ATTACHMENT 3

Written comment from National Ecological Foundation and J. Clark Akers, III, dated 30 June 2009

Written comment from Chester McConnell, dated 8 July 2009

Written comment from Jim W. Johnson, dated 10 July 2009

Written comment from Jim W. Johnson, dated 17 July 2009

Written comment from Richard Preston, President of Tennessee Ornithological Society, dated 22 July 2009

Written comment from Michael Butler, CEO of Tennessee Wildlife Federation, dated 22 July 2009

Written comment from Larry J. Smith, dated 30 June 2009

Memorandum For Record, Conversation with Tennessee Wildlife Resources Agency, dated 29 July 2009

National Ecological Foundation

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Andrew M. Akers
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30 June 2009

Col. Thomas P. Smith
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Dear Colonel Smith,

It is my understanding that a meeting was held on June 23 in Milan to discuss channel modifications within the Obion-Forked Deer Basins. I assume this meeting is merely a discussion of ideas for future drainage activities by the Corps of Engineers and/or the Tennessee Department of Conservation and Environment (TDEC). I was not present at this meeting but wish to advise parties that the National Ecological Foundation has a vested interest in the drainage activities within this basin and to remind everyone that those activities are governed by a Federal Court Agreed Order (NEF v. Alexander). We will reserve our comments until a later time when/if any project proposals are developed.

I was a plaintiff in the Federal lawsuit of 1970, Akers v. Resor. This suit was settled by Consent Decree in 1985. A large part of the Consent Decree spells out the boundaries and order of purchase of the 32,000 acres of mitigation to be obtained by the Corps and turned over to the TWRA in fee simple. One of the conditions which had to be met to satisfy public law 93-251 were letters from the Army, the Dept. of Interior and the Governor of TN approving the development plan for the mitigation lands. Primary among those acquisitions was Black Swamp, which was to be developed to provide a flooded cypress and gum hunting area of some 1000 acres.

Despite the prior approval of those agencies, the State of Tennessee and the Corps did not approve the permit request by TWRA.

I have difficulty understanding how activities which reference restoration of historic drainages can be discussed following the positions TDEC, the Corps, and EPA took when the TWRA restored a historic channel through a bean field on the mitigation land. TWRA was told there was no way the channel in the bean field could ever be permitted and forced the TWRA to convert the field back to agricultural land. They were specifically told by EPA the activity was not permittable. This begs the question of how can excavating a channel in a swamp wetland that drains productive waterfowl habitat be permitted?

I would also point out that neither NEF nor the plaintiffs in Akers v. Resor have been an obstacle to restoration of channels in this Basin. The Corps had developed a revised WTT Project design of river restoration which involved opening the historic channels on the Obion. This project would have been in compliance the Agreed Order. NEF supported that new initiative of the West Tennessee Tributaries Project. This effort was halted when TDEC denied the permit application of the Corps.

Before Akers v. Resor and the NEF stepped up to project the wetlands of the Obion-Forked Deer over 200,000 acres of swamps, oxbow lakes, and timber were destroyed through drainage. The remnants on the Forked Deer are the last of a critical wildlife habitat that exists in the Basin. A major portion of these swamps occur on mitigation lands which were selected to preserve that habitat type. I urge caution in now attempting to drain/alter these last remnants in the Forked Deer.

Respectfully submitted by,

NEF & J. Clark Akers, III

Signed: ____________________

July 8, 2009

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Mike Thron
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Dear Sirs:

I have reviewed your notice of "Intent to Prepare a Draft Supplement No. 2 to the final Environmental Impact Statement for the West Tennessee Tributaries (WTT) General Reevaluation" (Federal Register/Vol.74, No. 102, 5/29/09). Due to a death in my family, I was unable to attend the public scoping meeting in Milan, TN. However I am sending my written comments for you to consider. I appreciate the right to provide my views.

I have been involved in efforts associated with each step of the WTT project since the 1960's. It has always been my motive to encourage an intelligent project that seriously considers all resources in the project area. An intelligent project is a very difficult objective for the Corps to realize due to a largely poorly informed citizenry (including elected officials, government employees, landowners, sportsmen and conservation/environmental groups). Indeed, even for Corps personnel with substantial knowledge about such efforts as the WTT project and its associated environment, planning a project to aid in solving the various problems will be difficult. All interests must become knowledgeable in a variety of disciplines and remain closely associated with planning efforts if they hope to have positive input.

First, I offer a brief bit of advice based on history. The reason for past WTT planning failures has been directly related to small special interest groups and their political supporters. Both the Corps and the special interest groups believed that they had enough "power" to get what they wanted through their political supporters. Because of this mistake, the Corps of Engineers, rather than designing an intelligent project, catered to a small group of farmers and their congressman and focused on channelizing streams and draining wetlands. Hopefully by now the Corps understands that power is always shifting. So, my advice is to plan a project that will be scientifically sound and that will be acceptable to a diverse citizenry.

I hope that the Corps now knows that all concerned with the Obion-Forked Deer Basin must believe that they have received fair and just consideration of their needs and desires for any project plan to be implemented. To do less will result in more legal actions and more supplements to planning documents.

I support the Corps statement in the Federal Register that, the GRR and supplement no. 2 to the final EIS "…will focus on methods that reduce flood risk within the Obion-Forked Deer watershed by <u>restoring natural floodplain functions and reducing sedimentation that could cause channel blockages".</u> (emphasis mine) As I perceive this statement, it is the intelligent path to follow. The Corps appears to be on the correct path, but the devil is in the details!

The Corps first difficulty in this most recent planning effort will be how to deal with all the past WTT project documents, legal decisions and new related scientific publications. Most who will review the proposed new planning documents will not have access to the several old EIS's and related publications. Therefore it is advisable that all such documents are clearly summarized in the new supplemental documents for all interests to review.

As proposed, reducing flood risk within the Obion-Forked Deer watershed by <u>restoring natural floodplain functions</u> is an excellent concept. A problem immediately emerges when one considers "natural floodplains functions" in the watershed. The floodplains have been so drastically altered and abused that "natural conditions" are difficult to locate. All the major streams have been channelized. The floodplains have been largely altered and flood water flows are blocked by many miles of levees, roads, bridges, railroads and urban development. Tens of thousands of acres of floodplain forest have been cleared and tens of thousands of wetlands acres have been ditched and drained. These former bottomland forest and wetlands are now mostly intensively managed croplands which are subject to frequent flooding.

Based on the large, radical floodplain alterations some challenging decisions must be made. To restore natural floodplain functions, large areas of the floodplain must first be restored. My recommendation is definitely do no additional stream enlargement. Stream enlargement and straightening (channelization) has been the major factor in virtually all the other problems. It encouraged the invasion of floodplains by agriculture. And, while channelization may have prevented some upstream flooding, it always causes increased flooding on downstream areas.

Importantly, the straight channelized channels are, and will remain more unstable than natural meandering streams. Because of natural physical laws straight channels are continually attempting to return to a meandering pattern. This results in massive channel erosion. According to several studies, approximately 90 percent of the sand/sediment within channelized streams beds is from channel bank erosion. Eroded material from uplands mostly settles out in floodplain areas with a relatively small percentage reaching the channels.

The problem of headcutting within main stream channels, tributaries and ditches must be addressed. Deepening and widening of the Obion-Forked Deer River constructed channels in highly erosive soils resulted in massive headcutting. The headcutting expanded upstream and even through many agricultural fields natural drains causing massive on-farm erosion. Numerous bridges collapsed and others were damaged too severely to use. The U.S. Geological Survey described the massive problems with channelization in their 1983 publication "**Man-Induced Channel Adjustments in Tennessee Streams**".

USGS wrote: "Stresses imposed on stream channels by channel modifications led to downcutting, headward erosion, downstream aggradation, accelerated scour, bank instabilities, and in some cased contributed to bridge failures. Combinations of these effects are still affecting some bridge structures spanning the main-stem Obion River, the North and South Forks of the Obion River, the South Fork Forked Deer River, their tributaries, and probably other channelized streams in west Tennessee." USGS also compared the Obion-Forked Deer channelized rivers with the Hatchie River in west Tennessee. They wrote that the non-channelized Hatchie River withstood natural stresses that caused massive problems in the channelized streams. The USGS report findings must be carefully considered in the Corps planning and referenced in the new supplement to the Final EIS.

It would probably be impractical, and certainly unacceptable to many people to attempt to restore all the channelized streams back to their natural channels. For better or worse we may have to live with some of the sins of the past (channelization). Yet, even the channelized streams can be improved if properly managed. However, there are a number of areas where the old meandering stream channels could easily be made functional again. Where this can be accomplished, the river flows should be diverted from the channelized streams back into the old meandering segments. When any stream work becomes necessary, it should be conducted using the "**Stream Obstruction Removal Guidelines** (SORG)".

SORG is published jointly by the American Fisheries Society, The Wildlife Society and International Association of Fish and Wildlife Agencies. SORG promotes a "light touch" method which allows use of small equipment to remove stream blockages with minimum impact to stream habitats and riparian zones. By following the Guidelines, normal stream flow can be restored with minimal damage to the stream channel, riparian zones or water quality. I have found that the vast majority of riparian landowners prefer SORG type stream work when compared to channelization. Normally landowners simply want flood waters to drain from their land rather than "flood protection".

Dealing with wetlands will be a major problem. There are many wetland interests with many opposing views about how they should be managed. The knowledge level of these interests is highly variable. And, importantly, their personal desires about "their" individual wetlands differ greatly. For example one farmer may wish for all of his wetlands to be ditched and drained. Then, a waterfowl hunter who owns a wetland may desire that it remain flooded constantly (although that may not be best). Using these two examples the farmers wish could not be accommodated but the waterfowl hunters probably could be under the Corps' goal of "restoring natural floodplain functions". My point is that some things will be unacceptable while others may be acceptable <u>even though they may not be the best thing to do.</u>

The Corps will also hear from those who want all wetlands to be like they were "100 years ago". And some will want all wetlands to be in bottomland forest that flood as the streams flood and then drain as the stream returns to normal stage. Then others will want water to be standing on wetlands all or most of the time. I believe the Corps may be wise to accept virtually all wetlands as they are in their current condition and work from there. Then carefully analyze and learn what individual landowners' desire. Accommodate landowners desires if their do not conflict with the goal of restoring natural floodplain functions. Focus on the fact that natural succession will change all wetlands over time.

Persons experienced with wetlands recognize that they are constantly changing. Even under totally natural conditions this is true. Before man settled in the Obion-Forked Deer River basin, the rivers were meandering and continually migrating from one side of the floodplain to the other over time. During floods trees would fall into river channels and occasionally block the channels. The blockages would cause swift river waters to flow into the floodplain and cut a new channel. "Oxbow lakes" would be formed in the blocked sections. Water standing in the oxbow lakes would cause the bottomland trees there to die. Slowly the oxbow lakes would fill with soil during future floods. As they fill the oxbow lakes follows a natural succession to shrub swamps, then grass swamps and then back to bottomland forests. Again, with this in mind, it may be wise for the Corps to deal with most wetlands as they are, recognizing that they will change over time.

As an example, I would advise against attempting to rechannelize river segments such as the Jarrell Swamp area on the South Fork of the Obion River near McKenzie, TN. It was unfortunate that a stream blockage was allowed to remain in that area for many years. Thousands of acres of timber were killed by water standing in the floodplain and the sediment that flowed into the area. Yet the fact is that the timber is mostly dead and much of the water flows through the floodplain. However the shrub swamp and marsh that formed there attracted numerous waterfowl and large populations of other aquatic animals.

Hunters purchased the Jarrell Swamp land and they believe it is a treasure. To attempt to alter the swamp now would be met with strong resistance. And why alter it? The damage to the timber has already occurred. And for several years it has been evident that the area is returning, through succession, to bottomland forest. Of course this will require many more years. At one time, landowners were agreeable to divert the entire flow through the shrub swamp. I believe this would have solved the upstream sediment problems and lowered the water in the floodplain upstream. Unfortunately the <u>old</u> Obion-Forked Deer Basin Authority wanted to rechannelize the South Fork Obion River which would have drained Jarrell Swamp. This was unacceptable to the landowners. Importantly, even if the river was rechannelized and Jarrell Swamp drained, it would also require many more years to return to bottomland forest. Hopefully this example will offer you some insight to the dilemmas you will face.

The Obion-Forked Deer River floodplain has many more shrub swamps (resulting from permanently flood trees) than normal due to past channelization and levee development. When the rivers were channelized, the spoil was placed on the stream bank. These berms trapped water on the floodplains and killed thousands of acres of bottomland forests. Later landowners constructed numerous levees in the floodplains which also trapped water causing the death of many more acres of trees. Likewise, roadbeds were constructed across floodplains with too few outlets and there was more flooding, sediment fallout and more trees died. All of these man-caused problems made the area highly attractive to beavers which add to the problems. When all of this is combined it translates into one of the largest mismanagement fiascos in our nation's river systems.

So, what can be done to correct some of this mismanagement? Again, do not channelize anymore streams. Divert river flows into old natural meandering river channels where possible. Use the SORG to manage all streams. Then remove or breech as many floodplain obstructions (levees, stream bank berms, road fills) as practical. If need be, purchase landowner levees to remove them or create openings in them. Purchase, in fee simple, any lands that may flood too frequently to be acceptable to landowners. After all of these recommendations are implemented flood waters can spread out and move more naturally through the floodplain. Then allow the floodplains and remaining wetlands to follow their natural succession. Over time the floodplains would revert to healthy bottomland forest that flood during river flood stages and slowly drain during normal river stages. There would always be some locations where water would pool and these should be allowed.

As part of this new planning effort, the Corps should not provide permits to any future obstructions in the frequently flooded portion of the floodplain. All projects should be planned in a manner that will not obstruct natural flood flows. For example, no new levees should be allowed within the two year floodplain for waterfowl developments. Any such developments should be developed on the outer edges of the floodplains using low level terraces that follow contours. A good example of this type development is the White Lake Waterfowl Refuge developed by Tennessee Wildlife Resources Agency (TWRA). A terrible example of floodplain usage was the attempt by TWRA to construct an 800 feet levee across the one-year floodplain at Black Swamp and hold water on the floodplain for several months each year.

Much of what I have recommended can also be found in "**A Mission Plan for Reformulation of the West Tennessee Tributaries Project"** (Mission Plan). In 1992 Governor Ned McWhorter requested the Corps to reactivate the WTTP to find an environmentally sensitive design which would reduce flood damage, reduce erosion, restore floodplain integrity, and improve water quality. Governor McWhorter appointed the West Tennessee Tributaries Steering Committee to develop a plan to accomplish his desires. The committee consisted of a highly diverse group of 21 members from federal, state and county governments, private conservation/environmental groups, farmer groups and business interests. The Corps of Engineers chose not to be a member but had representatives at all meetings and had much input to the planning process. The committee was charged to develop a project reformulation concept responsive to today's conditions, to new opportunities, and to the desires of local landowners.

The WTT Steering Committee, as charged, developed the Mission Plan. It was approved by 100% total consensus of the committee. Governor Ned McWhorter (Democrat) approved the plan. The Tennessee General Assembly approved the plan with 100% agreement. The next governor, Don Sunquist (Republican) approved the plan. The Memphis District, Corps of Engineers committed to implement the plan. For the first time during the entire 70 year WTTP effort there was agreement on how the project should be implemented.

Later, several individuals could not get some of the unreasonable concessions they desired and threatened legal action. I believe these threats could have been defeated in federal court but key officials in the Sundquist administration chose not to throw down the gauntlet. Thus, due to poor, cowardly leadership, a great plan was shelved.

The Mission Plan is the best proposal that I have ever seen that was designed to correct numerous, long-term problems in a large river basin. In my view it was a model for the nation. I still believe it is an excellent plan. I encourage, and urge the Corps to carefully review the Mission Plan (in your files) and use it as a basis for your supplement No. 2 to the Final Environmental Impact Statement for the West Tennessee General Reevaluation.

Should you have questions, or need for clarification of my comments, please call me at 251-626-7804.

Chester McConnell

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July 10, 2009

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Dear Sirs:

Most of my career as a natural resource lands manager was involved in the management of West Tennessee rivers and wetlands, and in my retirement, I am still concerned about these important natural resources. Although unable to attend your recent public meeting regarding the West Tennessee Tributaries Project (WTTP), I have reviewed the Corps' notice of "Intent to Prepare and Draft Supplement No. 2 to the final Environmental Impact Statement for the West Tennessee Tributaries General Reevaluation". The following are my comments.

First, I should compliment you for the effectiveness of the brief outline I have in my hands of your West Tennessee Tributaries interagency meeting with the West Tennessee River Basin Authority (WTRBA). My first reaction to the announcement was disappointment: "Here we go again," I thought "More delays, redundant studies, wasted effort and public funds." I had reasons to think this since I had been a party to many environmental studies since the 1970s on wetland projects such as the WTTP and Reelfoot Lake. After nearly forty years, very little of it has produced projects on the ground. Today, the general public will find it very difficult to find a copy of any of these studies.

But after spending some time thinking about your presentation, I have changed my mind about the WTTP. After digesting the agenda of your meeting, it appears for the first time that a lasting consensus might be possible on how a state-federal joint effort can effectively manage the rivers of West Tennessee. Up until now, state, federal, and private parties involved have been at odds on nearly every aspect of the WTTP, especially the best ways and means to manage these rivers. That seems to have changed with newer concepts of managing these rivers, which makes the few hurdles still standing seem much easier to conquer. The WTTP and the WTRBA working under the umbrella of a comprehensive plan with complimentary principles and methods should greatly advance the goals many have worked for over the past thirty-odd years. However, there are still points to be made that seem to have been overlooked or minimized.

I am of the strong opinion that rivers are important natural resources that most of us do not want to give up. With very little background information available to the public, comments are received only from those directly affected. This leaves a huge gap in feedback from the public, and I doubt that they have been represented in the EIS processes I am familiar with. That gap should be covered in the new EIS. What the public needed more than anything during this protracted period was communications -- available and straightforward information, something that would have enlightened all of us about the stopgaps and the enormous benefits of our native rivers. Few understand why rivers have turned into muddy ditches and decadent swamps, or what solid alternatives are available for doing something about it. These are reasons I think it is worth the Corps' and state's effort, if not duty, to begin a concerted effort before the opinion survey with public information programs to inform the public not only about the issues but the status and potential of these river resources.

What the public does know is that there is something fundamentally wrong with a process when the foundational resources of a region have been lost -- in this case the native rivers and wetlands of West Tennessee. Along with it, wildlife and fishery resources, bottomland timber production, outdoor recreation, the native characteristics of the landscape, and much more have been lost. Such is the circumstance here today where the rivers and wetlands are no longer functional, free-flowing, or self-sustaining. What the public should also know in this EIS is that free-flowing rivers are essentially our only source of native wetlands in West Tennessee -- they create, nurture, and sustain all natural (healthy, sustainable) wetlands by constantly changing and being flooded. Not so with ditches and manmade streams: While we have hundreds of miles of streams and thousands of acres of floodplain wetlands, nearly all are manmade, inferior, not self-sustaining, and mostly detrimental to our use, pleasure, and prosperity.

Close to the issue is the subject of *flood control.* Rather than be justified for projects that improve the sustainability of rivers, the Corps has had only "flood control" to justify their work on the WTTP. The Corps and Congress need to take a fresh look at this oversight. Overlooked in these acts is the importance of free-flowing, sustainable rivers as methods for *flood control.* The capacity for rivers and wetlands to absorb and slow run-off, hold it, and redistribute this reservoir of moisture to aquifers, as needed for domestic use, and for plant and animal communities of the river ecosystem is enormous. Why is this not mentioned specifically in EIS alternatives? It is perhaps the most efficient and effective method known to man for flood control. But recognition of these attributes are completely lacking in the Water Resource Development Acts that authorized the West Tennessee Tributaries Project. Only the National Environmental Policy Act (NEPA) of 1969 has forced us to acknowledge some of them.

Why is this important to the Corps' proposed EIS? Because "flood control" alone has been the yardstick to decide whether or not Corps projects within the WTTP are justified. On the one hand, the use of "flood control" as the criterion has not taken into account the benefits of rivers and wetlands discussed above, which could limit or disallow the true benefits of the Corps' proposed project by an unfavorable benefit/cost ratio.

On the other hand, the dilemma might not be necessary -- it could be an advantage. That is, if river managers can agree that free-flowing rivers are efficient and equitable methods for *flood control*, why not accept the credits that come with the practice. Since a sustainable ecosystem is necessarily a function of free-flowing rivers, then there seems to be no good reason not to use these attributes as credits in a benefit/cost analysis.

Like it or not, I understand that time delay in the NEPA process is an unavoidable reality. At the same time, the process can be extremely important in teasing out the pros and cons of manipulating natural resources. I hope, however, we have had enough experience with this process not to abuse time and effort, and not to be unnecessarily redundant. Millions of dollars have already been spent on previous EIS projects addressing pretty much the same topics within the WTTP. Time is not on our side considering meager budgets and the rising cost of construction and land, not to mention further deterioration of our riverine ecosystems, the loss of property, infrastructure, crops, timber, outdoor recreational opportunities, and many other benefits.

While channelization has been judged a disastrous method after decades of arguing about it, this method is no longer acceptable in the WTTP. But we are well past this controversy. All parties involved in the WTTP have already stood on common ground. That "common ground" was the state's 1994 environmentally sensitive plan -- *A Mission Plan for Reformulation of the West Tennessee Tributaries Project* (Mission Plan). This plan received a total consensus by the parties involved to reject channelization and to accept the restoration of native floodplain integrity. The plan addresses all associated components including flood control, soil erosion control, and water quality.

The caveat here is that the plaintiffs in *Akers v. Resor* require compliance with the 1985 Consent Order: That the fee-simple purchase of mitigation land must coincide with the Corps' WTTP construction project, no matter what methods of management are used. The Corps has in the past flinched from this requirement on the grounds that the federal government has not and would not likely provide the funds to purchase these lands. Even if funds were available, the weight of costly land would result in an unfavorable cost/benefit ratio. This issue should be clarified and its solutions stated. Hopefully, the troublesome benefit/cost ratio will no longer be a problem for the Corps' analysis if the Mission Plan is accepted in the EIS process.

Thank you for allowing these comments. I find your outline for the public presentation to be extremely encouraging. I encourage the Corps to expedite this study in every way possible.

Sincerely,

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July 17, 2009

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Dear Sirs:

Wetland Alliance members have reviewed the Memphis District Corps of Engineers' notice of "Intent to Prepare a Draft Supplement No. 2 to the final Environmental Impact Statement for the West Tennessee Tributaries (WTT) General Reevaluation" (Federal Register/Vol.74, No. 102, 5/29/09). We are sending our written comments for your serious consideration. We sincerely appreciate the right to provide our views.

We are a private group with a special interest as a civic voice for the wise use and management of rivers and wetland, especially those in West Tennessee. Several of our members have been involved in efforts associated with the WTT project since the 1960's. All have been interested and involved for at least two decades. We believe we have accumulated much knowledge and insight to the problems associated with the Obion-Forked Deer River Basin. We will be pleased to share our experiences with the Corps as your planning efforts move forward. However, currently, we will be brief with our comments.

Wetland Alliance recommends that the Corps use, as a model for supplement No. 2 to the WTTP FEIS, "A Mission Plan for Reformulation of the West Tennessee Tributaries Project" (Mission Plan). In 1992 Gov. Ned McWherter requested the Corps to reactivate the WTTP to find an environmentally sensitive design which would reduce flood damage, reduce erosion, restore floodplain integrity, and improve water quality. Gov. McWherter appointed the West Tennessee Tributaries Steering Committee to develop a plan to accomplish his desires. The committee consisted of a highly diverse group of 21 members from federal, state and county governments, private conservation/environmental groups, farmer groups and business interests. The Corps of Engineers chose not to be a member but had representatives at all meetings and had much input to the planning process.

The Steering Committee was charged to develop a project reformulation concept responsive to today's conditions, to new opportunities, and to the desires of local landowners. The WTT Steering Committee developed the Mission Plan as charged. It was approved by 100% total consensus of the committee. Governor Ned McWherter (Democrat) approved the plan. The Tennessee General Assembly approved the plan with one hundred percent agreement. The following governor, Don Sunquist (Republican) also approved the plan. We also understand that the 70-odd years the WTTP effort has been in the making, there is agreement on how the West Tennessee rivers and the WTTP should be implemented.

Wetland Alliance believes that because the Mission Plan received such wide interest and support, and because it stands the test of a solid-based plan on sound principles, it is the best proposal to correct numerous, long-term problems in the Obion-Forked Deer River Basin watersheds, which will be a template and guide for the management of all West Tennessee tributaries. We encourage, and urge the Corps to carefully consider the Mission Plan as a basis for your supplement No. 2 to the Final Environmental Impact Statement for the West Tennessee General Reevaluation. It is our hope also that the Corps and the state will be able to issue a joint public statement in support of the principles agreed on in the Mission Plan, so that all agencies and the public will have a clear picture as to the future goals for managing West Tennessee rivers and wetlands.

Sincerely,

Jim W. Johnson, Coordinator
Wetland Alliance

TENNESSEE ORNITHOLOGICAL SOCIETY

Richard Preston, President
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July 22, 2009

Andy Simmerman
Project Biologist
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RE: West Tennessee Tributaries General Reevaluation comments

Dear Mr. Simmerman,

On behalf of the members of the Tennessee Ornithological Society, I respectfully submit the following comments for consideration prior to development of the draft supplement No. 2 to the final environmental impact statement for the West Tennessee Tributaries, General Reevaluation. The Tennessee Ornithological Society is a statewide 501(c)(3) nonprofit organization of over 1,000 members devoted to the enjoyment, scientific study and conservation of birds. As such, we have an interest in projects that affect wildlife habitats and the ability of the public to access and enjoy them.

The focus of the WTT Reevaluation is generally promising, since it highlights restoration of natural floodplain hydrology and “ancillary” environmental benefits. Our perspective is that environmental benefits in this project should not be considered ancillary, but rather integral to the project’s success. After all, it was real and perceived environmental degradation that ensued when this project was first implemented decades ago that eventually forced its halt. We are glad to see the Army Corps of Engineers and the West Tennessee River Basin Authority embrace a more ecosystem management-oriented approach, and our recommendation is that the analysis for this and future such projects include not only the costs and benefits of flood control, but also of vital ecosystem services provided by the river and its watershed. In addition, the economic value of recreational opportunities provided by a healthy ecosystem should be included in cost/benefit analyses.

We support the conceptual approach of minimizing sedimentation and restoring ecological function through measures such as levee modification/removal, meander restoration, retention basins, and reforestation. We recommend that any restoration plantings be undertaken using native species, and that forest restoration plantings be designed to maximize not only native habitat but structural diversity as well (for example, by planting in clumps or including native understory shrubs).

Bird monitoring is also an activity that should be considered anytime a significant level of habitat or floodplain restoration will occur. For a variety of reasons, birds are excellent indicators of ecosystem health, and they are relatively cost-effective to monitor. We urge you to consult the many specific restoration and monitoring recommendations provided in the continental bird conservation plans written for waterfowl, songbirds, and waterbirds. The plans specific to western Tennessee can be found at the North American Bird Conservation Initiative site, http://www.nabci-us.org/bcr27.html.

One of the break-out sessions at the public meeting held June 28, 2009 included comments by a farmer who was frustrated about his lack of ability to implement small, cost-effective solutions to erosion problems upstream from the main West Tennessee tributaries before they worsened and became expensive. One possibility for fostering such measures as part of this project could be to advise and provide small grants to farmers through a partnership with the National Fish and Wildlife Foundation, which works with federal agencies to implement targeted matching grant programs.

