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In cooperation with the
West Tennessee River Basin Authority

Shoals and Valley Plugs in the Hatchie River Watershed

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SIGNIFICANT FINDINGS

- Some incised, human-modified tributaries deliver excess sand that forms shoals in the Hatchie River.
- Shoals are associated with meander cutoffs and may mark locations at which valley plugs could block the Hatchie River.
- Tributaries blocked by valley plugs do not contribute excess sand, whereas channels restored through valley plugs contribute the most excess sand.

A tributary in natural condition, Lagoon Creek near Brownsville, Tennessee.

INTRODUCTION

Agricultural land use and gully erosion have historically contributed more sediment to the streams of the Hatchie River watershed than those streams can carry. In 1970, the main sedimentation problem in the watershed occurred in the tributary flood plains. This problem motivated channelization projects (U.S. Department of Agriculture, 1970). By the mid-1980's, concern had shifted to sedimentation in the Hatchie River itself where channelized tributaries were understood to contribute much of the sediment. The Soil Conservation Service [Natural Resources Conservation Service (NRCS) since 1996] estimated that 640,000 tons of bedload (sand) accumulates in the Hatchie River each year and identified roughly the eastern two-thirds of the watershed, where loess is thin or absent, as the main source of sand (U.S. Department of Agriculture, 1986a).

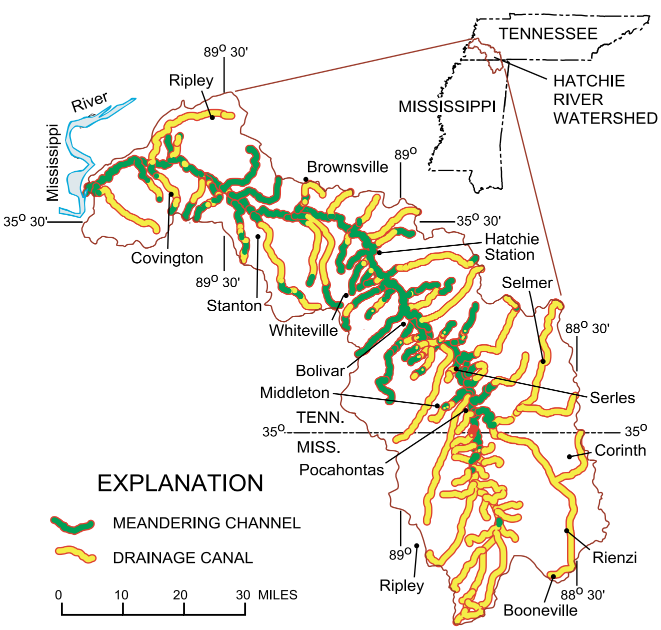


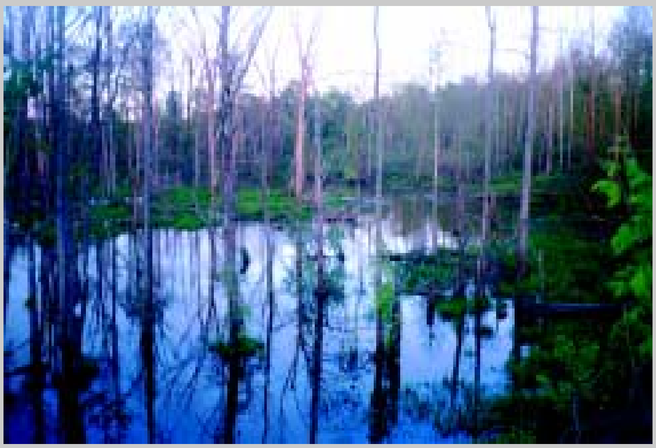
Figure 1. Location and channel network of the Hatchie River watershed in Tennessee and Mississippi.

The U.S. Geological Survey (USGS), in cooperation with the West Tennessee River Basin Authority (WTRBA), conducted a study of sediment accumulation in the Hatchie River and its tributaries. This report identifies the types of tributaries and evaluates sediment, shoal formation, and valley-plug problems. The results presented here may contribute to a better understanding of similar problems in West Tennessee and the rest of the southeastern coastal plain. This information also will help the WTRBA manage sedimentation and erosion problems in the Hatchie River watershed.

The source of the Mississippi section of the Hatchie River is in the sand hills southwest of Corinth, Mississippi (fig. 1). This section of the Hatchie River flows northward in an artificial drainage canal, gathering water from tributary streams that also are channelized. The drainage canal ends 2 miles south of the Tennessee State line.

