Suspended Sediment Retention in Bottomland Hardwood Forest Stream Corridors of the Upper Angelina River Basin, Texas

1999-2000 Project Report

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Prepared for the Texas Water Development Board, Austin

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Interim Report

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OVERVIEW

This report covers the first year of a cooperative research study by the Texas Water Development Board (TWDB) and the Department of Geography, College of Geosciences, Texas A&M University. This study seeks to document the effects of dam construction and operation on sedimentation processes in bottomland hardwood forests (BHF). The study area is Loco Bayou and Lake Nacogdoches in Nacogdoches County, Texas. Preliminary results suggest that, as expected, sedimentation in BHF immediately downstream of the dam is dramatically reduced. In this area there has been stream bed scouring and some floodplain erosion. At a site further downstream, however, there is no evidence of a major change in sediment regime in the BHF associated with Lake Nacogdoches. At a site just upstream of the impoundment, sedimentation in the BHF has been greatly enhanced due to a local rise in base level associated with the lake.

INTRODUCTION

The purpose of this study is to determine the extent to which impoundments on east Texas streams influence sedimentation regimes in bottomland hardwood forests. Bottomland hardwood forests (BHF's) provide a number of important functions and values in east Texas, as summarized by Wilkinson et al. (1987). Sedimentation in riparian forests is important from two perspectives. First, the sedimentation regime is important for the establishment and maintenance of BHF's. The ecosystem functions and values are partially dependent on flooding and associated sedimentation to supply nutrients and to maintain the BHF habitat. Further, particular geomorphic settings associated with channel and sediment dynamics are critical for the establishment of some important tree species in these environments (Friedman et al. 1998; Scott et al. 1996; Shankman and Kortright 1994). Second, retention of sediments is one of the important "filter" values provided by riparian wetlands. Trapping of sediments and sediment-associated pollutants is important to the maintenance and enhancement of water quality.

Dams and reservoirs have major influences on stream hydrology and on sediment transport and deposition. As of 1994 there were 205 reservoirs in Texas with capacities $\geq 6,115,000$ m^3 (5000 acre-feet), and ongoing concern over BHF's in east Texas. Thus the effects of impoundments on sedimentation in BHF's is an important concern from the perspective of both water and forest resource management.

Most dams and reservoirs trap a high proportion of the sediment entering them. The conventional wisdom has been that this starves floodplains downstream of sediment. While this is clearly the case in many instances, it is equally clear that the geomorphic response downstream of dams is complex, variable, and quite contingent on the specific characteristics of both the fluvial system and the impoundment (Williams and Wolman 1984; Friedman et al. 1998). In a study of 35 large rivers in the U.S. Great Plains (including the Neches, Brazos, and Colorado Rivers in Texas), the response of the downstream channel/floodplain geomorphology and associated floodplain ecology to dams varied so greatly that no generalizations could be made (Friedman et al. 1998). Evidence from Atlantic Coastal Plain streams suggests that erosion and tributary inputs downstream of dams allows sediment loads to recover very quickly, so that while the source of fluvial sediments may change, the sediment loads do not vary greatly (Phillips 1991a; 1991b). Further, in some fluvial systems the upper and lower basins are essentially decoupled in the sense that very little upper-basin sediment is delivered to the lower basin (Beach 1994; Brizga and Finlayson 1994; Olive et al. 1994; Phillips 1992; 1995). If this is the case the effect of dams on downstream sediment regimes will diminish rapidly with distance. While it would be expected that BHF's in east Texas immediately downstream from dams would experience dramatically reduced sediment supplies, this effect might well be restricted to a relatively small area.

The sediment-trapping efficiency of impoundments may be quite high (up to 99 percent; Williams and Wolman, 1984), and a reduction in sediment concentrations and loads downstream of several Texas impoundments has been documented (Solis et al., 1994). However, it is not clear whether sediment reductions are significant more than a short distance downstream. Double-mass curves plotting cumulative sediment loads (y-axis) against cumulative discharge (x-axis) were constructed for gaging stations on the lower reaches of nine Texas rivers by Solis et al (1994). A break in slope indicating a change in sediment regimes toward lower sediment loads was found for the Trinity, Nueces, and Lavaca Rivers. However, the Lavaca river is not impounded, measurements on the Nueces are from a station immediately downstream of a dam, and six of the stations show no clear evidence of a change in sediment delivery.

Hudson and Mossa (1997) examined sediment discharge records for the lowermost stations on four large rivers draining to the Gulf of Mexico, including the Rio Grande and Brazos. Sediment yield records are not generally adequate to directly determine whether a decline in sediment transport is associated with impoundment, due to a paucity of pre-impoundment data. Dams do not appear to have reduced mean discharges on the Brazos and Rio Grande, but Hudson and Mossa (1997) state that peak discharges, which are inordinately important in sediment transport, have likely been reduced.

It should be recognized that sedimentation is only one of many geomorphic phenomena closely related to the establishment, maintenance, and ecological relationships of riparian vegetation. Plants on floodplains are controlled by a combined gradient of available moisture and oxygen that is in itself controlled by flooding frequency and soil moisture (Hughes 1997). These are in turn influenced by hydrologic regimes and hydroperiods, floodplain elevation and topography, and variations in floodplain soil/sediment properties. Channel changes, channel migration, and the development of specific fluvial landforms are critical to the establishment of a number of bottomland tree species (Everitt 1968; Hughes 1997; Scott et al. 1996; Shankman 1991; Shankman and Kortright 1994). Hupp and Osterkamp (1984) detailed the relationships between bottomland vegetation and fluvial landforms in Virginia; the general pattern is evident in the correspondence between vegetation and communities and specific bottomland features in east Texas (Wilkinson et al. 1987).

Given the variety of geomorphic responses to dams (Williams and Wolman 1984; Friedman et al. 1998), it should not be surprising that there would also be a variety of bottomland vegetation responses. The perception of a particular vegetation response may depend on management objectives or aesthetic considerations. "Red" river bottoms in the southern U.S., for example, contain no old-growth forest as the term is generally understood. However, higher bottomland sites in these areas influenced by dramatic historic sedimentation often support diverse BHF communities with greater numbers of some species often considered desirable (for example, American beech) than the pre-disturbance forests (Shear et al. 1997).

An area largely neglected in previous studies is the influence of impoundments upstream. Ponding of water and an increase in the local base level would be expected to enhance sedimentation upstream of the reservoir due to backwater effects. However, this phenomenon is not well studied or documented.

Study Area and Study Design

The study area is Bayou Loco and Lake Nacogdoches in Nacogdoches County, Texas (Figure 1). Bayou Loco is a tributary of the Angelina River in east Texas. The total drainage area upstream of the lowermost study site is about 265 km^2, with about 228 km^2 lying upstream of Loco dam. The study area lies within the eastern Pineywoods region of the Texas coastal plain. The climate is humid subtropical, with a mean annual precipitation of about 1200 mm yr^{-1}. Although the precipitation is reasonably well distributed throughout the year, summer droughts are not uncommon and August is the driest month. Streamflow is typically highest from December through February, and lowest in mid to late summer.

Lake Nacogdoches provides water supply for the city of Nacogdoches. It has an area of 896 ha, and a volume of 48,224,087 m^3 (29,523 ac-ft) at the normal pool elevation of 85 m as of 1994 (TWDB 1994). Loco Dam was completed in 1976.

The study design is based on examination of sedimentation regimes at three sites. The first, termed the upper site, is upstream of the lake. While this site is 0.78 km (channel distance) above the lake, backwater ponding effects are clearly visible here. The second (middle) site is just downstream of Loco Dam. The third or lower site is 15.62 km downstream of the dam and 16 km upstream of the confluence with the Angelina River. Drainage area of the lower site is 264.7 km^2, 37.06 km^2 of which lies downstream of Loco Dam. By examining these three sites sedimentation regimes upstream, immediately downstream, and further downstream of an impoundment can be compared.

