4 BASELINE CONDITIONS

This chapter is an overview of current conditions in the Bois d'Arc Creek watershed based on historical data, data collected as part of this study, and modeled data. Data are grouped by the four main components of the study: hydrology and hydraulics, fluvial geomorphology, biology and water quality. More detailed information on these components may be found in the appendices of this report.

4.1 Hydrology and Hydraulics

HYDROLOGY

Stream flows are characterized by rapid rise and fall in response to rainfall events.

Limited historical flow data are available in watershed. Long-term hydrologic data are determined using models.

Overbank flows occur frequently, with a return period of less than 1 year.

Long-term median flow is <10 cfs. Many months have no flow.

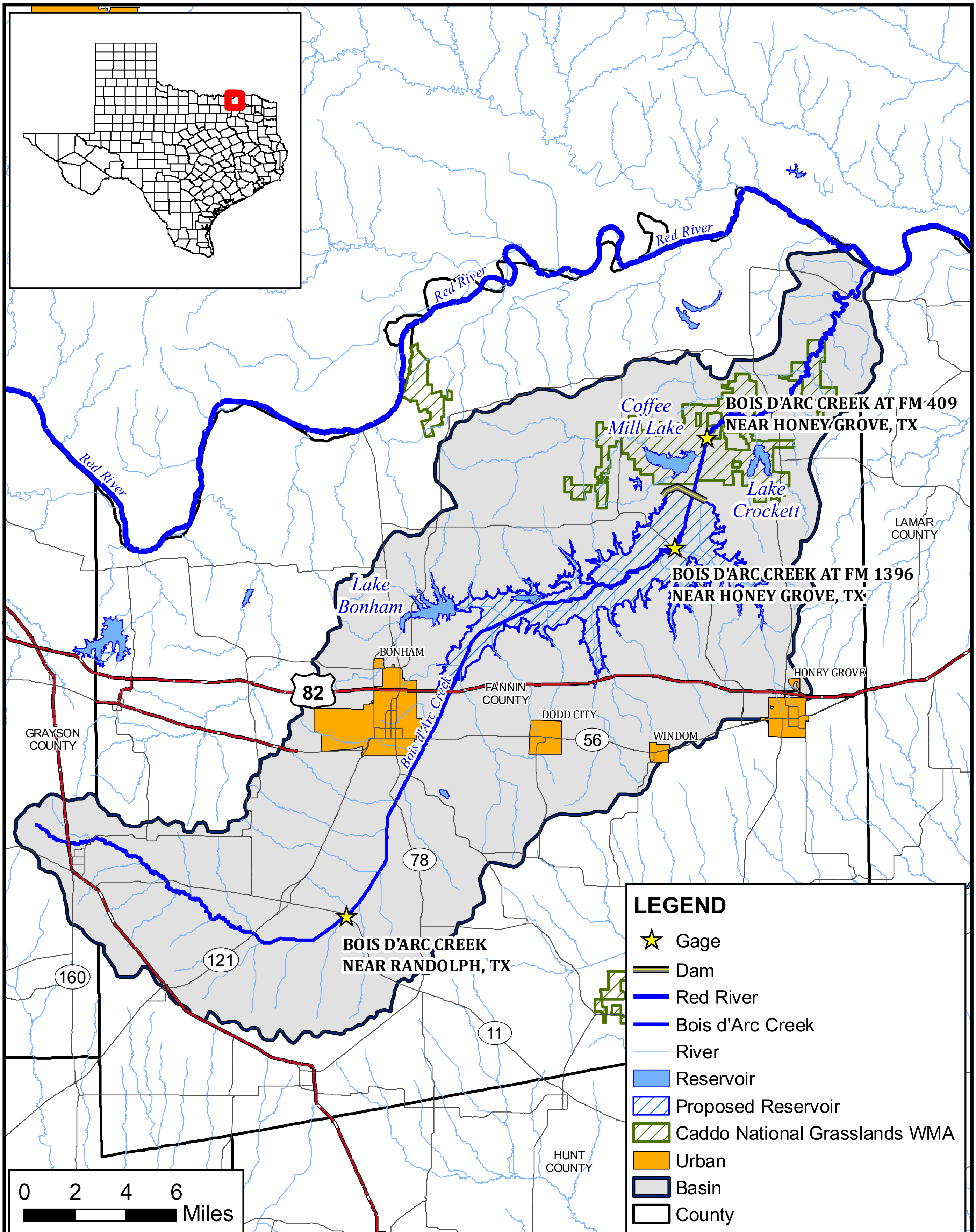
This portion of the study examines the current hydrologic conditions in Bois d'Arc Creek. The study used a combination of measured historical data and modeled hydrology. These data are essential to understand current geomorphic and biological conditions observed in the Bois d'Arc Creek watershed. This section gives a brief overview of the baseline hydrologic conditions. More detailed information may be found in Appendix B.

4.1.1 Gage Records

There are limited historical gage data in the Bois d'Arc Creek watershed (Table 4.1). The Randolph gage has the longest period of record (23 years), but only measured flow from 22 percent of the watershed. The FM 1396 gage has published data from July 2006 to September 2009. In addition, provisional flow data are available at the FM 409 gage (beginning in September 2009). Based on previous analyses by FNI, the North Sulphur River at Cooper appears to be the best surrogate for flows near the proposed Lower Bois d'Arc Creek Reservoir damsite. A comparison of these gages is included in Appendix B. The locations of these gaging stations are depicted in Figure 4.1.

Table 4.1 Relevant USGS Streamflow Records

Gauge Number	Gage Name	Start Date	End Date	Basin	County	Drainage Area (mi^2)
07332600	Bois d'Arc Ck nr Randolph, TX	Dec-62	Sep-85	Red	Fannin	72
07332620	Bois d'Arc Creek at FM 1396 nr Honey Grove, TX	June-06	Current	Red	Fannin	270
07332622	Bois d'Arc Creek at FM 409 nr Honey Grove, TX	Sep-09	Current	Red	Fannin	370
07343000	*N Sulphur Rv nr Cooper, TX*	*Oct-49*	*Current*	*Sulphur*	*Lamar*	*276*



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Map of Gage Locations

FN JOB NO	NTD06128
FILE	Figure4.1.mxd
DATE	May 2010
SCALE	1:335,000
DESIGNED	DLB
DRAFTED	BME

4.1
FIGURE

Figure 4.2 shows the historical flow data from the FM 1396 gage, plotted on both normal and logarithmic scales. The gage data show that Bois d'Arc Creek is a "flashy" watershed, characterized by a rapid rise and fall in response to rainfall events. There are extended periods of little or no flow. Low-flow periods include June 2006 to early October 2006 and July 2008 to May 2009. It is likely that the extreme flow characteristics of the watershed are exacerbated by the extensive channelization in the watershed.

One of the challenges faced by the USGS in measuring flows is the continuous horizontal and vertical movements of the channel bed at the FM 1396 and FM 409 gages. This has required several adjustments to the rating curves at these gages in the short period of time that these gages have been in operation (USGS 2010). As a result, unpublished USGS stage data are not easily converted to flows because of the constant adjustment of the rating curves. Not only has this made it difficult for the USGS to determine accurate flow data, but it has also made it difficult to correlate the reported flow data with measurements of water surface elevations. Water surface elevations at different flows were developed based on field measurements from this study. These elevations reflect conditions at the time the measurements were made and generally corresponded well with the USGS data for those dates; however, the measured elevations may not correspond to past or future rating tables from the USGS. In the future, flows will have different water surface elevations because of the on-going downcutting of the watershed.

4.1.2 Modeled Flows

Three types of modeling were used to help characterize current hydrologic conditions:

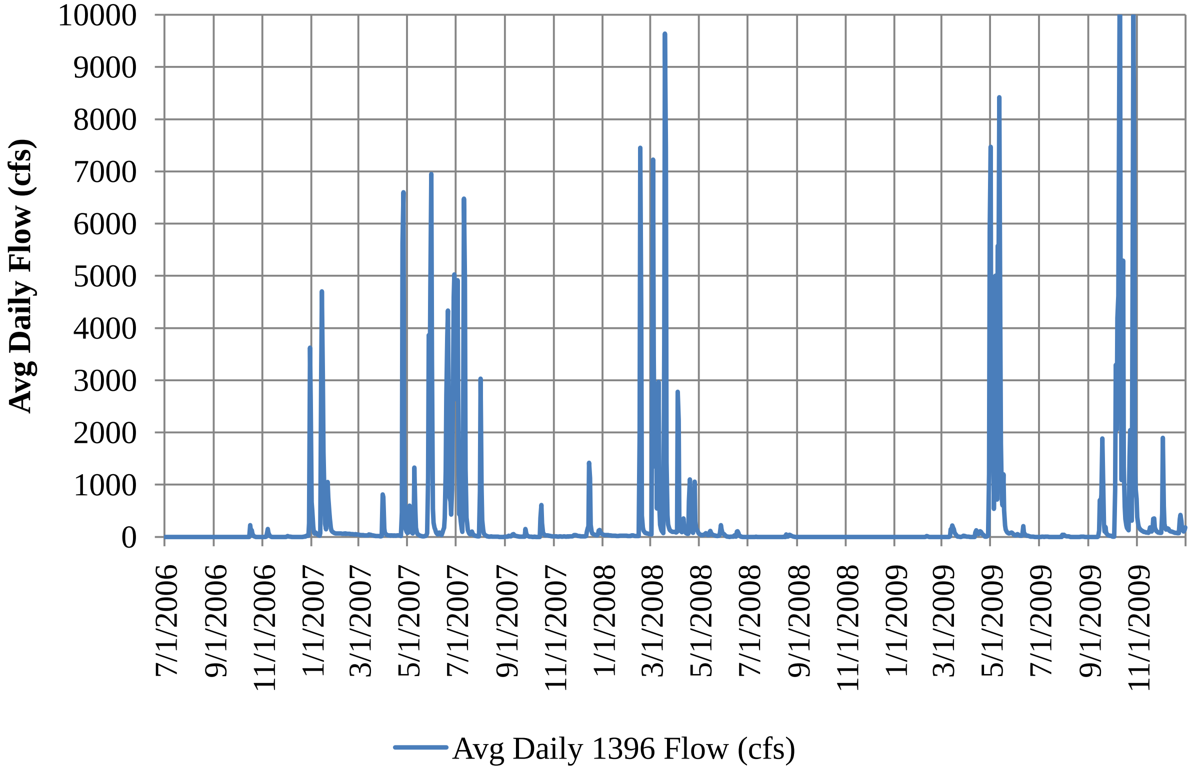
- Modeling of overbanking storm events using a HEC-RAS model of the watershed from about 23.6 miles above the proposed Lower Bois d'Arc Creek Reservoir dam site to just above the confluence with the Red River. This model is called the *Full Model*.

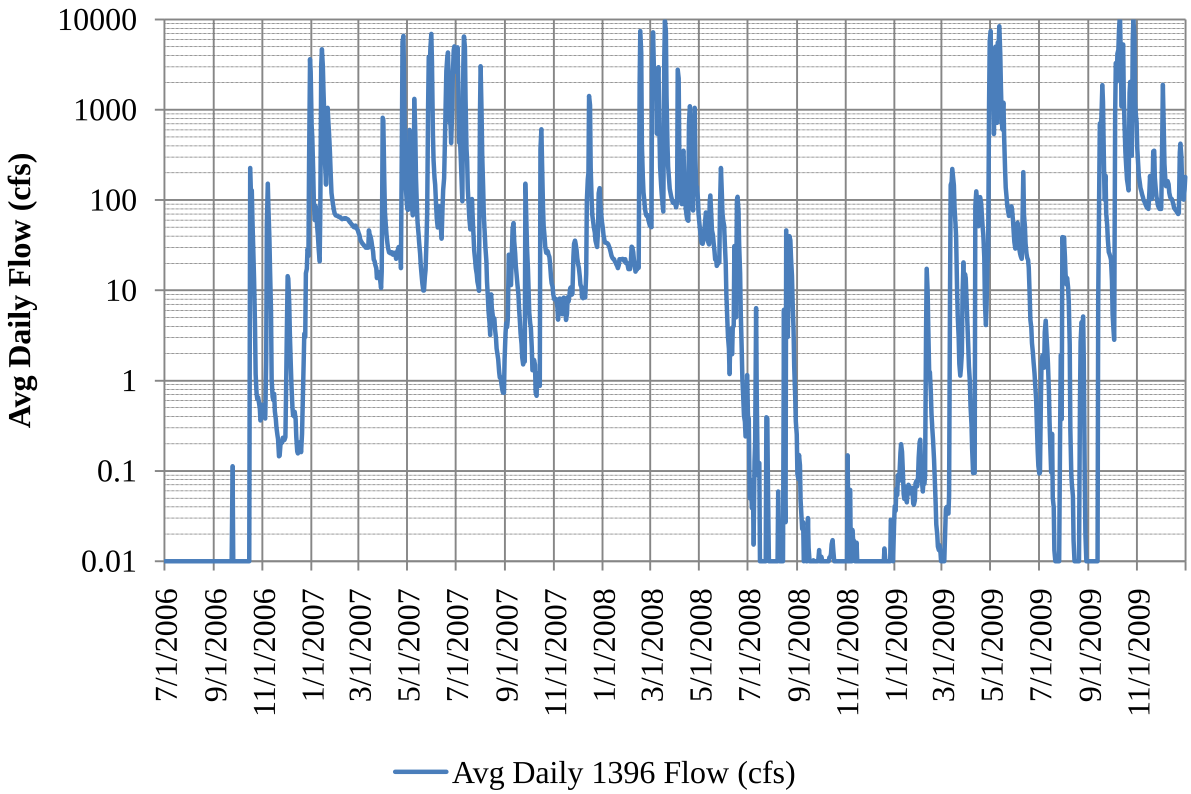
- Modeling of low-flows in the FM 1396 and FM 409 study reaches, also using the HEC-RAS model. These models are referred to as the *Reach Models*.

- Modeling of the long-term hydrologic response of the watershed using RiverWare.

A brief description of these models follows. More detailed information about the modeling may be found in Appendix B.

Figure 4.2 Historical Flow Data for USGS Gage 07332620 - Bois d'Arc Creek at FM 1396





4.1.2.1 HEC-RAS Modeling of Overbanking Events

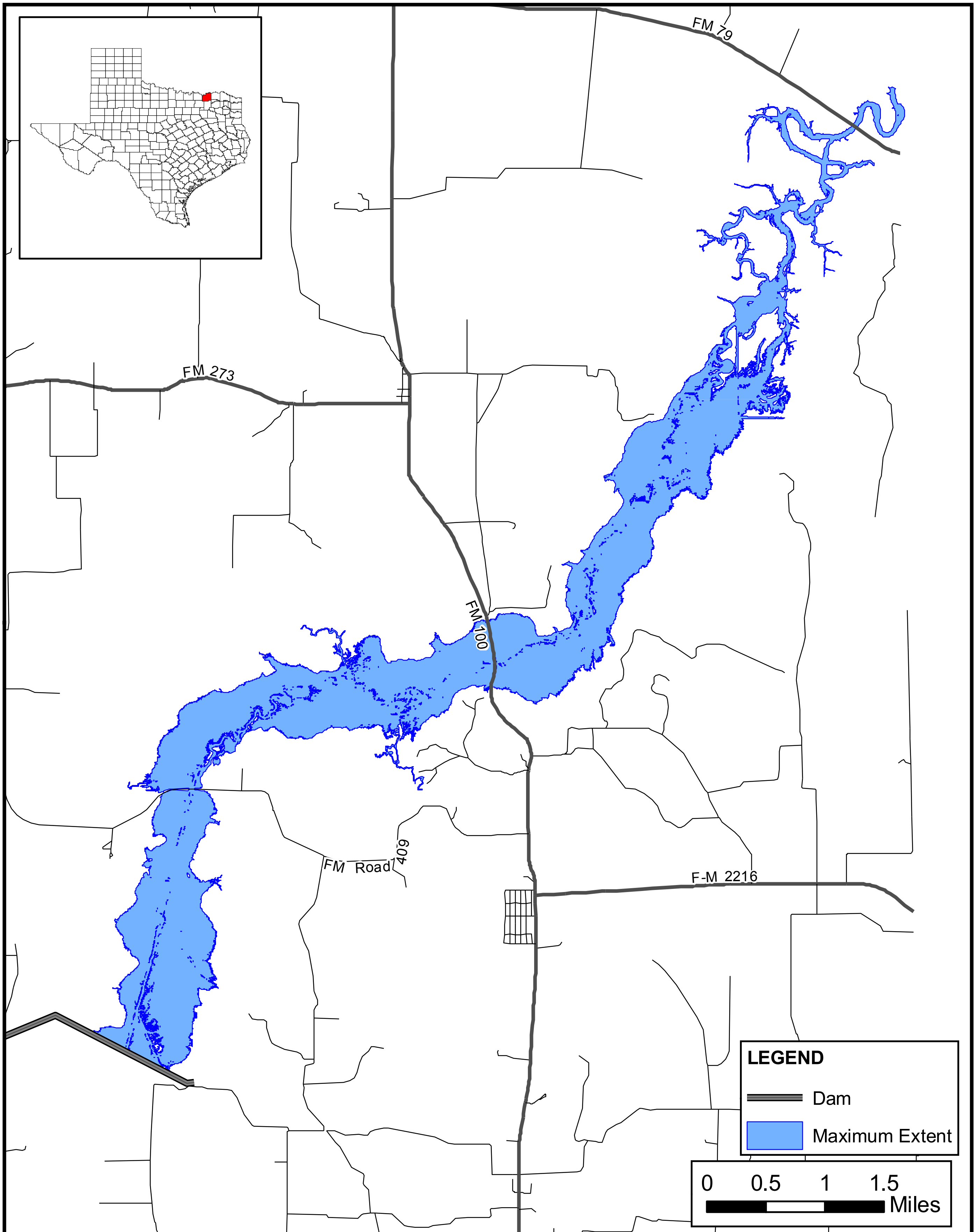
HEC-RAS is a one-dimensional hydrology and hydraulic modeling program developed by the US Army Corps of Engineers. A large scale HEC-RAS model of the watershed, called the Full Model, was used to identify the extent of overbank flooding for 1-year, 1.5-year, and 2-year storm events. Table 4.2 shows the peak flow and daily average flows for each of these events, as measured at FM 409 (model cross section 85046). Figure 4.3 through Figure 4.5 show the maximum inundation for each of these events from the proposed dam location to a point just below the FM 79 bridge, which is close to the confluence of Bois d'Arc Creek with the Red River. All three events cause similar overbank flooding from the proposed dam to a point between the FM 100 and FM 79 crossings. From that point the storm events are more confined, with inundation limited to cutoff channels and gullies. However, the Full Model does not include any backwater effects from the Red River. If flows in the Red River are high, there is potential for additional overbanking in the lower portions of Bois d'Arc Creek. These results show that under current conditions overbanking events are a relatively common occurrence in the Bois d'Arc Creek watershed and the corresponding floodplains are a relatively narrow corridor along Bois d'Arc Creek.

Table 4.2 Bois d'Arc Creek Flow Rates and Inundated Area for 1.0-Year to 2.0-Year Storm Events

	At FM 409		Dam to FM 79
Recurrence Interval	**Peak Flow (cfs)**	**24-hr Average Peak Flow (cfs)**	**Inundated Area (acres)**
1.0 Year	8,056	5,948	3,396
1.5 Year	11,095	8,814	3,709
2.0 Year	13,390	11,265	4,121

4.1.2.2 Development of Study Reach Rating Curves using HEC-RAS

Detailed HEC-RAS models were developed for the FM 1396 and FM 409 study reaches, referred to as the Reach Models. The Reach Models were calibrated using discharge and water surface data collected as part of this study and flow data collected by the USGS at the FM 1396 and FM 409 stream gages. These models were used to develop rating curves that relate water surface elevation to flow and velocity in the study reaches. These rating curves were used in habitat models described in the Biology sections of this report.



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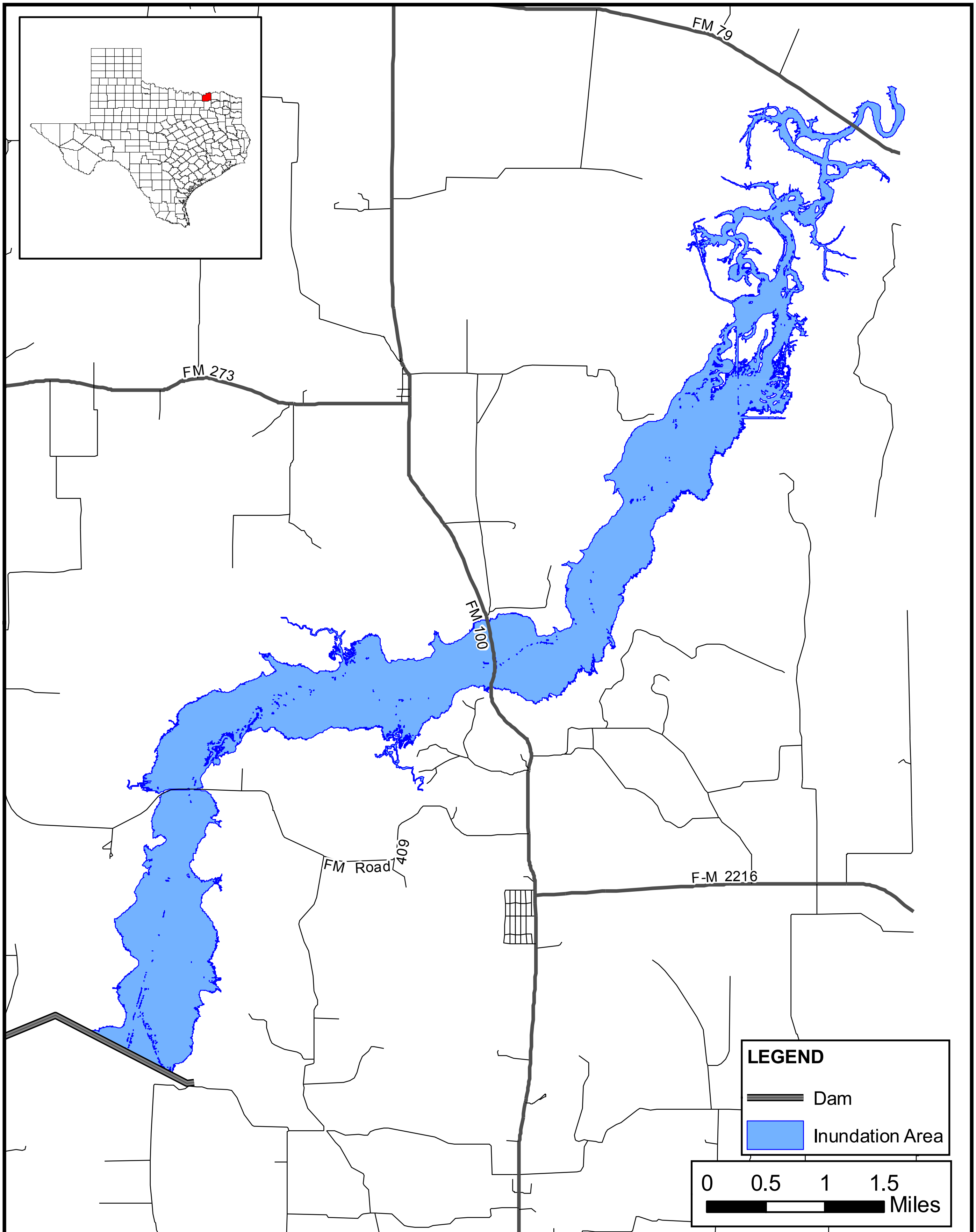
1 Year Flood Event