The Tennessee section of the Hatchie River winds north and west in a meandering natural channel to the Mississippi River. Although most of the Hatchie River tributaries are also drainage canals, the river's main stem has kept most of its natural character. The Hatchie River flows through a wide valley bottom occupied mostly by riverine wetland. Historically, the valley bottom has supported hardwood forests.

Since publication of the first Hatchie River report (U.S. Department of Agriculture, 1970), the channel of the river has become shallower, and flooding has increased (U.S. Department of Agriculture 1986b). These wetter conditions inhibit growth of hardwoods and lead to premature hardwood mortality. The NRCS has predicted that despite efforts to control erosion in the uplands, most of the valley-bottom forest will die:



"...swamping may be so prevalent as to change most of the Hatchie River Basin flood plain into a marsh condition, with only remnants of the present bottomland hardwood timber remaining." (U.S. Department of Agriculture, 1986b)

Loss of channel depth has been concentrated in short reaches near tributary mouths. At the mouths of Richland, Porters, Clover, and Muddy Creeks, navigation has become difficult for recreational users (Johnny Carlin, West Tennessee River Basin Authority, oral commun., 1998).

As the low-gradient alluvial system of the Hatchie River accumulates sediment, another common outcome has been the formation of valley plugs, areas where "channels are filled with sediment, and all the additional bedload brought downstream is then spread out over the flood plain until a new channel has been formed" (Happ, 1975). Valley plugs typically form where the slope of a sand-laden tributary decreases downstream, or where the tributary joins its parent stream (Happ and others, 1940; Diehl, 1994, 1997; Smith and Diehl, 2000).

Woody debris piled against tree during low overbank flood on the Hatchie River at Pocahontas, Tennessee.

METHODS

Analysis of selected 1:24,000 USGS topographic maps covering the Hatchie River watershed revealed many details of past and present stream characteristics. Photo-revised editions of 1:24,000 maps show natural and artificial changes in streams. Winding stream courses, forested or swampy flood plains, and secondary channels that flow parallel to the main channel indicate little or no stream modification. Straight streams between isolated remnants of meandering channels typically indicate drainage canals. Streams that meander, but to a lesser degree than natural streams, have been partly straightened, and commonly are incised. Flood plains with straight intermittent streams converging on a straight channel, and with little or no forest on the flood plain, imply that the main channel is incised enough to provide adequate drainage for farming. Areas with multiple, sometimes discontinuous stream lines, abandoned sections of drainage canals, and extensive swamps and ponds mark likely locations of valley plugs.

Although map analysis of the Hatchie River watershed suggested likely excess-sand-producing tributaries, this analysis alone could not be used to confirm current channel problems or to rank their severity. Field reconnaissance by boat and on foot revealed features that appear indistinctly or are not present on maps and in aerial photographs.

Field reconnaissance focused on indicators of channel stability or instability, and on valley plugs. Various features of the Hatchie River channel were observed – the width of the channel; large and small secondary channels entering and leaving the main channel; signs of bank instability such as bank height, bank steepness, and the freshness of failure scarps; fallen trees and woody debris; the size and material of point bars; and crevasses in levees bordering the channel. Several valley plugs in the Hatchie River watershed were explored by boat or on foot.

Depth profiles were produced for more than half the Hatchie River main channel, from Wolf Pen Road near Pocahontas downstream to a point near Stanton (figs. 1 and 2). Point-depth measurements were taken along the thread (the line of fastest flow and converging surface currents) of the river every 15 seconds when traveling by motorboat and every 30 seconds when canoeing. The thalweg (the line of deepest water) is near the thread along most of the channel, but the generated depth profile represents neither average depth nor thalweg depth. The raw depth profile was adjusted to reflect depth below the tops of point bars, scroll bars, and natural levees. This adjusted depth, called "channel depth" in this report, provided a common reference to easily observable features, independent of the current river stage. A smoothed average of several depth measurements along the profile shows the location of substantial shoals. In this report, "shoals" are defined as points where the depth decreases going downstream, and the "depth of shoaling" is defined as the amount by which the average depth decreases.

Floating debris forms a raft across the Hatchie River main channel near Serles, Tenn.