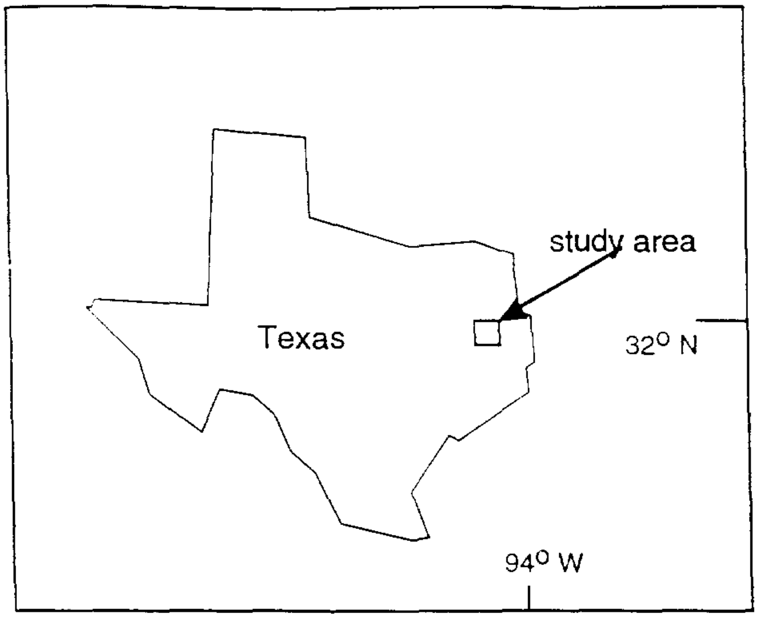


Figure 1. General location of study area.

Each site is instrumented with a Starflow ultrasonic doppler (Unidata, Inc.) device. While the Starflow is capable of measuring velocity and temperature, logistic constraints on equipment deployment required the instruments to be mounted on the channel side, where a pressure transducer measures water depth. By relating these depth measurements to discharge measurements, a stage-discharge relationship can be obtained. The sites are also instrumented with OBS (Optical Backscattering Sensor) devices to measure turbidity. By comparing the OBS turbidity measurements with manual measurements of suspended sediment concentrations, a relationship between turbidity and sediment concentrations can be established. Both instruments were set to record data at 15-minute intervals beginning in May 1999. Dataloggers record the data, which was downloaded at approximately one to two-week intervals from June 1999 through February 2000.

At each site a number of sediment disks are deployed to measure overbank sedimentation. These disks are composed of a heavy rough cloth, 3 mm thick rubber disk, and 4 mm thick steel plate, anchored to the ground with a 35 cm spike/nail. The disks are 14 cm in diameter, and mounted flush to the ground surface. The cloth components were pre-weighed so that they can be removed with sediment accumulations for weighing and analysis. A series of disks was emplaced along cross-floodplain transects surveyed at each site. Two or three feldspar marker beds were also constructed at each site and surveyed in.

Soil-stratigraphic and dendrogeomorphic evidence was examined at each site in an effort to determine historic sedimentation patterns, and aerial photographs of the sites from the 1970 - 1996 period were analyzed to examine changes. Trees were inventoried along the surveyed transects as described below.

SEDIMENTATION IN LAKE NACOGDOCHES

The upper Loco Bayou basin appears to be producing a great deal of sediment. The Texas Water Development Board conducted a detailed survey of Lake Nacogdoches in 1976 when the reservoir was constructed, and again in March, 1994 (TWDB 1998; 1994). Those data indicate a reduction in lake volume of 3,447,633 m^3, or 6.6% of the 1976 capacity. While several factors may contribute to changes in reservoir capacity (including improved measurement technology; TWDB 1994) the most likely and most important is infilling with fluvial sediment. Making the assumption that this is the cause of the volume reduction in the lake, the TWDB survey data suggest accumulation rates of 191,535 m^3 yr^{-1}.

Typical bulk densities of floodplain soils in east Texas range from 1.3 to 1.6 g cm^{-3}. Welborn (1967) studied the specific weight of fluvial sediment deposits in Texas, finding typical densities of 0.5 to 0.9 g cm^{-3} for newly-deposited sediment, and estimating densities of 1.1 to 1.3 g cm^{-3} for deposited sediments after 50 years, based on the initial density and the particle size distribution. A study of Ohio lakes found bulk densities of lake-bottom sediments to be 0.5 to 1.7 g cm^{-3} (USDA 1990). It is therefore reasonable to assume a bulk density of 1.0 g cm^{-3} for a rough estimate of the sediment mass deposited in the lake (this has the advantage of a direct conversion from cubic meters to metric tons). With a drainage area of 227.7 km^2, this implies a sediment yield for Lake Nacogdoches of 841 t km^2 yr^{-1}. Of the 40 Texas lakes for which similar comparative survey data are available (TWDB 1998), only a few suggest comparably high sediment yields.

Comparison of 1980 and 1996 black and white aerial photographs from the U.S. Natural Resources Conservation Service shows significant wetland and shoreline propagation in the upper Lake, particularly in the northeastern arm of the lake fed by Loco Bayou. This infilling is consistent with both the lake sedimentation rates discussed above and the aggradation observed at the upper site, as discussed later in this report.

FLOW AND TURBIDITY MEASUREMENTS

The entire period from May 1999 into February 2000 was characterized by low flows, associated with general drought conditions in east Texas. There were no overbank flow events at any study site, and thus no data from the flow conditions of interest and relevance to this study. Starflows emplaced subaqueously in May and June were subaerially exposed for much of the study period. The OBS sensor deployment is designed to keep the sensor at a constant 0.3 m depth from the surface. Because depths were often less than 0.3 m at the middle and lower sites the sensors were often in contact with the stream bottom, yielding spurious data.

Reliability of both the Starflow and OBS instruments was low. Both required regular maintenance and experienced occasional down time. Even when the sensors were functioning properly they often reflect readings which are not consistent with field observations, particularly with respect to the Starflows.

The low flows during the study period characterize the east Texas region in general. A nearby gaging site on the Angelina River near Alto illustrates this (Fig. 2). The discharge from late January 1999 to late January 2000 shows a dramatic decline in streamflow after a winter flood peak.