FN JOB NO	NTD06128
FILE	Figure4.3.mxd
DATE	May 2010
SCALE	1:72,000
DESIGNED	BME
DRAFTED	BME

4.3

FIGURE



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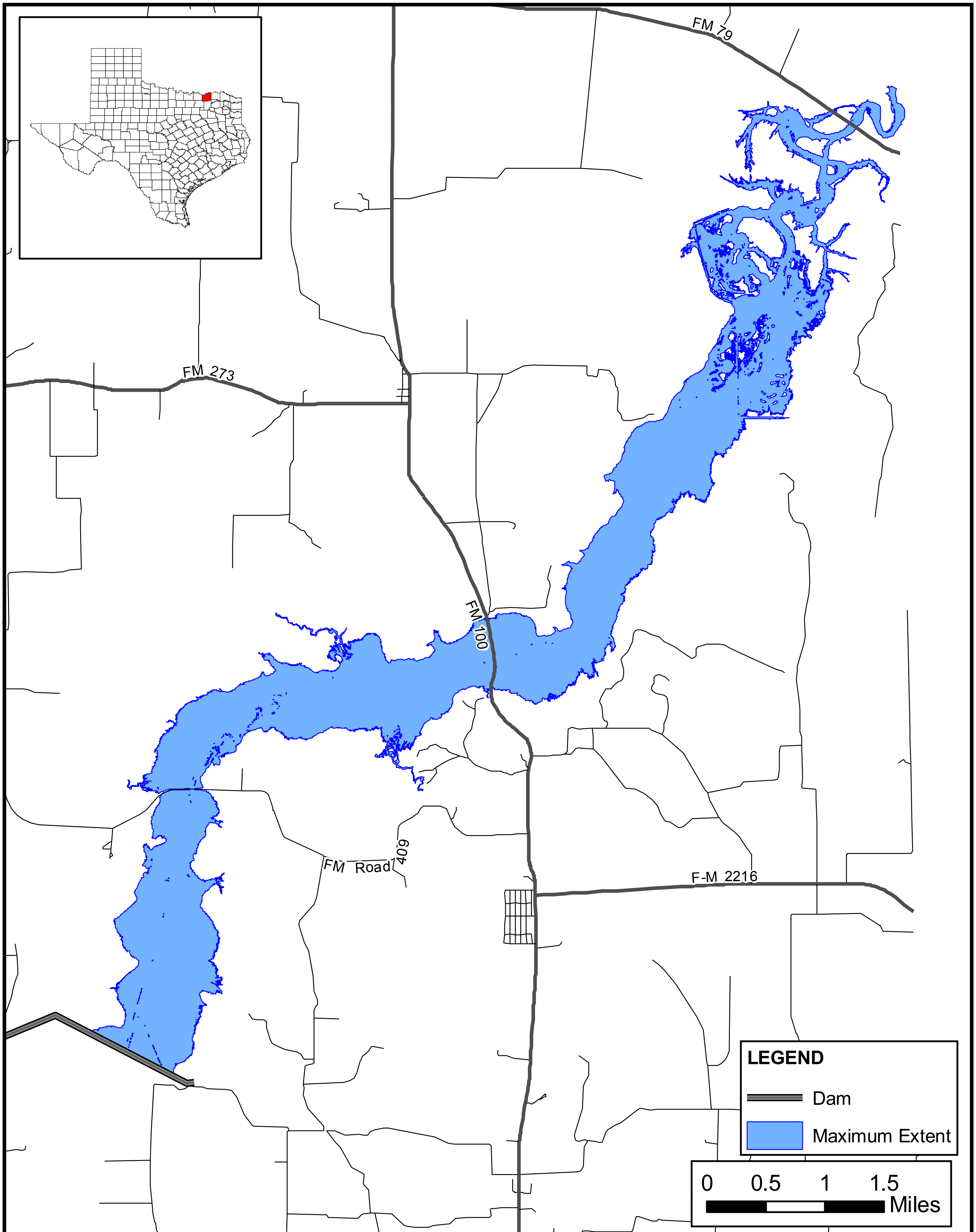
1.5 Year Flood Event

FN JOB NO	NTD06128
FILE	Figure4.4.mxd
DATE	May 2010
SCALE	1:72,000
DESIGNED	BME
DRAFTED	BME

4.4

FIGURE



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2 Year Flood Event

FN JOB NO	NTD06128
FILE	Figure4.5.mxd
DATE	May 2010
SCALE	1:72,000
DESIGNED	BME
DRAFTED	BME

4.5

FIGURE

4.1.2.3 Long-Term Hydrologic Modeling using RiverWare

The available USGS gage data at the reservoir site only show a small time window of flow conditions in Bois d'Arc Creek. A RiverWare model was developed to estimate the response of the watershed to changing stream conditions over a longer period of time. RiverWare is a hydrologic model designed to simulate management of reservoir and stream segments that was developed by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES), a division of the University of Colorado at Boulder. The model was used to assess the baseline conditions of the watershed as well as future conditions with the dam in place. Figure 4.6 shows the layout of the model. It includes explicit modeling of Lake Bonham, the FM 1396 gage (USGS 07332620), the proposed reservoir damsite, Lake Crockett, the FM 409 gage, Coffee Mill Lake, the FM 100 crossing and the reach from FM 100 to the Red River. Flows for the RiverWare model are based on data from the North Sulphur River near Cooper gage (USGS 07343000) and the TCEQ Red River Basin Water Availability Model (TCEQ WAM). The model uses a daily time step and covers the period from 1948 to 1998.

Figure 4.6 RiverWare Model Layout

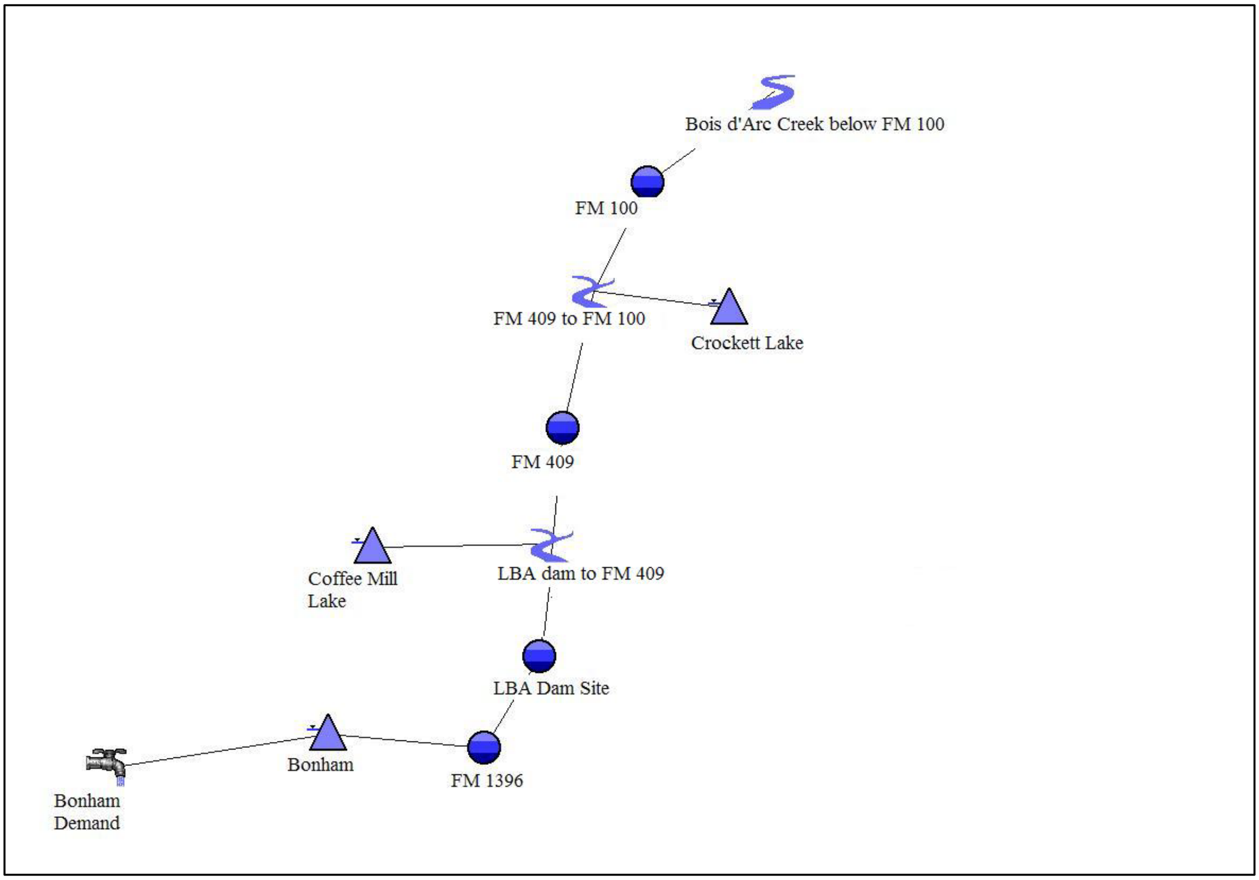


Table 4.3 is a statistical comparison of the modeled flows at FM 1396 to historical flows measured at FM 1396. In this study, we have identified three seasons based on the flow characteristics of the watershed. April, May, and June are typically high flow months associated with spring rains. July and August are typically low-flow months associated with high summer temperatures and lower rainfall, and these low flows tend to persist through September and October, which also tend to be relatively dry. November through March have variable flows, but are typically higher than the summer season. Note that in Table 4.3 the three years of historical data tend to be higher than the modeled flows for flows above the median, and tend to be lower than the modeled flows below the median. Conditions were relatively dry in the summer of 2006 and from the summer of 2008 through the winter months of 2009, and relatively wet in the other parts of the historical period. Although caution should be used when making conclusions based on such a short period of record, the results seem reasonable.

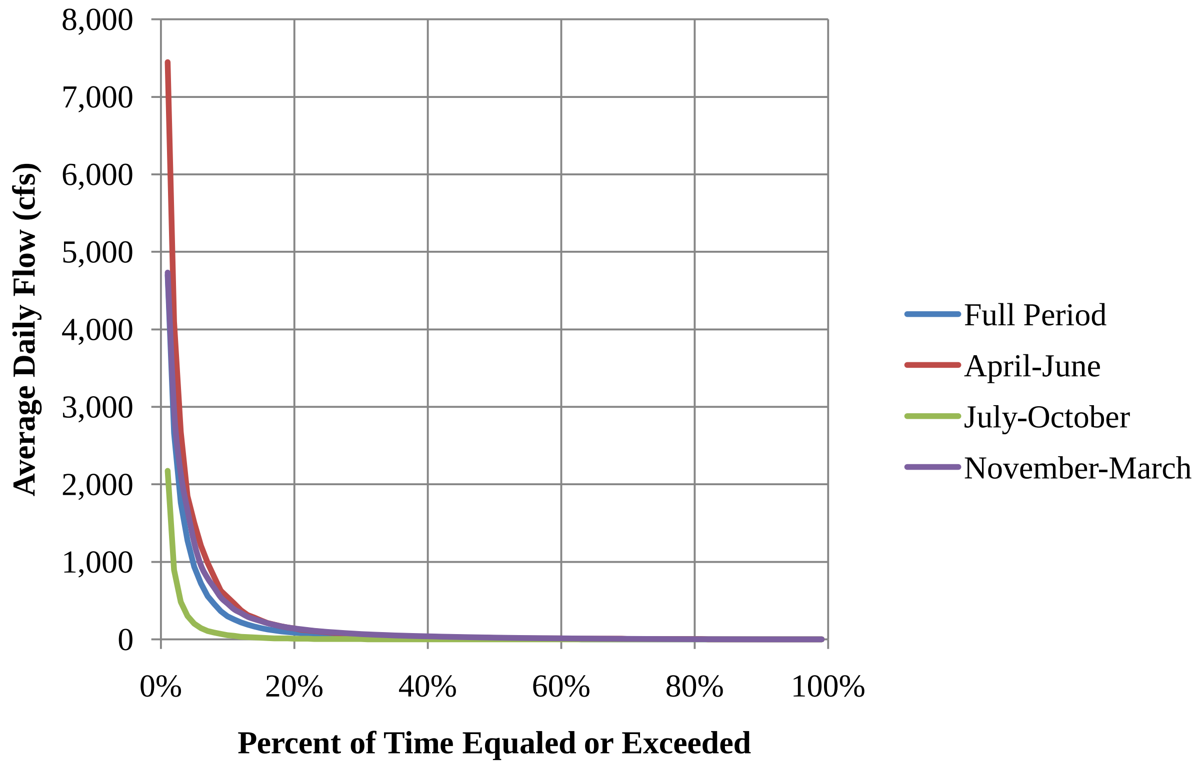
Figure 4.7 shows the exceedence frequencies for the modeled data, displayed using both linear and logarithmic scales. The median flow for an entire year is about 10 cfs. Note that the July-October flows are significantly less than the other two seasons, with flows less than 1 cfs about 60 percent of the time and less than 10 cfs about 80 percent of the time. Outside of the July-October season, flows are less than 1 cfs from 12 to 15 percent of the time and less than 10 cfs about 36 percent of the time.

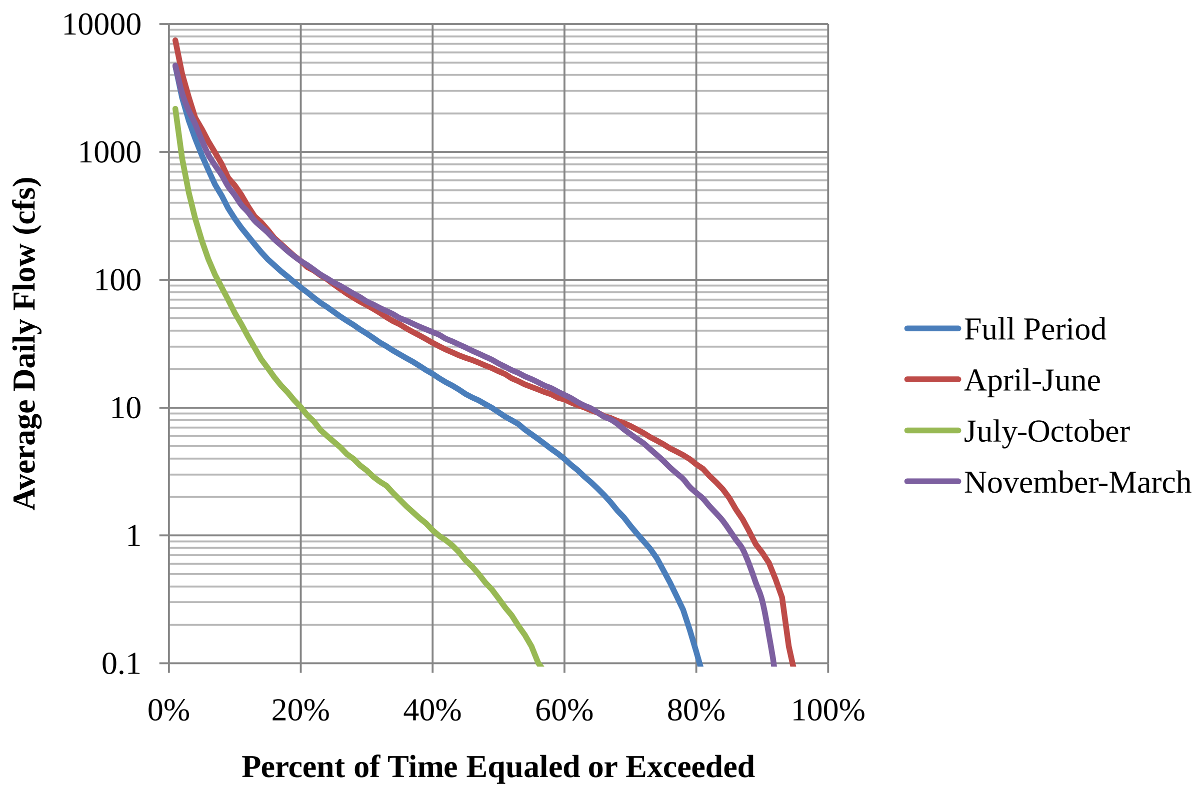
Table 4.3 Bois d'Arc Creek Flow Statistics at FM 1396

(Values in cfs)

Statistic	Modeled Flows (1948 – 1998)				Recorded Flows (July 2006 – Sept 2009)			
	Full Period	April-June	July-October	November-March	Full Period	April-June	July-October	November-March
Average	231	341	104	268	310	569	262	218
Minimum	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
15%	0.0	2.0	0.0	1.1	0.0	5.7	0.0	0.0
30%	1.2	7.2	0.0	6.2	0.2	26.0	0.0	0.5
Median	9.2	19.3	0.3	22.1	13.9	58.8	0.1	20.9
70%	38.1	63.5	3.2	67.7	57.2	128	6.4	65.5
85%	145	246	20	234	165	755	60.1	141
Maximum	34,914	34,914	30,163	28,091	11,627	8,420	11,627	9,641

Figure 4.7 Flow-Duration Curve of Modeled FM 1396 Flows





4.2 Fluvial Geomorphology

The fluvial geomorphology component of this study includes the classification and characterization of the Bois d'Arc Creek study reaches, identification and mapping of geomorphic units within study reaches, evaluation of lateral movement and erosive characteristics of the stream, and modeling of sediment transport. The results of these studies are summarized in the following section. Appendix C describes these studies in detail.

GEOMORPHOLOGY

Channelization has caused downcutting and degradation to the stream system including unchannelized reaches.

Incised channel restricts normal channel processes including floodplain migration and meandering.

Flows of less than 1 cfs can transport sediment load.

Gravel transport occurs at 25 cfs.

4.2.1 Stream Classification at the Reservoir Site

In a previous study, FNI conducted a Rapid Geomorphic Assessment on Bois d'Arc Creek and four major tributaries (Honey Grove Creek, Sandy Creek, Ward Creek, and Bullard Creek) within the inundation pool of the proposed reservoir (FNI, 2008). The study found that all of the reaches have been impacted by human activities and none of the reaches has reached a new state of dynamic equilibrium. The study classified the stream segments as "good", "fair" or "poor" pending the segment's state of equilibrium and stream stability. A "good" rating indicates a relatively stable channel with sediment transport capacity in balance with sediment supply, a "poor" rating indicates disequilibrium with unstable, eroding channel sections and degraded instream habitats, and a "fair" rating indicates moderately stable channel sections and the sediment transport and sediment transport capacity is not in balance with the sediment supply.

The 2008 geomorphic assessment classified 54 percent of Bois d'Arc Creek within the inundation pool of the proposed reservoir as "poor" with the remainder 46 percent being classified as "fair." Eighty-six percent of Honey Grove Creek was classified as "fair" with the remainder being classified as "good" (8%) or "poor" (6%). Ward Creek was classified as "fair" (84%) with the remainder of sixteen percent being classified as "poor." The majority of Bullard Creek (82%) and Sandy Creek (83%) were classified as "poor" with the remainder of 18 and 17 percent being classified as "fair," respectively.

4.2.2 Basin-Wide Stream Characterization

The River Styles™ methodology (Brierly and Fryirs, 2005) was used to characterize Bois d'Arc Creek throughout the watershed. River Styles is a geomorphic approach for characterizing stream forms and processes. In the first step of the process, the Bois d'Arc Creek watershed was divided into five landscape units based on geology, climate, soil, local relief, valley slope, and morphology. The landscape units were separated into 12 river styles defined by channel dimensions, channel planform (the layout of the stream channel on the landscape viewed from above), tributary confluences, transitions from a natural channel to channelized segments, changes in slope, changes in the underlying geology, or other features. Figure 4.9 is a map showing the landscape units and the reaches of each river style. (Although there are 13 segments, the Bois d'Arc Creek watershed has only 12 river styles. Segments 7 and 9 are classified as the same river style.)

Within each river style, geomorphic features were identified using aerial photographs and review of aerial video of Bois d'Arc Creek. This information was used when selecting the five study reaches. Table 4.4 describes the river styles for the five study reaches. A complete list of the Bois d'Arc Creek river styles may be found in Appendix C.

The geomorphic units were field mapped at four of the five instream flow study reaches (Figure 4.10 through Figure 4.13). Each of these reaches represents a different river style. Although the four study reaches do not cover every river style in the watershed, they are representative of the instream micro-habitat available for the aquatic life of Bois d'Arc Creek. These geomorphic base maps were used in habitat modeling to evaluate the amount of habitat available at different flows.