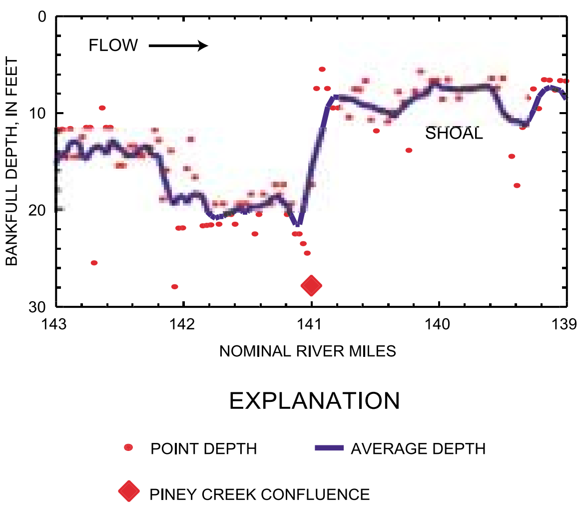


Figure 2. Depth profile of the Hatchie River bed at Piney Creek, in Tennessee.

GEOMORPHIC CONDITION OF THE HATCHIE RIVER

Six major shoals and four minor shoals were identified on the main stem of the Hatchie River at tributary mouths (fig. 3). Shoals (and other indicators of channel instability) are concentrated at the mouths of a few incised modified tributaries. The depth of shoaling ranged from 2 to 4 feet at the minor shoals to 8 to13 feet at the major shoals (fig. 3). At the mouth of Piney Creek, for example, the bed of the Hatchie River rises from about 21 feet below the bank tops upstream to about 8 feet below the bank tops downstream (fig. 2). In distinct shoals at the mouths of tributaries carrying excess sand, the depth decreases abruptly by more than one-sixth of the upstream depth and by more than 2 feet. Smaller depths of shoaling are difficult to distinguish from the background of constantly changing river depth. At the upstream end of a shoal, the slope of the water surface increases. Despite the shallower depth, flow is faster. The irregular shallow bed traps large floating debris such as logs and branches in rafts and jams.

Shoals are associated with signs of channel instability. In the reach of the Hatchie River with depth measurements, only 10 meander cutoffs have formed since the first editions of topographic maps (generally based on 1947 photographs) were printed. Of these 10 cutoffs, 5 are clustered in the shoal reach below the mouth of Piney Creek. Secondary channels commonly exit the Hatchie River above shoals, and return below, or cut across meander necks within shoals.

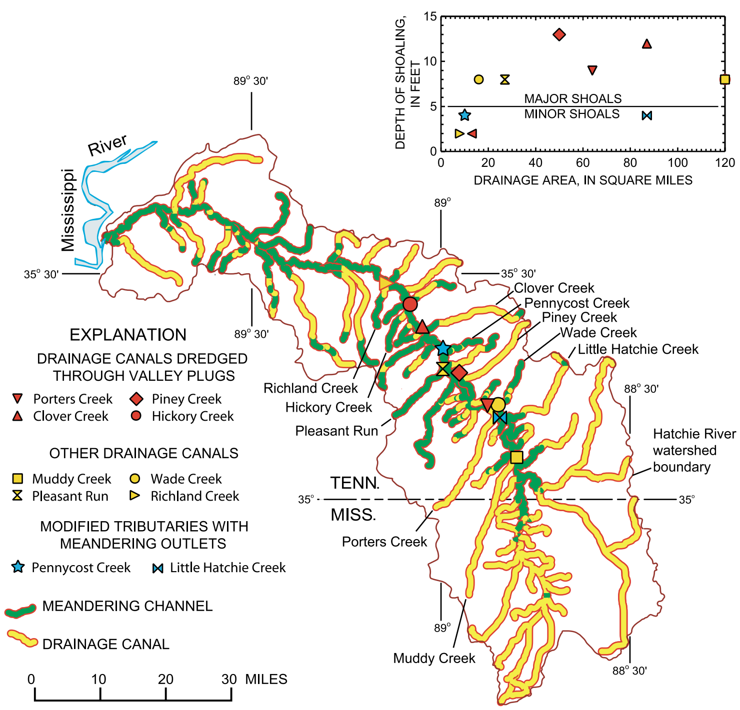


Figure 3. Shoals of the Hatchie River and drainage area of shoal-producing tributaries.

Currently, shoals are located at mouths of sand-laden tributaries and in reaches of the Hatchie River and tributary canals with lower than usual slope–the same settings in which valley plugs typically form. Within the channel of the Hatchie River away from tributary confluences, shoals also are associated with the entrances to secondary channels, points where flood flow divides between the main channel and a secondary channel. Return flow from these secondary channels is associated with deepening of the main channel.