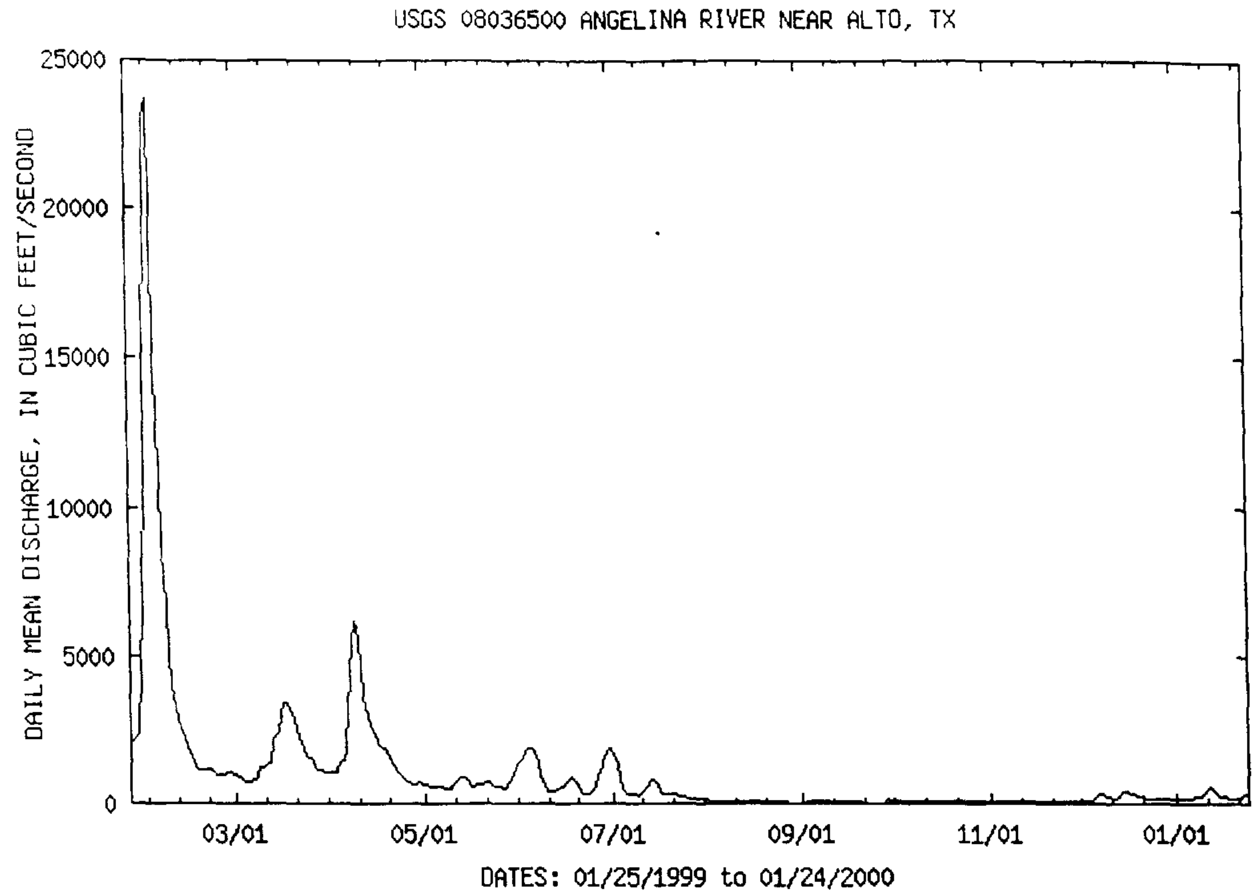


Figure 2. U.S. Geological Survey discharge data for Angelina River near the study area.

Observations at Bayou Loco are consistent with the Angelina data in Figure 2, both with respect to very low flows in the summer, fall, and early winter of 1999-2000, and with respect to the highest flows after instrument emplacement occuring around July 1.

Comparing OBS turbidity data for the upper and lower sites for the June 29 - July 5, 1999 period shows no evidence that the impoundment is resulting in any decrease in turbidity in Bayou Loco 15 km downstream of the dam (Fig. 3). Turbidity values at the lower site are generally an order of magnitude higher than at the upper site, indicating greater turbidity than in the waters flowing into the lake. Turbidity is presumed to be directly related to suspended sediment concentrations. However, flow conditions have not allowed enough data to be collected to develop reliable relationships between OBS readings and suspended sediment concentrations, and factors other than sediment may influence turbidity values.

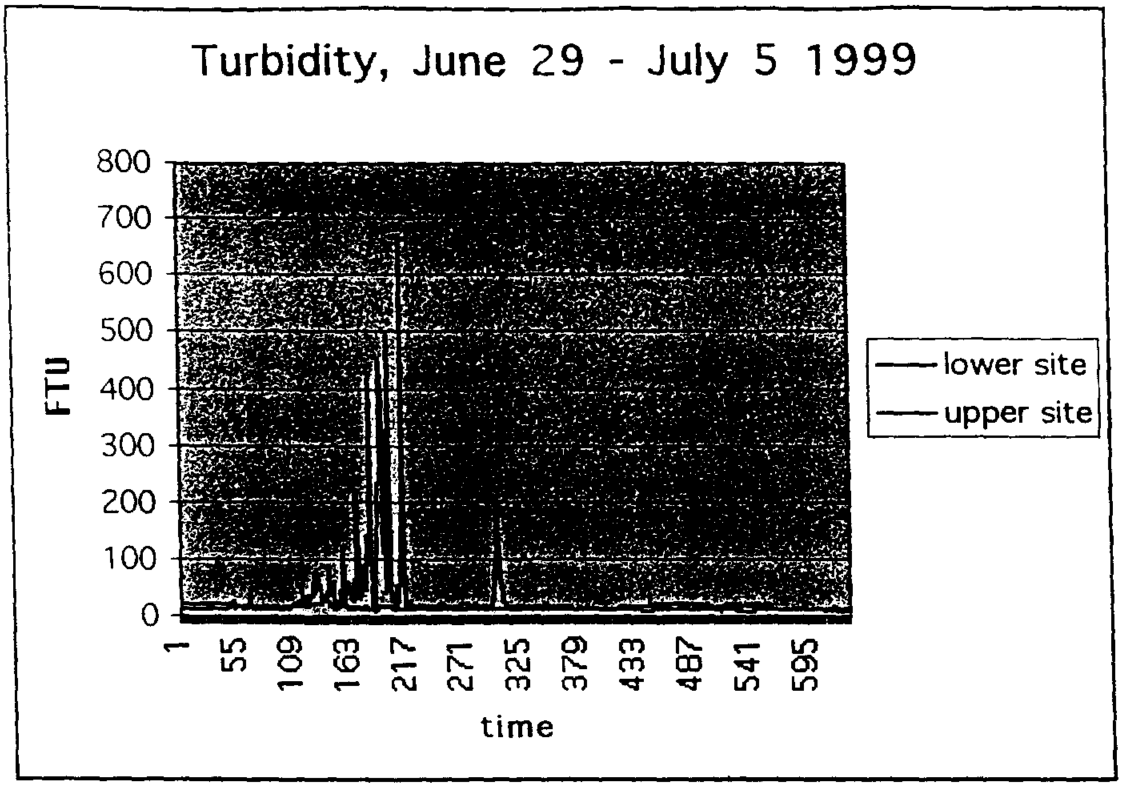
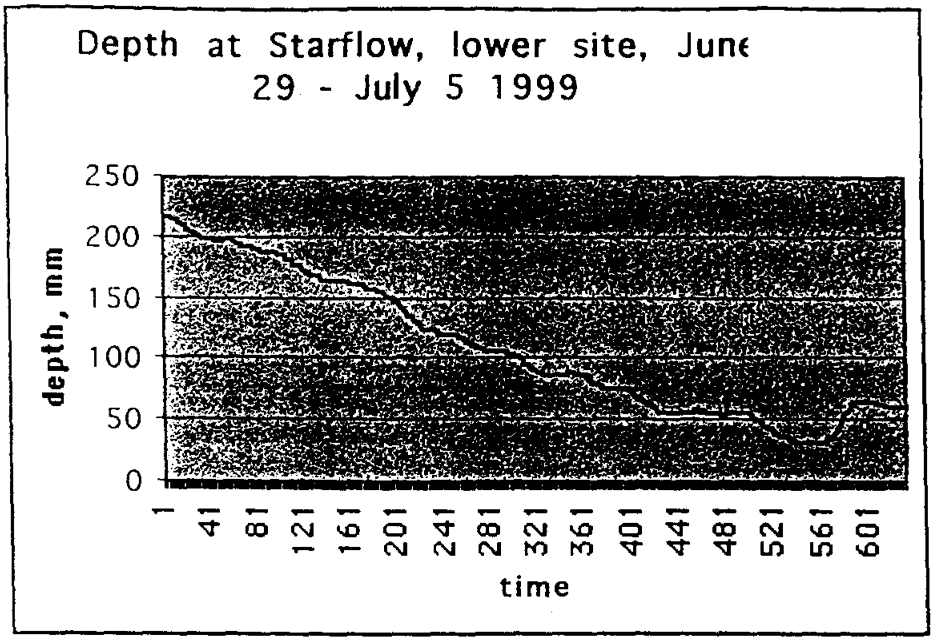


Figure 3. Comparison of turbidity readings in Formazine Turbidity Units (FTU) for the upper and lower sites.

