is on a prominent high point on the ridge.

The shovel tests and backhoe trenches produced a total of 36 artifacts (Table 9). The artifacts were recovered from Levels 1-6 (0-60 cmbs), with the highest densities in Level 2 (10-20 cmbs). The artifacts consisted of two biface fragments (1 chert, 1 silicified wood), one chert core, and 33 pieces of lithic debitage (17 chert, 4 quartzite, 12 silicified wood). Though no chronologically diagnostic materials were recovered, the lack of pottery sherds suggests the site dates to the Archaic period.

The bulk of the material seems to be concentrated along the easternmost ridgeline. There was also common charcoal throughout the profile. We did not delineate the site any further to the east and west because the ridge quickly goes to a steep degree slope after walking in those directions from the top of the ridge.

In summary, 41LB103 is a large prehistoric occupation site that dates to the Archaic period. The cultural deposits extend from Levels 1-6 (0-60 cmbs), and the artifact assemblage exhibits medium artifact density and diversity. We recommend that further investigations be conducted at the site in order to determine its significance and potential eligibility for the

National Register of Historic Places. Once the current report is finalized, the artifacts recovered from 41LB103 will be curated at TARL.

Table 9. Artifacts recovered from 41LB103.

STP/BHT	Level	Artifact Class	Count	Comments
53	2	Debris	1	silicified wood
53	2	Tertiary flake	1	silicified wood
53	2	Secondary flake	1	chert
53	3	Tertiary flake	2	chert
53	4	Tertiary flake	2	chert
53	4	Flake fragment	1	chert
53	5	Primary flake	1	silicified wood
53	5	Flake fragment	4	1 quartzite, 1 silicified wood, 2 chert
54	2	Tertiary flake	1	chert
294	1	Tertiary flake	2	chert
294	2	Secondary flake	1	silicified wood
572	3	Tertiary flake	1	silicified wood
573	2	Debris	1	pot lidded, silicified wood
574	2	Secondary flake	1	chert
575	2	Tertiary flake	2	1 quartzite, 1 silicified wood
576	2	Flake fragment	1	quartzite
577	2	Tertiary flake	1	quartzite
577	3	Tertiary flake	1	silicified wood
580	2	Debris	2	chert
580	2	Flake fragment	1	chert
584	2	Secondary flake	1	pot lidded, silicified wood
BHT 29	2	Biface	1	chert
BHT 29	3	Primary flake	1	silicified wood
BHT 30	2	Biface	1	silicified wood, preform
BHT 30	2	Debris	1	silicified wood
BHT 30	3	Primary flake	1	chert
BHT 30	3	Tertiary flake	1	chert
BHT 30	6	Core	1	chert
		Total	36	

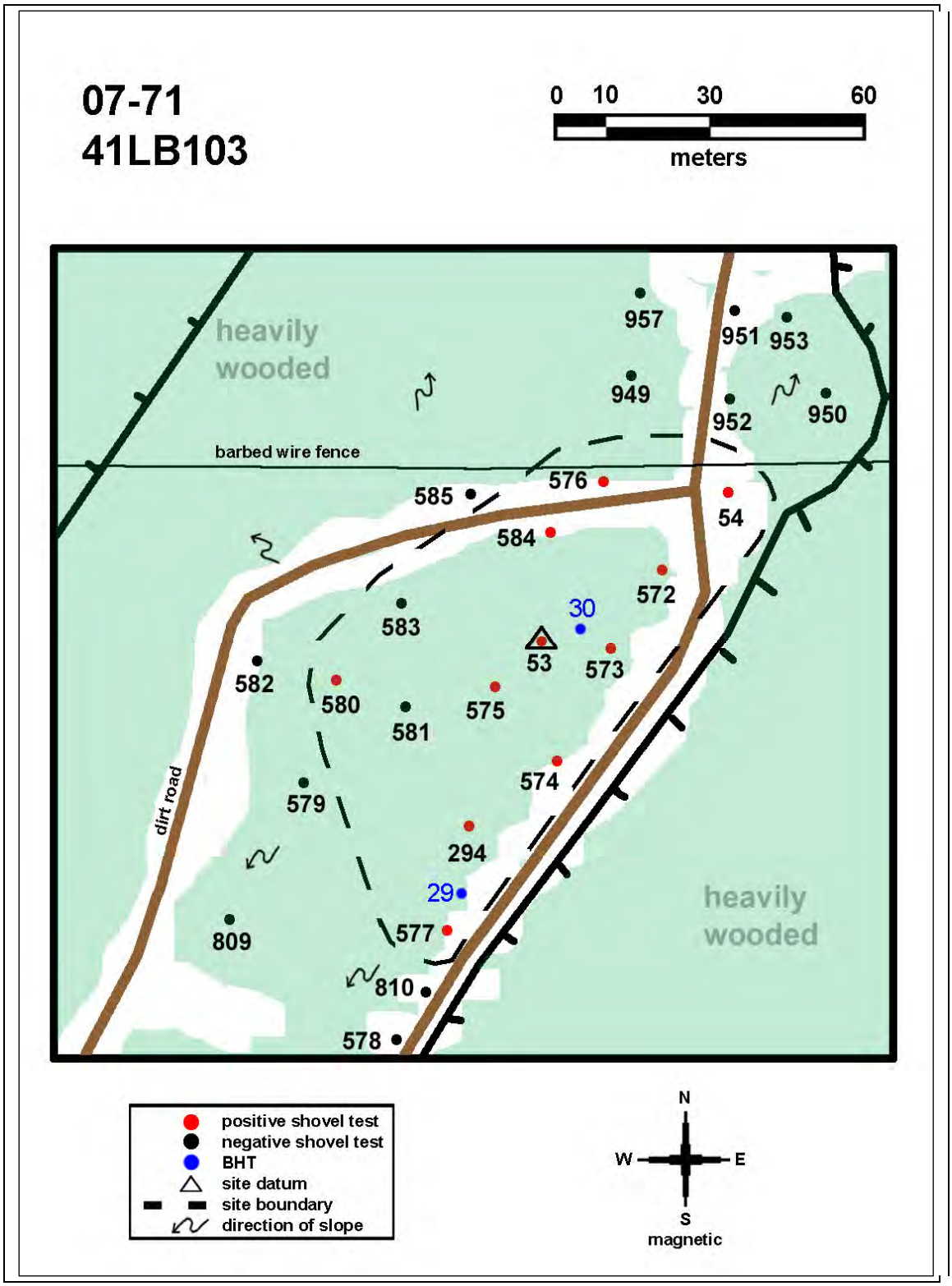
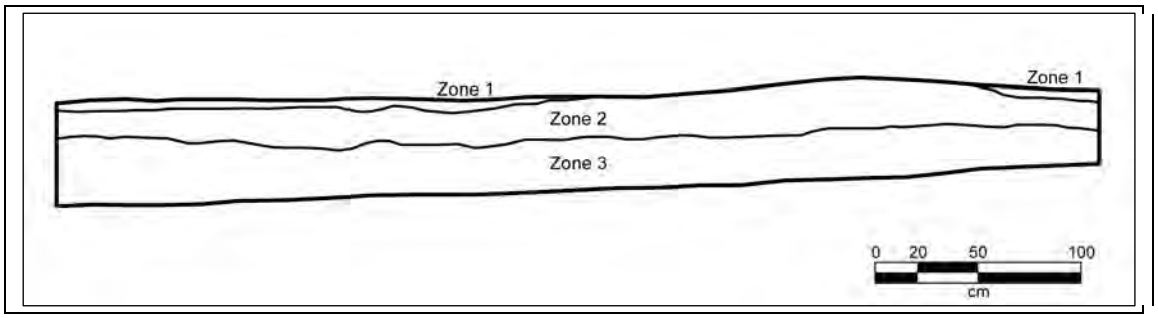
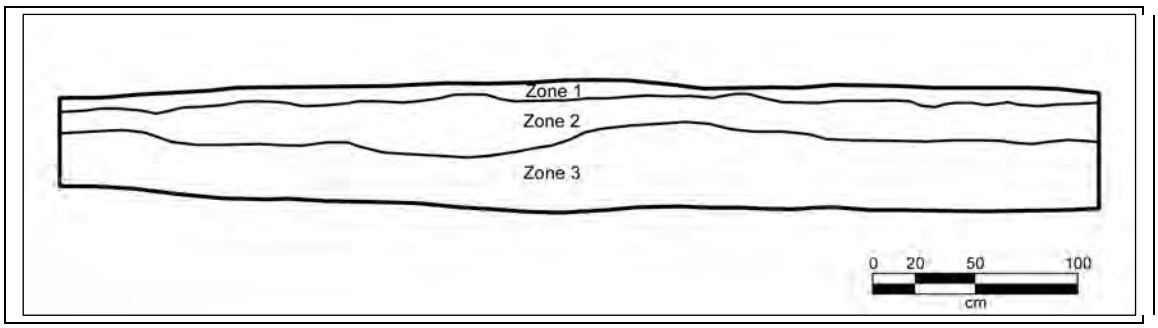


Figure 28. Map of 41LB103.



Zone 1	10YR4/3 Dark gray brown clay loam, moist and friable. Truncated and discontinuous across profile. Few roots and rootlets, bioturbated with a clear wavy boundary.
Zone 2	10YR5/3 Brown loamy clay, moist and firm. Few roots and rootlets, bioturbated, partially truncated with a clear wavy boundary.
Zone 3	10YR6/6 Brown yellow clay with many 10YR5/8 yellow brown mottles. Moist and firm, bioturbated at top with few roots. Subsoil.

Figure 29. Southwest profile of BHT 29, 41LB103.



Zone 1	10YR3/3 Dark brown fine sandy clay loam. Moist and friable, bioturbated with many roots and rootlets and a clear wavy boundary.
Zone 2	10YR5/4 yellow brown fine sand. Moist and friable, very few roots and rootlets, bioturbated. Very few iron concretions and charcoal fragments with a clear, wavy boundary.
Zone 3	10YR6/2 Light brown gray clay with many 7.5YR4/6 strong brown mottles. Very few roots and rootlets, moist and firm. Subsoil

Figure 30. East profile of BHT 30, 41LB103.

41LB104 (prehistoric) Parcel 1

41LB104 is a prehistoric buried campsite identified and horizontally defined on the basis of 21 shovel tests on a well-defined landform (Figure 31). Two backhoe trenches (BHTs 33, 34) were excavated within the site (Figures 32, 33). One of these trenches (BHT 104) produced cultural materials. This site sits on top of Capers Ridge about 45 m north of 41LB99 and about 35 m south of 41LB98, and is at the northern end of a 1 km long string of sites on this N/S leg of Capers Ridge. The site measures 80 m E/W by 65 m N/S. Nine of the shovel tests were positive for cultural materials.

The topography at this site consists of a general N/S running ridgeline that slopes off to the east and west into old meander scars of the Trinity River that contain seasonally inundated wetlands. There is a dirt road running along the apex of the ridge that cuts through the site. The vegetation here includes oak, pine, magnolia, yaupon, blackberry, and various grass species. The woods are sparse in and around the site where there is a lot of downed timber from recent hurricanes.

The shovel testing produced a total of 21 artifacts (Table 10). The artifacts were recovered from Levels 1-4 (0-40 cmbs). The artifacts included 18 pieces of lithic debitage (11 chert, 7 silicified wood) and three pieces of burned clay. Though no chronologically diagnostic materials were recovered, the lack of pottery sherds suggests the site dates to the Archaic period.

We did not delineate the site any further to the east and west because the ridge quickly goes to a steep degree slope after walking in those directions from the top of the ridge. Buried charcoal was common throughout the profile in the site but was not collected. The artifacts appear to be from 0-40 cmbs as the clay begins to appear by that time in this area. There was also a light scatter of modern historic debris in Level 1. There is a modern deer camp just SE of this site with an old school bus for a cabin.

In summary, 41LB104 is a medium-sized prehistoric occupation site that dates to the Archaic period. The cultural deposits extend from Levels 1-4 (0-40 cmbs), and the artifact assemblage exhibits medium artifact density and low artifact diversity. We recommend that further investigations be conducted at the site in order to determine its significance and potential eligibility for the National Register of Historic Places. Once the current report is finalized, the artifacts recovered from 41LB104 will be curated at TARL.

Table 10. Artifacts recovered from 41LB104.

STP/BHT	Level	Artifact Class	Count	Comments
55	1	Tertiary flake	1	chert
55	2	Secondary flake	1	silicified wood
55	4	Miscellaneous burned clay	3	
55	4	Primary flake	1	silicified wood
55	4	Secondary flake	1	chert
647	2	Flake fragment	1	chert
647	3	Secondary flake	1	silicified wood
648	1	Flake fragment	1	silicified wood
648	2	Flake fragment	1	chert
648	3	Tertiary flake	1	biface thinning, chert
649	1	Tertiary flake	1	chert
650	1	Tertiary flake	1	silicified wood
890	2	Secondary Flake	1	silicified wood
892	2	Flake Fragment	1	chert
915	1	Tertiary Flake	1	chert
968	2	Tertiary Flake	2	chert
BHT 33	3	Flake Fragment	1	chert
BHT 33	4	Flake Fragment	1	silicified wood
		Total	21	

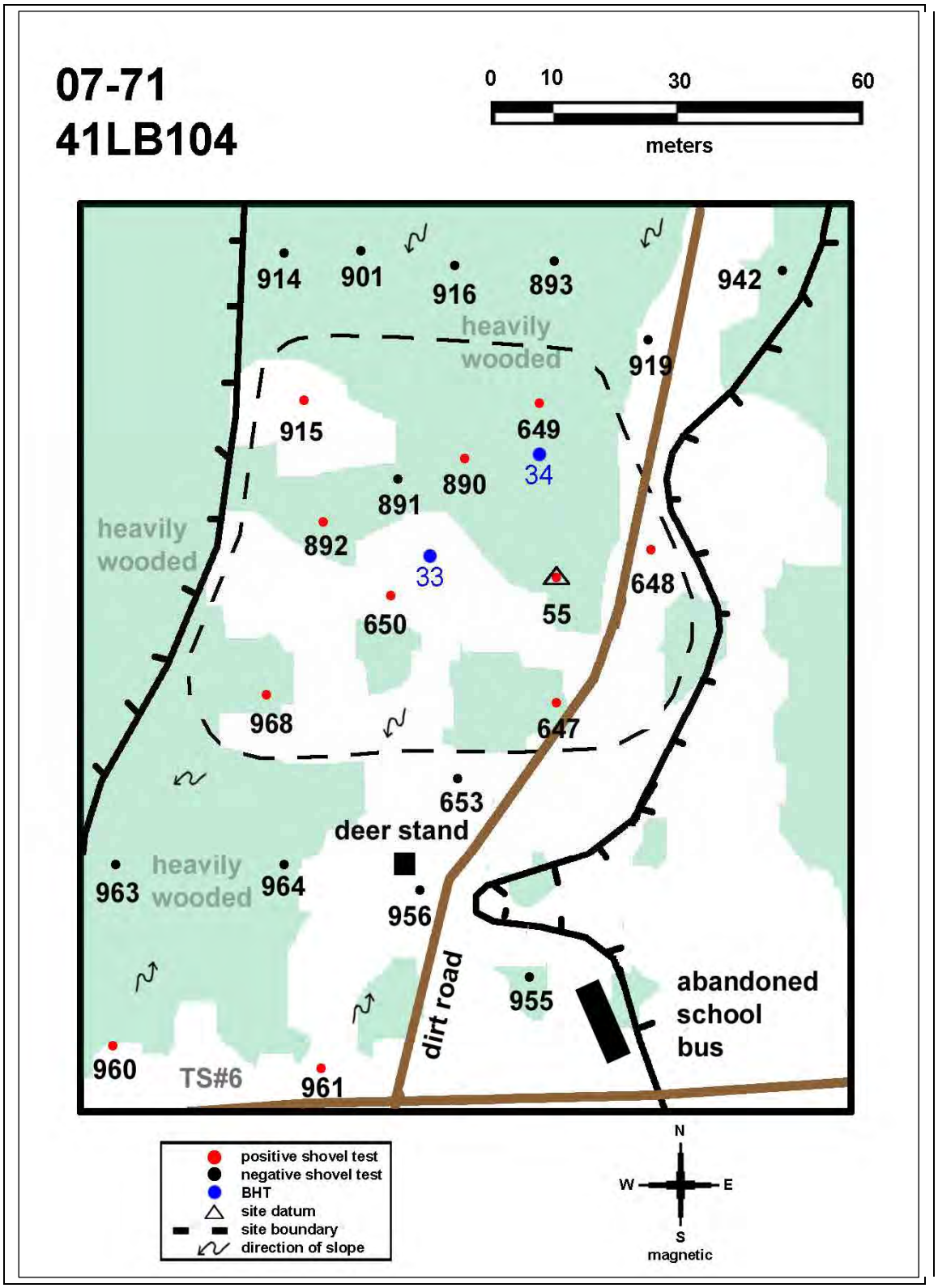
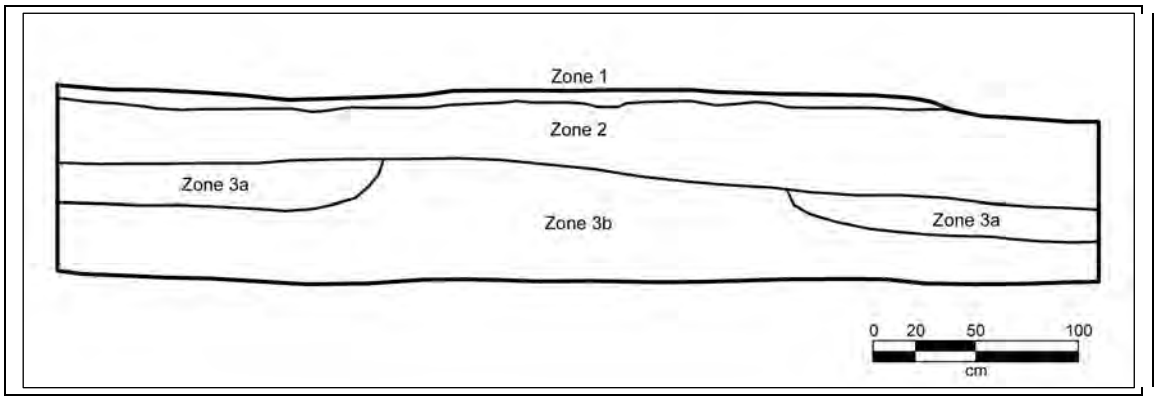
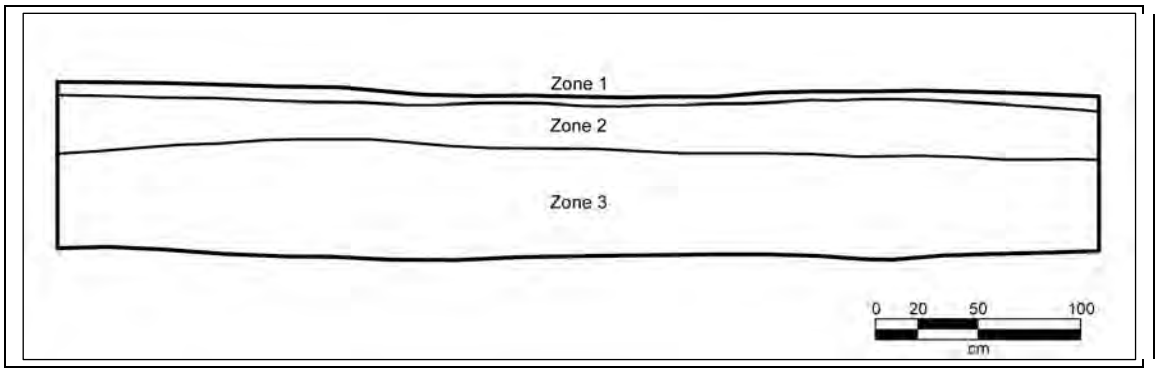


Figure 31. Map of 41LB104.



Zone 1	10YR3/3 Dark brown fine sandy loam. Moist and friable, bioturbated and partially truncated. Discontinuous across profile, many roots and rootlets with a clear wavy boundary.
Zone 2	10YR4/4 Dark yellow brown fine sand. Moist and friable with few roots and rootlets. Few iron concretions with a clear, smooth boundary.
Zone 3a	7.5YR4/4 Brown clay. Moist and firm with very few roots and rootlets. Very few iron concretions.
Zone 3b	10YR5/8 Yellow brown clay. Moist and firm with very few roots and iron concretions. Subsoil

Figure 32. East profile of BHT 33, 41LB104.



Zone 1	10YR3/3 Dark brown fine sandy loam. Moist and friable with many roots and rootlets. Bioturbated with a clear smooth boundary.
Zone 2	10YR6/4 Light yellow brown fine sand. Moist and friable with few roots and rootlets. Few iron concretions with a clear, smooth boundary.
Zone 3	7.5YR4/6 Strong brown fine sandy clay. Moist and firm with a few iron concretions in upper portion. Some roots. Subsoil.

Figure 33. West profile of BHT 34, 41LB104.

41LB105 (Prehistoric) Parcel 1

41LB105 is a prehistoric buried campsite identified and horizontally defined on the basis of 11 shovel tests on a riverside landform (Figure 34). A single backhoe trench (BHT 41) was excavated within the site, but produced no cultural materials or features (Figure 35). The site is about 375 m ENE of IF 2 and about 200 m NE of 41LB109. The site measures 25 m E/W by 25 m N/S. Four of the shovel tests were positive for cultural materials.

The topography at this site consists of the high bank side of the Trinity River. The site is about 30 m west of the Trinity River high bank drop off. The topography lies fairly flat with only a slightly elevated sandy ridge form paralleling the river. 41LB105 sits right on the northern PA boundary. The site undoubtedly continues northward out of the PA as the landform continues in that direction. The vegetation here includes oak, pine, sweetgum, yaupon, blackberry, and various grass species.

The shovel testing produced a total of 5 artifacts (Table 11). The artifacts were recovered from Levels 2-3 (10-30 cmbs). The artifacts included 4 pieces of lithic debitage (3 chert, 1 quartzite) and one Goose Creek plain sherd. The presence of the pottery sherd indicates the site dates to the Early-Late Ceramic period.

Some buried charcoal was found throughout the profile in the site but was not collected. There was some historic debris found in the upper levels of this site that were no doubt associated with 41LB41, a historic site nearby that had been national register tested previously and found ineligible.

In summary, the portion of the prehistoric occupation site 41LB105 that is located within the project APE is small in size, and exhibits a low artifact density and low artifact diversity. The portion of the site that lies within the APE does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Should impacts be planned for the portion of the site located outside the current APE boundary, additional investigations should be conducted to determine the NRHP eligibility for the additional site area. Once the current report is finalized, the artifacts recovered from 41LB105 will be curated at TARL.

Table 11. Artifacts recovered from 41LB105.

STP	Level	Artifact Class	Count	Comments
64	2	Native American ceramic- undecorated	1	
64	2	Tertiary flake	1	chert
552	2	Debris	2	chert
556	3	Debris	1	quartzite
		Total	5	

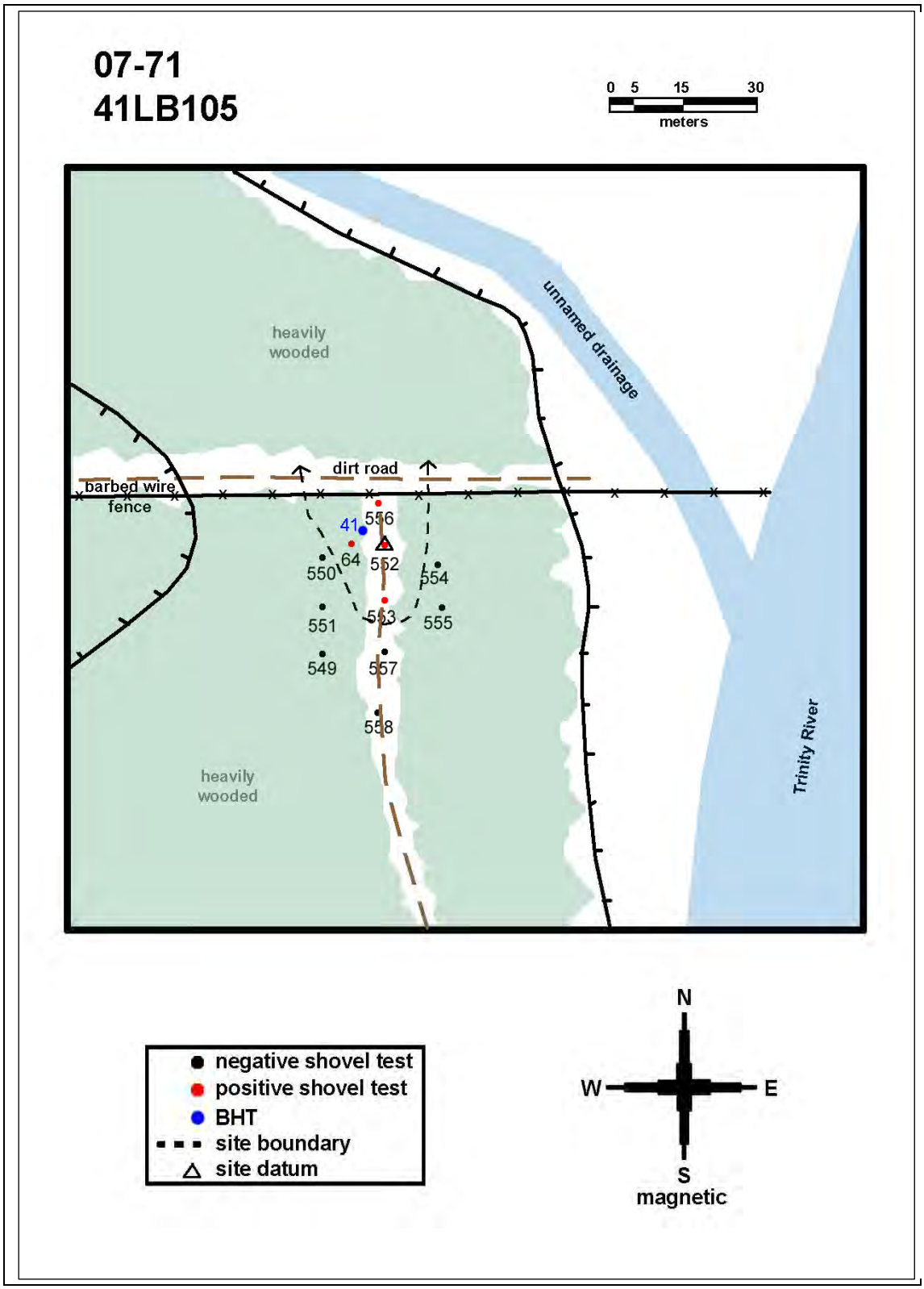
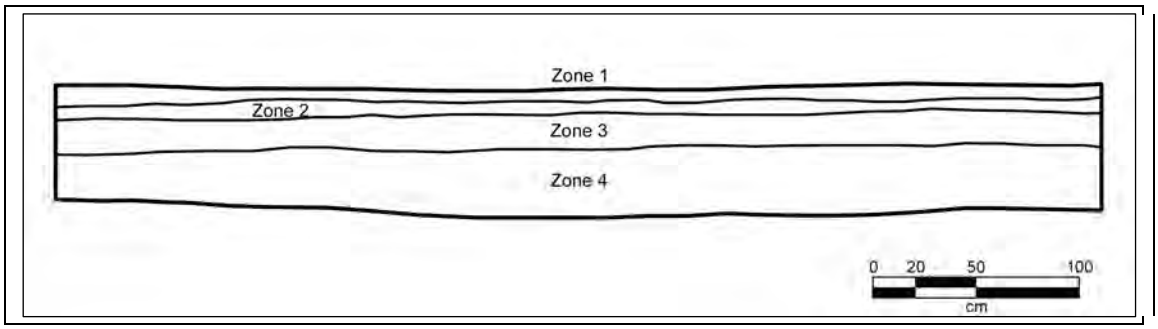


Figure 34. Map of 41LB105.



Zone 1	10YR3/2 Dark gray brown fine sandy loam. Moist and friable with many roots and rootlets. Disturbed and bioturbated with a clear wavy boundary.
Zone 2	10YR4/6 Dark brown fine sand. Moist and friable with few roots and rootlets. Clear, wavy boundary.
Zone 3	10YR4/4 Dark yellow brown fine sandy clay loam. Moist and friable with very few roots and rootlets and a clear wavy boundary.
Zone 4	10YR6/6 brownish yellow clay with many 5YR4/6 yellowish red mottles. Moist and firm with very few rootlets. Subsoil.

Figure 35. East profile of BHT 41, 41LB105.

41LB106 (Prehistoric) Parcel 4

41LB106 is a prehistoric buried campsite identified and horizontally defined on the basis of 13 shovel tests on a well-defined sandy mound landform (Figure 36). A single backhoe trench (BHT 1) was excavated within the site, but produced no cultural materials or features (Figure 37). The site is about 1700 m WSW of 41LB102 and about 200 m NNE of 41LB107. The site measures 50 m E/W by 35 m N/S and probably averages 50 cm in height. Four of the shovel tests were positive for cultural materials.

The topography at this site consists of a well-defined sandy mound in the uplands, among other sandy mounds. The site is about 300 m west of the fossil upland edge where an old channel of the Trinity River used to run. The topography around the mound is fairly flat, low lying, and seasonally inundated with water. The vegetation on the mound includes oak, pine, sweetgum, yaupon, blackberry, and various grass species. Off mound vegetation is similar but includes a few water tolerant species.

The shovel testing produced a total of 6 artifacts (Table 12). The artifacts were recovered from Levels 2-5 (10-50 cmbs). The artifacts included 5 pieces of lithic debitage (3 chert, 1 quartzite, 1 silicified wood) and one Goose Creek plain sherd. The presence of the pottery sherd indicates the site dates to the Early-Late Ceramic period. Some buried charcoal and fired clay fragments were found throughout the profile in the site but not collected.

In summary, 41LB106 is a medium-sized prehistoric occupation site that exhibits low artifact density diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB106 will be curated at TARL.

Table 12. Artifacts recovered from 41LB106.

STP	Level	Artifact Class	Count	Comments
676	4	Tertiary flake	2	1 chert, 1 silicified wood
676	5	Tertiary flake	1	quartzite
678	4	Tertiary flake	1	chert
681	2	Tertiary flake	1	chert
681	3	Native American ceramic- undecorated	1	
		Total	6	

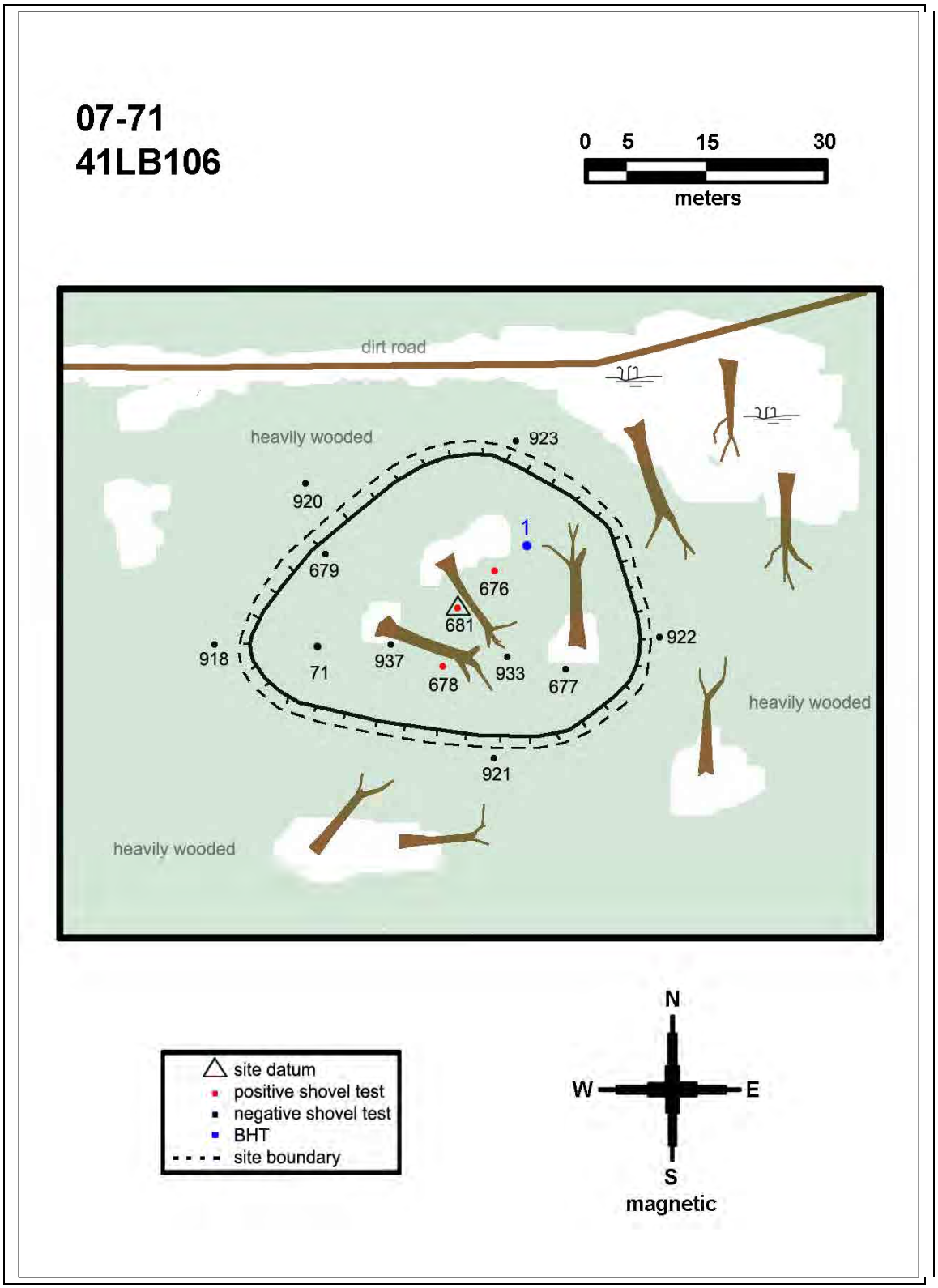
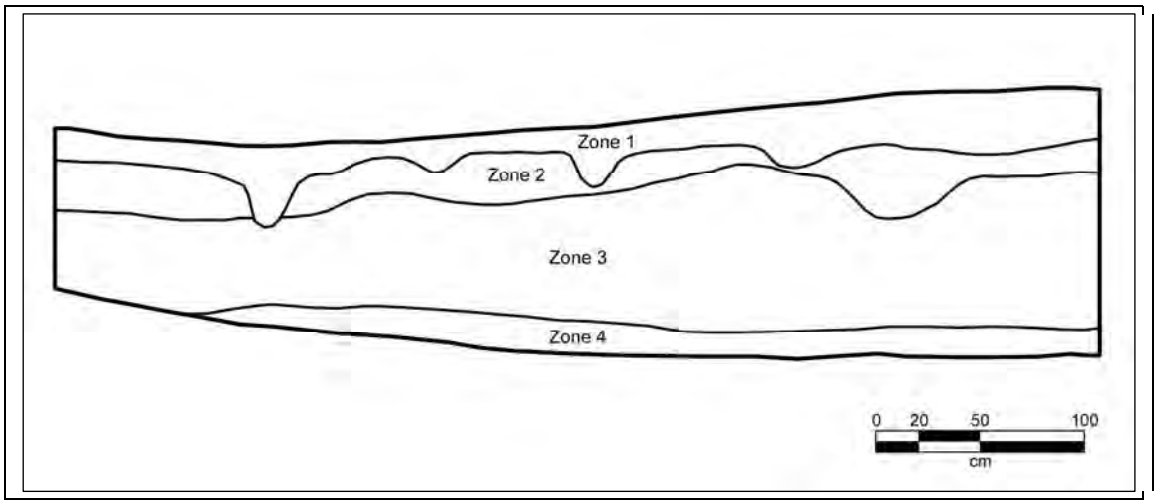


Figure 36. Map of 41LB106.



Zone 1	10YR3/3 Dark brown fine sandy loam, moist and friable. Clear, irregular boundary with many roots and rootlets and a few charcoal pieces.
Zone 2	10YR4/6 Dark yellowish brown fine loamy sand, moist and friable with a few iron concretions. Clear, wavy boundary with a few roots and rootlets and some charcoal.
Zone 3	10YR7/3 Very pale brown fine sand with many 10YR5/8 yellowish brown mottles. Moist and friable with a few iron concretions throughout and a zone of many concretions on top of the clay. Smooth, clear boundary.
Zone 4	10YR6/1 Gray clay with many 5YR4/6 yellowish red mottles. Moist and firm. Subsoil.

Figure 37. Southwest profile of BHT 1, 41LB106.

41LB107 (Prehistoric) Parcel 4

41LB107 is a prehistoric buried campsite identified and horizontally defined on the basis of 6 shovel tests on a well-defined sandy bermed pond landform (Figure 38). The site is about 200 m SSW of 41LB106. The site measures 12 m E/W by 25 m N/S and probably averages 50 cm in height. Three of the shovel tests were positive for cultural materials.

The topography at this site consists of a well-defined bermed pond in the uplands that has sandy berms surrounding a low area that is seasonally inundated with water. The site is about 300 m west of the fossil upland edge where an old channel of the Trinity River used to run. The topography around the berm is fairly flat, low lying, and seasonally inundated with water. The vegetation on the berm includes oak, pine, sweetgum, yaupon, blackberry, and various grass species. And off mound vegetation includes the same only with a few water tolerant species.

The shovel testing produced a total of six artifacts (Table 13). The artifacts were recovered from Levels 1-8 (0-80 cmbs). The artifacts included five pieces of lithic debitage (3 chert, 2 silicified wood) and one Goose Creek plain sherd. The presence of the pottery sherd indicates the site dates to the Early-Late Ceramic period. Some buried charcoal was found throughout the profile in the site but not collected.

In summary, 41LB107 is a small prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB107 will be curated at TARL.

Table 13. Artifacts recovered from 41LB107.

STP	Level	Artifact Class	Count	Comments
74	3	Flake fragment	1	chert
672	4	Secondary flake	1	silicified wood
672	8	Tertiary flake	1	chert
675	1	Tertiary flake	1	silicified wood
675	5	Native American ceramic- undecorated	1	
675	7	Secondary flake	1	chert
		Total	6	

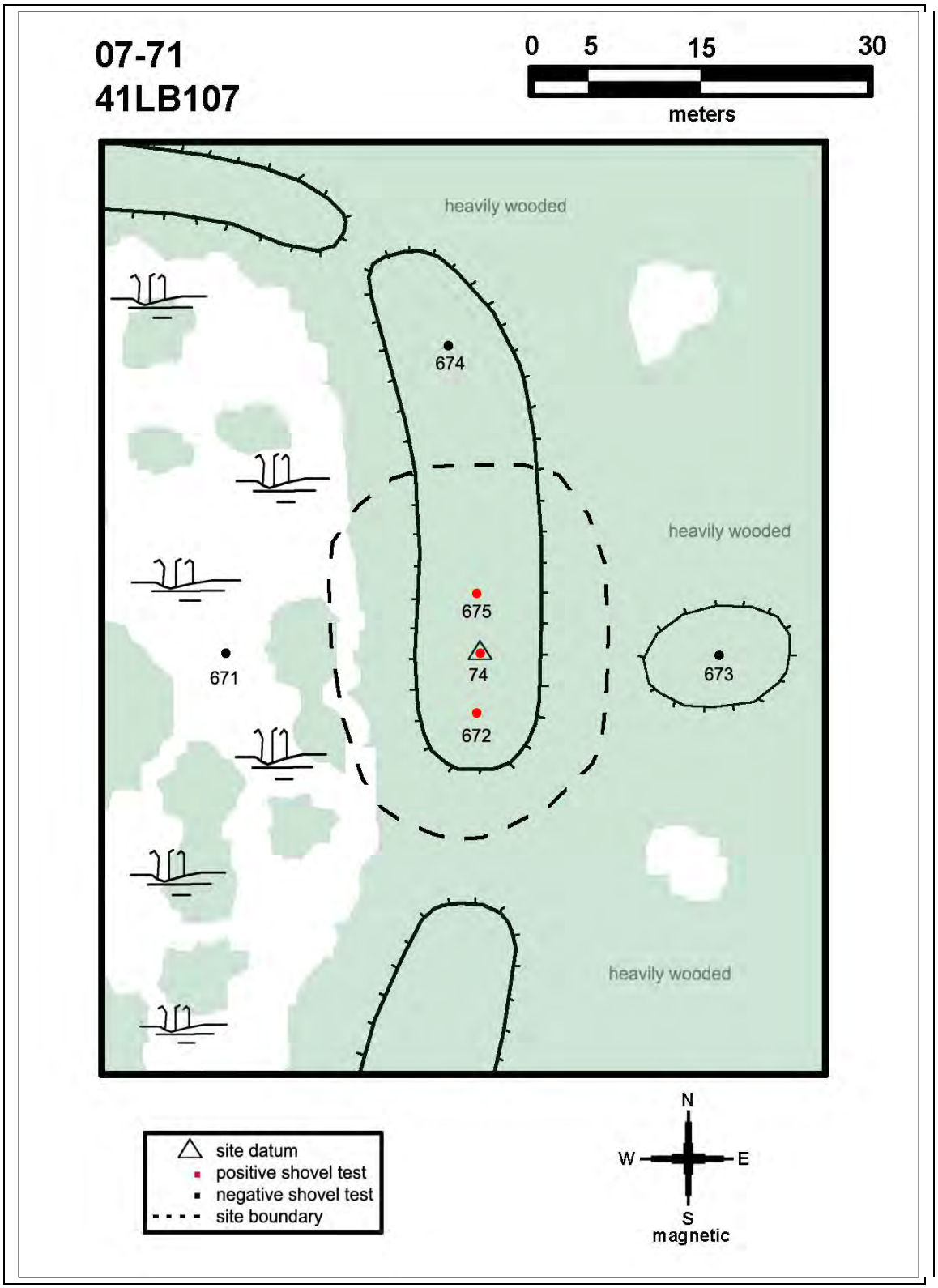


Figure 38. Map of 41LB107.

41LB108 (Prehistoric) Parcel 1

41LB108 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 10 shovel tests on a well-defined sandy mound landform (Figure 39). The site is about 75 m WSW of 41LB109. The site measures 35 m E/W by 20 m N/S and probably averages 30 cm in height. Two of the shovel tests were positive for cultural materials.

The topography at this site consists of a somewhat eroded sandy mound on the high, right bank-side of the Trinity River. The site is about 120 m west of the Trinity River. The topography around the mound slopes slightly toward the east, and toward the river. The vegetation around the site includes oak, pine, sweetgum, yaupon, blackberry, and various grass species.

The shovel testing produced a total of three artifacts (Table 14). The artifacts were recovered from Levels 1-3 (0-30 cmbs). The artifacts consisted of three pieces of lithic debitage (2 chert, 1 silicified wood). Though no chronologically diagnostic materials were recovered, the lack of pottery sherds suggests the site dates to the Archaic period. The artifacts occur on and off of the mound. There was also some historic glass found in Level 1.

In summary, 41LB108 is a medium-sized prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB108 will be curated at TARL.

Table 14. Artifacts recovered from 41LB108.

STP	Level	Artifact Class	Count	Comments
82	2	Debris	1	silicified wood
82	3	Flake fragment	1	chert
563	1	Tertiary flake	1	chert
		Total	3	

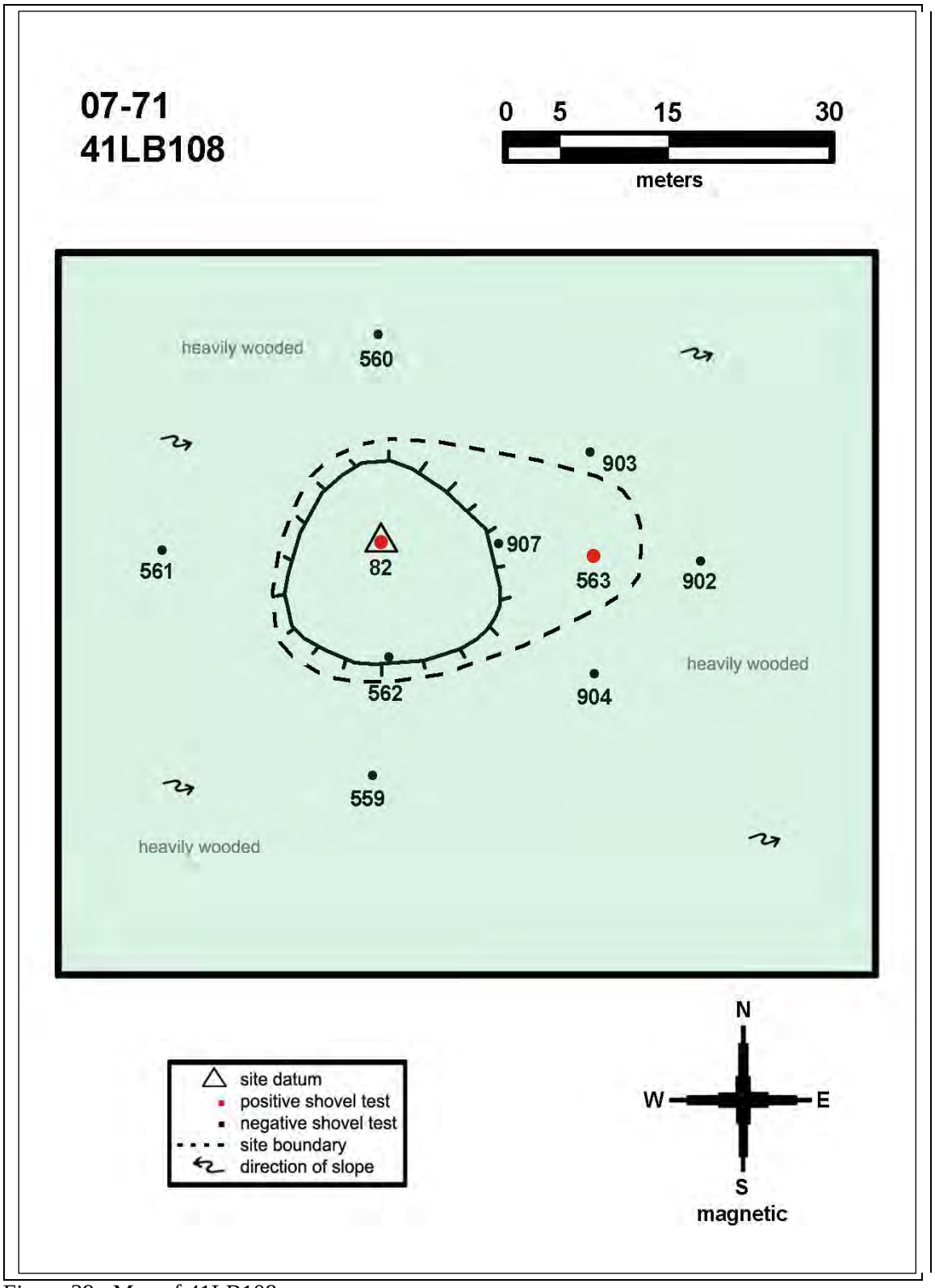


Figure 39. Map of 41LB108.

41LB109 (Prehistoric) Parcel 1

41LB109 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 12 shovel tests on a riverside high bank landform (Figure 40). The site is about 75 m ENE of 41LB108. The site measures 45 m E/W by 30 m N/S. Four of the shovel tests were positive for cultural materials. A single backhoe trench (BHT 40) was excavated within the site, but produced no cultural materials or features (Figure 41).

The topography at this site consists of a slightly eastward sloping flat area on the high, right bank-side of the Trinity River. The site is about 20 m west of the Trinity River. The vegetation around the site includes oak, pine, sweetgum, yaupon, blackberry, and various grass species.

The shovel testing produced a total of 12 artifacts (Table 15). The artifacts were recovered from Levels 1-3 (0-30 cmbs). The artifacts included 12 pieces of lithic debitage (9 chert, 3 silicified wood). Though no chronologically diagnostic materials were recovered, the lack of pottery sherds suggests the site dates to the Archaic period.

In summary, 41LB109 is a medium-sized prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB109 will be curated at TARL.

Table 15. Artifacts recovered from 41LB109.

STP	Level	Artifact Class	Count	Comments
83	2	Secondary flake	1	chert
83	3	Flake fragment	2	chert
659	2	Secondary flake	1	chert
659	2	Tertiary flake	2	chert
659	2	Flake fragment	1	silicified wood
659	2	Debris	1	chert
665	2	Tertiary flake	1	chert
910	1	Flake Fragment	2	silicified wood
910	1	Tertiary Flake	1	chert
		Total	12	

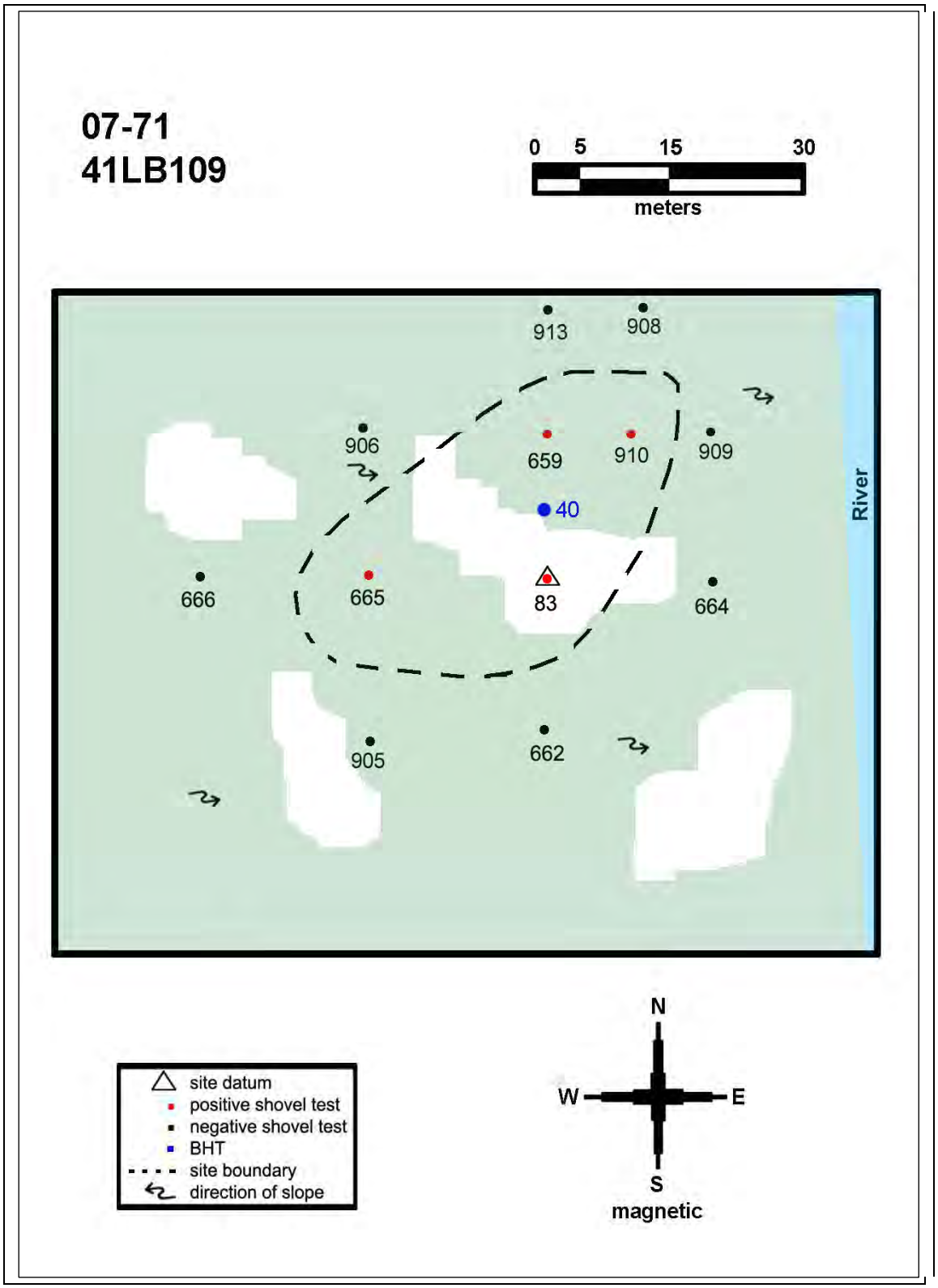
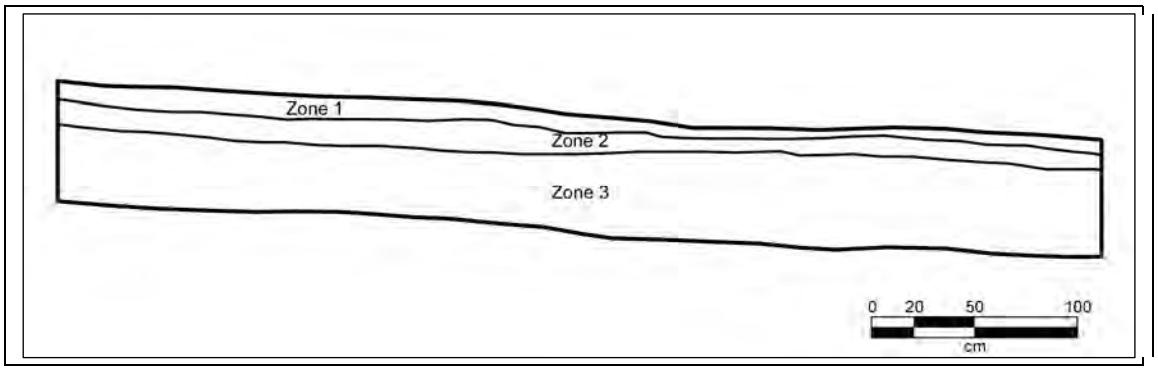


Figure 40. Map of 41LB109.



Zone 1	10YR3/3 Dark brown fine sandy loam, truncated. Moist and firm with many roots and rootlets. Clear wavy boundary, bioturbated.
Zone 2	10YR6/4 Light yellow brown fine sand moist and firm. Few roots and rootlets with a clear, wavy boundary, bioturbated.
Zone 3	10YR6/6 brownish yellow clay with many 5YR4/6 yellow red mottles. Moist and firm with very few roots and rootlets. Subsoil.

Figure 41. East profile of BHT 40, 41LB109.

41LB110 (Prehistoric) Parcel 1

41LB110 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 9 shovel tests (Figure 42). The site is about 120 m SSW of IF 2 and 320 m east of 41LB98. The site measures 35 m E/W by 15 m N/S. Two of the shovel tests were positive for cultural materials.

The topography at this site consists of the section of ground between the end of the Capers Ridge landform and the Trinity River. This area slopes gradually from Capers Ridge in the west to the river in the east. As the ground descends toward the river, the ridge character of Capers Ridge gradually flattens out. This site is on the south side remnant of Capers Ridge just above a seasonally inundated cypress wetland. The woods are sparse in and around the site where there is a lot of downed timber from recent hurricanes. The vegetation around the site includes oak, pine, sweetgum, yaupon, blackberry, and various grass species.

The shovel testing produced a total of three artifacts (Table 16). The artifacts were recovered from Levels 1 and 2 (0-10, 20-30 cmbs). The artifacts consisted of three pieces of lithic debitage (2 chert, 1 silicified wood).

In summary, 41LB110 is a medium-sized prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB110 will be curated at TARL.

Table 16. Artifacts recovered from 41LB110.

STP	Level	Artifact Class	Count	Comments
84	1	Secondary flake	1	chert
84	1	Flake fragment	1	silicified wood
663	3	Tertiary flake	1	chert
		Total	3	

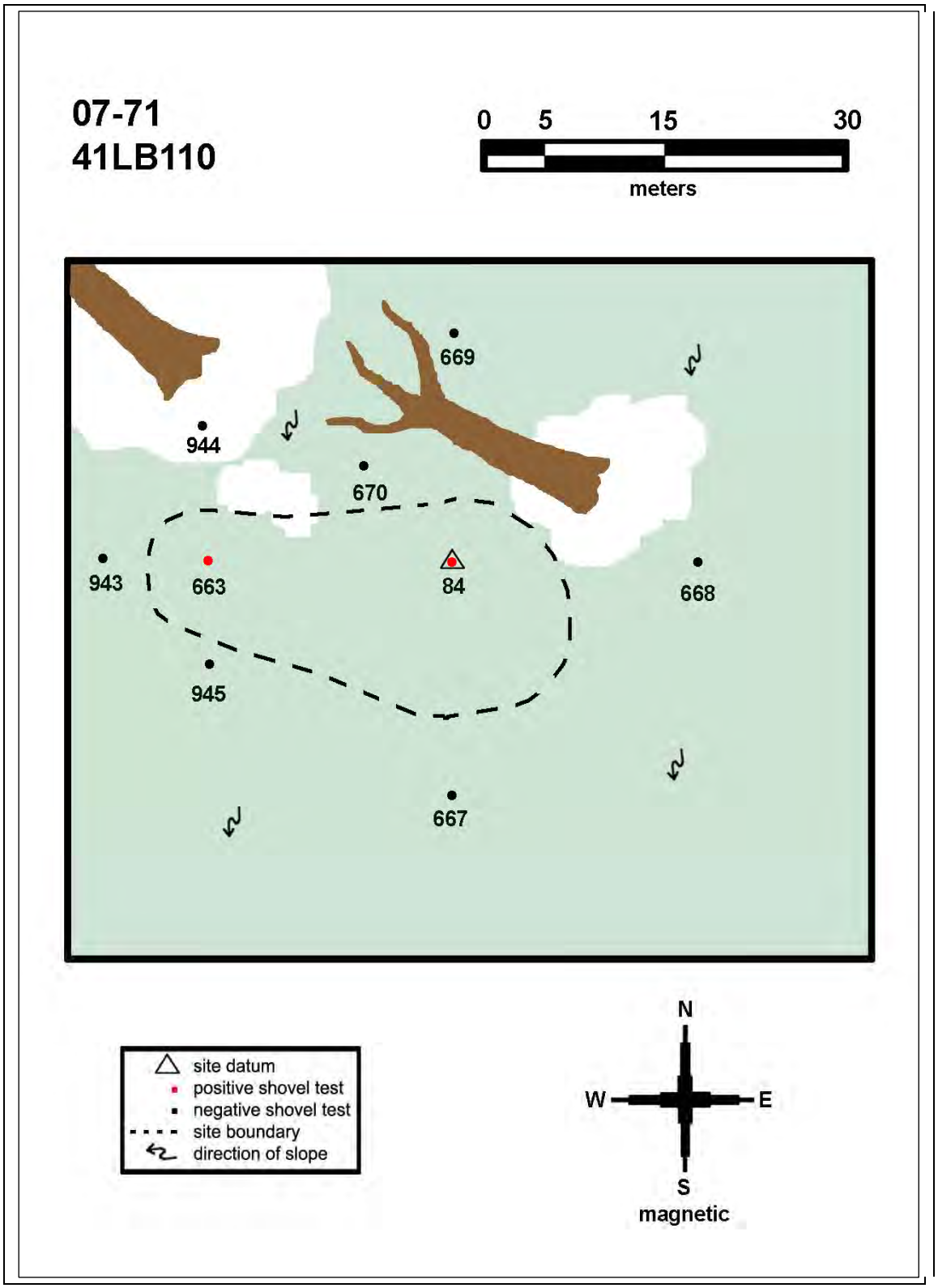


Figure 42. Map of 41LB110.

41LB111 (Prehistoric) Parcel 8

41LB111 is a buried prehistoric campsite identified and horizontally defined on the basis of 7 shovel tests on a well-defined sandy mound landform (Figure 43). The site is 160 m SSW of 41LB115. The site is atop an elliptical shaped sandy mound that measures 15 m in diameter by 1 m in height. Two of the shovel tests were positive for cultural materials.

The topography here consists of a natural sandy mound in a flat wooded area in the uplands near the east end of the PA. There is a pipeline that barely clips the site on its west side. The vegetation at the site consists of pine, oak, elm, yaupon, blackberry, and various grass species.

The shovel testing produced a total of four artifacts (Table 17). The artifacts were recovered from Levels 3-5 (20-50 cmbs). The artifacts included one piece of silicified wood lithic debitage and three Goose Creek plain sherds (2 plain, 1 incised). The presence of the pottery sherd indicates the site dates to the Early-Late Ceramic period.

In summary, 41LB111 is a small prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB111 will be curated at TARL.

Table 17. Artifacts recovered from 41LB111.

STP	Level	Artifact Class	Count	Comments
291	3	Native American ceramic- decorated	1	
291	3	Native American ceramic- undecorated	2	
291	5	Debris	1	silicified wood
		Total	4	

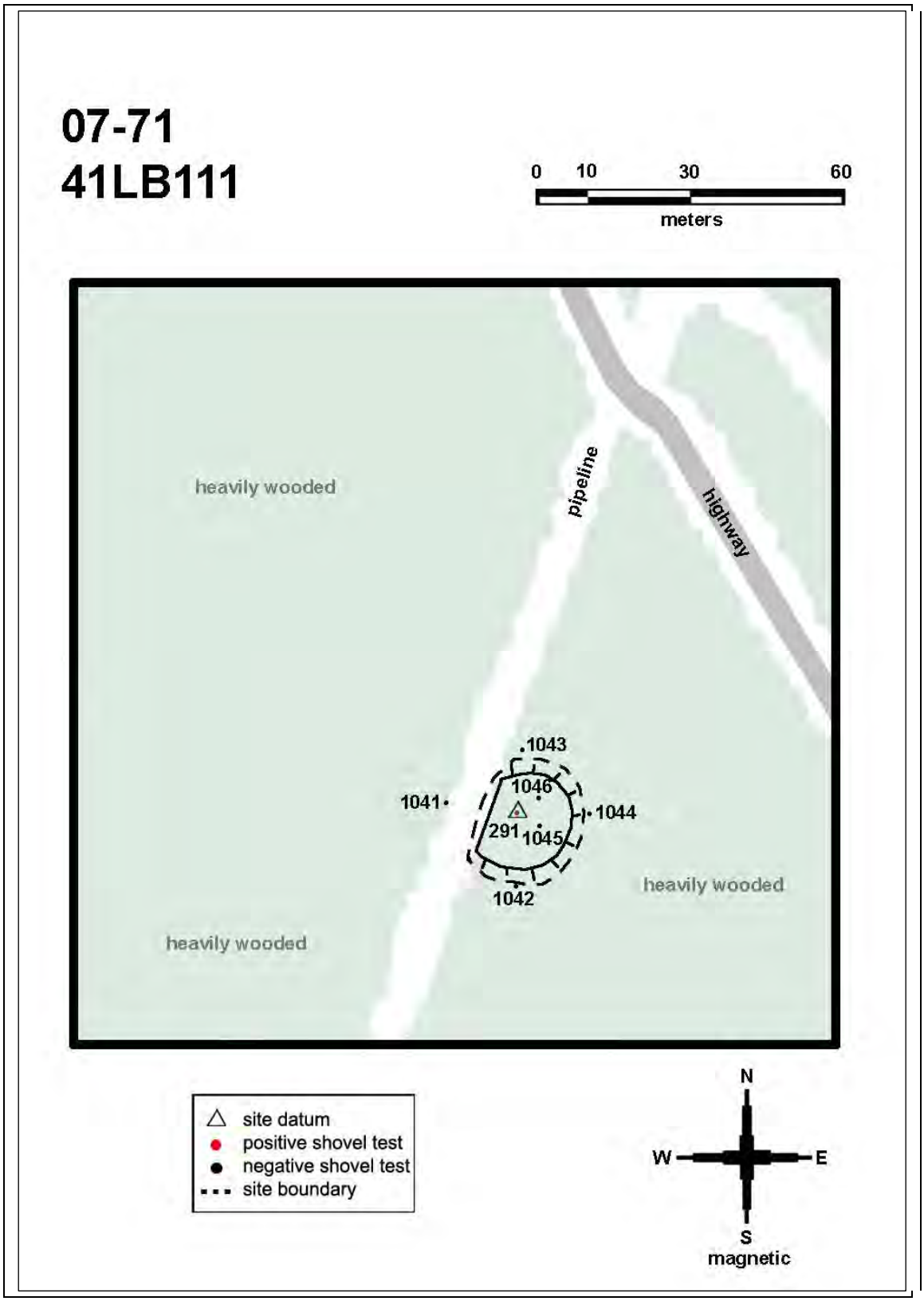


Figure 43. Map of 41LB111.

41LB112 (Prehistoric) Parcel 4

41LB112 is a prehistoric buried campsite identified and horizontally defined on the basis of 47 shovel tests on a well-defined landform (Figure 44). Nineteen of the shovel tests were positive for cultural materials. Two backhoe trenches (BHTs 27, 28) were excavated within the site, one of which produced cultural materials (Figures 45, 46). The site is 45 m SSW of 41LB103 and about 40 m north of 41LB97. This site is on a string of sites that runs for almost a kilometer on this N/S stretch of Capers Ridge. The site measures 145 m N/S by 60 m E/W.

The topography at this site consists of a general N/S running ridgeline that slopes off to the east and west into old meander scars of the Trinity River that contain seasonally inundated wetlands. There are also several remnants of sandy mounds that appear to be artifact concentration areas within this site. There are two dirt roads running along the ridge, which surround the site. The area is heavily wooded with oak, elm, holly, yaupon, pine, blackberry, and various grasses. There has been a recent forest fire in this site area that has cleared much of the smaller vegetation and burned some trees all the way through their root balls.

The shovel tests and backhoe trenches produced a total of 96 artifacts (Table 18). The artifacts were recovered from the surface and from Levels 1-6 (0-60 cmbs), with the highest densities in Levels 1-2 (0-20 cmbs). The artifacts included 78 pieces of lithic debitage (42 chert, 7 quartzite, 29 silicified wood), a dart point (***Kent***, Figure 47) and dart preform (***Gary/Kent***, Figure 48), four tested cobbles (1 chert, 3 silicified wood), and 12 Goose Creek plain sherds. The presence of the dart preform and the pottery sherds indicate the site dates to the Early Ceramic period.

The bulk of the material seems to be concentrated around three sandy mound remnants, not necessarily all on the mounds. There was also common charcoal throughout the profile but as mentioned before, there has been a recent extensive forest fire here that has burned many trees deep into the ground. We tried delineating down the 45-degree slope to the east of the site and were still getting cultural material. We came to the conclusion that these positive tests represented slope wash of soils and artifacts from further up on the flat part of the site. The artifacts are present from 0-60 cmbs in this site. The character of this site is that of obvious occupation zones interspersed by stretches of thin lithic scatter. The main artifact-producing portion of this site is around the eroded sandy mound area. Shovel tests 297, 586, 589, 590, 765, and 778 all had artifacts from several layers. This site seems to hold the possibility of intact features with stratified deposits.

In summary, 41LB112 is a large prehistoric occupation site that dates to the Early Ceramic period. The cultural deposits extend from Levels 1-6 (0-60 cmbs), and the artifact assemblage exhibits medium artifact density and diversity. We recommend that further investigations be conducted at the site in order to determine its significance and potential eligibility for the National Register of Historic Places. Once the current report is finalized, the artifacts recovered from 41LB112 will be curated at TARL.

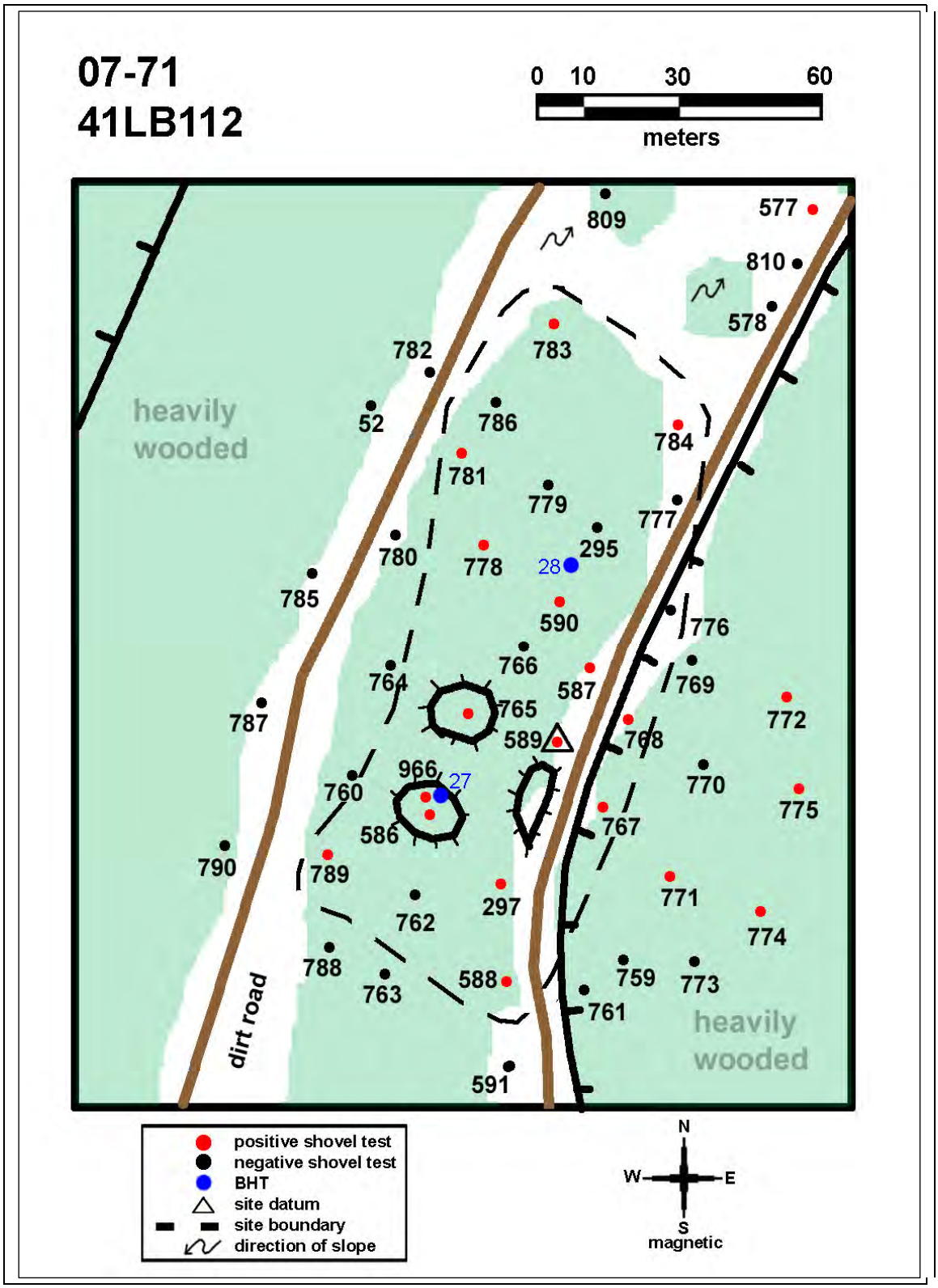
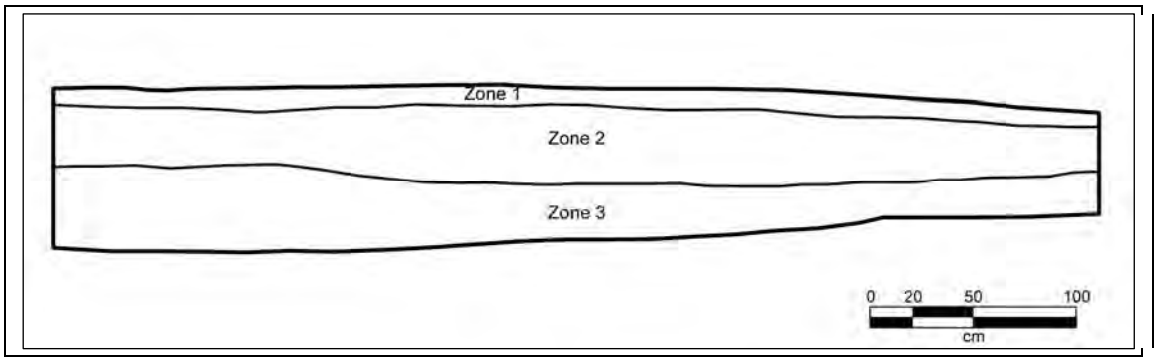
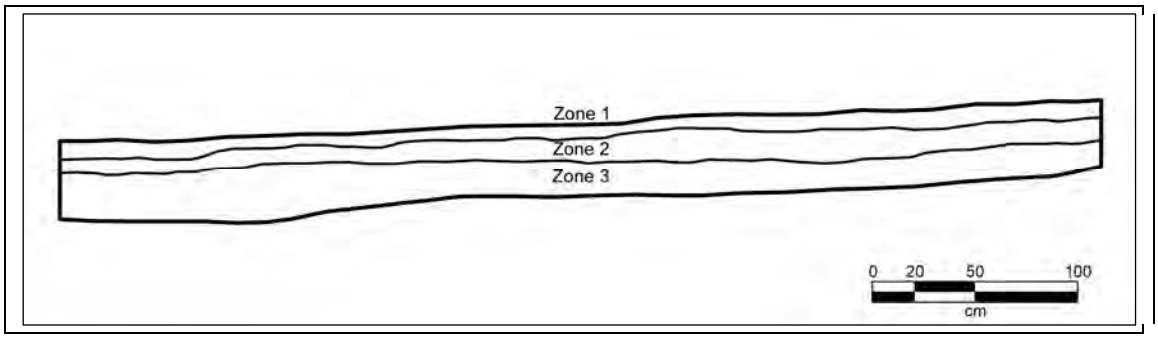


Figure 44. Map of 41LB112.



Zone 1	10YR4/3 Very fine sandy loam. Moist and friable, very bioturbated. Very few charcoal fragments with few roots and rootlets. Gradual, smooth boundary.
Zone 2	10YR6/4 Light yellow brown fine sand, moist and friable. Few roots and rootlets with few iron concretions. Very few charcoal fragments with a smooth, clear boundary.
Zone 3	10YR7/2 Light gray clay with many 5YR4/6 yellow red mottles, moist and firm. Subsoil

Figure 45. South profile of BHT 27, 41LB112.



Zone 1	10YR3/2 Very dark gray brown fine sandy loam. Moist and friable with few roots and rootlets. Very bioturbated with a clear wavy boundary.
Zone 2	10YR6/4 Light yellow brown fine sand with few 10YR5/8 yellow brown mottles. Moist and friable with few rootlets. Bioturbated with clear wavy boundary.
Zone 3	10YR6/6 Brownish yellow clay with many 5YR5/8 red mottles. Subsoil

Figure 46. South profile of BHT 28, 41LB112.

Table 18. Artifacts recovered from 41LB112.

STP/BHT	Level	Artifact Class	Count	Comments
297	1	Tertiary flake	2	chert
297	2	Secondary flake	1	chert
586	1	Tertiary flake	1	chert
586	2	Flake fragment	1	silicified wood
586	4	Secondary flake	2	silicified wood, chert
586	4	Dart point preform	1	chert
587	2	Flake fragment	1	silicified wood
588	2	Secondary flake	1	chert
589	1	Tertiary flake	3	1 chert, 1 quartzite, 1 silicified wood
589	2	Secondary flake	1	chert
589	2	Tertiary flake	1	chert
590	1	Secondary flake	3	1 quartzite, 2 silicified wood
590	1	Tertiary flake	1	chert
590	1	Debris	1	chert
590	2	Native American ceramic-undecorated	6	
590	2	Tertiary flake	1	quartzite
590	3	Flake fragment	1	silicified wood
590	3	Debris	1	silicified wood
765	1	Secondary Flake	1	silicified wood
765	2	Flake Fragment	1	chert
765	3	Tertiary Flake	1	chert
765	4	Flake Fragment	1	chert
765	4	Primary flake	1	silicified wood
765	4	Debris	1	quartzite
767	1	Secondary Flake	2	chert
767	1	Tertiary Flake	1	silicified wood
768	1	Tertiary Flake	1	silicified wood
771	1	Flake Fragment	1	silicified wood
772	1	Debris	1	chert
774	1	Flake Fragment	1	silicified wood
775	1	Secondary Flake	1	chert
778	2	Tertiary Flake	1	chert
778	2	Secondary Flake	1	silicified wood
778	2	Flake Fragment	1	silicified wood
778	3	Native American ceramic-undecorated	1	
778	4	Primary flake	1	chert
778	4	Native American ceramic-undecorated	1	
778	4	Secondary Flake	1	quartzite
778	4	Tertiary Flake	1	silicified wood
778	5	Flake Fragment	1	silicified wood
778	5	Secondary Flake	1	chert
778	6	Secondary Flake	1	chert
781	1	Tertiary Flake	1	chert
783	1	Tertiary Flake	1	silicified wood

784	2	Flake Fragment	1	silicified wood
789	1	Tertiary Flake	1	chert
966	1	Tertiary Flake	1	chert
966	1	Secondary Flake	1	chert
966	1	Flake Fragment	1	silicified wood
966	1	Tertiary Flake	1	quartzite
966	2	Tertiary Flake	2	chert
966	3	Secondary Flake	1	quartzite
966	3	Native American ceramic-undecorated	1	
966	3	Flake Fragment	1	chert
966	3	Flake Fragment	1	silicified wood
966	4	Flake Fragment	1	silicified wood
966	4	Flake Fragment	1	chert
966	5	Flake Fragment	2	chert
966	6	Secondary Flake	1	silicified wood
966	6	Tertiary Flake	1	chert
966	6	Flake Fragment	2	silicified wood, chert
966	6	Debris	1	chert
surface	0	Tertiary Flake	1	chert
surface	0	Tested cobble	1	possibly utilized, some bifacial working, silicified wood
surface	0	Secondary Flake	1	silicified wood
surface	0	Secondary Flake	1	chert
BHT 27	2	Flake Fragment	1	chert
BHT 27	3	Flake Fragment	2	chert
BHT 27	3	Native American ceramic-undecorated	3	
BHT 27	4	Primary Flake	1	silicified wood
BHT 27	4	Debris	1	silicified wood
BHT 27	4	Tested Cobble	3	1 chert, 2 silicified wood
BHT 27	4	Dart Point	1	Chert, *Kent*
BHT 27	5	Primary Flake	1	chert
BHT 27	6	Primary Flake	1	chert
BHT 27	6	Tertiary Flake	1	silicified wood
		Total	96	

Figure 47. ***Kent*** dart point recovered from BHT 27, 41LB112.

Figure 48. ***Gary/Kent*** dart point preform recovered from STP 586, 41LB112.

41LB113 (Prehistoric) Parcel 4

41LB113 is a prehistoric buried lithic scatter identified and horizontally defined on the basis of 6 shovel tests on a well-defined landform (Figure 50). Two of the shovel tests were positive for cultural materials. A single backhoe trench (BHT 23) was excavated within the site, but produced no cultural materials or features (Figure 49). The site is 600 m east of 41LB102 and about 140 m WSW of 41LB114. The site measures 20 m N/S by 30 m E/W.

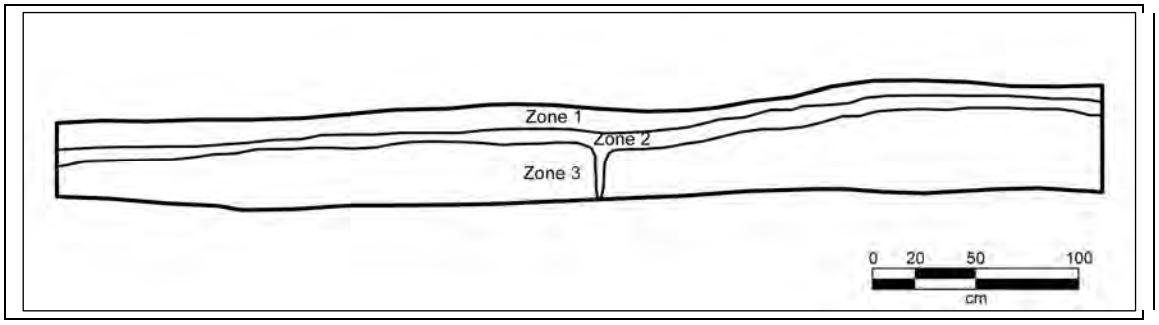
The topography at this site consists of a large flat area of uplands between the E/W and N/S legs of Capers Ridge. This large flat area is bisected by a deep drainage that does not appear on the topographic map. This site sits on the western bank of this drainage just east of an eroded sandy mound. The area is heavily wooded with oak, elm, yaupon, pine, and various grasses.

The shovel testing produced a total of three pieces of chert lithic debitage (Table 19). The artifacts were recovered from Levels 1-2 (0-20 cmbs).

In summary, 41LB113 is a medium-sized prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB113 will be curated at TARL.

Table 19. Artifacts recovered from 41LB113.

STP	Level	Artifact Class	Count	Comments
300	1	Tertiary flake	2	chert
687	2	Flake fragment	1	chert
		Total	3	



Zone 1	10YR4/2 Dark gray brown fine sandy clay loam. Moist and friable with many roots and rootlets, bioturbated with a clear wavy boundary.
Zone 2	10YR6/3 Pale brown fine sand with few 7.5YR5/6 strong brown mottles with few rootlets. Bioturbated at top, moist and friable.
Zone 3	10YR2/2 Light gray clay with many 2.5y4/6 red mottles. Moist and firm, bioturbated at top, with very few root casts. Subsoil.

Figure 49. Southeast profile of BHT 23, 41LB113.

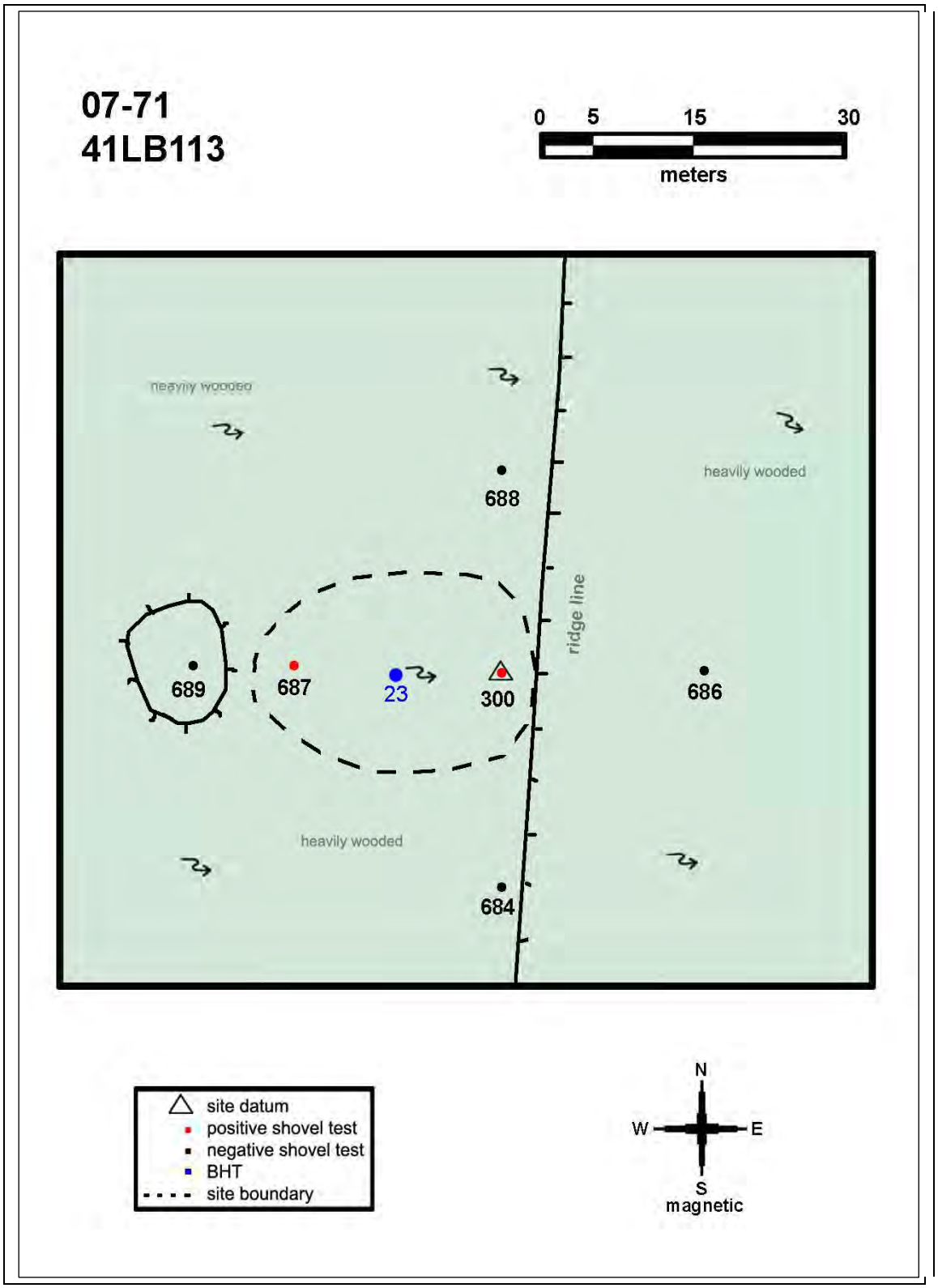


Figure 50. Map of 41LB113.

41LB114 (Prehistoric) Parcel 4

41LB114 is a prehistoric buried campsite identified and horizontally defined on the basis of 9 shovel tests on an eroded sandy mound landform (Figure 52). Five of the shovel tests were positive for cultural materials. A single backhoe trench (BHT 24) was excavated within the site, but produced no cultural materials or features (Figure 51). The site is 140 m east of 41LB113 and about 100 m W of 41LB97. The site measures 30 m N/S by 25 m E/W.

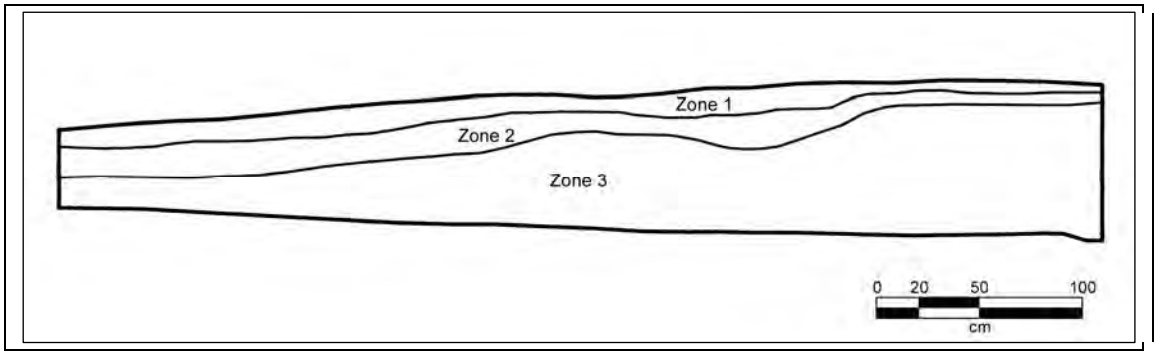
The topography at this site consists of a large flat area of uplands between the E/W and N/S legs of Capers Ridge. This large flat area is bisected by a deep drainage that does not appear on the topographic map. This site sits on the remnant of a sandy mound on eastern bank of this drainage. The area is heavily wooded with oak, elm, yaupon, pine, and various grasses.

The shovel testing produced a total of eight artifacts (Table 20). The artifacts were recovered from Levels 1-3 (0-30 cmbs). The artifacts consisted of eight pieces of lithic debitage (6 chert, 2 silicified wood).

In summary, 41LB114 is a medium-sized prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB114 will be curated at TARL.

Table 20. Artifacts recovered from 41LB114.

STP	Level	Artifact Class	Count	Comments
307	1	Secondary flake	1	chert
307	2	Tertiary flake	1	chert
307	2	Secondary flake	1	chert
307	3	Debris	1	chert
592	3	Secondary flake	1	silicified wood
593	2	Tertiary flake	1	chert
596	1	Flake fragment	1	chert
599	2	Tertiary flake	1	silicified wood
		Total	8	



Zone 1	10YR3/2 Very dark gray brown fine sandy loam. Moist and friable with few roots and rootlets. Bioturbated with a gradual wavy boundary.
Zone 2	10YR6/4 Light yellow brown fine sand moist and friable. Bioturbated with few rootlets and a clear, wavy boundary.
Zone 3	10YR6/6 Brownish yellow clay with many 5YR5/8 red mottles, moist and firm. Subsoil.

Figure 51. North profile of BHT 24, 41LB114.

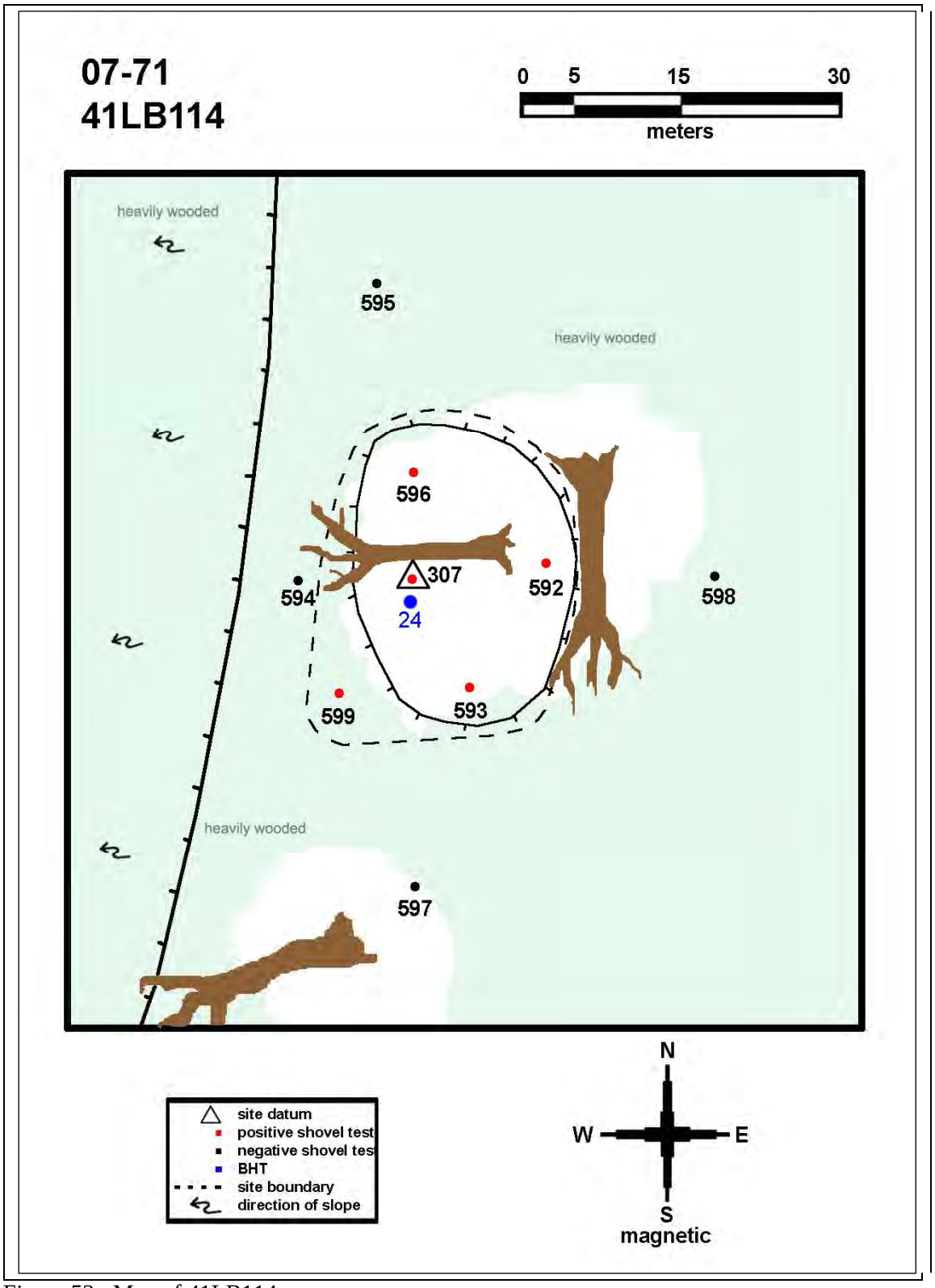


Figure 52. Map of 41LB114.

41LB115 (Prehistoric) Parcel 8

41LB115 is a buried prehistoric campsite identified and horizontally defined on the basis of 8 shovel tests and a well-defined sandy mound landform (Figure 53). The site is 160 m NNE of 41LB111. The site is atop a 12 m E/W by 18 m N/S by 1m in height sandy mound. Two of the shovel tests were positive for cultural materials.

The topography here consists of a natural sandy mound in a flat wooded area in the uplands near the east end of the PA. There is a pipeline that barely clips the site on its east side. There are also some drainage ditch disturbances to the site on its west side. The vegetation at the site consists of pine, oak, elm, yaupon, blackberry, and various grasses.

The shovel testing produced a total of two artifacts (Table 21). The artifacts were recovered from Levels 2-3 (10-30 cmbs). The artifacts included one piece of silicified wood lithic debitage, and one Goose Creek plain sherd.

In summary, 41LB115 is a small prehistoric occupation site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB115 will be curated at TARL.

Table 21. Artifacts recovered from 41LB115.

STP	Level	Artifact Class	Count	Comments
279	2	Tertiary flake	1	silicified wood
1037	3	Native American ceramic- undecorated	1	
		Total	2	

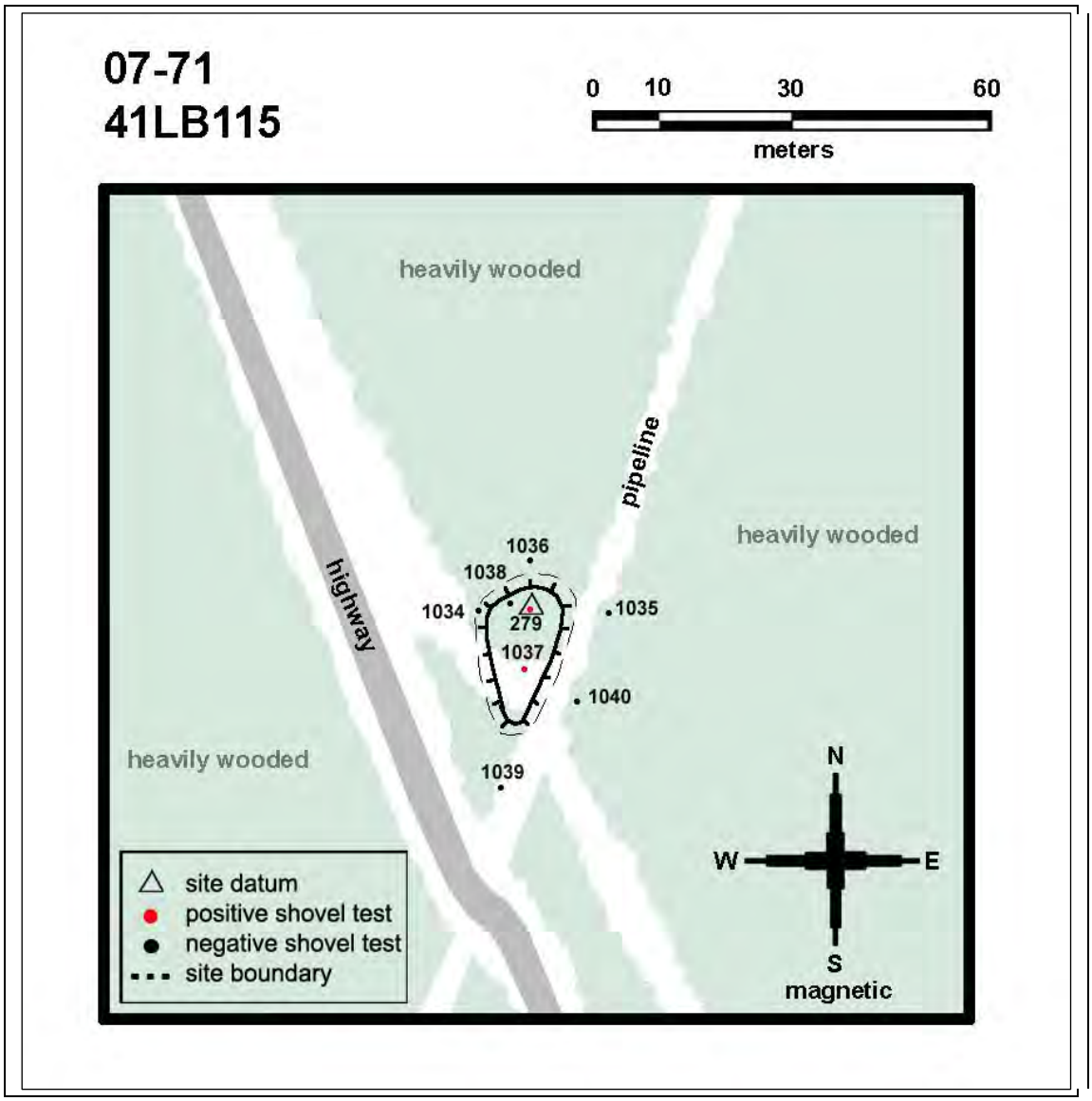


Figure 53. Map of 41LB115.

41LB116 (Prehistoric) Parcel 43b

41LB116 is a buried lithic scatter identified and horizontally defined on the basis of 7 shovel tests on a well-defined sandy mound landform (Figure 54). The site is 15 m in diameter and 1 m in height. Two of the eight shovel tests were positive for cultural material.

The topography here is a flat wooded area in the uplands near the west end of the PA. The woods are thin pine, oak, yaupon, and elm. The area is generally flat and there are a few of these natural sandy mounds in the area.

The site produced two pieces of chert lithic debitage at 20-30 cmbs of a single shovel test on top of the mound (Table 22). This appears to be a very minimal occupation probably representing an overnight hunter's camp.

In summary, 41LB116 is a small prehistoric occupation site that exhibits low artifact density and artifact diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41LB116 will be curated at TARL.

Table 22. Artifacts recovered from 41LB116.

STP	Level	Artifact Class	Count	Comments
453	3	Tertiary flake	2	chert

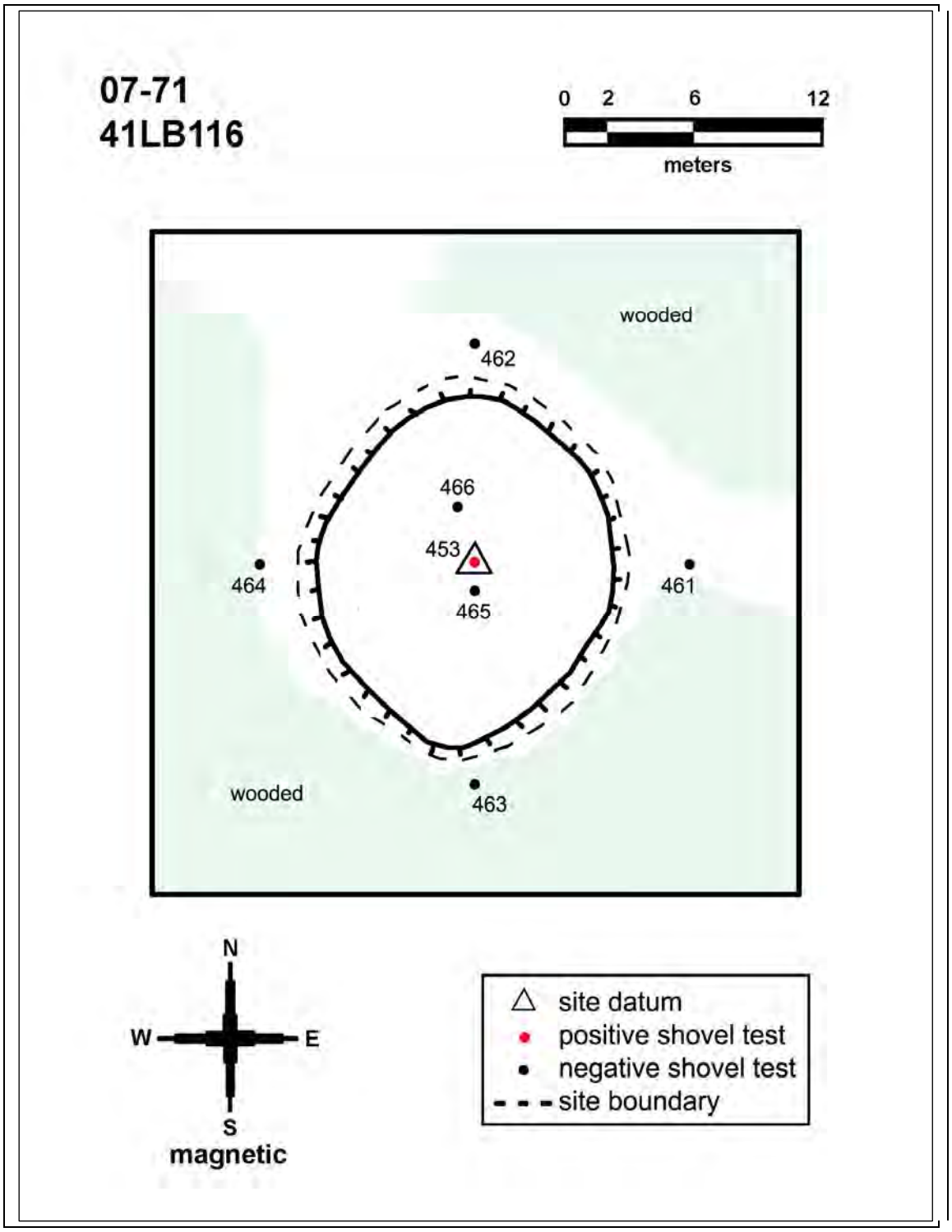


Figure 54. Map of 41LB116.

41LB117 (Prehistoric) Parcel 42

41LB117 is a buried prehistoric camp site identified and horizontally defined on the basis of 28 shovel tests and a well-defined sandy mound cluster (Figure 55). Two backhoe trenches (BHTs 43, 44) were excavated within the site, but produced no cultural materials or features (Figures 56, 57). The site is about 3,000 m north of 41LB116.

The topography here is a flat wooded area in the uplands near the west end of the PA. There is a cluster of about 12 sandy mounds here that are very prominent. The mounds average 20 m in diameter and over 1 m in height and are about 10-15 m apart. The area between the mounds is low and seasonally inundated with water. The woods are thin pine, oak, yaupon, and elm on the mounds with the same in between the mounds only with more water tolerant species. This site involves three of these mounds that are generally in a row E/W of each other. The site is 100 m E/W by 35 m N/S.

Six of the shovel tests were positive for cultural material. The cultural material was found only on the mounds and never off of them. The shovel testing produced a total of 22 artifacts (Table 23). The artifacts were recovered from Levels 1-8 (0-80 cmbs). The artifacts included nine pieces of chert lithic debitage, the medial fragment of a biface, and 12 Goose Creek plain sherds. The presence of the pottery sherds indicate the site dates to the Early-Late Ceramic period.

In summary, 41LB117 is a large prehistoric occupation site that dates to the Early-Late Ceramic period. The cultural deposits extend from Levels 1-8 (0-80 cmbs), and the artifact assemblage exhibits medium artifact density and diversity. We recommend that further investigations be conducted at the site in order to determine its significance and potential eligibility for the National Register of Historic Places. Once the current report is finalized, the artifacts recovered from 41LB117 will be curated at TARL.

Table 23. Artifacts recovered from 41LB117.

STP	Level	Artifact Class	Count	Comments
710	3	Biface	1	medial fragment, silicified wood
710	4	Flake fragment	1	chert
710	7	Tertiary flake	1	chert
711	1	Flake fragment	1	chert
711	3	Flake fragment	2	chert
711	7	Tertiary flake	2	chert
711	8	Native American ceramic- undecorated	10	
748	6	Debris	1	chert
748	6	Native American ceramic- undecorated	1	
754	7	Native American ceramic- undecorated	1	
758	5	Secondary Flake	1	chert
		Total	22	

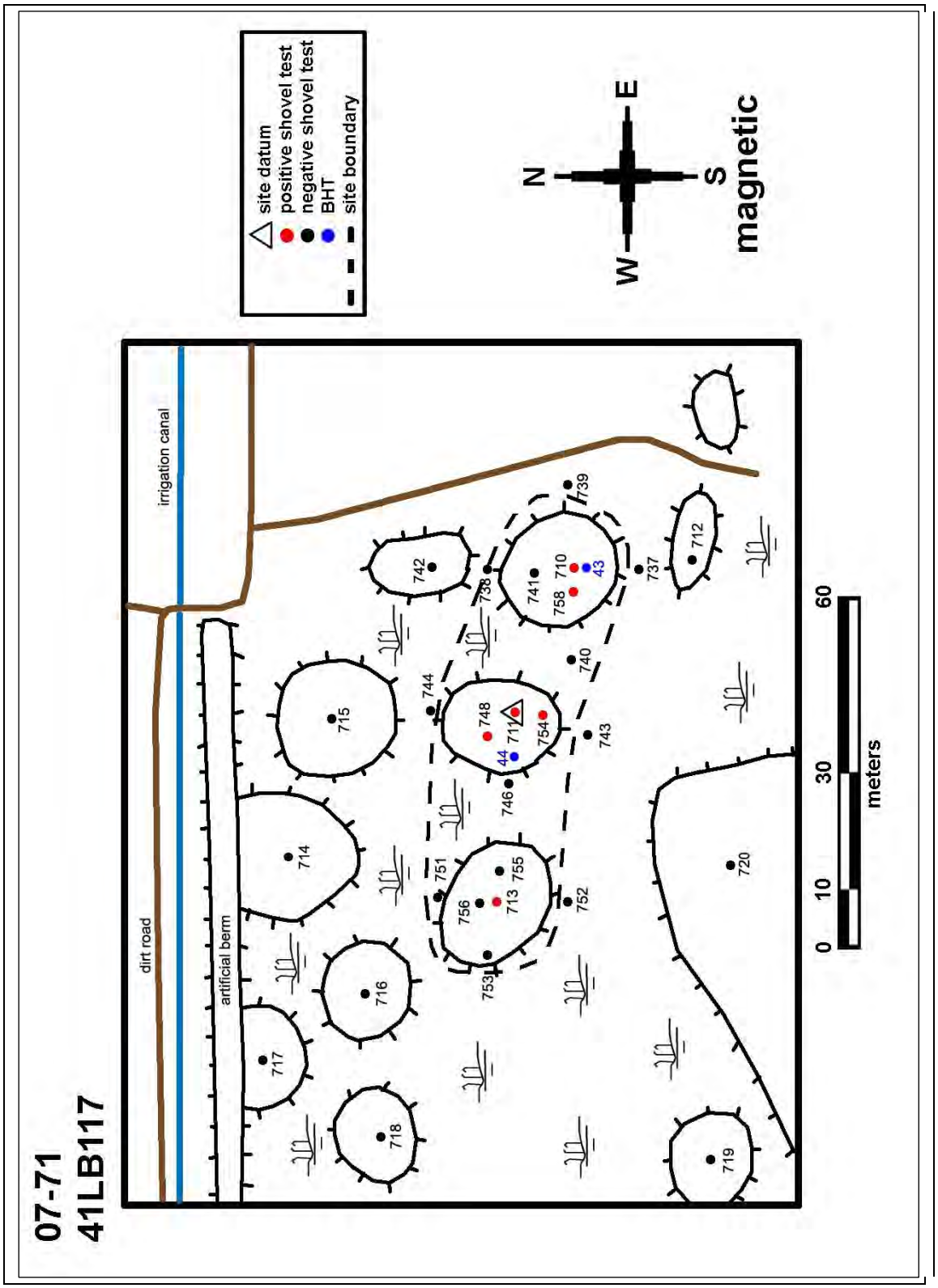
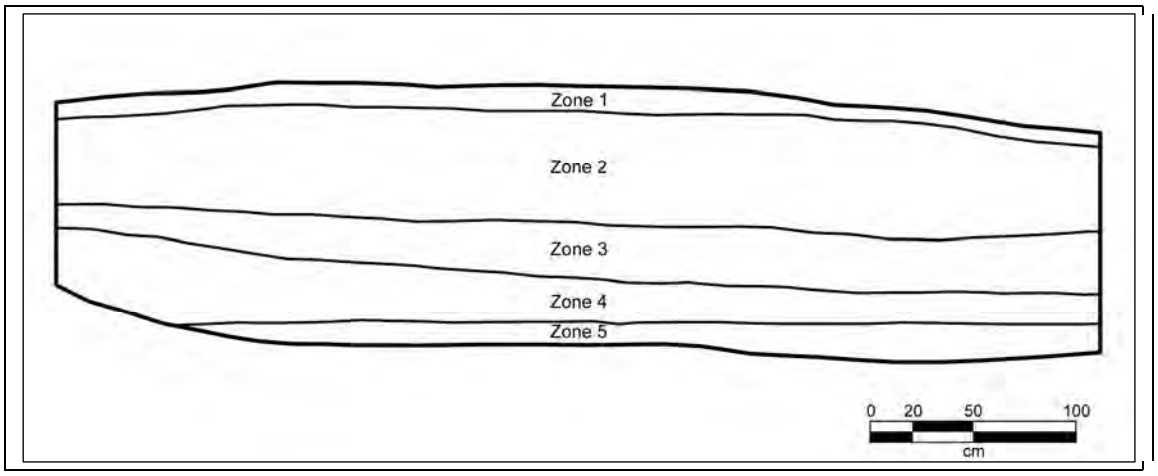
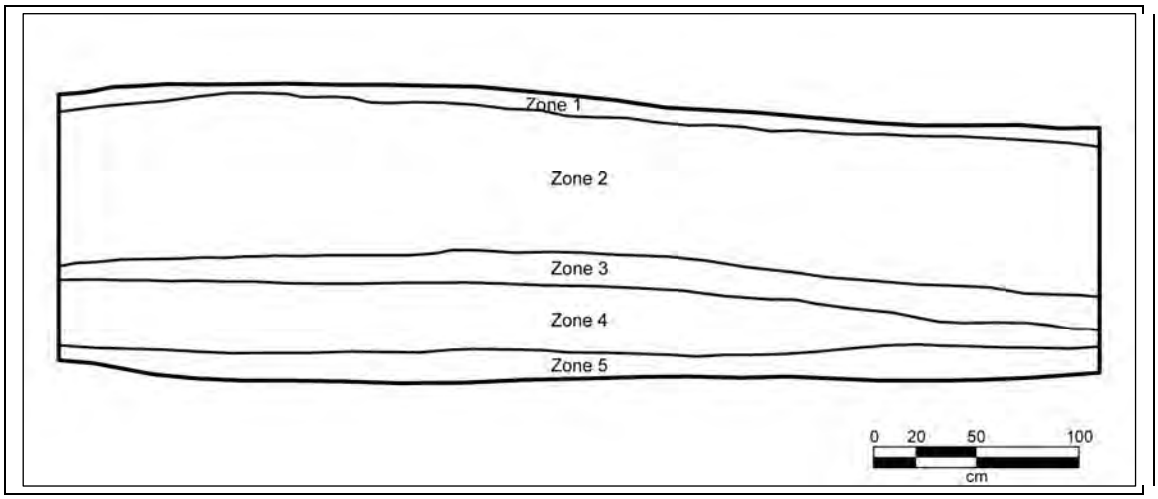


Figure 55. Map of 41LB117.



Zone 1	10YR2/2 Very dark brown fine sandy loam. Moist and friable with many roots and rootlets and a clear wavy boundary.
Zone 2	10YR4/2 Dark gray brown fine sand. Moist and friable with very few roots and rootlets. Abrupt, smooth boundary with few charcoal fragments.
Zone 3	10YR3/2 Very dark gray brown clay loam. Moist and friable with very few rootlets. Clear, smooth boundary.
Zone 4	10YR6/3 Pale brown clayey fine sand with few iron concretions. Moist and firm with a clear, smooth boundary.
Zone 5	10YR6/1 gray clay with few 10YR6/8 brown yellow mottles. Moist and firm with a few calcium carbonate concretions. Subsoil.

Figure 56. North profile of BHT 43, 41LB117.



Zone 1	10YR3/2 Very dark gray brown fine sandy loam. Moist and friable with many roots and rootlets. Bioturbated, with a clear wavy boundary.
Zone 2	10YR5/2 Gray brown fine sand, moist and friable with very few roots and rootlets. A very few iron concretions with a smooth, abrupt boundary.
Zone 3	10YR2/2 Very dark brown fine sandy loam. Moist and friable with a clear, smooth boundary.
Zone 4	10YR6/3 Pale brown clayey sand. Dry and hard with a few iron concretions. Clear, smooth boundary.
Zone 5	10YR6/2 Light brown gray clay with many 10YR6/8 brown yellow mottles with many calcium carbonate concretions. Subsoil.

Figure 57. Southeast profile of BHT 44, 41LB117.

41LB118 (prehistoric) Parcel 4

41LB118 is a prehistoric site on a sandy ridge along a fairly deep ENE/WSW drainage that drains a large flat area joining two sections of Capers Ridge (Figure 58). The site sits on the same edge of the drainage and about 100 m north of 41LB114. The current vegetation at the site is a mixture of pine with some oak and other hardwoods, yaupon, and blackberry.

A single shovel test was conducted and produced 4 pieces of lithic debitage from Level 1 (Table 24). There was also minimal charcoal in the profile. Clay was reached in the test at 18 cmbs. The site was not fully delineated because it lies outside the LBITP ROW and is no longer in the APE of the proposed project. The level of investigations conducted at this site were insufficient to assess it for NRHP eligibility. Consequently, additional delineation and assessment of site eligibility should be conducted if future impacts are proposed for the site.

Table 24. Artifacts recovered from 41LB103.

STP	Level	Artifact Class	Count	Comments
50	1	Flake Fragment	1	chert
50	1	Tertiary flake	3	chert
		Total	4	

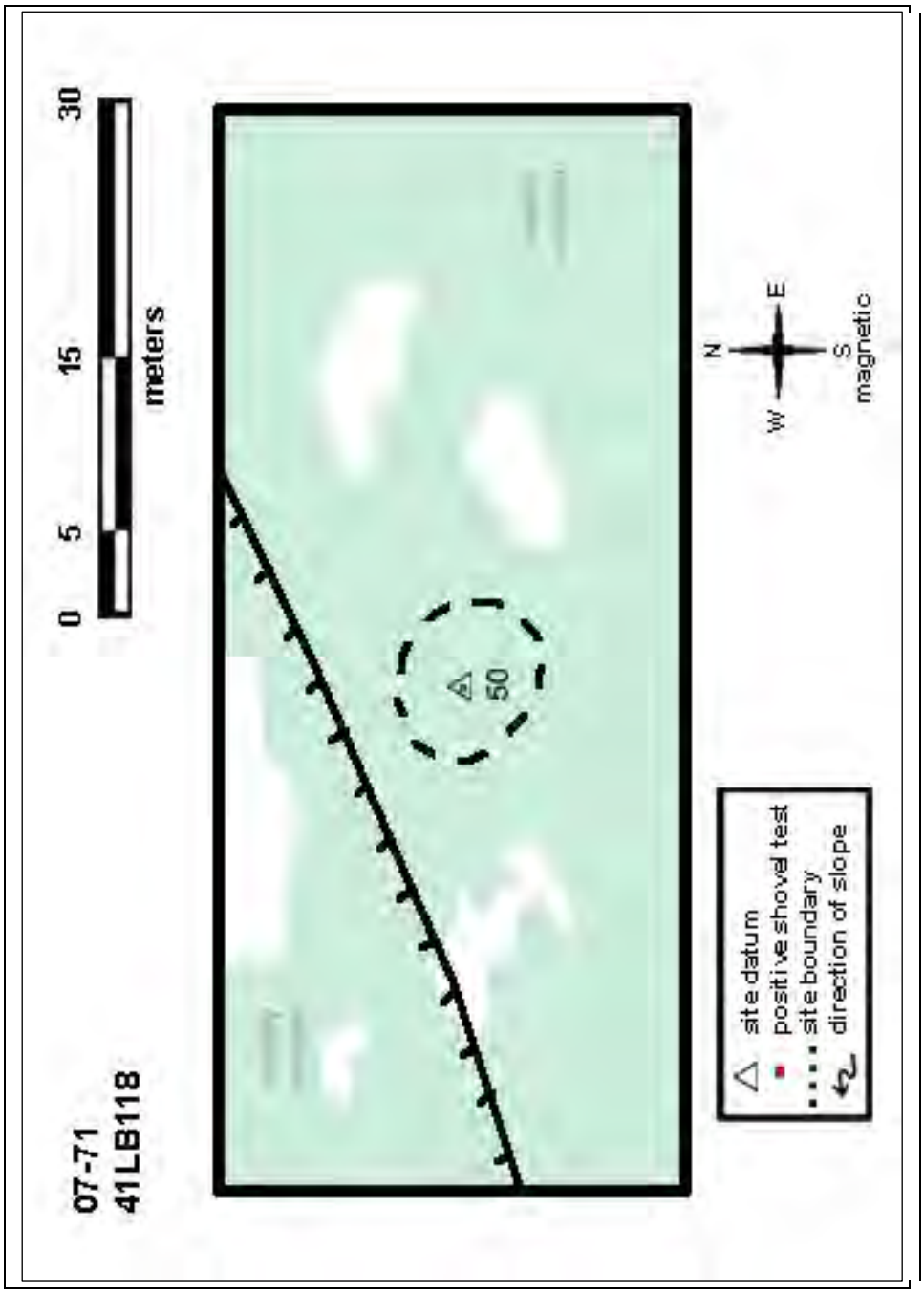


Figure 58. Map of 41LB118.

41HR1073 (Historic, early-mid twentieth century) Parcel 53

41HR1073 is a buried historic site that sits on the upland edge above Luce Bayou (Figure 59). The site was identified and horizontally defined on the basis of 34 shovel tests. Horizontal site dimensions are 115 m N/S by 95 m E/W. Seventeen of the shovel tests produced cultural material. 41HR1073 is on the western end of the Luce Bayou alignment near the town of Huffman.

The topography consists of a flat wooded area on the upland edge close to Luce Bayou. The woods are older growth with pine, oak, elm, cedar, yaupon, blackberry, and others. A structure is depicted at the location of this site on the 1920 and 1949 topographic maps. At the time of investigation there were no structures still standing, or above ground evidence remaining of the site.

The shovel testing produced 108 typical farmstead type artifacts (Table 25). They were recovered from Levels 1-4 (0-40 cmbs), with the majority in Levels 1-3 (0-30 cmbs). The artifacts included 22 sherds of historic ceramics (1 porcelain, 4 stoneware, 1 terra cotta, 16 whiteware), two pieces of metal hardware (1 rivet, 1 thumbtack), five cut nails and fragments, 28 wire nails and fragments, 16 shards of flat glass, 27 shards of curved glass, and eight brick fragments. There were no diagnostic artifacts that would indicate a date earlier than the early 20th century.

No noticeable subsurface features were identified other than a single sinkhole at the NE corner of the site. Excavation of a single shovel test (STP 482) in the sinkhole produced artifacts from 0-40 cm (Levels 1, 3, 4) below the surface. There was also a line of charcoal in the test at 8 inches below the surface. This small sinkhole could indicate a feature associated with the structure that was once here such as a well or cistern. But again, the artifacts found did not indicate occupation before the early 20th century. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the diagnostic artifacts recovered from 41HR1073 will be curated at TARL.

Table 25. Artifacts recovered from 41HR1073.

STP	Level	Artifact Class	Count	Comment
10	1	Euroamerican ceramic	1	whiteware
10	1	Flat glass	1	
10	1	Curved glass	2	
10	1	Metal nail - square cut	1	
10	1	Metal nail - round	1	
10	2	Flat glass	3	
10	2	Curved glass	1	
10	2	Euroamerican ceramic	2	whiteware
10	2	Euroamerican brick	2	fragment
10	2	Metal nail - round	2	whole
10	3	Metal nail - round	1	fragment
10	3	Euroamerican brick	1	fragment
10	3	Curved glass	3	
471	1	Metal nail - round	1	whole
471	2	Metal nail - round	1	whole
471	2	Flat Glass	1	
472	2	Metal nail - round	3	whole

472	2	Euroamerican ceramic	6	3 whiteware, 3 stoneware
472	2	Metal nail - round	2	
472	3	Euroamerican brick	1	fragment
472	3	Euroamerican ceramic	1	whiteware
472	3	Curved glass	1	
473	1	Flat glass	2	
473	1	Curved glass	5	
473	2	Metal nail - square cut	1	whole
473	2	Hardware	1	rivet
473	2	Euroamerican ceramic	1	whiteware
473	2	Curved glass	1	
474	2	Euroamerican ceramic	2	whiteware, porcelain
474	2	Metal nail - round	3	fragments
474	2	Flat glass	2	
474	3	Flat glass	1	
474	3	Curved glass	1	molded
475	1	Curved glass	2	
475	1	Metal nail - round	1	fragment
475	2	Flat Glass	2	
479	2	Curved glass	1	
479	2	Curved glass	1	
479	2	Flat Glass	1	
479	2	Hardware	1	tack
482	1	Curved glass	1	
482	3	Metal nail - round	1	
482	3	Euroamerican brick	2	fragment
482	4	Metal nail - round	1	whole
483	2	Euroamerican ceramic	1	stoneware
483	2	Curved glass	5	
483	2	Metal nail - round	3	fragment
527	1	Metal nail - round	1	
527	1	Euroamerican ceramic	4	whiteware
527	1	Curved glass	1	
527	1	Flat glass	1	
527	2	Euroamerican brick	1	fragment
527	2	Euroamerican ceramic	3	1 terra cotta, 2 whiteware
527	2	Metal nail - round	1	
529	1	Metal nail - round	2	whole
531	2	Euroamerican ceramic	1	whiteware
535	2	Metal nail - round	3	fragment
535	2	Flat Glass	2	
536	1	Metal nail - square cut	2	fragment
536	3	Curved glass	1	
536	3	Euroamerican brick	1	fragment
536	4	Metal nail - round	1	fragment
538	2	Metal nail - square cut	1	fragment
538	2	Curved glass	1	
		Total	108	

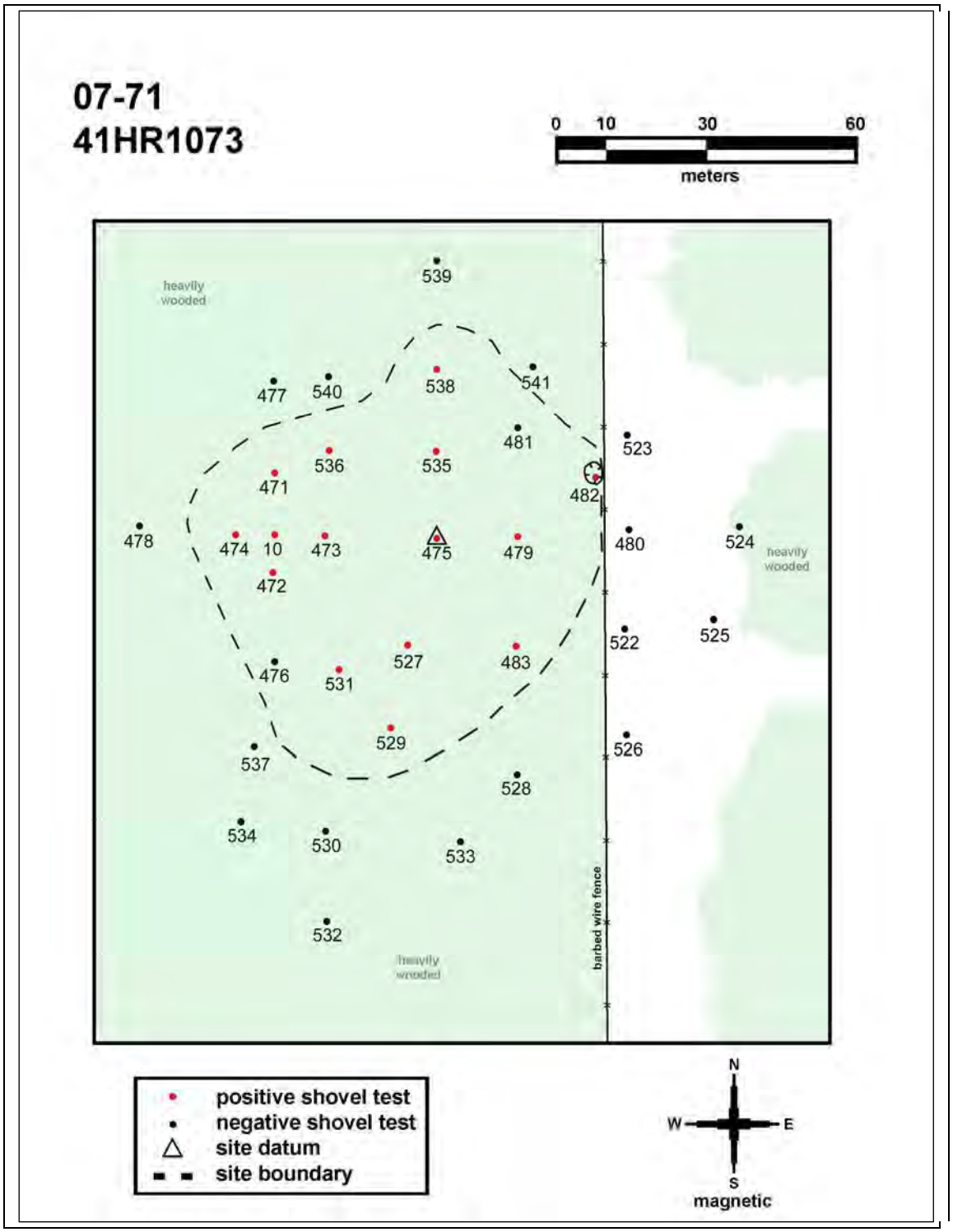


Figure 59. Map of 41HR1073.

41HR1074 (Prehistoric) Parcel 52

41HR1074 is a buried lithic scatter identified and horizontally defined on the basis of 8 shovel tests and a well-defined sandy mound landform (Figure 60). The site is atop an elliptical shaped sandy mound that measures 15 m in diameter by 1 m in height. Two of the eight shovel tests were positive for cultural materials. Recovered artifacts consisted of lithic debitage only.

The topography here is a flat wooded area in the uplands near the west end of the PA. The woods are thin pine, oak, and elm. The area is generally flat and there is roughly 4-6 of these natural sandy mounds in a cluster here. There has been modern historic occupation near this site, but the sandy mound appears to have been only minimally impacted. There is lots of water loving understory immediately around the mound.

The site produced one piece of chert lithic debitage from each of two different shovel tests that were only a meter apart from one another on top of the mound (Table 26). This appears to be a very minimal occupation probably representing an overnight hunter's camp.

In summary, 41HR1074 is a small prehistoric site that exhibits low artifact density and diversity. The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the artifacts recovered from 41HR1074 will be curated at TARL.

Table 26. Artifacts recovered from 41HR1074.

STP	Level	Artifact Class	Count	Comments
16	1	Tertiary flake	1	chert
546	6	Tertiary flake	1	chert
		Total	2	

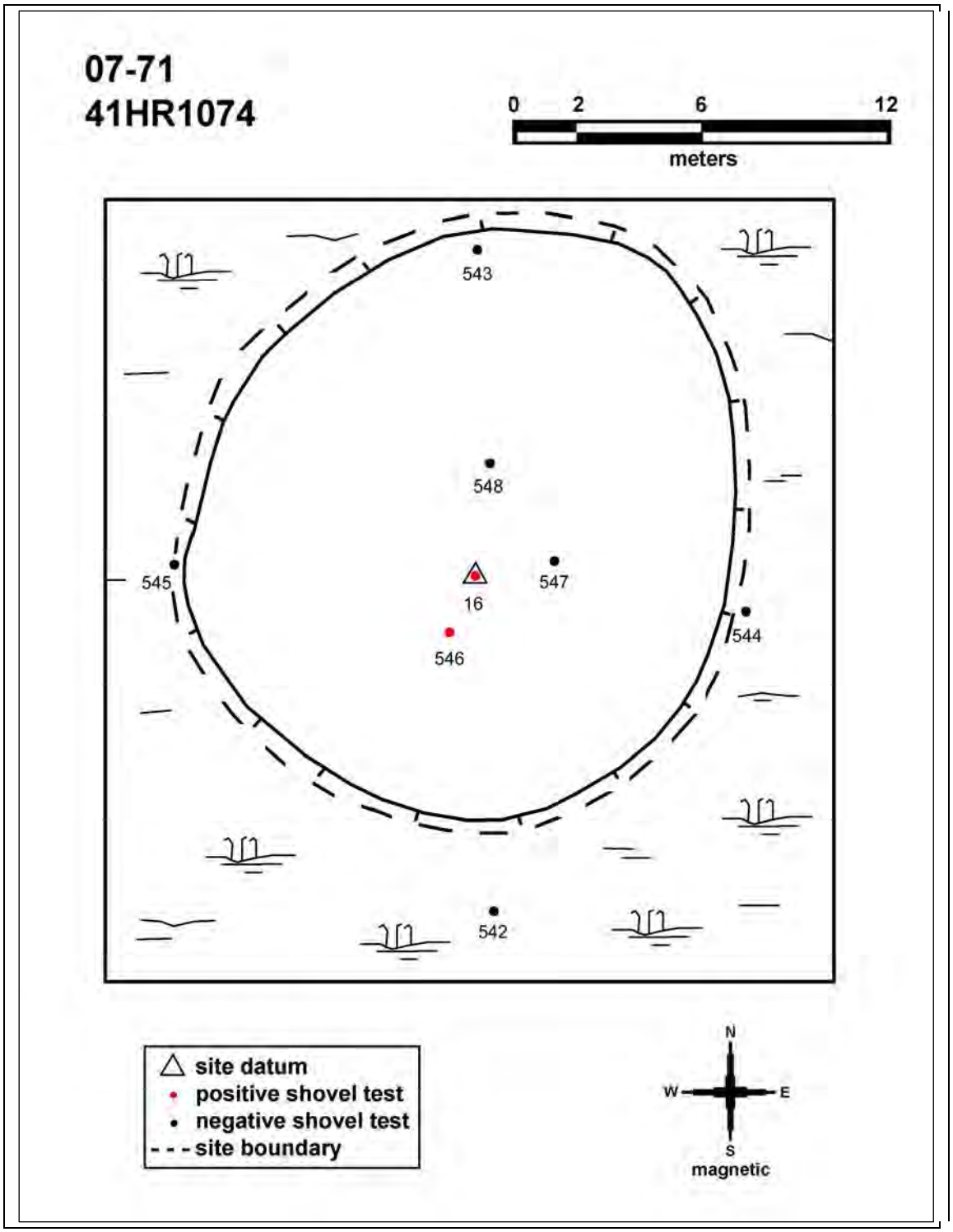


Figure 60. Map of 41HR1074.