On behalf of our members and the thousands of other Tennesseans who appreciate and enjoy our birdlife, we thank you for the opportunity to provide input to this project.

Sincerely,

Richard Preston
President

CC: Danny Ward
Project Manager
Project Management Branch, Memphis

Michael Thron
Project Biologist
Environmental Branch, Memphis

TENNESSEE WILDLIFE FEDERATION
Conserving Our Wildlife & Natural Resources Since 1946

22 July 2009

Mr. Danny Ward
Project Management Branch
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VIA ELECTRONIC MAIL AND U.S. POSTAL SERVICE

Dear Danny,

The Tennessee Wildlife Federation (TWF) appreciates this opportunity to make comment during the scoping phase for the West Tennessee Tributaries Project (WTTP) General Reevaluation process being conducted by your offices. As you may be aware, the Federation has maintained a long and involved history with the West Tennessee Tributaries Project.

As one of the original plaintiffs in the Akers vs. Resor lawsuit, we are very pleased to see USACE publicly committing to meeting the requirements of the suit's resulting consent decree. By doing this we fell that the Corps is turning over a new leaf and this is greatly appreciated.

Enclosed below are the issues that the TWF would like to see addressed in the NEPA process for this project.

<u>Regulatory Restrictions Placed Upon Floodplain Management Efforts that Conflict with Akers vs. Resor Remedies</u>

One of the most significant outcomes of the Akers vs. Resor case was the requirement placed upon USACE by the Memphis Federal District Court to purchase 32,000 acres of mitigation lands to offset impacts of the WTTP. As you may be aware, USACE initially purchased 13,567 acres of land prior to idling the project in the 1980s. While these lands were purchased by USACE, the authorization to acquire these lands and subsequently transfer of them to TWRA was and continues to be provided by Congress via Section 3 of the 1974 Water Resources Development Act (Public Law 93-251).

Additionally, this law requires that, prior to transfer of the lands to the state, management plans for these mitigation lands were to be completed and agreed to by the Secretary of the Army, Secretary of the Interior, and the Governor of the State of Tennessee after his consultation with the then Tennessee Game and Fish Commission.

> *"P.L. 93-251 Section 3 (c) Final details and designs of this mitigation feature shall consist of plans approved by the Secretary of the Army, the Secretary of the Interior, and the Governor of the State of Tennessee after consultation with the Tennessee Game and Fish Commission prior to the conveyance by the Secretary of the Army to the State of Tennessee as provided in subsection (d)."*

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Thus, a requirement of the transfer of these public lands was the creation and agreed to management of the mitigation lands described in the West Tennessee Tributaries Mitigation Lands Wildlife Management Plan approved by all parties in June of 1983 and subsequently amended in December 1990.

Recently, efforts to comply with the West Tennessee Tributaries Mitigation Lands Wildlife Management Plan by the Tennessee Wildlife Resources Agency (TWRA) were denied permits by EPA and TDEC . The reasons given by these regulatory agencies for denial of these permits appears to be in direct conflict with any flood control efforts (restoration related or otherwise) which the Corps may look to undertake via a reformulated version of the West Tennessee Tributaries Project. Additionally, it appears that policies applied on the ground by the EPA, NRC S and TDEC are inconsistent in these types of matters.

For these reasons, there are two important issues that the USACE should investigate and resolve as part of the this process; (1) the ability of the Corps to work in the river floodplains of west Tennessee given recent ruling and actions by EPA and TDEC, and (2) the ability of the Corps to ensure that future mitigation lands will be able to be managed via the standards and plans already developed and approved in the West Tennessee Tributaries Mitigation Lands Wildlife Management Plan via P.L. 93-251.

In addressing the first issue, we feel it important that the Corps fully vet and obtain an answer from the EPA Region 4 office and Tennessee's TDEC regarding conducting any work in floodplains that will alter waters of the state or the U.S. While we understand that the Corps plans on following all permitting requirements for any work it might undertake, restoration efforts in any of the Obion or Forked Deer river systems will result in the draining of existing wetlands –as must be the case given the enabling legislation and Corps requirements for the WTTP.

Additionally, previous efforts by EPA and NRCS have changed the designation of cropland from "prior converted" to "farmed wetland". In our opinion, this change, given the recent delineation by NRCS, will eventually place thousands of acres of previously considered "prior converted" cropland into the regulated category of "farmed wetlands" – thereby increasing the possibility of permits being denied for the project should these agencies act consistent with their previous actions.

Secondly, it is important for the Corps to determine if the requirements of PL 93-251 and the West Tennessee Tributaries Mitigation Lands Wildlife Management Plan can be met given the current issues raised by EPA and TDEC related to point number one. If these requirements cannot be met then the USACE may be unable to meet the requirements of the consent decree.

We firmly believe that these inconsistencies, policies and ability of the TWRA to comply with the West Tennessee Tributaries Mitigation Lands Wildlife Management Plan must be resolved and addressed in any project documents prior to the Corps undertaking any work, including the acquisition of mitigation lands to bring the project in compliance with the Akers vs. Resor consent decree.

Additional Considerations

Private lands impacts – for many decades the lands within and surrounding the WTTP were owned by farmers, but much has changed since project was implemented. Channelization has failed and the result has been massive hydrological issues that have destabilized the river, its tributary streams and the floodplain. These failures have also resulted in permanently ponded water on acres of lands which were previously only seasonally flooded. This water killed thousands of acres of bottomland hardwood timber and made bottomland farm fields too wet and therefore risky to farm. Three decades ago these newly created ponded wetlands appeared to be of little value to wildlife, a concept that continued into the 1990's. However, as time has passed these ponded wetlands have grown in value to both landowners and wildlife; and the rivers and streams in some cases have begun to recover themselves, albeit on a localized level. For these reasons, we ask the Corps to evaluate the following three issues:

- Impacts this project will have to existing wetlands which currently provide good habitat for wintering waterfowl and shorebirds. Many policy makers and some stakeholders have, in the past, claimed that these wetlands are not productive. We disagree and have not been able to find any research or literature that can either confirm or deny the wildlife diversity and stability of this area. Anecdotal information shows that the area, due to the permanent water, is important to waterfowl and shorebirds, as well as many species of furbearers and other wildlife. In examining the impacts a new WTTP would have on the wetlands, research and inventories of wildlife must also be thoroughly conducted and the potential impacts this project may have on them.

  It is important to note that some stakeholders may claim that a new reformulated WTTP would make these bottomlands more productive for wildlife and habitat than currently exists (i.e., enhancement), but this is not a self-evident claim. Draining these lands will impact wildlife and wildlife habitat, and if this project does not have thoughtful management scenarios for wildlife included in its design the potential exists for these lands to be permanently less productive – something that we cannot support.

- WTTP impacts to local landowners which have purchased many (formerly agricultural) acres of land in these floodplains for the express purpose of waterfowl hunting and other forms of recreation. Many of these privately owned bottomland acres in the project boundary were expressly purchased (or are currently leased) for recreational purposes. It is important to evaluate the damages that could occur to these private landowners if these lands were drained via a reformulated WTTP.

- The need and possibility of floodplain management for migratory waterfowl and shorebirds which allows for habitat to be maintained should the project move forward. Given previous points made in the first section of this letter with regards to federal and state regulatory bodies, it is imperative that water and wetland management be allowed to take place to offset potential negative impacts of this project

Sedimentation – Channelization of the Obion and Forked-Deer river systems has created an enormous amount of sediment which has had significant negative impacts to wildlife habitat and hydrology. We are aware that USACE Memphis District is in the process of or has developed a sediment plan for west Tennessee. We believe that the USACE should study and evaluate the impacts of the project as it relates to sediment and the potential impact of sediment resulting from the project – especially since a new WTTP would appear to begin in the middle of a reach of one of the rivers and not at its headwaters.

Impacts to Wetlands and Associated Wildlife – See previous comments, however we do believe that a complete biological assessment of the project area should be completed for flora and fauna, including aquatic life. This is a critical baseline component to have so that (1) this area can be compared to other areas in West Tennessee and the lower Mississippi basin regarding the quality of this area and its habitats and (2) the ability to measure the results of any project work in the future can be fully evaluated.

Expertise exists at the University of Tennessee (Dr. Matthew Gray) and at Tennessee Technological University (Dr. Tom Roberts) which has already developed models and techniques for conducting biological and hydrological assessments in the bottomland wetlands of west Tennessee. In conducting any biological assessments, wildlife evaluations or hydrological investigations we strongly recommend USACE involve these institutions and their expert staff.

The Tennessee Wildlife Federation is supportive of efforts to restore floodplain hydrology, rivers and associated streams in west Tennessee. In general, we believe that properly planned and executed restoration projects can improve wildlife habitat and the stability and diversity of wildlife populations. Given the systematic destruction of several hundred thousand acres of bottomland hardwoods by the original WTTP, a new reformulated and restoration based WTTP has the potential to do great things for the environment and wildlife in the project area.

However, if a newly reconstituted WTTP only becomes another mechanism by which USACE is able to drain wetlands, which will negatively impact wildlife and wildlife habitat and does not contain tools and authorizations to manage for wildlife in the floodplain, this project will have difficulty in gaining support for implementation. Thus, it is imperative that any new WTTP must contain mechanism that allow for management of wetlands in the project area for the purpose of enhancing lands for wildlife on both public (i.e., existing and future mitigation lands) and private lands.

Again, we sincerely appreciate your seeking our comments and should you wish to meet with us to discuss any of these items in further details then please do not hesitate to contact our offices.

Respectfully yours,

Michael Butler, CEO
Tennessee Wildlife Federation

Larry J. Smith
618 S. Cox
Memphis TN 38104
901-278-2396

June 30, 2009

Mr. Danny Ward
Project Management Branch
USAC, Memphis District
167 N. Main, Rm B-202
Memphis TN 38103

Mr. Andy Simmerman
Project Management Branch
USAC, Memphis District
167 N. Main, Rm B-202
Memphis TN 38103

Mr. Michael Thron
Environmental Branch
USAC, Memphis District
167 N. Main, Rm B-202
Memphis TN 38103

Re: Comments on Reevaluation of West Tennessee Tributaries Project

Thank you very much for the opportunity to comment on the above referenced project.

It is hard to know where to begin when commenting on the reevaluation of the West Tennessee Tributaries project. As many know, the West Tennessee Tributaries project has existed for years and was hard fought to stop. The history of the entire project is important to keep in mind as this process goes forward, especially in light of the fact that a new environmental impact statement will not be produced but rather a supplement built upon the older ones. This is important because it means the slate is not altogether clean since supplements cannot be done in a vacuum. A supplemental EIS must repudiate, confirm, acknowledge or supplement the existing document.

I attended the public hearing in Milan Tennessee on June 23, 2009 and viewed the power point presentation by Mr. Ward , Thron and Salyers. The majority of the presentation was performed by Mr. Salyers who focused on work his agency (West Tennessee River Basin Authority) has continued to perform in the project area since the federal side was closed down. The focus of the presentation was on upland and small tributary work with little or no mention of what is being considered for the main channel areas. There are some studies that show that re-establishing the main canal may not actually reduce flooding but increase flooding, in some cases by as much as 140%. See enclosed: **Discharge Response to Channelization of a Coastal Plain Stream, Wetlands Vol. 12, No. 3. Dec. 1992, pp 157-162** and Commercial Appeal article, "W. Tenn.'s Anti-flood River Plan Backfiring Study Says," 1-11-93.

The prior WTTP project actually was two projects, one performed by the U.S. Army Corps (USAC) and the second performed by the Obion Forked Deer Basin Authority, (OFDBA). The OFDBA continued implementing projects that would have drained areas such as the Jerrell swamp, a 13,000 acre high quality marsh and shrub swamp habitat on the South Fork of the Obion River near McKenzie TN, had they too not been stopped. Does the new WTTP project scope encompass the areas formerly given to the OFDBA for channel work? If not, then will the EIS that pertained to the OFDBA, now WTRBA, be updated?

See enclosed EIS cover dated 1982 and Commercial Appeal articles: "EPA, Corps Set up Rules for Draining Obion Basin," 2-11-91; "Changing Drainage Muddies the Waters on Forest vs. Marsh," 2-12-92; Editorial: "Channel Clash," 7-20-91; "Tenn. Marsh Shapes Arena for Test of Wetlands Policy," 7-1,1991; and Sierra Club newsletter, fall of 1991.

The debate regarding the merits of the work performed by the USAC and OFDBA along the Forked Deer and Obion rivers primarily hinged on a value judgment between the relative value of bottomland hardwood forest pitted against the value of open marsh and shrub swamp habitat. Typically, hardwood trees would die as a result of water impoundment due to canal blockage. The dead timber area would then steadily move through a progression of wetland types ranging from open water and marsh to shrub swamp, to semi-forested areas made up of maple, black willow, river birch, and even cypress-tupelo gum stands. Most of the areas of concern along the rivers within the project area share a mix of all these types of wetland ecosystems. One notable former "swamped out bottomland hardwood area" is now a cypress and tupelo gum stand that can be seen just west of Jackson TN. It parallels the south side of Interstate 40 just west of the South Fork of the Forked Deer River. In a number of other similar areas, old river meanders have been reclaimed by nature and new meanders formed as land is built up in the floodplain from the capture of sediments.

Of course, timber kills are nothing new in the floodplain ecosystem. For example, see: **Stream Channelization and Swamp Formation in the U.S. Coastal Plain, Physical Geography, 2004 Vol. 25, 1 pp.22 –38) Shankman et al.** But somehow those caused by plugged channels are deliberately put in a different light meant to minimize their importance as wetlands. The wetlands that have formed as a result of erosion or beaver activity or a combination of both are described in terms such as "loss of habitat," "unnatural," "swamped out," and even terms as extreme as "dead" and "decaying" have been used. A Tennessee law was even passed that denied protection to any wet wetland that formed after 1970. See: TCA 69-3-105 (k)(2)(A). The destruction of these wetlands is described as "restoration" and "natural." This would be laughable when applied to identical wetlands in other parts of the United States, and even other parts of Tennessee.

Reevaluation of this project must include a reevaluation of the way in which wetland functional values are documented and assessed and, most importantly, how these values are weighted. Thus, when judgments are made as to whether or not to destroy or highly alter one existing function and replace it with another, an honest inventory of the loss will exist. This lack of aquatic analysis is not a new issue. It was clearly stated in the 1982 OFDBA FEIS. (See enclosed: appendix G, page 3) For example, a vast marsh which has replaced a bottomland hardwood forest has a host of enhanced water quality values the prior forest lacked. A marsh would not have the same timber value as the forest, and a forest would not have the same fishing value as the marsh. The differences between an aquatic environment and terrestrial environment are obvious and would not normally be played off against each other. But a healthy portion of the driving force behind the old and new WTTP is based on the outcome of this debate.

Where bottomland hardwood forests have been replaced by well-established marsh and shrub swamp habitat, there are good arguments for allowing those areas to remain. These areas are after all a natural response to initial channel work. Several studies suggest that channel blockage in and of itself has gone on since rivers existed, thus the actual situation is nothing new and in fact was the likely source of canopy removal and subsequent formation of large cypress and tupelo gum swamps. See the following publications:

Stream Channelization and Swamp Formation in the U.S. Coastal Plain, Physical Geography, 2004 Vol. 25, 1 pp.22 –38, Shankman et al

Cyclic Perturbation of Lowland River Channels and Ecological Response, Regulated Rivers: Research and Management 16,, 307-325 (2000), Shields et al

Stream Channelizaiton and Changing Vegetation Patterns in the U.S. Coastal Plain, The Geographical Review 86, (2) 216-232, April 1996, Shankman

Shoals and Valley Plugs in the Hutchie River Watershed, U.S.Geological Survey/Water-Resources instigations Report 00-4279, December 2000

I would not oppose work done on functional canals that are recently blocked by debris or sediment and are otherwise functional as canals above and below that point. Bridges are a prime example of this type of situation. However, once the situation has been allowed to exist for years, draining such a site should come under intense scrutiny.

Where blockages have existed for more than a few years the river should be allowed to develop naturally in and around the blockage whenever possible. In areas where hardwood timber has died and marsh and shrub swamp formation are well underway, sediment storage and water quality values exist and the aquatic diversity index goes up. So, in the end, what are the real gains to draining such a site?

Light touch work along the main channel and major tributaries should be conducted primarily by hand labor. A "floating" backhoe will negatively impact any mussel bed it encounters. The author has observed several occasions on the Hatchie River where mussel beds have been destroyed by channel clearing work, and where the river's banks have been destabilized by the removal of embedded trees. River work should always err on the side of leaving fallen trees in place if well settled, and allowing leaning trees to remain unless otherwise damaged.

Normal river dynamics dictate shifting channels and woody material in the channel. If the end result of all the work the WTTP and WTRBA contemplates is to create a static straight or meandering channel then it will only have a limited ecological success and be in constant need of maintenance.

If you have any questions please feel free to contact me at 901-299-9488.

Sincerely,

Larry J. Smith

October 11,1991

U.S.Army Corps
Regulatory Functions
B-202 Federal Building
167 N. Main St.
Memphis TN 38103-1894

Subject: Correction of record, for OFDB-1

Attention: Colonel Willer

The draft environmental impact statement for the OFDB-1 project and the appendix for the final environmental impacts statement for OFDB-1 both contain an exclusion of aquatic considerations. This exclusion is clearly expressed.

I have viewed copies of the OFDB-1 FEIS appendix that are in the possession of the Memphis District of the Corps. In the Corps's copy, this exclusion was missing. This is quite odd for a number of reasons, not the least of which, is the bearing on the sufficiency of the environmental impact statement.

Enclosed pleas find copies of the draft and final appendix versions of this aquatic exclusion. These copies should be made a part of the official record if they are not already.

Sincerely,

Larry J. Smith
Chair Wetlands Committee, Sierra Club
4819 Barfield Rd
Memphis TN 38117

685-5643

DRAFT

ENVIRONMENTAL IMPACT STATEMENT

PERMIT ACTION
UNDER
SECTION 10 OF THE RIVERS AND HARBORS ACT
AND SECTION 404 OF THE CLEAN WATER ACT
FOR
STREAM RENOVATION ACTIVITIES
IN THE
OBION AND FORKED DEER RIVERS BASIN
OF WEST TENNESSEE

APPENDIXES

AUGUST 1982

APPENDIX F

by the Obion Forked Deer Basin Authority (OFDBA). This HEP does not include a quantification of impacts expected to occur on the aquatic environment. Therefore, decision-makers should utilize this analysis in conjunction with discussions on aquatic impacts to determine the most acceptable alternative. Due to the complicated nature of this analysis, it is in both narrative and tabular form, and both should be reviewed concurrently for the best understanding.

This analysis began in the fall of 1979 with the formulation of the evaluation team. The team consisted of representatives from the Tennessee Department of Conservation, the Tennessee Wildlife Resources Agency, the Corps of Engineers, and the U.S. Fish and Wildlife Service. All procedures and results of this HEP analysis were performed by the team or one of its members and approved by the team as a unit.

Alternative Identification - (Table 1)

Due to the amount of effort required to perform the HEP, only four of the eight identified alternatives were analyzed. The four analyzed alternatives were chosen by the evaluation team as the alternatives most likely to be implemented. An additional alternative (flowage easements) was added to the analysis to meet the requirement of a court stipulation. Table 1 displays a list of the original and analyzed alternatives. More detailed descriptions of each alternative are presented with the accompanying EIS.

In analyzing these alternatives a period of analysis of between 1974 and 2030 was utilized. This period was based on a 50 year "project life" beginning in 1980 and included those 6 years since the first work began (1974-1980). This period was chosen primarily for economic purposes, recognizing that project impacts such as induced land clearing may very well continue beyond the year 2030 if the project is properly maintained.

Evaluation Element Identification - (Table 2)

Prior to field analysis a list of twelve species or groups of species was developed by the evaluation team, and utilized in the development of a HUV for each habitat type. Table 2 displays the list of agreed-upon evaluation elements.

Habitat Type and Sample Site Identification - (Table 3)

During early coordination meetings the team identified, from aerial photography of the floodplain, five prominent habitat types. These habitat types included; (1) bottomland hardwoods, (2) tree swamps, (3) shrub swamps, (4) pasture, and (5) cropland. Table 3 contains a brief description of these habitat types.

These early coordination meetings also resulted in the selection of sample sites within each habitat type using a random numbers table and a grid overlay along with aerial photography. While no more than six sample sites were actually used per habitat type, about 15 sites were originally identified for each habitat type and numbered according to

FINAL

ENVIRONMENTAL IMPACT STATEMENT

PERMIT ACTION
UNDER
SECTION 10 OF THE RIVERS AND HARBORS ACT
AND SECTION 404 OF THE CLEAN WATER ACT
FOR
STREAM RENOVATION ACTIVITIES
IN THE
OBION AND FORKED DEER RIVERS BASIN
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APPENDIXES

DECEMBER 1982

APPENDIX G

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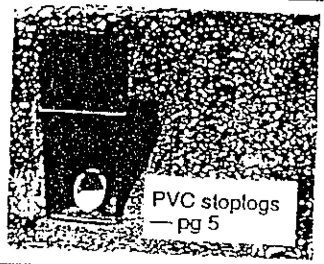
US Army Corps of Engineers
Waterways Experiment Station


PVC stoplogs — pg 5

The Wetlands Research Program

Bulletin

Volume 2
Number 1
April 1992

Cumulative impact assessment in wetlands

by Dr. John Nestler
U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

The importance of wetlands has focused the attention of researchers and decision-makers on methods for protecting, preserving, and managing these unique and fragile ecosystems. Wetlands can be impacted by a variety of human activities. Many of these activities either disrupt the underlying hydrologic patterns upon which the wetland depends or alter the large-scale spatial pattern — or landscape — of the wetland. Scientists commonly divide impacts of human activities on wetlands into two broad categories: single-action impacts (associated with a specific action or impact) and cumulative impacts (integrated results of many individual impacts).

Single and cumulative impacts — explanation of terms

Cumulative impact assessment is fundamentally different than assessment of single impacts, primarily because individual impact assessments usually are focused by a specific activity, such as draining, filling, or channelization. The specific nature of the impact helps to focus and direct the activities of regulatory and stewardship agencies. For example, filling of a portion of a wetland has a substantial effect on that part of the wetland in the immediate project area. However, filling of a portion of a wetlands also has a more subtle, cumulative impact component. For example, filling can disrupt the overall spatial pattern of the wetland ecosystem by reducing or eliminating critical wetland habitats or by fragmenting the wetland ecosystem into a system of smaller units unable to support wildlife species that range over extensive areas.

Cumulative impact assessment has an expanded temporal and spatial scale and reduced resolution compared to assessments of individual impacts. Cumulative impact assessment must not only summarize and synthesize individual impacts, but must also address synergistic effects that are in addition to the sum of individual impacts. In many cases, the magnitude of cumulative impacts on wetlands is not apparent until the existing state of an impacted wetlands is compared to historical information.

As the above simple example demonstrates, assessing cumulative impacts is important because many individual development activities over broad spatial and temporal scales may collectively produce major changes in wetland functions. Indeed, the importance of broad spatial and temporal changes in wetland ecosystems has been recognized to the point that the National Environmental Policy Act requires that Federal agencies with regulatory or stewardship responsibility for wetlands consider cumulative impacts in environmental assessments of wetlands. Clearly, wetlands impacts cannot be managed and assessed without considering the effects of cumulative impacts.

A determination of need

The Corps of Engineers, like other agencies, requires evaluation tools for assessing cumulative impacts on wetlands. Presently, no tools exist for systematic assessment of the effects of cumulative impacts on wetland ecosystem integrity. Consequently, the Corps and other agencies are unable to adequately gauge the effects of present and future impacts in order to optimally manage and regulate wetlands.

Research objectives defined

Cumulative impact assessment research conducted at the U.S. Army Engineer Waterways Experiment Station should provide scientists and engineers with a framework to defensibly assess cumulative impacts on wetlands.

The technical underpinnings of this work will be coordinated with and will build upon work performed by other agencies that also have stewardship or regulatory responsibility for wetlands. This approach will avoid duplication and ensure technical consistency. For example, experts at the Environmental Protection Agency and the U.S. Fish and Wildlife Service are developing approaches that will provide valuable information about wetland structure, dynamics, and function. These studies will complement the Corps work.

Corps research outlined

The basis of cumulative impact analysis work within the WRP is the formation of indices that summarize changes in spatial and hydrologic patterns in wetlands. Ongoing research will relate changes in wetland hydrology to changes in wetland landscape or spatial patterns. Changes in landscape patterns will, in turn, be related to changes in habitat value for wildlife. Although the approach focuses on the wildlife habitat function of wetlands it should, nevertheless, be general enough to apply to cumulative impact assessment of other wetland functions.

Landscape ecology

Landscape ecology adopts the premise that pattern in the distribution of major structural ecosystem features is the template upon which the distribution and abundance of many wildlife species are based.

For example, larger wetlands generally have more species than smaller wetlands. The area/diversity relationship suggests that an index assessing impacts in terms of changes in the size of wetland vegetation units can be used to relate changes in landscape to changes in wildlife populations. Similarly, corridors connecting similar vegetation categories within a single wetland are critical to movement of wildlife. An index measuring contiguity or connectiveness between similar units in a wetland can be related to known concepts describing movement patterns of wildlife. Indices can be tested for sensitivity and accuracy using existing wildlife information such as breeding bird surveys or Christmas Bird Counts available for some wetlands. Landscape ecology concepts will be particularly useful for

- describing impacts,
- summarizing effects of individual impacts, and
- integrating the effects of cumulative impacts on broad spatial patterns.

In the research conducted at WES, spatial patterns will be described using indices, each of which summarizes specific information about a pattern. For example, separate indices will be devised to measure the following:

- degree of contiguity (how interconnected are similar vegetation categories within a wetland?),
- size distributions of similar wetland categories (is a category composed of several large or many small units?),
- relative sizes of each wetland category (is there a critical vegetation category that needs to be protected?),
- watershed longitudinal location (is a cell nearer the headwater or nearer the mouth of a wetland?), and watershed lateral location (is a cell near a main channel or far removed from a channel?).

Indices will probably be added or deleted as necessary during the research period.

Hydrological analysis

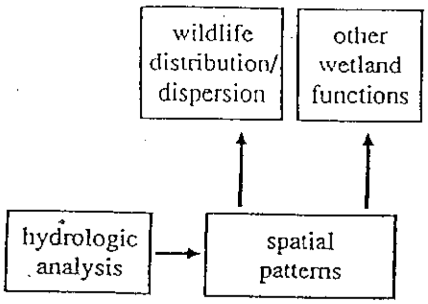
Hydrology is one of the major factors that determines wetland spatial patterns and wetland processes. Nearly all significant wetland processes are impacted by or can be partially described in hydrologic terms. Similarly, many impacts on wetlands (e.g., filling, draining, and stream regulation) can be characterized in terms of alterations in hydrologic regimes. Thus, long-term alterations in wetland hydrology can be used as a basis of assessing cumulative impacts.

Of key importance to the scientist is the possibility of relating changes in wetlands hydrology to changes in spatial patterns of vegetation categories using Geographical Information System (GIS) technology.