Separate depth and turbidity records for the upper and lower sites are shown in Figure 4. Low flow conditions have not allowed enough data to be collected to develop stage-discharge relationships, so depth at each site reflects only the submersion of the instrument. There is no apparent relationship within these very limited data sets between flow depth and turbidity. The different pattern of flow recession between the two sites is attributed to the buffering effect of the lake on the upper site.

Figure 5, comparing upper and lower site turbidity readings for the Dec. 17, 1999 - January 4, 2000 period, shows the same general trend of lower site turbidity which is usually, though not always, higher than that of the upper site. These data also show the sensitivity of the OBS meter to specific events. Note the rise in turbidity at the lower site in late December, including a pronounced spike in early January. Field observations on January 6 show recent logging (harvesting) operations on both sides of the bayou channel just upstream of the monitoring site. It was also evident from streamside tracks that cattle had recently been in the stream bank area. Both these activities would be expected to result in increased suspended sediment, as indicated in the turbidity data.



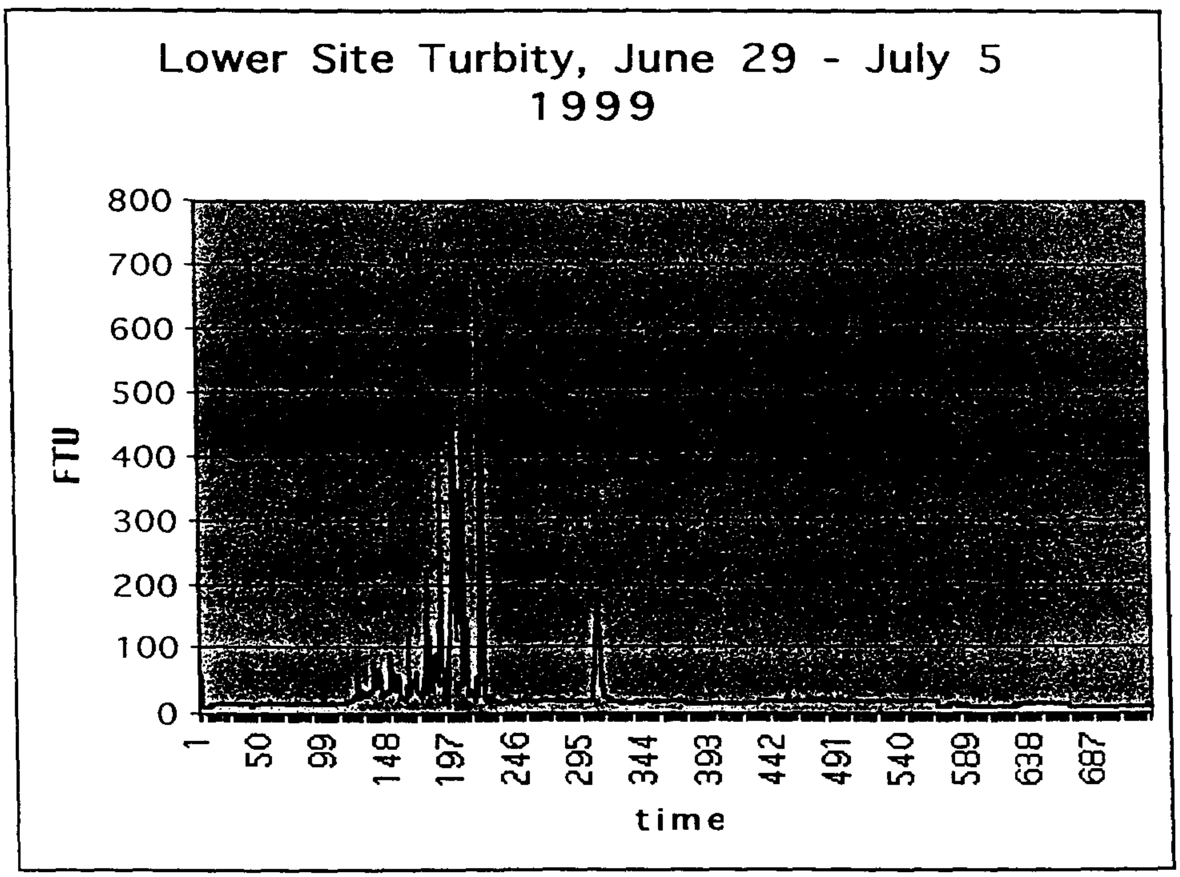
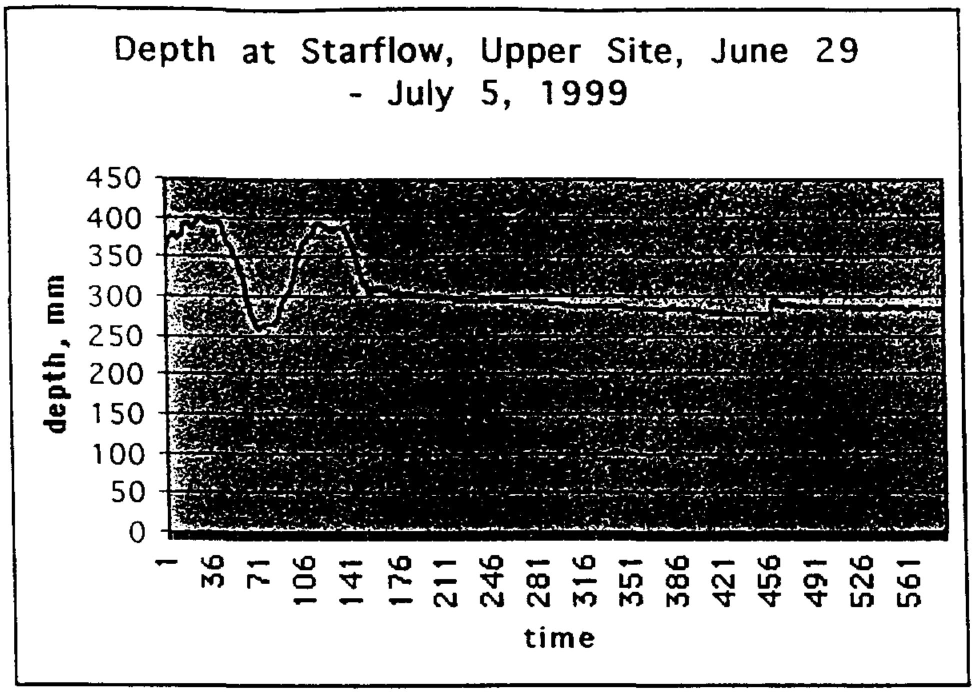


Figure 4 (continued next page)