41HR1075 (Historic) Parcel 51

41HR1075 is a historic site that sits on the east side of State Highway 2100 just north of Huffman, Texas (Figure 61). The site was identified, and horizontally defined on the basis of 37 shovel tests. Horizontal site dimensions are 55 m N/S by 35 m E/W. Twenty-one of the shovel tests produced cultural materials.

The topography here consists of a flat wooded area next to the highway. The woods are older growth with pecan, pine, oak, elm, yaupon, blackberry, and others.

The shovel testing produced 551 typical farmstead type artifacts (Table 27). They were recovered from Levels 1-8 (0-80 cmbs), with the majority in Levels 1-2 (0-20 cmbs). The artifacts included 36 sherds of historic ceramics, two pieces of metal hardware (1 axe head), 199 pieces of indeterminate metal, 18 cut nails and fragments, six wire nails and fragments, four pieces of wire, 18 shards of flat glass, 32 shards of curved glass, 147 bricks and brick fragments, nine pieces of mortar, one plastic button, and 79 pieces of faunal bone (some burned). There were no diagnostic artifacts that would indicate a date earlier than the late nineteenth to early 20th century. Also, no noticeable sub-surface features were identified other than a single sinkhole in the south central portion of the site. Excavation of a single shovel test (STP 980) in the sinkhole produced artifacts from 10-80 cm (Levels 2-8) below the surface. This small sinkhole could indicate a feature associated with the structure such as a well or cistern.

The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the diagnostic artifacts recovered from 41HR1075 will be curated at TARL.

Table 27. Artifacts recovered from 41HR1075.

STP	Level	Artifact Class	Count	Comments
350	1	Metal nail - round	1	whole
350	1	Euroamerican brick	24	fragment; small
350	2	Flat glass	4	
350	2	Metal nail - square cut	1	whole
350	2	Euroamerican brick	24	fragment; small
350	2	Flat Glass	1	
350	3	Euroamerican brick	3	fragment
350	3	Metal nail - round	1	whole
410	2	Euroamerican ceramic	5	whiteware
410	2	Flat glass	1	
410	2	Curved glass	1	
410	2	Euroamerican brick	1	fragment
410	2	Bone- nonhuman, unmodified	5	some burned
410	3	Euroamerican ceramic	1	whiteware
411	2	Euroamerican brick	2	
411	2	Metal nail - square cut	2	fragment
412	2	Bone- nonhuman, unmodified	2	
412	2	Curved glass	1	
412	2	Flat glass	2	
412	2	Euroamerican brick	1	
412	2	Metal nail - square cut	2	whole
412	3	Bone- nonhuman, unmodified	1	

412	3	Euroamerican brick	1	fragment
412	3	Flat glass	1	
412	3	Curved glass	1	
413	1	Curved glass	1	
413	1	Flat Glass	1	
413	1	Euroamerican brick	1	fragment
413	2	Euroamerican ceramic	1	blue transferware
414	1	Euroamerican ceramic	1	whiteware
414	1	Curved glass	1	
414	1	Euroamerican brick	1	1 whole, 2 fragment
414	1	Metal nail - square cut	3	
414	2	Euroamerican ceramic	1	whiteware
414	2	Curved glass	1	
414	3	Curved glass	1	
424	2	Euroamerican brick	8	fragment
424	2	Euroamerican ceramic	1	
424	2	Metal nail - square cut	1	whole
426	1	Euroamerican brick	2	fragment
426	1	Curved glass	1	
426	2	Euroamerican brick	2	fragment
426	2	Curved glass	3	
426	2	Euroamerican ceramic	1	ironstone
427	2	Euroamerican brick	2	fragment
428	1	Euroamerican brick	7	fragment
428	1	Curved glass	3	
428	1	Metal nail - square cut	5	fragment
428	1	Bone- nonhuman, unmodified	3	some burned
428	2	Curved glass	1	
428	2	Euroamerican brick	5	fragment
428	2	Metal nail - square cut	2	1 whole, 1 fragment
428	2	Bone- nonhuman, unmodified	6	some burned
969	1	EuroAmerican Brick	1	
972	2	EuroAmerican Brick	3	
973	2	EuroAmerican Ceramic	1	
973	2	EuroAmerican Brick	1	
975	2	EuroAmerican Brick	7	
975	2	Metal nail - round	1	
976	1	Metal - other	3	indeterminate
976	1	EuroAmerican Brick	1	
978	1	EuroAmerican Brick	1	
978	1	Curved glass	2	
978	1	Metal nail - square cut	1	
978	2	Metal nail - round	1	
978	2	EuroAmerican Brick	12	
978	2	Curved glass	5	
978	2	Flat Glass	1	
978	2	Curved glass	1	
978	2	EuroAmerican Ceramic	1	
978	2	Metal - other	7	indeterminate

979	2	Curved glass	1	burned
979	2	EuroAmerican Brick	1	burned
980	2	EuroAmerican Brick	3	
980	2	Metal - other	1	indeterminate
980	3	Metal - other	4	indeterminate
980	4	Metal - other	47	indeterminate
980	4	EuroAmerican Ceramic	1	
980	4	Metal nail - round	1	
980	5	Metal - other	61	indeterminate
980	6	Metal - other	40	indeterminate
980	6	Metal wire	4	rusted, connected together
980	6	EuroAmerican Brick	2	
980	6	Bone- nonhuman, unmodified	21	tusks, teeth, and bone
980	7	EuroAmerican Ceramic	1	decorated
980	7	Flat Glass	1	blue-green
980	7	Bone- nonhuman, unmodified	3	
980	7	Metal - other	7	indeterminate
980	8	Metal - other	10	indeterminate
980	8	Bone- nonhuman, unmodified	1	
981	2	Metal - other	10	indeterminate
981	2	EuroAmerican Ceramic	1	
981	2	EuroAmerican Brick	8	
981	2	Mortar	6	
981	2	Metal nail - round	1	
981	2	Flat Glass	2	blue-green
981	2	Curved glass	2	
981	2	Curved glass	1	
981	3	Mortar	1	
981	3	Flat Glass	2	1 clear, 1 green
982	1	Bone- nonhuman, unmodified	3	
982	1	Metal - other	3	indeterminate
982	2	Metal - other	2	indeterminate
982	2	Bone- nonhuman, unmodified	2	burned
982	2	EuroAmerican Ceramic	3	
982	2	Mortar	1	
982	2	Flat Glass	1	
982	3	Metal - other	1	indeterminate
983	1	Bone- nonhuman, unmodified	2	
983	1	Curved glass	2	1 green, 1 clear
983	1	EuroAmerican Ceramic	6	
983	1	EuroAmerican Brick	9	
983	1	Hardware	1	
983	2	Bone- nonhuman, unmodified	6	2 burned
983	2	Curved glass	1	
983	2	EuroAmerican Ceramic	1	
983	2	EuroAmerican Brick	7	
983	3	EuroAmerican Brick	4	
983	3	Mortar	1	
983	3	Curved glass	1	clear

983	3	EuroAmerican Ceramic	9	1 makers mark, 3 decorated
983	4	Bone- nonhuman, unmodified	16	
983	5	Bone- nonhuman, unmodified	8	
983	5	EuroAmerican Ceramic	1	
983	5	EuroAmerican Brick	1	
983	5	Curved glass	1	
984	1	Flat Glass	1	
984	2	Hardware	1	axe head
984	2	Metal - other	3	indeterminate
984	2	Button	1	plastic
984	2	EuroAmerican Brick	2	
984	3	Metal nail - square cut	1	
		Total	551	

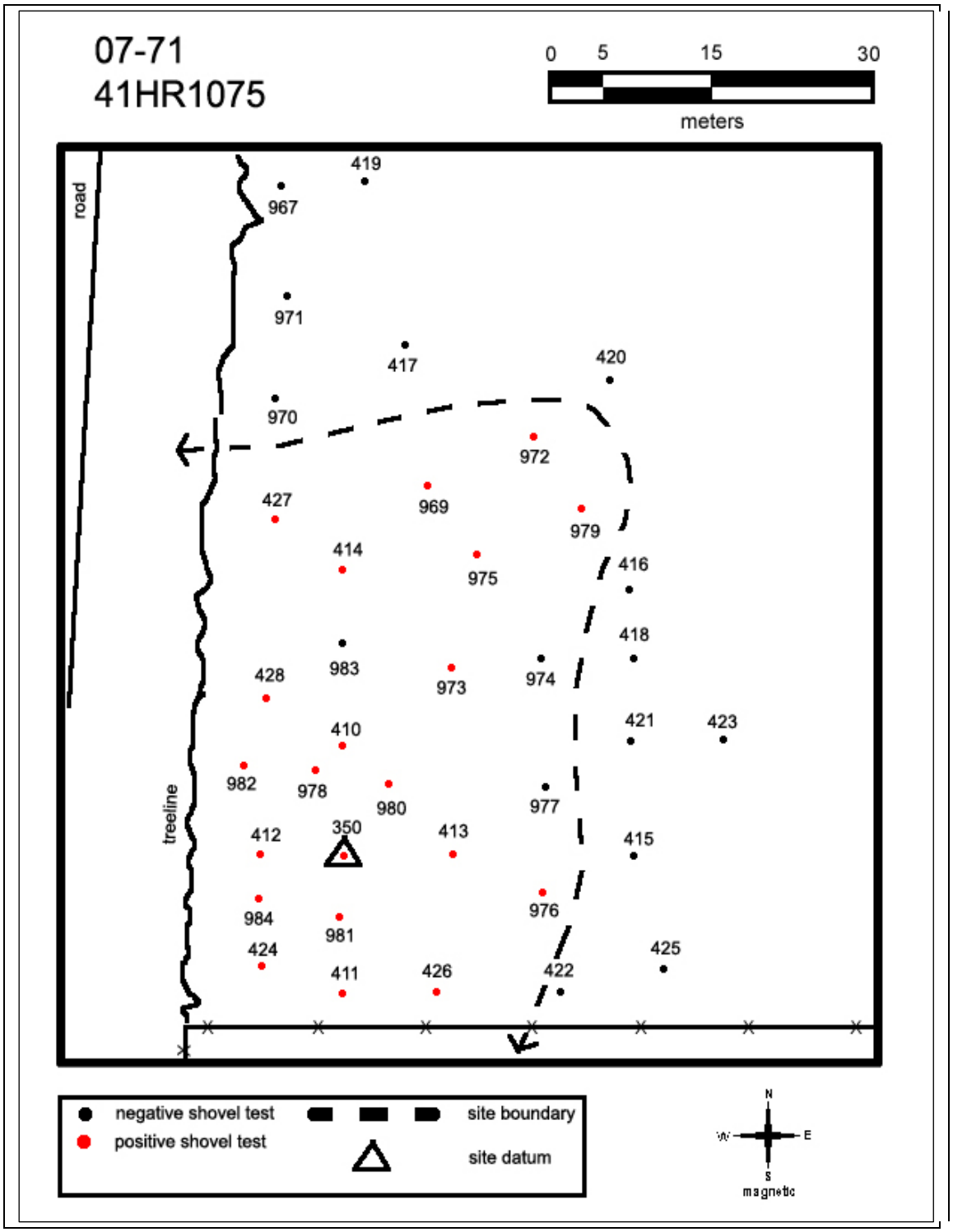


Figure 61. Map of 41HR1075.

41HR1076 (Historic) Parcel 47 (May Family Tract)

The site is a historic farmstead identified as the property of the May family. A total of 38 shovel tests were excavated, of which 32 were positive for cultural materials (Figure 62). Recovered artifacts consisted of historic ceramics, glass, iron, brick, mortar, and square nails. As with the nearby historic site 41HR1075, this site has a small sunken spot that proved to contain a debris deposit after a small test probe was excavated in its center. This area is a cattle pasture with a few very mature pecan, oak, sycamore, yaupon, and pine trees. The topography is flat with noticeable areas where the old road came through the property. There are also some mound-like features along the old entry road that may be associated with its construction.

On Wednesday, September 9, 2009, Roger Moore, Sarah Blake, and John Ferguson went to the May family home to meet with Mr. May and his daughter Robin to discuss the possibility of a family oak tree and home site on their property which a realignment of the LBITP would affect. The Mays gave us some information and family photos from the early 1900s that showed the oak and a couple of sycamore trees in association with a wood frame home. They then showed us the location of the trees on their property and the vantage point from which they believed the photos were taken. The spot looked convincing enough for us to go ahead with some shovel testing around the general area to try and assess whether there was a home site there, how old it might be, and whether there were any intact remnants.

The home site area is now used for cattle grazing. There are a few round bale hay feeders scattered across the lot. These feeders have been in place for so long that the elevation of the ground beneath them is a good deal higher than the surrounding area. The vegetation includes quite a few very mature trees, most of which could date back to the time of occupation or earlier. There is the one large 17 ft circumference oak, two or three large sycamore trees, the same number of old pecan trees, and quite a few younger trees of the same species. The surface of the ground is fairly flat excepting for a couple of old roadbeds to the north and south of the proposed home site. There are also a couple of low mounded areas to the north of the home site that follow the old roadbed.

On September 17 and 18, 2009, we returned to the May family tract and did some shovel testing and site delineation in the site we had looked at with the Mays in the previous week. We excavated a total of 38 shovel tests, six of which were negative. The artifacts seemed to come from generally levels 1-3. One of the tests, STP 486, recovered artifacts down to Level 8. STP 490, located next to a suspicious looking depression, had artifacts down to Level 6. The depression we found later was previously a hole (well, cistern), as a probe in its center produced an abundance of modern glass and ceramics. It is evident from STP 515 that the soils around the home site are probably intact as we found an intact wagon wheel rim in Level 1 that was still perfectly round. If the land had been plowed over, the rim would no doubt have been affected in some manner. We did not locate any well-defined features during the shovel testing that would indicate an exact location of the house site. However, based on the sheer numbers of artifacts per shovel test, it appears we were able to identify the area of most intense occupation activity. STP 521 is located about 10 m west of the possible well/cistern/privy pit, and contained a total of 315 artifacts. Other high-count tests within 20 m of STP 315 produced total artifact numbers of 124, 77, 78, 55, 51, and 44 respectively. The artifact counts per test decrease significantly after this 20 m radius. The old roadbed that led to the house runs about 25 m north of the highest count shovel test and the artifact counts subside substantially north of this. The artifacts do pick up again about 40 m south of STP 521 but the counts are not as high.

The shovel testing produced 210 typical farmstead type artifacts (Table 28). They were recovered from Levels 1-8 (0-80 cmbs), with the majority in Levels 1-3 (0-30 cmbs). The

artifacts included five sherds of historic ceramics, four pieces of metal hardware, 34 pieces of indeterminate metal, 17 wire nails and fragments, 25 pieces of wire, nine shards of flat glass, 29 shards of curved glass, 80 bricks and brick fragments, one piece of mortar, one round of modern ammunition, one piece of jewelry, and four pieces of faunal bone. The artifacts indicate a period of occupation around the turn of the 20th century or later.

The site does not appear to possess the potential for future study, and is thus not eligible for inclusion on the National Register of Historic Places. No further archeological work is recommended. Once the current report is finalized, the diagnostic artifacts recovered from 41HR1076 will be curated at TARL

Table 28. Artifacts recovered from 41HR1076.

STP	Level	Artifact Class	Count	Comments
484	4	Euroamerican brick	3	
486	6	Euroamerican brick	4	
486	7	Metal nail - round	1	
486	8	Curved glass	3	
488	1	Flat glass	3	
488	2	Hardware	1	
488	2	Euroamerican brick	5	
490	1	Metal - wire	15	
490	1	Hardware	1	
490	1	Hardware	1	
490	1	Metal - other	1	
490	1	Euroamerican brick	7	
490	2	Euroamerican brick	3	
490	2	Metal wire	1	
490	3	Metal wire	3	
490	3	Metal nail - round	1	
490	3	Euroamerican brick	7	
490	3	Euroamerican ceramic	1	
490	4	Euroamerican brick	3	
490	4	Metal - other	2	
490	5	Euroamerican brick	3	
490	5	Metal - other	3	
490	6	Metal - other	2	
491	1	Euroamerican brick	2	
491	1	Flat glass	1	
491	2	Euroamerican brick	14	
491	2	Curved glass	1	
491	2	Metal - other	9	
491	2	Flat glass	5	
491	3	Personal item	1	jewelry
491	3	Euroamerican brick	1	
491	3	Metal - other	2	
493	1	Bone- nonhuman, unmodified	3	
493	1	Euroamerican brick	2	
493	1	Metal - other	1	
493	2	Metal wire	3	

493	2	Metal - other	1	
493	2	Mortar	1	
493	2	Euroamerican brick	4	
493	2	Curved glass	4	
493	2	EuroAmerican ceramic	1	
493	3	Hardware	1	unknown
493	3	Metal - other	5	
493	3	Euroamerican ceramic	1	
493	3	Euroamerican brick	7	
493	3	Bone- nonhuman, unmodified	1	
493	3	Curved glass	3	
495	1	Metal nail - round	5	
495	2	Curved glass	3	
495	2	Euroamerican brick	6	
495	3	EuroAmerican Ceramic	2	
498	1	Metal nail - round	4	
499	1	Curved glass	7	
499	2	Metal nail - round	3	
499	3	Metal - other	5	
508	2	Metal nail - round	3	
509	1	Euroamerican brick	6	
512	2	Euroamerican brick	2	
515	2	Curved glass	2	
516	3	Euroamerican brick	1	
521	1	Metal wire	3	
521	1	Curved glass	6	
521	2	Ammunition	1	modern
521	3	Metal - other	3	
		Total	210	

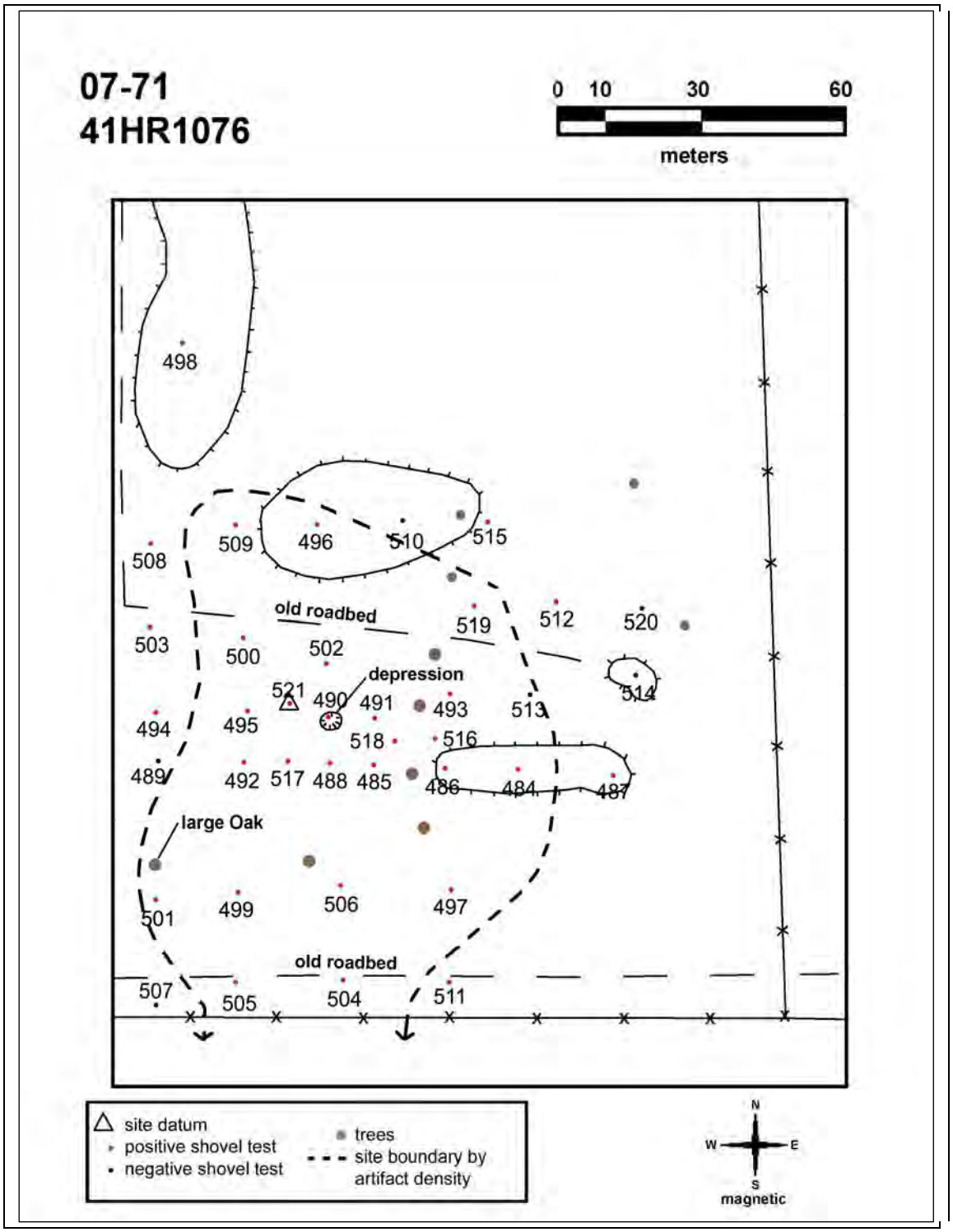


Figure 62. Map of 41HR1076.

IF 1 (Prehistoric) Parcel 4

Isolated find (IF) 1 produced only one piece of lithic debitage and will be designated as an isolated find (Figure 63). The isolated find was identified and horizontally defined on the basis of 8 shovel tests on a well-defined landform. One of the shovel tests was positive for cultural materials. This location appears to represent an isolated find and will not be recorded as a site.

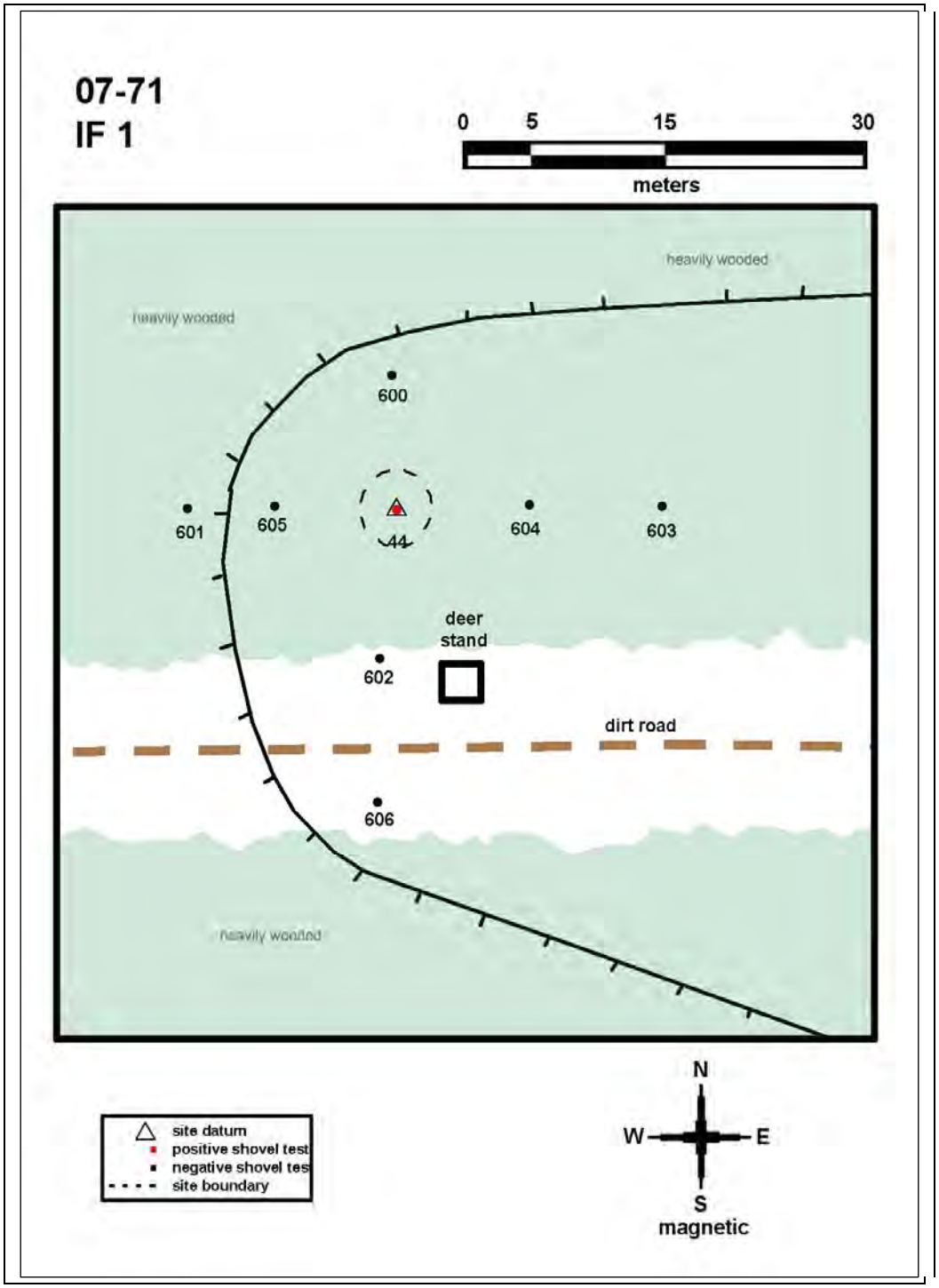


Figure 63. Map of IF 1.

IF 2 (Prehistoric) Parcel 1

Isolated find (IF) 2 is a prehistoric location identified and horizontally defined on the basis of 8 shovel tests on an eroded sandy mound landform (Figure 64). One shovel test was positive for cultural materials. A single piece of lithic debitage was recovered. This location appears to represent an isolated find and will not be recorded as a site.

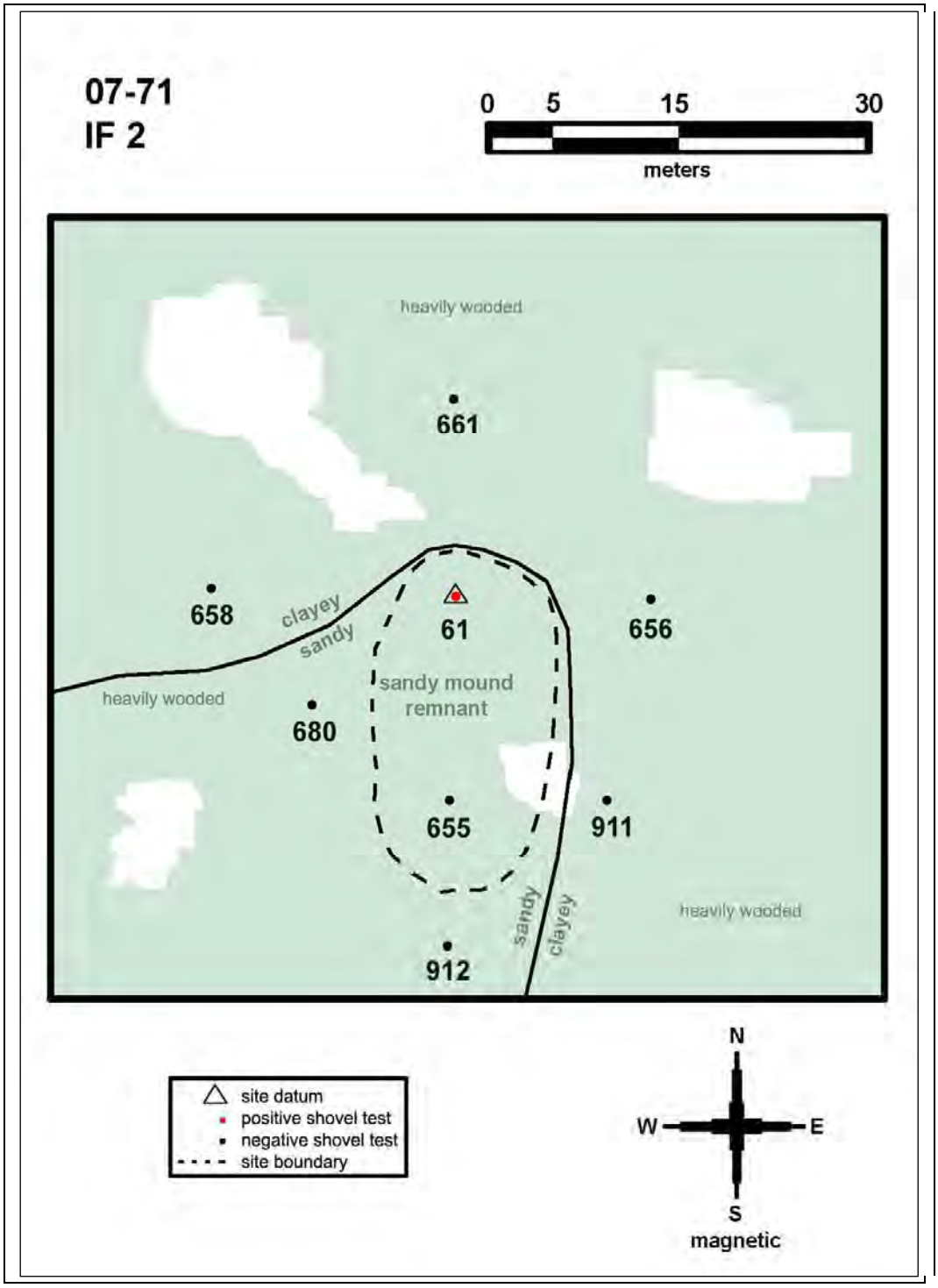


Figure 64. Map of IF 2.

IF 3 (Prehistoric) Parcel 4

This is a sandy mound far from water that had a single flake in the initial shovel test (Figure 65). We came back and put 4 more tests at the location with no more positive results. This location appears to represent an isolated find and will not be recorded as a site.

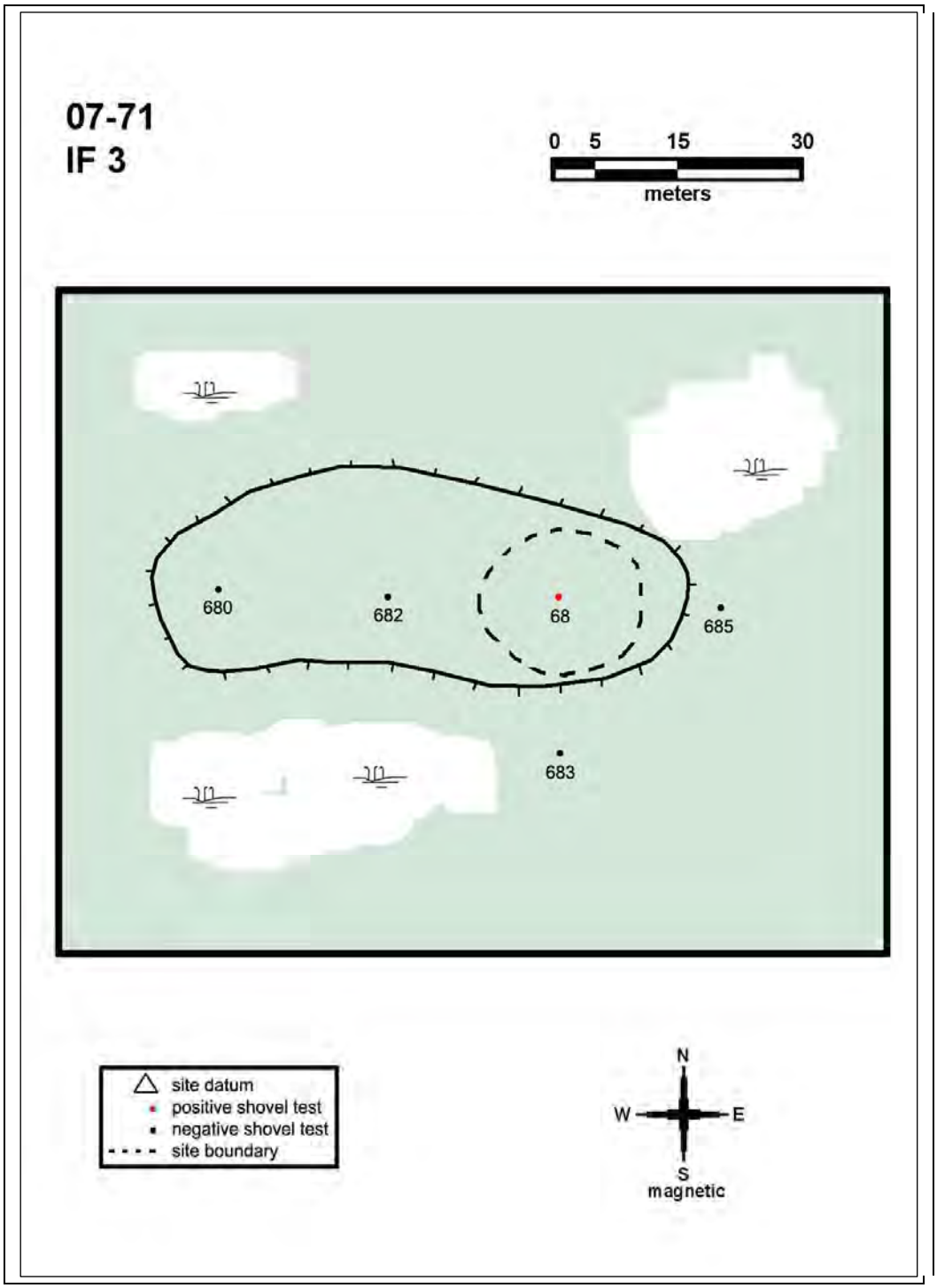


Figure 65. Map of IF 3.

IF 4 (Prehistoric) Parcel 1

This is a location on high ground far from water that had a single flake in the initial shovel test (Figure 66). Five additional shovel tests were excavated, but no more cultural materials were recovered. This location appears to be an isolated find and will not be recorded as a site.

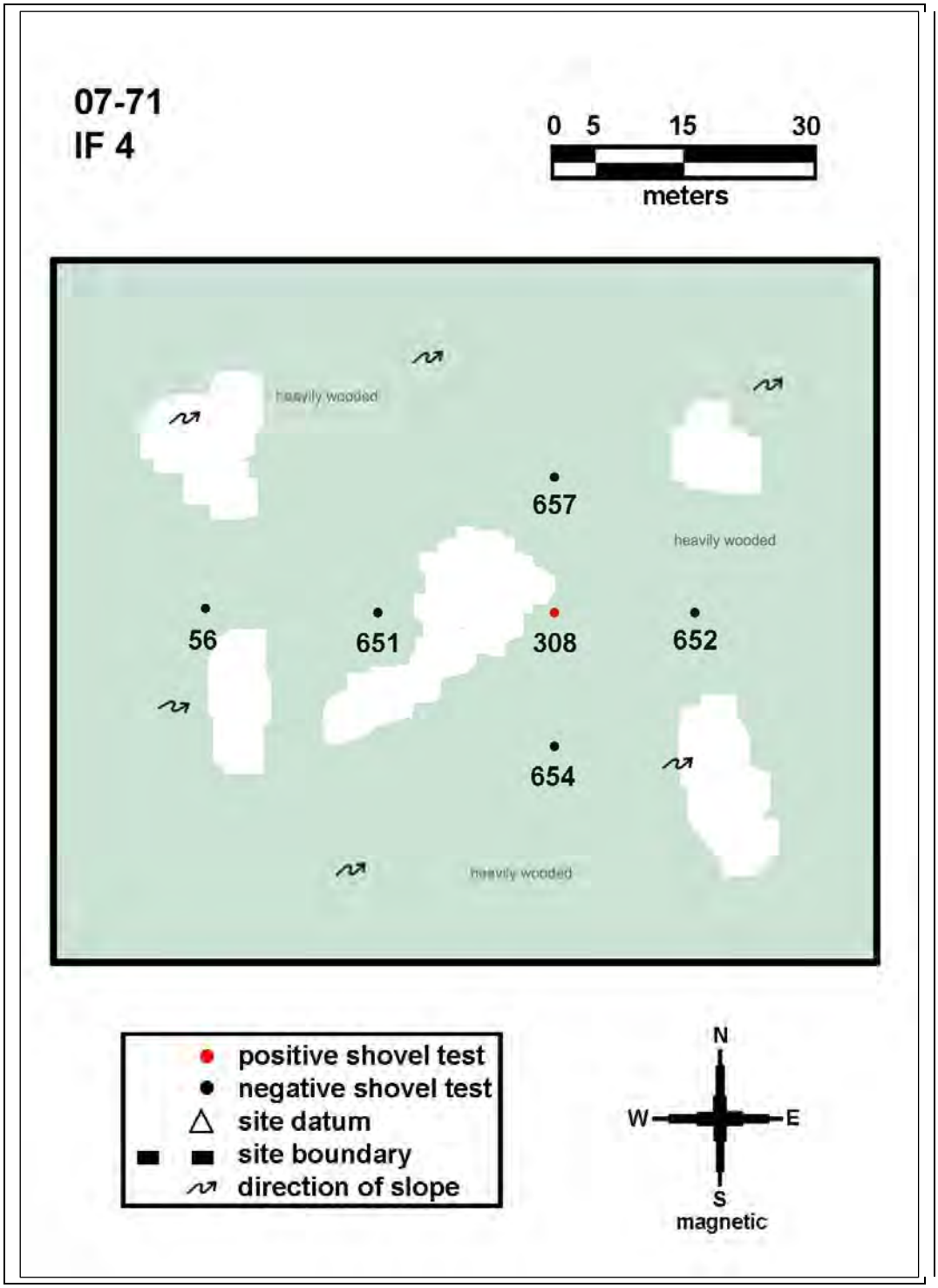
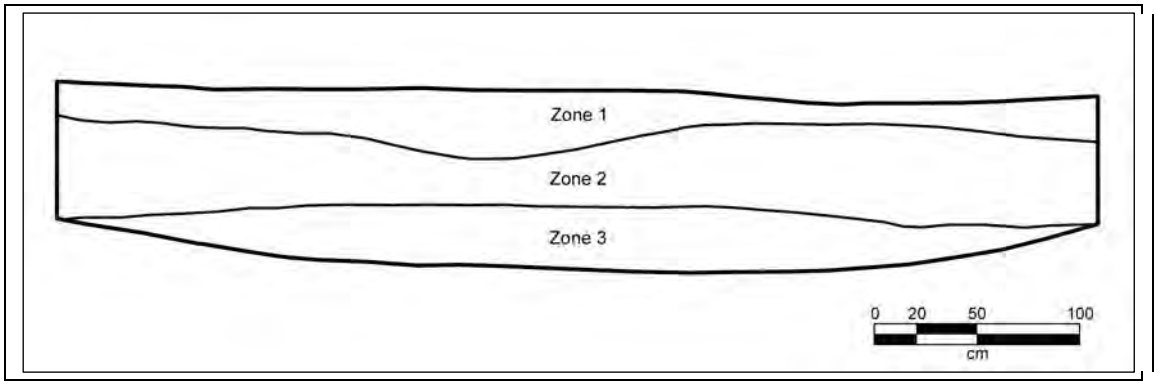


Figure 66. Map of IF 4.

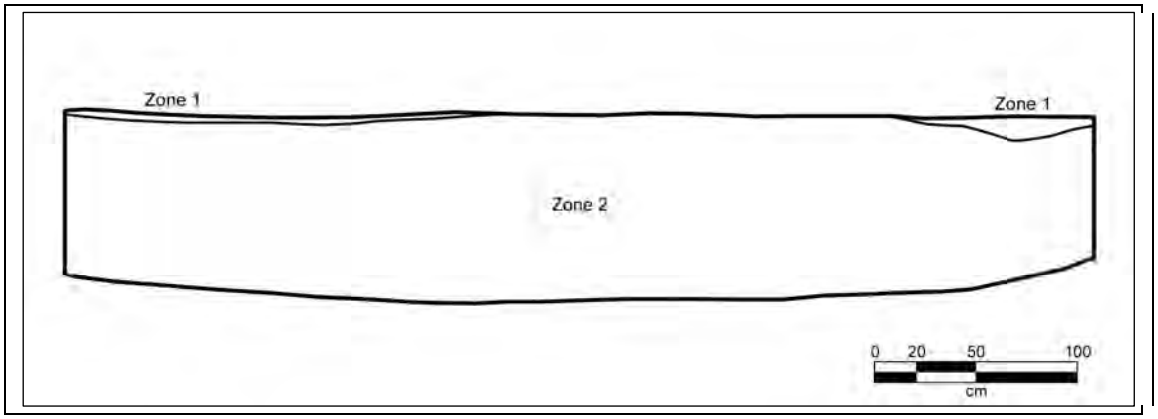
Backhoe Trenches Placed in Areas Between Sites

A total of 19 backhoe trenches were placed between sites located on Capers Ridge. Depending on the topography and the locations of identified site boundaries, these were located at intervals of approximately 150-200 m. None of these trenches produced cultural materials or features. Locations of the trenches are shown on Figures 67-85.



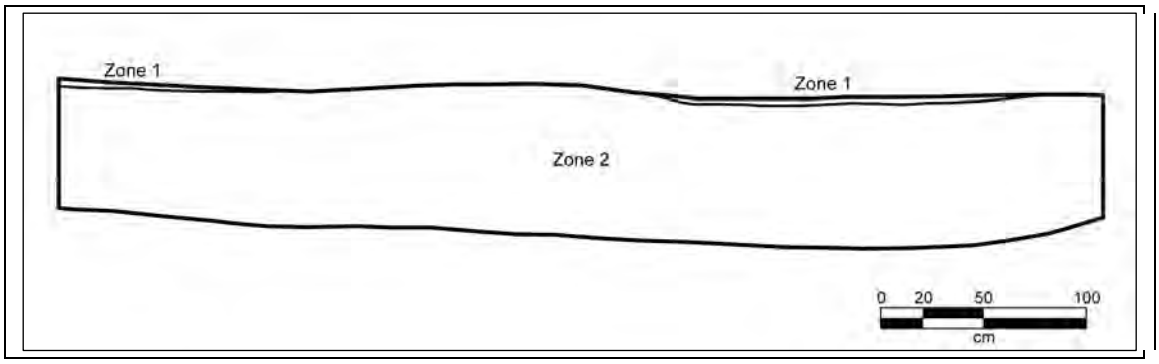
Zone 1	10YR3/3 Dark brown fine sandy loam. Moist and friable with a clear and wavy boundary, few charcoal flecks, and many roots and rootlets.
Zone 2	10YR7/1 Light gray fine sand with 10YR6/6 brownish yellow mottles. Moist and friable with a clear smooth boundary and a few rootlets.
Zone 3	10YR6/1 Gray clay with 2.5YR4/8 red mottles. Moist and firm, common krotovina. Subsoil.

Figure 67. Northeast profile of BHT 2.



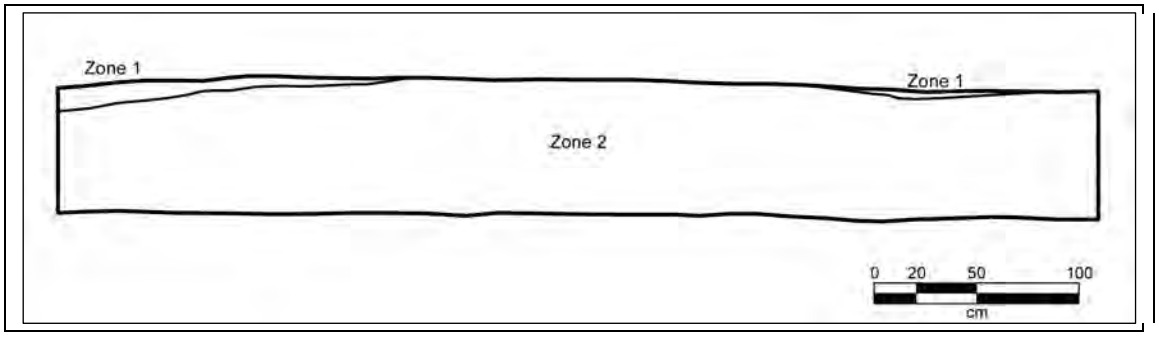
Zone 1	10YR5/3 Brown clay loam, moist and friable. Zone is truncated and discontinuous across profile. Smooth, clear boundary with many roots and rootlets.
Zone 2	10YR6/1 Gray clay with many 5YR4/6 yellowish red mottles. Moist and firm with a few root casts. Subsoil.

Figure 68. North profile of BHT 3.



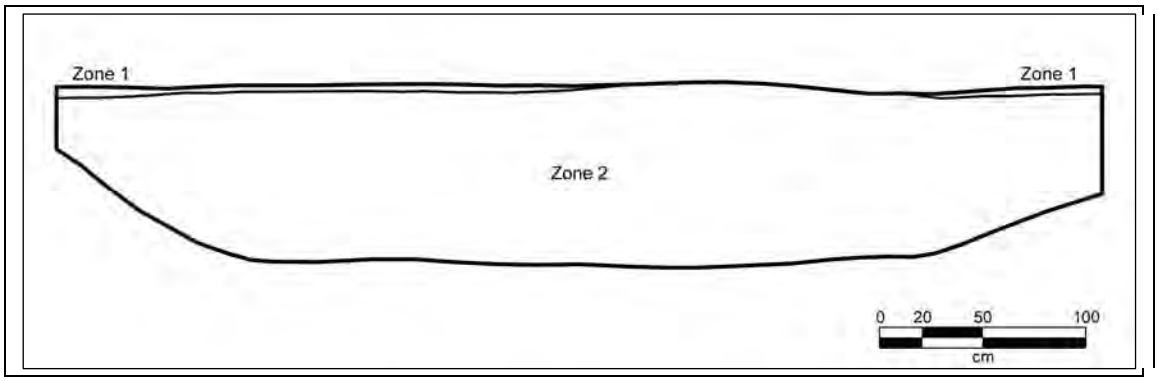
Zone 1	10YR3/2 Very dark grayish brown clay loam. Moist and friable, truncated at top. Discontinuous across profile but with a smooth clear boundary and many roots and rootlets.
Zone 2	10YR7/1 Light gray clay with 10YR5/8 yellowish brown mottles. Moist and firm. Subsoil.

Figure 69. East profile of BHT 4.



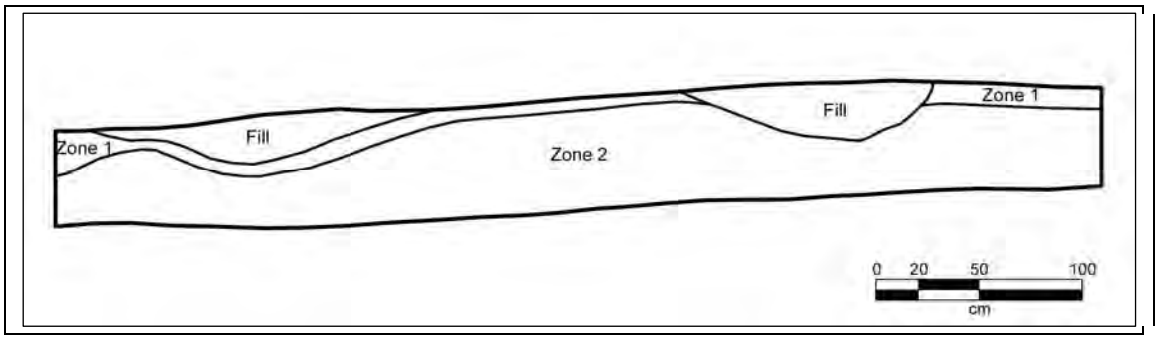
Zone 1	10YR4/3 Brown clay loam, moist and friable. Truncated at top and discontinuous across profile. Smooth, clear boundary with many roots and rootlets.
Zone 2	10YR6/2 Light brown gray clay with 10YR5/8 yellowish brown mottles, moist and firm. Subsoil.

Figure 70. East profile of BHT 5.



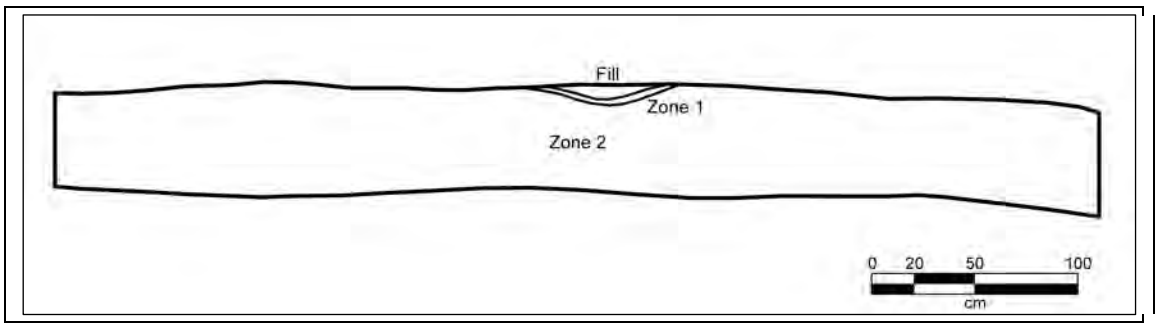
Zone 1	10YR3/3 Dark brown clay loam, moist and friable. Truncated at surface and discontinuous across profile. Smooth, clear boundary with many roots and rootlets.
Zone 2	2.5YR6/1 Gray clay with many 2.5YR4/6 red mottles, moist and firm. Subsoil

Figure 71. East profile of BHT 6.



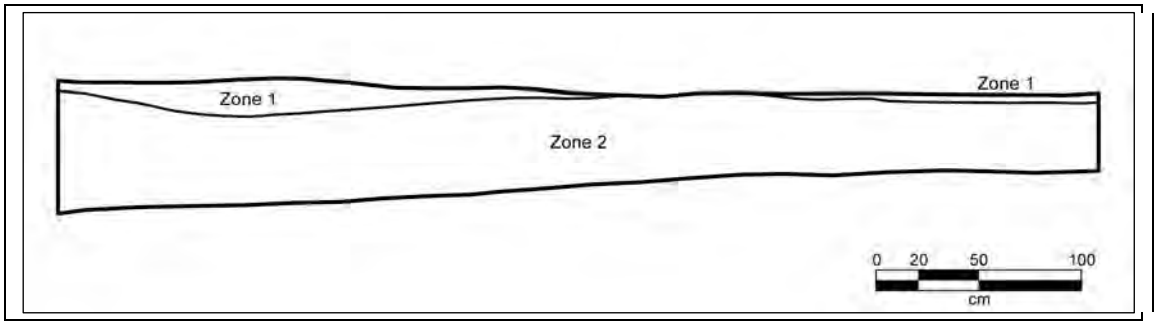
Zone 1	10YR3/3 Dark brown clay loam, moist and friable. Truncated at surface and discontinuous across profile with many roots and rootlets.
Zone 2	10YR2/2 Light gray clay with many 5YR4/6 yellowish red mottles. Moist and firm with few roots and rootlets. Subsoil.

Figure 72. South profile of BHT 7.



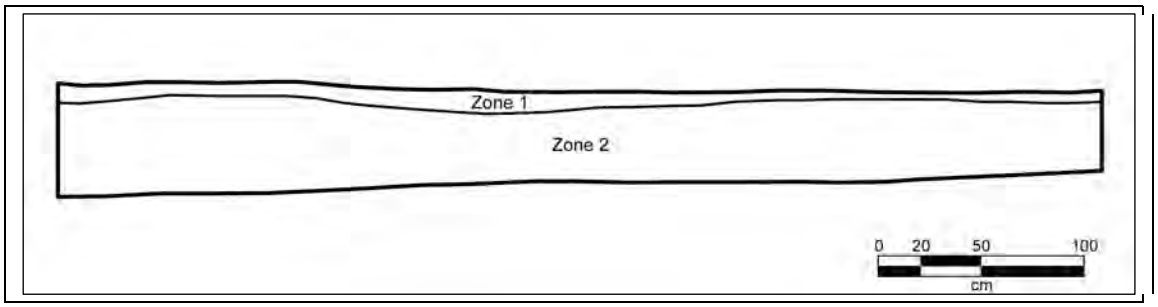
Zone 1	10YR3/3 Dark brown clay loam, moist and friable. Only a very small portion remains, mostly truncated with a smooth clear boundary.
Zone 2	10YR7/2 Light gray clay with 2.5YR4/8 red clay mottles, moist and firm. Subsoil.

Figure 73. South profile of BHT 8.



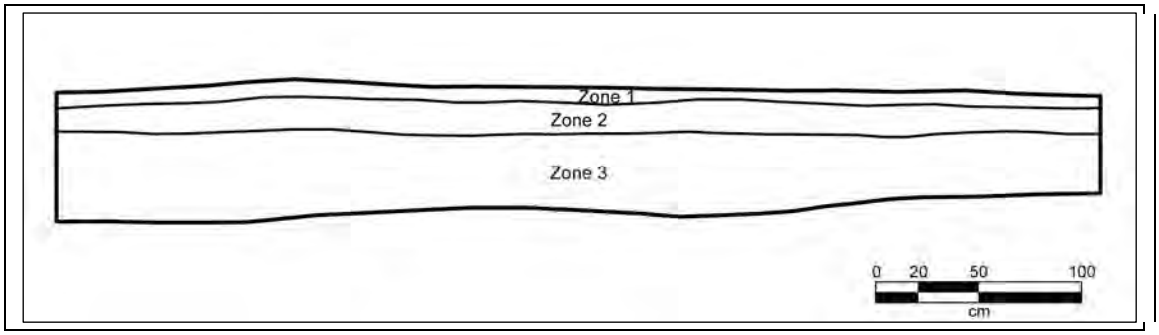
Zone 1	10YR3/3 Dark brown clay loam, moist and friable. Truncated at surface and discontinuous across profile. Smooth, clear boundary with few roots and rootlets.
Zone 2	7.5YR5/6 Yellowish brown clay with 5YR5/8 yellowish red mottles. Moist and firm with very few rootlets. Subsoil.

Figure 74. East profile of BHT 9.



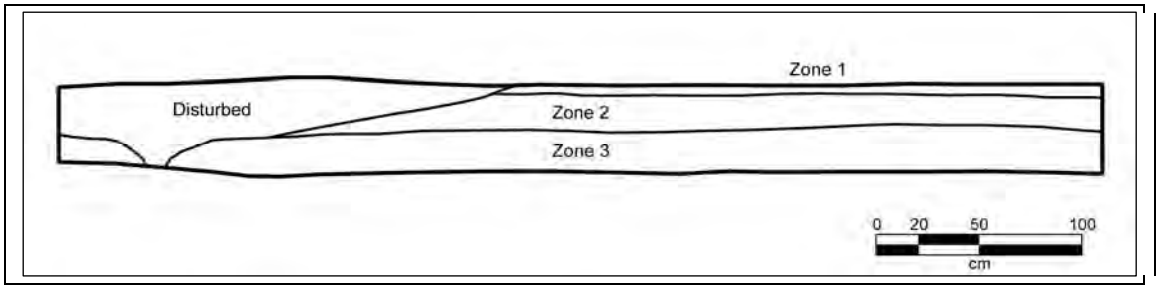
Zone 1	10YR3/3 Dark brown clay loam, moist and friable. Truncated with smooth, clear boundary.
Zone 2	10YR6/6 brownish yellow clay with 5YR5/8 yellowish red mottles, moist and firm. Subsoil.

Figure 75. West profile of BHT 10.



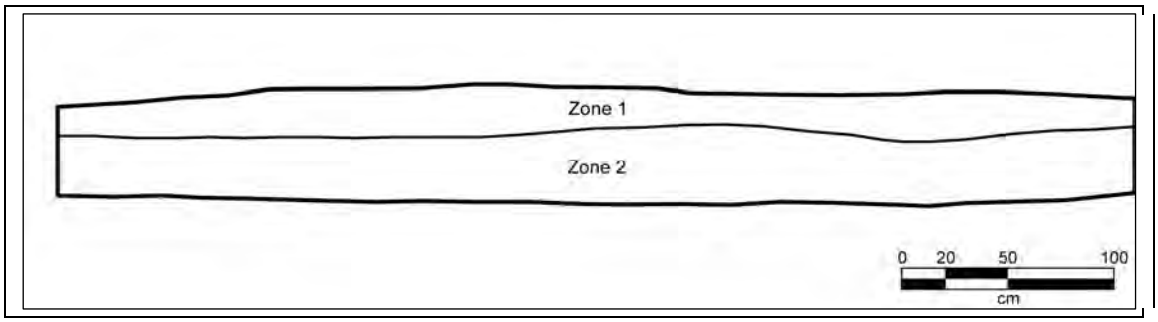
Zone 1	10YR4/4 Dark yellow brown fine sandy loam. Moist and friable with smooth, clear boundary.
Zone 2	10YR6/3 Pale brown fine sand. Moist and friable with smooth clear boundary and a few iron concretions.
Zone 3	7.5YR5/6 Strong brown clay, moist and firm. Subsoil.

Figure 76. South profile of BHT 11.



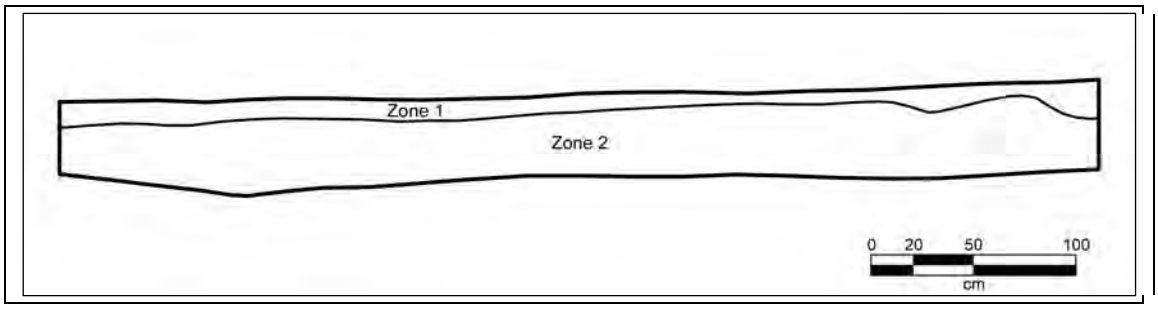
Zone 1	10YR4/3 Brown fine sandy loam, moist and friable, truncated. Bioturbated by hogs with few iron concretions. Smooth clear boundary, discontinuous across profile.
Zone 2	10YR6/3 Pale brown fine sand, moist and friable with a few iron concretions. Discontinuous across profile with a smooth clear boundary.
Zone 3	7.5YR5/6 Strong brown clay with many 10YR6/3 pale brown mottles. Discontinuous across profile, moist and firm. Subsoil.

Figure 77. North profile of BHT 18.



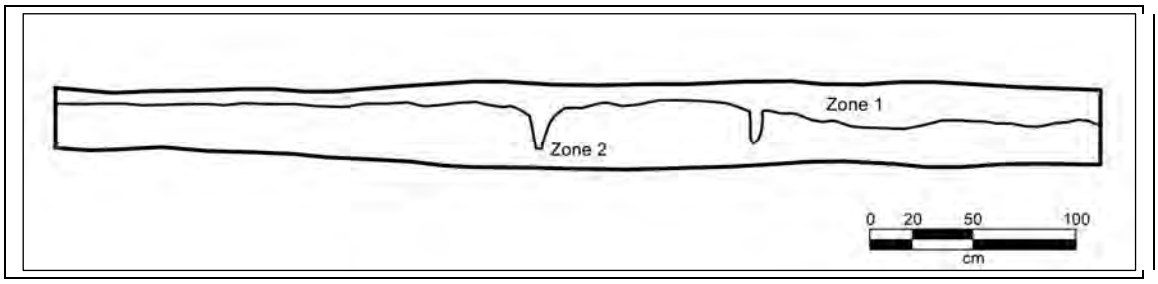
Zone 1	10YR3/3 Dark brown clay loam , moist and friable. Many roots and rootlets with a smooth clear boundary.
Zone 2	10YR6/6 Brownish yellow clay with many small calcium carbonate concretions. Moist and firm. Subsoil.

Figure 78. Northeast profile of BHT 20.



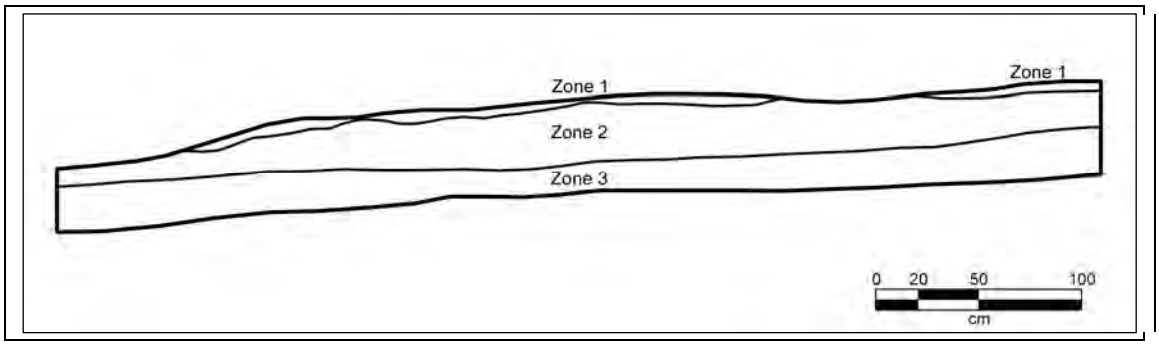
Zone 1	10YR3/3 Dark brown clay loam moist and friable. Few roots and rootlets with a few root casts that extend through zone 2. Clear, wavy boundary.
Zone 2	10YR7/1 Light gray clay with many 10YR5/8 yellowish brown mottles, moist and firm. Subsoil.

Figure 79. West profile of BHT 21.



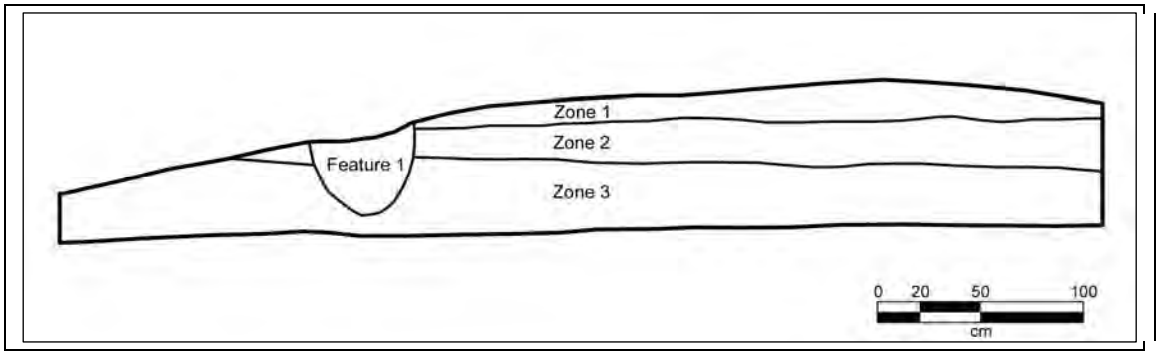
Zone 1	10YR3/2 Very dark grayish brown clay loam, moist and friable with many roots and rootlets. Clear, wavy boundary, bioturbated.
Zone 2	10YR6/2 Light brownish gray clay with many 7.5YR5/8 strong brown mottles. Moist and firm with few rootlets, bioturbated at top. Subsoil.

Figure 80. North profile of BHT 22.



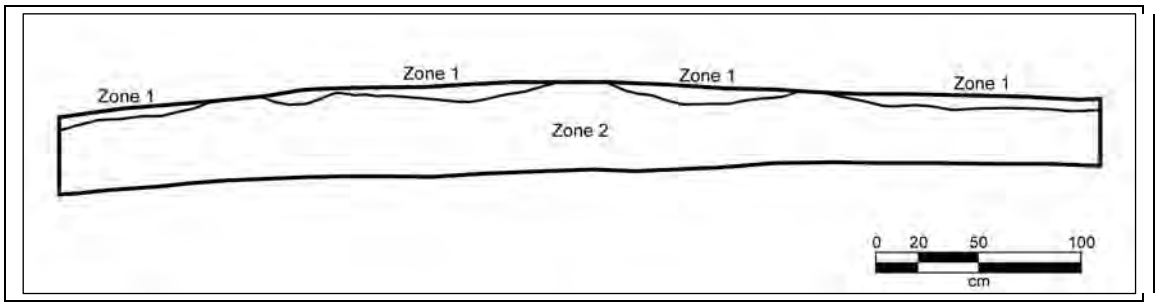
Zone 1	10YR3/3 Dark brown fine sandy loam. Moist and friable with many roots and rootlets. Discontinuous across profile with a clear, wavy boundary.
Zone 2	10YR6/4 Light yellow brown fine sand. Moist and friable, truncated in portion. A few roots and rootlets and some iron concretions with a clear, smooth boundary.
Zone 3	7.5YR5/6 Strong brown clay, moist and firm with a very few iron concretions. Subsoil.

Figure 81. Southwest profile of BHT 36.



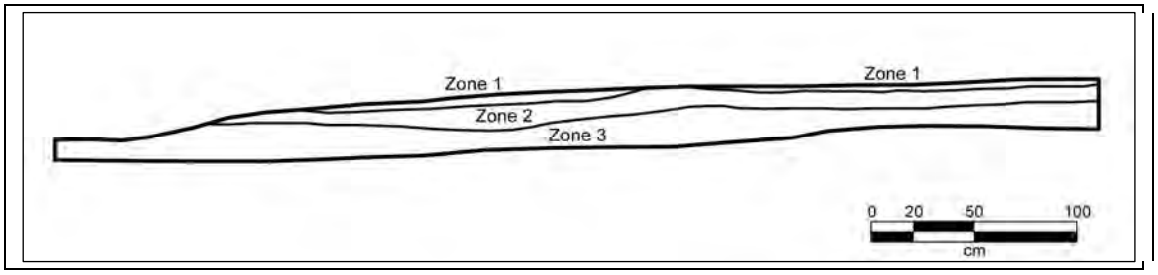
Zone 1	10YR3/3 Dark brown fine sandy loam. Moist and firm, truncated. Discontinuous across profile with many roots and rootlets. South end of profile cut by drainage with a clear wavy boundary.
Zone 2	10YR5/6 Yellow brown fine sand, moist and friable. Few roots and rootlets, few iron concretions. Truncated and discontinuous on south end with a clear smooth boundary.
Zone 3	5YR4/6 Yellowish red clay. Moist and firm with a few iron concretions. Subsoil.
Feature 1	10YR4/3 brown fine sandy loam. Screened a portion of soil, found no artifacts. Probably water erosion or krotovina.

Figure 82. West profile of BHT 37.



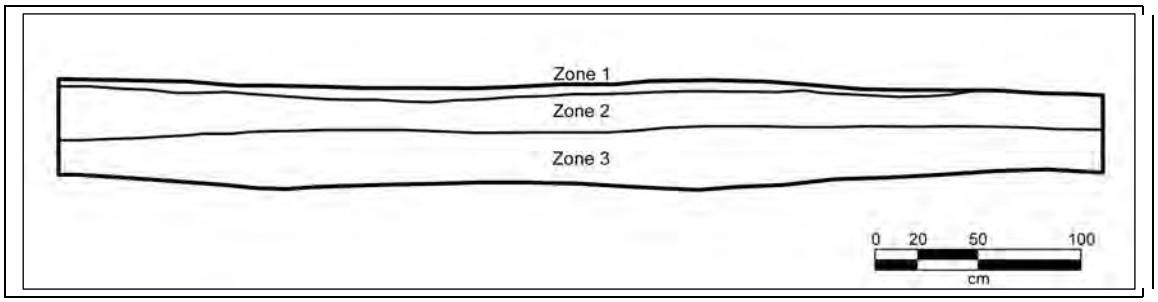
Zone 1	10YR3/4 Dark yellow brown fine sandy loam. Moist and friable with few roots and rootlets. Biotrubated, truncated, discontinuous across profile with a clear, wavy boundary.
Zone 2	10YR6/3 Pale brown clay with many 2.5YR4/8 red mottles. Moist and firm with few roots and rootlets. Subsoil.

Figure 83. Southwest profile of BHT 38.



Zone 1	10YR3/3 Dark brown clay loam. Moist and friable, truncated, and discontinuous across zone. Few roots and rootlets with a clear, wavy boundary.
Zone 2	10YR7/1 Light gray loamy clay with few 10YR6/6 brownish yellow mottles. Moist and friable with few roots and rootlets. Truncated and discontinuous across profile with a clear, wavy boundary.
Zone 3	10YR7/1 Light gray clay with many 2.5YR4/8 red mottles. Moist and firm, truncated at south end. Subsoil.

Figure 84. West profile of BHT 39.



Zone 1	10YR3/2 Very dark gray brown fine sandy loam. Moist and friable, truncated and bioturbated with many roots and rootlets and a clear, wavy boundary.
Zone 2	10YR5/4 Yellow brown fine sand, moist and friable with few rootlets. Truncated at north end. Bioturbated with a clear, wavy boundary.
Zone 3	10YR6/6 Brownish yellow clay with many 5YR4/6 yellow red mottles. Moist and firm with very few roots and rootlets. Subsoil.

Figure 85. West profile of BHT 42.

RECOMMENDATIONS

Moore Archeological Consulting, Inc. (MAC) conducted what began as a reconnaissance-level pedestrian cultural resource survey of a Capers Ridge Pump Station location and diversion alignment for the LBITP in Harris and Liberty Counties, Texas, and ultimately was expanded and enhanced, with constant agency consultation and agreement, into a 100 percent Intensive Cultural Resources Survey. That final product is presented herein. The pedestrian cultural resource investigations were performed between January 5, 2009 and April 2010. After consultation with the THC, mechanical trenching was conducted along portions of the LBITP alignment during December 2011. The project area is depicted on the Huffman, Plum Grove, Simmons Bottom, and Capers Ridge, Texas 7.5-minute USGS topographic quadrangle maps (Figures 1 and 1A through 1D). The initial objective of the investigation was to subdivide the project alignment into areas of high and low probability of the occurrence of cultural resources sites, as well as incorporate data on known cultural resource sites and surveys. This objective was modified, however, due to the large number of sites encountered. These investigations (MAC Report of Investigations No. 553) were conducted at the request of DESCO LP, WCW International, Inc., AECOM, and the Coastal Water Authority, under Texas Antiquities Permit Number 5082. The LBITP is also subject to permitting under Section 404 of the Clean Water Act and there is a USACE, Galveston District, Permit SWG-2009-00188 submitted for the proposed LBITP.

The pedestrian survey of the project area reported herein ultimately included both surface and subsurface (shovel test and backhoe) examination. A total of 1,046 shovel tests and 44 backhoe trenches were excavated. The investigations relocated one previously recorded site, 41LB42, and identified 26 new archeological sites (41HR1073-1076 and 41LB97-118). Four locations where shovel testing produced only a single prehistoric artifact were determined to be isolated finds (IF 1-4) and were not designated as archeological sites. A total of 1,568 artifacts were recovered during these investigations.

Of the 26 newly discovered locations, three are historic and 23 are prehistoric. 41HR1073 and 41HR1076 appear to be historic farmsteads that date to the early 20th century, while 41HR1075 contained artifacts associated with late 19th century occupations. All three appear to have potential subsurface features that may be partially filled cisterns. However, due to their late periods of occupation, none of these three historic sites appear to demonstrate potential for future study, and thus are not recommended for further investigations. Further, 41HR1076 is a historic farmstead located on the May family property (Parcel 47; Appendix 3) and the LBITP will avoid this property entirely. Once the current report is finalized, the diagnostic and non-redundant artifacts recovered from the three historic sites will be curated at TARL. No potentially historic structures were observed within or near the survey alignment.

Sixteen of the prehistoric sites, 41HR1074, 41LB98, 41LB100, 41LB101, 41LB102, 41LB105, 41LB106, 41LB107, 41LB108, 41LB109, 41LB110, 41LB111, 41LB113, 41LB114, 41LB115, and 41LB116, each appear to contain deposits of very limited artifact density and diversity, and are not recommended for further investigations. At one of these sites, 41LB105, only the portion of the site that was located within the APE was delineated and assessed for NRHP eligibility. Should impacts be planned for the portion of 41LB105 located outside the current APE boundary, additional investigations should be conducted to determine the NRHP eligibility for the additional site area.

One newly discovered site, 41LB118, was identified in an area that no longer is part of the LBITP ROW. This site was not fully delineated since it is no longer in the APE of the proposed project. The level of investigations conducted at this site was insufficient to assess it for NRHP eligibility. Consequently, additional delineation and assessment of site eligibility should be conducted if future impacts are proposed for the site.

Table 29. Recommendations by Site.

Site #	Type	Comments
41LB42	prehistoric	recommended for further investigations
41LB43	prehistoric	not relocated
41LB97	prehistoric	recommended for further investigations
41LB98	prehistoric	not eligible
41LB99	prehistoric	recommended for further investigations
41LB100	prehistoric	not eligible
41LB101	prehistoric	not eligible
41LB102	prehistoric	not eligible
41LB103	prehistoric	recommended for further investigations
41LB104	prehistoric	recommended for further investigations
41LB105	prehistoric	portion within APE not eligible
41LB106	prehistoric	not eligible
41LB107	prehistoric	not eligible
41LB108	prehistoric	not eligible
41LB109	prehistoric	not eligible
41LB110	prehistoric	not eligible
41LB111	prehistoric	not eligible
41LB112	prehistoric	recommended for further investigations
41LB113	prehistoric	not eligible
41LB114	prehistoric	not eligible
41LB115	prehistoric	not eligible
41LB116	prehistoric	not eligible
41LB117	prehistoric	recommended for further investigations
41LB118	prehistoric	site is outside APE, not evaluated
41HR1073	historic	not eligible
41HR1074	prehistoric	not eligible
41HR1075	historic	not eligible
41HR1076	historic	not eligible

Six of the newly discovered prehistoric sites, 41LB97, 41LB99, 41LB103, 41LB104, 41LB112, and 41LB117, appear to potentially contain intact cultural deposits that exhibit low-moderate artifact densities and diversity. Each of these six sites warrant further investigations to determine their potential significance for future research. These sites should be avoided, or if this is impossible, additional investigations will be necessary to determine eligibility prior to the initiation of construction.

The previously identified prehistoric site, 41LB42, was greatly expanded in size by the current investigations, and areas of denser and more diverse artifact concentrations within the site were identified that warrant further investigations. Another previously identified prehistoric site, 41LB43, could not be relocated at the published coordinates. This site was either originally plotted incorrectly or has eroded away. If misplotted, the site may lie outside the surveyed alignment or could be represented by one of the newly discovered sites 41LB100 or 41LB101 (which are located more than 200 m to the east of the site's reported UTMs). Once the current

report is finalized, the artifacts recovered from 41LB42 and the 23 newly discovered prehistoric sites will be curated at TARL.

In addition, Parcel 43A (North) would require survey-level investigations after right of entry (ROE) has been obtained, or when property acquisition has been completed. These recommendations are subject to review and concurrence. The parcel location map is located in Appendix 1 as Figure 1-1.

In the event that additional archeological deposits or features should be encountered during construction, work should cease in the immediate vicinity and the Archeology Division of the Texas Historical Commission contacted for further consultation.

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APPENDIX 1
Archeological Results and Status by Land Parcel

Parcel No.	Property Owner	ROE/ Ownership	Date of Investigation	Prehistoric Site	Historic Site	Additional Survey-Level Work Needed	
	Name	Status	Daily Field Log Date	Y or N or N/A	Y or N or N/A	Y or N	Comments
1	Capers Ridge PumpStation	CWA/City of Houston	2/6/2009 2/12/2009 3/5/2009 10/6/2009	Yes	Yes	No	Survey complete. Delineation of 41LB98, 41LB104, 41LB105, 41LB108, 41LB109, 41LB110, IF 2, IF 4 complete. Historic site 41LB41 deemed not significant by prior testing.
2	Shirley and Sons Construction (2A) and CWA (2B)	Expired (2A)/Yes (2B)	4/7/2010	Yes	Yes	No	Survey complete. 41LB99 located and delineation completed.
3	Forestland Estates	Yes	4/7/2010	No	No	No	Survey completed; investigated area along new road and entry gate.
4	Formerly owned by Forest Primeval Inc., but now owned by Coastal Water Authority (CWA)	Yes	1/19/2009 2/3/2009 2/5 and 2/6/2009 2/12/2009 and 2/13/2009 7/2 and 7/3/2009 7/16 and 7/17/09 10/7 and 10/8/2009; 10/12/09 and 10/15/09	Yes	No	No	Survey complete. Delineation of 41LB97, 41LB100-103, 41LB106, 41LB107, 41LB112-114, IF 1, IF 3 and previously recorded site 41LB42. 41LB118 was identified in an area that no longer is part of the LBITP ROW APE and was not delineated.
4.5	Formerly Capers Ridge Ranches, LLC. Now owned by CWA	Yes	1/19/2009 2/3/2009 2/5 and 2/6/2009 2/12 and 2/13/2009 7/2 and 7/3/2009 7/16 and 7/17/09 10/7 and 7/8/2009 10/12 through 10/15/2009	Yes	No	No	Survey complete, same as above.
5	Floyd Herman and Gail Page	Yes	4/8/2010	No	No	No	Not within LBITP ROW.
6	Floyd Herman and Gail Page	Yes	9/26/2009 6/29/2009 6/30/2009 7/2/2009 7/3/2009	No	No	No	Survey completed for Parcel 6; no sites identified.

7	Davis Wirt TR	Expired	6/19/2009 6/24-26/2009 7/6/2009	No	No	No	Survey completed for Parcel 7; no sites identified.
8	Davis Wirt TR	Expired	7/3/2009 7/6/2009 8/18/2009 4/19/2010	Yes	No	Yes	Survey completed for Parcel 8. Delineation of 41LB111 and 41LB115 completed.
9	Randolph Rolke, et. Al.	Yes	8/18/2009	No	No	No	Survey completed for Parcel 9; no sites identified.
10	Core Value L P	Yes	8/18/2009	No	No	No	Survey completed for Parcel 10; no sites identified.
11	Carl Edwin Aucoin Jr.	No ROE	8/18/2009	No	No	No	This parcel extends minimally into the LBITP ROW; survey complete.
12	Pura Vida Timberlands LLC	Yes	5/20/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 12; no sites identified.
13	Pura Vida Timberlands LLC	Yes	5/20/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 13; no sites identified.
14	Wheat Holdings	Yes	5/20/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 14; no sites identified.
15	Madelyn A. Durdin	Yes	5/20/2009, 5/21/09, 5/29/09	No	No	No	Survey completed for Parcel 15; no sites identified.
16	Madelyn A. Durdin	Yes	5/20/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 16; no sites identified.
17	Ronnie Ponder	Yes	5/22/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 17; no sites identified.
17.5	Timothy and Tiffany Gault	No ROE	N/A	N/A	N/A	No	Not within LBITP ROW, no survey required.
18	Fred Jr. and Lisa Majors	Yes	10/8/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 18; no sites identified.
19	Ronnie Ponder	Yes	5/22/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 19; no sites identified.

20	Ronnie Ponder	Yes	5/22/2009, 5/26/09, 5/29/09	No	No	No	Survey completed for Parcel 20; no sites identified.
21	Ronnie Ponder	Yes	5/22/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 21; no sites identified.
22	Ponder Ronnie	Yes	5/22/2009, 5/26/09, 5/28/09, 5/29/09	No	No	No	Survey completed for Parcel 22; no sites identified.
23	Pino Grande Timberlands	Yes	8/21/2009	N/A	N/A	No	Not within LBITP ROW, no survey required.
23.2	Stilson Properties	Yes	8/19/2009, 8/20/09	No	No	No	Survey completed for Parcel 23.2; no sites identified.
23.4	Riceland Properties	Yes	8/19/2009, 8/20/09	No	No	No	Survey completed for Parcel 23.4; no sites identified.
23.6	Enstor Houston HUB Storage	Yes	4/13/2010	No	No	No	Previous investigations conducted in 2007 by ENSTOR Houston HUB Storage; visual survey conducted, no additional investigation needed.
24	Pino Grande Timberlands	Yes	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
25	Pino Grande Timberlands	Yes	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
25.2	Carolyn Johnson Epple	Yes	8/20/2009 4/13/2010	No	No	No	Survey completed for Parcel 25.2; no sites identified.
25.4	Riceland Properties	Yes	8/20/2009	No	No	No	Survey completed for Parcel 25.4; no sites identified.
25.6	Carolyn Johnson Epple	Yes	8/20/2009	No	No	No	Survey completed for Parcel 25.6; no sites identified.
26	Riceland Properties	Yes	4/13/2010	No	No	No	Visual survey completed; no survey required.
27	Kari L. Reidland Quinn Trust	Yes	4/13/2010	No	No	No	Visual survey completed, no additional investigations needed
28	Ena Stoesser	Expired	7/29/2009	No	No	No	Survey completed for Parcel 28; no sites identified.
29	Ena Stoesser	Expired	7/29/2009	No	No	No	Survey completed for Parcel 29; no sites identified.
30	Ena Stoesser	Expired	7/29/2009	No	No	No	Survey completed for Parcel 30; no sites identified.
31	Ena Stoesser	Expired	7/29/2009	No	No	No	Survey completed for Parcel 31; no sites identified.
32	Ena Stoesser	Expired	7/29/2009	No	No	No	Survey completed for Parcel 32; no sites identified.

33	Stoesser Farms	Expired	7/29/2009	No	No	No	Survey completed for Parcel 33; no sites identified.
34	Guthrie F E Etal	No ROE	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
35	Stoesser Farms	Expired	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
36	Stoesser Farms	Expired	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
37	HF Houston Green Land	Yes	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
37.5	Stoesser Farms	Expired	7/29/2009	No	No	No	Survey completed for Parcel 37.5; no sites identified.
38	HF Houston Green Land	Yes	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
39	HF Houston Green Land	Yes	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
39.2	Stoesser Farms	Expired	7/29/2009	No	No	No	Survey completed for Parcel 39.2; no sites identified.
39.4	E L and F V Bender Estate	ROE	4/13/2010	No	No	No	Possible historic barn structure outside of the LBITP ROW; no further action needed.
39.6	Stoesser Farms	Expired	7/29/2009	No	No	No	Survey completed for Parcel 39.6; no sites identified.
39.8	Stoesser Farms	Expired	7/29/2009	No	No	No	Survey completed for Parcel 39.8; no sites identified.
40	J T Timberlands	Yes	N/A	N/A	N/A	No	Not within LBITP ROW; no survey required.
40.5	Stoesser Farms	Expired	7/29/2009	No	No	No	Survey completed for Parcel 40.5; no sites identified.
41	J T Timberlands	Yes	9/5/2009	No	No	No	Survey completed for Parcel 41; no sites identified.
42	Ned Holmes, Trustee	Yes	11/23/2009 11/24/2009 12/10/2009 12/28/2009 12/31/2009 1/7/2010	Yes	No	No	Survey complete. Delineation of 41LB117 complete.
North 1/2 of 43 (43A)	Richard and Sylvia Bumstead	No ROE	N/A	N/A	N/A	Yes	Cleared area owned by Bumstead; open (non-forested) northern section has not been surveyed. Property access dependent on property acquisition by CWA.
South 1/2 of 43 (43B)	Richard and Sylvia Bumstead	Yes	9/5/2009, 9/6/2009, 9/8/2009, 9/9/2009, 9/10/2009	Yes	No	No	Forested area owned by Bumstead; southern wooded section has been surveyed. Survey complete. 41LB116 discovered and delineated.
44	Cedarwood Properties	Yes	6/3/2009, 8/5/09	No	No	No	Survey completed for Parcel 44; no sites identified.

44.5	Roy A Seaberg, Sr. et al	No ROE	4/13/2010	No	No	No	Easement area adjacent between Parcel 44 and Parcel 45; survey completed.
45	Walter E McGinnis	Yes	8/5/2009	No	No	No	Survey completed for Parcel 45; no sites identified.
46	Walter E and Lauren McGinnis	Yes	8/5/2009	No	No	No	Survey completed for Parcel 46; no sites identified.
46.5	Riceland Properties	No ROE	N/A	No	No	No	Not within LBITP ROW; no survey required.
47	Robin April May	No ROE	N/A	No	No	No	41HR1076 identified and delineation complete. Not within LBITP ROW; no further surveys required.
47.5	Cooper Value III	Yes	9/6/2009, 9/17/2009, 9/18/2009	No	Yes	No	Survey completed for Parcel 47.5, no sites identified.
48	Rosetta Scott Venables	Yes	8/4/2009	No	No	No	Survey completed for Parcel 48; no sites identified.
49	Rosetta Scott Venables	Yes	8/4/2009	No	No	No	Survey completed for Parcel 49; no sites identified.
50	Texas Land Fund No. 6 L.P.	Yes	8/3/2009, 8/4/09	No	No	No	Survey completed for Parcel 50; no sites identified.
51	Texas Land Fund No. 6 L.P.	Yes	8/4/2009	No	Yes	Yes	Survey complete. 41HR1075 delineation complete.
52	Formerly E C Gilbreath, now owned by CWA	Yes	1/5/2009, 1/7/2009, 1/13/2009, 9/14/2009, 9/24/2009 4/13/2010	Yes	No	No	Survey complete. 41HR1074 delineation complete.
53	Formerly Woodland Shores Partners, now owned by CWA	Yes	1/5/2009, 1/7/2009, 1/13/2009, 9/14/2009, 9/21/2009	Yes	Yes	No	Survey complete. 41HR1073 delineation complete.
54	Formerly Woodland Shores Partners, now owned by CWA	Yes	1/5/2009, 1/7/2009, 1/13/2009	No	No	No	Survey complete. No sites identified.

See also Appendix 1, Figure 1-1 for location of the parcels identified by this tabulated summary.

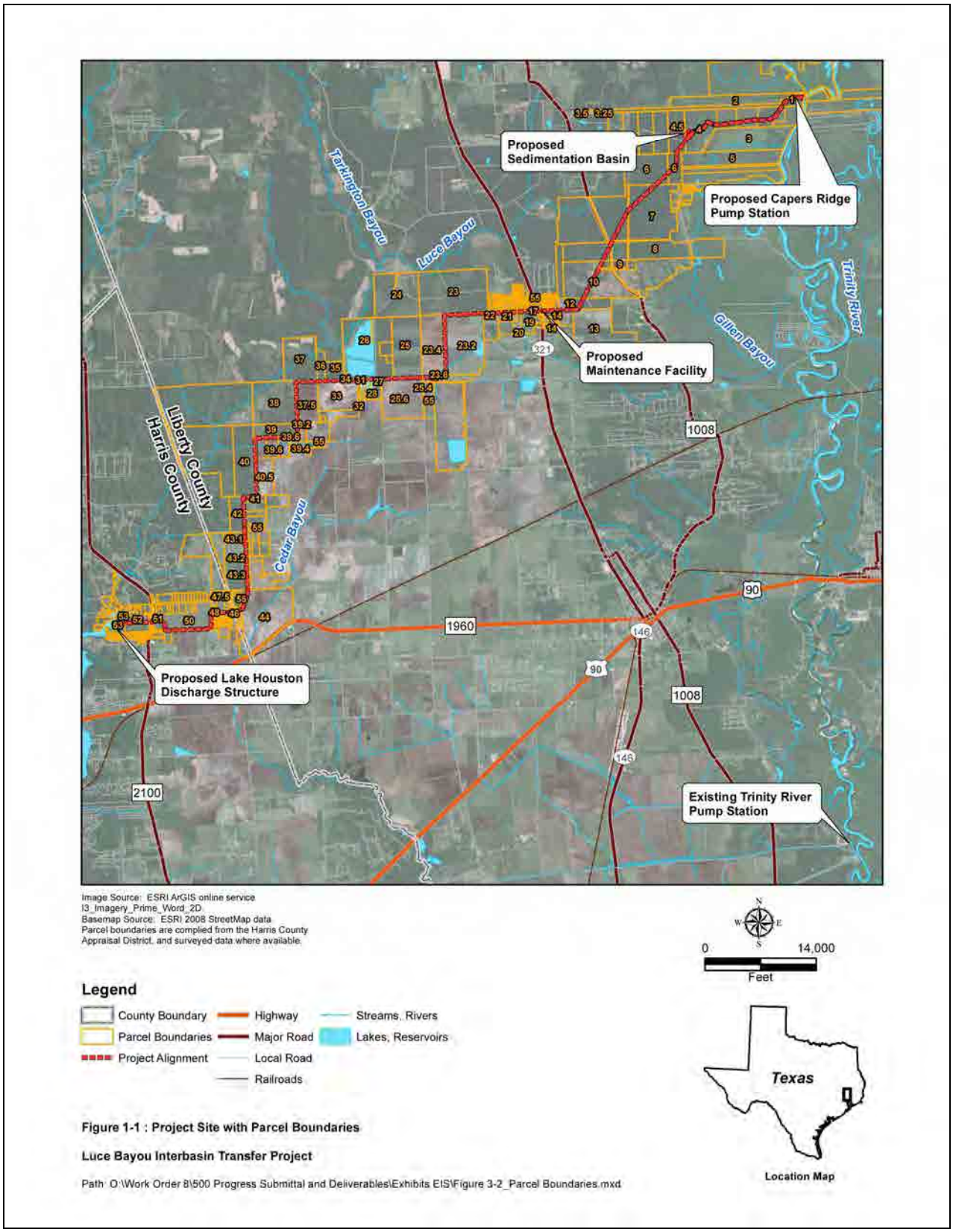

Figure 1-1. Project site with parcel boundaries (map provided by AECOM).

APPENDIX 2
Shovel Test Inventory

STP No.	Status	Excavator	Depth (cmbs)	Description	Comments
1	negative	Ferguson	0-12	10YR3/3 dark brown fine sandy loam	
			12-24	10YR4/6 dark yellowish brown fine loamy sand	
			24-50	10YR4/4 dark yellowish brown fine sandy clay loam	
			50-80	10YR6/3 pale brown fine loamy sand	
			80-96	10YR5/2 grayish brown fine sandy clay	subsoil
2	negative	Ferguson	0-10	10YR3/3 dark brown fine sandy loam	
			10-21	10YR4/6 dark yellowish brown fine loamy sand	
			21-52	10YR4/4 dark yellowish brown fine sandy clay loam	
			52-74	10YR6/3 pale brown fine loamy sand	
			74-84	10YR5/2 grayish brown fine sandy clay	subsoil
3	negative	Ferguson	0-8	10YR3/3 dark brown fine sandy loam	
			8-33	10YR5/6 yellowish brown fine loamy sand	
			33-48	5YR4/4 reddish brown clay	subsoil
4	negative	Ferguson	0-9	10YR3/3 dark brown fine sandy loam	
			9-25	10YR5/6 yellowish brown fine loamy sand	
			25-38	5YR4/4 reddish brown clay	subsoil
5	negative	Ferguson	0-6	10YR3/3 dark brown fine sandy loam	
			6-17	10YR5/6 yellowish brown fine loamy sand	
			17-50	5YR4/4 reddish brown clay	subsoil
6	negative	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam	
			8-13	10YR6/4 light yellowish brown fine sandy clay loam	
			13-50	5YR4/6 yellowish red clay with few 10YR6/2 brownish gray mottles	subsoil
7	positive?	Ferguson	0-8	10YR4/3 brown fine sandy loam	
			8-30	mottled 10YR4/3 brown & 10YR6/3 pale brown sandy loam	
			30-50	10YR6/4 light yellowish brown fine loamy sand	
			50-65	10YR5/4 yellowish brown fine sandy clay	subsoil
8	negative	Ferguson	0-6	10YR3/2 very dark grayish brown fine sandy loam	
			6-14	10YR6/4 light yellowish brown fine loamy sand	
			14-26	10YR5/4 yellowish brown fine sandy clay	subsoil
9	negative	Ferguson	0-4	10YR3/3 dark brown fine sandy loam	
			4-15	10YR5/4 yellowish brown fine loamy sand	
			15-29	10YR5/4 yellowish brown fine sandy clay	subsoil
10	positive	Ferguson	0-13	10YR3/2 very dark grayish brown fine sandy loam	
			13-29	10YR5/4 yellowish brown fine loamy sand	
			29-40	10YR5/4 yellowish brown fine sandy clay	subsoil
11	negative	Ferguson	0-12	10YR3/3 dark brown fine sandy loam	
			12-30	10YR4/6 dark yellowish brown fine sandy loam	
			30-40	10YR5/2 grayish brown fine sandy clay	subsoil
12	negative	Ferguson	0-32	brown & grayish brown sandy loam	flood deposit
			32-42	same as above but sandy clay loam	
			42-70	mottled gray, dark gray, & orange loamy sand	
			70-74	same as above but sandy clay loam	wet, sticky, subsoil
13	negative	Ferguson	0-12	dark grayish brown fine sandy loam	disturbed
			12-20	pale brown sandy loam	disturbed
			20-70	10YR4/3 brown fine loamy sand	
			70-80	10YR5/2 grayish brown fine sandy clay	subsoil
14	negative	Ferguson	0-9	10YR4/3 brown fine sandy loam	
			9-20	10YR6/4 light yellowish brown fine sandy loam	
			20-30	10YR6/4 light yellowish brown fine sandy clay	subsoil
15	negative	Ferguson	0-15	10YR4/3 brown fine sandy loam	
			15-38	10YR6/4 light yellowish brown fine loamy sand	

			38-62	10YR6/4 light yellowish brown fine sandy clay loam that grades to fine sandy clay at bottom	subsoil
16	positive	Ferguson	0-70	10YR4/3 brown fine sandy loam	mound
			70-86	mottled 10YR5/3 brown & 10YR5/2 grayish brown & orange fine sandy clay loam	dense and dry subsoil
17	negative	Ferguson	0-9	10YR4/3 brown fine sandy loam	
			9-62	10YR6/4 light yellowish brown fine loamy sand	
			62-72	10YR6/4 light yellowish brown fine sandy clay	subsoil
18	negative	Ferguson	0-5	10YR4/3 brown fine sandy loam	
			5-11	10YR6/4 light yellowish brown fine sandy clay loam	
			11-24	10YR5/4 yellowish brown fine sandy clay	subsoil
19	negative	Ferguson	0-19	10YR4/2 dark grayish brown fine sandy loam	mound
			19-29	10YR6/4 light yellowish brown fine loamy sand	
			29-59	10YR6/3 pale brown fine sandy clay loam	
			59-72	10YR5/2 grayish brown fine sandy clay	subsoil
20	negative	Ferguson	0-8	10YR4/2 dark grayish brown fine sandy loam	mound
			8-22	10YR6/4 light yellowish brown fine loamy sand	
			22-70	10YR6/3 pale brown fine sandy clay loam	
			70-80	10YR5/2 grayish brown fine sandy clay	subsoil
21	positive	Carroll	0-103	10YR5/3 brown sand	
22	positive	Ferguson	0-9	10YR4/2 dark grayish brown fine sandy loam	
			9-32	10YR3/3 dark brown sandy loam	
			32-50	10YR06/3 pale brown sandy clay	subsoil
23	positive	Ferguson	0-11	10YR4/2 dark grayish brown sandy loam	
			11-25	10YR5/3 brown loamy sand	
			25-75	10YR5/4 yellowish brown loamy sand	midden
			75-120	10YR5/3 brown loamy sand	
24	positive	Carroll	0-15	7.5YR4/2 brown sandy loam	
			15-40	Mottled, 7.5YR4/2 brown and 7.5YR5/6 strong brown, sandy clay	
			40-60	7.5YR4/3 brown sand	
			60-65	7.5YR5/8 yellow brown clay	subsoil
25	positive	Ferguson	0-20	10YR4/2 dark grayish brown sandy loam	
			20-38	10YR5/6 yellowish brown fine loamy sand	subsoil
26	negative	Carroll	0-10	10YR5/3 brown sandy loam	
			10-35	10YR5/4 yellow brown sandy clay	
			35-45	10YR5/8 yellow brown clay	subsoil
27	negative	Ferguson	0-8	10YR4/2 dark grayish brown clay	
			8-30	10YR5/6 yellowish brown clay	subsoil
28	negative	Carroll	0-15	7.5YR3/2 dark brown loamy clay	
			15-45	10YR5/8 yellow brown clay	subsoil
29	negative	Ferguson	0-5	10YR4/2 dark grayish brown clay	
			5-23	10YR5/6 yellowish brown clay	subsoil
30	negative	Carroll	0-25	7.5YR3/2 dark brown loamy clay	
			25-45	10YR5/8 yellow brown clay	subsoil
31	negative	Ferguson	0-9	10YR4/2 dark grayish brown clay	
			9-28	10YR5/6 yellowish brown clay	subsoil
32	negative	Carroll	0-10	10YR4/3 brown loam	
			10-30	10YR5/3 brown clay loam	
			30-45	10YR5/8 yellow brown clay	subsoil
33	negative	Ferguson	0-7	10YR5/2 grayish brown clay	
			7-27	10YR7/2 light gray clay with many reddish orange mottles	
34	negative	Carroll	0-10	7.5YR4/3 brown loam with some clay	
			10-40	Mottled layer with lots of concretions	probably fill
			40-50	10YR5/8 yellow brown clay	subsoil
35	negative	Ferguson	0-3	Humic	
			3-23	10YR5/4 yellowish brown fine sandy loam	
			23-33	10YR7/2 light gray clay with many reddish orange mottles	

36	negative	Carroll	0-4	10YR5/2 grayish brown clay loam	
			4-50	10YR5/2 grayish brown clay mottled with 10YR5/8 yellowish brown clay	
37	negative	Carroll	0-110	7.5YR5/2 brown sand	
38	negative	Ferguson	0-16	10YR4/2 dark grayish brown clay	
			16-34	10YR5/4 yellowish brown clay	
39	negative	Carroll	0-10	10YR2/1 black humic loam	
			10-25	10YR5/3 brown clay loam with some sand	
			25-45	10YR2/2 very dark brown clay loam with lots of sandstone	
			45-50	10YR4/6 dark yellowish brown clay, compact	
			50-55	10YR4/6 dark yellowish brown clay, moist	
40	negative	Ferguson	0-18	10YR4/2 dark grayish brown clay	
			18-34	10YR5/4 yellowish brown clay	
41	negative	Ferguson	0-6	10YR3/2 very dark grayish brown fine sandy loam	
			6-24	10YR5/4 yellowish brown fine loamy sand	
			24-35	10YR5/8 yellow brown clay	subsoil
42	positive	Carroll	0-5	7.5YR5/3 brown humic loam	
			5-35	10YR7/4 very pale brown sand with concretions increasing with depth	
			35-45	10YR7/4 very pale brown sand, hard-packed with few concretions	
			45-100	10YR5/6 yellowish brown clay	
43	negative	Ferguson	0-9	clay fill	
			9-14	10YR4/2 dark grayish brown fine sandy loam	
			14-25	10YR5/6 yellowish brown fine loamy sand	
			25-38	7.5YR4/6 strong brown clay	subsoil
44	positive	Carroll	0-15	7.5YR5/2 brown loam	
			15-30	10YR6/8 brownish yellow clay loam	
			30-40	5YR4/4 reddish brown clay	subsoil
45	negative	Ferguson	0-8	Mottled grayish brown/dark grayish brown fine sandy clay loam, very bioturbated and disturbed by hogs	
			8-20	grayish brown fine sandy clay loam with chunks of red clay, bioturbated	
			20-30	Mottled 2.5YR4/8 red and 10YR6/2 light brownish gray clay	subsoil
46	negative	Carroll	0-10	10YR7/2 light gray sand	
			10-30	10YR6/3 pale brown sand	
			30-40	5YR4/4 reddish brown clay	subsoil
47	negative	Ferguson	0-10	Mottled grayish brown/dark grayish brown fine sandy clay loam, very bioturbated and disturbed by hogs	
			10-15	grayish brown fine sandy clay loam with chunks of red clay, bioturbated	
			15-25	Mottled 2.5YR4/8 red and 10YR6/2 light brownish gray clay	subsoil
48	negative	Ferguson	0-12	10YR5/2 grayish brown fine sandy loam	
			12-30	10YR6/4 light yellowish brown fine loamy sand	
			30-42	2.5YR4/8 red clay	
49	negative	Carroll	0-8	7.5YR3/2 dark brown humic loam	
			8-25	10YR4/3 brown sandy loam	
			25-40	5YR4/6 yellowish red clay	subsoil
50	positive	Ferguson	0-6	10YR2/2 very dark brown fine sandy loam	
			6-18	10YR5/4 yellowish brown fine loamy sand	
			18-29	2.5YR4/8 red clay	subsoil
51	negative	Carroll	0-8	7.5YR3/2 dark brown humic loam	
			8-35	10YR4/3 brown sandy loam	
			35-45	5YR4/6 yellowish red clay	subsoil
52	negative	Ferguson	0-5	10YR4/2 dark grayish brown fine sandy loam	
			5-25	10YR5/4 yellowish brown fine loamy sand	
			25-32	2.5YR4/8 red clay	subsoil
53	positive	Carroll	0-5	7.5YR3/2 dark brown humic loam	
			5-40	10YR4/3 brown sandy loam	
			40-50	5YR4/6 yellowish red clay	subsoil

54	positive	Ferguson	0-4	10YR4/3 brown fine sandy loam	
			4-16	10YR5/4 yellowish brown fine loamy sand	
			16-25	10YR4/6 dark yellowish brown clay with many orange mottles	subsoil
55	positive	Carroll	0-5	7.5YR3/2 dark brown humic loam	
			5-45	10YR4/3 brown sandy loam	
			45-55	5YR4/6 yellowish red clay	subsoil
56	negative	Ferguson	0-14	2.5y3/3 dark olive brown clay	
			14-28	10YR4/4 dark yellowish brown clay	
57	negative	Carroll	0-8	7.5YR3/2 dark brown humic loam	
			8-30	10YR4/3 brown sandy loam	
			30-40	5YR4/6 yellowish red clay	subsoil
58	negative	Ferguson	0-6	10YR4/2 dark grayish brown fine sandy loam	
			6-28	10YR5/4 yellowish brown fine loamy sand	
			28-38	2.5YR4/8 red clay	subsoil
59	negative	Carroll	0-4	humic	
			4-50	7.5YR6/1gray clay w/ orqange mottles	subsoil
60	negative	Ferguson	0-4	humic	
			4-35	2.5y6/2 light brownish gray clay w/ orange mottles	subsoil
61	positive	Carroll	0-4	humic	
			4-35	10YR6/4 light yellowish brown fine loamy sand	
			35-45	2.5YR4/6 red clay	subsoil
62	negative	Ferguson	0-3	humic	
			3-29	10YR5/4 yellowish brown fine loamy sand	
			29-40	5YR4/6 yellowish red clay	subsoil
63	negative	Carroll	0-4	humic	
			4-30	10YR5/4 yellowish brown fine loamy sand	
			30-35	2.5YR4/6 red clay	subsoil
64	positive	Ferguson	0-4	humic	
			4-12	10YR5/4 yellowish brown fine loamy sand	
			12-28	10YR5/4 yellowish brown fine sandy clay loam	
			28-35	7.5YR4/6 strong brown clay	subsoil
65	negative	Carroll	0-2	humic	
			2-40	10YR6/4 light yellowish brown fine loamy sand	
			40-60	10YR6/4 light yellowish brown fine sandy clay loam w/ orange mottles	
			60-65	10YR6/4 light yellowish brown fine sandy clay w/ orange mottles	subsoil
66	negative	Ferguson	0-3	humic	
			3-8	10YR3/2 very dark grayish brown clay loam	
			8-33	10YR6/3 pale brown clay w/ orange mottles	subsoil
67	negative	Carroll	0-2	humic	
			2-35	7.5YR6/1gray clay w/ orqange mottles	subsoil
68	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam	mound
			10-21	mottled brown & yellowish brown fine sandy loam	bioturbated
			21-80	10YR5/4 yellowish brown fine loamy sand	
			80-86	10YR7/2 light gray clay with many reddish orange mottles	subsoil
69	negative	Carroll	0-8	humic	mound
			8-60	10YR6/4 light yellowish brown fine loamy sand	
			60-70	10YR6/4 light yellowish brown fine sandy clay w/ orange mottles	subsoil
70	positive	Ferguson	0-8	10YR4/2 dark grayish brown fine sandy loam	
			8-28	10YR5/4 yellowish brown fine loamy sand	
			28-52	10YR5/4 yellowish brown fine sandy clay loam	subsoil
71	positive	Carroll	0-6	humic	
			6-45	10YR6/4 light yellowish brown fine loamy sand	
			45-70	10YR6/4 light yellowish brown fine sandy clay loam w/ orange mottles	
			70-75	10YR6/4 light yellowish brown fine sandy clay w/ orange mottles	subsoil

72	negative	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam	mound
			10-41	10YR5/5 yellowish brow fine loamy sand	
			41-80	10YR7/2 light gray fine sandy clay loam w/ many orange mottles	
			80-90	10YR7/2 light gray fine sandy clay w/ many orange mottles	subsoil
73	negative	Ferguson	0-12	10YR4/2 dark grayish brown fine sandy loam	mound
			12-85	10YR5/4 yellowish brown fine loamy sand	
			85-100	10YR7/2 light gray fine loamy sand w/ many orange mottles	
74	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam	berm
			10-73	10YR5/4 yellowish brown fine loamy sand	
			73-95	10YR7/2 light gray fine loamy sand w/ many orange mottles	
75	negative	Carroll	0-8	humic	
			8-55	10YR6/4 light yellowish brown fine loamy sand	charcoal
			55-70	10YR6/4 light yellowish brown fine sandy clay loam w/ orange mottles	
			70-75	10YR6/4 light yellowish brown fine sandy clay w/ orange mottles	
76	negative	Ferguson	0-4	humic	
			4-18	10YR4/2 dark grayish brown clay loam	
			18-30	10YR5/4 yellowish brown fine sandy clay loam w/ many orange mottles	impassible root
77	negative	Carroll	0-4	10YR3/4 dark yellowish brown sandy clay loam	
			4-80	10YR4/6 dark yellowish brown clay with many orange mottles	subsoil
78	negative	Ferguson	0-8	10YR3/2 very dark grayish brown sandy loam	
			8-30	10YR5/6 yellowish brown loamy sand	
			30-45	10YR5/4 yellowish brown sandy clay w/ many orange mottles	subsoil
79	negative	Carroll	0-105	10YR6/4 light yellowish sand	
80	negative	Ferguson	0-3	10YR3/2 very dark grayish brown sandy loam	
			3-20	10YR5/6 yellowish brown loamy sand	
			20-31	10YR5/4 yellowish brown sandy clay w/ many orange mottles	subsoil
81	negative	Carroll	0-6	10YR6/4 light yellowish brown sand	
			6-60	10YR5/3 brown clay loam	
			60-75	10YR5/3 brown clay w/ orange mottles	subsoil
82	positive	Ferguson	0-6	10YR3/2 very dark grayish brown sandy loam	
			6-30	10YR6/4 light yellowish brown loamy sand	
			30-43	5YR4/6 yellowish red clay	subsoil
83	positive	Carroll	0-2	10YR3/2 very dark grayish brown sandy loam	
			2-35	10YR5/4 yellowish brown loamy sand	
			35-45	7.5YR5/6 strong brown clay	subsoil
84	positive	Ferguson	0-6	10YR3/2 very dark grayish brown sandy loam	
			6-29	10YR6/4 light yellowish brown loamy sand	
			29-38	5YR4/6 yellowish red clay	subsoil
85	negative	Carroll	0-40	10YR4/3 brown clay loam	
			40-50	7.5YR5/6 strong brown clay	subsoil
86	negative	Rodriguez	0-38	10YR4/1 dark gray clay	subsoil
87	negative	Ferguson	0-20	10YR3/1 very dark gray clay	
			20-38	10YR4/1 dark gray clay	subsoil
88	negative	Rodriguez	0-38	10YR4/1 dark gray clay	subsoil
89	negative	Ferguson	0-24	10YR4/1 dark gray clay	
			24-36	2.5y5/2 grayish brown clay	subsoil
90	negative	Rodriguez	0-12	10YR3/1 very dark gray clay	
			12-32	10YR4/1 dark gray clay	subsoil
91	negative	Ferguson	0-16	2.5y3/1 very dark gray clay	
			16-50	a bit darker than above	subsoil
92	negative	Rodriguez	0-35	10YR4/1 dark gray clay	subsoil
93	negative	Ferguson	0-50	fill from drainage	
			50-70	10YR4/1 dark gray clay	subsoil
94	negative	Rodriguez	0-32	10YR4/1 dark gray clay	subsoil

95	negative	Ferguson	0-3	humic	
			3-15	10YR5/2 grayish brown fine sandy clay loam	
			15-36	10YR4/1 dark gray clay	
			36-50	10YR5/2 grayish brown clay	subsoil
96	negative	Rodriguez	0-35	10YR4/1 dark gray clay	subsoil
97	negative	Rodriguez	0-18	10YR5/2 grayish brown fine sandy clay loam	
			18-48	10YR3/3 dark brown fine sandy loam	
			48-56	10YR5/4 yellowish brown silty clay loam	
			56-63	10YR5/4 yellowish brown silty clay	subsoil
98	negative	Ferguson	0-5	humic	
			5-25	10YR5/4 yellowish brown clay w/ light gray and orange mottles	subsoil
99	negative	Ferguson	0-5	humic	
			5-23	10YR5/4 yellowish brown clay w/ light gray and orange mottles	subsoil
100	negative	Ferguson	0-3	humic	
			3-23	10YR5/4 yellowish brown clay w/ light gray and orange mottles	subsoil
101	negative	Ferguson	0-24	10YR6/3 very pale brown fine loamy sand w/ brown mottles	
			24-50	10YR5/6 yellowish brown fine sandy clay loam w/ pale brown mottles	
			50-55	10YR5/6 yellowish brown clay w/ pale brown mottles	subsoil
102	negative	Ferguson	0-6	10YR3/3 dark grayish brown humic	
			6-20	10YR6/3 pale brown fine sandy loam w/ many orange mottles	
			20-42	10YR5/2 grayish brown fine sandy loam w/ many orange mottles	
			42-52	Mottled 10YR5/2 grayish brown, 10YR6/3 pale brown, orange fine sandy clay	subsoil
103	negative	Ferguson	0-3	humic	
			3-20	10YR5/4 yellowish brown fine sandy loam	
			20-42	10YR5/3 brown fine sandy loam	
			42-63	10YR6/1 light brown gray fine sandy clay loam	
			63-75	10YR6/1 light brown gray fine sandy clay	subsoil
104	negative	Ferguson	0-3	humic	
			3-20	10YR5/4 yellowish brown fine sandy loam	
			20-53	10YR5/3 brown fine sandy loam	
			53-80	10YR6/1 light grayish brown fine sandy clay loam	
			80-85	10YR6/1 light brown gray fine sandy clay	subsoil
105	negative	Ferguson	0-3	humic	
			3-26	10YR5/4 yellowish brown fine sandy loam	
			26-45	10YR5/3 brown fine sandy loam	
			45-79	10YR6/1 light grayish brown fine sandy clay loam	
			79-88	10YR6/1 light grayish brown fine sandy clay	subsoil
106	negative	Ferguson	0-5	humic	
			5-35	10YR5/4 yellow brown fine sandy loam	
			35-65	10YR6/1 light grayish brown fine sandy clay loam	
			65-76	10YR6/1 light grayish brown fine sandy clay	subsoil
107	negative	Ferguson	0-3	humic	
			3-25	10YR5/4 yellowish brown fine sandy loam	
			25-53	10YR5/3 brown fine sandy loam	
			53-65	10YR6/1 light grayish brown fine sandy clay loam	
			65-75	10YR6/1 light grayish brown fine sandy clay	subsoil
108	negative	Carroll	0-20	7.5YR3/2 dark brown clay	subsoil
			20-30	7.5YR3/2 dark brown clay w/ orange clay mottles; bioturbated by roots	subsoil, bioturbated
			30-45	7.5YR3/2 dark brown clay w/ orange mottles bioturbated by roots	subsoil, bioturbated
109	negative	Ferguson	0-8	10YR4/2 dark grayish brown clay	
			8-30	10YR5/2 gray brown clay w/ red orange mottles	subsoil
110	negative	Alba	0-11	10YR4/2 dark gray brown sandy clay	

			11-31	10YR5/2 dark brown clay	subsoil
111	negative	Carroll	0-55	10YR3/3 dark brown loam w/ charcoal concentrations and burned clay at surface	charcoal, burned clay
			55-60	10YR5/2 grayish brown clay w/ orange mottles	subsoil
112	negative	Ferguson	0-35	10YR4/3 brown fine sandy loam	mound
			35-47	10YR5/2 grayish brown clay w/ orange mottles	subsoil
113	negative	Carroll	0-60	10YR4/3 brown loam w/ clay mottles	mound
			60-65	10YR5/2 grayish brown clay w/ orange mottles	subsoil
114	negative	Alba	0-12	10YR4/2 dark grayish brown sandy clay	
			12-27	10YR5/2 grayish brown clay w/ red clay mottles	subsoil
115	negative	Ferguson	0-22	soil push	disturbed, mound
			22-40	10YR5/2 grayish brown clay w/ orange mottles	subsoil
			40-48	Mottled 10YR5/2 grayish brown, 10YR7/1 light gray, and orange clay	
116	negative	Carroll	0-65	10YR4/3 brown loam w/ clay mottles	mound
			65-75	10YR5/2 grayish brown clay w/ orange mottles	subsoil
117	negative	Alba	0-10	10YR7/1 light gray sandy clay	mound
			10-30	10YR4/2 dark grayish brown clay	
			30-37	10YR4/2 dark grayish brown clay w/ red clay mottles	subsoil
118	negative	Ferguson	0-50	10YR4/3 brown fine sandy loam	mound
			50-88	10YR5/2 grayish brown fine sandy clay loam	subsoil
119	negative	Carroll	0-65	10YR4/3 brown loam w/ clay mottles	mound
			65-75	10YR5/2 grayish brown clay w/ orange mottles	subsoil
120	negative	Alba	0-7	10YR7/2 light gray sandy clay	
			7-32	10YR4/2 dark grayish brown clay w/ red clay mottles	subsoil
121	negative	Ferguson	0-35	10YR3/2 very dark grayish brown clay	
			35-40	10YR4/2 dark grayish brown clay	subsoil
122	negative	Carroll	0-30	7.5YR3/2 dark brown clay	
			30-40	7.5YR3/2 dark brown clay w/ orange mottles	subsoil
123	negative	Alba	0-8	10YR7/2 light gray sandy clay	
			8-31	10YR4/1 dark gray clay	subsoil
124	negative	Ferguson	0-38	10YR5/2 grayish brown clay	
			38-50	10YR5/2 grayish brown clay w/ orange mottles	subsoil
125	negative	Carroll	0-25	7.5YR3/2 dark brown clay	
			25-35	7.5YR3/2 dark brown clay w/ orange mottles	subsoil
126	negative	Alba	0-3	10YR4/2 dark grayish brown clay	subsoil
127	negative	Carroll	0-30	7.5YR3/2 dark brown clay	
			30-35	7.5YR3/2 dark brown clay w/ orange mottles	subsoil
128	negative	Carroll	0-65	10YR5/3 brown sandy loam	
			65-75	10YR5/3 brown clay w/ orange mottles	subsoil
129	negative	Ferguson	0-10	10YR4/2 dark grayish brown clay	
			10-34	10YR3/1 very dark gray clay	subsoil
130	negative	Morehead	0-6	10YR4/2 dark grayish brown clay	
			6-36	10YR3/1 very dark gray clay	subsoil
131	negative	Carroll	0-30	10YR4/2 dark grayish brown clay w/ orange mottles	subsoil
132	negative	Ferguson	0-13	10YR4/1 dark grayish brown clay	
			13-30	10YR3/1 very dark gray clay	subsoil
133	negative	Morehead	0-13	10YR3/2 very dark grayish brown clay w/ yellowish brown mottles	subsoil
134	negative	Carroll	0-10	10YR4/2 dark grayish brown clay loam	
			10-35	10YR4/2 dark grayish brown clay w/ orange mottles	subsoil
135	negative	Ferguson	0-9	10YR6/2 light brownish gray fine sandy loam	mound
			9-19	10YR6/3 pale brown fine loamy sand	
			19-54	Mottled 10YR5/3 brown, 10YR6/3 pale brown fine sandy clay loam	
			54-68	Mottled 10YR5/2 grayish brown, 10YR5/3 brown, orange fine sandy clay	subsoil
136	negative	Morehead	0-65	10YR5/2 grayish brown fine sandy clay, bioturbated by roots	bioturbated

137	negative	Carroll	0-60	10YR6/4 light yellowish brown sandy loam	
			60-70	10YR6/4 light yellowish brown clay w/ orange mottles	subsoil
138	negative	Ferguson	0-3	10YR4/2 dark grayish brown humic	pond
			3-15	10YR6/4 light yellowish brown fine sandy clay loam w/ orange mottles	
			15-40	10YR6/1 gray fine sandy clay w/ orange mottles	
139	negative	Morehead	0-62	10YR7/4 very pale brown fine sandy loam	bioturbated, mound
140	negative	Carroll	0-55	10YR6/4 light yellowish brown sandy loam	mound
			55-70	10YR6/4 light yellowish brown clay w/ orange mottles	subsoil
141	negative	Ferguson	0-5	humic	mound
			5-35	10YR6/3 pale brown fine loamy sand	
			35-70	Mottled 10YR6/3 pale brown, 10YR5/3 brown fine sandy clay loam	
			70-83	10YR6/1 gray fine sandy clay w/ orange mottles	
142	negative	Morehead	0-28	10YR5/2 grayish brown fine sandy loamy clay	impassible root
143	negative	Carroll	0-55	10YR6/4 light yellowish brown sandy loam	mound
			55-65	10YR6/4 light yellowish brown clay w/ orange mottles	subsoil
144	negative	Morehead	0-21	10YR6/3 pale brown fine sandy clay	mound
145	negative	Ferguson	0-23	Mottled 10YR5/4 yellowish brown, 10YR7/1 light gray, orange clay	disturbed
			23-38	10YR7/2 light gray clay w/ orange mottles; intact	subsoil
146	negative	Morehead	0-3	humic	
			3-29	10YR7/1 light gray clay w/ orange mottles	
			29-45	10YR6/1 gray clay w/ orange mottles	subsoil
147	negative	Carroll	0-20	10YR5/6 yellowish brown clay	
			20-30	10YR6/2 light brownish gray clay w/ orange mottles	subsoil
148	negative	Ferguson	0-4	10YR2/2 very dark brown humic	
			4-20	10YR4/4 dark yellowish brown clay w/ light brown and orange mottles	
			20-30	Mottled 7.5YR7/2 light gray, 10YR5/8 yellowish brown clay	subsoil
149	negative	Morehead	0-5	10YR3/3 dark brown humic	
			5-10	10YR5/3 brown clay w/ orange mottles	
			10-32	10YR7/1 light gray clay w/ orange mottles; bioturbated by roots	subsoil, mound, bioturbated
150	negative	Carroll	0-10	10YR6/4 light yellowish brown sandy loam	
			10-35	10YR5/6 yellowish brown clay	subsoil
151	negative	Ferguson	0-2	humic	
			2-8	10YR6/3 pale brown fine sandy loam	
			8-30	10YR6/4 light yellowish brown fine loamy sand w/ orange mottles	
			30-44	Mottled 2.5YR7/2 light gray, 10YR5/8 yellowish brown clay	subsoil
152	negative	Morehead	0-16	10YR5/6 yellowish brown fine loamy clay; charcoal found at surface and in level	
			16-51	10YR7/1 light gray clay w/ orange mottles	subsoil, mound, charcoal
153	negative	Carroll	0-2	10YR6/4 light yellowish brown sandy loam	
			2-30	10YR5/6 yellowish brown clay	
			30-35	10YR6/2 light brownish gray clay w/ orange mottles	subsoil, mound
154	negative	Ferguson	0-5	humic	
			5-28	10YR6/4 light yellowish brown fine loamy sand	
			28-70	10YR6/2 light brownish gray fine sandy clay loam w/ orange mottles; final 10 cm very high in clay	subsoil
155	negative	Morehead	0-4	10YR6/3 pale brown fine sandy loamy clay	
			4-16	10YR6/4 light yellowish brown fine sandy clay	
			16-69	10YR6/3 pale brown clay w/ orange mottles	subsoil, mound
156	negative	Carroll	0-50	10YR6/4 light yellowish brown sand	
			50-65	10YR5/6 yellowish brown clay w/ orange mottles	subsoil, mound
157	negative	Ferguson	0-3	humic	
			3-72	10YR5/4 yellowish brown fine loamy sand	
			72-90	10YR6/2 light brownish gray fine sandy clay loam	
			90-100	10YR6/2 light brownish gray fine sandy clay w/ few orange mottles	mound

158	negative	Morehead	0-4	humic	
			4-70	10YR6/2 light brownish gray fine sandy clay loam	
			70-90	10YR6/2 light brownish gray fine sandy clay	
			90-96	10YR6/2 light brownish gray sandy clay	mound, bioturbated
159	negative	Ferguson	0-4	humic	
			4-77	10YR5/4 yellowish brown fine loamy sand	
			77-80	10YR6/2 light brownish gray fine sandy clay loam	
			80-92	10YR6/2 light brownish gray fine sandy clay w/ orange mottles	mound
160	negative	Morehead	0-5	humic	
			6-23	10YR6/2 light brownish gray fine sandy clay	
			23-65	10YR5/2 grayish brown clay w/ orange mottles	subsoil, mound
161	negative	Ferguson	0-4	humic	
			4-14	10YR5/4 yellowish brown fine loamy sand	
			14-50	10YR4/4 dark yellowish brown fine loamy sand	
			50-86	10YR5/4 yellowish brown fine loamy sand	
			86-98	Mottled 10YR5/4 yellowish brown, 10YR8/2 very pale brown fine loamy sand	mound
162	negative	Morehead	0-5	humic	
			5-22	10YR6/3 pale brown fine sandy loam	
			22-75	10YR5/2 grayish brown fine sandy clay loam w/ orange mottles	
			75-85	10YR6/2 light brownish gray clay w/ dark orange mottles	subsoil, mound
163	negative	Ferguson	0-3	humic	
			3-30	10YR5/4 yellowish brown fine loamy sand	
			30-48	10YR5/4 yellowish brown fine loamy sand w/ orange mottles	
			48-74	10YR6/2 light brownish gray fine sandy clay w/ few orange mottles	
			74-85	10YR6/2 light brownish gray fine sandy clay w/ many orange mottles	subsoil, mound
164	negative	Ferguson	0-2	humic	
			2-20	10YR5/4 yellowish brown fine loamy sand	
			20-35	10YR5/4 yellowish brown fine loamy sand w/ many orange mottles	
			35-53	10YR6/2 light brownish gray fine sandy clay loam	
			53-63	10YR5/2 grayish brown clay w/ few orange mottles	subsoil, mound
165	negative	Ferguson	0-103	pure sand fill; glass fragment at 70 cmbs	20 m west of large metal cylinder with cap; completely welded up, no visibile access holes
166	negative	Morehead	0-20	fill	
			20-26	gravel layer	
			26-51	10YR4/2 dark grayish brown clay w/ orange mottles	subsoil
167	negative	Ferguson	0-33	Mottled 2.5YR4/1 dark gray clay, 2.5YR5/3 light olive clay	subsoil
168	negative	Morehead	0-8	10YR7/1 light gray loamy sand	
			8-34	10YR4/2 dark grayish brown clay w/ orange mottles	subsoil
169	negative	Ferguson	0-15	10YR3/2 very dark grayish brown clay	
			15-30	10YR4/2 dark grayish brown clay w/ few CaCO3 concretions throughout	
			30-40	10YR5/2 grayish brown clay	subsoil
170	negative	Morehead	0-11	10YR6/2 light brownish gray sandy clay	
			11-32	10YR2/2 very dark brown clay w/ brown mottles	subsoil
171	negative	Ferguson	0-8	10YR5/2 grayish brown clay	
			8-28	10YR4/1 dark gray clay	subsoil
172	negative	Morehead	0-10	10YR6/2 light brownish gray fine sandy loamy clay	
			10-34	10YR3/2 very dark grayish brown clay w/ light brown and orange mottles	subsoil
173	negative	Morehead	0-17	10YR6/2 light brownish gray fine sandy clay	
			17-49	10YR5/2 grayish brown sandy clay	
			49-58	10YR5/2 grayish brown sandy clay w/ iron concretions	
174	negative	Ferguson	0-4	10YR4/2 dark grayish brown fine sandy loam; humic	mound
			4-105	10YR6/4 light yellowish brown fine loamy sand; iron concretions throughout	

			105-118	10YR6/2 light brownish gray fine sandy clay w/ light yellowish brown and orange mottles	
175	negative	Morehead	0-6	10YR5/3 brown humic	mound
			6-60	10YR6/4 light yellowish brown fine loamy sand	
			60-99	10YR6/4 light yellowish brown fine loamy sand w/ orange and light gray clay mottles; many iron concretions	
176	negative	Alba	0-4	10YR5/2 grayish brown humic	mound
			4-93	10YR6/3 pale brown silty sand; iron concretions throughout	charcoal fragments
			93-102	10YR6/3 pale brown silty sand w/ orange clay mottles; iron concretions throughout	
177	negative	Ferguson	0-4	10YR4/2 dark grayish brown fine silty loam	mound
			4-52	10YR6/4 light yellowish brown fine loamy silt	
			52-70	10YR6/2 light brownish gray fine silty clay loam w/ orange and light brownish gray mottles	
			70-83	10YR6/2 light brownish gray fine sandy clay w/ orange and light brownish gray mottles	
178	negative	Morehead	0-4	10YR5/3 brown humic	slight rise
			4-33	10YR6/4 light yellowish brown fine silty loam	
			33-54	mottled 10YR7/1 light gray and 7.5YR6/8 reddish yellow clay	subsoil
179	negative	Alba	0-5	10YR5/2 grayish brown humic	mound
			5-56	10YR6/3 pale brown silty sand; charcoal fragments 0-40 cmbs; iron concretions throughout	
			56-80	10YR5/3 brown silty sand w/ orange clay deposits; iron concretions throughout	
180	negative	Ferguson	0-38	10YR6/2 light brownish gray, 10YR6/4 light yellowish brown, and orange fine sandy clay loam; increased clay composition with depth	subsoil
181	negative	Ferguson	0-4	10YR4/2 dark grayish brown fine sandy loam	
			4-21	10YR6/4 light yellowish brown fine loamy sand	
			21-35	10YR6/2 light brownish gray fine sandy clay loam w/ orange and light yellowish brown mottles	
			35-45	10YR6/2 light brownish gray fine sandy clay w/ orange and light brownish gray mottles	
182	negative	Morehead	0-6	10YR5/3 brown humic	mound
			6-23	10YR6/4 light yellowish brown sandy loam	
			23-43	10YR6/4 light yellowish brown fine sandy loam w/ light gray and orange clay mottles	
			43-60	10YR7/1 light gray clay w/ yellowish orange mottles	subsoil
183	negative	Ferguson	0-3	10YR6/3 pale brown fine sandy loam humic	mound
			3-23	10YR6/4 light yellowish brown silty loam	
			23-45	10YR8/2 very pale brown clay; moist and firm; few iron concretions throughout	upper subsoil
184	negative	Morehead	0-3	10YR5/3 brown humic	
			3-9	10YR6/4 light yellowish brown fine silty loam	
			9-50	10YR6/4 light yellowish brown fine loamy clay w/ light gray and orange clay mottles	upper subsoil
185	negative	Ferguson	0-2	10YR6/3 pale brown fine sandy loam; humic	mound
			2-18	10YR6/4 light yellowish brown silty loam	
			18-52	10YR8/2 very pale brown clay; moist and firm; increased clay deposition with depth	upper subsoil
186	negative	Morehead	0-5	10YR5/3 brown humic	
			5-13	10YR7/1 light gray sandy loam w/ white mottles	
			13-18	10YR6/4 light yellowish brown fine silty loam w/ gray and orange clay mottles	
			18-35	10YR7/1 light gray clay w/ orange mottles	
187	negative	Ferguson	0-14	very mottled 10YR4/2 dark grayish brown, 10YR3/3 dark brown, and 10YR5/3 brown clay	
			14-30	mottled 10YR7/2 light gray and 7.5YR5/8 strong brown clay	subsoil
188	negative	Morehead	0-4	10YR5/3 brown humic	
			4-21	10YR6/4 light yellowish brown fine silty loam	
			21-50	10YR6/4 light yellowish brown fine loamy clay w/ orange mottles	upper subsoil
189	negative	Ferguson	0-3	humic	
			3-24	mottled 10YR7/2 light gray and 7.5YR5/8 strong brown clay	subsoil
190	negative	Morehead	0-4	humic	slight mound