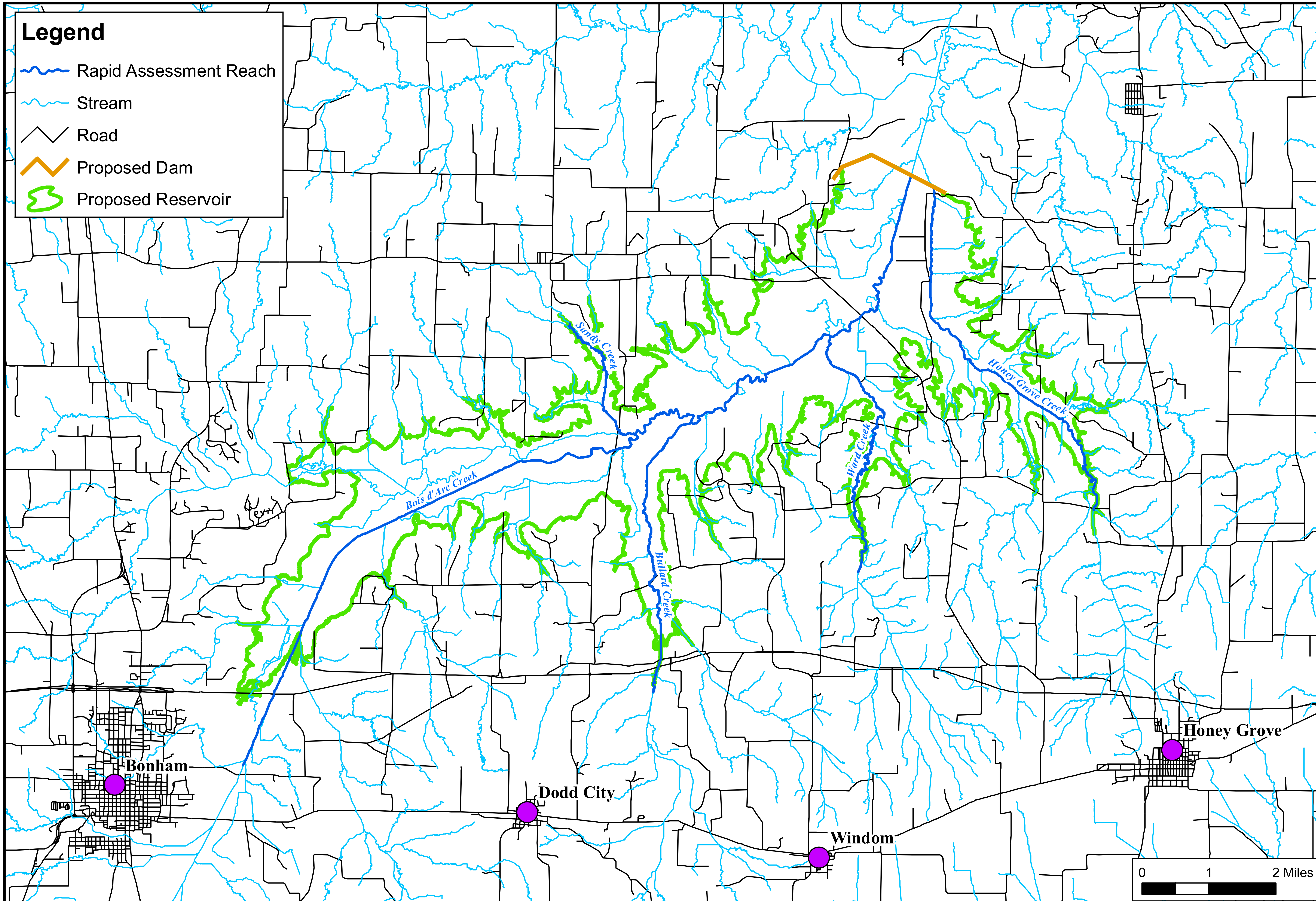


Figure 4.8

FN JOB NO	NTD06128
FILE	Figure4.8.mxd
DATE	May 2010
SCALE	1:85,000
DESIGNED	SVC
DRAFTED	BME

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Rapid Geomorphic Assessment

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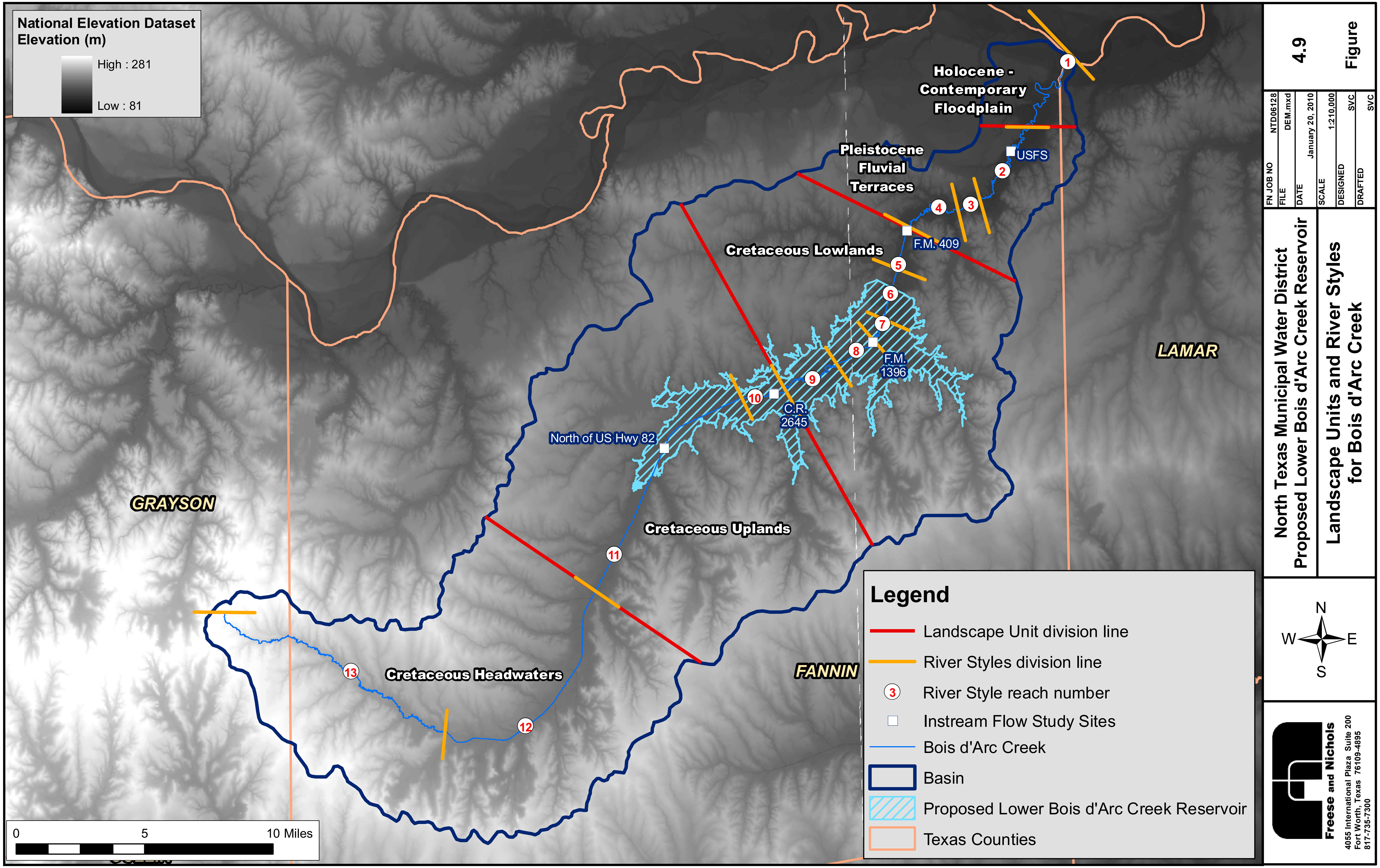
National Elevation Dataset
Elevation (m)
High : 281
Low : 81
Holocene - Contemporary Floodplain
Pleistocene Fluvial Terraces
Cretaceous Lowlands
Cretaceous Uplands
Cretaceous Headwaters
USFS
F.M. 409
F.M. 1396
C.R. 2645
North of US Hwy 82
1
2
3
4
5
6
7
8
9
10
11
12
13
GRAYSON
LAMAR
FANNIN
0
5
10 Miles
Legend
Landscape Unit division line
River Styles division line
River Style reach number
Instream Flow Study Sites
Bois d'Arc Creek
Basin
Proposed Lower Bois d'Arc Creek Reservoir
Texas Counties
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North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir
Landscape Units and River Styles
for Bois d'Arc Creek
Figure
4.9
FN JOB NO NTD06128
FILE DEM.mxd
DATE January 20, 2010
SCALE 1:210,000
DESIGNED SVC
DRAFTED SVC
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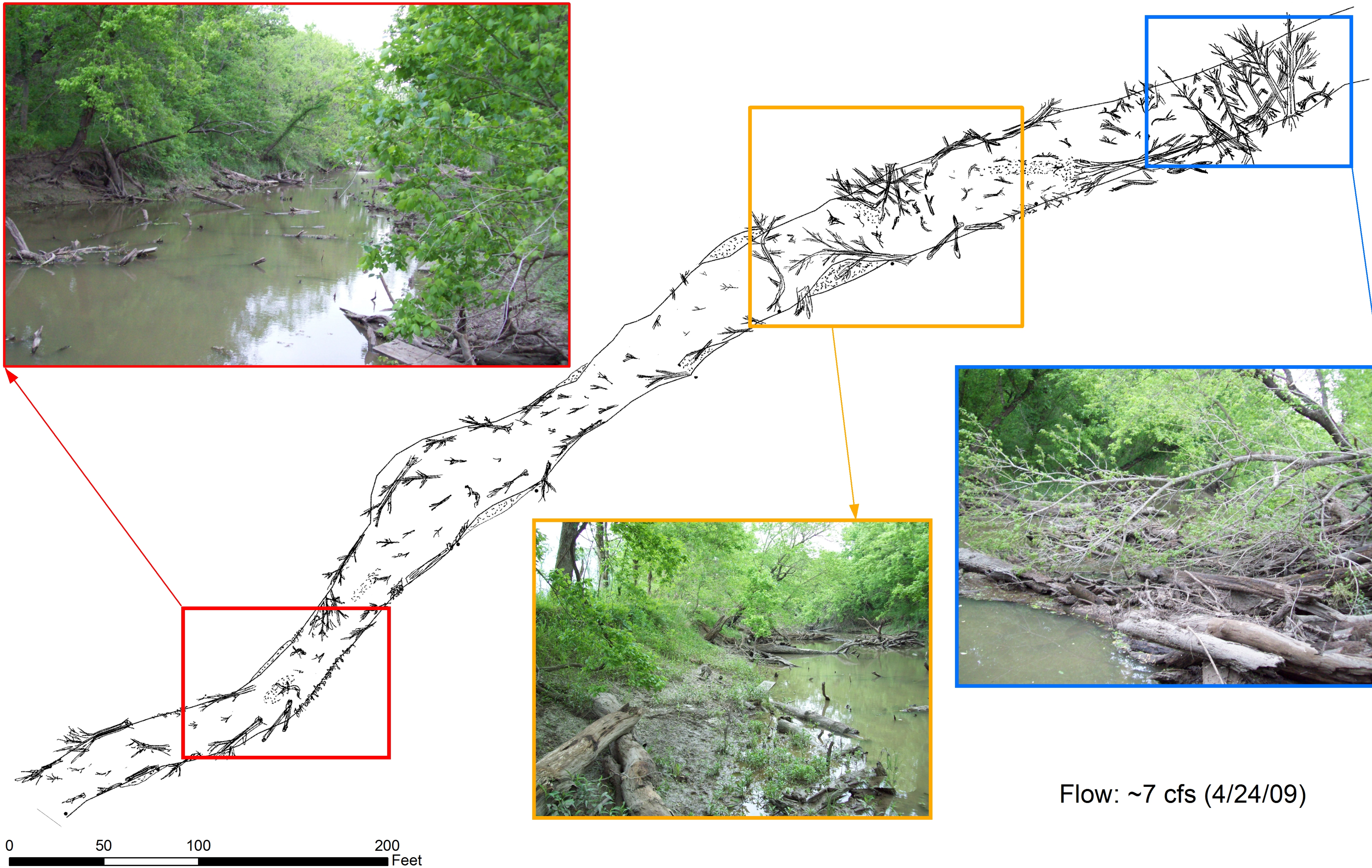
Table 4.4 River Styles at Study Reaches

Landscape Unit	River Style Reach Number	Study Reach and Location*	Valley Setting	River Style	Channel Planform	Bed Material	Geomorphic Units
Cretaceous Uplands - Rolling to nearly level plains, underlain by interbedded chalks, marls, limestones, and shales of Cretaceous age. Strongly dissected primarily on the Bonham Marl and Blossom Sand formations and intermittent streams.	11	US 82 site (Stream mile 40.4 to 30.5)	Laterally Unconfined	Unconfined Valley Moderately Entrenched Confined Channel - The channel morphology and alignment are controlled by channel incision into clay and marl. Continuous floodplain where not constricted by levee control. Channel geometry is a uniform incised channel that is laterally stable.	Straightened single thread	Bed material is weathered clay and marl with minor outcrops of limestone which are lined with silt and clay.	• Log/debris jams resulting in sediment deposition and mid-channel bars. • Elongated deep pools • Undercut banks • Tree topples/falls
	10	CR 2645 site (Stream mile 30.5 to 28.4)	Laterally Unconfined	Unconfined Valley Confined Channel and Flood Channels – The channel is controlled by incision into clay and marl. Floodplain pockets along both valley margins and flood events connect the main channel to flood channels.	Modified single-thread with low sinuosity (1.09)	Bed material is weathered clay and marl with a minor number of coarse sand and fine gravel midchannel and bank-attached lateral bars.	• Runs and shallow pools • Midchannel sand bars • Coarse gravel lateral bars • Undercut banks • Large woody debris/log jams • Floodchannels
Cretaceous Lowlands - Generally level and gently rolling, moderately dissected surface composed of Eocene and Paleocene age formations underlain by Cretaceous age formations.	8	FM 1396 (Stream mile 24.4 to 22.5)	Laterally Unconfined	Unconfined Valley Entrenched Channel - Channel morphology and alignment are controlled by incision and widening into the weathered shale. Continuous floodplain along both valley margins. Channel geometry is a trapezoidal channel with near vertical banks.	Modified single-thread with low sinuosity (1.10)	Bed material is weathered shale and marl. Slaked material from the lower bank and streambed is mixed within the coarse sand/gravel point and midchannel bars. Fine silts overlay the majority of the streambed	• Runs with long, thin scour features carved in the in the weathered bedrock. • Deep pools located in midchannel and along concave banks. • Bank-attached lateral bars and point bars • Vegetated island sand bars • Mass wasting – bank failures on curved reaches and rotational slumps on straight reaches.
	5	FM 409 site (Stream mile 19.0 to 17.2)	Partially Confined	Partially Confined Valley Straightened Channel with Abandoned Flood Flow Channel - The channel morphology and alignment are controlled by the incising and slumping processes. Continuous floodplain along both valley margins. The abandoned channel is utilized at overbanking flows. Streambank alternate concave and s-shape	Straightened single-thread	Bed material is weathered marl. Eroded bank material from the lower bank is mixed within the bedload. Midchannel bars are composed of coarse sand and fine gravels. Lateral bank-attached bars are composed of fine gravels to coarse gravels.	• Elongated runs and pools • Midchannel bars • Bank-attached lateral bars • Large woody debris with downstream sand deposition • Undercut banks • Scour pools • Vegetated rotational slumps • Chute cutoff
Pleistocene Fluvial Terraces - Located within the Pleistocene fluvial terrace deposits and Pleistocene age to Holocene age alluvial deposits. Gently rolling with low relief. Erosion has dissected the Pleistocene fluvial deposits, exposing underlying Cretaceous age formations.	2	USFS site (Stream mile 12.1 to 6.3)	Left laterally Confined	Left Laterally Confined Valley High Sinuosity Channel - The channel morphology and alignment are controlled to a significant degree by the sinuosity and the bed and bank material. The banks are concave on the outside of meanders and s-shaped on the inside on meanders. The left side on the channel is confined to the valley wall. The right side is continuous floodplain, engraved with rills and gullies.	Tortuous meandering single-thread with high sinuosity natural channel (1.70)	Bed material is sand and gravel from the fluvatile terrace deposits.	• Runs and pools • Sand sheets • Point bars • Bank-attached lateral bars • Midchannel bars • Chute cutoff • Large woody debris • Floodchannels • Floodplain pockets • Gullies

* The study reaches are only a portion of the river style reach.



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U.S. 82 Geomorphic Unit Base Map

F&N JOB NO. NTD06128
DATE: April 2010
SCALE: 1:580
DESIGNED: SVC
DRAFTED: MJA
FILE: Figure3_12.mxd

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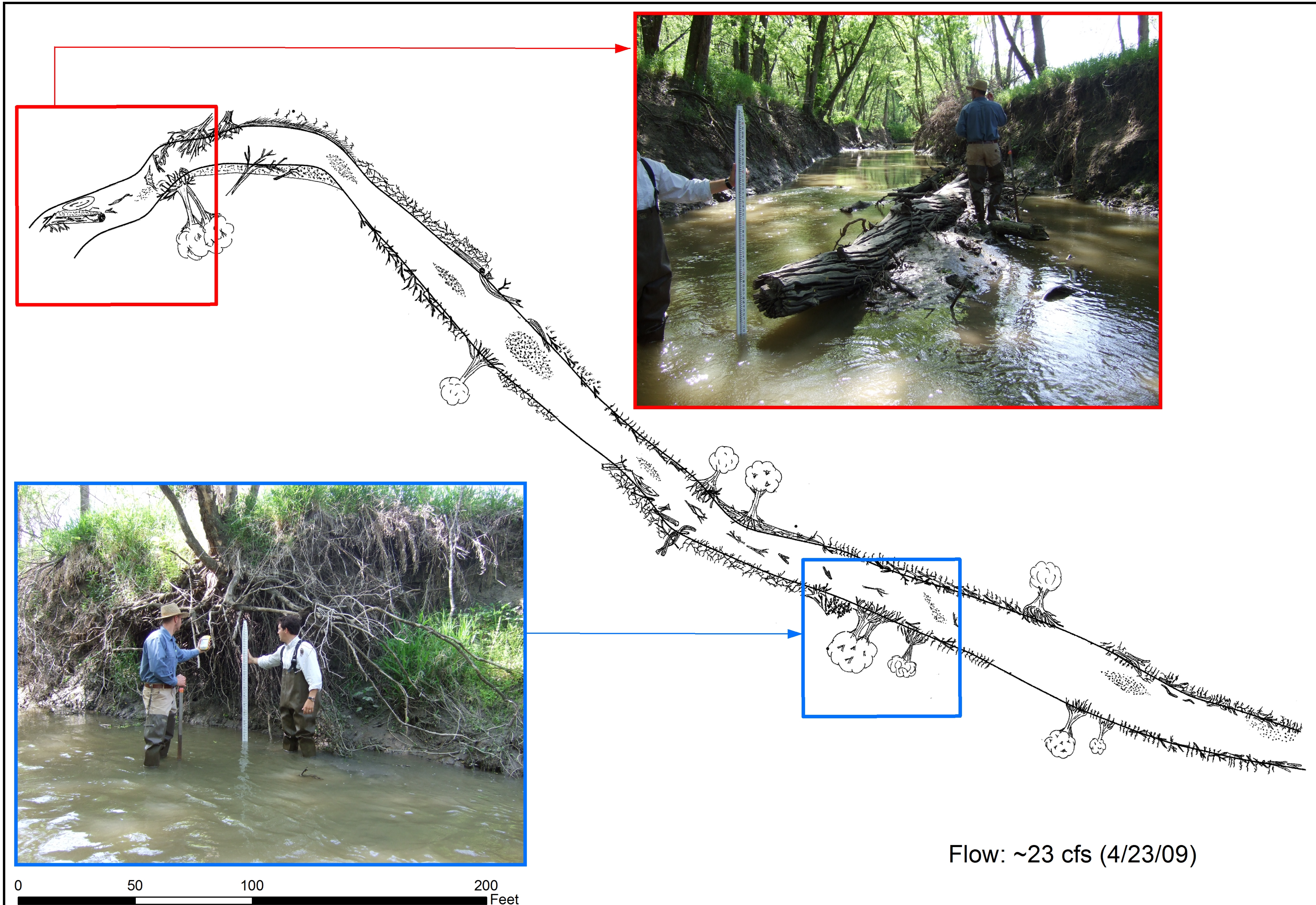
FIGURE
4.10



F&N JOB NO.	NTD06128
DATE:	April 2010
SCALE:	1:445
DESIGNED:	SVC
DRAFTED:	MJA
FILE:	Figure3_13.mxd

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C.R. 2645 Geomorphic Unit Base Map

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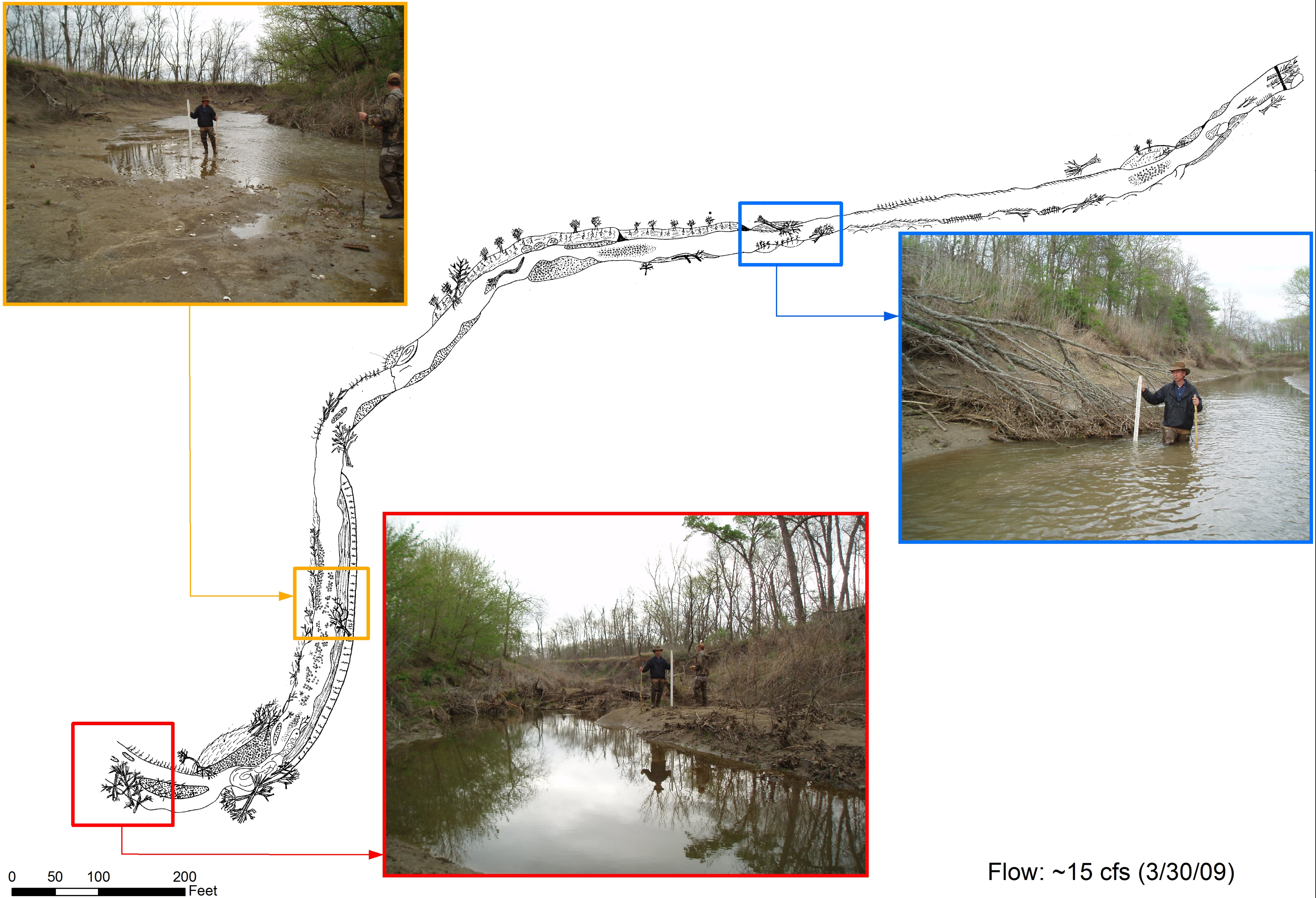
4.11
FIGURE



Flow: ~15 cfs (3/30/09)

F&N JOB NO. NTD06128
DATE: April 2010
SCALE: 1:1,200
DESIGNED: SVC
DRAFTED: MJA
FILE: Figure3_14.mxd

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Proposed Lower Bois d'Arc Creek Reservoir

F.M. 1396 Geomorphic Unit Base Map

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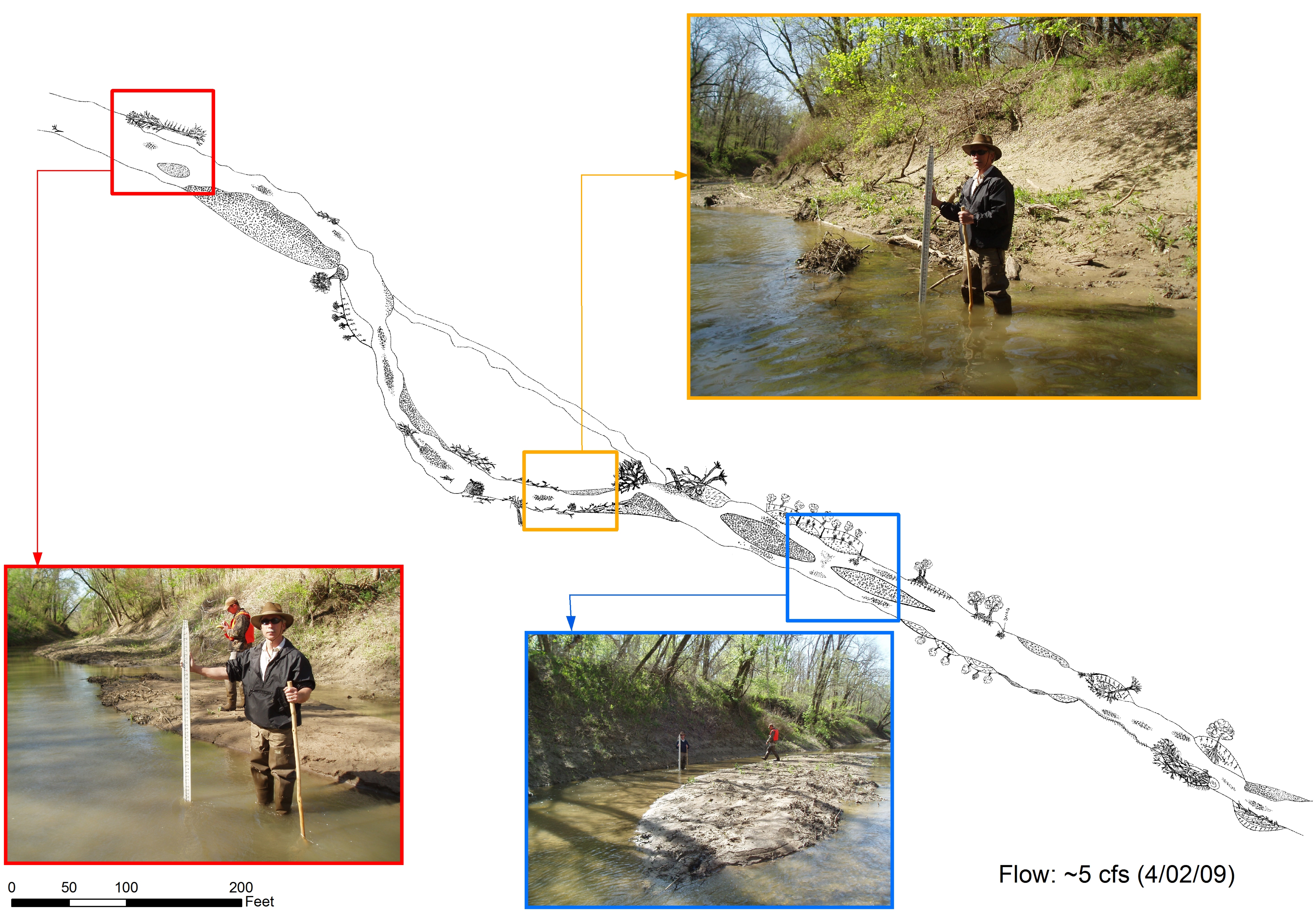
4.12
FIGURE



F&N JOB NO. NTD06128
DATE: April 2010
SCALE: 1:915
DESIGNED: SVC
DRAFTED: MJA
FILE: Figure3_15.mxd

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Proposed Lower Bois d'Arc Creek Reservoir

FM 409 Geomorphic Unit Base Map

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FIGURE 4.13

4.2.3 Planform Stability and Erosion

Planform stability refers to the lateral movement of a stream across a floodplain, or the tendency of a stream to meander. Stream bank erosion refers to the rate at which material on the stream bank is detached and displaced or transported by water. In general, the banks of Bois d'Arc Creek are actively eroding, resulting in channel widening and limited meander migration.

Figure 4.14 to Figure 4.18 compare the historical planform view of the areas surrounding the five study reaches. The earliest information is from a series of maps made in 1915, while the later data are from aerial photographs of the watershed. Four of the study reaches (US 82, CR 2645, FM 1396, and FM 409) are located within channelized sections of Bois d'Arc Creek. The USFS study reach (Figure 4.18) is located in a relatively natural, meandering section of stream.

It can be assumed that Bois d'Arc Creek was a natural, meandering stream prior to the channelization efforts. There is evidence of meander scars that indicate that Bois d'Arc Creek historically migrated across the floodplain over time. The straightening and resectioning of the stream resulted in abandoned channels or artificial oxbows that can be seen in the figures. The four study reaches located within channelized sections no longer migrate across the floodplain. Instead they are widening from fluvial erosion, subaerial erosion, and mass wasting. Based on the historical map and aerial photograph comparison, it can be estimated that bank loss in the straightened reaches of Bois d'Arc Creek is approximately 0.5 feet per year. All stream migration in the channelized reaches is confined within the incised straightened channel. In the sinuous segments of Bois d'Arc Creek, the historical map and aerial photographs indicate approximately between 0.9 to 2.1 feet per year of meander migration over the past 95 years (Figure 4.18). The migration is a result of the same erosional processes occurring in the straight reaches. The erosion and deposition processes of a meandering stream are present, but not at a large enough scale to cause the channel to migrate across the floodplain. It is likely that the entire stream modified its structure and function to adjust to the impacts of channelization.