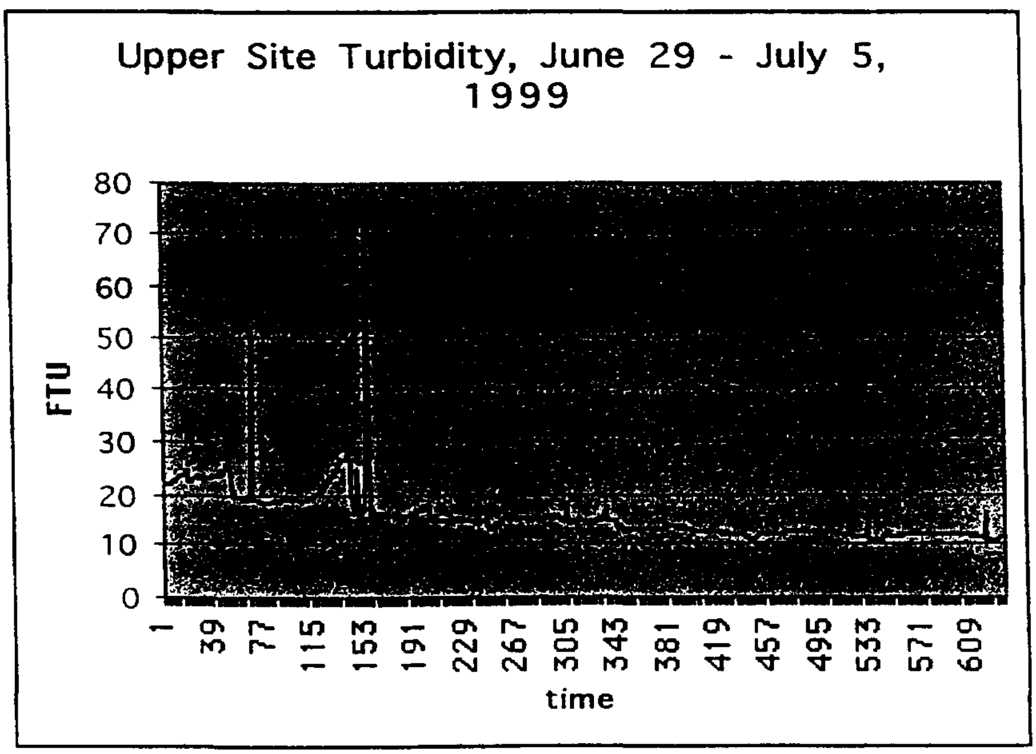


Figure 4. (continued from previous page). Depth recorded at Starflow instruments and turbidity for the upper and lower sites. All readings start at 1015 June 29 and represent readings taken every 15 minutes thereafter. Turbidity data in formazine turbidity units (FTU).

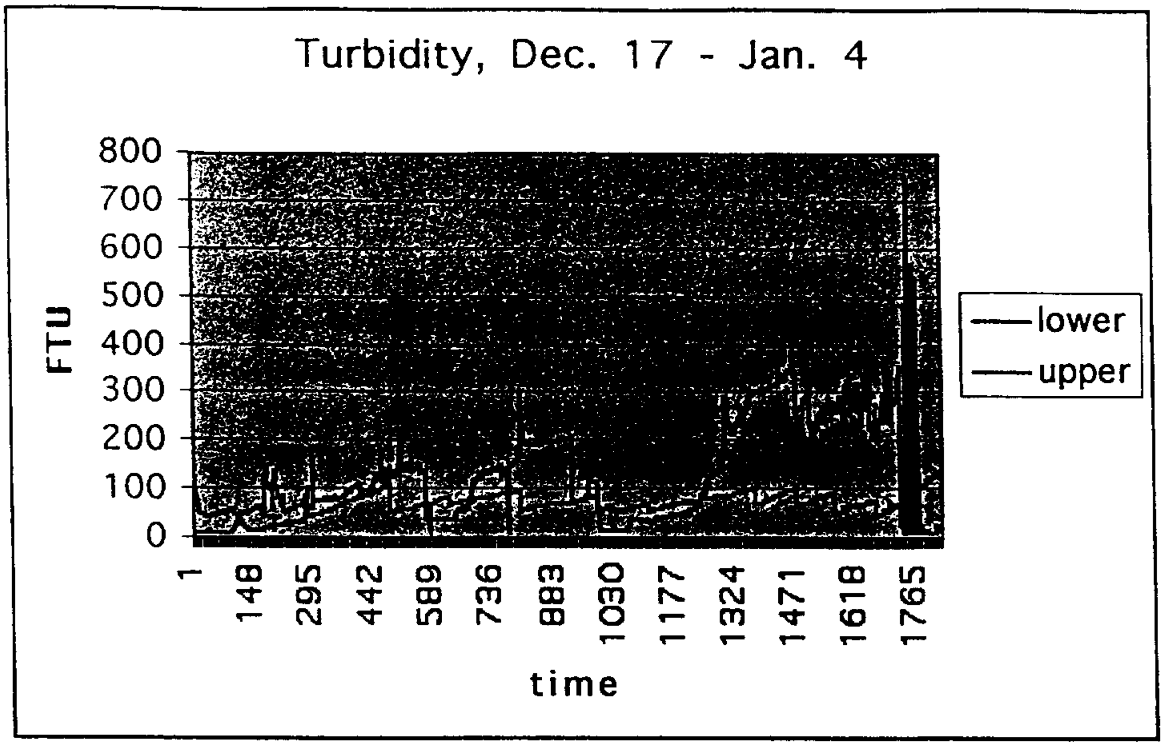


Figure 5. Comparison of turbidity readings in Formazine Turbidity Units (FTU) for the upper and lower sites. Readings are taken every 15 minutes.

SEDIMENT DISK MEASUREMENTS

Because there were no overbank flow events, the sediment disks and marker beds recorded no alluvial sedimentation. Field observations suggest that the disks are accumulating, to varying degrees, thin coatings of organic matter, aeolian dust, and sediment disturbed by faunal burrowing and other processes.

BOTTOMLAND VEGETATION

At each study site a vegetation transect was established in January, 2000. Using previously-surveyed cross-floodplain lines as a centerline, all living trees or shrubs in a 2 m swath (1 m either side of the centerline) were identified and the diameter at breast height (DBH) measured with a dendrological diameter tape. Trees were included in the survey if any part of the basal trunk was within a meter of the centerline. The transect data are given in Table 1 and discussed below. All tree species found are listed in the checklist of the vascular plants of Texas as occurring in the eastern Pineywoods region of the state in which the study area lies (Hatch et al. 2000).

Calculation of vegetation indices for transects:

1. Basal area (m^2) $=[\pi (DBH/100)^2]/4$,
   where DBH = diameter at breast height, in cm
2. Relative dominance of species A = basal area of A/basal area of all trees
3. Relative density of species A = number of individuals of A/number of all trees
4. Basal area ratio: Basal area/area of transect
   transect area excludes the bankfull stream channel and pasture areas
5. Density: number of trees/area of transect

At the upper (upstream) site the most striking trend is the prevalence of young beech (*Fagus grandifolia)* trees. Beech was the most prevalent species, comprising almost half (21 of 43; 48.8%) the individuals. The trees were quite small, however--18 of 21 had a DBH of less than 5 cm, and the largest had a DBH of 14.9 cm. The largest trees were tulip-tree (*Liriodendron tulipifera*) on the left floodplain and willow oak (*Quercus phellos*) on the right. The largest tree in the vicinity of the sample transect was an oak (tentatively identified as willow oak) with a DBH of nearly 106 cm. Beech represents eight percent of the total basal area of the transect (relative dominance = 0.08), but 49 percent of the individuals (relative density = 0.49). Tulip-tree, by contrast, has a relative dominance of 0.84 and a relative density of 0.19.

Tulip-tree (also called tulip or yellow poplar) is generally a shade-intolerant pioneer species which often invades open sites. Beech is a climax species which grows underneath an overstory (USFS 1998). The species distribution on the left floodplain is therefore consistent with a transitional stage in which the older early invading species are being replaced by a climax species. This suggests a degree of both substrate and hydroperiod stability in recent years.

Willow oak grows best on floodplains that are commonly flooded in winter and early spring, but rarely or briefly during the growing season (USFS 1998), which is consistent with streamflow regime in east Texas. The slightly higher elevation of the right floodplain as compared to the left probably accounts for the prevalence of willow oaks.