Many wetland systems have hydrologic patterns that have a strong seasonal component, with peaks during the wet season and depressions during the dry season. The hydrologic pattern for these systems can often be described using harmonic analysis methods in which a cosine function can be fitted to a summary time series of gauge data. In its simplest form, a cosine function can be described by four coefficients. Each of the coefficients provides well-defined information about a hydrologic time series and thus can serve as an index describing ecologically important patterns contained in gauge records. The use of simple coefficients that summarize hydrologic patterns facilitates the identification and description of linkages between wetlands hydrology and the resultant spatial patterns.

Relationship conceptualization

The conceptual relationship between hydrology, landscape patterns, and wildlife is depicted below.



Combining the above components into a systematic cumulative impact assessment methodology requires the following steps.

- First, a number of indices that summarize information content in spatial patterns must be formulated and evaluated. At WES, spatial index formulation will be explored using either existing data or model predictions for selected wetlands. Maps, aerial photographs, or model output can be overlaid with a grid fine enough (e.g., 20- by 20-m cells) to depict vegetation patterns. Cells will be categorized by dominant vegetation type or other pertinent information. Cell patterns in an entire wetland will be described and summarized using indices that both distill specific information about landscape patterns and reflect accepted wildlife distribution and dispersion.
- Second, long-term gauge records from wetlands having extensive hydrologic data will be evaluated using harmonic analysis. Harmonic analysis typically generates four coefficients that can be used to describe a process resembling a cosine function. These coefficients will be used to devise indices summarizing hydrologic trends resulting from activities that impact wetlands. The information content and behavior of the hydrologic indices will be evaluated for sensitivity and accuracy.
- Third, for wetlands having historical aerial photographs or maps in addition to long-term hydrologic information, regression and correlation analysis will be used to relate long-term hydrologic changes to changes in wetland spatial patterns (Fig. 1). In particular, investigations will be focused on nonlinear, or threshold, responses in wetlands spatial patterns.
- Fourth, changes in spatial patterns will be correlated to responses to wildlife community structure.

Steps 1-4 will be repeated until sensitivity and accuracy are optimized.

Presently, WES scientists are using data from the extensive wetlands downstream of Fort Randall

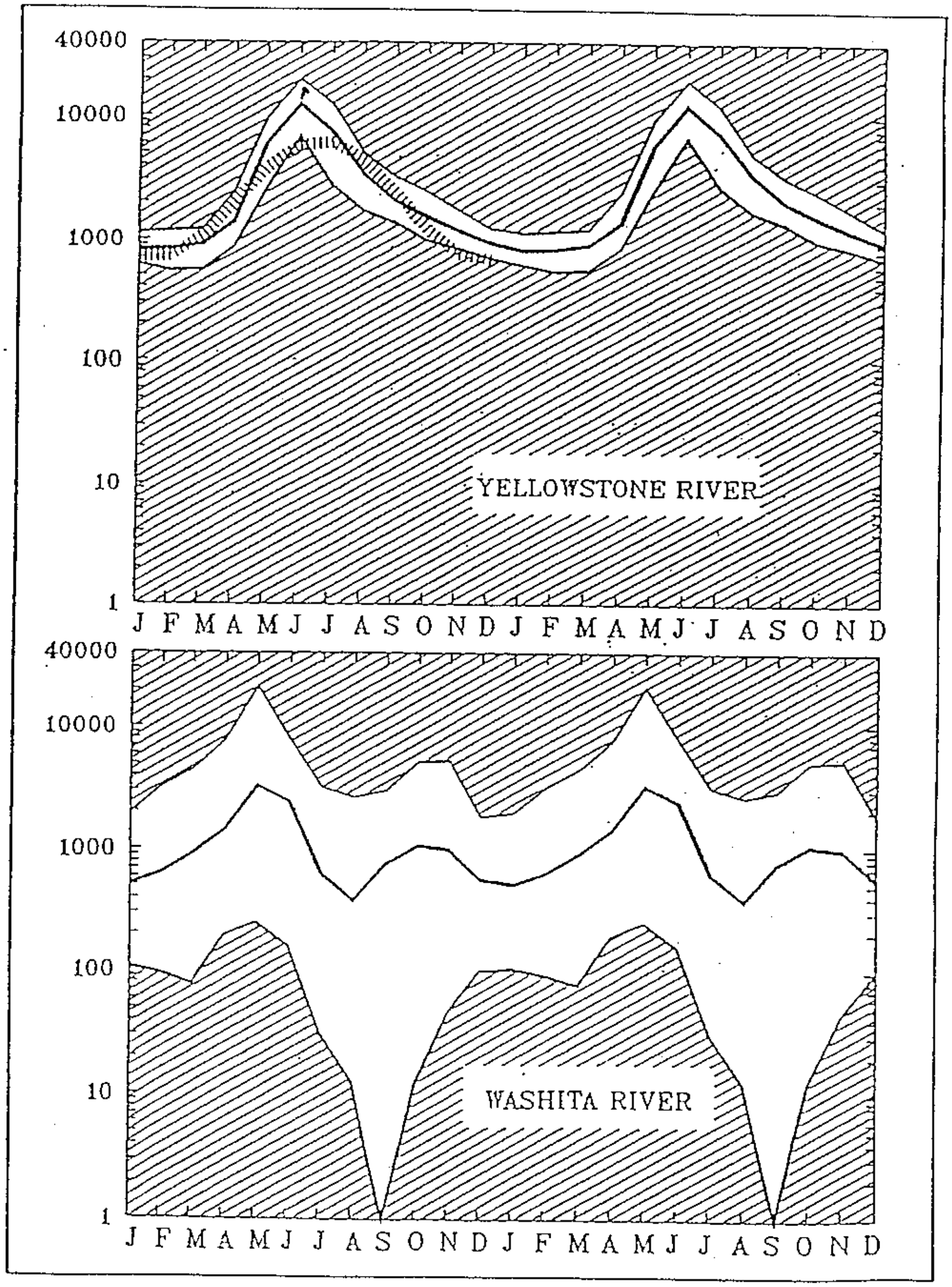


Figure 1. Hydrologic patterns

Dam on the main stem Missouri River (Fig. 2) to develop a general, Corps-wide cumulative impact analysis framework based on the steps described above. The Missouri River site is ideal because it has a detailed database that includes hydraulic/ hydrologic information, vegetation surveys, and an existing GIS. Additionally, this site provides habitat for two bird species that are threatened or endangered--the Least Tern and Piping Plover.

Availability of a widely-accepted framework for cumulative impact assessment will allow Corps scientists and engineers to better manage and regulate wetlands. In some cases, the unique perspective offered by cumulative impact analysis may provide new insight into wetlands ecology.

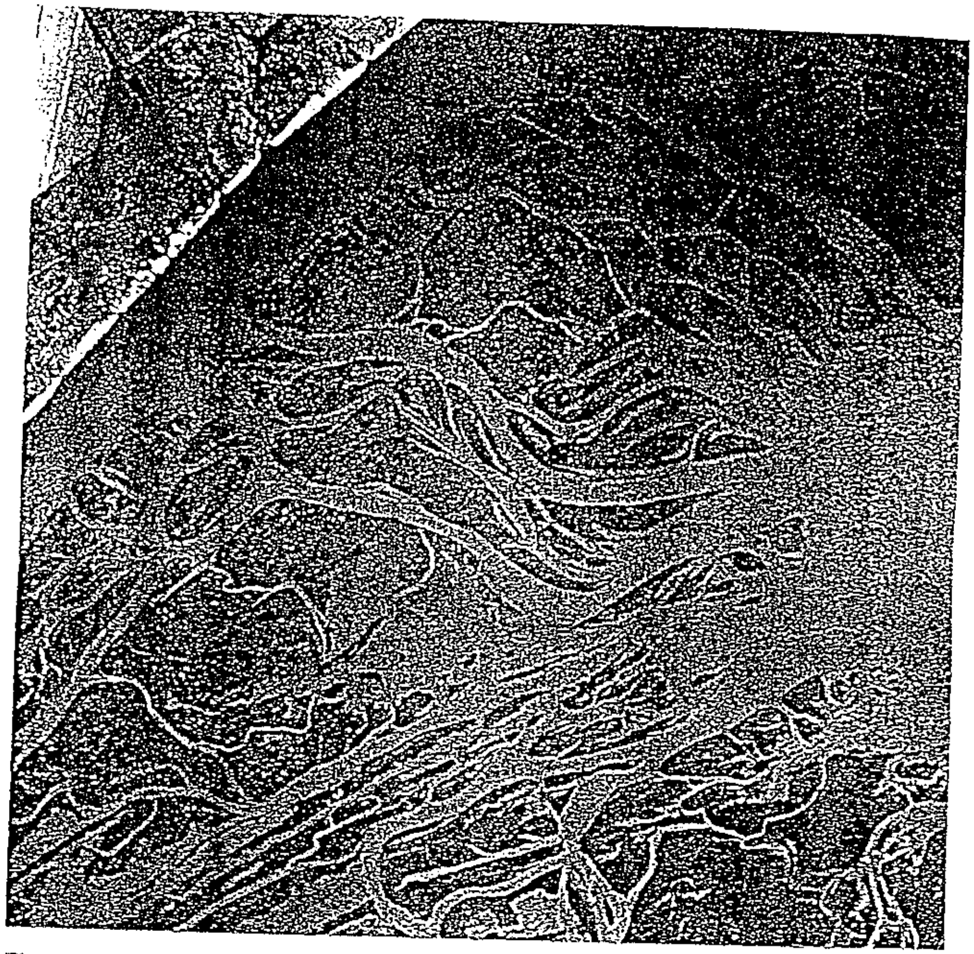


Figure 2. Aerial view of wetland region on the Missouri River

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DISCHARGE RESPONSE TO CHANNELIZATION OF A COASTAL PLAIN STREAM

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Abstract: The Obion River in western Tennessee was channelized by the U.S. Army Corps of Engineers in the 1960s. The primary purpose was to reduce flooding that inhibits agricultural productivity in the lower bottomlands. Channel enlargement and straightening has improved hydraulic efficiency. The increase in water velocity has effectively decreased flooding in the upper sections of the Obion River. However, runoff from the channelized portion of the drainage basin converges at downstream locations faster than the stream channel can accommodate, resulting in higher peak discharges and an increase in flood frequency. During the growing season months (May–October), the number of floods on the lower Obion River increased 140 percent following channelization. The greater flow efficiency allows water to move rapidly out of the Obion River drainage, decreasing the average duration of flood events. Brief periods of inundation, however, can destroy crops; therefore, the change in flood duration caused by channelization is not a desirable alternative to the higher number of floods that also occur. Conditions for bottomland cultivation have improved in the upper channelized sections of the Obion River. However, the higher flood frequency during the growing season on the lower river segments will limit agricultural productivity, which is contrary to the initial justification for channelization.

Key Words: channelization, discharge, flooding, Tennessee.

INTRODUCTION

The alluvial valleys of the southeastern Coastal Plain are highly productive agricultural areas. The floodplains have relatively low relief and fertile soils, and a high proportion of the land surface is in cultivation. The lower bottomlands flood most years in the winter and spring for periods ranging from a few days to several weeks, and often there is more than one flooding event. High water levels during the spring often make agricultural fields inaccessible and delay planting. If river stage stays low for the remainder of the growing season, the lower bottomland sites can still be highly productive. Flooding late in the growing season is infrequent but does occasionally destroy crops.

Channelization has been used extensively for flood-control in the southeastern Coastal Plain and typically includes deepening and widening the stream channel and shortening its length by cutting off meanders. The purpose is to increase channel capacity and flow velocity so that water moves more efficiently downstream and flooding is reduced. Periodic dredging and maintenance are necessary to remove sediment that typically accumulates on the downstream sections of channelized rivers because of the gentler gradient there (Emerson 1971, Schumm et al. 1984, Simon 1989) and prevent the redevelopment of meanders.

A large portion of the Obion River, a tributary of the Mississippi River in western Tennessee, was channelized by the U.S. Army Corps of Engineers (COE) in the 1960s. The principal justification for this project was to reduce flooding that inhibits cultivation. Shankman and Samson (1991) conducted a study to determine the effectiveness of channelization in reducing flooding along the Obion River. They found that flooding decreased substantially after channelization in the upper sections of the watershed. In contrast, on the lower Obion River, the growing season flooding (May–October) increased. The findings of Shankman and Samson (1991) are consistent with other studies in the eastern U.S. that have found higher peak flows and greater downstream flooding following channelization (Hillman 1936, Lane 1947, Emerson 1971, Campbell et al. 1972, Little 1973, Hill 1976).

Brookes (1988) suggested that channelization, by preventing floods on the upper reaches of streams, decreases the storage of water that would have spread across the floodplain. Ordinarily, floodwater is stored in soils and by surface impoundment (Hill 1976). However, after channelization, the water is mostly con-

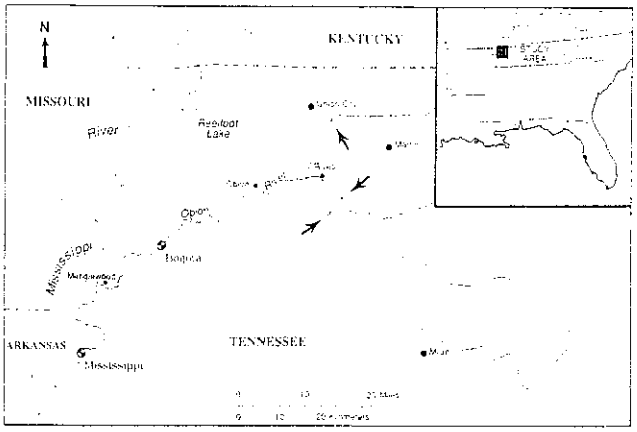

Figure 1. The Obion River in Western Tennessee. Locations of the gaging stations and precipitation recording stations are shown. Arrows indicate upper limit of channelization by the Army Corps of Engineers.

tained within the enlarged and straightened channel and quickly moves downstream. Shankman and Samson (1991) hypothesized that channelization of the Obion River resulted in higher peak flows following precipitation during the growing season. The purpose of this investigation is to test this hypothesis by examining stream response to precipitation, the magnitude of peak flows, and flood frequency on the lower Obion River before and after channelization.

STUDY AREA

The Obion River is a low gradient meandering Coastal Plain stream (Robbins and Simon 1983) (Figure 1). It has dissected a loess-covered plateau and formed a floodplain typically 3–5 km wide bounded by late Pleistocene terraces (Saucier 1987). The alluvium of the active floodplain consists of eroded loess and sediments from underlying Coastal Plain formations. The uplands are covered by loess that is several meters thick near the Mississippi River and gradually thins to the east (Springer and Elder 1980). The loess is fine textured (silt-loam) and allows rapid infiltration. Most of the land surface of the watershed has been cultivated since the early 1900s (U.S. Department of Commerce, 1929–1987). Much of the lower bottomlands, however, have remained forested.

The Obion River and its major tributaries have been channelized by county governments or drainage districts since the early part of the century. These streams were not being maintained and presumably were reverting to a condition that would no longer facilitate rapid runoff. Much of the Obion River was rechannelized by the COE under the West Tennessee Tributaries Project. Dredging and channel maintenance occurred along some sections of the river from 1974 to 1978 and is planned for the future.

METHODS

The time period for this study consists of ten-year periods both preceding channelization (1952–1961) and afterwards (1968–1974, 1976, 1978–1979). The years 1975 and 1977 were excluded from analysis because of missing data. The months of May–October were selected for analysis. These months include most of the growing season and are within the time of year noted by Shankman and Samson (1991) with increasing flood frequency after channelization of the lower Obion River. The Palmer Drought Index (Palmer 1965), which is commonly used to identify abnormal wet and dry climatic periods (e.g., Diaz 1983, Karl 1983, Soule 1990), indicates similar climatic conditions before and after channelization.

Daily precipitation data were compared to stream discharge and stage records on the lower Obion River to determine stream response to major precipitation events. Daily discharge and stage records for the study period were obtained from the COE for the streamflow gaging station at Bogota (U.S. Army Corps of Engineers 1952–1980) (Figure 1). Daily precipitation measurements from three recording stations within the upper Obion River drainage basin (Union City, Martin, and Milan) were obtained from the National Climatic Data Center for the same period (EarthInfo Inc. 1989). An average daily precipitation value for the three stations was calculated to distinguish major precipitation events, those in which precipitation occurs over a large part of the watershed, from localized rainfall. Major precipitation events were defined as those in which average rainfall for the three climate recording stations exceeded 2.5 cm in a 24-hour period.

A total of 40 major precipitation events during the 10-year period before channelization and 67 during the 10-year period afterwards were identified. Not all of these rainfall events, however, were included in the analysis. Major precipitation events and corresponding hydrologic data were excluded if 1) the Mississippi River stage was high enough to back up the lower Obion River causing flooding or affecting discharge by significantly reducing surface-water gradient (which occurs most frequently during the early part of the growing season) or 2) there was significant rainfall within a period of seven days before or after the event. This standard was established to ensure a clear picture of stream response to a specific precipitation event. Eleven precipitation events before channelization (27.5% of the total) and 16 afterwards (23.8%) were used to analyze stream response to channelization. The downstream flood-wave travel time (the period of time

Table 1. Median monthly peak discharge in m³/second (cfs in parentheses) and range during the growing season for 10-year periods both before and after channelization on the lower Obion River at Bogota.

Month	Before		After		% Change
	Median	Range	Median	Range	
May	122 (4,315)	37–694	246 (8,689)	103–515	+101
June	82 (2,885)	23–377	114 (4,025)	57–726	+40
July	51 (1,815)	18–306	66 (2,320)	32–328	+28
Aug.	29 (1,025)	12–82	127 (4,495)	33–470	+338
Sept.	19 (675)	11–43	101 (3,560)	28–278	+427
Oct.	16 (572)	13–50	36 (1,275)	17–243	+122

from precipitation until peak discharge) for all events selected before and after channelization was compared using the Mann-Whitney test (Hammond and McCullagh 1978).

Discharge data both before and after channelization were used to calculate mean monthly peak discharge during the growing season (May–Oct.). Stage data were examined to determine the number of flood events and their duration for the study periods before and after channelization. Pearson correlation analysis and linear regression were used to examine peak discharge/flood duration relationships. Flooding is defined as river stage exceeding bankfull elevation.

RESULTS

The magnitude of peak flows on the lower Obion River following major precipitation events increased after channelization. Peak flows following the 11 selected rainfall events before channelization ranged from 16 to 38 m³/second (cms). Eight of the 12 selected precipitation events (of about the same magnitude) after channelization had corresponding peak flows exceeding this range (Figure 2). This increase seems to be related to lower flow resistance following channelization that allows floodwater to quickly converge downstream. The period of time from a major precipitation event within the Obion River watershed until peak discharge downstream decreased after channelization from an average of 3.3 days ($s = 1.4$) to 1.3 days ($s = 1.2$) (Mann-Whitney, $P < 0.002$) (Figure 3). This is a reduction of downstream flood-wave travel time of 60 percent. Median peak discharge also increased for each month during the growing season on the lower Obion River, ranging from 28 percent in July to 427 percent in September (Table 1). Although average peak flows on the lower Obion River were significantly lower before channelization, discharge during this period was occasionally very high. Two of the three highest dis-

Table 2. Peak discharges in m³/second during floods (stage exceeding bankfull: 79.9 m above m.s.l.) for 10-year study periods both before and after channelization on the lower Obion River at Bogota. Flooding events are ranked by stage.

Date	Discharge	Stage
Before channelization		
May 22, 1953	719	82.78
May 27, 1957	682	82.72
May 9, 1958	399	81.86
July 5, 1957	306	81.75
June 20, 1961	188	80.31
After channelization		
May 10, 1979	510	82.48
June 18, 1970	761	82.45
August 27, 1971	470	81.86
May 1, 1974	396	81.35
July 7, 1976	312	81.14
May 10, 1978	320	80.71
July 19, 1972	328	80.65
June 26, 1976	228	80.47
September 25, 1979	249	80.37
September 21, 1970	270	80.34
August 1, 1972	224	80.16
May 19, 1976	200	80.16

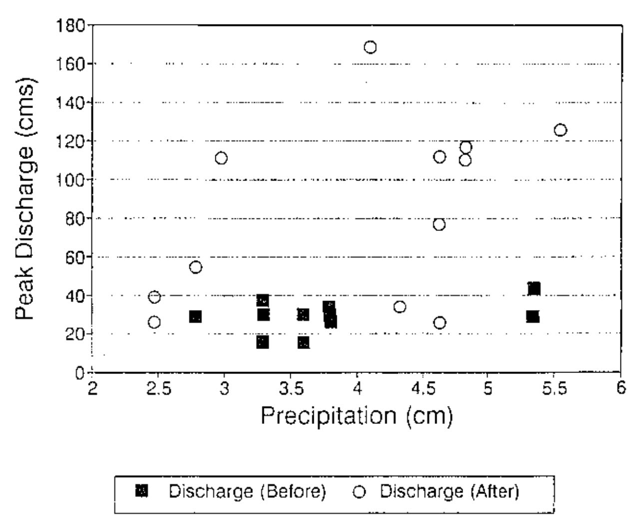

Figure 2. Magnitude of peak flows (m³/second) versus intensity of precipitation for selected precipitation events (between 2.5–5.5 cm) on the lower Obion River at Bogota before channelization and afterwards.

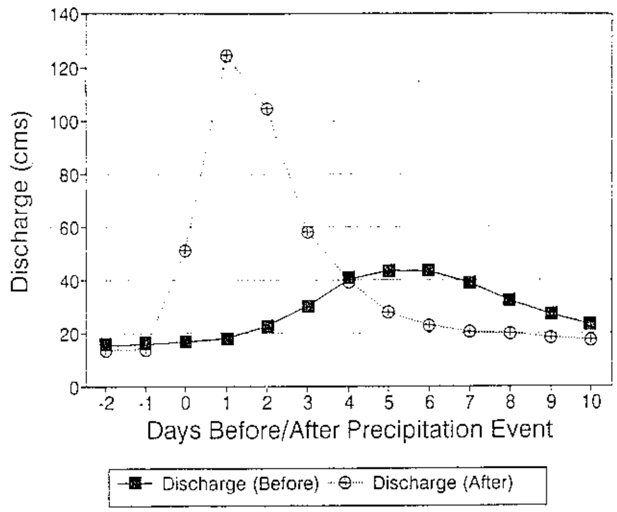

Figure 3. Discharge hydrograph of a precipitation event before channelization (Aug. 29, 1959) and afterwards (Oct. 24, 1971) showing time to peak discharge for the lower Obion River at Bogota.

charge events (where discharge exceeded 600 cms (21,190 cfs)) occurred before channelization (Table 2). These floods occurred after heavy rainfall over a two- to three-week period.

The number of flood events on the lower Obion River at Bogota was significantly higher after channelization. There were 5 growing-season floods during the 10-year period before channelization (0.5 floods/year). Flooding occurred 4 of the 10 years during this period and always during the first half of the growing season. In comparison, there were 12 growing-season floods during the 10-year study period afterwards (1.2 floods/year), an increase of 140 percent (Table 2). After channelization, flooding occurred during seven of the 10 years studied and during all months of the growing season except October, which is the driest month of the year (averaging about 5 cm precipitation). While flooding was more common after channelization, the highest stage recorded during the study period (and therefore the greatest surface area submerged during flooding) occurred beforehand (Table 2).

The average duration of floods decreased after channelization. Regression analysis indicates that peak discharge and duration of a flood had a strong positive relationship ($P < 0.001$) both before and after channelization (Figure 4). In both cases, when duration was regressed against peak discharge, r values exceeded 0.90. A visual interpretation of Y-intercept values and slope of the regression lines indicates that the average duration of floods of the same magnitude decreased after the Obion River was channelized.

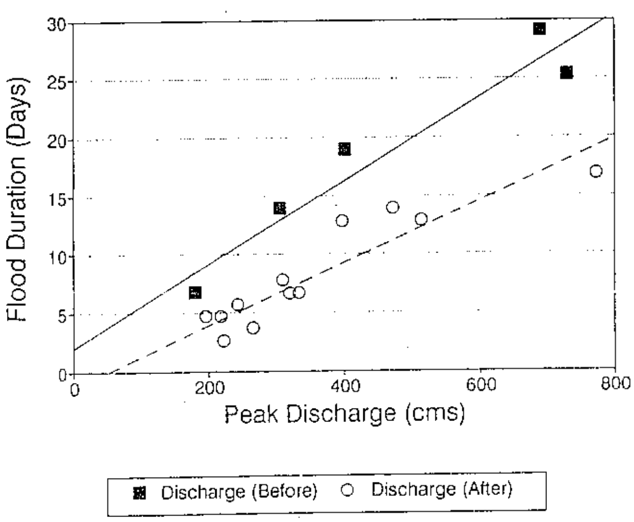

Figure 4. Flood duration-peak discharge relationships on the lower Obion River at Bogota before channelization and afterwards. The regression before channelization ($Y = .03X + 2.37$) and afterwards ($Y = .02X - 0.78$) were significant ($P < 0.001$).

DISCUSSION

The results of this investigation support Shankman and Samson's (1991) hypothesis that channelization resulted in higher peak flows on the lower Obion River. The results also strongly suggest that the higher discharges contributed to greater flood frequency. The significant reduction in downstream flood-wave travel time after channelization is related to improved hydraulic efficiency. Channel enlargement reduces frictional resistance by creating a smoother perimeter and more uniform channel and by increasing the cross section area-to-perimeter ratio. Also, the straightened alignment increases the water-surface gradient. These changes in channel morphology result in an increase in water velocity. Runoff from the channelized portion of the drainage basin converges at downstream locations faster than the stream channel can accommodate, resulting in an increased flood frequency.

While the magnitude of peak flows and number of flood events during the growing season on the lower Obion River increased after channelization, the average duration of flooding decreased. Greater flow efficiency increased peak discharge and flood frequency but also allowed flood water to move more quickly downstream and out of the Obion River drainage. However, even brief periods of inundation will destroy crops, and therefore, the decrease in flood duration since channelization is not a desirable alternative to higher flood frequency that also occurs.

The intensity of precipitation is not by itself a reliable predictor of downstream peak discharge. Hydrologic response to precipitation will vary depending on soil moisture conditions. During droughts that typically occur during the mid-summer to fall months, there is little soil moisture. Rainfall easily infiltrates the ground surface, and runoff only occurs after the upper-most soils are saturated and impounded low-lying areas begin to overflow. Occasionally, there is heavy precipitation or frequent rainfall during the latter part of the growing season. All but the highest precipitation events during the summer have no more than a minor effect on discharge because of dry conditions. Conversely, during the spring and early summer, the soil is more likely near saturation because of frequent rainfall. Under these conditions, a high proportion of precipitation will run off as opposed to infiltrate the soil surface. Therefore, at this time, streams typically respond faster to an equal amount of rainfall.

Channelization usually includes increasing the channel cross-sectional area. Robbins and Simon (1983) and Simon and Hupp (1987), however, have presented strong evidence to suggest that channelization causes downstream sediment deposition on the lower Obion River that has reduced the channel cross-sectional area and contributed to continuing high flood frequency there. Channelization by the COE shortened the length of the lower Obion River by about 29 percent. The steeper gradient and faster water velocity after channelization cause stream-bed degradation at the upstream end of the channelized section of the Obion River and headward migration of the knickpoints by as much as 1 km/year. Downcutting results in heightened and steepened channel banks, which are composed of highly erodible loess. Unstable banks have retreated, in some cases more than 1 m/year (Hupp 1987). Eroded sediment is transported downstream, where it is deposited because of the gentler gradient there. Downstream sediment deposition at Bogota was estimated to be higher than 10 cm/year immediately following channelization (Robbins and Simon, 1983). Aggradation reduces the cross-sectional channel area and may have aggravated flooding. Because of these changes in channel size, discharge can not be used to accurately predict stage. Channel incision, bank erosion, and downstream deposition after channelization on the Obion River are consistent with that found along other alluvial streams in the eastern U.S. (e.g., Emerson 1971, Yearke 1971, Piest et al. 1977, Schumm et al. 1984, Yodis 1990).