At least one, and probably two valley plugs have formed in the main stem of the Hatchie River. A valley plug that formed upstream from the mouth of Brush Creek in the channelized section of the Hatchie (fig. 4) grew upstream to cover about 4 miles of the Hatchie River bottoms with ponded swamp (Larry Smith, Wolf River Conservancy, oral commun., 1999). The drainage canal was re-dredged through the valley plug in 1999. In the mid-1970's, a cutoff channel was dredged past the mouth of Piney Creek to relieve flooding caused by channel aggradation that verged on formation of a valley plug. Before 1947, a straight channel was dynamited past the mouth of Hickory Creek. The choice of blasting rather than dredging along the natural channel alignment suggests a high degree of aggradation, possibly a valley plug.

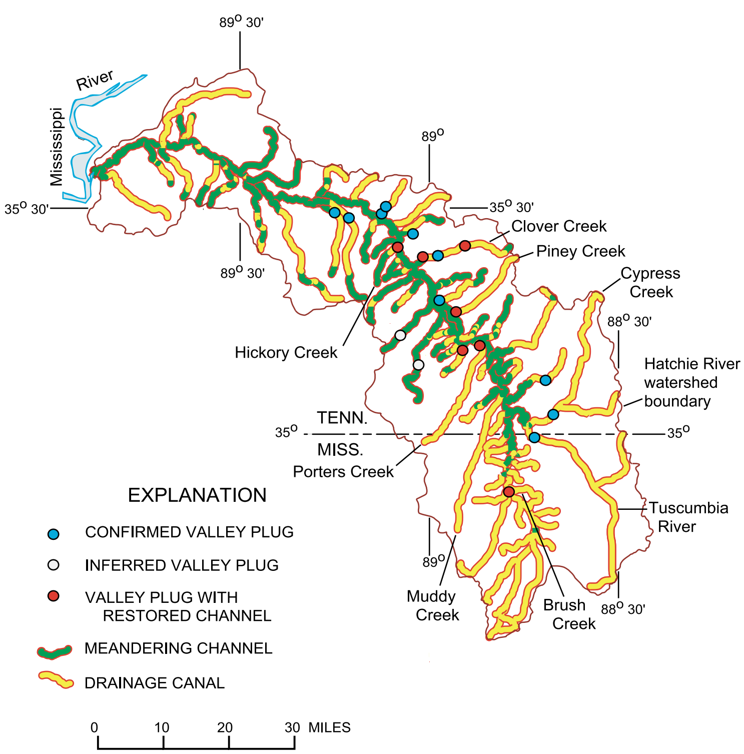


Figure 4. Locations of valley plugs in the Hatchie River and its tributaries.

Sand-laden tributary, Muddy Creek, near Hatchie Station, Tennessee.

Typical features of current valley plugs in Hatchie River tributaries include: a flat, sandy bed decreasing in depth as the valley plug is approached from upstream; multiple small channels draining flow from the main channel; a woody debris accumulation spanning the main channel and infilled with sediment; a transition to a central section of shallow ponds and silt deposition; and, at the downstream end of the plug, an area of convergent, confluent flow paths (Happ and others, 1940; Diehl, 1994, 1997). Some valley plugs end in a deep, narrow channel that has recovered some of the characteristics of natural channels (Smith and Diehl, 2000).

Tributaries are grouped into four classes on the basis of their channel characteristics and the presence or absence of a shoal downstream of their confluence with the Hatchie River (fig. 5). These classes are:

1. natural tributaries,
2. modified tributaries without shoals or valley plugs,
3. tributaries associated with shoals in the Hatchie River, and
4. tributaries containing valley plugs.

Where a tributary watershed includes more than one type of channel, classification is based on the downstream section of the main stem channel. Within watersheds of tributaries associated with shoals, sub-watersheds that drain into sediment retention ponds and valley plugs were separately evaluated and added to the valley-plug category. Hickory Creek (fig. 3), which is associated with a small shoal and also contains a valley plug near its mouth, was grouped with other shoal-associated tributaries.

Natural stream channels are small in the West Tennessee landscape relative to the rest of the eastern United States (Turrini-Smith and others, 2000). Since their meandering channels are about twice as long as the length of the valleys they occupy, natural channel slopes are half the slope of their own valleys. Sand transport increases with slope, width, and depth (Vanoni, 1975), and these three variables are low in natural streams of the Hatchie River watershed, suggesting that natural tributaries have little capacity to transport sand to the Hatchie River. Frequent overbank flooding and the deposition of substantial natural levees are typical. Shoals were not found at the mouths of natural tributaries, some of which enter the Hatchie River at unusually deep pools.