STREAM BANK EROSION

Erosion on Bois d'Arc Creek is causing:

- **Channel widening**
- **Limited meander migration**
- **Reduced connectivity with riparian corridor**
- **Bank failure and habitat destruction**

Although Bois d'Arc Creek does not exhibit much tendency toward lateral migration, field measurements and observations indicate that stream bank erosion and downcutting are actively occurring at a relatively high rate in the watershed. Erosion rates are higher at the FM 1396 study reach than in the FM 409 study reach. Upstream of FM 1396 the stream banks and riparian corridor of Bois d' Arc Creek are less densely vegetated and have a narrower forested riparian buffer than other reaches. As a result, the banks are subject to increased rates of drying by direct sunlight and lack the stability provided by roots. During this study numerous mass failures were observed in this study reach. Downstream of FM 1396, the channel of Bois d' Arc Creek enters USFS property where the riparian corridor has been protected from vegetation removal. In these reaches, including the FM 409 study reach, the forested riparian corridor shades the stream banks, effectively decreasing the rate of weathering by dessication. Plant roots reinforce bank material and slow flowing water at the bank margin, reducing shear stress during high flow events. It was observed in the field that the FM 409 study reach contains active slump failures occurring on both channel banks. These slumps are slow-moving creep failures, instead of the catastrophic streambank retreat observed at the FM 1396 site.

4.2.4 Sediment Transport Analysis

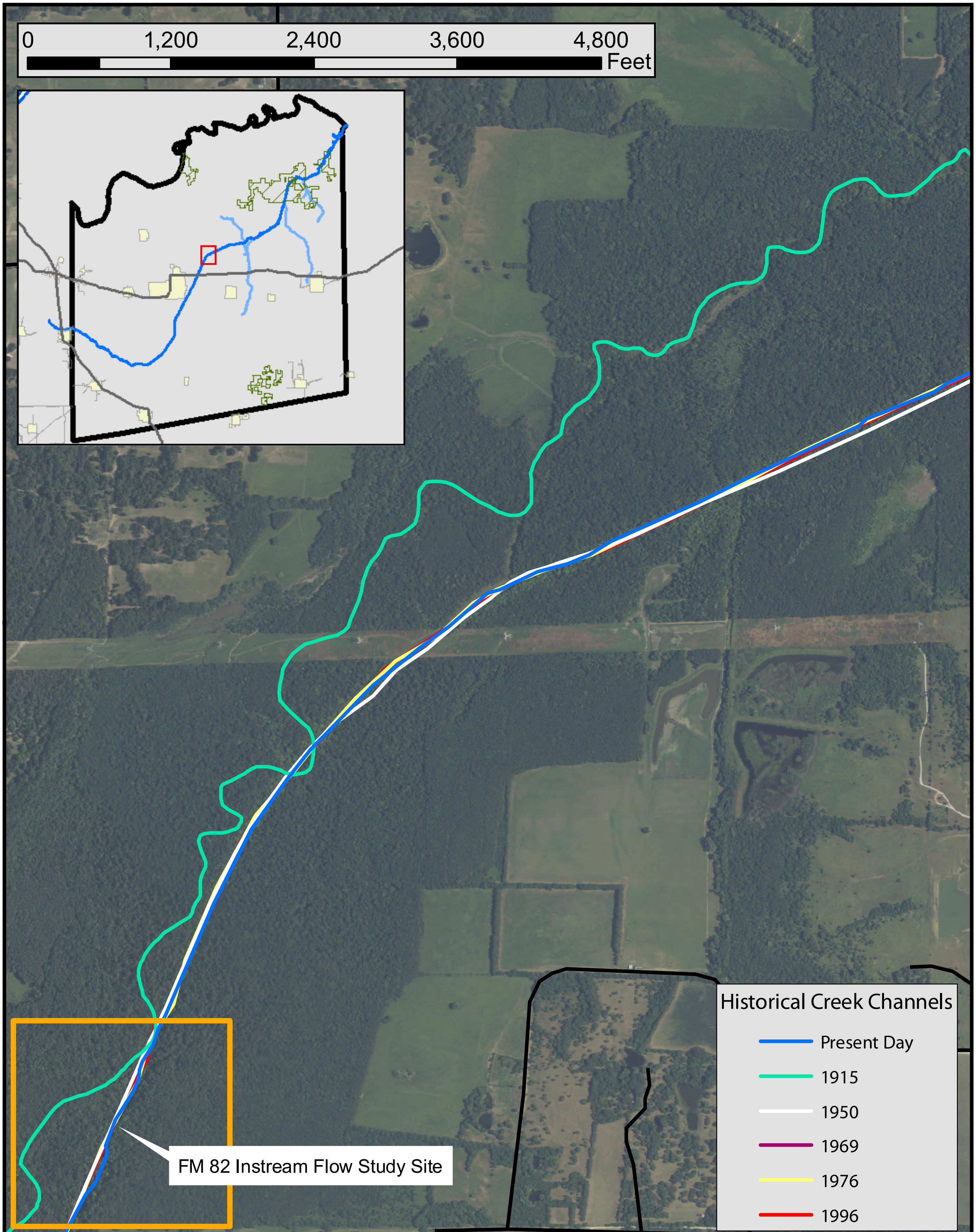
Bois d'Arc Creek is a threshold bedrock channel. The channel has incised into weathered clays, marls and shales. The Bois d'Arc Creek system has limited sources of coarse sediment. The gravel and sand material is irregularly dispersed along the creek in the form of bar deposits.

A particle size analysis quantified the bar deposit material particle size by evaluating the frequency distribution of particles sizes contained within the bar material sample. Surface and subsurface bar material was collected at representative geomorphic depositional features in the FM 1396 and FM 409 study reaches. The surface and subsurface data provide information on erosional processes and sediment transport. The surface and subsurface bar material samples at FM 1396 had a median grain size (D_{50}) on the order of 4.5 mm and 0.8 mm, respectively. Similarly, the surface and subsurface bar material samples at FM 409 had a D_{50} on the order of 4.75 mm and 0.6 mm, respectively. The surface sediment is coarser than the sediment below the surface. The difference in particle size is tied to the flow regime and the upstream sediment supply.

The particle size distribution data from the bar material samples were used in the SAMWin (Stable channel Analytical Model, Windows version) to estimate sediment entrainment and transportation potential within each reach. Interactions between flow and the channel boundary lead to adjustments in channel dimension, which result from processes of erosion, transport, and deposition.

Stream power determines the capacity of a given flow to transport sediment. The available stream power is related to the water surface slope and discharge of the channel. Identifying the flows capable of carrying sediment particles is an important part to the proper assessment of channel equilibrium slope as well as planform and vertical channel stability. A channel is in balance if the stream power is exactly sufficient to transport the sediment load, and therefore there is no net erosion or deposition along the reach.

This analysis demonstrates that even flows below 1 cfs have the potential to transport sediment. Flows between 1cfs to 10 cfs have the potential to transport approximately 0.26 ton per day to 5.3 tons per day, respectively of the fine grained particles (sand, silt and clay).



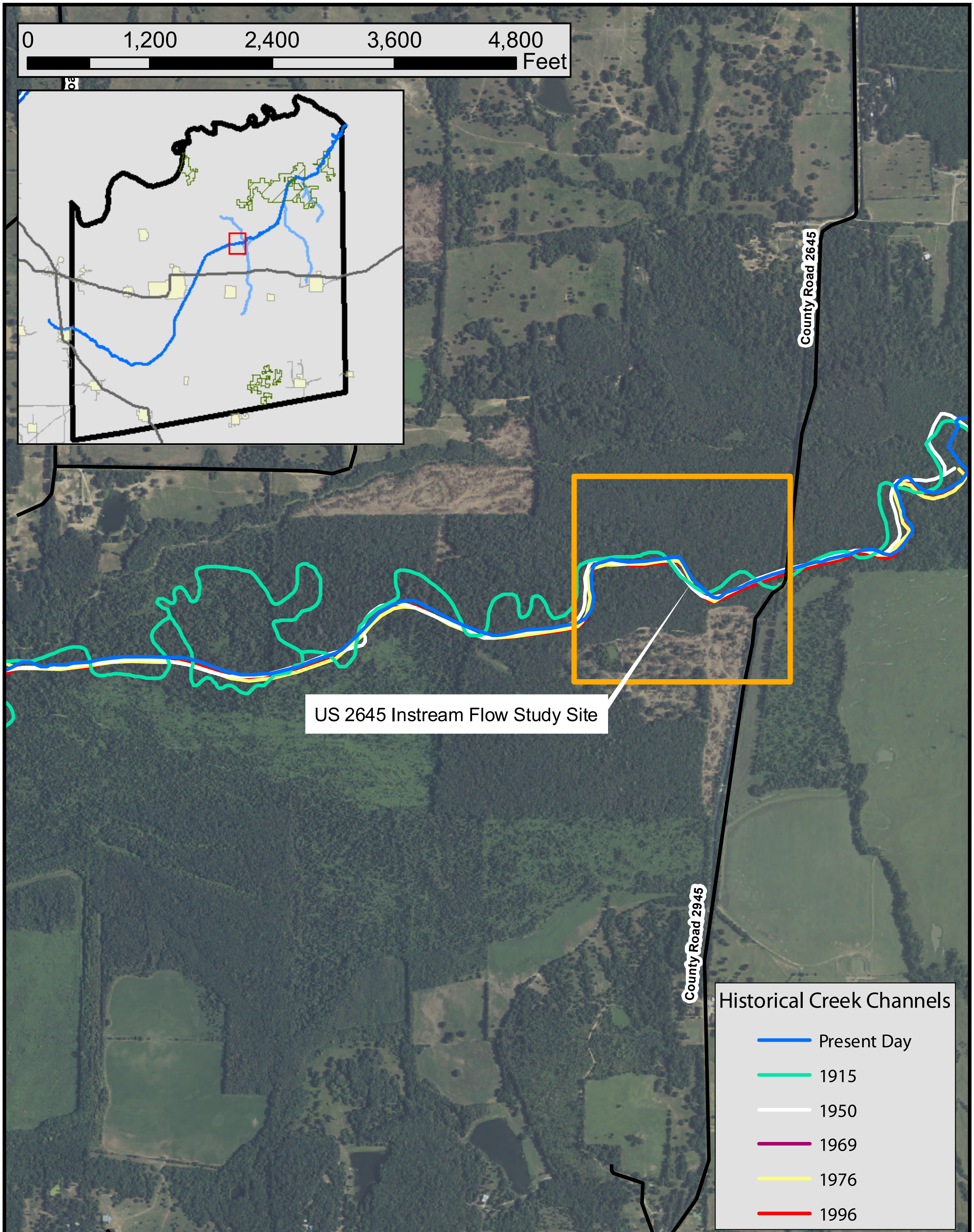
Freese and Nichols
4055 International Plaza, Suite 200
Fort Worth, TX 76109 - 4895
Phone - (817) 735 - 7300

North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Planform View of Lower Bois d'Arc Creek near FM 82

FN JOB NO	NTD06128
FILE	Mapbook.mxd
DATE	January 22, 2010
SCALE	1:13,500
DESIGNED	SVC
DRAFTED	BME

4.14
FIGURE



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Fort Worth, TX 76109 - 4895
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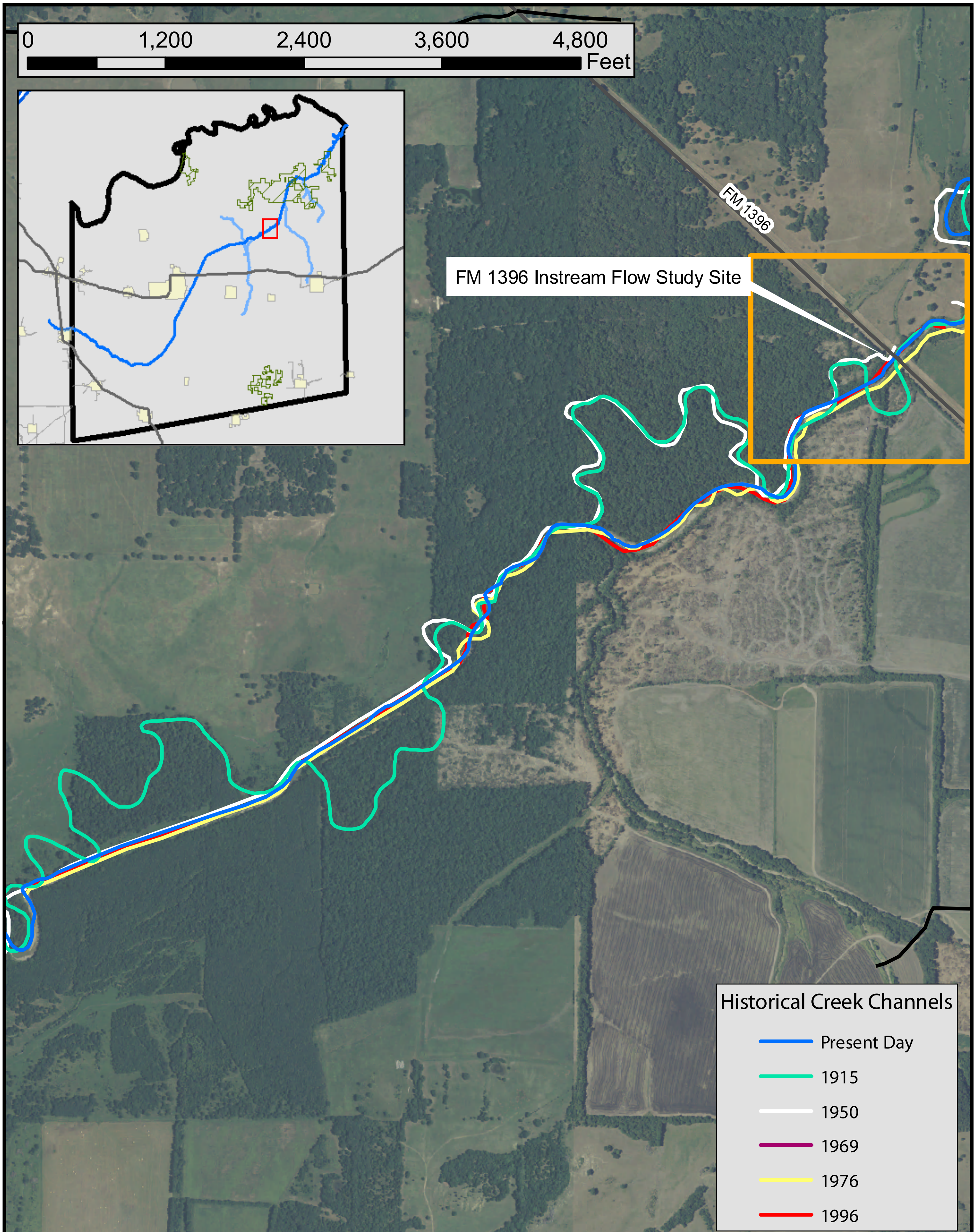
North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Planform View of Lower Bois d'Arc Creek near CR 2645

FN JOB NO	NTD06128
FILE	Mapbook.mxd
DATE	January 22, 2010
SCALE	1:15,800
DESIGNED	SVC
DRAFTED	BME

FIGURE 4.15



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4055 International Plaza, Suite 200
Fort Worth, TX 76109 - 4895
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N
W E
S

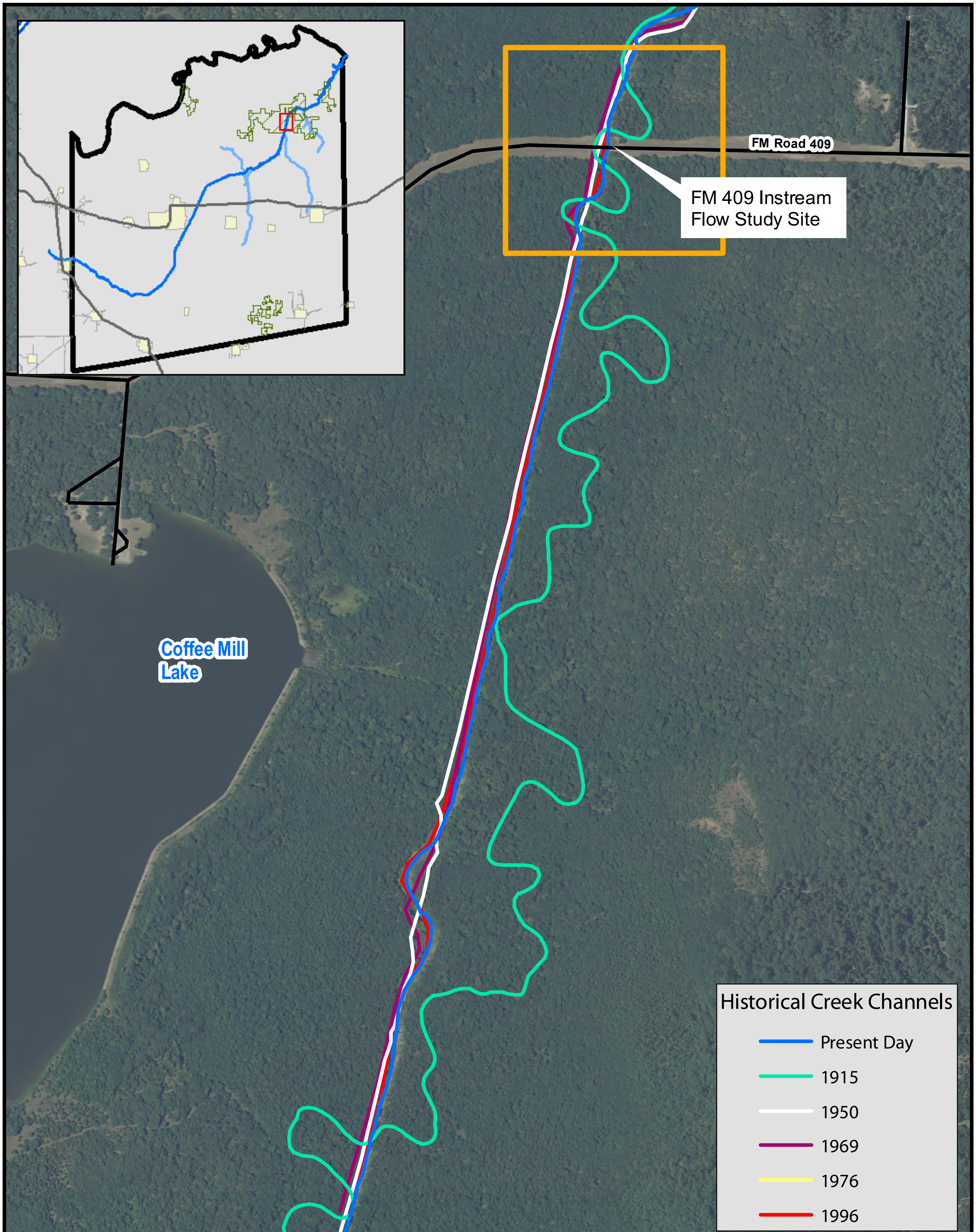
North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Planform View of Lower Bois d'Arc Creek near FM 1396

FN JOB NO	NTD06128
FILE	Mapbook.mxd
DATE	January 22, 2010
SCALE	1:14,000
DESIGNED	SVC
DRAFTED	BME

4.16

FIGURE



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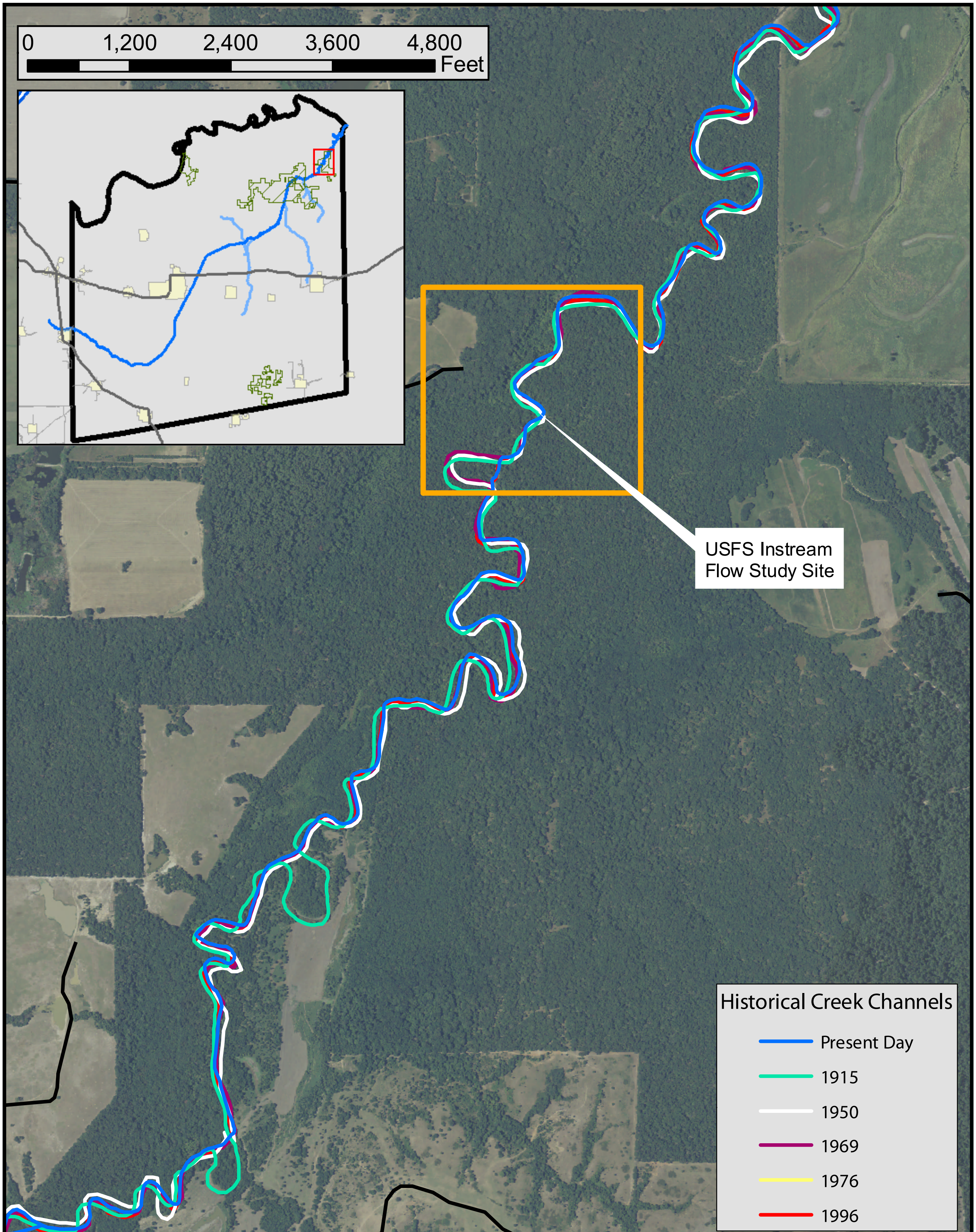
North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Planform View of Lower Bois d'Arc Creek near FM 409

FN JOB NO	NTD06128
FILE	Mapbook.mxd
DATE	January 22, 2010
SCALE	1:12,000
DESIGNED	SVC
DRAFTED	BME

4.17

FIGURE



Freese and Nichols
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Fort Worth, TX 76109 - 4895
Phone - (817) 735 - 7300

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North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Planform View of Lower Bois d'Arc Creek on USFS Property

FN JOB NO	NTD06128
FILE	Mapbook.mxd
DATE	January 22, 2010
SCALE	1:19,000
DESIGNED	SVC
DRAFTED	BME

4.18
FIGURE

Figure 4.19 to Figure 4.22 show the results of this analysis. Four sediment transport equations appropriate for use in these study reaches were used to produce a range of values. Although the curves slightly vary depending on the transport equation used, transport regimes are similar for the two study reaches when the results from a single equation are compared.

A separate SAMWin analysis was performed on the gravel-sized portion (larger than 2 mm) of the bar material to determine flows that initiate movement of the larger sized particles. Significant gravel transport for surface and subsurface sediment (more than 1 ton/day) occurs between 20 cfs and 38 cfs, at FM 1396, and between 25 cfs and 40 cfs at FM 409, respectively.

Currently, the stream power exceeds what is needed to transport the sediment load through the reach. The excess energy has to be expended somehow, so it is used to entrain sediment from the bed and erode the banks. In this case erosion and channel degradation predominates. Detailed sediment transport modeling results are presented in Appendix C.

