Geomorphology 201 (2013) 148–156

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Human-induced stream channel abandonment/capture and filling of floodplain channels within the Atchafalaya River Basin, Louisiana

Daniel E. Kroes [a,*], Thomas F. Kraemer [b]

[a] United States Geological Survey, Louisiana Water Science Center, 3535 S. Sherwood Forest Blvd, Suite 120, Baton Rouge, LA 70816, USA
[b] United States Geological Survey, National Center, 12201 Sunrise Valley Dr., MS 430, Reston, VA 20192, USA

ARTICLE INFO

Article history:
Received 20 December 2012
Received in revised form 13 June 2013
Accepted 15 June 2013
Available online 29 June 2013

Keywords:
Induced channel abandonment
Flow capture
Access channel
Hydraulic damming

ABSTRACT

The Atchafalaya River Basin is a distributary system of the Mississippi River containing the largest riparian area in the lower Mississippi River Valley and the largest remaining forested bottomland in North America. Reductions in the area of open water in the Atchafalaya have been occurring over the last 100 years, and many historical waterways are increasingly filled by sediment. This study examines two cases of swamp channels (<85 m^3/s) that are filling and becoming unnavigable as a result of high sediment loads and slow water velocities. The water velocities in natural bayous are further reduced because of flow capture by channels constructed for access. Bathymetry, flow, suspended sediment, deposited bottom-material, isotopes, and photointerpretation were used to characterize the channel fill. On average, water flowing through these two channels lost 23% of the suspended sediment load in the studied reaches. Along one of the studied reaches, two constructed access channels diverted significant flow out of the primary channel and into the adjacent swamp. Immediately downstream of each of the two access channels, the cross-sectional area of the studied channel was reduced. Isotopic analyses of bottom-material cores indicate that bed filling has been rapid and occurred after detectable levels of Cesium-137 were no longer being deposited. Interpretation of aerial photography indicates that water is bypassing the primary channels in favor of the more hydraulically efficient access channels, resulting in low or no-velocity flow conditions in the primary channel. These swamp channel conditions are typical in the Atchafalaya River Basin where relict large channel dimensions result in flow velocities that are normally too low to carry fine-grained sediment. Constructed channels increase the rate of natural channel avulsion and abandonment as a result of flow capture.

Published by Elsevier B.V.

1. Introduction

Intentional flow redirection and channelization have been a component of floodplains since humanity began irrigating crops and draining land for farming in floodplains. Remote and vast swamps and marshes were typically unaffected by channelization until the advent of excavation machinery (Kroes and Hupp, 2010; Schenk et al., 2011). Canals were dug to float timber out of high value stands in swamps like the Atchafalaya River Basin that were too wet to be drained or for railways to be installed. In the twentieth century, where reserves of oil and gas were discovered in deep swamps, exploration and development of that resource resulted in the excavation of numerous canals that were large enough to barge in drilling equipment. Pipeline canals were dug to move products into and out of the swamps as well as across rivers. Although smaller examples of unintentional flow redistribution exist in many locations, numerous large-scale unintentional, natural-channel abandonment resulting from access canals can be seen in aerial imagery (Google Inc., 2013) with the greatest density in the Atchafalaya River Basin, USA. Globally, aerial imagery appears to show this type of channel abandonment to a lesser degree in the wetlands of Centla and Terminos, Mexico, and the Niger River delta, Nigeria.

The Atchafalaya River Basin (hereafter the Basin) lies entirely within the Coastal Plain physiographic province (Hunt, 1967) and is the largest remaining forested wetland in the United States with an area of about 5700 km^2. This floodplain is typically inundated for several months annually. Sediment accretion rates on these floodplains could be among the highest of any physiographic province in the U.S. (Hupp, 2000). In 1927, the Mississippi River (hereafter Mississippi) experienced its flood of record and caused the cross-sectional area of the Atchafalaya River (hereafter Atchafalaya) to increase, resulting in its capturing greater amounts of flow from the Mississippi. The percentage of flow going down the Atchafalaya

Abbreviations: GIWW, Gulf Intracoastal Water Way; BP, Big Bayou Pigeon; P, Bayou Postillion; D2RB, Distributary 2 Right Bank; D3RB, Distributary 3 Right Bank; BLR, Atchafalaya River at Butte La Rose gage.