			4-17	10YR6/4 light yellowish brown fine sandy loam w/ gray and orange clay mottles; some modern charcoal 0-10 cmbs	
			17-35	10YR7/2 light gray clay w/ orange mottles	
191	negative	Ferguson	0-6	very mottled 10YR4/2 dark grayish brown, 10YR3/3 dark brown, and 10YR5/3 brown clay	
			6-25	mottled 10YR7/2 light gray and 7.5YR5/8 strong brown clay	subsoil
192	negative	Morehead	0-5	humic	mound
			5-12	10YR6/3 pale brown fine sandy loam	
			12-19	10YR6/4 light yellowish brown fine sandy loam	
			19-35	10YR6/4 light yellowish brown fine sandy loam w/ light gray dry clay mottles	
			35-45	10YR7/2 light gray clay w/ orange mottles; moist, firm	subsoil
193	negative	Ferguson	0-4	humic	
			4-27	mottled 10YR7/2 light gray and 7.5YR5/8 strong brown clay	subsoil
194	negative	Morehead	0-2	10YR5/3 brown humic	large mound
			2-7	10YR7/1 light gray sandy loam w/ white mottles	
			7-76	10YR6/4 light yellowish brown fine silty loam w/ gray and orange clay mottles	
			76-97	10YR7/1 light gray clay w/ orange mottles	subsoil
195	negative	Ferguson	0-3	humic	small mound
			3-15	10YR6/4 light yellowish brown silty loam	
			15-27	10YR6/3 pale brown clay w/ many orange mottles	
196	negative	Ferguson	0-3	humic	
			3-35	mottled 10YR8/2 very pale brown, 10YR6/3 pale brown, and orange clay; increased clay deposition with depth	subsoil
197	negative	Ferguson	0-2	humic	mound; few iron concretions throughout
			2-8	10YR6/3 pale brown fine sandy loam	
			8-33	10YR6/4 light yellowish brown fine loamy sand	
			33-78	10YR6/4 light yellowish brown fine loamy sand w/ many orange mottles	
			78-97	10YR6/4 light yellowish brown fine loamy sand w/ few orange mottles	
198	negative	Morehead	0-3	10YR6/2 light brownish gray humic	mound
			3-38	mottled 10YR8/1 chite and 10YR6/6 yellowish brown fine sandy loam	
			38-50	10YR6/4 light yellowish brown fine sandy clay loam w/ light gray and orange clay mottles	upper subsoil
199	negative	Ferguson	0-20	10YR6/2 light brownish gray clay w/ pale brown and brown mottles	
			20-32	10YR7/2 light gray clay w/ many orange mottles	
200	negative	Morehead	0-6	10YR7/1 light gray fine sandy loam	large rise
			6-35	10YR6/4 light yellowish brown fine sandy loam	
			35-50	10YR6/4 light yellowish brown fine sandy clay loam w/ pale gray and orange clay mottles	
201	negative	Ferguson	0-3	humic	
			3-18	10YR6/2 light brownish gray clay w/ pale brown and brown mottles	
			18-33	10YR7/2 light gray clay w/ many orange mottles	subsoil
202	negative	Morehead	0-2	10YR3/3 dark brown humic	mound; some iron concretions throughout
			2-25	10YR6/4 light yellowish brown fine sandy loam	
			25-40	10YR7/1 light gray clay w/ orange and yellow mottles	subsoil
203	negative	Ferguson	0-3	humic	
			3-10	10YR6/2 light brownish gray clay w/ pale brown and brown mottles	
			10-36	10YR7/2 light gray clay w/ many orange mottles	
204	negative	Morehead	0-3	10YR5/3 brown humic	
			3-15	10YR6/4 light yellowish brown fine sandy clay loam	
			15-30	mottled 10YR8/1 white and 10YR7/8 yellow clay; moist and firm.	subsoil
205	negative	Ferguson	0-3	humic	slight mound
			3-18	10YR6/4 light yellowish brown fine loamy sand	
			18-28	10YR7/2 light gray clay w/ many orange mottles	
206	negative	Morehead	0-8	10YR7/1 light gray fine sandy loam	mound
			8-14	10YR6/4 light yellowish brown fine loamy clay sand	

			14-30	10YR8/1 white clay w/ orange mottles	
207	negative	Ferguson	0-3	humic	
			3-15	10YR6/2 light brownish gray clay w/ pale brown and brown mottles	
			15-30	10YR7/2 light gray clay w/ many orange mottles	
208	negative	Morehead	0-25	10YR6/4 light yellowish brown fine sandy clay	mound
			25-50	10YR6/4 light yellowish brown fine sandy clay w/ many white and orange clay mottles	
209	negative	Ferguson	0-5	humic	mound
			5-23	10YR6/4 light yellowish brown fine sandy loam	
			23-50	10YR7/2 light gray clay w/ many orange mottles; increased clay deposition with depth	
210	negative	Morehead	0-10	10YR6/4 light yellowish brown clay w/ orange mottles	
			10-30	10YR8/1 white clay w/ orange mottles; moist and firm	subsoil
211	negative	Alba	0-5	10YR7/2 light gray sand	
			5-37	10YR6/3 pale brown silty sand	
			37-48	10YR6/3 pale brown sandy clay w/ orange mottles	
212	negative	Ferguson	0-3	10YR2/2 very dark brown humic	
			3-27	10YR7/3 very pale brown silty loam w/ few yellow mottles; dry and hard	
			27-37	2.5YR5/2 grayish brown clay w/ many orange mottles	subsoil
213	negative	Morehead	0-36	10YR7/1 light gray clay w/ dark orange and dark brown mottles; dry and hard; few iron concretions throughout	
214	negative	Alba	0-7	10YR6/1 gray sand; humic	charcoal fragments
			7-30	10YR6/1 gray sandy clay	
			30-41	10YR7/8 yellow clay w/ gray mottles	
215	negative	Ferguson	0-4	10YR5/2 grayish brown humic	
			4-24	10YR7/3 very pale brown silty loam w/ few yellow mottles	
			24-36	2.5YR5/2 grayish brown clay w/ many orange mottles	
216	negative	Morehead	0-3	humic	mound
			3-25	10YR3/3 dark brown fine loamy clay w/ gray and orange clay mottles	
			25-45	10YR6/1 gray clay w/ orange and brown mottles	subsoil
217	negative	Alba	0-4	10YR7/1 light gray silty sand	sandy mound; iron concretions throughout
			4-70	10YR6/3 pale brown silty sand	
			70-75	10YR6/3 pale brown sandy clay w/ orange mottles	
218	negative	Ferguson	0-7	10YR6/2 light brownish gray silty loam	mound
			7-20	10YR6/3 pale brown silty loam	
			20-48	10YR6/4 light yellowish brown loamy silt	
			48-85	mottled 10YR6/4 light yellowish brown, 10YR6/3 pale brown, and orange clay loam	
			85-95	2.5YR5/2 grayish brown clay w/ many orange mottles	
219	negative	Morehead	0-14	10YR6/4 light yellowish brown fine sandy clay loam	mound
			14-23	10YR6/4 light yellowish brown fine sandy clay w/ light gray and orange clay mottles	
			23-46	10YR7/2 light gray clay w/ orange and red mottles	subsoil
220	negative	Alba	0-5	10YR7/1 light gray sand; humic	iron concretions throughout
			5-19	10YR6/3 pale brown silty sand	
			19-37	10YR6/3 pale brown sandy clay w/ orange mottles	
221	negative	Ferguson	0-2	humic	
			2-18	10YR6/3 pale brown silty clay loam w/ few orange mottles	
			18-54	2.5YR5/2 grayish brown clay w/ many orange mottles; increased clay deposition with depth	
222	negative	Morehead	0-36	10YR6/4 light yellowish brown silty loam	mound
			36-55	10YR6/4 light yellowish brown silty clay w/ many iron concretions	
223	negative	Alba	0-4	10YR6/1 gray silty sand; humic	
			4-50	10YR6/3 pale brown silty sand	
			50-52	10YR6/3 pale brown sandy clay w/ orange mottles	
224	negative	Ferguson	0-3	humic	
			3-36	2.5YR5/2 grayish brown clay w/ many orange mottles	

225	negative	Morehead	0-40	10YR6/4 light yellowish brown w/ light gray and orange clay mottles	
			40-52	10YR7/2 light gray clay w/ orange and red mottles	
226	negative	Ferguson	0-3	humic	mound
			3-17	10YR6/3 pale brown silty loam	
			17-38	10YR6/4 light yellowish brown silty loam	
			38-50	2.5YR5/2 grayish brown clay w/ many orange mottles	
227	negative	Morehead	0-31	10YR6/4 light yellowish brown loamy clay; dry and hard	
			31-40	10YR7/1 light gray clay w/ orange mottles; moist and firm	
228	negative	Morehead	0-5	10YR6/3 pale brown humic	mound
			5-53	10YR6/4 light yellowish brown silty loam	
			53-65	10YR7/2 light gray clay w/ orange mottles and iron concretions	
229	negative	Morehead	0-26	10YR6/4 light yellowish brown fine silty loam w/ few iron concretions and modern charcoal	mound
			26-75	10YR6/4 light yellowish brown silty loam w/ dark orange and red clay mottles; many iron concretions and modern charcoal	
			75-85	10YR6/4 light yellowish brown moist clay w/ pale gray and orange mottles; many iron concretions	
230	negative	Alba	0-16	10YR6/3 pale brown silty sand	sandy mound
			16-72	10YR6/4 light yellowish brown silty sand; many iron concretions	
			72-90	10YR6/3 pale brown clay w/ orange mottles	
231	negative	Ferguson	0-1	humic	slight rise; iron concretions throughout
			1-16	10YR6/3 pale brown silty loam	
			16-78	10YR6/4 light yellowish brown loamy silt w/ moderate orange and brown mottling	
			78-96	10YR6/4 light yellowish brown clay w/ many reddish orange mottles	
232	negative	Morehead	0-36	10YR6/4 light yellowish brown fine silty loam w/ few iron concretions and modern charcoal	mound
			36-67	10YR6/4 light yellowish brown fine silty loam w/ light gray and orange clay mottles; many iron concretions	
			67-75	10YR7/1 light gray clay, moist and firm; many orange mottles and moderate iron concretions	
233	negative	Alba	0-2	10YR6/1 gray silty sand	sandy mound; iron concretions throughout
			2-30	10YR6/3 pale brown silty sand	
			30-70	10YR6/3 pale brown silty loam w/ orange clay mottles	
234	negative	Ferguson	0-4	humic	mound
			4-82	10YR6/4 light yellowish brown loamy silt	
			82-100	mottled 10YR6/3 pale brown, 10YR6/4 light yellowish brown and orange clay; iron concretions throughout	
235	negative	Morehead	0-15	10YR6/4 light yellowish brown fine silty loam	mound
			15-100	10YR7/3 very pale brown fine silty loam w/ few iron concretions	
236	negative	Alba	0-6	10YR6/1 gray silty sand	sandy mound; glass flake 10-20 cmbs
			6-42	10YR6/3 pale brown silty sand	
			42-63	10YR6/3 pale brown silty loam w/ orange clay mottles	
237	negative	Ferguson	0-4	humic	
			4-8	10YR5/3 brown loamy silt	
			8-60	mottled 10YR7/2 light gray, 10YR7/3 very pale brown, and orange clay; increased clay deposition with depth; few iron concretions	
238	negative	Morehead	0-6	10YR6/4 light yellowish brown fine silty loam	mound
			6-98	10YR7/3 very pale brown fine silty loam w/ few iron concretions	
239	negative	Alba	0-11	10YR7/2 light gray silty sand	
			11-46	10YR6/3 pale brown silty sand	
			46-80	10YR6/3 pale brown silty loam w/ orange mottles	
240	negative	Ferguson	0-44	10YR6/4 light yellowish brown loamy silt	high spot
			44-74	mottled 10YR7/1 light gray, 10YR7/3 very pale brown, and orange clay	
			74-89	mottled 10YR7/1 light gray, 10YR7/3 very pale brown, and orange clay w/ orange and red mottles	
241	negative	Alba	0-9	10YR7/1 light gray silty sand	sandy mound; iron concretions throughout

			9-51	10YR6/3 pale brown silty sand	
			51-81	10YR6/3 pale brown silty loam w/ orange clay mottles	
242	negative	Ferguson	0-3	humic	mound
			3-13	10YR5/3 brown silty loam	
			13-40	10YR6/4 yellowish brown loamy silt	
			40-80	mottled 10YR7/1 light gray, 10YR7/3 very pale brown, and orange clay	
			80-90	mottled 10YR7/1 light gray, 10YR7/3 very pale brown, and orange clay w/ orange and red mottles	
243	negative	Ferguson	0-3	humic	
			3-27	10YR7/2 light gray clay w/ many orange mottles; dry and hard; increased clay deposition with depth	
244	negative	Alba	0-8	10YR6/1 gray silty sand	sandy mound; iron concretions throughout
			8-23	10YR6/3 pale brown silty sand	
			23-58	10YR6/3 pale brown silty loam w/ orange clay mottles	
245	negative	Ferguson	0-3	humic	
			3-50	mottled 10YR6/3 pale brown, 10YR6/4 light yellowish brown, and orange clay w/ few iron concretions	
			50-67	10YR7/1 light gray silty clay w/ few orange mottles	
246	negative	Ferguson	0-4	10YR6/1 gray silty sand	sandy mound; charcoal fragments
			4-26	10YR6/3 pale brown silty sand	
			26-70	10YR6/3 pale brown silty loam w/ orange clay mottles	
247	negative	Ferguson	0-8	10YR6/2 light brownish gray fine sandy loam	
			8-37	10YR6/4 light yellowish brown fine loamy sand	
			37-51	10YR6/4 light yellowish brown fine loamy sand w/ few orange mottles	
			51-67	mottled 10YR6/3 pale brown, 10YR6/4 light yellowish brown, and orange clay w/ few orange mottles	
			67-78	10YR6/1 gray clay w/ few red mottles	
248	negative	Alba	0-4	10YR6/1 gray silty sand	iron concretions throughout
			4-21	10YR6/3 pale brown silty loam	
			21-52	10YR6/3 pale brown loamy clay w/ orange clay mottles	
249	negative	Ferguson	0-17	10YR5/2 grayish brown silty loam	
			17-25	10YR8/2 very pale brown silty clay; dry and very hard; orange and black mottles	
250	negative	Alba	0-5	10YR6/1 gray silty sand	sandy mound; iron concretions throughout
			5-45	10YR5/3 brown silty sand	
			45-66	10YR5/3 brown silty loam w/ orange clay mottles	
251	negative	Ferguson	0-2	humic	
			2-26	10YR6/3 pale brown fine sandy loam	
			26-46	10YR6/4 light yellowish brown fine loamy sand	
			46-83	mottled 10YR6/3 pale brown, 10YR6/4 light yellowish brown, and orange fine sandy clay loam	
252	negative	Morehead	0-31	10YR6/3 pale brown loamy clay w/ dark brown and red mottles	slightly forested; west of CL
253	negative	Ferguson	0-6	10YR4/4 dark yellowish brown fine sandy loam	wooded; on mound
			6-62	10YR5/4 yellowish brown fine loamy sand w/ few iron concretions	
			62-75	mottled 10YR7/2 light gray,l 10YR5/4 yellowish brown, 5YR4/6 yellowish red fine sandy clay, few iron concretions	
254	negative	Morehead	0-8	10YR6/3 pale brown silty sand	large mound; east of CL; heavily forested
			8-86	10YR7/3 very pale brown silty loam with many iron concretions, charred seeds and charcoal	
			86-100	10YR7/3 very pale brown silty clay w/ reddish yellow mottles; charcoal	
255	negative	Ferguson	0-10	10YR4/4 dark yellowish brown fine sandy loam	wooded; on ridge
			10-70	10YR5/4 yellowish brown fine loamy sand w/ few iron concretions	
			70-80	mottled 10YR7/2 light gray,l 10YR5/4 yellowish brown, 5YR4/6 yellowish red fine sandy clay, few iron concretions	
256	negative	Morehead	0-3	10YR5/2 light gray brown silty sand	rise; west of CL; heavily forested; charcoal throughout
			3-54	10YR5/4 yellowish brown fine sandy clay w/ iron concretions, dry	
			54-60	10YR5/4 yellowish brown loamy clay w/ dark orange mottles, moist	

			60-71	10YR5/2 light gray brown clay, moist and firm w/ dark orange mottles and iron concretions	
257	negative	Ferguson	0-6	10YR4/4 dark yellowish brown fine sandy loam	wooded, slight grade
			6-44	10YR5/4 yellowish brown fine loamy sand w/ few iron concretions	
			44-68	mottled 10YR7/2 light gray,l 10YR5/4 yellowish brown, 5YR4/6 yellowish red fine sandy clay, few iron concretions	
258	negative	Morehead	0-32	10YR7/3 very pale brown loamy clay, dry, very hard w/ brown and orange mottles	slightly forested; west of CL
259	negative	Ferguson	0-38	10YR7/2 light gray clay w/ many orange and brown mottles	wooded, flat, grassy
260	negative	Morehead	0-28	mottled 10YR5/1 gray, 10YR5/3 brown, and 10YR6/3 pale brown loamy clay; very hard and dry; some orange mottle	slightly forested; west of CL
261	negative	Ferguson	0-36	10YR7/2 light gray clay w/ many orange and brown mottles	wooded, flat, grassy
262	negative	Morehead	0-13	10YR6/1 gray loamy clay w/ yellow mottles	mound, east of cl, slightly forested
			13-17	10YR8/1 white sand	
			17-35	10YR7/3 very pale brown clay w/ brown and orange mottles	
263	negative	Ferguson	0-33	10YR7/2 light gray clay w/ many orange and brown mottles	wooded, flat, grassy
264	negative	Ferguson	0-6	10YR5/2 gray brown silty loam	
			6-80	10YR6/4 light yellowish brown loamy silt	
			80-90	10YR6/4 light yellow brown clay w/ orange mottles	
			90-96	10YR7/2 light gray clay w/ reddish orange mottles	
265	negative	Morehead	0-11	10YR6/3 pale brown loamy clay w/ orange and yellow mottles	east of CL; flat, open, grassy woods
			11-30	10YR7/1 light gray clay w/ reddish yellow mottlesm, moist and crumbly	
266	negative	Alba	0-3	10YR6/1 gray loamy clay	sparse, mixed forest; on edge of xsect
			3-26	10YR6/3 pale brown loamy clay	
			26-47	10YR6/3 pale brown clay w/ orange mottle	
267	negative	Ferguson	0-35	10YR7/2 light gray clay w/ many orange mottles	flat, open, grassy woods
268	negative	Morehead	0-3	humic	east of CL; flat, open, grassy woods
			3-39	10YR5/2 grayish brown loamy clay w/ light orange and yellow mottles; dry and hard	
269	negative	Alba	0-6	10YR4/1 dark gray humic	sandy mound, mixed forest (yaupon)
			6-39	10YR6/3 pale brown silty sand	
			39-60	10YR6/3 light brown sandy clay w/ orange mottle	
270	negative	Ferguson	0-14	10YR6/2 light brownish gray fine sandy loam	mound
			14-45	10YR6/4 light yellowish brown fine loamy sand	
			45-65	10YR7/2 light gray clay w/ many orange mottles	
271	negative	Morehead	0-90	10YR6/4 light yellowish brown silty sand	west of Cl; large rise
			90-100	10YR6/4 light yellowish brown silty sand w/ orange clay mottle	
272	negative	Alba	0-6	10YR4/1 dark gray humic	sandy mound, mixed pine forest with several vines; charcoal fragments throughout
			6-26	10YR6/3 pale brown silty sand	
			26-110	10YR5/4 yellowish brown silty loam	
273	negative	Ferguson	0-26	10YR6/3 pale brown fine loamy sand	high mound, 1-1.5 m
			26-70	10YR6/4 light yellowish brown fine loamy sand	
			70-98	10YR6/4 light yellowish brown fine loamy sand w/ few orange mottles and iron concretions, increase in density w/ depth	
274	negative	Morehead	0-43	10YR6/4 light yellowish brown silty loam	west of CL; rise; burnt bone fragment
			43-56	10YR6/3 pale brown loamy clay w/ many dark orange mottles and iron concretions throughout; dry and very hard	
275	negative	Alba	0-3	10YR4/1 dark gray humic	mound in dense mixed forest; east of CL
			3-58	10YR6/3 pale brown silty sand	
			58-78	10YR6/3 pale brown loamy clay w/ orange clay mottles	
276	negative	Ferguson	0-2	humic	high ridge; iron concretions throughout
			2-10	10YR6/3 pale brown fine sandy loam	
			10-42	10YR6/4 light yellowish brown silt	
			42-80	10YR6/4 light yellowish brown silt; dry, hard, few brown mottles	
			80-92	10YR7/2 light gray fine sandy clay w/ orange mottles	
277	negative	Morehead	0-9	10YR5/2 gray brown humic	east of CL, slight rise
			9-37	10YR6/4 light yellowish brown silty loam	

			37-51	10YR7/1 loamy clay w/ orange and red mottles; moist and firm	
278	negative	Ferguson	0-5	humic	small ridge
			5-20	10YR6/4 light yellowish brown fine loamy sand	
			20-62	10YR6/4 light yellowish brown silt w/ few orange and pale brown mottles	
			62-78	10YR6/1 gray clay (bottom is same color, but w/orange mottles)	
279	positive	Ferguson	0-3	humic	
			3-18	10YR6/3 pale brown fine sandy loam	
			18-45	10YR6/4 light yellowish brown fine loamy sand	
			45-75	10YR6/4 light yellowish brown silt; dry, hard, few brown mottles	
			75-85	10YR7/2 light gray fine sandy clay w/ few orange mottles	
280	negative	Morehead	0-1	10YR5/2 light grayish brown silty sand/humic	moderately forested, iron concretions throughout
			1-31	10YR7/3 very pale brown loamy clay w/ dark orange mottles	
281	negative	Alba	0-59	10YR6/3 pale brown silty sand	sandy mound, mixed forest (yaupon)
			59-69	10YR6/3 pale brown silty loam w/ hard orange clay mottles	
282	negative	Ferguson	0-2	humic	small ridge
			2-21	10YR6/4 light yellowish brown fine loamy sand, many of mottles in final 10cm	
			21-41	10YR6/3 pale brown clay w/ many orange mottles	
			41-48	10YR6/1 gray clay w/ many orange mottles	
283	negative	Morehead	0-5	10YR5/2 grayish brown humic	mound; moderately forested, few charcoal in first 10cm, iron concretions throughout
			5-54	10YR6/4 light yellowish brown sandy loam	
			54-60	10YR7/1 light gray clay w/ orange mottles, dry and hard	
284	negative	Alba	0-4	humic	sandy mound, yaupon patch
			4-10	10YR4/1 dark gray silty sand	
			10-31	10YR6/3 pale brown silty loam	
			31-45	10YR6/3 pale brown silty loam w/ orange and red clay mottles	
285	negative	Ferguson	0-56	10YR7/2 light gray clay loam	
			56-65	10YR6/2 light brownish gray clay loam	
286	negative	Morehead	0-12	10YR7/2 light gray clay loam	
			12-48	10YR6/4 light yellowish brown fine sandy loam.	
			48-57	10YR7/1 light gray clay	
287	negative	Alba	0-3	humic	
			3-26	10YR6/4 light yellowish brown fine sandy loam.	
			26-48	10YR6/3 pale brown silty loam	
			48-54	10YR6/3 pale brown silty clay loam	
288	negative	Ferguson	0-5	humic	
			5-36	10YR6/4 light yellowish brown fine loamy sand.	
			36-68	10YR6/3 pale brown silty clay loam	
			68-80	10YR6/1 gray clay	
289	negative	Morehead	0-3	humic	
			3-44	10YR6/4 light yellowish brown clay loam.	
			44-57	10YR7/2 light gray clay.	
290	negative	Alba	0-4	humic	
			4-42	10YR6/4 light yellowish brown fine loamy sand.	
			42-54	10YR6/3 pale brown silty clay loam	
291	positive	Ferguson	0-2	humic	
			2-21	10YR5/3 brown fine sandy loam	
			21-60	10YR6/4 light yellowish brown fine loamy sand.	
			60-94	10YR6/4 light yellowish brown fine sandy clay loam.	
292	negative	Morehead	0-6	humic	
			6-51	10YR6/4 light yellowish brown clay loam.	
			51-60	10YR7/2 light gray clay.	
293	negative	Alba	0-6	humic	
			6-70	10YR6/4 light yellowish brown silt loam.	

			70-79	10YR6/4 light yellowish brown fine sandy clay loam.	
294	positive	Alba	0-17	10YR6/3 pale brown compact clay	
			17-33	7.5YR4/6 strong brown compact clay	
295	negative	Ferguson	0-19	10YR6/3 pale brown fine sand	edge of ridge, thin woods
			19-27	7.5YR4/6 strong brown clay	
296	negative	Alba	0-23	10YR6/3 pale brown sandy clay	
			23-32	7.5YR4/6 strong brown clay	
297	positive	Ferguson	0-17	10YR6/3 pale brown fine sand	
			17-27	7.5YR4/6 strong brown clay	
298	negative	Alba	0-12	10YR5/2 gray brown sandy clay	
			12-27	7.5YR4/6 strong brown clay	
299	negative	Ferguson	0-3	10YR5/2 gray brown sandy clay loam	charcoal level 1
			3-10	mottled 10YR5/2 gray brown, 10YR6/3 pale brown and orange hard, dry clay	
300	positive	Alba	0-14	10YR5/2 gray brown sandy clay	
			14-28	7.5YR4/6 strong brown clay	
301	negative	Ferguson	0-2	10YR5/2 gray brown fine sandy loam	on upland next to drainage
			2-22	10YR6/4 light yellowish brown fine sand	
			22-35	10YR6/4 light yellowish brown fine sandy clay w/ many orange mottles	
302	negative	Alba	0-8	10YR6/3 pale brown silty sand	sandy mound w/ pine and yaupon
			8-39	10YR6/3 pale brown sandy clay	
			39-54	7.5YR4/6 strong brown clay	
303	negative	Ferguson	0-26	10YR6/3 pale brown fine sand	on mound
			26-31	7.5YR4/6 strong brown clay	
304	negative	Alba	0-5	10YR6/3 pale brown silty sand	65 m from drainage
			5-10	10YR6/4 light yellowish brown sandy clay	
			10-26	7.5YR4/6 strong brown clay	
305	negative	Ferguson	0-33	10YR7/3 very pale brown fine sand	rear road
			33-47	very hard 10YR7/4 very pale brown silty clay loam w/ orange mottles	
306	negative	Ferguson	0-2	humic	
			2-16	10YR6/3 pale brown silty loam	
			16-26	7.5YR4/6 strong brown clay	
307	positive	Ferguson	0-9	10YR6/3 pale brown silty loam	slight rise
			9-25	10YR7/4 very pale brown silt	
			25-35	7.5YR4/6 strong brown clay	
308	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam	highland form
			10-20	10YR6/3 pale brown silt w/ few iron concretions	
			20-30	10YR5/8 yellowish brown clay	
309	negative	Alba	0-4	humic	
			4-16	10YR4/2 dark grayish brown silty loam	
			16-26	10YR5/2 grayish brown sandy clay	
			26-33	7.54/6 strong brown clay	
310	negative	Ferguson	0-9	10YR4/2 dark grayish brown fine sandy loam	
			9-22	10YR6/3 pale brown fine sand w/ many iron concretions	
			22-30	10YR5/8 yellowish brown fine sandy clay loam w/ many iron concretions	
311	negative	Alba	0-7	humic	50 m north of road
			7-18	10YR6/3 pale brown sandy clay	
			18-31	10YR5/8 yellowish brown clay	
312	negative	Blake	0-25	10YR3/1 very dark gray clay	
			25-30	10YR4/1 dark gray clay w/ orange mottles	
313	negative	Alba	0-25	10YR3/1 very dark gray clay	
			25-30 cm	10YR4/1 dark gray clay w/ some orange mottling	
314	negative	Ferguson	0-10	10YR5/2 grayish brown clay, moist and very firm	Former rice field, drainage furrows still present. Now a cow pasture
			10-30	10YR3/1 very dark gray clay, moist and very firm	

315	negative	Blake	0-30	10YR3/1 very dark gray clay	Edge of pasture, west of road. St. Augustine grass and 2 rectangular stones side by side
			30-35	10YR4/1 dark gray clay w/ orange mottles	
316	negative	Alba	0-2	10YR4/1 dark gray sandy clay, dry	
			2-30	10YR4/1 dark gray clay, moist	
317	negative	Ferguson	0-30	10YR5/2 grayish brown clay. Orange and yellow mottles in final 10 cm.	
318	negative	Blake	0-30	10YR5/1 gray clay w/ orange mottles	pasture near tree line
319	negative	Alba	0-3	10YR4/1 dark gray sandy clay, dry	
			3-29	10YR4/1 dark gray clay w/ some orange mottles, moist	
320	negative	Ferguson	0-16	10YR4/1 dark gray clay	on west side of drainage
			16-32	10YR5/2 grayish brown clay w/ many orange mottles	
321	negative	Blake	0-30	10YR5/1 gray clay w/ orange mottles	
322	negative	Alba	0-31	10YR4/1 dark gray clay w/ some orange mottles, moist	edge of pasture 10 m from drainage
323	negative	Ferguson	0-25	10YR3/1 very dark gray clay	on west side of drainage
			25-34	10YR4/1 dark gray clay	
324	negative	Blake	0-30	10YR5/1 gray clay w/ orange mottles	
325	negative	Alba	0-2	10YR4/1 dark gray clay w/ some orange mottles	pasture, 50 m north of wooded fence line
326	negative	Ferguson	0-19	10YR5/2 grayish brown clay	
			19-30	10YR3/1 very dark gray clay	
327	negative	Blake	0-30	10YR5/1 gray clay w/ orange mottles	
328	negative	Alba	0-4	10YR4/1 dark gray sandy clay	
			4-36	10YR3/1 very dark gray clay w/ some orange mottles	
329	negative	Ferguson	0-32	10YR3/1 very dark gray clay	west side of drainage in rice field
330	negative	Blake	0-30	10YR5/1 gray clay w/ orange mottles	
331	negative	Alba	0-3	10YR4/1 dark gray sandy clay	
			3-31	10YR3/1 very dark gray clay w/ some orange mottles	
332	negative	Ferguson	0-29	10YR3/1 very dark gray clay	
333	negative	Blake	0-30	10YR5/1 gray clay w/ orange mottles	
334	negative	Alba	0-2	10YR4/1 dark gray sandy clay	
			2-32	10YR3/1 very dark gray clay w/ some orange mottles	
335	negative	Alba	0-3	10YR4/1 dark gray sandy clay	
			3-31	10YR3/1 very dark gray clay w/ some orange mottles	
336	negative	Blake	0-30	10YR5/1 gray clay w/ orange mottles	
337	negative	Blake	0-30	10YR3/1 very dark gray clay w/ some orange mottles	edge of woods
338	negative	Ferguson	0-6	10YR5/2 grayish brown clay	west side of tract 50
			6-30	10YR3/1 very dark gray clay, moist and very firm	
339	negative	Blake	0-30	10YR3/1 very dark gray clay w/ some orange mottles	
340	negative	Ferguson	0-11	10YR5/2 grayish brown clay	
			11-25	10YR3/1 very dark gray clay, moist and very firm	
341	negative	Blake	0-30	10YR3/1 very dark gray clay w/ orange and 10YR5/1 gray mottles	
342	negative	Ferguson	0-10	10YR5/2 grayish brown clay	
			10-32	10YR3/1 very dark gray clay, moist and very firm	
343	negative	Blake	0-20	10YR3/2 very dark grayish brown sandy clay	mound
			20-40	10YR5/1 gray sandy clay w/ white and orange mottles	
			40-50	10YR6/2 light brownish gray clay w/ lots of orange and white mottles	
344	negative	Ferguson	0-9	10YR5/2 grayish brown clay	
			9-30	10YR3/1 very dark gray clay, moist and very firm	
345	negative	Blake	0-25	10YR4/2 dark grayish brown sandy clay	
			25-40	10YR5/3 brown sandy clay w/ lots of orange and white mottles	
346	negative	Ferguson	0-8	10YR5/2 grayish brown clay	
			8-30	10YR3/1 very dark gray clay, moist and very firm	
347	negative	Blake	0-20	10YR4/2 dark gray brown sandy clay	
			20-30	10YR5/3 brown sandy clay w/ orange and white mottles	
348	negative	Ferguson	0-18	10YR3/2 very dark grayish brown clay loam	

			18-30	10YR3/1 very dark gray clay	
349	negative	Blake	0-30	10YR3/1 very dark gray clay w/ orange mottles	
350	positive	Ferguson	0-14	10YR3/2 very dark grayish brown clay loam	
			14-25	10YR4/2 dark grayish brown fine sandy clay loam	
			25-40	10YR4/3 brown fine sandy clay	
351	negative	Blake	0-30	10YR3/1 very dark gray clay w/ orange mottles	
352	negative	Ferguson	0-15	10YR4/1 dark gray clay	
			15-28	10YR3/1 very dark gray clay	
353	negative	Blake	0-15	10YR5/1 gray sandy loam	
			15-30	10YR3/1 very dark gray clay	
354	negative	Ferguson	0-20	10YR4/1 dark gray clay	
			20-30	10YR3/1 very dark gray clay	
355	negative	Blake	0-10	10YR5/1 gray sandy loam	
			10-35	10YR3/1 very dark gray clay	
356	negative	Ferguson	0-20	mottled dark gray and very dark gray clay	plow zone
			20-30	10YR3/1 very dark gray clay, intact	
357	negative	Ferguson	0-18	10YR4/1 dark gray clay	
			18-30	10YR3/1 very dark gray clay	
358	negative	Blake	0-30	10YR4/1 dark gray clay w. small amounts of orange mottling	
359	negative	Blake	0-2	humic	
			2-45	10YR8/2 very pale brown sandy clay w/ orange mottling	
360	negative	Ferguson	0-2	humic	
			2-40	mottled 10YR8/1 white, 10YR7/1 light gray and orange clay loam	
361	negative	Blake	0-30	10YR8/2 very pale brown sandy clay w/ orange mottling	pine tree farm
362	negative	Ferguson	0-22	fine sandy loam plow zone	
			22-44	10YR7/3 very pale brown fine loamy sand	
			44-69	10YR7/3 very pale brown fine sandy clay loam w/ pale brown and orange mottling	
363	negative	Blake	0-32	10YR7/3 very pale brown sandy clay w/ orange mottling	
364	negative	Ferguson	0-10	10YR6/2 light brownish gray fine sandy clay loam w/ few orange mottles	
			10-28	10YR6/2 light brownish gray fine sandy clay w/ few orange mottles	
365	negative	Blake	0-30	0-30 10YR7/3 very pale brown sandy clay	
366	negative	Ferguson	0-5	humic	
			5-32	10YR6/3 pale brown clay w/ many orange mottles	
367	negative	Blake	0-31	10YR6/3 pale brown cclay w/ lots of orrange mottling	
368	negative	Ferguson	0-10	humic	
			10-52	10YR7/3 very pale brown fine loamy sand	
			52-62	10YR7/3 very pale brown fine sandy clay loam w/ many light gray and orange mottles	
369	negative	Blake	0-16	10YR5/3 brown sandy loam	
			16-60	10YR6/4 light yellowish brown fine silty sand w/ some charcoal	
			60-84	10YR5/4 yellowish brown sandy clay w/ lots of orange mottles	
370	negative	Ferguson	0-5	humic	
			10-52	10YR7/3 very pale brown fine loamy sand	
			52-62	10YR7/3 very pale brown fine sandy clay loam w/ many light gray and orange mottles	
371	negative	Blake	0-33	10YR7/3 very pale brown sandy clay	
372	negative	Ferguson	0-3	humic	
			3-13	10YR7/3 very pale brown fine loamy sand	
			13-25	10YR7/3 very pale brown fine sandy clay loam w/ many light gray and orange mottling	
373	negative	Blake	0-34	10YR7/3 very pale brown sandy clay w/ orange mottling	
374	negative	Blake	0-3	10YR4/2 dark grayish brown loam	possible plow zone
			3-34	10YR4/3 brown clay w/ orange and gray mottling	
375	negative	Ferguson	0-6	10YR4/2 dark grayish brown clay	bioturbated

			6-32	10YR5/2 grayish brown clay w/ few orange mottles	
376	negative	Blake	0-32	10YR3/1 very dark gray clay w/ orange, light gray, and brown mottling	
377	negative	Ferguson	0-14	clay plow zone	bioturbated
			14-32	2.5YR6/3 light yellowish brown clay w/ many orange mottles	
378	negative	Blake	0-4	10YR4/2 dark grayish brown loam	possible plow zone
			4-30	10YR3/2 very dark grayish brown clay w/ some orange and light gray mottling	
379	negative	Ferguson	0-14	clay plow zone	
			14-30	10YR4/1 dark gray clay w/ few orange mottles	bioturbated
380	negative	Blake	0-14	10YR4/3 brown clay loam	possible plow zone
			14-35	mottled clay- 10YR6/8 brownish yellow, 10YR6/4 light yellowish brown, and 10YR5/1 gray	
381	negative	Ferguson	0-13	plow zone	bioturbated
			13-35	10YR4/1 dark gray clay w/ few orange mottles	
382	negative	Blake	0-31	10YR4/2 dark grayish brown clay w/ orange and black mottles	
383	negative	Ferguson	0-10	road fill	
			10-38	10YR4/1 dark gray clay w/ few orange mottles	
384	negative	Blake	0-30	10YR4/2 dark grayish brown clay w/ orange mottles	
385	negative	Ferguson	0-10	10YR4/2 dark grayish brown clay	
			10-48	10YR4/1 dark grayish clay w/ feww orange mottles	
386	negative	Blake	0-30	10YR3/1 very dark gray clay w/ orange mottles	
387	negative	Ferguson	0-14	plow zone	
			14-32	10YR4/1 dark gray clay w/ few orange mottles	
			32-36	10YR5/1 gray clay w/ few orange mottles	
388	negative	Blake	0-36	10YR4/1 dark gray clay w/ orange mottles	
389	negative	Ferguson	0-12	disturbed native clay	
			12-30	10YR4/1 dark gray clay w/ few orange mottles	
			30-38	10YR5/1 gray clay w/ few orange mottles	
390	negative	Blake	0-30	10YR4/1 dark gray clay w/ some shell fragments	
391	negative	Ferguson	0-18	disturbed native clay	
			18-33	10YR4/1 dark gray clay w/ few orange mottles	
392	negative	Blake	0-31	10YR4/1 dark gray clay	
393	negative	Ferguson	0-12	10YR4/2 dark grayish brown clay	
			12-29	10YR4/1 dark gray clay w/ few orange mottles	
394	negative	Blake	0-30	10YR4/1 dark gray clay	
395	negative	Ferguson	0-17	10YR4/2 dark grayish brown clay	
			17-27	10YR4/1 dark gray clay w/ few orange mottles	
396	negative	Blake	0-32	10YR4/1 dark gray clay w/ orange and yellowish brown mottles	
397	negative	Ferguson	0-26	10YR4/2 dark grayish brown clay	
			26-32	10YR4/1 dark gray clay w/ few orange mottles	
398	negative	Blake	0-31	10YR5/3 brown sandy clay w/ gray and orange mottles	
399	negative	Ferguson	0-20	10YR5/3 brown clay	
			20-32	10YR5/2 grayish brown clay w/ few orange mottles	
400	negative	Blake	0-30	10YR5/4 yellowish brown sandy clay fill w/ gray and orange mottles	
401	negative	Ferguson	0-34	native clay fill	
402	negative	Blake	0-2	10YR4/1 dark gray sandy clay loam plow zone	
			2-31	10YR4/1 dark gray clay w/ amount of orange mottling increasing w/ depth	
403	negative	Ferguson	0-12	gray clay plow zone	
			12-33	10YR4/1 dark gray clay	
404	negative	Blake	0-7	10YR3/1 very dark gray clay plow zone	
			7-32	10YR2/1 dark grayish brown clay w/ orange mottles	
405	negative	Ferguson	0-10	gray clay plow zone	
			10-34	2.5YR4/2 dark grayish brown clay w/ few orange mottles	
406	negative	Blake	0-29	10YR4/2 dark grayish brown clay w/ orange mottles	
407	negative	Ferguson	0-11	gray clay plow zone	

			11-30	2.5YR4/2 dark grayish brown clay w/ few orange mottles	
408	negative	Blake	0-34	10YR5/2 grayish brow sandy clay w/ orange and white mottles	
409	negative	Ferguson	0-9	gray clay plow zone	
			9-28	2.5YR6/2 light brownish gray clay w/ many orange mottles	
410	positive	Blake	0-3	humic	10 m north of TS30
			3-27	10YR3/2 very dark grayish brown sandy loam	
			27-51	10YR4/2 dark grayish brown clay	
411	positive	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam	10 m south of 350, 3 m north of easement/ property line
			8-23	10YR3/3 dark brown fine sandy clay loam w/ few pale brown inclusions	
			23-42	10YR4/2 dark grayish brown loamy clay	hard
412	positive	Blake	0-6	humic	10 m west of TS30
			6-37	10YR3/3 dark brown sandy loam	
413	positive	Ferguson	0-3	humic	10 m east of 350
			3-10	10YR3/3 dark brown fine sandy loam	
			10-33	10YR3/2 dark grayish brown fine sandy clay loam	
			33-38	10YR3/2 dark grayish brown loamy clay	
			38-42	10YR5/2 grayish brown clay w/ many orange mottles	
414	positive	Blake	0-4	humic	30 m north of TS30
			4-24	10YR5/2 grayish brown sandy loam	
			24-49	10YR4/2 dark grayish brown clay	
415	negative	Ferguson	0-13	10YR4/2 dark grayish brown fine sandy loam	20 m east of 413
			13-26	10YR3/3 dark brown fine sandy clay loam	
			26-37	10YR5/2 grayish brown clay w/ few orange mottles	
416	negative	Blake	0-6	humic	20 m east of 414
			6-26	10YR5/2 grayish brown sandy loam	
			26-37	10YR4/2 dark grayish brown clay	
417	negative	Ferguson	0-23	10YR4/3 brown fine sandy loam	20 m north of 414
			23-33	10YR5/2 grayish brown clay w/ few orange mottles	
418	negative	Blake	0-4	humic	10 m east of 416
			4-19	10YR4/2 sandy loam	
			19-32	10YR3/1 very dark gray clay	
419	negative	Ferguson	0-15	10YR5/2 grayish brown fine sandy loam	20 m north of 417
			15-24	10YR4/2 dark grayish brown fine sandy clay loam	
			24-33	10YR5/3 brown clay w/ few dark grayish brown mottles	
420	negative	Blake	0-9	humic	20 m northwest of 418
			9-30	10YR5/2 grayish brown silty loam	
			30-41	10YR3/4 dark yellowish brown clay	
421	negative	Ferguson	0-15	10YR4/2 dark grayish brown fine sandy clay loam	30 m west of 410
			15-30	mottled 10YR4/3 brown and 10YR3/2 very dark grayish brown clay	
422	negative	Blake	0-8	humic	12 m east of 426
			8-36	10YR5/2 grayish brown silty loam	
			36-47	10YR3/4 dark yellowish brown and 10YR5/2 grayish brown clay	
423	negative	Ferguson	0-16	10YR4/3 brown fine sandy loam	10 m east of 421
			16-23	10YR3/2 very dark grayish brown loamy clay	
			23-33	10YR5/2 grayish brown clay w/ few orange mottles	
424	positive	Blake	0-4	humic	southwest corner of road and fence
			4-24	10YR3/2 very dark grayish brown silty clayey sand	
			24-36	10YR3/2 very dark grayish brown clay	very hard
425	negative	Ferguson	0-19	10YR4/3 brown fine sandy loam	10 m south/southeast of 415
			19-28	10YR4/2 dark graysih brown loamy clay	
			28-32	10YR5/2 grayish brown clay w/ few orange mottles	
426	positive	Ferguson	0-20	10YR4/2 dark grayish brown fine sandy loam	10 m east of 411 and 3 m north of fence
			20-27	10YR3/2 very dark grayish brown loamy clay	
			27-39	10YR5/2 grayish brown clay w/ few orange mottles	

427	positive	Blake	0-8	humic	15 m north of 428
			8-24	10YR3/3 dark brown silty clay loam	
			24-40	10YR4/2 dark grayish brown silty clay	
428	positive	Ferguson	0-13	10YR3/2 very dark grayish brown fine sandy loam	15 m south of 427, 3 m from wood edge, 10 m south of center line
			13-20	10YR3/3 dark brown loamy clay	
			20-38	10YR5/2 grayish brown clay w/ few orange mottles	
429	negative	Blake	0-32	10YR7/1 light gray silty clay loam w/ orange mottles	
			32-43	10YR5/1 gray sandy clay loam	hard
430	negative	Ferguson	0-40	10YR5/2 grayish brown silty loam	
			40-48	laminate, 10YR4/1 dark gray and 10YR8/1 white silty clay	
431	negative	Blake	0-13	mottled 10YR7/1 light gray and 10YR5/1 gray silty clay loam	
			13-23	10YR4/1 dark gray silty clay loam w/ slightly more clay content	
			23-44	10YR3/1 very dark gray clay loam	hard
432	negative	Ferguson	0-15	10YR5/2 grayish brown silty loam	few charcoal flecks
			15-70	10YR4/2 dark gray silty clay loam w/ few white mottles	
			70-82	10YR5/2 grayish brown silty clay w/ few white mottles and calcium carbonate concretions	
433	negative	Blake	0-5	humic	
			5-31	mottled 10YR7/1 light gray and 10/YR5/1 gray silty clay loam w/ orange mottles	hard
434	negative	Ferguson	0-38	clay fill, natural soils	
			38-48	10YR3/2 very dark grayish brown clay w/ few orange mottles	
435	negative	Blake	0-48	10YR4/2 dark gray silty clay loam w/ clay content increasing w/ depth	
436	negative	Ferguson	0-20	10YR3/2 very dark grayish brown clay	bioturbated
			20-40	10YR3/1 very dark gray clay	
			40-55	10YR4/1 dark gray clay w/ few yellow mottles	
437	negative	Blake	0-32	10YR3/1 very dark gray clay w/ orange mottles	
438	negative	Ferguson	0-41	10YR4/1 dark gray clay, yellow mottles in final 10 cm	
439	negative	Blake	0-31	10YR3/1 very dark gray clay w/ orange and white mottles, orange mottles increasing w/ depth	
440	negative	Ferguson	0-38	10YR4/1 cark gray clay w/ few yellow mottles in final 10 cm	
441	negative	Blake	0-16	10YR4/2 dark grayish brown sandy loam	
			16-62	10YR4/2 dark grayish brown clay loam	
			62-79	10YR3/2 very dark grayish brown clay w/ orange mottles and calcium concretions	
442	negative	Ferguson	0-50	10YR4/1 dark gray clay	
443	negative	Blake	0-4	10YR4/1 dark gray sandy loam	
			4-39	10YR4/1 dark gray sandy clay loam	hard
444	negative	Ferguson	0-12	10YR5/2 grayish brown clay loam	somewhat friable
			12-48	10YR4/2 dark grayish brown clay loam w/ few white mottles	
445	negative	Blake	0-43	10YR5/2 grayish brown silty loam	
			43-52	10YR5/2 grayish brown silty clay loam w/ white mottles	hard
446	negative	Ferguson	0-16	10YR4/2 dark grayish brown silty loam	friable
			16-60	10YR3/2 very dark grayish brown silt	friable
			60-76	10YR4/2 dark grayish brown silty clay	
447	negative	Blake	0-28	10YR5/2 grayish brown silty loam w/ white mottles	
			28-39	10YR5/2 grrayish brown silty clay loam w/ orange mottles and lots of white mottles	
448	negative	Ferguson	0-6	black clay loam w/ many burned clay fragments and charcoal	
			6-22	10YR4/1 dark gray clay	
			22-34	10YR3/1 very dark gray clay	
449	negative	Blake	0-17	10YR4/2 dark grayish brown silty loam	
			17-33	10YR4/1 dark gray silty loam	
			33-68	10YR3/2 very dark grayish brown silty loam w/ white mottles	
			68-82	10YR6/2 light brownish gray silty clay loam w/ lots of white mottles	very hard
450	negative	Ferguson	0-17	10YR6/2 light brownish gray silty loam	

			17-64	10YR5/2 grayish brown silty clay loam	
			64-73	10YR5/2 grayish brown silty clay	very hard
451	negative	Blake	0-63	10YR5/2 grayish brown silty clay loam w/ white mottles	harder w/ depth, modern plastic debris in first 10 cm
452	negative	Ferguson	0-26	10YR4/2 dark grayish brown silty loam	
			26-36	10YR4/2 dark grayish brown silty clay	hard
453	positive	Blake	0-13	10YR6/2 light brownish gray silty loam w/ light gray mottles	
			13-37	10YR6/2 light brownish gray silty clay loam w/ clay content increasing w/ depth and white and orange mottles in last 10 cm.	very hard in last 10 cm
454	negative	Ferguson	0-6	humic	on mound
			6-40	Mix of 10YR6/2 light brownish gray and 10YR7/2 light gray silty loam	
			40-69	Mix of 10YR4/2 dark grayish brown and 10YR8/2 very pale brown silty clay w/ orange mottles in final 10 cm.	hard
455	negative	Blake	0-49	10YR4/2 dark grayish brown silty loam	
			49-56	10YR5/2 grayish brown silty clay loam w/ light gray mottles	
			56-64	10YR5/2 grayish brown silty clay w/ white mottles	very hard
456	negative	Ferguson	0-7	humic	
			7-55	10YR4/3 brown silty loam	
			55-65	10YR4/2 dark grayish brown silty clay w/ few orange mottles	hard
457	negative	Blake	0-56	10YR5/2 grayish brown silty clay loam w/ light gray and orange mottles and iron croncretions	hard w/ depth
458	negative	Ferguson	0-7	humic	
			7-38	10YR4/2 dark grayish brown silty loam	
			38-60	10YR4/2 dark grayish brown silty clay w/ orange and pale brown mottles	clayier w/ depth
459	negative	Blake	0-34	10YR3/2 very dark grayish brown silty clay w/ light gray, white, and orange mottles	
460	negative	Ferguson	0-8	humic	
			8-25	10YR4/2 dark grayish brown silty loam	
			25-41	10YR4/2 dark grayish brown silty clay w/ orange and pale brown mottles	clayier w/ depth
461	negative	Blake	0-4	10YR5/2 grayish brown silty clay loam	10 m east of 453
			4-33	10YR3/2 very dark grayish brown clay w/ white and orange mottles	
462	negative	Ferguson	0-16	10YR4/2 dark garyish brown silty clay loam w/ few orange mottles	10 m north of 453
			16-30	10YR5/2 grayish brown silty clay w/ few orange mottles	hard
463	negative	Blake	0-7	10YR5/2 grayish brown silty clay loam	10 m south of 453
			7-34	10YR3/2 very dark grayish brown clay w/ white and orange mottles	
464	negative	Ferguson	0-16	10YR4/2 dark grayish brown silty clay loam	10 m west of 453
			16-30	10YR3/2 very dark grayish brown silty clay w/ few pale brown mottles	
465	negative	Blake	0-7	10YR6/2 light brownish gray silty loam w/ white mottles	1.5 m south of 453 on mound
			7-36	10YR6/2 light brownish gray silty clay loam w/ white and orange mottles	clay content increasing w/ depth
466	negative	Ferguson	0-18	Mottled 10YR7/2 light gray and 10YR6/2 light brownish gray silty loam	2 m @ 330 degrees from 453 on mound
			18-27	10YR7/2 light gray silty clay loam	
			27-37	10YR4/2 dark grayish brown silty clay	hard
467	negative	Ferguson	0-10	10YR5/3 brown silty loam	10 m north of STP7
			10-33	Mottled 10YR5/4 yellowish brown and 10YR7/3 very pale brown fine loamy sand w/ few iron concretions	
			33-49	10YR6/4 light yellowish brown fine sandy clay loam w/ common iron concretions	
			49-63	10YR6/2 light brownish gray clay w/ many orange mottles	
468	negative	Blake	0-10	10YR5/2 graish brown sandy loam	10 m south of STP7
			10-44	10YR6/4 light yellowish brown fine sand w/ many iron concretions	
			44-56	10YR6/3 pale brown and 10YR5/8 yellowish brown sandy clay	
469	negative	Ferguson	0-8	10YR5/3 brown silty loam	10 m east of STP7
			8-14	Mottled 10YR5/4 yellowish brown and 10YR7/3 very pale brown fine loamy sand w/ few iron concretions	

			14-28	10YR6/2 light brownish gray fine sandy clay w/ many orange mottles	
470	negative	Blake	0-9	10YR5/2 grayish brown sandy loam	10 m west of STP7
			9-35	10YR6/4 light yellowish brown fine sand w/ many iron concretions	
			35-46	10YR6/2 light brownish gray clay w/ orange and red mottles	
471	positive	Ferguson	0-20	10YR3/2 very dark grayish brown fine sandy loam w/ few iron concretions	10 m north of STP10
			20-26	10YR6/2 light brownish gray fine sandy clay w/ many orange mottles	
			26-39	Mottled 10YR6/2 light brownish gray and 5YR5/6 yellowish red clay	
472	positive	Blake	0-14	10YR4/2 dark grayish brown sandy loam	10 m south of STP10
			14-37	10YR5/4 yellowish brown sand	
			37-42	Mottled 10YR6/4 light yelloish brown and 10YR6/8 brownish yellow and 10YR7/1 light gray clay	
473	positive	Ferguson	0-16	10YR3/2 very dark grayish brown fine sandy loam w/ few iron concretions and gravel	10 m east of STP10
			16-33	10YR6/4 light yellowish brown fine loamy sand	
			33-43	10YR7/2 light gray clay w/ many orange mottles	
474	positive	Blake	0-9	10YR4/2 dark grayish brown sandy loam	10 m west of STP10
			9-33	10YR5/4 yellowish brown sand	
			33-42	Mottled 10YR5/8 yellowish brown and 10YR6/8 brownish yellow clay	
475	positive	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam w/ few iron concretions	20 m east of 473
			8-25	10YR5/3 brown fine loamy sand w/ few orange mottles	
			25-40	10YR7/2 light gray clay w/ many orange mottles	
476	negative	Blake	0-6	10YR4/2 dark grayish brown sandy loam	20 m south of 472
			6-39	10YR5/4 yellowish brown sand	
			39-48	Mottled 10YR4/3 very pale brown, 7.5YR4/6 strong brown and 10YR5/6 yellowish brown sandy clay	
477	negative	Ferguson	0-10	10YR3/3 dark brown fine sandy loam	20 m north of 471
			10-19	10YR5/3 brown fine loamy sand	
			19-29	10YR6/4 light yellowish brown clay w/ many orange mottles	
478	negative	Blake	0-5	10YR4/2 dark grayish brown sandy loam	20 m west of 474
			5-28	10YR5/4 yellowish brown sand	
			28-38	Mottled 10YR7/3 very pale brown, 7.5YR4/6 strong brown, and 10YR5/6 yellowish brown sandy clay	
479	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam	20 m east of 475
			10-28	10YR6/4 light yellowish brown fine sandy loam w/ many orange mottles	
			28-38	10YR6/2 light brownish gray clay w/ many orange mottles	
480	negative	Blake	0-3	humic	20 m east of 479
			3-32	Mottled 10YR7/3 very pale brown, 7.5YR4/6 strong brown, and 10YR5/6 yellowish brown sandy clay	
481	negative	Ferguson	0-6	10YR3/2 very dark grayish brown fine sandy loam	20 m north of 479
			6-10	10YR5/3 brown fine loamy sand w/ orange mottles	
			10-20	10YR6/2 light brownish gray clay w/ many orange mottles	
482	positive	Blake	0-13	10YR4/2 dark grayish brown sandy loam	20 m northeast of 479 in a sinkhole
			13-39	Mottled 10YR7/3 very pale brown and 10YR5/6 yellowish brown clay	
			39-51	7.5YR4/6 strong brown and 10YR7/1 light gray clay	layer of charcoal @ 19 cmbs on the southwest wall
483	positive	Ferguson	0-7	10YR4/2 dark grayish brown fine sandy loam	20 m south of 479
			7-20	10YR5/3 brown fine loamy sand w/ few orange mottles	
			20-30	10YR6/2 light brownish gray fine sandy clay w/ many orange mottles	
484	positive	Blake	0-21	10YR2/1 black loam	
			21-76	10YR3/1 very dark gray fine sandy clay loam more clay with depth	
				last 10 cm loamy clay	
485	positive	Goings	0-20	10 YR5/2 grayish brown soft sandy loam and clay	first corner next to smaller tree
			20-30	10 YR4/2 dark gray brown loam and clay	
			30-50	10YR3/2 very dark grayish brown	

486	positive	Carroll	0-33	10YR3/3 dark brown loam and cow manure	4 m from sycamore tree
			33-98	10YR5/2 grayish brown silty loam	
			98-103	10YR6/2 light grayish brown clay with few orange mottles	
487	positive	Ferguson	0-15	dark brown cow manure	
			15-38	10YR3/2 very dark gray brown fine sandy loam moist and friable	
			38-85	10YR3/1 very dark gray fine sandy clay	
			85-100	10YR4/2 dark gray brown loamy clay with few orange mottles	
488	positive	Blake	0-29	10YR3/2 very dark grayish brown clay loam	10 m west of 485
			29-62	10YR4/1 dark gray clay with white mottles increasing with depth along with hardness	
489	negative	Goings	0-22	10YR5/2 grayish brown soft silt loam and clay	left of big oak
			22-40	10YR4/2 dark gray brown loam and clay	
			40	Clay and calcium carbonate	
490	positive	Carroll	0-40	10R3/3 dark brown clay	located in slight depression, possibly a cistern
			40-100+	10YR2/2 very dark brown clay fill with lots of mottling-calcium carbonate at 80cms and below	
491	positive	Ferguson	0-27	10YR3/2 very dark gray brown fine sandy loam moist and friable	
			27-49	10YR3/1 very dark gray fine sandy clay loam	
			49-64	10YR5/1 gray loamy clay with a few yellow mottles	
492	positive	Blake	0-26	10YR4/2 dark grayish brown silty loam	
			26-59	10YR3/2 very dark grayish brown loamy clay calcium carbonate concentrations in final 10cm	
493	positive	Goings	0-23	10YR3/2 very dark grayish brown fine sand loam	in back of pecan tree left of first hay bale holder
			24-38	10YR3/1 very dark gray fine sandy clay loam	
			38-50	10YR4/2 dark grayish brown loamy clay with calcium carbonate	
494	positive	Carroll	0-10	10YR5/2 grayish brown sandy loam	5 m from old road in area with Chinese tallows
			10-75	2.5YR5/2 grayish brown clay loam, very compact with calcium carbonate at 70-75cm	
495	positive	Ferguson	0-18	10YR3/2 very dark gray brown clay loam	
			18-38	10YR3/1 very dark gray clay loam	
			38-50	10YR4/1 dark gray clay with calcium carbonate concentration	
496	positive	Blake	0-8	10YR3/2 very dark grayish brown silty loam	
			8-48	10YR4/3 brown loamy clay with orange mottles, hardness increasing with depth	
497	positive	Carroll	0-42	10YR3/2 very dark grayish brown clay loam	35 m east of oak tree
			42-60+	10YR4/2 dark grayish brown very compact clay with calcium carbonate at 55cms	
498	positive	Carroll	0-25	10YR5/2 gray brown silt	10 m from old road bed, directly north of old Oak tree
			25-65	2.5YR5/2 gray brown clay, very compact, calcium carbonate at 60-65	
499	positive	Ferguson	0-13	10YR5/2 gray brown clay loam	
			13-40	10YR3/2 very dark gray brown clay loam	
			40-50	10YR4/2 dark gray brown clay with calcium carbonate concentration and yellow mottling	
500	positive	Blake	0-9	10YR4/2 dark grayish brown clay loam	
			9-40	10YR3/2 very dark grayish brown clay with orange mottles, hardness of clay increasing with depth.	
501	positive	Blake	0-45	10YR3/2 very dark grayish brown clay loam, more clay with depth, last 10cm loamy clay	20 m west of 499, 10 m south of old tree
502	positive	Carroll	0-35	10YR5/2 gray brown silt	10 m north of 490
			35-60+	2.5YR5/2 gray brown clay, very compact, calcium carbonate at 60-65	
503	positive	Ferguson	0-30	10YR3/2 very dark gray brown clay, some calcium carbonate	
			30-48	10YR4/2 dark gray brown clay	
504	positive	Carroll	0-45	10YR3/2 very dark grayish brown clay loam	southeast of oak tree, 5 m north of fence line
			45-65	10YR4/2 dark grayish brown very compact clay with calcium carbonate at 60cms	
505	positive	Blake	0-32	10YR3/2 very dark grayish brown clay loam	20 m south of 499 in road
			32-41	10YR4/1 dark gray clay with calcium carbonate concentrations, very hard	

506	positive	Goings	0-11	10YR5/1 gray brown silt	south of 517
			11-30	10 YR5/2 grayish brown soft silt loam and clay	
			30-46	10YR4/2 dark grayish brown loamy clay	
507	negative	Ferguson	0-33	10YR4/2 dark gray loamy clay	
			33-43	10YR4/2 dark gray clay with many yellow mottles and a few calcium carbonate	
508	positive	Carroll	0-55	10YR3/2 very dark grayish brown clay loam	north of oak tree
			55-70+	10YR4/2 dark grayish brown very compact clay with calcium carbonate at 65cms	
509	positive	Blake	0-35	10YR3/2 very dark grayish brown loamy clay	20 m west of 496
510	negative	Goings	0-35	10YR4/2 dark gray loam and sand	east of 496
			35-55	10YR5/2 gray brown sand and loam	
511	positive	Ferguson	0-18	10YR3/2 very dark gray brown clay loam	
			18-32	10YR4/2 dark gray clay with few calcium carbonates, soil very hard and compacted.	
512	positive	Carroll	0-60	10YR4/2 dark gray loam and sand	
			60-75+	10YR5/3 brown clay, very compact with few orange mottles	
513	negative	Blake	0-12	10YR4/2 dark gray loam and sand	12 m north of 484
			12-41	10YR3/2 very dark gray brown clay loam	
			41-52	10YR6/3 pale brown clay with calcium	
514	negative	Goings	0-26	10YR5/2 gray brown sand and loam	south of 523, north of last hay bale holder
			26-40	10YR5/3 brown loam and clay with few orange mottles	
515	positive	Ferguson	0-18	10YR3/2 very dark gray brown clay	
			18-45	10YR4/2 dark grayish brown loamy clay	
516	positive	Carroll	0-50	10YR3/2 very dark grayish brown clay loam	5 m north of 486
			50-60+	10YR4/2 dark grayish brown very compact clay with calcium carbonate at 55cms	
517	positive	Blake	0-49	10YR3/2 very dark grayish brown clay loam	10 m west of 488
			49-57	10YR6/3 pale brown clay with calcium carbonate concentrations	
518	positive	Goings	0-10	10YR3/2 very dark grayish brown sand loam	in between and west of 485 and 491
			10-20	10YR5/2 gray brown sand and loam	
			20-35	10YR4/2 dark grayish brown loamy clay	
519	positive	Ferguson	0-10	10YR3/2 very dark grayish brown clay	
			10-48	10YR4/2 dark gray loamy clay	
520	negative	Ferguson	0-10	10YR3/2 very dark grayish brown clay	
			10-32	10YR4/2 dark gray loamy clay	
521	positive	Ferguson	0-32	10YR3/2 very dark grayish brown clay loam	
			32-42	10YR4/2 dark gray clay	
522	positive	Blake	0-8	10YR5/4 yellowish brown, sandy loam with clay nodules and orange nodules	20 m south of 480
			8-37	10YR6/1 gray sandy clay with many orange nodules	
523	negative	Goings	0-15	10YR5/4 yellowish brown, sandy loam	20 m north of 480
			15-30	10YR6/1 gray sandy clay with white mottles and many orange mottles	
524	negative	Ferguson	0-3	humic	
			3-22	10YR5/4 yellowish brown, fine sandy loam with few charcoal fragments	
			22-36	Mottled 10YR7/3 pale brown, 10YR5/3 brown and 7.5YR5/8 strong brown, fine sandy clay	
525	negative	Blake	0-38	10YR6/1 gray sandy clay with white mottles and many orange mottles	20 m east of 522
526	negative	Goings	0-12	10YR5/4 yellowish brown, sandy loam	20 m south of 522
			12-30	10YR6/1 gray sandy clay with white mottles and many orange mottles	
527	positive	Ferguson	0-15	10YR4/2 dark grayish brown fine sandy loam	20 m west of 403
			15-25	10YR5/4 yellowish brown, fine sandy loam with a few orange mottles and charcoal fragments	
			25-39	Mottled 10YR7/3 pale brown, 10YR5/3 brown and 7.5YR5/8 strong brown, fine sandy clay	
528	negative	Blake	0-9	10YR6/2 light brownish gray sandy loam	24 m south of 483
			9-52	10YR6/1 gray sandy clay with many orange mottles increasing with depth	
529	positive	Goings	0-20	10YR7/3 pale brown soft sandy loam	20 m south of 527

			20-30	10YR5/4 yellowish brown, fine sandy loam with a few yellow mottles	
530	positive	Ferguson	0-10	10YR7/3 very pale brown fine sandy loam	30 m south of 531
			10-30	10YR7/3 very pale brown fine sandy clay with many mottles	
531	positive	Blake	0-7	10YR6/2 light brownish gray sandy loam	12 m east of 476
			7-36	10YR7/3 very pale brown fine sandy clay with many orange mottles that gets harder with depth	
532	negative	Goings	0-9	10YR7/3 pale brown soft sandy loam	20 m south of 530
			9-25	10YR5/4 yellowish brown, fine sandy loam with a few yellow mottles	
533	negative	Ferguson	0-10	10YR7/3 very pale brown fine sandy loam	25 m east of 530
			10-34	10YR7/3 very pale brown fine sandy clay with many mottles	
534	negative	Blake	0-10	10YR6/2 light brownish gray sandy loam	22 m west of 530
			10-61	10YR7/4 very pale brown fine sand	
			61-66	10YR7/3 very pale brown fine sandy clay	
535	positive	Goings	0-20	10YR7/3 pale brown soft sandy loam	20 m north of 475
			20-30	10YR5/4 yellowish brown, fine sandy loam with many orange mottles	
536	positive	Ferguson	0-16	10YR5/4 yellowish brown, fine sandy loam	20 m north of 473
			16-36	10YR4/6 dark yellow brown fine loamy sand	
			36-47	10YR6/4 light yellowish brown, fine sandy clay with many orange mottles	
			47-58	10YR6/4 light yellowish brown, fine sandy clay with many orange mottles	
537	negative	Blake	0-8	10YR6/2 light brownish gray sandy loam	20 m north/northeast of 534
			8-39	10YR7/4 very pale brown fine sand	
			39-44	10YR7/3 very pale brown sandy clay, very hard	
538	positive	Goings	0-10	10YR5/2 gray brown, fine sandy loam	20 m north of 535
			10-25	10YR7/3 pale brown soft sandy loam	
			25-40	10YR5/4 yellowish brown, fine sandy loam with orange mottles	
539	negative	Ferguson	0-10	10YR5/2 gray brown, fine sandy loam	
			10-18	10YR6/4 light yellowish brown, fine loamy sand with orange mottles	
			18-28	10YR5/4 yellowish brown, fine sandy clay with many orange mottles	
540	negative	Blake	0-5	10YR6/2 light brownish gray sandy loam	20 m north of 536
			5-32	10YR7/4 very pale brown fine sand	
			32-41	10YR6/4 light yellowish brown clay with strong brown mottles	
541	negative	Blake	0-4	10YRhumic	20 m east of 538
			4-28	Mottled 7.5 5/6 strong brown, 10YR6/6 brownish yellow, and 10YR7/4 very pale brown clay	
542	negative	Ferguson	0-18	Gray, pale brown mixed fill. silt clay loam	10 m south of 16
			18-48	10YR 5/2 gray brown. Silt, loam with few pale brown mottles.	
			48-62	10YR 5/2 gray brown. Silt, clay with pale brown and/or mottles.	
543	negative	Blake	0-9	10YR4/2 dark grayish brown, fine sandy loam.	10 m north of 16 on edge of mound.
			9-46	10YR6/2 light brownish gray silty loam	
			46-65	10YR6/2 light brownish gray silty clay loam with orange and white mottles- harder with depth	
544	negative	Goings	0-17	10YR4/2 dark grayish brown, fine sandy loam.	10 m east of 16
			17-33	10YR6/2 light brownish gray silty clay loam with orange and white mottles	
			33-48	10YR 5/2 gray brown. Silt, clay	
545	negative	Ferguson	0-17	Gray, pale brown mixed fill. Silt,clay, loam	10 m west of 16
			17-32	10YR 5/2 gray brown. Silt, loam with few pale brown mottles.	
			32-54	10YR 5/2 gray brown. Silt, clay with pale brown and/or mottles.	
546	positive	Blake	0-32	10YR4/3 brown silty loam	2 m south/southwest of 16 on mound
			32-60	10YR5/3 brown silty loam	
			60-69	10YR6/3 pale brown silty clay loam with white and orange mottles, very hard.	
547	negative	Goings	0-18	10YR5/3 brown silty loam	24 m east of 16

			18-60	10YR6/3 pale brown silty clay loam with white and orange mottles, very hard,	
548	negative	Ferguson	0-20	10YR4/3 brown fine sandy loam	on mound 3 m north of 16
			20-63	10YR5/3 brown silt	
			63-73	10YR 5/2 gray brown. Silt, clay with few orange mottles, dry and very hard.	
549	negative	Ferguson	0-4	humic	10 m south of 551
			4-29	10YR5/4 yellow brown fine sandy clay loam	
			29-39	7.5YR4/6 strong brown clay	
550	negative	Goings	0-8	10YR3/2 very dark grayish brown sandy loam with clay	10 m north of 551
			8-18	10YR4/4 dark yellowish brown sand with clay nodules.	
			18-24	10YR5/6 yellow brown fine sandy clay loam	
			24-30	7.5YR4/6 strong brown clay	
551	negative	Blake	0-11	10YR3/2 very dark grayish brown sandy loam	
			11-33	10YR4/4 dark yellowish brown sand with clay nodules.	
			33-45	7.5YR4/6 strong brown clay	
552	positive	Ferguson	0-4	humic	10 m east of 550, 10 m south of barb wire fence-easement edge
			4-16	10YR5/4 yellow brown fine sandy loam	
			16-30	10YR5/6 yellow brown fine sandy clay loam	
			30-40	7.5YR4/6 strong brown clay	
553	positive	Goings	0-4	10YR3/2 very dark grayish brown sandy loam	10 m south of 552
			4-10	10YR4/4 dark yellowish brown sand with clay nodules.	
			10-21	10YR5/6 yellow brown fine sandy clay loam	
			21-33	5YR4/4 reddish brown clay	
554	negative	Blake	0-5	10YR4/2 dark grayish brown loam	12 m east of 552
			5-23	10YR5/4 yellowish brown sand	
			23-34	5YR4/4 reddish brown clay	
555	negative	Ferguson	0-2	humic	10 m east of 553
			2-10	10YR5/4 yellow brown fine sandy loam	
			10-18	10YR5/6 yellow brown fine sandy clay loam	
			18-30	7.5YR3/4 dark brown clay	
556	positive	Blake	0-7	10YR4/3 brown loam	10 m north of 552
			7-30	10YR5/4 yellowish brown sand	
			30-41	5YR3/4 dark reddish brown clay	
557	negative	Blake	0-6	10YR4/3 brown loam	10 m south of 553
			6-23	10YR5/4 yellowish brown clayey sand	
			23-33	5YR3/4 dark reddish brown clay	
558	negative	Ferguson	0-5	humic	10 m south of 82
			5-16	10YR4/4 dark yellow brown clay.	
			16-30	10YR3/2 very dark gray brown clay	
559	negative	Blake	0-4	10YR4/2 dark grayish brown loam	20 m south of original positive
			4-12	10YR6/4 light yellowish brown sand	
			12-31	5YR4/6 yellowish red clay	
560	negative	Goings	0-4	10YR4/2 dark grayish brown loam	20 m south of positive
			4-34	10YR6/4 light yellowish brown sand	
			34-45	5YR4/6 yellowish red clay	
561	negative	Ferguson	0-5	10YR3/4 dark yellow brown fine sandy loam	
			5-17	10YR5/4 yellow brown fine sandy loam	
			17-29	5YR4/6 yellowish red clay	
562	negative	Blake	0-5	10YR4/2 dark grayish brown loam	10 m south of original positive
			5-21	10YR5/4 yellowish brown sand	
			21-33	5YR4/6 yellowish red clay	
563	positive	Ferguson	0-5	10YR3/4 dark yellow brown fine sandy loam	
			5-13	10YR5/4 yellow brown fine sandy loam	
			13-26	5YR4/6 yellowish red clay	
564	negative	Ferguson	0-12	parking lot driveway grown over with grass	20 m west of hwy
			12-32	10YR4/2 dark grayish brown clay with few orange mottles.	

565	negative	Goings	1-30	10YR4/2 dark grayish brown clay with few orange mottles.	100 m east of 566
566	negative	Blake	0-30	10YR4/2 dark grayish brown clay with few orange mottles.	
567	negative	Ferguson	0-2	10YR3/2 very dark gray brown clay loam	back w/property line
			2-23	10YR4/2 dark grayish brown clay with few orange mottles.	
			23-30	10YR4/1 dark grayish brown clay with few orange mottles.	
568	negative	Goings	0-2	mulch	
			2-28	10YR4/2 dark grayish brown clay with few orange mottles.	
569	negative	Blake	0-31	10YR4/1 dark grayish brown clay with few orange mottles.	
570	negative	Ferguson	0-2	10YR3/2 very dark gray brown clay loam	south side of property
			2-18	10YR4/2 dark grayish brown clay with few orange mottles.	
			18-26	10YR4/1 dark grayish brown clay with few orange mottles.	
571	negative	Blake	0-13	10YR4/2 dark grayish brown clay with few orange mottles.	
			13-29	10YR6/2 light brownish gray clay with many orange mottles	
572	positive	Blake	0-5	humic	20 m southwest from original TS13 positive shovel test.
			5-12	10YR5/4 yellowish brown clayey sand	
			12-26	10YR5/3 brown sandy clay with orange mottles	
			26-37	10YR5/4 yellowish brown clay	
573	positive	Goings	0-4	humic	40 m south of TS13
			4-18	10YR5/4 yellowish tan sandy clay with silt	
			18-26	10YR5/4 yellowish brown sandy clay	
			26-31	10YR5/4 yellowish brown clay	
574	positive	Ferguson	0-8	10YR3/3 dark brown sandy loam with some iron concretions.	on ridge edge
			8-14	10YR5/4 yellowish brown loamy sand with many iron concretions.	
			14-27	10YR5/4 yellowish tan sandy clay with a few orange mottles that are dry and hard	
			27-40	7.5YR5/6 strong brown clay	
575	positive	Blake	0-4	humic	20 m northwest of 574
			4-26	10YR7/3 very pale brown fine sandy loam	
			26-38	5YR4/6 yellowish red clay with some charcoal	
576	positive	Goings	0-5	humic	20 m west of gate and 13
			5-30	5YR4/6 yellowish red clay	
577	positive	Ferguson	0-4	10YR3/3 dark brown fine sandy loam	on ridge edge
			4-12	10YR5/4 yellowish brown fine loamy sand	
			12-24	10YR5/4 yellowish brown sandy clay	
			24-40	7.5YR5/6 strong brown clay	
578	negative	Blake	0-8	10YR3/3 dark brown clay loam	20 m south of 577
			8-25	10YR3/4 dark yellowish brown clayey sand with lots of gravel and iron concretions	
			25-36	10YR5/6 yellowish red clay with some charcoal.	
579	negative	Goings	0-3	10YR3/2 dark gray brown sandy loam	20 m south of 180
			3-25	10YR5/4 yellowish brown sandy clay	
			25-34	5YR4/6 yellowish red clay	
580	positive	Ferguson	0-10	10YR3/2 dark gray brown sandy loam many charcoal fragments	20 m west of ridge
			10-20	10YR5/4 yellowish brown fine loamy sand	
			20-30	7.5YR5/6 strong brown clay	
581	negative	Blake	0-11	humic	20 m north of 580
			11-18	10YR5/4 yellowish brown sandy clay loam	
			18-37	5YR4/4 reddish brown clay	
582	negative	Goings	0-3	10YR5/2 gray brown loamy clay with orange mottles	
			3-30	5YR4/4 reddish brown clay	
583	negative	Ferguson	0-3	10YR5/2 gray brown fine sandy loam	
			3-20	10YR6/4 light yellow brown fine loamy sand	
			20-30	7.5YR5/6 strong brown clay	
584	positive	Blake	0-7	humic	
			7-23	10YR6/4 light yellow brown fine loamy sand	
			23-31	5YR4/4 reddish brown clay	

585	negative	Ferguson	0-4	10YR5/2 gray brown fine sandy loam	
			4-10	10YR5/4 yellowish brown fine loamy sand	
			10-26	7.5YR5/6 strong brown clay	
586	positive	Ferguson	0-16	10YR4/3 brown sandy loam	25 m north/northwest of 297, southwest of TS 13
			16-37	10YR6/4 light yellow brown loamy sand	
			37-60	2.5YR4/8 red clay with many gray brown mottles.	
587	positive	Goings	0-4	10YR6/4 light yellow brown loamy sand	25 m southeast of 589
			4-40	10YR6/3 pale brown silty clay loam with orange clay nodules	
588	positive	Blake	0-18	10YR4/2 dark grayish brown silt loam with lots of clay	
			18-32	10YR6/3 pale brown silty clay loam with orange clay nodules	
			32-41	5YR4/4 reddish brown clay	
589	positive	Ferguson	0-9	10YR4/3 brown sandy loam	
			9-20	10YR6/4 light yellow brown loamy sand	
			20-32	2.5YR4/8 red clay with many gray brown mottles.	
590	positive	Goings	0-3	10YR5/2 gray brown fine sandy loam	25 m southeast of 587
			3-29	10YR6/4 light yellow brown loamy sand	
			29-38	5YR4/6 yellowish red and 10YR6/2 light brownish gray clay	
591	negative	Blake	0-31	10YR3/4 dark yellowish brown clayey sand with orange mottles and iron concretions	20 m south/southeast of 588
592	positive	Blake	0-10	humic	22 m northeast of 307
			10-37	10YR7/2 light gray silty clay loam with orange mottles	
			37-49	5YR4/6 yellowish red and 10YR6/2 light brownish gray clay	
593	positive	Ferguson	0-6	10YR4/3 brown sandy loam	10 m southeast of 307
			6-12	10YR6/4 light yellow brown loamy sand	
			12-23	2.5YR4/8 red clay with many gray brown mottles.	
594	negative	Goings	0-3	10YR6/4 light yellow brown loamy sand, 10YR7/2 light gray silty clay loam	10 m west of 307
			3-28	2.5YR4/8 red clay	
595	negative	Blake	0-4	humic	10 m north of 596
			4-36	10YR7/3 very pale brown	
			36-48	2.5YR4/6 red and 10YR7/2 light gray clay	
596	positive	Ferguson	0-10	10YR4/3 brown sandy loam	10 m north of 307
			10-15	10YR6/4 light yellow brown loamy sand	
			15-25	2.5YR4/8 red clay with many gray brown mottles.	
597	negative	Goings	0-2	10YR7/2 light gray silty clay loam with orange mottles	20 m east of 599
			2-22	10YR6/4 light yellow brown sand with clay	
			22-23	10YR6/4 light yellow brown clay with many orange mottles	
598	negative	Ferguson	0-10	10YR4/3 brown sandy loam	
			10-16	10YR6/4 light yellow brown loamy sand	
			16-30	2.5YR4/8 red clay with many gray brown mottles.	
599	positive	Ferguson	0-12	10YR5/2 gray brown sandy loam	west of 307
			12-29	10YR6/4 light yellow brown clay with many orange mottles	
600	negative	Dahlin	0-6	dark brown humic sand	10 m north of 44
			6-19	10YR5/2 gray clayey sand	
			19-31	5YR4/6 yellowish red and 10YR6/3 pale brow clay	
601	negative	Blake	0-4	humic	20 m west of 44
			4-7	10YR5/4 yellowish brown clayey sand	
			7-28	5YR4/6 yellowish red and 10YR6/3 pale brown clay	
602	negative	Goings	1-13	10YR4/2 dark grayish brown clay and loam	12 m south of 44
			13-30	5YR4/6 yellowish red and 10YR6/3 pale brown clay	
603	negative	Ferguson	0-28	7.5YR4/6 strong brown clay, moist and firm	20 m east of 44
			28-42	2.5YR7/2 light gray clay with many 5YR4/6 strong orange mottles	
604	negative	Dahlin	0-14	10YR5/2 gray clayey sand	10 m east of 44
			14-30	5YR4/6 yellowish red and 10YR6/3 pale brown clay	
605	negative	Blake	0-12	10YR4/2 dark grayish brown very fine sandy loam	10 m west of 44
			12-22	10YR6/3 pale brown sandy clay with orange mottles	

			22-36	5YR4/6 yellowish red and 10YR6/3 pale brown clay	
606	negative	Goings	1-3	10YR4/2 dark gray brown loamy clay	29 m south of 44
			3-18	5YR4/6 yellowish red	
607	negative	Ferguson	0-6	10YR4/2 dark gray brown	
			6-24	10YR6/4	
			24-34	10YR6/8	
608	negative	Dahlin	0-10	humic	20 m northeast of 608
			10-35	2.5YR7/2 light gray sand with gravel	
			35-50	5YR4/6 yellowish red with some concretions	
609	negative	Blake	0-9	humic	
			9-41	10YR6/4 light yellow brown sand with iron concretions	
			41-53	10YR6/6 brownish yellow sandy clay- hard with iron concretions.	
610	positive	Goings	0-23	10YR6/6 brownish yellow sandy clay	19 m south of 42
			23-40	5YR4/6 yellowish red sandy clay, more clay with depth	
611	positive	Ferguson	0-7	10YR3/2 very dark gray brown sandy loam	20 m south of 22
			7-50	10YR3/3 dark brown loamy sand	
			50-65	10YR5/3 brown loamy sand	
			65-78	10YR4/3 brown sandy clay	
612	negative	Dahlin	0-4	humic	20 m northeast of 608
			4-33	10YR6/4 light yellow brown sand with iron concretions	
			33-43	10YR6/6 brownish yellow sandy clay with iron staining	
613	negative	Blake	0-13	10YR4/2 dark gray brown sandy loam	20 m southeast of 610
			13-21	10YR5/4 yellowish brown loamy sand	
			21-44	5YR4/6 yellowish red sandy clay, more clay with depth	
614	negative	Goings	0-15	10YR4/2 dark gray brown sandy loam with clay	15 m east of 613
			15-35	5YR4/6 yellowish red sandy clay, more clay with depth	
615	positive	Ferguson	0-7	10YR3/2 very dark gray brown sandy loam	
			7-30	10YR5/4 yellowish brown loamy sand	
			30-46	10YR5/3 brown loamy sand	
			46-133	10YR5/4 yellowish brown loamy sand	
616	negative	Dahlin	0-20	10YR5/3 brown clayey sand with basal clay	20 m north of 22
			20-38	10YR5/4 yellowish brown clayey sand	
			38-50	5YR4/6 yellowish red sandy clay	
617	negative	Blake	0-8	humic	20 m west of 22
			8-15	10YR4/3 brown sand	
			15-33	5YR4/6 yellowish red clay	
618	negative	Goings	0-58	10YR5/4 yellowish brown loamy sand	20 m east of 22
			58-65	10YR5/4 yellowish brown loamy sand	
619	positive	Dahlin	0-8	humic	20 m west of 626
			8-60	10YR4/3 brown sand	
			60-70	10YR4/3 brown sand and 5YR4/6 yellowish red clay	
			70-80	5YR4/6 yellowish red clay with 2.5y 7/2 light gray sand	
620	negative	Dahlin	0-80	10YR4/3 brown sand	20 m west of 615
			80-110	2.5y 7/2 light gray sand drier with depth	
621	positive	Blake	0-10	humic	
			10-61	10YR4/3 brown sandy loam	
			61-100	10YR7/3 very pale brown sand	
622	positive	Goings	1-116	10YR4/3 brown sandy loam	20 m west of 620
			116-126	10YR7/3 very pale brown sand	
623	positive	Dahlin	0-6	humic	20 m southwest of 624
			6-65	10YR4/3 brown fine sand	
			65-75	5YR4/6 yellowish red sandy clay	
624	positive	Ferguson	0-10	10YR4/2 dark gray brown sandy loam	20 m west of 625 south side of Ridge Rd in tree line
			10-20	10YR5/4 yellowish brown loamy sand	
			20-45	10YR3/2 very dark gray brown loamy sand	

			45-70	10YR5/4 yellowish brown sand	
			70-75	10YR4/4 dark yellow brown clay	
			75-100	10YR6/3 pale brown sand	
			100-105	10YR4/4 dark yellow brown sandy clay.	
625	positive	Goings	0-80	10YR5/4 yellowish brown sand	20 m east of 624
			80-90	10YR6/3 pale brown sand	
			90-100	10YR7/3 very pale brown sand	
626	positive	Blake	0-10	humic	
			10-31	10YR4/2 dark gray brown sandy loam	
			31-56	5YR4/6 yellowish red sandy clay	
627	positive	Dahlin	0-6	humic	20 m north of 24
			6-33	10YR4/3 brown fine sand with some gravel	
			33-43	5YR4/6 yellowish red sandy clay	
628	positive	Ferguson	0-10	10YR3/2 very dark gray brown loamy sand	20 m and across rd from 24
			10-50	10YR5/4 yellowish brown sand	
			50-58	10YR6/3 pale brown sand	
			58-70	10YR4/4 dark yellow brown clay.with red mottles	
629	negative	Goings	0-65	10YR5/4 yellowish brown sand	20 m east of 630
			65-90	10YR7/3 very pale brown sand	
630	negative	Blake	0-8	humic	
			8-90	10YR6/3 pale brown sand	
			90-100	10YR7/3 very pale brown sand with clay nodules	
631	positive	Dahlin	0-4	humic	20 m east of 633, 10 m west of 630
			4-62	10YR4/3 brown fine sand	
			62-73	2.5y 7/2 light gray sand drier with depth	
632	negative	Ferguson	0-8	10YR4/2 dark gray brown fine sandy loam	20 m west of north side of ridge road
			8-28	10YR5/4 yellowish brown fine loamy sand	
			28-38	10YR5/4 yellowish brown sand and clay, 10YR4/4 dark yellow brown clay.with red mottles	
633	negative	Goings	0-70	10YR5/4 yellowish brown sand	20 m west of 632
			70-80	10YR7/3 very pale brown sand	
634	negative	Blake	0-4	humic	20 m west of 24
			4-46	10YR6/3 pale brown sand	
			46-59	5YR4/6 yellowish red sandy clay with yellowish brown mottles	
635	negative	Dahlin	0-3	humic	20 m west of Randy's STP
			3-26	10YR4/3 brown fine sand with a few gravels	
			26-36	10YR5/4 yellowish brown sandy clay with iron staining	
636	negative	Ferguson	0-9	10YR5/2 gray brown fine sandy clay	20 m west of 25
			9-18	10YR6/4 light yellow brown fine sandy clay	
			18-28	10YR6/4 light yellow brown fine sandy clay with orange mottles	
637	negative	Goings	0-30	10YR4/2 dark gray brown sandy loamy clay	
			30-40	5YR4/6 yellowish red sandy clay	
638	positive	Dahlin	0-63	10YR4/3 brown fine sand with a few gravels	20 m east of STP 21
			63-100	2.5y 7/2 light gray sand drier with depth	
639	positive	Ferguson	0-10	10YR4/2 dark gray brown sandy	20 m south of 21, south side of rd
			10-34	10YR5/4 yellowish brown loamy sand	
			34-58	10YR3/2 very gray brown sandy loam	
			58-90	10YR6/3 pale brown sand	
640	negative	Goings	0-31	10YR4/2 dark gray brown sandy loam	20 m across rd from TS 8 initial shovel test
			31-42	5YR4/6 yellowish red clay	
641	positive	Dahlin	0-63	10YR4/3 brown fine sand	20 m east of 638
			63-73	10YR5/4 yellowish brown sandy clay	
642	positive	Ferguson	0-8	clay fill	40 m west of 639, south side of rd and treeline.
			8-20	10YR3/2 very gray brown sandy clay	
			20-33	10YR6/6 yellow brown clay with few pale brown mottles	

643	negative	Blake	0-5	humic	
			5-44	10YR3/2 very dark gray brown loamy sand	
			44-52	10YR4/6 dark yellowish brown clay, very hard	
644	negative	Blake	0-11	humic	
			11-37	10YR5/4 yellowish brown sandy loam	
			37-51	5YR4/6 yellowish red sandy clay with yellowish brown mottles	
645	positive	Blake	0-6	humic	20 m west of 21
			6-103	10YR6/3 pale brown sand	
646	negative	Blake	0-21	10YR3/2 very dark gray brown loamy sand	20 m southwest of 645
			21-34	5YR5/6 yellowish red clay	
647	positive	Ferguson	0-6	10YR3/2 very dark gray brown clay	15 m south of 55 on edge of steep slope
			6-27	10YR5/4 yellowish brown fine loamy sand	
			27-43	7.5YR5/6 strong brown clay	
648	positive	Blake	0-6	humic	18 m east of 55
			6-28	10YR5/3 brown sand	
			28-44	10YR5/8 yellowish brown sandy clay	
649	positive	Dahlin	0-4	humic	20 m south of 55
			4-29	10YR5/3 brown fine sand with some gravel	
			29-39	5YR4/6 yellowish red sandy clay with yellowish brown mottles with some gravel	
650	positive	Goings	0-12	10YR3/2 very dark gray brown clay with loam	20 m east of 55
			12-30	5YR4/6 yellowish red sandy clay with yellowish brown mottles with some gravel	
651	negative	Ferguson	0-5	10YR3/2 very dark gray brown clay	20 m west of 308
			5-20	7.5YR5/6 strong brown clay	
652	negative	Blake	0-8	humic	18 m east of 308
			8-21	10YR5/3 brown clayey sand	
			21-45	10YR6/6 yellow brown clay harder with depth	
653	negative	Dahlin	0-3	humic	20 m south of 650
			3-23	10YR5/3 brown clayey sand with some gravel	
			23-37	5YR4/6 yellowish red sandy clay with yellowish brown mottles with some gravel	
654	negative	Goings	0-26	10YR6/3 pale brown sandy clay	20 m south of 308
			26-31	5YR4/6 yellowish red sandy clay with yellowish brown mottles	
655	positive	Ferguson	0-8	10YR3/2 very dark gray brown sandy loam	15 m south of 61
			8-22	10YR5/4 yellowish brown fine loamy sand	
			22-35	7.5YR5/6 strong brown clay	
656	negative	Blake	0-25	10YR4/2 dark gray brown clay with orange mottles	20 m east of 61
657	negative	Dahlin	0-3	humic	20 m north of 308
			3-37	10YR5/3 brown fine sand	
			37-50	5YR4/6 yellowish red sandy clay with yellowish brown mottles	
658	negative	Goings	0-2	10YR3/2 very dark gray brown loamy clay	20 m west of 61
			2-31	10YR6/3 pale brown clay with orange	
659	positive	Ferguson	0-3	10YR3/2 very dark gray brown fine sandy loam	15 m north of 83
			3-22	10YR5/4 yellowish brown fine loamy sand	
			22-36	10YR6/3 pale brown clay with few orange mottles	
660	negative	Blake	0-7	humic	10 m west of 655
			7-32	10YR6/4 light yellow brown fine sand	
			32-43	5YR4/6 yellowish red clay	
661	negative	Dahlin	0-8	2.5y 7/2 light gray clay	20 m north of 61
			8-22	10YR4/2 dark gray brown clay iron staining	
662	negative	Goings	0-2	10YR3/2 very dark gray brown loamy clay	20 m south of 83
			2-28	5YR4/6 yellowish red clay with sand	
663	positive	Ferguson	0-13	10YR3/2 very dark gray brown fine sandy loam	20 m west of 84
			3-18	10YR5/4 yellowish brown fine loamy sand	
			18-38	10YR6/3 pale brown clay with few orange mottles	

			38-50	10YR5/3 brown clay with many orange mottles	
664	negative	Blake	0-4	humic	20 m east of 84
			4-29	10YR6/4 light yellow brown clayey sand	
			29-41	10YR6/3 pale brown clay with orange mottles	
665	positive	Dahlin	0-4	humic	20 m west of 83
			4-28	10YR5/3 brown fine sand	
			28-38	5YR4/6 yellowish red sandy clay with yellowish brown mottles	
666	negative	Goings	0-31	10YR5/4 yellowish brown clayey sand	20 m west of 665
			31-41	5YR4/6 yellowish red sandy clay with yellowish brown mottles	
667	negative	Goings	0-3	10YR4/2 dark gray brown fine sandy loam	20 m south of 84
			3-38	5YR4/6 yellowish red sandy clay with yellowish brown mottles	
			38-46	10YR6/3 pale brown clay with orange mottles	
668	negative	Blake	0-4	humic	20 m east of 84
			4-23	10YR5/4 yellowish brown clayey sand	
			23-35	10YR6/3 pale brown clay with orange mottles	
669	negative	Dahlin	0-4	humic	20 m north of 84
			4-24	10YR5/4 yellowish brown sandy clay with iron staining	
670	negative	Dahlin	0-24	10YR5/3 brown fine clayey sand	20 m northwest of 84
			24-34	10YR5/4 yellowish brown sandy clay with iron staining	
671	negative	Ferguson	0-8	10YR4/2 dark gray brown fine sandy loam	20 m west of 74, to west of berm in low area
			8-46	10YR7/2 light gray fine sandy clay with orange mottles	
			46-56	10YR7/1 light gray clay with reddish orange mottles	
672	positive	Blake	0-11	humic	8 m south of 74
			11-59	10YR5/4 yellowish brown sand	
			59-93	10YR8/2 pale brown sandy clay loam w/ many orange mottles, harder and clayier with depth	
673	negative	Dahlin	0-44	10YR4/2 dark gray brown fine sandy loam	20 m east of 74
			44-70	10YR6/4 light yellow brown w/few light gray mottles, clay is harder.	
674	negative	Goings	0-3	10YR4/2 dark gray brown fine sandy loam	20 m north of 74
			3-68	10YR5/4 yellowish brown sand	
			68-90	10YR6/4 light yellow brown w/few light gray mottles, clay is harder.	
675	negative	Ferguson	0-4	10YR4/2 dark gray brown fine sandy loam	5 m north of 74 on berm
			4-47	10YR5/4 yellowish brown fine loamy sand	
			47-77	10YR6/4 light yellow brown w/few light gray mottles	
			77-87	10YR6/4 light yellow brown w/few light gray mottles, clay is harder.	
676	positive	Blake	0-7	humic	30 m west/southwest of 71
			7-76	10YR5/4 yellowish brown sand	
			76-91	10YR8/2 pale brown sandy clay loam w/ many orange mottles, harder and clayier with depth	
677	negative	Dahlin	0-67	10YR5/4 yellowish brown sand with very few pebbles	30 m east of 71
			67-80	10YR6/4 light yellowish brown sandy clay with iron concretions, very dry and compact	
678	positive	Goings	0-3	10YR4/2 dark gray brown fine sandy loam	10 m east of 71
			3-61	10YR5/4 yellowish brown sand	
			61-70	10YR6/4 light yellowish brown sandy clay, very dry and compact	
679	negative	Ferguson	0-12	10YR3/2 very dark gray brown fine sandy loam	on northwest edge of mound
			12-40	10YR5/4 yellowish brown fine loamy sand	
			40-62	10YR8/2 pale brown sandy clay loam w/ many orange mottles and some iron concretions	
680	negative	Blake	0-9	humic	
			9-65	10YR5/4 yellowish brown fine loamy sand	
			65-97	10YR8/2 very pale brown sandy clay loam w/ many orange mottles	
681	positive	Dahlin	0-6	humic	5 m southwest of 676
			6-83	10YR5/4 yellowish brown fine loamy sand with few iron concretions	

			83-97	10YR6/4 light yellowish brown fine sandy clay, with many orange mottles, more iron concretions	
682	negative	Goings	0-8	10YR4/2 dark gray brown fine sandy loam	10 m west of 68
			8-68	10YR5/4 yellowish brown sand	
			68-76	2.5YR4/6 red clay with pale brown mottles	
683	negative	Ferguson	0-15	10YR4/2 dark gray brown fine sandy clay loam	10 m south of 68
			15-40	10YR6/4 light yellowish brown fine sandy clay, with many orange mottles, gradually gets clayier with depth	
684	negative	Blake	0-12	humic	20 m south of 300
			12-35	10YR6/4 light yellowish brown sandy loam	
			35-47	5YR4/6 yellowish red and 10YR6/3 pale brown clay	
685	negative	Dahlin	0-6	humic	10 m east of 68
			6-15	10YR5/3 brown fine sand	
			15-32	10YR5/4 yellowish brown sandy clay loam with iron staining	
			32-42	10YR6/4 light yellow brown sandy clay with light brown sandy clay	
686	negative	Goings	0-3	10YR4/2 dark gray brown fine sandy loam	20 m east of 300
			3-26	2.5YR4/6 red clay with pale brown mottles	
687	positive	Ferguson	0-15	10YR4/2 dark gray brown fine sandy clay loam	20 m west of 300
			15-40	10YR5/4 yellowish brown fine loamy sand	
			26-44	2.5YR4/6 red clay with pale brown mottles	
688	negative	Dahlin	0-12	10YR4/2 dark gray brown sandy loam	20 m north of 300
			12-29	2.5YR4/6 red clay with pale brown mottles	
689	negative	Dahlin	0-6	humic	12 m south/southwest of 687
			6-46	10YR5/3 brown fine sand	
			46-56	2.5YR4/6 red clay with pale brown mottles	
690	negative	Blake	0-34	10YR3/1 very dark gray clay w/ few orange mottles	
691	negative	Goings	0-30	10YR4/2 dark grayish brown clay	18 m east of line
692	positive	Ferguson	0-10	10YR4/1 dark gray and 10YR3/2 very dark grayish brown fine sandy loam	
			10-44	10YR2/2 very dark brown fine sandy clay loam w/ few tan mottles	
			44-65	10YR3/2 very dark grayish brown clay loam w/ few tan mottles	
693	negative	Blake	0-4	humic	
			4-32	10YR3/2 very dark grayish brown loamy sand	
			32-61	10YR4/1 dark gray clay loam w/ 10YR7/2 light gray sand	
694	negative	Goings	0-62	10YR4/2 dark grayish brown loamy clay	230 degrees east of line
695	negative	Ferguson	0-55	10YR3/2 very dark grayish brown fine sandy clay loam, clayier to bottom	
			55-67	2.5y 6/1 gray and 2.5y 7/2 light gray clay, few calcium concretions	
696	negative	Blake	0-83	10YR3/2 very dark grayish brown sandy clay loam	
			83-97	10YR5/2 grayish brown sandy clay loam w/ few orange mottles and calcium concretions	
697	negative	Goings	0-50	10YR4/2 dark grayish brown loamy clay	230 degrees east of line
			50-70	10YR5/2 grayish brown sandy loam	
698	negative	Ferguson	0-58	10YR3/2 very dark grayish brown fine sandy clay loam	
			59-84	10YR4/2 dark grayish brown loamy clay	
699	negative	Blake	0-51	10YR3/2 very dark grayish brown sandy clay loam	
			51-86	10YR6/2 light brownish gray sandy clay	
700	negative	Goings	0-60	10YR5/2 grayish brown loam	
			60-80	10YR5/3 brown sandy loam	
701	negative	Blake	0-58	10YR3/2 very dark grayish brown silty loam	
			58-68	10YR5/2 grayish brown fine sandy clay loam w/ orange mottles	
702	negative	Ferguson	0-80	10YR3/2 very dark grayish brown clay loam w/ few calcium concretions	
			80-98	10YR5/2 grayish brown and 10YR4/2 dark grayish brown clay loam w/ few orange mottles and calcium concretions that increased w/ depth	
703	negative	Blake	0-24	10YR3/2 very dark grayish brown silty loam	
			24-41	10YR4/2 dark grayish brown silty clay loam	

			41-72	10YR5/2 grayish brown fine sandy clay loam w/ some orange mottles	
704	negative	Ferguson	0-83	10YR3/2 very dark grayish brown clay loam, friable	
			83-100	10YR4/2 dark grayish brown and 10YR5/2 grayish brown clay loam, friable w/ many calcium concretions	
705	negative	Blake	0-60	10YR3/2 very dark grayish brown silty loam	
			60-73	10YR5/2 grayish brown fine sandy loam w. some orange mottles	
706	negative	Ferguson	0-8	10YR3/2 very dark grayish brown clay	
			8-40	10YR3/1 very dark gray clay	
707	negative	Blake	0-32	10YR3/1 very dark gray clay	
708	negative	Ferguson	0-16	10YR3/1 very dark gray clay, disturbed w/ gravel	
			16-38	10YR5/2 grayish brown loamy clay	
709	negative	Blake	0-16	10 YR3/2 very dark grayish brown clay	
			16-30	10YR2/1 black clay	
710	positive	Blake	0-3	10YR5/3 brown fine sandy loam	on mound
			3-54	10YR5/2 grayish brown fine sandy loam	
			54-76	10YR4/1 dark gray fine sandy clay loam	
			76-93	10YR6/3 pale brown fine sandy clay	
711	positive	Ferguson	0-10	10YR5/3 brown fine sandy loam	on mound
			10-75	10YR5/2 grayish brown fine sandy loam	
			75-85	10YR4/1 dark gray fine sandy clay loam	
			85-95	10YR6/3 pale brown fine sandy clay	
712	negative	Blake	0-7	10YR5/3 brown fine sandy loam	on mound
			7-63	10YR5/2 grayish brown fine sandy loam	
			63-76	10YR4/1 dark gray fine sandy clay loam	impassible root
713	positive	Ferguson	0-8	10YR5/3 brown fine sandy loam	on mound
			8-72	10YR5/2 grayish brown fine sandy loam	
			72-80	10YR4/1 dark gray fine sandy clay loam	
			80-98	10YR6/3 pale brown fine sandy clay	
714	negative	Blake	0-4	10YR5/3 brown fine sandy loam	on mound
			4-23	10YR5/2 grayish brown fine sandy loam	
			23-102	10YR6/3 pale brown fine sandy clay loam	
715	negative	Ferguson	0-28	10YR5/3 brown fine sandy loam	on mound
			28-78	10YR5/2 grayish brown fine sandy loam	
			78-88	10YR4/1 dark gray fine sandy clay loam	
			88-100	10YR6/3 pale brown fine sandy clay	
716	negative	Ferguson	0-18	10YR5/3 brown fine sandy loam	on mound
			18-62	10YR6/3 pale brown fine sand	
			62-88	10YR5/2 grayish brown fine sandy loam	
			88-98	10YR6/3 pale brown fine sand	
717	negative	Blake	0-2	humic	on mound
			2-90	10YR6/3 pale brown silty loam	
718	negative	Goings	0-97	10YR6/3 pale brown fine sand	
719	negative	Ferguson	0-8	10YR5/3 brown fine sandy loam	on mound, north end of tract
			8-57	10YR4/3 brown fine sandy loam	very few Fe concretions
			57-77	10YR4/3 brown fine sandy clay loam	
			77-87	10YR4/2 dark grayish brown fine sandy clay w/ few yellow orange mottles	
720	negative	Blake	0-4	humic	on mound
			4-15	10YR6/3 pale brown silty loam	
			15-52	10YR4/2 dark grayish brown silty clay loam	
			52-62	10YR4/2 dark grayish brown silty clay	
721	negative	Goings	0-35	10YR4/2 dark grayish brown sandy loam	
			35-52	10YR4/2 dark grayish brown clay	
722	negative	Ferguson	0-28	10YR3/2 very dark grayish brown clay loam w/ few tan mottles	on mound
			28-66	10YR4/2 dark grayish brown clay, clayier w/ depth	
723	negative	Blake	0-9	humic	on mound

			9-30	10YR3/2 very dark grayish brown silty clay loam	
			30-40	10YR3/2 very dark grayish brown silty clay	
724	negative	Goings	0-50	10YR3/2 very dark grayish brown sandy loam	
			50-60	10YR4/2 dark grayish brown sandy clay loam	
725	negative	Ferguson	0-30	10YR3/2 very dark grayish brown clay loam w/ few tan mottles	on mound
			30-54	10YR4/2 dark grayish brown clay, clayier w/ depth	
726	negative	Blake	0-3	humic	on mound
			3-32	10YR3/2 very dark grayish brown silty clay loam	
			32-42	10YR3/2 very dark grayish brown silty clay	
727	negative	Goings	0-30	10YR3/2 very dark grayish brown sandy loam	
			30-40	10YR4/2 dark grayish brown sandy loamy clay	
728	negative	Ferguson	0-38	10YR3/2 very dark grayish brown clay loam w/ few tan mottles	on mound, north end of tract
			38-55	10YR4/2 dark grayish brown clay, clayier w/ depth	
729	negative	Blake	0-5	humic	small mound
			5-36	10YR3/2 very dark grayish brown silty clay	
730	negative	Ferguson	0-40	10YR3/2 very dark grayish brown clay loam w/ few tan mottles	on mound
			40-50	10YR4/2 dark grayish brown clay, clayier w/ depth	
731	negative	Ferguson	0-2	humic	flat
			2-34	10YR4/2 dark grayish brown clay w/ few pale orange mottles	
732	negative	Goings	0-30	10YR4/2 dark grayish brown clay w/ few pale orange mottles	
733	negative	Blake	0-30	10YR4/1 dark gray clay	
734	negative	Ferguson	0-38	10YR5/1 gray clay	
735	negative	Ferguson	0-10	10YR4/1 dark gray clay	
			10-35	10YR3/1 very dark gray clay	
736					
737	negative	Goings	0-25	10YR4/2 dark grayish brown sandy loamy clay	
			25-46	10YR3/2 very dark grayish brown sandy loam	
738	negative	Ferguson	0-5	10YR3/3 dark brown fine sandy loam	
			5-12	10YR4/3 brown fine sandy loam	
			12-20	10YR3/3 dark brown fine sandy clay loam	
			20-55	10YR4/1 dark gray fine sandy clay loam	clayier w/ depth
739	negative	Goings	0-45	10YR4/1 dark gray fine sandy clay loam	
740	negative	Ferguson	0-7	10YR3/2 very dark grayish brown fine sandy loam	
			7-15	10YR4/3 brown fine sandy clay loam	
			15-50	10YR4/1 dark gray fine sandy clay loam	clayier w/ depth
741	negative	Goings	0-2	10YR3/3 dark brown fine sandy loam	humic
			2-54	10YR4/3 brown fine sandy loam	
			54-75	10YR4/1 dark gray fine sandy clay loam	clayier w/ depth
742	negative	Ferguson	0-8	10YR3/3 dark brown fine sandy loam	humic
			8-15	10YR4/3 brown fine sandy loam	
			15-22	10YR3/3 dark brown fine sandy loam	
			22-34	10YR3/2 very dark grayish brown fine sandy loam	
			34-48	10YR4/3 brown fine sandy loam	
			48-75	10YR4/1 dark gray fine sandy clay loam	clayier w/ depth
743	negative	Goings	0-3	10YR3/3 dark brown fine sandy loam	humic
			3-22	10YR4/3 brown fine sandy loam	
			22-50	10YR4/1 dark gray fine sandy clay loam	clayier w/ depth
744	negative	Ferguson	0-9	10YR3/3 dark brown fine sandy loam	humic
			9-40	10YR4/3 brown fine sand	
			40-60	10YR4/1 dark gray fine sandy clay loam	clayier w/ depth
745	negative	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy clay loam	
			8-22	10YR5/3 brown fine sandy loam	
			22-45	10YR3/2 very dark grayish brown fine sandy clay loam	clayier w/ depth
746	negative	Ferguson	0-5	10YR3/3 dark brown fine sandy loam	humic

			5-30	10YR4/3 brown fine sand	
			30-50	10YR4/1 dark gray fine sandy clay loam	clayier w/ depth
			50-62	10YR3/2 very dark grayish brown fine sandy clay loam	
747	negative	Goings	0-30	10YR4/1 dark gray fine sandy clay loam	
748	positive	Ferguson	0-10	10YR3/3 dark brown fine sandy loam	humic
			10-75	10YR5/4 yellowish brown fine sand	
			75-85	10YR3/2 very dark grayish brown fine sandy clay loam	
			85-103	10YR3/2 very dark grayish brown & 10YR5/2 grayish brown fine sand.	
749	negative	Carroll	0-20	7.5YR3/2 dark brown sandy loam	
			20-55	10YR4/3 brown fine sandy clay loam	
750	negative	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam	
			8-10	10YR5/3 brown fine sandy loam	
			10-18	10YR3/2 very dark grayish brown fine sandy clay	
			18-43	10YR4/2 dark grayish brown fine sandy clay	
751	negative	Ferguson	0-12	10YR3/2 very dark grayish brown fine sandy loam	
			12-60	10YR5/2 grayish brown fine sand	
			60-72	10YR4/2 dark grayish brown fine sandy clay	
752	negative	Goings	0-15	10YR4/2 dark grayish brown fine sandy clay	
			15-50	10YR4/1 dark gray fine sandy clay loam	
753	negative	Carroll	0-10	7.5YR3/2 dark brown sandy loam	
			10-55	7.5YR5/2 brown fine sand	
			55-75	7.5YR5/2 brown sandy clay	
754	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam	
			10-70	10YR4/3 brown fine sandy loam	
			70-80	10YR3/3 dark brown fine sandy loam	
			80-98	10YR4/2 dark grayish brown fine sandy clay loam.	
755	negative	Goings	0-78	10YR4/2 dark grayish brown fine sandy loam	
			78-90	10YR4/3 brown fine sandy loam	
756	negative	Carroll	0-2	humic	
			2-80	7.5YR5/2 brown fine sand	
			80-100	7.5YR5/2 brown fine sandy clay	
757	negative	Carroll	0-30	7.5YR3/2 dark brown sandy loam	
			30-101	10YR4/3 brown fine sandy clay loam	
758	positive	Carroll	0-30	10YR3/2 dark grayish brown sandy loam	
			30-80	7.5YR5/2 brown fine sand	
759	negative	Ferguson	0-12	10YR4/3 brown clay loam	
			12-32	7.5YR5/6 strong brown clay	
760	negative	Goings	0-10	10YR6/4 light yellowish brown fine sandy clay loam	
			10-30	7.5YR5/6 strong brown clay	
761	negative	Ferguson	0-5	10YR4/3 brown clay loam	
			5-27	7.5YR5/6 strong brown clay	
762	negative	Goings	0-10	10YR4/2 dark grayish brown fine sandy loam.	
			10-18	10YR5/4 yellowish brown fine sandy loam.	
			18-30	5YR5/8 yellowish red clay.	
763	negative	Ferguson	0-3	10YR3/2 very dark grayish brown fine sandy loam	
			3-10	10YR5/3 brown clay loam	
			10-31	10YR6/3 pale brown clay, many orange mottles.	
764	negative	Goings	0-12	10YR5/6 yellowish brown fine sandy clay loam	
			12-29	5YR5/8 yellowish red clay.	
765	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam.	
			10-40	10YR6/4 light yellowish brown fine sand.	
			40-60	10YR7/2 light gray clay, many orange mottles.	
766	negative	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam.	
			10-28	10YR6/4 light yellowish brown fine sandy clay loam.	
			28-40	10YR7/2 light gray clay, many orange mottles.	
767	positive	Ferguson	0-8	10YR4/2 dark grayish brown fine sandy loam.	

			8-15	10YR6/4 light yellowish brown fine sand.	
			15-32	7.5YR5/6 strong brown clay, few light gray mottles.	
768	positive	Ferguson	0-8	10YR4/2 dark grayish brown fine sandy loam.	
			8-15	10YR6/4 light yellowish brown fine sand.	
			15-30	7.5YR5/6 strong brown clay, few light gray mottles.	
769	negative	Ferguson	0-6	10YR5/3 brown fine sandy clay loam.	
			6-23	7.5YR5/6 strong brown clay.	
770	negative	Goings	0-9	10YR4/3 brown fine sandy loam	
			9-20	10YR6/6 brownish yellow fine sandy clay.	
			20-35	7.5YR5/8 strong brown clay, few light gray mottles.	
771	positive	Carroll	0-30	10YR5/3 brown fine sandy clay loam.	
			30-40	10YR5/6 yellowish brown fine sandy clay	
772	positive	Ferguson	0-8	10YR3/3 dark brown fine sandy clay loam	
			8-27	7.5YR5/6 strong brown clay.	
773	negative	Goings	0-9	10YR3/3 dark brown fine sandy loam	
			9-29	7.5YR5/6 strong brown clay.	
774	positive	Carroll	0-22	10YR3/3 dark brown fine sandy loam	
			22-35	7.5YR5/6 strong brown clay.	
775	positive	Ferguson	0-10	10YR3/3 dark brown fine sandy clay loam	
			10-27	7.5YR5/6 strong brown clay.	
776	negative	Goings	0-9	10YR4/3 brown fine sandy loam	
			9-29	7.5YR5/6 strong brown clay.	
777	negative	Carroll	0-5	10YR5/3 brown fine sandy clay loam.	
			5-16	10YR5/4 yellowish brown fine sandy clay loam.	
			16-30	7.5YR5/8 strong brown clay.	
778	positive	Ferguson	0-7	10YR4/3 brown fine sandy loam	
			7-53	10YR6/4 light yellowish brown fine sand, charcoal.	
			53-72	10YR6/1 light gray clay, many orange mottles.	
779	negative	Goings	0-12	10YR5/4 yellowish brown fine sandy loam.	
			12-30	2.5YR4/8 red clay	
780	negative	Carroll	0-2	10YR5/3 brown fine sandy clay loam.	
			2-25	10YR6/4 light yellowish brown clayey fine sand.	
			25-35	7.5YR5/8 strong brown clay.	
781	positive	Ferguson	0-6	10YR4/3 brown fine sandy loam	
			6-19	10YR6/4 light yellowish brown fine sand.	
			19-30	7.5YR5/6 strong brown clay.	
782	negative	Goings	0-9	10YR3/6 dark yellowish brown fine sandy clay loam	
			9-26	2.5YR4/8 red clay	
783	positive	Carroll	0-4	10YR5/3 brown fine sandy clay loam.	
			4-25	10YR6/4 light yellowish brown clayey fine sand.	
			25-35	7.5YR5/8 strong brown clay.	
784	positive	Ferguson	0-5	10YR5/3 brown fine sandy loam.	
			5-29	10YR6/4 light yellowish brown fine sand.	
			29-42	7.5YR5/6 strong brown clay.	
785	negative	Goings	0-5	10YR3/3 dark brown fine sandy loam	
			5-37	10YR6/4 light yellowish brown clayey fine sand.	
			37-45	2.5YR4/8 red clay	
786	negative	Carroll	0-1	10YR5/3 brown fine sandy clay loam.	
			1-8	10YR6/4 light yellowish brown clayey fine sand.	
			8-15	7.5YR5/8 strong brown clay.	
787	negative	Ferguson	0-15	brown clay loam, disturbed	
			15-33	10YR5/4 yellowish brown clay loam	
			33-43	10YR5/4 yellowish brown & 7.5YR5/6 strong brown clay	
788	negative	Ferguson	0-20	very disturbed native soils	
			20-37	10YR6/1 light gray fine sandy clay, many orange mottles.	
789	positive	Carroll	0-2	10YR5/3 brown fine sandy clay loam.	

			2-15	10YR6/4 light yellowish brown clayey fine sand.	
			15-25	7.5YR5/8 strong brown clay.	
790	negative	Goings	0-2	10YR5/3 brown fine sandy clay loam.	
			2-40	2.5y7/1 light gray & 10YR6/8 brownish yellow clay	
791	positive	Ferguson	0-6	10YR4/2 dark grayish brown fine sandy loam	
			6-24	10YR5/3 brown fine sandy clay loam.	
			24-45	10YR6/1 light gray fine sandy clay, many orange mottles.	
792	negative	Goings	0-14	10YR3/2 very dark grayish brown fine sandy clay loam	
			14-30	2.5YR4/8 red clay	
793	positive	Ferguson	0-4	10YR4/2 dark grayish brown fine sandy loam	
			4-20	10YR5/3 brown fine sandy clay loam.	
			20-42	10YR6/1 light gray fine sandy clay, many orange mottles.	
794	negative	Goings	0-24	10YR5/4 yellowish brown fine sandy clay loam.	
			24-34	5YR5/8 yellowish red fine sandy clay.	
795	negative	Ferguson	0-6	10YR4/2 dark grayish brown fine sandy clay loam	
			6-18	10YR5/3 brown fine sandy clay loam.	
			18-29	7.5YR5/8 strong brown clay w/ many yellowish brown mottles	
796	negative	Goings	0-10	10YR4/2 dark grayish brown fine sandy clay loam	
			10-29	2.5YR4/8 red clay	
797	positive	Ferguson	0-7	10YR4/2 dark grayish brown fine sandy clay loam	
			7-18	10YR5/3 brown fine sandy clay loam.	
			18-30	7.5YR5/8 strong brown clay w/ many yellowish brown mottles	
798	positive	Goings	0-22	native soil fill	
			22-37	10YR7/1 light gray fine sandy clay w/ much orange mottles	
			37-55	5YR5/8 yellowish red fine sandy clay.	
799	positive	Ferguson	0-11	10YR5/3 brown fine sandy clay loam.	
			11-28	7.5YR5/8 strong brown & 10YR6/1 light gray clay	
800	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy clay loam	
			10-32	10YR6/6 brownish yellow fine sandy clay w/ many orange mottles.	
801	positive	Ferguson	0-5	10YR4/2 dark grayish brown fine sandy clay loam	
			5-11	10YR5/3 brown fine sandy clay loam.	
			11-26	7.5YR5/8 strong brown clay w/ many yellowish brown mottles	
802	negative	Ferguson	0-5	10YR4/2 dark grayish brown fine sandy clay loam	
			5-32	mottled 10YR6/6 brownish yellow & 10YR6/3 pale brown fine sandy clay loam.	
			32-45	10YR6/6 brownish yellow fine sandy clay w/ many orange mottles.	
803	positive	Goings	0-18	10YR4/2 dark grayish brown fine sandy clay loam	
			18-30	7.5YR5/8 strong brown clay w/ many yellowish brown mottles	
804	positive	Ferguson	0-9	disturbed clay loam/native soils	
			9-25	10YR4/3 brown fine sandy clay loam	
			25-36	10YR6/6 brownish yellow fine sandy clay w/ many orange mottles.	
805	negative	Goings	0-2	10YR4/2 dark grayish brown fine sandy loam	
			2-16	10YR6/3 pale brown fine sandy loam	
			16-35	5YR5/8 yellowish red fine sandy clay.	
806	negative	Ferguson	0-6	10YR3/2 very dark grayish brown fine sandy clay loam	
			6-29	10YR6/1 light gray clay, many orange mottles.	
807	negative	Goings	0-6	10YR4/2 dark grayish brown fine sandy clay loam	
			6-22	5YR5/8 yellowish red fine sandy clay.	
808	negative	Ferguson	0-6	native soil fill	
			6-18	10YR4/2 dark grayish brown fine sandy loam	
			18-37	10YR6/4 light yellowish brown fine sand.	
			37-50	7.5YR5/6 strong brown clay	
809	negative	Ferguson	0-5	10YR3/2 very dark grayish brown fine sandy clay loam	
			5-20	10YR5/4 yellowish brown fine sandy clay loam.	