Figure 4.19 Sediment Rating Curve of the Surface Sediment at FM 1396

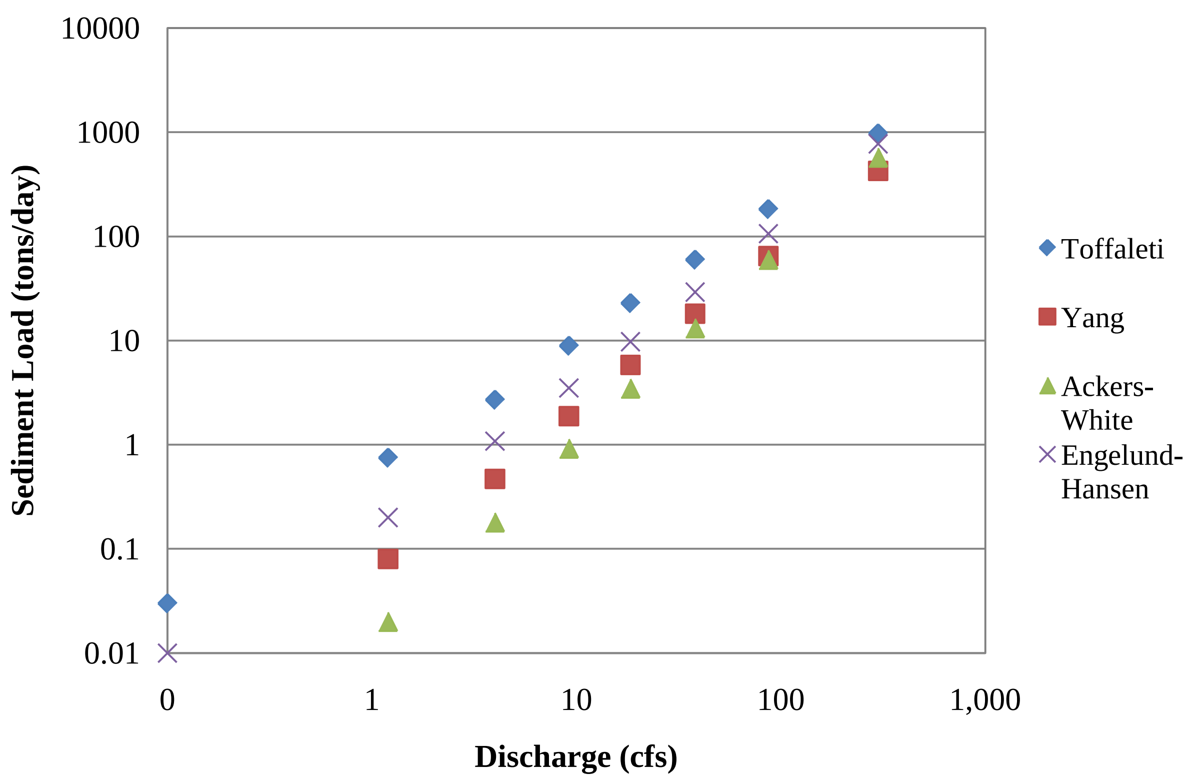


Figure 4.20 Sediment Rating Curve of the Subsurface Sediment at FM 1396

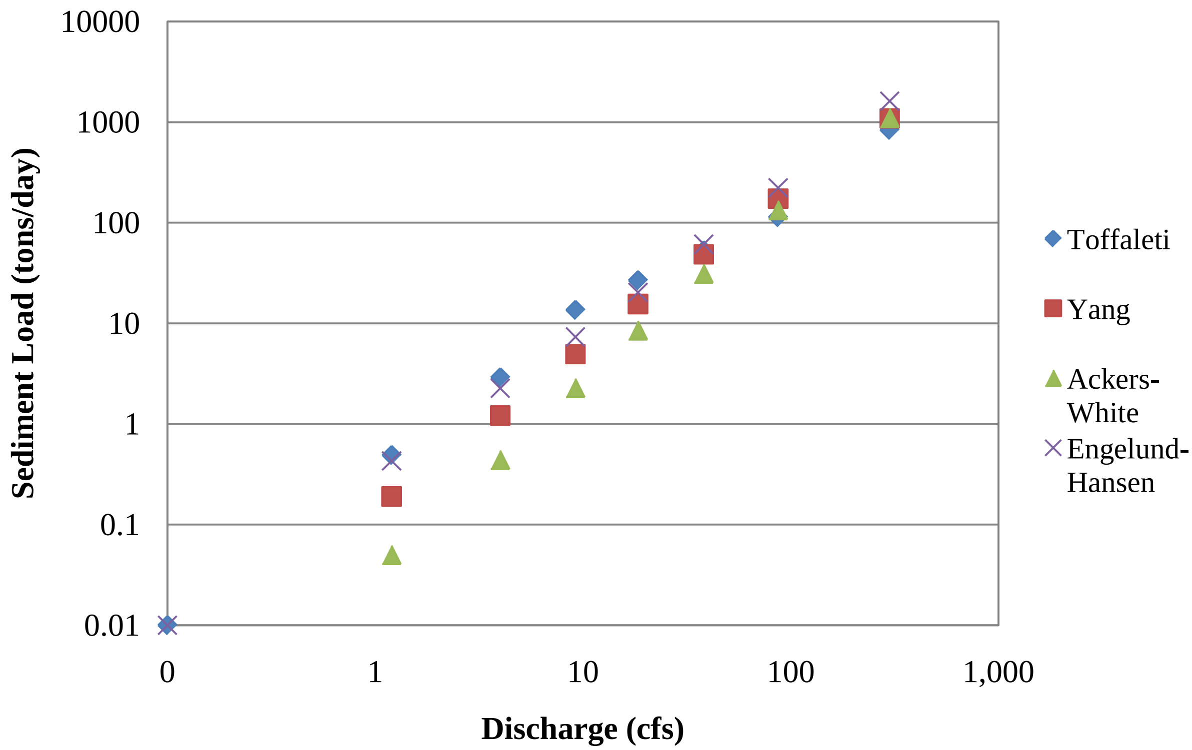


Figure 4.21 Sediment Rating Curve of the Surface Sediment at FM 409

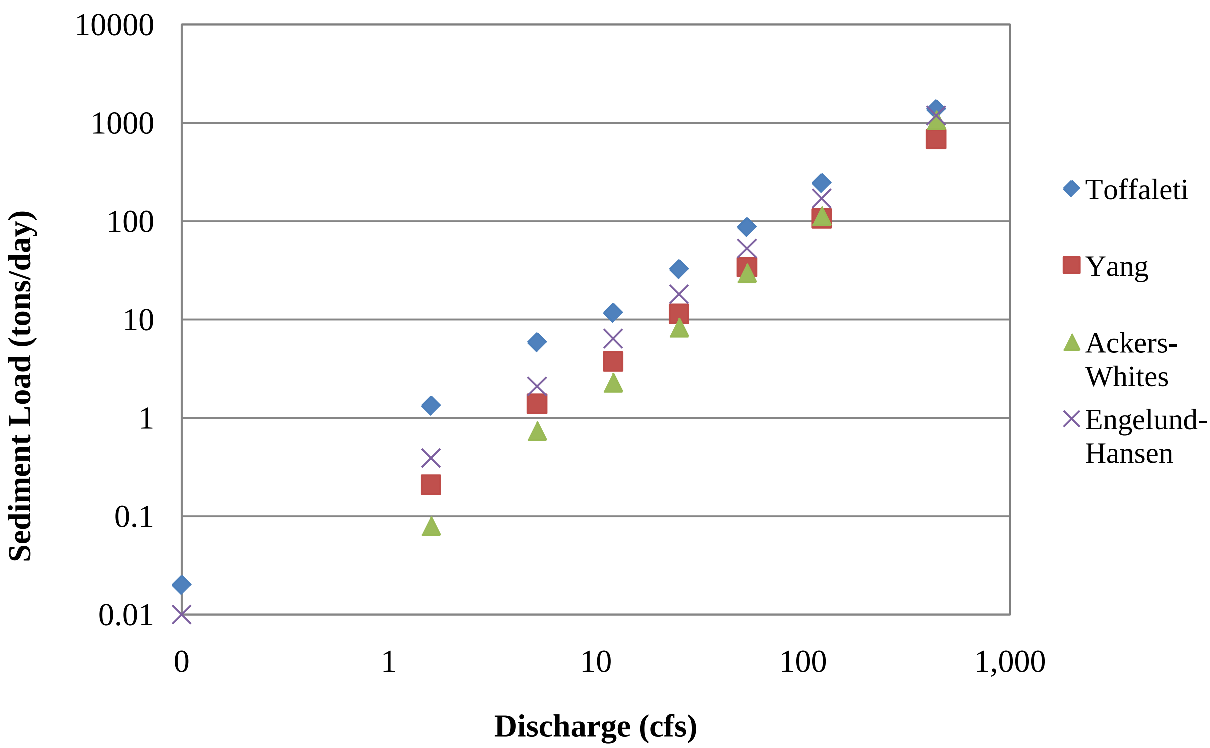
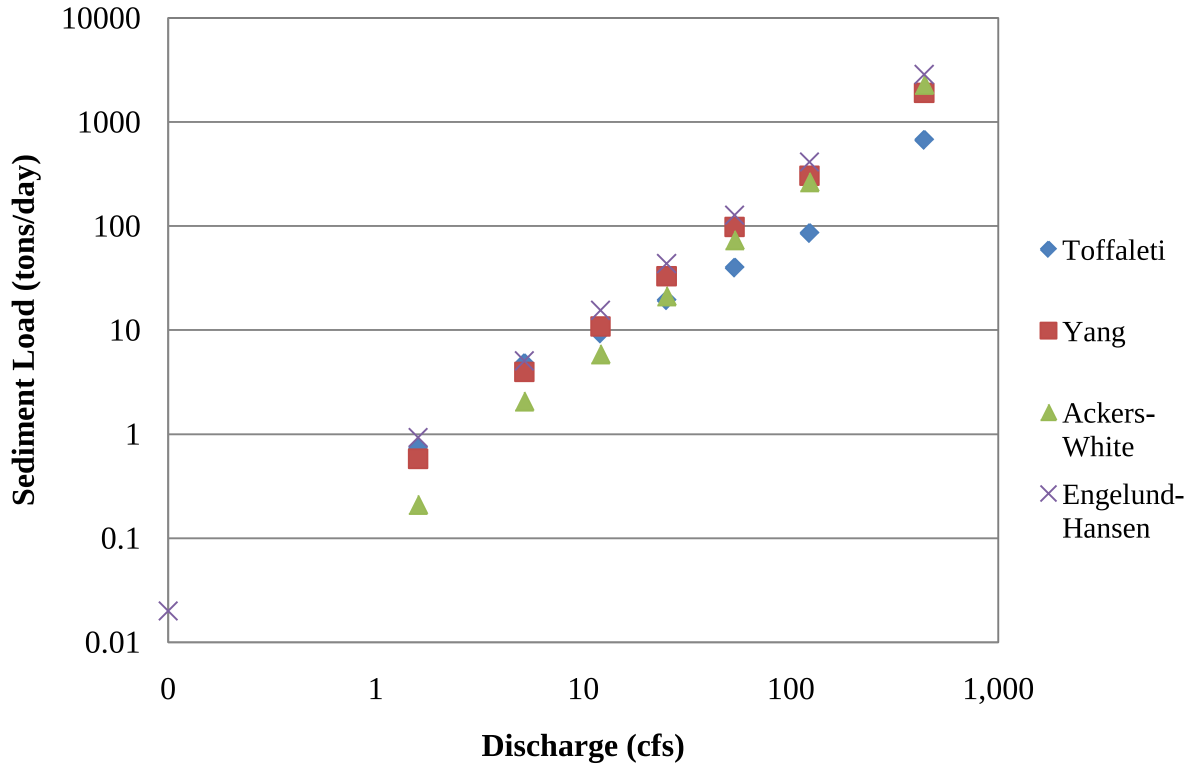


Figure 4.22 Sediment Rating Curve of the Subsurface Sediment at FM 409



4.3 Biology

> **BIOLOGY**
>
> **42 species of fish were collected during this instream flow study.**
>
> **Generalist species are dominant with red shiner most abundant.**
>
> **No listed threatened or endangered species**
>
> **Fish IBI scores are generally in High Aquatic Life Use category.**

Biological analyses considered both field sampling data from this study and previous studies conducted within the watershed and associated ecoregions. The stream fish assemblage collected during this study is dominated by headwater colonizer species (i.e., smaller-bodied and short-lived fish). A previous study conducted by Linam et al. (2002) collected a total of 47 fish taxa from the Central Texas Plains and the Texas Blackland Prairies ecoregions. Resident species in streams similar to Bois d'Arc Creek are generally adapted to extreme environmental variation (Rahel and Hubert 1991) and illustrate rapid post-disturbance recolonization (Schlosser 1987). Prairie streams such as Bois d'Arc Creek have been described as lacking spatial heterogeneity in aquatic habitat and substrata (Osting et al. 2004), and are dominated by pools and backwater areas with silty-clay substrate. There is generally little cobble or gravel substrate in Bois d'Arc Creek, and subsequently no true riffle habitat (as defined according to standard methods; Arend 1999). Aquatic systems with these characteristics are often dominated by generalist fish taxa (Poff and Allen 1995), and recent studies conducted in neighboring watersheds have found that assemblage structure was not strongly linked to physical habitat measurements (Gelwick and Li 2002; Osting et al. 2004).

Most of the fish species (81%) collected from Bois d'Arc Creek during this instream flow study are generalist species, with only a few that are characteristically found only in flowing water or considered fluvial specialists (cential stoneroller, ribbon shiner, blackspot shiner, sand shiner, suckermouth minnow, freckled madtom, slough darter, and dusley darter).

Bois d'Arc Creek is classified as a 3rd to 4th order stream for the sampling reaches of this instream flow study. The order of a stream provides an indication of the relative size, depth and strength of specific channels within stream networks. It can also be used to understand the sediment potential in a stream segment and to determine what types of aquatic life might be present in the waterway. The 3rd and 4th order designations indicate the upper end of the overall drainage system (Red River basin). The study reaches US 82 and CR 2645 are 3rd order streams. Bois d'Arc Creek becomes a 4th order stream below the confluence with Bullard Creek. Sampling sites FM 1396, FM 409, and USFS are 4th order streams.

Field surveys identified four mesohabitats available for aquatic use. These mesohabitats were sampled for physical habitat features and fish composition, whereas macroinvertebrates were qualitatively sampled by stream reach for biotic integrity metrics. Fish species composition was found to be consistent with recorded occurrences for the Red River drainage basin (Thomas et al. 2007), as were biotic integrity scores (RRA 1999). The following is a summary of the biological analyses. Detailed descriptions of biological sampling and analyses are presented in Appendix D.

4.3.1 Mesohabitats

Four mesohabitats were found in the study reaches, including runs, riffles, structures (large woody debris, root wads, etc. that provide cover for aquatic species), and pools. Mesohabitats were sampled for fish and macroinvertebrates at discharges ranging from 1.2 to 21.5 cfs. These samples had measured current velocities ranging from 0.34 to 1.28 ft/sec and water depths ranging from 0.48 to 1.51 ft. Table 4.5 summarizes measured features of each mesohabitat. Runs and structural habitats had current velocities that were approximately double that of pool habitats (mean: 0.61, 0.67, and 0.34 ft/sec; run, structure, and pool, respectively), and riffle current mean velocity was greater than all other mesohabitats (1.28 ft/sec). Mean water depth was generally consistent across mesohabitats (slightly above 1 ft), except for riffles where mean water depth was 0.5 ft. Physicochemical measures (i.e., water temperature, pH, DO, and specific conductivity) were similar across all mesohabitats.

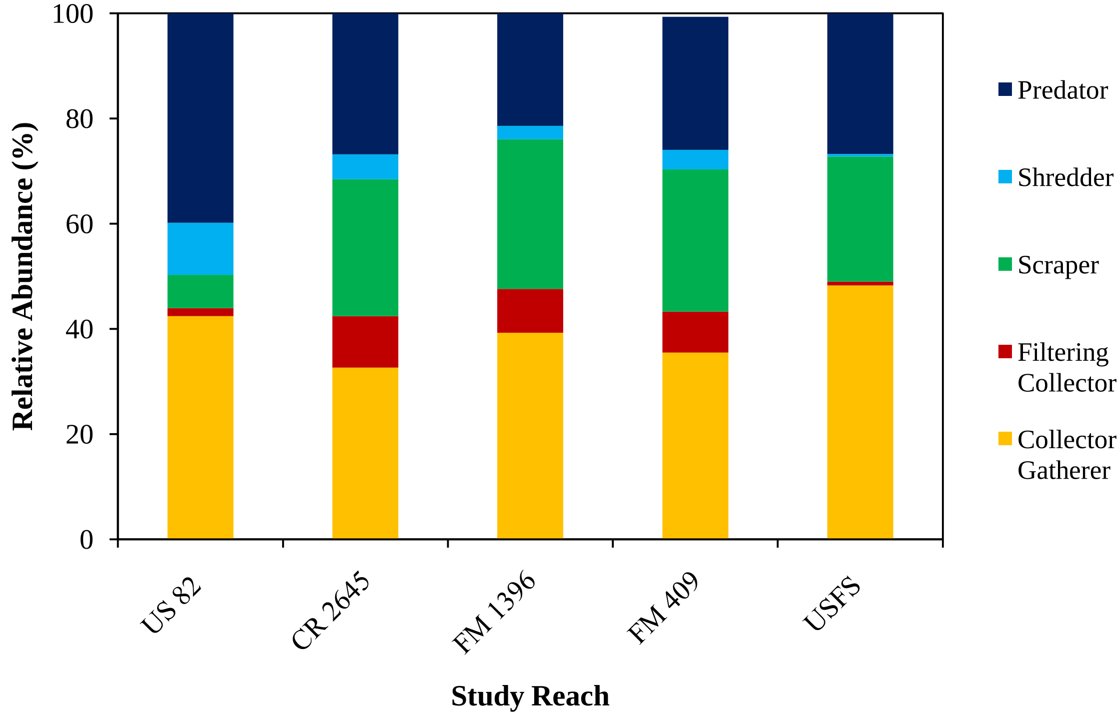
Table 4.5 Means, Standard Deviations, and Ranges for Selected Water Features by Mesohabitat.

	Run ($n = 8$)				**Pool** ($n = 4$)			
	Mean	[St Dev]	Min	Max	Mean	[St Dev]	Min	Max
Current Velocity (ft/s)	0.61	[0.55]	0.03	1.45	0.34	[0.27]	0.09	0.59
Depth (ft)	1.16	[0.50]	0.28	1.90	1.40	[0.69]	0.85	2.41
Temp (°C)	28.2	[1.79]	25.7	30.1	28.3	[1.64]	26.4	30.0
Dissolved O_2 (mg/L)	7.21	[2.52]	2.90	10.8	9.45	[1.25]	8.16	10.9
pH	7.49	[0.57]	6.26	7.98	7.98	[0.18]	7.77	8.21
Sp. Cond (uS/cm)	497	[79.5]	393	654	469	[48.5]	439	541
	Structure ($n = 8$)				**Riffle** ($n = 2$)			
	Mean	[St Dev]	Min	Max	Mean	[St Dev]	Min	Max
Current Velocity (ft/s)	0.67	[0.36]	0.11	1.17	1.28	[0.70]	0.78	1.77
Depth (ft)	1.51	[0.79]	0.63	2.80	0.48	[0.05]	0.45	0.52
Temp (°C)	29.9	[1.62]	5.27	32.0	28.5	[2.26]	26.9	30.1
Dissolved O_2 (mg/L)	7.91	[2.05]	5.27	10.5	9.55	[1.48]	8.50	10.6
pH	7.95	[0.22]	7.63	8.20	7.80	[0.13]	7.71	7.89
Sp. Cond (uS/cm)	485	[32.7]	431	520	524	[96.9]	455	592

4.3.2 Macroinvertebrates

A total of 2,621 aquatic and terrestrial insects, consisting of 103 identified genus and 46 families, were collected from March to July 2009. The relative abundance of functional feeding groups was calculated to evaluate trophic structure. Results indicated that collector-gatherers, predators, and scrapers dominated Bois d'Arc Creek (> 80%), with few filter feeding or shredder species. A high percentage (>36%) of collector-gatherers indicates degradation (TCEQ, 2007) while a low to moderate percentage (4% to 15%) of predators reflect a balanced tropic structure. The trophic structure in Bois d'Arc Creek suggests an abundance of coarse particulate organic matter (i.e., leaf litter) and a healthy prey population. There was no apparent longitudinal pattern in benthic macroinvertebrate trophic structure across mainstem sampling stations (Figure 4.23).

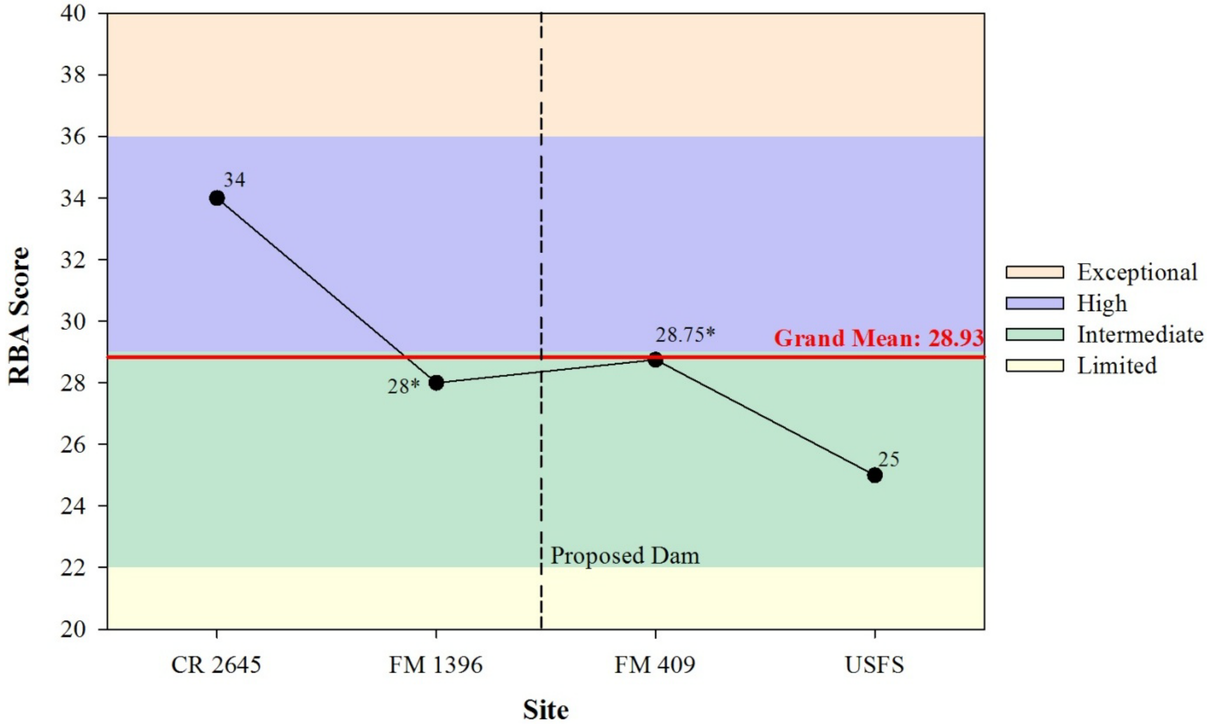
Figure 4.23 Benthic Macroinvertebrate Trophic Structure at Bois d'Arc Creek Study Sites



4.3.2.1 Macroinvertebrate Rapid Bioassessment (RBA)

Macroinvertebrates were sampled using TCEQ 2007 SWQM Rapid Bioassement Protocol (Texas RBP). Rapid bioassessments provide a standardized method for sampling and data analysis that can be used to provide a numerical value for the quality of a stream. The numerical scores determined using the Texas RBP are used to describe Aquatic Life Use categories for a stream (>36 is Exceptional, 29-36 is High, 22-29 is Intermediate, and <22 is Limited). As shown on Figure 4.24, the overall biological integrity of Bois d'Arc Creek's macroinvertebrate community was at the higher end of the intermediate range (mean: 28.9). Mainstem sampling site scores ranged from 22 (intermediate) to 37 (high)). These results are consistent with previous studies (RRA 1999, Hamilton 2009). Bois d'Arc Creek tributary scores were lower than mainstem sites, as Bullard and Honey Grove Creeks had scores of 25 and 28, respectively.

Figure 4.24 Rapid Bioassessment Results (Upstream to Downstream)



*Indicates average metric score from multiple collections (i.e., CR 2645: 31, 37; FM 1396: 31, 22, 31, 29; FM 409: 25, 31, 28, and 31).

4.3.2.2 Mussels

In accordance with the recommendations of the Inter-Agency Team, mussels were collected or photographed when they were encountered during other data collection efforts. A total of six species were collected or photographed and later identified as part of this effort Table 4.6).

According to the USFWS, no federally listed threatened or endangered mollusk species occur in Fannin County. A review of the *Texas Parks and Wildlife Department (TPWD) Annotated List of Rare Species for Fannin County* indicates that seven mollusk species are listed for Fannin County. None of these species were collected or identified in Bois d'Arc Creek during the current instream flow study. Additional information on mussels is presented in Appendix D.