Channelization will have no effect on flood frequency or duration if Mississippi River stage is very high. The Mississippi River often backs up and floods the Obion River 30–50 km and occasionally may indirectly cause flooding at an even greater distance upstream by reducing surface-water gradient and slowing runoff (Shankman and Samson 1991). Changes in channel configuration have no effect on stage during these flooding events. Therefore, regardless of the effectiveness of channelization in increasing water velocity, the flood frequency on the lower sections of the river will be greater than upstream. The Mississippi River will only occasionally cause flooding of the lower Obion River after the earliest part of the growing season. Maximum stages on the lower Mississippi River occur mostly between early January and early May (Shankman and Samson 1991).

Additional channelization of the main stream or tributaries will increase the rate of runoff from an even larger portion of the watershed and may further increase peak flows and affect downstream flooding. Large amounts of water are stored in wetlands by surface impoundment and in soils (Sammell et al. 1966, Hill 1976). The stored water gradually moves into the streams and sustains baseflow during dry periods (Brookes 1988). However, by reducing flooding, a much smaller amount of water is stored in the adjacent bottomlands. Instead of water spreading across the floodplain as would be expected before channelization, it is mostly contained within the channel and quickly moves downstream, contributing to main-stream peak flows.

A small channelization project may have a minor impact on the Obion River system or other systems of equal or larger size. However, several small drainage projects will incrementally increase downstream flooding during the growing season and will limit agricultural productivity in the adjacent floodplain. The permit process for channelization (which is regulated primarily by the Federal Clean Water Act, Sections 401 and 404) focuses on the impact of a specific project and does not usually consider cumulative impacts (Gosselink et al. 1990). The consideration of additional channelization projects, even those designed to drain a small area, should include reasonably foreseeable cumulative hydrologic changes. The failure to do so for the Obion River and other Coastal Plain streams will likely result in a further increase in downstream flooding, which will cause a decline in bottomland agricultural productivity.

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STREAM CHANNELIZATION AND CHANGING VEGETATION PATTERNS IN THE U.S. COASTAL PLAIN

DAVID SHANKMAN

ABSTRACT. Plant-community patterns in the alluvial wetlands of the southeastern U.S. Coastal Plain are highly complex, depending on the hydroperiod, the height of the water table, the age of the surface age, and a variety of natural and human-induced disturbances. The range of physical conditions that many terrestrial species on lower bottomland sites require to maintain themselves and regenerate is narrow. Stream channelization causes a dramatic alteration of the magnitude and duration of flooding and sedimentation, and it precludes channel migration. These changes in hydrogeomorphic processes disrupt critical river–floodplain interactions, which in many cases alter the conditions of bottomland habitats and the composition of plant communities. The modified hydrology along some stream segments, in particular lower peak discharges in the upper sections of watersheds caused by channelization, has promoted deforestation and land-use conversion to agriculture. *Keywords: channelization, floodplain, U.S. Coastal Plain, wetlands.*

The southeastern U.S. Coastal Plain contains high-density stream networks and the largest area of alluvial wetlands in North America. Among the most common flood-control methods in this region is stream channelization. Its purpose is to increase channel capacity and flow velocity so that water moves more efficiently downstream and thereby reduces flooding. Channelization typically includes deepening and widening the stream channel and shortening it by cutting off meanders. Landowners and those who cultivate in the adjacent floodplains are the primary beneficiaries. In addition to closely involved government agencies, such as the U.S. Army Corps of Engineers and the U.S. Soil Conservation Service, local landowners have been the strongest advocates for channelization.

Awareness of the physical and biological problems caused by channelization is growing. Environmental degradation of alluvial habitats has been given serious attention in channelization project planning in recent years. Less destructive channel modifications have been implemented, and some attempts have been made to restore riparian habitats affected by channelization. For example, the Kissimmee River in south Florida, which was channelized in the 1960s, is being restored by reintroducing river flow into remnant channels (Loftin, Toth, and Obeysekera 1990; Shen, Tabios, and Harder 1994). The primary justification is the reestablishment of natural hydrologic conditions and the consequent enhancement of the river's biological resources. A similar restoration project is in the early planning stages for the Obion–Forked Deer River system in western Tennessee, also channelized in the 1960s.

The destructive effects of channelization on water quality and aquatic ecosystems are well documented in Brookes's review of 1988. But until recently, little at-

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tention has been paid to the effects of channelization on bottomland terrestrial ecosystems. Flood frequency and related physical conditions (including the depth of surface water and the water table, as well as the accumulation of sediment and organic matter) are among the most important factors controlling the presence and distribution of bottomland terrestrial species and are the basis for most classifications of floodplain plant communities (Penfound 1952; Huffman and Forsythe 1981; Wharton and others 1982). Stream channelization significantly alters these conditions in the adjacent bottomlands. But few attempts have been made to link changes in floodplain hydrogeomorphic conditions following stream channelization directly to plant-community composition.

Western Tennessee and northwestern Mississippi is an area of the Gulf Coastal Plain in which almost all of the major streams and many of their large and small tributaries have been channelized (Figure 1). These river systems have been studied extensively, and much is known about channel behavior, floodplain hydrology, and bottomland vegetation (Schumm, Harvey, and Watson 1984; Hupp 1987; Simon and Hupp 1987; Simon 1989, 1994; Shankman and Drake 1990; Shankman and Pugh 1992). But the response of forest communities to changing physical conditions is by no means clear. Most floodplain tree species in this region live for decades or centuries, which greatly exceeds the amount of time that has elapsed since extensive channelization began. As a result, short-term observations of bottomland forest are, in all but a few cases, unlikely to reveal forthcoming changes.

In this article I examine the potential effects of channelization on bottomland terrestrial habitats in the southeastern United States. Probable changes induced by channelization in forest communities are assessed based on geomorphic processes and life-history characteristics of common bottomland species. In addition, changes in flooding, sedimentation, and restricted-channel migration that follow channelization are evaluated. Changes in natural hydrogeomorphic conditions are directly linked to floodplain habitats and to regeneration of bottomland species. I also address the ecological effects of bottomland deforestation, which has recently accelerated in the alluvial valleys of this region.

Regional Overview

All of the major rivers in western Tennessee and northwestern Mississippi flow westward before entering the lower Mississippi River Valley. These are low-gradient, meandering streams that have dissected loess deposits up to 20 meters thick underlain by Coastal Plain formations. The largest streams have created floodplains with little relief, typically 3–5 kilometers across, which occupy as much as 10 percent of the entire land surface. These streams flood most years, during the winter and spring. Portions of the floodplain may be submerged for a few days to several weeks, and there is often more than one period of submergence. The loess soils are highly erodible, and rates of sedimentation in the adjacent floodplains are typically very high (Trimble and Carey 1974; Schumm, Harvey, and Watson 1984; Wolfe and Diehl 1993).

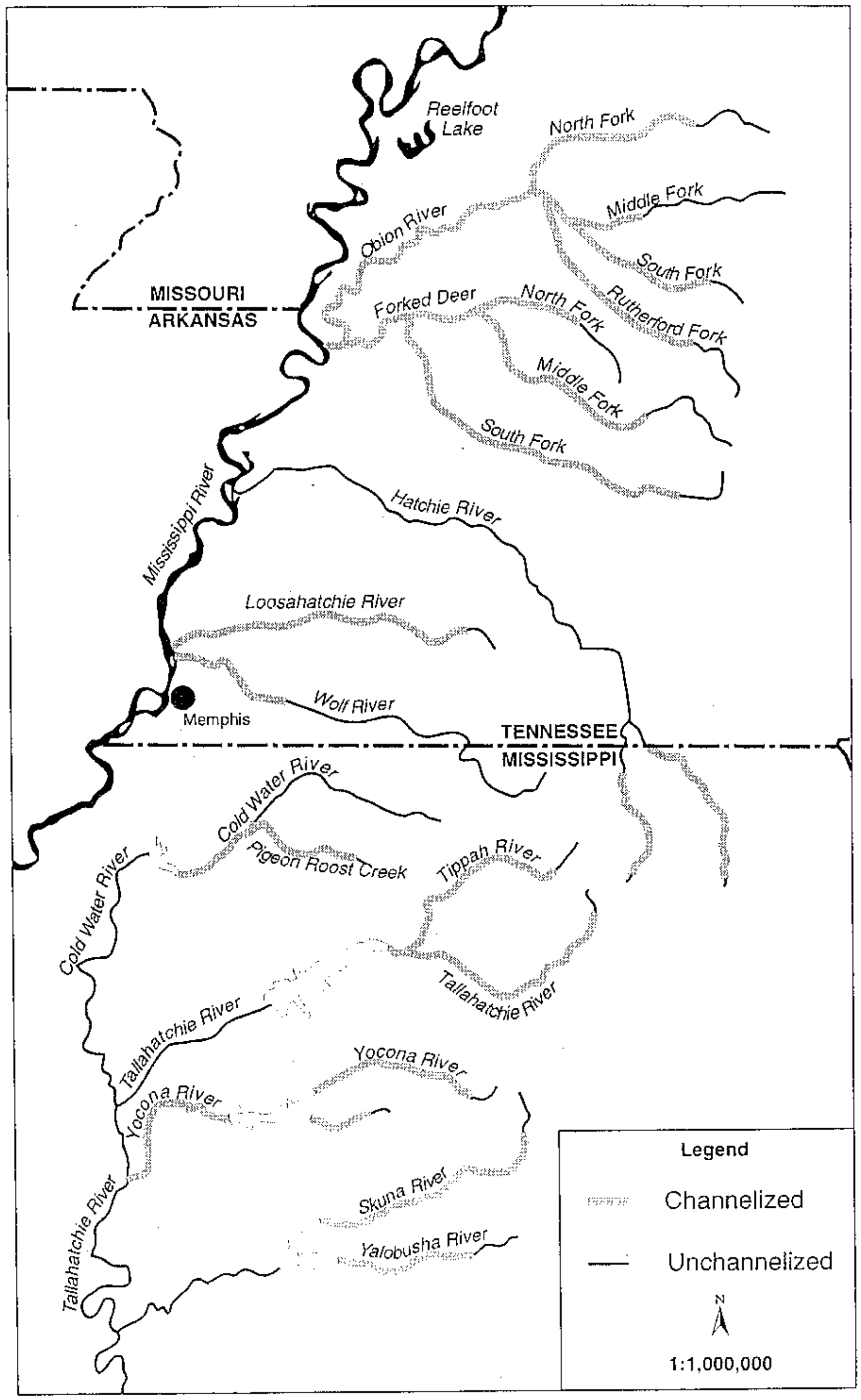

FIG. 1—Major rivers in western Tennessee and northwestern Mississippi. The channelized sections of each river are shown. (Cartography by the University of Alabama Cartographic Research Laboratory)

The alluvial valleys of the Gulf Coastal Plain support a diverse forest vegetation. Plant-community patterns within the alluvial valleys are highly complex, depending on the hydroperiod (flooding, impoundment of surface water, and height of the water table), channel migration and surface age, and complex disturbance regimes (White 1979). Because of the high flood frequency, a fairly large portion of the lower bottomlands—the surfaces within or immediately adjacent to the meander belts—have remained forested. Extensive portions of the outer floodplains, however, have been deforested and are now cultivated. Klopatek and others (1979) estimated that 63 percent of the original southern floodplain forest has been lost.

The active floodplains of many alluvial streams surrounding this region are bounded by later Pleistocene terraces (Saucier 1987). These surfaces are remnants of ancient floodplains that formed during the interglacial periods of the last 2 million years, when average discharge, channel width, and meander wavelength were much greater than they are today. Pleistocene river terraces, in a few cases, encompass large parts of alluvial river valleys. They rarely flood, however, and therefore support many upland plant species that are uncommon in modern floodplains.

Most of the major streams in this region, in addition to many tributaries, have been channelized (Table I). These include the Obion, Forked Deer, Loosahatchie, and Wolf Rivers in western Tennessee, and the Cold Water, Tippah, Tallahatchie, Yocona, Skuna, and Yalobusha Rivers in Mississippi. During the early part of this century, channels were filling with sediment as a result of both extensive deforestation during the late 1800s and notably poor soil-conservation practices (Ashley 1910). Channelization by county or state governments became widespread during the 1920s and 1930s. These were largely efforts to reduce seasonal flooding and to remove channel obstructions that created shallow swamps which covered large areas of the floodplains (Speer and others 1965).

Many of the first attempts at channelization had a relatively minor impact on the streams. Few meanders were cut off, and in most cases channel enlargement was minimal. Also, the channelized sections of the rivers were usually not maintained, so they began to revert to a hydrologically inefficient, meandering channel. But since the 1950s the Army Corps of Engineers and the Soil Conservation Service, which often provided funding and personnel, have been responsible for channelization projects on a much larger scale in western Tennessee and northern Mississippi. The Hatchie River is the sole remaining major stream in the area without major modifications along most of the main channel (Figure 2). It is generally regarded as free-flowing and in 1968 was designated a scenic river by the state of Tennessee. But plans are currently being developed to channelize or rechannelize several streams, including the upper sections of the Hatchie River.

Discussion

The hydrologic condition of a floodplain is a dominant factor controlling plant-community structure and composition. With increasing distance from the lower floodplain there is a decrease in flood frequency and a corresponding spatial gradient of

TABLE I—MAJOR CHANNELIZED STREAMS IN WESTERN TENNESSEE AND NORTHWESTERN MISSISSIPPI[a]

WESTERN TENNESSEE	NORTHWESTERN MISSISSIPPI
Obion River	Cold Water River (15)
North Fork (82)	Camp Creek (16)
Cypress Creek (18)	Byhalia Creek (12)
South Fork (70)	Red Banks Creek (25)
Middle Fork of the Obion (36)	Pidgeon Roost Creek (35)
Spring Creek (27)	Cutoff Creek (14)
Crooked Creek (18)	Beartail Creek (15)
Mud Creek (30)	Hickahala Creek (30)
Rutherford Fork of the Obion (45)	Senatobia Creek (17)
	Arkabutla Creek (34)
Forked Deer River	
North Fork of the Forked Deer (55)	Tallahatchie River (55)
Pond Creek (27)	Tippah River (60)
Middle Fork of the Forked Deer (136)	Okannatie Creek (20)
Cypress Creek (10)	Mud Creek (20)
Buck Creek (10)	McIvor Canal–Floyd Creek (15)
South Fork of the Forked Deer (121)	
Nixon Creek (21)	Yocona River (30)
Black Creek (16)	Otoucalofa Creek (17)
Mud Creek (14)	
North Fork (15)	Yalobusha River (30)
	Skuna River (55)
Hatchie River[b]	Topashaw Creek (25)
Muddy Creek (40)	Sabougla Creek (25)
Porters Creek (23)	
Piney Creek (16)	
Cypress Creek (25)	
Tuscumbia River (50)	
Upper Hatchie (38)	
Loosahatchie River (75)	
Laurel Creek (14)	
Beaver Creek (25)	
West Beaver Creek (10)	
Big Creek–Crooked Creek (36)	
Cypress Creek (24)	
Wolf River (33)	

[a] The rivers are arranged in latitudinal order, from north to south. The lengths of the channelized sections are shown, in kilometers, in parentheses.

[b] Only the upper sections of the Hatchie River have been channelized.

FIG. 2—A meander of the lower Hatchie River in western Tennessee, 1994. (Photograph by the author)

plant communities that are made up of species with progressively lower flood tolerance (Penfound 1952; Bedinger 1971; Huffman and Forsythe 1981; Wharton and others 1982). Only the most flood-tolerant species occur in the lower bottomland sites (Table II). Many of these tree species have seeds that are dispersed primarily by water (including bald cypress, water tupelo, green ash, water hickory, overcup oak, and black willow), so they occur almost exclusively on floodplain surfaces that regularly flood.

Channelization limits flooding most effectively on the upper reaches of streams (Shankman and Samson 1991). Water, instead of spreading across the floodplain in the upper sections of the drainage basin, as would be expected if there were no channelization, is quickly moved downstream by the straightened and enlarged channels (Figure 3). Along stream segments where flood frequency and depth are reduced, the distribution of many species is affected. The most flood-tolerant, water-dispersed species are restricted to a narrow portion of the floodplain (flood-tolerance classes I and II, Table II). Reduced frequency and duration of flooding can also affect the distribution of less flood-tolerant bottomland species that occur on higher floodplain surfaces (flood-tolerance classes III and IV). Diminished flooding, particularly during the growing season, will allow these species to establish on lower sites nearer the meander belt that, before channelization, were too wet for them to regenerate.

Significantly drier conditions caused by channelization will also allow the establishment of upland species previously precluded from floodplains by inundation.

TABLE II—FLOOD TOLERANCE OF COMMON BOTTOMLAND TREE SPECIES IN WESTERN TENNESSEE AND NORTHWESTERN MISSISSIPPI

	FLOOD-TOLERANCE CLASSES					
	Seedlings		Mature Trees			
SPECIES	S[a]	P[b]	I[c]	II[d]	III[e]	IV[f]
Water tupelo (*Nyssa aquatica*)	×	×	×			
Black willow (*Salix nigra*)	×	×	×			
Bald cypress (*Taxodium distichum*)		×	×			
Silver maple (*Acer saccharinum*)		×		×		
Water elm (*Planera aquatica*)		×		×		
Swamp privet (*Foresteria acuminata*)		×		×		
River birch (*Betula nigra*)		×		×		
Cottonwood (*Populus deltoides*)		×		×		
Sycamore (*Platanus occidentalis*)		×		×		
Green ash (*Fraxinus pennsylvanica*)		×		×		
Hackberry (*Celtis laevigata*)		×		×		
Box elder (*Acer negundo*)		×		×		
Pecan (*Carya illinoensis*)		×		×		
Water locust (*Gleditsia aquatica*)				×		
Water hickory (*Carya aquatica*)				×		
Overcup oak (*Quercus lyrata*)				×		
Nutall oak (*Quercus nuttallii*)				×		
Willow oak (*Quercus phellos*)				×		
American elm (*Ulmus americana*)					×	
Swamp chestnut oak (*Quercus michauxii*)					×	
White oak (*Quercus alba*)					×	
Water oak (*Quercus nigra*)					×	
Sweetgum (*Liquidambar styraciflua*)					×	
Persimmon (*Diospyros virginiana*)						×
Hornbeam (*Carpinus caroliniana*)						×
Cherrybark oak (*Quercus falcata*)						×
Winged elm (*Ulmus alata*)						×
Red maple (*Acer rubrum*)						×
Honey locust (*Gleditsia triacanthos*)						×
Mulberry (*Morus rubra*)						×

Sources: Penfound 1952; Bedinger 1971; Broadfoot and Williston 1973; Teskey and Hinckley 1977; Wharton and others 1982).

[a] Total submersion during part of the growing season.

[b] Partial submersion.

[c] Constant inundation for up to one year.

[d] Constant inundation for a large part of the growing season.

[e] Long-term seasonal flooding.

[f] Occasional seasonal flooding.

Most upland species tolerate root submersion for only very short periods, but they may be able to invade bottomland sites that, following channelization, only flood during exceptionally wet years. The rates of successful colonization depend on flood frequency and duration, which vary greatly among stream segments. Even after channelization, almost all lower bottomland sites flood at least occasionally during

FIG. 3—A channelized section of Hickahala Creek in northern Mississippi, 1995. (Photograph by the author)

the wettest years (Shankman and Pugh 1992). The regeneration rates of upland species under these conditions are not clear. It is unlikely that species intolerant of flooding will ever dominate bottomland sites that are still subject to flooding. They may, however, thrive on the outer, highest floodplain surfaces that only rarely flood after channelization.

Although channelization can effectively decrease flooding upstream, the higher discharge boosts flooding downstream (Hillman 1936; Emerson 1971; Campbell, Kumas, and Johnson 1972). Channel enlargement reduces frictional resistance by creating a smoother perimeter and a more uniform channel and by increasing the hydraulic radius (the ratio of channel cross-sectional area to the wetted perimeter). Also, a straightened alignment increases the water-surface gradient. These changes in channel morphology increase water velocity. In contrast to the decrease in flooding in the upper sections of the watershed, runoff from the channelized portion of the drainage basin converges at downstream locations faster than the stream channel can accommodate it, resulting in higher peak flows (Shankman and Pugh 1992). Even though the frequency of downstream floods increases, the greater flow efficiency allows water to move rapidly out of the river drainage, decreasing the average duration of these floods.

Many of the most common species in the lower bottomland sites are unlikely to be affected by higher flood frequency on the lower stream sections. During most years these sites are under water for periods of at least several weeks, and in unusually wet years the lowest portions of the floodplains remain submerged for several months. Mature individual trees will easily tolerate a somewhat higher number of flood events. But when additional flooding occurs during the growing season, as opposed to earlier in the year, even short-duration floods can affect the colonizing ability of some species. In almost all cases, bottomland species germinate on surfaces that are exposed after the floodwaters recede. Flooding during the late spring or summer can prevent regeneration by submerging and killing first- or second-year seedlings. Bottomland species at all ages tolerate root submersion very well, but few tolerate complete submersion for more than a short period (Teskey and Hinckley 1977).

CHANGES IN CHANNEL MORPHOLOGY

Greater water velocity following channelization can cause rapid stream incision (Schumm, Harvey, and Watson 1984; Simon and Hupp 1987). Incision of the main channel creates a lower base level for tributaries, which initiates headward erosion and down-cutting. The encroachment of newly created gullies onto the valley floor will drain shallow impoundments caused by beavers (*Castor canadensis*) or other types of channel obstructions. Small, semipermanent impoundments, usually covering an area of no more than a few hectares, are relatively common in the lower bottomland sites adjacent to main river channels and smaller tributaries. The water that stands on these sites for much of the year maintains distinctive plant communities typically dominated by bald cypress, water tupelo, or both (Figure 4). No other tree species, including those that are often found in the lower bottomland sites, survives long in these habitats. The drainage of these sites allows the establishment of other bottomland species that do well in areas subject to seasonal flooding but that cannot tolerant continuous inundation (flood-tolerance classes II and III).

Channel-bed erosion of large streams following channelization is usually discontinuous. Rejuvenation of tributaries moves progressively upstream, creating higher and steeper channel banks that are highly susceptible to erosion (Hupp 1987). Sediment delivery to the main channel as a result of tributary erosion becomes so great that down-cutting ceases and the channel bed begins to aggrade (Robbins and Simon 1983; Schumm, Harvey, and Watson 1984; Simon and Hupp 1987). The cross-sectional area of the downstream channels shrinks, so they are less able to contain the higher peak flows that follow channelization.

Along some streams the high sediment loads completely clog the main channels. These so-called valley plugs usually develop at the mouth of tributaries but can occur elsewhere (Happ, Rittenhouse, and Dobson 1940; Diehl 1994). Channel obstructions like these force water into the surrounding floodplain, even during periods of low flow. Because alluvial valleys are areas of low relief, the clogged channels can cause the submergence of large floodplain surfaces, amounting in some cases to thousands of hectares, that before channelization and its ancillary effects flooded only during the wettest time of the year. Beaver commonly occupy newly inundated sites and

FIG. 4—A bald cypress–water tupelo swamp along the Wolf River in western Tennessee, 1994. (Photograph by Larry J. Smith)

can augment flooding by building their own dams. These semipermanent flooded sites are fairly common in western Tennessee and northwestern Mississippi.

Shallow swamps created by channel obstructions significantly affect riparian landscapes. Most bottomland species adapted to seasonal flooding will not tolerate long-term root submersion and die within a year or two of inundation (Figure 5). Bald cypress is the most frequent colonizer of these sites, rapidly occupying shallow and frequently but impermanently flooded sites. On the deepest, long-flooded areas, regeneration will be limited but does occur. On occasion, bald cypress colonizes permanently flooded sites by establishing on downed logs and floating vegetation mats (Hunt 1943; Dennis and Batson 1974; Huffman and Lonard 1983). These mats are composed of fine sediment and partially decayed organic matter interwoven with dense root systems of aquatic plants. The roots of bald cypress grow through these mats and establish themselves in underlying sediment.

TRIBUTARY CHANNELIZATION

The channelization of tributary waterways can have a significant effect on the hydrology downstream and affect terrestrial vegetation in the adjacent bottomlands. The floodplains of small tributaries are relatively narrow, compared with the major rivers in the region, and have less cultivated land subject to flooding. Small streams, however, are often channelized and transformed into drainage canals for flood con-

FIG. 5—A shallow marsh on a tributary of the Hatchie River created by channel obstructions, 1993. (Photograph by the author)

trol, a trend that was continued in recent years. These many small flood-control projects can have a significant cumulative impact on the major rivers in the region. This has happened on the Hatchie River, most of which is not channelized. Any single construction project on a tributary may be justified by the requirements of local flood control or other economic rationales, particularly if, when viewed in isolation, one channelizing project has an evidently negligible effect on the river. But the collective effect of channel construction projects within the watershed incrementally alters how the main stream functions, with an impact on both the physical and ecological characteristics of the overall floodplain. Rapid runoff from low-order streams in the upper sections of the drainage basin increases the magnitude of peak flows in the main channels. Higher sediment delivery downstream still contributes to channel aggradation and the development of valley plugs. Clearly, channelizing tributaries contributes to higher flood frequency and floodplain inundation downstream, affecting even segments along major rivers that have not been channelized (Nabb 1996).

CHANNEL STABILIZATION AND LOSS OF HABITAT DIVERSITY

The complex vegetation patterns in the alluvial wetlands are not entirely a consequence of gradients in the hydroperiod. The finer-scale vegetation patterns in lower bottomland sites are attributable to the lateral movement of meandering streams.

Channel migration results in complex patterns of new surfaces, created by point-bar deposition and the filling in of oxbow lakes. This process results in a mosaic of distinct forest communities, whose composition depends largely on surface age and elevation (Shelford 1954; Shankman 1991, 1993). The new surfaces are rapidly colonized by species with high flood tolerance that require flooding for seed dispersal and exposed sites and high light levels for successful establishment.

The creation of point bars by lateral accretion is the dominant process for the development of new floodplain surfaces. Slower water velocity on the inside of channel bends allows sediment deposition. Vertical accretion raises surfaces that are eventually exposed during low water levels. Young point-bar surfaces typically are dominated by black willow, cottonwood, and silver maple. However, these are short-lived species that are shade intolerant. They do not regenerate beneath themselves, and within a few decades of their initial establishment they are replaced by shade-tolerant species such as green ash, water hickory, sugarberry, and overcup oak, among many others.

Abandoned meanders, or oxbow lakes created by channel cutoffs, also are common features in alluvial valleys of the Gulf Coastal Plain. Young oxbows typically hold water during much, if not all, of the year. Initial colonizing shrubs and trees establish at the lake margins, where seasonal water-level fluctuations expose surfaces necessary for germination. Establishment of terrestrial vegetation at the center of the abandoned channel occurs only after the deposition of sediment and organic debris creates new surfaces exposed during low water levels. The earliest colonizers in abandoned channels are black willow, water tupelo, and bald cypress, because of their flood tolerance. As on point bars, the early colonizers are shade intolerant and will not replace themselves.