* Corresponding author. Tel.: +1 225 298 5481; fax: +1 225 298 5490.
E-mail address: dkroes@usgs.gov (D.E. Kroes).

0169-555X/$ – see front matter. Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.geomorph.2013.06.016

continued to increase, and in 1963 the Old River Control Structure was completed in order to control the flow leaving the Mississippi into the Atchafalaya (Barry, 1997; Reuss, 2004).

Prior to 1850, the Basin existed as a back swamp of the Mississippi located between the Teche and the St. Bernard delta lobes (Kolb and Van Lopik, 1958). As such, the Basin had limited connection to the Mississippi and only received significant sediment during large floods of the Mississippi (Frazier, 1967). Because of this isolation from sediment, the Basin contained ~10% of its area as open water. After 1850, the Basin was permanently connected to the Mississippi and has experienced substantial amounts of sediment deposition leading to the filling of numerous channels (bayous), lakes, and backswamp areas within the last 80 years (Roberts et al., 1980; Tye and Coleman, 1989; McManus, 2002). Between the late 1800s to the mid-1950s, open water area decreased from 490 to 290 km^2; and from the 1950s until 2010, open water decreased from 290 km^2 to 190 km^2 (Hale et al., 1999; Y.C. Allen, U.S. Army Corp of Engineers, written communication, 2010). Much of this loss was from channels that accessed areas of historic, recreational, and economic significance. As upstream channels and floodplains filled and became hydraulically abandoned or isolated, sediment deposits begin to fill areas farther south where the Basin is subjected to prograding delta processes (Tye and Coleman, 1989). Water flow and sediment delivery in these swamps have been heavily modified by the construction of channels to enable movement of materials and people. Although it is largely unknown what the flow patterns could have been historically, the floodplain currently (2013) experiences flow reversals in many channels and across the floodplain, large areas of near-zero water velocities, and water with high sediment concentrations entering open water areas and deep swamps.

The hydrologic cycle on riparian floodplains has four phases: rising, peak, falling, and low-water. During the rising phase, the hydraulic gradient extends from the river to the floodplain, and water with high sediment content and typically a higher flow velocity enters the floodplain laterally. Once the floodplain and the river waters reach the same elevation, a peak phase occurs where flow is no longer lateral but downstream. If the river stage is above bankfull during peak phase, water could be exchanged bilaterally between the floodplain and the river channel as the channel crosses the river valley. During the falling phase, the hydraulic gradient extends from the floodplain toward the river. Water velocities are slow, and sediment concentrations are low. In a vast floodplain swamp like the Basin, water leaving the swamp could have sediment concentrations <10 mg/l. The floodplain is often dry during low-water phase, although local ponding could occur. Rainwater could also create flows that drain toward the river with low mineral sediment concentrations and high concentrations of dissolved organic material.

In the twentieth century, numerous large channels were constructed in the Basin to access oil and gas and for pipelines. These constructed channels likely changed the hydrologic patterns of the Basin and contributed to the abandonment of natural channels and the filling of deepwater habitats. These extra, constructed channels have contributed to a situation where the amount of water and sediment moving through the area does not have the flow velocity necessary to keep sediments in suspension and maintain the cross-sectional area of channels. This could have contributed to the abandonment and filling of swamp channels (natural channel branches of an anastomosing river system that go through a swamp forest). These channels are neither true distributaries nor tributaries to the main river because all flows come from and go back into the primary channel, often through discontinuous channels. The primary channel is the main channel of flow that other channels converge into or diverge from.