4.3.3 Fish

4.3.3.1 Historical Collections

There is little baseline data on the stream fisheries of Bois d'Arc Creek. There have been several collections in the mainstem Red River, with studies in the 1950's conducted throughout the Red River basin (Bonn 1957). However, these documents give a compilation of collected species, and do not identify specific tributaries for individual collections. Only one study was found specific to Bois d'Arc Creek (i.e., RRA 1999) that documented collection location, date, and

Table 4.6 Mussel Species Collected during Instream Flow Study on Bois d'Arc Creek

Species	Habitat	Glochidia Host(s)
Bleufer *Potamilus purpuratus*	Streams, rivers, and reservoirs	freshwater drum (*Aplodinotus grunniens*)
Fragile Papershell *Leptodea fragilis*	Streams, rivers and possibly reservoirs	freshwater drum (*Aplodinotus grunniens*)
Mapleleaf *Quadrula quadrula*	Large streams, rivers, and lakes	flathead catfish (*Pylodictis olivaris*)
Pink Papershell *Potamilus ohiensis*	Large rivers and possibly reservoirs	freshwater drum (*Aplodinotus grunniens*) white crappie (*Pomoxis annularis*)
Washboard *Megalonaias nervosa*	Rivers, lakes, and reservoirs	American eel (*Anguilla rostrata*) black crappie (*Pomoxis nigromaculatus*) bluegill (*Lepomis macrochirus*) channel catfish (*Ictalurus punctatus*) flathead catfish (*Pylodictis olivaris*) freshwater drum (*Aplodinotus grunniens*) largemouth bass (*Micropterus salmoides*) sauger (*Stizostedion canadense*) white bass (*Morone chrysops*) white crappie (*P. annularis*)
Yellow Sandshell *Lampsilis teres*	Streams, rivers, and oxbow lakes*	alligator gar (*Lepisosteus spatula*) black crappie (*Pomoxis nigromaculatus*) green sunfish (*Lepomis cyanellus*) largemouth bass (*Micropterus salmoides*) longnose gar (*L. osseus*) shortnose gar (*L. platostomus*) shovelnose sturgeon (*Scaphirhynchus platorynchus*) warmouth (*L. gulosus*) white crappie (*P. annularis*)

Sources: Howells, R.G., et al. 1996. Freshwater Mussels of Texas. Texas Parks and Wildlife Press. Austin, Texas.

Roe, Kevin J. 2002. Conservation Assessment for the Yellow Sandshell (*Lampsilis teres*). USDA Forest Service, Region 9. Saint Louis, MO.

collected taxa. An additional species list for Bois d'Arc Creek was acquired from the Texas Natural History Collection (TNHC) Ichthyology archives, but the TNHC list did not identify collection location, date, or numerical species accounts.

4.3.3.2 FNI Collections and Relative Abundance Analysis

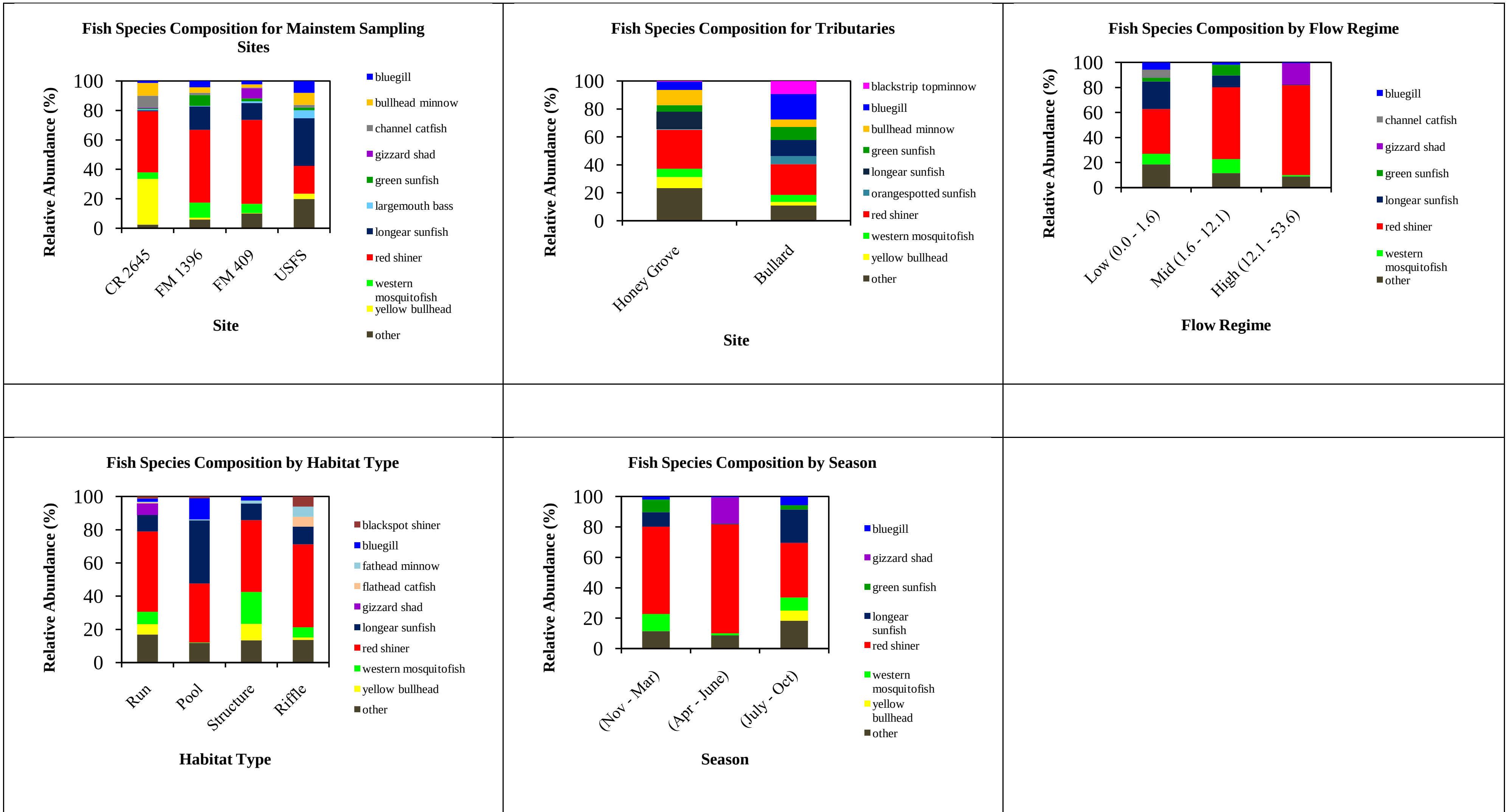
A total of 3,138 fish, consisting of 42 species and 11 families, were collected from March to July 2009 (Table 4.7). The most abundant family was Cyprinidae (59% in percent total relative abundance), followed by Centrarchidae (20%), Poeciliidae (8%), Ictaluridae (6%), and Clupeidae (3%). Complete collection data and literature-based life history accounts for dominant species are presented in Appendix D.

Species relative abundance across site, mesohabitat, flow, and season illustrated similar patterns of dominant species (Figure 4.25). Across all analyses, community composition was dominated by generalist species tolerant of a wide range of environmental conditions. In general, the two most dominant species were red shiner (50% total relative abundance) and longear sunfish (13.7%). Species composition for tributary sites was similar to the mainstem sites, although abundance scores were more evenly distributed across species. Across flow regimes, relative abundance of longear sunfish, bluegill, green sunfish, and western mosquitofish declined at higher flows, while red shiner abundance increased. There was no distinguishable seasonal pattern, except that red shiner was particularly abundant in the summer. Gizzard shad were only found during the spring sampling event, which may have been associated with migratory spawning behavior. There was no apparent pattern across mesohabitat, except that Centrarchid (sunfish) species were more abundant in pool habitats.

Table 4.7 Fish Collected During Bois d'Arc Creek Instream Flow Study

Species	Number Collected	Species	Number Collected
Lepisosteus oculatus	1	Pylodictis olivaris	10
Lepisosteus osseus	1	Labidesthes sicculus	7
Dorosoma cepedianum	69	Fundulus notatus	33
Dorosoma petenense	1	Gambusia affinis	247
Campostoma anomalum	20	Lepomis cyanellus	154
Cyprinella lutrensis	1,417	Lepomis gulosus	12
Cyprinella venusta	21	Lepomis humilis	28
Cyprinella hybrid	3	Lepomis macrochirus	151
Cyprinus carpio	0	Lepomis megalotis	421
Lythrurus fumeus	25	Lepomis microlophus	24
Notropis atrocaudalis	1	Lepomis hybrid	18
Notropis stramineus	27	Micropterus punctulatus	3
Phenacobius mirabilis	26	Micropterus salmoides	37
Pimephales vigilax	147	Pomoxis annularis	5
Carpiodes carpio	4	Pomoxis nigromaculatus	2
Ictiobus bubalus	2	Etheostoma gracile	3
Moxostoma erythrurum	1	Percina caprodes	10
Ameiurus melas	20	Percina macrolepida	1
Ameiurus natalis	112	Percina phoxocephala	1
Ictalurus punctatus	39	Percina sciera	22
Noturus gyrinus	2	Aplodinotus grunniens	1
Noturus nocturnus	9		
Total Number Collected			***3,138***
Total Taxa			***42***

Figure 4.25 Relative Abundance of Fish Taxa by Sample Site, Flow Regime, Mesohabitat, and Season.



*"Other" includes those species with a relative abundance of less than 5%

4.3.3.3 Fish Trophic Structure

Analysis of fish functional feeding groups illustrated that Bois d'Arc Creek is largely dominated by generalist species with opportunistic feeding strategies. Red shiner and sunfish species (particularly longear) mostly forage in the form of benthic grazing or water surface predation. These feeding strategies are a response to Bois d'Arc Creek's turbid waters and general lack of favorable microhabitat.

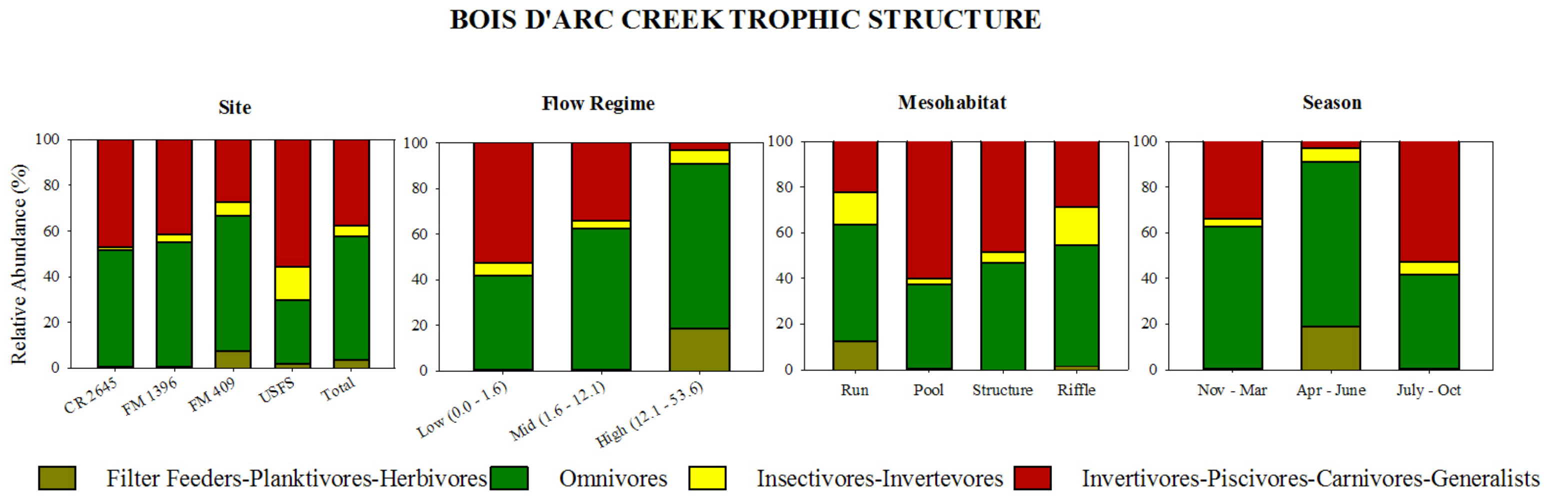
There was no clear pattern of trophic structure across sites, though there were some apparent patterns across flow, mesohabitat, and season. More top-level predators (i.e., sunfish) were collected from pools, particularly in the low flow summer sampling event. This is not surprising, as sunfish species will likely thrive under these conditions compared to fluvial specialists. The only other apparent pattern was that more filter feeders-planktivores-herbivores were collected during the spring high flow sampling event, which is likely a result of increased primary productivity and increased movement associated with spawning.

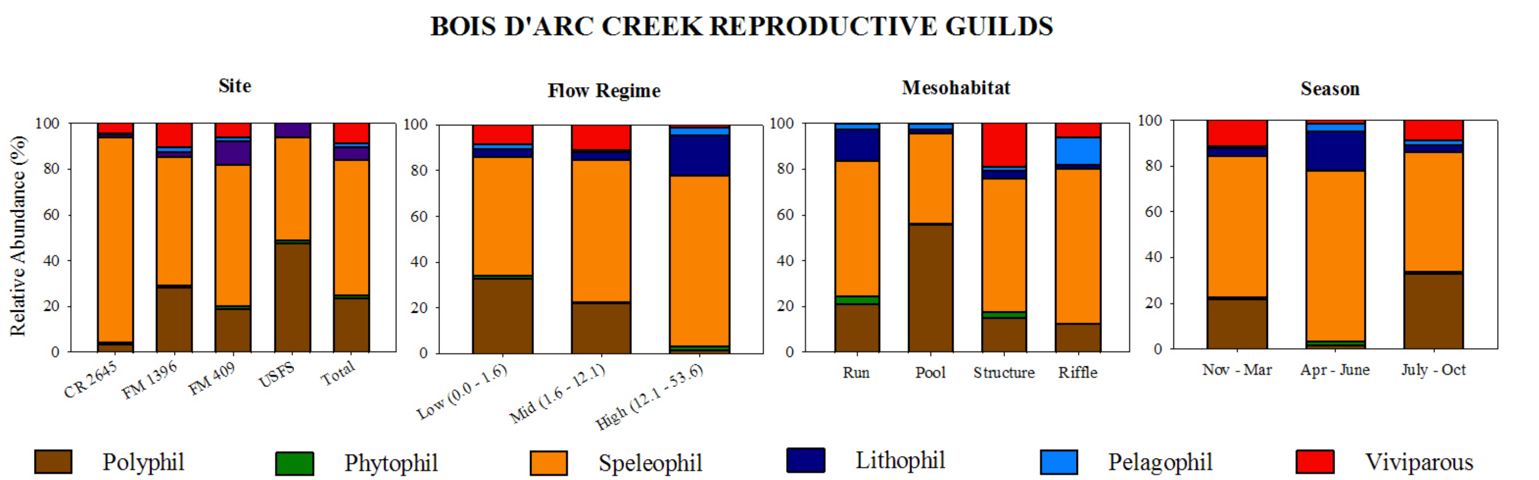
Literature review of reproductive strategies for collected fishes revealed that most of the species collected are largely opportunistic, dominated by speleophilic and polyphilic spawners. Speleophils (i.e., crevice spawners) will deposit eggs in submerged structures, but have no specific structural requirements. Polyphilic species deposit eggs directly onto stream bed substrates, and generally lack a specific substrate preference. Similar to structural patterns found with functional feeding group, sunfish species (largely polyphils) dominated pool habitats and were particularly abundant during the low flow summer sampling event. Speleophils dominated reproductive strategy across all categories, as the pervasive red shiner is a speolophilic spawner. The relative abundance of functional feeding groups and reproductive guilds by site, flow regime, mesohabitat, and season is displayed in Figure 4.26.

4.3.3.4 Fish Reproduction

Physical habitat requirements and reproductive timing for fish taxa observed in Bois d'Arc Creek were identified from published literature. Fluvial specialist species, particularly members of the families Cyprinidae and Percidae, require specific current velocities, depths, or specific substrates for reproduction. Literature review identified typically shallow depth (i.e., < 3 ft), swifter current velocities (i.e., > 1 ft/sec), and gravel or cobble substrate preference for these fluvial specialist species. However, the reproductive cues of fishes of Bois d'Arc Creek appear to be largely temperature dependent. Dominant species (as determined by the relative abundance analyses) spawn from February to October with the largest proportion in the months of May and June. The graph presented in Figure 4.27 shows the average observed temperature and flow conditions in Bois d'Arc Creek during the typical spawning periods of the dominant fishes observed in the creek. After mid-June, flow in Bois d'Arc Creek decreases to little to no flow, indicating unfavorable spawning conditions for fluvial specialists that require flowing water for spawning. However, the generalist species (or those that do not require flowing water for

Figure 4.26 Bois d'Arc Creek Trophic Structure and Reproductive Guild by Site, Flow Regime, Mesohabitat, and Season





Flow values in cfs.
Polyphil = various spawning substrates, adhesive eggs are attached singly or in clusters. Phytophil - obligatory plant spawner characterized by an adhesive egg envelope sticking to submerged plants Speleophil = cavity roof nesters and bottom burrow nesters. Lithophil - nesting, where eggs are in spherical or elliptical envelopes, always adhesive, free embryos are photophobic or with cement glands, embryos swing tail-up in respiratory motions, moderate to well-developed embryonic respiratory structures present, and many young feed first on mucus of the parent. Pelagophil = pelagic spawner with numerous buoyant eggs, not guarded. Viviparous = giving birth to active, free-swimming young.

spawning) may find suitable spawning habitat in persistent pools along Bois d'Arc Creek channel.

4.3.4 Habitat and Species Associations

Canonical correspondence analysis (Braak 2002) was used to assess correlations between fish assemblage data and habitat data (CANOCO Version 4.5; Braak and Smilauer 2002). The modeled habitat variables included: substrate (as percent bedrock, sand, silt, gravel), current velocity, depth and conductivity. To identify associations with particular habitat types, sample observations were delineated by mesohabitat. This procedure was used to identify individual species or groups of species associated with a particular mesohabitat.

According to the canonical correspondence analysis, golden redhorse, bigscale logperch, threadfin shad, and gizzard shad have an affinity for swifter water and gravel substrates. Slough darter, logperch, dusky darter, and four centrarchid species prefer slower moving or backwater areas. Freckled madtom, central stoneroller, and blacktail shiner are associated with deeper water and sandier substrates. Results indicate that the remaining 28 species can be found across a wider range of physical habitat conditions. Species-mesohabitat associations were not found.

The results from the canonical correspondence analysis did not identify clear species habitat groups or indicator species, but they reaffirmed that Bois d'Arc Creek is dominated by generalist species inhabiting a homogenized physical environment. Therefore, river modeling procedures were designed to predict physical habitat with the goal of maximizing diversity of microhabitat components (i.e., current velocity, depth, and substrate).

4.3.5 Fish Index of Biological Integrity

The regionalized Index of Biotic Integrity (IBI) (TPWD 2002) is a measure of fish communities that includes components of species composition, trophic composition, and abundance and condition (Linam et al., 2002). It is typically used by TCEQ as a water quality indicator, with higher scores indicating better water quality. In this study, IBI scores for fish community structure were intermediate to high (mean: 43.83), and increased longitudinally within the mainstem of Bois d'Arc Creek (Figure 4.28). Scores were higher than the intermediate designation reported in the 1999 RRA study. Mainstem site scores ranged from 33 (limited) to 49 (high), and tributary scores were also in the high range (i.e., 46 and 43, Honey Grove and Bullard Creek, respectively).

Figure 4.27 Reproductive Timing of Dominant Species in Bois d'Arc Creek Compared with Mean Monthly Temperature and Median Monthly Stream Discharge

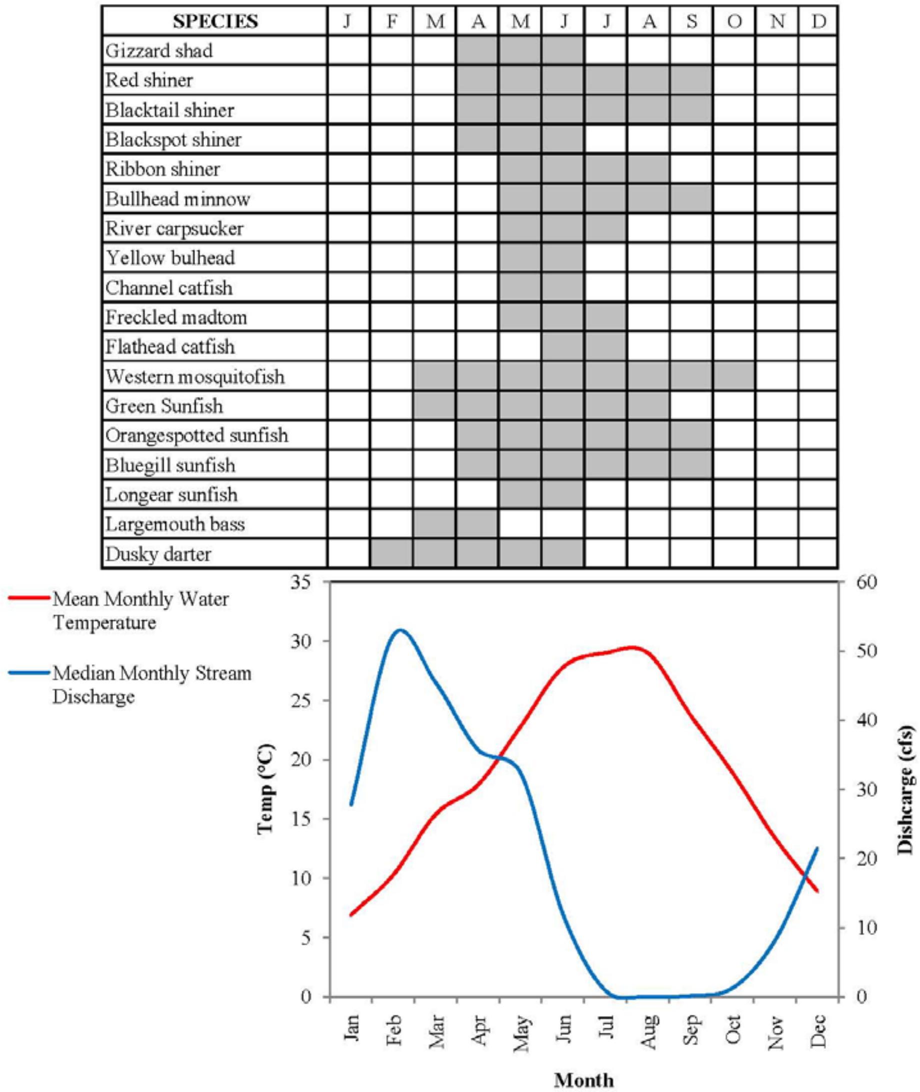
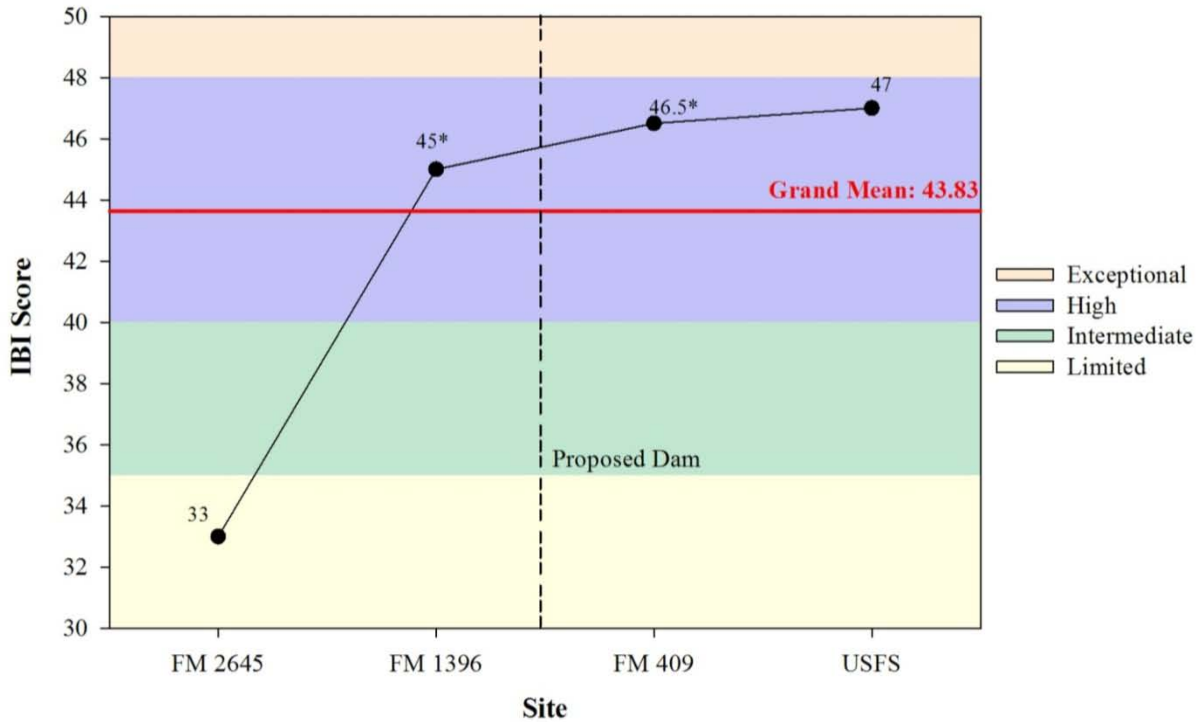


Figure 4.28 Fish Index of Biological Integrity (IBI) Results from Bois d'Arc Creek Study Reaches

(Upstream to Downstream)



* Indicates average IBI from multiple collections (i.e., FM 1396: 49, 41; FM 409: 45, 48)

4.3.6 Habitat Modeling

River 2D was used to model habitat variables (current velocity and water depth) in the FM 409 study reach, which is downstream of the proposed dam site. Habitat simulations were conducted incrementally at low discharges to evaluate stream connectivity. Higher discharges were modeled to evaluate mesohabitat abundance.