Beech is absent at the middle site, where water ash (*Fraxinus caroliniana*) is the most common species on the transect (relative dominance = 0.40; relative density = 0.50). An overcup oak, water ash, and sweetgum are the three largest individuals on the transect (23 to 33 cm DH), while the largest nearby tree is a Nuttall (?) oak with a DBH of 67 cm. The water ash is entirely on the lower, left, floodplain side of the channel. On the higher right side there are also some pines among the hardwoods, though none were on the sample transect.

On the left side of the transect at the lower site small beech trees (<5 to 5.9 cm DBH) are becoming established. The largest tree in the sample is an overcup oak (*Quercus lyrata*), but the largest trees in the vicinity are sweetgum (*Liquidambar styraciflua*; largest individual DBH = 110 cm). Sweetgum is a pioneer, invading species, so the vegetation data again indicate that older early invading species are being replaced by a climax species. The right floodplain is higher, and much of it is in pasture. Water oak (*Quercus nigra*) dominates the streambank zone. A filled slough further out of the floodplain contains various oaks, the largest an overcup oak. The location of water oak on the streambank levee is consistent with its preference for locations which flood frequently and deeply but drain rapidly (USFS 1998). Altogether the oaks dominate the transect, with relative dominance of 0.90 and relative density of 0.61.

The basal area ratios are 0.0031, 0.0027, and 0.0088, respectively, for the upper, middle, and lower sites. Messina et al. (1997) found basal area ratios of 0.0032 for trees >4 cm DBH in an east Texas bottomland forest. The stem densities are 0.23, 0.12, and 0.25 trees per m^2, respectively. This comparies to 0.08 trees m^{-2} found by Messina et al. (1997) in bottomlands along the Neches River.

Table 1. Bayou Loco Vegetation transects.

All transects left to right across previously surveyed lines where sediment disks were emplaced. All living trees identified in 2 m swath (1 m either side of transect line); DBH recorded. Distances are from transect start to middle of tree.

Upper site

Distance (m)	Species	DBH (cm)
2.37	tulip-tree (*Liriodendron tulipfera)*	10.2
4.25	beech (*Fagus grandifolia)*	<5
7.30	beech (*Fagus grandifolia)*	<5
7.53 .	beech (*Fagus grandifolia)*	<5
7.92	beech (*Fagus grandifolia)*	<5
8.49	elm (*Ulmus americana)*	<5
8.65	elm (*Ulmus americana)*	6.7
9.30	beech (*Fagus grandifolia)*	<5
9.48	beech (*Fagus grandifolia)*	6.7
10.72	beech (*Fagus grandifolia)*	<5
12.86	beech (*Fagus grandifolia)*	6.2
13.10	beech (*Fagus grandifolia)*	<5
14.96	beech (*Fagus grandifolia)*	14.9
15.18	tulip-tree (*Liriodendron tulipifera*)	19.5
15.36	tulip-tree (*Liriodendron tulipifera*)	42.5
17.30	tulip-tree (*Liriodendron tulipifera*)	12.4
19.49	beech (*Fagus grandifolia)*	<5
21.50	beech (*Fagus grandifolia)*	<5
23.55	beech (*Fagus grandifolia)*	<5
23.56	beech (*Fagus grandifolia)*	<5
28.44	beech (*Fagus grandifolia)*	<5
30.26	water oak (*Quercus nigra*)	10.2
32.60	beech (*Fagus grandifolia)*	<5
35.10	sweetgum (*Liquidambar styraciflua*)	<5
35.49	beech (*Fagus grandifolia)*	<5
36.44	beech (*Fagus grandifolia)*	<5
39.51	beech (*Fagus grandifolia)*	<5
43.51	tulip-tree (*Liriodendron tulipifera*)	17.0
43.62	tulip-tree (*Liriodendron tulipifera*)	15.8
43.75	elm (*Ulmus americana*)	11.4
55.30	ash (*Fraxinus caroliniana* or *F. pensylvanica*)	<5
55.50	tulip-tree (*Liriodendron tulipifera*)	57.3
59.97	tulip-tree (*Liriodendron tulipifera*)	<5
60.69	beech (*Fagus grandifolia)*	7.9
69.90	beech (*Fagus grandifolia)*	<5
72 to 82.5	bankfull channel	
76.20	ash (*Fraxinus caroliniana* or *F. pensylvanica*)	<5
94.21	arrow-wood (*Viburnum nudum*)	<5
98.01	arrow-wood (*Viburnum nudum*)	5.3
98.31	willow oak (*Quercus phellos*)	25.5
100.20	ash (*Fraxinus caroliniana* or *F. pensylvanica*)	<5
100.21	arrow-wood (*Viburnum nudum*)	<5
102.81	ash (*Fraxinus caroliniana* or *F. pensylvanica*)	<5
105.00	willow oak (*Quercus phellos*)	43.0

Table 1. Continued.
Upper Site, continued

Largest tree in vicinity: willow oak (*Quercus phellos*) (?), DBH = 109.6 cm

	Basal area:	N of individuals	
Beech	0.0474 m^2	21	(8% of b.a.; 49% of stems)
Tulip-tree	0.4933	8	(84% of b.a.; 19% of stems)
ash	0.0050	4	
elm	0.0150	3	
arrow wood	0.0005	3	
oaks	0.0244	3	
sweetgum	0.0012	1	
Total	0.5868	43	

187 m^2 area (excluding channel)

Basal area: 0.0031 m^2/m^2
Stem density: 0.23 m^{-2}

Middle site

Distance (m)	Species	DBH (cm)
0	winged elm (*Ulmus alata*)	8.5
0.91	winged elm (*Ulmus alata*)	5.3
13.69	water ash (*Fraxinus caroliniana*)	28.7
19.69	water ash (*Fraxinus caroliniana*)	8.8
22.21	water ash (*Fraxinus caroliniana*)	6.8
23.27	water ash (*Fraxinus caroliniana*)	7.5
28.49	water ash (*Fraxinus caroliniana*)	12.4
29 - 34	channel	
41.13	sweetgum (*Liquidambar styraciflua*)	23.2
44.20	oak (*Quercus spp.*)	<5
47.50	overcup oak (*Quercus lyrata*)	32.8

Largest tree in vicinity of sample transect:
nuttall oak ? (*Quercus nuttallii*) 66.6

	Basal area	Number
water ash	0.0909	5
oak	0.0857	2
winged elm	0.0080	2
sweetgum	0.0423	1
Total	0.2269	10

Transect area: 85 m^2

Basal area: 0.00267 m^2/m^2
Stem density: 0.12 m^{-2}

Table 1 continued.

Lower site

Distance (m)	Species	DBH (cm)
2.01	beech (*Fagus grandifolia*)	5.0
3.11	beech (*Fagus grandifolia*)	5.9
3.69	beech (*Fagus grandifolia*)	5.1
3.75	water oak (*Quercus nigra*)	13.0
9.68	beech (*Fagus grandifolia*)	<5
13.93	overcup oak (*Quercus lyrata*)	36.1
15.24	elm (*Ulmus americana*)	10.1
17 - 21.3	channel	
21.42	elm (*Ulmus americana*)	<5
21.97	water oak (*Quercus nigra*)	22.0
22.16	sweetgum (*Liquidambar styraciflua*)	23.2
23.36	water oak (*Quercus nigra*)	55.1
23.40	water oak (*Quercus nigra*)	11.8
25 - 81	pasture	
82.56	oak (*Quercus spp.*)	<5
84.16	willow oak (*Quercus phellos*)	7.8
84.50	willow oak (*Quercus phellos*)	25.5
95.72	overcup oak (*Quercus lyrata*)	35.2

Largest tree in vicinity of sample transect:
sweetgum (*Liquidambar styraciflua*) 109.6

	Basal area	Number
oak	0.5621	11 (90% basal area, 61% of stems)
beech	0.0080	4
elm	0.0090	2
sweetgum	0.0422	1
Total	0.6213	18

Transect area: 70.84 m^2 (excludes channel and pasture)

Basal area: 0.00877 m^2/m^2
Stem density: 0.25 m^{-2}

FIELD EVIDENCE OF SEDIMENTATION REGIMES

Upper site

An auger sample of the soil/sediment at the upper site revealed no clear evidence of distinct sedimentary episodes. To a depth of 60 cm the alluvial soil was a dark yellowish brown (10YR 4/6) sandy loam with moderate fine to medium subangular blocky structure. From 60-85 cm the material was similar, but with an olive brown (2.5Y 4/4) color. From 85 to 200 cm the structure is similar, but the texture finer (silty clay loam). From 85-120 cm the color is light olive brown (10YR 5/6). Below 120 cm the color is dark yellowish brown (10YR 4/6) matrix and grayish brown (10YR 5/2) and strong brown (7.5YR 5/8) mottles. The mottling is consistent with a fluctuating water table in this zone. Under the microscope, samples from the horizons below 85 cm depth show evidence of clay films coating ped faces and grains. This suggests translocation of clays within the soil profile.