Many of the drainage canals in the Hatchie River watershed do not have shoals at their mouths. Drainage canals in the western third of the watershed drain an area underlain by silty loess, where little sand is available for erosion (U.S. Department of Agriculture, 1970), and therefore, lack shoals. Other drainage canals are not associated with identifiable shoals in the Hatchie River despite having erodible sandy subsoils exposed over much of their watersheds.

Channels of drainage canals and incised tributaries associated with shoals in the Hatchie River are larger and steeper than channels of natural streams having the same drainage areas. The width and depth of tributary channels associated with shoals are large compared to natural streams, and the beds of these channels are wide, flat, and covered with sand bars. Tributaries associated with shoals are straight or nearly straight, so their channel slopes approach the valley slope; bed slopes observed in these tributaries are high near the Hatchie River.

Porters Creek (fig. 4) provides an example of the importance of channel slope. The downstream section of the Porters Creek canal filled completely with sediment in the first winter after the canal was constructed (U.S. Department of Agriculture, 1981). Filling occurred in the downstream section of the canal because its slope is about the same as the valley slope of the Hatchie River (0.0004), while the upper

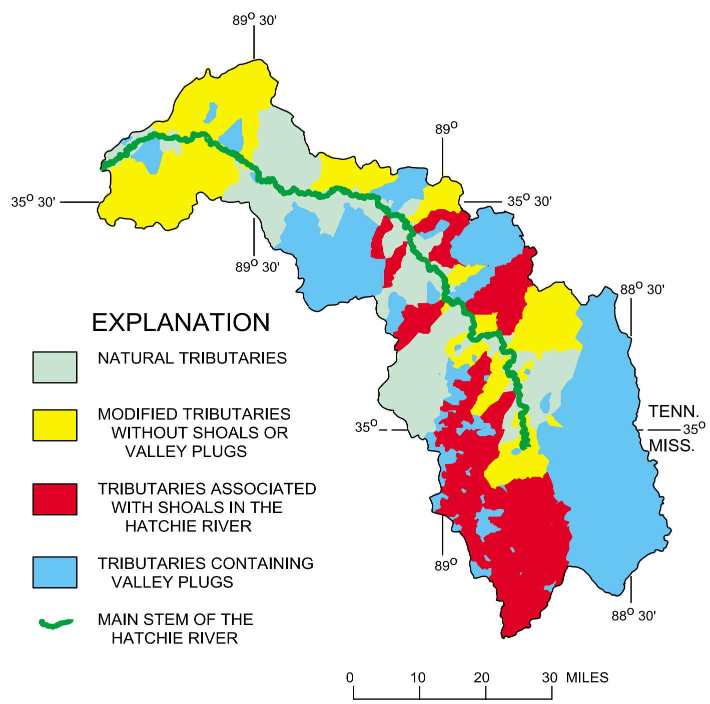


Figure 5. Geomorphic conditions in the Hatchie River watershed.

Upstream end of the valley plug on the Tuscumbia River at the Mississippi-Tennessee State line.

sections of the canal have the much higher slope of the Porters Creek valley (0.0012), nearly double the maximum stable slope (U.S. Department of Agriculture, 1981).

Watersheds of tributaries associated with shoals contain areas of easily eroded soils such as Smithdale, Lexington, Ruston, Eustis, Luverne, and Providence that formed in and above poorly consolidated marine sands of the Claiborne and Wilcox Formations and the McNairy Sand. Areas of these soils mapped as severely eroded, and steep areas without an erosion rating, typically contain gullies. Although most of these areas are no longer used for agriculture, some gullies continue to erode.

Valley plugs block the channels of several tributaries (fig. 4), most of which are deeply incised canals with abundant sand on the bed, similar to those tributaries that are associated with confluence shoals in the Hatchie River main stem. With the exception of Hickory Creek, however, shoals are not found at the confluences of these plugged tributaries with the Hatchie River. Deep pools in the Hatchie mark the mouths of some plugged tributaries.

In tributary valleys upstream from valley plugs, water stands just below the flood plain during base flow. Backwater slows the stream, allowing sand to accumulate on its bed. As a result, the valley plug grows upstream by accretion (Happ and others, 1940; Diehl, 1994; Smith and Diehl, 2000).