Sediment deposited on point bars and meander scars during flooding raises young surfaces, making them less susceptible to later inundation and more suitable for the establishment of somewhat less flood-tolerant species. These species eventually replace the early arrivals. Therefore, the early colonizing species are uncommon on older surfaces. Under natural hydrogeomorphic conditions, the rate of channel migration and creation of new surfaces by point-bar deposition and the filling in of oxbow lakes maintain these early successional communities in the lower floodplain. Stabilized channels preclude the formation of point bars and oxbows, so an important disturbance mechanism controlling habitat diversity and spatial heterogeneity is eliminated.

BOTTOMLAND DEFORESTATION AND CONVERSION TO AGRICULTURE

I have discussed how stream channelization affects forest communities by disrupting natural flooding conditions and channel migration. A more direct impact on bottomland ecosystems is the deforestation that is also, at least in part, a response to channelization. The alluvial valleys of the Coastal Plain are areas of fertile soils and low relief and, therefore, are among the most productive farmlands in the eastern United States. Large portions of many of the alluvial valleys have been cleared for agriculture. The remaining forests occur mostly on the lowest floodplain surfaces that are in or immediately adjacent to the meander belt. These sites are often too wet for cultivation. But the modified hydrology along some stream segments, in particular the lower peak discharges in the upper parts of the watershed caused by channelization, has promoted clear-cut deforestation and land-use conversion to agriculture, even on surfaces previously unsuitable for cultivation.

The removal of bottomland forest vegetation affects the magnitude of downstream floods. Floodwater slows as it moves out of the channel and into the surrounding floodplain, like water flowing across a counter after it overflows from a sink. The vegetative cover and surface organic debris in the forested bottoms increase the frictional resistance to overland flow (Gosselink and others 1990). Also, debris and beaver dams in gullies and small tributaries cause frequent surface impoundment in the lower bottomlands. Slower water velocity and impoundments enhance surface-water infiltration, which increases bottomland water-storage capacity—water flows, slows, ponds, and sinks in. Deforestation and removing organic matter from bottomland sites eliminates many of the impoundments and allows faster runoff. These contribute to higher downstream peak flows and a likelihood of flooding there.

Coastal Plain streams generally carry a large load of sediment, which is also the case in the loess regions of western Tennessee and Mississippi (Trimble and Carey 1974; Schumm, Harvey, and Watson 1984; Wolfe and Diehl 1993). Slower velocity of water as it moves out of the channel into the floodplain allows sediment deposition and the gradual buildup of floodplain surfaces. Some sediment is carried back into the stream channels by receding floodwater. Faster runoff from bottomland sites caused by deforestation and removal of organic matter results in the rapid development of gullies and increases the potential for erosion and transportation of sediment into river channels. This is particularly important when the land is cultivated, because there is little surface organic debris to hold soils in place. The low-gradient Coastal Plain streams are rarely able to transport the additional sediment. As a result, the riverbed aggrades, reducing the cross-sectional area of the channel (Nabb 1996). Stream channels that are shrinking because of high rates of erosion and sedimentation have a higher water-surface elevation with an equal discharge and, therefore, a greater probability of flooding. The higher peak flows caused by deforestation and rapid runoff from the previously forested floodplain overwhelm the shrinking channels downstream.

Conclusions

Plant-community patterns in the alluvial wetlands of the southeastern U.S. Coastal Plain are highly complex, depending on the hydroperiod (including seasonal flooding and impoundment of surface water), the height of the water table, the age of the surface, and a variety of other disturbances. Many terrestrial species occurring in the lower bottomland sites require a narrow range of physical conditions to maintain themselves and regenerate. Channelization dramatically alters the magnitude and

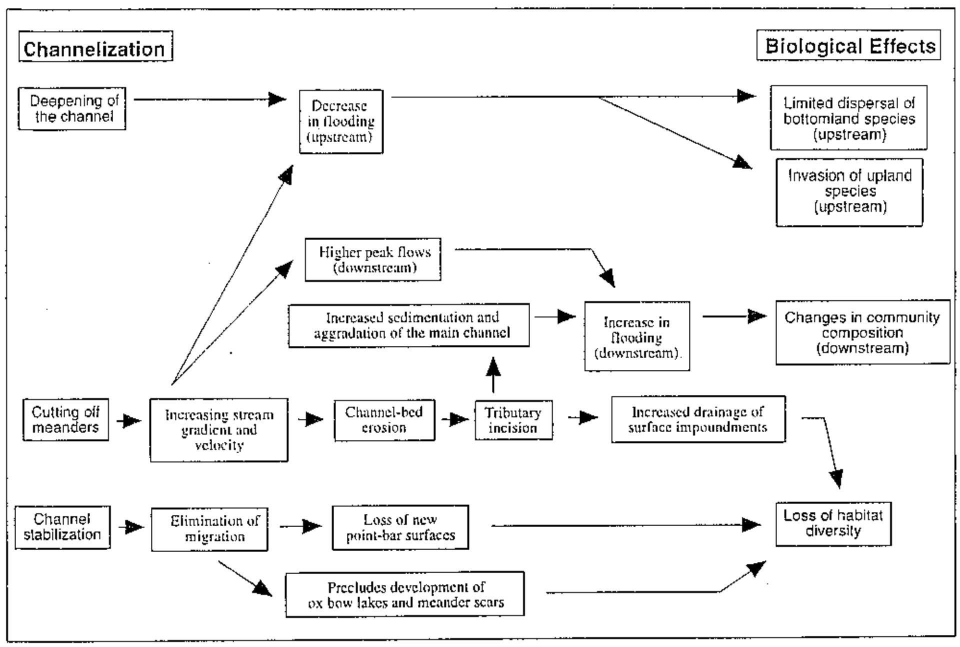

FIG. 6—The effects of channelization on floodplain terrestrial habitats in western Tennessee and northwestern Mississippi.

duration of flooding and sedimentation and precludes channel migration. These changes in hydrogeomorphic processes disrupt critical river–floodplain interactions that, in many cases, alter the conditions of bottomland habitats (Figure 6).

Based on our understanding of stream processes, channel and sedimentation responses to channelization, and life histories of floodplain tree species, it is possible to forecast probable changes in community composition. A significant decrease in flooding that typically occurs along upper stream segments will most likely affect the distribution of bottomland species within the floodplain. Furthermore, upland species may be able to establish on the drier floodplain surfaces, but only where floods are rare and of extremely short duration. It is less clear how plant communities will respond to the increased flooding that typically occurs downstream after channelization. It seems probable that a higher flood frequency during the growing season will limit regeneration, either by precluding germination or by killing seedlings on sites that were previously suitable for colonization.

Studies of the regeneration requirements of bottomland species are abundant, and much is known about their life-history characteristics. However, the precise hydrologic conditions necessary for regeneration of many bottomland species is unknown. Average—or what may be regarded as normal—hydrologic conditions may not be favorable for establishment. Successful colonization for some species may well be episodic, depending on exceptionally dry years or a series of dry years that allow individual trees to become firmly enough established to tolerate later flooding events. If, in fact, episodic climatic-hydrologic conditions control regeneration, a clear picture of bottomland community responses may not emerge for several decades after channelization.

The response of plant communities to hydrologic changes following channelization is partially speculative. It is clear, however, that channelization will directly or indirectly cause the loss of habitat and plant-community heterogeneity in adjacent floodplains. Historically, the variable hydroperiod and surface ages caused by channel migration combined to create a complicated mosaic of different forest stands. Tributary incision that follows channelization will eventually drain impounded sites. The maintenance of straightened channels eliminates new surface development by stopping the formation of point bars and the filling in of oxbow lakes. Each of these sites has supported unique plant communities that will largely disappear after channelization.

Clearly, riparian ecosystems and physical processes are strongly linked, and an appreciation of these integrated processes is an important step toward understanding the forces that shape riparian landscapes. A more-detailed understanding of the effects of channelization on plant communities in the Gulf Coastal Plain, however, requires long-term, site-specific investigations. But even detailed, fine-scale observations will not provide a complete understanding of plant-community responses. The geomorphic and hydrologic character of these streams have been studied extensively, but much is still unknown. Further complicating the attempts to understand the response of bottomland ecosystems to river channelization are ongoing changes in land use, increased urbanization, and the failure of state and local government agencies to resolve flood-control management issues. As long as hydrogeomorphic conditions continue to change, plant communities will, to a degree, continue to adjust, and our comprehension of the response of bottomland terrestrial vegetation will not increase.

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STREAM CHANNELIZATION AND SWAMP FORMATION IN THE U.S. COASTAL PLAIN

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Abstract: Most of the major rivers and their largest tributaries in western Tennessee were channelized during the 1950s and 1960s to reduce floods. Channelization of the tributaries causes stream bed incision that destabilizes these channel systems. Headward erosion following channelization results in bank instability and collapse that produces large quantities of sediment. This sediment is transported downstream eventually clogging river channels. These channel blockages back-up water on lower floodplains creating, in some cases, large swamps. Lower floodplain surfaces prior to swamp formation would typically flood only during the wet winter and spring months; now they are often submerged for most of the year. Most bottomland trees adapted to seasonal floods cannot tolerate long-term root submersion and die within a year or two of inundation. Baldcypress is the most frequent colonizer within the swamps, rapidly occupying shallow parts of these wetlands. But many woody shrubs, small trees, and a wide variety of aquatic vascular plants also become established on these sites. Before European settlement of this region, swamps covered much larger areas of the alluvial valleys than today. The development of swamps as a result of stream channelization is in some ways transforming the lower bottomlands of these streams so that they more closely resemble conditions before European settlement. [Key words: channelization, floodplain, U.S. Coastal Plain, wetlands.]

INTRODUCTION

The southeastern U.S. Coastal Plain is a region of low relief containing high-density stream networks. These are mostly meandering streams that have created broad alluvial valleys. Areas within the meander belts and adjacent bottomlands flood most years during the winter and early spring. Floodplain inundation may last several days or weeks, and some years there may be more than one flood event. Vegetation patterns within these alluvial wetlands are highly complex, but plant-community composition is generally attributable to flood duration and impoundment of surface water. With increasing distance from the lower floodplain, there is a decrease in flood frequency and a corresponding spatial gradient of plant communities composed of species with progressively lower flood tolerance.

Channelization has been used extensively in the U.S. Coastal Plain for flood control. Western Tennessee is within the Coastal Plain and is the regional focus of this

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investigation. Here, most of the rivers and many of their largest tributaries have been channelized. Channelization usually includes deepening and widening the stream channel and shortening it by cutting off meanders. The purpose is to increase channel capacity and flow velocity so that water moves more efficiently downstream. Higher velocity within the channel leads to stream incision, bank instability, and increased sediment delivery to the downstream reaches. Increased sediment delivery can cause downstream channel bed aggradation (Robbins and Simon, 1983; Simon and Hupp, 1987) that in some cases cause channel blockages that have been referred to as "valley plugs" (Happ et al., 1940). Channel blockages usually form where a channelized tributary enters a larger stream, but they can occur elsewhere. As channel blockages form, the rate of sediment deposition is enhanced by slower stream velocity causing additional sediment to drop.

Channel blockages force water into the surrounding floodplain, even during periods of low flow. The lower alluvial valleys, areas within or near the meander belt, have very little relief. Therefore, clogged channels can cause the submergence of large floodplain surfaces, in some cases thousands of hectares that before channelization flooded only during the wet winter and spring months. These blockages account for a majority of surfaces within the alluvial wetlands of western Tennessee that are submerged for much of the year. The shallow swamps created by channel blockages significantly alter bottomland forest vegetation. Most bottomland species adapted to seasonal flooding cannot tolerate long-term root submersion and therefore will die after swamps develop. Other species can regenerate in these environments, but not in all cases. Forest-community composition and species dominance are highly variable depending on water depth and the frequency and duration of surface exposure. The purpose of this paper is to describe the linkage between tributary channelization and swamp formation in western Tennessee. Specifically, this paper discusses (1) the relationship between tributary channelization and the formation of channel blockages, (2) the formation of swamps upstream of these blockages, and (3) changes in bottomland forest vegetation after these swamps develop.

REGIONAL OVERVIEW

All of the major rivers in western Tennessee and northwestern Mississippi flow westward before entering the Mississippi River alluvial valley (Fig. 1). These are low-gradient, meandering streams that created floodplains typically 3–5 km across. The lower floodplain surfaces flood most years during the winter and early spring. These streams have dissected loess deposits underlain by Coastal Plain formations. The loess is up to 20 meters thick at the edge of the Mississippi River valley and rapidly thins to the east. The active floodplains in many cases are bounded by late Pleistocene terraces (Saucier, 1987). These surfaces are remnants of ancient floodplains that have formed over the last 2 million yrs., during intervals when average discharge, channel width, and meander belt wavelength were much greater than they are today.

The alluvial valleys are occupied by diverse forest communities. Bottomland vegetation patterns are closely linked to flood duration and the impoundment and depth of surface water. Vegetation patterns can also be attributed to channel

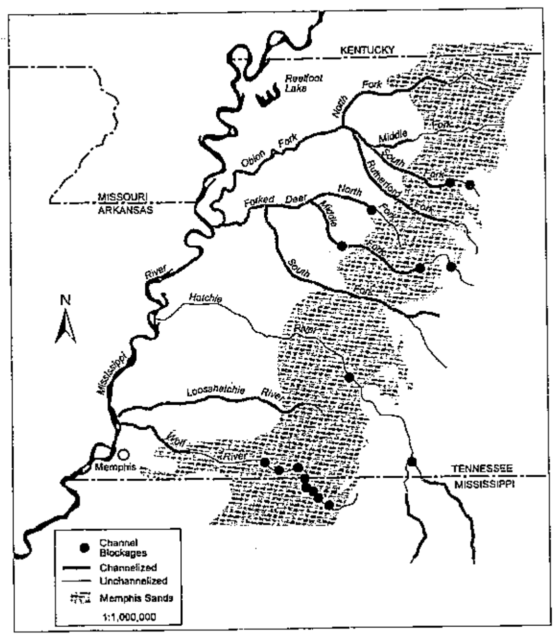

Fig. 1. Major rivers in western Tennessee, the positions of channel blockages caused by sediment delivery at the mouth of channelized tributaries, and the Memphis Sands outcrop.

migration. There is a direct relationship between surface age, determined by the period of time since a site was last occupied by the active channel, and successional stages of forest development (Shankman, 1993). Beaver (*Castor canadensis*) ponds, abandoned channels, and other sites with poor drainage are dominated by baldcypress (*Taxodium distichum*) or mixed baldcypress—water tupelo (*Nyssa aquatica*) stands. Both species easily tolerate long-term root submersion. Point bars and river banks that are often submerged during winter and spring floods, but exposed for most of the year, typically support silver maple (*Acer saccharinum*), black willow (*Salix nigra*), cottonwood (*Populus deltoides*), and sycamore (*Platanus occidentalis*). Slightly higher surfaces subject to shorter duration floods are typically occupied by overcup oak (*Quercus lyrata*), green ash (*Fraxinus pennsylvanica*),

hackberry (*Celtis laevigata*), and water hickory (*Carya aquatica*). Many others can be added to this list. Extensive portions of the outer alluvial plains, including Pleistocene river terraces, rarely flood.

Large parts of these surfaces are deforested and cultivated. From the 1780s until 1980s, Tennessee lost 4800 km^2 of wetlands, mostly from the clearing and drainage of lower floodplain surfaces so they could be put into agricultural production (Dahl, 1990). Most of the converted wetlands were within the broad alluvial valleys of western Tennessee. The central and western sections of the state are not within the Coastal Plain and have narrow stream valleys and a relatively small percentage surface area classified as wetlands.

The southeastern Unite States is a humid subtropical region. The growing season in western Tennessee extends from early April until early November and the winters are generally short and mild. The dominant precipitation mechanisms throughout the year are cyclonic storms and fronts. Convectional thunderstorms occur during the summer, but these storms usually account for only a small percentage total rainfall. Precipitation, stream discharge, and flood frequency are greatest during late winter and early spring. During unusually wet years, however, floods will occur during the late spring and early summer months. Late summer and fall are much drier, generally receiving only about one-half as much rainfall as during the winter and spring months, so floods almost never occur during this period. Prolonged droughts will sometimes occur during the summer and fall, but these are unusual events.

Most of the major streams in this region and many of their largest tributaries have been channelized (Table 1). Channelization by county or state governments became widespread during the 1920s and 1930s. These projects typically included channel enlargement and removal of downed trees (Speer et al., 1965). In some cases meander bends were cutoff to shorten the channel length, but often the streams were left with a meandering pattern. Channelized streams were not regularly maintained, so they began to revert to a hydrologically inefficient channel. Landowners are the primary beneficiaries of flood-control efforts. Since the 1950s, the United States Army Corps of Engineers and Soil Conservation Service (now Natural Resources Conservation Service) has been responsible for larger scale channelization projects in this region.

All of the major rivers in western Tennessee have been channelized, some to a much greater extent than others. The entire downstream sections of the Obion and Forked Deer Rivers and all of their major tributaries have been channelized (Fig. 1). The same is true of the Loosahatchie River to the south. The Hatchie River is the only major stream without major modification along much of the main channel. Its uppermost section in northern Mississippi and almost all of its large tributaries have been channelized, but it is still regarded as free-flowing and in 1968 it was designated a scenic river by the state of Tennessee. The downstream section of the Wolf River was channelized as were most of its large tributaries. Typically, only the downstream sections of the tributaries were channelized because of the wider floodplains and therefore large surface area that could support cultivation.

Table 1. Major Streams in Western Tennessee, Listed in Latitudinal Order, North to South

River	Channelized tributaries (length in km)
Obion River	North Fork of the Obion (82)
	Cypress Creek (18)
	South Fork of the Obion (70)
	Middle Fork of the Obion (36)
	Spring Creek (27)
	Crooked Creek (18)
	Mud Creek (30)
	Rutherford Fork of the Obion (45)
Forked Deer River	North Fork of the Forked Deer (55)
	Pond Creek (27)
	Middle Fork of the Forked Deer (136)
	Cypress Creek (10)
	Buck Creek (10)
	South Fork of the Forked Deer (121)
	Nixon Creek (21)
	Black Creek (16)
	Mud Creek (14)
	North Fork (15)
Hatchie River[a]	Muddy Creek (40)
	Porters Creek (23)
	Piney Creek (16)
	Cypress Creek (25)
	Tuscumbia River (50)
	Upper Hatchie (38)
Loosahatchie River (75)	Laurel Creek (14)
	Beaver Creek (25)
	West Beaver Creek (10)
	Big Creek–Crooked Creek (36)
	Cypress Creek (24)
Wolf River[b] (33)	

[a]Only the upper sections of the Hatchie River have been channelized.
[b]Most of the major tributaries of the Wolf River have been channelized. The lengths of the channelized sections of its tributaries are mostly less than 10 km.
Source: Shankman, 1996.

CHANNELIZATION

The downstream sections of most of the large tributaries in western Tennessee have been channelized, and therefore they possess a high degree of geomorphic

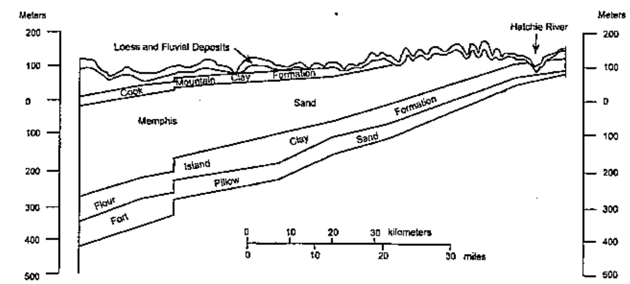

Fig. 2. Cross section of western Tennessee showing the position of the Memphis Sands.

instability. Channelization of tributary streams typically involved straightening, deepening, and widening existing channels, as well as clearing snags. These changes in channel morphology reduced water flow resistance by smoothing the channel perimeter and increasing the hydraulic radius (Schumm et al., 1984). Also, straightening such channels by artificially cutting-off meanders increased their gradient. Together, these changes in channel morphology dramatically increase flow velocity. Significantly higher velocity increased scouring of the channel bed (Emerson, 1971; Schumm et al., 1984). The downstream sections of the tributary rapidly incise after channelization, typically creating steep, and in some cases almost vertical, banks that are in some cases 3–4 m deep.

Channel incision on the downstream sections of tributary streams has destabilized these drainage systems. Small lateral channels have actively responded to a lower base-level. In almost all cases, headward erosion and incision have progressed upstream into the lowest order streams in the uppermost reaches of the watershed. This is consistent with Winkley's (1971) documentation of rapid headward erosion in northern Mississippi, which is only a short distance south of the Wolf River watershed. Incision of lower order stream segments makes channel banks highly susceptible to erosion. Evidence of bank instability, frequently observed throughout the region, was based on slumping of steep banks and trees toppling into the channel. The collapse of unstable banks caused rapid widening of the channel along many stream sections. The watersheds of most tributaries occur within an outcrop of a Coastal Plain formation known as the Memphis Sands (MS). This formation can extend to a depth of more than 100 m (Fig. 2). These are unconsolidated marine sands that are easily eroded.

Channel bank instability and frequent collapse has produced large quantities of sediment that are transported downstream. As a result, the lower stream segments which incised immediately after channelization, have ceased eroding and are now filled with sediment. In some cases, sand has completely filled the former channel.

Aggradation of these channels has progressed to the point that base flow is no longer evident on the surface of the channel bed. Instead, during periods of low discharge, water moves beneath the surface of the sand deposits that can be greater than 3 m deep. Normal discharge, which before channelization was contained within the channel, now spills out of the clogged stream into the adjacent floodplain. Under these conditions, surfaces that were supposed to be protected from floods by channelization are much more frequently inundated.

FORMATION OF CHANNEL BLOCKAGES

Channel blockages that Happ et al. (1940) refer to as "valley plugs" typically form at or immediately downstream of the mouth of channelized tributaries. After channelization, the tributaries deliver more sediment than the larger streams can transport. As a result, sediment accumulates and in some cases entirely fills the channel. These sediment dams slow water velocity, further reducing the stream's ability to transport sediment. This accelerates sediment accumulation and tends to cause channel blockages to grow in the upstream direction (Diehl, 2000). Also, driftwood is trapped in the sediment dams, contributing to their development. When the channel is entirely blocked, water is eventually forced onto the surrounding floodplain, finding its way down valley through old meander scars, in newly created channels, and/or as sheet flow across the flat lower floodplain surfaces.

Channel blockages have created many large swamps. The alluvial valleys are areas of low relief. Therefore, when the entire channel becomes blocked, water is backed-up and typically spreads over a large area. The downstream valley gradient is very low. Not only does water behind channel blockages spread across the floodplain, but submerged surfaces may extend many kilometers up the river valley. All of the major rivers in western Tennessee (Obion and Forked Deer Rivers, Hatchie River, Loosahatchie River, and Wolf River) flow throughout the year, even during prolonged drought that sometimes occur during the middle to late summer and early fall months. The lower floodplains, including areas within the meander-belt and adjacent surfaces, immediately upstream of blockages are almost always submerged. With distance upstream of the channel blockages and toward the outer edges of the floodplain, surfaces may be alternately submerged and exposed during the wet and dry times of the year. Precipitation and river discharge is greatest during the late winter and early spring, and it is during this time that water covers the largest area.

Sixteen major channel blockages observed by the authors or documented by others have occurred along major streams in western Tennessee and northern Mississippi, almost always at the mouths of channelized tributaries (United States Army Corps of Engineers, 1995; Diehl, 2000). Eight blockages are located on the middle and upper sections of the Wolf River. Almost this entire region is within the Memphis Sands outcrop (MS). The high erodibility of these sandy soils and substrata likely contributed to the frequent blockages that occur there. The largest swamp along the Wolf River occurs near the mouths of Early Grove and Mount Tena Creeks (Fig. 3). During the winter and spring, the submerged area may exceed 8–10 km^2. To the north, the Hatchie River has at least two major blockages, in addition to at least two other sites where blockages appear to be forming (Diehl, 2000). One of the blockages occurs within the MS. The other, at the confluence of the upper Hatchie River and the Tuscumbia River, which is upstream of the MS, was cleared by the United States Army Corps of Engineers during the late 1990s. The Obion–Forked Deer River system, north of the Hatchie River, has the largest watershed in western Tennessee. Six major blockages have occurred along these rivers. Four of the tributaries creating blockages are at least partially within the MS. Two others are immediately downstream. The largest swamp along this channel system is located at the junction of Beaver Creek and the South Fork of the Obion River. The permanently inundated area is greater than 10 km^2. Some of the other blockages in the Obion-Forked Deer Rivers have been cleared by the United States Army Corps of Engineers. There are no major blockages on the Loosahatchie River, which has the smallest watershed in the region, most of which is located outside the MS.

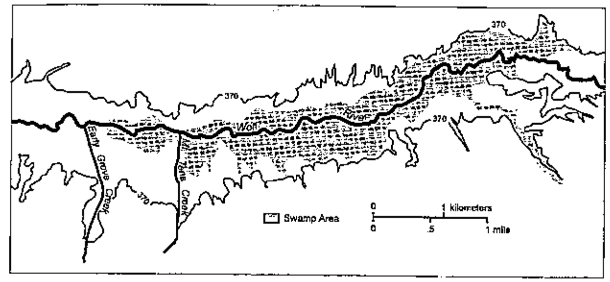

Fig. 3. A swamp of the Wolf River created by channel blockages at the mouths of Mount Tena and Early Grove Creeks. The floodplain is delineated by the 370 foot contour.

VEGETATION RESPONSE

Small-scale vegetation patterns within the floodplains of Coastal Plain streams are highly complex. But at a larger scale there is an easily identifiable spatial gradient of forest communities with distance from the meander belt, composed of species with progressively lower flood tolerance. As shown in Table 2, there are few tree species that can tolerate root submersion for up to a year (flood-tolerance class I). There are, however, several species that regularly occur on sites subject to long-term seasonal flooding (flood-tolerance classes II and III), and an additional group of species found on higher floodplain surfaces that flood only occasionally (flood-tolerance class IV). The development of swamps upstream of channel blockages disrupts the normal annual winter-spring flood cycles common to lower bottomland sites. Continuous inundation after swamp formation kills most trees within 1–2 yrs. The most common exception is baldcypress that maintains itself on

Table 2. Flood Tolerance of Common Bottomland Tree Species in Western Tennessee and Northwestern Mississippi

	Flood-tolerance class					
	Seedlings[a]		Mature trees[b]			
Species	S	P	I	II	III	IV
Water tupelo (*Nyssa aquatica*)	x	x	x			
Black willow (*Salix nigra*)	x	x	x			
Baldcypress (*Taxodium distichum*)		x	x			
Silver maple (*Acer saccharinum*)		x		x		
Water elm (*Planera aquatica*)		x		x		
Swamp privet (*Foresteria acuminata*)		x		x		
River birch (*Betula nigra*)		x		x		
Cottonwood (*Populus deltoides*)		x		x		
Sycamore (*Platanus occidentalis*)		x		x		
Green Ash (*Fraxinus Pennsylvanica*)		x		x		
Hackberry (*Celtis laevigata*)		x		x		
Boxelder (*Acer negundo*)		x		x		
Pecan (*Carya illinoensis*)		x		x		
Water locust (*Gleditsia aquatica*)				x		
Water Hickory (*Carya aquatica*)				x		
Overcup oak (*Quercus lyrata*)				x		
Nutall oak (*Quercus nuttallii*)				x		
Willow oak (*Quercus phellos*)				x		
American elm (*Ulmus Americana*)					x	
Swamp chestnut oak (*Quercus michauxii*)					x	
White oak (*Quercus alba*)					x	
Water oak (*Quercus nigra*)					x	
Sweetgum (*Liquidambar styraciflua*)					x	
Persimmon (*Diospyros virginiana*)						x
Hornbeam (*Carpinus caroliniana*)						x
Cherrybark oak (*Quercus falcata*)						x
Winged elm (*Ulmus alata*)						x
Red maple (*Acer rubrum*)						x
Honey locust (*Gleditsia tricanthos*)						x
Mulberry (*Morus rubra*)						x

[a]S = total submersion during part of the growing season; P = partial submersion.
[b]Flood-tolerance classes: (I) constant inundation for up to one year; (II) constant inundation for a large part of the growing season; (III) long-term seasonal flooding; (IV) occasional seasonal flooding.
Sources: Penfound, 1952; Bedinger, 1971; Broadfoot and Williston, 1973; Teskey and Hinckley, 1977; Wharton et al., 1982; Shankman, 1991; Shankman, 1996).

permanently submerged sites almost indefinitely. Water tupelo can also survive long-term root submersion, but it is not as common on these sites.