			20-32	7.5YR5/6 strong brown clay	
810	negative	Ferguson	0-5	10YR3/2 very dark grayish brown fine sandy clay loam	
			5-18	10YR5/4 yellowish brown fine sandy clay loam.	
			18-28	7.5YR5/6 strong brown clay	
811	positive	Carroll	0-120	10YR5/2 grayish brown fine sand	
812	positive	Goings	0-57	10YR3/3 dark brown fine sandy loam	
			57-110	10YR5/3 brown fine sand	
813	positive	Ferguson	0-20	10YR2/2 very dark brown fine sandy loam	
			20-64	10YR3/3 dark brown loamy fine sand	
			64-106	10YR6/3 pale brown fine sand	
814	positive	Carroll	0-100	10YR5/2 grayish brown fine sand	
815	positive	Goings	0-30	7.5YR3/4 dark brown fine sandy loam	
			30-40	5YR5/8 yellowish red fine sandy clay.	
816	negative	Ferguson	0-10	10YR2/2 very dark brown fine sandy loam	
			10-62	10YR3/3 dark brown loamy fine sand	
			62-105	10YR6/3 pale brown fine sand	
817	positive	Carroll	0-30	10YR4/3 brown clay loam	
			30-40	10YR4/3 brown clay w/ orange mottles	
			40-50	10YR5/8 yellowish brown clay	
818	positive	Goings	0-40	10YR3/3 dark brown fine sandy loam	
			40-91	10YR5/4 yellowish brown fine sand	
			91-	2.5YR5/8 red clay	
819	positive	Ferguson	0-48	sandy native soil fill	
			48-109	10YR4/3 brown fine sand	
			109-135	10YR6/3 pale brown fine sand	
820	negative	Carroll	0-40	10YR3/2 very dark grayish brown fine sandy clay loam	
			40-50	10YR5/8 yellowish brown clay	
821	negative	Carroll	0-25	10YR3/2 very dark grayish brown fine sandy loam	
			25-35	10YR4/6 dark yellowish brown fine sandy clay	
			35-45	10YR5/8 yellowish brown clay	
822	positive	Ferguson	0-35	10YR3/3 dark brown loamy fine sand	
			35-48	7.5YR5/6 strong brown clay	
823	negative	Carroll	0-35	10YR3/2 very dark grayish brown fine sandy clay loam	
			35-45	10YR5/8 yellowish brown clay	
824	positive	Carroll	0-12	10YR3/2 very dark grayish brown fine sandy loam	
			12-52	10YR4/6 dark yellowish brown fine sandy clay	
			52-60	10YR5/8 yellowish brown clay	
825	positive	Ferguson	0-5	10YR3/3 dark brown fine sandy loam	
			5-20	10YR6/4 light yellowish brown fine sand.	
			20-40	10YR3/2 very dark grayish brown clay	
826	positive	Carroll	0-30	10YR5/2 grayish brown fine sandy loam	
			30-102	10YR5/2 grayish brown fine sand	
827	positive	Ferguson	0-12	10YR5/3 brown fine sandy loam	
			12-45	10YR6/2 gray fine sand	
			45-60	10YR6/1 light gray sandy clay	
828	negative	Ferguson	0-34	fill/push from road.	
			34-42	10YR3/2 very dark grayish brown clay	
829	negative	Goings	0-17	10YR4/3 brown fine sandy loam	
			17-34	5YR5/8 yellowish red fine sandy clay.	
830	positive	Carroll	0-10	10YR3/2 very dark grayish brown fine sandy loam	
			10-35	10YR4/6 dark yellowish brown fine sandy clay	
			35-45	10YR5/8 yellowish brown clay	
831	negative	Ferguson	0-5	10YR2/1 black fine sandy loam	
			5-16	10YR4/2 dark grayish brown fine sand	
			16-32	10YR4/1 dark gray clay	
			32-40	10YR5/1 gray clay	

832	negative	Goings	0-8	10YR4/3 brown fine sandy loam	
			8-30	10YR4/4 dark yellowish brown fine sand	
			30-40	7.5YR5/8 strong brown fine sandy clay	
833	negative	Carroll	0-15	10YR3/2 very dark grayish brown fine sandy loam	
			15-40	10YR4/6 dark yellowish brown fine sandy clay	
			40-50	10YR5/8 yellowish brown clay	
834	positive	Ferguson	0-26	10YR4/2 dark grayish brown fine sandy loam	
			26-45	10YR3/2 very dark grayish brown fine sandy loam	
			45-58	10YR6/1 light gray clay	
835	positive	Carroll	0-6	10YR3/2 very dark grayish brown fine sandy loam	
			6-26	10YR5/4 yellowish brown fine sand	
			26-36	5YR5/8 yellowish red fine sandy clay.	
836	negative	Carroll	0-15	10YR3/2 very dark grayish brown fine sandy loam	
			15-25	10YR4/6 dark yellowish brown fine sandy clay	
			25-35	10YR5/8 yellowish brown clay	
837	positive	Ferguson	0-15	10YR4/2 dark grayish brown fine sandy loam	
			15-32	10YR4/3 brown fine sand	
			32-50	7.5YR5/6 strong brown clay	
838	positive	Goings	0-6	10YR3/2 very dark grayish brown fine sandy loam	
			6-76	10YR4/3 brown fine sand	
			76-100	10YR5/3 brown fine sand	
839	negative	Carroll	0-10	10YR3/2 very dark grayish brown fine sandy loam	
			10-40	10YR4/6 dark yellowish brown fine sandy clay	
			40-50	10YR5/8 yellowish brown clay	
840	positive	Ferguson	0-4	10YR4/2 dark grayish brown fine sandy loam	
			4-24	10YR4/3 brown fine sand	
			24-37	2.5YR4/8 red clay	
841	negative	Goings	0-29	7.5YR2.5/1 black fine sandy loam	
			29-40	7.5YR5/8 strong brown clay	
842	negative	Carroll	0-10	10YR3/2 very dark grayish brown fine sandy loam	
			10-40	10YR4/6 dark yellowish brown fine sandy clay	
			40-50	10YR5/8 yellowish brown clay	
843	positive	Ferguson	0-10	fill/push from road.	
			10-21	10YR3/2 very dark grayish brown fine sandy loam	
			21-33	7.5YR5/6 strong brown clay	
844	negative	Carroll	0-15	10YR4/3 brown fine sandy loam	
			15-25	7.5YR5/8 strong brown clay	
845	negative	Carroll	0-20	10YR3/2 very dark grayish brown fine sandy loam	
			20-40	10YR4/6 dark yellowish brown fine sandy clay	
			40-50	10YR5/8 yellowish brown clay	
846	positive	Ferguson	0-9	10YR4/2 dark grayish brown fine sandy loam	
			9-46	10YR3/3 dark brown fine sand	
			46-105	10YR6/3 pale brown fine sand	
847	negative	Ferguson	0-5	10YR3/2 very dark grayish brown fine sandy loam	
			5-26	10YR5/3 brown loamy fine sand	
			26-45	10YR6/4 pale brown fine sand	
			45-55	7.5YR5/6 strong brown clay	
848	negative	Goings	0-26	10YR4/2 dark grayish brown fine sandy loam	
			26-43	7.5YR6/8 reddish yellow fine sandy clay	
849	negative	Carroll	0-55	10YR4/3 brown fine sandy loam	
			55-65	7.5YR5/8 strong brown clay	
850	positive	Ferguson	0-6	10YR3/2 very dark grayish brown fine sandy loam	
			6-60	10YR5/3 brown loamy fine sand	
			60-80	10YR6/4 pale brown fine sand	
851	negative	Goings	0-60	10YR4/3 brown fine sandy loam	
			60-64	2.5YR4/8 red clay	

852	negative	Carroll	0-102	10YR5/2 grayish brown fine sand.	
853	positive	Ferguson	0-10	10YR5/2 grayish brown fine sandy loam	
			10-26	10YR6/4 light yellowish brown fine sand.	
			26-60	10YR5/3 brown loamy fine sand	
			60-135	10YR6/4 pale brown fine sand	
854	positive	Goings	0-13	fill/push from road.	
			13-80	10YR5/4 yellowish brown fine sandy loam	
			80-100	10YR6/3 pale brown fine sand	
855	positive	Carroll	0-40	10YR5/2 grayish brown fine sandy loam.	
			40-55	10YR4/2 dark grayish brown fine sandy loam	
			55-75	10YR5/2 grayish brown fine sandy loam.	
			75-80	7.5YR5/8 strong brown clay	
856	negative	Ferguson	0-9	10YR3/2 very dark grayish brown fine sandy loam	
			9-28	10YR4/3 brown fine sand	
			28-40	7.5YR5/6 strong brown clay	
857	negative	Goings	0-22	10YR5/4 yellowish brown fine sandy loam	
			22-80	2.5y7/3 pale yellow sand	
			80-88	10YR5/8 yellowish brown clay	
858	positive	Carroll	0-45	10YR4/2 dark grayish brown fine sandy loam	
			45-55	7.5YR5/8 strong brown clay	
859	positive	Ferguson	0-16	10YR3/2 very dark grayish brown fine sandy loam	
			16-42	10YR5/3 brown loamy fine sand	
			42-52	10YR3/2 very dark grayish brown & 7.5YR5/6 strong brown clay	
860	negative	Goings	0-21	10YR4/2 dark grayish brown fine sandy loam	
			21-90	10YR6/3 pale brown fine sand	
			90-110	10YR5/3 brown fine sand	
861	positive	Carroll	0-35	10YR5/2 grayish brown fine sandy loam.	
			35-110	10YR4/2 dark grayish brown fine sandy loam	
862	negative	Ferguson	0-120	disturbed sand & clay	
863	negative	Goings	0-31	10YR4/3 brown fine sandy loam	
			31-90	10YR5/4 yellowish brown fine sand	
			90-100	2.5YR4/8 red clay	
864	positive	Carroll	0-30	10YR4/3 brown fine sandy loam	
			30-35	7.5YR5/8 strong brown clay	
865	negative	Ferguson	0-12	10YR3/2 very dark grayish brown fine sandy loam	
			12-75	10YR5/4 yellowish brown fine sand	
			75-85	10YR4/3 brown & 7.5YR5/6 strong brown clay	
866	negative	Carroll	0-40	10YR5/2 grayish brown fine sandy loam	
			40-50	7.5YR5/8 strong brown clay	
867	positive	Carroll	0-75	10YR5/2 grayish brown fine sandy loam	
			75-85	7.5YR5/8 strong brown clay	
868	positive	Ferguson	0-4	10YR3/2 very dark grayish brown fine sandy loam	
			4-45	10YR5/4 yellowish brown fine sand	
			45-53	10YR4/3 brown & 7.5YR5/6 strong brown clay	
869	negative	Goings	0-50	10YR4/3 brown fine sandy loam	
			50-56	2.5YR4/8 red clay	
870	positive	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam	
			8-15	10YR6/3 pale brown fine sand	
			15-40	10YR3/3 dark brown fine sand	
			40-130	10YR5/3 brown fine sand	
871	negative	Carroll	0-50	10YR4/3 brown fine sandy loam	
			50-60	7.5YR5/8 strong brown clay	
872	positive	Goings	0-43	10YR3/4 dark yellowish brown fine sandy loam	
			43-54	7.5YR5/8 strong brown clay	
873	positive	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam	
			8-26	10YR5/4 yellowish brown fine sand	

			26-38	7.5YR5/8 strong brown clay	
874	negative	Carroll	0-45	10YR4/3 brown fine sandy loam	
			45-55	7.5YR5/8 strong brown clay	
875	negative	Goings	0-43	10YR4/3 brown fine sandy loam	
			43-57	10YR5/6 yellowish brown clay	
876	negative	Ferguson	0-9	10YR3/2 very dark grayish brown fine sandy loam	
			9-26	10YR5/4 yellowish brown fine sand	
			26-37	7.5YR5/8 strong brown clay	
877	positive	Carroll	0-80	10YR5/2 grayish brown fine sandy loam	
			80-90	7.5YR5/8 strong brown clay	
878	negative	Goings	0-26	10YR3/3 dark brown fine sandy loam	
			26-34	7.5YR5/8 strong brown clay	
879	positive	Ferguson	0-9	10YR4/2 dark grayish brown fine sandy loam	
			9-24	10YR5/2 grayish brown fine sand	
			24-38	7.5YR5/8 strong brown clay	
880	negative	Carroll	0-30	10YR4/3 brown fine sandy loam	
			30-40	7.5YR5/8 strong brown clay	
881	negative	Goings	0-20	10YR4/3 brown fine sandy loam	
			20-30	7.5YR5/8 strong brown clay	
882	negative	Ferguson	0-11	fill/push from road.	
			11-26	10YR5/3 brown fine sandy loam	
			26-37	7.5YR5/8 strong brown clay	
883	positive	Ferguson	0-20	Native fine saand fill/push	
			20-50	10YR3/6 dark yellowish brown fine sand, truncated	
			50-135	10YR6/3 pale brown fine sand	
884	positive	Ferguson	0-10	10YR2/2 very dark brown fine sandy loam	
			10-35	10YR4/4 dark yellowish brown fine loamy sand	
			35-75	10YR4/3 brown fine sand	
			75-128	10YR6/3 pale brown fine sand	
885	positive	Ferguson	0-6	10YR3/2 very dark grayish brown fine sandy loam	
			6-38	10YR4/4 dark yellowish brown fine loamy sand	
			38-52	7.5YR5/6 strong brown fine sandy clay	
886	positive	Ferguson	0-12	10YR3/2 very dark grayish brown fine sandy loam	
			12-23	10YR4/4 dark yellowish brown fine sand	
			23-70	10YR3/4 dark yellowish brown fine sand	
			70-130	10YR5/4 yellowish brown fine sand	
887	negative	Ferguson	0-2	10YR3/2 very dark grayish brown clay loam	
			2-30	10YR4/2 dark grayish brown clay loam	
			30-44	7.5YR3/6 strong brown clay	
888	positive	Ferguson	0-7	10YR3/2 very dark grayish brown fine sandy clay loam	
			7-36	10YR4/4 dark yellowish brown fine sandy clay loam	
			36-46	7.5YR5/6 strong brown clay	
889	negative	Ferguson	0-9	10YR3/2 very dark grayish brown fine sandy loam	
			9-36	10YR5/3 brown fine sandy clay loam	
			36-43	7.5YR5/6 strong brown clay	
890	positive	Ferguson	0-5	10YR3/2 very dark grayish brown fine sandy loam	
			5-20	10YR5/4 yellowish brown fine sand	
			20-32	5YR4/6 yellowish red clay	
891	negative	Ferguson	0-3	10YR3/2 very dark grayish brown fine sandy loam	
			3-17	10YR5/4 yellowish brown fine sand	
			17-27	5YR4/6 yellowish red clay	
892	positive	Ferguson	0-5	10YR3/2 very dark grayish brown fine sandy loam	
			5-32	10YR5/4 yellowish brown fine sand w/ large Fe concretions	
			32-42	7.5YR5/6 strong brown clay	
893	negative	Ferguson	0-3	10YR4/4 dark yellowish brown clay loam	
			3-37	7.5YR4/6 strong brown clay	

894	positive	Ferguson	0-4	10YR3/2 very dark grayish brown fine sandy loam	
			4-18	10YR5/4 yellowish brown fine sand	
			18-30	5YR4/6 yellowish red clay	
895	negative	Ferguson	0-3	10YR3/2 very dark grayish brown fine sandy loam	
			3-21	10YR5/4 yellowish brown fine sand	
			21-30	7.5YR4/6 strong brown clay	
896	positive	Ferguson	0-8	10YR5/3 brown fine sandy loam	
			8-20	10YR5/4 yellowish brown fine sand	
			20-31	7.5YR4/6 strong brown clay	
897	negative	Ferguson	0-3	10YR3/2 very dark grayish brown clay loam	
			3-20	10YR5/4 yellowish brown clay loam	
			20-30	7.5YR4/6 strong brown clay	
898	negative	Ferguson	0-3	10YR3/2 very dark grayish brown clay loam	
			3-7	10YR5/4 yellowish brown clay loam	
			7-17	7.5YR4/6 strong brown clay	
899	positive	Ferguson	0-4	10YR3/2 very dark grayish brown fine sandy loam	
			4-20	10YR5/4 yellowish brown fine sand	
			20-33	5YR4/6 yellowish red clay	
900	negative	Ferguson	0-4	10YR3/2 very dark grayish brown fine sandy loam	
			4-18	10YR5/4 yellowish brown fine sand	
			18-28	5YR4/6 yellowish red clay	
901	negative	Ferguson	0-5	10YR3/2 very dark grayish brown clay loam	
			5-18	10YR5/4 yellowish brown clay loam	
			18-30	7.5YR4/6 strong brown clay	
902	negative	Carroll	0-10	10YR4/2 dark grayish brown clay w/ some loam	
			10-45	5YR4/4 redish brown clay	
903	negative	Goings	0-2	humic	
			2-23	10YR6/4 light yellowish brown sand w/ loam	
			23-32	5YR4/4 reddish brown clay	
904	negative	Ferguson	0-4	10YR3/3 dark brown clay loam	
			4-30	10YR3/4 dark yellowish brown clay	
905	negative	Carroll	0-40	10YR6/4 light yellowish brown sandy clay	
			40-50	5YR4/4 reddish brown clay	
906	negative	Goings	0-3	humic	
			3-20	10YR5/6 yellowish brown sand w/ loam	
			20-29	5YR5/8 yellowish red clay.	
907	negative	Ferguson	0-6	10YR3/3 dark brown fine sandy loam	
			6-16	10YR6/4 light yellowish brown loamy sand	
			16-28	7.5YR5/6 strong brown clay	
908	negative	Carroll	0-40	10YR4/2 dark grayish brown clay	
			40-50	5YR4/4 reddish brown clay	
909	negative	Goings	0-2	humic	
			2-28	5YR5/8 yellowish red clay.	
910	positive	Ferguson	0-3	10YR3/3 dark brown fine sandy loam	
			3-28	10YR6/4 Light yellowish brown fine sand to fine sandy clay loam	
			28-39	10YR5/3 brown clay w/ many orange mottles	
911	negative	Carroll	0-40	10YR6/4 light yellowish brown sandy clay	
			40-50	5YR4/4 reddish brown clay	
912	negative	Goings	0-3	humic	
			3-32	10YR6/4 light yellowish brown sand w/ loam	
			32-45	5YR5/6 yellowish red clay	
913	negative	Ferguson	0-2	10YR3/3 dark brown fine sandy clay loam	
			2-25	10YR4/2 dark grayish brown clay w/ few orange mottles	
914	negative	Carroll	0-12	10YR3/2 very dark grayish brown sandy loam	
			12-25	10YR6/4 light yellowish brown sandy clay	
			25-35	5YR4/4 reddish brown clay	

915	positive	Goings	0-5	humic	
			5-35	10YR5/6 yellowish brown sandy clay loam w/ iron concretions	
			35-48	5YR4/6 yellowish red clay	
916	negative	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam	
			8-27	10YR5/4 yellowish brown fine sand to fine sandy clay loam	
			27-40	7.5YR5/6 strong brown clay	
917	positive	Carroll	0-100	10YR6/4 light yellowish brown sand	
918	negative	Ferguson	0-8	10YR4/2 dark grayish brown fine sandy clay loam	
			8-25	10YR7/2 light gray fine sandy clay	
919	negative	Ferguson	0-6	10YR3/2 very dark grayish brown clay loam	
			6-30	10YR4/4 dark yellowish brown clay	
920	negative	Goings	0-5	humic	
			5-20	10YR5/2 grayish brown wet sandy loam	
			20-41	10YR6/2 light brownish gray clay w/ tan streaks	
921	negative	Ferguson	0-8	10YR4/3 brown fine sandy loam	
			8-29	10YR6/4 light yellowish brown fine sandy clay loam w/ common orange mottles	
			29-42	10YR7/2 light ray fine sandy clay w/ common orange mottles	
922	negative	Goings	0-12	humic	
			12-32	10YR6/4 light yellowish brown sandy loam	
			32-43	10YR6/6 brownish yellow sandy clay	
923	negative	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy loam	
			10-28	10YR6/4 light yellowish brown fine sand	
			28-42	10YR6/3 pale brown fine sand	
			42-67	10YR7/1 light gray fine sandy clay w/ common orange mottles	
924	negative	Goings	0-17	humic	
			17-35	10YR5/6 yellowish brown sandy clay loam w/ iron concretions	
			35-42	7.5YR5/8 strong brown clay	
925	negative	Ferguson	0-4	10YR4/2 dark grayish brown fine sandy loam	
			4-20	10YR5/4 yellowish brown fine sand	
			20-65	10YR6/4 light yellowish brown clayey sand	
			65-88	10YR7/1 light gray sandy clay w/ many orange mottles	
926	negative	Goings	0-76	10YR5/4 yellowish brown sand w/ clay	
			76-83	7.5YR7/1 light gray and 7.5YR5/6 strong brown clay	
927	negative	Ferguson	0-6	10YR4/2 dark grayish brown fine sandy loam	
			6-17	10YR5/4 yellowish brown fine sand	
			17-54	10YR6/4 light yellowish brown clayey sand	
			54-70	10YR7/1 light gray sandy clay w/ many orange mottles	
928	negative	Ferguson	0-14	10YR4/2 dark grayish brown fine sandy loam	
			14-72	10YR5/4 yellowish brown fine sand	
			72-90	10YR7/1 light gray clayey fine sand w/ many orange mottles	
929	negative	Ferguson	0-13	10YR4/2 dark grayish brown fine sandy loam	
			13-60	10YR6/4 light yellowish brown fine sand	
			60-87	10YR7/1 light gray clayey fine sand	
930	negative	Ferguson	0-4	10YR3/2 very dark grayish brown fine sandy loam	
			4-15	10YR4/2 dark gray brown fine sandy loam	
			15-45	10YR5/4 yellowish brown fine sand	
			45-60	10YR5/4 yellowish brown, 10YR7/1 light gray and 7.5YR5/6 strong brown fine sandy clay	
931	negative	Goings	0-8	humic	
			8-48	10YR4/4 dark yellowish brown sandy loam	
			48-62	10YR6/8 brownish yellow , 10YR7/1 light gray mottled clay	
932	negative	Blake	0-30	10YR4/2 dark grayish brown silty clay loam	
			30-58	10YR7/1 light gray silty clay	
933	negative	Ferguson	0-7	10YR4/2 dark grayish brown fine sandy loam	
			7-48	10YR5/4 yellowish brown fine sand	

			48-90	10YR5/4 yellowish brown, 10YR7/1 light gray and 7.5YR5/6 strong brown fine sandy clay loam	
934	negative	Goings	0-8	humic	
			8-48	10YR4/4 dark yellowish brown sandy loam	
			48-62	10YR6/8 brownish yellow, 10YR7/1 light gray mottled clay	
935	negative	Blake	0-8	10YR4/2 dark grayish brown fine sandy loam	
			8-69	10YR5/6 yellowish brown silty clay loam, increased clay w/ depth, orange mottles in last 10 cm	
936	negative	Blake	0-9	10YR4/2 dark grayish brown very fine sandy loam	
			9-41	10YR5/6 yellowish brown silty loam	
			41-57	10YR4/4 dark yellowish brwon sandy loam	
937	negative	Goings	0-13	humic	
			13-40	10YR5/6 yellowish brown sandy loam	
			40-52	10YR7/1 light gray and 10YR6/8 brownish yellow clay	
	negative	Blake	0-4	humic	
			4-42	10YR5/6 yellowish brown sandy clay loam	
			42-60	7.5YR5/6 strong brown clay w/ light gray mottles	
939	negative	Goings	0-5	humic	
			5-20	10YR5/4 yellowish brown sandy loam	
			20-30	5YR4/6 yellowish red clay	
940	negative	Ferguson	0-8	10YR3/2 very dark gryaish brown fine sandy loam	
			8-28	10YR5/4 yellowish brown fine sand	
			28-38	7.5YR5/6 strong brown fine sandy clay	
941	negative	Blake	0-6	humic	
			6-27	10YR5/4 yellowish brown sandy clay loam	
			27-39	7.5YR5/6 strong brown clay	
942	negative	Goings	0-7	humic	
			7-30	10YR5/6 yellowish brown sandy clay	
943	negative	Ferguson	0-8	10YR3/2 very dark grayish brown fine sandy loam	
			8-24	10YR5/4 yellowish brown fine sand	
			24-32	7.5YR5/6 strong brown fine sandy clay	
944	negative	Blake	0-5	humic	
			5-31	10YR5/4 yellowish brown sandy cloay loam	
			31-43	7.5YR5/6 strong brown clay	
945	negative	Goings	0-9	humic	
			9-25	10YR5/8 yellowish brown sandy clay	
946	positive	Ferguson	0-9	10YR4/2 dark gryaish brown fine sandy loam	
			9-24	10YR4/3 brown fine sandy loam	
			24-57	10YR3/3 dark brown fine sand	
			57-100	10YR5/3 brown fine sand	
			100-110	10YR5/2 grayish brown fine sandy clay loam w/ few orange mottles	
947	positive	Blake	0-10	grayish brown sandy loam	
			10-89	10YR5/8 yellowish brown sand	
			89-102	10YR6/4 light yellowish brown sand	
948	negative	Goings	0-6	humic	
			6-50	10YR5/4 yellowish brown sand w/ loam	
			50-115	10YR5/3	
949	negative	Blake	0-8	humic	
			8-33	7.5YR5/6 strong brown clay	
950	negative	Goings	0-5	humic	
			5-18	10YR6/6 brownish yellow sand w/ clay	
			18-30	5YR5/8 yellowish red sandy clay	
951	negative	Ferguson	0-6	10YR4/2 dark grayish brown fine sandy clay loam	
			6-13	10YR5/4 yellowish brown fine sand	
			13-23	7.5YR5/6 strong brown clay	
952	negative	Blake	0-6	humic	
			6-26	7.5YR5/6 strong brown clay	

953	negative	Goings	0-12	humic	
			12-28	7.5YR5/8 strong brown sandy clay	
954	positive	Ferguson	0-10	10YR4/2 dark grayish brown fine sandy clay loam	
			10-15	10YR5/4 yellowish brown fine sandy clay	
			15-25	7.5YR5/6 strong brown clay	
955	negative	Blake	0-5	humic	
			5-35	7.5YR5/6 strong brown clay	
956	negative	Goings	0-7	humic	
			7-35	5YR5/8 yellowish red sandy clay	
957	negative	Ferguson	0-7	10YR4/2 dark grayish brown fine sandy clay loam	
			7-16	10YR5/4 yellowish brown fine sand	
			16-30	7.5YR5/6 strong brown clay	
958	positive	Blake	0-8	humic	
			8-21	10YR5/4 yellowish brown sandy loam	
			21-33	7.5YRstrong brown clay	
959	positive	Goings	0-5	humic	
			5-20	10YR5/6 yellowish brown clayey sand	
			20-30	5YR4/6 yellowish red sandy clay	
960	positive	Ferguson	0-6	10YR4/2 dark grayish brown fine sandy clay loam	
			6-23	10YR5/4 yellowish brown fine sand	
			23-35	7.5YR5/6 strong brown clay	
961	positvie	Blake	0-4	humic	
			4-18	10YR5/4 yellowish brown sandy loam	
			18-32	7.5YRstrong brown clay	
962	negative	Goings	0-5	humic	
			5-19	10YR5/6 yellowish brown clayey sand	
			19-26	5YR4/6 yellowish red sandy clay	
963	negative	Ferguson	0-7	10YR4/2 dark grayish brown fine sandy clay loam	
			7-25	10YR5/4 yellowish brown fine sand	
			25-35	7.5YR5/6 strong brown clay	
964	negative	Blake	0-6	humic	
			6-27	10YR5/4 yellowish brown sandy loam	
			27-40	7.5YRstrong brown clay	
965	positive	Goings	0-4	humic	
			4-7	10YR5/6 yellowish brown clayey sand	
			7-12	5YR4/6 yellowish red sandy clay	
966	positive	Ferguson	0-9	10YR4/2 dark grayish brown fine sandy loam	
			9-47	10YR6/4 light yellowish brown fine sand	
			47-75	10YR5/4 yellowish brown & 7.7YR5/6 strong brown clay	
967	negative	Ferguson	0-28	10YR3/2 very dark grayish brown clay loam	
			28-40	10YR4/2 dark grayish brown clay	
968	positive	Goings	0-7	humic	
			7-38	10YR5/6 yellowish brown clayey sand	
			38-47	5YR4/6 yellowish red sandy clay	
969	positive	Ferguson	0-4	humic	
			4-17	10YR4/2 dark grayish brown clay loam	
			17-30	10YR4/2 dark grayish brown clay	
970	negative	Blake	0-4	humic	
			4-33	10YR4/2 dark grayish brown clay loam	
			33-51	10YR4/2 dark grayish brown clay	
971	negative	Goings	0-5	humic	
			5-34	10YR3/2 very dark grayish brown clayey loam	
			34-43	10YR5/3 brown loamy clay	
972	positive	Ferguson	0-3	humic	
			3-19	10YR4/2 dark grayish brown clay loam	
			19-30	10YR4/2 dark grayish brown clay	

973	positive	Blake	0-5	humic	
			5-28	10YR4/2 dark grayish brown clay loam	
			28-42	10YR4/2 dark grayish brown clay	
974	negative	Goings	0-6	humic	
			6-52	10YR3/2 very dark grayish brown clayey loam	
			52-60	10YR5/8 yellowish brown loamy clay	
975	positive	Ferguson	0-4	humic	
			4-15	10YR4/2 dark grayish brown clay loam	
			15-30	10YR4/2 dark grayish brown clay	
976	positive	Blake	0-3	humic	
			3-25	10YR4/2 dark grayish brown clay loam	
			25-35	10YR4/2 dark grayish brown clay	
977	negative	Goings	0-5	humic	
			5-22	10YR3/3 dark brown clayey loam	
			22-44	10YR4/3 brown loamy clay	
978	positive	Ferguson	0-15	10YR2/1 black clay loam	
			15-34	10YR3/2 very dark grayish brown clay	
979	positive	Blake	0-4	humic	
			4-30	10YR4/2 dark grayish brown clay loam	
			30-45	10YR4/2 dark grayish brown clay	
980	positive	Goings	0-8	humic	
			8-45	10YR4/2 dark grayish brown loamy clay	
			45-60	7.5YR, 5/8 strong brown rusty clay due to all the rusted metal	
			60-77	10YR4/2 dark grayish brown loamy clay with bits of gray and orange mottled clay	
981	positive	Ferguson	0-6	10YR2/1 black clay loam	
			6-29	10YR3/2 very dark grayish brown loamy clay	
			29-40	10YR5/2 grayish brown clay w/ many orange mottles	
982	positive	Blake	0-4	humic	
			4-28	10YR4/2 dark grayish brown clay loam	
			28-42	10YR4/2 dark grayish brown clay	
983	positive	Goings	0-9	humic	
			9-27	7.5YR2.5/2 very dark brown sandy loam	
			27-47	10YR3/2 very dark grayish brown loamy clay	
			47-55	10YR4/3 brown clay	
984	negative	Blake	0-3	humic	
			3-16	10YR4/2 dark grayish brown clay loam	
			16-37	10YR4/2 dark grayish brown clay	
			37-48	10YR4/3 brown clay	
985	negative	Goings	0-3	humic	
			3-94	10YR6/4 light yellowish brown sand	
986	negative	Blake	0-8	humic	
			8-75	10YR6/4 light yellowish brown fine sandy loam	
			75-85	10YR6/1 gray sandy clay w/ orange mottles	
987	negative	Goings	0-4	humic	
			4-60	10YR6/4 yellowish brown sandy loam	
			60-70	10YR7/1 light gray sandy clay with orange mottles	
988	negative	Blake	0-2	humic	
			2-48	10YR5/2 grayish brown sandy clay loam	
			48-60	10YR6/1 gray sandy clay w/ orange mottles	
989	negative	Blake	0-33	10YR6/1 gray clay w/ orange mottles	
990	negative	Blake	0-30	fill	
			30-50	10YR6/1 gray clay	
991	negative	Blake	0-11	humic	
			11-74	10YR5/4 yellowish brown fine sandy loam	
			74-85	10YR6/1 gray sandy clay w/ orange mottles	
992	negative	Blake	0-35	10YR5/2 grayish brown sandy clay w/ orange mottles	

993	negative	Blake	0-14	humic	
			14-87	10YR5/4 yellowish brown fine sandy loam	
			87-100	10YR6/1 gray sandy clay w/ orange mottles	
994	negative	Goings	0-9	humic	
			9-40	10YR6/6 brownish yellow clayey sand	
			40-54	5YR5/8 yellowish red sandy clay	
995	negative	Blake	0-15	10YR5/2 grayish brown sandy clay loam	
			15-43	10YR6/1 gray sandy clay w/ orange mottles	
996	negative	Blake	0-9	humic	
			9-50	10YR6/6 brownish yellow clayey sand	
			50-60	7.56/8 reddish yellow sandy clay	
997	negative	Goings	0-7	humic	
			7-20	10YR5/6 yellowish brown clayey sand	
			20-36	10YR7/1 light gray sandy clay w/ orange mottling	
998	negative	Blake	0-9	10YR5/2 grayish brown sandy clay loam	
			9-35	10YR6/1 gray clay w/ many orange mottles	
999	negative	Goings	0-8	humic	
			8-49	10YR5/6 yellowish brown clayey sand	
			49-66	10YR7/1 gray sandy clay w/ orange mottling	
1000	negative	Blake	0-30	10YR6/1 gray clay w/ many orange mottles	
1001	negative	Goings	0-6	humic	
			6-60	10YR6/6 brownish yellow clayey sand	
			60-77	10YR7/1 gray sandy clay w/ orange mottling	
1002	negative	Blake	0-8	humic	
			8-71	10YR5/6 yellowish brown sandy loam	
			71-80	10YR6/1 gray sandy clay w/ orange mottles	
1003	negative	Blake	0-30	10YR6/1 gray clay w/ many orange mottles	
1004	negative	Blake	0-3	humic	
			3-35	10YR6/1 gray sandy clay w/ many orange mottles	
1005	negative	Goings	0-86	10YR5/3 brown loamy sand	
			86-93	10YR5/3 brown loamy sand w/ clay, orange mottles, and Fe concretions	
1006	negative	Blake	0-7	humic	
			7-20	10YR7/1 light gray silty loam	
			20-45	10YR5/2 grayish brown silty loam	
			45-62	10YR6/1 gray silty clay	
1007	negative	Ferguson	0-20	10YR3/2 very dark grayish brown loamy clay.	Upper 15 cm disturbed. Probably plow zone w/ shell fragments and charcoal
			20-30	10YR3/1 very dark gray clay	
1008	negative	Goings	0-29	10YR3/1 very dark gray clay	
1009	negative	Ferguson	0-20	10YR3/1 very dark gray clay w/ few reddish orange mottles	
			20-28	10YR4/1 dark gray clay w/ few rew reddish orange mottles	
1010	negative	Blake	0-30	10YR4/1 dark gray clay	
1011	negative	Blake	0-30	10YR4/1 dark gray clay	
1012	negative	Ferguson	0-15	10YR6/2 light brownish gray clay loam	
			15-28	10YR7/1 light gray clay	
1013	negative	Blake	0-42	10YR6/3 pale brown	
			42-50	10YR6/1 gray clay w/ many orange mottles	
1014	negative	Ferguson	0-5	humic	
			5-18	10YR6/2 light brownish gray clay loam	
			18-50	10YR4/1 dark gray clay	
1015	negative	Ferguson	0-18	10YR3/2 very dark grayish brown loamy clay	
			18-35	10YR3/1 very dark gray clay	
1016	negative	Ferguson	0-23	10YR3/1 very dark gray clay w/ few reddish orange mottles	
			23-30	10YR4/1 dark gray clay w/ few reddish orange mottles	
1017	negative	Ferguson	0-30	10YR4/1 dark gray clay	
1018	negative	Ferguson	0-29	10YR3/1 very dark gray clay	

1019	negative	Ferguson	0-30	10YR4/1 dark gray clay	
1020	negative	Ferguson	0-30	10YR3/1 very dark gray clay	
1021	negative	Ferguson	0-12	10YR6/2 light brownish gray clay loam	
			12-30	10YR7/1 light gray clay w/ many orange mottles	
1022	negative	Goings	0-19	hard packed clayey loam w/ light plow zone	
			19-35	10YR4/1 dark gray clay loam	
1023	negative	Ferguson	0-25	10YR5/2 grayish brown clay loam plow zone	Modern iron and glass in plow zone
			25-40	10YR3/1 very dark gray clay w/ few orange red mottles	
1024	negative	Blake	0-18	10YR7/1 light gray sandy clay loam	
			18-32	10YR4/1 dary gray clay	
1025	negative	Goings	0-30	10YR4/1 dark gray clay w/ lots of rotted wood	
1026	negative	Ferguson	0-30	10YR4/1 dark gray clay	
1027	negative	Blake	0-30	10YR4/1 dark gray clay	
1028	negative	Goings	0-28	10YR4/1 dark gray clay	
1029	negative	Ferguson	0-25	10YR4/1 dark gray clay	
1030	negative	Blake	0-35	10YR4/1 dark gray clay w/ some orange mottles	
1031	negative	Goings	0-14	10YR6/6 brownish yellow sandy clay	
			14-25	5YR5/8 yellowish red clay	
1032	negative	Ferguson	0-14	5YR3/4 dark reddish brown clay	
			14-50	5YR4/4 reddish brown clay	
1033	negative	Blake	0-6	humic	
			6-17	10YR6/3 pale brown	
			17-30	10YR4/6 strong brown clay	
1034	negative	Ferguson	0-8	10YR5/2 grayish brown clay loam	10 m west of 279 on edge of ditch
			8-36	10YR7/1 light gray clay w/ many orange mottles	
1035	negative	Goings	0-6	humic	
			6-40	10YR5/2 grayish brown sandy clay w/ orange mottling	
1036	negative	Blake	0-15	humic	
			15-47	10YR4/4 dark yellowish brown sandy loam	
			47-89	10YR6/4 light yellowish brown fine sandy loam	
			89-100	10YR6/1 gray clay w/ many orange mottles	
1037	positive	Ferguson	0-13	10YR5/2 grayish brown clay loam	
			13-58	10YR6/4 light yellowish brown fine sand with few iron concretions	
			58-74	10YR6/4 light yellowish brown fine sandy clay loam w/ few orange mottles and iron concretions getting clayier w/ depth	
1038	negative	Goings	0-3	humic	
			3-85	10YR5/6 yellowish brown sand	
			85-93	10YR7/1 light gray sandy clay w/ orange mottling	
1039	negative	Blake	0-31	10YR4/4 dark yellowish brown sandy loam	
			31-73	10YR6/4 light yellowish brown fine sandy loam	
			73-85	10YR6/1 gray clay w/ many orange mottles	
1040	negative	Ferguson	0-16	10YR5/2 grayish brown fine sandy loam	across pipeline from 137
			16-33	10YR7/1 light gray clay loam	
			33-48	10YR6/2 light brownish gray clay loam w/ many orange and brown mottles	
1041	negative	Ferguson	0-12	10YR5/2 grayish brown fine sandy loam	
			12-57	10YR6/4 light yellowish brown fine sand- packed w/ few brown mottles	
			57-68	10YR7/1 light gray clay w/ many reddish orange mottles	
1042	negative	Blake	0-5	humic	
			5-67	10YR6/3 pale brown fine sandy loam	
			67-75	10YR6/1 gray clay w/ many orange mottles	
1043	negative	Goings	0-6	humic	
			6-50	10YR5/4 yellowish brown loamy sand	
			50-70	10YR6/4 light gray and yellowish brown sandy clay	
1044	negative	Ferguson	0-8	10YR5/2 grayish brown fine sandy loam	10 m east of 291
			8-16	10YR5/3 brown fine sandy loam	

			16-27	darker zone w/ charcoal	
			27-50	10YR6/2 light brownish gray clay loam clayier w/ depth	
1045	negative	Blake	0-8	humic	
			8-52	10YR4/4 dark yellowish brown sandy loam	
			52-95	10YR6/4 light yellowish brown sandy loam	
			95-100	10YR6/1 gray sandy clay w/ many orange mottles and few iron concretions	
1046	negative	Goings	0-6	humic	
			6-90	10YR5/4 yellowish brown loamy sand	
			90-98	10YR7/1 light gray and yellowish brown sandy clay	

APPENDIX 3
Historic Sites in the Gilbert Brooks League, Harris County, Texas

Terri Meyers
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This section of the report discusses the origins and development of two historic period resources in the Gilbert Brooks League, Harris County, Texas. It is part of a larger archeological survey and assessment of historic cultural resources in support of a proposed revised alignment segment of the Luce Bayou Project corridor. This section contains a description of the methodology used by the Project Historian to develop a context within which the historic-period homesteads identified as 41HR1075 on State Highway 2100 (also known as the Crosby-Huffman Road), and 41HR1076, on Wolf Road, can be understood and evaluated. Both homesteads lie within the Gilbert Brooks League (Abstract 6). Although the league straddles the Harris-Liberty County line northeast of Houston, most of the subject properties lie within Harris County. In addition to the context, this report also provides a brief history of each site, including identification of early landowners and land uses through the historic period ending in 1960.

Methodology

The Project Historian conducted primary and secondary research to develop a historic context to cover European exploration and early American settlement for the area including the subject land parcels 41HR1075 (Huffman-Somers homesteads) and 41HR1076 (Samuel May homestead). It includes a narrative history of the May and Huffman families who were among the first Americans to settle in western Liberty and eastern Harris counties in the late 1830s, and of Ben Somers, who later purchased a farm on the Crosby-Huffman Road, possibly from descendants of the Huffman family.

The Project Historian first reviewed documentation supplied by the Project Archeologist, Roger Moore, including property descriptions, deed references, and a preliminary archeological report. She attempted to trace a chain of title from the various deed references and property descriptions to identify early owners and occupants in the project area.

Secondary source materials provided general background material on the region in which the project area lies. The Project Historian obtained the following books for their relevance to the subject property and surrounding area: ***Houston: A History*** (David G. McComb, 1981), ***Seven Pines: Its Occupants and Their Letters, 1825-1872*** (Camilla Davis Trammel, 1986), and ***Liberty, Liberty County, and the Atascosito District*** (Miriam Partlow, 1974). She then accessed articles from T***he Handbook of Texas Online*** about Liberty and Harris counties, the town of Liberty, and the communities of Crosby, Huffman, and Lynchburg, which are among the oldest and closest communities to the subject properties. From these sources the Project Historian gained an understanding of the historical settlement and development of western Liberty and eastern Harris counties.

Further investigations were conducted at the Texas Historical Commission library which houses files on all Texas National Register properties and state historical markers. The Project Historian reviewed all files for properties and subjects in Liberty and Harris counties. No direct links could be made to the subject properties but some files were copied for contextual information. The Project Historian also reviewed files for Texas Family Land Heritage properties at the Texas Department of Agriculture. The Billy J. Smith Ranch on FM 2100 was registered in the program. The ranch lies on the Crosby-Huffman Road, very close to TS-30. In fact, Billy J.

Smith's son, Guy, married a direct descendant of David Huffman, Willie Mary Scott, and the couple lived on the ranch for the remainder of their lives. No other files were directly linked to the May or Huffman properties but several nearby farms were included in the program and files for these farms and ranches were copied for contextual information.

Since little or no references to the May or Huffman families were found in secondary sources, primary research was essential to the project. The Project Historian reviewed Population, Agricultural, and Slave schedules in the United States census records at the Texas State Archives and Library and online through Heritage Quest. She also researched 19th century ad valorum tax records, voter registration rolls, and land certificate records for the May and Huffman families at the State Archives.

Primary records proved fruitful. Although the first diennial census of Texas was not conducted until 1850, 20th century historians have compiled a record of male occupants in Texas in 1840 based on a variety of legal documents including tax and land grant records. Samuel May, the original settler of the May Farmstead, was identified as a resident of Texas in 1840, on the basis of his land grant issued April 1838. According to this unofficial census, David Huffman was not living in Texas in 1840. His conditional land grant was issued in 1841. Family accounts, however, claim that Huffman lived in Texas in the late 1830s and founded the community of Huffman in 1839. Susan Huffman, a relative of David, also lived in the area by 1840. The May and Huffman families appear in the 1850 and 1860 census records for Harris County. Neither May, Huffman, nor their immediate neighbors appear in the 1870 Population or Agricultural census records; they were likely neglected by the enumerator as they were all recorded ten years later in the 1880 census. By the turn of the 20th century, Samuel May, David Huffman, and Susan Huffman had passed from the scene but several of their children including Adam Huffman and Robert May appear in early 20th century census records.

Census records show that the Huffmans came to Texas from Louisiana. Samuel May, although born in Mississippi, lived in Louisiana where he met his wife, Sarah Huffman May. As southerners, they would have been accustomed to slavery. Slave schedules for 1850 and 1860 show that several members of the Huffman family owned three or four slaves but May owned no slaves in 1850 and only one in 1860. Few of their immediate neighbors owned significant numbers of slaves and many owned none. Agricultural records from the antebellum period indicate that little plantation farming was conducted in the area which could account for the relatively small number of slaves.

The Project Historian traveled to eastern Harris County and met with archeologist Roger Moore to view the project area for a better understanding of the land and its resources. She returned to the area and conducted research at the Sam Houston Regional Archives in Liberty. No information directly related to the subject properties was found there.

Ms. Myers obtained a copy of the 1966 Edgar Tobin Aerial Survey ownership map of northern Harris County to identify property owners at the end of the historic period. She found that several members of the Somers family, including father Ben H. Somers and his sons, Joe and Willie, owned the land containing the Huffman Cemetery and surrounding property. A comparison between the ownership maps and the survey site maps indicated that either Willie Somers or his father, Ben, owned the subject property (TS-30) in 1966. From their locations relative to neighboring properties in early 20th century census records, the Project Historian was able to determine that Ben Somers purchased the land between 1900 and 1910. His sons lived with him through 1930. He later subdivided his property into three farms as shown on the Tobin map; he retained his homestead and provided a farm for each of his sons.

From these secondary and primary sources the Project Historian wrote a general context for the project area and more specific histories for the subject properties.

Historic Context: Western Liberty and Eastern Harris Counties

European Exploration and Settlement

Although most of the Gilbert Brooks League now lies in northeastern Harris County, its early history may be more closely tied to that of nearby Liberty County, on the east. Prehistoric Indian artifacts found in Liberty attest to its occupation as early as 1,000 B. C. and in Harris County as early as 4,000 B.C. It was not until the 18th century that Europeans began to explore the area in earnest. From the early 18th century to the early 19th century, Spain and France vied for hegemony throughout the region now encompassed by Liberty and Harris counties. France hoped to extend its reach westward from its territory in Louisiana while Spain considered the area part of its vast domain to the south and west. As early as the 1730s, French explorers from Louisiana ventured into present Harris County where they traded with local Indians at Spring Creek. They also appeared on the Gulf coast in present Liberty County. Although they established no settlements, the French carried on trade in present East Texas until about 1745. When the Spanish heard rumors of the French intrusion into what they considered their territory, they sent exploratory expeditions to discourage further French forays into the region.

To establish a presence in the area, the Spanish built missions and presidios. In 1756, they built Nuestra Señora de la Luz Mission to serve the Akokisa and Bidai in present Liberty County. They also founded San Augustin de Ahumada Presidio near the mission. By the following year, Spanish maps depicted the settlement as Atascosito and outlined the Atascosito Road, which crossed the Trinity River near the present town of Liberty. At the same time, they erected a mission and presidio complex at the mouth of the Trinity River in present Harris County. The missions and presidios were short-lived, however; Nuestra Señora de la Luz was destroyed in a storm in 1766 and San Augustin de la Ahumada presidio was abandoned in 1772. A small trading outpost called Arkokisa or Arkosisa lingered near the later townsite of Liberty, from about 1770 to 1790. The mission and presidio at the mouth of the Trinity River were abandoned by 1771 (Kleiner "Liberty County"; Henson "Harris County").

Direct Spanish influence in the area faded in the late 18th century and French ex-patriots sought to fill the void. In 1818, Charles F. A. Lallemand and Antoine Rigaurd sought to establish a refuge for exiled Bonapartists near the present town of Liberty. The effort proved futile, however, and its demise spelled an end to further French ambitions in the territory (Kleiner, "Liberty County").

Mexican Texas and the War for Texas Independence

While the Spanish succeeded in staving off French intrusion, they were unable to stem the flow of American immigrants to Texas, many of whom came from Louisiana and Mississippi, attracted by the prospect of open land. Some of the first Americans in Texas launched filibustering expeditions to aid Mexican Republicans in their rebellion against Spain. Mexico won its independence in 1820 and assumed authority over present Texas, including present Liberty and Harris counties. After Mexico won its sovereignty from Spain in 1820, Americans were encouraged to settle in Texas. The government promised large land grants to ***empresarios*** who brought immigrant parties to the country. In 1826, the Mexican government granted much of the land that includes present Liberty County and adjacent territory to empresario Joseph B. Vehlein. That same year, new settlers established a new Atascosito District as an independent

colony. The district included the Gilbert Brooks League in present Liberty County (Kleiner, "Liberty County").

During the period of pioneer settlement in the 1820s and 1830s, American men typically came to the Atascosito District ahead of their wives and families. They explored the region in search of good farmstead sites and many built log houses before returning to their home states to collect their families. They often traveled in small groups of related families that formed the nucleus of rural communities once they arrived in the new land. This is apparently the course taken by Samuel May and David Huffman in the Gilbert Brooks League. The men came to Texas in the early to mid-1830s and brought their families to the region about 1840.

Texians chafed against Mexican authority from the outset. The Mexican government prohibited slavery, expected colonists to convert to Catholicism, and demanded obedience to Mexican law. Mexican leaders became increasingly suspicious of American settlers and by virtue of the Law of April 6, 1830, the government stopped further American immigration to Texas. The law did little to discourage the now constant flow of Americans into the region, however, and new settlers joined with old in defying Mexican rule.

In 1831, Mexican land commissioner José Francisco Madero organized a local government in the Atascosito District dubbed Villa de la Santisima Trinidad de la Libertad. The formation of the municipality was intended to support local landowners and give them a greater measure of security and self-determination. The municipality was bounded by the Sabine River on the east, by the San Jacinto on the west, by the Nacogdoches Municipality on the north, and the Gulf of Mexico on the south. The new seat of government, which lay about three miles southwest of old Atascosito, was called Liberty. By 1835, about 1,000 people lived in the municipality (Kleiner "Liberty County").

As more Americans flooded the region in the early 1830s, tensions grew between the Texians and the Mexican government. The men of Liberty formed volunteer militias to protect their homes and families. In the ensuing war, the Liberty Volunteers fought at the battle of Concepción and the siege of Bexar. Liberty also contributed the Third Infantry Company, Second Regiment, which fought at the Battle of San Jacinto. After Texas gained its independence, Liberty County was organized in 1836. Originally, the county included all of the future Tyler County and parts of what later became Hardin, Chambers, San Jacinto, and Polk counties. The town of Liberty was named the county seat and incorporated in 1837 (Kleiner "Liberty County").

Antebellum Era

In the twenty-five years between the Texas Revolution and the Civil War, Liberty and Harris counties developed fairly diverse economies largely invested in farming, stock raising, timber, and shipping. Numerous plantations were established along the Trinity River where crops including cotton, sugarcane, tobacco, indigo, grains, and vegetables were grown. As early as 1831, James Taylor White ran 3,000 head of cattle on what became an extensive cattle ranch at Turtle Bayou in present Chambers County (Partlow 1974: 123). Others followed suit and in just a few years, stock raisers were driving large herds of cattle to market in New Orleans, while others sold animals to meatpacking plants at Liberty Landing. Cattle formed the basis of the area's agricultural economy during the antebellum period; the county counted 14,058 head of cattle in 1840, a number that more than tripled to 45,670 head by 1850 (Kleiner "Liberty County").

The East Texas region was heavily forested and a number of sawmills emerged in Liberty County in the 1840s and 1850s. In fact, lumber grew to rival stock raising in importance and was the county's major industry during this period. At the same time, shipping became an important occupation. Timber products and agricultural goods, including cotton, hides, Indian corn, and cattle were all shipped down the Trinity River to waiting vessels in the Gulf. Transportation through the county improved and steamboat traffic on the Trinity flourished. Efforts to extend the navigable portion of the Trinity began in 1852 and continued off and on thereafter. Railroad construction was also initiated in the area during the 1850s. By 1860, the Texas and New Orleans Railroad laid rail lines from Houston, via Liberty and Beaumont, to Orange. An early attempt to build a railroad from Liberty to Livingston was interrupted by the Civil War (Kleiner "Liberty County").

Civil War and Reconstruction

Along with most Texas counties, Liberty sided with the South in the Civil War. Many early settlers in the region had emigrated from southern states, particularly Mississippi and Louisiana. Slave ownership was common across economic lines in Liberty and Harris counties; wealthy plantation owners, small farmers, and businessmen alike owned slaves, though the numbers varied widely (U. S. Bureau of the Census, Slave Schedule, Harris County, 1850). Not surprisingly, Liberty County voted 422 to 10 for secession and contributed to several Confederate units in the Civil War. A militia company was charged with protecting the home front (Kleiner "Liberty County").

After the war and the emancipation of slaves, some freedmen remained with their former masters for awhile before starting their own small farms. The black population of Liberty County rose considerably from 1860 to 1870, possibly due to an influx of immigrants – both white and black – from southern states that had been devastated by the war. In 1860, the census counted 1,079 slaves in Liberty County; in 1870, the number of freedmen was nearly double that at 1,975. The loss of "property" and the rise in the black population after Emancipation may have contributed to significant racial conflict in the Reconstruction era. Former Confederates resented the Freedmen's Bureau that operated in Liberty from 1866 to 1868. Tensions grew so intense that the number of Republicans in the county fell from 255 in 1869 to 0 in 1873, so hated were they by the defeated Confederates. Despite these difficulties, the numbers of black and white citizens of Liberty County were nearly the same in 1880. Thereafter, blacks decreased in proportion to whites and comprised about a third of the population through the early 20th century (Kleiner "Liberty County").

Steamboat travel on the Trinity River resumed after the Civil War but the construction of numerous railroad lines through the area dealt a blow to the port of Liberty. Railroads reached the many timber towns, which once shipped their products by boat, to outside markets. Nevertheless, efforts were made to improve navigation on the Trinity River and several hundred miles of waterways were constructed in the county by 1940 (Kleiner "Liberty County").

Timber and agriculture remained the county's greatest industries and attracted many new residents in the latter part of the 19th century; occupations in these fields attracted many new residents and the county's population nearly doubled from 4,230 in 1890 to 8,102 in 1900. In the following years, the development of rice culture and the discovery of oil expanded the county's economic base even further. Around the turn of the 20th century, irrigation systems were installed in the county to promote rice farming, which grew to rival cattle raising as the county's top agricultural product. At the same time, oil fever began to take hold in Liberty County as

numerous wells were struck, primarily in the southern part of the county, and pipelines criss-crossed the county (Kleiner "Liberty County").

Early 20th Century

The county's population continued to grow in the early 20th century, from 14,637 residents in 1920 to 24,541 in 1940. Agriculture remained an economic staple and farms in the county rose from 1,001 in 1900, to an all-time high of 1,961 in 1940. Corn, rice, and cotton, the major crops, accounted for 85 to 92 percent of Liberty County's agricultural revenue in the 1920s and 1930s. Farmers continued to raise beef cattle and hogs in large numbers throughout the first half of the 20th century. The county typically claimed about 30,000 head of cattle through 1950 and in the 1930s, it led the state with 31,242 hogs. Timber remained an important source of revenue through the early 20th century, as well (Kleiner "Liberty County").

Due to its diverse economy, Liberty County survived the agricultural ravages of the 1920s and the economic crisis of the Great Depression better than some Texas counties. The boll weevil infestation in the 1920s may have contributed to the increase in tenant farming; their numbers grew from 294 in 1920, to 709 (46 percent of county farmers) in 1930 and remained high through the 1930s. Despite the rise in tenancy, farm values actually increased by nearly 30 percent during the 1930s and agriculture and timber remained the county's largest employers on the eve of World War II (Kleiner "Liberty County").

In 1930, the Gilbert Brooks League remained a sparsely settled corner of rural northeastern Harris County. The Crosby-Huffman Road traversed the area north to south, connecting farmsteads and logging camps to the town of Huffman a few miles to the south. Principal east-west roads were Wolf Road, to the north, Havard Road, to the southwest, and the Huffman-Eastgate Road to the southeast. No settlements lay in the area but a grocery store fronted onto the Crosby-Huffman Road south of its intersection with Wolf Road (U. S. Bureau of the Census, Population Schedule, Harris County, 1930). About thirty-five households lay between Wolf Road on the north and Havard Road on the south, toward Huffman. In addition, a number of single men lived in the area.

Most of the area's residents were engaged in agriculture, either as farmers or farm laborers, but a number worked as section hands for the railroad, and still others worked in logging camps. One man was a merchant who ran the grocery store where he and his children worked. Virtually all of the farmers lived in households with their families, which generally consisted of two parents and their minor children. Households might also include in-laws, nieces and nephews, and grandchildren. Of the thirty-five heads of household, 18 owned their homes and 13 rented. Several were not identified as owners or renters. Railroad workers and loggers typically lived in boarding houses or camps near their job sites (U. S. Bureau of the Census, Population Schedule, Harris County, 1930).

All of the inhabitants of this dispersed community were listed as "white" in the 1930 census, though a number of "Mexican" section hands for the railroad lived nearby, to the south. A few residents were foreign born; one family hailed from Germany and another from Czechoslovakia. The great majority, however, were southerners, among them many native Texans, Mississippians, and Louisianans. Virtually all spoke and read English. Young children attended public school while older ones worked as farm laborers, likely on their family farms. The nearest community center was Huffman, a few miles to the south.

World War II and the Postwar Era

At the onset of World War II, Liberty County had little in the way of manufacturing businesses but industries sprang up to meet the demands of war. Industrial plants more than doubled from the pre-war figure of 22 plants employing 370 workers in 1940, to 52 firms employing 744 workers in 1948. Among the county's new industries was the Texas Gulf Sulfur Company which mined sulfur at Moss Bluff, south of Liberty. Manufacturing and chemical plants increased in the postwar years, as well. During that time, Cleveland became a lumber and oilfield supply center, Dayton a rice and oilfield center, and Liberty rose as a key port on the barge canal, shipping sulfur, chemicals, and steel. (Kleiner "Liberty County").

Despite new industries, agriculture remained the mainstay of the county's economy in the postwar era. Farm tenancy had declined dramatically in the 1940s and agribusiness emerged on the scene. Cotton and corn no longer dominated agricultural production but soybeans rose to become one of the county's most important crops, along with rice. By the 1980s, 52 percent of Liberty County remained in farmland with 36 percent of the land under cultivation during the 1980s. Principal crops included rice, soybeans, wheat, sorghum and hay, although some land was devoted to watermelons, peaches, and pecans. While the majority of the county land was dedicated to agriculture, the number of individual farms decreased to 858 in 1980, about half of that recorded in 1940 (Kleiner "Liberty County"). Some of the decline can be attributed to agribusiness with its tendency to purchase and consolidate numerous adjoining farms.

In addition to agriculture, new industries located in Liberty County and established ones flourished in the 1980s. The county produced oil and gas, sulfur, veneer and plywood, concrete, steel, and metal goods. The region continues to be known for its forests, both for timber products and recreation. In the 1990s, a section in the northern part of the county was designated as the Big Thicket National Preserve (Kleiner, Liberty County, handbook). In addition, the county boasted over 900 businesses. While new jobs were created, Liberty County residents increasingly commuted to Houston for work thanks to the construction of U.S. Highway 59 which was built through the county in the 1960s (Kleiner "Liberty County").

The May, Huffman, and Somers Farmsteads

Introduction

Samuel May, Susan Huffman, and David Huffman were among the first settlers in the Gilbert Brooks League which straddles the Harris and Liberty County line, northeast of Houston, Texas. They arrived in Texas from Louisiana in the mid- to late-1830s and selected farmsteads along present Wolf Road and the Crosby-Huffman Road (FM 2100). In 1839, David Huffman founded the community of Huffman, a few miles south of his homestead. About 1840, Samuel May and David Huffman returned to Louisiana to retrieve their families and bring them back to their farmsteads in the Gilbert Brooks League. Susan Huffman and her young son, Adam, moved to Texas and settled near Samuel May and David Huffman. Members of the Huffman and May families occupied their farms through the 19th century and into the early 20th century. Descendants of Samuel May still own and occupy their traditional farmstead. At least one direct descendant of David Huffman lived on an adjacent ranch, the Smith Ranch near the intersection of FM 2100 and 1960, through the 20th century. Her name was Willie Mary Scott and she married Guy C. Smith in 1920. Susan Huffman's son, Adam, was one of the last members of the family to live on his farmstead as recorded in the 1900 census. He appears to have sold at least part of his land to Ben Somers who settled on the Crosby-Huffman Road between 1900 and 1910. Somers and his sons owned farms along the road from before 1910 through at least 1966.

Gilbert Brooks League

The project area is in the Gilbert Brooks League, most of which lies in eastern Harris County; a small portion extends across the county line to western Liberty County. The league was granted to Gilbert Brooks, a Connecticut native who came to Texas in 1831 when he was just 24 years of age. David G. Burnet may have persuaded the young man to seek his fortune in Texas by building and operating a sawmill at Lynch's Ferry (aka Lynchburg). As soon as Brooks arrived in the area, the two men formed a partnership and by the end of the year they established a boiler and a steam engine at Lynch's Ferry, at the confluence of Buffalo Bayou and the San Jacinto River, in east-central Harris County. Nathaniel Lynch had established the crossing at the north end of Burnet Bay in 1822. In 1834 or 1835, shortly after Brooks and. Burnet located their mill at the site, Nathaniel Lynch platted his property into town lots and named the town Lynchburg after himself. It became one of the principal settlements in the region before the battle of San Jacinto (***About Cedar Bayou: A Condensed History***).

Burnet may have funded the mill project but Brooks oversaw its day-to-day operations. In 1834, Brooks petitioned for, and received, a league (4,428.4 acres) and Labor (177.1 acres) of land in the Mexican municipality of Villa de la Santisima Trinidad de la Libertad – today in far western Liberty County and northeastern Harris County (White Vol. 3). When hostilities broke out between the Mexican Government and the Texians in the Texas War for Independence, Brooks enlisted for service under the command of Colonel Morgan (Young 1995: 46). At the battle of San Jacinto, Sam Houston detached Brooks to escort Burnet and state documents to safety (***About Cedar Bayou: A Condensed History***).

After the Texas War for Independence, Brooks settled in Cedar Bayou where he established a home and farm. In 1837, Brooks married Frances Whiting, the daughter of an early settler in the area, Dr. Harvey Whiting. He later married Caroline Chamberlain, in 1850, and finally, Melissa Whiting Bauer, sister of his first wife, in 1855. Brooks fathered a number of children by his three wives and today he has many descendants in the Cedar Bayou area (Young 1995: 46).

Brooks was also active in civic affairs and in 1844, he was one of nine organizers of the Cedar Bayou Methodist Church. In 1847, the trustees oversaw the construction of a log church building on ten acres of land on the west side of Cedar Bayou. Known as Alexander Chapel for the presiding elder of the Galveston District, the church quickly became the center of community activity. Soon after its construction, the congregation held a Fourth of July ceremony and barbeque attended by none other than Sam Houston. The Cedar Bayou church was one of the most important stations on a circuit that included Lynchburg, San Jacinto, Harmony Grove, and Bay Mission. In 1855, Brooks chaired a committee to build a new church near the site of the log building; the frame church was completed in 1857 and doubled as a public school house (***About Cedar Bayou: A Condensed History***).

Huffman and May Farmsteads

Members of the Huffman and May families came to Texas from Louisiana in the mid- and late-1830s. Susan Huffman and David Huffman were born in Louisiana and lived in Rapides Parish by 1820 (U.S. Bureau of the Census, 1820, 1830). The 1850 census indicates that Susan

lived in Texas as early as 1835, but that may be a mistake in the record.[1] She likely came with her husband in the late 1930s as later census records show that her son Adam was born in Louisiana about 1838. David Huffman, possibly Susan's son or nephew, came to Texas by 1839. His wife, Elira, gave birth to her first child, Eliza, in Texas in 1840 (U.S. Bureau of the Census, Population Schedule, Harris County, 1850).

Samuel May was related to the Huffmans by marriage. He was born in Mississippi about 1816,[2] and moved to Louisiana in the 1830s, likely with his parents. As a young adult, May traveled to the Republic of Texas. He is thought to have arrived in Texas between March 2, 1836 and October 1, 1837, because he later became eligible for a Class 2 land certificate based on his residency during that time (General Land Office). His exact whereabouts are unknown, though he may have lived near Lynch's Ferry in what was then Liberty County, now eastern Harris County. On April 26, 1838, May filed for a conditional Class 2 land certificate as a married man. Under the terms of the allotment, a married head of household was entitled to 1,280 acres of land (White 1966).

May apparently returned to Louisiana where he married Sarah Huffman, a girl of thirteen, by April 1838. Sarah is thought to be David Huffman's sister. Sarah gave birth to their first child, Robert, in Louisiana, about 1839.[3] Samuel may have returned to Texas ahead of his family to claim residency and establish a homestead in what was then Liberty County. May's family joined him in Texas by 1839. When he proved up his land certificate on October 4, 1841, May claimed that he had lived in Texas for three years, since at least 1838 (White 1966).

By 1840, the Susan Huffman, David Huffman, and Samuel May families all lived near one another in the Gilbert Brooks League. May's closest neighbor was his brother-in-law, David Huffman, who is thought to have lived in Texas as early as 1839.[4] May and Huffman probably knew each other in Louisiana and may have come to Texas together. A close neighbor of the May and Huffman families was Susan Huffman who headed her own household consisting of herself, her son Adam, and daughter Hester. Susan Huffman was born about 1795. Like David Huffman and Sarah Huffman May, she was born in Louisiana. Susan's children, Adam and Hester, were probably born in Louisiana in 1835 and 1837, respectively (U.S. Bureau of the Census, Population Schedule, Harris County, 1850). Susan was likely related to Sarah Huffman May and David Huffman by marriage, but their exact relationship is unknown.

Early Settlement in the Gilbert Brooks League

The land Samuel May chose for his homestead lay in the Gilbert Brooks League (Abstract 6) in the piney woods of what was then Liberty County. May's brother-in-law, David Huffman, occupied the land to the west by 1839. Other members of the Huffman family lived nearby and together the May and Huffman homesteads formed the nucleus of a small, dispersed, agricultural settlement.

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[1] Early census records show that Susan Huffman's son, Adam, was born in Texas in 1835, placing Susan in the state at that early date. Later records show Adam's birthplace as Louisiana. These records are likely correct.

[2] Census records disagree; some indicate that he was born in 1816 while others indicate 1815.

[3] Sources differ as to Robert's birthplace. The 1850 census indicates that Robert was born in Texas but the 1860 and 1880 records show that he was born in Louisiana. These later records are probably correct.

[4] ***The Handbook of Texas*** states that David Huffman founded the settlement of Huffman in 1839.

When the May and Huffman families moved to the Gilbert Brooks League in the late 1830s, the territory was almost entirely forested; they were among the first settlers in the league. A few scattered farmsteads dotted the landscape but they were rare. The closest settlements were at Lynchburg, which lay about 17 miles to the south, and Cedar Bayou, which was about 40 miles to the south. In 1839, David Huffman established the first settlement in the Brooks League. It was called Huffman, a name it holds to the present.

The Huffman and May families had much in common with others in northeastern Harris County. Nearly all adults in the vicinity of Huffman had emigrated to Texas from other Southern states. They typically were single or headed young families and most of their children were born in Texas. Nearly all adult men worked as farmers or stock raisers, most on their own land (U.S. Bureau of the Census, Population and Agricultural schedules, Harris County, 1850).

Little else is known about the pioneers before the 1850 census. By then, the county lines had been redrawn and the May and Huffman families were enumerated in Harris County. The families likely lived in one- or two-room log houses until they could build more substantial homes. Their first activities in the unbroken land probably consisted of clearing trees for household gardens and building animal shelters or enclosures for horses, cattle, hogs, and chickens. Following that, they cleared land for field crops as indicated in the 1850 agricultural census.

By 1850, Samuel and Sarah added three more children to their family, Joseph (age 10), Elizabeth (age 5), and Hester Anne (age 3). Robert, the oldest, was 12 years old. The family's closest neighbors were Sarah's brother, David Huffman (age 35), and his family consisting of his wife Elira (age 30), and five daughters Eliza (10), Sarah (8), Susan (6), Anne Elizabeth (3), and Mary (1). David and Elira Huffman had both been born in Louisiana but all their children were born in Texas, starting in 1840[5] (U.S. Bureau of the Census, Population Schedule, Harris County, 1850).

In 1850, Susan Huffman headed her own household consisting of herself (55), her son Adam (13), daughter Hester (13), and a boarder, William Owens (19). Owens, a native of Louisiana, was listed as a farmer in her household. According to the 1850 census, Susan Huffman also owned seven slaves. One was a thirty-year old woman but the rest were children under the age of fourteen. Susan may have brought the woman and older children with her from Louisiana but the younger children were probably born in Texas. Neither Samuel May nor David Huffman owned slaves according to the 1850 census (U.S. Bureau of the Census, Population and Slave schedules, Harris County, 1850).

1850 Population Census, Harris County

Name	Age	Occupation	State of Birth	Cash on Hand
David Huffman	31	Farmer	LA	$200
Elira	30		LA	
Eliza	10		TX	
Sarah	8		TX	
Susan	6		TX	
Anne Elizabeth	3		TX	
Mary	1		TX	

[5] The Handbook of Texas states that David Huffman founded the settlement of Huffman in 1839.

Samuel May	35	Farmer	MS	$200
Sarah	25		LA	
Robert	12		TX	
Joseph	10		TX	
Elizabeth	5		TX	
Hester Anne	3		TX	
Susan Huffman	55		LA	$200
Adam	13		TX	
Hester	13		TX	
William Owens	19	Farmer	LA	

All three families engaged in modest crop production with much more unimproved land (pasture, woodland, other), than improved (crop fields). The 1850 agricultural census for Harris County shows that Samuel May owned 15 acres of improved land and 185 acres of woodland; David Huffman owned 8 acres of improved land and 292 acres of unimproved land; Susan Huffman owned 20 acres of improved land and 180 acres of unimproved land. While they likely all had vegetable gardens, their only field crops were sweet potatoes and Indian Corn. Susan Huffman's farm produced 80 bushels of Indian corn and 80 bushels of sweet potatoes; Samuel May's farm yielded 250 bushels of Indian corn and 70 bushels of sweet potatoes; and David Huffman's farm produced 250 bushels of Indian corn and 80 bushels of sweet potatoes in 1850. They planted no oats, wheat, rye, rice, or tobacco (U.S. Bureau of the Census, Agricultural Census, Harris County, 1850). Almost certainly, the sweet potatoes and Indian corn were grown for personal use and as food for livestock, rather than for sale.

In fact, the families could better be described as stock raisers than farmers. All three families owned considerable livestock, as did their surrounding neighbors. Each listed horses, milch cows, working oxen, beef cattle, and hogs. Susan Huffman owned ten horses, well above the average number in the area. Each of the families appeared to have substantial dairy operations; Samuel May owned 15 milch cows, producing 350 pounds of butter, Susan Huffman owned 30 milch cows, yielding 100 pounds of butter, and David Huffman owned 35 milch cows, producing 100 pounds of butter. The families owned between 20 and 50 swine apiece. Beef cattle, however, surpassed all other livestock; May owned 200 head of cattle, Susan Huffman owned 200 head of cattle, and David Huffman owned 100 head of cattle. The families valued their livestock at $650 for David Huffman, $1,050 for May, and $1,200 for Susan Huffman. May and Susan Huffman both valued their farms at $600 while David Huffman's farm was worth only $300 (U.S. Bureau of the Census, Agricultural Schedule, Harris County, 1850).

1850 Agricultural Census, Harris County

Name	Improved Acres	Unimproved Acres	Farm Cash Value	Horses	Milch Cows	Working Oxen	Other Cattle
David Huffman	8	292	$300	2	35	2	100
Samuel May	15	185	$600	7	15	4	200
Susan Huffman	20	180	$600	10	30	4	200

1850 Agricultural Census, continued-

Name	Swine	Value of Livestock	Bushels Indian Corn	Bushels Sweet Potatoes	Pounds of Butter	Value of Slaughtered Animals
David Huffman	20	$650	250	80	100	$150
Samuel May	50	$1,050	250	70	350	$100
Susan Huffman	40	$1,200	80	80	100	$100

The 20 farms surrounding the May and Huffman properties ranged from 5-50 acres of improved land and 10-1,180 acres of unimproved land with most consisting of 10-20 acres of improved land and 200 acres of unimproved land, much like the Huffman and May operations. Likewise, the surrounding farms were valued at $100-$1,000 but most were worth between $200 and $500, similar to David Huffman's farm at $300 and Susan Huffman and Samuel May's farms at $600 apiece. Virtually all the surrounding farmers raised some beef cattle with most possessing between 10 and 50 head, although one prosperous stock raiser owned 900 head of cattle. Although livestock values varied widely from $60-$4,000 per farmer, most listed their worth at between $500 and $800 total. The Huffman and May herds were worth slightly more than average for their area (U.S. Bureau of the Census, Agricultural Schedule, Harris County, 1850).

After a little more than a decade on the land, the Huffman and May families had succeeded in establishing fairly substantial farms. They may have replaced their initial log dwellings with somewhat larger, if still modest, houses to accommodate their growing families. The first known occupants of the region, they cleared the wilderness for 8-20 acres of field crops. They probably built and maintained shelters for their large numbers of milch cows, swine, and poultry but left their beef cattle to forage in the woodland areas of their farms. Some of the first cattle drives in Texas originated in this part of the state; they were driven to Louisiana and points further east. Since the May and Huffman families raised substantial numbers of beef cattle – as did their neighbors – they may have participated in such cattle drives.

On the Brink of Civil War

By 1860, the Huffman and May families were well-established in the Gilbert Brooks League having lived there for more than a decade. They were enumerated in the Lynchburg Post Office district of Harris County. Susan Huffman may have passed away as she was not listed in the 1860 census, but her son Adam appears to have assumed her estate based on its proximity to Samuel May and David Huffman in the census record; Adam Huffman was listed next to Samuel May in the place where Susan Huffman had previously been shown (U.S. Bureau of the Census, Population Schedule, Harris County, 1860).

Samuel May and David Huffman headed large households that included their wives, numerous children, and several laborers. Samuel and Sarah May had nine children living at home in 1860. Their eldest son, Robert or R. J., was 21 years old, living with his parents, and engaged in farming either for his father or another farmer. The other children ranged in age from seventeen to two years old. P.J. Sessums, a 21-year old laborer, and James Fowler, a 26-year old horse breaker, lived on the May farm. Samuel May's occupation was given as "farmer". He

owned $7,000 worth of real estate and $2,855 in personal property in 1860 (U.S. Bureau of the Census, Population Schedule, Harris County, 1860).

David and Elira Huffman had eight daughters living at home. Their oldest, Eliza, was apparently gone from the household. Of the remaining daughters, Sarah, age 16, and Susan, 15, may have been named for Susan Huffman and Sarah Huffman May, who were possibly their grandmother and aunt, respectively. In addition to the immediate family, a young man named R.J.D. Curtis lived with in the household. No occupation was given for Curtis but he was born in Louisiana and may have been related to the Huffman clan. David Huffman, too, listed his occupation as "farmer". His wealth was comparatively high for the area; he claimed $10,788 worth of real estate and $1,722 in personal property (U.S. Bureau of the Census, Population Schedule, Harris County, 1860).

Adam Huffman was a young man of twenty-two in 1860. He listed his occupation as "stock raiser" instead of "farmer". His wife, Emeline, was nineteen years old and the couple had a two-year old girl named Caroline. Despite his youth, Adam Huffman claimed $1,000 worth of real estate and commanded $3,120 in personal property (U.S. Bureau of the Census, Population Schedule, Harris County, 1860).

1860 Population Census, Harris County

Name	Age	Occupation	State of Birth	Cash on Hand	Value of Real Estate
David Huffman	41	Farmer	LA	$1,722	$10,788
Elira	41		LA		
D.A. (male)	2		TX		
Su? (female)	15		TX		
A.E. (female)	13		TX		
M.A. (female)	11		TX		
J. Ann (female)	9		TX		
M.E. (female)	7		TX		
E.J. (female)	5		TX		
E.A. (female)	16		TX		
R.J.D. (male)	15				
Samuel May	47	Farmer	MS	$2,855	$7,000
Sarah	37		LA		
R.J.(male)	21	Farmer	LA		$800
J.F. (male)	11		TX		$320
E.E. (female)	15		TX		
H.A. (female)	13		TX		
M.A. (female)	10		TX		
Thomas	8		TX		
L.J. (male)	5		TX		
M (female)	2		TX		
P.T. Sessums	21	Laborer	AL		
Jas. Fowler	26	Horse Breaker	TN		
Adam Huffman	22	Stock Raiser	LA	$3,120	$1,000

Emeline	19		SC		
Caroline	2		TX		

In addition to family members and hired help, the Huffman and May families owned a number of slaves in 1860. David Huffman owned four slaves outright and held two in trust for unnamed minor heirs. Nancy Huffman, possibly David's eleven year old daughter, owned one slave, a thirty-three year old woman. Samuel May owned one slave in 1860, a twenty-two year old man. Adam Huffman was not listed in the Slave Schedule of 1860. By their sexes and ages, the Huffman and May slaves may have been among those listed as belonging to Susan Huffman in the 1850 census. As property, the slaves would have been subject to distribution among her heirs (U.S. Bureau of the Census, Slave Schedule, Harris County, 1860).

1860 Slave Schedules, Harris County

Owner's Name	Slave	Age	Notes
David Huffman	Black Male	21	
David Huffman	Black Female	20	
David Huffman	Black Female	12	
David Huffman	Black Female	18	In trust for minor heir
David Huffman	Black Female	3	In trust for minor heir
David Huffman	Black Female	33	In trust for minor heir (Nancy Huffman)
Samuel May	Black Male	22	

In the ten years since 1850, the May and Huffman families considerably expanded their fields, acquired more unimproved land, and increased their wealth. In 1860, Samuel May claimed 30 acres of improved land and 1,370 acres of unimproved land, David Huffman had 25 acres of improved land and 275 acres of unimproved land, while Adam Huffman increased his improved land to 50 acres and unimproved land to 500 acres. Their farms were similar to others in the region. A study of 20 nearby farms showed that while the range of improved land extended from only 10 acres to 170 acres, most farmers had between 25 and 50 acres of tilled fields. Most farmers in the sample owned between 150-300 acres of unimproved land (woodland, pasture). In this regard, Samuel May and Adam Huffman greatly exceeded the average (U.S. Bureau of the Census, Agricultural Schedule, Harris County, 1860).

May's farm was valued at $7,000, while David Huffman's farm was worth $3,000 and Adam Huffman's land was worth $1,000. If Adam Huffman's farm value was lower than his neighbors', his livestock operation far surpassed theirs; Samuel May owned 78 head of beef cattle, David Huffman owned 100 head, but Adam Huffman owned 500 head of beef cattle, far more than most of the surrounding farmers. All three farmers owned milch cows, working oxen, and large number of hogs. They had significant numbers of horses; Samuel May owned nine horses while David Huffman owned 40 and Adam Huffman owned 45 head. While the May and Huffman families, and their neighbors, all grew some crops – mainly Indian Corn –livestock was the most valuable component of their farms. Samuel May valued his livestock at $1,544, David Huffman valued his at $2,421, and Adam Huffman approximated the worth of his livestock at $4,120. All made some money from the sale of slaughtered animals, with the average farm yielding between $100 and $200 per year (U.S. Bureau of the Census, Agricultural Schedule, Harris County, 1860).

Indian corn remained the most important field crop for the Huffman and May families, as it did for all of the surrounding farmers. The yield varied widely from farm to farm; of 20 nearby farms, including those of the May and Huffman families, corn production ranged from 20 to 600 bushels in 1860. Most of the farmers raised between 200 and 300 bushels of corn, however. Samuel May and Adam Huffman each grew 300 bushels of corn while David Huffman doubled that amount at 600 bushels. The farmers in this area did not typically grow wheat, rye, or rice, but they were beginning to grow cotton. Most produced 1-3 bales although Samuel May produced six bales and Elle Dunks, his immediate neighbor, grew 51 bales. Since each bale consisted of 400 pounds of ginned cotton, May raised 2,400 pounds and Dunks produced a whopping 20,400 pounds (U.S. Bureau of the Census, Agricultural Census, Harris County, 1860).

On the eve of the Civil War, the Samuel May, David Huffman, and Adam Huffman families appeared to have successful farm and ranch operations. May owned the largest, most valuable, farm but had fewer head of horses and beef cattle than his in-laws. At the same time, May turned some of his acreage to cotton, a cash crop that promised increased stability, and even wealth, in the future.

1860 Agricultural Census, Harris County

Name	Improved Acres	Unimproved Acres	Farm Cash Value	Horses	Milch Cows	Working Oxen	Other Cattle
David Huffman	25	275	$3,000	40	35	4	100
Samuel May	30	1,370	$7,000	9	22	6	78
Adam Huffman	50	500	$1,000	45	13	10	500

Continued-

Sheep	Swine	Value of Livestock	Bushels Indian Corn	Pounds of Wool	Bushels Sweet Potatoes	Value of Slaughtered Animals
12	50	$2,421	600	20	25	$203
0	50	$1,544	300	0	0	$300
0	20	$4,120	300	0	0	$105

Reconstruction and Latter 19th Century

It is not known how the May and Huffman families fared in the years following the Civil War. Neither they, nor their immediate neighbors, appear in the 1870 census record for either Liberty or Harris counties. Likewise, the community was omitted in the 1870 Agricultural Schedule. It appears that the enumerator simply passed over their part of the county.

1880 Population Census, Harris County							
Name	**Age**	**Occupation**	**State of Birth**	**Father's Birthplace**	**Mother's Birthplace**	**Cash on Hand**	**Value of Real Estate**
David Huffman	61	Stock Raiser	LA	MS	LA		
Adam Huffman	42	Farmer	LA				
Emeline	40	Keeps house	SC				
Samantha	16	At home	TX				
Ara Jane	13		TX				
Elira	3		TX				
Marcus	3		TX				
RT May	41	Farmer	LA				
Louisa May	35	Keeps house	Germany				
Joseph	15		TX				
Augusta	12		TX				
Henrietta	7		TX				
Emma	6		TX				
Thomas	2		TX				
Samuel May	63	Farmer	MS				
Sarah	55	Keeps house	LA				
Jackson	17	At home	TX				

All three families appear in the 1880 population and agricultural census records. By that time, the families had lived in eastern Harris County for over 40 years. However, their fortunes appear to have diminished somewhat by 1880. All had less improved acreage and all reported lower farm values than they had in 1860; Samuel May had only 15 tilled acres and 300 unimproved acres – down from 1,370 in 1860 – David Huffman had 22 tilled acres but claimed 600 unimproved acres, and Adam Huffman had 10 tilled acres and 185 unimproved acres. More telling were the farm values. Samuel May reported that his farm was worth $700 and his livestock worth $200, David Huffman assessed his farm at $1,000 and his livestock at $2,000, and Adam Huffman claimed his farm was worth $700 and his livestock $5,000 (U.S. Bureau of the Census, Agricultural Schedule, Harris County, 1880).

May, in particular, was less prosperous and less productive in 1880. His farm had been reduced in value from $7,000 to $200, his cattle had been reduced in number from 78 head to 15, and their value slashed from $1,544 to $200. He had no oxen, no milch cows, no swine, and only ten chickens. Furthermore, he did not produce any field crops, including Indian corn, and grew no cotton. In comparison, David Huffman owned five oxen, 13 milch cows, 285 beef cattle, 15 hogs, and 75 chickens. He grew 300 bushels of Indian corn and ginned three bales of cotton. Likewise, Adam Huffman claimed 15 milch cows, 600 beef cattle, 15 hogs, and 75 chickens. In addition, he produced 150 bushels of Indian corn on his 15 acres of tilled soil. According to the 1880 agricultural census, David and Adam Huffman owned farms on par with their neighbors, all

of whom grew some Indian corn but also owned considerable livestock (U.S. Bureau of the Census, Agricultural Schedule, Harris County, 1880).

1880 Agricultural Census, Harris County							
Name	**Tilled Acres**	**Woodland Acres**	**Farm Cash Value**	**Value of Livestock**	**Oxen**	**Milch Cows**	**Other Cattle**
David Huffman	22	600	$1,000	$2,000	5	13	285
Samuel May	15	300 or 500	$200	$200	0	0	15
Adam Huffman	15	185	$700	5,000	0	15	600

1880 Agricultural Census, continued-

Swine	**Barnyard Animals**	**Acres Indian Corn**	**Bushels Indian Corn**	**Acres Cotton**	**Bales Cotton**	**Acres Sweet Potates**	**Bushels Sweet Potatoes**
5	75	30	300	4	3	0	0
0	10	0	0	0	0	0	0
15	75	15	150	0	0	0	0

Turn of the 20th Century

Between 1880 and 1900, all of the original Huffman and May pioneers disappeared from Harris County. They were all represented in the 1880 census but the 1900 census has no record for Samuel or Sarah May, David or Elira Huffman.[6] A search of all Texas census records failed to locate any of these early settlers and it may be that they died or moved from the state in the two decades since they were last recorded in 1880.

Among the second generation, Adam Huffman and two of Samuel and Sarah May's sons still lived in the Huffman community in 1900. All were married and heads of large households. Robert J. May was a 60-year old farm laborer who rented his farm. He was married to a German native, Louisa (Mary Louisa), and was the father of four children still living at home. His three sons, Eugene (18), Kenny (14), and Emery (14), all worked as farm laborers while his daughter, Vera (10), attended school. Although Robert rented his farm, he appears to have been living on his parents' homestead, judging from the names of his immediate neighbors who were listed next to his parents in the 1880 census. Everyone in the family was literate (U.S. Bureau of the Census, Population Schedule, Harris County, 1900).

[6] The 1890 census was destroyed in a fire.

1900 Population Census, Harris County							
Name	**Age**	**Occupation**	**State of Birth**	**Father's Birthplace**	**Mother's Birthplace**	**Cash on Hand**	**Value of Real Estate**
Adam Hoffman (Huffman)	63	Farmer	LA	KY	LA		
Emeline	60		SC				
Ara Jane Butter	23	Daughter	TX	LA	TX		
Chas. O. Butter		Son-in-Law	TX				
Sara B.	5	Grand daughter	TX				
Adolphus Mills	33	Hired Man	MS				
Robert May	60	Farm Laborer	LA	LA	LA		
Louisa	52		Germany				
Eugene	18	Farm Laborer	TX	LA	Germany		
Kenny	14	Farm Laborer	TX	" "	" "		
Emery	14	Farm Laborer	TX	" "	" "		
Vera	10	At School	TX				

Robert's brother, Thomas, owned a farm in a nearby community comprised largely of Bohemian, Austrian, and Swedish immigrants. In 1900, Thomas was 47 and his wife, Maggy, was 31. Maggy's mother was an Irish immigrant. Thomas and Maggy's three oldest children, James (14), John (12), and David (10), attended school. Six younger children were daughters Carmin (8), Myrtle (4) and Masel (4), and sons Milton (6), Addison (3), and Aaron? (1). The adults and school-aged children could all read and write (U.S. Bureau of the Census, Population Schedule, Harris County, 1900).

Ben Somers

By 1910, the Huffman presence in the area had diminished. Sometime after 1880, David and Adam Huffman began to sell their land on the Crosby-Huffman Road to various farmers including the Williams, Smith, Scott, and Somers families. In the late 19th or early 20th century, a farmer named Ben H. (Henry) Somers purchased several hundred acres of land just south of Wolfe Road. His property straddled the Crosby-Huffman Road and the 2-acre Huffman cemetery lay in the western part of the parcel.

Somers was the son of Henry and Sarah Summers. His father was from Germany and apparently met and married his mother, Sarah, in Mississippi where their son George Montgomery was born about 1848. The family moved to Texas sometime between 1848 and 1854, when their daughter, Angeline was born. By 1860, they resided at Cedar Bayou, in Chambers County. The household consisted of Henry, then a 38-year old farmer, his 40-year old wife, Sarah, daughter Angeline, age 6, and sons George Montgomery (12), Henry B. (2), and

Breckinridge (1). In later census records, Henry B. was known as Ben H. Somers (U.S. Bureau of the Census, Population Schedule, Chambers County, 1860).

1860 Population Census, Cedar Bayou, Chambers County					
Name	**Age**	**Occupation**	**State of Birth**	**Cash on Hand**	**Value of Real Estate**
Henry Summers	38	Farmer	Germany	$500	$1,000
Sarah	40		MS		
George Montgomery	12		MS		
Angeline	6		TX		
Henry B.	2		TX		
Breckinridge	1		TX		

By 1870, Henry and Sarah Somers were no longer represented in the census. It is possible that they died as Angeline lived in the household of John and Martha Bauer (Bamer?) in Houston's first ward. Because Martha Bauer was born in Mississippi, like Angeline's mother, Sarah, it is possible that Martha and Sarah were sisters. Martha may have taken Angeline into her household (U.S. Bureau of the Census, Population Schedule, Harris County, 1870).

Ben Somers was not located in the 1870 census but he appeared in the 1880 record. Listed as Benjamin H. Somers, he worked as a farm laborer for the Bayland Orphan's Home and Farm (Census, Harris County 1880). About 1887, Ben Somers (Summer) married his wife Fanny. At that time, Ben was a young man of twenty-nine and Fanny was a girl of fifteen. Although Fanny and her father were born in Texas, her mother was a native of Mississippi. By 1900, the couple lived in Justice Precinct 4 in Harris County. Somers was a farmer and owned his own farm. By then, they had three young sons, Bertran, age eight, Robert J., age four, and Willie C. J., age one. A hired man, Henry C. Copeland, shared the household (U.S. Bureau of the Census, Population Schedule, Harris County, 1880, 1900).

1900 Population Census, Harris County							
Name	**Age**	**Occupation**	**State of Birth**	**Father's Birthplace**	**Mother's Birthplace**	**Cash on Hand**	**Value of Real Estate**
Benjamin H. Summer	42	Owns farm	TX	Germany	MS		
Fanny, wife	28		TX	TX	MS		
Bertran N.	8		TX	TX	TX		
Robert J.	4		TX	TX	TX		
Willie C. J.	1		TX	TX	TX		
Henry C. Copeland	58	Hired hand	AR				

Between 1900 and 1910, Ben Somers purchased a little over 300 acres of land in the Gilbert Brooks League, possibly from David or Adam Huffman. David Huffman, who was enumerated in the 1900 census, was the last of his immediate family to live in the area. He may have sold his farm to Ben H. Somers (Summers, Sommers) between 1900 and 1910. The land straddled the Crosby-Huffman Road just south of Wolfe Road. In the 1910 census record, Ben H.

Sommers (sic) was enumerated as living with his sons Joe (Robert J.) and Willie along the Crosby-Huffman Road at or near the site of TS 30. His wife, Fanny, was not counted in the household and later records indicate that she and Ben divorced. Although still young, both surviving sons worked for a living: Joe, age fourteen, worked as a cook on a farm and Willie, age 12, worked as a farm laborer (U. S. Bureau of the Census, Population Schedule, Harris County 1910, 1930).

1910 Population Census, Harris County							
Name	**Age**	**Occupation**	**State of Birth**	**Father's Birthplace**	**Mother's Birthplace**	**Cash on Hand**	**Value of Real Estate**
Ben H. Sommers	50	Head of Household	TX	Germany	MS		
Joe	14		TX	TX	MS		
Willie	12		TX	TX	TX		

When the Ben Somers family moved to the Gilbert Brooks League, nearly all of the neighboring families worked in agriculture, either as general farmers, truck farmers, or farm laborers. Many heads of household owned their own homes and farms. A few other occupations were listed including that of river ferry operator, engineer man, and log teamster. Several women worked as seamstresses and school teachers. All of the people along the Crosby-Huffman and Huffman roads were white and many were born in southern states or had parents who were born in the south (U.S. Bureau of the Census, Population Schedule, Harris County, 1910).

Although none of the Somers family members appear in the 1920 census, they were likely overlooked by the census as they lived on the land in 1910 and 1930. In fact, none of the known residents along the Crosby-Huffman Road were enumerated in the 1920 census.

By 1930, Ben Somers was an elderly man of seventy-two. He still lived on the Crosby-Huffman Road, just south of Wolfe Road, where he owned his farm. At that time, his son Joe lived with him. Joe was thirty years old and worked as a laborer. Willie was not recorded in the household and did not appear to live in the vicinity (U. S. Bureau of the Census, Population Schedule, Harris County, 1930). About that time, Ben divided his farm and gave each of his sons a farm. All three farms straddled the Crosby-Huffman Road. Willie owned 115.5 acres close to Wolfe Road. His land surrounded the 2-acre Huffman cemetery. Ben (Henry B.) Somers retained 115.5 acres for his homestead. He carved a 1-acre plot on the east side of the road that he sold to E. L. Spear. Joe Summers owned the farm immediately south of his father's land. He sold 47.27 acres on the west side of the road to Jack C. Smith and retained a 73.8-acre tract for himself (Edgar Tobin Aerial Surveys, 1966).

1930 Population Census, Harris County							
Name	**Age**	**Occupation**	**State of Birth**	**Father's Birthplace**	**Mother's Birthplace**	**Cash on Hand**	**Value of Real Estate**
Ben H. Somers	72	Divorced; was farmer	TX	Germany	MS		
Joe	30	Laborer	TX	TX	MS		

In 1930, the project area remained a sparsely settled corner of rural northeastern Harris County. The Crosby-Huffman Road traversed the area north to south, connecting farmsteads and logging camps in the project area to the town of Huffman a few miles to the south. Principal east-west roads were Wolf Road, to the north, Havard Road, to the southwest, and the Huffman-Eastgate Road to the southeast. No settlements lay in the area but a grocery store fronted onto the Crosby-Huffman Road south of its intersection with Wolf Road (U. S. Bureau of the Census, Population Schedule, Harris County, 1930). About thirty-five households lay between Wolf Road on the north and Havard Road on the south, toward Huffman. In addition, a number of single men lived in the area.

Most of the area's residents were engaged in agriculture, either as farmers or farm laborers, but a number worked as section hands for the railroad, and still others worked in logging camps. One man was a merchant who ran the grocery store where he and his children worked. Virtually all of the farmers lived in households with their families, which generally consisted of two parents and their minor children. Households might include in-laws, nieces and nephews, and grandchildren. Of the thirty-five heads of household, 18 owned their homes and 13 rented. Several were not identified as owners or renters. Railroad workers and loggers typically lived in boarding houses near their job sites (U. S. Bureau of the Census, Population Schedule, Harris County, 1930).

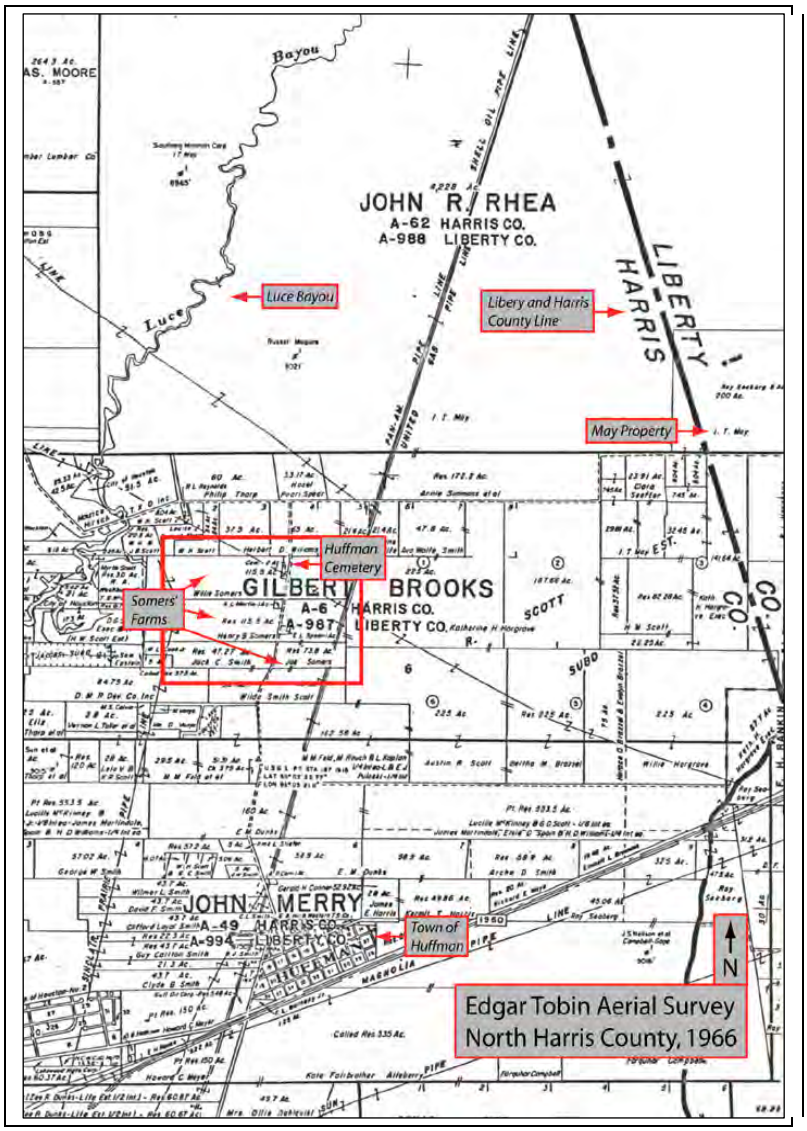
All of the inhabitants of this dispersed community were listed as "white" in the 1930 census, though a number of "Mexican" section hands for the railroad lived nearby, to the south. A few residents were foreign born; one family hailed from Germany and another from Czechoslovakia. The great majority, however, were southerners, among them many native Texans. Most spoke and read English. Young children typically attended public school while older ones worked as farm laborers, likely on their family farms (U.S. Bureau of the Census, Population Schedule, Harris County, 1930).

Because census records after 1930 are not available, and because no secondary sources have been found that document the farming community along the Crosby-Huffman Road, little is known about its later history. When an ownership map of the area was prepared in 1966, it identified the farms and acreage of Henry B. Somers (Ben), Joe and Willie. By that time, the Pan American and Sinclair Prairie pipelines crossed the farms north to south, roughly paralleling the Crosby-Huffman Road. Other long time families were represented on the map in the many Scott, Smith, Dunks and Wolfe tracts, all neighbors to the Somers men. Most plots ranged between 40 and 160 acres, although larger and smaller parcels existed (Edgar Tobin Aerial Surveys, 1966). The area north of Huffman to Wolfe Road had not been subdivided into suburban housing tracts and probably remained in cultivation or forest land at the end of the historic period.

Conclusion

The first known inhabitants of the area encompassing both 41HR1075 and 41HR1076, were Samuel May, his wife, Sarah Huffman May, Susan Huffman and her son Adam, and David and Elira Huffman. These related families came to Texas seeking land and settled in the Gilbert Brooks League of Harris County, near the Liberty County line. Members of the May family remain in the area to the present. Although David Huffman founded the nearby community and cemetery, no family members bearing the Huffman name are known to live on their original homesteads. Billy J. Smith who owns a ranch nearby is a descendant of David Huffman through his mother, Willie Mary Scott. Some members of the Huffman family sold parts of their homesteads to other families, including Ben Somers and his sons who owned the property through 1966. Somers and his sons farmed adjoining parcels of land from about 1905 through 1930 and possibly beyond.

41HR1075 appears to lie on the Willie B. Somers 115.5-acre farm and may have been occupied earlier by one of the Huffman families, likely Adam Huffman. Members of the Huffman family lived in the area since at least 1839 but it is unknown when 41HR1075 was first occupied. 41HR1076 lies on the Samuel May farm which was later occupied by his son, Robert. Samuel May applied for his land certificate in 1838 and brought his family to Texas about 1839. It is unknown whether 41HR1076 is the original or later May homestead site. No significant events in Texas history are associated with either site; they appear to have been typical farmsteads owned and occupied by early pioneer settlers in the area.



Labeled 1966 Tobin Aerial Survey.

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United States Bureau of the Census

1850a Harris County, Population Schedule
1850b Harris County, Agricultural Schedule
1850c Harris County, Slave Schedule

1860a Harris County, Population Schedule
1860b Harris County, Agricultural Schedule
1860c Harris County, Slave Schedule

1880a Harris County, Population Schedule
1880b Harris County, Agricultural Schedule

1900 Harris County, Population Schedule

1910 Harris County, Population Schedule

1930 Harris County, Population Schedule

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APPENDIX 4
Site Location Maps (THC copy only)

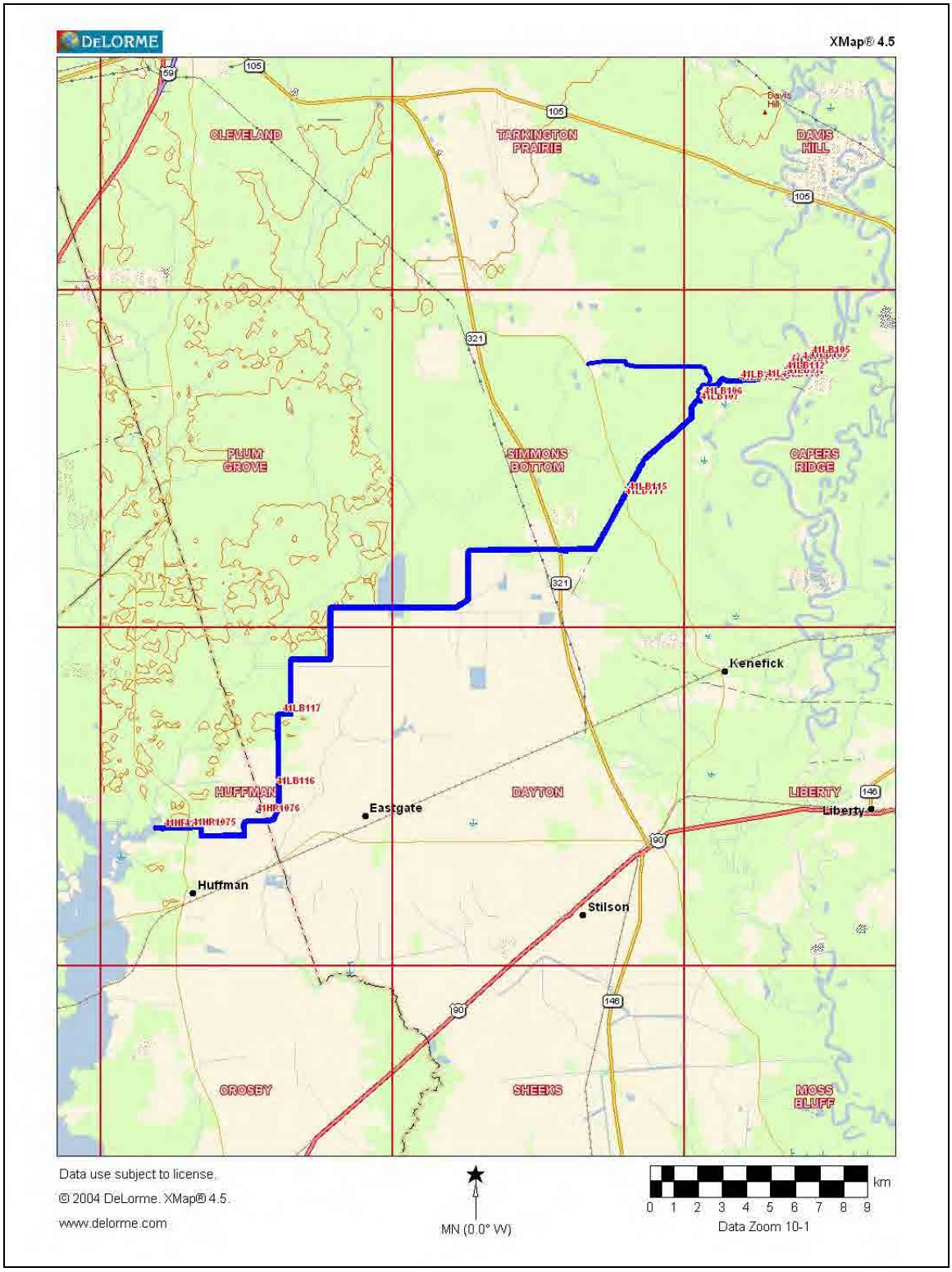

Figure 4-1. Overview map showing LBITP alignment and general locations of sites.

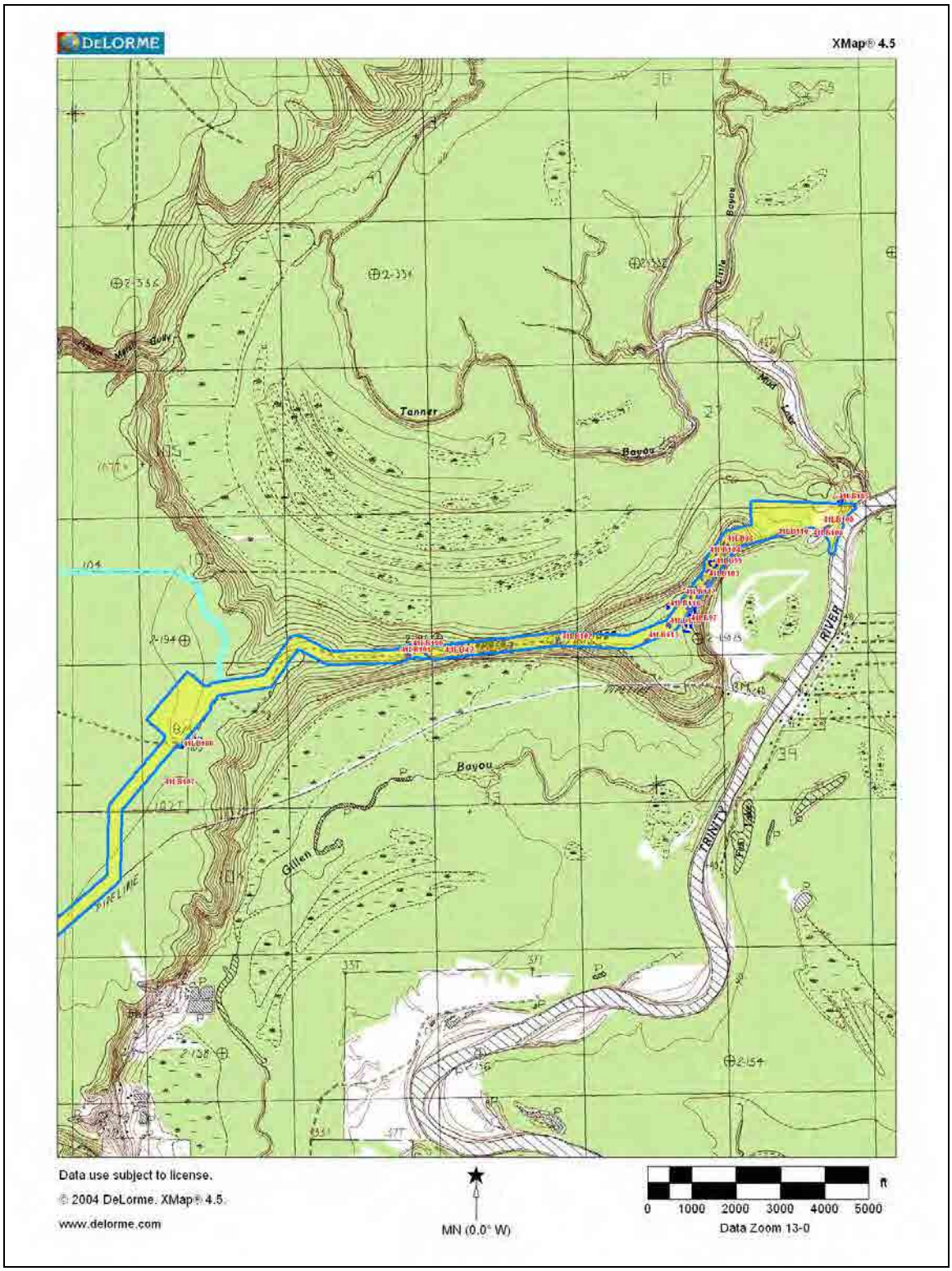

Figure 4-2. Map showing LBITP alignment and sites located on Capers Ridge USGS quad.

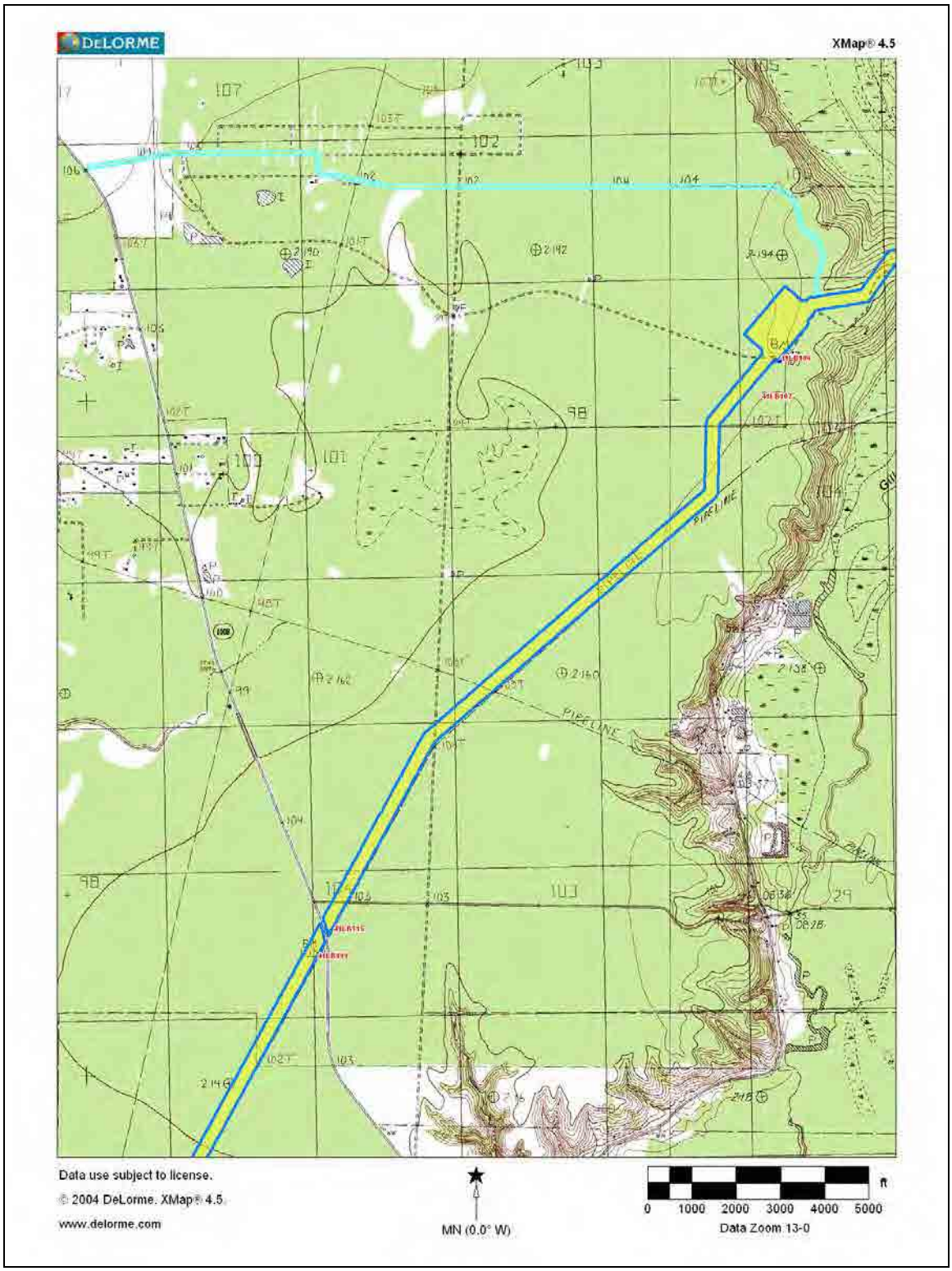

Figure 4-3. Map showing LBITP alignment and sites located on Capers Ridge and Simmons Bottom USGS quads.

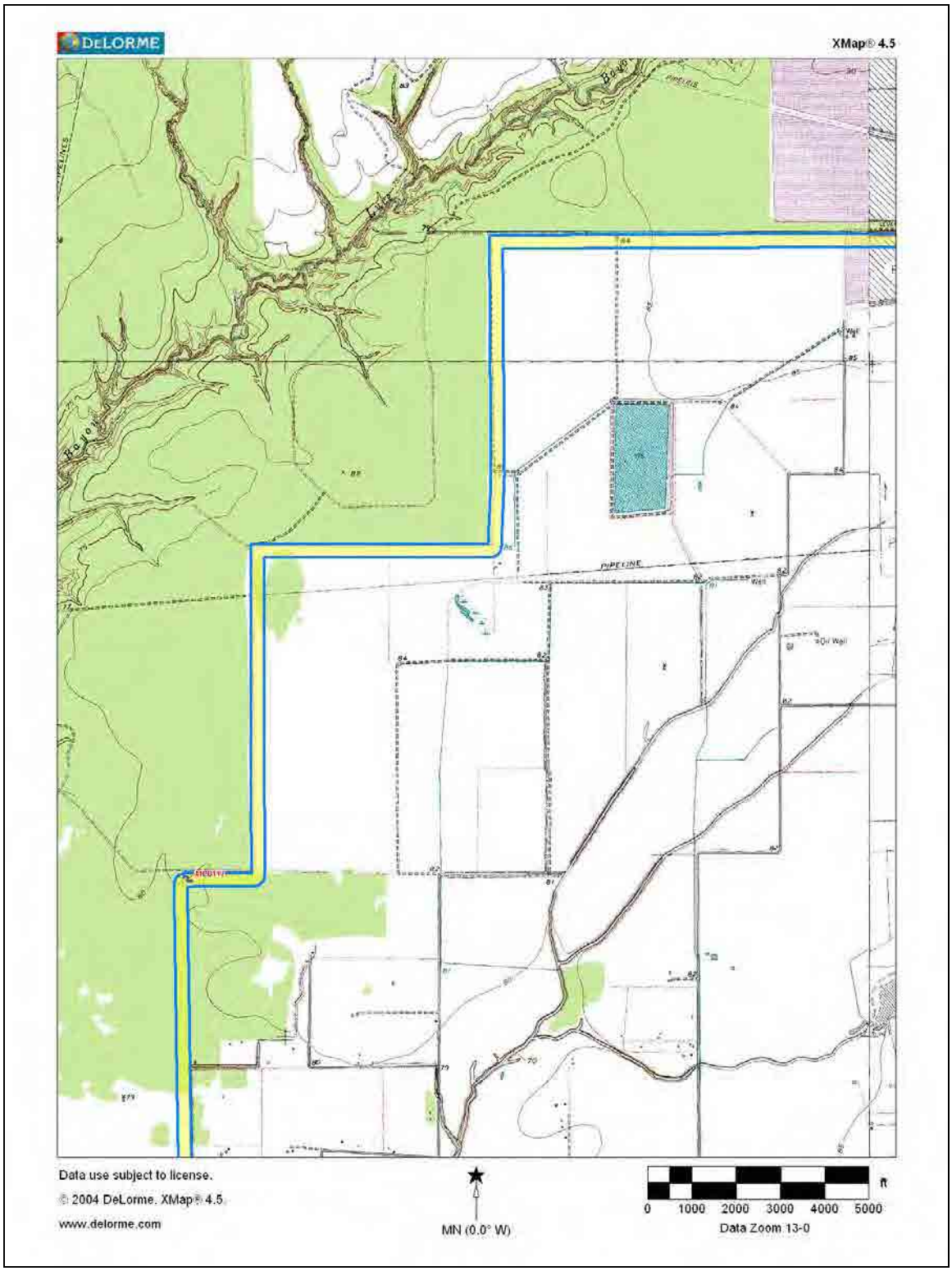

Figure 4-4. Map showing LBITP alignment and site located on north half of Huffman USGS quad.

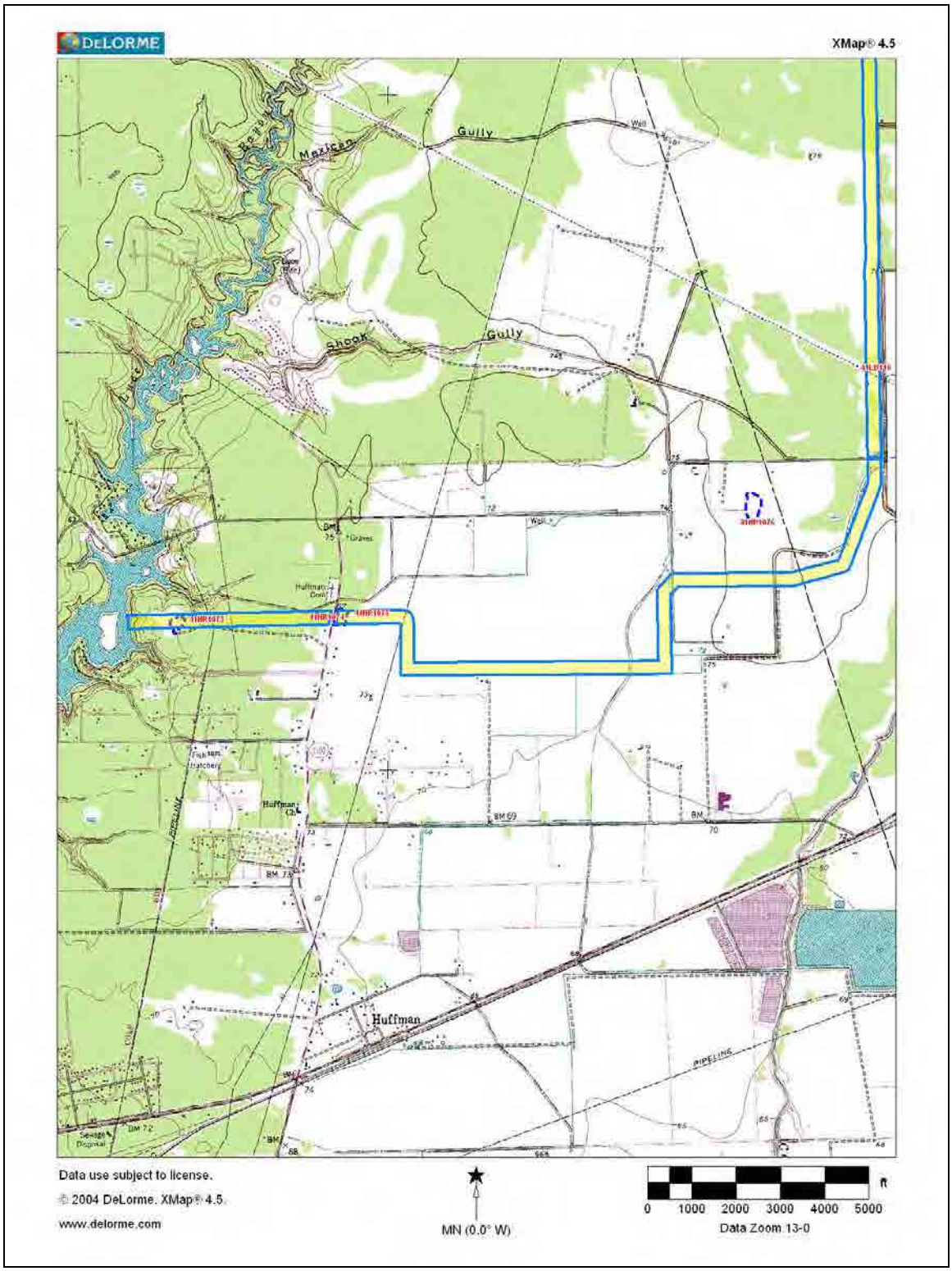

Figure 4-5. Map showing LBITP alignment and sites located on south half of Huffman USGS quad.

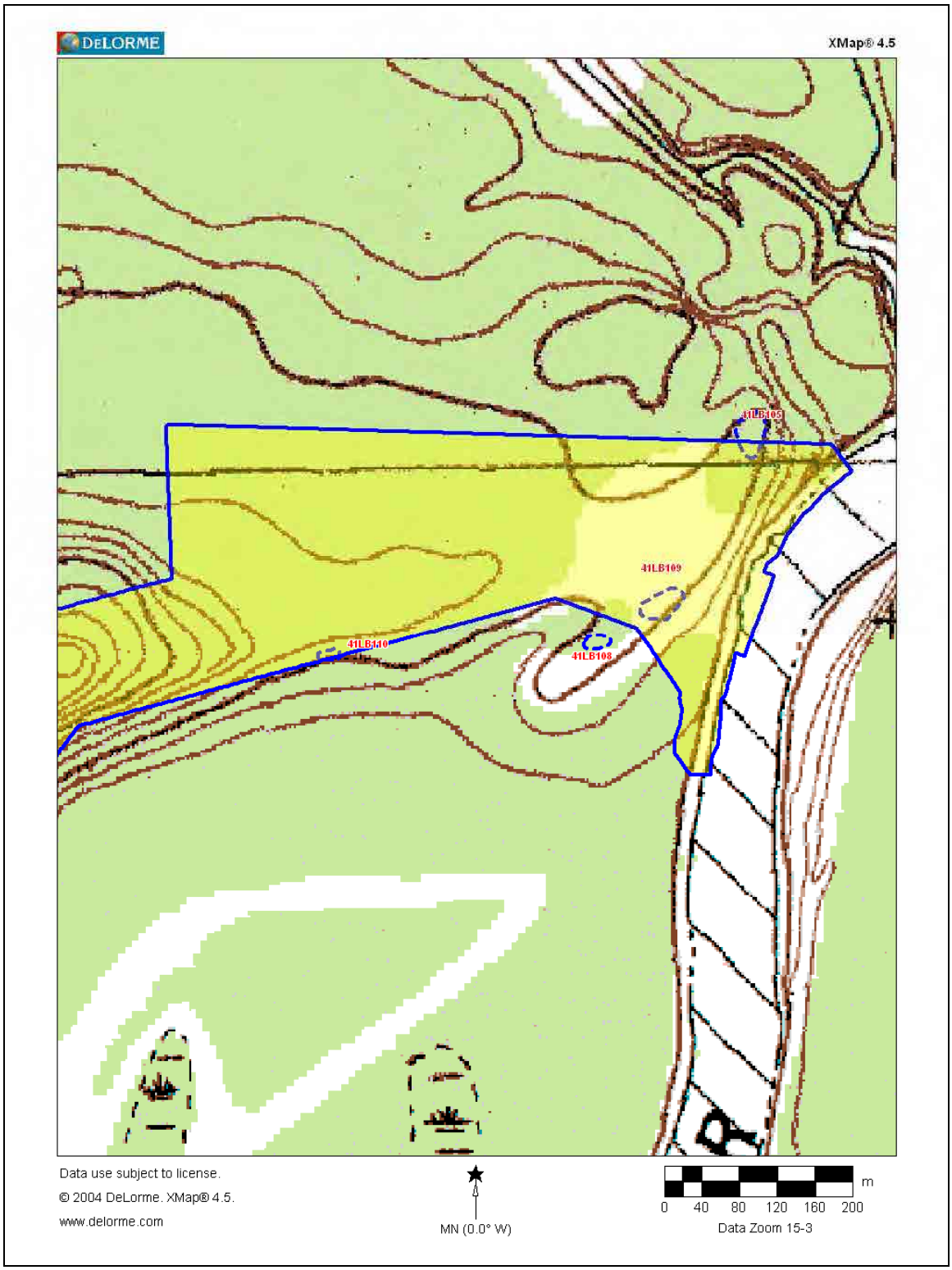

Figure 4-6. Detail map showing location of LBITP ROW and sites 41LB105, 41LB108, 41LB109, 41LB110 (Capers Ridge, USGS).

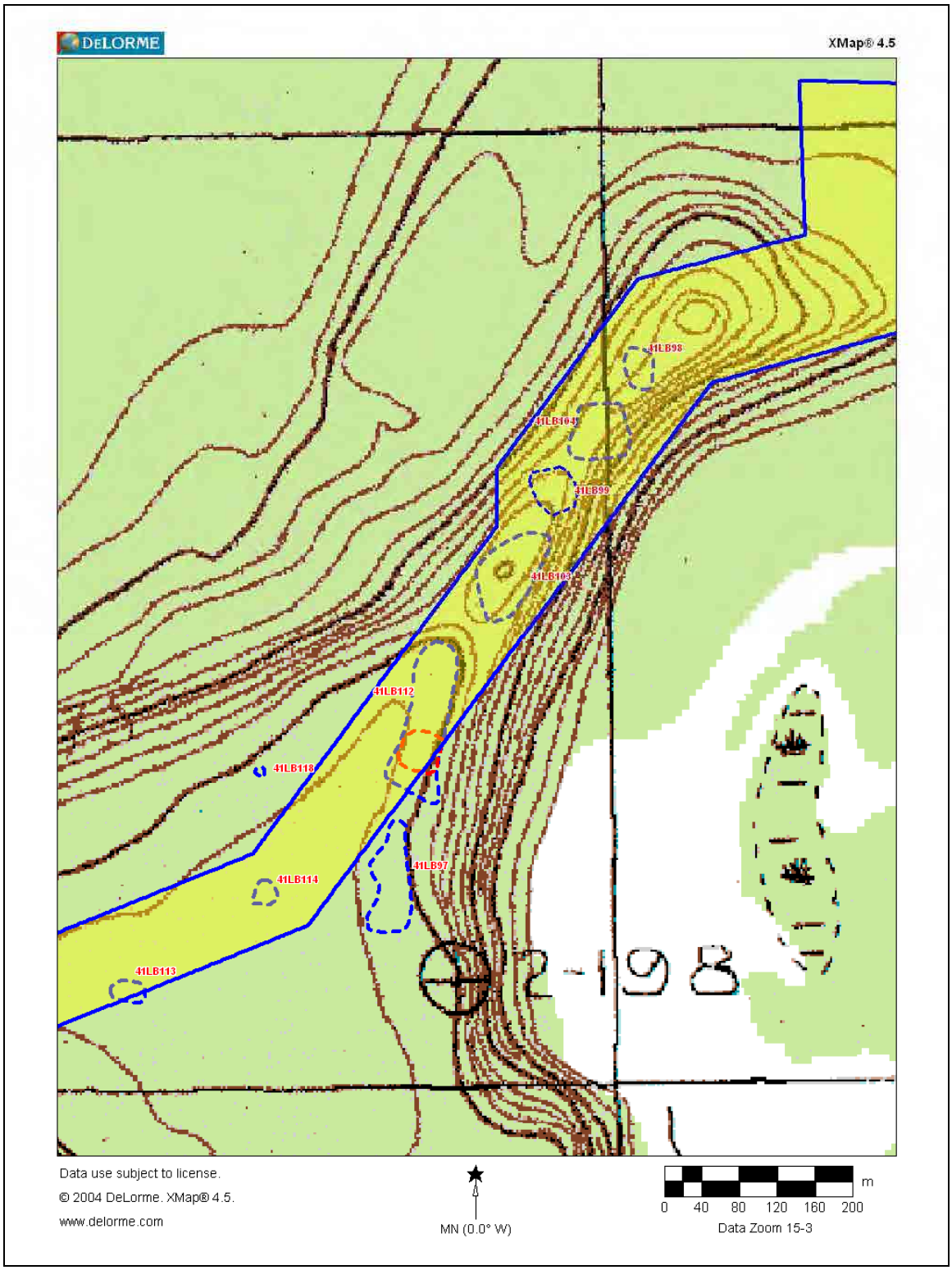

Figure 4-7. Detail map showing location of LBITP ROW and sites 41LB97, 41LB98, 41LB99, 41LB103, 41LB104, 41LB110, 41LB112, 41LB114, 41LB118 (Capers Ridge, USGS).

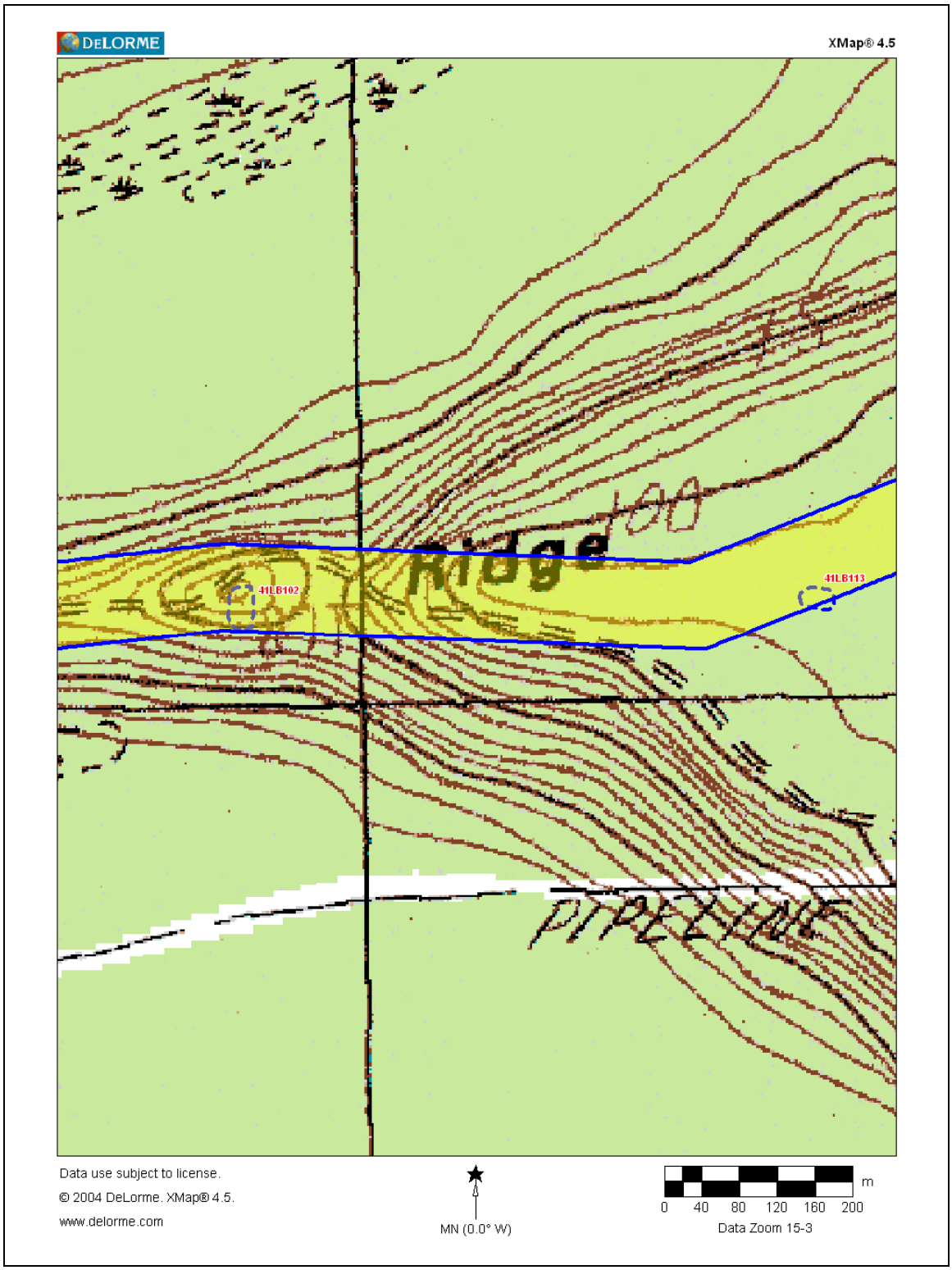

Figure 4-8. Detail map showing location of LBITP ROW and sites 41LB102, 41LB113 (Capers Ridge, USGS).

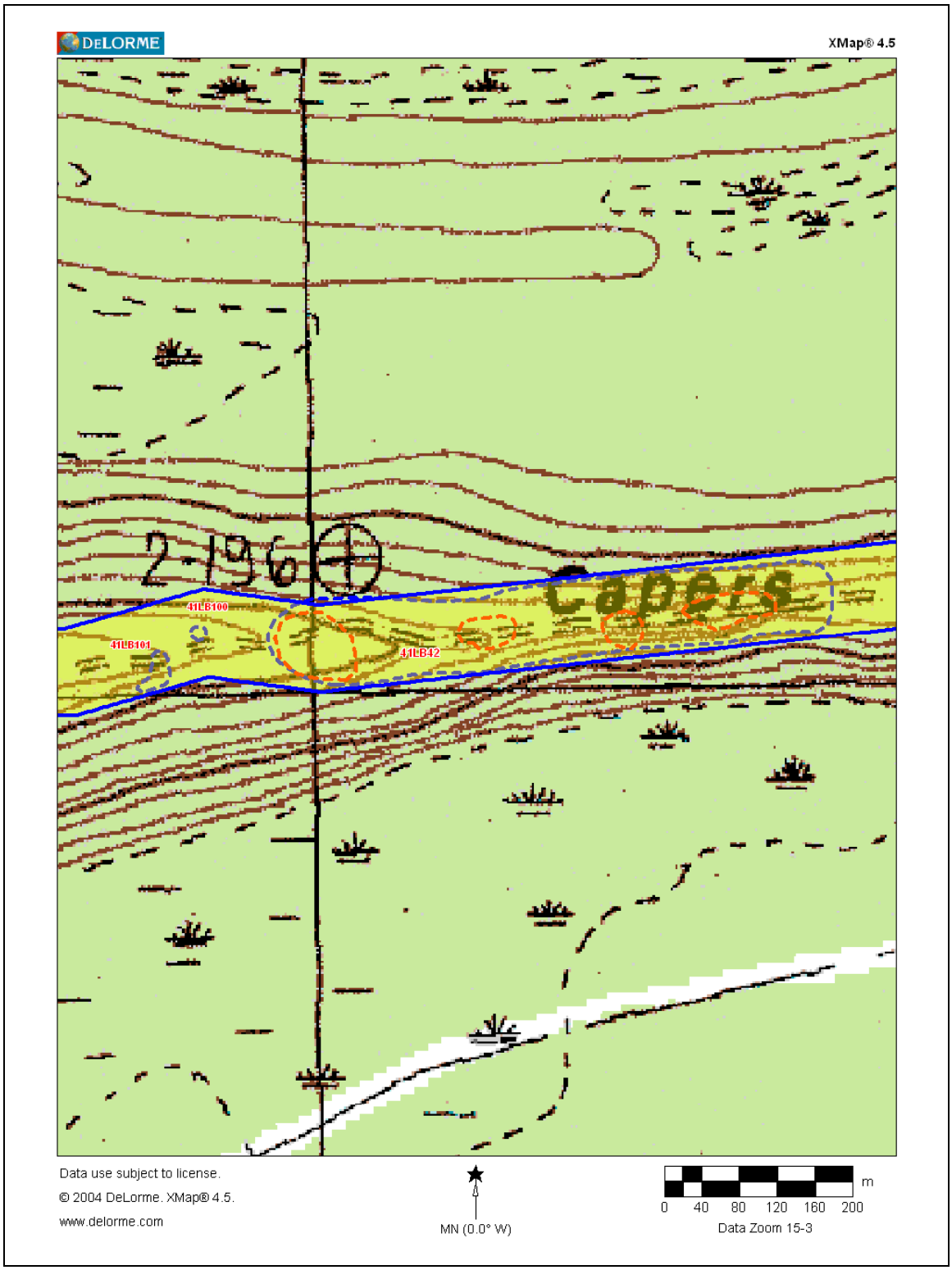

Figure 4-9. Detail map showing location of LBITP ROW and sites 41LB42, 41LB100, 41LB101 (Capers Ridge, USGS).

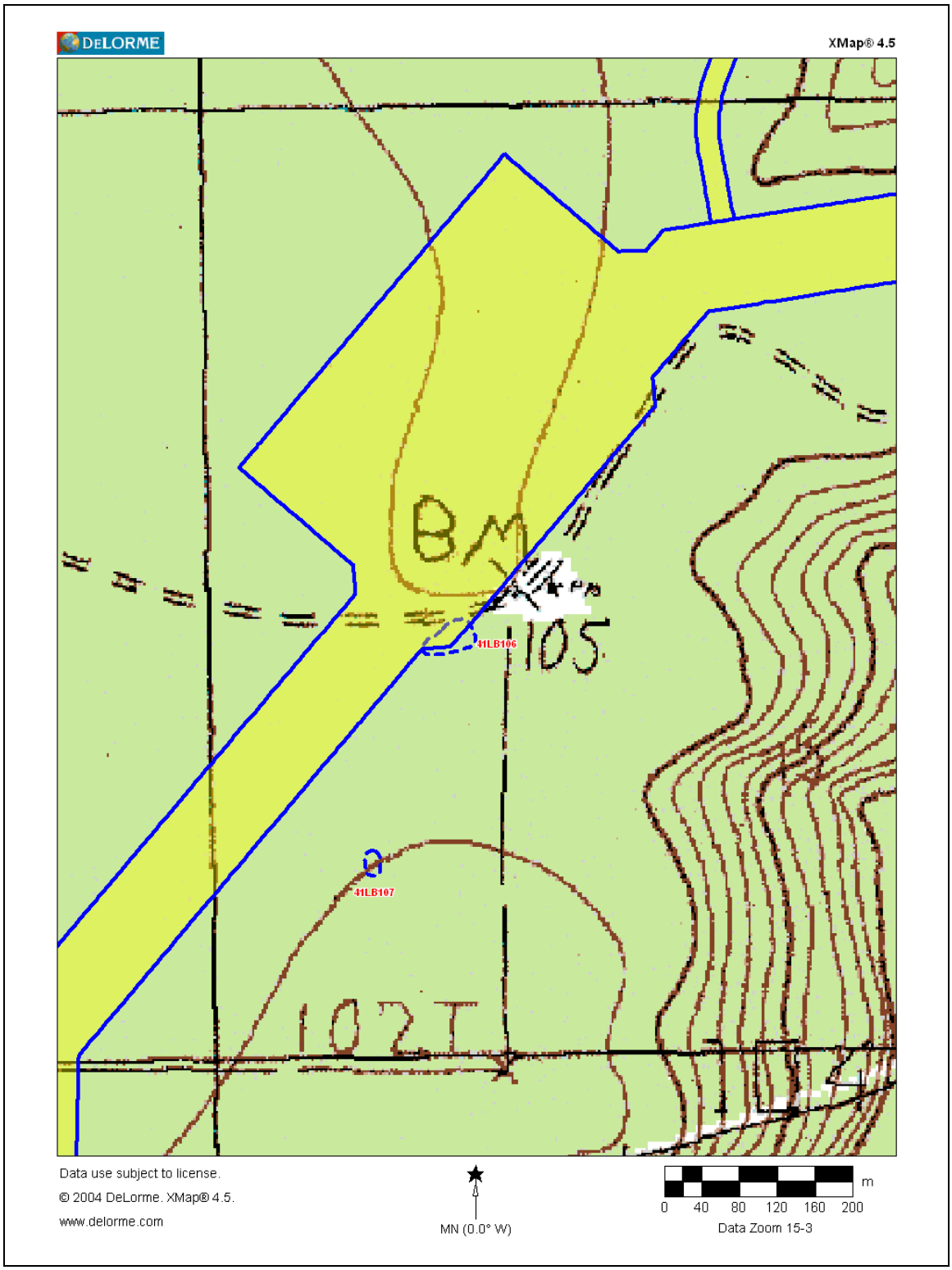

Figure 4-10. Detail map showing location of LBITP ROW and sites 41LB106, 41LB107 (Capers Ridge, USGS.

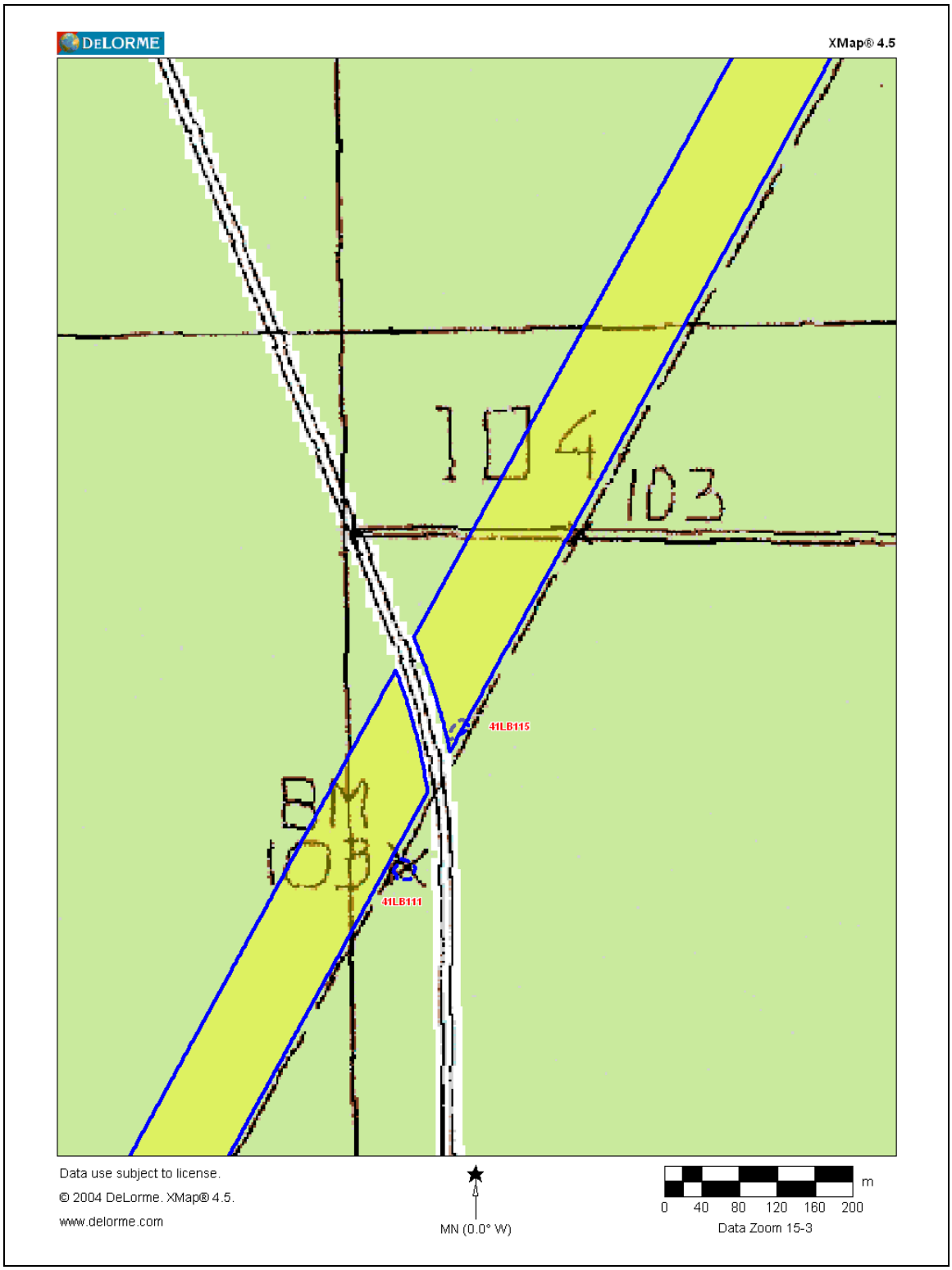

Figure 4-11. Detail map showing location of LBITP ROW and sites 41LB111, 41LB115 (Simmons Bottom, USGS).