Channel avulsion (rapid whole-channel change) and abandonment (slower changing of channels where one channel expands and another constricts and becomes blocked) are relatively common occurrences in stream systems that have high sediment loads. The bulk of research on this topic has been conducted in braided, arid systems (Field, 2001; Ashworth et al., 2004), in humid systems in relation to channelization (Pierce and King, 2007; Hupp et al., 2009; Kroes and Hupp, 2010), and the Mississippi River oxbow lakes (Rowland et al., 2005).

1.1. Study sites

During 1984–2007, the Atchafalaya received on average 35% of the sediment and 25% of the discharge of the Mississippi (Arthur Horowitz, U.S. Geological Survey, written communication, 2010) as well as the entire flow of the Red and Black Rivers, in effect providing for the largest, although indeterminate, watershed in the United States. The Basin traps 4.3 billion kg of sediment annually, of which ~10% is organic material and thus a globally important carbon sink (Hupp et al., 2008). Deltas forming in the Basin and at the two Atchafalaya outlets to the Gulf of Mexico are the primary locations of land growth along the eroding and subsiding coastline of Louisiana (Couvillion et al., 2011). The average annual air temperature in the Basin is 20.1 °C and has an average annual precipitation of 1.56 m (U.S. Climate Data, 2013). The average discharge of the Atchafalaya from 1984 to 2011 was 6500 m^3/s measured by the U.S. Army Corps of Engineers gage (03045) at Simmesport, LA (U.S. Army Corp of Engineers, USACE, 2013).

Two typical examples of the channel filling that occurs in this area of the Basin are Big Bayou Pigeon and Bayou Postillion (Fig. 1). These two bayous were chosen to determine whether commonalities exist between two seemingly unrelated channels. They differ in orientation, flow patterns, cross section, and the area of swamp drained or filled; however, both of these channels demonstrate the effect of flow capture by access canals that have greater hydraulic efficiency than the natural channels and facilitate sediment deposition conditions associated with the prograding delta front. The 170-km^2 Bayou Pigeon/Postillion area contains ~2 km of dredged, constructed channels (>30 m in width) for every 1 km of natural channel (>30 m in width) (Google Inc., 2013). Bayou Postillion has filled, been abandoned, been dredged open, and has started to fill again; the same fate is likely in the near future for Big Bayou Pigeon as well.

Bayou Pigeon directly connects to the Gulf Intracoastal Water Way (GIWW), the primary conduit of water and sediment to the east side of the Basin. Big Bayou Pigeon diverges from Bayou Pigeon 5 km downstream of the GIWW. Bayou Pigeon continues past the divergence as Little Bayou Pigeon (Fig. 2). Normally all of these bayous flow away from the GIWW. In the Big Bayou Pigeon study reach, two access canals were excavated (30–50 m in width, 2–3 m in depth). The upstream access canal (D2RB) was begun prior to 1968 and was finished prior to 1978 (USGS, 1969, 1980). The next access canal in the reach (D3RB; Fig. 2) was excavated between 1968 and 1978. Vegetation along the channel of Big Bayou Pigeon shows that the bayou has been decreasing in width and depth for at least 20 years. As the channel narrowed and sediment was deposited on the channel edges, the pioneer species willow (*Salix nigra*) and cocklebur (*Xanthus* sp.) became established along its banks in cohort bands as the channel narrowed. At the time of study in 2010, the oldest cohort of willow was18–20 years old, and beaver suppressed the channel edge saplings for an indeterminate amount of time. As willow and cocklebur become established on banks and bars, they increase the resistance of flow in the primary channel (McKenney et al., 1995) and increase the relative hydraulic efficiency of the access channels. Over the last 10 years (2002–2012), navigation in the upstream portions of Big Bayou Pigeon during mid- to low-river stages has become limited to boats requiring <0.3 m of depth. The smallest cross section of Big Bayou Pigeon exists just downstream of D3RB (4 m^2). This appears to be the location of an imminent channel plug and abandonment.