Bottomland forest communities that rapidly decline after swamp formation are often replaced by baldcypress, and in a few cases mixed baldcypress–water tupelo stands. Although previously established baldcypress will survive after swamp formation, its dominance on these sites is primarily because of its ability to regenerate there. Baldcypress occurs on all shallow swamps created by channel blockages during the past few decades in western Tennessee. However, the density of baldcypress on these sites is highly variable. In some cases, it has established a nearly continuous forest canopy. On other sites, it has highly clustered spatial patterns, with sections of some swamps occupied by only a few scattered individuals. The conditions accounting for these inconsistent spatial patterns are not entirely known. But it is likely that its presence and density are related to surface elevation and surface exposure periodicity. Baldcypress seeds are spread by flood water, but successful establishment depends on the seeds being deposited on exposed surfaces (Demaree, 1932; Schneider and Sharitz, 1988). Therefore, baldcypress rapidly colonizes shallow and frequently exposed sites. Sites that are infrequently exposed support relatively few individuals. But occasional surface exposure coincident with high seed production may allow widespread colonization. Some baldcypress occur in deep water. In most cases, these individuals were present on stream banks or shallow impoundment before swamp formation.

Baldcypress can regenerate on permanently flooded sites by establishing on downed logs and on floating vegetation mats. The vegetation mats observed in several western Tennessee swamps are similar to those described in other parts of the southeastern Coastal Plain (Hunt, 1943; Dennis and Batson, 1974; Huffman and Lonard, 1983). These mats are composed of fine sediment and partially decayed organic matter interwoven with dense root systems of aquatic plants typically 10–20 cm in depth. The mats allow terrestrial species, including baldcypress, to become established. Baldcypress seeds germinate on these surfaces. The roots eventually grow through the mats and into the underlying sediment. The increasing weight of colonizers will eventually cause the mat to sink killing flood intolerant species (Huffman and Lonard, 1983). Baldcypress is the only tree species among the mat colonizers that can survive long-term root submersion. Baldcypress establishment on these vegetation mats was only occasionally observed by the authors.

Baldcypress longevity far exceeds that of the other colonizing species and may dominate a site for several centuries (Stahle et al., 1985, 1988; Shankman and Drake, 1990). Because inundation excludes most other tree species, extensive forest stands composed almost entirely of baldcypress can develop. Baldcypress is extremely shade intolerant and will not regenerate after the development of a forest canopy. First year seedlings are common in the lower alluvial bottoms, but none survive if in the shade of other individuals. Therefore, regeneration is discontinuous (Demaree, 1932; Shankman and Drake, 1990). Because of its shade intolerance, the age range of baldcypress within a single stand is no greater than the period of time from initial establishment until the development of a forest canopy.

Large parts of these swamps cover areas with a slightly higher surface elevation that is toward the outer edge of the floodplain or well upstream of the channel blockages. Water is usually shallow and surfaces are often exposed during the dry summer and early fall months. These sites can support forest communities that typically consist of species listed in flood-tolerance class II, and a few other species in class III. The presence and density of species depends on a complex relationship between surface inundation and regeneration. The ability of tree species to colonize and survive on these sites depends on the timing and duration of surface exposure. Seed germination requires continuous surface exposure during the late spring and early summer months. The conditions necessary for regeneration do not occur every year, and possibly during only a small number of years. Therefore, establishment of flood tolerant plants is likely highly episodic. Once individuals of these species are well established, most can tolerate winter floods, even those of long duration. However, long-term root submersion during the growing season will kill most trees. Continuous inundation, even when the water is very shallow, precludes regeneration of almost all bottomland tress, except for baldcypress.

Some areas of the swamps are dominated by shrubs or small trees. Among the most common are Virginia willow (*Itea virginica*), button bush (*Cephalanthus occidentalis*), hazel alder (*Alnus serrulata*), possum haw (*Ilex deciduas*), rose mallow (*Hibiscus moscheutos*) and swamp privet (*Forestiera acuminate*). These species colonize only on exposed surfaces. But once established they can thrive on what later become permanently submerged sites. Shrub swamps may include scattered baldcypress, and some sites are transitional from forest stands to open water in which there are no woody species.

FUTURE PROSPECTS AND MANAGEMENT IMPLICATIONS

Channelization has been widely used for flood control in the Coastal Plain, most notably in the lower Mississippi River Valley where sections of almost all rivers have been modified. The high number of channel blockages in western Tennessee, however, is unique to this region. There are two factors that distinguish western Tennessee from most other parts of the Coastal Plain. First, small tributaries have been frequently channelized, not only along the downstream sections that are within the floodplains of the larger rivers, but also channels farther upstream and in the surrounding uplands. Second, large sections of these watersheds are within the outcrop of the Memphis Sands. These unconsolidated, highly erodible soils facilitate channel incision and bank erosion after channel networks are destabilized by channelization.

The floodplains of the small channelized tributaries are typically narrow, most no more than 1–1.5 km wide. The total bottomland area along each stream that was to be protected from floods by channelization was typically only a few km^2. Tributary channelization failed to alleviate floods as intended. To the contrary, these projects have increased the frequency and duration of floods along both these streams and the rivers into which they flow. The sediment derived from channel incision and bank erosion after tributary drainage systems were destabilized has clogged channels that were initially widened and deepened. In some cases the sediment accumulated until it reached a bankfull elevation. These channels now hold less water than before channelization. During the dry summer and fall months often there is no surface flow, although water is likely moving below the surface of the sediment that is often saturated. Higher discharge events common during winter and spring, which before channelization may have been entirely contained within the channel, now spill over into the surrounding floodplain. Channel blockages in the larger streams cause long-term inundation of bottomland sites ranging from less than one to several km^2. Before channelization these floodplain surfaces were inundated only during seasonal floods, mostly during the winter and early spring. Further, there are extensive areas at slightly higher elevation immediately beyond the continuously submerged sites. Before swamp formation, these higher surfaces would flood only during extreme flood events. Now however, they are affected by annual floods. Clearly, the use of channelization for flood control along small tributary streams in this region has failed.

There is strong evidence that before European settlement of this region, swamps covered much larger areas of the alluvial valleys than today. There are three factors that likely accounted for poorer bottomland drainage during that time. First, beaver were much more common and the dams they created backed up water over large areas. Beaver were hunted almost to extinction throughout much of the southeastern United States (Butler, 1991). The population has increased significantly in recent decades, but beaver will never again have the same numbers nor influence as during pre-European times because intensive bottomland cultivation and logging dramatically altered what is otherwise an ideal habitat. Second, because of the rich alluvial soils, floodplains are the most intensively cultivated sites in the southeastern United States. During the past few decades, there have been major efforts throughout the region to improve agricultural productivity by draining the lower bottomlands. The most widespread drainage method was channelization. The third factor accounting for poorer drainage before European settlement is that the unlogged floodplain forests were occupied by significantly older and larger trees. Downed trees of great size created substantial channel blockages that led to the development of large swamps. These three factors resulted in extensive surface impoundments in lower bottomland sites that supported baldcypress and other species tolerant of long-term submersion.

Early settlers in this region described extensive swamps and floods along the rivers. Among the most notable of these settlers was David Crockett (1834), who settled along the Rutherford Fork of the Obion River in 1822. He wrote:

> The house which was nearest me was seven miles off, and on the different side of the Obion river, belonged to a man by the name of Owens; and I started to go there as there was no boat to cross the river in, and it was so high that it had overflowed all the bottoms and low country near it. We now took to the water like so many beavers and waded on. The water would sometimes be up to our necks, and at others not so deep; but I went on, of course, before, and carried a pole, with which I would feel along before me, to see how deep it was, and to guard against falling into a slough, as there was many in our way. but we worked on till at last we got to the channel of the river, which made it about half a mile we had waded from where we took water. When we got over this (river channel), it was still a sea of water as far as our eyes could reach. We

took into it again, and went ahead, for about a mile, hardly ever seeing
a single spot of land, and sometimes very deep.

John Bell's 1832 survey of northern Mississippi was conducted when the region was sparsely settled. The survey includes the upper section of the Wolf River and indicates extensive swamps in the surrounding floodplains (Fig. 4).

Forest vegetation patterns are a consequence of physical site factors, but are also attributable to natural disturbance (White, 1979; Pickett, 1980). Disturbance (such as fire, insect infestation, windstorms, and channel migration) often destroy stands covering areas ranging from less than a hectare to hundreds of square kilometers, and create discrete patches and large scale spatial heterogeneity. Swamp formation is a major disturbance mechanism and an important determinant of landscape and biotic diversity in alluvial valleys in the southeastern U.S. Coastal Plain. Long-term inundation kills most bottomland tree species. These forest stands are replaced by species that have the reproductive and ecological characteristics necessary to colonize these sites: water dispersed seeds, fast growth rates, and high flood tolerance. By far, the most common tree species reproducing on these sites is baldcypress. But many other species occur there. The high species richness is accounted for by many woody shrubs and small trees and wide variety of aquatic vascular plants.

Swamps created by channel blockages may exist for decades without human intervention. Yet, these are not necessarily permanent features in these alluvial valleys. New channels eventually form as water seeks a path downstream, in which case the swamps are drained. The previously inundated sites will often flood during the winter and spring, but will no longer favor the regeneration of baldcypress and other swamps species, and they are eventually replaced by diverse bottomland forests. Therefore, the initiation and continual presence of swamp plant communities depends on the formation of new swamps. Under natural conditions, as occurred before European settlement, swamp formation was common. Now, the largest swamps are an unforeseen consequence of small-stream channelization. Regardless of the formation mechanism, the continued existence of large swamps and the plant communities they support are threatened by flood control projects that will destroy the blockages and drain the bottomlands.

Annual winter-spring floods are generally viewed as undesirable, but are recognized as an unavoidable process affecting floodplains. In contrast, poorly drained areas subject to long-term submersion have been considered for many years to be degraded sites. This is clearly demonstrated by United States Army Corps of Engineers' publications and other federal and state government documents that commonly refer to swamps as "degraded wetlands" (e.g., United States Army Corps of Engineers, 1982; Tennessee Department of Agriculture, 2002). These same agencies often referred to channelization as "channel improvement." The Obion-Forked Deer Basin Authority (1983), an agency funded by the State of Tennessee, stated in their comprehensive plan that channelization would "restore floodplain integrity," even though the same document acknowledges that these construction projects alter natural geomorphic and ecological processes.

In recent years, views have changed regarding the value of swamps in western Tennessee. The best evidence of revised thinking during the past few years is that

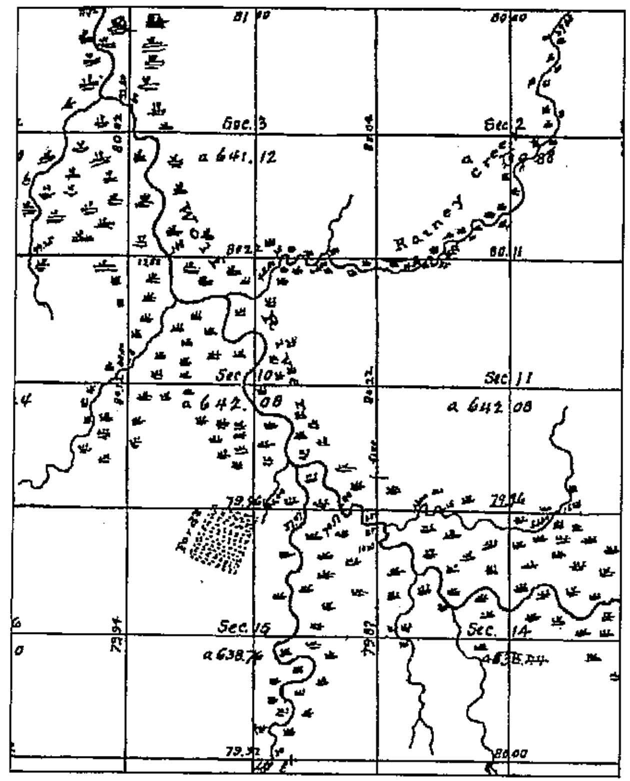

Fig. 4. The 1832 survey of the upper Wolf River. This is the first survey of the region and indicates extensive swamps adjacent to these channels.

the State of Tennessee bought land to protect swamps created by channel blockages on both the Wolf and Forked Deer Rivers. The Forked Deer River swamp was once the center piece of a proposed drainage project, but now has a long boardwalk for visitors. There are still many advocates for draining swamps. Also, there are strong efforts to revive large scale projects to rechannelized the large rivers in the region that were proposed years ago but never funded. But it is clear that there are some who now recognize that swamps along Coastal Plain streams are a consequence of natural processes that, in the absence of extensive land-use management, would be common and cover large areas of the lower floodplains.

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CYCLIC PERTURBATION OF LOWLAND RIVER CHANNELS AND ECOLOGICAL RESPONSE

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ABSTRACT

Certain lowland streams have experienced prehistorical and historical cycles of aggradation, occlusion, degradation, headward incision, and renewed aggradation. Historical cycles appear to be related to human activities. A case study is presented of the Yalobusha River in Mississippi with emphasis on the effects of blockage and removal on aquatic habitats and fish. The adjacent Skuna River, which was channelized and unblocked, was used in space for time substitution to infer effects of blockage removal on the Yalobusha. Variables describing physical aquatic habitat and fish were sampled from three groups of river reaches: unblocked channelized, channelized and blocked, and naturally sinuous. Fish collections were used to compute six indicators of ecological integrity. At baseflow, mean water depths were an order of magnitude lower in the unblocked channelized stream than for the others. In-channel aquatic habitat volume per unit valley length was 5, 85, and 283 m^3/m for the channelized, blocked channelized, and natural reaches, respectively. Mean values for all six ecological indicators were lowest for the channelized group. Species richness was greatest for the channelized blocked reach. The ecological indicators displayed gradients in response to the range of observed physical conditions. Management of corridors susceptible to the cycle described above should involve a blend of measures designed to conserve higher quality habitats.

KEY WORDS: aquatic habitats; cyclic perturbation; ecological integrity; ecological response; fish; indicators; lowland rivers

INTRODUCTION

Streams draining lowland watersheds sometimes completely fill with sediment, forcing flows overbank. As explained by a Task Committee of the American Society of Civil Engineers (1971):

> This extreme condition may result from some chance obstruction, such as a log jam, or from tributary contribution of bed load which the main stream cannot carry away, or from inadequate outlet for an artificially improved channel. The term 'valley plug' has been used for such areas of local channel filling, with numerous bordering splay deposits, in small valleys affected by excessive channel filling from gullying of sandy upland subsoils.

Accelerated valley filling that occurred due to formation of valley plugs following European settlement has been documented for watersheds in states from Mississippi (Happ *et al.*, 1940) to Texas (Jones, 1948 in Vanoni, 1975). Valley plugs, or 'channel blocks', have been formed in channels following deforestation and cultivation of uplands (Lowe, 1922; Little and Murphey, 1981), and at the downstream ends of straightened channels (Mississippi Board of Development, 1940; Diehl and Wolfe, 1992). In some cases, channel blockage may be due to natural causes and occur on a much larger scale. One of the most impressive cases of valley plugging occurred between ca. 1790 and 1873 on the Red River in Louisiana which affected 390–480 km of channel as well as many tributaries over a period of 375 years, forming several large lakes (Triska, 1984). Channel blocks formed by debris jams and sediments derived from upstream channel instability currently exist in Western Tennessee (Diehl, 1994) and northwestern Mississippi (Simon, 1998). Partial blocks comprised of sand are common in streams of southeastern Australia (Rutherfurd, 1996). Some evidence suggests that similar structures occurred in prehistoric times,

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creating extensive shallow lakes (Pflug, 1969; Saucier, 1974; Schumm *et al.*, 1981, 1984), although this hypothesis has been debated when applied to northwestern Mississippi (Grissinger and Murphey, 1983). Nevertheless, there is evidence in northwestern Mississippi lithology for a cycle of valley sedimentation–channel incision–valley sedimentation over the last 16000 years (Grissinger and Murphey, 1982, 1983). Such plugs are one type of channel obstruction that forms whenever there is a discontinuity in sediment or woody debris conveyance. Another type of obstruction is typified by large megaform bars and braided reaches that form in montane gravel-bed rivers when slugs of bed material are introduced by mass wasting, climate change, or other factors (Church and Jones 1982).

Existing literature (e.g. Vanoni, 1975) focuses on the effects of these plugs on the stratigraphic record. Happ (1968) reported that borings taken in 1937–1939 showed mean accumulations of 0.3 to 1 m of recent sediment on floodplains within 14 northwest Mississippi watersheds ranging in size from 11 to 57 km^2. Deposits were thickest in upper parts of valleys, on alluvial fans at tributary mouths, and upstream from completely filled sections of stream channels. Filled channels occurred at random locations in natural channels, near the lower ends of artificially straightened reaches (e.g. Watson *et al.*, 1997), or, in one case, upstream of a beaver dam. Channel filling forced all flow overbank, causing extensive swamping and sediment deposition on the floodplain.

Additional evidence for formation of modern channel blocks in the lower reaches of channelized streams has been derived from analysis of river stage data. A simple approach is to construct plots of annual minimum stage versus time. When coupled with a chronology of channel modifications, these plots provide a history of channel modification and response. In Figure 1, the authors have redrawn plots previously published by others for six streams in northern Mississippi. Locations of guaging stations are shown in Figure 2. Sources of data are listed in Table I. Each plot in Figure 1 shows one, two, or three abrupt drops of 1–2 m in annual minimum stage corresponding to human activities such as channelization or large-scale removal of woody debris and riparian vegetation. The decline in stage is more gradual for the Coldwater River, probably because the bed lowering was due to headward incision in response to channelization of downstream reaches rather than at the gauge site. With the exception of the Skuna River, these degradational events were followed by periods of gradually increasing annual minimum stage, with rates ranging from about 3 to 10 cm year^{-1}, implying a cycle period of 10–60 years. Similar patterns were reported for the Homochitto River in southwestern Mississippi, with a rate of annual minimum stage change of 4 cm year^{-1} (Kesel and Yodis, 1992). These trends of increasing annual minimum stage are interpreted as evidence of system response to human disturbance (Schumm *et al.*, 1984; Harvey and Watson, 1986; Simon, 1989; Kesel and Yodis, 1992). Base level lowering by channelization results in headward incision, often by upstream progression of knickpoints and knickzones which lead to massive bank failures in upper reaches. Woody debris and sediments derived from this erosion are transported downstream to the vicinity of the gauge with resulting bed aggradation and in extreme cases such as the Yalobusha, channel blockage.

Response of fishes of the southeastern USA and their habitats to lowland river channel blockages has not been studied in a comprehensive fashion. Diehl (1994) inspected several perturbed watersheds in Western Tennessee and noted that increased flooding due to valley plugs promoted vegetational changes over extensive areas of valley bottom. Open-water communities, marshes, and wetland shrub communities were replacing bottom land hardwood swamps and croplands. Additional inferences regarding likely response of riverine systems in the southeastern USA can be drawn based on evidence regarding fish utilization of naturally occurring flooded forests (Baker *et al.*, 1991; Killgore and Baker, 1996; Light *et al.*, 1998) or river lakes and lentic backwaters (Baker *et al.*, 1991). The majority of fish species occurring in rivers of this region use seasonally flooded areas, particularly forests, for feeding, spawning, nursery areas (Killgore and Baker, 1996), refugia from high velocities (Matheney and Rabeni, 1995) or other purposes. For example, of the 91 species of freshwater fish recorded for the nontidal Apalachicola or lower Chipola Rivers, 73 are known to occur in river floodplains. Fifty-one of the 73 have been collected from the Apalachicola floodplain using limited sampling gears and approaches (Light *et al.*, 1998). Streams in this region which periodically inundate their floodplains support fish assemblages distinct from those which do not because of channel incision (Shields *et al.*, 1998).

These facts lead to the hypothesis that channel blockage is beneficial to many fish species since it produces growth in the area of permanent lentic river corridor habitats and seasonal flooded forest. A corollary to this hypothesis is that clearance of blockage is deleterious to many species when clearance transforms physical habitat conditions. This hypothesis is examined below using data describing aquatic habitat conditions and fish populations in reaches typical of rivers with blocked channels, cleared channelized rivers, and cleared natural rivers. Fish community structure is often a valuable indicator of ecosystem health in agricultural watersheds (Wichert and Rapport, 1998). The objective of this study is to develop more enlightened approaches for managing lowland riverine corridors historically subjected to cyclic perturbations. These approaches will generally involve tradeoffs between allowing natural processes

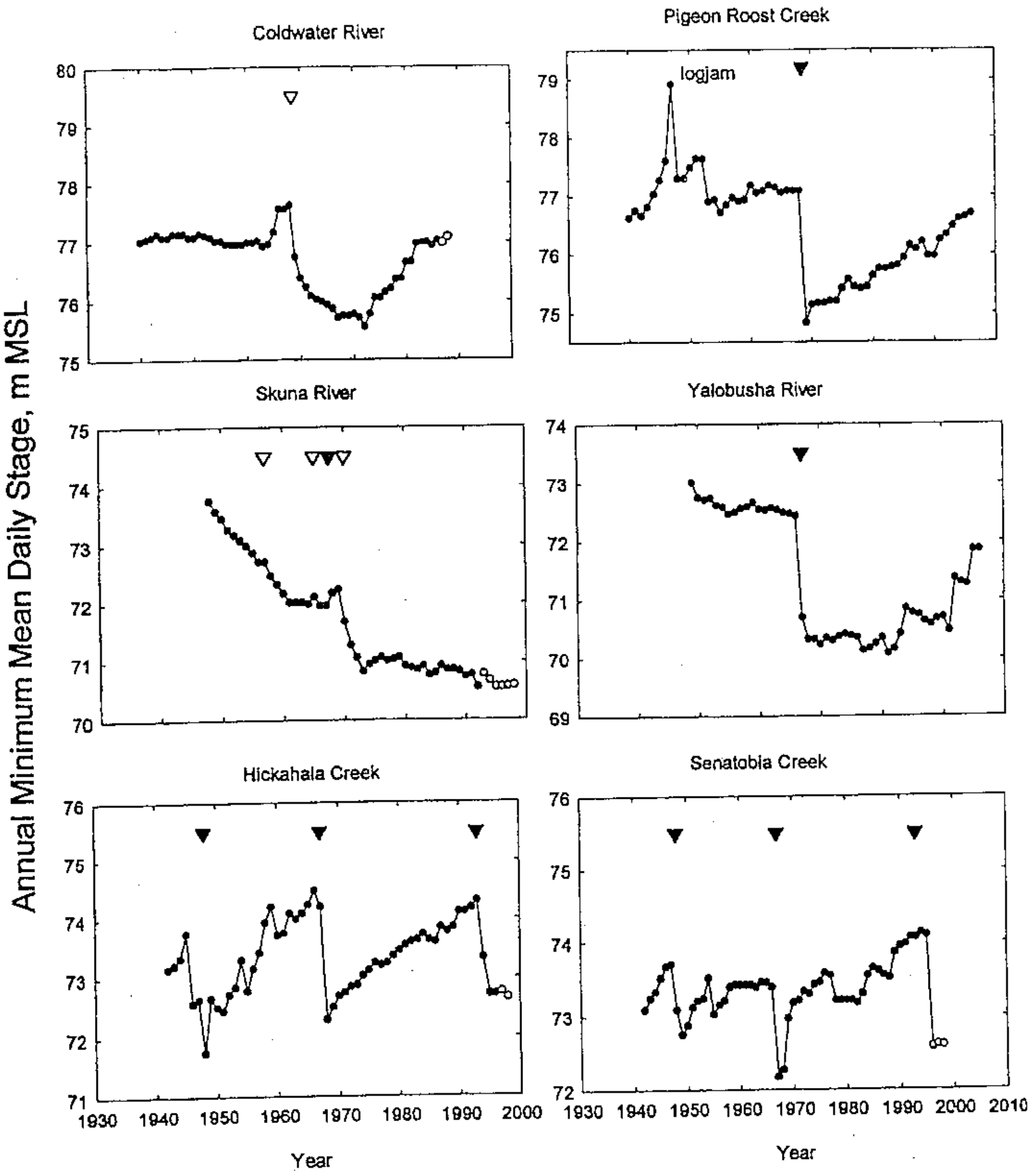


Figure 1. Annual minimum stage versus year for six lowland rivers in northern Mississippi. Black circles are data obtained from sources listed in Table I, while white circles are data obtained from the US Corps of Engineers (Coldwater and Pigeon Roost) or the US Geological Survey and added. Black triangles indicate channelization through the reach containing the gauge, while white triangles indicate channelization or debris removal in downstream reaches

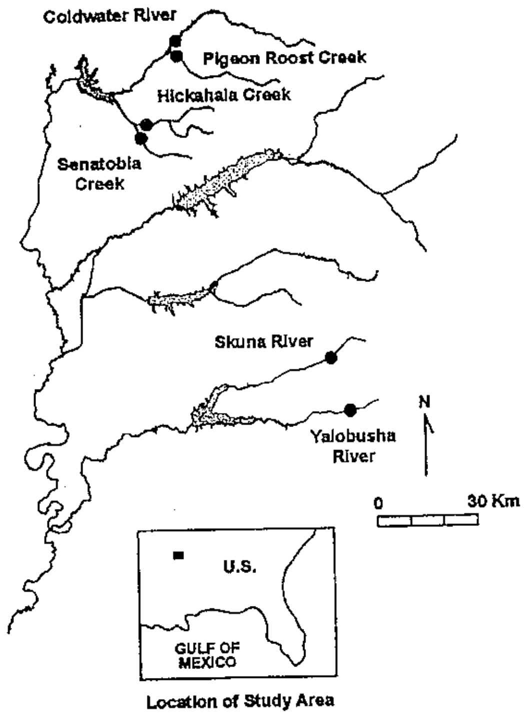


Figure 2. Location of gauges that were sources of the annual minimum stage data for Figure 1

to proceed unhindered and structural intervention. The goal is to refine knowledge regarding the relative merits of available strategies.