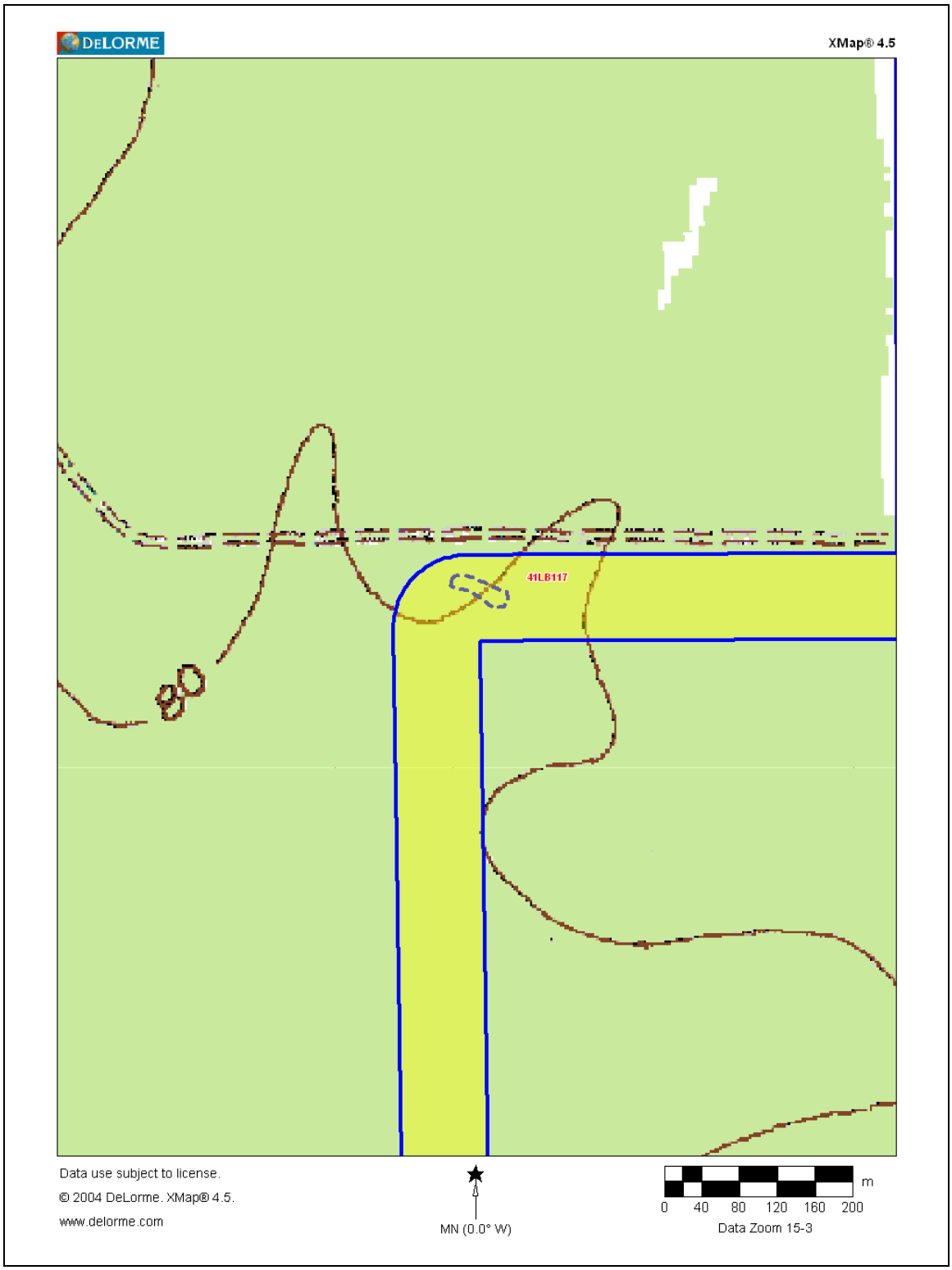

Figure 4-12. Detail map showing location of LBITP ROW and site 41LB117 (Huffman, USGS).

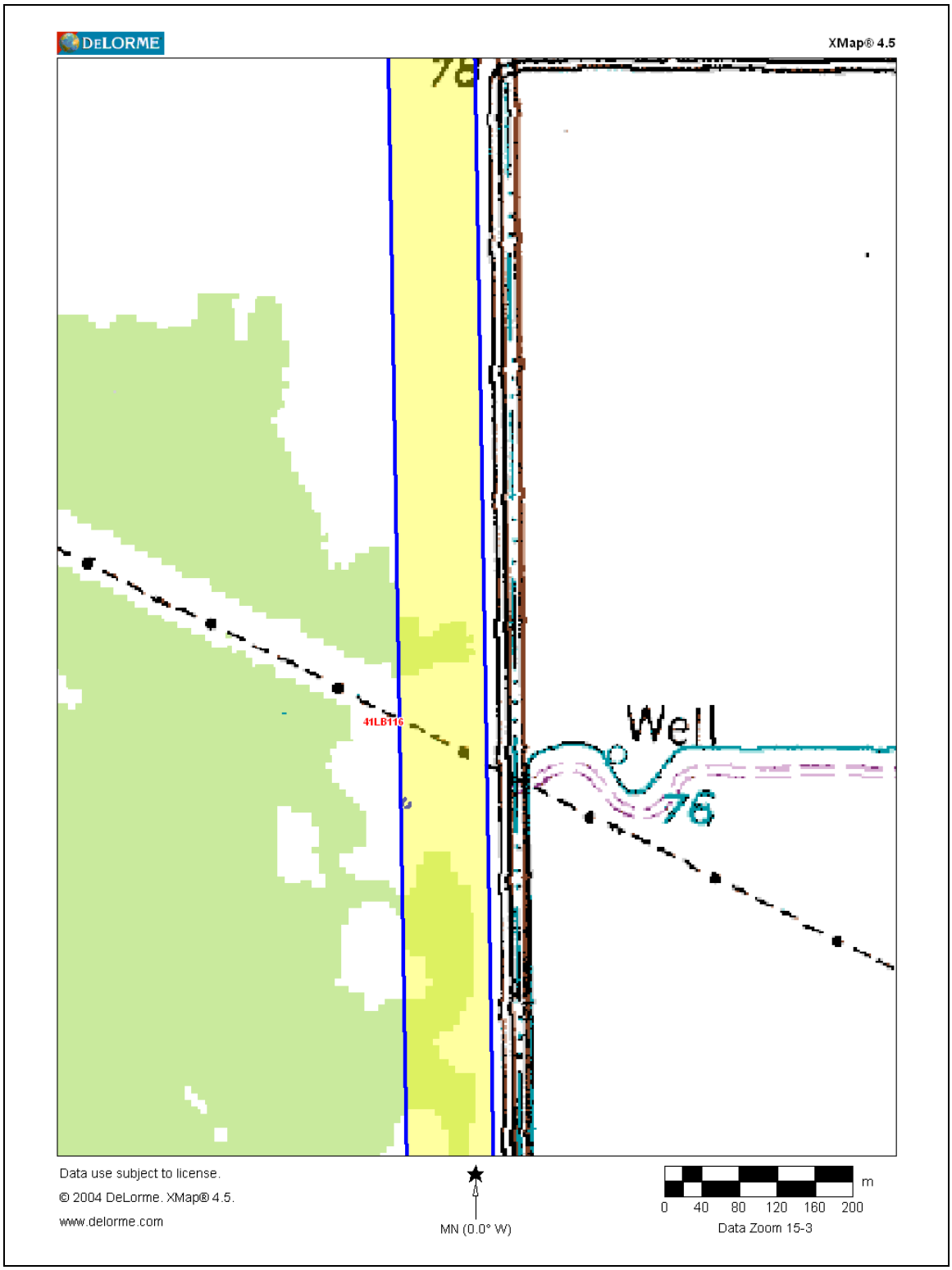

Figure 4-13. Detail map showing location of LBITP ROW and site 41LB116 (Huffman, USGS).

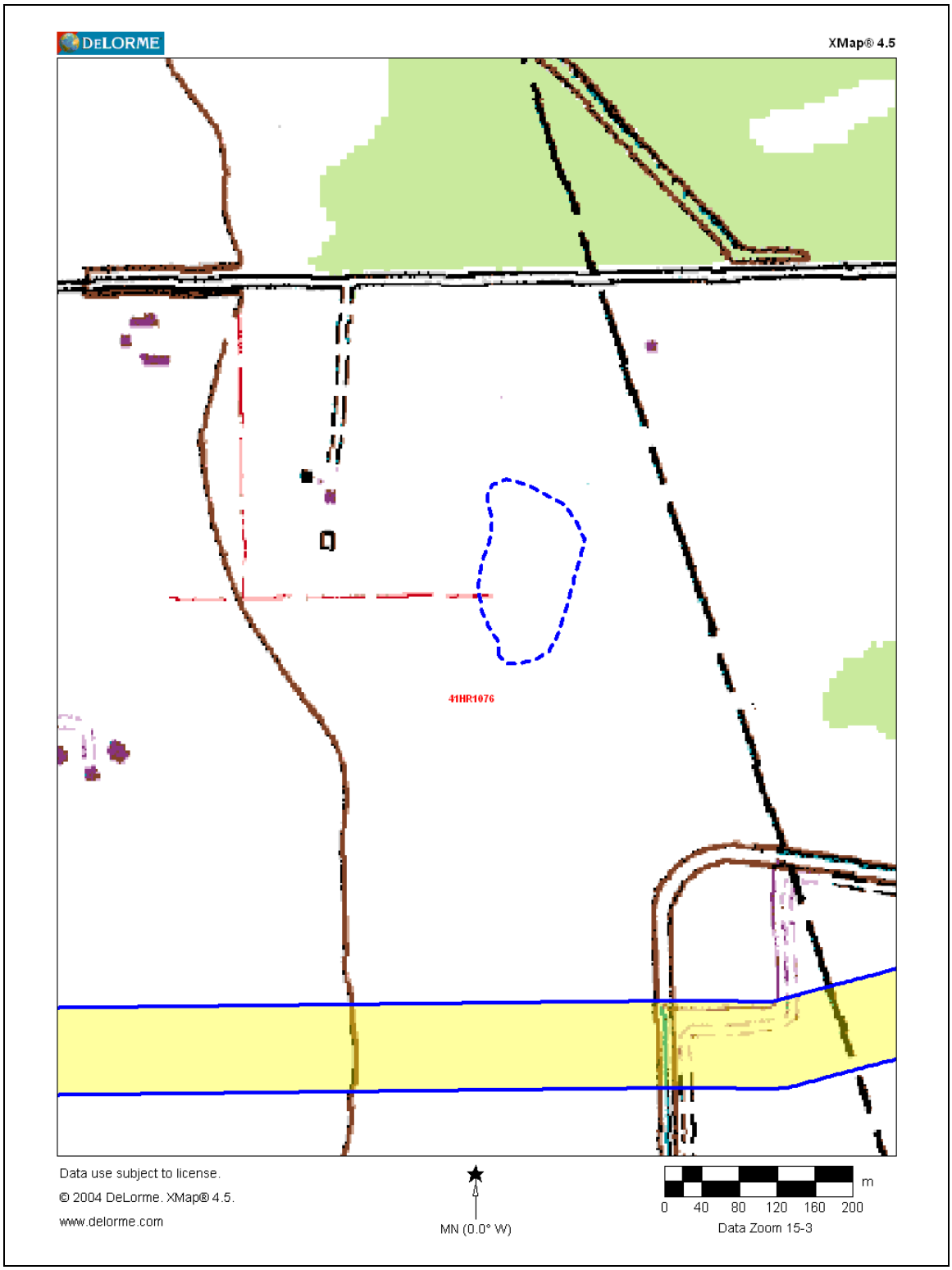

Figure 4-14. Detail map showing location of LBITP ROW and site 41HR1076 (Huffman, USGS).

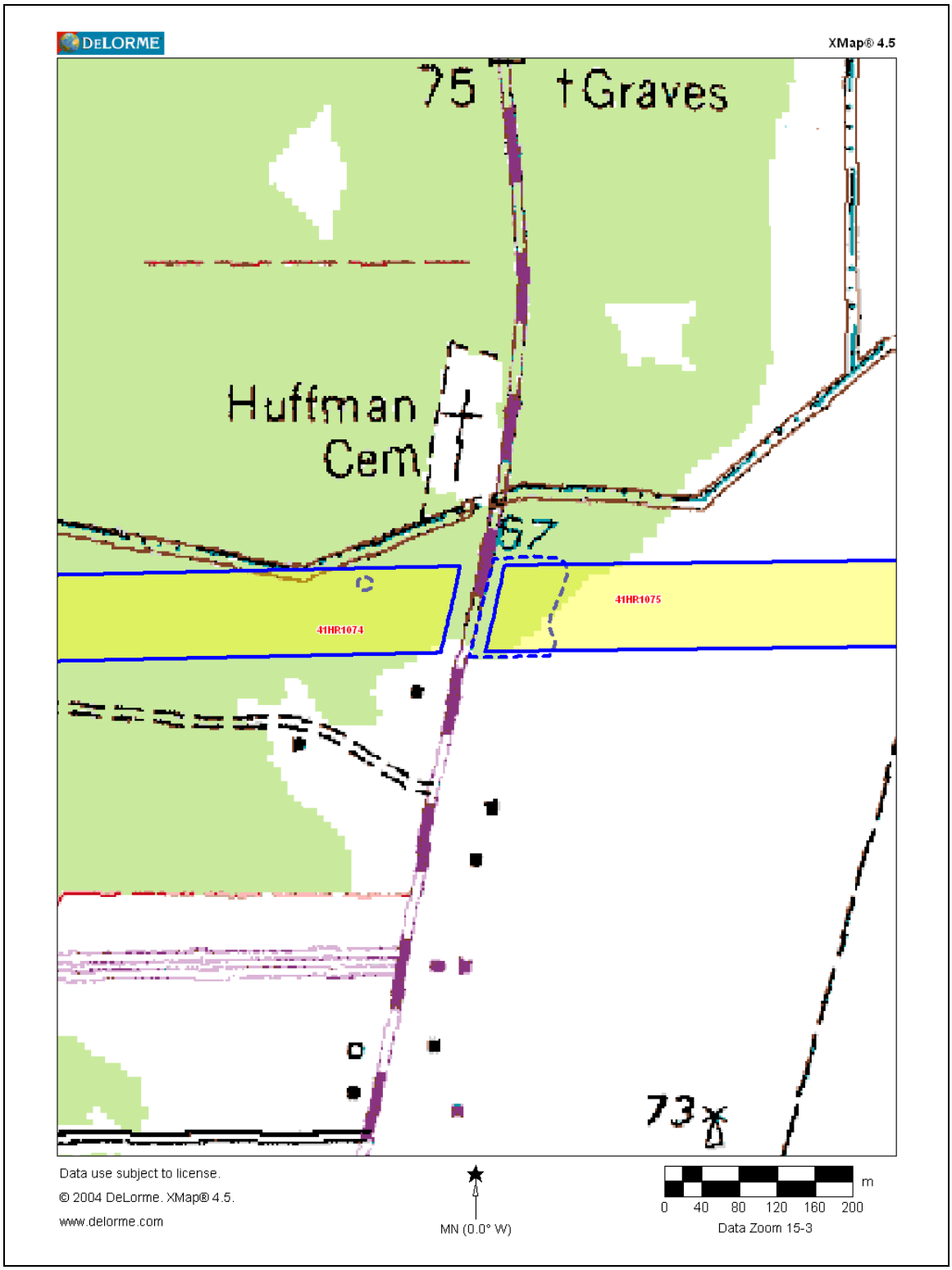

Figure 4-15. Detail map showing location of LBITP ROW and sites 41HR1074, 41HR1076 (Huffman, USGS).

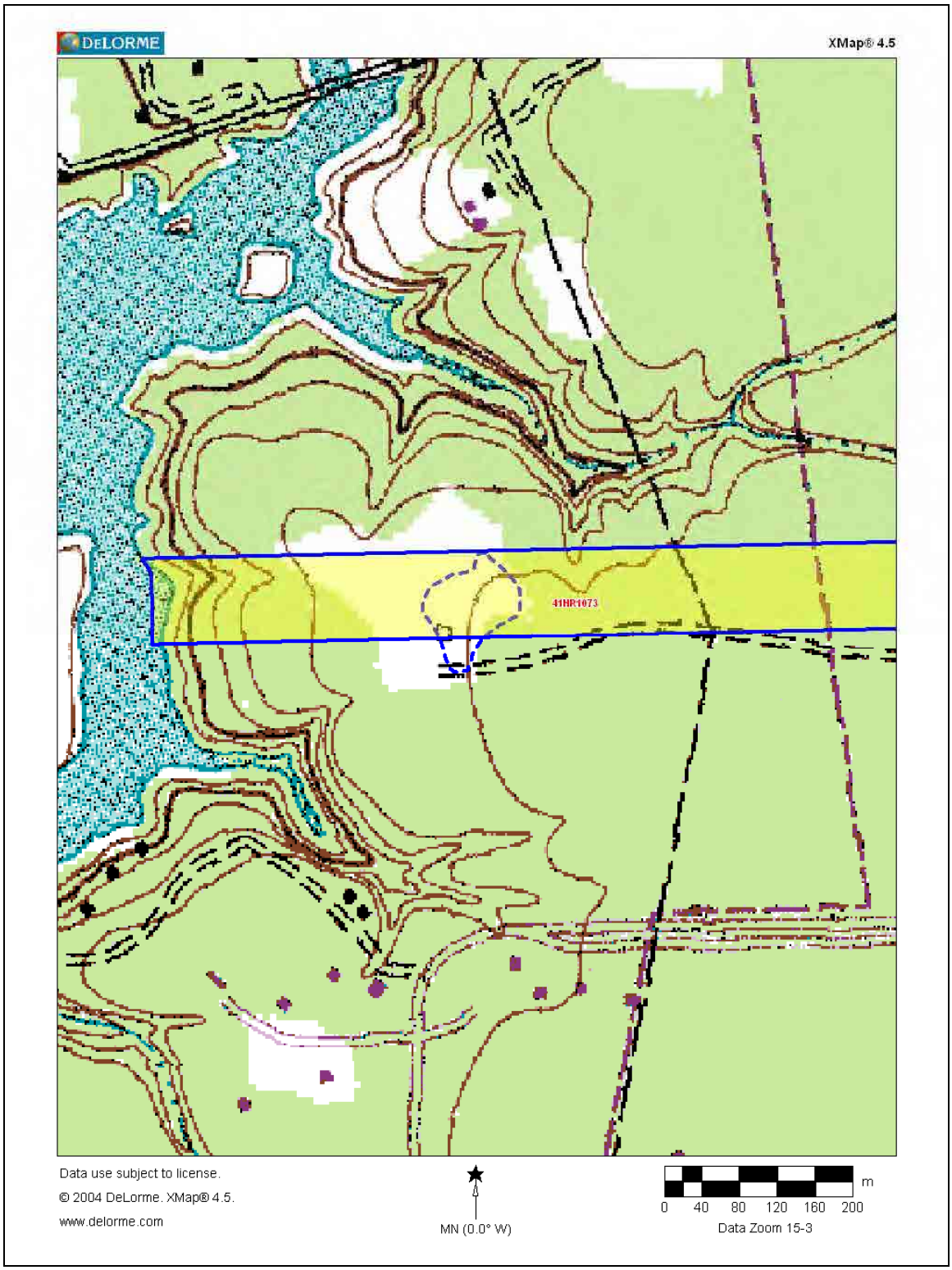

Figure 4-16. Detail map showing location of LBITP ROW and site 41HR1073 (Huffman, USGS).

Moore Archeological Consulting, Inc.

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September 13, 2012

Kelly Krenz, PG
AECOM
5757 Woodway, 101 West
Houston, TX 77057

Re: Archeological Assessment for Alternates 4 and 6 of the Luce Bayou Interbasin Transfer Project, Harris and Liberty Counties, Texas (MAC PN 12-54)

Ms. Krenz,

We have examined the map plotting for the above referenced project per your request. The subject property has been reviewed with reference to the State of Texas archeological site files, soil classifications in Harris County, topography, and possible tract disturbances. These data were then compared to an existing site location predictive model (Moore 1996) for prehistoric sites in the region as well as additional Moore Archeological Consulting, Inc., GIS databases.

Location

The assessment examined two prospective alternate routes for the proposed Luce Bayou Interbasin Transfer Project connecting the Trinity River with the San Jacinto River at Lake Houston. The alternate alignments are designated as Alternative 4 in the north, and Alternative 6, located further south (Figures 1, 2). Alternative 6 extends for a total of approximately 20.5 miles, from the Gordon Lake area on the Trinity River, to the southern end of Lake Houston near the community of Newport. Alternative 4 extends for a total of approximately 25.2 miles, from the Capers Ridge area on the Trinity River, to Lake Houston, at a point just south of the community of Huffman. At the eastern end of this alignment, an approximately 8 mile long section appears to be identical to that of a third prospective route, Alternative 3A. This alternative runs from the Capers Ridge area to the Luce Bayou branch of Lake Houston north of Huffman, and was the subject of an intensive pedestrian archeological survey which examined one previously discovered site and discovered 21 new sites (Ferguson et al. 2012). Of these sites, six were determined to be potentially significant and recommended for further investigations.

Previously Identified Cultural Resources

A review of Texas Sites Atlas electronic records of the Texas Historical Commission was conducted. This review indicated that there are no previously recorded prehistoric or historical sites are located within the Alternative 6 alignment, or within the portions of the Alternative 4 alignment that differ from the Alternative 3A alignment. However, it should be noted that there have been very few archeological surveys conducted in the areas around the two alignments.

Potential for Cultural Resources

The project area was also assessed with respect to the following hierarchy of environmental factors that combine to make a locality attractive for prehistoric settlement within the region. The factors in combination constitute a set of settlement rules that define good locations for prehistoric campsites (Moore 1996). These include preferences for the following:

(1) Site locations in forested environments.

(2) Site locations in the floodplain or on the floodplain/upland margin.

(3) Site locations in proximity to sources of potable water.

(4) Site locations on well-drained, loamy soils.

(5) Site locations on topographic high points.

(6) Site locations on geologic terraces in watersheds with broad 100-year floodplains. These terraces may range from 100-1000 meters in width and may be of Late Pleistocene age or younger. They thus present good settings for the discovery of cultural remains as much as 10,000-12,000 years old.

(7) Site locations on the upland/floodplain margin typified by the Lissie and Beaumont slopes to streams with broad floodplains. As geologically old surfaces, these upland margins also present potentially good settings for prehistoric remains.

<u>Alternative 4</u>

The Alternate 4 alignment is located on sheet 37 of the *Soil Survey of Harris County, Texas* (Wheeler 1976), and on sheets 29, 30, 34, 39, and 40 of the *Soil Survey of Liberty County, Texas* (Griffith 1996). Soil associations located with the project alignment include Lake Charles-Bernard, Midland-Beaumont, Clodine-Addicks-Gessner, and Aldine-Ozan in Harris County, and the Beaumont-Lake Charles, Bernard-Morey-Mocarey, Vamont-Woodville-Aldine, and Kaman-Fausse-Mantache in Liberty County. Correlating these soil associations with that of the PALM predictive model developed by Abbott (2001), indicates that Lake Charles-Bernard, Midland-Beaumont, Beaumont-Lake Charles, Bernard-Morey-Mocarey, and Vamont-Woodville-Aldine soils tend to be associated with areas of low probability for prehistoric site preservation, while the Clodine-Addicks-Gessner, Aldine-Ozan,

and Kaman-Fausse-Mantache associations contain areas ranging from moderate to high probabilities for prehistoric site preservation. Approximately 67% of the alignment is located within the low probability associations, while 33% crosses areas of moderate to high potential (almost all of the moderate to high probability areas on this route were covered in the Alternative 3A survey).

The association with sources of water has been demonstrated to be a dominant factor affecting the probability of prehistoric sites in southeast Texas. Most sites within the region are found within 300 m of a current or former source of natural potable water. The Alternative 4 alignment does not appear to cross any major streams, though each of its termini are located in high probability upland areas (again, the eastern high probability area was included in the Alternative 3A survey).

In terms of potential historic resources, a review of curated USGS topographic maps as well as the 1936 Harris County General Highway Map and Google Earth historical imagery, indicate that alignment does not cross any major historical communities. However, a detailed examination of those maps for individual historic farmsteads was not made at this level of initial assessment.

Alternative 6

The Alternate 6 alignment is located on sheets 50 and 61 of the *Soil Survey of Harris County, Texas* (Wheeler 1976), and on sheets 50 and 61 of the *Soil Survey of Liberty County, Texas* (Griffith 1996). Soil associations located with the Alternative 6 alignment are the same set of associations included in the Alternate 4 alignment, and include Lake Charles-Bernard, Midland-Beaumont, Clodine-Addicks-Gessner, and Aldine-Ozan in Harris County, and the Beaumont-Lake Charles, Bernard-Morey-Mocarey, Vamont-Woodville-Aldine, and Kaman-Fausse-Mantache in Liberty County. Correlating these soil associations with that of the PALM predictive model developed by Abbott (2001), indicates that Lake Charles-Bernard, Midland-Beaumont, Beaumont-Lake Charles, Bernard-Morey-Mocarey, and Vamont-Woodville-Aldine soils tend to be associated with areas of low probability for prehistoric site preservation, while the Clodine-Addicks-Gessner, Aldine-Ozan, and Kaman-Fausse-Mantache associations contain areas ranging from moderate to high probabilities for prehistoric site preservation. Approximately 68% of the alignment is located within the low probability associations, while 32% crosses areas of moderate to high potential. In addition, this route contains four points at which it crosses major streams that would require mechanical trenching to prospect for deeply buried sites.

The association with sources of water has been demonstrated to be a dominant factor affecting the probability of prehistoric sites in southeast Texas. Most sites within the region are found within 300 m of a current or former source of natural potable water. As noted above, the Alternative 6 alignment does cross two major streams, Cedar Bayou and Gum Gully, as well as cross into the Trinity and San Jacinto Rivers floodplains at each end. Further, the presence of a wide floodplain at the alignmentôs west end (as indicated by the large area marked as PALM Unit 1) could require extensive mechanical trenching, depending on the precise location of the western terminus.

As with the Alternative 4 alignment, a review of curated maps for potential historic resources, indicates that this alignment does not cross any major historical communities. However, a detailed examination of those maps for individual historic farmsteads was not made at this level of initial assessment.

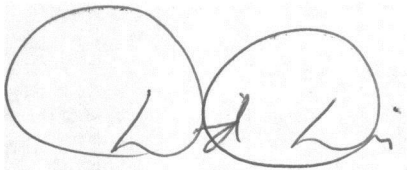
Conclusions

In summary, no historic or prehistoric archeological sites have been documented within the Alternative 6 alignment, or the portion of the Alternative 4 alignment that was not covered in the previous Alternative 3A alignment survey. Both alignments cross a wide variety of terrain, including soil types, topography and related environments that are associated with moderate to high probability areas for containing preserved prehistoric sites (including areas that could contain deeply buried sites). For both Alternatives 4 and 6, these areas total a minimum of 30% of each alignment. Subsequently, we recommend pedestrian archeological survey, including shovel testing and/or backhoe trenching where appropriate for these sections. Due to the large scale of the project, the remaining low probability areas should be examined for the presence of mapped historic farmsteads, and for limited areas of topography and soils associated with prehistoric occupations that might not be visible at the resolution of the current study. In addition, we recommend at least a reconnaissance level of investigation for the remainder of the alignment, with shovel testing as appropriate.

Concurrence with these recommendations should be sought from the Archeology Division of the Texas Historical Commission prior to the beginning of any construction. Further, in the event that unanticipated archaeological deposits are encountered during construction, work should be halted immediately and the Archeology Division of the Texas Historical Commission should be contacted.

Thank you for the opportunity to evaluate this project location. If you have any questions or comments regarding this assessment, please do not hesitate to contact me.

Sincerely,



David Driver, Ph.D., RPA
Senior Staff Archaeologist
wdaviddriver@hotmail.com

References Cited

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2001 *Houston Area Geoarcheology: A Framework for Archeological Investigation, Interpretation, and Cultural Resource Management in the Houston Highway District*. Texas Department of Transportation, Environmental Affairs Division, Archeological Studies Program, Report 27.

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1996 *Soil Survey of Liberty County, Texas*. United States Department of Agriculture, Soil Conservation Service in cooperation with the Texas Agricultural Experiment Station and the Texas State Soil and Water Conservation Board.

Moore, Roger G.
1996 *An Empirical Analysis of Elements of Prehistoric Site Location and Formation in Harris County, Texas*. Report of Investigations No. 149. Moore Archeological Consulting, Inc., Houston.

Wheeler, Frankie F.
1981 *Soil Survey of Harris County, Texas*. United States Soil Conservation Service, Washington, D.C.

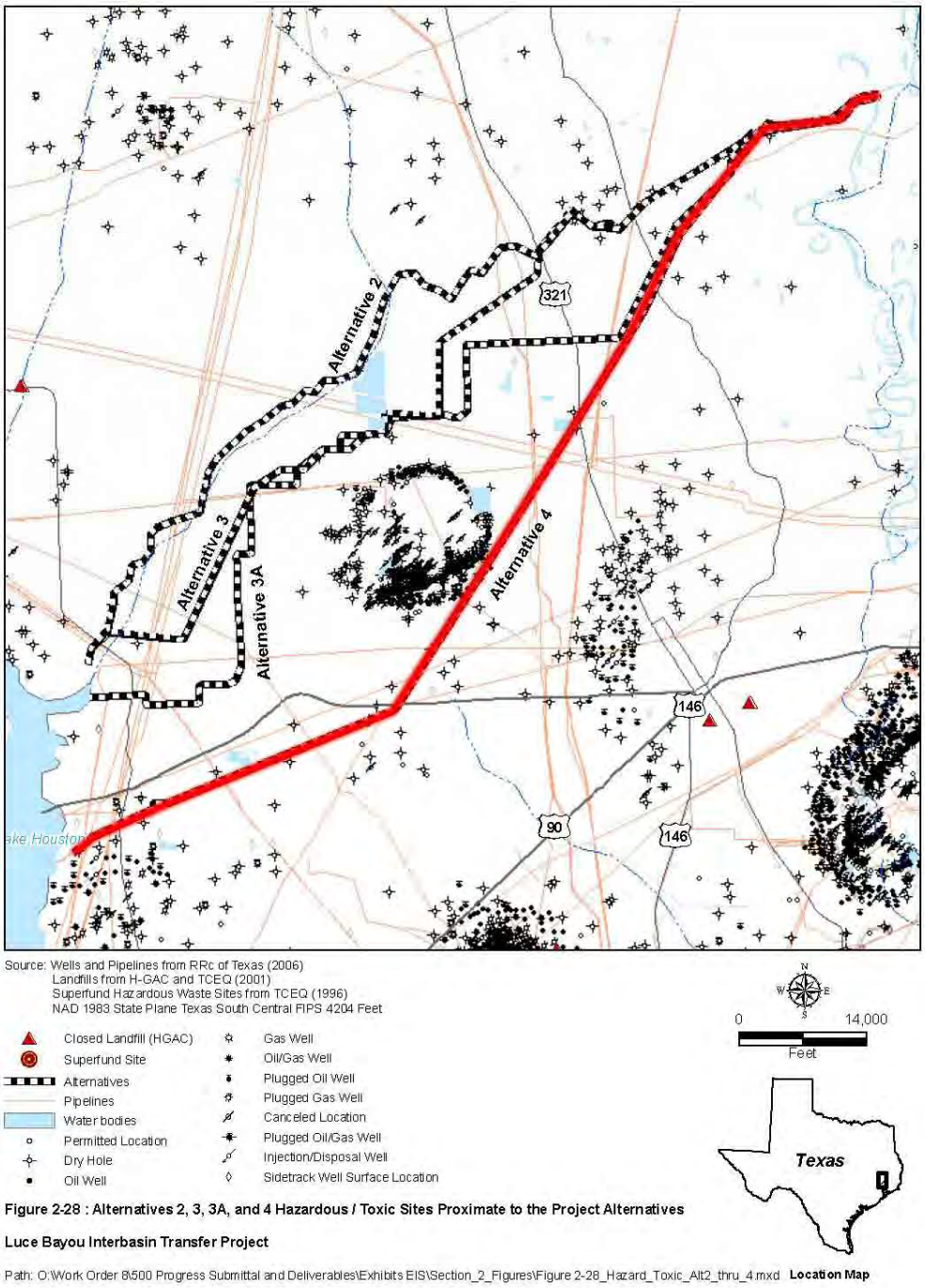

Figure 1. Map of the general project area showing the location of Alternative 4 in red (map provided by AECOM).

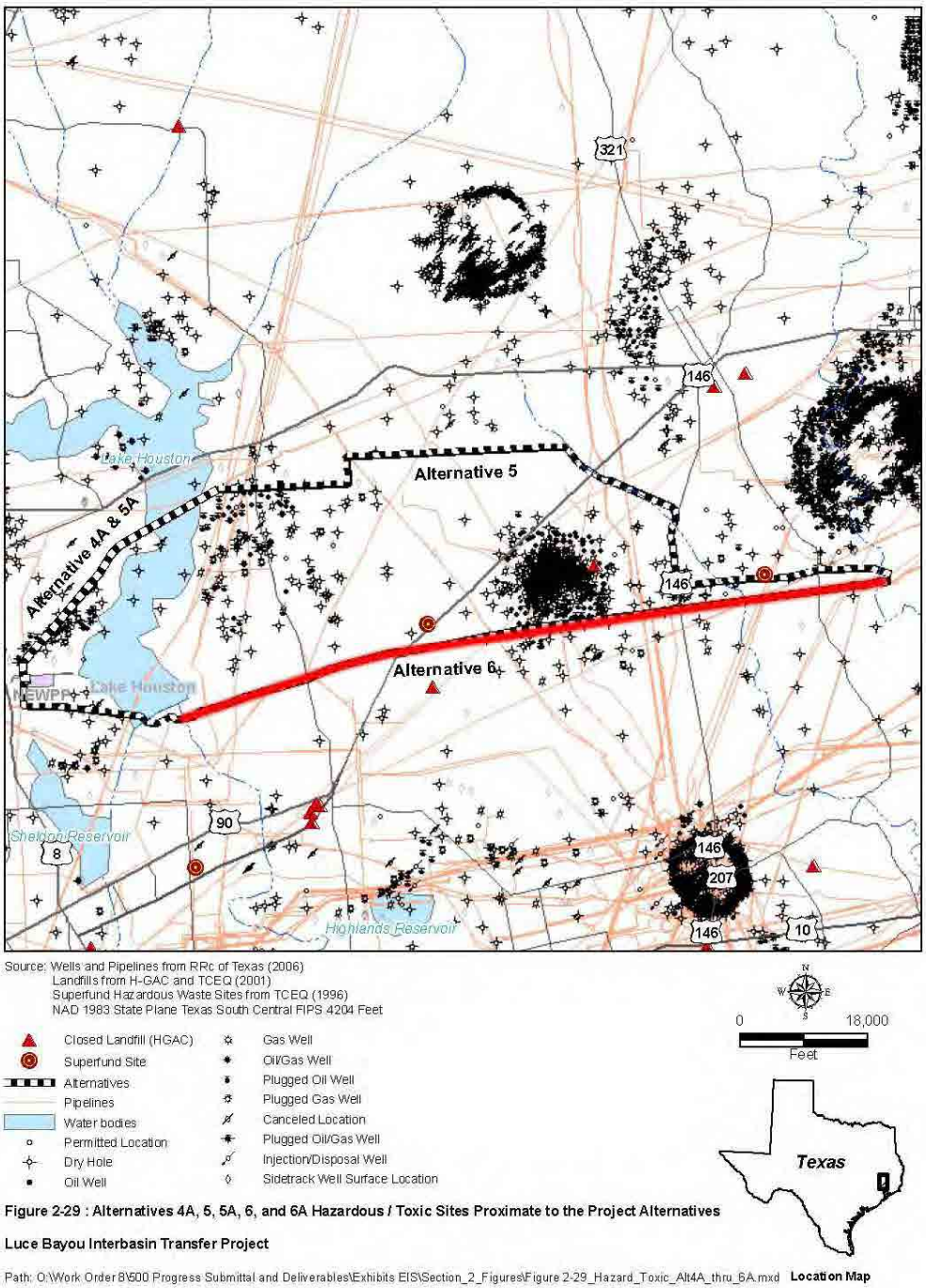

Figure 2. Map of the general project area showing the location of Alternative 6 in red (map provided by AECOM).

Appendix H

2012

US Army Corps of Engineers Galveston District

DEPARTMENT OF THE ARMY
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553-1229

AUG 23 2012

RECEIVED
AUG 27 2012
Texas Historical Commission

REPLY TO
ATTENTION OF:

Evaluation Section

SUBJECT: Project Review of Permit SWG-2009-00188
Luce Bayou, conveyance of water from the Trinity River to Lake Houston

Mr. Mark Wolfe
State Historic Preservation Officer
Texas Historical Commission
P.O. Box 12276
Austin, Texas 78711-2276

Dear Mr. Wolfe:

The U.S. Army Corps of Engineers, Galveston District (USACE) Staff Archeologist has reviewed the draft report titled, *An Archaeological Cultural Resources Survey and Historic Evaluation of the Luce Bayou Interbasin Transfer Project, Harris and Liberty Counties, Texas*, prepared for DESCO, LP by Moore Archeological Consulting, Inc., dated June 2012. The draft report was submitted in response to our initial request for a cultural resource investigation of the permit area. The applicant was requested to provide a copy of this report to you.

As documented in the report, the survey resulted in the identification of 25 archeological sites that occur within the project area and one that is now located outside the project area. Of the 25 sites that occur within the project area, seven are unevaluated for inclusion in the National Register of Historic Places (NRHP). These seven are: 41LB42, -97, -99, -103, -104, -112, and -117. The remaining 18 sites are recommended as not eligible under all criteria, these sites are: 41HR1073, -1074, -1075, 41LB98, -100, -101, -102, -105, -106, -107, -108, -109, -110, -111, -113, -114, -115, and -116. In addition, site 41LB43 could not be relocated in the area previously mapped and is likely part of the expanded boundary for site 41LB42. The project alignment was changed and site 41LB118 is now located outside the project area and will not be affected by the proposed project. Additional investigations will be needed on the seven unevaluated sites to determine if they are eligible for inclusion in the National Register of Historic Places.

We note that your office has already reviewed a copy of the referenced report and agreed with its recommendations in a letter dated 1 August 2012. However, we do request your concurrence with our determination that sites 41HR1073, -1074, -1075, 41LB98, -100, -101, -102, -105, -106, -107, -108, -109, -110, -111, -113, -114, -115, and -116 are not eligible for inclusion in the NRHP, that site 41LB118 is outside the area of potential effect, and that sites 41LB42, -97, -99, -103, -104, -112, and -117 are currently unevaluated for inclusion in the NRHP and require additional investigations to determine their eligibility or they will need to be avoided by the project.

SEP 20 2012

Thank you for your cooperation in this review process. If you have any questions concerning our review or if we can be of further assistance, please contact Mr. Jerry Androy at 409-766-3821.

Sincerely,

Casey Cutler
Chief, Policy Analysis Section

Copy Furnished:

PE-PR – Mr. J.L. Androy

CONCUR
by
for Mark Wolfe
State Historic Preservation Officer
Date 9/13/12
Track#

Copperhead Road Geosciences, LLC
720 Bullock Place
Lexington, KY 40508
859-252-9942 jdp@uky.edu

13 March 2012

To: AECOM, Houston, TX

Through: Kelly Krenz, PG

From: Jonathan Phillips, Chief Scientist

Review of the W.F. Baird Hydrodynamics and Sedimentation Report

As requested, I have reviewed the report from W.F. Baird & Associates, Ltd., entitled *Luce Bayou Interbasin Transfer Project. Hydrodynamic and Sedimentation Modeling,* dated January 2010 and submitted to AECOM. I gave particular attention to issues related to effects of the proposed pump station on the Trinity River channel up- and downstream of the project site, and the recommended mitigation measures.

General

In general, I found the report to be a very thorough and competent analysis. Though modeling is not my specialty, both the selection and implementation of the models seem appropriate, and reflecting the current state of the profession. The authors (hereafter Baird) conducted, in my view, data collection and analysis consistent with the state of the art in applied river science. The vast majority of their findings and interpretations I find to be correct (where that can be determined) or reasonable (with respect to predictions and inferences). The remainder of this report will focus on a few areas where I have identified uncertainties, or find myself in disagreement, with the report, rather than enumerate the many aspects that I fully support.

Possible Meander Cutoff

One area that is problematic (luckily, in a way that poses fewer problems for the project) is Baird's assessment of the migration of the meander bend upstream of the pump station site and the likelihood of future cutoff. Baird uses analyses of historical imagery to estimate lateral channel migration rates and to project future rates based on this. In my view *near-future lateral migration is likely to be much less than indicated by Baird, and cutoff of this bend is unlikely in coming decades.*

The meander associated with PB 9 indeed began accelerated migration as it adjusted to the cutoff of the meander upstream. As mentioned in the text, Wellmeyer et al. (2005) identified this cutoff as occurring in the 1989-1995 period.

However, this most likely occurred during the October, 1994 flood, the flood of record for this area. January, 1995 aerial photography indicates that the cutoff is very recent. The Baird analysis (figure A.5) shows that almost all the bank changes occurred between 1995 and 2004. Thus, it appears that the major adjustment to the upstream cutoff had been mainly completed by 2004, an assessment confirmed by an evaluation of 2010 and 2011 aerial photography, which shows bank locations very similar to those in 2004-2006 images.

This pattern of donwstream lateral and planform adjustment following an upstream cutoff being completed within a decade or so is consistent with a major meander cutoff downstream near Kenefick, known to have occurred in the 1994 flood. The channel downstream responded via lateral migration, but by 2005 the channel course had stabilized. *Therefore, the migration rates indicated in the report are not a reliable guide to near-future rates,* which will be much slower, pending another major channel-changing event. The geometry of the bend does not suggest a neck cutoff for several decades at least, and a chute cutoff (rare in this area) is even more unlikely.

Because of the slowing/temporary cessation of lateral migration here, the *bank stabilization measures may not be necessary*, or at least not to the extent recommended. However, if stabilization/erosion control measures are installed, I agree with Baird that the *submerged vanes are more likely to be successful than other methods*. This is based less on my familiarity with the vanes than on my observation of obvious failure or suboptimal performance of other bank erosion control structures and measures throughout the lower Trinity River.

I also *strongly endorse Baird's recommendation to closely monitor channel change* in the area, and (if the vanes are not installed) to have a contingency plan available if significant lateral migration is reinitiated. There is no indication at present (based on information in the report and my own experience in the area) to suggest that this is imminent, but (as Baird notes) sand-bed alluvial streams can be subject to rapid changes. An event comparable to the 1994 flood (what I call a "clock-resetting event") could conceivably reset the dynamics of this reach—as the 1994 flood did.

Avulsion

An avulsion causing flow to (partially) bypass the proposed intake is a possibility. This is due to the presence of an occupiable paleochannel (Green's Bayou on the eastern part of the valley bottom is a former Trinity River channel), and potential local slope advantages should a crevasse (levee breach) occur along the left (east) bank upstream of Caper's Ridge. Further, the Green's Bayou channel, despite its high sinuosity, appears to have a significantly steeper slope than the Trinity River channel locally (as determined from a 10 m DEM). Baird's higher-resolution data may allow for some refinement of this.

The most likely location for a crevasse leading to a successful avulsion is the outside (east) portion of the bend near the 1994 cutoff, in the vicinity of 30.239, -94.802. The key factors promoting avulsion (other than a general aggradational regime and high-flow trigger events) are channel bed aggradation rates greater than flood plain accretion, breaches or weaknesses in the natural levee, and flow deflectors such as large logjams. An increase in channel aggradation appears unlikely, given the shear stress modeling, though the critical point is just out of the modelled area shown in Appendix I. Any *monitoring programs should include this area*, and note the factors mentioned above. If activities such as livestock and ATV access across the levee can be prevented this would also be helpful. At present such activities appear unlikely due to the nature of the bank.

Caper's Ridge

I agree with Baird's assessment of Caper's Ridge as a structure that effectively blocks flow on the right (west) side of the valley, and it appears that water levels corresponding to stages higher than the record stages at Romayor or Liberty would be necessary to overtop the low point in the ridge. However, the low point in the ridge is a good 10-12 lower than the rest of the feature, and some detailed attention on precisely what water level would be necessary to overtop would be advisable.

The ridge feature is shown as part of the Beaumont formation on the geologic map, with a late Pleistocene "Deweyville" terrace on the upstream side. On the soil map, most of Caper's Ridge is composed of the Woodville series, an upland soil. However, the low gap in the ridge is mapped as the sandy Bienville series, a stream terrace soil. This indicates that the ridge was breached at some time in the past (almost certainly pre-Holocene). The low point in the ridge is about 6 m above the level of the Deweyville paleochannel scare just upstream (north) of the ridge.

In Appendix G, an "inlet" to Muddy Lake Bayou (referred to elsewhere in the report as Mud Creek) is referred to. While there may well be reverse flow (i.e., from the Trinity River up this channel) during high flows, this is primarily a tributary draining floodplain lakes and paleochannels. The plume from this feature into the Trinity is clearly visible on many of the aerial images. The flow models do, correctly, show the Mud Creek channel as a pathway for flood flow return to the Trinity.

Miscellaneous Notes

•Fieldwork was undertaken following an extended period of relatively low flows. Such low water periods can allow vegetation establishment on point bars and channel margins that does not necessarily represent a successional or bar evolution pathway, unless the vegetation can attain size and vigor sufficient to withstand the next flood and/or a general increase in water levels.

•On p. 58, several plausible reasons for the reduced discharge at Liberty compared to Romayor are noted. The backwater effects are the most plausible. While

floodwater storage and diversions into oxbow lakes are common between Romayor and Liberty, flow bypassing the gage is unlikely.

•Appendix F (Tree Coring) is problematic. Sycamore and cottonwood are by no means endemic to the area; they are in fact widespread. Cottonwood is a good geomorphic indicator, as it typically occupies new point bars. Sycamore, by contrast, can be found in any number of moist sites (or in other environments, along fractures allowing access to ground water). Dogwood is referred to as a climax species, whereas it is normally an early-successional species. However, I do not think these errors have serious impacts on the study overall.

•Section 4.4.1.1 states: ”A very important result from this table occurs when river flow approaches, and exceeds the 2 year recurrence interval event. This is because, at this flow, maximum in-channel velocities occur because all momentum is contained within the channel. The 2-year event can be generally equated with the "bank-full" discharge, that flow which, when aggregated over the frequency and duration of all flow events, does the most work in shaping and maintaining the form of an alluvial river.” However, the water level indicated is well below the banktop shown in Fig. 3.17, and the discharge is well below the Q2 levels for Romayor or Liberty. Further, while traditional conventional wisdom has long attached special significance to bankfull flow, and equated this with a 1 to 2-year event, fluvial geomorphologists now question these assumptions.

•Has any detailed analysis been done to reconstruct geomorphic changes associated with the water withdrawals downstream at the CWA canal or other withdrawal points? This might identify potential issues for the Luce Bayou project.

Final Comments

I did not find any significant problems with the analyses with respect to Luce Bayou. Howver, as I was asked to focus on the Trinity River portion of the study area, I did not examine the Luce Bayou results in as much detail.

If you have questions about my comments above, please feel free to contact me.

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Meeting Minutes

Subject	Impact of Raw Water Intake on East Bank of Trinity River Luce Bayou Interbasin Transfer Project
Project Reference	60236806.10000.3c
Place	Teleconference
Meeting date	3/19/2012
Date prepared	3/20/2012
Prepared by	David Munn
Attendees	David Munn (AECOM), Mark Riedel (Baird and Associates)

The following is a summary of a teleconference conversation between the listed attendees. The purpose of the conversation was to clarify statements within the *Luce Bayou Interbasin Transfer Project Hydrodynamic and Sedimentation Modeling Study* provided by W.F. Baird and Associates (Baird), particularly in regard to the impact of the raw water intake structure associated with the Luce Bayou Interbasin Transfer Project on the east bank of the Trinity River directly across from the intake. Page 96 of the report states,

> "The intake structure causes the shift of main river flow to the east and bank protection may be required on the east bank at the intake. This shift is most pronounced with flood events where the proposed intake structure and grading, above the banks, deflects overbank flows to the east. This, in combination with flow deflection caused by return flow from Muddy creek, shifts flows from the center of the channel to east bank. Refinements of the proposed intake design will allow for minimization or even elimination of this flow deflection."

The following questions were asked by AECOM and answered by Baird during the teleconference:

1. AECOM Question: What dimensions where used for the intake structure and how far out into the river did it protrude? Referencing the notes made to the attachment 'Excerpt from Appendix I', does the vertical boundary line marked "x" in figure I-19 correlate to the vertical boundary lines marked "A", "B", or "C" in figure I.18?

   Baird Response: The intake structure was correctly modeled such that the vertical boundary line marked "x" in the attached figure I-19 correlates to the vertical boundary line marked "B" in figure 1-18; however, the intake was modeled as abruptly extending into the river with no gradual transition back into the river bank. The model was developed according to the 30% complete design provided by AECOM. Due to the design only being 30% complete at the time of modeling, it did not include design details for how to transition the intake structure back into the river bank. The deflection of flows onto the east bank of the Trinity River predicted by the model is influenced by the abrupt manner in which the intake extends beyond the river bank. While a smooth transition to the intake (both upstream and downstream) using wing-walls, shore protection, or other treatments will reduce turbulence and flow deflection, it will not eliminate it. In addition to flow deflection by the intake, the proposed apron also induced scour and flow deflection that will need to be addressed in final design to prevent undermining of the intake foundation and toe scour.

2. AECOM Question: Would the issues discussed on page 96 of the report, namely deflection of flow to the east bank, be eliminated if the intake structure does not protrude out into the river channel? If so, how far back (west) would the intake need to be moved to eliminate this effect?

   Baird Response: Flow deflection and its associated negative effects could be minimized or eliminated through improvements made to intake structure during the final design process. Such improvements include providing a gradual transition from the river bank to the edge of the intake structure and/or pulling the intake structure back into the river bank such that it does not extend as far into the river. Such improvements would minimize, or potentially eliminate the need for bank protection along the east bank of the Trinity River. Based on the available information it is difficult to determine how far back the intake will have to be pulled to the west; however, through further design and modeling there is a high degree of confidence that the negative impacts to the Trinity River associated with the flow diversion will be greatly reduced or eliminated. In addition to the location of the intake and upstream approach, refined design to the intake apron would allow for optimization of the apron and reduce or eliminate the potential for toe scour and undermining of the intake foundation. Future modeling practices could be utilized to demonstrate the elimination of river scour on the east bank prior to construction. Back and forth iterations between the design and modeling of alternatives are a common industry practice to resolve issues of this nature.

Note: These teleconference minutes have been reviewed and approved by both participants.

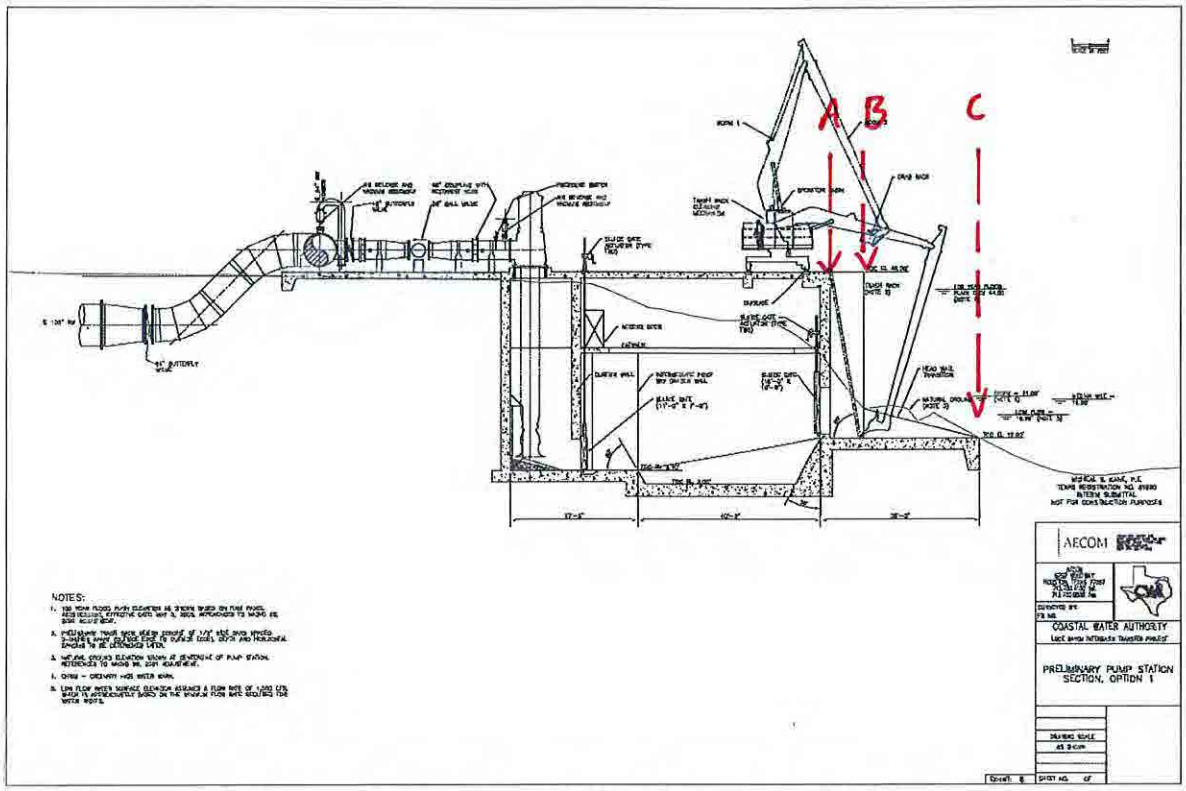

Figure I.18: The 30% design concept cross section for proposed pumpstation on Trinity River.

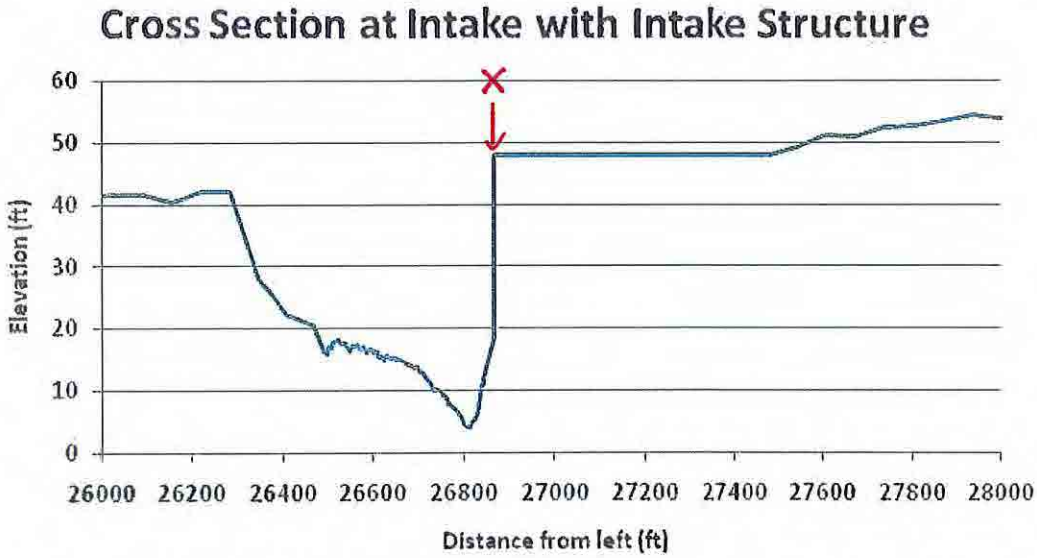

Figure I.19: The modified cross-section at the intake for post-project model run (Note: x-axis points to west, cross-section looking downstream)

Baird

oceans

engineering

lakes

design

rivers

science

watersheds

construction

Luce Bayou Interbasin Transfer Project

Hydrodynamic and Sedimentation Modeling

January 2010
11208.101

Luce Bayou Interbasin Transfer Project

Prepared for
AECOM
Houston, TX

Prepared by

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11208.101

This report was prepared by W.F. Baird & Associates Ltd. for AECOM. The material in it reflects the judgment of Baird & Associates in light of the information available to them at the time of preparation. Any use which a Third Party makes of this report, or any reliance on decisions to be made based on it, are the responsibility of such Third Parties. Baird & Associates accepts no responsibility for damages, if any, suffered by any Third Party as a result of decisions made or actions based on this report.

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1.0 EXECUTIVE SUMMARY

The purpose of this study was to examine the impacts of a proposed water diversion project on the hydrodynamics and sediment transport processes of the Trinity River and on the outfall at Luce Bayou in Lake Houston. W.F. Baird & Associates Ltd was contracted to conduct this study. To assess the potential impacts of the diversion, numerous analytical methods were completed including a thorough review of existing literature and information, analyses of historic flow, water level, sediment, and aerial imagery data, geomorphic analyses, and hydraulic, hydrodynamic, and sediment transport modeling. Field studies were completed to document the existing conditions of Luce Bayou and Trinity River, collect relevant field data for the completion of above methods, and conduct geomorphic and vegetation surveys of the site settings.

During the early phases of this study, unavoidable constraints (e.g. data quality, low water levels, weather, etc.) required slight modification of planned study methods and scope of services to achieve the study goals. The two main constraints came from unusually low water levels and water and sediment data quality concerns for the Trinity River. The low water levels significantly limited site access and provided for collection of low flow data for model calibration. Instability of the flow records from the USGS gage at Romayor, along with limited observed sediment data, required and adaptation of the modeling approach and precluded quantitative calibration of sediment transport data and estimation of river sedimentation rates. With the adapted study scope, neither of these constraints prevented execution of this study or would be anticipated to alter study results.

1.1 General Description of Methods

A combination of desktop analyses, field data collection, and hydraulic and hydrodynamic modeling were used to assess the impact that the proposed intake and outfall will have on the Trinity River and Luce Bayou. A comprehensive literature review was conducted that included the examination geomorphic history of the Trinity River and various methods for river engineering for sand-bed rivers.

1.1.1 Desktop

A thorough literature review was conducted to learn of project related information and studies. Relevant hydrologic and sediment data were gathered and analyzed during the desktop analyses, and prepared for use in modeling. This included any relevant GIS data to examine existing and historic conditions of the area, geologic and soil conditions, and terrain information. Historic river alignments were mapped to illustrate how the Trinity River course has changed over time. Sediment budget analyses were conducted for the existing and proposed water withdrawal scenarios. These used a combination of flow, sediment, and modeling results (below), to assess potential impacts of withdrawal scenarios on downstream sediment transport capacity.

1.1.2 Field Methods

Hydrographic surveys were completed by AECOM to collect multi-beam and single-beam sonar data of the Trinity River near the intake site and Luce Bayou. Baird used the raw data from these surveys to develop bathymetric and shoreline data required for the modeling efforts.

Geotechnical sampling in June and July was conducted by Fugro. Laboratory results and a data report summarizing geotechnical properties from deep bore holes at the proposed intake site were provided to Baird for use to develop conceptual intake protection measures.

Field data collection by Baird was completed from June 1st to June 10th, 2009. This included collection of flow and sediment data at numerous locations on Luce Bayou and the Trinity River to support the modeling efforts and completion of geomorphic assessments of river bank and shoreline processes and conditions.

Flow conditions during this period in the Trinity River were continually decreasing during the fieldwork period to as low as 930 cfs at Romayor, TX. While this prevented further field work because of boat access limitations, sufficient data had already been collected to proceed with the remaining tasks. Flow in Luce Bayou was similarly very low, only 75 cfs at the upstream gage with no measurable currents in Luce Bayou. Flow measurements were gathered using Acoustic Doppler Current Profiler (ADCP) paired with a differential global positioning system (dGPS) to collect high-level accuracy 3D velocity data and water level data for model calibration and validation.

Several sediment samples were taken from the bed and banks of both Trinity River and Luce Bayou. These were analyzed by Fugro to determine particle size distributions and physical properties of sediments. Results were used to parameterize the numerical models and to support morphodynamic analyses.

Point bar and vegetation surveys were conducted in the proximity of the proposed intake site. Vegetation patterns and general communities were noted, and tree cores were extracted from a number of species, to document bar evolution. Mapping and spatial analyses of bars and vegetation was conducted using GIS.

Bank stability/erosion surveys were conducted on the Trinity River near the proposed intake site examining channel bank sediment characteristics, bank morphology, erosion mechanisms, and vegetation characteristics, including an assessment of the banks according to the Pfankuch Channel Stability Index. Shoreline reconnaissance of Luce Bayou was completed that included visual inspection of locations of bank protection and classification of eroding banks; a GIS database was developed with the results of these observations, including photographs and inventories of bank conditions.

1.1.3 Numerical Modeling - Overview

Hydrodynamic and sediment transport models were built, calibrated, tested, and applied for the Trinity River. Similarly, a hydrodynamic model was developed for Luce Bayou. The initial models were developed with results from the desktop analyses and field data collection to document and assess the existing conditions. The models were used to assist with preliminary engineering of the proposed intake on Trinity River, and the proposed outfall on Luce Bayou, as per specifications provided by AECOM. A number of interim model runs and analyses of results were conducted to facilitate refinement of alternative scenarios and identify the final proposed intake and outfall conditions.

1.1.4 Numerical Modeling - Trinity River

The Trinity River was simulated using a nested model approach to achieve appropriate boundary conditions, allow for data acquisition, appropriate analytical resolution, and computational times. The nested model consisted of, 1) a 1D hydrodynamic model, with upstream and downstream boundary conditions at USGS gages in Romayor and Liberty, Texas, respectively, and 2) a 3D hydrodynamic and sediment transport model from the State Highway (SH) 105 bridge (upstream control) to approximately 3 miles downstream of the proposed intake location.

The 1D model was the Danish Hydraulic Institute (DHI) MIKE11 model. Flow and water level data from the USGS gages were used as boundary conditions, and the model was calibrated using the flow and water level data collected near the intake site by the Baird field team. A suite of eleven different scenarios were completed following calibration of the model, including six low-flow scenarios up to the average daily flow and five flooding events.

The 3D model was then developed using the Baird MISED model for the area near the proposed intake site. The model domain included the entire river valley to account for flood inundation. Boundary conditions for the 3D model were extracted from the calibrated 1D model, and the model was calibrated using flow and water level data collected by the Baird field team. The same suite of 11 scenarios from the 1D model were modeled, using 1D modeling results for boundary conditions of the 3D model.

The 1D and 3D models were then modified to include the proposed intake structure design, provided by AECOM, and simulate several withdrawal rates in relation to different river flows. The cross section at the proposed intake location in the 1D model was altered to reflect the change in river geometry due to the construction of the intake and a point extraction was used to simulate the different withdrawal rates. The results from the altered 1D model were used for boundary conditions for the 3D model simulating the river hydrodynamics proposed conditions. The 3D mesh was altered to include the geometry of the proposed intake and the water withdrawal was simulated. A suite of five different river discharge/withdrawal scenarios were modeled to examine the impact of the structure and water withdrawal on the hydraulics and sediment transport of the Trinity River.

1.1.5 Modeling - Luce Bayou

To assess the existing conditions of Luce Bayou, a 2D model was developed from the Crosby Huffman Bridge to Lake Houston using the DHI MIKE21 software. The model was calibrated using flow data collected by the Baird field team and from the USGS gage upstream of the study location. Following calibration, four different scenarios were modeled representing extreme and typical combinations of water levels and flow from Luce Bayou. The 2D model for Luce Bayou was then modified to include the proposed outfall. The same runs were repeated to assess impacts of the proposed outfall on flow patterns and erosion potential within Luce Bayou. Several different outfall configurations were tested to determine the optimal orientation to minimize threat of channel bottom and bank erosion.

1.2 Results

1.2.1 Desktop

Results of the desktop analysis were summarized and included in appendices. Review of historical river alignments showed changes in the Trinity River course and were used to estimate migration rates. Past river migration patterns indicated the large meander immediately upstream of the proposed intake location (point bars 9 and 10, see main report) was moving at a fast rate (ranging from 60 – 80 ft over a couple of years to ~300 ft over 10 year period) and may allow the river to ultimately short-cut through the meander bend and bypass the intake site with the new channel joining the existing channel just downstream of the proposed intake site. The time for such a process to occur cannot be specified because of the nature of climatic variability however, results from this study and reviewed literature suggest 50 to 100 years as a probable time frame. If the river does cutoff the meander, the intake site will still be connected to the river via the cutoff channel. The intake site itself, at Capers Ridge, has been stable over the past 100 years.

Sediment budget analyses for the Trinity River were conducted for the existing and proposed water withdrawal scenarios. These used a combination of flow, sediment, and modeling results (described below), to assess potential impacts of various withdrawal and flow scenarios on river sediment budgets. The results of the sediment budget analyses found two potential impacts of the proposed pump station and water diversion on the sediment budget and transport:

1. The first is a minor increase in sediment load during drought conditions, and only when pumping at high rates is paired with compensation flow releases from Lake Livingston. Over long-term average conditions (based on historical records), this may occur every 2 to 5 years. Because flows are so low under this condition, any potential sedimentation downstream of the intake would be restricted to only the finest sediment sizes (e.g. fine sand). Resultant sedimentation would be minor (less than 0.1% of the sediment budget) and would be remobilized by the Trinity River with return to typical flow conditions.

2. Under larger flows, ranging from average annual through the 10 year event, small reductions in transport capacity were predicted downstream of the proposed intake site. These were all less than -0.3%. Due to the small nature of these effects (they are within the margin of uncertainty), and that pumping would not occur with larger events, any potential resultant sedimentation would be negligible (immeasurable) and regularly redistributed and exported by subsequent small magnitude flood events.

Results of desktop, field, and numerical modeling methods were used to develop conceptual designs for bank protection upstream of the intake site, conceptual protection measures for the proposed intake, and recommend potential measures for the river bank opposite the proposed intake site.

1.2.2 Field Methods

Results of field methods were summarized and included in appendices. Hydrographic survey, sediment sampling, and flow measurement data were used to support modeling. Results from the bank erosion, bank stability, and vegetation surveys were used to assess the rates of point bar growth, recent river meandering, and channel and bank stability. Bar and vegetation growth patterns and rates provided estimates of current river meandering rates that were consistent with historical rates.

1.2.3 Numerical Modeling - Trinity River

Results for the Trinity River showed typical flow patterns over a wide range of flow scenarios including, helical flow currents (secondary flow), and overbank return flow from floods. Capers Ridge was found to be critical because it blocks the western portion of the floodplain and forces all flood flows to the east and north, to go around Capers Ridge and the proposed intake site. These flood waters re-enter the Trinity River at Mud Creek, and have the effect of deflecting high velocity flood flows eastward, away from the proposed intake location on the outside meander bend towards the center of the channel.

The results of the modeling with proposed intake and withdrawal scenarios were very dependent upon withdrawal rates and river flow. During low flow conditions, intake withdrawal had a profound effect on river currents, sediment transport, and possible areas of scour and deposition. However, because the river flows were low, these effects were limited to infrequent events and only the finest sediment. Typical flow conditions during any year were sufficient to maintain the river channel at the proposed intake site. During flood events, return flow from Capers Ridge was deflected by the proposed intake, causing it to be more strongly directed to the east, against the inside of the meander bend opposite the proposed intake. The effect of this would be to cause scour of the small bar there, and shoreline erosion. Scour at the toe of the intake apron was also noted to occur during large events, suggesting toe protection would be necessary.

1.2.4 Numerical Modeling - Luce Bayou

Luce Bayou modeling also showed anticipated flow patterns over the range of extreme and typical conditions. The side embayments showed very little flow except during flood flow conditions. During extreme low water and high discharge events, high velocity produced localized areas of high shear.

The proposed outfall results were very dependent upon water levels and flow rates. During low water and low flow conditions, the outfall showed areas of high velocity and shear at the outfall and along banks. Alternative outfall alignments were tested to minimize this risk with an outfall alignment of 36 to 40 degrees having the best results. With this result, protection of shoreline and the outfall would still be required to protect these areas from erosion.

1.3 Recommendations

1.3.1 Trinity River

The results of this study indicate Capers Ridge, the selected location for the proposed intake site for the Luce Bayou Interbasin Transfer Project, is an optimal location for the proposed intake and pump station. This is due to the long term stability of Capers Ridge within the otherwise, very active Trinity River floodplain and valley system. Capers Ridge is an obstruction that effectively blocks the western half of the Trinity River valley. This "bottle neck" has a profound effect on water and sediment transport processes in the Trinity River at this location. During bankfull and flood events, when flow and sediment transport is at maximum rates, Capers Ridge funnels overbank flows back in to the river channel, immediately upstream of the proposed intake site. While this backs up flood waters upstream of Capers Ridge, it concentrates flow at Capers Ridge. As shown by the modeling, field work, and sediment budget results, the effect of this is to greatly limit point bar formation at the project site and increase local hydraulic shear and sediment transport capacity. Once past the project site, the floodwaters may spill back onto the floodplain, allowing for reduced in channel shear and increased rates of point bar formation and maintenance. This, combined with the relatively small impact of proposed water withdrawal (as compared to river flow rates) allows us to conclude the proposed project will have minimal impacts on sediment transport capacity through the study area. Any potential impacts that might occur were estimated to be so small they were within the margin of uncertainty, as limited by the quality and amount of observed sediment data.

While this study did identify active erosion in a meander located immediately upstream of the proposed intake location (located at point bars 9 and 10) that will eventually allow the river to bypass the current proposed intake location, this scenario would not constitute a project failure or be likely to lead to chronic challenges with pump station operation. There is also potential for a major channel avulsion, or re-alignment, to occur with a large flood event, on the order of a 100 year flood. While the likelihood of predicting such an occurrence was beyond the scope of this study, the probability of observing a 100 year event in 50 years is 40%. For this reason, and because

a channel avulsion event would be most likely to occur at this same meander bend mentioned, the following activities are recommended:

1. Implement a long term monitoring plan for erosion of this meander bend, as well as for erosion of the river bank across from the proposed intake location;
2. Fully quantify the likelihood (risk) and time frame for erosion of this meander loop to bypass the intake and ascertain if this is acceptable;
3. If the risk is acceptable, continue the monitoring program and develop a contingency plan for maintenance of the intake channel to the pump station in case the meander does bypass the intake station, or;
4. If the risk is unacceptable, fully develop the meander and bank protection concepts provided in this report and stabilize the meander loop.

The results of the modeling study also indicated the preliminary pump station would likely increase flow deflections towards the eastern river bank, opposite the intake. Additional refinement of the pump station with subsequent design, possibly combined with bank erosion protection, will minimize or eliminate this threat.

For the proposed intake and pump station, three alternative river bank and infrastructure protection concepts were developed. These were based on preliminary intake design concepts and will need to be refined to accommodate changes in the intake design and establishment of final project risk levels. All of the alternatives provide bank protection across a range of flows extending from upstream the proposed intake, to downstream of the proposed intake, and tie directly in to the intake structure on the river bank. As each of the methods provide different configurations, require various amounts of earth moving and construction time, and differing costs for construction, and operations and maintenance, final selection will be dependent on intake design, construction logistics, and client needs.

1.3.2 Luce Bayou

The results of this study indicate the proposed outfall location on Luce Bayou, for the proposed intake site for the Luce Bayou Interbasin Transfer Project, is reasonable from an engineering perspective and challenges identified with the proposed outfall may be resolved by refining the proposed design. The initial outfall layout, perpendicular to the channel, resulted in high flow and shear values in the channel north of the proposed outfall location. The channel orientation was adjusted to 36 degrees to the bank to reduce the high flow and shear in the narrow channel to the north of the outfall.

Using the re-aligned outfall channel, five scenarios were modeled to examine the potential impacts of the outfall on Luce Bayou. The typical daily conditions, normal water levels in Lake Houston and normal discharge from Luce Bayou, result in maximum flow speed values of approximately 5.6

ft/s and shear values of 1 Pa and higher reaching up to 60 feet downstream, but not affecting the island on the opposite bank. Shear values for the typical observed scenario showed results of up to 20 Pa confined to the proximity of the outfall.

During low-water level periods on Lake Houston, which are dependent on lake releases, and typical flow conditions from Luce Bayou, flow from the outfall flows through the narrow north channel, with velocities of 2 ft/s reaching approximately 90 feet upstream. With this scenario, the proximity of the outfall and the bank of the island direction across from the outfall will experience high shear; the opposite bank will experience these elevated shear values approximately 60 feet upstream of the outfall and 120 feet downstream of the outfall. The likelihood of this scenario is dependent on the frequency of low water levels for Lake Houston.

The results of the 2-year Luce Bayou flow with low water levels in Lake Houston showed similar, but slightly higher results as compared to the normal flow scenario. With the 10 and 100 year events modeled, the maximum shear stresses in the channel are lower than the first three scenarios modeled due to the fact that the flow patterns are dominated by the Luce Bayou flows and not the outfall.

Recommendations:

1. Implement a long term monitoring plan for erosion near the outfall apron, as well as for the river bed within proximity of the proposed outfall;

2. Recommend study for bank protection and to refine estimates of extent of potential shoreline erosion at outfall and islands given the high shear values observed with the modeling results within the area of the outfall during typical flow conditions.

1.4 Summary

To support the initial design and permitting phases of the Luce Bayou Interbasin Transfer Project, extensive analytical, field, and numerical modeling activities were conducted. These characterized the existing conditions of flow, hydrodynamics, fluvial processes, and sediment transport for Luce Bayou and the Trinity River, in proximity to proposed intake and outfall structures. Modifications to the numerical models, combined with geomorphic analytical methods, were used to assess how the proposed structures, and their operation, would likely affect the Trinity River and Luce Bayou. A number of results illustrated specific combinations of discharge, water withdrawal, and water levels that would affect hydrodynamic and geomorphic processes in the Trinity River and Luce Bayou. Recommendations for conceptual solutions to address these effects, and possible areas of shoreline instability were identified. Further analyses to support engineering concept and design to the final testing and construction stage will be greatly facilitated through application of the tools and results developed here, including hydrodynamic testing of final intake and bank protection designs.

2.0 INTRODUCTION

The goal of this study is to estimate the effects of the Luce Bayou Interbasin Transfer project on erosion and sediment transport in the Trinity River, near the proposed intake, and on the proposed outfall for the water transfer canal in Luce Bayou and Lake Houston. The project, as presently defined, conveys water via a canal system generally parallel to the existing Luce Bayou channel.

Large water diversions, such as the proposed Luce Bayou Interbasin Transfer, can affect the hydrodynamics and sediment transport conditions of the source channel. The sediment transport characteristics of the river near the intake site would be affected by the proposed intake pumping equipment and also must be accounted for to determine the intake design, pump selection, and sediment removal requirements.

This study examined the current state of the Trinity River and how the proposed intake site might affect changes in existing hydrodynamic and sediment conditions. A significant diversion of water from the Trinity River has the potential to change the sedimentation processes downstream of the diversion site. Removal of water from the Trinity River at the proposed intake site may also require flow augmentation releases from the Livingston Dam to maintain minimum stream flow during dry periods. Specifically, water withdrawal at the proposed intake site would require a similar increase in water release from Lake Livingston Dam when the natural flow rate is insufficient to meet demand. This flow augmentation may impact sediment transport and stream erosion during low flows in the study area.

The study area is located in a highly dynamic, sandy river channel that has demonstrated the capacity to migrate across the floodplain in the Trinity River valley system. This study addresses the need to assess whether the proposed intake is located in an area that may be subject to river channel migration over the proposed lifespan of the project. The need for bank stabilization in the vicinity of the intake is assessed, and the nature of such stabilization is defined. All of these factors have been addressed through a combination of background research, numerical modeling, field investigation, analytical research, and engineering design.

The proposed outfall for the diversion is located on Luce Bayou, a tributary of Lake Houston. This study uses numerical modeling to assess the impacts of the proposed outfall discharge on hydrodynamics and the potential for bank erosion and bed scour near the outfall location.

2.1 Existing Conditions in the Trinity River

The Trinity River watershed, covering an area of 17,800 mi^2, rises in northern Texas and flows to the Trinity Bay, part of the Galveston Bay system on the Gulf of Mexico. The major cities are Dallas and Fort Worth in the upper part of the watershed; Lake Livingston Dam regulates flow in the lower part of the watershed. This study focuses on a subsection of the Lower Trinity River, south of Lake Livingston, between SH 105 and the city of Liberty, TX (Figure 2.1). The climate in the study area is

humid subtropical, receiving an average of 50-60 inches of rainfall per year, and mean January and July temperatures of 74°F and 90°F respectively. Hurricanes are active in this area during the summer months.

The Trinity River is a major river on the Gulf Coastal Plain in east Texas. The river exhibits evidence of extensive flooding, bank erosion and point bar accretion. The lower Trinity floodplain contains numerous oxbow lakes, meander scars and other evidence of historical river channel change, showing that the channel is presently and historically migrating. The channel is confined within an incised valley, with evidence of historic (Pleistocene) channel migration on alluvial terraces (Phillips and Slattery, 2008).

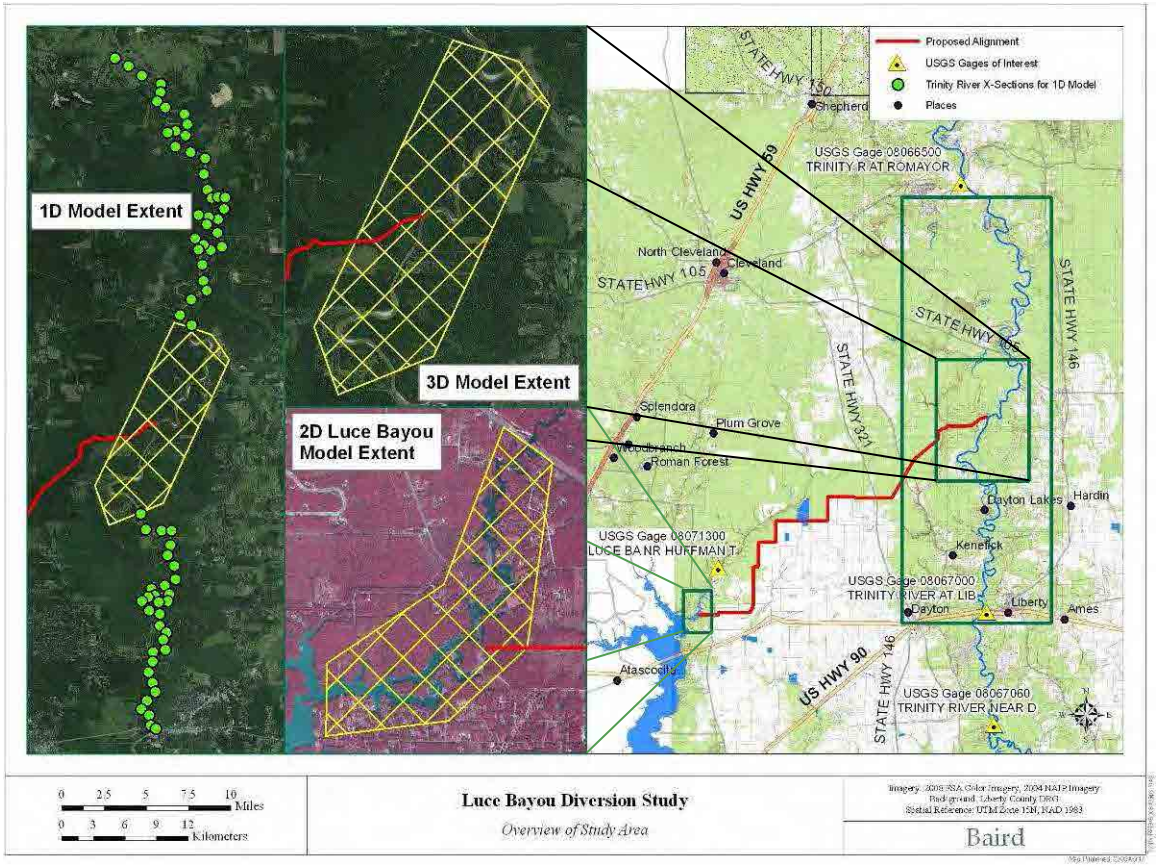

Figure 2.1: Location Map of Study Area

2.2 Existing Conditions in Luce Bayou

The proposed outfall is located on the eastern bank of Luce Bayou, which ends at Lake Houston (Figure 2.2). The meandering river has a width of approximately 75 to 350 feet in this range and becomes much narrower upstream from Huffman Cleveland Rd Bridge. The distance from the proposed outfall to Lake Houston is approximately 1.5 miles, and the flow pattern in this area is affected by both the river discharge from upstream and the water level at Lake Houston.

Near the proposed outfall, the river channel is divided into two branches by an island, and the outfall is located at the eastern shoreline of the eastern branch.

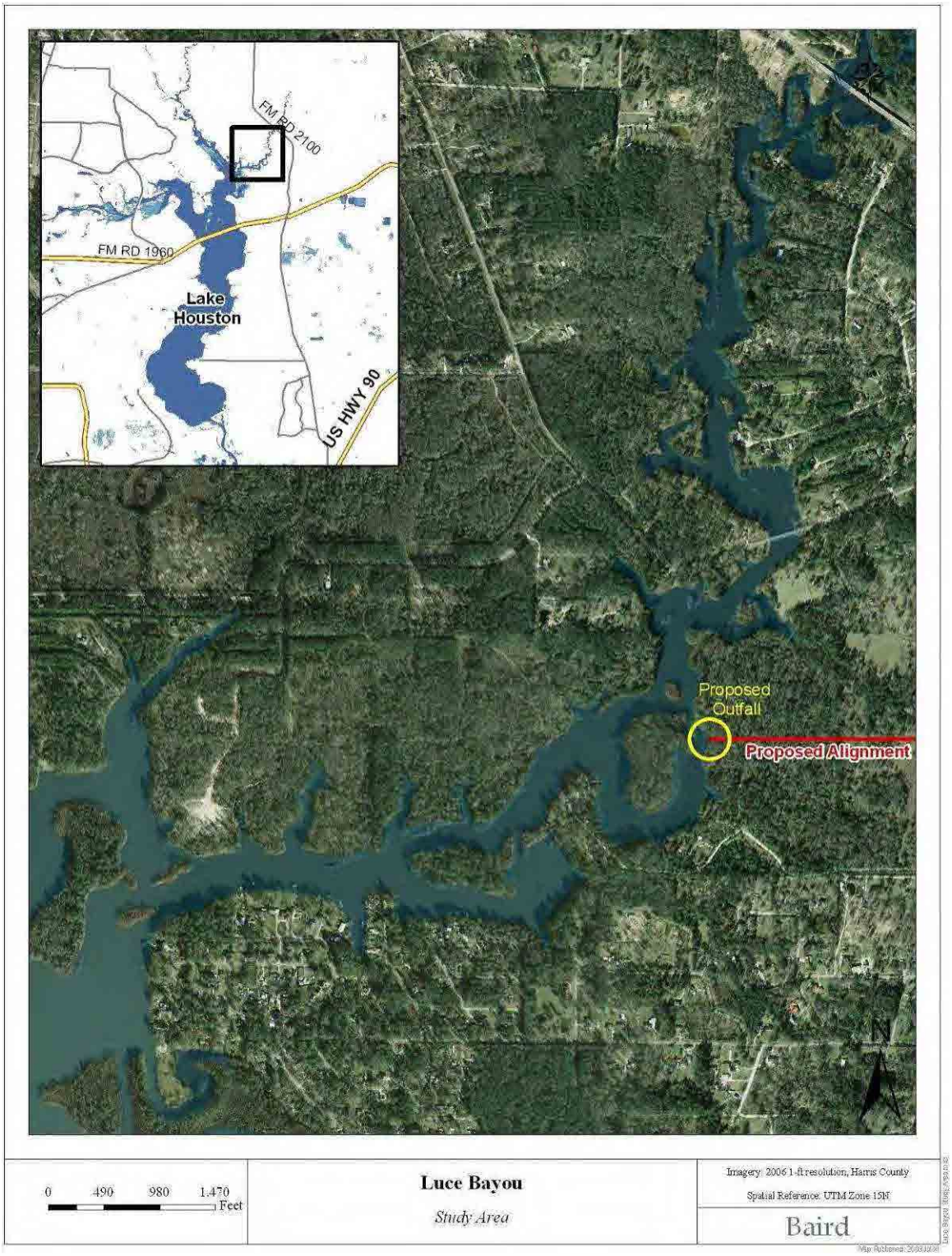

Figure 2.2: Location of proposed outfall

2.3 Literature Review

2.3.1 Geomorphic History of the Trinity River

A comprehensive study of the geomorphic characteristics of the study area has been undertaken by Phillips and Slattery over the period 2003-2008. This is a very detailed study, covering multiple aspects of the geomorphology of the lower Trinity River. The findings of Phillips and Slattery have been published in many reports and journal articles. These and other related articles were reviewed during the desk study phase of this project. The main topics and findings of these reports are summarized in Table 2.1. The annual project reports by Phillips and Slattery are summarized in Phillips (2008a), and they are therefore not included as separate items in Table 2.1.

Phillips and Slattery present much valuable geomorphic data on the study area throughout their studies. This includes:

- Analysis of historic aerial photographs of the study area;
- Analysis of flow and sediment discharge records in the study area;
- Morphometric analysis of channel characteristics, including cross-sectional and longitudinal profile form;
- Construction of sediment budgets for the study area;
- Identification of major geomorphic zones in the study area.

It is not the intention of the Baird study to replicate the geomorphic analysis undertaken by Phillips and Slattery. The Baird study uses the previous work, and then supplements the findings of Phillips and Slattery with additional geomorphic fieldwork, analysis of recent aerial photographs and numerical modeling with special attention paid to the areas near the proposed intake and outfall. The purpose of this is to gain a detailed picture of channel dynamics such as channel migration and bank erosion, and predictions of sediment loads in the study area.

Many reservoirs upstream serve to trap the natural sediment load of the river, which leads to a 'deficit' in sediment load in the river downstream from the dam. Philips and Slattery (2008) summarize the downstream geomorphic effects of Lake Livingston Dam (110 miles above Trinity Bay), showing that river channel changes attributable to the dam extend about 35–38 miles downstream of the dam. These river channel changes are associated with the sediment starvation effects of Livingston Dam. The limit of this zone corresponds with changes in valley shape, reflected in a wider valley, lower elevations and frequent oxbow lakes downstream (Phillips et al., 2005).

In the study area (downstream from the zone of sediment starvation), there is a pronounced increase in sediment storage and a corresponding decrease in sediment transport (Phillips et al., 2004). This is referred to as the 'critical zone' by Phillips and Slattery (2008). The proposed intake location is in this 'critical zone' that includes a sediment transport 'bottleneck' in the river,

characterized by the river building channel sediment bars and depositing a large amount of sediment on the floodplain during flood events. The higher river channel sinuosity (a measure of the degree of meandering of a river) downstream of the critical zone has led to the suggestion that the transition corresponds to the upstream limit of historic sea-level rise effects on the Trinity River (Phillips et al., 2005). The influence of this 'critical zone' on the detailed morphodynamic behavior of the channel in the vicinity of the proposed intake is discussed in Section 5.

Phillips and Slattery (2008) report that the reaches up- and downstream of the critical zone also differ significantly in sinuosity, channel slope and stream power (associated with the river's ability to transport sediment). Stream power at any given reference flow is 4.5–33 times greater at Romayor compared to Liberty, despite higher discharges downstream. Unit stream power is 20-100 times higher upstream of the critical zone (Phillips and Slattery, 2006). These differences are mainly attributable to slope, as channel bed slopes are 25 times steeper upstream of Romayor.

Analysis of suspended sediment transport data from gauging stations at Romayor, about 5 miles upstream of the critical zone, and Liberty, about 28 miles downstream, show pronounced differences in sediment transport regimes (Phillips et al., 2004). Mean annual sediment yield at Romayor has been estimated by Phillips et al. (2004) to be nearly 4.2 million tons per year, with a specific yield (amount of sediment produced per square mile of watershed) of 218 tons/mi2/yr. At Liberty, by contrast, the numbers are less than 76,000 tons/yr, and 4.6 tons/mi2/yr (Phillips et al., 2004). While the Romayor station shows a clear reduction in sediment transport following closure of the Livingston Dam, there is no evidence of any change at Liberty (Phillips et al., 2004). Downstream of Liberty, low stream power and ample accommodation space creates a sediment storage bottleneck such that little upstream sediment was reaching the lower reaches of the river even before the dam was constructed. A full discussion and explanation of the significance of this for the hydrodynamic and sediment transport characteristics in the intake zone is given in Section 5.

Table 2.1: Literature and Previous Studies on the Trinity River

Date	Authors	Type of Report	Key Points
2008a	Phillips	Final Project Report for TWDB	• Conveys results of 5-year geomorphic study of Trinity River; • Delineates major geomorphic process zones based on flow energetic; • Identifies geomorphic transition zones in the river; • Detailed background data on study area, including flow regimes; • Identifies potential future avulsion zones.
2008b	Phillips	Journal Article	• Discusses avulsions in the Trinity River; • Uses a combination of aerial imagery, digital elevation models and field surveys; • Makes distinction between reoccupation of former channels and meander cutoffs; • Lateral channel migration as an important avulsion mechanism; • Channel avulsions function differently at different flow levels – can function as distributaries under high flows.
2008	Phillips and Lutz	Journal Article	• Examines profile shapes in alluvial rivers; • Shows flood power decreases downstream in Trinity River.
2008	Phillips and Slattery	Journal Article	• Discusses importance of antecedent (pre-existing modern) alluvial morphology; • Identifies critical 'hinge point' in river - transition zone between fluvial and coastal dominance; • Transition zone corresponds with the upstream limit of Holocene sea-level rise; • Discusses Holocene history of study area.
2007	Phillips and Slattery	Journal Article	• Examines downstream changes in stream power in the lower Trinity River; • Downstream reduction in bankfull steam power largely due to reduction in slope, though lower banks downstream cause a tendency to reach bankfull at lower discharges; • Stage-discharge curves at different points in the lower Trinity for the Hurricane Rita-associated event in 2005; • Shows that tributaries function as distributaries during high flows.
2007	Slattery and Phillips	Final Study Report Year 5	• Study Report
2006a	Phillips and Slattery	Journal Article	• Discussion of sediment storage in the lower sections of coastal plains rivers; • Role of transport capacity (and channel slope) in alluvial storage and buffering of sediment delivery to coastal zones;

Date	Authors	Type of Report	Key Points
			• Analysis of gage data with respect to stream power at Romayor and Liberty; • Reduction in stream power from Romayor to Liberty causes sediment transport 'bottleneck'
2006b	Phillips and Slattery	Final Study Report Year 4	• Study Report
2006	Robertson	Journal Article	• Distribution of tree species on point bars; • Specific reference to Lower Trinity River.
2005	Phillips et al.	Journal Article	• Downstream effects of Livingston Dam extend about 55-60 km of the dam; • Cross section analyses show evidence of channel scour and widening between Livingston Dan and Romayor in response to construction of the dam, and no effects downstream from Romayor. • Critical transition zone identified in the coastal plain portion of the Trinity River, reflecting in sediment dynamics, valley morphology and channel response to upstream disturbances.
2005	Slattery	Final Study Report Year 3	• Study Report
2005	Wellmeyer et al.	Journal Article	• Examines flow regime and channel planform change in the lower Trinity River; • Summarizes annual flow records at Romayor and Liberty; • Historic analysis of meander cutoff upstream from intake location; • Demonstrates active channel migration in the study area; • Suggests flow frequency and flood magnitude at annual scale are not strongly affected by Lake Livingston flow regulation;
2004	Phillips	Interim Study Report Year 2	• Study Report
2004	Phillips et al.	Journal Article	• Constructs a sediment budget for the lower Trinity River; • Shows effects of Livingston Dam on disrupting sediment load are undetectable in the lower part of the study area (beyond 52 km downstream from dam); • Identifies extensive floodplain sediment storage, and sediment transport 'bottleneck' in lower river; • Majority of sediment in the study area is likely derived from channel scour and bank erosion; • Sediment shortage upstream from Romayor; • Presents field evidence of channel scour and floodplain sediment storage.

Date	Authors	Type of Report	Key Points
2004	Slattery	Final Study Report Year 2	• Study Report
2003	Slattery	Final Study Report Year 1	• Study Report
2001	TPWD	Technical Report	• Examines freshwater inflows to Trinity-San Jacinto Estuary.
1998	Conrod et al.	Technical Report for CRWR	• Data analysis of suspended sediment loads in Texas Rivers; • Establishes sediment rating curves; • Includes Trinity River at Romayor.
1998	Land et al.	USGS Report	• Study of water quality in the Trinity River Basin 1992-1995; • Summarizes general hydrologic conditions in the Trinity River Basin.
1993	White and Morton	Technical Report for TPWD	• Determine sedimentation rates in the Trinity River; • Uses 210Pb dating of 12 sediment cores; • Area is downstream from this study area; • Identifies relative sea level rise in area as 6 mm year-1.
1990	White and Calan	Technical Report for TPWD	• Examines deltaic wetland sedimentation in rivers including Trinity River; • Area is downstream from present study area.

2.3.2 River Engineering and Bank Stabilization for Sandbed Rivers

Sandbed rivers have long been identified as among the most unstable and problematic with regard to "unpredictable" behavior, hydraulic and sediment transport instability, and engineering design of river structures. A thorough review of literature was conducted to specifically address the unique considerations that must be addressed when working with a large mobile river, such as the Trinity River. For the sake of brevity, rather than summarizing these works here, these sources are listed in the references section of the report and cited where appropriate in the body of the report.

3.0 METHODS

This study addressed the potential effects of the proposed Luce Bayou Interbasin Transfer project on erosion and sediment transport in the Trinity River, near the proposed intake, and on the proposed outfall for the water transfer canal in Luce Bayou. In order to do so, a variety of techniques were used, including desktop analysis; field investigations; 1D, 2D and 3D hydrodynamic and sediment transport numerical models; morphodynamic analysis and engineering design. These are described in this section of the report and associated Appendices (Table 3.0). The overall layout of the study components is summarized in Figure 3.1.

Table 3.0: Index of Appendices

Appendix	Contents
Appendix A	Historic River Course Analysis
Appendix B	Hydrographic Survey
Appendix C	Flow Measurements
Appendix D	Sediment Sampling and Analysis
Appendix E	Point Bar Surveys
Appendix F	Tree Coring
Appendix G	Bank Survey and Erosion
Appendix H	Pfankuch Stability Survey
Appendix I - Trinity River Numerical Modeling	Full Report of 1D and 3D Modeling
Appendix I-1	Figures to accompany full report
Appendix I-2	Figures for calibration results
Appendix I-3	Existing flow patterns
Appendix I-4	Existing bed shear stress
Appendix I-5	Existing velocity and shear profile
Appendix I-6	Existing secondary flow at intake
Appendix I-7	Sediment concentration at intake
Appendix I-8	Post-project flow patterns
Appendix I-9	Post-project bed shear stress
Appendix I-10	Post-project velocity and shear profiles
Appendix I-11	Velocity and shear changes
Appendix I-12	Post-project sediment concentration at intake
Appendix J	Luce Bayou Numerical Modeling
Appendix K	Bank Stabilization/Protection Concepts

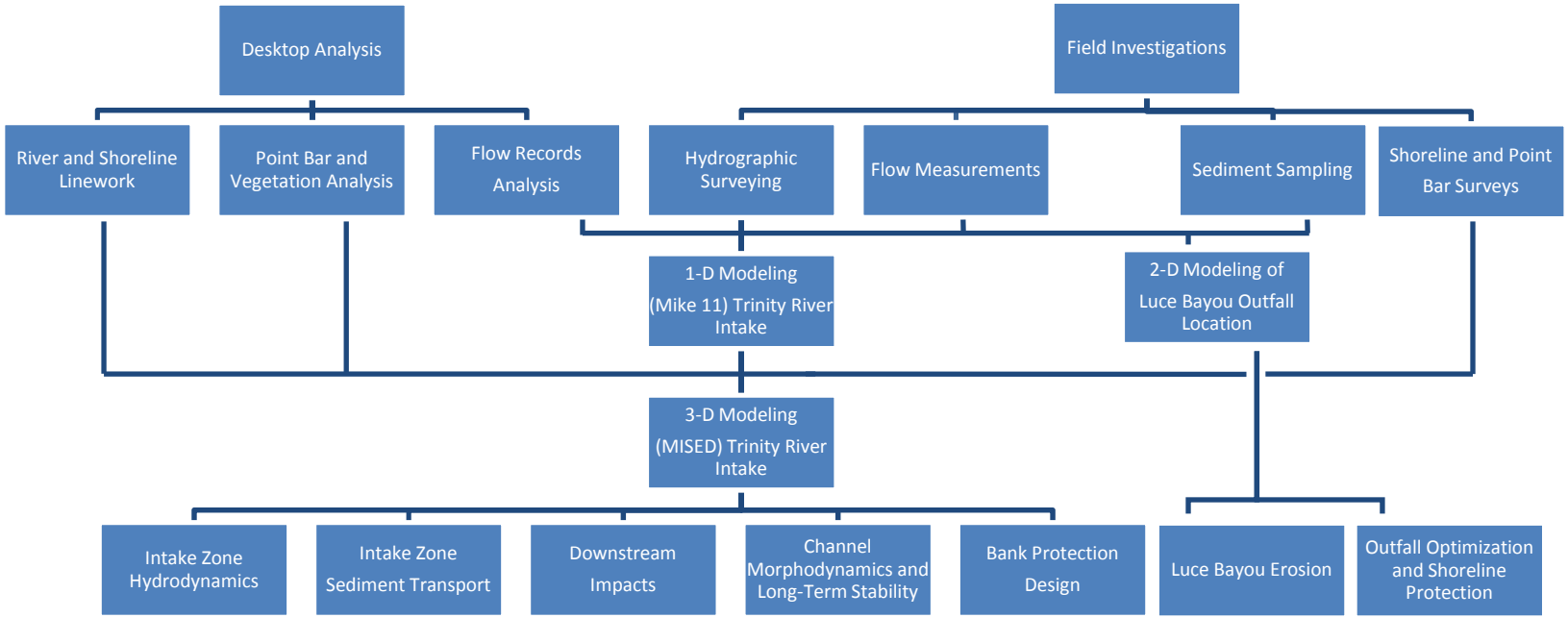

Figure 3.1: Organization Chart of Baird Study

3.1 Desktop Analysis

This task commenced with acquisition of the data and documentation needed to support the proposed modeling, analytical and design components of the study. The relevant and available scientific literature with respect to the Trinity River and Luce Bayou were identified and reviewed. These are summarized in Section 2.3 of this report.

The existing data relevant to the study were obtained from project partners and agencies. Any data gaps were identified, and any needed additional data were obtained. The geospatial and tabular data were collated into a project GIS database. These data include historic river alignments; terrain data (DEM, LIDAR, etc); hydrography (EPA RF3, watersheds, etc), and geologic data (bedrock, sediment types, etc). The datasets acquired and used in this study are included in the project CD. Detailed descriptions of additional desktop analyses are summarized below.

3.1.1 River Course Analysis

River banks were digitized for the Trinity River study area in order to determine river channel migration rates over the available time periods of aerial photographs (orthophotos). Available aerial photographs were downloaded from the Texas Natural Resources Information System (TNRIS) website (http://www.tnris.state.tx.us/) for 1995, 2004, 2006, and 2008. Previous years were not included in the bank migration analysis as they have already been addressed by Wellmeyer et al. (2005). Bank lines were then digitized from the orthophotos along the Trinity River from the SH 105 crossing near Romayor to approximately 5 miles due south of the proposed intake site. The channel bank delineation was determined for the top of bank location (i.e. the intersection of the sloped channel bank with the floodplain surface). Aerial photographs taken during high flow events were used to delineate the river channel along the waterline. In periods where lower flow conditions exist, the channel boundary was determined where the break between annual and perennial vegetation occurred. River bank migration analyses are in Appendix A.

3.1.2 Point Bar and Vegetation Analysis

Meandering in the Trinity River is driven by point bar deposition inside river bends and subsequent erosion of outside banks of river bends. To better assess meandering in proximity to the proposed intake site, point bars and riparian vegetation were mapped and surveyed during field reconnaissance (discussed in section 3.2.4). The meander located immediately upstream of the proposed intake location, PB9 and PB10, Figure 3.2, is of particular concern because this meander is actively moving to the southwest, towards PB11 and PB12. If this meander erodes through the land at PB10, the river course will short cut past the proposed intake location, and connect downstream between PB11 and PB12. While the proposed intake site would likely remain connected to the active river channel via the cut off section of channel between PB10 and PB11, this would become a backwater and may cause maintenance and operational issues for the proposed pump station.

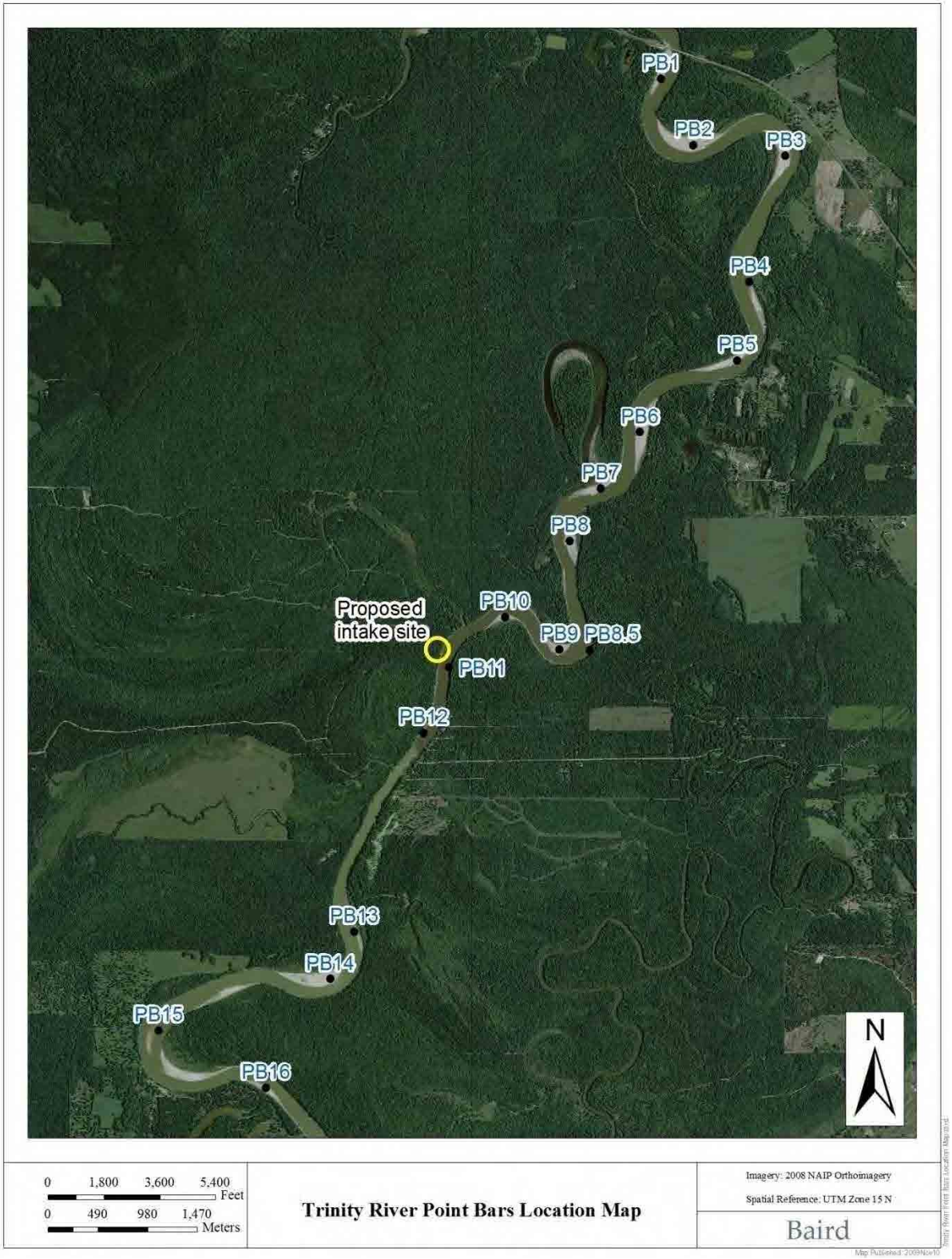

Figure 3.2: Point bar surveys on the Trinity River (PB 15 wraps along the east bank from PB 14 to PB 16, but is partially submerged in this aerial photo).

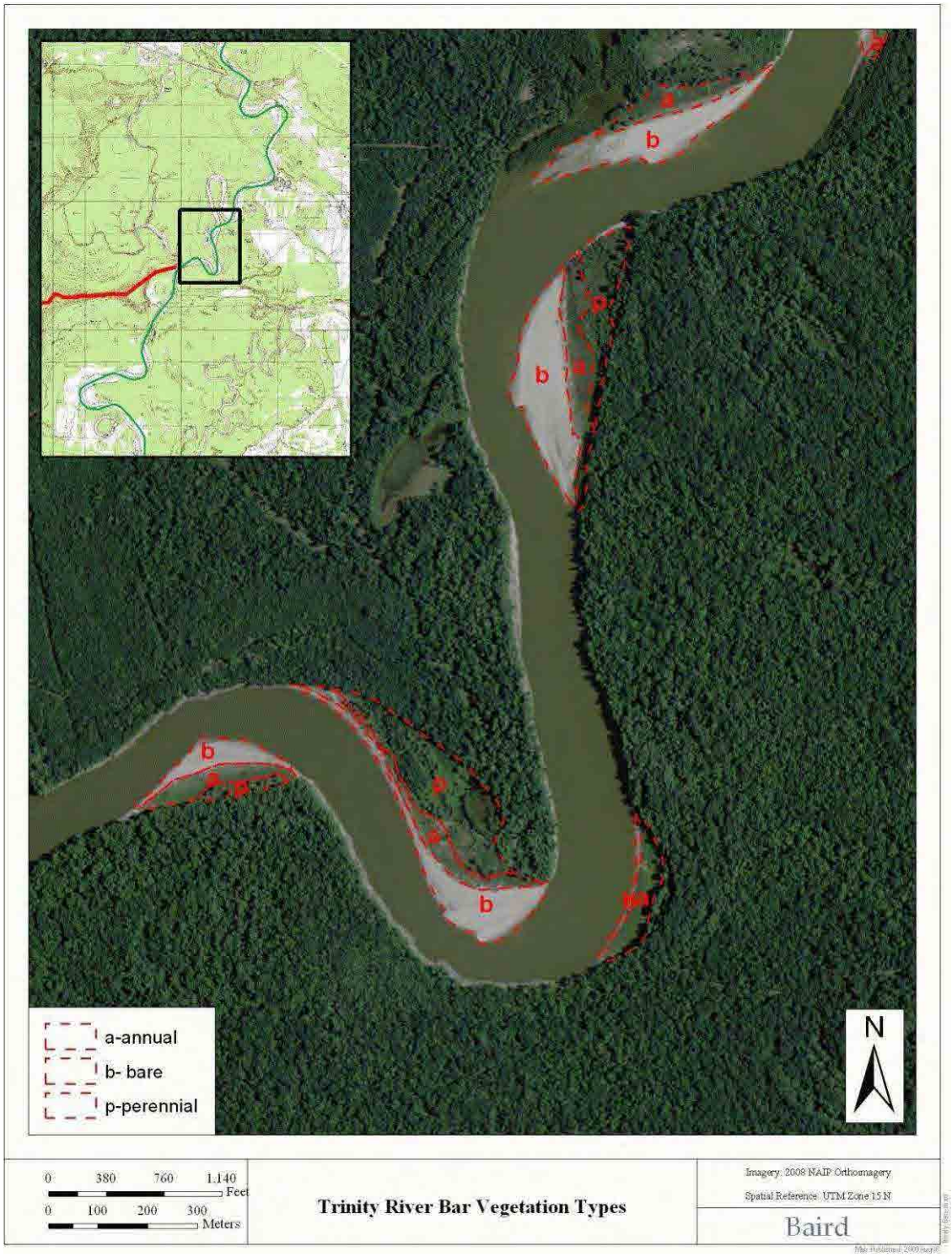

Figure 3.3: Example of point bar on Trinity River with three stages of bar evolution delineated. The most active and lowest section is bare (b), the next section has recruited annual plants and been stable for at least one growing season (a), and the highest section depicted has been stable for at least three growing seasons and has recruited stable perennial vegetation including woody shrubs and saplings (p).

Mapping of the point bars, comparisons with vegetation patterns, and point bar formation rates are described here. Point bars were digitized using USDA-2008 National Agricultural Imagery Program (NAIP) 1 meter imagery available from http://datagateway.nrcs.usda.gov. The delineations were verified with field GPS survey of bars, identification of plant species, and aging of trees using tree coring (dendrochronology). The study extent covered from the SH 105 crossing near Romayor to approximately 5 miles due south of the proposed intake site (Figure 3.2). The bars were delineated based upon their stage of evolution and maturity (e.g. Figure 3.3).

Bare bars (denoted as 'b') represent newly formed and active bar sections with no vegetation present (Figure 3.4). Within the river channel, these bars start from the thalweg of a river bend (deepest portion of the channel) and extend up towards the bankfull floodplain elevation. The amount of bare bar visible in aerial imagery was dependent upon water levels consequently, bare bars were not used to infer project results. Rather, bare bars served as the boundaries for the other bars. Bare bars are frequently inundated and growing with deposition of sand during flood events consequently, these parts of the bars are regularly re-worked throughout the year and are unstable.

Figure 3.4: Example of the bare phase (b) of a point bar

Annual bars (denoted as 'a') represent the transition from the bare bar sections up to the approximate floodplain elevation (Figure 3.5). At this elevation, inundation is less frequent and of relatively shorter duration. These sections are more stable than bare bars and, because they have recruited annual plants (grasses, forbes, etc.), can be interpreted as being stable for at least one year to have completed a cycle of seed recruitment, germination, and growing season maturation.

Perennial bars (denoted as 'p') represent the next phase in bar evolution, begin along the upper margin of annual bars, extend up into the floodplain elevation; these portions of the bars tend to be relatively flat (Figure 3.6). Here, perennial vegetation (woody shrubs, vines and saplings) have

become established along with annual species. The river has deposited so much bar material here that, the bar has become part of the floodplain and inundation is even less frequent (approximately two out of every three years). This section of the bar represents newly formed floodplain constructed by the river. The perennial portion of bars is delineated from mature floodplain forest by stark difference in tree ages and species composition along the margin of the bar and established floodplain forest. In addition to mature pioneer species, an established floodplain forest includes shade tolerant species and climax forest species.

The results of the bar mapping were used to develop estimates of bar longevity and growth rates for each of the bars. Bar mapping was also used to estimate bar volumes as a proxy for accretion rates. These results, and their application for predicting future growth rates, are described in the results section of this report.

Figure 3.5: Transition from bare (b) to annual phase (a) of a point bar

Figure 3.6: Transition from annual (a) to perennial phase (p) of a point bar

3.1.3 Analysis of Flow Records

This task is a component of the background analysis to develop the hydrologic, climatic, and sediment data necessary to understand the present and historic conditions in the study area, and to calibrate and run the hydrodynamic erosion and sedimentation models. The modeling domain on the Trinity River has a U.S. Geological Survey stream flow gage at its upper end to establish initial boundary conditions and provide reference data for model calibration on the Trinity River. Flow record data analyses were conducted in order to assist in the Trinity River and Luce Bayou river modeling. Historical peak and daily discharge data along with stage height data were downloaded from the USGS website (http://www.usgs.gov/) for the following stations located within the study area: USGS 08066500 Trinity River at Romayor (Romayor gage), USGS 08067000 Trinity River at Liberty (Liberty gage), and USGS 08071280 Luce Bayou above Lake Houston near Huffman (Luce Bayou gage).

Annual flood frequency analyses were conducted for Romayor and Huffman gaging stations using the USGS PeakFQ (version 5.2) software package, which provides flow estimates for a range of recurrence intervals (Flynn et al. 2006). The description of the functionality of PeakFQ from the user's manual is shown below (Flynn et al. 2006):

> "Program PeakFQ estimates the parameters of the log-Pearson Type III frequency distribution from the logarithmic sample moments (mean, standard deviation, and coefficient of skewness) of the record for annual flows, with adjustments for low outliers, high outliers, historic peaks, and generalized peak skew. The parameter values are used to

calculate the percentage points (or quantiles) of the log-Pearson Type III distribution for selected exceedence probabilities."

The PeakFQ analyses were done for the Trinity and Luce Bayou sites using instantaneous peak discharge values as well as the annual maximum daily discharge values. Furthermore, stage and water elevations were determined for each recurrence interval based upon a daily stage/discharge relationship that was developed for each site.

3.1.4 Trinity River Sediment Budget Analysis

While there is a sediment supply limitation in the Trinity River just downstream of Lake Livingston, the Trinity River is sediment transport limited downstream of Romayor, through the proposed intake location, all the way to Liberty. This is from the combined effects of reduction in river slope and introduction of numerous sediment sources. A sediment budget desktop analysis was conducted for the Trinity River to quantify the potential impacts of the proposed withdrawal and transfer project on sediment flux through the Trinity River. Results from the calibrated 3D sediment transport model, discussed in Section 3.4.2, were used to develop a cross section average sediment transport and discharge relationship, Figure 3.7. A cross section averaged value was used to capture total sediment budget and likely river bed impacts downstream of the proposed intake location. While the sediment concentration results near the river bed were significantly higher than higher elevations in the cross section, the concentration results near the water surface were much lower than the rest of the cross section. By using a cross section averaged value, this method captures total sediment flux and capacity through the intake reach.

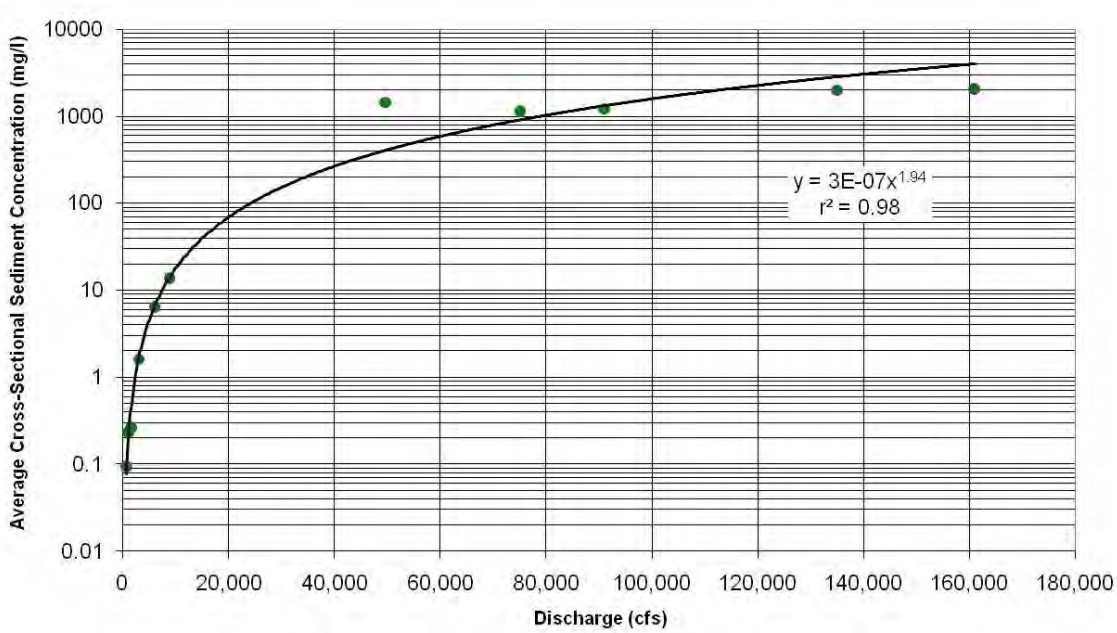

Figure 3.7: Relationship between discharge and sediment concentration from results of 3D model

Sediment transport was computed for the 11 "existing conditions" flow scenarios to estimate the sediment flux rates for each flow (Table 3.1). This approach relies on the transport limited condition of the Trinity River. This means the Trinity River always has more sediment available than it can transport. The transport limited condition is well-supported by a wealth of previous research (see Section 2.3), the fact that the Trinity River valley is a large coastal outwash plain, as well as by the results of this study (Riedel, et. al., 2009).

Table 3.1: Trinity River modeling scenarios

Scenario Number	Flow Conditions	Discharge at Romayor (cfs)
1	7Q2 – 602 cfs	602
2	Low Flow Condition 1 – 1,000 cfs	1,000
3	Low Flow Condition 2 – 1,500 cfs	1,500
4	3,000 cfs	3,000
5	6,000 cfs	6,000
6	Average Daily Flow	8,770
7	2-Yr Flood	49,600
8	5-Yr Flood	75,100
9	10-Yr Flood	91,000
10	100-yr Flood	135,000
11	500-yr Flood	161,000

Sediment fluxes for each flow scenario were computed for upstream and downstream of the proposed intake using two withdrawal rates, 400 MGD and 227 MGD. These scenarios were chosen because at the time of analysis, these were the most likely withdrawal rates, as per discussions with AECOM. Compensation flow releases were assumed from Lake Livingston Dam to maintain minimum instream flow of 700 cfs; this rate was established with discussions with AECOM to estimate the impact that a minimum flow requirement would have on the sediment transport near the proposed project site. This represents a "worst-case" scenario, as compared to only using observed flow records, because it produces the highest flows. The results were annualized to estimate sediment flux for a "typical" year by integrating the sediment fluxes in proportion to their observed frequency from USGS gage records at Romayor.

The sediment budget analysis focused on silt and coarser size sediments. This was for two reasons. First, because finer clay size sediments move as washload and are not a component of bed material sediment. Consequently, they do not affect river morphodynamic processes. The second reason is because observed suspended sediment data were not available for calibration. Total suspended solids (TSS) data do exist for the observed USGS data at Romayor, however; these were not treated to determine the organic fraction of TSS. As the organic fraction can be a very large component of TSS, using TSS data to estimate suspended sediment can greatly over estimate sediment fluxes (Sun, et. al., 2004; Riedel, et. al., 2004; Riedel and Vose, 2002).

3.2 Field Methods: Trinity River

There are two purposes for the fieldwork undertaken as part of this study:

1) to gather river and sediment data needed to support the modeling activities and,

2) to conduct geomorphic assessment of the site that will identify any potential problem areas.

River and sediment data collected include river hydraulic characteristics (e.g. channel size, floodplain information, entrenchment, etc.) and sediment physical properties (type, grain size distribution, bar formations, etc.). Due to the lack of flow and sediment data available for the intake and outfall sites, the fieldwork data collection included bank erosion assessments, flow velocity, water level, and sediment (river bed and bank material) sampling. The field reconnaissance, together with review of existing study reports, in conjunction with assessment of the results from the numerical modeling, is essential to understanding the likely long-term morphological behavior of the study area. Results of the field work are presented in the Appendices and discussed in Section 4.

The Baird project team visited the study area from June 1st to June 10th, 2009 to collect field data in Trinity River and Luce Bayou. The field study area in the Trinity River was located between SH 105 and SH 90 near Liberty, TX. Weather conditions during fieldwork were generally good, with only isolated thunderstorms impacting the field program. Flow conditions at the USGS gage at Romayor ranged from approximately 3,500 cfs on May 30th down to approximately 930 cfs on June 10th (USGS, 2009), after which boat access was not possible due to low water levels.

3.2.1 Hydrographic Surveying

Hydrographic surveys of Luce Bayou and the Trinity River were conducted by AECOM. These data were gathered using a combination of multi-beam sonar, single-beam sonar, and standard surveying methods. All field surveying and processing of survey data was performed by AECOM survey staff. Baird obtained these data in raw form and used them to develop the bathymetric, river survey, and shoreline data needed for the development of the hydrodynamic and sediment transport models. Maps of the data used in this study are in Appendix B.

3.2.2 Flow Measurements

Velocity readings and cross sectional profile information were taken along Luce Bayou and the Trinity River using an Acoustic Doppler Current Profiler (ADCP). The ADCP was paired with a Trimble differential global positioning system (dGPS) to obtain highest accuracy for both horizontal (latitude and longitude) and vertical (elevation) accuracy. This system provides for up to +/-5mm vertical and +/- 5mm horizontal accuracy in readings. The ADCP uses the survey data and velocity readings to estimate discharge at the time of measurement.

Model numbers of the ADCP and dGPS equipment, along with maps illustrating ADCP flow measuring locations, are in Appendix C.

3.2.3 Channel Bed Material Sediment Sampling

Channel bed and bank samples were collected for the Trinity River. The locations of these samples are shown in Figure 3.2. The samples were then analyzed to determine their grain size distribution characteristics. The results are discussed in Section 4.2 and the full laboratory analyses are contained in Appendix D.

3.2.4 Point Bar and Vegetation Surveys

Given the importance of excess sediment supply and transport limiting characteristics of the Trinity River, river meandering is driven by point bar deposition and floodplain accretion as the river builds bars to store bed material sediments. The building of point bars encroaches on the active channel of the river, reducing its cross-sectional area, and subsequent erosion on the downstream banks of meanders to maintain conveyance capacity. While the formation of point bars is a continuous process and can include altering phases of erosion and deposition, bar deposition exceeds erosion and the bars build spatially and vertically. The highest elevation of point bars reaches to the active floodplain. Due to the nature of point bar evolution over time, frequency and duration of bar inundation relative to bar elevation, and continued disturbance of bar sediments, various plant communities are restricted to unique sections of each bar.

Point bars and bar vegetation in proximity to the proposed intake were inspected and mapped. Bars numbering 8, 10, 11, 13, and 14 (Figure 3.2) were inspected and plant communities (annual, perennial, and established floodplain forest) were mapped. The application of tree coring and dating (dendrochronology) to determine the ages of floodplain deposits is a well documented practice and allows for the estimation of rates of fluvial geomorphic processes (Robertson; Riedel, et. al., 2005; Riedel, et. al., 2002; Hupp and Osterkamp, 1996). Both Robertson (2006) and Phillips (2001) used dendrochronology to estimate ages of floodplains and bar formations in the Trinity River however, neither were on the section of the river for the proposed project.

Using an incremental borer, tree cores were extracted from a number of trees representing all phases of point bar and floodplain evolution (Figure 3.8, Figure 3.9). Trees were identified according to U.S.D.A. Forest Service handbook FS-466: Important Forest Trees of the Eastern United States (1968) and the guidebook of Cox and Leslie (1999). The results of the bar survey and tree coring were used to complete the bar mapping, Appendix E. Data and photographic records of cored trees are in Appendix F.

Figure 3.9: Extraction of a tree core from an established American Sycamore (Platanus occidentalis) on the floodplain at point bar (PB) 10.

Figure 3.10: Core extracted from American Sycamore (Platanus occidentalis) pictured in the previous figure. This 40 – 42 year old tree had a diameter at breast height (dbh) of 1.5 feet (the outer bark is not shown in this core).

3.2.5 Bank Erosion / Bank Stability Surveys

Eroding banks in the vicinity of the proposed intake site were surveyed by the Project Geomorphologist. Sketches were made of dominant channel bank sediment characteristics, bank morphology, erosion mechanisms and vegetation characteristics. These sections were also assessed according to the Pfankuch Channel Stability Index (Pfankuch, 1975). This method is a federally accepted standard for inventorying and quantifying river bank stability (Riedel, et. al., 2006; FISRWG, 1998). Bank erosion survey locations are the same as the bank sediment sample locations shown in Figure 3.11. Bank Erosion survey data and notes are in Appendix G and Pfankuch Channel Stability data sheets are in Appendix H.

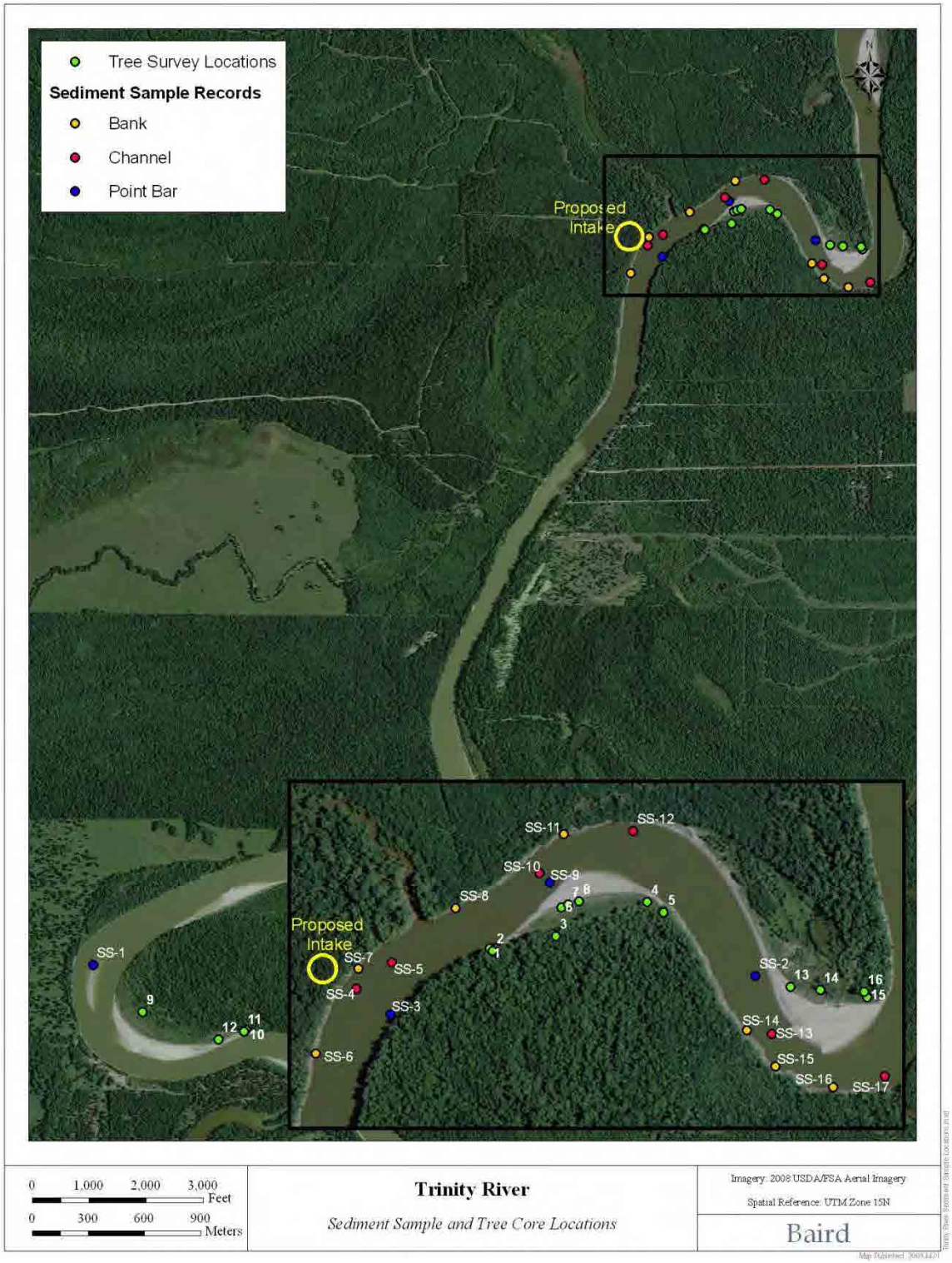

Figure 3.11: Sediment, bank, and tree sample locations on the Trinity River near the proposed intake site

3.3 Field Methods: Luce Bayou

The Baird project team visited Luce Bayou to collect field data on June 2nd and June 10th, 2009. The upstream boundary of the field study area for Luce Bayou was at the Crosby Huffman Rd/FM 2100 bridge to where Luce Bayou joins Lake Houston near Lakewater Drive.

3.3.1 Hydrographic Surveying

Hydrographic surveying of Luce Bayou was conducted to develop the bathymetric data required for the development of the hydrodynamic model. These data were gathered using single-beam sonar. All field surveying and processing of survey data was performed by AECOM survey staff. Maps illustrating the domain of surveying and reports summarizing survey methodologies are in Appendix B.

3.3.2 Flow Measurements

Discharge readings were taken along Luce Bayou using an Acoustic Doppler Current Profiler (ADCP). Locations of the ADCP readings are shown in Figure 3.12. Full methods and results are presented in Appendix C.

3.3.3 Channel Bed Material Sediment Sampling

Channel bed and bank samples were collected for Luce Bayou in the vicinity of the intake, and on a nearby island, respectively. The locations of these samples are shown in Figure 3.12. The samples were analyzed by Fugro to determine their grain size distribution characteristics. The results are discussed in Section 4.2.3 and presented in Appendix D.

3.3.4 Shoreline Reconnaissance

A shoreline reconnaissance of Luce Bayou was performed on June 10th, 2009 from the bridge at Huffman Cleveland Road to the confluence of Luce Bayou with Lake Houston. This reconnaissance included visual identification of eroding shoreline areas, and the type and condition of shoreline protection. Mapping was conducted at a general level, and classified the shoreline into relatively homogenous sections, according to shoreline morphological characteristics. Eroding banks were classified as wherever a steep, vegetation-free face was observed at water level. A GIS database was developed to inventory the condition of all shoreline and photographs of all shore protection types and conditions.