> **HABITATS**
>
> **Mesohabitats dominated by pools (70-80% Weighted Useable Area) and runs (14-28% WUA).**
>
> **No statistically significant species-habitat associations.**
>
> **Longitudinal connectivity in Bois d'Arc Creek with 3 cfs flow at FM 409 study reach.**

4.3.6.1 Channel Connectivity

Modeling of low discharges identified that flows between 2 and 3 cfs maintain longitudinal stream connectivity. At this discharge, modeled pool habitats remained connected by run-riffle habitats. At 3 cfs, modeled physical attributes include a maximum water depth of 2.68 ft and a mean velocity of 0.61 ft/s at FM 409 (Figure 4.29 and Figure 4.30).

In a comprehensive analysis of fish species-habitat association, Aaland (1993) found that medium-sized pool habitat maintained both the highest age-class and species diversity. He found that medium-sized pools typically ranged from 2 to 4.9 feet deep with current velocities of less than 0.98 ft/s (Figure 4.31). As physical habitat attributes in Bois d'Arc Creek at 3 cfs fall within this range, 3 cfs would not only maintain connectivity but also could be expected to promote biodiversity.

4.3.6.2 Mesohabitat Distribution

Weighted Usable Area (WUA) calculations from River 2D output were used to evaluate mesohabitat presence and abundance at discrete discharges. Results from WUA analyses confirmed field observations that Bois d'Arc Creek is a run-pool dominated system. Under all discharge scenarios combined run and pool habitat accounted for over 96 percent of usable area (Table 4.8).

Table 4.8 Modeled Habitat Distribution at FM 409

	Habitat Distribution (%)			
Discharge (cfs)	**Run**	**Riffle**	**Pool**	**Structure**
3	14.69	0.26	84.94	0.11
10	25.48	0.52	73.65	0.35
30	28.18	0.54	70.11	1.17
50	27.17	0.48	70.57	1.78
100	24.19	0.96	72.45	2.40
1,000	25.16	0.01	71.58	3.25
7,000	24.19	0.00	74.28	1.53

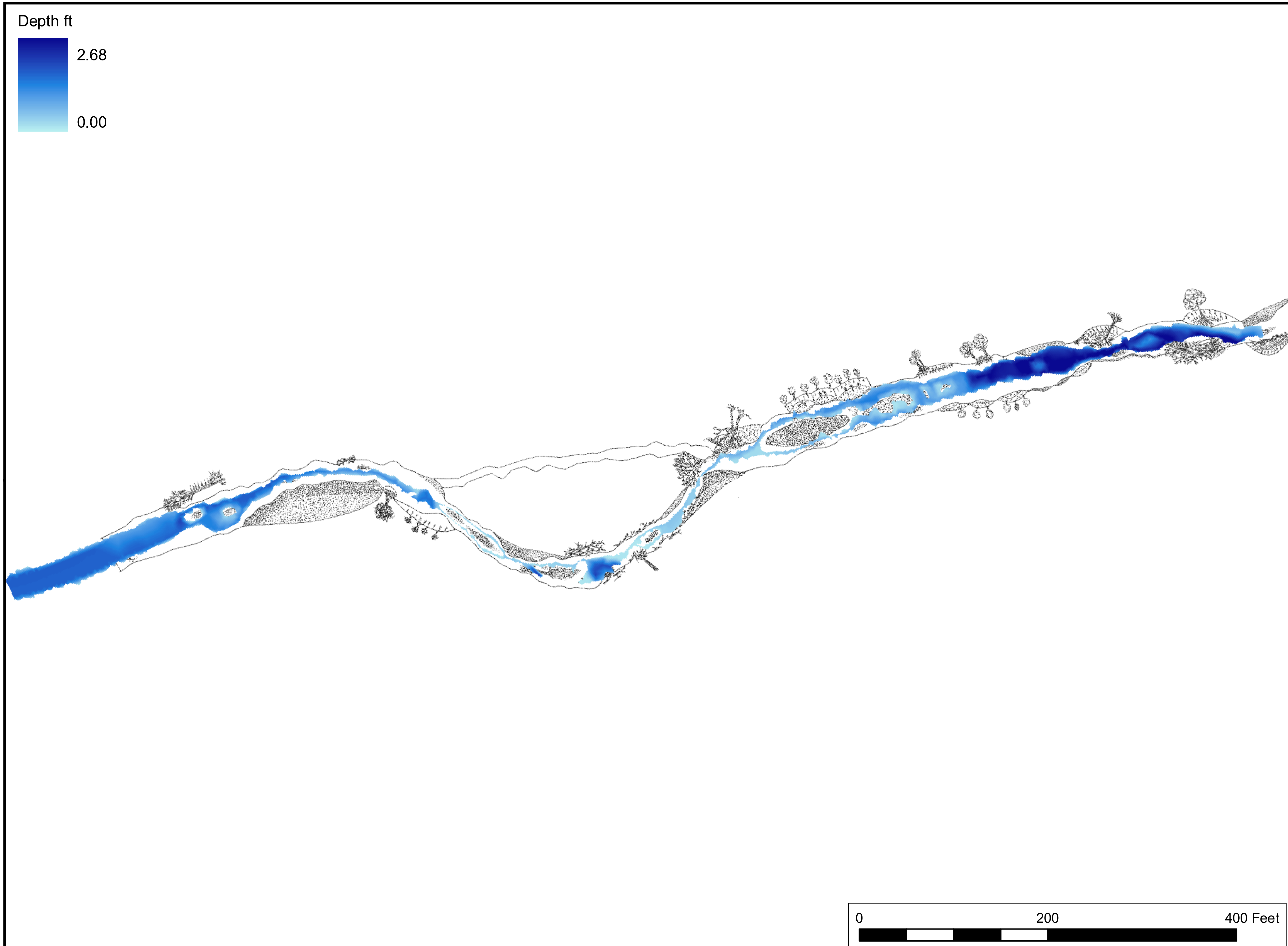


Figure
4.29

FN JOB NO	NTD06128
FILE	4.30_Depth_3.mxd
DATE	April 2010
SCALE	1:1,200
DESIGNED	MJA
DRAFTED	MJA

North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

F.M. 409 Depth
3 CFS

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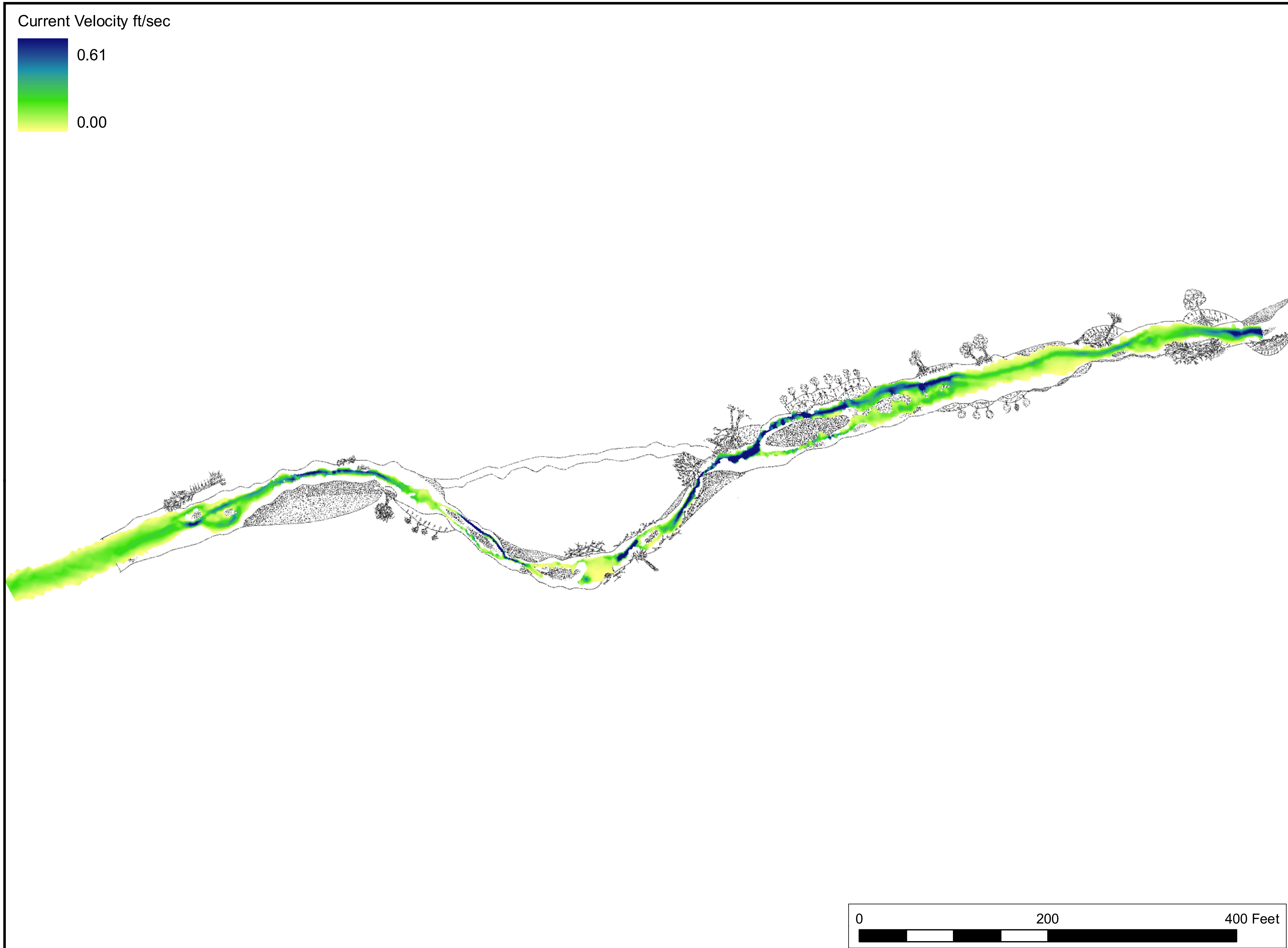

North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

F.M. 409 Current Velocity
3 CFS

FN JOB NO	NTD06128
FILE	4.31_CV_3.mxd
DATE	April 2010
SCALE	1:1,200
DESIGNED	MJA
DRAFTED	MJA

Figure 4.30

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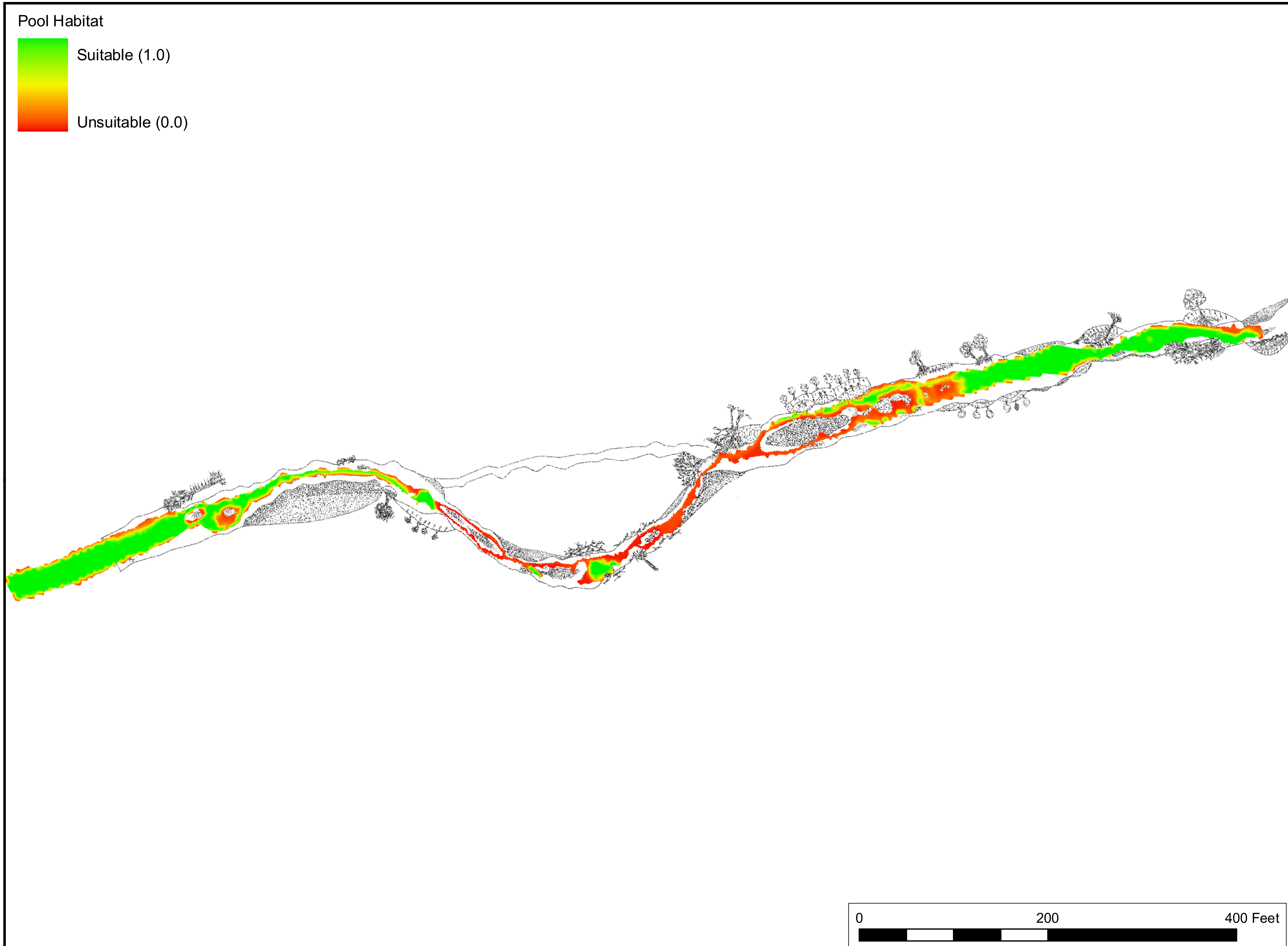
Fort Worth, Texas 76109-4895
817-735-7300



North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

F.M. 409 Pool Habitat Suitability
3 CFS

FN JOB NO	NTD06128
FILE	4.32_Pool_3.mxd
DATE	April 2010
SCALE	1:1,200
DESIGNED	MJA
DRAFTED	MJA

Figure
4.31

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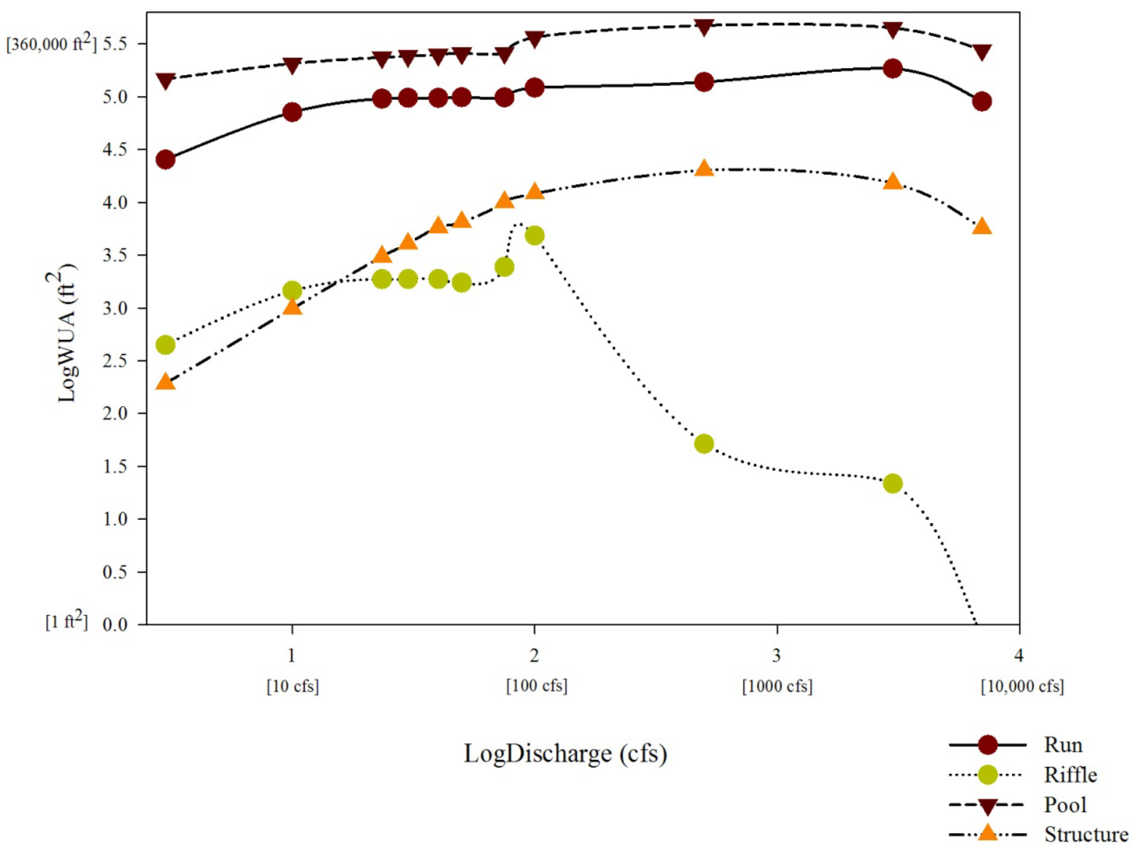
Fort Worth, Texas 76109-4895
817-735-7300

Figure 4.32 graphically illustrates the relationship of discharge to usable habitat, using the WUA calculations. Run and pool habitat curves are high and relatively stable across all discharges. Structure increases until flows reach approximately 100 cfs. At flows between 100 cfs and 7,000 cfs, the amount of usable structure habitat is relatively stable. Above 7,000 cfs the amount of structure habitat begins to decrease. Riffle habitats increase as flows increase up to 10 cfs. Between 10 cfs and 100 cfs riffle habitats remain relatively constant, and then decline rapidly at flows above 100 cfs. Due to the stream morphology there is not sufficient large size bed material to support regular riffle function and habitat at higher flows. At flows greater than 100 cfs, riffle habitat becomes inundated deeply and Bois d'Arc Creek habitats become a complex of fast pools and river runs. The anomalous increase in riffle habitat at approximately 100 cfs shown on Figure 4.32 is caused by a side channel, which becomes inundated at approximately 100 cfs (based on model output and visual observation).

Figure 4.32 Weighted Usable Area (WUA) versus Simulated Discharges at FM 409



It should be noted that physical habitat attributes were measured only at flows less than 30 cfs. Physical habitat variables measurements could not be conducted during higher flows due to unsafe wading conditions and inaccessibility by boat.

4.4 Water Quality

Water quality was evaluated based on data from historical and ongoing water quality monitoring as well as data that were collected as part of the current study. Baseline water quality conditions are summarized in this chapter with an emphasis on dissolved oxygen and temperature. More detailed information on water quality in Bois d'Arc Creek is presented in Appendix D.

WATER QUALITY

- **Dissolved oxygen levels meet high aquatic life criteria except during extremely low flows.**
- **No wastewater discharges are located below proposed dam site.**

4.4.1 Existing Water Quality

Several data sources were available to evaluate existing water quality conditions of Bois d'Arc Creek. Water quality data were collected by the United States Geological Survey (USGS) in cooperation with the North Texas Municipal Water District, the Red River Authority of Texas (RRA) in cooperation with the Texas Commission on Environmental Quality (TCEQ), North Texas Municipal Water District (NTMWD), and Freese and Nichols, Inc (FNI). The sampling site locations are depicted in Figure 4.33 and are described as follows:

- USGS gage at FM 1396 (USGS 07332620), located within the proposed reservoir.
- USGS gage at FM 409 (USGS 07332622), located downstream of the proposed reservoir.
- RRA sampling station (station ID 15749) located upstream of the proposed reservoir.
- NTMWD sampling sites at several locations in and around the proposed reservoir.
- FNI instream flow study data at five locations in and around the proposed reservoir.

The USGS real-time stream gage data on Bois d'Arc Creek at FM 1396 provides the longest continuous water quality record. The gage was installed in August 2006 and records dissolved oxygen, temperature, pH, and specific conductance measurements at 15-minute intervals. The USGS gage at FM 409 was installed in June 2009 and measures the same parameters at the same frequency as the FM 1396 gage. The FM 409 gage would provide post-dam construction flow and water quality monitoring data for Bois d'Arc Creek downstream of the proposed reservoir. Both gages are currently operating and data from these gages can be accessed online from the USGS National Water Information System.

The mean monthly water temperature from the USGS FM 1396 gage is plotted in Figure 4.34. Water temperatures ranged from a low of 6.9 °C in January to a high of 29.0 °C in July and August.

Dissolved oxygen concentrations from October 2006 through January 2010 ranged between 3.6 mg/L and 17.0 mg/L at the USGS FM 1396 gage (Figure 4.35). As expected, dissolved oxygen concentrations in Bois d'Arc Creek exhibited a fairly strong inverse relationship to water temperature, with approximately 60% of the variation in dissolved oxygen being explained by temperature (i.e., $R^2 = 0.59$). While no significant correlation was indicated between dissolved oxygen concentration and flow (Figure 4.36), it was noted that the only recording of dissolved oxygen below the 5.0 and 5.5 mg/L criteria for high aquatic life use set by the Texas Surface Water Quality Standards (Table 4.9) occurred during flows approaching zero. At all other flows, and even in the low flow range, dissolved oxygen concentrations typically exceeded 5.5 mg/L.

The RRA conducted water quality monitoring on Bois d'Arc Creek at a sampling site near FM 78 (Figure 4.33) in conjunction with the TCEQ's Clean Rivers Program (RRA 2005). The purpose of the RRA sampling was to characterize water quality and flow for specific streams in the Red River Basin. Ten samples were collected between March 2004 and July 2005 upstream of the proposed reservoir site within one half mile of the City of Bonham Wastewater Treatment Plant. The sampling data are summarized in Table 4.10.