STUDY AREA

Two adjacent lowland river corridors in northern Mississippi with similar patterns of land use, soils, and relief but at different points within the cycle of occlusion and response were selected for study. Both are referenced in Table I and Figures 1 and 2. The Skuna River (Figure 3) is channelized and has experienced

Table I. Characteristics of streams experiencing cyclic perturbation evidenced by variations in annual minimum stage as shown in Figure 1

Stream	Contributing drainage area (km^2)	Source of data depicted in Figure 1	Remarks
Coldwater River	565	Doyle and Shields (1998)	Downstream reach channelized 1968–1969
Pigeon Roost Creek	591	Doyle and Shields (1998)	Entire contributing drainage net channelized 1920–1927 and 1968–1969
Hickahala Creek	316	Wilson (1997)	Channelized in late 1940s, late 1960s and 1992–1993
Senatobia Creek	209	Wilson (1997)	Channelized in late 1940s, late 1960s and 1992–1993
Skuna River	658	Wilson and Turnipseed (1994)	Initial channelization ca. 1925, but additional modifications in 1957 and 1965–1970
Yalobusha River	887	Simon (1998)	Initially channelized in 1910s and 1920s, additional major work in 1967

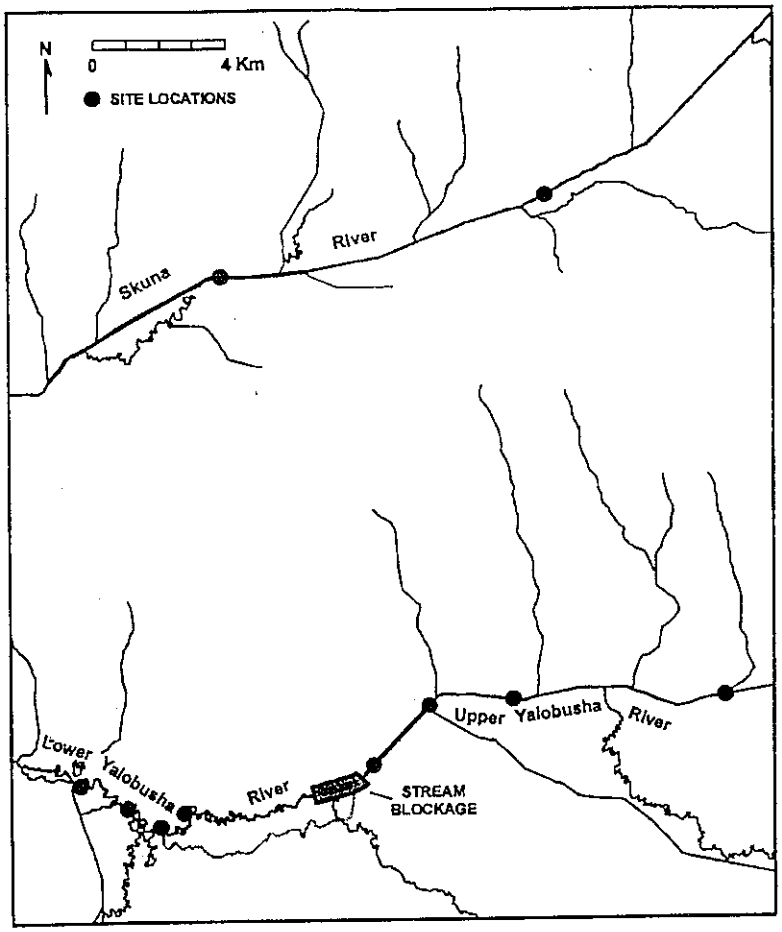


Figure 3. Location of study reaches on Skuna and Yalobusha Rivers. Reaches were 500–700-m-long segments centered on the black circles

major degradation over the last 50 years, with only one minor cycle of aggradation. Currently the channel is incised, and flow is not impeded by blockage. The Yalobusha River is presently occluded by a major blockage comprised of sediment and woody debris (Simon, 1998 and Figure 4). The river flows in a straight, trapezoidal canal (due to channelization in 1967) upstream from the block, and in a naturally sinuous channel downstream. Both rivers are tributary to the Yazoo River, which flows into the Mississippi River. Watershed relief is about 60 m. Although consolidated clays are found in deeply incised channel beds, gravel is rare and bedrock is absent. Most soils are sandy or loess. Annual rainfall within this region averages 1400 mm. About half of the land supports forests, while almost all of the remainder is cultivated, used for pasture, or idle.

In order to assess the effects of cyclic perturbation on fishes and their habitats, rivers were sampled in opposite parts of the blockage cycle (Table II and Figure 3). The Skuna River provided information regarding unblocked conditions in a channelized river, and historical information regarding physical habitat conditions for the Upper Yalobusha River prior to formation of the existing block was used to verify the suitability of the Skuna as a representative. Currently existing conditions on the Upper Yalobusha River were selected to represent a fully blocked channel. In order to provide a point of reference, the Lower Yalobusha River was also sampled as a representative of a naturally sinuous, unblocked channel.

Figure 4. Upstream end of sediment and debris blockage in Yalobusha River, 1997

The blockage in the Yalobusha River formed following channelization in 1967 because the excavated channel terminated at its downstream end in a naturally sinuous meandering channel. Key characteristics of the excavated channel and the sinuous channel at their junction are shown in Table III. The thalweg was lowered as much as 1.7 m by excavation of the 1967 channel, but by 1997 as much as 6 m of deposition had occurred, creating a negative thalweg slope over a 6 km reach. Examination of repeated cross-section surveys showed that sediment plug vertical thickness increased most rapidly in the 2 years immediately after construction, and more slowly thereafter in a classical nonlinear fashion (Simon, 1998).

METHODS

The ten sites that were sampled were 500–700 m long and were distributed along about 10 km of valley bottom for each of the three river stretches (Figure 3). Differences in physical habitat quality were assessed by measuring water width, depth, velocity; and bank stability, bank vegetation type and density, woody debris density, and bed material types were visually assessed. In the Yalobusha River, an echosounder coupled with a differential global positioning system was used to obtain data for contour

Table II. Lowland rivers selected for study

River	Condition	Number of reaches sampled	Total length (m)	Sinuosity
Skuna	Channelized, unblocked	2	1000	1.0
Upper Yalobusha	Channelized, blocked	4	2700	1.0[a]
Lower Yalobusha	Natural, sinuous	4	2400	2.2[b]

[a] Three of the four reaches sampled were straight, while one had a gradual bend.
[b] Value for stretch containing the sampled reaches. Sampled reach sinuosity ranged from 1.4 to 3.5.

Table III. Hydraulic characteristics of the channelized reach of the Yalobusha River and the downstream sinuous reach at their junction ca. 1967[a]

Variable	Upper Yalobusha	Lower Yalobusha
Bankfull discharge (m^3 s^{-1})	570	70
Width (m)	52	38
Depth (m)	5.2	3
Slope	0.0005	0.0002
Sinuosity	1.0	2.2
Sediment load at bankfull (t day^{-1})	40 000	200

[a] Sediment loads estimated using the Yang (1973) approach.

maps of the study reaches. Horizontal positions were determined with RMS errors < 1.5 m. Water depths measured by the echosounder were converted to bed elevations using known or estimated water surface elevations. Digital forms of the contour maps of the sites located in the blocked reach were used to compute water volume and surface area for selected water surface elevations in order to predict the effects of blockage removal on aquatic habitat volume and area (Keckler, 1997). It was assumed that removal of the blockage from the Upper Yalobusha would decrease baseflow stages by an amount equivalent to the mean water depth observed for blocked conditions. Mean water depth was computed by dividing water volume by surface area, while mean water width was obtained by dividing water surface area by reach length. An acoustic-doppler current profiler was used to obtain detailed water velocity measurements in the upper and Lower Yalobusha River reaches for a range of low to medium discharges. Physical data were collected from Yalobusha reaches during the 2 years following fish collection. No major changes in river conditions or alignment occurred during this time.

Physical habitat data for the Skuna River sites were collected concurrently with fish. At each site, water widths were measured during baseflow at 21 transects placed at 25-m intervals. Water depths were measured at five evenly spaced points along each transect using a wading rod. Transect data were used to compute water volume and surface area using the same software package as for the Yalobusha data sets (Keckler, 1997). Discharge was measured at a selected transect using an electromagnetic velocity meter and standard techniques, and mean velocity was computed for each transect by dividing the discharge by the cross-sectional area.

In order to compare current conditions on the unblocked Skuna with historical conditions on the Yalobusha prior to block formation, discharge measurement notes were obtained from the US Geological Survey for the upper Yalobusha River. Records of baseflow water width, depth, velocity, and discharge were tabulated for a selected date for each of the years between 1973 and 1976, inclusive. This period follows channelization of the upper Yalobusha, but precedes formation of the current blockage.

To obtain an assessment of species richness and composition, fish were sampled from each site in 1997 (Yalobusha sites) and 1998 (Skuna sites). Techniques involved using backpack electroshockers for wadeable sites (Skuna) and boat-mounted electroshockers for deeper waters (Yalobusha). Hoop nets and seines were also employed in the deeper waters.

For data analysis, all captures were lumped together regardless of gear type. Although the authors are aware of the problems presented by gear bias, the analysis is based on species presence and absence and does not utilize species relative abundance, which is less sensitive to environmental perturbation than metrics based on species number (Paller, 1996). Therefore it was appropriate to compile species lists obtained by using a mix of gear types appropriate to the sampled habitats (Fago, 1998; Wichert and Rapport, 1998).

Fish species lists were used to compute six quantities proposed by Wichert and Rapport (1998) as indicators of ecological integrity in agricultural watersheds drained by warmwater streams. Following Wichert and Rapport (1998), first, integer scores were assigned to each fish species captured, based upon habitat orientation and feeding group in such a way that a higher scores were associated with greater sensitivity to ecosystem stress (Table IV). Then values of the first five indicators shown as columns in Table IV were computed for each site and for each river as follows:

Table IV. Estimates[a] for characteristics of fishes of the Yalobusha and Skuna Rivers

Family	Species	Age at maturity (year)	Maximum size (mm)	Habitat orientation[b]	Habitat flow preference[c]	Feeding group, trophic level[d]
Amiidae	*Amia calva*	II[f]	610	2	2	5
Aphredoderus	*Aphredoderus sayanus*	II[i]	144	2	2	3
Atherinidae	*Labidesthes sicculus*	II[f]	100	4	2	3
Catostomidae	*Ictiobus bubalus*	III[g]	890	3[f]	1	4
	Ictiobus cyprinellus	III[g]	890	3	2[f]	6[f]
	Minytrema melanops	I to II[g]	460	3	2	4
Centrarchidae	*Lepomis cyanellus*	I	200[k]	3[k]	2	4[k]
	Lepomis gulosus	I[h]	203	4	2	3[i]
	Lepomis humilis	II[h]	102	2	2[e]	3
	Lepomis macrochirus	I[g]	256	4[c]	2	3[k]
	Lepomis megalotis	I[h]	178	4	1	3[i]
	Lepomis microlophus	I[h]	279	4	2	4[i]
	Micropterus punctulatus	I[i]	432	2	1	5[i]
	Micropterus salmoides	II[i]	762[h]	2[h]	2[h]	5[h]
	Pomoxis annularis	II	508	4	2	5
	Pomoxis nigromaculatus	I[h]	460	4	2	5[i]
Clupeidae	*Dorosoma cepedianum*	II[l]	520[f]	5	2	6[f]
Cyprinidae	*Cyprinella venusta*	I[f]	128[f]	4[f]	1[f]	4[f]
	Cyprinella camura	I[f]	114[e]	4[e]	1[e]	3[f]
	Cyprinus carpio	III[f]	700[f]	3	3	1[f]
	Lythrurus fumeus	I	66[f]	5	2[f]	4
	Lythrurus umbratilis	I	81[f]	5[e]	2[e]	4[f]
	Notropis atherinoides	I	124[e]	5[f]	3[f]	3
	Notropis buchanani	I	50	3	2	1
	Notropis rafinesquei	I[i]	45[i]	3[i]	1[i]	4[i]
	Opsopoeodus emiliae	I	65	4[f]	2	1
	Pimephales notatus	I[i]	110[f]	3[i]	1	4[f]
	Pimephales vigilax	II[f]	92[f]	3[i]	1	1
Esocidae	*Esox americanus*	I[l]	380[m]	2[f]	3[f]	5[f]
Fundulidae	*Fundulus notatus*	I	74	1	2	3
	Fundulus olivaceus	I	97	1	2	3
Ictaluridae	*Ameiurus natalis*	II[g]	380	3	2	1
	Ictalurus furcatus	I[g]	1550[f]	3	1	1
	Ictalurus punctatus	I[g]	540[f]	3[i]	3[i]	1[i]
	Pylodictis olivaris	IV[g]	985[f]	3	2[i]	5
Lepisosteidae	*Lepisosteus oculatus*	II m III f[i]	1120[f]	2[f]	2[f]	5[f]
	Lepisosteus osseus	III m VI f[e]	1830[f]	4	3[f]	5[f]
	Lepisosteus platostomus	III[l]	800[f]	5[f]	1[f]	5[f]
Moronidae	*Morone chrysops*	II	380	5	3	5
Percidae	*Percina sciera*	I[j]	110	3[j]	1[10]	4[j]
Poeciliidae	*Gambusia affinis*	II[g]	55	1	2	3
Sciaenidae	*Aplodinotus grunniens*	III	711	5	2	4

[a] Based on Mettee *et al.* (1996) except where noted otherwise.
[b] 1 = surface; 2 = littoral or vegetation; 3 = benthic; 4 = general; and 5 = pelagic.
[c] 1 = lotic; 2 = lentic; 3 = both lotic and lentic.
[d] 1 = omnivore; 2 = herbivore; 3 = general invertebrates; 4 = benthic invertebrates; 5 = fish and large invertebrates; and 6 = plankton and microcrustaceans.
[e] Pfleiger (1975).
[f] Etnier and Starnes (1993).
[g] Carlander (1969).
[h] Carlander (1977).
[i] Personal observation, S.S. Knight.
[j] Kuehne and Barbour (1983).
[k] Scott and Crossman (1973) in Wichert and Rapport (1998).
[l] Wallus *et al.* (1990).
[m] Trautman (1981).

$$SACS_j = \frac{\sum_{i=1}^{N} SCS_{ij}}{N},$$

where SACS = species association characteristic score j; SCS_{ij} = value of indicator j for species i as shown in Table IV; and N = number of species. When different values occurred for the age at maturity for males and females, the average value was used in analysis. The number of species constituted the sixth indicator. Relationships among the indicators and physical habitat metrics were examined.

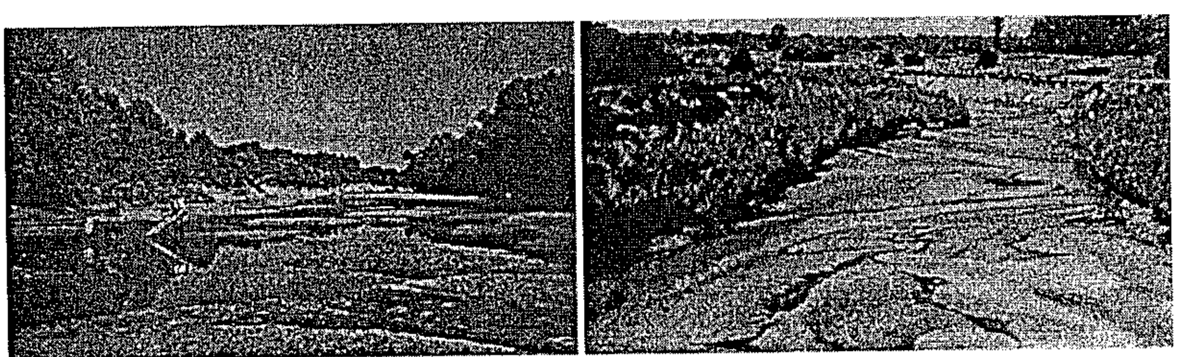
RESULTS

Physical habitat—qualitative

The unblocked, channelized Skuna sites were flanked by bare, near vertical banks 5–8 m high crowned with mature trees. Since top bank widths were approximately 60 m, canopy over the water surface was minimal. Beds were comprised primarily of shifting sand with some consolidated clay outcrops. Large woody debris was present, but scarce, with a horizontal surface density of less than 30 m^2 ha^{-1} water surface. A buffer of forest up to 50 m wide separated the channel from cultivated fields. Current photographs of the Skuna resemble photographs of the Yalobusha taken prior to formation of the existing channel blockage (Figure 5).

The blocked channel was straight, trapezoidal, and quite wide. Sand waves (dunes) were observed on the echosounder screen, and some submerged woody debris. Submerged and emergent woody debris became more common closer to the upstream face of the blockage. Banks were stable except for occasional rotational failures, and covered with deciduous pioneer species (*Salix* sp., *Betula nigra*, *Platanus occidentalis*) at lower levels. Embankments of excavated material about 5–10 m high were located within 20 m of top banks, and the crowns of these banks were covered with pines (*Pinus* sp.) evidently planted about the time of channel construction (1967). Repeated observations indicated that the blocked channel hydraulically resembled a lake with a broad spillway, and water surface elevation varied little with discharge. As discharge increased, water flowed out of the channel through relief openings in the embankments and flowed across the forested floodplain. On the southern floodplain, overflows found their way into an abandoned channel and made their way to the Lower Yalobusha. The course of this channel was mapped using a Global Positioning System (Figure 3).

Although Lower Yalobusha River mapping was confined to the sinuous main channel, water covered the floodplain on both sides of the channel for an indeterminate distance. The top bank was underwater, but its approximate location was clearly marked by a dense growth of woody vegetation that bordered the channel on both banks. Woody debris was common if not abundant, and there were numerous



(a) (b)

Figure 5. Conditions in channelized streams during unblocked segment of cycle. (a) Skuna River, 1998. (b) Upper Yalobusha River, 1972

baldcypress trees (*Taxodium distichum*) within and adjacent to the channel. Submerged woody debris was often observed on the echosounder screen. Variation of water depth laterally and longitudinally was relatively slight.

Physical habitat—quantitative

Summary statistics for physical habitat measurements highlight the radical differences in the three channel conditions (Table V). Measurements in the Skuna River appear typical of observations for the Upper Yalobusha prior to blockage. Investigators who sampled the Upper Yalobusha study reach in 1973–1976 described habitat as a riffle–shallow pool combination (Cooper and Johnson, 1980). Bed materials were mainly sand and gravel with some clay and silt deposits in pools. Water depths ranged from 0.05 to 0.2 m in riffles and 0.5 to 1.5 m in pools. Velocities at low flow were described as 'sluggish'. Stream gauging measurements made in the Upper Yalobusha during the same period indicated that cross-sectional mean water depths were 0.08–0.11 m and current velocities were between 9 and 50 cm s^{-1} when discharges were in the range of 0.1–0.3 m^3 s^{-1}. Cross-sectional mean water depths were observed from 0.03 to 0.59 m and cross-sectional mean current velocities between 2 and 54 cm s^{-1} in the Skuna when discharges were 0.3–0.7 m^3 s^{-1}.

Contour maps and cross-section plots revealed that the channelized, blocked reach (Upper Yalobusha) was geometrically less complex than the sinuous natural reach downstream (Lower Yalobusha) (Figures 6 and 7). Despite the effects of blockage on the Upper Yalobusha, water depths were greater in the natural reach downstream (Table V). Greater depths and sinuosity in the Lower Yalobusha produced higher values of aquatic habitat area (1.7 ×) and volume (3.3 ×) per unit downvalley distance than for the wider, straighter, shallower blocked channel upstream (Table VI). Aquatic habitat volume for the Skuna was about two orders of magnitude smaller than for the other reaches, and predicted values for the Yalobusha following blockage removal were similar to those for the Skuna.

Typical velocity fields for the Upper and Lower Yalobusha measured using the acoustic doppler current profiler are shown in Figure 8. The data shown in Figure 8 were collected at discharges of 20.4 and 23.5 m^3 s^{-1} for the Upper and Lower Yalobusha, respectively. This level of flow is exceeded about 25% of the time in the Upper Yalobusha (Simon, 1998). Figure 8 emphasizes the low-velocity, depositional nature of upstream reaches, and the nearly lentic habitat they provide. In contrast, reaches downstream are more riverine, with turbulence related to the strong secondary circulation typical of a meandering channel.

Table V. Aquatic habitat quality in Yalobusha and Skuna Rivers at baseflow

River	Condition	Mean water width (m)	Mean water depth (m)	Cross-sectional mean water velocity (cm s^{-1})	Substrate	Discharge range for observations (m^3 s^{-1})
Skuna	Channelized, unblocked	24	0.2	19	93% sand	0.3–0.7
Upper Yalobusha	Channelized, blocked	48	1.7	7–21	Sand and woody debris. Local deposits of silty mud and clay	11–28
Lower Yalobusha	Natural, sinuous	38	3.5	2–120	Unknown—but almost certainly sand in view of velocities observed and upstream geology	2–63

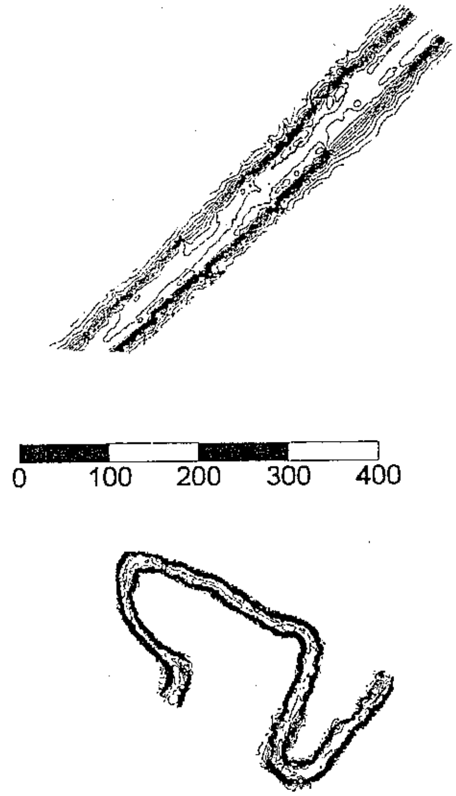


Figure 6. Contour maps of the beds of typical reaches of the Upper Yalobusha (top) and Lower Yalobusha (bottom) River

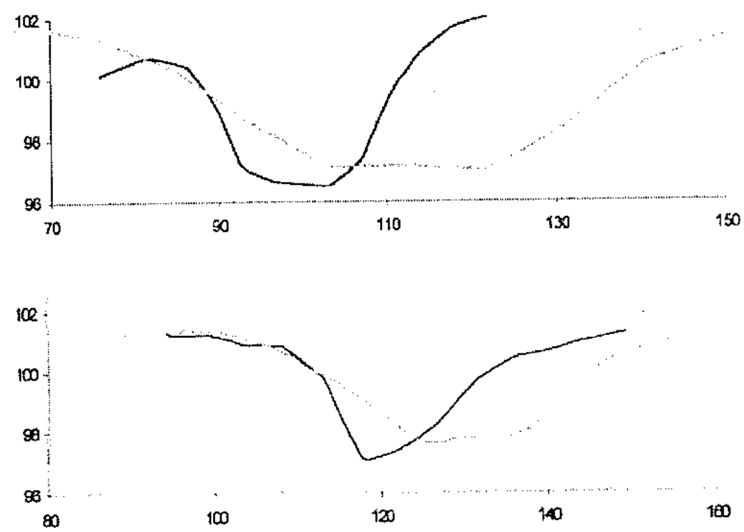


Figure 7. Typical cross sections for reaches of the Upper (heavy gray line) and Lower (light black line) Yalobusha Rivers

Table VI. Quantitative aquatic habitat conditions in Yalobusha and Skuna Rivers

River	Condition	Channel water surface area per meter of downvalley distance (m)	Channel water volume area per meter of downvalley distance (m^2)
Skuna	Channelized, unblocked	26	5
Upper Yalobusha	Channelized, blocked	49	85
Lower Yalobusha	Natural, sinuous	84	283
Upper Yalobusha	Predicted conditions following removal of blockage	16	8

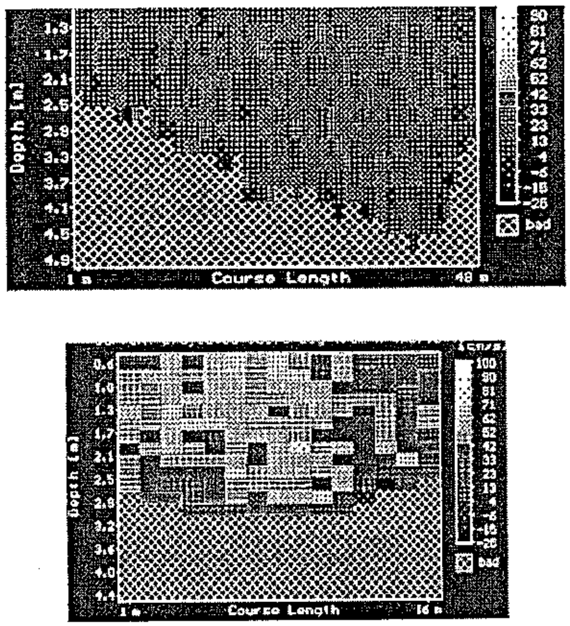


Figure 8. Velocity distributions for cross sections of the Upper Yalobusha (top) and Lower Yalobusha (bottom) River. Velocity is projected in the direction of the channel centerline. Figures shown are screen dumps from the TRANSECT program. Reproduced by permission of RD Instruments, San Diego, CA

Fish

A list of fishes captured for this study is presented in Table VII. The natural reach and the unblocked, channelized reach yielded only 18 and 17 species, respectively, while 31 species were captured within the blocked, channelized reach. The natural, blocked, and unblocked reaches yielded an average of 9.25, 17.25, and 13.5 species per sampled site, respectively. Species richness was greatest for the two sites immediately upstream from the sediment and debris jam, perhaps due to the high levels of woody debris, greater depths, and moderate levels of disturbance there relative to other reaches.

SACS values for each river computed as described above are presented in Table VIII. All six indicators were lowest for the channelized, unblocked Skuna, and all indicators except number of species were greatest for the naturally sinuous Lower Yalobusha. The blocked canal (Upper Yalobusha) yielded intermediate values for all indicators except for number of species.