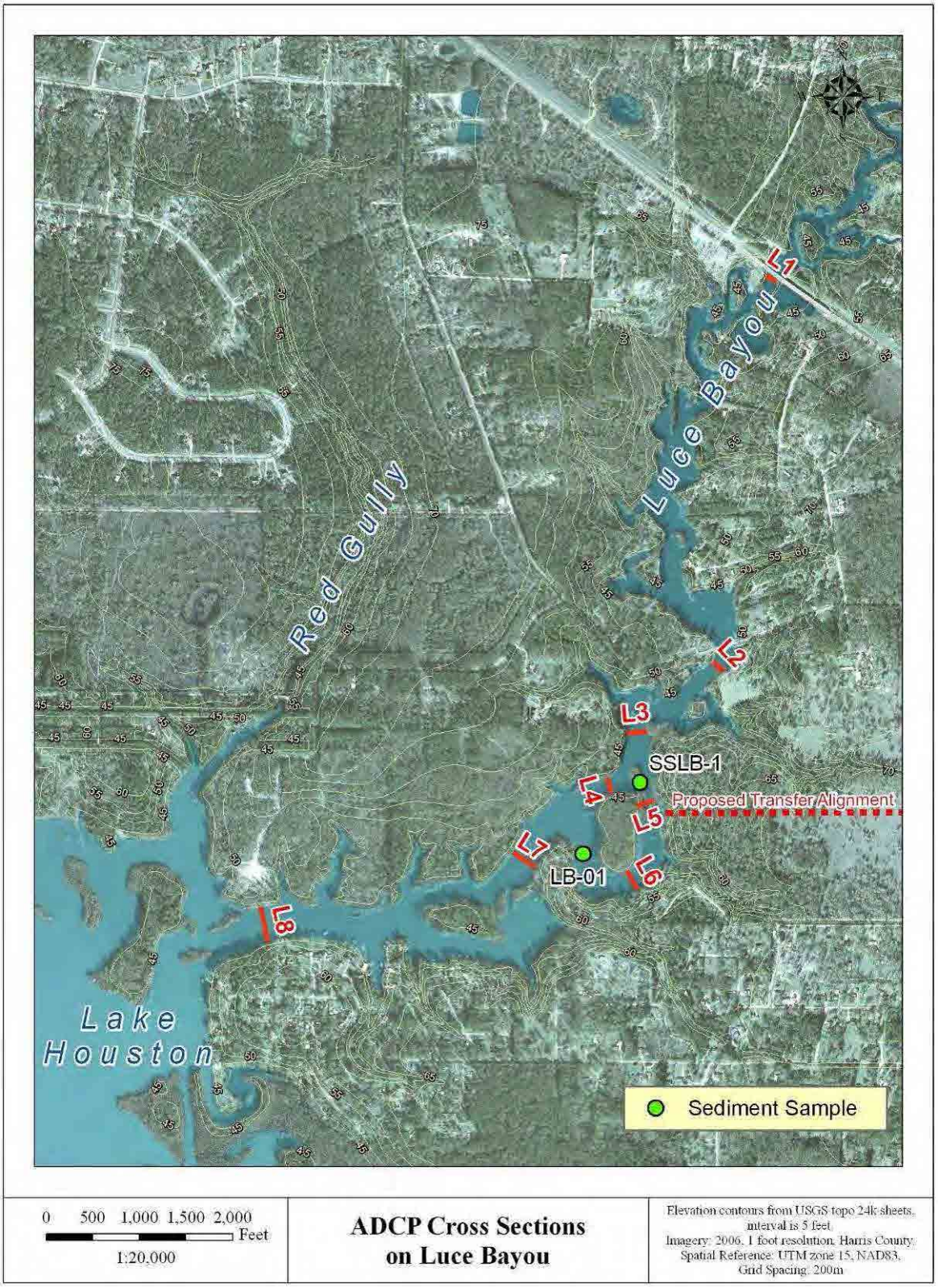

Figure 3.12: ADCP Cross section and sediment sample locations within Luce Bayou study area

3.4 Numerical Modeling Methodology: Trinity River

Numerical modeling for the existing and proposed pump station conditions on the Trinity River required numerous large tasks and data processing stages. Preparatory tasks such as hydrographic survey and development of boundary conditions have already been presented in this report. This section focuses exclusively on the development of the models, model parameterization, calibration, testing, and application for existing and proposed conditions. A summary of the key tasks and methods is provided here. The reader is directed to Appendix I and associated sub-appendices (Table 3.2) for thorough treatment of methods, explanation of science and engineering in the modeling, limitations and assumptions inherent in the modeling.

Table 3.2: Index of Numerical Modeling Appendices

Appendix	Contents
Appendix I - Trinity River Numerical Modeling	Full report of 1D and 3D model development and
Appendix I-1	Figures to accompany full report
Appendix I-2	Figures for calibration results
Appendix I-3	Existing flow patterns
Appendix I-4	Existing bed shear stress
Appendix I-5	Existing velocity and shear profile
Appendix I-6	Existing secondary flow at intake
Appendix I-7	Sediment concentration at intake
Appendix I-8	Post-project flow patterns
Appendix I-9	Post-project bed shear stress
Appendix I-10	Post-project velocity and shear profiles
Appendix I-11	Velocity and shear changes
Appendix I-12	Post-project sediment concentration at intake

Numerical modeling of the Trinity River was completed for the area from Romayor to Liberty. A 1D model was developed for the entire study area of the river to provide boundary conditions for the 3D model near the proposed intake site. Using a calibrated 1D model nested with a smaller study area for the 3D model allowed for a computationally efficient yet detailed model to best understand the hydrodynamics of the river near the proposed intake site and the potential effects that the intake may have on the hydraulics and sediment transport characteristics of the river.

Discharge and water level data from the USGS gages at Romayor and Liberty were used to provide boundary conditions for the 44-mile 1D hydraulic model. Water-level measurements gathered during field data collection were used to calibrate the 1D model. Table 3.1 shows the suite of 11 different scenarios that were modeled following calibration of the 1D model.

A 3D model was developed for the area near the proposed intake site to understand the hydrodynamics and the potential impact of the intake in detail. The results from the 1D model provided boundary conditions for the 3D model. The 3D model was calibrated using a

combination of field measurements by the Baird team of velocity and water level and additional output from the 1D model.

3.4.1 MIKE11 1D Modeling of the Study Area

A 1D model was developed for the Trinity River from the USGS gage at Romayor, TX to the USGS gage at Liberty, TX using the Danish Hydraulic Institute (DHI) MIKE11 software. This software has been reviewed and approved for regulatory purposes by the Federal Emergency Management Agency and the U.S. Army Corps of Engineers. Cross sections for the river channel bed and the floodplain were developed using a combination of multi-beam sonar data and single-beam sonar data collected by AECOM, LIDAR data near the proposed intake site, and 10m DEM data available from the USGS. The 1D model network included 116 cross sections along the 44-mile segment of the Trinity River between the two USGS gages. Flow and water surface elevation measurements collected by the Baird field team and data collected from the USGS gages at the upstream and downstream boundaries of the model were used to calibrate the model.

The USGS gages provided boundary conditions for the 1D model. Discharge data from the Romayor gage and water level data from Liberty gage during the time when field data was collected were obtained from the USGS. These were 15-minute interval measurements during the calibration period corresponding to the field measurements collected by the Baird field team.

Field measurements including water level, flow, and velocity taken near the intake site from June 4th to June 7th were used to calibrate the 1D model. The Manning's roughness (n) was calibrated to best match measured field results. The calibrated n-value was 0.031 for the river channel and 0.1 for overbank areas. Figure 3.13 shows the comparison of the calibrated model water levels with the measured water levels. Figure 3.14 shows the results of the measured velocity against the calibrated model results. The velocity results show more scatter than the water level results due to the nature of measuring the velocity profiles with the ADCP. Given that the ADCP is unable to measure the flows near the edges of the river due to boat navigation and measurement difficulties, the ADCP data will slightly over-estimate the velocities.

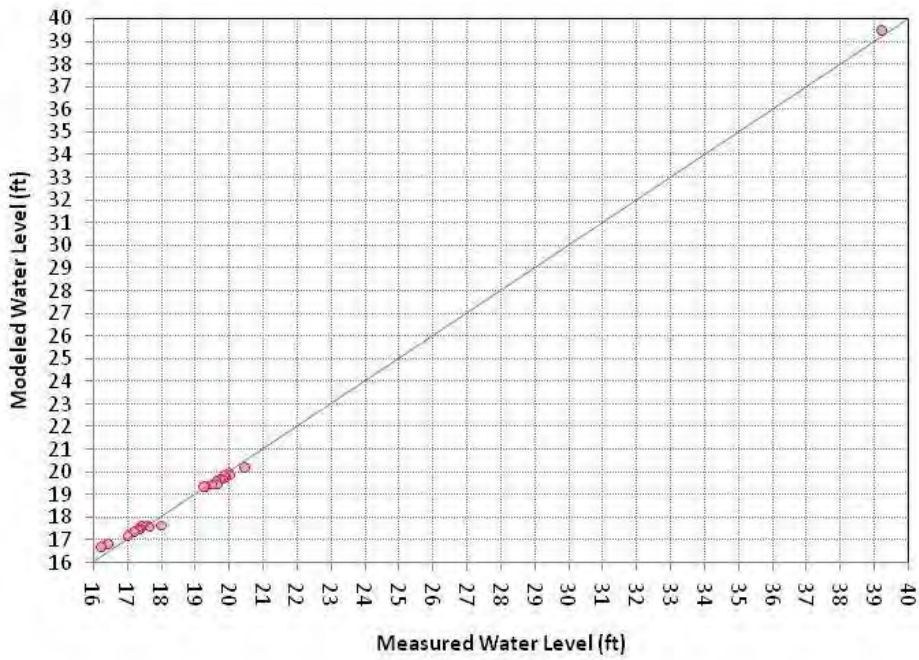

Figure 3.13: Comparison of measured water level with modeled water level from the calibration 1D model (39 ft measurement from USGS gage at Romayor, all other measurements completed by Baird field team).

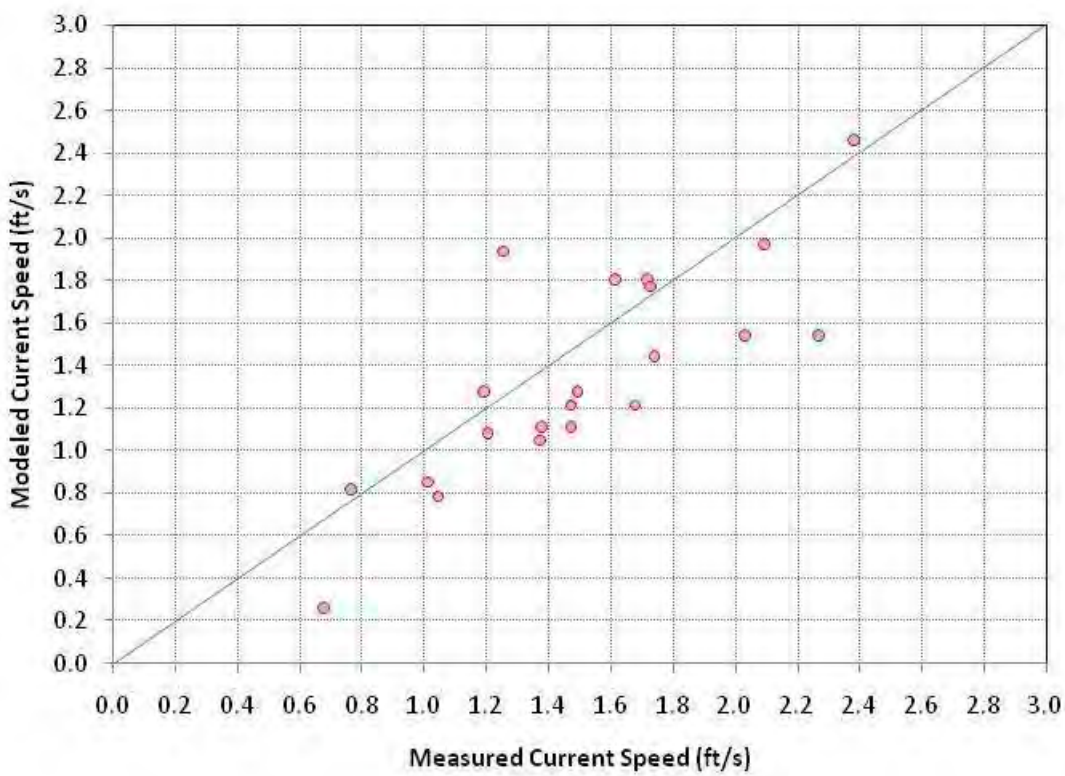

Figure 3.14: Comparison of measured current speed with modeled current speed of the calibrated 1D model

3.4.2 MISED 3D Modeling of the Intake Location

A 3D hydrodynamic model was developed to simulate hydrodynamics and sediment transport in the vicinity of the intake in detail. The Baird in-house model, MISED, was used for this study. MISED is a three-dimensional numerical model that simulates hydrodynamics, sediment transport, and morphology in rivers, estuaries, and coastal areas. It is a finite element model developed by Dr. Lu (Lu & Wai, 1998).

The domain of the 3D model is from the SH 105 bridge crossing to 3.4 miles downstream of the proposed intake location and extended laterally to approximately the 70-ft contour. Two grids were generated for the 3D model: a finite element grid to cover the entire 3D model domain including the floodplain and a more detailed nested grid approximately 2.4 miles long near the intake. The grid was developed using a combination of multi-beam and single-beam sonar data collected by AECOM, LIDAR data near the proposed intake site, and 10m data from the USGS.

Boundary conditions for the model were extracted from the results of the 1D model at the upstream and downstream extents of the 3D model domain.

MISED calculates the bed shear stress for the sediment transport model using Manning's formula, $\tau_b = \rho g \frac{n^2 U^2}{h^{1/3}}$ where U is the depth-averaged flow velocity. The direction for bed shear is calculated by using the flow direction near the river bottom.

For the sediment transport simulation, the median grain size of the bed sediment near the proposed intake site, a d50 of 0.3mm, was used. The model runs with two different sediment classes with a standard deviation: a d50 for bed sediment and a suspended sediment load. The total incoming suspended sediment concentration (SSC), minus clay fraction, was calculated by using the relationship between TSS and flow at the Romayor gage. The clay fraction was excluded because observed suspended sediment data were not available for calibration. Total suspended solids (TSS) data do exist for the observed USGS data at Romayor; however, these were not treated to determine the organic fraction of TSS. As the organic fraction can be a very large component of TSS, particularly in the clay fraction, using TSS data to estimate suspended sediment can greatly over estimate sediment fluxes (Sun, et. al., 2004; Riedel, et. al., 2004; Riedel and Vose, 2002).

The 3D model was calibrated to observed water level and flow data collected from June 4th to June 7th, 2009 (described in Section 3.2). Flow for the upstream boundary of the 3D model and water level from the downstream boundary were extracted from the 1D model for the same calibration period. The MISED model uses a Manning's n value that varies with water depth. The calibrated minimum n value was 0.012 for the river channel and 0.1 for the overbank values. The actual n value varied from 0.012 to 0.1, depending on the water depth.

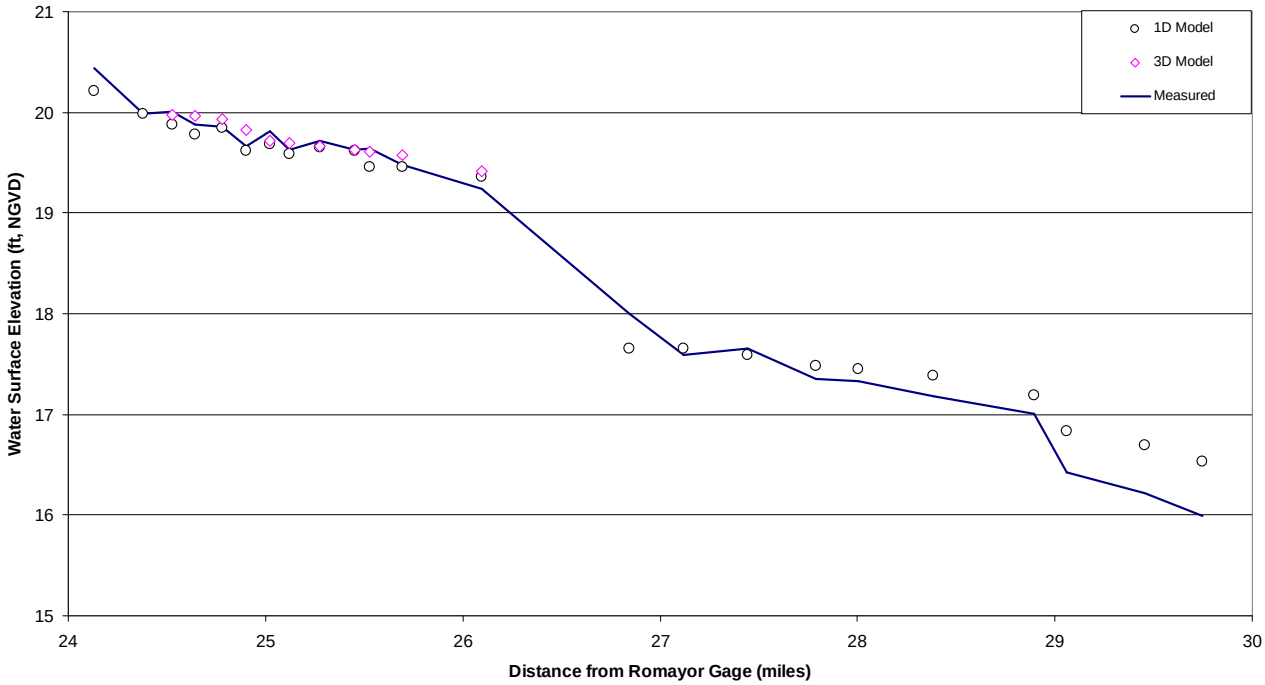

Figure 3.15: Comparison of modeled and measured water levels near the proposed intake site (~25 mile)

The comparison of the 3D model water levels with the measured water levels is shown in Figure 3.15. The measured flow data used to calibrate model to best match observed flow direction and magnitude; an example of the comparison is shown in Figure 3.16. Full model comparison results are shown in Appendix I.

Figure 3.16: Comparison of modeled and measured flow vectors near the proposed intake site (App I-2)

At the time of the field survey, the flow was very low resulting in no measurable suspended sediment. Therefore, direct calibration of SSC was not possible. SSC results were compared to the observed SSC relationship at the Romayor gage however, excessive scatter in the observed SSC data (4 mg/l to over 100 mg/l) prevented drawing any meaningful conclusions (Baird, 2009).

3.4.3 Trinity River Model Alternatives and Intake Design

Following completion of the existing conditions runs, a number of interim modeling results and coordination meetings were held to facilitate the development of the best plan for the proposed intake design. Analyses and reviews of water levels, hydraulics, sediment transport, bed stability, and sediment concentration results for numerous scenarios were conducted to determine an optimal elevation range for the intake invert and apron for the preliminary intake design.

3.4.4 Trinity River Proposed Intake Concept Modeling

AECOM provided Baird with a proposed intake design to be used as the proposed project condition (Appendix I). The main features of this design that altered the model domain were the physical presence of the pump station intake, the intake apron, and revised grade for the pump station. To account for the proposed pump station, the cross section in the 1D model was modified to include the geometry of the proposed intake structure, as shown in Figure 3.17. For each flow scenario, all other physical model parameters remained unchanged from the pre-project model. For the post project modeling, a combination of five flow and water withdrawal scenarios were modeled, Table 3.3.

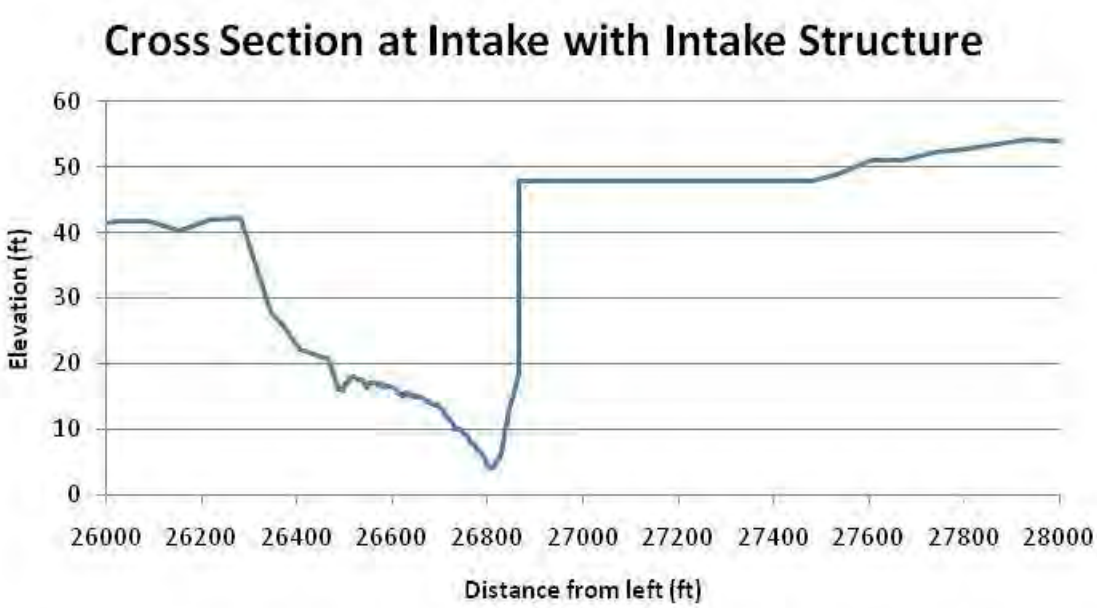

Figure 3.17: The modified cross section at the intake for post-project model run (Note: cross section looking downstream)

Water extractions were simulated in the 1D model as point withdrawals at the modified pump station cross section to account for the pumping withdrawal rates. The pumping rates are also listed in Table 3.3.

Table 3.3: The flow discharge and pumping rates of the five scenarios for post-project model runs

Scenarios for Existing	River Discharge cfs	Pumping Rates MGD (cfs)
Run03 - 1500 cfs	1,500	500 (774)
Run04 - 3000 cfs	3,000	227 (351)
Run07 - 2yr event	49,617	293 (453)
Run08 - 5yr event	75,114	500 (774)
Run10 - 100yr event	135,008	0 (0)

The hydrographic survey, bathymetric, and terrain data that were used to build the terrain and model domain of the 3D model were modified to reflect the presence of the proposed pump station both in cross section and plan view. This had the effect of raising overbank elevation, changing river bank slopes and bank at the intake location, and creating the sloping apron on the bottom of the river channel. All coordinate locations and elevations were checked with AECOM to verify consistency with the provided plans and intended pump station configuration. The existing and proposed river conditions are shown in Figures 3.18 and 3.19, respectively.

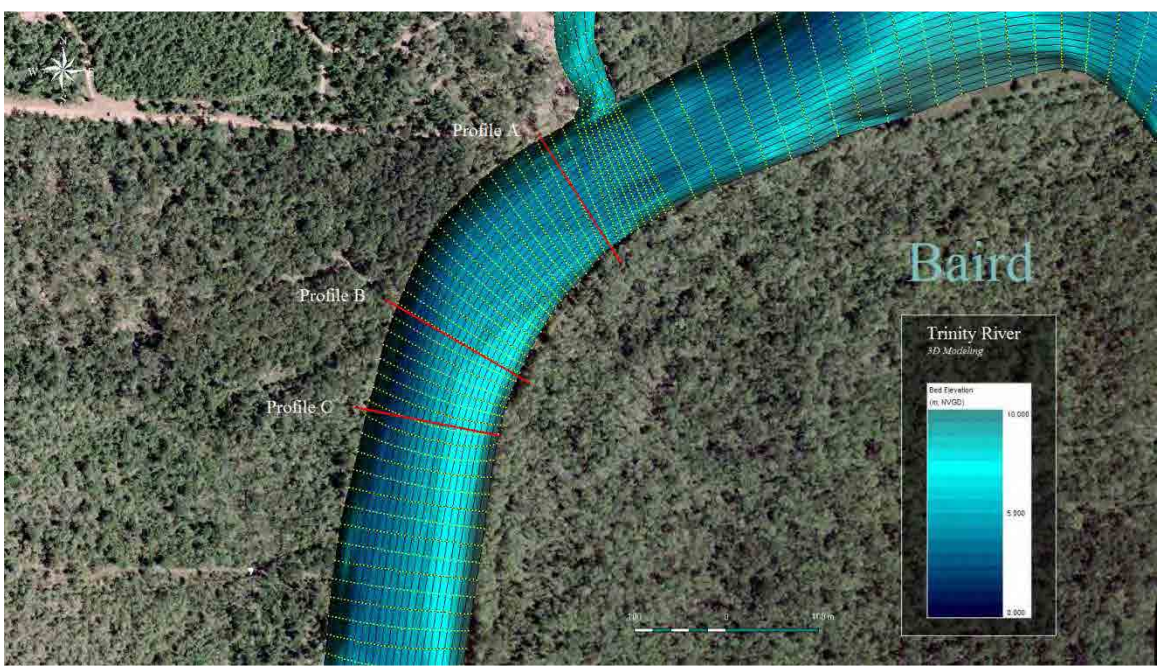

Figure 3.18: Location of the proposed intake site showing existing condition river bathymetry (App I-1)

Figure 3.19: A close-up of the modified river bathymetry model showing the proposed pump station intake, apron, and modified overbank areas. The floodplain model grids were also modified to irregular grid to account for changes to terrain. (App I-1)

Water withdrawals in the 3D model were simulated as extractions from a submerged weir, representing the invert elevation of the specified apron. Sediment withdrawal occurred with water removal at a rate consistent with the concentration of sediment throughout the vertical and horizontal layers of the 3D model. Visualization of the altered flow vectors and water withdrawal with pumping during the 1,500 cfs flow and 500MGD withdrawal scenario is shown in Figure 3.20.

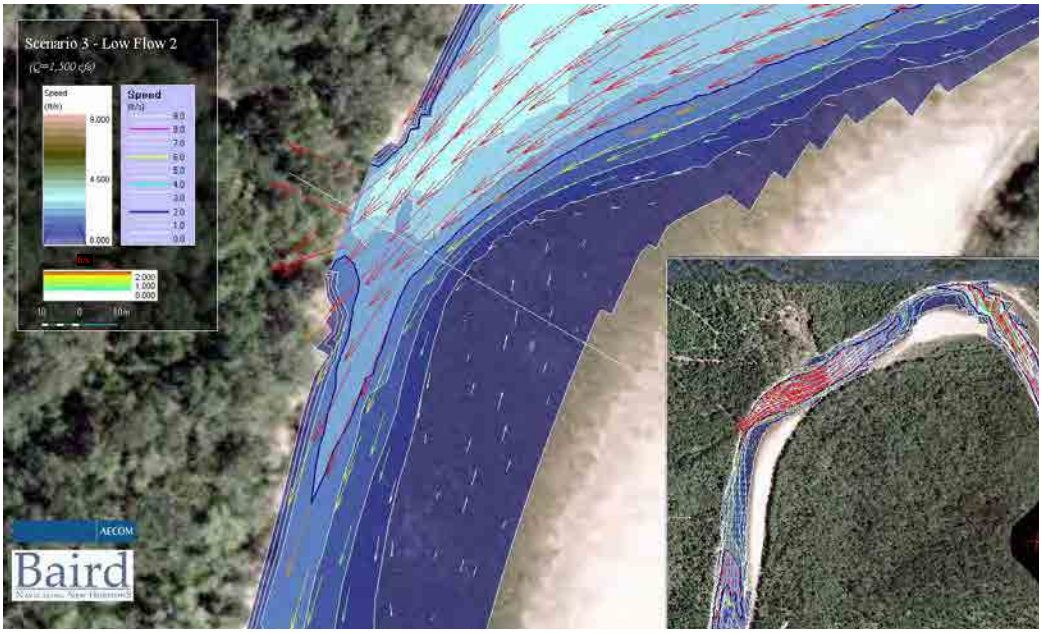

Figure 3.20: A close-up of the proposed condition at the pump station location showing flow vectors and current changes due to water withdrawal. (App I-1)

3.5 Numerical Modeling Methodology: Luce Bayou

This section provides a summary description of the Luce Bayou modeling methods. The reader is directed to Appendix J for a thorough treatment of the modeling methods and results.

The purpose of the numerical model for Luce Bayou was to document the anticipated impacts of the proposed outfall and water diversion from the Trinity River on Luce Bayou, a tributary of Lake Houston. The scope of work for the 2D model study included the following activities:

- Set up of a 2D model domain of Luce Bayou extending from the Crosby Huffman Bridge to Lake Houston;
- Model calibration to observed discharge and water level data.
- Numerical modeling of water level and flow scenarios that encompass the range of extremes and more typical conditions for Luce Bayou, presented in Table 3.4.

Table 3.4: Flow and water level scenarios for the Luce Bayou model

Scenario	Upstream river discharge (ft3/s)	Lake water level (ft)	Description
1	35	44.1	Calibration to observed data
2	53	43.5	Normal water level & river discharge(or low discharge)
3	53	40.1	Low water level & normal river discharge
4	4,340	40.1	Low water level & 2 year river discharge
5	13,621	40.1	Low water level & 10 year river discharge
6	31,159	40.1	Low water level & 100 year river discharge

3.5.1 Numerical Modeling Background

The hydrographic survey of Luce Bayou (Section 3.2 and Appendices), with particular emphasis on the area surrounding the proposed outfall, was used to build the model bathymetry and domain for Luce Bayou, Figure 3.21. The analyses of observed flow and water level records (Section 3.1) were used to establish boundary conditions and simulation parameters for the numerical modeling. The field sampling program (Section 3.3 and Appendices) established flow dynamics and sediment properties for parameterization and calibration of the Luce Bayou model.

3.5.2 Numerical Modeling Overview

The MIKE21 numerical modeling system, as developed by the Danish Hydraulic Institute, was employed in this study. This commercial software system consists of a series of related modules capable of simulating two-dimensional free surface flows, wave growth and transformation, sediment movement, water quality and ecology. The software is very widely applied and accepted

for regulatory compliance by most regulatory agencies including water level and flood studies for FEMA and the U.S. Army Corps of Engineers.

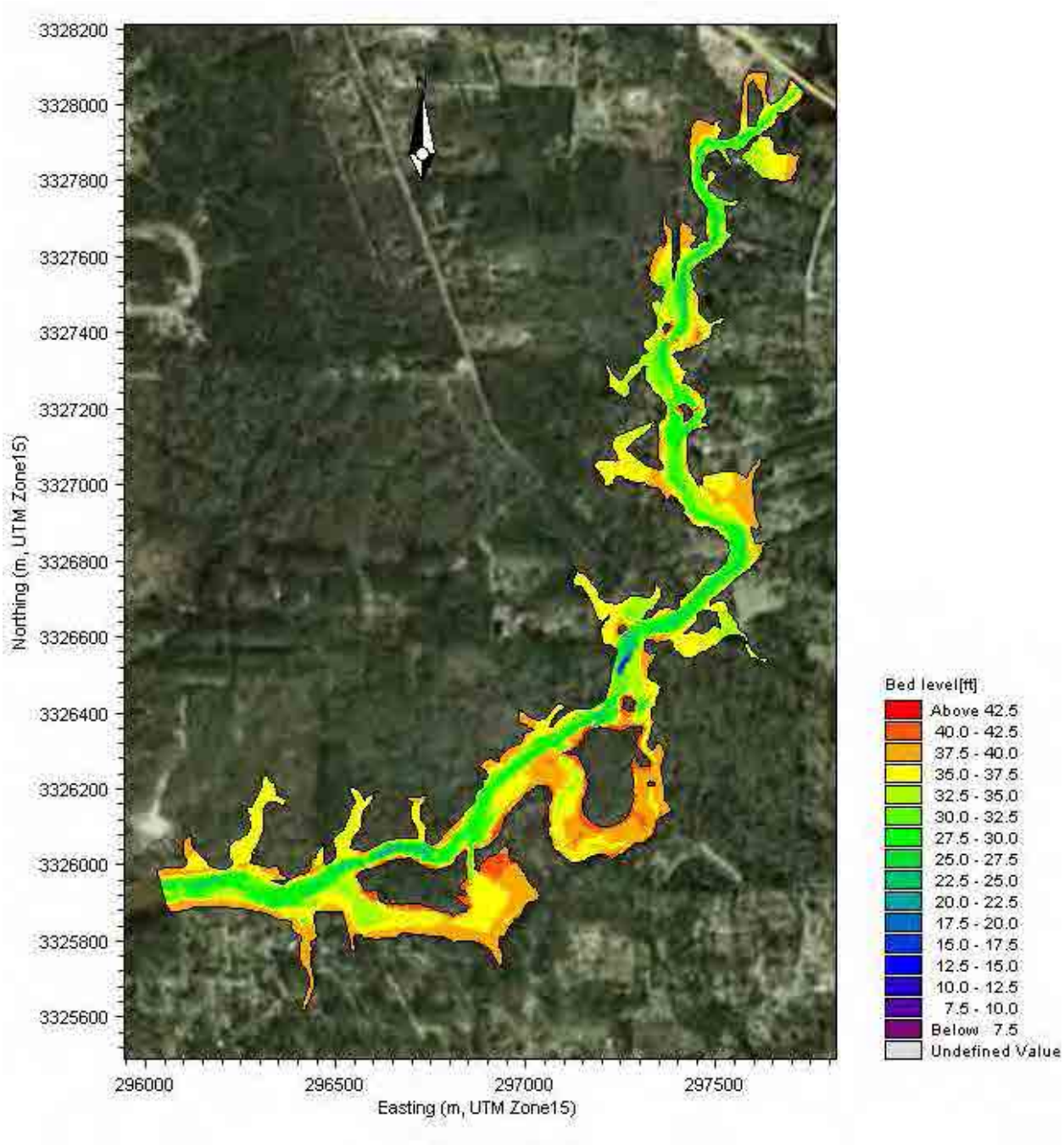

Figure 3.21: Model domain and bathymetry

MIKE21 is based on use of an unstructured mesh employing linear triangular elements. This model is well suited for modeling large complex areas that, at the same time, require a detailed resolution of specific features, such as the Luce Bayou site. To account for complex flow dynamics around the

islands and through Luce Bayou, the MIKE21 Flexible Mesh (M21FM) Hydrodynamic Module was employed with increased mesh density near islands and the proposed outfall (Figure 3.22).

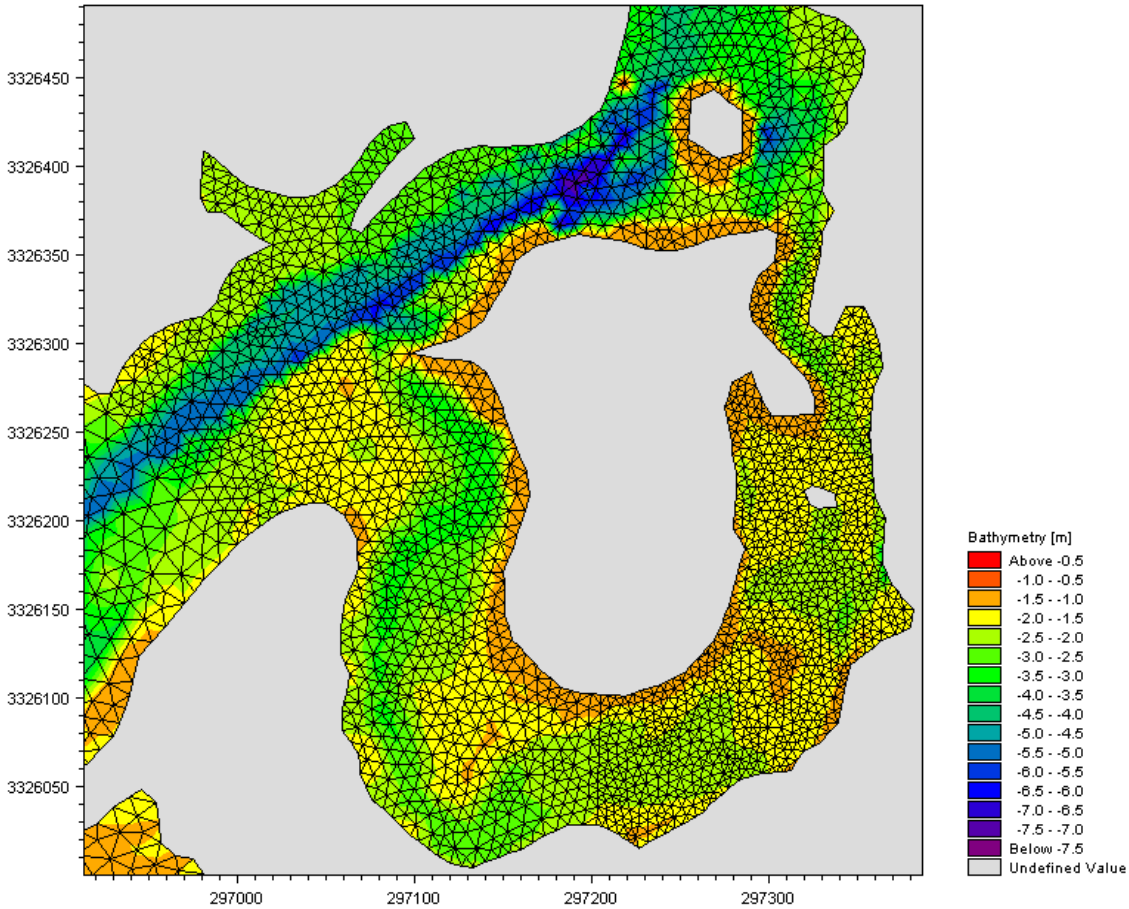

Figure 3.22: Mesh system near proposed outfall

The reader is directed to Appendix J for a full description of model calibration, testing, application to proposed outfall scenarios, selection of recommended outfall alternative, and presentation of results.

3.6 Bank Analysis and Stabilization Concept

Results of river modeling, field work, geotechnical data and analyses (Fugro, 2009), and the concept design of the proposed pump station were used to conduct bank stability analysis, identify locations where bank instability could threaten the future integrity of the proposed pump station, and develop three conceptual bank protection alternatives to reinforce outside bank of the meander bend where the proposed intake is to be located.

3.6.1 River Banks Upstream and Downstream of Intake Location

Possible locations of meander migration, river realignment, and meander cutoff that would threaten integrity of the proposed intake were identified. While the Trinity River is an actively meandering river with numerous bends, the large meander bend located at point bar (PB) 9 (Figure 3.2) is of particular importance. This section has been identified previously as a likely candidate for meander cutoff as continued erosion of this bend would allow the Trinity River to cut a new river channel, circumventing the proposed intake location (Phillips, 2008a).

Due to the size of the Trinity River, excessive bank height, and scale of the meander at this point bar, typical bank protection practices alone would not suffice to protect this meander from further erosion. Consequently, in-channel hydraulic structures were also considered as alternatives to reduce the risk of meander cutoff at this location (Odgaard, 2009; USACE, 2005; Thorne, et. al., 1997). Recommended concepts for addressing instability of this bend are presented in Appendix K.

3.6.2 Hardened Banks at Intake Location

Concept drawings for the proposed intake were used to assess the potential extent of bank hardening. Geotechnical logs and bore records were provided by Fugro and used to conduct geotechnical analysis of the banks (Fugro, 2009). Elevation and survey data included LIDAR terrain data and multi-beam hydrographic survey data of the river that were provided by AECOM. Full details of the concept methods are provided in Appendix K. Of a number of potential scenarios considered, three have been selected as the most likely concepts to consider for full development. These are discussed in the results section.

In all three alternatives, stone gradations and layer thickness were conceptually designed using empirical methods outlined in the Coastal Engineering Manual (2006) and Engineering Manual 1110-2-1601 Hydraulic Design of Flood Control Channels (USACE 1994). Sheet pile walls were conceptually designed for short and long term loading conditions based upon analysis of water level records and provided soils and geotechnical information (Fugro, 2009).

4.0 RESULTS

4.1 Desktop Analysis

4.1.1 River Course Analysis

River bank migration analysis was undertaken to better understand the historic changes in channel alignment in the vicinity of the proposed intake site and to help identify likely areas of future channel instability. This analysis was undertaken on the river from the SH 105 crossing down to approximately three miles downstream from the intake site. Digital orthophotos were analyzed for the years 1995, 2004, 2006 and 2008. Previous periods were analyzed by Wellmeyer et al. (2005), who identified a major meander cutoff event upstream from the intake in the period 1989-1995 (Figure 4.1).

The full set of bank migration analysis results are in Appendix A. Analysis of the 1995-2008 photographs did not identify any meander cutoff or channel avulsion event (major relocation of the river channel) in the study area. However, there was significant migration of meander bends and point bars in the period 1995-2004. For the meander bend PB9 and PB10, immediately upstream from the intake site, the downstream portion (below the meander apex) of the cutbank on the meander bend migrated downstream by approximately 260 feet, giving a mean migration rate of around 30 feet per year (Figure 4.2). Bank analysis on the point bar indicates that downstream migration of the lee side of the bar was approximately 380 feet over the same time period, or an average of 43 feet per year. Similarly, there has been significant meander migration at PB10, just upstream of the intake. Meander migration is not constant over time because migration can be greatly accelerated during higher flow events, so an annual rate should be taken as a very approximate guide, especially given the short time period of the analysis. Inspection of the flow records for Romayor (Table 4.3) shows several large flows during this time period, when the majority of meander migration would have occurred. A full discussion of meander migration rates in the vicinity of the project site is presented in Section 5.0.

In contrast to the active meander migration observed at PB9 and PB10, Figure 4.3 shows that the river bank at the intake site has been relatively stable (within the errors of the bank migration analysis) over the period 1995-2004, and historically nearly 100 years from the literature review. This likely reflects the influence of Capers Ridge, both as being more resistant to erosion than other alluvial sediments in the valley, and also the potential for Capers Ridge to redirect flood flows away from the bank at the intake site (see Section 5.0 for discussion).

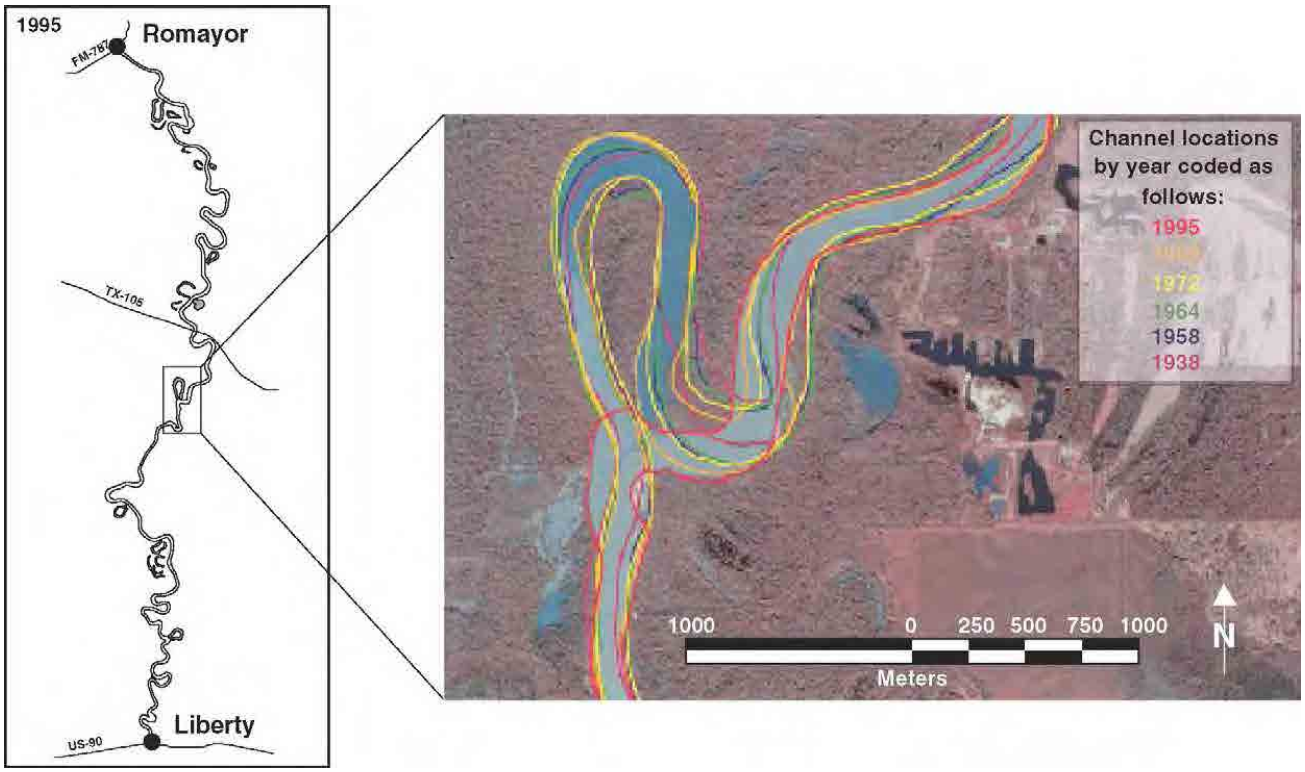

Figure 4.1: Channel changes upstream of intake location 1938-1995 (Source: Wellmeyer et al., 2005)

Figure 4.2: Historic bank analysis for meander bends upstream from intake site

Figure 4.3: Historic bank analysis for banks at the intake site

4.1.2 Point Bar and Vegetation Analysis

General observations from the point bar and vegetation surveys are summarized here. The reader is directed to Appendix E for specific results for each bar. The results from mapped point bars (Figure 3.2) provide measurements of bar size in surface area and volume, Figures 4.4 and 4.5, respectively. Results from both the area and volume estimates show moderate growth of upstream bars (PBs 2 through 9), very reduced, to no bar growth in proximity to the proposed intake site (PBs 10, 11, and 12), and moderate to large growth of bars downstream (PBs 13 to 16).

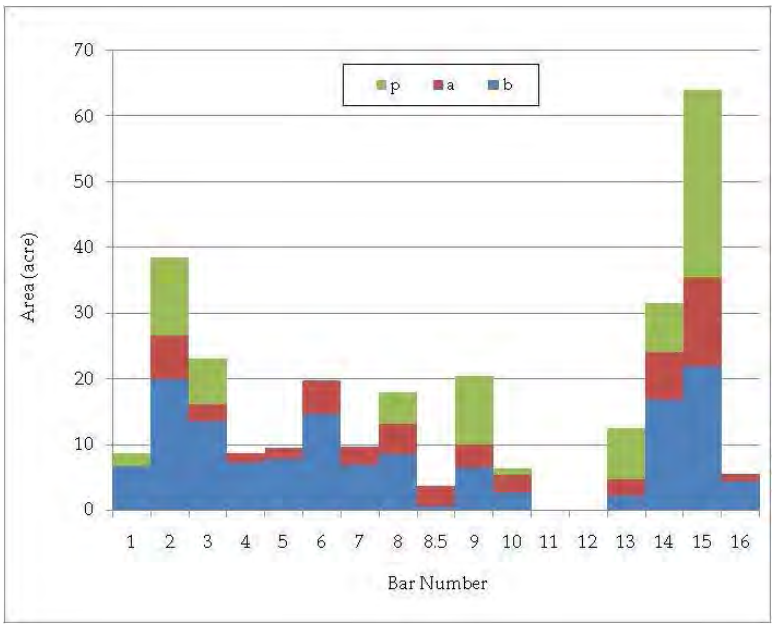

Figure 4.4: Trinity River surveyed bar areas.

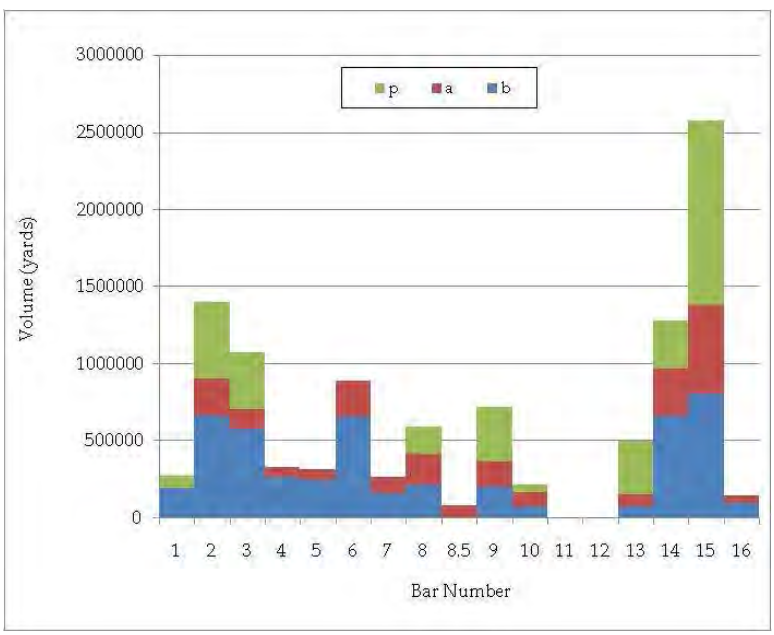

Figure 4.5: Trinity River surveyed bar volumes.

4.1.3 Analysis of Flow Records

Hydrologic events such as precipitation, river flow, and "design event" floods are stochastic processes. It is imperative to understand the nature of such processes, and the concepts of probability, risk, and stationarity. This is especially true for critical infrastructure projects, such as the proposed Luce Bayou Interbasin Transfer Project.

Probability is simply the "odds" of observing a selected outcome. For example, when using the annual maximum series of flow records, from a "stationary" flow record, the probability of experiencing the actual "100 year event" in any given year is one percent. This probability is the same every year, regardless of how recent or distant the last "100 year event" occurred. This is because design events are, by definition, independent; the occurrence of any design event in a given year does not change the probability of another similar event in subsequent years, or even the same year. However, as the probability of a single occurrence is additive with time, the risk of occurrence and potential project failure increase with time.

Risk represents the cumulative probability of experiencing at least one specific outcome over a certain number of observations. For example, the risk of experiencing at least one 100 year event in any random 50 year period is 39.5%, Table 4.1 (Haan, 1994; Kite, 1988).

Table 4.1: Tabulated risks of failure by design event and expected project life. Note, values displayed as 99.9% represent theoretically maximum risks as 100% risk of failure does not exist.

Prob. of Exceedance	Recurrence Interval	Expected Project Life in Years					
		10	20	30	40	50	100
50%	2	99.9%	99.9%	99.9%	99.9%	99.9%	99.9%
20%	5	89.3%	98.8%	99.9%	99.9%	99.9%	99.9%
10%	10	65.1%	87.8%	95.8%	98.5%	99.5%	99.9%
5%	20	40.1%	64.2%	78.5%	87.1%	92.3%	99.4%
2%	50	18.3%	33.2%	45.5%	55.4%	63.6%	86.7%
1%	100	9.6%	18.2%	26.0%	33.1%	39.5%	63.4%

The example above is just for the occurrence of at least one, 100 year event; this does not include additional risk for multiple occurrences or larger events. This, combined with a desired project life span, disproportionately increases the probability, or “risk”, of observing an event that exceeds the desired life span. Thus, disproportionately larger design storms need to be used with increasing project life to maintain an acceptable level of risk. For example, if the capacity of a hydraulic structure is designed to have a 5% risk of being exceeded in 10 years time, a design event with 0.5% probability of exceedance (note – this would be equivalent to a “195 year recurrence interval” event) would need to be used for design purposes (Table 4.2).

Table 4.2: Tabulated values of annual maximum event return periods necessary to meet expected project life and desired risk of failure. (Adapted from Kite, 1988; Yen and Ang, 1971).

Risk of Failure	Recurrence Interval	Expected Project Life in Years					
		10	20	30	40	50	100
50%	2	15	29	44	58	73	145
20%	5	45	90	135	180	225	449
10%	10	95	190	285	380	475	950
5%	20	195	390	585	780	975	1,950
2%	50	495	990	1,485	1,980	2,475	4,950
1%	100	995	1,990	2,985	3,980	4,975	9,950

For large projects, where project components may experience independent or different stochastic processes due to spatial separation and/or differences in climatic regime, the concepts of "joint probability" and "join risk" must be considered. This is the case for the Luce Bayou Interbasin Transfer Project because there is enough separation between the proposed intake, canal, and outfall, that each project component may likely experience independent events. Thus, when the combined probability and risk of all project components are added up, the "joint risk" of the system failing (because of a single critical element failure) is higher than the risk of any given component failing. The treatment of "joint probability" and "joint risk" are complex subjects beyond the scope of the current study. However, they are of critical importance and therefore, warrant mention.

The importance of the concepts of probability and risk, and understanding what these terms really mean, has been discussed. The concept of "stationarity", or of "stationary" records, refers to stochastic processes and the databases we develop to understand them. A stochastic record, such as precipitation intensity or flow records, is stationary if the settings and conditions that produce the event, as well as the settings and conditions under which the event is measured, are not changing over time. Thus, there is no bias in the data record due to either instrumentation or change in regimes, such as climatic change. Stationarity is very important because it forms the foundation upon which all stochastic statistics are based. If stationarity is violated, all statistics associated with probability, risk, and the values tabulated in Tables 4.1 and 4.2 are inaccurate.

Historically, we relied upon stationarity in records for design purposes. This assumption may no longer be valid because hydrologic risk is changing; this has been widely published and validated throughout the world. The anticipated effects in the southern coastal region are increasing risk of storminess, large scale climatic driven natural hazards, and increased frequency and magnitude of flooding (Hurrell, 2007; Riedel, 2006; Hayden and Hayden, 2003; Hurrell, 2003; Hurrell, et. al., 2003). Over the period of record, the Trinity River at Romayor exhibits a positive bias in flood magnitude (described below); this is consistent with published long-term USGS review of records for the eastern United States which attributes this to step-wise increase in storm events - a break in stationarity (McCabe and Wolock, 2002).

4.1.3.1 Trinity River

Analysis of USGS historical peak flow data from 1938-2009 at the Romayor gage site shows the largest annual peak flow on record of 122,000 cfs, as having occurred on October 19th, 1994. Table 4.3 summarizes the largest annual peak flows recorded in the post-dam construction period. While the highest peak flow was in 1994, the largest overall flow event may be that of 1990, during which peak flows were sustained over many days. Figures 4.6 and 4.7 illustrate the observed flow data using color gradation, for the period 1969 to present for the USGS gages at Romayor and Liberty, respectively. This period represents the current flow regimes and conditions since completion of Lake Livingston Dam. In these figures, low flow periods are represented by red regions, with moderate to higher flows shifting to green and blue colors. The highest flow periods are black while periods of missing data are white. The annual pattern of variation shown in these figures shows a dry season from July through to October/November, and wetter conditions in the remainder of the year, during which floods may occur. This is typical of the humid subtropical climate in the region. Median daily variation for flow data at Romayor are shown in Figure 4.8.

Table 4.3: Largest Annual Peak Flows Recorded at Romayor USGS Gage

Date	Flow (cfs)	Rank
10/19/1994	122,000	1
5/21/1990	105,000	2
6/15/1973	99,000	3
11/15/1998	98,600	4
1/3/1992	85,300	5
7/2/1989	83,500	6
11/7/2002	78,100	7
1/8/1998	77,300	8
6/11/2001	76,100	9
6/27/1993	63,800	10
1/19/1991	63,400	11
7/2/2004	62,600	12
4/22/1979	61,500	13
1/28/1974	59,900	14
7/20/2007	59,300	15
9/25/2005	57,400	16
6/27/1986	54,200	17
5/22/1983	52,700	18
3/13/1997	52,700	18
4/22/1977	52,300	20

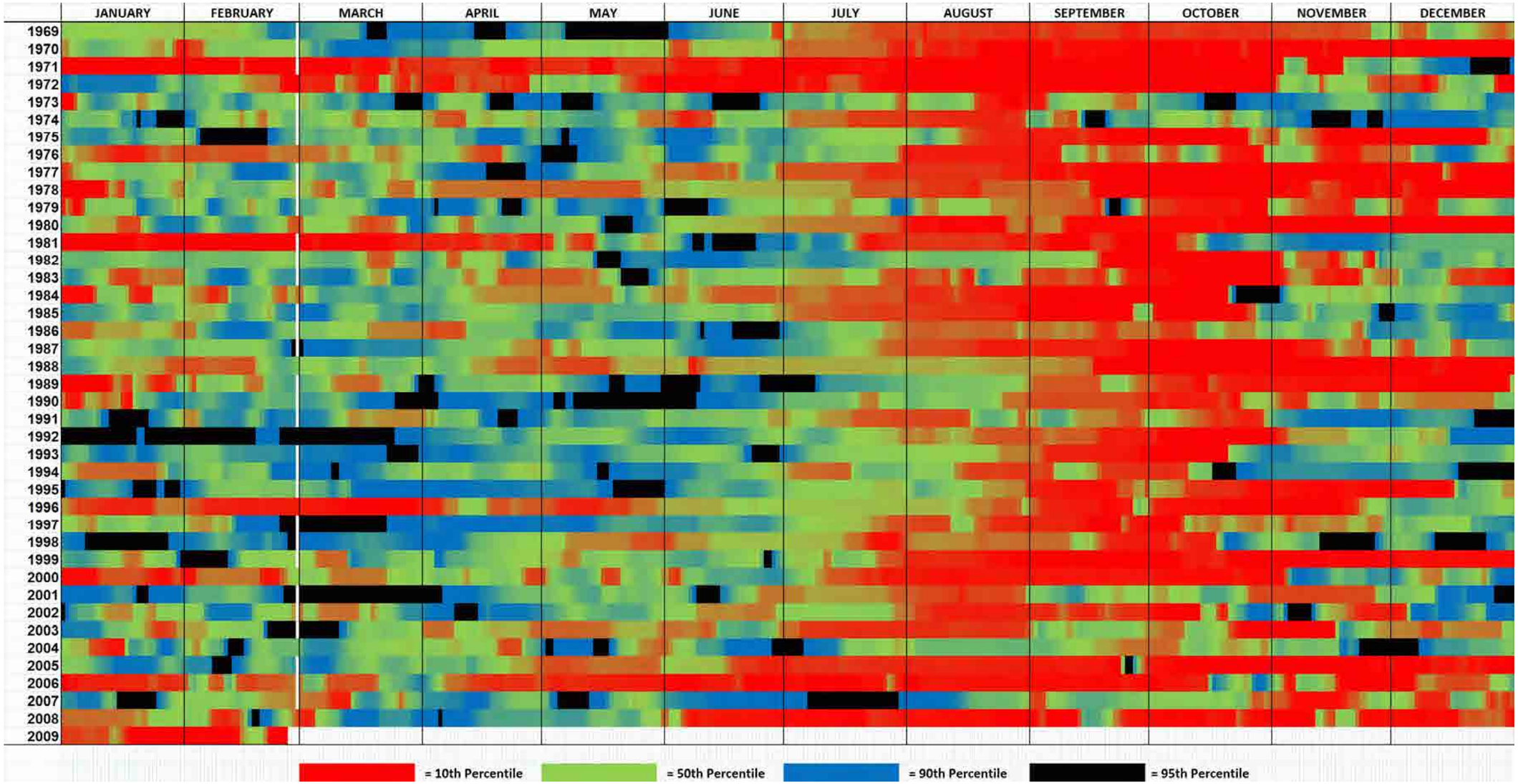

Figure 4.6: Flow history for the period 1969-2009 for the USGS gage at Romayor, TX

Figure 4.7: Flow history for the period 1969-2008 for the USGS gage at Liberty, TX (white areas indicate areas where water level fell below a threshold of measurement for discharge or no measurement available)

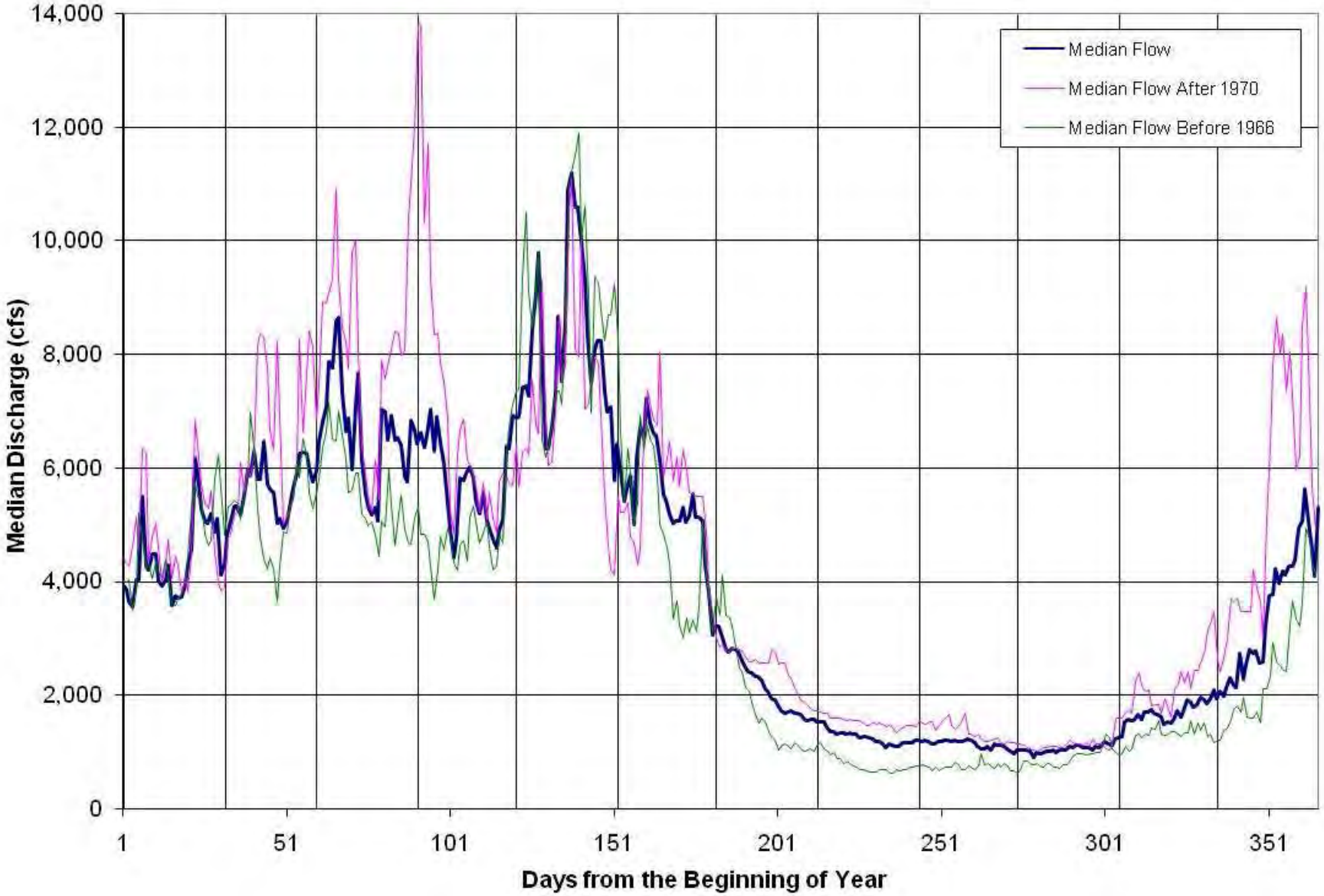

Figure 4.8: Median daily flow variations for the USGS gage at Romayor, TX

General summary statistics for Romayor and Liberty are shown in Table 4.4. Summary statistics for Liberty water levels were used as the downstream boundary conditions for numerical modeling.

Table 4.4: Discharge (cfs) Summary Statistics for Romayor and Liberty gaging stations

	Romayor Discharge	Liberty Discharge	Liberty Water Level
Period of Record	1969-2008	1969-2008	1996-2008
Count	14,610	4,477	1,227
Mean	8,726.6	22,328.7	19.51
Median	2,970	19,900	19.76
Min	292	2,200	9.24
Max	117,000	130,000	26.61
StDev	11,959.1	12,940.2	4.01
Skew	2.47	1.56	-0.12
Range	116,708	127,800	17.37
1st Quartile	1,440	13,000	16.14
3rd Quartile	11,400	29,000	22.80

4.1.3.2 Luce Bayou

Analysis of USGS historical peak flow data from 1990-2008 at the Huffman gage site shows the largest annual peak flow on record of 23,000 cfs. Table 4.5 summarizes annual peak flows. Observed water level data for Lake Houston (USGS) were converted to elevations for the period of reliable measurement (1996-2008). The maximum and minimum water levels are 40.11 and 49.26 feet (above MSL) respectively. The mean water level is 44.1 feet.

Table 4.5: Discharge (cfs) Summary Statistics for Huffman gaging station

Period of Record	1990-2008
Count	6,913
Mean	197.1
Median	9.6
Min	0
Max	23,000
StDev	806.5
Skew	13.04
Range	23,000
1st Quartile	1.5
3rd Quartile	76

4.1.3.3 Flow Return Period

Flow return period is an expression of the likelihood of a river system experiencing a flow of a given magnitude. Understanding the return period of flows in the Trinity River is essential to appropriate intake and bank protection design, and also to understanding the morphodynamic behavior of the river system in the vicinity of the proposed intake. The flow return period for the Trinity River was determined using the USGS computer program, PeakFQ, for the following stations:

- #08066500 - Trinity River at Romayor, TX
- #08067000 - Trinity River at Liberty, TX

PeakFQ provides estimates of instantaneous annual-maximum peak flows for a range of recurrence intervals, including 1.5, 2, 2.33, 5, 10, 25, 50, 100, 200, and 500 years (annual-Exceedance probabilities of 0.67, 0.50, 0.43, 0.20, 0.10, 0.04, 0.02, 0.01, 0.005, and 0.002, respectively). The Pearson Type-III frequency distribution was fit to the logarithms of instantaneous annual peak flows following Bulletin 17B guidelines of the Interagency Advisory Committee on Water Data. Figure 4.9 shows the output from PeakFQ for flow frequency at the Romayor gage.

The construction of Livingston Dam in 1968 has had a significant impact on the flow characteristics of the lower Trinity River, so the frequency analysis was carried out for three periods: all data records; post-dam operation, and pre-dam operation (Table 4.6).

Table 4.6: Summary of Frequency Analysis for Annual Peak Flow

		Return Year/Return Flow (Years / CFS)					
Station	Years	2	5	10	25	50	100
	All Records (1924-2008)	43,300	67,200	83,100	103,000	117,000	131,000
Romayor	Pre-Dam (1924-1968)	38,400	60,100	75,100	94,300	109,000	123,000
	Post-Dam (1969-2008)	49,600	75,100	91,000	110,000	123,000	135,000
	All Records (1940-2008)	41,700	65,600	81,900	103,000	118,000	133,000
Liberty	Pre-Dam (1940-1968)	36,400	59,900	77,300	101,000	119,000	139,000
	Post-Dam (1969-2008)	46,000	69,600	84,600	103,000	115,000	127,000

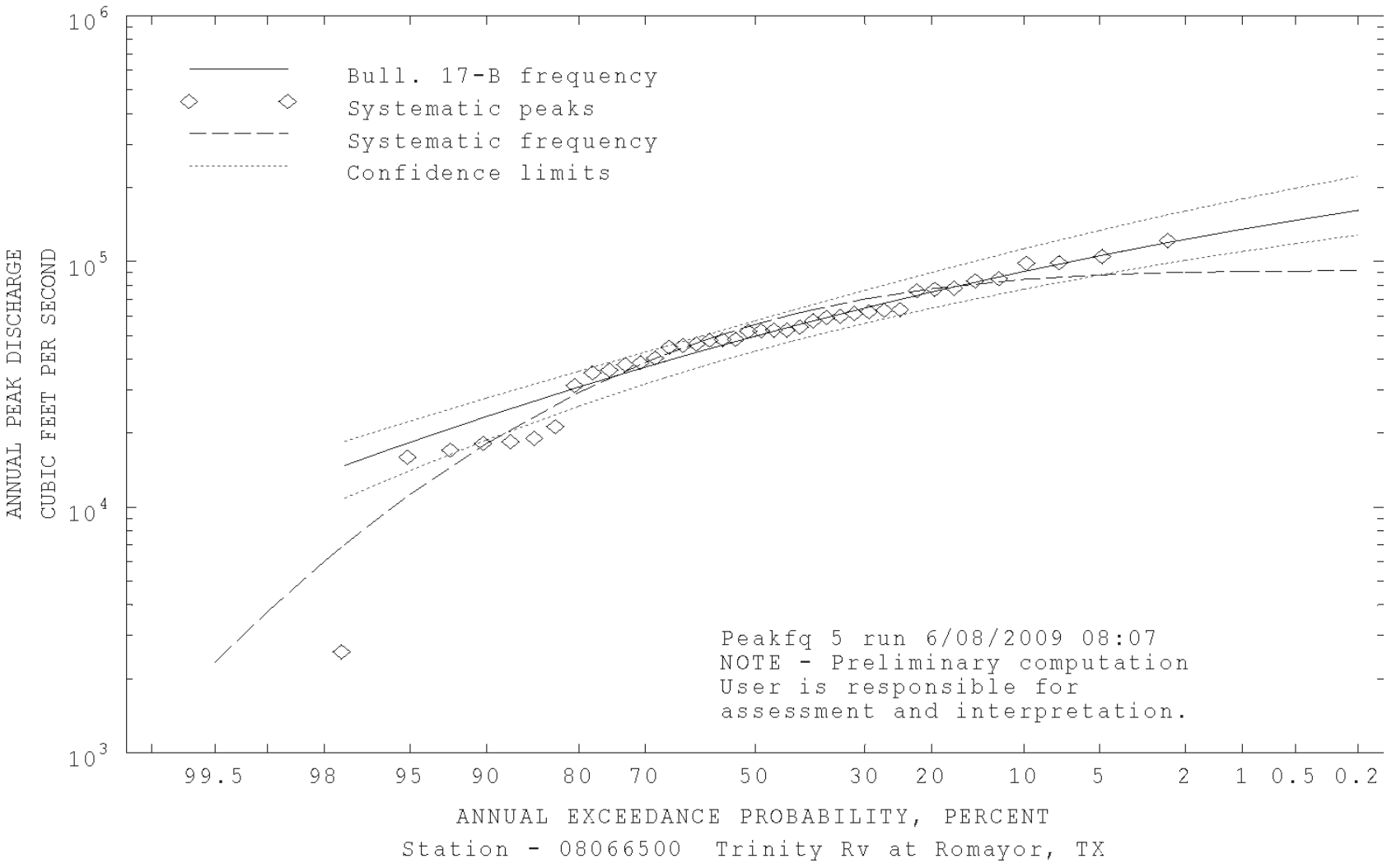

Figure 4.9: PeakFQ Output for Flow Frequency Analysis at Romayor

Table 4.6 shows that discharge during the post-dam period at Romayor is approximately 7 % larger than discharge at the Liberty gage. This net decrease in downstream discharge may be due to a combination of groundwater recharge, flow diversion into floodplain storage (e.g. oxbow lakes) and distributaries along this river segment. Additionally, tidal fluctuations from Galveston Bay extend up river to the Liberty gage causing backwater effects that likely reduce peak discharge values; total discharge volume of large floods would be conserved. The frequency analysis shows that the impact of Livingston Dam on the river flow is significant and therefore the flow return period analysis conducted for the post-dam period was used for this project and is recommended for any design considerations.

The daily (as opposed to peak) streamflow data for the Romayor and Liberty gages span over 80 and 60 years of record, respectively. These data were also analyzed by using PeakFQ (Table 4.7). The flow return period estimated for the post-dam period at Liberty is again approximately 7% smaller than that at Romayor.

Table 4.7: Summary of Frequency Analysis for Daily Flow

		Return Year/Return Flow (Years / CFS)					
Station	Years	2	5	10	25	50	100
	1926-2008	42,300	66,400	82,300	102,000	116,000	130,000
Romayor	1926-1968	36,900	58,900	74,400	94,500	110,000	125,000
	1969-2008	48,600	73,100	88,300	106,000	118,000	130,000
	1941-2008	41,200	64,900	80,800	101,000	115,000	130,000
Liberty	1941-1968	36,200	60,500	78,400	103,000	122,000	141,000
	1969-2008	45,100	67,700	81,900	98,800	111,000	122,000

4.1.3.4 Stage

As an initial approximation prior to determination of flow stage by numerical modeling, flow stage at the project site was estimated by using a linear interpolation between stages at Romayor and Liberty. In order to determine the stages for different flow return periods, the correlation between stage and discharge was developed using daily stage and flow. Peak stage and flow data were added to the analysis to extend the dataset for larger flows. Figures 4.10 and 4.11 show the correlation between stage and flows at the USGS gages at Romayor and Liberty, respectively. The equations of the fit lines and the r-squared value are listed in Table 4.8. The fit-line equation was used to determine the stages at the gages for different year return flows.

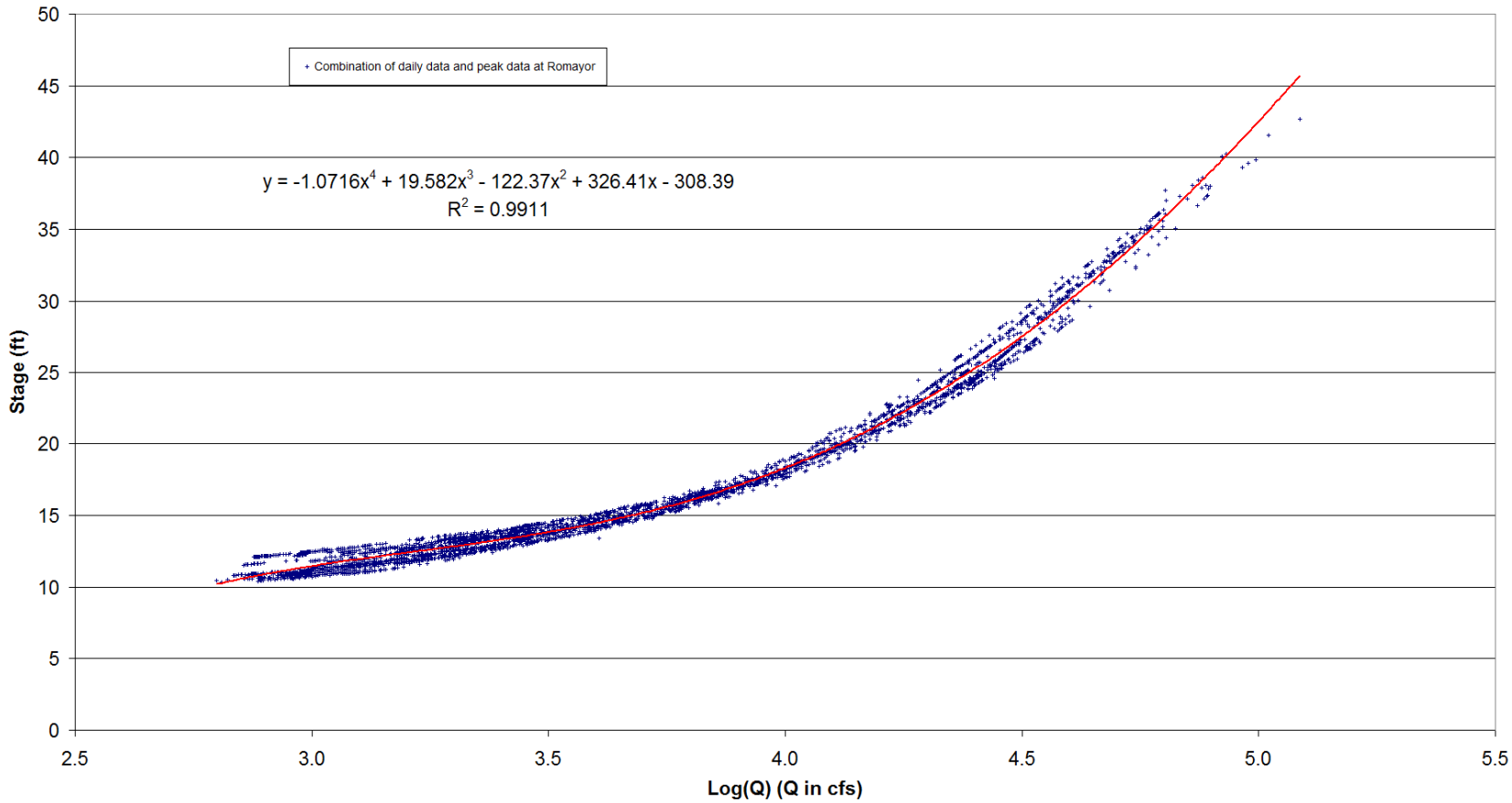

Figure 4.10: Correlation of stage and discharge at the Romayor gage

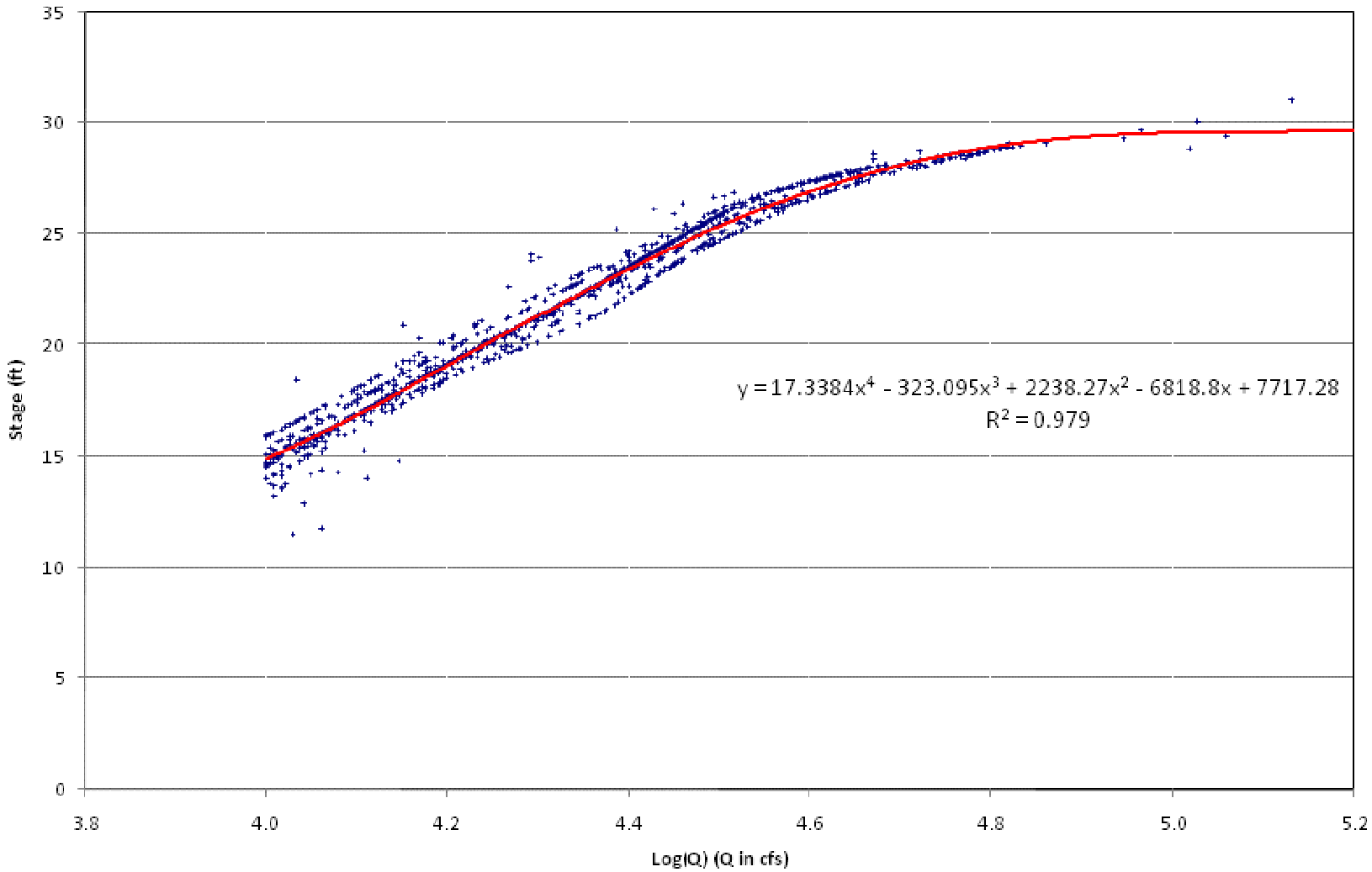

Figure 4.11: Correlation of stage and discharge at the Liberty gage

Table 4.8: Fit-line Equation and Correlation Coefficient for Stage and Discharge Relationship

Gage	Romayor	Liberty	Huffman
Fit line equation	$y = -1.0716x^4 + 19.582x^3 - 122.37x^2 + 326.41x - 308.39$	$y = 17.337x^4 - 323.08x^3 + 2238.1x^2 - 6818.3x + 7716.7$	$y = -0.168x^4 + 1.461x^3 - 2.3442x^2 + 2.0054x + 8.2172$
r^2	0.99	0.98	0.99

Where x = log(Q), Q flow discharge in cfs and y is stage in feet. The above equation was used to determine the stage at the gage for different return flows.

4.1.4 Trinity River Sediment Budget Analysis

The results of the sediment budget analysis for the eleven flow, and 400 and 277 MGD withdrawal scenarios are shown in Figures 4.12 and 4.13, respectively. These two withdrawal rates represent the most likely range of withdrawal rates that will be implemented; at the time of analysis, final decisions regarding what rates would ultimately be used had not been made. Predicted daily sediment fluxes for existing conditions, upstream of the proposed intake, and downstream of the intake are plotted as bars against discharge for the eleven flow scenarios. For each of the 11 scenarios analyzed for daily sediment flux, the analysis used a constant flow for an entire day; the difference between the upstream and downstream fluxes is the load from upstream minus the amount of sediment estimated to be withdrawn with intake water. The sediment concentrations for each flow were estimated based on the relationship between discharge and modeled average cross section sediment concentration (Figure 4.14). These results are treated within the context of all study results in the discussion section of this report.

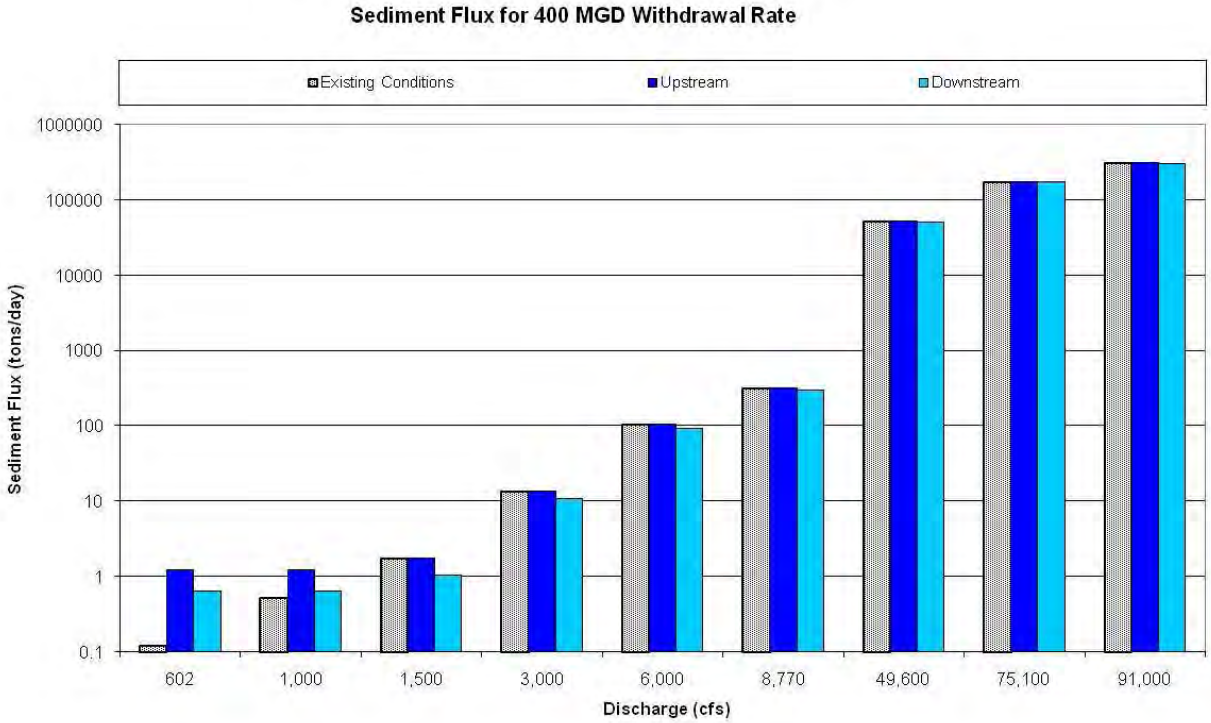

Figure 4.12: Estimated sediment flux and intake rates for 400 MGD withdrawal scenario

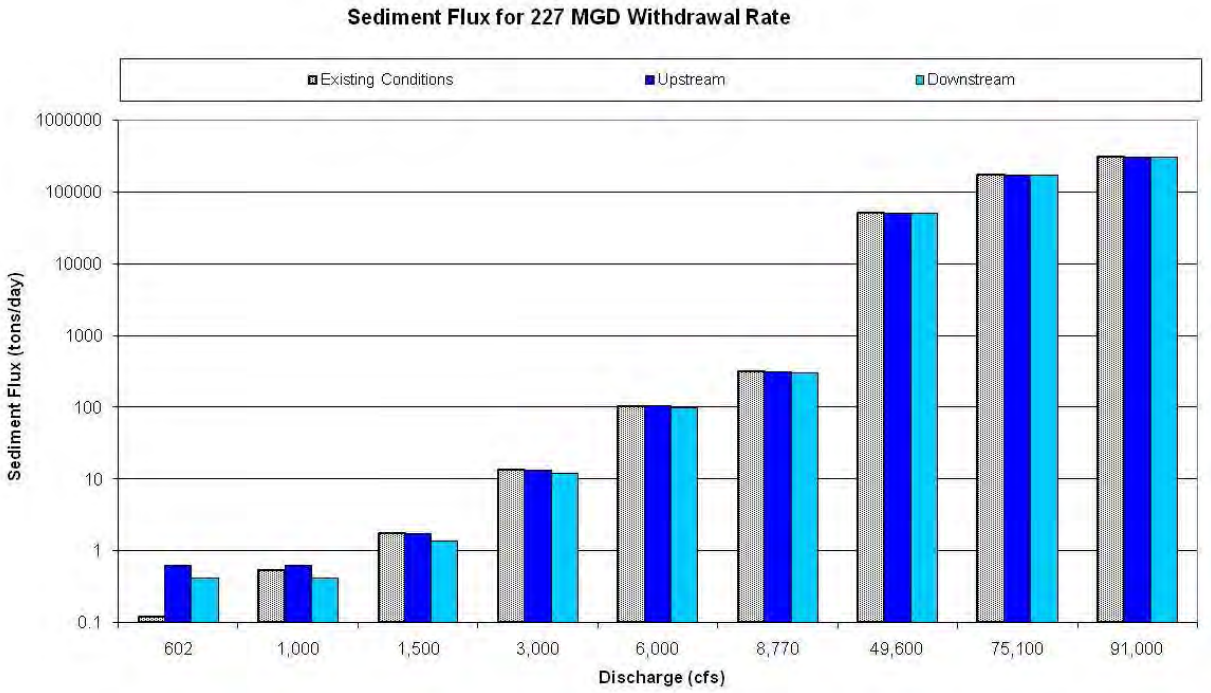

Figure 4.13: Estimated sediment flux and intake rates for 227 MGD withdrawal scenario

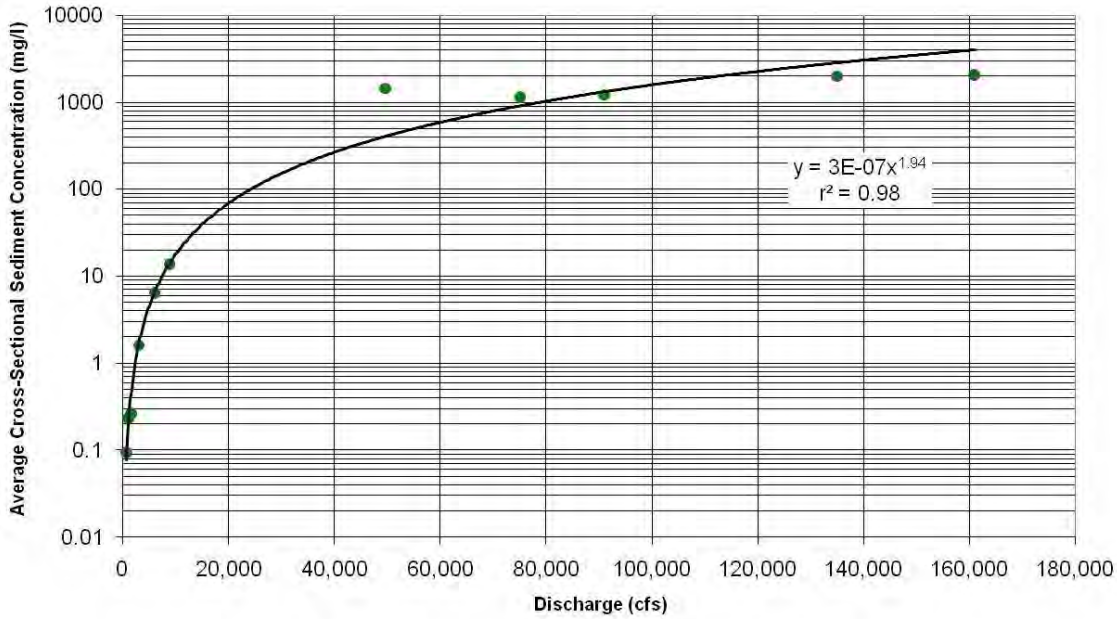

Figure 4.14: Relationship between discharge and sediment concentration from results of 3D model

The sediment budget results were "annualized" to represent "typical" conditions that might be expected for any given year by integrating the flows over the observed discharge frequency at the Romayor USGS stream gage (Figures 4.15, Figure 4.16). The annualized sediment budget approach is a method developed by the U.S. Army Corps of Engineers for this purpose (USACE 2006b). Flow values listed along the x-axis of these figures were chosen to represent the full range of flows over which water withdrawal would occur (up to, and including, the 10 year event). In this analysis, only flow records from after the Lake Livingston Dam was built were used for frequency analysis to best represent current and future conditions. Flow releases from Lake Livingston were assumed in the frequency analysis to maintain flows of at least 700 cfs downstream of the intake. The 700 cfs minimum flow value was established with discussions with AECOM to estimate the impact that a minimum flow requirement would have on the sediment transport near the proposed project site. For example, for a 400 MGD scenario, which equates to approximately 620 cfs, the flow upstream of the diversion would not drop below 1,320 cfs because of release from Lake Livingston. This provides a "worst-case" scenario analysis as additional flow releases produce the greatest hydraulic stress on the river.

The difference between the upstream and downstream results, Figures 4.15 through 4.16, is the amount of sediment estimated to be withdrawn based on the average cross section sediment concentration estimated from the 3D modeling results. The log scales in these figures emphasize small changes with low flows but mask changes during high flows. Figures 4.17 through 4.18 show the percent change in annualized sediment load from the existing conditions under constant withdrawal scenarios, 400 MGD and 227 MGD respectively.

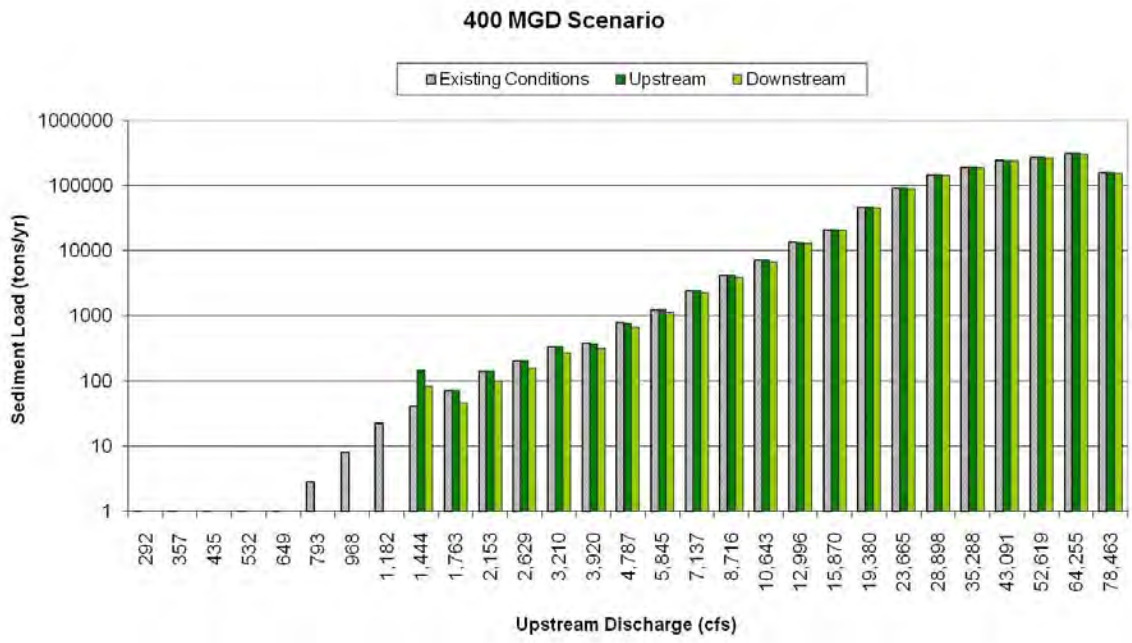

Figure 4.15: Estimated Annualized sediment load estimation for the 400 MGD scenario based on the observed flow data after the construction of Lake Livingston Dam

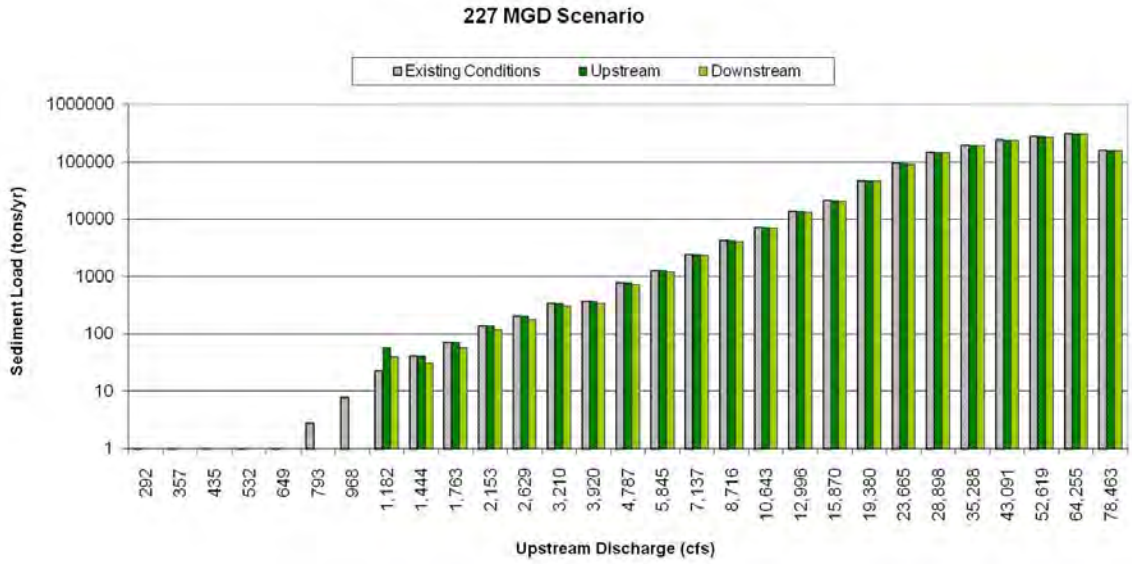

Figure 4.16: Estimated Annualized sediment load estimation for the 227 MGD scenario based on the observed flow data after the construction of Lake Livingston Dam

The results of Figures 4.15 and 4.16 show a very small increase in sediment load at lowest flow; this is due to the impacts of flow releases from Lake Livingston dam to maintain minimum instream flow of 700 cfs. Figure 4.17 and Figure 4.18 plot the above results as the percentage change in sediment load. These figures show that the small increase in sediment load from the Lake Livingston releases are less than 0.01% of the sediment budget. For larger flows with no release from Lake Livingston and constant withdrawal rates, the withdrawal slightly reduces the

downstream sediment load. The largest sediment load reductions for the 400 and 227 MGD scenarios were approximately - 0.2% and - 0.1%, respectively.

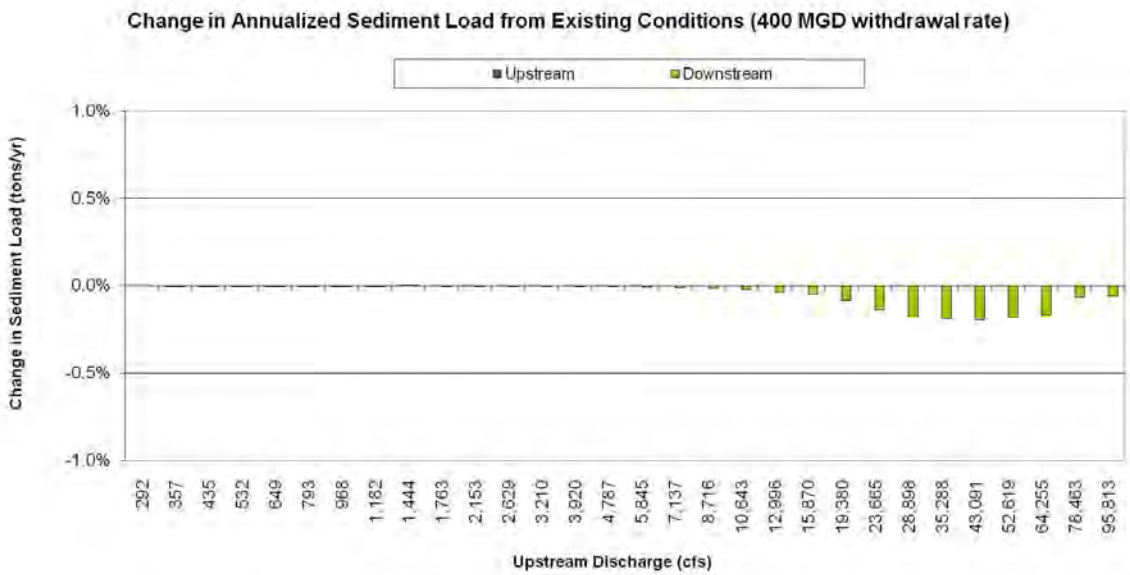

Figure 4.17: Estimated change in annualized sediment load from upstream to downstream of the project site assuming a 400 MGD withdrawal rate

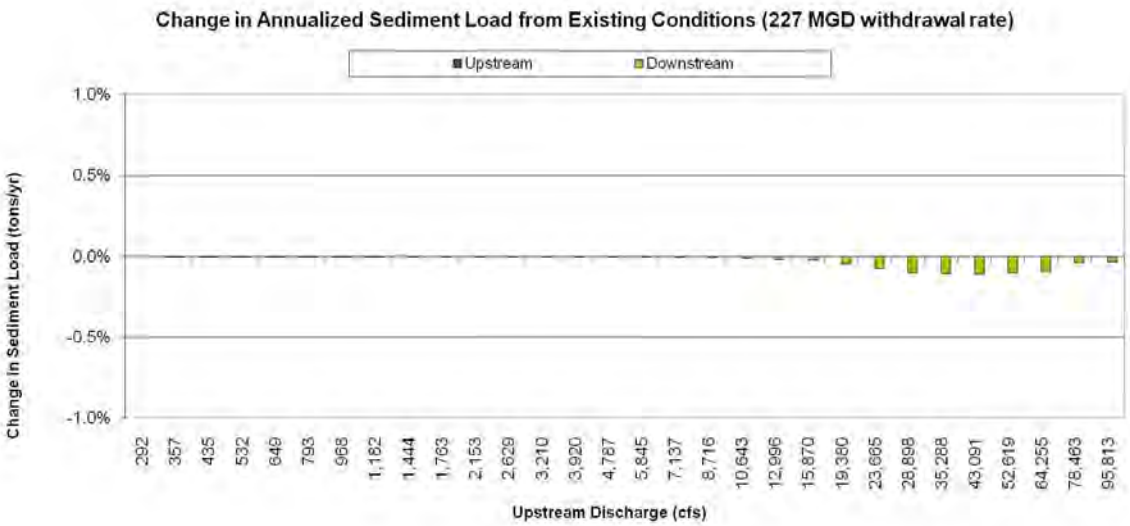

Figure 4.18: Estimated change in annualized sediment load from upstream to downstream of the project site assuming a 227 MGD withdrawal rate

The previous results look at sediment balance only, and do not account for the effects of discharge on transport capacity. For example, while the previous results show water withdrawal will slightly reduce the downstream sediment load, they do not indicate how withdrawal will affect sediment transport capacity. Sediment transport capacity decreases disproportionally with decreasing

discharge (Figure 4.14). To account for the combined effects of changes in sediment load and changes in discharge on sediment transport, the above results were analyzed using the sediment transport capacity to determine sediment fluxes downstream of the proposed intake, along with "sediment excess". Figures 4.19 and 4.20 show the estimated change in downstream sediment transport capacity after withdrawal of diversion water. The percent change in downstream capacity is the difference between pre and post project capacity divided by the total pre-project capacity. For this analysis, it was assumed that the downstream sediment capacity is the amount of sediment the river is able to transport at the downstream flow value (upstream flow minus withdrawal rate) based on the relationship between flow and sediment concentration (Figure 4.14). This relationship represents carrying capacity given that the river is transport limited in this region.

The x-axis for these plots is the same log-flow axis used for the previous plots for comparative purposes. While these flows represent the discharge upstream of the proposed project site, no flows are lower than 1,000 cfs due to the 700 cfs minimum flow requirement and flow release from Lake Livingston.

The results in these figures indicate there is no significant change in downstream sediment transport capacity until approximately the average daily flow, 8,770 cfs. The largest reduction in transport capacity, -0.3% and -0.2% for 400 and 227 MGD scenario, respectively, occurs with flows around the 2 year event (49,600 cfs). Reductions in transport capacity are less than -0.1% for both the 400 and 227 MGD scenarios for larger flows such as the 5 and 10 year events. Due to the small magnitude of these reductions, it bears mention while theoretically correct, these are well within the margin of uncertainty for this analysis. It would not be possible to measure such reductions from actual field data.

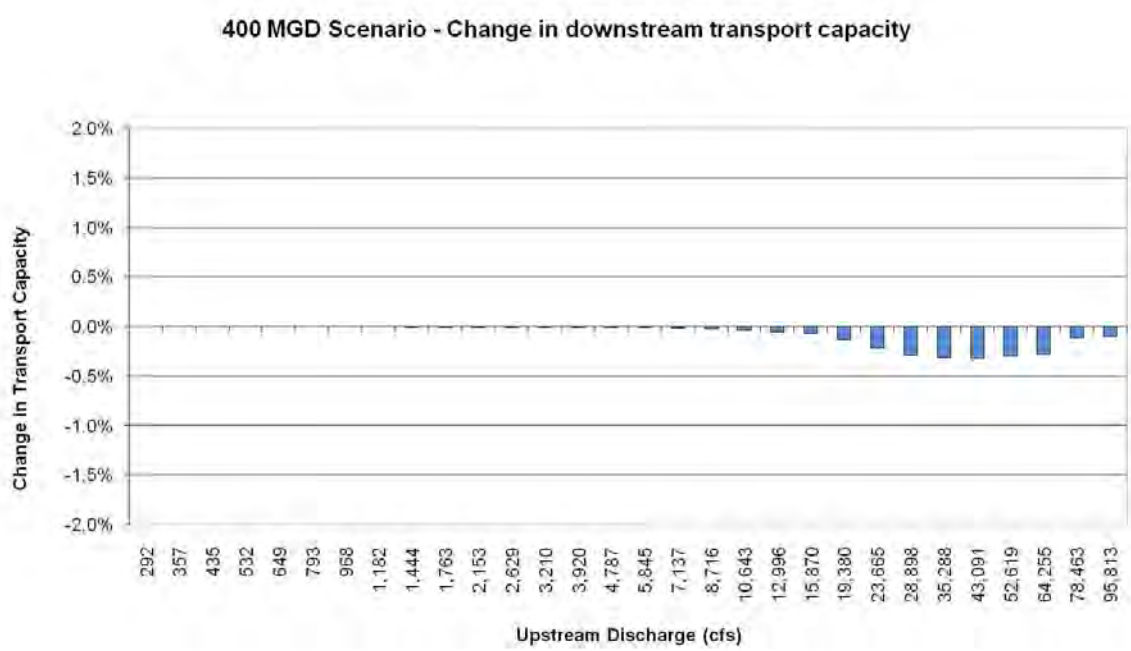

Figure 4.19: Change in transport capacity downstream of the proposed intake site, 400 MGD scenario

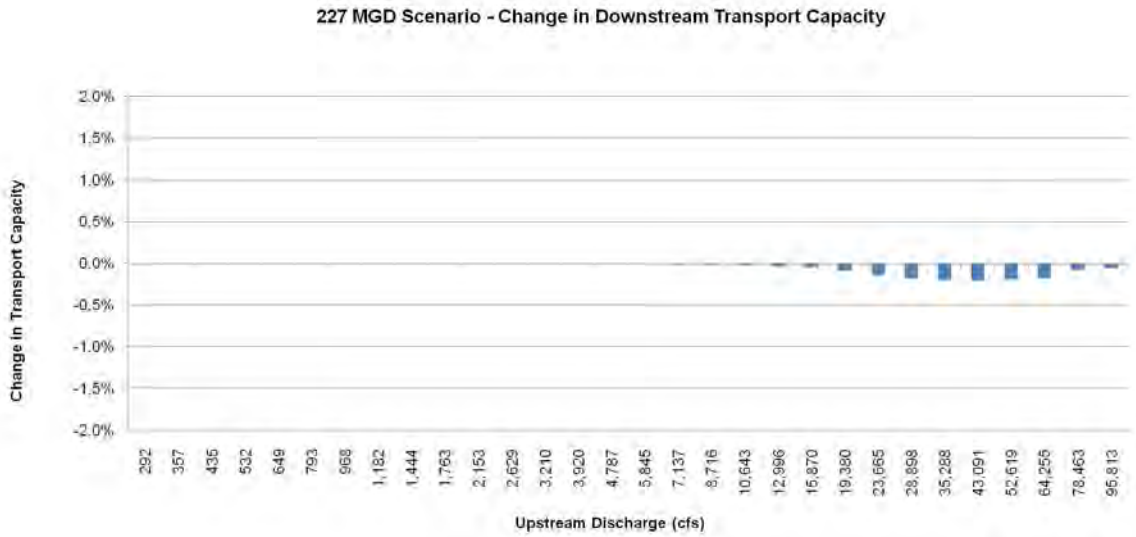

Figure 4.20: Change in transport capacity downstream of the proposed intake site, 227 MGD scenario

4.2 Field Methods

4.2.1 Hydrographic Surveying

The hydrographic survey data are presented in Appendix B. Surveys of the Trinity River provided cross-sectional data for the 1D hydrodynamic model and very high quality multi-beam sonar data for the development of the 3D hydrodynamic and sediment transport models. To allow for modeling of high flow events and overbank flows, the bathymetric data were merged with LIDAR data (provided by AECOM) and digital elevation models of the Trinity River valley (USGS).

The hydrographic survey of Luce Bayou included a number of cross sections within the main channel combined with a high density grid of single beam sonar data in the embayment where the proposed outfall is to be located. While much of Luce Bayou is very shallow – complete survey coverage was provided and included survey of all shoreline and islands.

4.2.2 Flow Measurements

ADCP flow measurements were taken at 25 locations on the Trinity River from June 4th to June 7th. These are summarized in Appendix C. The flow during this period was less than 1/5 of the long term median and declined throughout the duration of data collection due to release control from the Lake Livingston Dam (Figure 4.21). Full results of flow data collection on the Trinity River can be found in Appendix C.

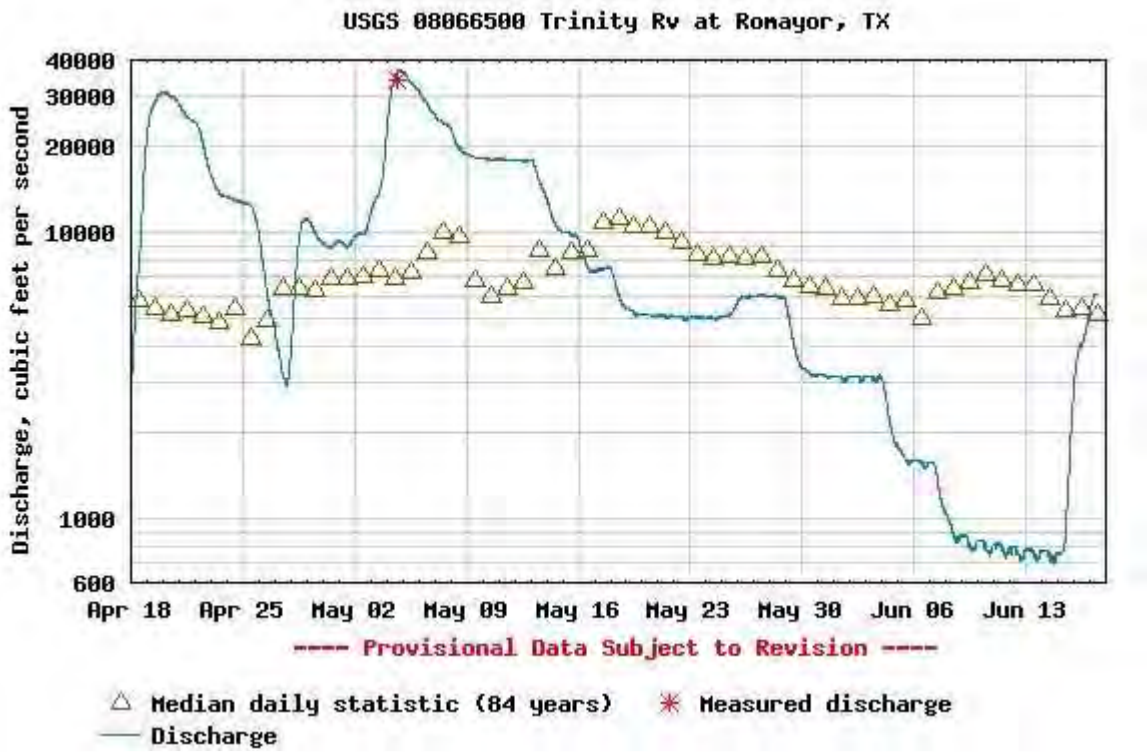

Figure 4.21: Trinity River flow data upstream of the project site during field data collection

Flow measurements were gathered by the Baird field team on June 2nd at eight separate locations through the study area on Luce Bayou using the ADCP. Discharge during this period was relatively low, less than the median flow from the period of record (Figure 4.22). Results are summarized in Appendix B. Due to the low discharge and large cross section of Luce Bayou, there was no significant current velocity during the field collection period.

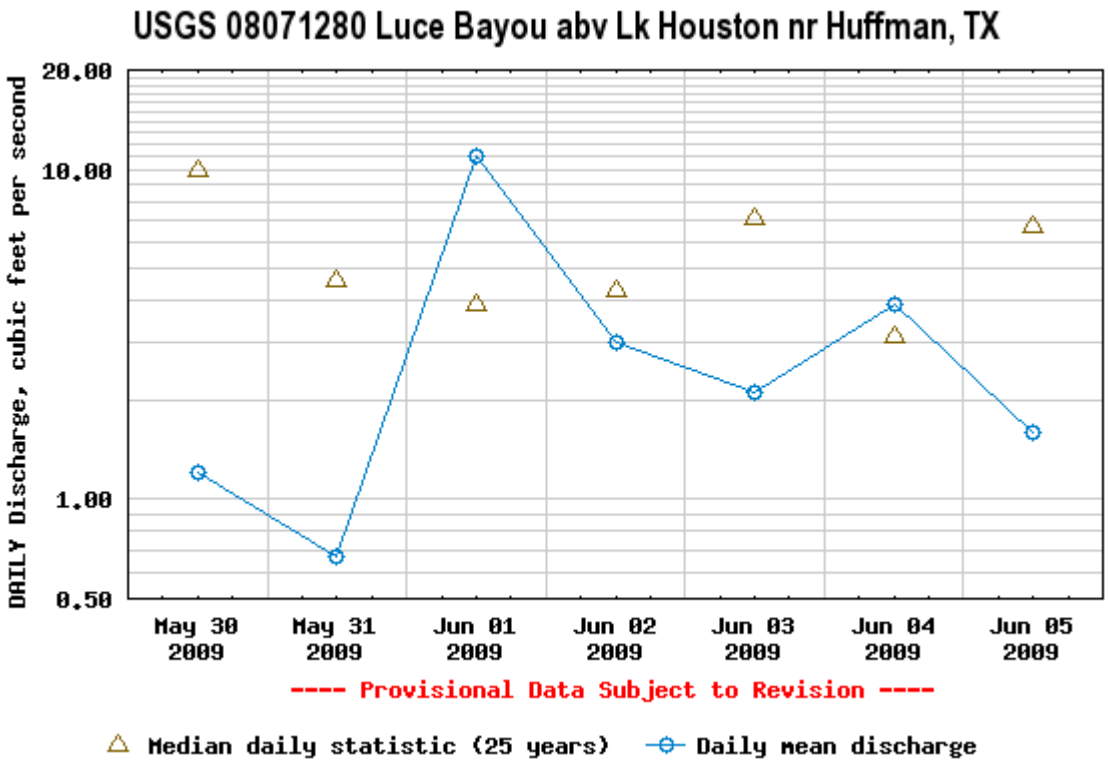

Figure 4.22: Luce Bayou flow data upstream of the proposed outfall site during field data collection

4.2.3 Channel Bed Material Sediment Sampling

Sediment samples of the bed, point bars and banks in the vicinity of the intake were collected during the field program and analyzed for grain size distribution. The locations of the samples are shown in Figure 3.2, and the results of the grain size analysis are summarized in Appendix D. Surface samples from the point bars in the vicinity of the intake are almost entirely sand, with a mean sand content of approximately 96%. The grain size distributions of samples from the channel bed are more variable, although still mainly composed of sand. The sand content of the channel bed surface samples is an average of 94%. While samples SS-5B and SS-5C, taken deeper into the channel bed, have coarser and finer distributions, respectfully, these differences are minor and the overall composition of the samples is similar to the other samples.

The grain size distribution of the bank materials in the vicinity of the intake is finer than the bed and bar sediments. The average grain size distributions for the banks are 32% sand, 35% silt, and 33% clay (excluding SS-7C, sample not analyzed for silt and clay). This finer grain size distribution reflects historic floodplain sedimentation processes in the Trinity River Valley that led to the formation of the alluvial bank materials, compared to deposition on the bed and bars of sands during higher flows. In addition, the grain size distributions of the bank samples are more variable, as a result of different depositional layers in the alluvial materials (See Section 4.2.6). Values for sand content of the bank materials ranges from 6-61%, silt content is between 20-49 % and clay content is between 12-55%.

Two sediment samples were collected from Luce Bayou during site survey on June 9th, 2009. The first sample was collected from the island bank near the outfall location (Sample ID SSLB-1). The second sample was collected from the river bed in the outfall area (Sample ID LB-01). The material is mainly silt and clay, and the D50 is approximately 0.018mm. Sample from the river bank is mainly silty clay sand with D50 of 0.09mm.

The critical bed shear stress of fine sand, silty clay or mud can vary widely with site specifics. For the purposes of this study, erosion of the shoreline and channel bottom near the proposed outfall were the primary areas of concern. Given the outfall area for Luce Bayou is a homogenous side bay, it was assumed that the bed material can be divided into two layers. The top layer is extending to 0.7 feet, and the critical bed shear stress is 0.2 N/m^2, which represents an easily mobilized layer of surface. The lower layer extends to 3.3 feet, and the critical bed shear stress is 1.0 N/m^2, which represents a relatively hard layer.

4.2.4 Point Bar and Vegetation Surveys – Trinity River

The results of the field vegetation survey allow for the estimation of potential rates of bar growth, or pro-grading, over short time intervals corresponding to the recruitment, colonization, and growth rates of endemic pioneer annual and perennial plant and tree species. The assumptions inherent in the interpretation of dendrochronologic records are presented in Appendix F. Based on these results, the upstream bars are growing at average rates of 30 – 130 ft/yr and downstream bars are growing at rates 80 – 190 ft/yr (Figure 4.23).

Actual bar growth rates may not be uniform, from year to year, as large bar forming and reworking events are associated with irregular flood events. For example, looking at PB9 which shows total growth of 120 ft/yr, part or all of this growth could have happened with only one event, in a three to five year period – the typical age of recruitment for sapling trees on stable perennial bars. In that same time period, the annual bar could have been re-worked multiple times by smaller, more frequent storm events.

The general trend inferred from the vegetation surveys of the bars shows moderate, consistent bar building upstream of Capers Ridge, no bar building for locations in proximity to Capers Ridge, and moderate to large bar building downstream of Capers Ridge.

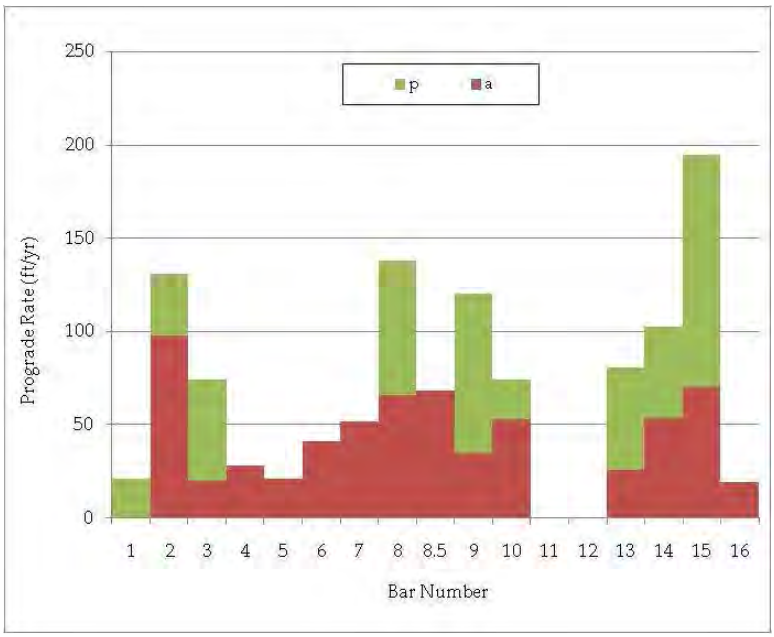

Figure 4.23: Trinity River bar prograde rates.

4.2.5 Bank Erosion / Bank Stability Surveys – Trinity River

Geomorphic reconnaissance of the river banks in the vicinity of the intake were undertaken at locations shown in Figure 3.2. The purpose of the bank surveys was to identify the major bank erosion mechanisms in the vicinity of the intake and to identify the relative susceptibility of the banks to erosion as preliminary input to the bank protection design. This section presents the results of the bank surveys. A summary of relevant field notes and panoramic photographs of the proposed intake location showing the overall pattern of vegetated upper banks, cut marks, and bank failures in the vicinity of the intake are in Appendix G.

The Modified Pfankuch Channel Stability survey was assessed at each bank sample location. The analysis is a descriptive assessment of the stability of the upper banks, lower banks and channel at a given location. The stability of surveyed banks along this reach all rated as poor, according to the indicators in the Pfankuch assessment. The stability results for surveyed reaches are shown in Figure 4.24. For comparative purposes, the standard scores for Excellent, Good, Fair, and Poor are shown for upper banks, lower banks, and the channel bottom. Given the uniform nature of the river in proximity to the intake, there is little variation between sites.

The bank survey at sample point SS-7 (in the vicinity of the proposed intake) shows a bank approximately 20 ft high, with a composition of fine sand, silts and clays. Numerous cuts in the bank profile were observed, reflecting recent elevated water levels, along with bank failures and colluvial deposition at the base of the bank (Figure 4.25). The upper banks were generally steep, and showed evidence of frequent mass wasting (bank failure). Little woody debris was present at

the sites, and vegetative cover was under 50% as a result of the mass wasting and steep banks. Upper bank stability was fair to poor.

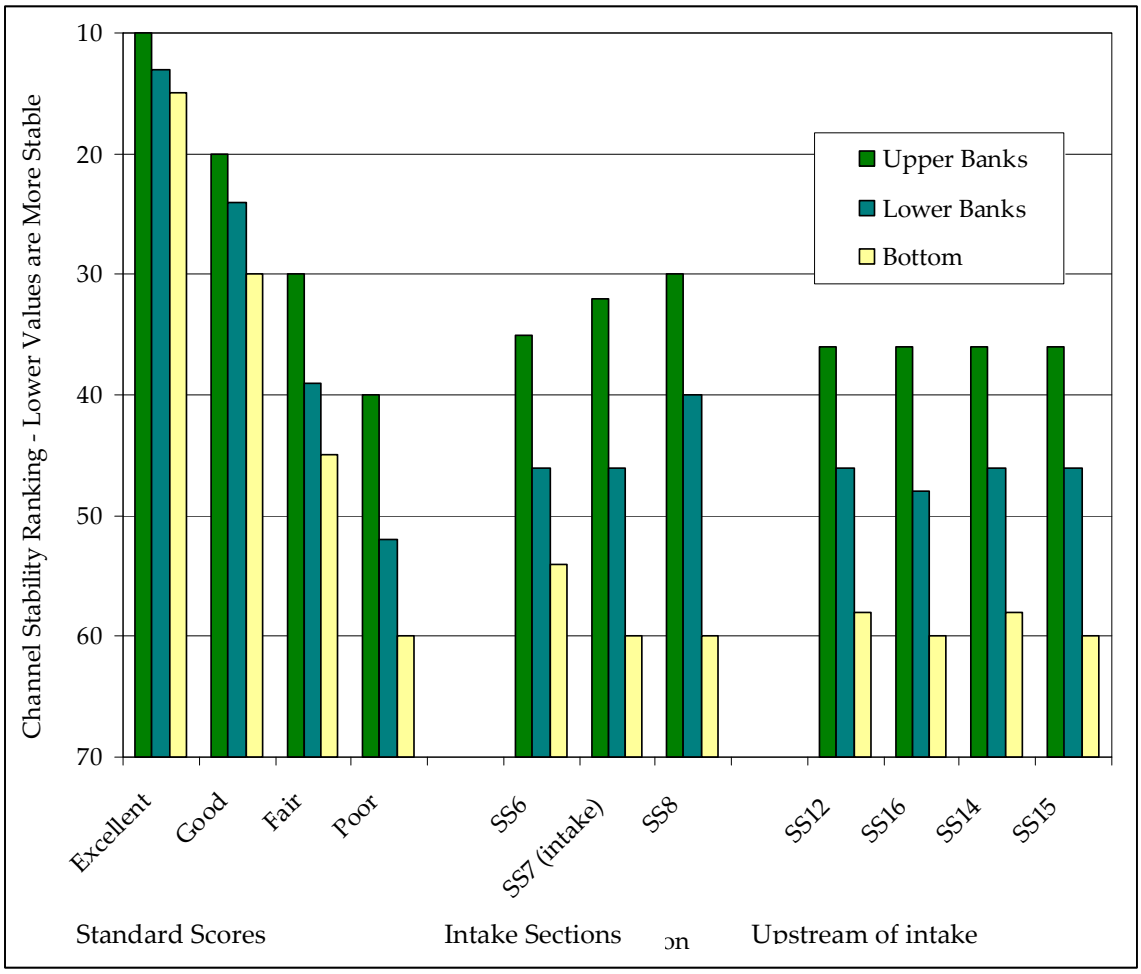

Figure 4.24: Pfankuch Channel Stability survey results. Lower scores are most stable.

Lower banks also rated as having fair to poor stability. Adequate channel size and few obstructions to flow allowed for sufficient channel capacity however, the banks have low rock content, and show almost continuous cuts and frequent overhangs at the bottom of the banks, contributing to the poor stability for the lower banks.

The channel bottom stability of the sites is predominantly poor, due to the loose packing of bed sediments and evidence of frequent scouring and deposition, such as absence of aquatic vegetation, and the brightness of bed sediments.

Upstream of the proposed intake site, channel stability ratings for the meander bends near PBs 9 and 10 were very uniform with fair to poor stability ratings. Full results of the Pfankuch Stability Ratings are contained in Appendix H.

Figure 4.25: Upper/lower bank interface near proposed intake site

4.2.6 Shoreline Reconnaissance - Luce Bayou

The shoreline reconnaissance of Luce Bayou was an assessment of general shoreline conditions and characterization of existing erosion. Consequently, erosion rates cannot be inferred from the results. The entire shoreline of Luce Bayou was assessed. Characteristics examples of shoreline condition were documented at specific locations on Luce Bayou, Figure 4.26.

Most of the shoreline surveyed showed little (under one foot high of eroding shoreline) or no shoreline erosion (Figure 4.27). In areas where shoreline was adjacent to the main channel of Luce Bayou, eroding banks were slightly higher, in the range of 1-2 and 2-3 feet high (Figures 4.28 and 4.29). Figures 4.30 - 4.34 shows typical shoreline characteristic and island in the vicinity of the outfall location, this area is very sheltered with no shoreline erosion and extensive vegetation.

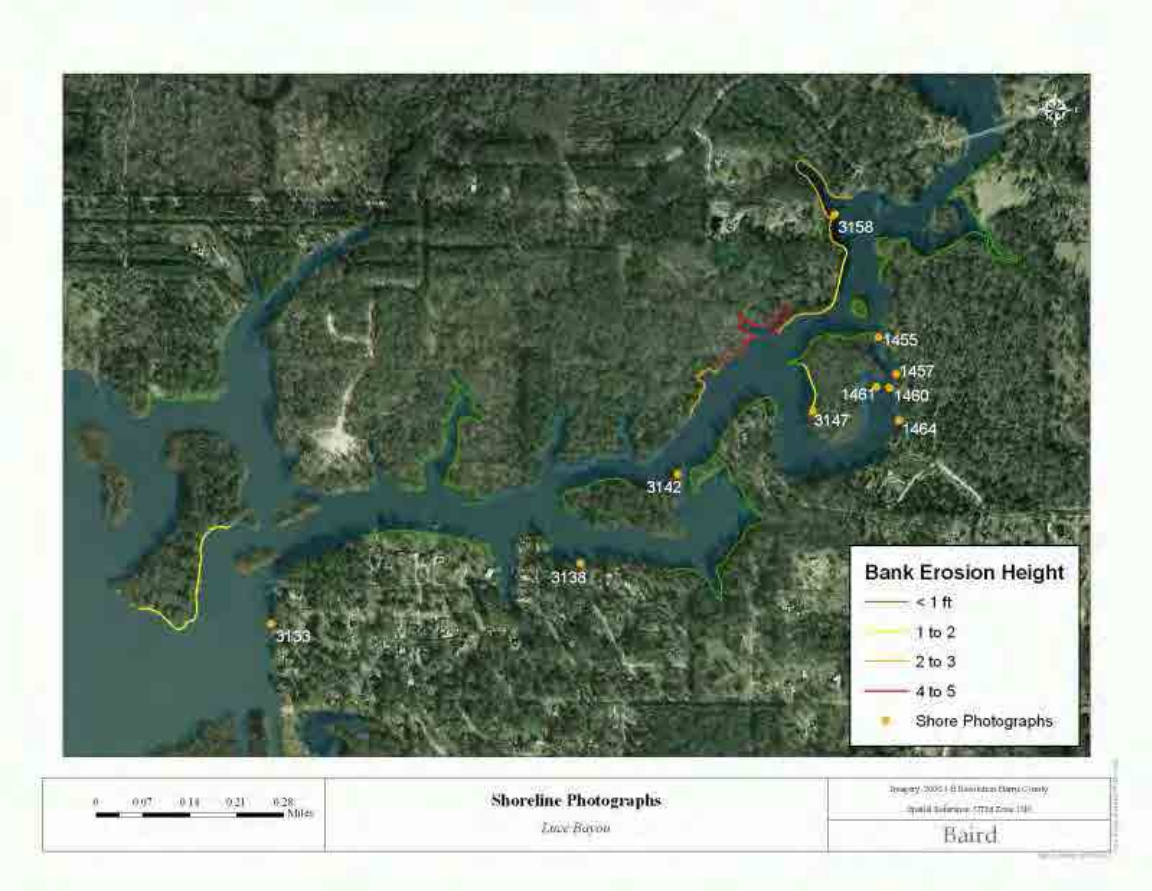

Figure 4.26: Location of photographs taken during Luce Bayou shoreline reconnaissance

Figure 4.27: Low eroding banks in sheltered area of Luce Bayou (Photo 3142)

Figure 4.28: 2-3 ft eroding banks on main channel in Luce Bayou (Photo 3158)

Figure 4.29: 1-2 ft eroding banks on island in main channel of Luce Bayou (Photo 3147)

Figure 4.30: Sheltered north channel approach to outfall site - no bank erosion (Photo 1455)

Figure 4.31: Sheltered north channel approach to outfall site - no bank erosion (Photo 1457)

Figure 4.32: Small island south of outfall site - no bank erosion (Photo 1461)

Figure 4.33: Island shoreline immediately south and west of proposed outfall (Photo 1460)

Figure 4.34: Shoreline in bay just south of proposed outfall location (Photo 1464)

The existing bank erosion observed in Luce Bayou reflects the interaction of several factors, including water level fluctuation, shoreline flow currents, wind waves, boat wake-induced erosion, and human/animal disturbance of the shoreline. The low values of shoreline erosion height compared to other areas reflect the low-energy environment in Luce Bayou. This is consistent with the short fetches (i.e. sheltered water) meaning little wind-wave energy. In addition, there is a relatively low water level fluctuation (Texas Parks and Wildlife, 2009), with mean daily water levels at the USGS #08072000 gage on Lake Houston in the range of 44.5-45.5 feet, and peak record highs and lows of approximately 50 feet and 40 feet, respectively. Boat wake activity in the immediate vicinity of the outfall location is thought to be minimal, due to the difficulties of navigating in the backwater area.

The Geologic Atlas of Texas mapping of the surficial geology for Luce Bayou (Figure 4.35) shows that the shoreline geology in the area is part of the Beaumont Formation (Qbs). This unit is comprised of sandy clays and sands in multi-storied stacks of flood basin mud and splay sands (Blum et al. 1995, summarized in Nordt et al., 2008). Spatial distribution of the Beaumont Formation reflects the historic presence of features including river channels, point bars, levees, barrier islands, coastal marshes, mudflats, and littoral facies (Nordt et al., 2008). The Beaumont lithostratigraphic unit (Qbs), part of the overall Beaumont Formation, is mainly meander belt, levee, crevasse splay, and distributary sand facies that are dominantly clayey sand and silt of moderate permeability and drainage, low to moderate compressibility and shrink-swell potential, level relief with local mounds and ridges, and high shear strength (Barnes 1992). This correlates well with a shoreline sediment sample collected by Baird from the island in the vicinity of the outfall, which

was classified as a brown silty clayey sand (0.9% medium sand; 60.1% fine sand; 33.2% silt; 5.8% clay).

Typical shear stresses for the entrainment of fine sand are in the range of 0.10-0.12 Pa. Increasing to 0.25 Pa for silt, and above 1.0 Pa for clay. Laboratory determination of the precise erodibility characteristics of the Beaumont Formation materials was beyond the scope of this study, and a literature review did not find values from other studies, so the general values for the particle size classes above were considered in this study.