Table 4.9 Dissolved Oxygen Criteria by Aquatic Life Use Designation

Dissolved Oxygen Criteria, mg/L			
Aquatic Life Use Subcategory	Freshwater mean/minimum	Freshwater in Spring Spawning Period mean/minimum	Saltwater mean/minimum
Exceptional	6.0/4.0	6.0/5.0	5.0/4.0
High	5.0/3.0	5.5/4.5	4.0/3.0
Intermediate	4.0/3.0	5.0/4.0	3.0/2.0
Limited	3.0/2.0	4.0/3.0	

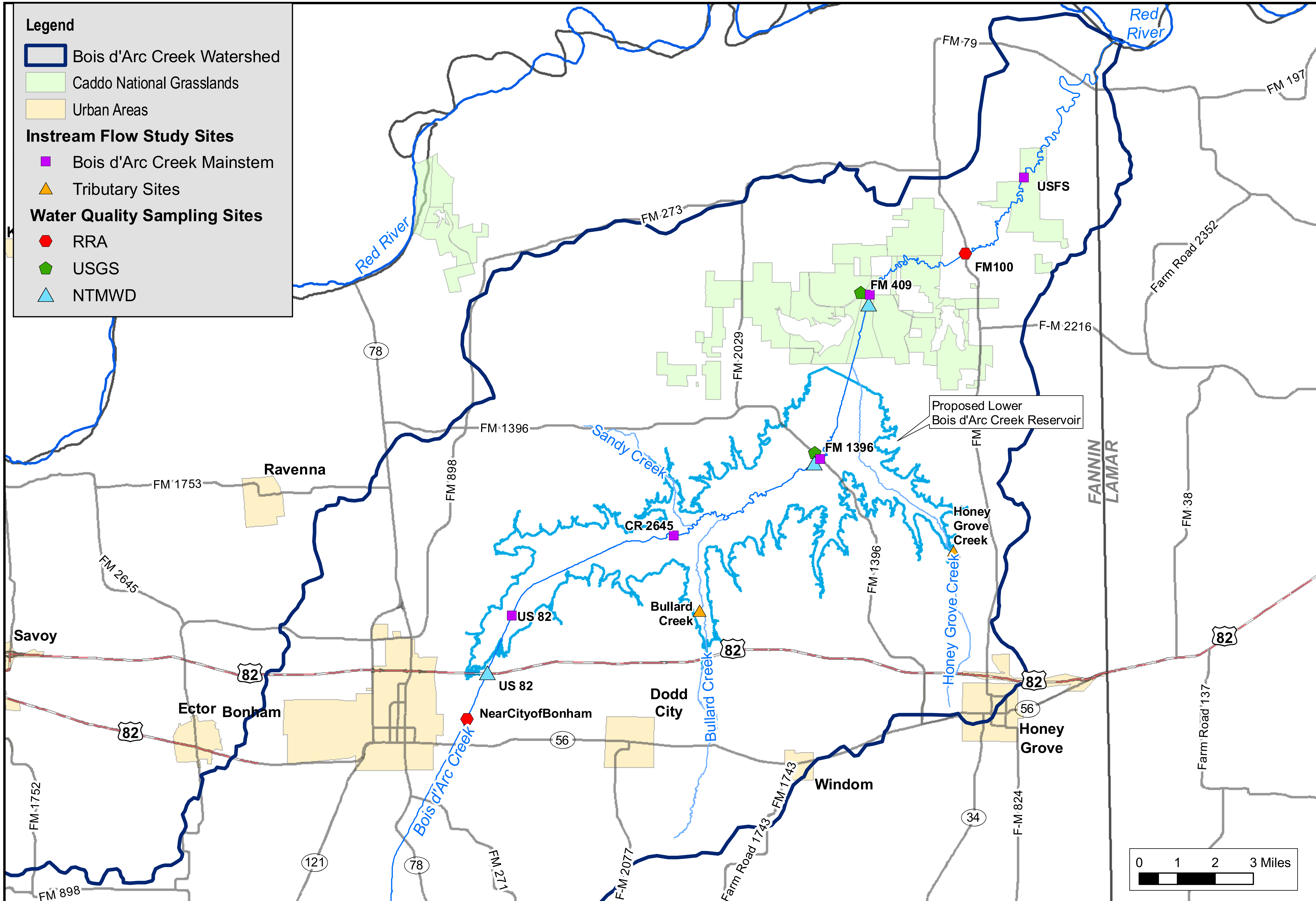


Figure 4.33

North Texas Municipal Water District
Proposed Lower Bois d'Arc Creek Reservoir

Water Quality Sampling Sites

FN JOB NO	NTD06128
FILE	Figure4.33.mxd
DATE	February 1, 2010
SCALE	1:149,333
DESIGNED	BME
DRAFTED	BME

Freese and Nichols
4055 International Plaza Suite 200
Fort Worth, Texas 76109-4895
817-735-7300

Figure 4.34 Mean Monthly Water Temperature at the USGS FM 1396 Gage (September 2006 through September 2009)

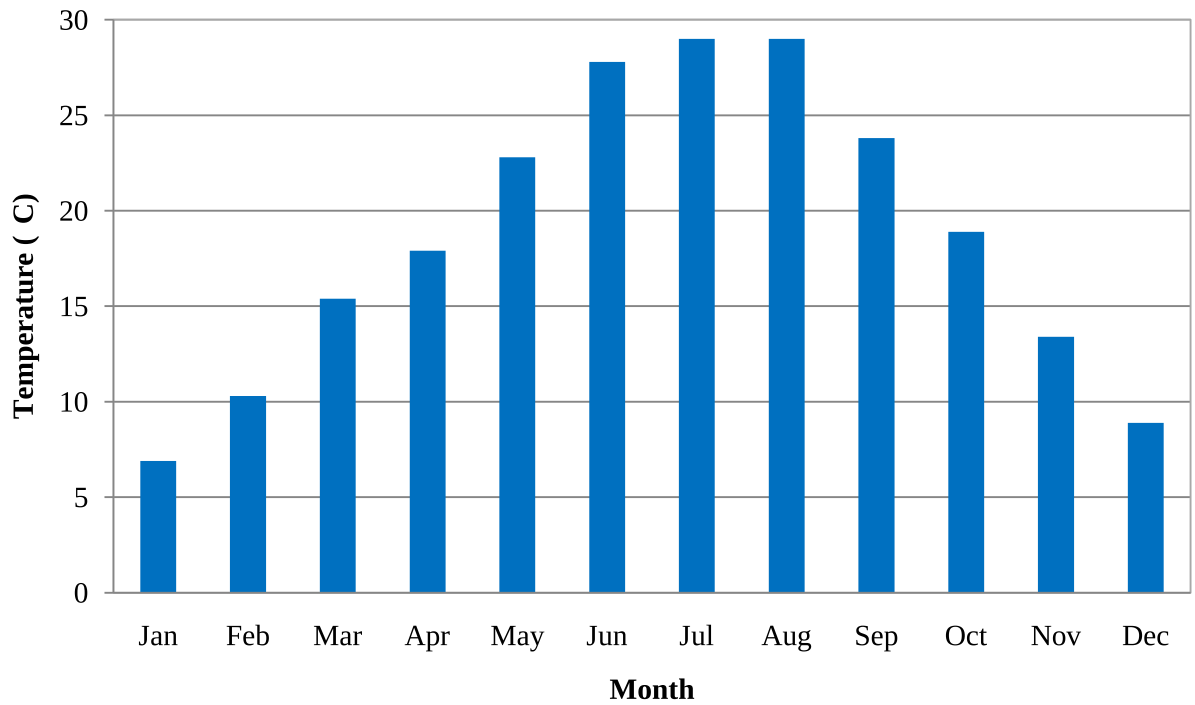


Figure 4.35 Daily Mean Dissolved Oxygen vs. Temperature at the USGS FM 1396 Gage (October 2006 through January 2010)

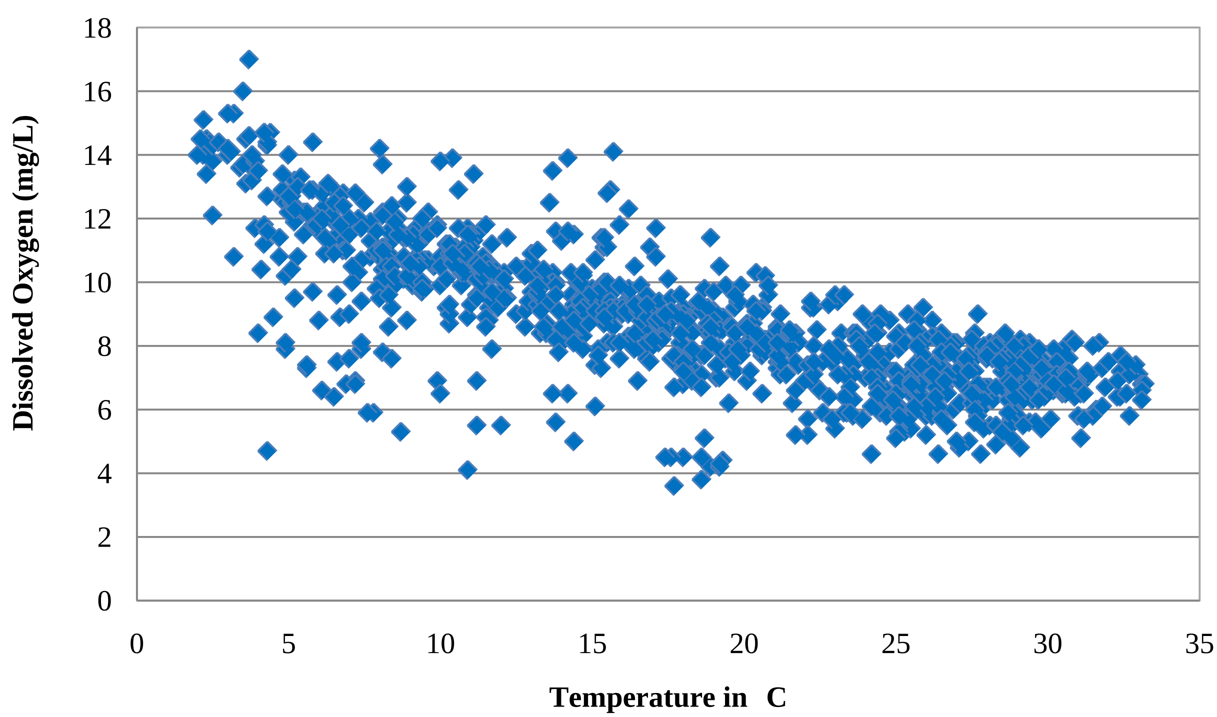


Figure 4.36 Daily Mean Dissolved Oxygen vs Flow at the USGS FM 1396 Gage (October 2006 through January 2010)

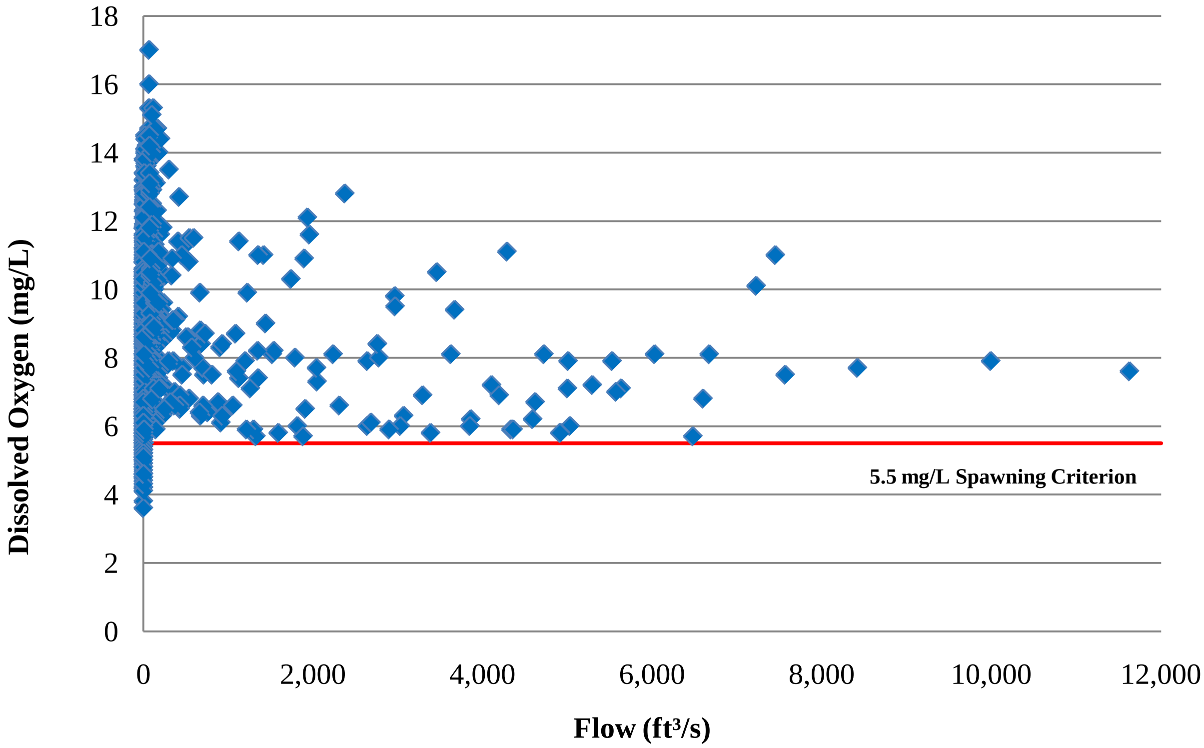


Table 4.10 Summary of Red River Authority Water Quality Data from Bois d'Arc Creek Near Bonham

Sampling Years	Range of Flow (cfs)	Mean Temperature (°C)	Mean Specific Conductance (µS/cm)	Mean pH (SU)	Mean Dissolved Oxygen (mg/L)	Mean Lab Turbidity (NTU)	Number of Samples (n)
2004 to 2005	0.0375 to 52	19.2	542	8.1	8.1	9.4	10

North Texas Municipal Water District (NTMWD) collected water samples at three locations along Bois d'Arc Creek (Figure 4.33) on nearly a monthly basis from June 2007 through December 2008. A statistical summary of the NTMWD water quality sampling data is included in Table 4.11. The dissolved oxygen measurements at all sites ranged between 2.5 mg/L and 13.0 mg/L. The dissolved oxygen concentrations observed by NTMWD at its three Bois d'Arc Creek sampling locations are compared in Figure 4.37, and the associated flows at the USGS FM 1396 gage on the respective sampling dates are depicted in Figure 4.38. Most of the observed dissolved oxygen concentrations were above the applicable criteria set by the Texas Surface Water Quality Standards for high aquatic life uses. The lower concentrations were primarily associated with extreme low flow conditions. A detailed description of NTMWD sampling data for Bois D'Arc Creek is presented in Appendix E.

Table 4.11 Summary of NTMWD Bois d'Arc Creek Water Quality Data (June 2007 through December 2008)

Sample Site	Mean Temperature (°C)	(n)	Mean Specific Conductance (µS/cm)	(n)	Mean pH (SU)	(n)	Mean Dissolved Oxygen (mg/L)	(n)	Mean Lab Turbidity (NTU)	(n)
US 82	18.1	22	497	19	7.53	8	6.45	22	137	22
FM 1396	17.9	17	428	15	8.06	3	7.69	17	151	17
FM 409	18.1	18	488	16	7.95	4	7.69	18	119	18

Figure 4.37 Dissolved Oxygen Concentrations at NTMWD Sampling Sites in Bois d'Arc Creek

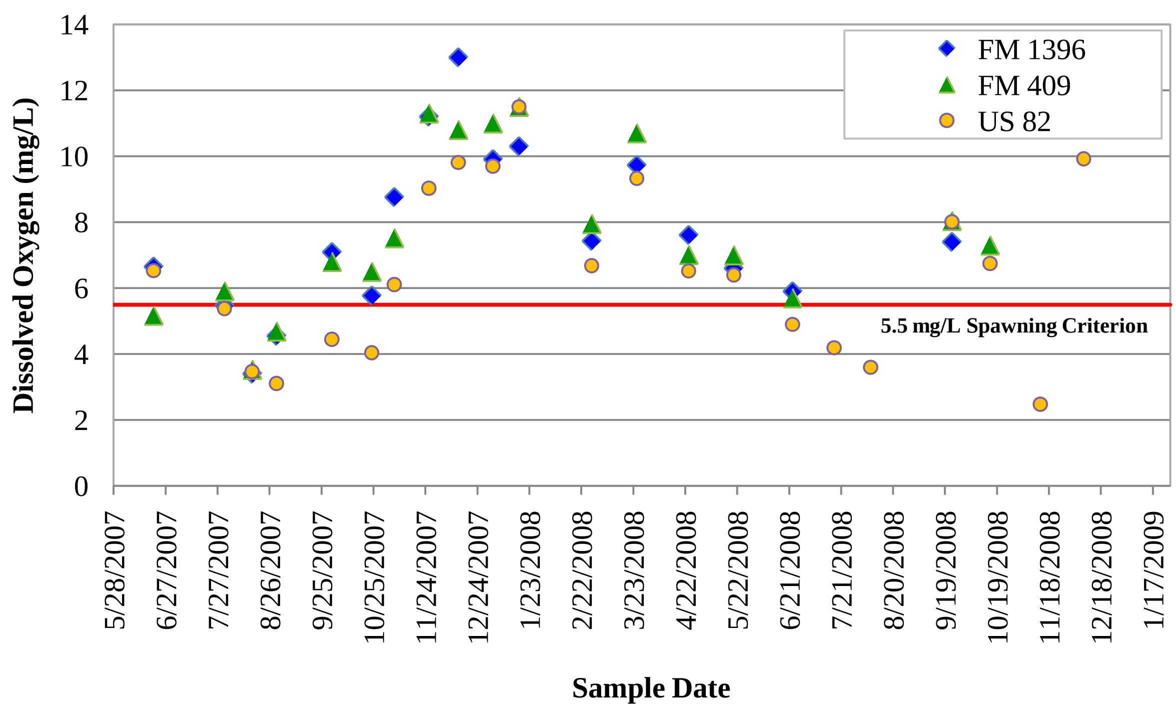
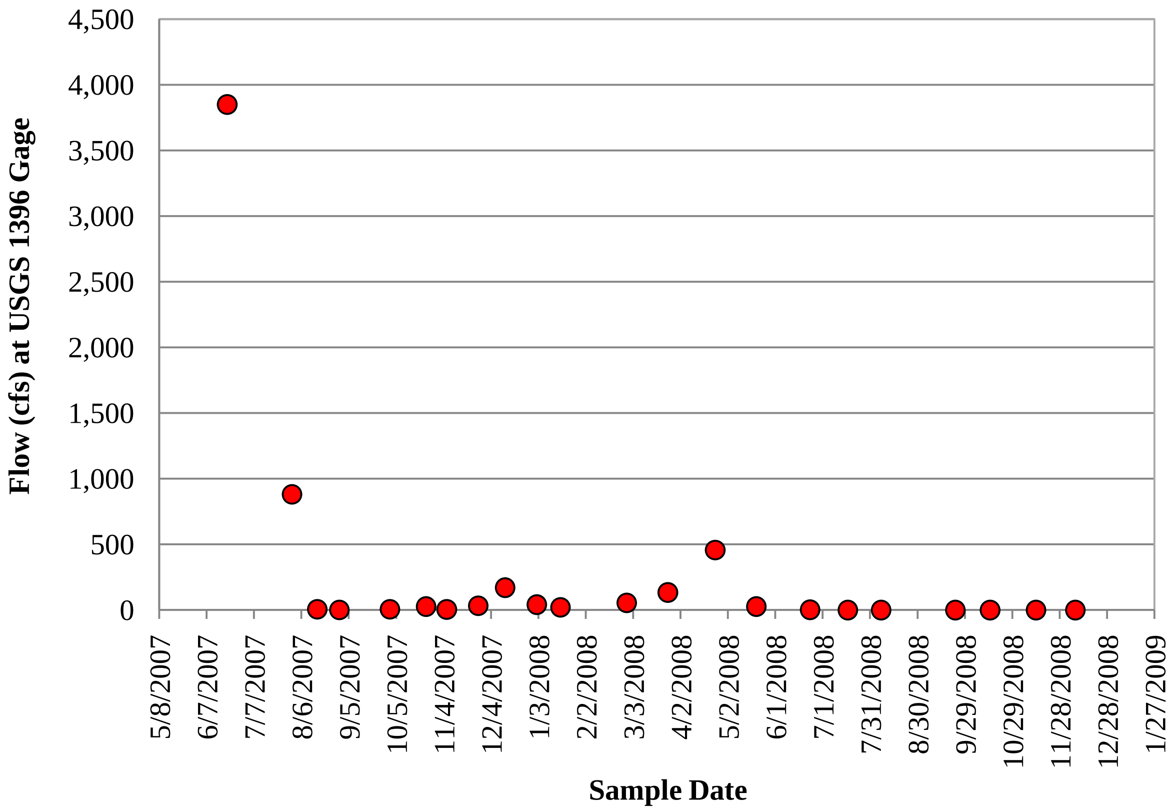


Figure 4.38 Mean Daily Flow in Bois d'Arc Creek at the USGS FM 1396 Gage on the NTMWD Water Sampling Dates



FNI measured dissolved oxygen, temperature, pH, specific conductance, and streamflow during biological sampling events at five locations along Bois d'Arc Creek (Figure 4.33). The observed dissolved oxygen concentrations and other water quality measurements from the sampling events are summarized in Table 4.12 The mean dissolved oxygen concentrations ranged between 5.4 and 10.7 mg/L at all but the US 82 site. At this site, dissolved oxygen levels ranged between 2.8 and 2.9 mg/L. These low readings were attributed to warm water temperature and low current velocity due to a logjam that blocked the creek's flow. By comparison, dissolved oxygen measurements made on the same day at the next downstream sampling location (CR 2645) ranged between 5.9 and 6.2 mg/L.

Table 4.12 Summary of FNI Water Quality Sampling Data (June and July 2009)

Site	Date	Mean Dissolved Oxygen (mg/L)	Mean Temperature (°C)	Mean Conductivity (us/cm)	pH (su)	Mean Instantaneous Flow (cfs)	Measure -ments (n)
FM1396	6/8/09	9.0	28.5	424	7.90	0.94	8
FM409	6/9/09	8.2	29.1	435	7.97	1.21	7
CR2645	6/10/09	5.4	28.6	503	7.67	0.94	5
FM1396	7/7/09	9.4	28.4	443	7.89	0.30	9
FM409	7/7/09	10.7	30.1	552	7.99	0.54	7
CR2645	7/8/09	6.1	30.5	508	7.68	0.73	2
US82	7/8/09	2.9	25.9	481	7.21	0.03	2
USFS	7/9/09	6.6	25.7	654	7.39	0.10	4

4.4.2 Water Quality Modeling

The TCEQ developed a waste load evaluation for Bois d'Arc Creek using the Qual-TX water quality model. The model was used by TCEQ to evaluate the effects on dissolved oxygen of treated effluent discharges from five publicly owned treatment works (POTWs) in the Bois d'Arc Creek watershed in order to issue Texas Pollutant Discharge Elimination System (TPDES) permits. The POTWs are identified in Table 4.13 along with their permitted flow, effluent limitations, and effluent outfall location upstream from the proposed dam site. No POTWs were identified downstream of the proposed dam site.

Table 4.13 Publicly Owned Treatment Works Authorized by TPDES Permit to Discharge in the Bois d'Arc Creek Watershed

Publicly Owned Treatment Work	Permitted Flow (Million Gallons per Day)	Effluent Limitations (CBOD/TSS/NH_3-N/DO, mg/L)	Distance of Outfall Upstream from Proposed Reservoir, (Stream Miles)
Whitewright, TX	6.272	20/20/5/5	41.4
Randolf, TX	0.022	30/30/8/4	28.5
Bonham, TX	2.500	10/15/2/6	17.3
Dodd City, TX	0.048	30/30/8/4	15.8
Windom, TX	0.032	30/30/8/4	16.5
Honey Grove, TX	0.500	30/30/8/4	9.1

CBOD- carbonaceous biochemical oxygen demand
TSS - total suspended solids
DO – minimum dissolved oxygen
NH_3-N ammonia-nitrogen

The TCEQ uses the Qual-TX model to establish effluent limitations for TPDES permits that will maintain the dissolved oxygen criteria prescribed by the Texas Surface Water Quality Standards for the effluent receiving streams affected by each POTW. Thus, the effluent limitations listed in Table 4.13 are presumed to be protective of dissolved oxygen criteria in Bois d'Arc Creek and the tributaries receiving effluent from these POTWs.

4.5 Future Conditions in Bois d'Arc Creek without the Proposed Reservoir

Without any changes in the watershed, Bois d'Arc Creek is expected to continue to downcut and erode. As the channel becomes even more incised, lateral connectivity with the surrounding flood plain will decrease. Due to the unstable nature of much of the stream banks along Bois d'Arc Creek and easily erodible bed materials, the stream channel will continue to enlarge. This will further reduce longitudinal connectivity at low flows and continue to constrain aquatic species to specific habitats that contain water (e.g., pools).

The Bois d'Arc Creek watershed has been significantly impacted by channelization, which began in the 1920s and continued well into the 1970s. The channelization was probably in response to frequent overbanking events in the watershed. As a result of the channelization, the watershed is no longer in equilibrium. Downcutting and streambank erosion have increased, and lateral migration of the stream (i.e., meander creation) has slowed. Channelization has also most likely increased the "flashy" nature of flows in the watershed, with rapid rise and fall in flow in response to rainfall events. This probably has reduced base flows in the watershed as well. Habitats in the watershed change rapidly, as high flows wash away gravel bars and large woody debris or low flows reduce connectivity along the stream. The frequency of extreme flow events, both high and low, has resulted in an environment that favors generalist species. Although water quality in the watershed is generally good, Bois d'Arc Creek is not able to support a large variety of aquatic life because the relatively few habitat features in the watershed are frequently washed away by high flow events, and the apparent lack of reliable subsistence or baseflow hydrology from year to year may be a limiting factor for fish and other aquatic species.

Water quality does not appear to have been a primary limiting factor to aquatic life in Bois d'Arc Creek, and this would be expected to hold true into the future in the absence of large scale watershed or stream system modifications that would result in a combination of decreased streamflow and increased water temperatures. Observed data indicated that dissolved oxygen concentrations were adequate to support aquatic life as long as there was adequate flow in the creek. Dissolved oxygen levels were depressed primarily during periods when streamflow approached zero and especially during warm months of the year when higher water temperatures limited the amount of oxygen that could be dissolved in the stream. It is assumed that TCEQ would continue to protect water quality in Bois d'Arc Creek and its tributaries in accordance with the Texas Surface Water Quality Standards if the proposed reservoir is not built. This would include waste load allocation permitting and evaluation of effluent limits through the use of appropriate water quality modeling tools such as Qual-TX to ensure that applicable water quality criteria would be met in the receiving waters.