There is considerable evidence of recent, rapid aggradation in this area. A small, intermittent tributary draining across the floodplain is downcutting near its mouth, with a nickpoint migrating upstream across the floodplain. This could occur due to a lowering of base level or to rapid accretion of the floodplain surface. The former is not possible (base level has been raised since 1976 by the lake), so the morphology of this feature suggests aggradation.

The low water of 1999 presented problems for some parts of this study, but revealed clear evidence of a previous floodplain surface exposed in the stream banks. There is a visually obvious stratigraphic discontinuity, and a distinct root layer and some *in situ* trees rooted in the buried surface clearly identify it as a former floodplain surface. By measuring the vertical distance from the floodplain surface to this buried surface along the stream bank the vertical accretion can be measured. There were five measurements along the right and six along the left bank. In every case measurements were made adjacent to a tree, buried and subsequently exposed, rooted in the former surface so that the latter could be definitively identified. The thickness of alluvium burying the old surface varies from 163 to 190 cm on the right bank (mean = 1.7 m). On the left bank, measurements range from 99 to 170 cm (mean = 1.4 m), but the bank top in this area is 20 to 30 cm lower than the general floodplain elevation. It seems safe to say that about 1.5 m of sediment have accumulated here. Given the small size of some trees rooted in the former surface, the aggradation clearly postdates the construction of Loco Dam.

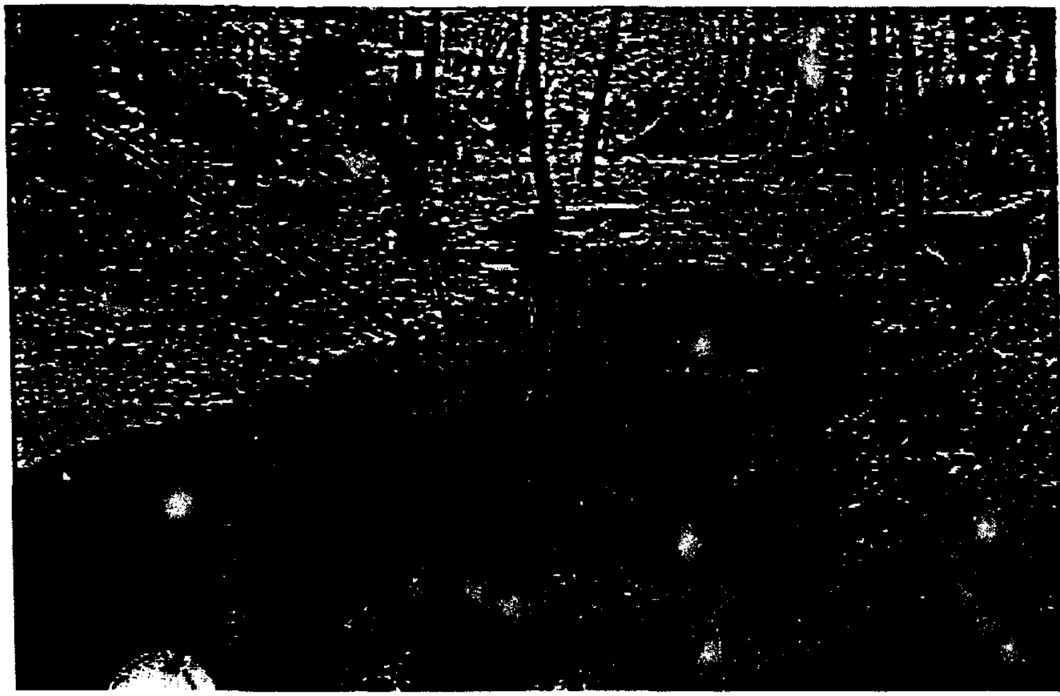
An abandoned channel meander which holds standing water except after extended drought exists at this site. The "plugs" separating this feature and the active channel contain several large trees (DBH of 28 to 41 cm), indicating that the channel change predates Lake Nacogdoches. This is confirmed by 1969 aerial photography which show both channels. The same pattern of burial of a previous floodplain surface described above is visible in the banks of the cutoff channel.

Field evidence here shows clear evidence of accelerated sedimentation in the BHF associated with the impoundment of Bayou Loco.

Middle site

An augering of the floodplain on the left side of the middle site showed dark yellowish brown (10YR 4/6) sandy loam to a depth of 60 cm. Below this gley mottles appear, with a mixture of loam and sandy clay loam from 60 to 77 cm, and sandy clay loam from 77 to 98 cm. Below this level the matrix is gleyed, with a dark grayish brown (10YR 4/2) color and a silty clay texture to 124 cm. There is a 10 cm thick layer (124 to 134 cm) of the same color, with a mixture of loam and sandy clay loam, with quite distinct mottles of grayish brown (10YR 5/2) and dark brown (7.5YR 3/4). From 134 to 185 cm there is a mottled grayish brown (10YR 5/2) and reddish yellow (7.5YR 5/8) mixture of silty clay and clay loam. The clay becomes harder and firmer with depth. In general, this profile is consistent with an alluvial sequence minimally modified by pedogenesis, and subject to fluctuating water tables.

The general channel morphology at this site suggests downcutting. The channel is entrenched below a layer of erosionally-exposed roots which may represent the former channel bank (Fig. 6). There is some exposure of tree roots and basal flares on trees on the left floodplain. This indicates some erosional scour. The floodplain is also characterized by tilted tree trunks (Fig. 6). This has been shown to typify the degradation phases of alluvial channels, when downcutting in the channel leads to slumping of the nearby alluvium and subsequent tilting of bottomland trees (Hupp and Simon 1991; Hupp and Osterkamp 1996).