Existing shore protection in Luce Bayou was also mapped as part of the shoreline reconnaissance. Two main areas of shore protection, away from the outfall location were identified (Figures 4.36-4.38). Given the location of these areas away from the outfall, and their position on the lee-side of shoreline compared to flow direction, these areas of existing protection are unlikely to be affected by the outfall.

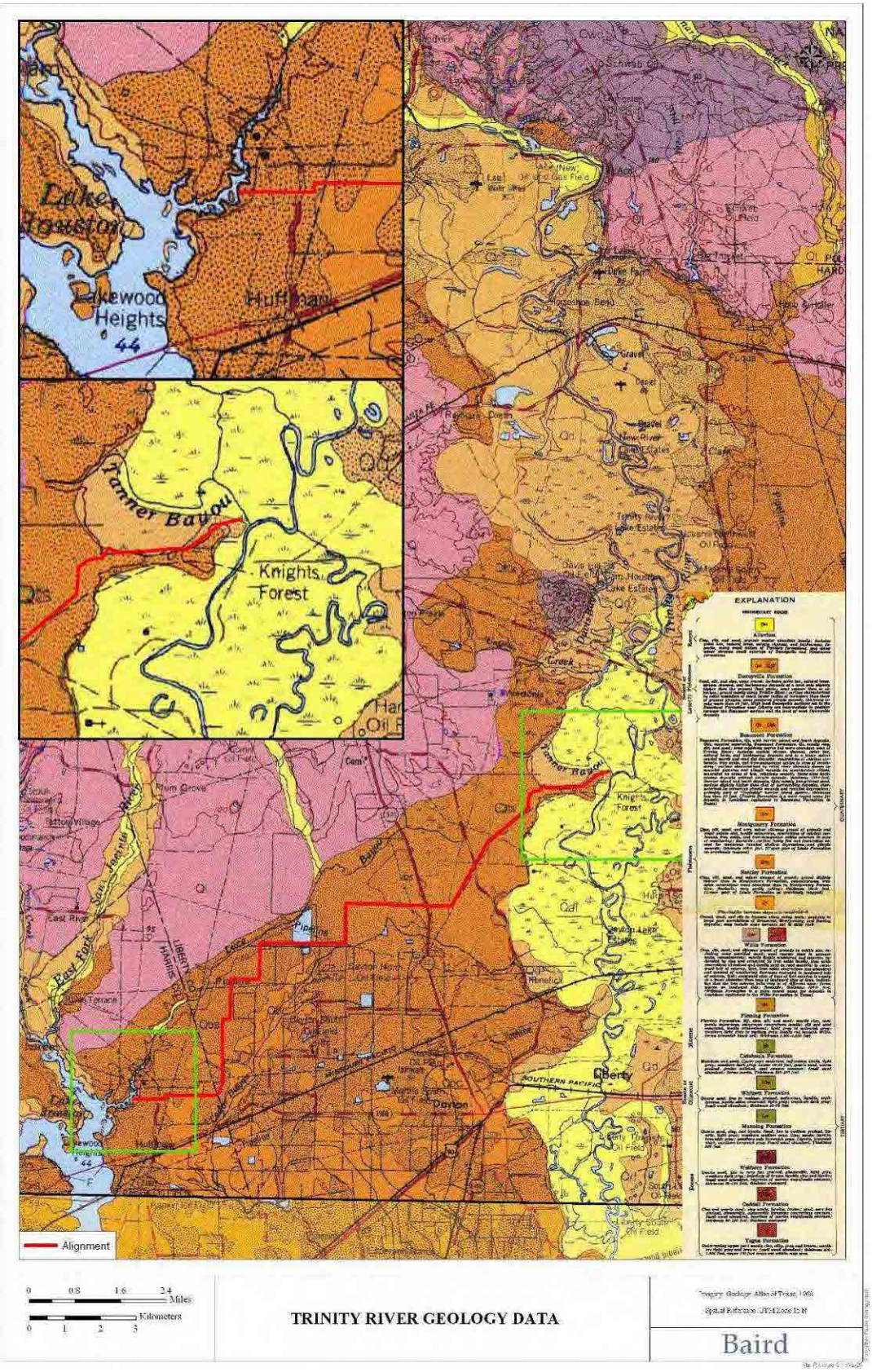

Figure 4.35: Texas Geological Survey Mapping of Luce Bayou Interbasin Transfer study

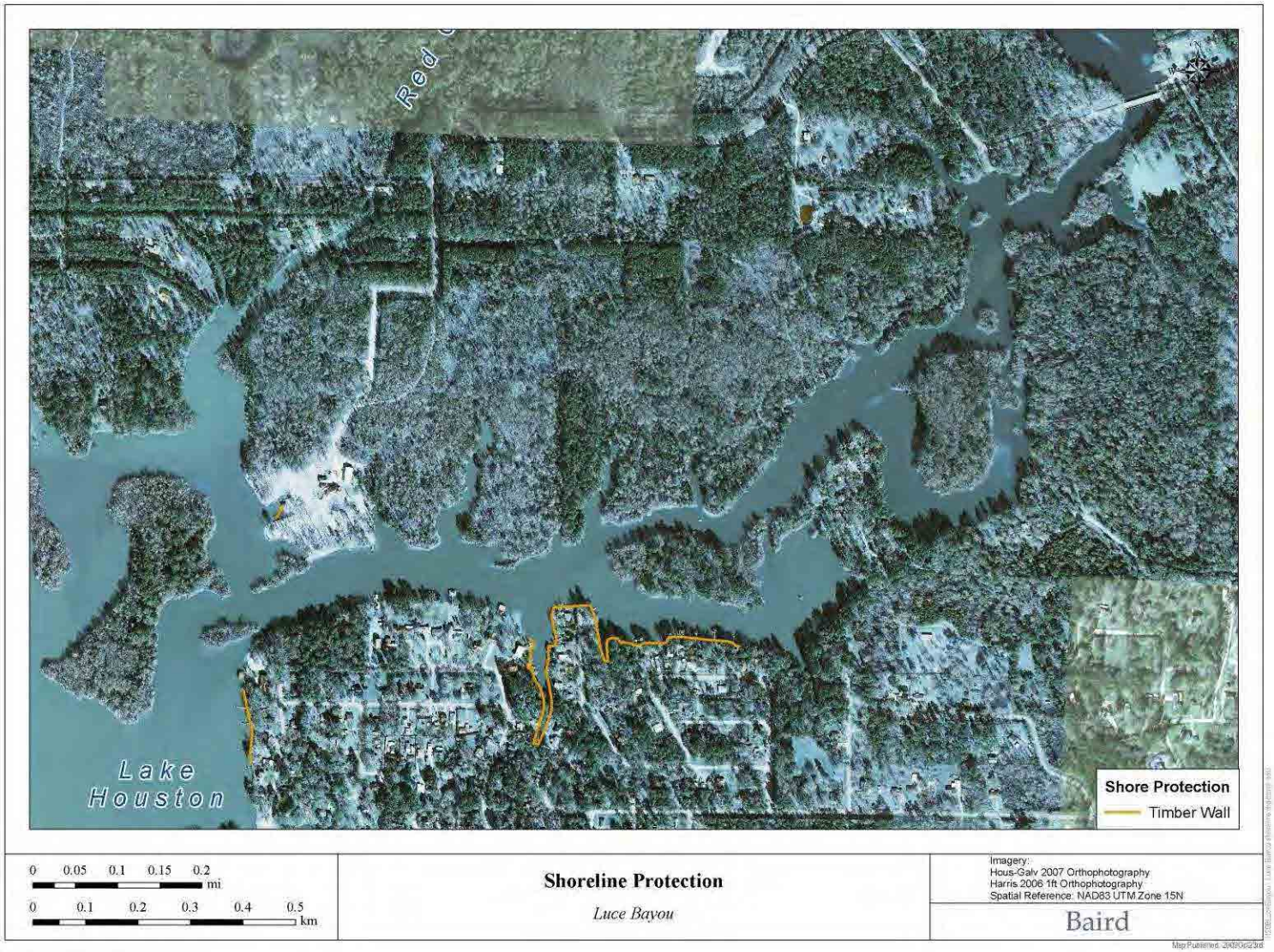

Figure 4.36: Existing Shoreline Protection around Luce Bayou

Figure 4.37: Typical timber wall around Luce Bayou (Photo 3133)

Figure 4.38: Typical timber wall around Luce Bayou (Photo 3138)

4.3 MIKE11 1D Model Results

4.3.1 1D Modeling Results of Existing Conditions

The calibrated 1D model was used to simulate a suite of 11 different flow conditions. The eleven flow scenarios were selected to represent the wide range of flow variation that happens in the Trinity River, including six low flow conditions and five flood events. The results were used as boundary conditions for the same suite of flows modeled by the 3D model.

During the 1D model testing, it was noted that flood water levels at the proposed intake site for the 1D model were significantly lower than that for the 3D model. Part of this difference was simply explained by differences in how the models operate. The main reason for this discrepancy is because the 1D model only operates using cross section average conditions. Due to the structure of Capers Ridge, with a knoll near the river and ridge angling back to the valley wall, the 1D model could not accurately represent this floodplain obstruction. Consequently, the 1D model had larger over-bank flow capacity at the proposed intake location, allowing for lower water levels to pass the same discharge. Conversely, the 3D model did account for the obstruction and large overbank flow reversal caused by Capers Ridge. This resulted in more accurate with flow being routed via Mud Creek back upstream of the proposed intake location. This has no effect on this study because the 1D model was only used for water level and discharge boundary conditions for the 3D model, which were calibrated and validated.

These results in conjunction with the 3D modeling results were then used by AECOM to design develop alternative preliminary intake designs. The result of this was the proposed pump station and intake. This was then modeled with an additional suite of flows to simulate the impact of the proposed intake structure and pumping scenarios selected by AECOM.

4.3.2 1D Modeling Results of Post-Project Conditions

Table 4.9 shows the scenarios modeled for the proposed pump station and intake. As with the existing condition scenario, results from the 1D proposed model condition were used as boundary conditions for the 3D model.

Table 4.9: The flow discharge and pumping rates of the five post-project model runs

Scenarios for Existing	River Discharge	Pumping Rates
	cfs	MGD
Run03 - 1500 cfs	1,500	500
Run04 - 3000 cfs	3,000	227
Run07 - 2yr Event	49,617	293
Run08 - 5yr Event	75,114	500
Run10 - 100yr Event	135,008	0

4.4 MISED 3D Model Results

Results from the 3D modeling of the hydrodynamics and sediment transport under existing and proposed pump station scenarios include extensive narrative, figures and tables to fully explain the complex nature of what was done, and how to interpret the results. This section summarizes the key results from the 3D modeling of the existing and proposed intake scenarios. The reader is directed to Appendix I, and the associated sub-appendices I-1 through I-12 (listed in Table 4.10) for full treatment and explanations of the modeling

Table 4.10: Index of Numerical Modeling Appendices

Appendix	Contents
Appendix I - Trinity River Numerical Modeling	Full report of 1D and 3D modeling
Appendix I-1	Figures to accompany full report
Appendix I-2	Figures for calibration results
Appendix I-3	Existing flow patterns
Appendix I-4	Existing bed shear stress
Appendix I-5	Existing velocity and shear profile
Appendix I-6	Existing secondary flow at intake
Appendix I-7	Sediment concentration at intake
Appendix I-8	Post-project flow patterns
Appendix I-9	Post-project bed shear stress
Appendix I-10	Post-project velocity and shear profiles
Appendix I-11	Velocity and shear changes
Appendix I-12	Post-project sediment concentration at intake

The calibrated 3D model was used to simulate the hydrodynamics and sediment transport for the eleven selected scenarios under the existing conditions and for the five selected scenarios under the post-project condition. All model runs for the existing conditions were carried out using the same model settings as used in the model calibration except the open boundary conditions. The open boundary conditions for the scenario runs are extracted from the 1D model. The hydraulic conditions of these scenarios at Romayor and Liberty are listed in Table 3.1. The model results for these scenarios are summarized in this section.

4.4.1 Existing Conditions

4.4.1.1 Hydrodynamic Results

This section provides a synthesis of important hydrodynamic results for existing conditions in the Trinity River. A summary of hydraulic results from each of the existing scenarios is presented in Table 4.11. A full treatment of these can be found in Appendix I: Trinity River Modeling, and Appendices I-1 through I-7.

Table 4.11: Results of the 3D model at the proposed pump station location. Peak discharge values differ from boundary conditions at Romayor because of flood wave routing.

		3D Model				
		At Point (324800, 3345050)			Profile B*	
	Scenarios	Water Level (ft)	Surface Speed (ft/s)	Total Discharge (ft3/s)	Discharge (ft3/s)	Max. Flow Speed (ft/s)
1.	7Q2 – 602 cfs	16.1	1.2	600	600	1.2
2.	Low Flow Condition 1 – 1,000 cfs	16.9	1.7	990	1,000	1.9
3.	Low Flow Condition 2 – 1,500 cfs	17.8	1.7	1,480	1,500	1.7
4	3,000 CFS	19.8	2.2	3,000	3,000	2.2
5.	6,000 CFS	22.3	2.9	6,000	5,900	3.1
6.	Average Daily Flow	23.9	3.4	8,760	8,600	3.6
7.	2-Yr Flood	35.6	6.6	48,100	43,400	7.0
8.	5-Yr Flood	41.5	2.6	69,360	49,400	6.7
9.	10-Yr Flood	42.1	2.6	85,390	52,300	7.1
10.	100-yr Flood	44.0	3.8	120,460	69,900	8.2
11.	500-yr Flood	44.7	4.0	153,160	73,500	8.1

* Results for Profile B only include in channel flow

A very important result from this table occurs when river flow approaches, and exceeds the 2 year recurrence interval event. This is because, at this flow, maximum in-channel velocities occur because all momentum is contained within the channel. The 2-year event can be generally equated with the "bank-full" discharge, that flow which, when aggregated over the frequency and duration of all flow events, does the most work in shaping and maintaining the form of an alluvial river. In the meander bend at the proposed intake site, the 2 year event has strong secondary flow currents, also called helical flow, that result from super elevation of water along the outside of the meander bend (Figure 4.39).

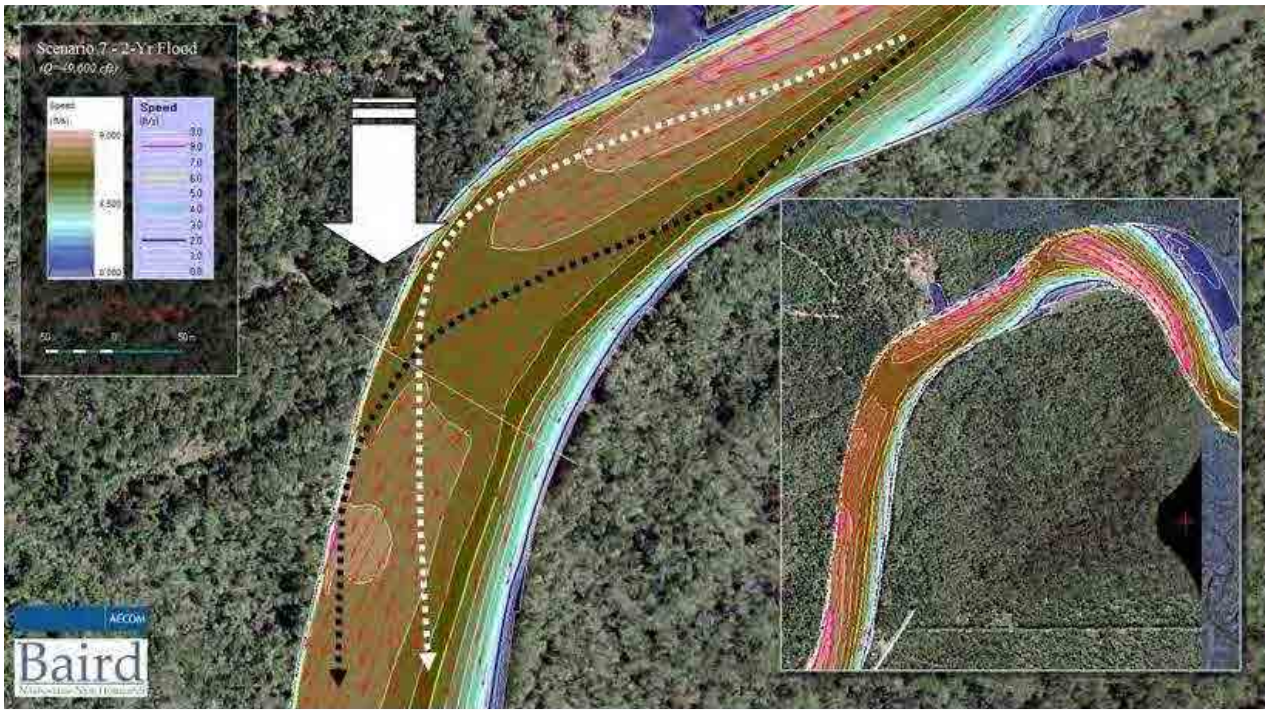

Figure 4.39: Secondary flow currents during the 2 year event. In this figure, the white path represents surface currents while the black path represents bottom currents. The crossing of these currents sets up secondary flow that maintains the hole in the meander bend. (App I-1)

This is especially important for interpreting the results because, due to the location of Capers Ridge and its effect of diverting overbank flood flows from the western half of the Trinity River valley, flows above the 2-year event at Capers Ridge become very complex as overbank flood flows are diverted back in to the active channel. These return flood flows are introduced via Mud Creek and have a deflection effect that pushes flood flows away from the outside of the meander bend, towards the inside bank of the east side of the river (Figure 4.40, Figure 4.41).

The deflection of overbank currents from the west bank to the east bank results in high shear on the inside of the meander bend, opposite the proposed intake site, during even modest flood events (Figure 4.42). The deflection is more pronounced with larger flood events.

Figure 4.40: Complex flow currents and return overbank flow during the 100 year event. (App I-1)

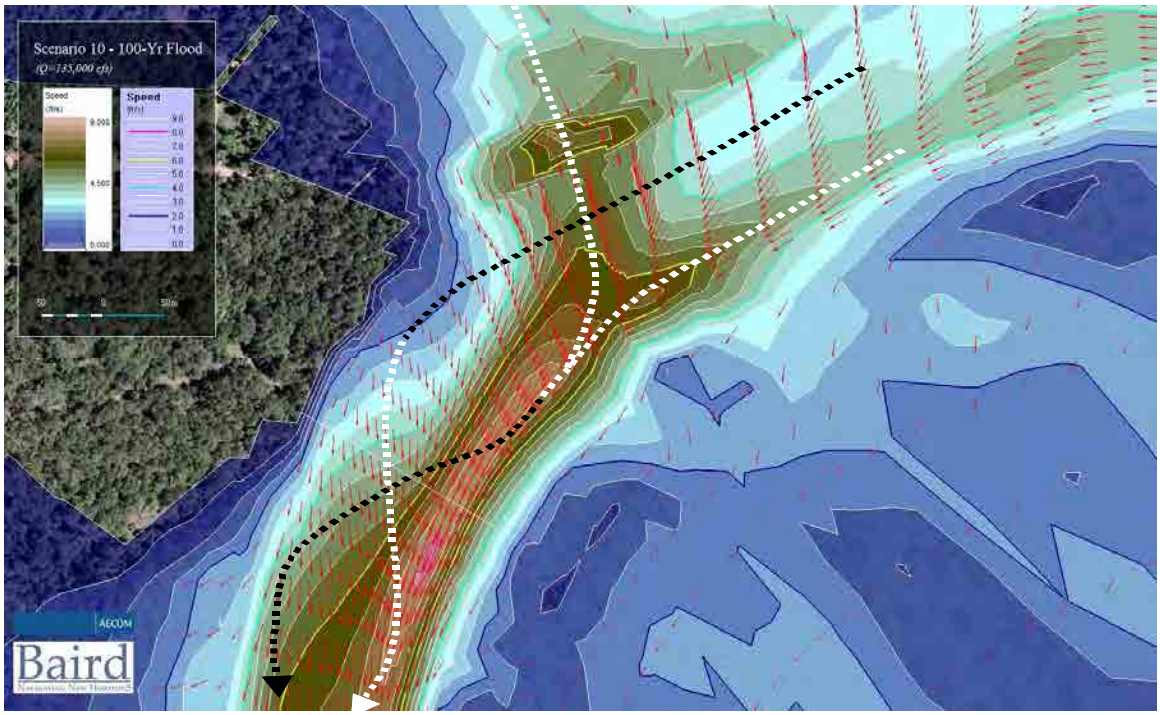

Figure 4.41: Flood flows disrupt secondary flow currents and divert shear to the east bank. (App I-1)

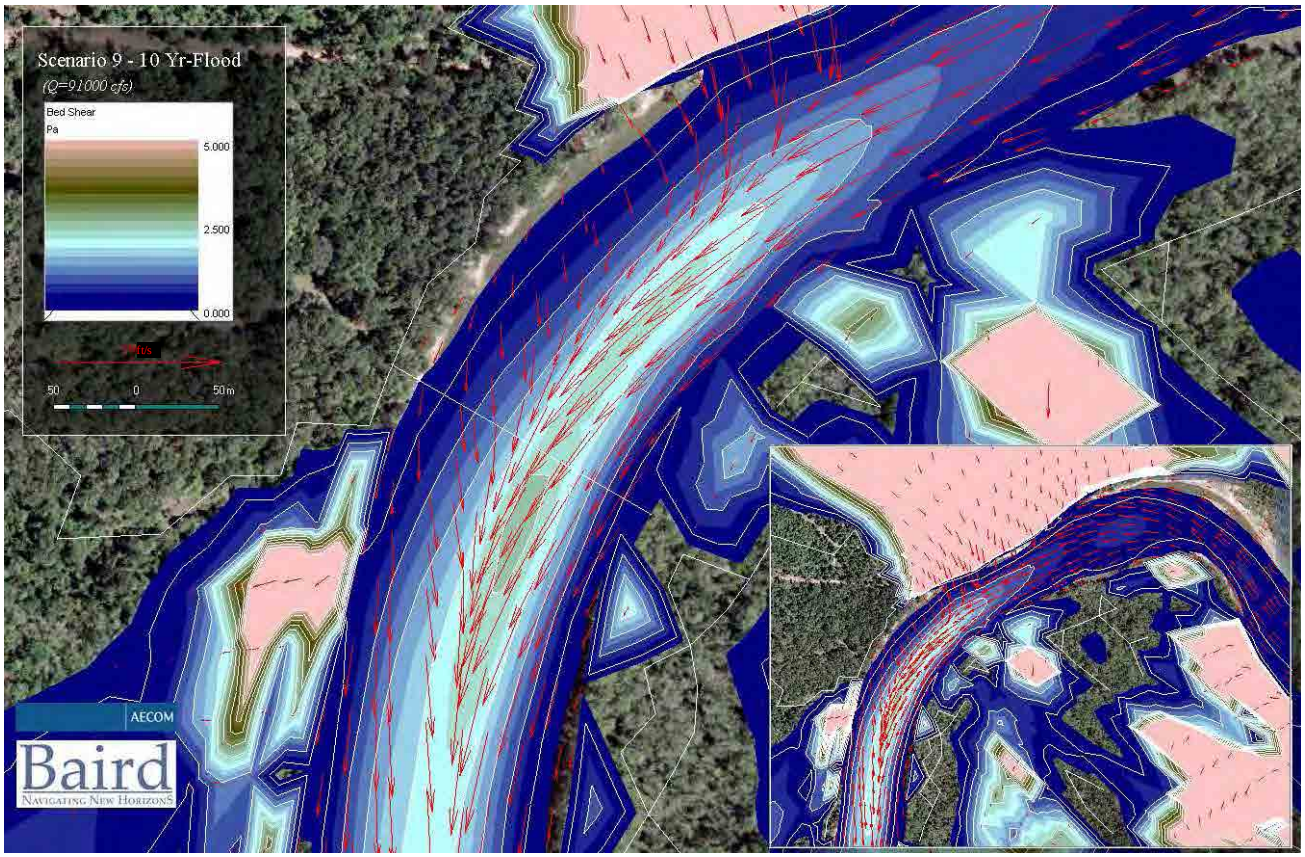

Figure 4.42: Current deflection from overbank return flow (10 year event) via Mud Creek causes zone of high shear to be pushed away from the outer bank and towards the inside of the meander bend. The degree of deflection increases with flood magnitude. (App I-4)

4.4.1.2 Sediment Transport Results

During typical channel flow events, flow through the meander bend at the proposed intake location follow expected hydraulic and fluvial processes. However, because of the large amount of sand in the river bed and strong helical flow, even small flows such as scenario 4 (3,000 cfs) are capable of transporting most of the sand size classes, found in the bed material, as bed load (Figure 4.43).

With the two-year event, the river can transport the entire range of particle sizes in its bed material, including medium gravel, with fine sand being distributed through most of the water column (Figure 4.44). Larger flood events have even greater transport capacity (Appendix I-1).

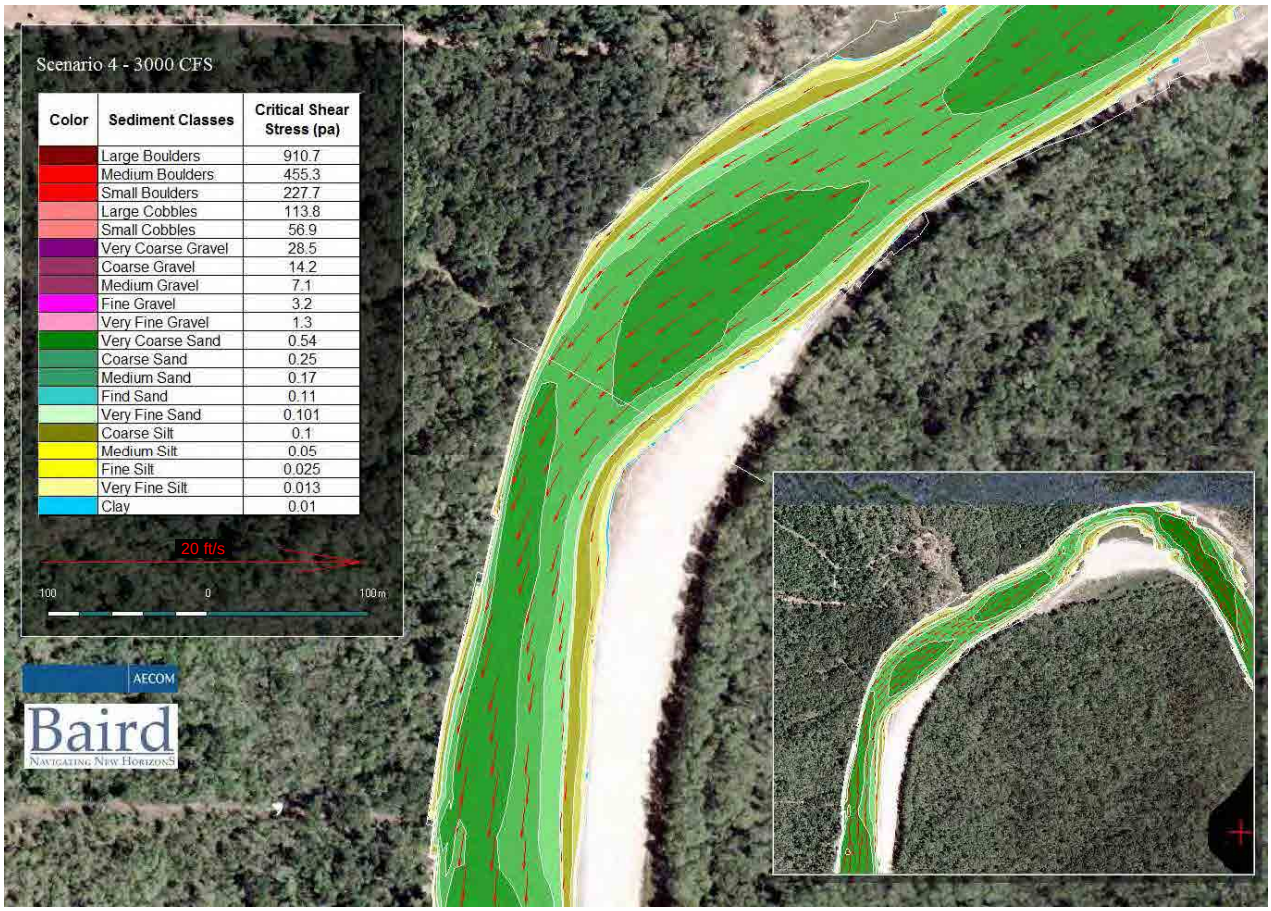

Figure 4.43: The 3,000 cfs flow has sufficient bed shear to transport most of the sand size classes (in green) through the meander bend. In the legend, pink colors reflect the shift to gravel. (App I-1)

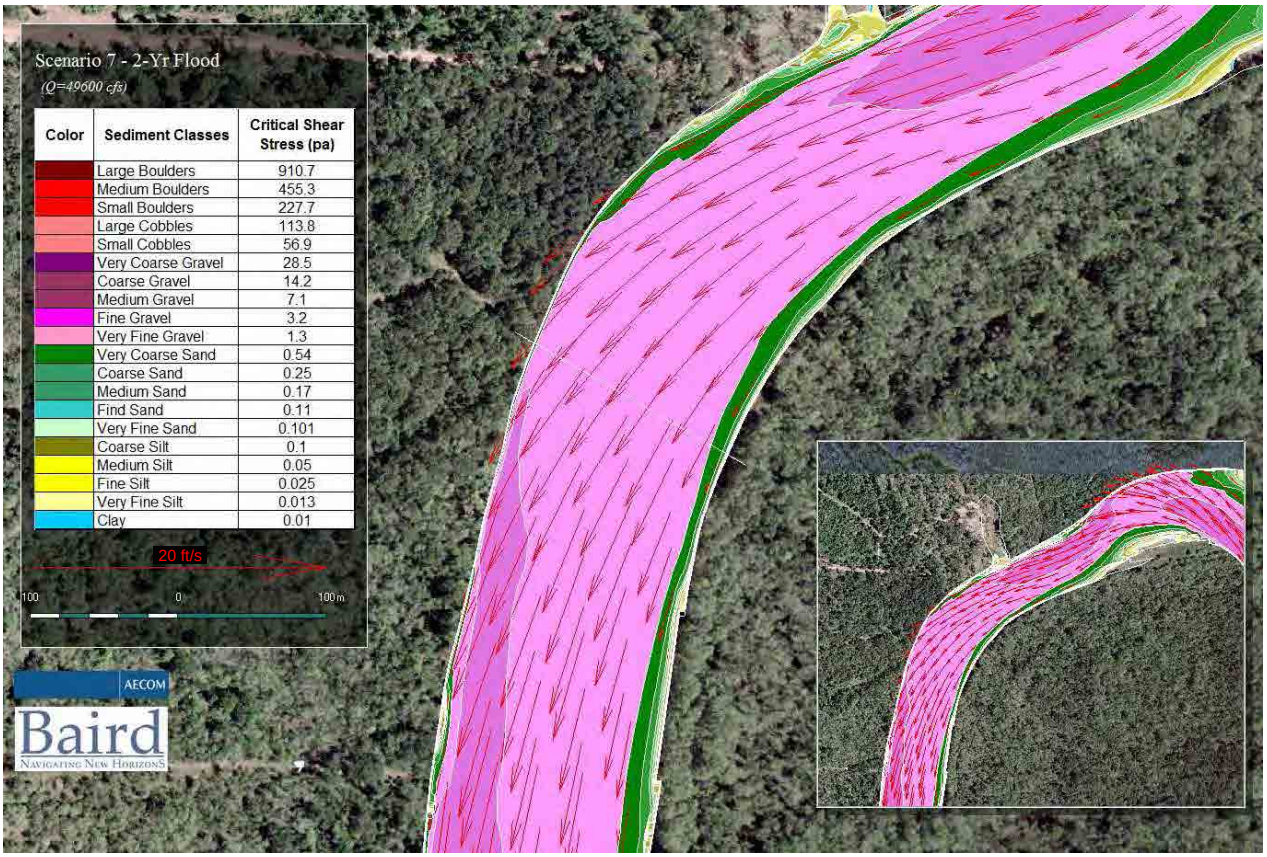

Figure 4.44: The 2 year event has sufficient bed shear to transport all sand and fine gravel through the meander bend - these sediments represent nearly 100% of the bed material sampled. (App I-1)

The suspended sediment concentration was calculated by the model for each scenario under the existing conditions. Figures 16 and 17 (Appendix I) show the profiles of suspended sediment concentration (SSC) at a distance of 65 feet from the bank, which was calculated under the low flow conditions and under flood events, respectively. Note that the SSC calculated by the model represents the sediment suspended from the riverbed but excludes the clay part of SSC transported from the USGS gage at Romayor (as described in Section 3.1.4). This is because the clay part of suspended sediment moves as wash load under all conditions and will pass through the system with no significant morphologic impacts.

The model results suggested that the suspended sediment concentration at the intake for the low flow conditions is very small and could be neglected. For the daily mean flow condition (Scenario 6), the SSC at the bottom is only about 16 mg/l at the intake. However, the model predicted the high SSCs for the flood events ranging from 1400 mg/l to 3,800 mg/l near the bottom at the intake. The SSC decreases quickly from bottom to surface due to large settling velocity of suspended sediment, i.e. the grain size of suspended sediment is big. The vertical SSC at the intake ranged from 660 mg/l to 2,300 mg/l for these selected flood events. It is noted that the SSC in 2-year return flow condition are larger than 5-year and 10-year return flows. This is because the 2-year flow conditions produce the maximum flow speed in the river and the occurrence of flood reduces the flow speed in the river for 5-year and 10-year return flow.

4.4.2 Proposed Project Conditions

This section provides a summary of anticipated changes to hydrodynamics and sediment transport resulting from the proposed intake and pump station. The detailed set of all results and figures can be found in Appendix I: Trinity River Modeling, and Appendices I-8 through I-12.

4.4.2.1 Hydrodynamic Results

A summary of hydraulic results from each of the existing scenarios is presented in Table 4.12.

Table 4.12: Results of the 3D model at the proposed pump station location.

Scenarios for Existing	River Discharge	Pumping Rates	Water Level at the Intake (ft, NGVD)		
	cfs	MGD	Existing	Post-Project	Difference
Scenario 3 - 1500 cfs	1,500	500	17.7	16.2	-1.5
Scenario 4 - 3000 cfs	3,000	227	19.6	19.2	-0.4
Scenario 7 - 2yr event	49,617	293	34.7	34.7	0
Scenario 8 - 5yr event	75,114	500	36.8	36.8	0
Scenario 10 - 100yr event	135,008	0	39.7	39.7	0

In the most extreme case of 1,500 cfs discharge and 500 MGD withdrawal, water level decrease steepens river slope and dramatically increases river velocity upstream (Figure 4.45)

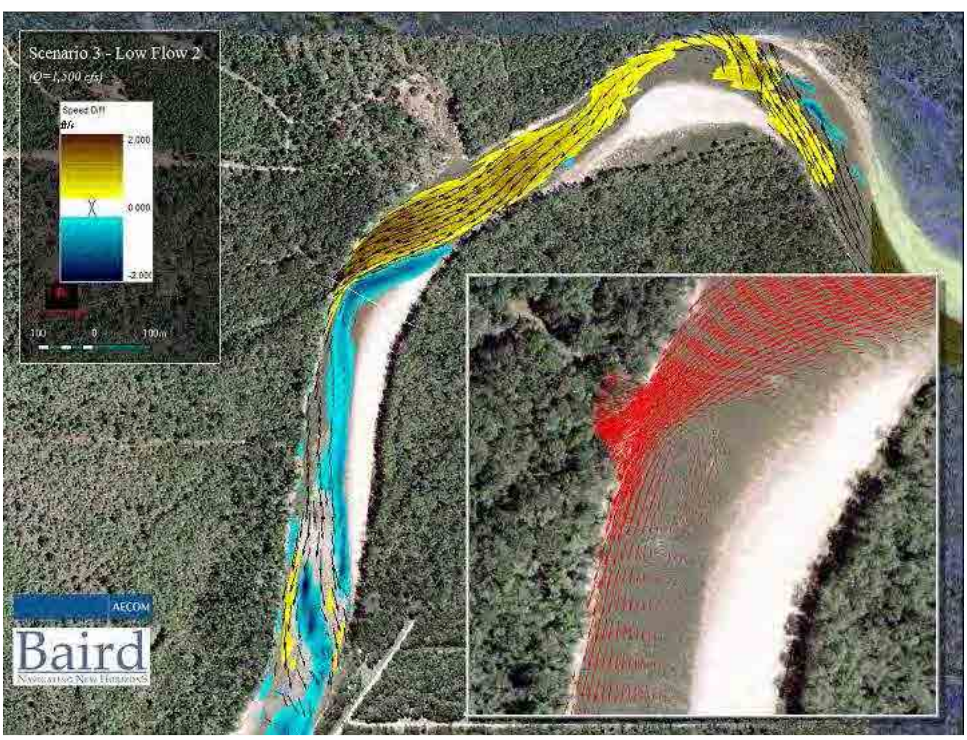

Figure 4.45: Changes in river velocity during 500 MGD withdrawal, 1,500 cfs river discharge. (App I-1)

The increase is so large because the withdrawal rate equates to nearly 1/3 of the available river flow. As a result, the water surface slope steepens and also increases bed shear (Figure 4.46)

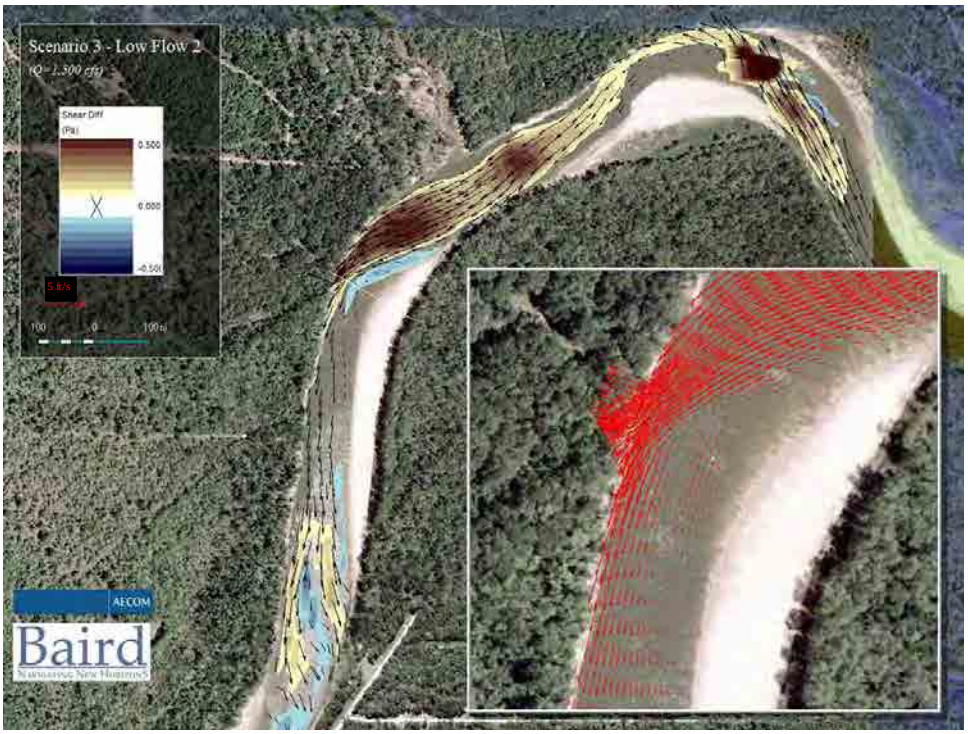

Figure 4.46: Changes in bed shear during the 500 MGD withdrawal, 1,500 cfs discharge scenario. (App I-1)

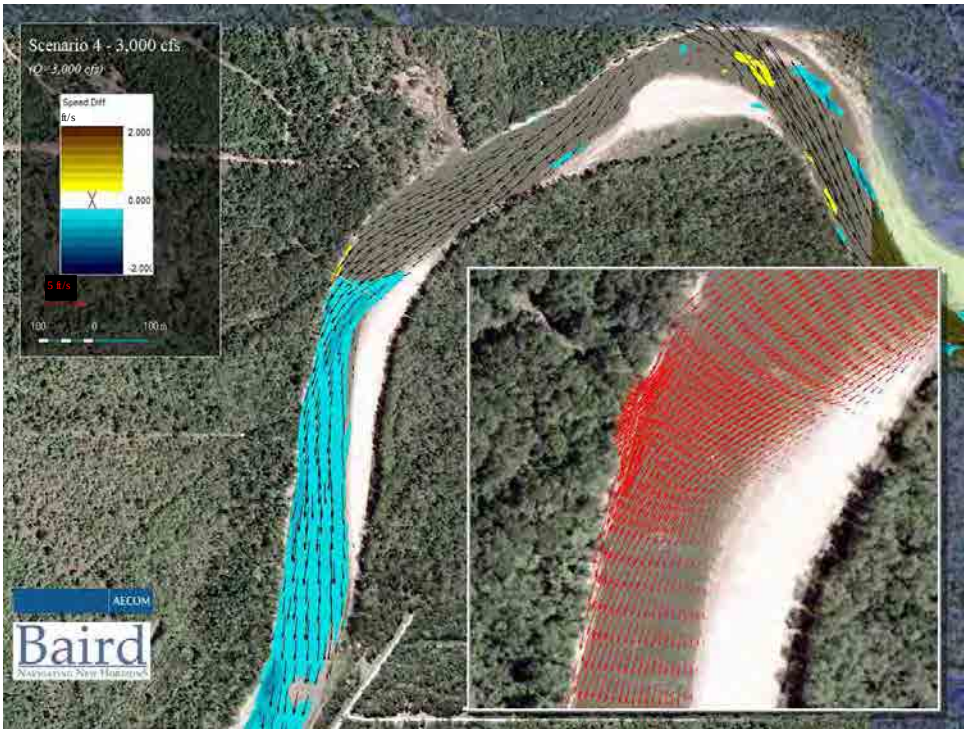

Figure 4.47: The 227 MGD and 3,000 cfs scenario does not increase upstream velocity however, downstream velocity is reduced. (App I-1)

The degree of water level depression is related to the ratio of pump rate and river discharge. For the 227 MGD, 3,000 cfs, water level depression does not propagate upstream (Figure 4.47). However, velocity is still reduced downstream as is bed shear. The reduction in bed shear is enough that it will likely induce sedimentation of fine sand downstream of the intake.

For the 2 year scenario with 293 MGD withdrawal, velocity along the intake reach increases and causes marked increases in bed shear along the entire reach (Figure 4.48).

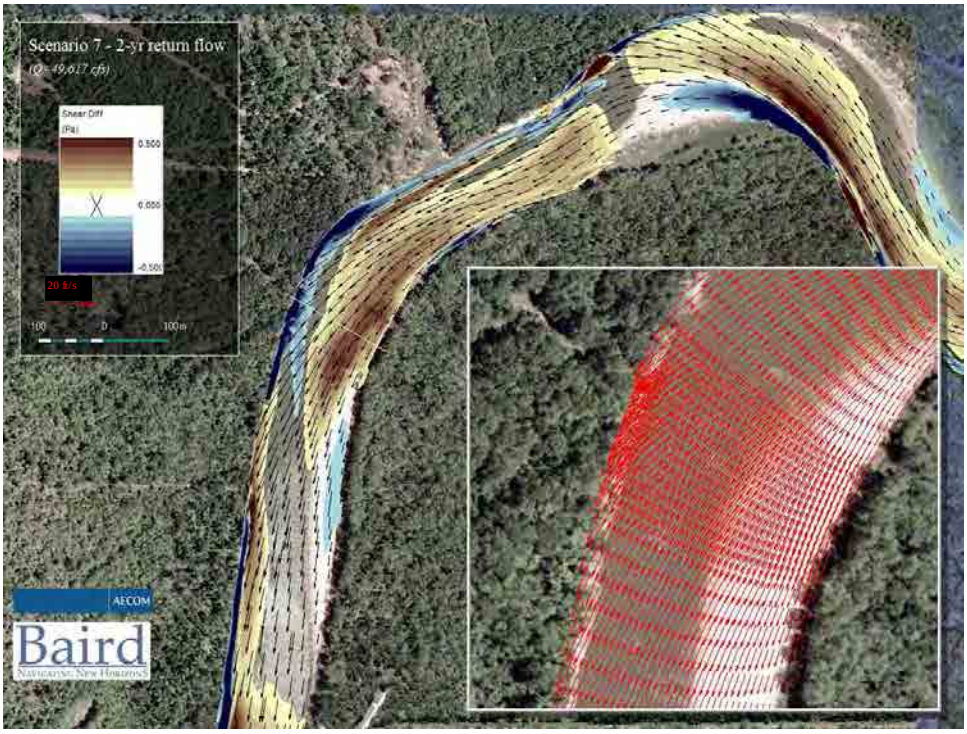

Figure 4.48: The 293 MGD and 2 year scenario results in increased bed shear along much of the reach. (App I-1)

The other effect of the proposed pump station, even when not operating, is to divert flood flows against the east bank. For example, under the 100 year event, the zone of high shear is deflected far to the east bank, where it impinges strongly opposite the intake structure, and elevated shear continues along the east bank for a distance of over 700 feet (Figure 4.49). Scour is also concentrated at the toe of the intake structure apron - this will likely induce scour during flood events.

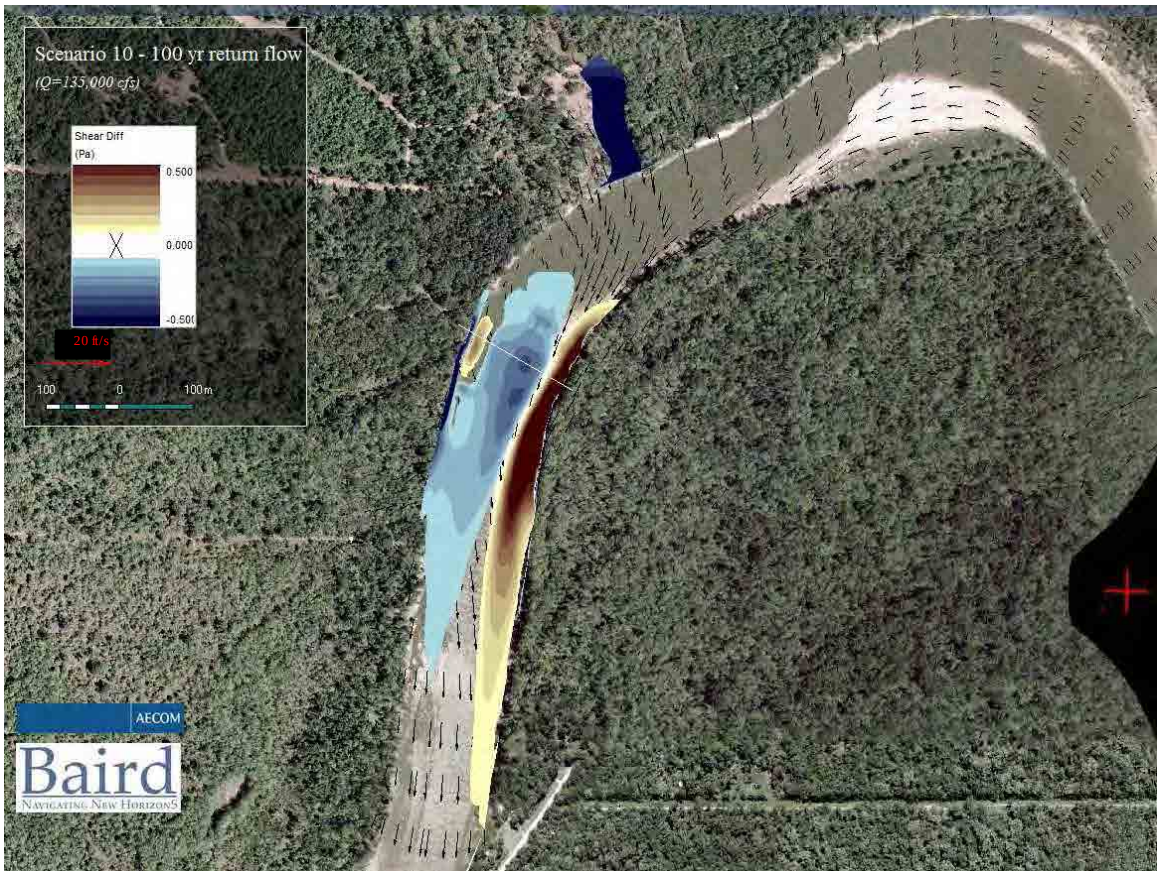

Figure 4.49: During the 100 year event, the intake structure deflects currents against the east bank and produces a zone of high bank shear. There is also a zone of high shear along the edge of the intake apron - this will likely cause scour at the toe of the intake. (App I-1)

In summary, the intake operation significantly decreases the flow velocity downstream of intake for the low flow conditions and it may result in the sedimentation at the downstream. However, it has less impact on flow patterns for large flow conditions. The intake structure may shift flow patterns near the intake for the large flow conditions. The main river flow is forced to shift east.

Water extraction decreases bed shear downstream of the intake. The large portion of water extraction could cause significant increase of bed shear at the upstream of intake, depending on the ratio of the pumping rate to river flow discharge. The intake structure causes the shift of main river flow to east and the bank protection may be required on the east bank at the intake. This shift is most pronounced with flood events where the proposed intake structure and grading, above the banks, deflects overbank flows to the east. This, in combination with the flow deflection caused by return flow from Muddy creek, shifts flood flows from the center of the channel to the east bank. Refinements of the proposed intake design will allow for minimization, or even elimination, of this flow deflection.

The bed stress at the front of proposed intake structure increases for large flow conditions. While this may result in the erosion of river bed at the front of intake, refinement of the intake and toe protection for the apron will allow for solutions to this scour.

4.4.2.2 Sediment Transport Results

The results of sediment transport are shown in Figures 34 and 35, Appendix I-1. For Scenario 3, the SSC at the front of intake increase significantly (to 13 mg/l). This mainly results from the bed shear increase at the upstream of the intake. For average condition of Scenario 4, the SSC level at the front of intake has no significant change. For Scenario 7, the SSC has a slight decrease at the front of intake corresponding to the decrease of bed shear. Due to uncertainties in the sediment data used for building the sediment transport model, this result may not be significant. The SSC for scenario 8 and scenario 10 increases slightly due to the increase of bed shear stress at the front of take.

In summary, the SSC at the front of intake may increase slightly for the large flow conditions due to the increase of bed shear stress at the front of the intake. The SSC level has no significant increase for the normal future operation (i.e. Scenario 4).

4.5 Numerical Modeling – Luce Bayou

4.5.1 Luce Bayou - Existing Conditions

This section provides a summary of the numerical modeling and analytical results from all methods conducted in this study. The reader is directed to Appendix J and relevant sections of this report for full details on methods and comprehensive presentation and discussion of results.

4.5.2 Luce Bayou - Proposed Conditions

The original layout of outfall canal, perpendicular to Luce Bayou, was revised because it diverted flow to the north river channel near the outfall and would likely result in significant shoreline and channel erosion through this area (Figure J.10). An alternative outfall orientation of 45° eliminated the flow diversion, however it focused current speeds and threatened shoreline erosion along the eastern bank of Luce Bayou (Figure J.15). Tests of alternative outfall orientations revealed an approach of 36° to 40° produced the optimum balance of preserving flow patterns and isolating shoreline from excessive flow currents and erosive shear forces (Figures J.25 - J.28). While these revised canal orientation angles minimize potential for shoreline erosion, they do not eliminate this threat.

Review of the 2D model results for Luce Bayou (Figure J.15) shows that under normal water level and flow conditions, bed shear stress in the vicinity of the outfall is typically well in excess of 1.0 Pa, and it increases with decreasing water level (Figure J.17). This effect is somewhat moderated by increasing river flow discharge in Luce Bayou, which causes backwatering in the vicinity of the outfall (Figure J.21). These results suggest that bank protection is necessary in the vicinity of the

outfall in order to preserve existing shoreline boundaries. Protection measures to prevent river bank and river bed erosion are recommended in the outfall area. This will be useful to avoid potential erosion by complicated flow in the outfall area and by high speed flow during high river flood events. Specific design and testing of such shore and outfall protection were beyond the scope of this study.

The impact of the proposed outfall discharge on existing water levels was found to be very limited (below reasonable sensitivity levels), and can be neglected in high water level events cases (such as extreme river discharge event of 10 to 100 year return period). The proposed outfall was not predicted to cause extra flooding in this river stretch.

4.6 Bank Analysis and Stabilization Concept

This section describes the results of extensive review, analytical methods and concept design of recommended alternatives for bank stabilization and protection methods both upstream of, and at the proposed pump station intake location. These results are based on the concept design of the proposed intake structure and, as per the scope of work for this project, they are conceptual in nature. While standard engineering methods have been used to produce reasonable design recommendations, these are not to be used for construction purposes. Full engineering analyses, numerical modeling, and design refinements to match a future, final intake design will be required. The field methods, analytical methods, and model development and testing described herein provide an excellent starting point for the process of concept refinement to final engineering design, including construction oversight, monitoring, and QA/QC compliance.

4.6.1 River Banks upstream and downstream of Intake Location

The outside meander bend located immediately upstream of the proposed intake site, between PB9 and PB10, has been identified as a critical area where the combined processes of bar building, ongoing erosion of the bend, and meander migration are pushing this meander down-valley. Results from historical river course analysis and point bar accretion rates indicate migration rates on the order of tens to hundreds of feet per year, depending on the type of flow events in any given year. Given the large size of these banks, natural instability of the banks and sand bed river, and infrastructure that will be at risk, a river protection concept including a combination of in-channel hydraulic structure, bank re-grading, and vegetation/bioengineering has been developed.

This concept, with figures showing the area of concern, and a sample images showing concepts of river channel and bank works are included in Appendix K. This approach has been recommended based on prior experience, the results of extensive literature review, and inspections of wide spread failure of simple bank hardening measures (e.g. spur jetties, rip-rap revetments, etc.). The combined approach of using submerged vane arrays, which work with the river hydraulics to achieve a stable form, and bank re-grading and vegetation/bioengineering of banks address both the causes and symptoms of the eroding banks.

Similarly, bank protection works are recommended for the banks opposite the proposed intake. This is because numerical modeling and point bar/vegetation survey results indicate this bank will experience elevated velocity and shear stresses from flood flows diverted across the river by the intake structure.

4.6.2 Hardened Banks at Intake Location

Three conceptual shore protection alternatives were developed to reduce the risk of erosion of the river bank and compromising of the intake structure. Schematics of these, along with Probable Opinions of Construction Cost for each alternative can be found in Appendix K. Descriptions of each alternative follow.

Alternative I

Alternative I consists of a layer of stone protection placed at a 2:1 slope starting approximately 150 feet south of the north property line and continuing to a point approximately 200 feet downstream of the proposed intake structure. Specially placed armor stone extends 25 feet on both sides of the intake structure to prevent undermining that may result due to currents produced by the protrusion of the intake into the river channel. The remainder of the bank length is protected with graded stone riprap. A bench, 15 feet in width, is included in the design at elevation +30 to allow for future monitoring and maintenance below the water line.

The lower limit of stone protection was conceptually set at +4 following a numerical analysis that estimated the likelihood of down cutting at the structure toe. The upper limit of protection was extended to the crest of the river channel at an elevation of +48 to match the top of the proposed intake structure.

Alternative II

Alternative II consists of a tied back vertical sheet pile wall, which extends 115 feet on both sides of the intake structure. The upper elevation of the wall terminates at +36 to prevent inundation during the 2-year event. Graded stone riprap protects the slope between the top of the sheet pile wall and the access road. The toe of the wall is keyed into existing clays that are naturally resistant to scour. Additional scour stone protects the toe of the sheet pile wall and the toe of the intake pad. The remainder of the channel bank is left in its natural condition.

Alternative II provides more scour protection to the immediate upstream and downstream sides of the intake than Alternative I and prevents large objects floating in the river from damaging the sides of the intake structure during a 2 year event.

Alternative III

Alternative III is similar to alternative II in concept, in that both sides of the intake will again be protected by steel structures. However, the tied back sheet pile wall in Alternative II is replaced with an open cellular structure in Alternative III. Open cellular structures are a unique design solution that incorporates benefits of both regular tie-back wall and cellular fill structure. Open cellular are more easily constructed than full cellular structure yet, safely provide greater heights than traditional tied back walls. This is because open cellular structures are more efficient to construct than traditional cellular structures while having added anchoring force from the vertical sheet pile anchor walls.

The upper elevation of the wall matches the top of the proposed intake (+48). Vertical sheet pile walls extend back into the bank to anchor the open cellular structure. Similar to Alternative II, the base of the structure is keyed into existing clays and is protected by scour stone. The remainder of the channel bank is left in its natural condition.

Alternative III provides more scour protection to the immediate upstream and downstream sides of the intake than Alternative I and prevents large objects floating in the river from damaging the sides of the intake structure during any event.

4.6.3 Discussion

Protection along the entire length of the property may not be warranted, as historical aerial photos have revealed the channel bank has been relatively stable over the past 100 years. Under any shore protection scenario, a monitoring program is essential to maintain the integrity of the structures. If a diminished shore protection plan is adopted, additional monitoring may be required. Surface water management is essential, and storm water should not be allowed to discharge over the top of the proposed shore protection structures.

Additional alternatives such as bioengineering, geogrids, and articulated concrete mats were investigated as possible slope protection measures. While it may be possible to integrate these solutions into the final design, stone and steel sheet pile are recommended as the materials that, based upon our coastal and shoreline engineering experience and extensive review of similar protection measures, will produce the most reliable results over life of the project.

Aspects of the all three alternatives can be mixed and matched to provide various design scenarios. For instance, the City of Houston could provide immediate protection on both sides of the intake similar to Alternatives II or III (to any elevation) and also provide stone protection along any length of its property.

4.6.4 Opinion of Probable Construction Costs

Unit costs were developed through discussion with suppliers and past experience in shore and coastal construction. Values represent 2009 dollars. A contingency of 25% was implemented, as the design is conceptual. A summary of these costs and descriptions of methods are provided in Appendix K. Considerable additional engineering and analysis are required to complete the designs.

5.0 DISCUSSION AND CONCLUSION

This section provides a summary of the numerical modeling and analytical results from all methods conducted in this study. The reader is directed to the Appendices and relevant sections of this report for full details on methods and comprehensive presentation and discussion of results.

5.1 Trinity River - Existing Conditions

Fluvial processes in the Trinity River within the vicinity of the proposed intake location are typical for a river of this type and in such a geologic setting. The river is located on a vast outwash plain where river slope decreases with the confluence of the Trinity River to the Gulf of Mexico. While the Gulf of Mexico seems a long distance from the intake site, tidal fluctuations are a daily part of river water levels even upstream of the Trinity River at Liberty, Texas.

In this region, the river has a much gentler slope than upstream sediment source areas (e.g. Romayor, Texas) and must continue to wind and force its meandering path through the vast outwash deposits while, at the same time, carrying its own excess sediment load. As a consequence, the river is continually building bars, eroding meander bends, depositing sediments in floodplain berms, cutting off meanders, and avulsing sections of channel. Indeed, the river deposits so much sediment in this region that much of the actual river channel and bed are at elevations higher than the surrounding floodplain (e.g. Figure 3, Appendix I-1). What we perceive as an "unstable" river, one that has time and again, undermined bridges, caused structural failures, and eroded away neighborhoods and transportation networks, is a river that is simply following the laws of thermodynamics, finding the easiest path to move water and sediment down-slope.

There are two key aspects to long-term channel stability of the Trinity River in the study area. These both relate to the planform stability of the channel (i.e. the overall location and pattern of the channel as viewed on a map). The first aspect of long-term stability is bank erosion, particularly on the outside bank of meander bends, leading to meander cutoffs. These outer banks are subject to ongoing erosion, and this is associated with point bar growth and evolution on the inside of the meander bend. This was evaluated in Sections 4.2.4 and 4.2.5 of this report. The second aspect of long-term stability is channel avulsion due to reoccupation of former river channels (see below). Note that we draw the distinction between meander cutoffs and channel avulsions.

5.2 Trinity River - Proposed Conditions

This section provides a summary of the numerical modeling and analytical results for the Trinity River. The reader is directed to Appendix I and relevant sections of this report for full details on methods and comprehensive presentation and discussion of results.

5.2.1 Potential Short-Term Channel Stability Effects

Sediment budget analysis and numerical modeling were completed for the Trinity River near the proposed intake site using a combination of observed discharge data since the completion of Lake Livingston Dam, modeled sediment concentration results, and observed suspended sediment data from the USGS gage at Romayor. The sediment budget results showed that, while the diversion would have mixed effects on sediment load, these effects were very small compared to the total sediment budget – within margin of uncertainty for sampling protocols. These results showed that, under low flow conditions with release from Lake Livingston and withdrawal, proposed water diversion would slightly increase downstream sediment load during lowest flow conditions while decreasing sediment load during higher flow conditions. The decrease during low flow periods was due to increased flows, upstream of the proposed intake, resulting from augmentation flow from Lake Livingston. Decreases during higher flows were due to removal of sediment with water withdrawals.

The proposed withdrawal scenarios were predicted to decrease downstream transport capacity for flows ranging from the average daily flow, through the 2 year event, and up to the 10 year event. However, as with the previous results, the flow reduction values were so low, < -0.3%, as to be well within the margin of uncertainty for this analysis. The augmentation flows only occurred during driest periods consequently; they had minimal impact on upstream sediment transport capacity and would only mobilize the smallest bed material size classes.

It is important to consider these results within the context of the river setting. The bed material sampled at the site has an approximate mean D50 of 0.29 mm, which is a fine-medium sand. Bed samples were well-sorted consisting of mainly of sand, so they behave without cohesion (which decreases mobility). Figure 5.1 shows a general relationship between particle size and the critical shear stress for entrainment. A particle with a D50 of 0.29 mm has a critical shear stress of motion of approximately 0.19 Pa. Review of the model outputs for shear stress through the three profiles in the vicinity of the intake show that this threshold is not exceeded during the 1,500 cfs flow. This means that the flow releases from Lake Livingston are unlikely to be sufficient to significantly increase sediment sourcing and entrainment into the project reach. Since the river system is transport-limited, and because the compensation flows are not great enough to push the river flow above the 1,500 cfs threshold for motion, the compensation flows are not likely to have a significant impact on annual bedload sediment through the study area.

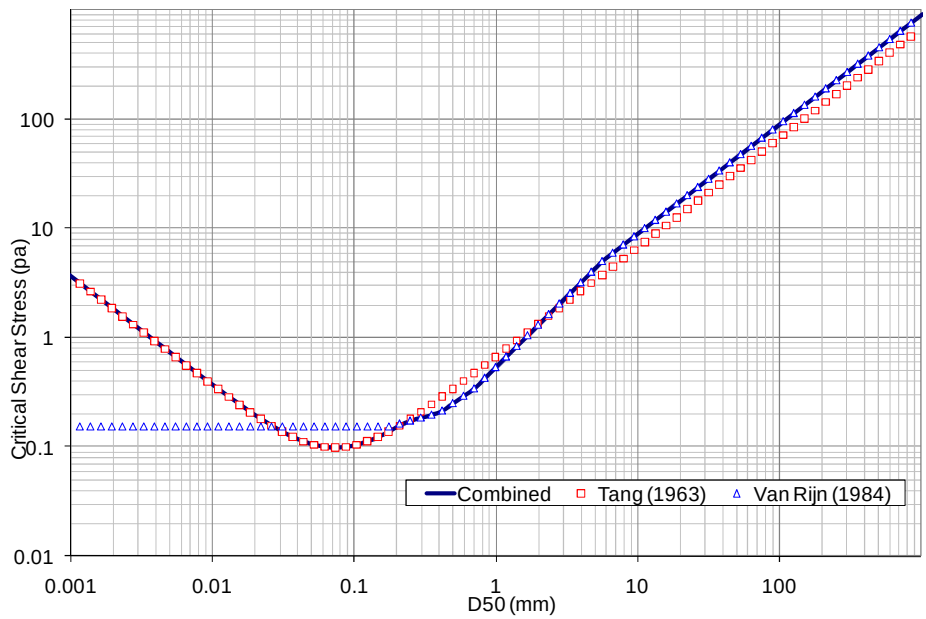

Figure 5.1: Relationship between particle size and the critical shear stress for entrainment

In addition, the results of the historic river bank analysis, point bar and vegetation surveys found bar formation and maintenance have not occurred at the proposed intake location, and downstream to the next meander bend. This can most likely be attributed to the effects of Capers Ridge on overbank flood flows for the Trinity River. During flood events, overbank flows on the western floodplain are obstructed by Capers Ridge, even up to the 500-year flood elevation. These flood water are diverted by Capers Ridge, to Mud Creek, and back in to the main river channel, immediately upstream of the proposed intake location. The current vectors of these floodwaters are nearly orthogonal to flows in Trinity River and deflect highest currents towards the inside of the meander bend, opposite the proposed intake site. This diversion of flood flows also directs bed shear towards the inside of this meander bend, and likely explains why point bars have not established there.

One potential impact revealed for the preliminary intake design is erosion of the eastern shore, opposite the intake structure. Results from flood events indicated velocity vectors and shear would likely be deflected by the intake structure, towards the east bank. During low flow conditions, such as those when field work was conducted, there is a long thin point bar along the east bank, PB11. This point bar and adjacent shoreline would be exposed to additional shear from these diverted flows. Subsequent revisions of the proposed intake will mitigate this potential impact and any remaining threat of bank erosion will be addressed with additional bank protection measures.

There is the potential for slightly elevated suspended sediment downstream of intake site as a result of the increased suspended sediment loading from compensation flows, and the withdrawal of water. This is because there is a non-linear relationship between discharge and sediment transport capacity, which leads to a relative excess of sediment, even when water is withdrawn with the same sediment concentration as the main flow. However, the relative impact for SSC

between a 700 cfs and a 1,500 cfs flow is very small, especially relative to the amount of sediment in motion at higher flows.

5.2.2 Channel Stability Upstream from the Intake

Bank erosion of the outside of meander bends over many years will lead to an increase in the sinuosity of the channel, eventually cutting off the meander bend at PB9 and PB10, Figure 3.2. The major cutoff event between 1989-1995, identified by Wellmeyer et al., (2005), is a neck cutoff, across the floodplain (as opposed to a chute cutoff across a point bar). The cutoff was formed was mainly through bend extension (where the bend moves laterally and increases with amplitude), with some translation (the bend moves downstream without changing its shape). This is the same process occurring in the meander between PB9 and PB10. While there are no general conclusions as to the frequency and distribution of these movement types, Hooke (1984), in an analysis of meander bend movement of approximately 100 alluvial bends, showed that 25% translated downstream, and 15% extended laterally. Hooke (1984) also suggested that translating bends tends to be of tight curvature, which would support the cutoff observations in the study area.

The main future area of concern for cutoffs with respect to this project is the meander around PB9 and PB10 (Section 4.2.4). This point bar does not appear to be extending downstream, based on the airphotos from the period 1995-2008. Bar formation and vegetation on the upstream outside of the meander bend (Section 4.2.4) suggest that the channel is attempting to maintain its cross-sectional form as it is translating downstream, although the permanence of this feature (and the establishment of perennial vegetation) may be being disturbed by higher flow events. While bar formation is sporadic and varies from year to year, the downstream part of the meander is growing in a downstream (translation) direction at a rate equivalent to approximately 30 ft per year. The rate at which the meander is moving downstream cannot be related precisely to the magnitude, duration and frequency of historic flood events on the Trinity River, due to the sporadic timeframe of the airphotos giving a small sample size, and multiple events occurring between photo times. However, four of the twenty highest flow events on record occurred in the period 1995-2004, including Tropical Storm Allison in June 2001, which tracked close to the study area. During this timeframe, the downstream bank of the meander translated approximately 260 ft. A large event in July 2007 also contributed to the observed difference in the 2006-2008 banks. Similar rates were obtained from the results of point bar and vegetation surveys.

5.2.3 Long-Term Channel Stability Upstream at the Project Site and Downstream

The detailed flow dynamics and sediment transport characteristics of flood flows in the intake reach are discussed in Section 4.4.2. This section examines the likelihood of channel avulsion events under extreme flood conditions which could serve to relocate the river channel within the valley floodplain. While this may be highly improbable, review of the 3D MISED model output suggests that this may be possible under extreme conditions. For example, Figures 4.40 and 4.41 show significant flow across the floodplain on the 100-year flood event. While much of the flood flow in concentrated in the existing channel, some flow leaves the channel (the distributary effect noted by

Phillips, 2008b) and re-enters it several times throughout the study area. The flow in the floodplain serves to reactivate former channels and increase flow in tributary channels. Note that a major reentry point is Mud Creek immediately upstream from the intake.

A major point at which flow leaves the channel is the meander bend on the outside of PB9, showing that a portion of flow bypasses the intake at extreme flood levels. Figure 5.2 shows the 100-year return period flow in the vicinity of PB9 and the Project Site. This shows that flow is exiting the channel at the PB9 bend at a speed of 3-5 ft/s. The resulting bed shear stress in the floodplain area immediately outside the bend varies between 20-40 Pa during the 100-year flow event. This high shear stress over the floodplain is typical in meandering rivers because of the shallow flows and large amounts of obstructions from trees, logs, etc. While this shear would be sufficient to cause erosion of bare, un-vegetated floodplain outside the meander, the floodplain forest will normally prevent such erosion. However, large bank failures can undermine floodplain trees and allow the river to cause rapid bank and floodplain erosion during bankfull and larger events. For this reason, we recommend that appropriate steps be taken to protect this meander bend to ensure that flow does not initiate accelerated erosion (discussed later).

While beyond the scope of this study, it is also possible for a large scale channel avulsion. Avulsion is a large-scale relocation of a river channel within the valley floodplain, and it is usually associated with extreme flood events. The avulsion can occur either as a results of relocation of the channel to a lower point in the floodplain as a result of floodplain aggradation (excessive floodplain building from sediment deposition) around the former channel, or it can result from reactivation of relict river channels (abandoned river channels, oxbows, etc) and tributaries within the floodplain system. The latter occurs when, during a large flood event, the flood waters take advantage of other channels in the floodplain, subsequent erosion of the floodplain connects those with the main channel, and floodwaters are diverted from the existing channel to the newly connected channel. Both avulsion types have occurred historically in the Trinity River valley. Given the extensive floodplain sediment storage in the area (Phillips et al., 2004), and the existence of relict channels in the floodplain (see below), there is potential for avulsion to occur in the study area. Over the historical period of record, such events are infrequent, typically occurring with flood events on the order of 100 year or greater events. While probability cannot be assigned to channel avulsion events because of their highly unpredictable nature, the probability of observing at least one 100 year event over a 50 year period is 40% (Table 4.1). Given the active erosion of the meander located between PB9 and PB10, the fact that this is likely to shortcut past the proposed intake site, and this added concern that erosion of this meander may facilitate channel avulsion during larger flood event, it is imperative to monitor erosion of this meander bend and fully investigate the case for stabilization of this meander bend.

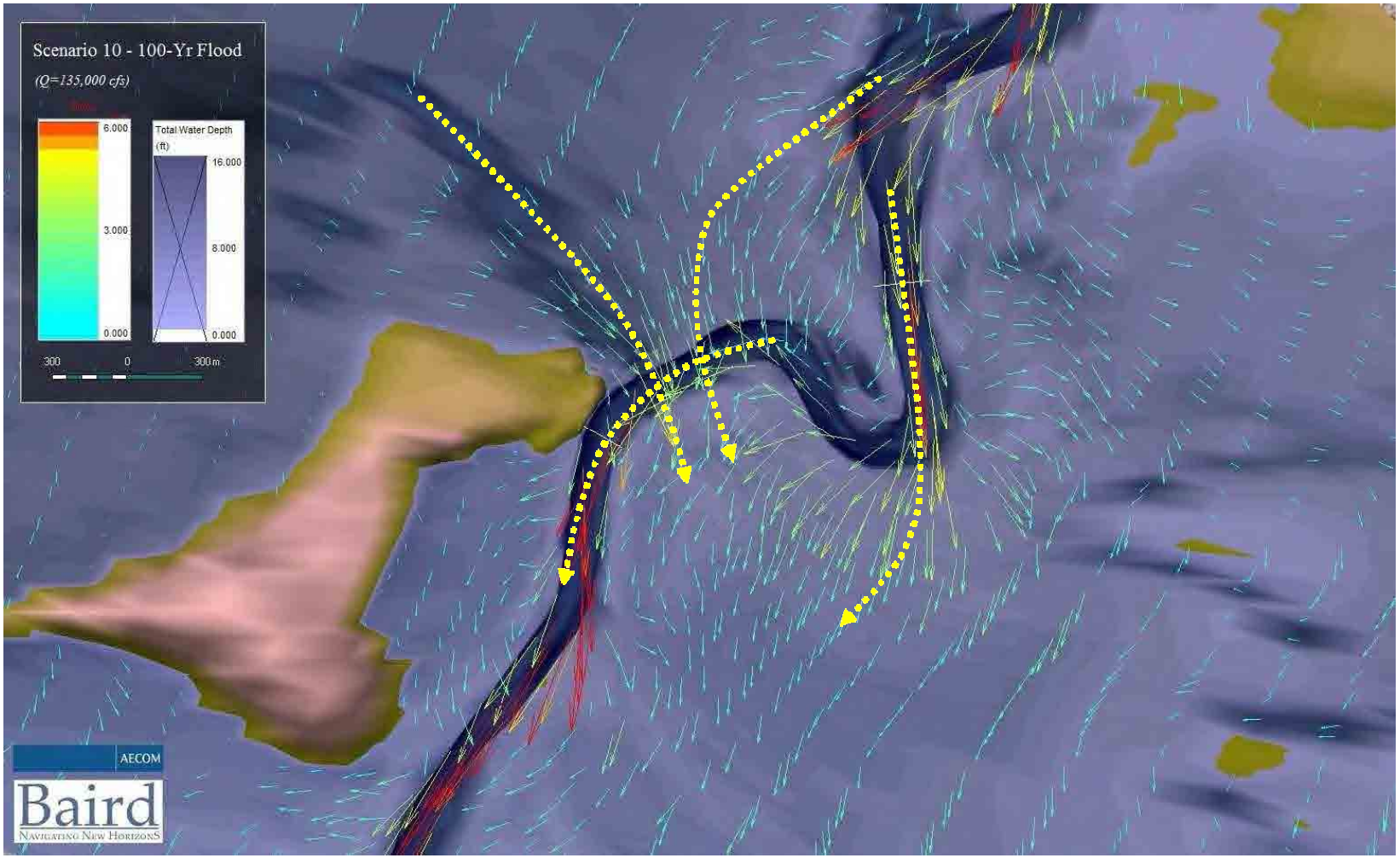

Figure 5.2: 100-year flow in the vicinity of PB9 and the Project Site

5.3 Trinity River - Conclusion

5.3.1 Project Setting

The results of the many methods employed in this study indicate the Trinity River will do what rivers like this do, despite efforts to "control" it. Consequently, the approaches we recommend strive to work with the river within its typical flow and flood regimes, rather than fighting it. For catastrophic floods, such as those that cause major channel realignments or entire river course avulsion, where the price of true "flood protection" measures are simply cost prohibitive, there is little to be done but wait for flood waters to recede and repair damage. The conceptual designs and recommendations we have provided are consistent with standard accepted engineering methods; however they should not be expected to survive such forces undamaged.

And, perhaps the most imperative point, the selection of the Capers Ridge location for the proposed pump station is perhaps the most ideal location for a "stable" project foot print. Over recent history, Capers Ridge has withstood the "test of time," and from all available records of river channel changes and review of literature, the Capers Ridge site has been "stable."

5.3.2 Recommendations

Extensive data review, analytical, numerical modeling, and field investigations have been conducted to characterize the existing conditions of the Trinity River in proximity to the proposed intake site. The Trinity River exhibits typical behavior for a sand bed river on an outwash plain - it is transport limited. Consequently, it is continually reworking its banks, bars, and floodplain sediments to increase storage through floodplain accretion in the river valley. Given the scope and scale of the proposed pump station and water diversion, anticipated impacts of the project on sediment transport are quite minimal. Given the infrequency, limited duration, and ability of the river to easily remobilize bed sediment, there are not any anticipated chronic downstream impacts on hydraulics and sediment transport.

However, meander erosion and migration do pose a real challenge for the proposed project. Erosion of the upstream meander threatens to cut-off the proposed intake structure from the main channel of the river. Rates estimated from empirical evidence and literature reviews suggest this is likely in a 50 to 100 year time frame. The results of this study suggest the cutoff rate will be closer to the 50 year estimate, plus or minus 10 years. The exact rate of time cannot be determined because of inherent uncertainties in the occurrence of future storm events and droughts that could accelerate or decelerate the erosion rates, respectively. When the cutoff occurs, the intake would likely be isolated to an oxbow cutoff channel.

In addition, the river bank opposite the preliminary intake design location has been identified as a location that would experience elevated velocity and bed shear during high flow events. This is likely to induce erosion of the bar and banks at this location. This effect will be minimized with further refinement of the proposed intake and pump station design and bank protection.

Recommendations for conceptual channel and meander stabilization have been proposed. At a minimum, a permanent river bank, river alignment and stability monitoring program should be initiated on the river. This should start well upstream of the proposed intake location, near PB6, to capture river adjustments from the recent channel cutoff at PB7, and extend through PB9 and PB 10, past the proposed pump station, to PB12. The results of this study can be used to establish the baseline condition for the project. Subsequent surveys of bathymetry, fluvial processes, repeated survey of control sections for bank erosion, and photo logging will identify any potential changes in river behavior and stability.

5.4 Luce Bayou – Existing Conditions

This section provides a summary of the numerical modeling and analytical results from all methods conducted in this study. The reader is directed to relevant sections of this report and Appendices for full details on methods and comprehensive presentation and discussion of results.

Existing conditions on Luce Bayou are typified by generally stable water levels. Shoreline conditions in proximity to the proposed outfall were dominated by natural banks showing none to low levels of eroding banks. This was attributed to sheltered nature of this particular embayment. Shoreline erosion was more pronounced along the main trunk of Luce Bayou. While causal studies were not conducted to determine the specific drivers, shoreline erosion is caused by a combination of water level fluctuation, wind waves, currents, and boat wakes. Given the exposure of the main trunk to boat traffic, yet still having sheltered conditions like the adjacent embayments, it is likely that eroding shorelines in the main trunk is significantly exacerbated by boat traffic.

A few properties along the main trunk of Luce Bayou, and near its outfall to Lake Houston, had constructed extensive shore protection. There was no shore protection in the embayment of the proposed outfall location.

5.5 Luce Bayou - Proposed Conditions

The proposed outfall alignment was designed to minimize the threat of scour for shorelines along the embayment and islands. Discharge from the proposed outfall will increase currents and potential for scour, particularly along the shore adjacent to the outfall and in the body of the embayment, where the outfall discharges into the body of the bay. During typical flow conditions, the potential for scour was not significantly increased. However, during combination of low water levels in Luce Bayou and tested outfall discharge rate, shear stresses are maximized and may induce localized erosion and scour. Shore and scour protection is recommended for these areas to minimize this threat.

5.6 Luce Bayou - Conclusion

Potential impacts of the proposed outfall on bed and shoreline scour, in proximity to the proposed outfall, have been identified. It has been recommended that scour protection is needed to protect

banks from erosive forces. A permanent shoreline and bathymetric monitoring program should be initiated on Luce Bayou, in the embayment surrounding the proposed outfall location, to document existing conditions, track potential deviations in fluvial processes and identify any potential changes in stability.

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Appendix J

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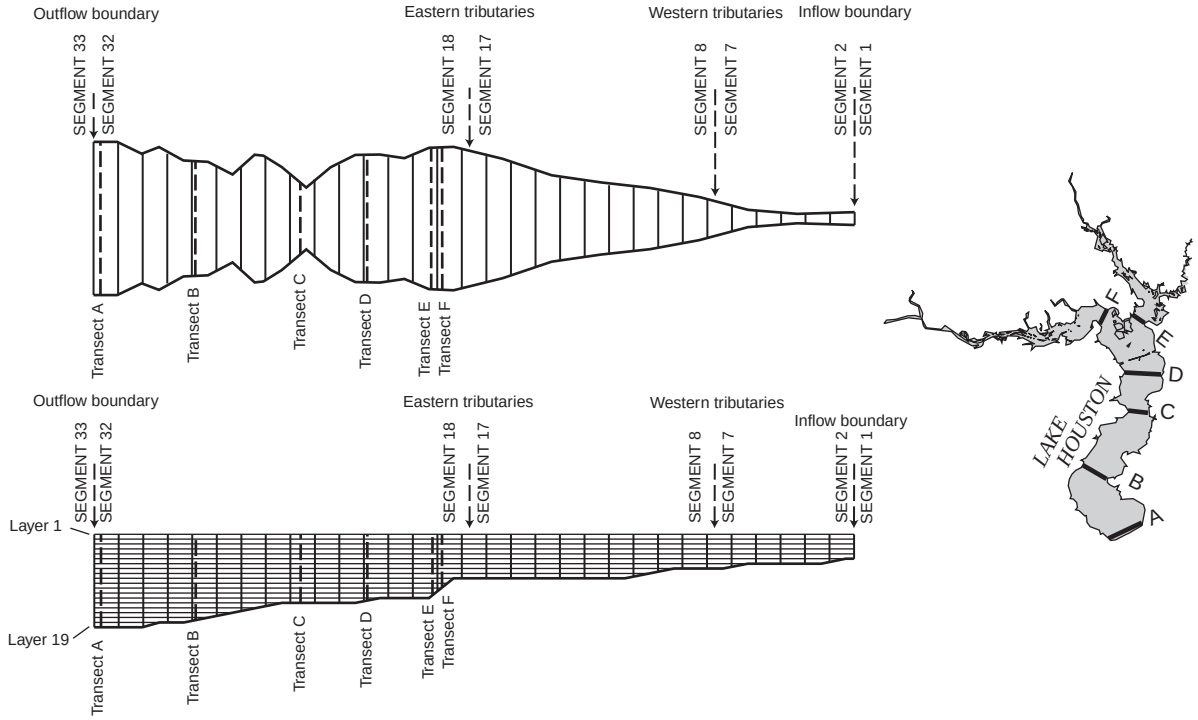
In cooperation with the City of Houston

Estimated Effects on Water Quality of Lake Houston From Interbasin Transfer of Water From the Trinity River, Texas

Water-Resources Investigations Report 00–4082



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Estimated Effects on Water Quality of Lake Houston From Interbasin Transfer of Water From the Trinity River, Texas

By Fred Liscum and Jeffery W. East

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 00–4082

In cooperation with the City of Houston

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VERTICAL DATUM

Sea level: In this report “sea level” refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called “Mean Sea Level of 1929.”

Abbreviations:

acre-ft, acre-feet
ft^3/s, cubic feet per second
°C, degrees Celsius
°F, degrees Fahrenheit
ft, feet
in., inches
m, meters
mi, miles
mi^2, square miles
mi/hr, miles per hour

Estimated Effects on Water Quality of Lake Houston From Interbasin Transfer of Water From the Trinity River, Texas

By Fred Liscum *and* Jeffery W. East

Abstract

The City of Houston is considering the transfer of water from the Trinity River to Lake Houston (on the San Jacinto River) to alleviate concerns about adequate water supplies for future water demands. The U.S. Geological Survey, in cooperation with the City of Houston, conducted a study to estimate the effects on the water quality of Lake Houston from the transfer of Trinity River water.

A water-quality model, CE–QUAL–W2, was used to simulate six water-quality properties and constituents for scenarios of interbasin transfer of Trinity River water. Three scenarios involved the transferred Trinity River water augmenting streamflow in the East Fork of Lake Houston, and three scenarios involved the transferred water replacing streamflow from the West Fork of the San Jacinto River.

The estimated effects on Lake Houston were determined by comparing volume-weighted daily mean water temperature, phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, and dissolved oxygen simulated for each of the transfer scenarios to simulations for a base dataset. The effects of the interbasin transfer on Lake Houston do not appear to be detrimental to water temperature, ammonia nitrogen, or dissolved oxygen. Phosphorus and nitrite plus nitrate nitrogen showed fairly large changes when Trinity River water was transferred to replace West Fork San Jacinto River streamflow. Algal biomass showed large decreases when Trinity River water was transferred to augment East Fork Lake Houston streamflow and large increases when Trinity River water was transferred to replace West Fork San Jacinto River streamflow. Regardless of the scenario simulated, the model indicated that light was the limiting factor for algal biomass growth.

INTRODUCTION

Lake Houston on the San Jacinto River is a reservoir currently (1999) used as a water supply by the City of Houston, Texas (fig. 1). Because of concerns about adequate water supplies from Lake Houston to meet future water demands, the City of Houston is considering the transfer of water from adjacent or other nearby drainage basins to Lake Houston. The Trinity River is being considered as one of the potential sources for the transferred water. The water that would be transferred into Lake Houston could have different chemical and biological properties and constituents than the water currently supplied to the lake from its surrounding drainage basin. These properties and constituents are documented in Liscum and others (1999). Consequently, the introduction of Trinity River water into Lake Houston has the potential to substantially change or affect the current water quality of the lake. In addition, it is also possible that water could be exported from the Lake Houston watershed to augment water supplies in developing areas that are located west of the City of Houston. On the basis of these possible scenarios, the City of Houston needs to identify and assess the types and relative magnitude of water-quality changes that could occur to ensure that the water quality of Lake Houston is not degraded. This study was conducted by the U.S. Geological Survey (USGS), in cooperation with the City of Houston, to determine potential effects on the water quality of Lake Houston from interbasin transfer of water from the Trinity River.

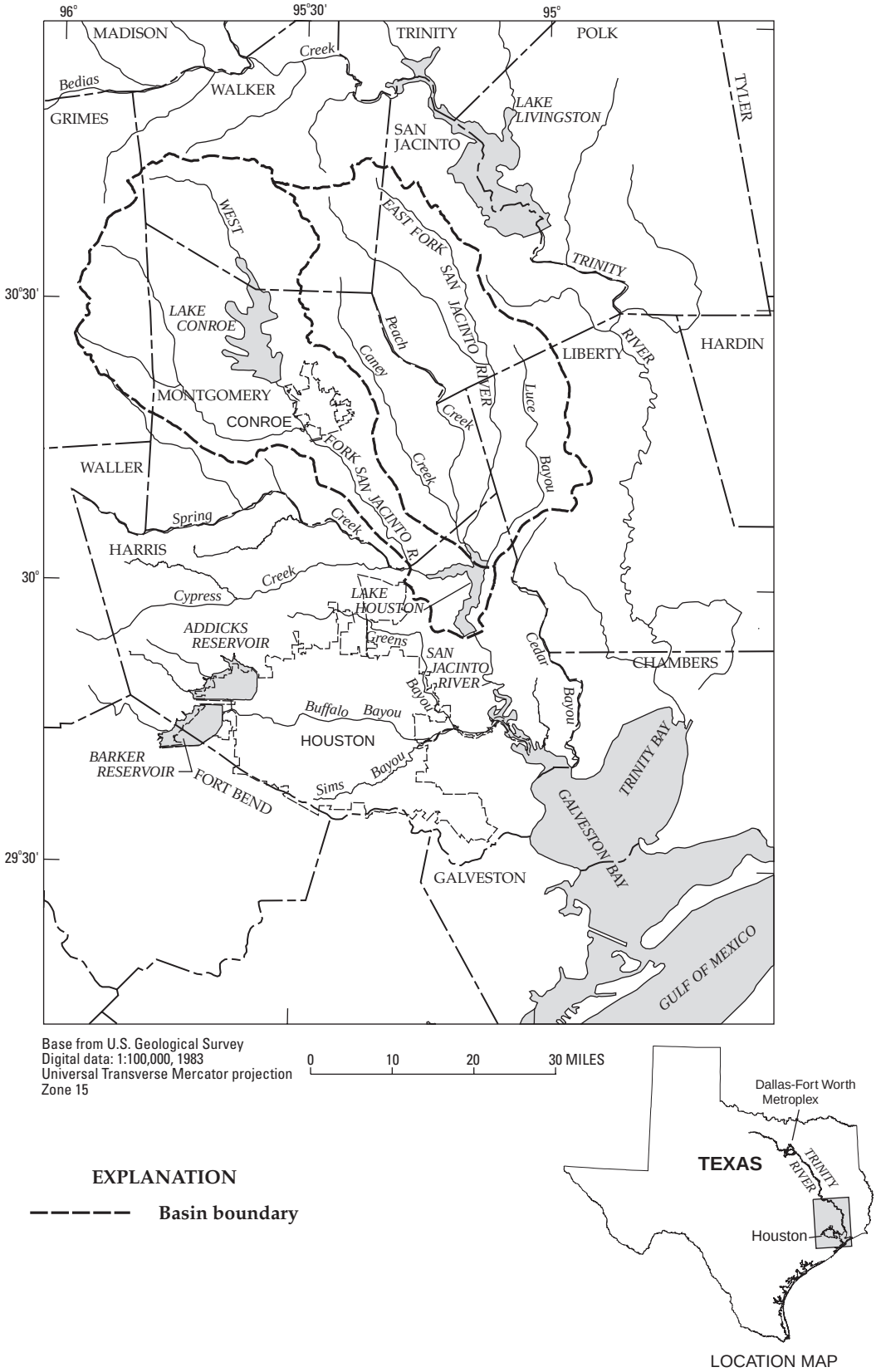

Figure 1. San Jacinto River Basin, Texas.

Purpose and Scope

The purpose of this report is to present the estimated effects on selected chemical and biological properties and constituents of Lake Houston that could result from interbasin transfer of water from the Trinity River. The City of Houston is concerned that Lake Houston has a strong potential for eutrophication, on the basis of nutrient inputs. These concerns are addressed by a study of water-quality changes as estimated using CE–QUAL–W2, a reservoir water-quality model developed by the U.S. Army Corps of Engineers (Cole and Buchak, 1995), for the following targeted properties and constituents: water temperature, selected nutrients (phosphorus, ammonia nitrogen, and nitrite plus nitrate nitrogen), algal biomass, and dissolved oxygen. To model these six targeted properties and constituents, five additional constituents must be calibrated—total dissolved solids, labile dissolved organic matter (DOM), refractory DOM, detritus, and iron. The model allows for an evaluation of the primary limiting factors affecting eutrophication—nutrients (nitrogen or phosphorus) or light. The report includes an overview of the selected water-quality model, a summary of model calibration and testing, and a comparison of estimated water-quality effects for different interbasin-transfer scenarios. The effects of the transfer of Trinity River water on Lake Houston water quality were estimated using reservoir model simulations for January 1985–September 1990. Inputs to the model were defined for the Lake Houston watershed and for the Trinity River using data collected during 1983–90 (Liscum and others, 1999). Pertinent data concerning water withdrawals from Lake Houston for the selected period also were used to configure the model.

Description of Study Area

Lake Houston is an impoundment located on the San Jacinto River, approximately 25 mi east-northeast of downtown Houston, in southeast Texas (fig. 2). Lake Houston was constructed by the City of Houston as a water supply for Houston, for the Houston-Baytown area industrial complex, and for local irrigators. The drainage basin for Lake Houston is 2,828 mi^2. The dam closure was completed on April 9, 1954. The dam forming the reservoir consists of two earthfill embankment sections and a 3,160-ft-long uncontrolled concrete spillway midway between the embankment sections, for a total length of 12,100 ft. Storage capacity of Lake Houston at the spillway crest (43.8 ft above sea level) is 146,700 acre-ft with a surface area of 12,240 acres. Mean depth for Lake Houston is 12 ft with a maximum depth of about 50 ft. Theoretical residence time computed for Lake Houston varies with flow conditions from a maximum of about 400 days during extreme low flows (when the only withdrawals are by the City of Houston) to a minimum of about 0.5 day during extreme high flows. Theoretical residence time for average flow conditions is computed to be about 40 days.

The lake has two main inflow branches or forks. The eastern branch (East Fork) drains a mainly non-urbanized rural watershed, and the western branch (West Fork) drains a more urbanized drainage basin. The major tributaries that drain into the East Fork are the East Fork San Jacinto River, Caney Creek, Peach Creek, and Luce Bayou, which drain about 935 mi^2 (about 33 percent of the Lake Houston drainage basin). The major tributaries that drain into the West Fork are the West Fork San Jacinto River, Spring Creek, and Cypress Creek, which drain about 1,725 mi^2 (about 61 percent of the drainage basin). The part of the watershed immediately surrounding Lake Houston below the tributary inflows drains about 6 percent of the watershed.

Land use in the Lake Houston drainage basin during the data-collection period was about 73 percent forest and about 14 percent pasture. Other land uses in the basin included gravel operations, oil production, agriculture, and urban. The East Fork tributary subbasin was predominantly agricultural, and the West Fork tributary subbasin was agricultural and urban (Matty and others, 1987). Other major land uses in the West Fork tributary subbasin included the Houston Intercontinental Airport (west of the lake), gravel operations, and transportation corridors (Bedient and others, 1980). The most active urban development during the study period occurred in the West Fork tributary subbasin along the lower part of the Cypress Creek watershed (fig. 2).

The climate of the study area is characterized by short mild winters, long hot summers, high relative humidity, and prevailing southeasterly winds. Annual precipitation in the Lake Houston drainage basin averages about 40 to 47 in. (Kingston, 1991). The temperatures typically range from a mean minimum of about 46 °F (8 °C) in January to a mean maximum of about 93 °F (34 °C) in July (Kingston, 1991). Wind speed

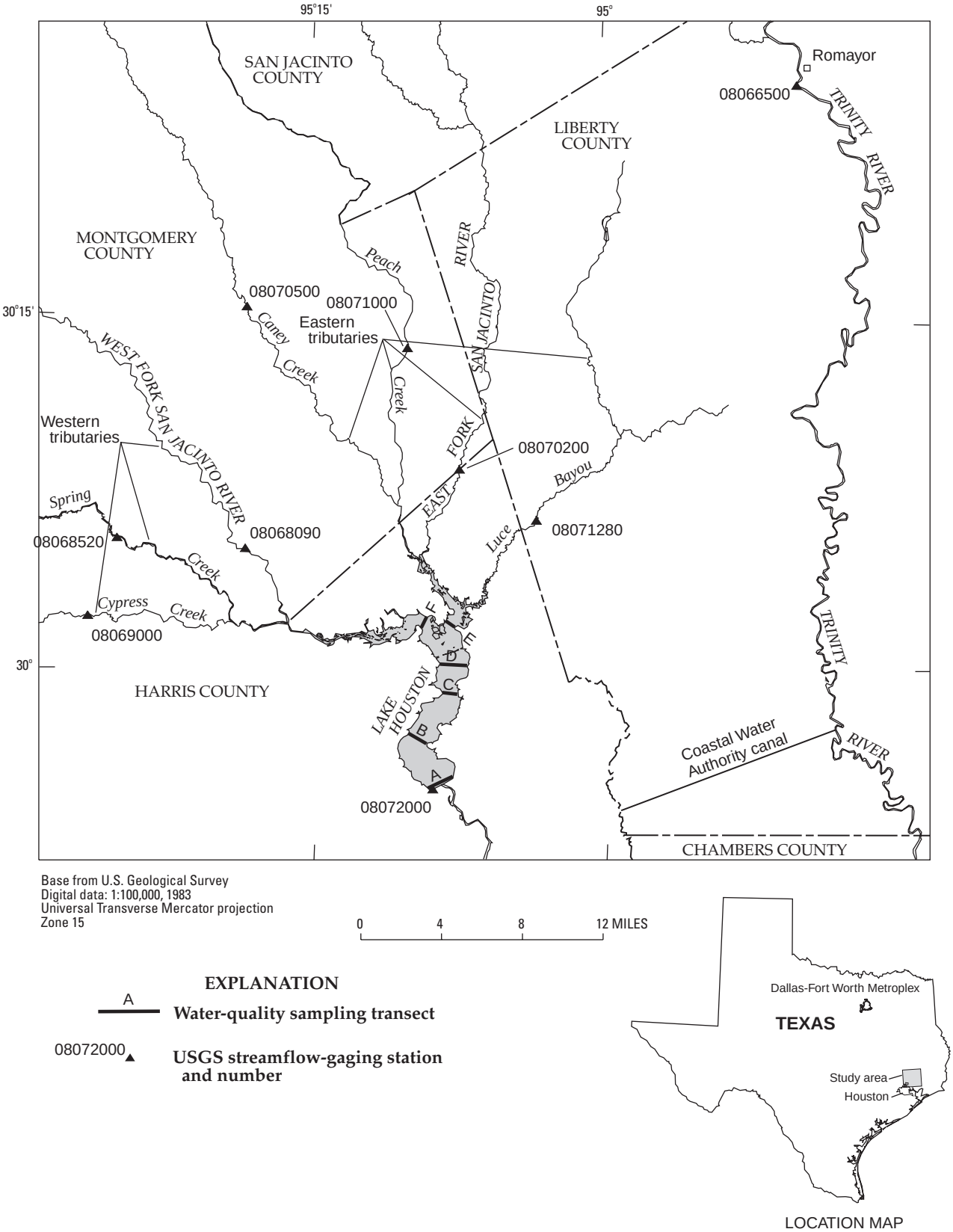

Figure 2. Location of study area and data-collection sites.

averages about 8 mi/hr and is from the south-southeast nearly the entire year (Baca and others, 1982; Houston-Galveston Area Council, 1984).

The Trinity River originates north of the Dallas-Fort Worth metroplex, about 300 mi north-northwest of Houston (fig. 2). As the Trinity River flows south, it is impounded by Lake Livingston, about 50 mi north of Lake Houston. Water-quality conditions upstream and downstream of Lake Livingston are considerably different, as suspended sediment and other water-borne constituents tend to settle out of suspension as velocity of the water slows as it passes through the reservoir. The Trinity River flows downstream from Lake Livingston and east of Lake Houston and, at its closest point to Lake Houston, is only about 3 mi from the upstream end of Luce Bayou. Thus, Luce Bayou is a possible diversion point for the interbasin transfer of Trinity River water to Lake Houston.

Water-Quality Data Available for 1983–90

A total of 59 water-quality constituents and properties were sampled in Lake Houston, its tributaries, and the Trinity River during August 1983–September 1990. These data were used to define current hydrologic and water-quality conditions for the various water bodies. Nine of the available properties and constituents were used to calibrate and test the model and to simulate the various interbasin-transfer scenarios. Liscum and others (1999) provide a detailed characterization of the data.

The data-collection sites for Lake Houston and its tributaries (table 1) are grouped as: main body of the lake (transects A, B, C, and D), East Fork of the lake (transect E), West Fork of the lake (transect F), eastern tributaries (East Fork San Jacinto River, Caney Creek, Peach Creek, and Luce Bayou), and western tributaries (West Fork San Jacinto River, Spring Creek, and Cypress Creek) (fig. 2).

The lake sampling sites consist of the six transects (A–F) across the lake, each transect with a sampling site in the old river channel (center of transect) and a sampling site on either side of the center, between the old channel and the shoreline. Samples were collected at several points in the water column (1 ft beneath the surface, at selected intermediate depths, and 1 ft above the bottom). Initially, samples were collected at the three sampling sites in each transect. However, statistical tests indicated no significant variance between the three sampling sites for constituents sampled at the same relative depth in the water column (Liscum and others, 1999). Beginning in May 1987, the center of transect sites were sampled more frequently than the two other sites on each transect. Only water-quality data were collected at the six transects. The volume of water stored in the reservoir and the amount of flow from the reservoir over the uncontrolled spillway were determined using USGS streamflow-gaging station 08072000 Lake Houston near Sheldon. Data describing public supply withdrawals from the lake just upstream of the spillway were obtained from the City of Houston.

The tributary sampling sites (fig. 2) are either existing or newly-established USGS streamflow-gaging stations. Stream-discharge and water-quality data were collected at the tributary sampling sites. Only six of the seven tributaries were sampled; Peach Creek was not sampled because it is hydrologically similar to nearby Caney Creek.

Trinity River water-quality samples were collected at station 08066500 Trinity River at Romayor (fig. 2, table 1), about 15 mi upstream of a likely diversion point that would connect to Luce Bayou. Stream-discharge and water-quality data also were collected at this site.

Nine properties and constituents were required for the model to estimate selected water-quality changes—water temperature; total phosphorus; total ammonia nitrogen; total nitrite plus nitrate nitrogen; chlorophyll *a*; dissolved oxygen; total dissolved solids; total organic carbon (TOC); and dissolved iron (hereinafter referred to as iron). Water temperature and total dissolved solids affect water density and, thus, influence water movement throughout the reservoir. Total phosphorus, total ammonia nitrogen, and total nitrite plus nitrate nitrogen were the nutrients selected for this study. Chlorophyll *a* is an indicator of the amount of algal biomass present. Chlorophyll *a* was collected only at sampling sites in the euphotic zone (near the surface) of Lake Houston. Chlorophyll *a* was greater during the summer at each site sampled (Liscum and others, 1999). Dissolved oxygen, which is essential for higher forms of life and controls many chemical reactions through oxidation, is an indicator of potential degradation of reservoir water quality. Dissolved oxygen concentrations indicate the general health of an aquatic system such as Lake Houston. TOC is a measure of the organic material that influences nutrient and algal biomass cycles in the reservoir; organic material for the model was defined as labile DOM, refractory DOM,

Table 1. Surface-water-quality sampling sites in Lake Houston, Trinity River, and tributaries to Lake Houston

[mi^2, square miles]

Station no. or site identification no.	Station or site name	Drainage area (mi^2)	Latitude	Longitude	Purpose
	Lake Houston sampling sites				
08072000	Lake Houston near Sheldon, Tex.	2,828	29°54'58"	95°08'28"	Define outflow from reservoir and volume of water stored in Lake Houston
295516095080801	Transect A, center at dam	--	29°55'16"	95°08'08"	Define water quality in main body of Lake Houston
295702095091401	Transect B, center	--	29°57'02"	95°09'14"	Define water quality in main body of Lake Houston
295902095074201	Transect C, center	--	29°59'02"	95°07'42"	Define water quality in main body of Lake Houston
300016095073401	Transect D, center	--	30°00'16"	95°07'34"	Define water quality in main body of Lake Houston
300158095074601	Transect E, center at mouth of East Fork to Lake Houston	--	30°01'58"	95°07'46"	Define water quality in East Fork of Lake Houston
300209095091201	Transect F, center at mouth of West Fork to Lake Houston	--	30°02'09"	95°09'12"	Define water quality in West Fork of Lake Houston
	Trinity River and tributary sampling sites				
08066500	Trinity River at Romayor, Tex.	17,186	30°25'30"	94°51'02"	Define flow and water quality in Trinity River
08068090	West Fork San Jacinto River above Lake Houston near Porter, Tex.	962	30°05'09"	95°17'59"	Define flow and water quality in West Fork San Jacinto River
08068520	Spring Creek at Spring, Tex.	419	30°05'31"	95°24'21"	Define flow and water quality in Spring Creek
08069000	Cypress Creek near Westfield, Tex.	285	30°02'08"	95°25'43"	Define flow and water quality in Cypress Creek
08070200	East Fork San Jacinto River near New Caney, Tex.	388	30°08'43"	95°07'27"	Define flow and water quality in East Fork San Jacinto River
08070500	Caney Creek near Splendora, Tex.	105	30°15'34"	95°18'08"	Define flow and water quality in Caney Creek; estimate flow and water quality in Peach Creek (08071000)
08071280	Luce Bayou above Lake Houston near Huffman, Tex.	218	30°06'34"	95°03'35"	Define flow and water quality in Luce Bayou

and detritus, all determined from TOC. Iron affects nutrients through adsorption and settling.

Data collected August 1983–September 1990 indicated differences among the eastern and western tributaries and the Trinity River for eight of these properties and constituents (Liscum and others, 1999):

1. Total phosphorus, total ammonia nitrogen, total nitrite plus nitrate nitrogen, and total dissolved solids concentrations in the western tributaries generally were greater than in the eastern tributaries and were similar to concentrations in the Trinity River.
2. Water temperature and dissolved oxygen concentrations in the Trinity River generally were greater than in the eastern and western tributaries, which were similar.
3. Iron concentrations in the eastern tributaries were greater than in the western tributaries and

Trinity River, and concentrations in the western tributaries were greater than in the Trinity River.

4. TOC concentrations, which were similar in the eastern and western tributaries, were slightly greater than concentrations in the Trinity River.

Interbasin Water-Transfer Scenarios

The objective of this study was to estimate the effects of transferring water into Lake Houston from a source outside the reservoir drainage basin that would provide additional water supply for the City of Houston. For this study, the Trinity River was selected as the source of interbasin transfer of water because it is the closest river basin of those considered (Trinity, Neches, and Sabine Rivers). A previous study (Turner, Collie, and Braden, Inc., 1972) also indicated the Trinity River as a potential source of water for transfer into Lake Houston.

To estimate the amount of water to be transferred into Lake Houston from the Trinity River, two assumptions were made regarding the need to supplement Lake Houston water. First, the continued population growth of Houston would require a larger supply of water than Lake Houston currently (1999) can provide. Second, if water from the San Jacinto River Basin that currently supplies Lake Houston was transferred to another basin (a possible result under a State water plan [Texas Water Development Board, 1990] to transfer water from the "water rich" areas of the State to those areas that are normally in need of water), additional water supply to Lake Houston would be needed to replace the water transferred out of the San Jacinto River Basin. These assumptions were used to develop six scenarios to transfer water from the Trinity River into Lake Houston.

The first three scenarios are related to East Fork streamflow and are based on the assumption that increased streamflow from the Trinity River would be transferred to the East Fork of the lake to satisfy increased demand for water supply. Streamflow is assumed to be transferred from the Trinity River unless any of the East Fork tributaries are in "flood." A "flood" is defined as flows greater than two times the annual mean discharge. The three scenarios are:

1. Trinity River streamflow equal to 50 percent of East Fork streamflow is transferred to streamflow entering Lake Houston through the East Fork.

2. Trinity River streamflow equal to 100 percent of East Fork streamflow is added to streamflow entering Lake Houston through the East Fork.

3. Trinity River streamflow equal to 200 percent of East Fork streamflow is added to streamflow entering Lake Houston through the East Fork.

The last three scenarios are based on the assumption that streamflow from the West Fork San Jacinto River is being transferred to another basin in the State. Streamflow from the Trinity River is transferred to the East Fork (by way of Luce Bayou) so that the same amount of streamflow (as transferred from the West Fork San Jacinto River) enters Lake Houston. Streamflow is assumed to be transferred from the Trinity River unless any of the West Fork tributaries are in "flood." The three scenarios are:

4. Trinity River streamflow is used to replace 25 percent of West Fork streamflow, which has been transferred out of the basin.

5. Trinity River streamflow is used to replace 50 percent of West Fork streamflow, which has been transferred out of the basin.

6. Trinity River streamflow is used to replace 100 percent of West Fork streamflow, which has been transferred out of the basin.

Table 2 summarizes flow, including average annual import and export, for each of the six scenarios during 1985–90.

These scenarios were developed to represent a range of possible interbasin water transfers that could occur. The scenarios should provide estimates of the possible effects that such transfers might have on the water quality in Lake Houston.

Acknowledgments

The authors thank Jim Greenlee, Public Works Operations Manager, City of Houston, for helping to develop water-transfer scenarios involving transfer of streamflow from the Trinity River into Lake Houston. The authors also appreciate the comments and

Table 2. Summary of flow for six water-transfer scenarios, 1985–90, Trinity River into Lake Houston

[ft^3/s, cubic feet per second; --, not available]

Simulation year	Average annual Trinity River flow imported through East Fork (ft^3/s)	Average annual flow in East Fork (ft^3/s)	Average annual flow in West Fork (ft^3/s)	Average annual flow exported from West Fork (ft^3/s)	Average annual water use, Lake Houston (ft^3/s)
Scenario 1—Import Trinity River flow equal to 50 percent of East Fork flow					
1985	177	691	1,280	0	301
1986	169	812	941	0	205
1987	199	697	1,080	0	166
1988	94.6	209	338	0	216
1989	119	737	809	0	173
1990	198	518	756	0	179
Scenario 2—Import Trinity River flow equal to 100 percent of East Fork flow					
1985	223	691	1,280	0	301
1986	202	812	941	0	205
1987	232	697	1,080	0	166
1988	159	209	338	0	216
1989	175	737	809	0	173
1990	215	518	756	0	179
Scenario 3—Import Trinity River flow equal to 200 percent of East Fork flow					
1985	288	691	1,280	0	301
1986	286	812	941	0	205
1987	292	697	1,080	0	166
1988	231	209	338	0	216
1989	252	737	809	0	173
1990	275	518	756	0	179
Scenario 4—Import Trinity River flow equal to 25 percent of West Fork flow, which has been transferred out of basin					
1985	243	691	1,280	576	301
1986	202	812	941	435	205
1987	209	697	1,080	468	166
1988	84.4	209	338	165	216
1989	126	737	809	355	173
1990	178	518	756	344	179
Scenario 5—Import Trinity River flow equal to 50 percent of West Fork flow, which has been transferred out of basin					
1985	273	691	1,280	550	301
1986	272	812	941	391	205
1987	286	697	1,080	421	166
1988	157	209	338	118	216
1989	222	737	809	299	173
1990	282	518	756	282	179
Scenario 6—Import Trinity River flow equal to 100 percent of West Fork flow, which has been transferred out of basin					
1985	389	691	1,280	493	301
1986	341	812	941	363	205
1987	347	697	1,080	389	166
1988	287	209	338	32.8	216
1989	286	737	809	271	173
1990	299	518	756	280	179

suggestions from the CE–QUAL–W2 model developer, T.M. Cole, U.S. Army Corps of Engineers, Vicksburg, Miss.

APPLICATION OF CE–QUAL–W2 MODEL TO LAKE HOUSTON

The introduction of transferred water into Lake Houston has the potential to substantially change or affect the water quality of the lake. Collection and analysis of hydrologic data alone do not provide a means to adequately assess possible future effects from interbasin transfer of water on the water quality of Lake Houston. A calibrated reservoir water-quality model, however, can be used to estimate these possible effects by simulating reservoir response to selected inflow scenarios.

Models are simplified representations of complex systems and allow the entire system to be visualized in a manner that otherwise might not be possible. The actual processes in nature cannot be described completely through mathematical formulas; therefore, models must be conceptual in nature. Additionally, models must be calibrated and tested using field-collected data. For this project, a large database was available to calibrate and test the model.

Model Characteristics

The U.S. Army Corps of Engineers water-quality model, CE–QUAL–W2, was chosen for this project. The model incorporates finite-difference techniques to approximate the solutions to the governing equations. The model "is a two-dimensional, longitudinal/vertical hydrodynamic and water-quality model" that is "best suited for relatively long and narrow water bodies exhibiting longitudinal and vertical water-quality gradients" (Cole and Buchak, 1995, p. 1). Additionally, the model accepts input from more than one inflow tributary, whereas many models accept input from only one inflow tributary. Lake Houston is a reservoir with seven major inflow tributaries and exhibits the longitudinal and vertical water-quality gradients recommended for the model.

CE–QUAL–W2 can be used to compute as many as 22 water-quality components. The model relies on a defined rectangular grid to describe the water body longitudinally and vertically. The water-quality components are modeled using either a conservative or nonconservative approach. For example, total dissolved solids are modeled conservatively; phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, dissolved oxygen, labile DOM, refractory DOM, detritus, and iron are modeled using a nonconservative approach that includes tracking the internal flux between the target component and the other components (which are influences). The water-temperature dependence of the biological and chemical rates are controlled using a temperature-rate multiplier function. The controlling or limiting factor for biological activity (production and decline of algal biomass) is influenced predominantly by the interaction of three constituents or properties—the level of nitrogen in the lake, the level of phosphorus in the lake, or the amount of light energy available for photosynthesis in the lake. More detailed discussions regarding the theoretical basis and application of CE–QUAL–W2 are given by Cole and Buchak (1995).

Application of the model requires six types of data: (1) geometric data, (2) initial conditions, (3) boundary conditions, (4) coefficients and constants, (5) calibration data, and (6) simulation data.

Geometric data are used to define a rectangular grid for the finite-difference representation of the water body being modeled. These data, referred to as the bathymetry data, are composed of a sufficient number of typical cross sections to define the geometry of the water body. Bathymetry data define the longitudinal spacing between typical cross sections; the vertical spacing represents depth. A typical cross section is used to define a segment. A group of linearly linked segments define a branch for a water body. The vertical spacing is referred to as layer thickness. The computational grid for Lake Houston was defined as one branch with 31 active segments and 19 active layers (fig. 3). The model used a longitudinal spacing (DLX) of 1,000 m, a layer thickness (H) of 1.0 m, and average cross-sectional widths defined using data interpreted from sonar surveys at multiple traverses on the reservoir. The most upstream active segment for the model, segment 2, is at the location of the West Fork San Jacinto River near Porter (08068090). Tributary inflow enters the computational grid at segment 7 for the remaining western tributaries, Spring Creek (08068520) and Cypress Creek (08069000), and at segment 17 for the eastern tributaries, East Fork San Jacinto River (08070200), Caney Creek (08070500), Peach Creek (08071000), and Luce Bayou (08071280). Segment 19 is located at transect E, just downstream from sampling transect F; and segment 32 is located

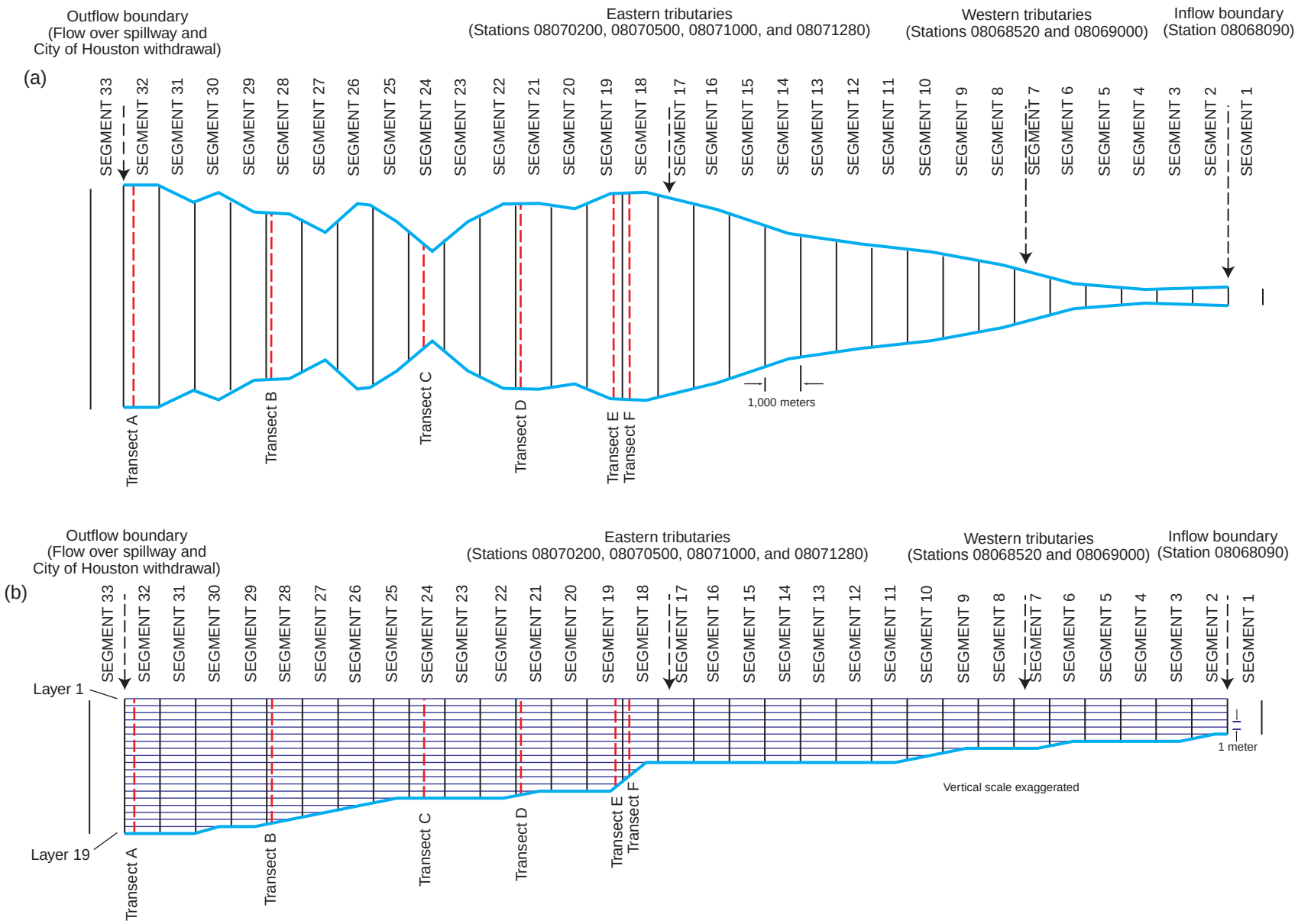

Figure 3. Schematic showing views of Lake Houston as represented in CE–QUAL–W2 model: (a) Plan view of surface layer; (b) Longitudinal cross-section view.

near the dam, at the reservoir outflow and city withdrawal point (fig. 3).

Initial conditions set the beginning values for the water-surface elevation of the reservoir, water temperature throughout the reservoir, and concentrations of each water-quality constituent. Application of the model on Lake Houston was restricted to calendar year runs. Thus, initial values of the water-surface elevation, water temperature throughout the reservoir, and water-quality constituents were determined for January 1 of each year modeled (1985–90) from available observed data. The reservoir was assumed to be well mixed.

Boundary conditions set the limits for computing the various governing equations. The type and number of boundary conditions required were determined by the physiography of the water body being modeled. The required boundary conditions for Lake Houston were divided into three groups: inflows into the reservoir, outflows from the reservoir, and conditions between the water and the atmosphere at the boundary.

Lake Houston was modeled as one branch (fig. 3) with a single inflow (West Fork San Jacinto River) and six tributaries (Spring Creek, Cypress Creek, East Fork San Jacinto River, Caney Creek, Peach Creek, and Luce Bayou). The “one branch” configuration was adequate as depths were not sufficiently different in the two forks of the reservoir to require more branches; also, the use of “one branch” reduced computational time. The West Fork was chosen as the “branch” as opposed to the East Fork because the drainage area for the West Fork tributaries is about twice that of the East Fork tributaries. Observed data were used to define streamflow, water temperature, and concentrations of the water-quality constituents for the single inflow and for five of the six tributaries. Data for Peach Creek were estimated on the basis of the observed data for Caney Creek (08070500). Distributed tributary inflow was also used to define flow into the reservoir from areas (about 6 percent of the drainage basin) that were not gaged. The distributed tributary inflow was estimated as a prorated average of the inflow from the gaged basins (08068090, 08068520, 08069000, 08070200, 08070500, and 08071280).

Two outflows were defined for the reservoir. One was the flow over a nearly 3,200-ft-wide uncontrolled spillway, and the other was the flow withdrawn from Lake Houston for public supply. The outflow over the spillway was estimated on the basis of a stage-discharge relation that was accurate for flows greater than 2,500 ft^3/s and a mass balance of all flows into and out of the reservoir for flows less than 2,500 ft^3/s (when wind can affect flow over the wide spillway). The data describing public supply withdrawals from Lake Houston (just upstream of the spillway) were furnished by the City of Houston.

Knowledge of boundary conditions between the water and the atmosphere is required so that surface heat exchange, solar radiation absorption, wind stress, and gas exchange can be included in the model. Detailed meteorologic data were available from the National Weather Service recording gage at Houston Intercontinental Airport (about 10 mi west of Lake Houston). These data, which include hourly values of air and dew point temperatures, wind speed, wind direction, and cloud cover, were provided by the U.S. Army Corps of Engineers Waterways Experiment Station at Vicksburg, Miss.

For this study, CE–QUAL–W2 was used to compute 11 of the possible 22 water-quality components—water temperature, phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, dissolved oxygen, total dissolved solids, labile DOM, refractory DOM, detritus, and iron. Six of the water-quality components—water temperature, phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, and dissolved oxygen—are also the targeted properties and constituents that are the main focus of this report. Five of the water-quality components—total dissolved solids, labile DOM, refractory DOM, detritus, and iron—are required by the model to compute the targeted properties and constituents. To compute the water temperature and water budget, the model requires 10 coefficients (table 3). A total of 42 coefficients affect constituent kinetics for the 10 remaining water-quality properties and constituents computed for the report (table 3). The values for the kinetic coefficients were determined during calibration, although Cole and Buchak (1995) provide guidelines and ranges to aid in the calibration process. In addition to the 42 kinetic coefficients, 8 other constants are defined; 7 of these define required stoichiometric equivalents and 1 defines the limiting value for dissolved oxygen concentrations, below which anaerobic processes begin. Table 3 presents all 60 coefficients and constants with their final values, typically the default values, which have been shown in applicable literature to provide the best model results. Cole and Buchak (1995) list default values and present a more complete discussion concerning recommendations for model coefficient selection.

Table 3. Selected coefficients and constants determined for Lake Houston application of CE–QUAL–W2

[m, meter; sec, second; --, not applicable; W, watts; °C, degrees Celsius; g, gram; SOD, sediment oxygen demand; DOM, dissolved organic matter]

Applicable model component	Coefficient or constant	Value	Unit
Water temperature	Longitudinal eddy viscosity	1.0	m^2-sec^{-1}
	Longitudinal eddy diffusivity	1.0	m^2-sec^{-1}
	Chezy coefficient	70.0	$m^{0.5}$-sec^{-1}
	Wind sheltering coefficient	1.0	--
	Fraction of incident solar radiation absorbed in the surface layer	.45	--
	Coefficient of bottom heat exchange	7.0^{-8}	W-m^2-sec^{-1}
	Bottom-sediment temperature	20.4 (1988) 21.0 (1989)	°C
	Extinction coefficient for pure water	.45	m^{-1}
	Extinction coefficient for inorganic solids	.01	m^2-g^{-1}
	Extinction coefficient for organic solids	.40	m^2-g^{-1}
Phosphorus	Sediment release rate of phosphorus as fraction of SOD	.005	--
	Phosphorus partitioning coefficient for suspended solids	1.2	--
	Algal half-saturation constant for phosphorus	.003	g-m^{-1}
Ammonia nitrogen	Sediment release rate of ammonia as fraction of SOD	.005	--
	Ammonia decay rate	.05	day^{-1}
	Algal half-saturation constant for ammonia	.007	g-m^{-1}
	Lower temperature for ammonia decay	5.0	°C
	Lower temperature for maximum ammonia decay	25.0	°C
	Fraction of nitrification rate at lower temperature for ammonia decay	.1	--
	Fraction of nitrification rate at lower temperature for maximum ammonia decay	.98	--
Nitrite plus nitrate nitrogen	Nitrate decay rate	2.0	day^{-1}
	Lower temperature for nitrate decay	5.0	°C
	Lower temperature for maximum nitrate decay	25.0	°C
	Fraction of denitrification rate at lower temperature for nitrate decay	.1	--
	Fraction of denitrification rate at lower temperature for maximum nitrate decay	.98	--
Algal biomass	Algal growth rate	1.10	day^{-1}
	Algal mortality rate	.01	day^{-1}
	Algal excretion rate	.01	day^{-1}
	Algal dark respiration rate	.045	day^{-1}
	Algal settling rate	.01	day^{-1}
	Saturation intensity at maximum photosynthetic rate	100.0	W-m^2
	Fraction of algal biomass lost by mortality to detritus	.80	--
	Lower temperature for algal growth	10.0	°C
	Lower temperature for maximum algal growth	30.0	°C
	Upper temperature for maximum algal growth	35.0	°C
	Upper temperature for algal growth	40.0	°C
	Fraction of algal growth rate at lower temperature for algal growth	.1	--
	Fraction of maximum algal growth rate at lower temperature for maximum algal growth	.99	--
	Fraction of maximum algal growth rate at upper temperature for maximum algal growth	.99	--
	Fraction of algal growth rate at upper temperature for algal growth	.1	--

Table 3. Selected coefficients and constants determined for Lake Houston application of CE–QUAL–W2—Continued

Applicable model component	Coefficient or constant	Value	Unit
Dissolved oxygen and others (sediment, phosphorus, ammonia nitrogen, carbon dioxide, and iron)	Sediment oxygen demand	2.10 (segment 19) 1.10 (segment 32)	$g\text{-}m^2\text{-}day^{-1}$
Dissolved oxygen	Dissolved oxygen concentration at which anaerobic processes begin	.2	$g\text{-}m^{-3}$
DOM, labile and refractory	Labile DOM decay rate	.001	day^{-1}
	Labile to refractory decay rate	.001	day^{-1}
	Maximum refractory DOM decay rate	.0005	day^{-1}
Particulate organic matter (detritus)	Detritus decay rate	.001	day^{-1}
	Detritus settling rate	.001	day^{-1}
	Lower temperature for organic matter decay	4.0	°C
	Lower temperature for maximum organic matter decay	25.0	°C
	Fraction of organic matter decay at lower temperature for organic matter decay	.1	--
	Fraction of organic matter decay at lower temperature for maximum organic matter decay	.98	--
Iron	Iron sediment release rate as fraction of SOD	.30	--
	Iron settling velocity	.50	$m\text{-}day^{-1}$
Algae, organic matter, phosphorus, ammonia, nitrate, and dissolved oxygen	Oxygen stoichiometric equivalent for ammonia decay	4.57	--
	Oxygen stoichiometric equivalent for organic matter decay	1.4	--
	Oxygen stoichiometric equivalent for dark respiration	1.4	--
	Oxygen stoichiometric equivalent for algal growth	1.4	--
	Stoichiometric equivalent between organic matter and phosphorus	.011	--
	Stoichiometric equivalent between organic matter and nitrogen	.08	--
	Stoichiometric equivalent between organic matter and carbon	.45	--

Calibration data are crucial for any model application and, in this instance, consist of data to define the conditions in the water body at selected times as well as the contributions from inflows into the reservoir. Calibration data for Lake Houston were collected at six transects (fig. 2) in the reservoir during August 1983–September 1990. Most of the data were collected at transect A, indicative of the water quality for the main body of Lake Houston and the public supply; transect E, representing the East Fork of the lake; and transect F, representing the West Fork of the lake. The greatest number of samples were collected during intensive sampling May 1987–September 1990 (Liscum and others, 1999). Water-quality data also were collected during these periods at the tributaries so that the contributions from the inflows could be defined.

Four constituents included in the model application could not be sampled directly—algal biomass, labile DOM, refractory DOM, and detritus. Chlorophyll *a* (in milligrams per liter), measured during the study as an indicator for algal biomass, was used to define the algal biomass (in milligrams per liter) by the following relation (Cole and Buchak, 1995):

$$\text{algal biomass} = 67 * \text{chlorophyll } a. \qquad (1)$$

TOC (in milligrams per liter) was used to define DOM (labile and refractory) and particulate organic

matter (detritus) (in milligrams per liter) by the following relations (Walter Rast, U.S. Geological Survey, written commun., 1991; Martin, 1987):

$$\text{labile DOM} = 0.30 * \frac{(\text{TOC})}{0.45}, \quad (2)$$

$$\text{refractory DOM} = \frac{0.70 * (\text{TOC})}{0.45}, \text{and} \quad (3)$$

$$\text{detritus} = \frac{0.30 * (\text{TOC})}{0.45}. \quad (4)$$

The final type of data required for a model application is simulation data. To simulate water-quality conditions in Lake Houston, data characterizing inflow and outflow conditions are required. Inflow conditions are described using the six tributary sites, stations 08068090, 08068520, 08069000, 08070200, 08070500, and 08071280 (table 1). Outflow conditions are characterized by data from the reservoir site (station 08072000, table 1), and by data from the City of Houston detailing withdrawals from Lake Houston for public supply. Also, this application for Lake Houston required data representing water from the Trinity River. The Trinity River at Romayor (08066500) is the site closest to the probable withdrawal point (fig. 2). The data from this site are used to define the water quality of any flow withdrawn from the Trinity River and transferred to Lake Houston.

Model Calibration and Testing

Model calibration is an iterative process in which the user adjusts model coefficients until there is acceptable agreement between observed data and simulated results for the calibration period. Testing is a check of the calibrated model to determine if simulations are acceptable for a period different from that used for calibration. If the results of testing indicate poor agreement between observed and simulated data, the model is recalibrated and retested.

The Lake Houston CE–QUAL–W2 model was calibrated using observed flow and water-quality data for the 1988 calendar year; the model was tested using data for the 1989 calendar year. These periods were selected because more water-quality data were available for Lake Houston and the six tributaries for these 2 years than for other years. It is assumed that model calibration is more accurate and model testing is more representative using periods of the most observed data available. Streamflows for the 1988 calendar year are the smallest of any of the 6 years considered (1985–90), with a mean of 209 ft^3/s for the combined eastern tributaries and 338 ft^3/s for the combined western tributaries. Streamflows for the 1989 calendar year are larger, with a mean of 739 ft^3/s for the combined eastern tributaries and 809 ft^3/s for the combined western tributaries.

Calibration consisted of three steps. First, the model was checked to ensure that the observed water budget was reproduced by comparing observed and simulated water-surface elevations for the reservoir and by comparing associated computed volumes of water in the reservoir. Differences between observed and simulated water-surface elevations and differences between the associated computed reservoir volumes result from incorrect bathymetric data, incomplete or inaccurate flow data, poor simulation of evaporation, and seepage gains or losses. The bathymetric data were checked to within about 10 percent of the current capacity table throughout the range of water-surface elevations. All inflow and outflow water data were checked using simple mass-balance computations; when problems developed from using estimated flows, model inputs were adjusted to provide for mass balance. The effects of evaporation were accounted for by the original observed data; seepage gains or losses for Lake Houston were not substantial enough to affect calibration. Comparisons of the hydrographs of observed and simulated water-surface elevations for the calibration year (1988) and for the test year (1989) indicate that the shape of the hydrographs are reproduced very well. Differences between computed volumes of water in the reservoir for the observed and simulated water-surface elevations were less than 1 percent.

Second, the model was calibrated for simulation of water temperature. Water temperature is affected by surface and bottom heat exchange, as well as by hydrodynamics. Modeling water temperature is affected by mainstem and tributary inflows and their water temperature and location; outlet and withdrawal flows and their location; bathymetric data; and meteorologic variables. The model coefficients and constants that affect temperature (table 3) are longitudinal eddy viscosity; longitudinal eddy diffusivity; Chezy coefficient; wind-sheltering coefficient; fraction of incident solar radiation absorbed in the surface layer; coefficient of bottom heat exchange; bottom-sediment temperature; and extinction coefficient for light (consisting of a coefficient for pure water, for inorganic solids, and for

organic solids). Cole and Buchak (1995, p. 26) state "applications on numerous reservoirs under a wide variety of conditions have shown that the model generates remarkable, accurate predictions using default values," and "the wind-sheltering coefficient has the most effect on temperature." This was the case for Lake Houston, where default values proved to be adequate for most of the previously mentioned coefficients and constants after the wind-sheltering coefficient was set to 1.00 (for open land) and the bottom-sediment temperature for each calendar year was set to the average yearly temperature for Lake Houston.