Some tributary channels have been reopened after being blocked by valley plugs—either by dredging along their original alignment, or by replacing with another maintained channel. The three deepest tributary-mouth shoals in the Hatchie River main stem are located at the mouths of such channels. In contrast to channelization of meandering tributaries, which has nearly ceased in recent years, dredging canals through valley plugs has continued through the period of this study. For example, in 1999 the Hatchie River drainage canal was re-dredged through a valley plug that blocked the canal upstream from the mouth of Brush Creek.

EFFECTS OF SEDIMENTATION IN THE HATCHIE RIVER WATERSHED

Bed elevations in the Hatchie River at the mouth of each tributary reflect the balance between the ability of the river to transport sand and the amount of sand available for transport. Downstream from a large tributary, the river carries more water and can transport more sand. If the tributary contributes little or no sand, then the river erodes its own bed below the tributary mouth, forming a pool. If the tributary adds balanced amounts of water and sand, then the river has about the same depth above and below the tributary mouth.

Some incised, modified tributaries carry so much sand that the river is unable to move all the sand away from the tributary mouth. Each shoal at a tributary mouth identifies that tributary as a substantial source of excess sand in the Hatchie River. The greater-than-natural channel width, depth, and slope in the outlets of shoal-producing tributaries, and the wide flat beds of loose sand, imply accelerated sand transport.

High bluff along Hatchie River showing sand formation.

Shoals and instability in the Hatchie River are concentrated in settings typical of valley plugs, and valley plugs have occurred in the Hatchie River main stem. Shoals are a less severe symptom of excess sediment than valley plugs; some may be precursors of valley plugs in the Hatchie River.

A section of the Hatchie River near Hatchie Station, Tennessee, which has been straightened.

Valley plugs have formed in several tributaries that receive more sand than they can transport to the Hatchie River. In tributaries, valley plugs typically form at the edge of the Hatchie River valley bottom where channel slope decreases. Except for the minor shoal below the former outlet of Hickory Creek, these plugged tributary canals lack shoals at their mouths. Sand carried by these tributary canals accumulates in the valley plug, with little if any sand reaching the Hatchie River. Thus, valley plugs mark tributaries that have the potential to contribute excess sand to the Hatchie River main stem.

By trapping sand, valley plugs in tributaries help alleviate flooding problems in the Hatchie River bottoms. Valley plugs concentrate sedimentation and flooding in the valley bottom of the plugged tributaries upstream from the Hatchie River bottoms. Sand that would otherwise contribute to excess-sediment problems in the Hatchie River promotes aggradation and flooding along the tributary. Conversely, when a canal is dredged through a valley plug, excess sand that would have accumulated near the upstream end of the valley plug is delivered to the Hatchie.

Canal dredging through valley plugs may be the dominant current cause of increased shoaling and flooding problems along the Hatchie River main stem. Shoals caused by canal restoration include the three largest shoals in the Hatchie River, and include those with the most indications of channel instability. Because valley plugs form where excess sand accumulates, plugged tributaries have the highest potential to deliver excess sand to the Hatchie. Dredging a canal through a valley plug mobilizes sand stored in the channel, delivers the sand downstream, and provides a path for further excess sand to follow. Problems of sedimentation and flooding then shift downstream from the tributary valley to the Hatchie River bottoms.

Upstream from Brush Creek, clearing, snagging, and dredging along a plugged canal reach in 1999 enabled excess sand from about 225 square miles of the upper Hatchie River watershed to travel downstream. Sand bars and woody debris produced a narrow, fast, irregular, shallow reach just downstream from the end of the dredged canal section. This sand will either accumulate into a new valley plug just below the downstream end of the maintained canal, or will be carried farther downstream, creating a long shoal. In either case, part of the Hatchie River downstream from the maintained reach will be subject to increased sand deposition and prolonged flooding.

If the amount of sand entering the Hatchie River is reduced, then the existing shoals may erode. Shoals likely existed at the mouths of the incised, sandy tributaries that are now plugged, but erosion of the river bed has eliminated most of these shoals (with the exception of the shoal at the mouth of Hickory Creek) after the source of excess sand was cut off by the valley plug. Likewise, the present shoals will probably begin to disappear gradually when tributaries stop delivering excess sand into them. As the Hatchie River channel deepens, the duration of overbank flooding will decline.

Re-dredged drainage canal, Hatchie River at the mouth of Brush Creek, Mississippi.

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Ponded swamp with dead hardwoods and live cypress.

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