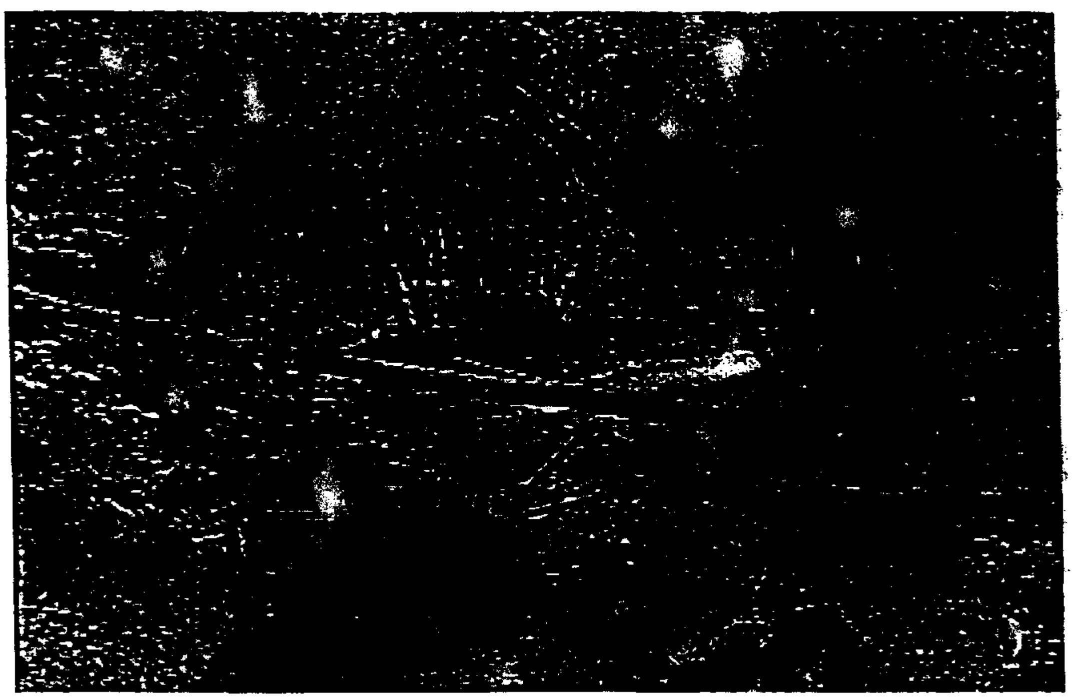


Figure 6. Photographs looking downstream (top) and upstream (bottom) from the middle site on Bayou Loco. A indicates the apparent level of the pre-entrenchment surface. B shows tilted trees characteristic of floodplains adjacent to a degrading channel.

Channel degradation downstream of dams is quite common. Despite the reduced and regulated flows, the very low sediment concentrations of the water released mean that the sediment transport capacity for a given flow is quite high. The scouring at the middle site is thus not unexpected, and in this vicinity there is clearly a reduced supply of sediment to the bottomland forests.

Lower site

Several sample augerings were taken at the lower site, as described in table 2. The left side of the channel is a vegetated point bar environment and is lower in elevation than the right side, where there is a cut bank. The alluvial soils on the left floodplain are generally consistent with an environment receiving deposition of material derived from upland erosion, as evidenced by the oxidized colors. Pedogenic development appears to be minimal. Given the water marks on trees, the flood debris evident on the floodplain surface, and the numerous crawfish towers and burrows, this area is saturated relatively often or for an extended period during a typical year. The generally oxidized colors in this environment suggests recent or rapid deposition during historic time.

There is no obvious pattern of either burial or exposure of bottomland trees, though no detailed dendrogeomorphic work has yet been conducted. Examination of aerial photographs from 1969, 1980, and 1996 shows no channel changes in the vicinity of the lower site and no visually obvious changes in the sedimentation regime.

Table 2. Floodplain soils at the lower site.

1. Upper floodplain, left bank.

Depth (cm)	Color	Texture	Other
0-40	dark yellowish brown 10YR 4/6	sandy loam & loam	Intensely bioturbated
40-80	dark yellowish brown 10YR 4/6	sandy clay loam	some gleying around root channels, 65-80 cm
80-168	dark yellowish brown 10YR 4/6; gray (10YR 5/1) mottles & yellowish red (5YR 5/8) streaks & mottles	sandy clay	Gray mottles mainly associated w/ organic features; redder mottles increase w/ depth
168-200	dark yellowish brown (10YR 4/6); gray (10YR 5/1) mottles & yellowish red (5YR 5/8) streaks & mottles	sandy clay	Gray mottles not necessarily associated w/ organic features; redder streaks/mottles more common than above.

2. Lower floodplain, left bank.

Depth (cm)	Color	Texture	Other
0-160	dark yellowish brown (10YR 4/6); yellowish red (5YR 4/6) mottles; very dark greyish brown (10YR 3/2) streaks and mottles	sandy loam to sandy clay loam	Mottling increases w/ depth; texture is sandy clay loam in lower portion
160-227	very dark greyish brown (10YR 3/2); yellowish brown (10YR 5/6) mottles	sandy clay loam	
227 - ?	Grey (10 YR 5/1); dark brown (10 YR 3/3) mottles	silty clay loam	

3. Right bank, just behind natural levee.

Depth (cm)	Color	Texture	Other
0-28	dark yellowish brown (10YR 3/6)	silty clay loam	
28-206	Yellowish brown (10 YR 5/8); grayish brown (10YR 5/2) mottles	silty clay loam	Mottling increases with depth; charcoal fragments evident below 128 cm
206-245	grayish brown (10YR 5/2); Yellowish brown (10 YR 5/8) mottles	silty clay loam	
245-287	dark yellowish brown (10YR 4/4)?	silty clay loam	Very wet; color due to mixing gray, brown

Other sites

Field observations at other sites provide some additional insight into trends at Bayou Loco. Well upstream of the upper site, the channel is deeply incised with apparently stable banks. There are some sandy surficial deposits on the upper banks apparently deposited by floods, but no true BHF environments were observed.

Other tributaries of Lake Nacogdoches (New Caney Creek and Little Loco), observed from Highway 21 near the lake, show clear evidence of recent deposition. Buried trees are evident, as were muddy veneers on the floodplain surface. Just below the Loco Dam spillway, there has been obvious channel degradation and narrowing, consistent with observations at the middle site a short distance downstream.

Recent floodplain sedimentation is evident at several locations between the middle and lower sites, in the form of sandy surface splays evident in Spring 1999. The channel is somewhat incised in this general area, with relatively high (approximately 2 m), steep banks. However, there is no obvious evidence (such as exists at the middle site) to suggest that any entrenchment is a recent, post-dam phenomenon.

On lower Bayou Loco, downstream of the lower monitoring site and between Highway 7 and the confluence with the Angelina River, several treethrows and grab samples show oxidized soil similar to that of the lower study site. There is no obvious pattern of root crown burial. Some trees are buried, but many root crowns and basal flares are visible on trees of all ages. Three young trees (DBH $\leq$ 5 cm) were found to have their bases buried by 4 to 10 cm of alluvium. Some recent flood deposits were evident in late winter 1999; these were thin (1 mm to 1 cm), discontinuous, and mixed with organic litter.

SUMMARY AND RECOMMENDATIONS

Summary

The effects of Loco Dam and Lake Nacogdoches on sedimentation retention in bottomland hardwood forests appears to be localized. At the upper site, the impoundment has promoted accelerated sedimentation. Vertical accretion has proceeded to the point that flooding has been reduced. It thus appears that the accelerated aggradation here is unlikely to continue.

At the middle site just downstream of the dam there has been some channel narrowing and degradation. At the lower site about 16 km downstream from the dam there is no evidence of sediment starvation. Turbidity is generally higher at this downstream site than in the water entering the lake, as reflected in data from the upper site.

This summary must of course be regarded as preliminary, pending further data collection, analysis, and interpretation.

Recommendations

Drought and low flow conditions have limited the utility of the instrumental (Starflow and OBS) measurements. However, given the maintenance requirements and erratic performance of these instruments, the TWDB may wish to consider eliminating them from the study. The vast majority of personnel field time is spent downloading data, changing batteries and dessicants, and troubleshooting, repairing, and replacing equipment. The useful data obtained from these instruments is likely to be disproportionately low compared to the manpower and time expenditures even under the best of circumstances.

One or two years of data are unlikely to be representative of conditions on Bayou Loco, be those years wet, dry, or "normal." The financial and manpower resources would likely be better served to concentrate on stratigraphic, dendrogeomorphic, and other techniques which offer more promise of an historically integrated picture of trends in the study area.

An alternative is to leave the instruments deployed and ready for activation during or in anticipation of high flow events, but not to attempt continuous data recording.

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