The third step of calibration was to determine the values of the kinetic coefficients needed to compute the 10 remaining water-quality constituents (phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, dissolved oxygen, total dissolved solids, labile DOM, refractory DOM, detritus, and iron). This consisted of iterative runs using 1988 calendar year data, comparing plots of various simulated water-quality properties and constituents versus observed data for selected days, and comparing "goodness-of-fit" criteria among model runs using kinetic coefficients with different values. Testing was similar for 1989 calendar year data. The "goodness-of-fit" criteria were defined by the following evaluations:

1. Profile plots of the 11 properties and constituents on selected dates of data collection at the sampling transects in the lake were reviewed for visual comparison between observed and simulated data.

2. Volume-weighted concentration of each property and constituent at defined segments for each 1-hour increment during a model run were computed as:

$$VWC_{ji} = \frac{\sum (C_j(k, i) * DLX(i) * BH(k, i))}{\sum (DLX(i) * BH(k, i))}, \quad (5)$$

where

VWC = volume-weighted concentration of constituent j at active segment i,

$C_j(k, i)$ = concentration of constituent j at layer k in segment i,

DLX(i) = reach length for segment i, and

BH(k, i) = product of the thickness of layer k times the width of segment i at layer k.

From these data, the annual volume-weighted daily means were determined for observed and simulated data. A comparison of these values indicates how well the model performs for the annual time series.

3. The reliability index (RI), which compares the observed to the simulated data, was computed and used to evaluate how well the model performs (Leggett and Williams, 1981). The RI for a constituent is as follows:

$$RI = \frac{1 + \sqrt{\frac{1}{N} \cdot \sum_{n=1}^{N} \left[\frac{1 - (Y_o)/(Y_s)}{1 + (Y_o)/(Y_s)}\right]^2}}{1 - \sqrt{\frac{1}{N} \cdot \sum_{n=1}^{N} \left[\frac{1 - (Y_o)/(Y_s)}{1 + (Y_o)/(Y_s)}\right]^2}}, \quad (6)$$

where

N = all matching pairs of observed and simulated data,

Y_o = observed data, and

Y_s = simulated data.

An RI of 1.0 indicates perfect agreement between observed and simulated data; RI increases as observed and simulated data diverge. RI values do not depend on whether the observed or simulated value is greater. If all comparisons are on average one-half order of magnitude apart, RI would be 5.0 (Environmental Laboratory, 1986). Wlosinski (1984) considered RI to be the best statistic for aggregating model results using CE–QUAL–R1, the predecessor to CE–QUAL–W2. Martin (1987) also relied on RI to evaluate CE–QUAL–W2 in his study. RI values less than about 3.0 are considered to indicate an acceptable calibration. An RI greater than 10 might indicate extremely small values, usually for simulated data, which can mislead interpretation of results (Environmental Laboratory, 1986). RI values were used in this report to evaluate the final calibration and test run data.

The coefficients and constants required to calibrate CE–QUAL–W2 are summarized in table 3. The coefficients and constants determined for the Lake Houston model appear reasonable when compared to those determined by other users of this and similar models (Bowie and others, 1985; Cole and Buchak, 1995; Environmental Laboratory, 1986; Martin, 1987). The calibration and test run results were evaluated using the

Table 4. Volume-weighted daily means computed for observed and simulated data for selected properties and constituents at segments 19 and 32 during calibration and test years

[°C, degrees Celsius; mg/L, milligrams per liter; DOM, dissolved organic matter]

Property or constituent (unit of measure)	1988 (model calibration year)				1989 (model test year)			
	Segment 19		Segment 32		Segment 19		Segment 32	
	Observed	Simulated	Observed	Simulated	Observed	Simulated	Observed	Simulated
Water temperature (°C)	27.1	27.3	25.8	25.6	23.6	24.2	23.0	23.4
Phosphorus (mg/L)	.18	.93	.14	.72	.16	.62	.18	.57
Ammonia nitrogen (mg/L)	.03	.04	.02	.04	.05	.05	.05	.05
Nitrite plus nitrate nitrogen (mg/L)	.10	1.04	.13	.85	.10	.76	.14	.60
Algal biomass (mg/L)	.50	.18	.19	.16	.20	.04	.07	.06
Dissolved oxygen (mg/L)	6.18	6.11	5.93	6.06	6.02	6.63	5.88	6.43
Total dissolved solids (mg/L)	140.1	191.6	142.5	175.3	112.5	218.7	118.5	215.5
Labile DOM (mg/L)	3.95	3.25	4.18	3.34	5.09	3.28	5.43	3.23
Refractory DOM (mg/L)	9.21	8.60	9.77	9.18	11.87	8.16	12.68	8.17
Detritus (mg/L)	5.64	4.85	5.97	5.07	7.27	4.79	7.76	4.75
Iron (mg/L)	.03	.07	.04	.06	.18	.06	.21	.07

"goodness-of-fit" criteria (previously stated) for two main parts of the reservoir (segment 19, transect E just downstream from transect F; and segment 32, transect A near the dam—as shown in fig. 3).

Calibration and testing results are summarized by comparing observed and simulated data at segments 19 and 32 of Lake Houston on three selected dates for the calibration year (May 20, July 13, and September 6) and for the testing year (June 16, July 13, and September 7) (figs. 4a–v at end of report); by comparing observed and simulated volume-weighted daily means between calibration and testing years (table 4); and by assessing the RI for calibration and testing years (table 5). The results are summarized for both the targeted properties and constituents—water temperature, phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, and dissolved oxygen—as well as those required by the model to compute the targeted properties and constituents—total dissolved solids, labile DOM, refractory DOM, detritus, and iron. Calibration and testing results are considered sufficiently accurate and reliable if they compare favorably to results from previous application. Calibration and testing results from Martin (1987) were compared to results from this study.

The model produced reliable results for water temperature and dissolved oxygen. In the authors' opinion, profile plots indicate very good correlation between observed and simulated data (figs. 4a–b, 4k–l). RI for model calibration and testing ranged from 1.04 to 1.15 for water temperature and from 1.17 to 1.23 for dissolved oxygen (table 5). The model also produced reliable results for ammonia nitrogen, total dissolved solids, labile and refractory DOM, and detritus. Profile plots indicate good correlation between observed and simulated data (figs. 4e–f, 4m–t). RI for model calibration and testing for the organic matter constituents ranged from a best (refractory DOM, 1.10 to 1.61) to a worst (ammonia nitrogen, 1.53 to 2.13). Observed and simulated phosphorus data are shown in figs. 4c–d. While vertical variation was simulated sufficiently, the model consistently overpredicted observed values at all sites. This overprediction was most likely caused by the fact that total phosphorus data were used as model input while CE–QUAL–W2 expects orthophosphorus. Orthophosphorus data were not collected from Lake Houston, therefore, total phosphorus was used as a surrogate. However, total phosphorus most probably settles in the reservoir but does not in the simulation, thus the overprediction. The objective of the model is not to make exact predictions of phosphorus concentrations but instead is to allow for comparison of the various water-transfer scenarios. As such, the use of total phosphorus still allows comparison of relative values, which meets the stated purpose.

Table 5. Summary of reliability index computed for selected properties and constituents at segments 19 and 32 during calibration and test years

[DOM, dissolved organic matter]

Property or constituent	Reliability index for 1988 (model calibration year)		Reliability index for 1989 (model test year)	
	Segment 19	Segment 32	Segment 19	Segment 32
Water temperature	1.05	1.04	1.15	1.11
Phosphorus	4.42	4.42	3.92	3.18
Ammonia nitrogen	2.13	2.08	1.53	1.57
Nitrite plus nitrate nitrogen	9.78	7.27	6.55	4.44
Algal biomass	4.14	3.08	33.10	31.95
Dissolved oxygen	1.19	1.17	1.23	1.21
Total dissolved solids	1.37	1.24	2.02	1.95
Labile DOM	1.25	1.26	1.61	1.74
Refractory DOM	1.16	1.10	1.53	1.61
Detritus	1.21	1.19	1.57	1.68
Iron	2.95	3.24	5.45	4.09

RI values for model calibration and testing for nitrite plus nitrate nitrogen, algal biomass, and iron, which ranged from a best (iron, 2.95 to 5.45) to a worst (algal biomass, 3.08 to 33.10), indicate that model results might be inaccurate. As was the case for phosphorus, the objective of the model is not to make exact predictions of constituent concentrations but instead is to allow for comparison of the various water-transfer scenarios. As such, even though the model did not accurately predict nitrite plus nitrate nitrogen, algal biomass, and iron, relative comparison of simulated values for these constituents can still be made for various scenarios to assess potential effects of interbasin transfer.

This also is indicated by the profile plots for these constituents (figs. 4g–j, 4u–v). Improvements in the model calibration could be accomplished through improvements to various algorithms, as well as improvements to the calibration database. For instance, a more reliable computation of algal biomass and the inclusion of suspended sediment data for the inflows to Lake Houston and for the lake itself could improve the model components because of the interaction between either nutrients or iron and suspended sediments. However, RI values computed for these water-quality constituents are quite similar to those reported by Martin (1987). Therefore, it was determined that the Lake Houston model was sufficiently calibrated within acceptable model tolerances.

ESTIMATED EFFECTS OF INTERBASIN TRANSFER

After calibrating and testing the model using observed data, model simulations were run for three categories of input data. These consisted of a base dataset and data for the two general water-transfer scenarios (augmenting East Fork tributary streamflow, replacing West Fork tributary streamflow) developed for this study. (See “Interbasin Water-Transfer Scenarios” section.) The base dataset was developed by a simulation using the observed data for January 1985–September 1990 at the tributary sites to Lake Houston and the model coefficients and constants determined in the calibration. The possible effects that interbasin transfers could have on the six targeted water-quality properties and constituents (water temperature, phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, and dissolved oxygen) in Lake Houston were estimated by comparing the results of model simulations using the base dataset to the results of model simulations using the data for the two general water-transfer scenarios.

Model simulations using the model coefficients and constants determined during calibration (table 3)

were made for each calendar year (or partial year) during January 1985–September 1990 for the base dataset and for each of the six water-transfer scenarios. Model results are illustrated by the volume-weighted daily mean concentrations simulated for each targeted property or constituent by day, selected calendar year, and entire simulation period. The selected calendar years were 1988, the low-flow year for the period, and 1985, the high-flow year for the period. Changes in the volume-weighted daily mean concentrations of the targeted properties and constituents for each of the six scenarios are shown for the low-flow and high-flow years (figs. 5a–f at end of report).

The estimated effects of the six water-transfer scenarios were evaluated on the basis of a compatibility index (CI) and a comparison of the means of the volume-weighted daily mean properties and constituents. The CI compares the simulated values of the properties and constituents for the base dataset to those for each water-transfer scenario in the same way that the RI compares observed and simulated data during calibration runs. The CI for this report is computed as:

$$CI = \frac{1 + \sqrt{\frac{1}{N} \cdot \sum_{n=1}^{N} \left[\frac{1 - (Y_s)/(Y_b)}{1 + (Y_s)/(Y_b)} \right]^2}}{1 - \sqrt{\frac{1}{N} \cdot \sum_{n=1}^{N} \left[\frac{1 - (Y_s)/(Y_b)}{1 + (Y_s)/(Y_b)} \right]^2}}, \qquad (7)$$

where

N = all matching pairs of simulated values for base dataset and for a water-transfer scenario,

Y_s = simulated value for water-transfer scenario, and

Y_b = simulated value for base dataset.

A CI of 1.0 indicates no difference between base dataset results and water-transfer-scenario results. The CI increases as the difference increases.

The effects of the transfer of Trinity River water into Lake Houston were assumed to be of most consequence when considering the reservoir as a public supply. Furthermore, that part of Lake Houston nearest the City of Houston withdrawal point was considered critical. This section, nearest the spillway and including transect A (fig. 2), is segment 32 of the model (fig. 3). The following discussion of model results for the six water-transfer scenarios is limited to the values of the six targeted properties and constituents simulated for segment 32.

The comparison between volume-weighted daily means simulated for the base dataset and for the water-transfer scenarios (figs. 5a–f) gave the following results:

Low-flow year (1988)

Water temperature - no appreciable difference
Phosphorus - appreciable difference
Ammonia nitrogen - minimal difference
Nitrite plus nitrate nitrogen - appreciable difference
Algal biomass - appreciable difference
Dissolved oxygen - no appreciable difference

High-flow year (1985)

Water temperature - no appreciable difference
Phosphorus - minimal difference
Ammonia nitrogen - minimal difference
Nitrite plus nitrate nitrogen - minimal difference
Algal biomass - no appreciable difference
Dissolved oxygen - no appreciable difference

The CI for water temperature indicated close agreement between simulations for the base dataset and each transfer scenario (table 6).The percent change between simulations for the base dataset and each transfer scenario was zero (table 7).

The CI confirmed that the differences between volume-weighted daily mean phosphorus, ammonia nitrogen, and nitrite plus nitrate nitrogen simulated for the base dataset and for the transfer scenarios increase as the percentage of transferred Trinity River water increases (table 6). As the percentage of transferred Trinity River water to augment East Fork tributary streamflow increased (scenarios 1–3), the volume-weighted daily means simulated for the nutrients generally stayed about the same or decreased slightly (figs. 5b–d); and as the percentage of transferred Trinity River water to replace West Fork tributary streamflow increased (scenarios 4–6), the volume-weighted daily means simulated generally decreased somewhat more than for the East Fork augmentation scenarios. However, the authors have less confidence in the results for phosphorus and nitrite plus nitrate nitrogen than for some of the other constituents because of problems encountered during calibration of these two nutrients. The percent change between simulations for the base dataset and for each of the water-transfer scenarios (table 7) indicated that replacing West Fork San Jacinto River streamflow with Trinity River water had a greater

Table 6. Summary of compatibility index for volume-weighted daily mean properties and constituents simulated for base dataset and for six water-transfer scenarios at segment 32 in Lake Houston, during selected simulation periods

[DOM, dissolved organic material]

Property or constituent	Compatibility index for simulation period, 1985–90					
	Transfer scenario 1 (50 percent of East Fork flow)	Transfer scenario 2 (100 percent of East Fork flow)	Transfer scenario 3 (200 percent of East Fork flow)	Transfer scenario 4 (25 percent of West Fork flow)	Transfer scenario 5 (50 percent of West Fork flow)	Transfer scenario 6 (100 percent of West Fork flow)
Water temperature	1.01	1.01	1.01	1.00	1.01	1.00
Phosphorus	1.06	1.15	1.18	1.15	1.29	1.65
Ammonia nitrogen	1.07	1.09	1.14	1.10	1.17	1.25
Nitrite plus nitrate nitrogen	1.05	1.07	1.10	1.14	1.29	1.71
Algal biomass	5.83	6.09	6.27	5.11	5.15	5.19
Dissolved oxygen	1.02	1.03	1.04	1.01	1.01	1.02

Property or constituent	Compatibility index for low-flow year (1988)					
	Transfer scenario 1 (50 percent of East Fork flow)	Transfer scenario 2 (100 percent of East Fork flow)	Transfer scenario 3 (200 percent of East Fork flow)	Transfer scenario 4 (25 percent of West Fork flow)	Transfer scenario 5 (50 percent of West Fork flow)	Transfer scenario 6 (100 percent of West Fork flow)
Water temperature	1.01	1.01	1.01	1.00	1.00	1.01
Phosphorus	1.06	1.11	1.19	1.27	1.51	2.53
Ammonia nitrogen	1.10	1.16	1.19	1.09	1.16	1.31
Nitrite plus nitrate nitrogen	1.02	1.05	1.11	1.18	1.44	2.66
Algal biomass	1.48	1.85	1.98	1.17	1.31	1.64
Dissolved oxygen	1.02	1.02	1.02	1.01	1.01	1.02

Property or constituent	Compatibility index for high-flow year (1985)					
	Transfer scenario 1 (50 percent of East Fork flow)	Transfer scenario 2 (100 percent of East Fork flow)	Transfer scenario 3 (200 percent of East Fork flow)	Transfer scenario 4 (25 percent of West Fork flow)	Transfer scenario 5 (50 percent of West Fork flow)	Transfer scenario 6 (100 percent of West Fork flow)
Water temperature	1.01	1.01	1.01	1.01	1.01	1.01
Phosphorus	1.12	1.05	1.05	1.04	1.07	1.12
Ammonia nitrogen	1.05	1.09	1.15	1.11	1.19	1.32
Nitrite plus nitrate nitrogen	1.11	1.12	1.14	1.14	1.19	1.33
Algal biomass	1.22	1.21	1.22	1.12	1.12	1.04
Dissolved oxygen	1.02	1.02	1.04	1.01	1.02	1.02

Table 7. Summary of percent change between volume-weighted daily mean properties and constituents simulationed for base dataset and for six water-transfer scenarios at segment 32 in Lake Houston, 1985–90

[°C, degrees Celsius; mg/L, milligrams per liter; DOM, dissolved organic matter; <, less than]

Property or constituent (unit of measure)	Base dataset volume-weighted daily mean	Percent change in volume-weighted daily mean for water transfer to augment East Fork flow			Percent change in volume-weighted daily mean for water transfer to replace West Fork flow		
		Transfer scenario 1 (50 percent of East Fork flow)	Transfer scenario 2 (100 percent of East Fork flow)	Transfer scenario 3 (200 percent of East Fork flow)	Transfer scenario 4 (25 percent of West Fork flow)	Transfer scenario 5 (50 percent of West Fork flow)	Transfer scenario 6 (100 percent of West Fork flow)
Water temperature (°C)	21.3	0	0	0	0	0	0
Phosphorus (mg/L)	.47	-2	-2	-11	-13	-23	-38
Ammonia nitrogen (mg/L)	.06	0	0	0	0	0	-17
Nitrite plus nitrate nitrogen (mg/L)	.62	0	0	-2	-6	-19	-34
Algal biomass (mg/L)	.05	-20	-20	-20	+20	+20	+40
Dissolved oxygen (mg/L)	6.77	+1	+1	+2	<+1	<+1	+1

effect on nutrient concentrations than augmenting East Fork streamflow.

Simulation results indicated that transferring water from the Trinity River would have an effect on algal biomass; however, the problems calibrating algal biomass also might affect the accuracy of the simulation results. Except for the high-flow year, the CI indicated that the differences between the simulations for the base dataset and for each water-transfer scenario increased as the percentage of transferred Trinity River water increased (table 6). The percent change between simulations for the base dataset and for each of the water-transfer scenarios (table 7) indicated that as the percentage of transferred Trinity River water to augment East Fork streamflow increased (scenarios 1–3), algal biomass decreased; as the percentage of transferred Trinity River water to replace West Fork San Jacinto River streamflow increased (scenarios 4–6), algal biomass increased. Model results indicated that light was the limiting factor for algal biomass growth for each scenario simulated. These results are in agreement with Lee and Rast (1997) who concluded that primary production of algal biomass in Lake Houston is limited by light rather than by the nutrients, phosphorus and nitrogen.

The CI for dissolved oxygen indicated close agreement between simulated results for the base dataset and for each water-transfer scenario (table 6). The percent change between simulations for the base dataset and for each of the water-transfer scenarios (table 7) indicated that as the percentage of transferred Trinity River water to augment East Fork streamflow increased (scenarios 1–3), dissolved oxygen concentrations increased; as the percentage of transferred Trinity River water to replace West Fork streamflow increased (scenarios 4–6), dissolved oxygen concentrations increased.

The estimated effect on the water quality of Lake Houston from the transfer of Trinity River water to augment East Fork streamflow during the 1985–90 simulation period is as follows (table 7): Water temperature was not affected. The nutrients phosphorus and nitrite plus nitrate nitrogen decreased only slightly as the percentage of transferred Trinity River water increased—phosphorus by 2 to 11 percent, nitrite plus nitrate nitrogen by 0 to 2 percent; ammonia nitrogen did not change. Algal biomass decreased by 20 percent for all transfers of Trinity River water. Dissolved oxygen increased only slightly, by 1 to 2 percent, as the percentage of transferred Trinity River water increased.

The estimated effect on the water quality of Lake Houston from the transfer of Trinity River water to

replace West Fork streamflow during the 1985–90 simulation period is as follows (table 7): Water temperature was not affected. Phosphorus and nitrite plus nitrate nitrogen decreased considerably as the percentage of transferred Trinity River water increased—phosphorus by 13 to 38 percent, nitrite plus nitrate nitrogen by 6 to 34 percent; ammonia nitrogen decreased by 0 to 17 percent. Algal biomass increased by 20 to 40 percent as the percentage of transferred Trinity River water increased. Dissolved oxygen increased about 1 percent for all transfers of Trinity River water.

The effects of transferring Trinity River water into Lake Houston, either to augment East Fork streamflow or to replace West Fork streamflow, do not appear to be detrimental to water temperature, ammonia nitrogen, or dissolved oxygen regardless of water-transfer scenario. Phosphorus and nitrite plus nitrate nitrogen showed fairly large changes if Trinity River water was transferred into Lake Houston to replace West Fork streamflow and minimal or no change if Trinity River water was transferred to augment East Fork streamflow. Algal biomass showed large decreases if Trinity River water was transferred into Lake Houston to augment East Fork streamflow and large increases if Trinity River water was transferred to replace West Fork streamflow. Regardless of the water-transfer scenario simulated, the model indicated that light was the limiting factor for algal biomass growth. It should be noted that improvements to this model application, including an improved algorithm for computing algal biomass and data for inflowing suspended sediments, might change the magnitude of some of the results, especially for phosphorus, nitrite plus nitrate nitrogen, and algal biomass. However, any changes between properties and constituents simulated for the various water-transfer scenarios should be consistent with results presented here because extensive experience with the model has shown that the model produces results consistent with the input data used.

SUMMARY

The City of Houston is considering the transfer of water from the Trinity River to Lake Houston on the San Jacinto River to alleviate concerns about adequate water supplies for future water demands. The U.S. Geological Survey, in cooperation with the City of Houston, conducted a study to estimate the effects on the water quality of Lake Houston from the transfer of Trinity River water. A water-quality model, CE–QUAL–W2, developed by the U.S. Army Corps of Engineers was selected for the study.

Two general assumptions for water transfer were made. First, it was assumed that the continued population increase of Houston would require a larger supply of water than that currently (1999) available from Lake Houston. Second, it was assumed that if water that currently supplies Lake Houston were transferred to an area of the State in need of water, an additional water supply to Lake Houston would be needed. Six scenarios for water transfer from the Trinity River into Lake Houston were developed—three scenarios with Trinity River water augmenting streamflow from the East Fork of the lake and three scenarios with Trinity River water replacing streamflow from the West Fork of the San Jacinto River.

After calibrating and testing the model, model simulations were run for a base dataset (developed using observed data for January 1985–September 1990), the water-transfer scenarios augmenting East Fork streamflow, and the water-transfer scenarios replacing West Fork San Jacinto River streamflow. The model simulated volume-weighted daily means for six targeted properties and constituents—water temperature, phosphorus, ammonia nitrogen, nitrite plus nitrate nitrogen, algal biomass, and dissolved oxygen. Estimated effects were determined by comparing the results for each of the transfer scenarios to the results for the base dataset.

The estimated effect on the water quality of Lake Houston from the transfer of Trinity River water to augment East Fork streamflow during the 1985–90 simulation period is as follows: Water temperature and ammonia nitrogen were not affected. As the percentage of transferred Trinity River water increased, phosphorus and nitrite plus nitrate nitrogen decreased slightly and dissolved oxygen increased slightly. Algal biomass decreased by 20 percent for all transfers of Trinity River water.

The estimated effect on the water quality of Lake Houston from the transfer of Trinity River water to replace West Fork San Jacinto River streamflow during the 1985–90 simulation period is as follows: Water temperature was not affected; dissolved oxygen increased slightly. As the percentage of transferred Trinity River water increased, phosphorus decreased by 13 to 38 percent, ammonia nitrogen decreased by 0 to 17 percent, and nitrite plus nitrate nitrogen decreased by 6 to 34 percent. Algal biomass increased by 20 to 40 percent.

The effects of transferring Trinity River water into Lake Houston, either to augment East Fork streamflow or to replace West Fork San Jacinto River streamflow, do not appear to be detrimental to water temperature, ammonia nitrogen, or dissolved oxygen regardless of water-transfer scenario. Phosphorus and nitrite plus nitrate nitrogen show fairly large changes when Trinity River water is transferred into Lake Houston to replace West Fork streamflow and minimal or no change when Trinity River water is transferred to augment East Fork streamflow. Algal biomass shows large decreases when Trinity River water is transferred into Lake Houston to augment East Fork streamflow and large increases when Trinity River water is transferred to replace West Fork streamflow. Regardless of the water-transfer scenario simulated, the model indicated that light was the limiting factor for algal biomass growth.

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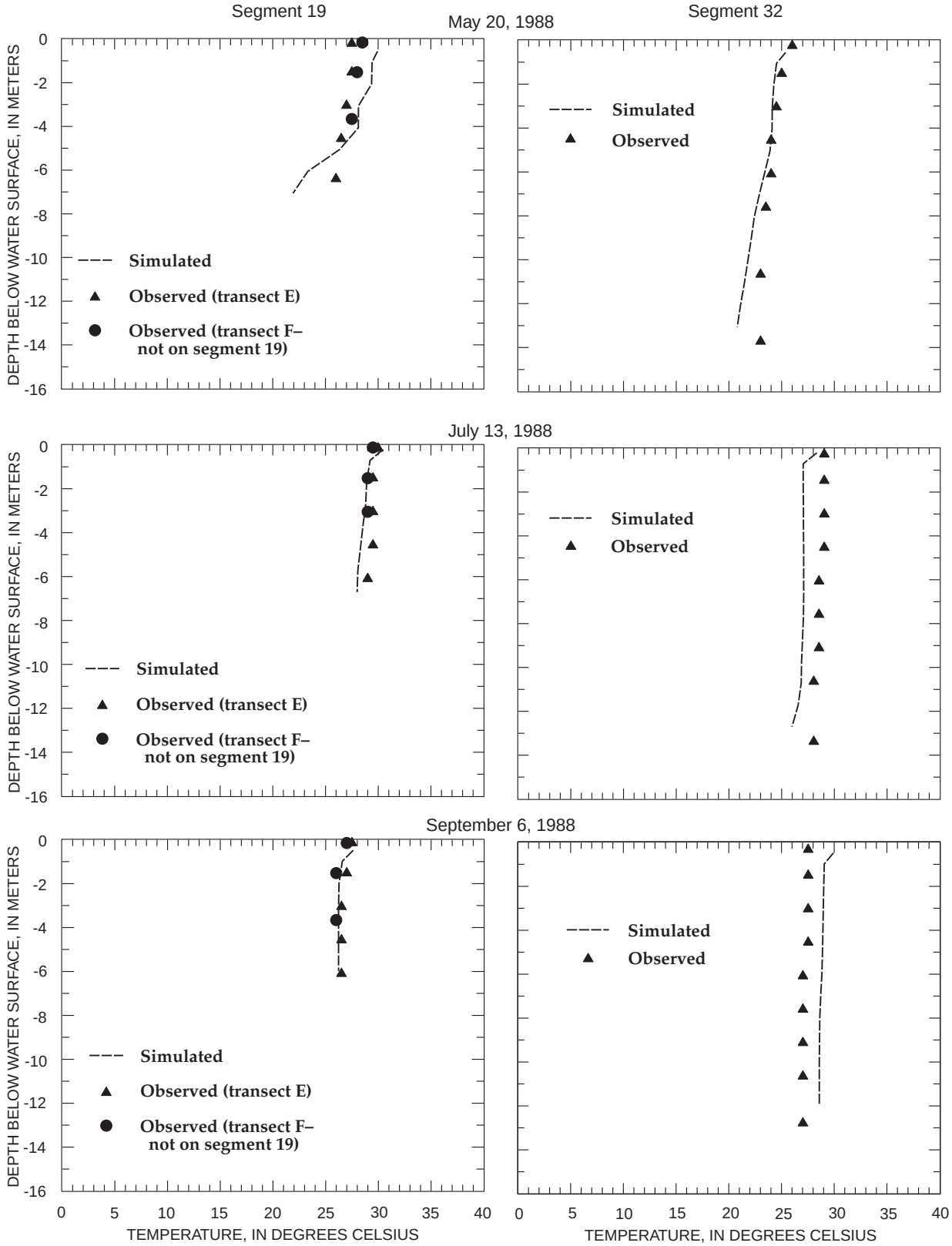

Figure 4a. Water temperature as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

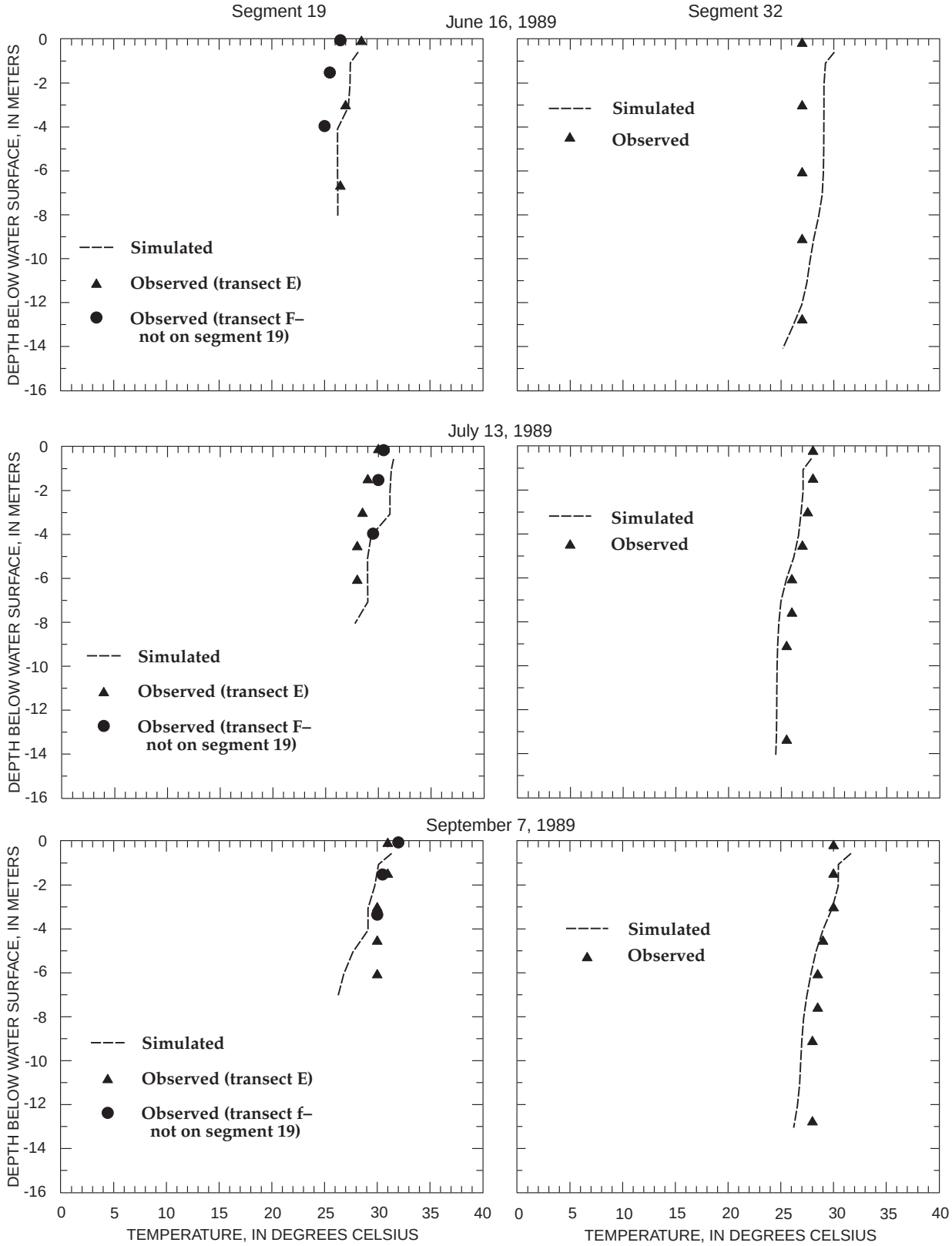

Figure 4b. Water temperature as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

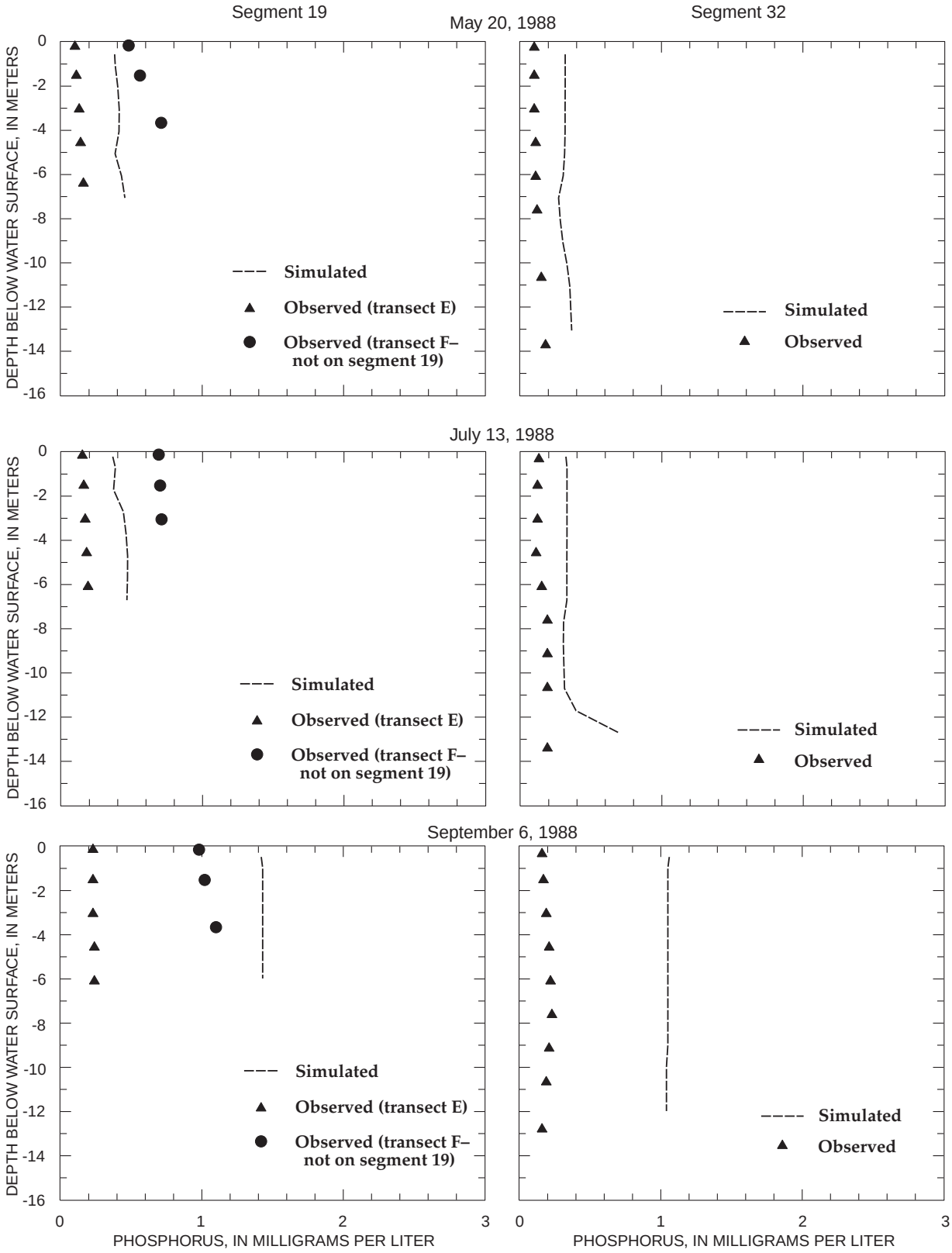

Figure 4c. Phosphorus as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

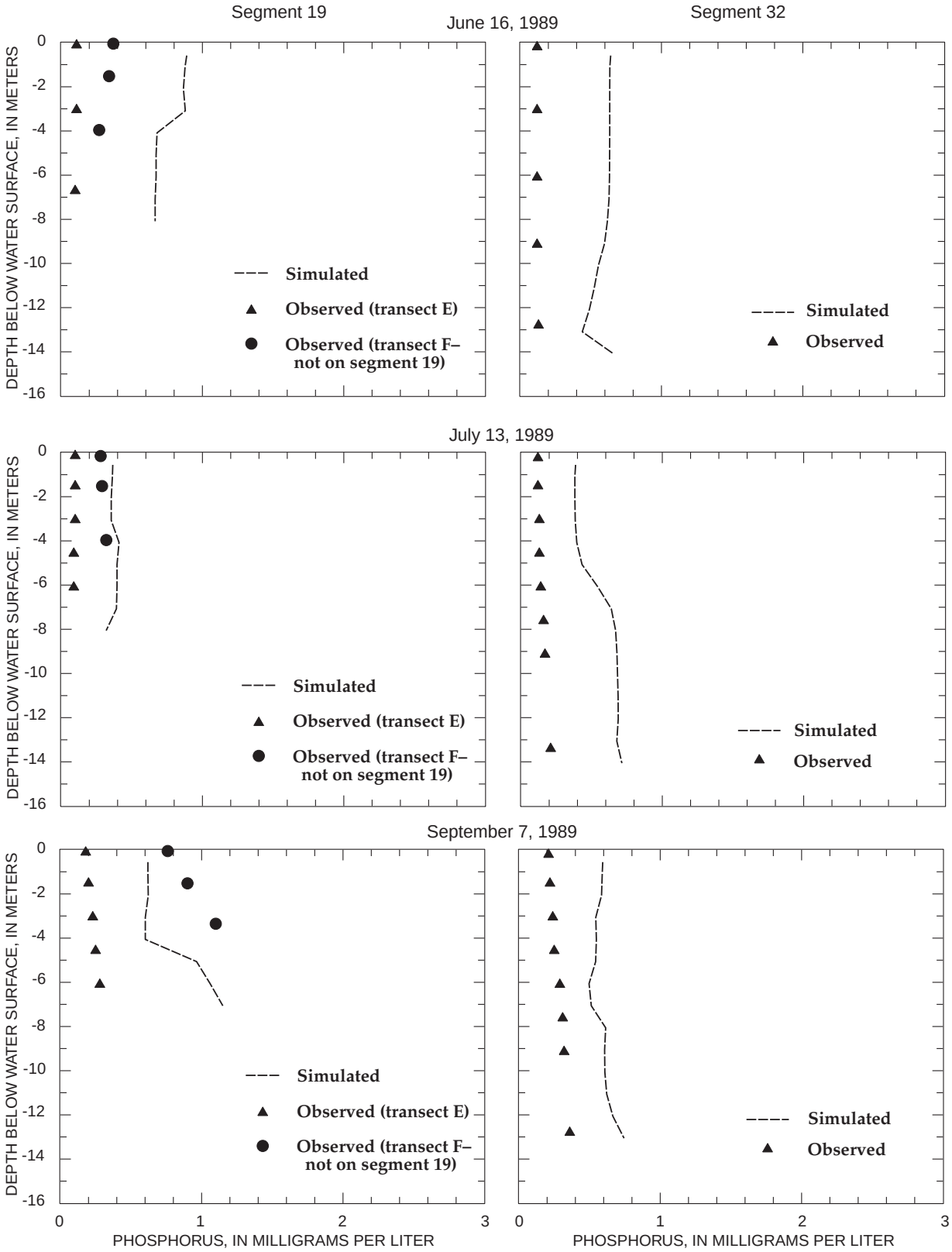

Figure 4d. Phosphorus as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

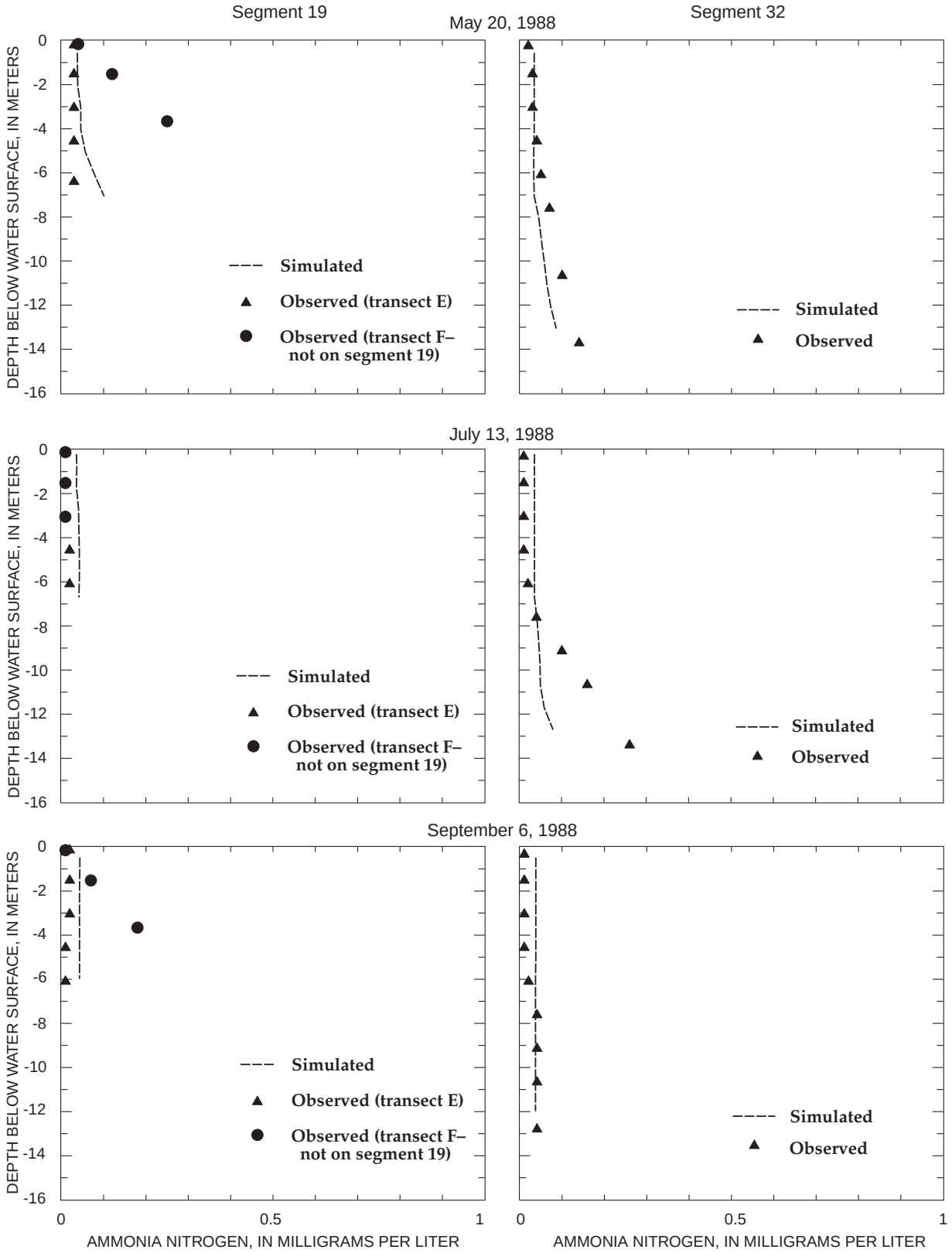

Figure 4e. Ammonia nitrogen as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

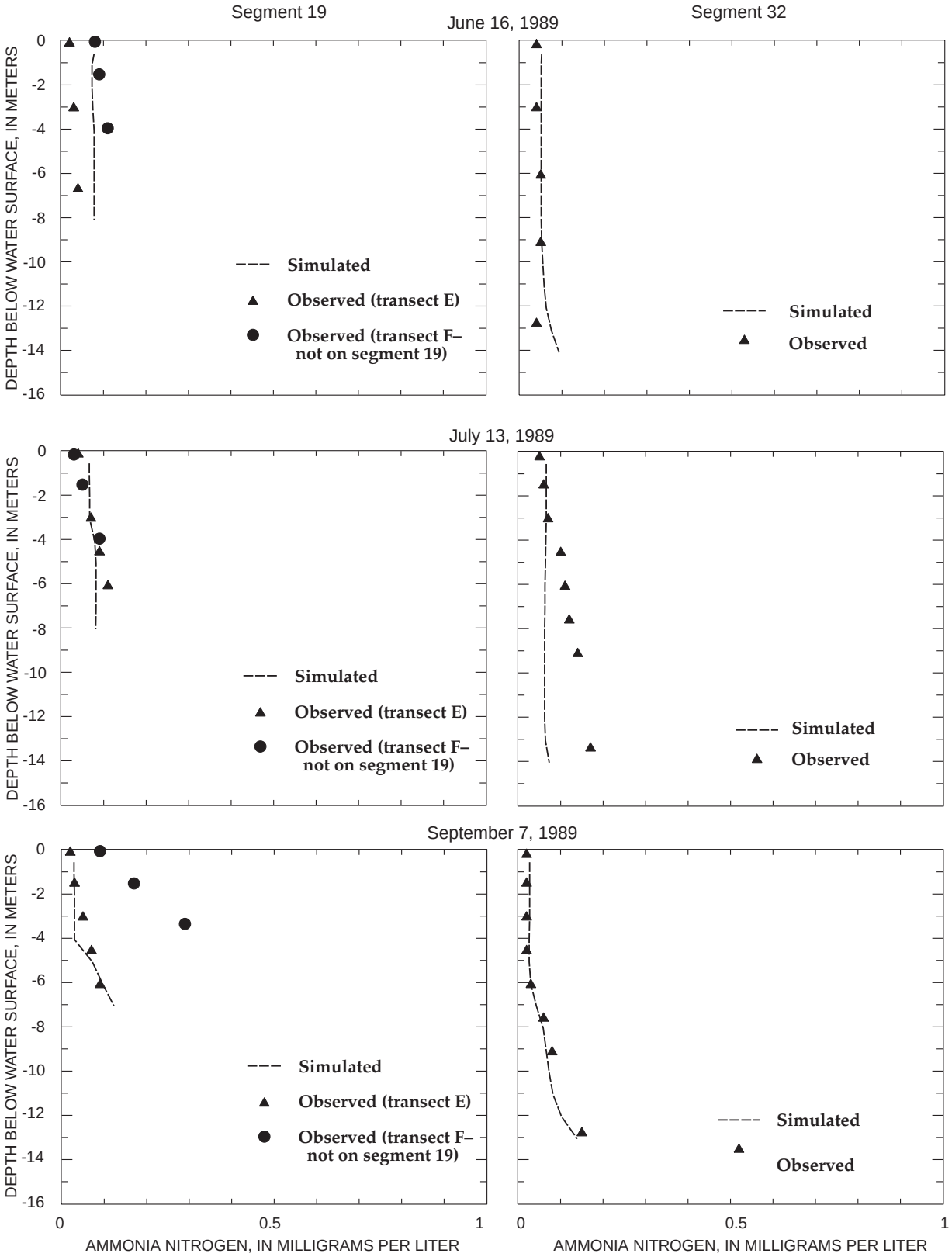

Figure 4f. Ammonia nitrogen as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

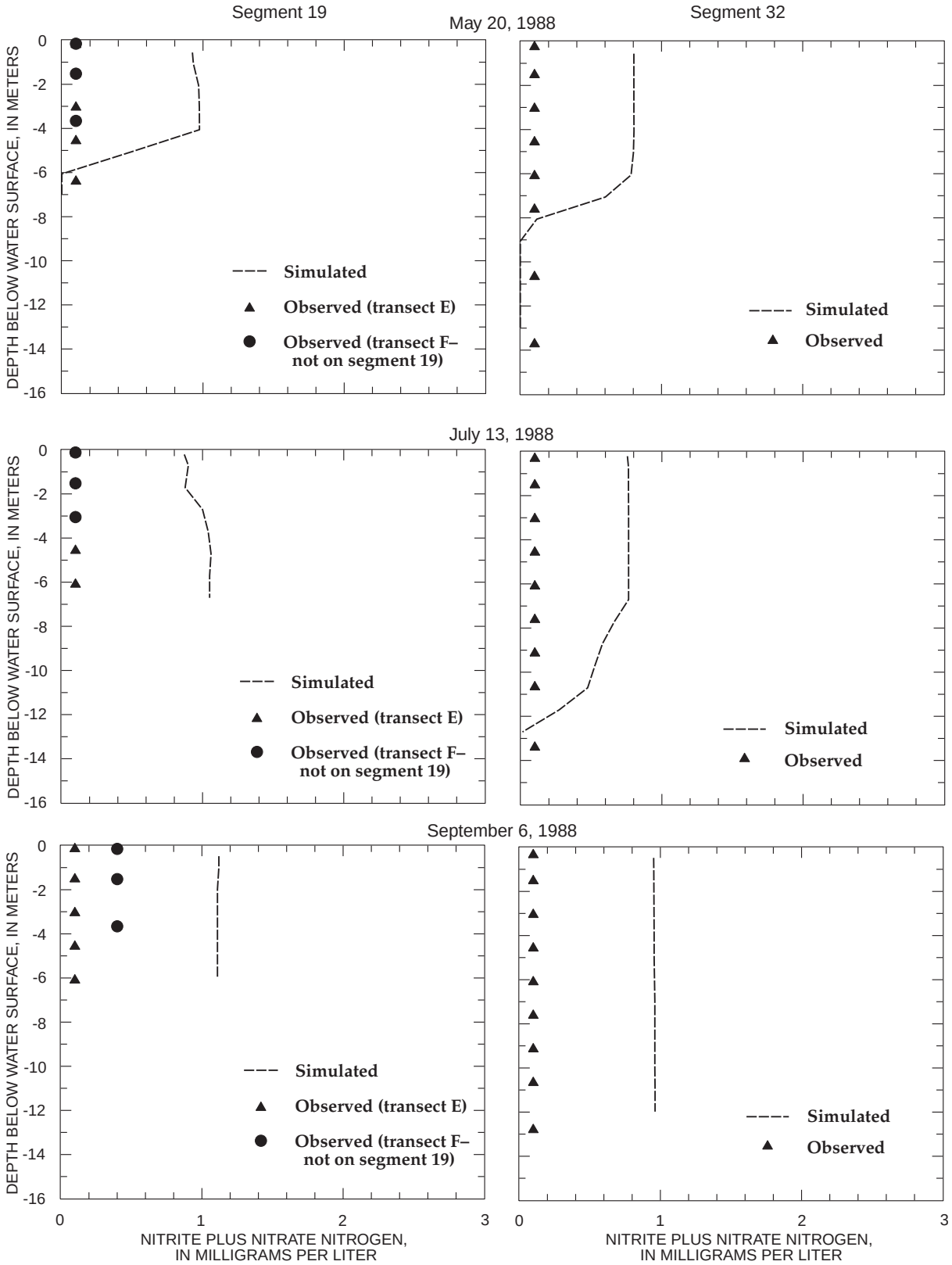

Figure 4g. Nitrite plus nitrate nitrogen as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

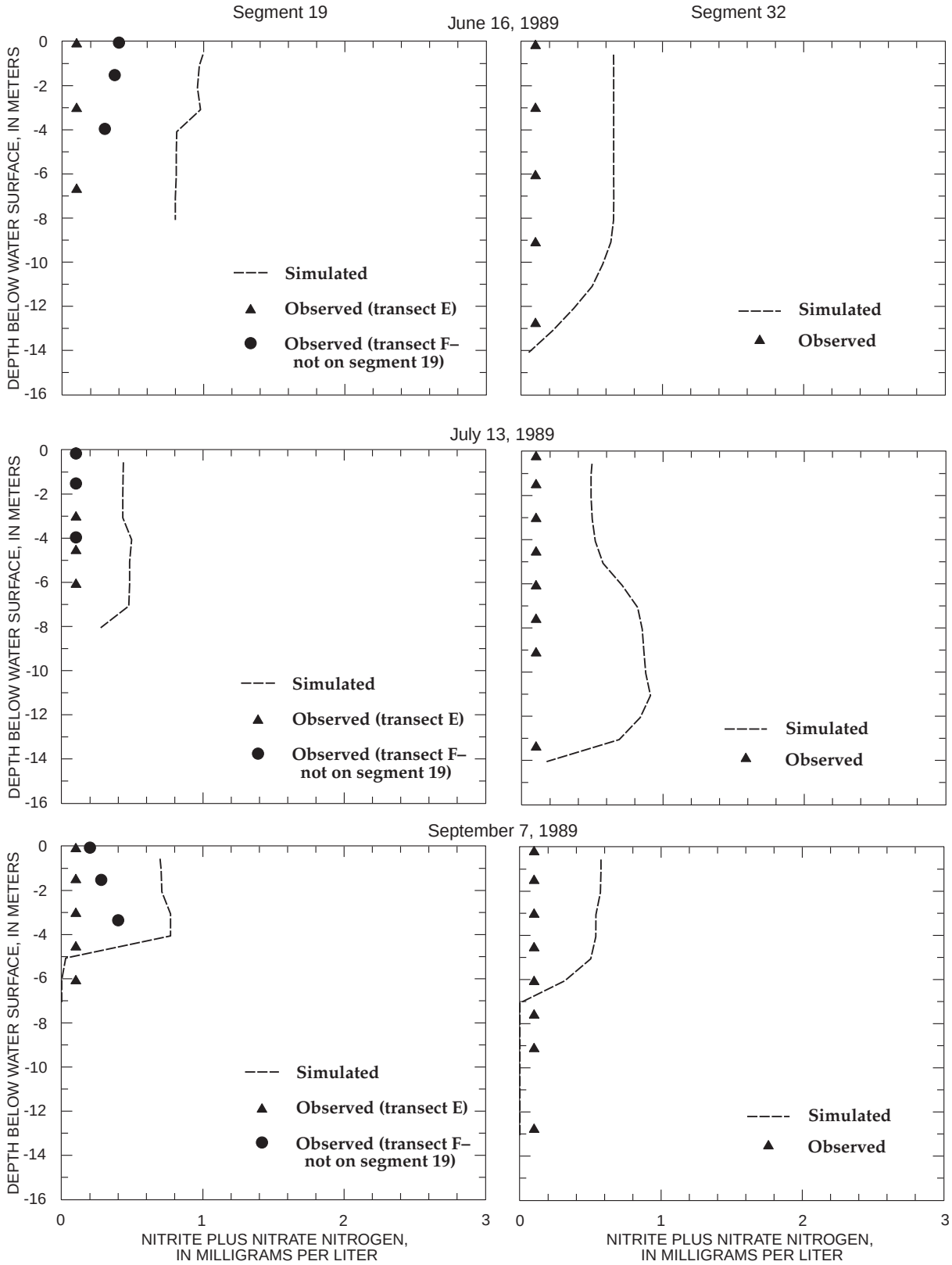

Figure 4h. Nitrite plus nitrate nitrogen as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

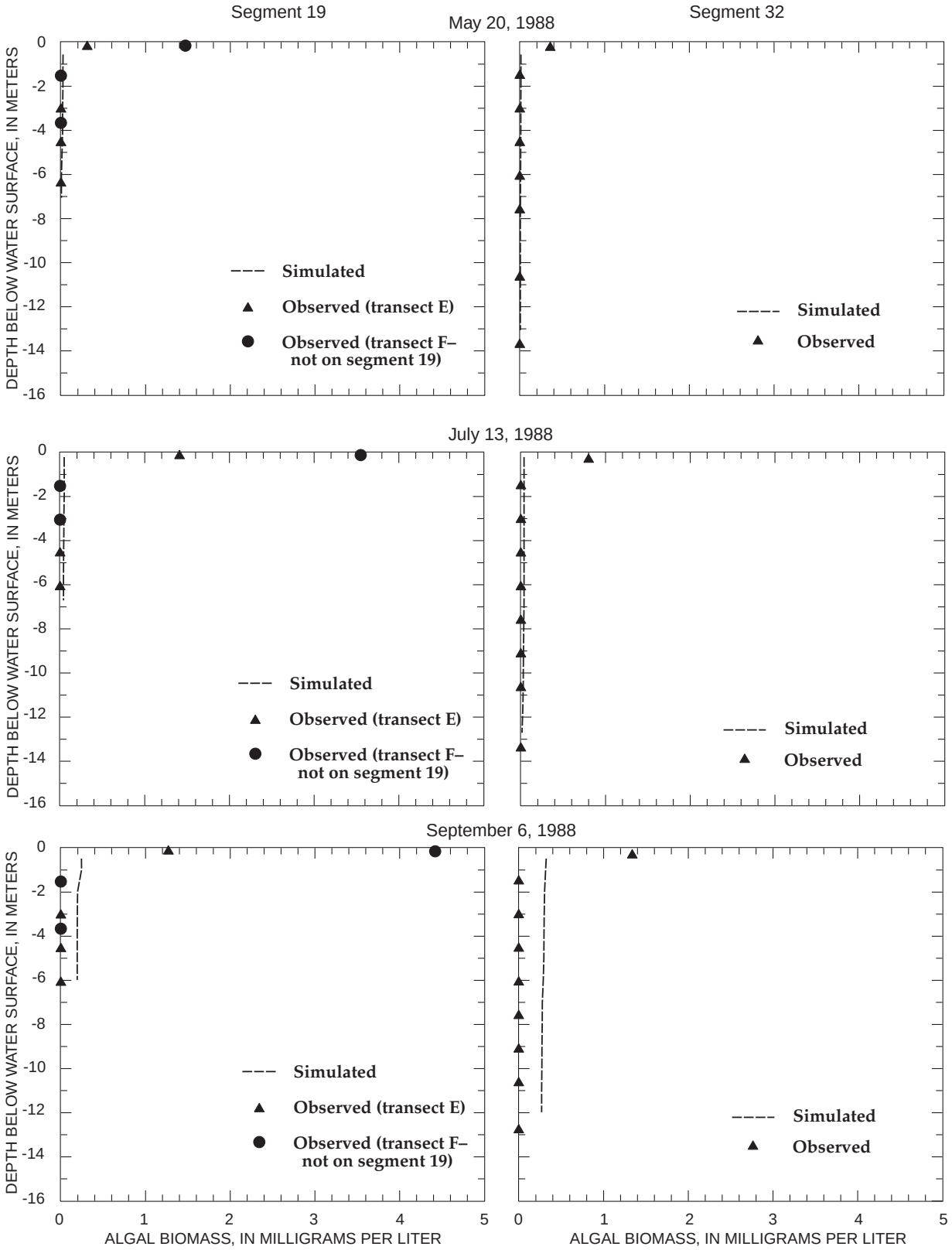

Figure 4i. Algal biomass as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

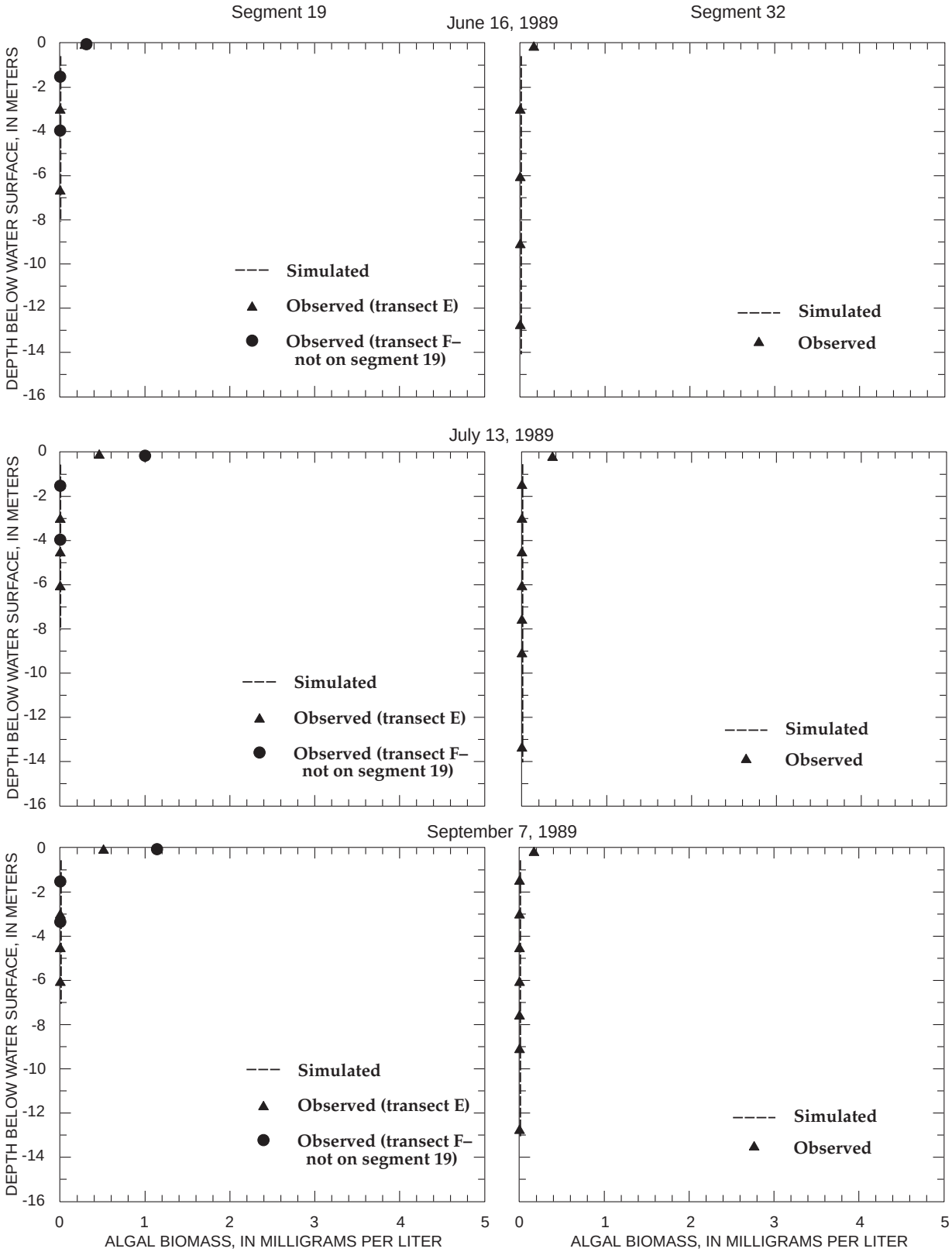

Figure 4j. Algal biomass as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

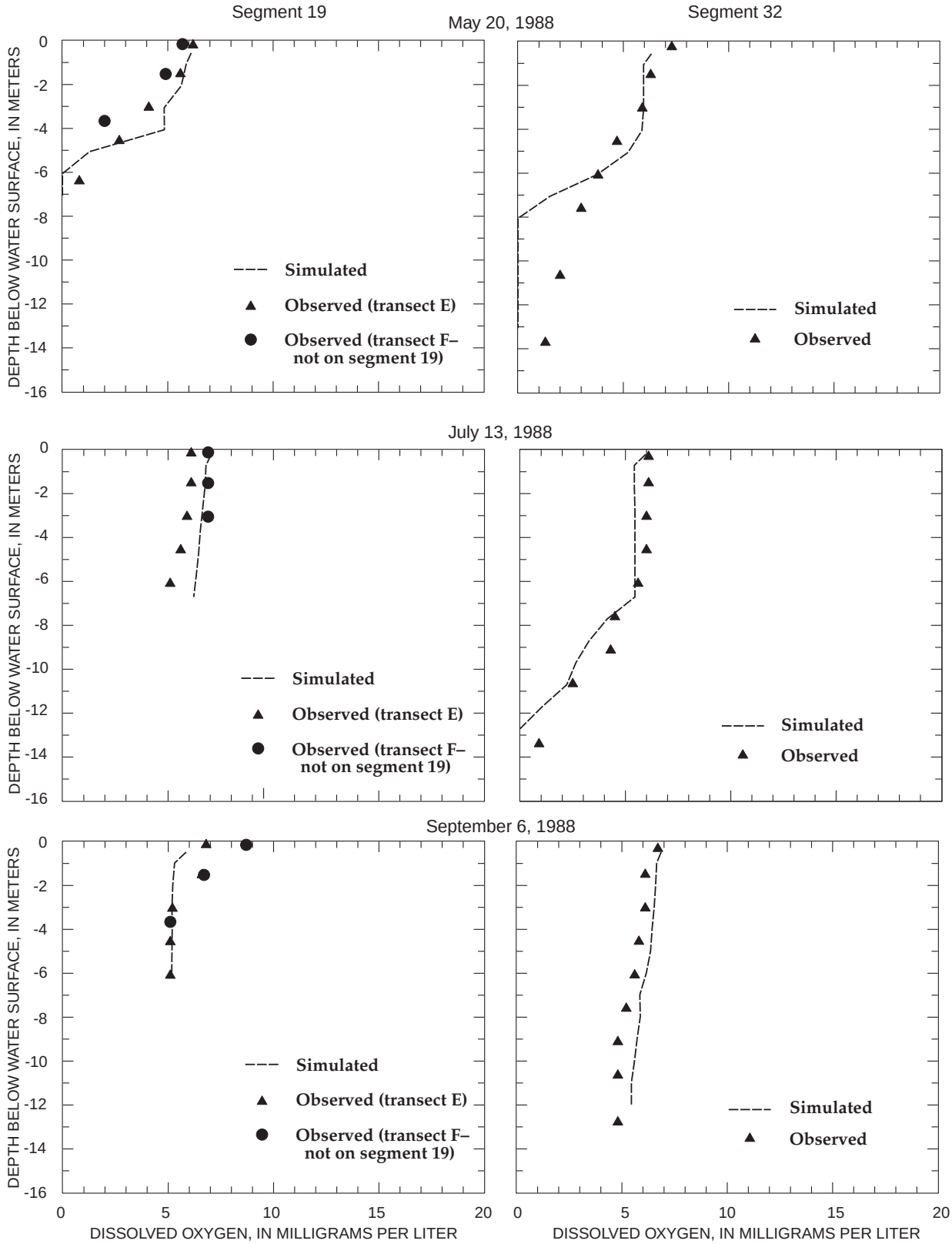

Figure 4k. Dissolved oxygen as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

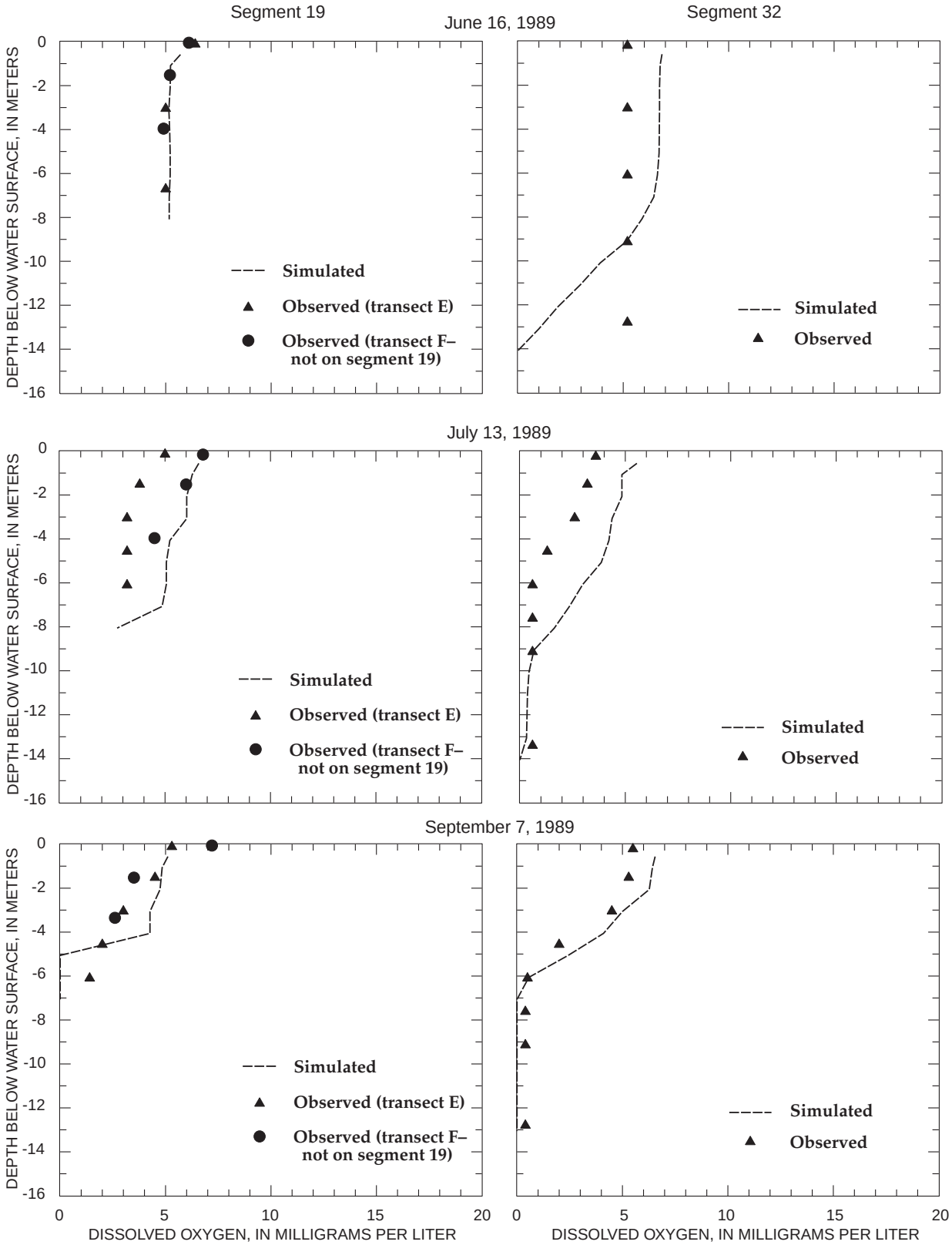

Figure 4l. Dissolved oxygen as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

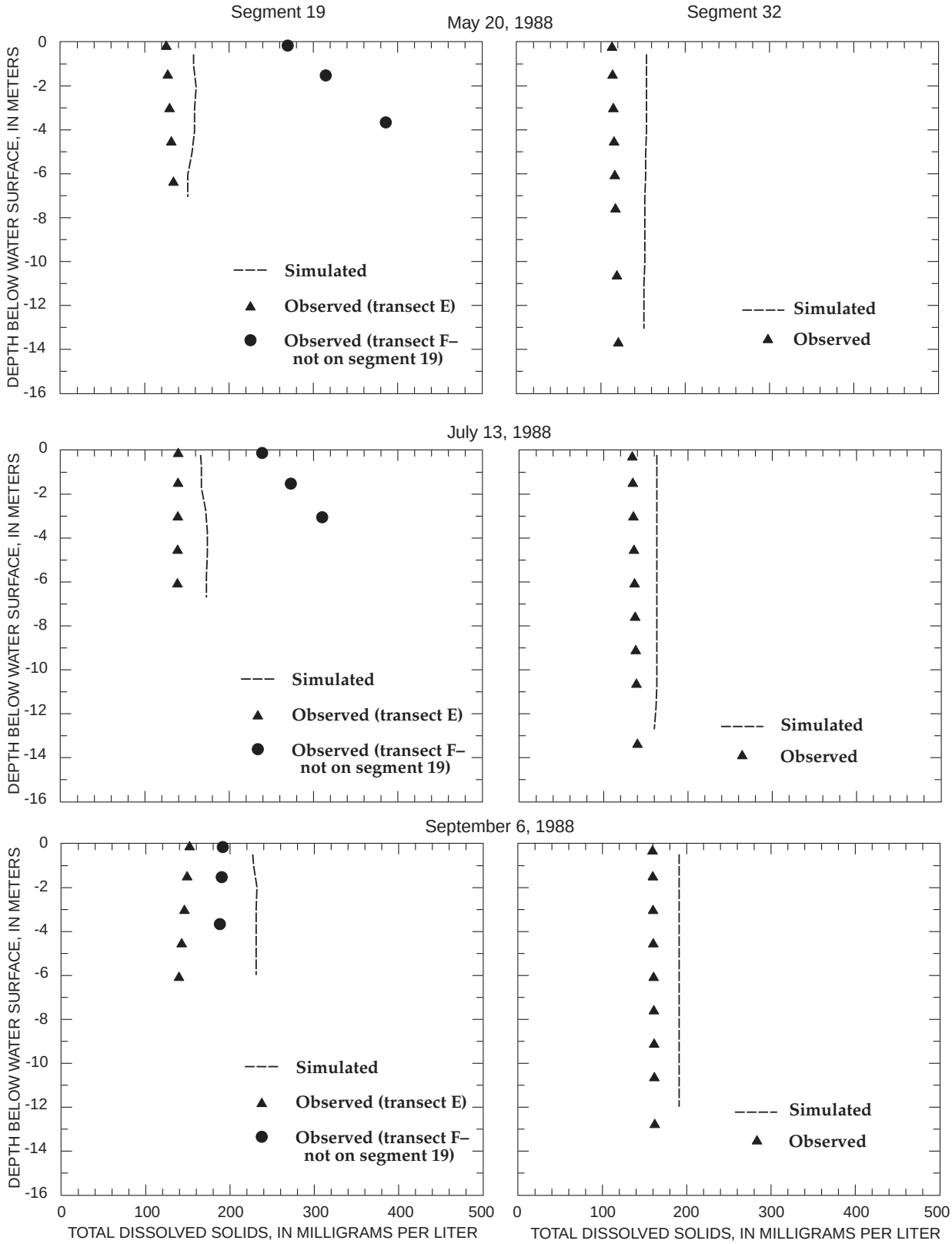

Figure 4m. Total dissolved solids as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

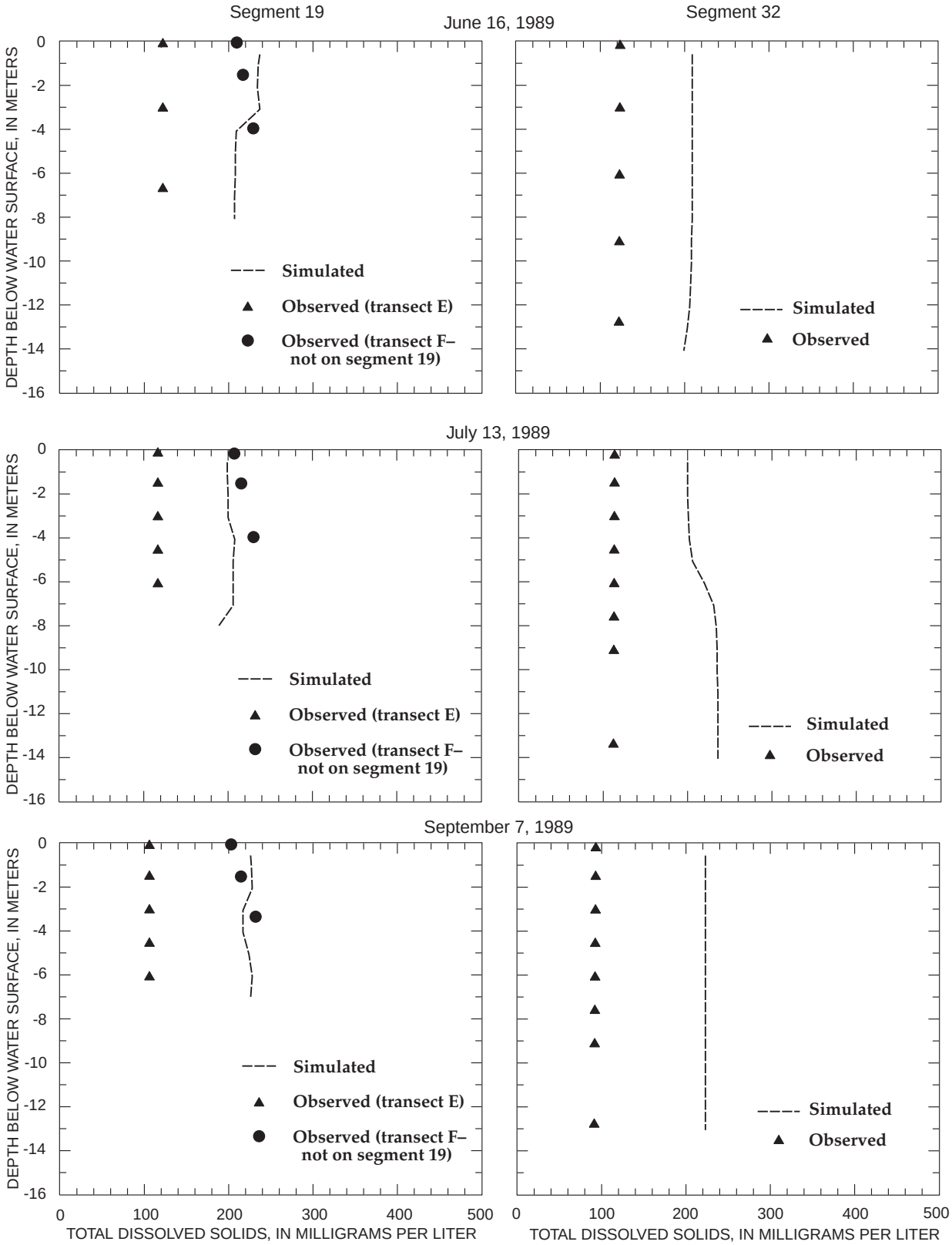

Figure 4n. Total dissolved solids as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

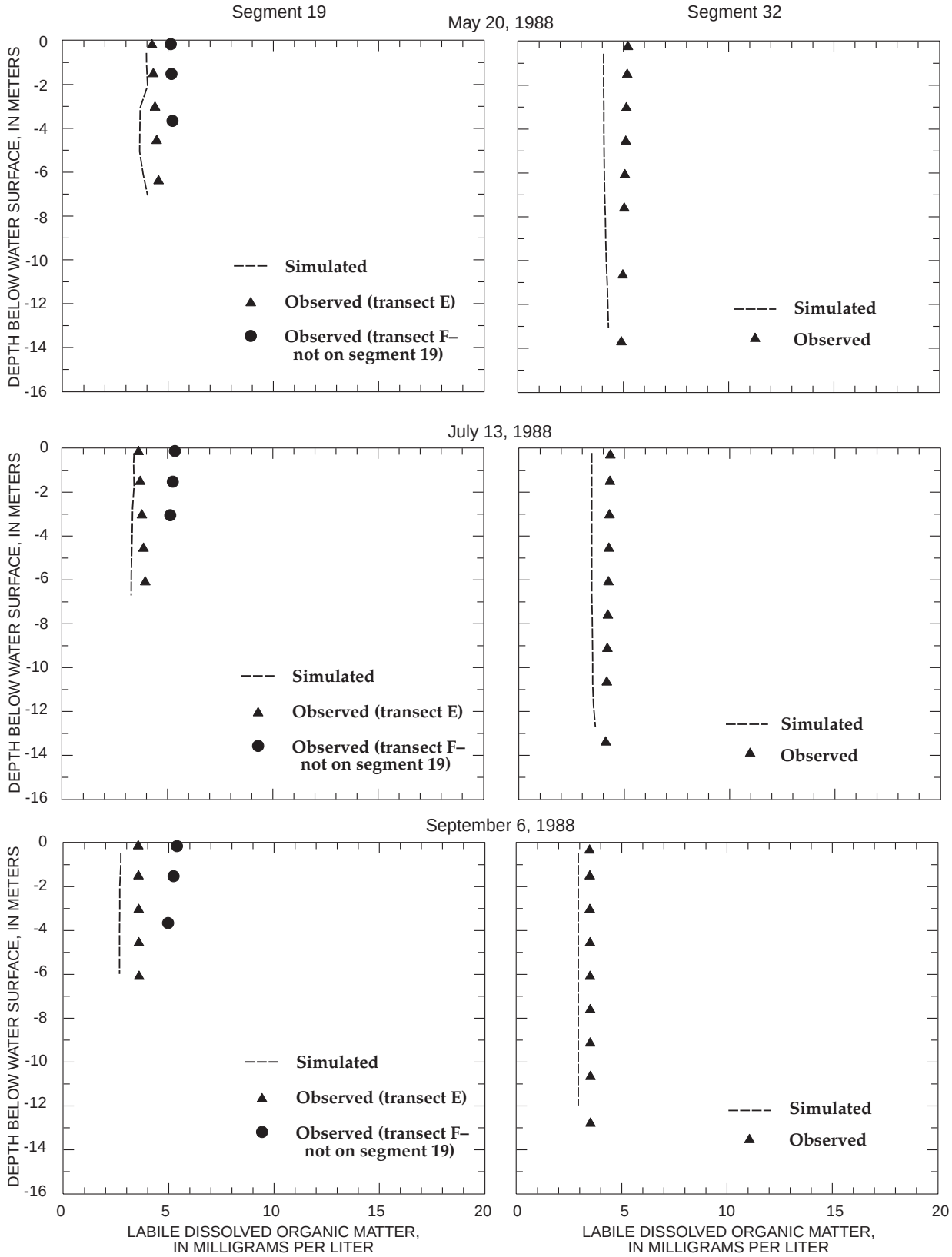

Figure 4o. Labile dissolved organic matter as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

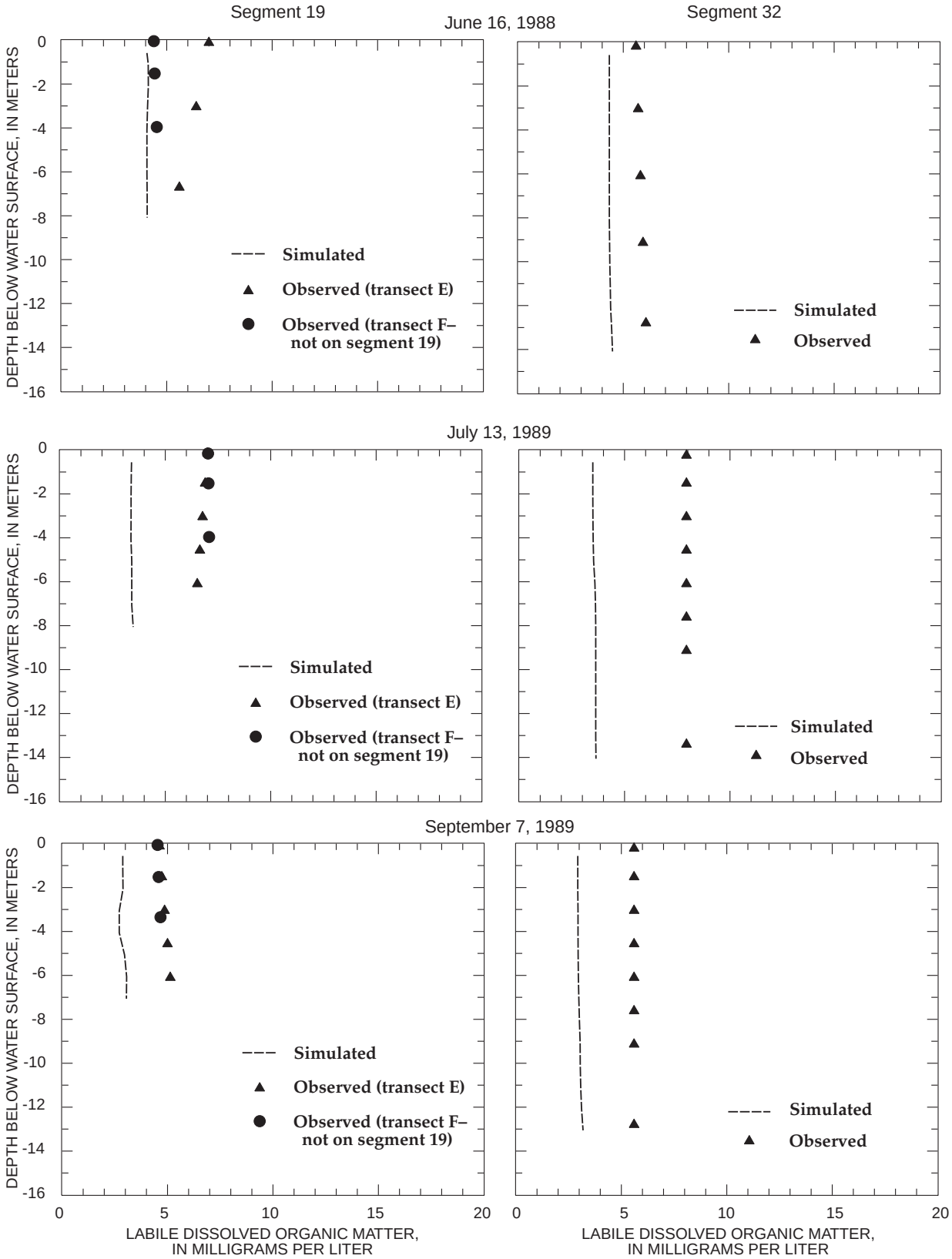

Figure 4p. Labile dissolved organic matter as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

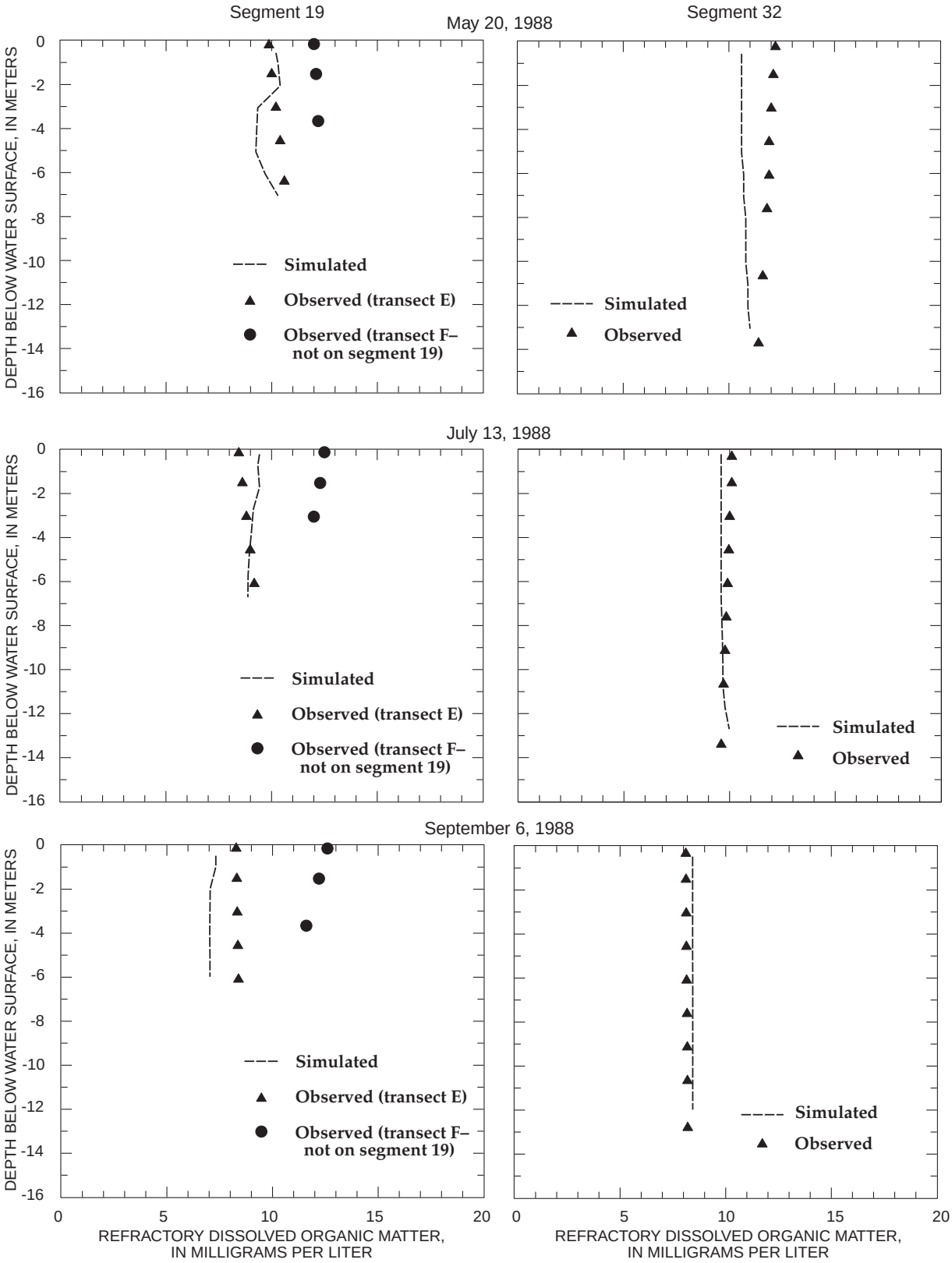

Figure 4q. Refractory dissolved organic matter as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

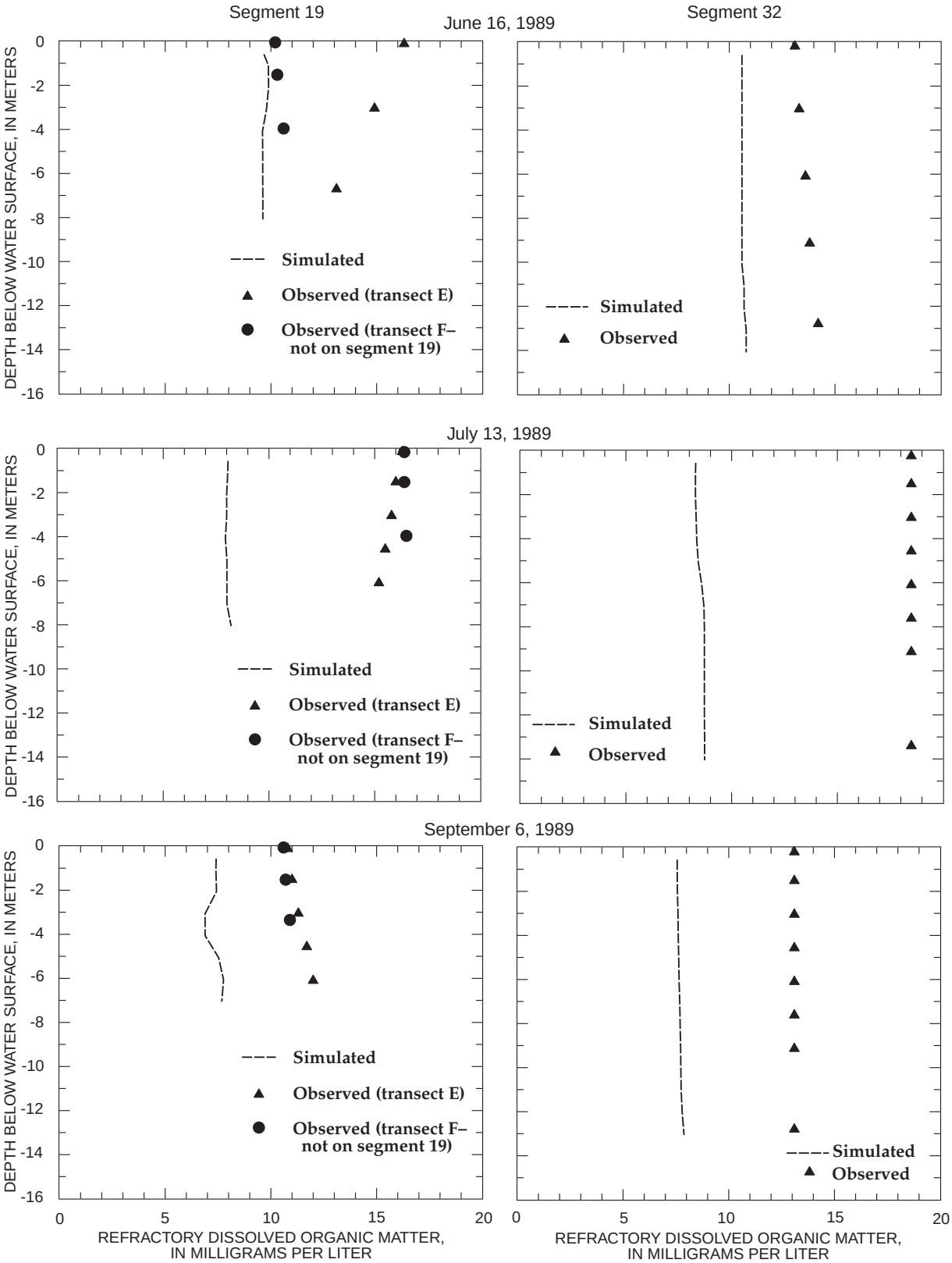

Figure 4r. Refractory dissolved organic matter as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

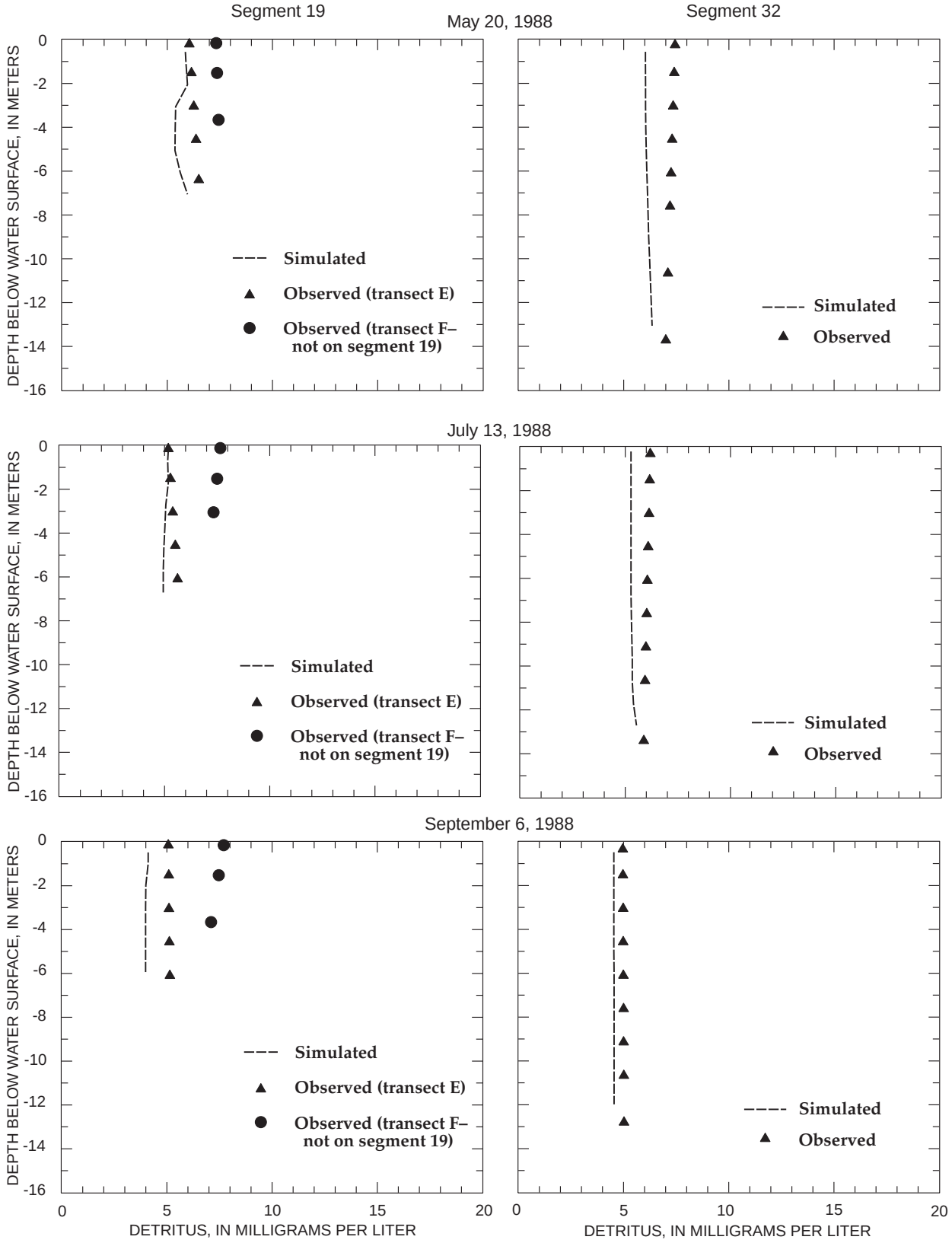

Figure 4s. Detritus as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

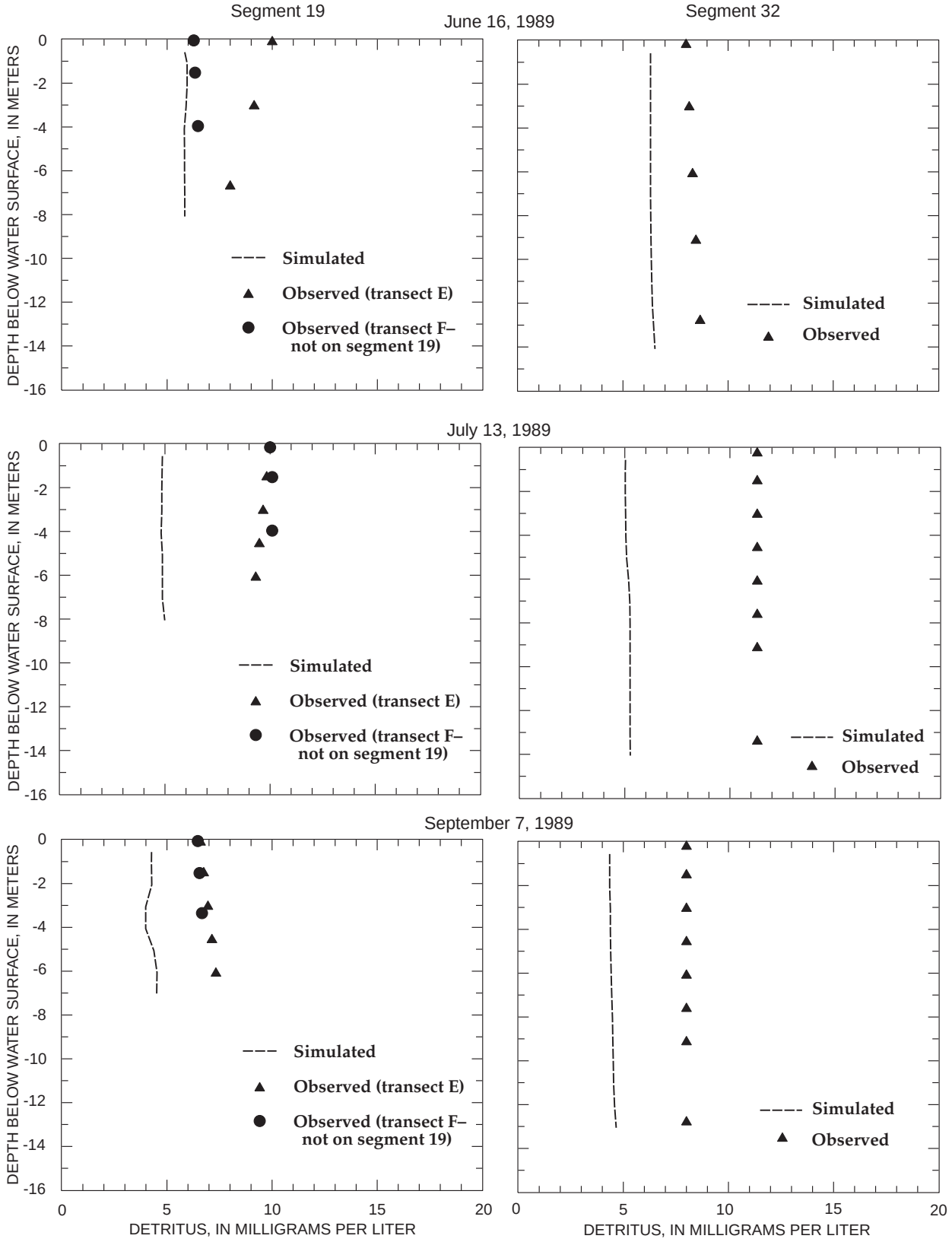

Figure 4t. Detritus as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

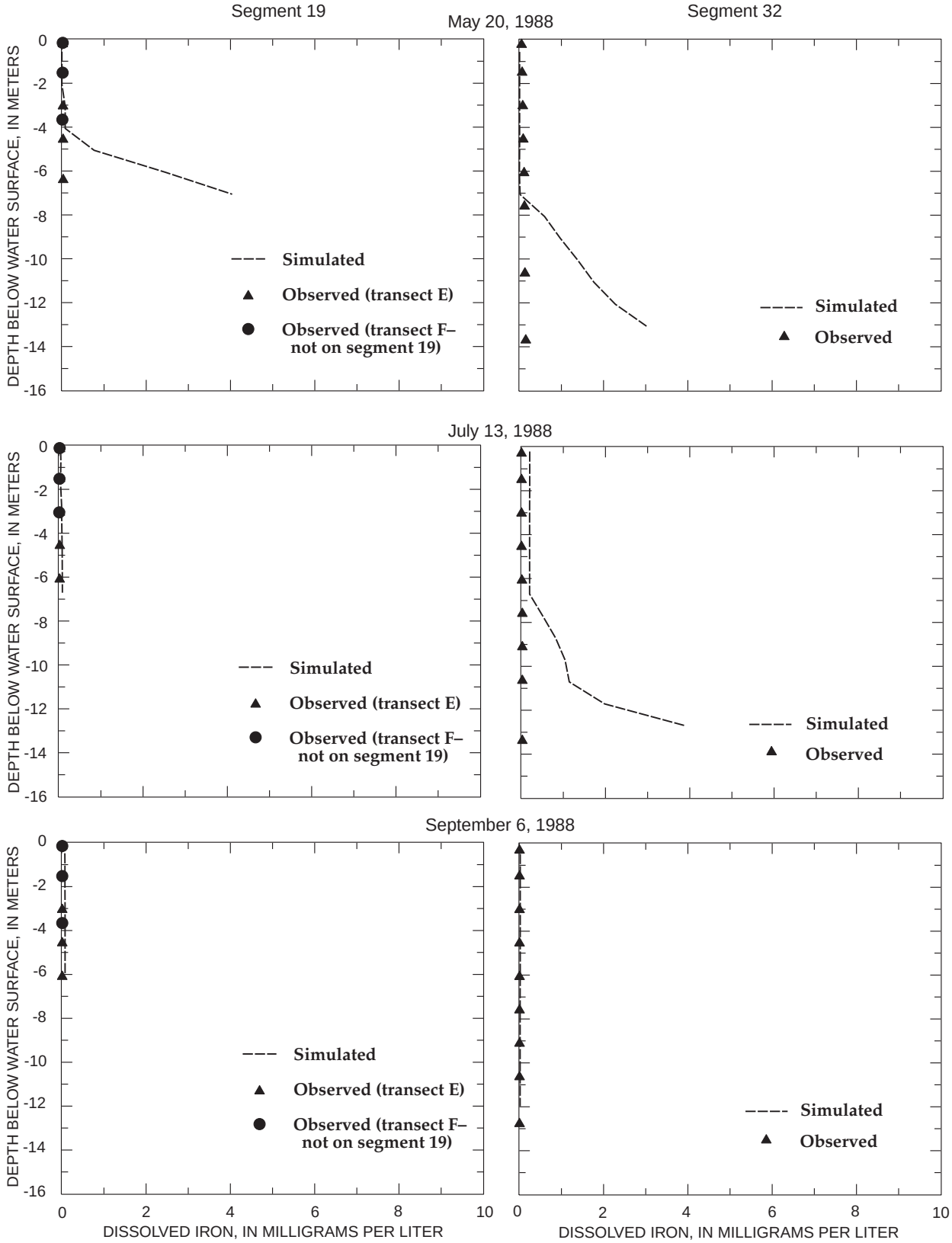

Figure 4u. Dissolved iron as computed during model calibration at segments 19 and 32 in Lake Houston for selected dates.

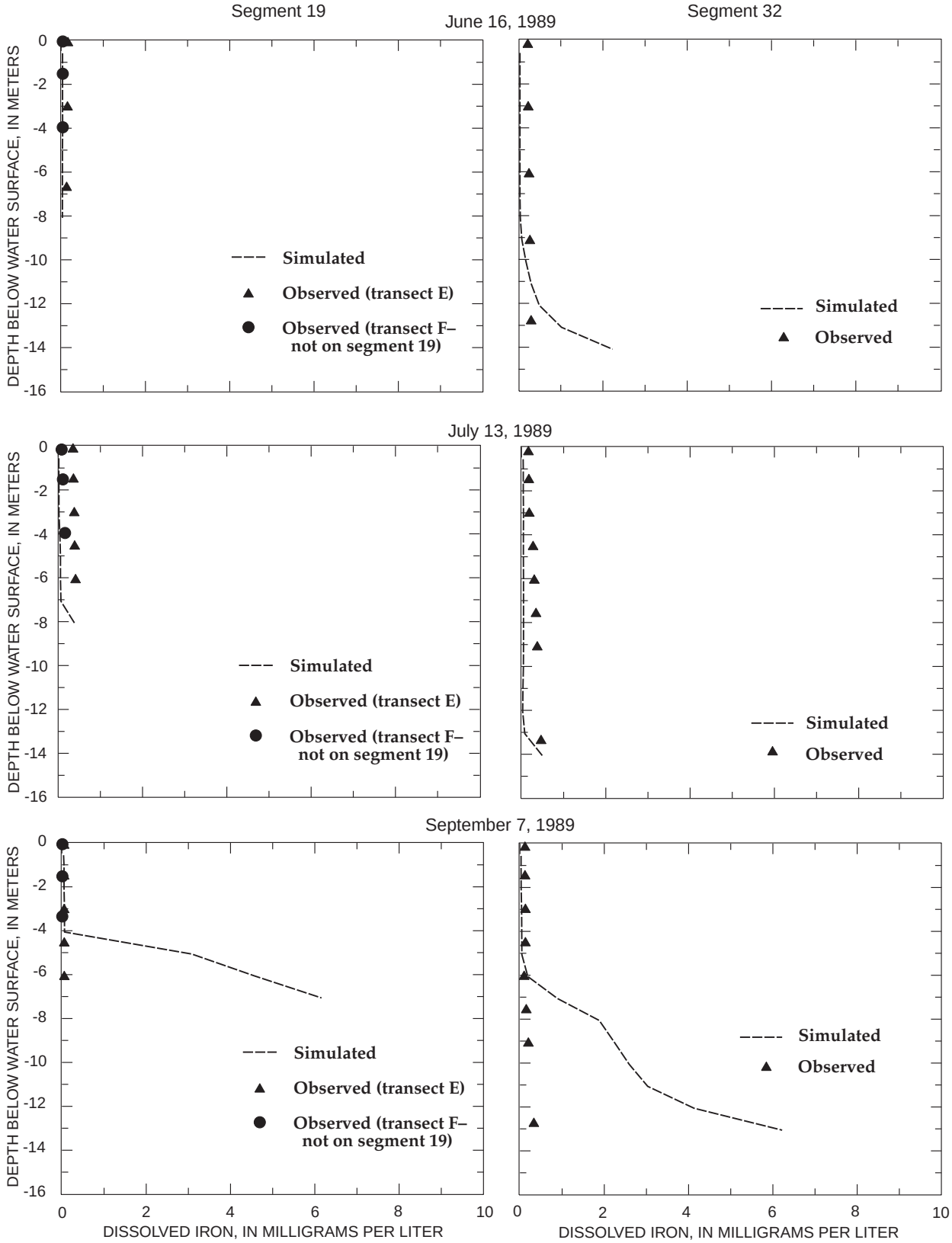

Figure 4v. Dissolved iron as computed during model test run at segments 19 and 32 in Lake Houston for selected dates.

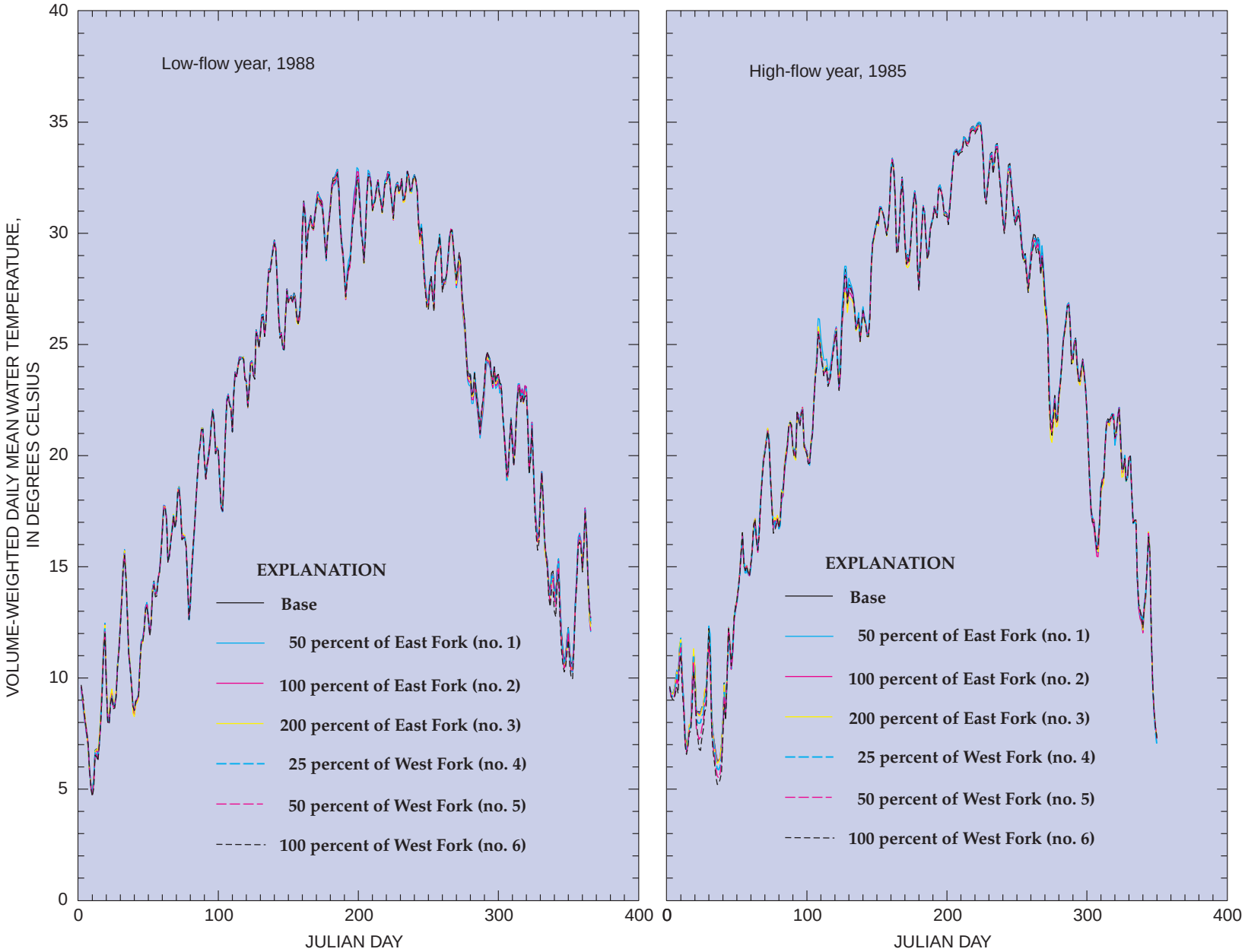

Figure 5a. Simulated volume-weighted daily mean water temperature for segment 32 in Lake Houston using base dataset and six water-transfer scenarios for low- and high-flow years.

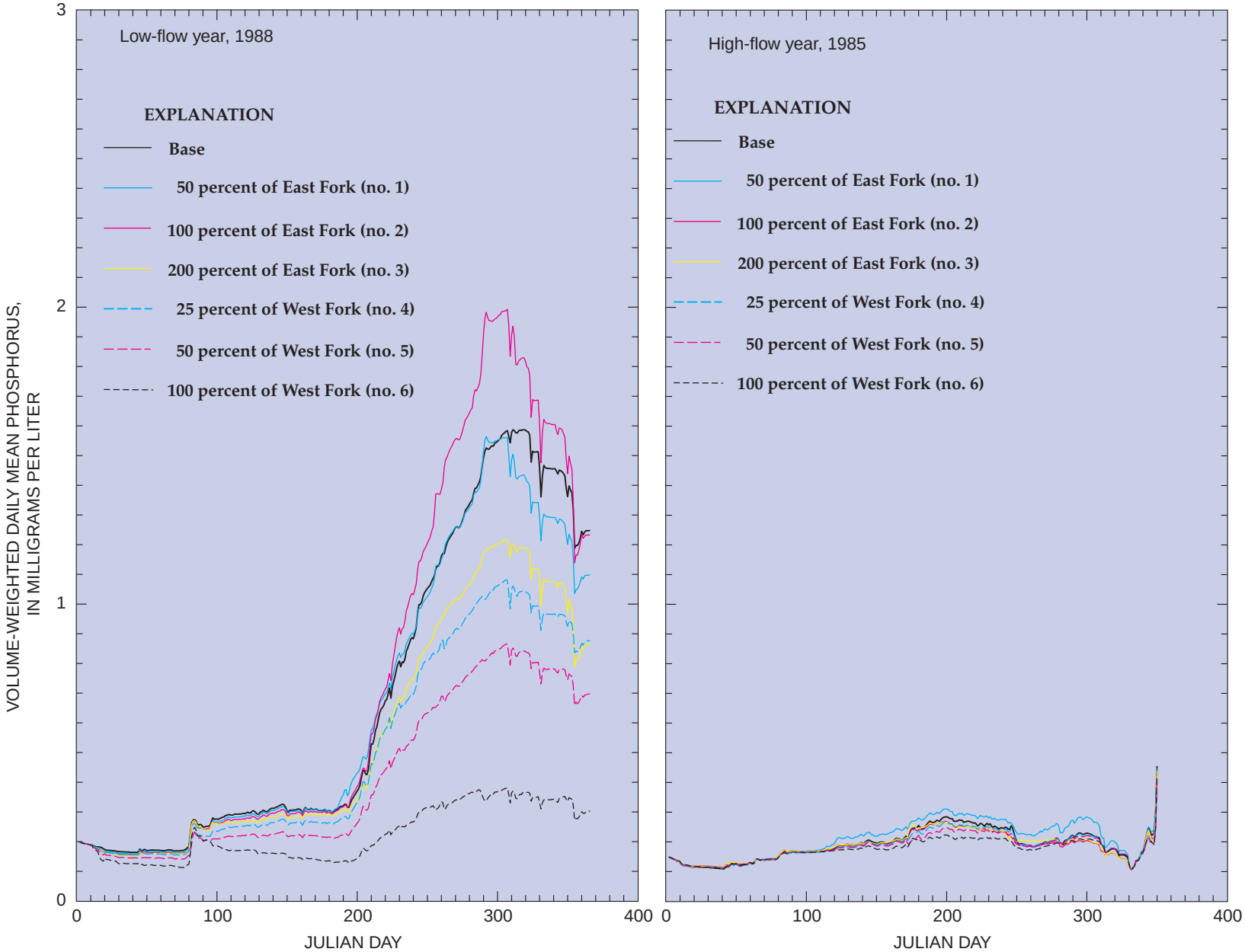

Figure 5b. Simulated volume-weighted daily mean phosphorus for segment 32 in Lake Houston using base dataset and six water-transfer scenarios for low- and high-flow years.

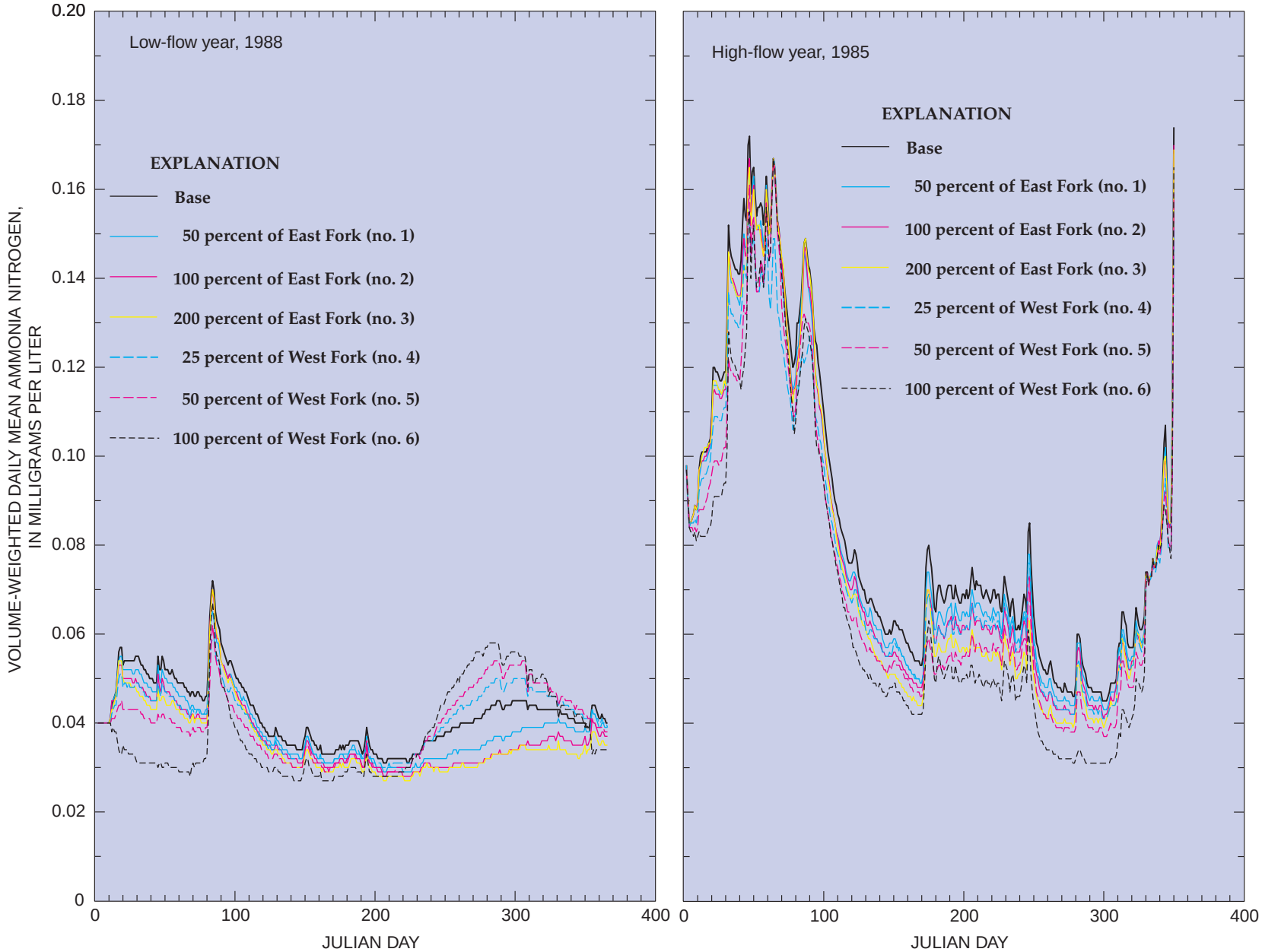

Figure 5c. Simulated volume-weighted daily mean ammonia nitrogen for segment 32 in Lake Houston using base dataset and six water-transfer scenarios for low- and high-flow years.

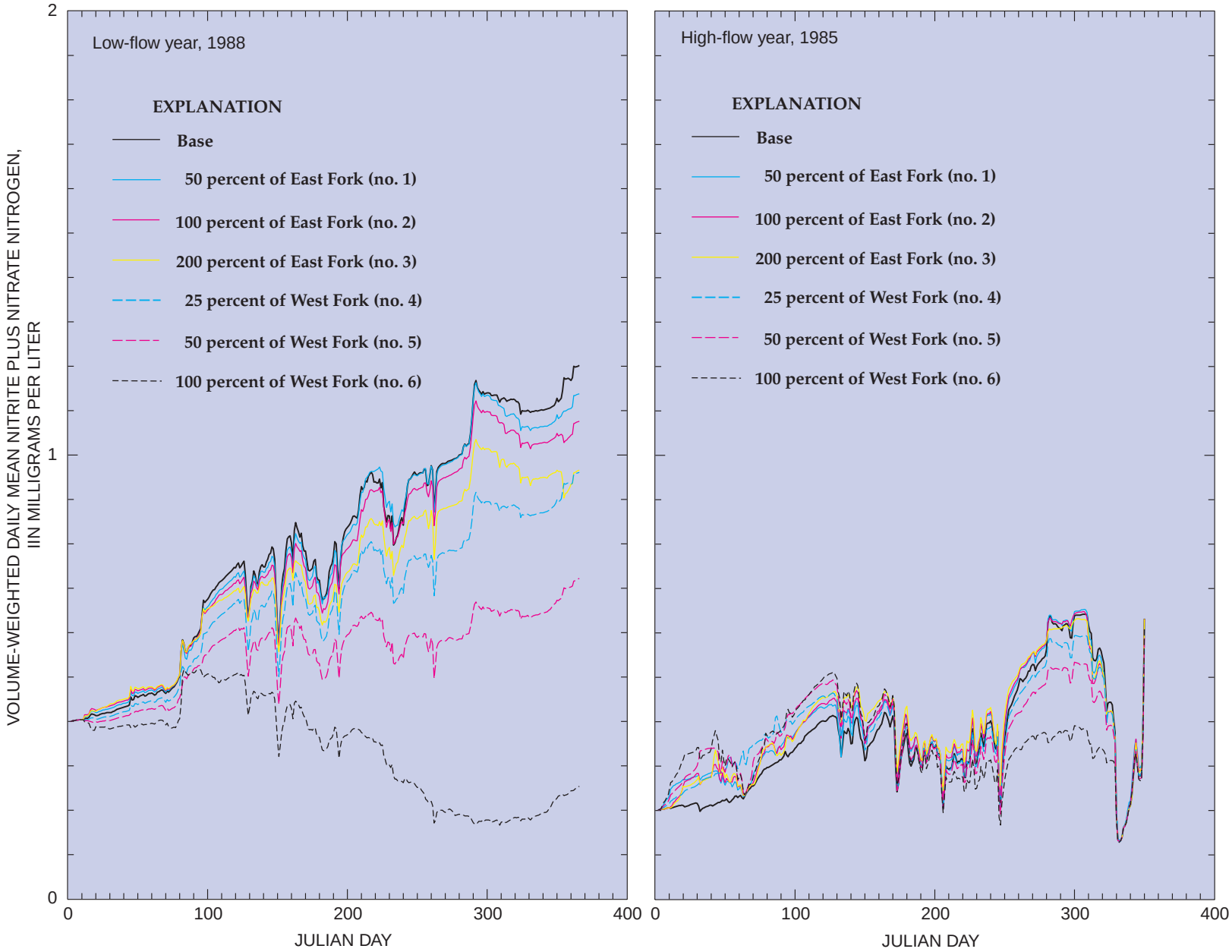

Figure 5d. Simulated volume-weighted daily mean nitrite plus nitrate nitrogen for segment 32 in Lake Houston using base dataset and six water-transfer scenarios for low- and high-flow years.

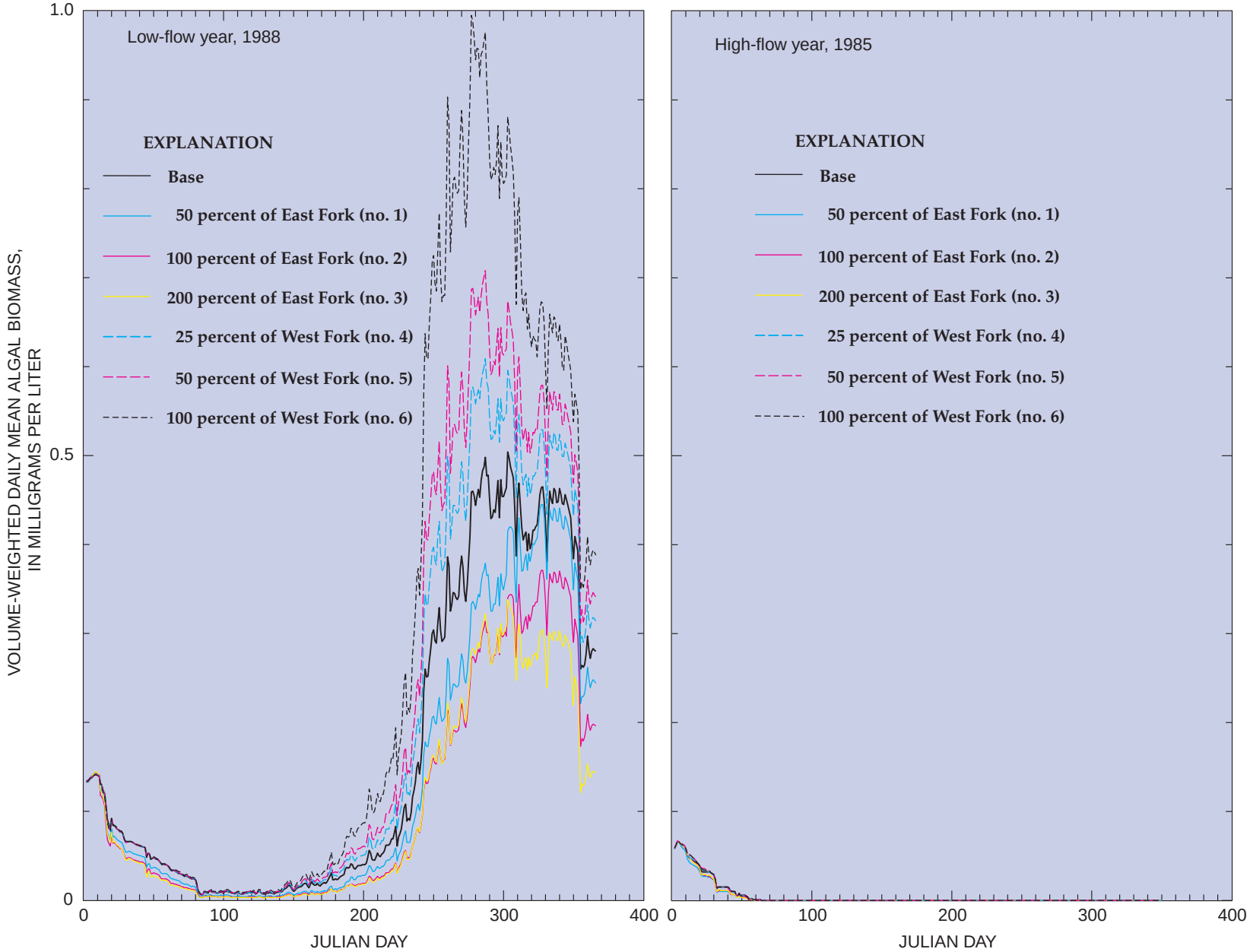

Figure 5e. Simulated volume-weighted daily mean algal biomass for segment 32 in Lake Houston using base dataset and six water-transfer scenarios for low- and high-flow years.

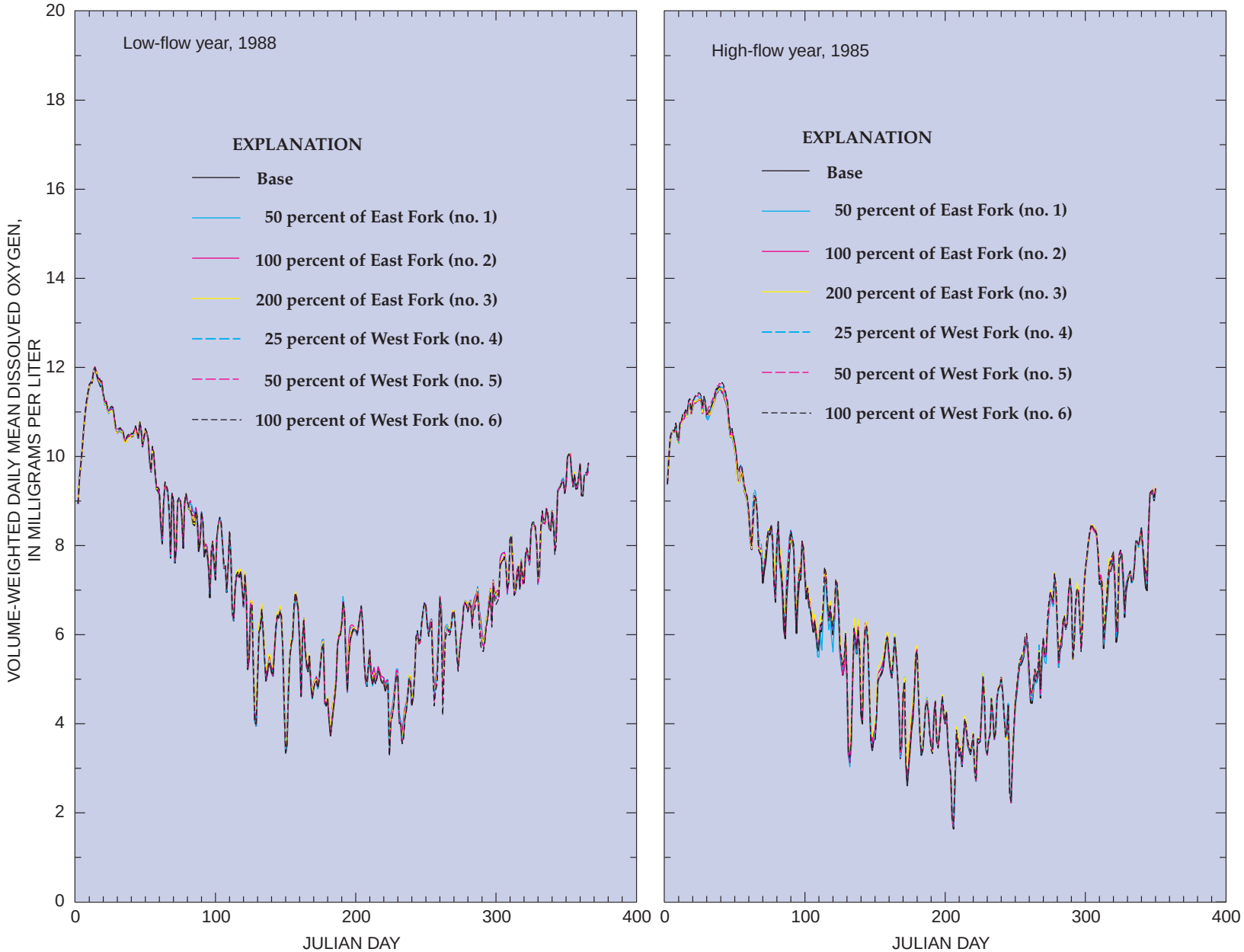

Figure 5f. Simulated volume-weighted daily mean dissolved oxygen for segment 32 in Lake Houston using base dataset and six water-transfer scenarios for low- and high-flow years.