With the exception of number of species, SACS indicators computed for each of the ten sites were correlated with descriptors of physical habitat (e.g. mean depth). For example, variation in mean depth

Table VII. Fish collections from Yalobusha and Skuna Rivers

Family	Species	Lower Yalobusha	Skuna	Upper Yalobusha
Amiidae	*Amia calva*			1
Aphredoderus	*Aphredoderus sayanus*		1	
Atherinidae	*Labidesthes sicculus*			5
Catostomidae	*Ictiobus bubalus*	419	1	35
	Ictiobus cyprinellus	2		49
	Minytrema melanops			1
Centrarchidae	*Lepomis cyanellus*		11	3
	Lepomis gulosus	1	2	2
	Lepomis humilis			4
	Lepomis macrochirus		171	29
	Lepomis megalotis		14	
	Lepomis microlophus			3
	Micropterus punctulatus	1		
	Micropterus salmoides		7	
	Pomoxis annularis	1		4
	Pomoxis nigromaculatus	2		1
Clupeidae	*Dorosoma cepedianum*	4		38
Cyprinidae	*Cyprinella venusta*	3	640	90
	Cyprinella camura		1	
	Cyprinus carpio	18		38
	Lythrurus fumeus			12
	Lythrurus umbratilis			52
	Notropis atherinoides	25		18
	Notropis buchanani			1
	Notropis rafinesquei		128	
	Opsopoeodus emiliae			1
	Pimephales notatus			1
	Pimephales vigilax		8	5
Esocidae	*Esox americanus*			3
Fundulidae	*Fundulus notatus*		5	
	Fundulus olivaceus	1		
Ictaluridae	*Ameiurus natalis*			3
	Ictalurus furcatus			2
	Ictalurus punctatus	9	18	37
	Pylodictis olivaris	13	1	5
Lepisosteidae	*Lepisosteus oculatus*	6	9	19
	Lepisosteus osseus	3		39
	Lepisosteus platostomus	6		
Moronidae	*Morone chrysops*	5		
Percidae	*Percina sciera*		1	
Poeciliidae	*Gambusia affinis*		104	2
Sciaenidae	*Aplodinotus grunniens*	3		2
	Totals	522	1122	505

and in the area of aquatic habitat per unit valley length explained 87% and 49%, respectively, of the variation in maximum fish size. Many of the SACS were also correlated with one another, which confirms findings by Wichert and Rapport (1998). The intercorrelation of many of the indicators evidently shows that they are linked to a suite of ecosystem responses to physical stress. To display the ecological response to the observed physical habitat gradients, two of the SACS indicators were selected that were free of significant intercorrelation ($r^2 < 0.32$, $p > 0.05$), and plotted against two uncorrelated variables that were descriptive of key habitat conditions (Figure 9). A gradient of ecological indicators occurred in response to the range of physical conditions that occurred moving from the unblocked, channelized river, through the blocked channel and was greatest for the naturally sinuous reach. Fishes preferring pelagic or benthic

Table VIII. Species association characteristic scores based on fish collections from Yalobusha and Skuna Rivers

River	Condition	Age at maturity (year)	Maximum size (mm)	Habitat orientation	Habitat flow preference	Feeding group, trophic level	Number of species
Skuna	Channelized, unblocked	1.6	347	2.8	1.6	3.4	17
Upper Yalobusha	Channelized, blocked	1.8	466	3.4	2.0	3.5	31
Lower Yalobusha	Natural, sinuous	2.2	629	3.6	2.1	4.2	18

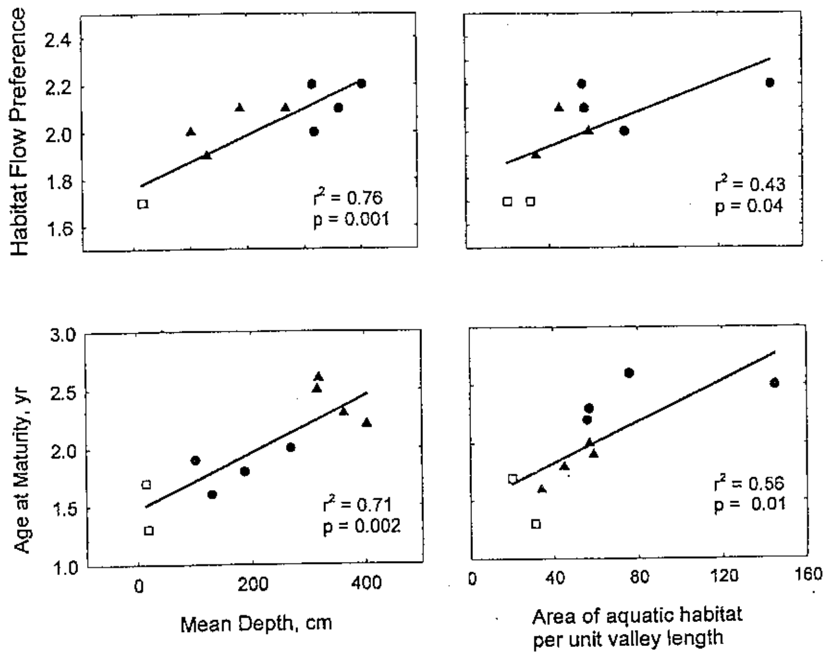


Figure 9. Plots of selected SACS for each of the ten sampled sites (Figure 3) versus selected descriptors of physical habitat. Open squares represent Skuna River (channelized, unblocked), black triangles represent Upper Yalobusha River (channelized, blocked), and black circles represent Lower Yalobusha River (natural, sinuous). Lines are ordinary least-squares regression lines, and coefficients of determination (r^2) and associated probability values are from the regression

habitats were common in deeper waters, while the shallow unblocked channel was dominated by those preferring surface and littoral habitats. Species capable of attaining larger sizes preferred deeper waters and were most common in the sinuous Lower Yalobusha, which offered greater depth and habitat quantity per unit valley length. Species richness was relatively insensitive to the observed range of water depth, width, and habitat quantity. Evidently the relatively diverse fauna typical of the unblocked, channelized Skuna and similar habitats in this region (Paller, 1994; Shields *et al.*, 1995) compensated for the absence of many of the larger species found in the natural Lower Yalobusha (Table VII).

DISCUSSION

The metrics devised by Wichert and Rapport (1998) and adapted for use here were highly correlated with physical variables in a fashion that the authors judge as reflective of ecological response to physical stresses (Figure 9). The formulation of these indicators may be criticized because they are based on the arithmetic mean of certain discrete and continuous variables, and therefore return the same value for associations comprised of one or a few species with values that cluster about the mean and for associations with extreme values that have the same mean. However, warmwater fish communities tend to respond to physical habitat degradation associated with channelization and erosion in ways outlined by Schlosser (1987) that are well documented by means of the selected characteristics. The ecological mechanisms responsible have been well described by Schlosser (1987), Wichert and Rapport (1998), and others, and thus are not repeated here. The authors' application of the work of Wichert and Rapport (1998) may be more specifically criticized in that the metrics were used for spatial rather than temporal comparisons and that a relatively modest number of fish samples were used. Although more data are almost always desirable, the spatial differences observed are striking enough to at least provide a caution to those responsible for manipulating these systems. Without time travel machines, spatial comparisons are often required to generate prediction. The indicators were used to digest the data from the fish samples, not to create results.

Lowland river corridors susceptible to blockage via valley plug formation present a vexing problem for managers. Too often choices are made that maintain a cycle of disturbance that requires costly maintenance and result in environmental degradation. These choices are not made entirely through ignorance. Four decades ago, it was noted by Miller (1960):

> ... in channel straightening where the slope is increased significantly it is easy to create upstream problems because of induced degradation and downstream problems because of aggradation and increased flood impact by more efficient transfer of water (and sediment) from above to below an altered reach.

Evidently economic forces and political expedience often dictate what must be done. Diehl (1994) identified five types of strategies available for responding to lowland river blockage by valley plug formation (Table IX). It would seem that the best solution in most cases would be a mix of these five strategies. In any case, a pivotal issue will always be matching sediment supply and transport capacity. For example, channel excavation, if applied alone, will temporarily relieve flooding and accelerated sedimentation immediately upstream from the block, but will likely rejuvenate incised reaches upstream, thus repeating the cycle of perturbation depicted in Figure 1. On the other hand, if grade-control structures are used to reduce erosion in the watershed upstream from the block, these must be designed to create and maintain a balance between flow energy and sediment supply balance. In some cases, downstream degradation followed construction of grade-control structures, thereby destabilizing channel banks (Simon and Darby, 1997). In addition, sediment control structures employed throughout the watershed may not impact sediment load downstream for many decades due to lagging fluvial response (Trimble, 1975; Trimble and Lund, 1982).

Schemes which feature forced deposition of sediments in a transition zone between upstream sediment sources and the sink area produced by the plug may provide opportunity for floodplain habitat rehabilitation, particularly if coupled with restoration of a naturally sinuous channel through or around the plug. As noted by Miller (1960):

> The desirable procedure is to design a sinuous channel... wherein a slope between two control points is established that is compatible with the sediment load and the channel design shape thereby minimizing any upstream effects and grade control requirements.

Sinuous channels offer additional benefits in terms of ecological function, since habitat depth and velocity distributions tend to be less uniform in meandering channels, and physical habitat diversity is an indicator of fish habitat values (Gorman and Karr, 1978; Schlosser, 1987). Some evidence suggests rivers with complex cross-sections including shelf-like features are more retentive of organic matter than more uniform channels (Thoms and Sheldon, 1996). The variance of depth has been correlated with the number

Table IX. Alternative strategies for managing lowland river corridors blocked by valley plugs (Diehl, 1994)

Alternative	Advantages	Disadvantages
Channel excavation	The channel can be straight or sinuous: it can follow a new alignment or the existing channel. Provides the best likelihood for locally increasing the areas available for profitable agriculture and forestry	Channel might need dredging periodically to maintain channel capacity. Can lead to upstream degradation and widening, and increase the amount of sediment entering the excavated reach
Removal of woody debris	Less disturbance to the environment and lower cost than excavation	Removal of fish and invertebrate habitat. Less effective than excavation in reducing flooding and sedimentation
Forced deposition of sediment in selected areas	Sediment deposition upstream can reduce the potential for valley plug formation in downstream reaches	Difficult to design and locate depositional areas that retain the right quantities of sediment
Erosion reduction in the watershed upstream from the blockage, particularly from gullies and low-order tributaries	Erosion control across the watershed treats one of the primary causes of the problem and offers greatest likelihood of sustainability	Sediment sources are extremely diffuse, and cost of structural control for a significant fraction may be prohibitive
Adaptation to existing conditions by changing land use patterns and objectives	Reduced need for construction projects. Preservation of habitats created by valley plug and channel blockage	Significant expenditures may be required for land and easement purchases and subsidies. Removal of land from production may be politically unpopular

and diversity of fish species richness in a restored river (Jungwirth *et al.*, 1993, 1995). The results suggest that simply clearing the channel obstruction and restoring an unblocked, channelized regime is detrimental to ecosystem integrity. The ecological indicators computed from fish species composition suggest that the unblocked, channelized condition represents a state of greater distress (Rapport *et al.*, 1985) than the blocked condition, which may be thought of as a first step in natural recovery to the disturbance of channelization and attendant channel incision. Clearly, under either natural conditions or those created by human disturbances, the habitats created by channel occlusion and valley plugging are temporally unstable relative to those found in the natural meandering reach.

An optimal solution to the problem of channel blockage might include sediment control structures in watershed headwaters, sediment storage in channels enlarged by erosion or channelization, and creation of a meandering channel within an enlarged floodway around the channel blockage. The enlarged floodway could be used for sediment storage. Project maintenance might include periodic removal of sediment from storage areas. Sediments could be used to develop upland habitats, ridge-and-swale floodplain topography, or for construction of levee embankments to confine flooding to the designated floodway.

CONCLUSIONS

Historical approaches to watershed management have led to an acceleration of a natural cycle involving formation of valley plugs, breaching or local destruction of the plugs, and headward incision leading to generation of sediment and debris that occlude channels and form new plugs. Despite the technological advances of recent decades, strategies adopted for managing disturbed watersheds often lead to headward erosion and formation of channel blocks or valley plugs. Removal of blocks or breaching plugs triggers a new wave of headward erosion, generating excess sediments which deposit to form a new block. This cycle may be broken by adapting land use objectives and policies to the hydrologic regime created by the channel blockage or by a variety of structural approaches. The best approach for a given watershed is likely to be a mix of channel clearing, channel construction, upstream erosion controls, and forced deposition of sediment in designated storage zones.

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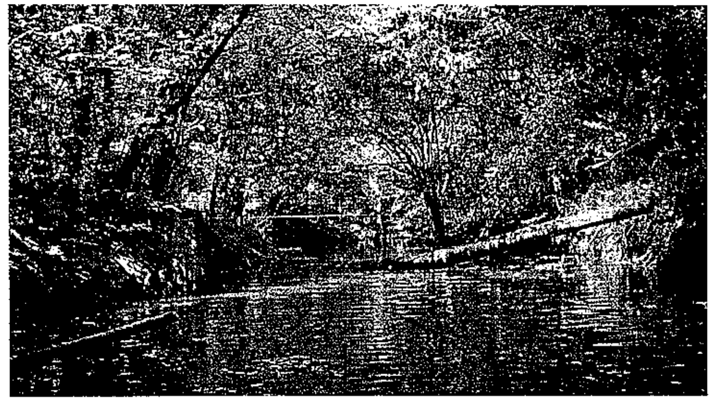
Shoals and Valley Plugs in the Hatchie River Watershed

By Timothy H. Diehl

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).

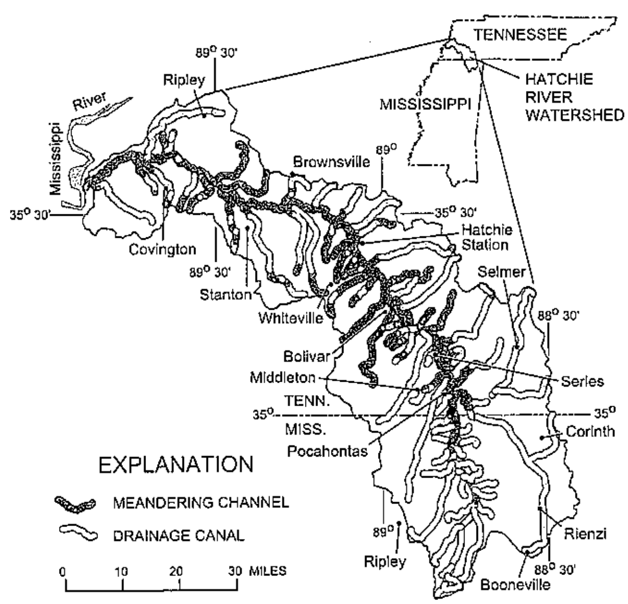


Figure 1. Location and channel network of the Hatchie River watershed in Tennessee and Mississippi.

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. Photorevised 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.

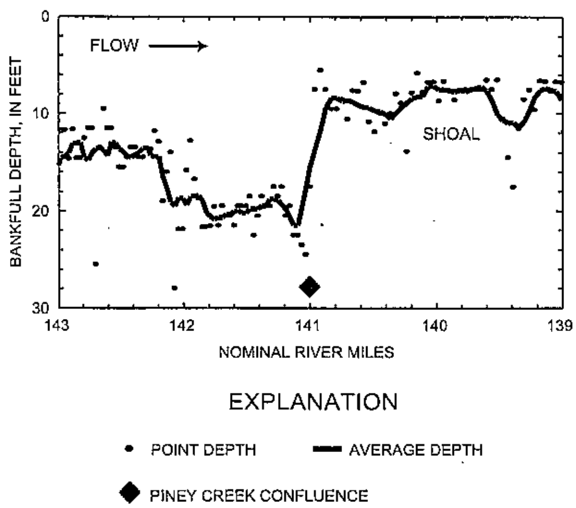


Figure 2. Depth profile of the Hatchie River bed at Piney Creek, in Tennessee.

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.

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

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.

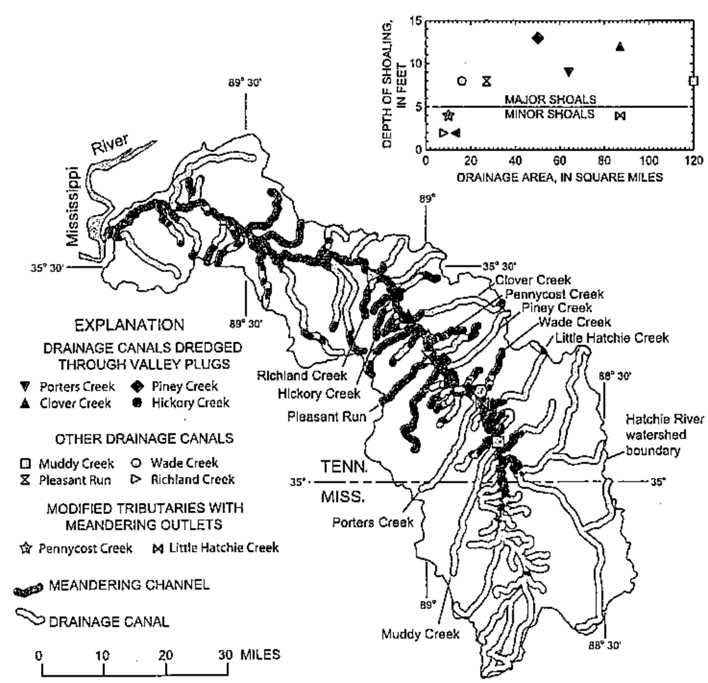


Figure 3. Shoals of the Hatchie River and drainage area of shoal-producing tributaries.

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.

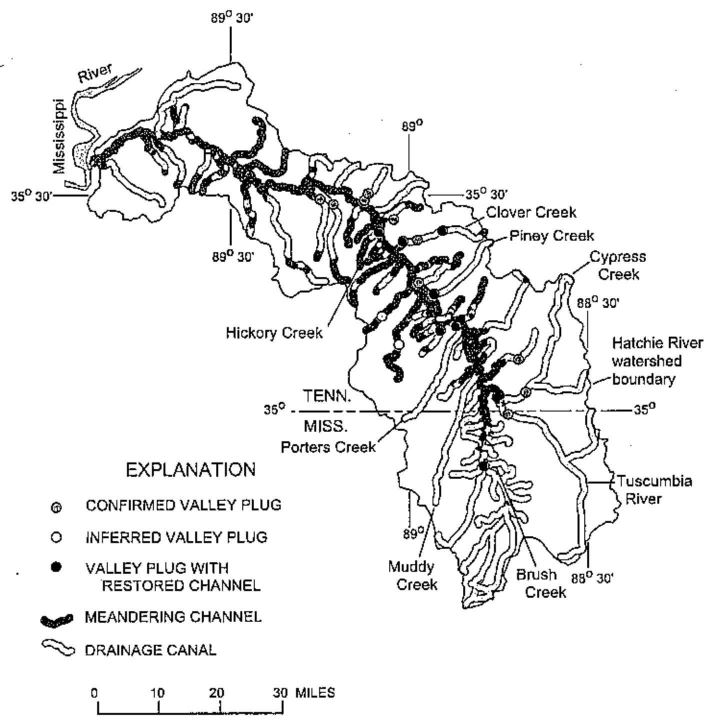


Figure 4. Locations of valley plugs in the Hatchie River and its tributaries.

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

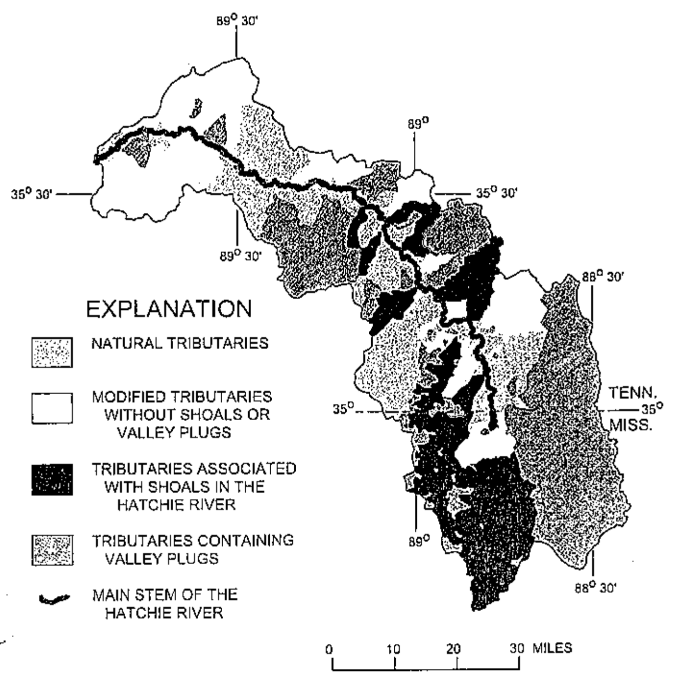


Figure 5. Geomorphic conditions in the Hatchie River watershed.

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.

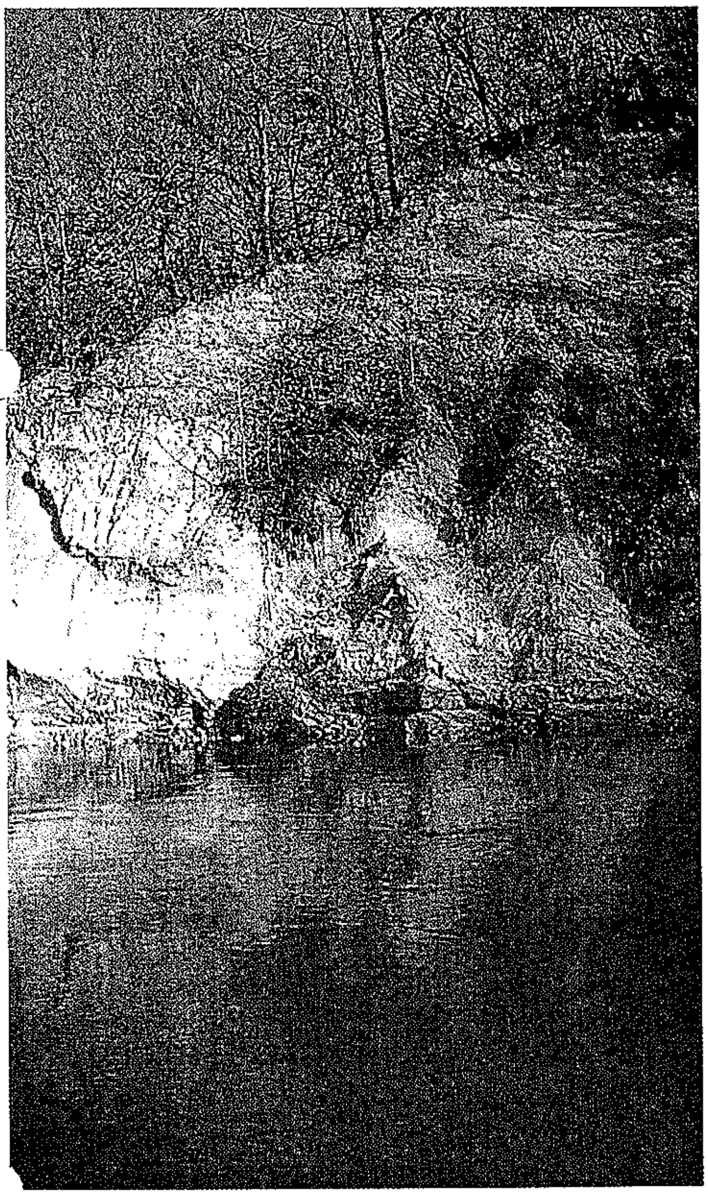
In tributary valleys upstream from valley plugs, water stands just below the flood plain during base flow. Backwater slows the stream, allowing sand to accumulate on its bed. As a result, the valley plug grows upstream by accretion (Happ and others, 1940; Diehl, 1994; Smith and Diehl, 2000).

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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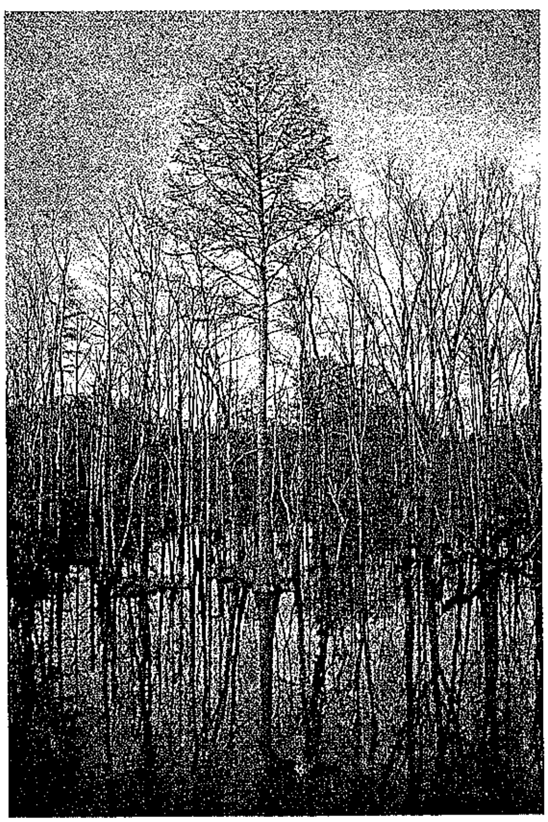

Ponded swamp with dead hardwoods and live cypress.

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Adventure In Jarrell Swamp

One of the numerous channelized sections of the Obion and Forked Deer Rivers.

Nature Makes A Comeback

by LARRY SMITH

On August 6, 1991, four explorers set out for high adventure and to carry out steps in saving a vast wetland from being drained. These four explorers set out to mark a permanent boat trail through a trackless 13,000 acre swamp and marsh. Many area residents fish and hunt in the swamp, but all said there was no route all the way through the swamp except during times of high water. The explorers would prove that a navigable route existed year round through the swamp.

A little history of the swamp is in order here. At the turn of the century the Obion and Forked Deer Rivers were wonderful braided cypress lined channels, flowing through vast hardwood forests of oak and hickory trees. Then came the white men, who turned these meandering rivers into huge eroding ditches. Then the swamps were drained and most of the forests were cleared.

As time went by, the erosion caused by all the ditching and land clearing, filled the canals with soil and silt. This soil also buried the roots of the few remaining stands of hardwoods thus killing them. As the ditches and canals filled with silt vast marshes formed along these ditches. This also killed the hardwood trees which could not stand the year around water. It is unfortunate that the trees had to pay for man's greed and stupidity but nature has a way of healing itself.

Canoeists enjoy floating through the swamp among the huge cypress trees.

A wonderful, new ecosystem has replaced the hardwood forests. Nature has stabilized the terrible erosion caused by man's ditches through the existence of these marshes. These wetlands are a totally natural response to the ecological destruction caused by the original ditches. These marshes have allowed the rivers to reclaim their natural meanders in some cases. These marshes also act as a stabilizer by filtering and settling the millions of tons of silt sent into the marsh by the surrounding farms. This filtering allows land building to take place in the marsh. The oaks and hickories will return as the land building continues. In the meantime, a thriving marsh exists that filters our water, resupplies our groundwater and provides habitat for fish, waterfowl and aquatic mammals like the otter.

This is the case along the South Fork of the Obion River in Carroll County, Tennessee. The Obion River has recaptured its meanders and also flows through a vast marsh. The manmade ditch has been completely abandoned by the river and actually has trees growing in the old canal. The real Obion River flows through 13,000 acres of marsh, cypress swamp and its original meanders. It is threatened with immediate destruction by the Obion Forked Deer Basin Authority, which plans to re-dredge the canal and drain the swamp.

The purpose of establishing a canoe trail bears a direct relationship to saving the swamp from destruction. By establishing a trail, recreational use and enjoyment of the area will increase. Also it proves that the river has completely abandoned the Obion Ditch and for the last 20 years has flowed through the swamp and meanders.

Back to the expedition. Like other expeditions this one set out prepared to spend the night in the swamp if necessary. Lights, netting and plenty of food and water were all stored on the canoes.

We began our trip in a spot known as the Hornet's Nest. Named because of the unusual number of large wasp nests in that section of the swamp. We learned the name was correct. After carefully picking and marking a trail through this section, we counted ten huge paper wasp nests, each covered with hundreds of wasps. The trail follows the current and channel through the cypress swamp and manages to skirt most of the nests. Future boaters beware in this section of the river. It is safe as long as you keep a sharp lookout.

The Hornet's Nest section of the river empties out into a vast marsh area. The marsh stretches nearly to the horizon in all directions - a river of grass with herons and egrets flying all about. We followed the current through the majority of the marsh. We had to pull through mats of smartweed and cattails only once for a short distance. Paddling through the water lilies and smartweed beds is like going through the Everglades. At one point, a mink was sitting on a log as we passed it. The mink panicked and dove head first toward the canoe. It promptly popped up on the other side of the canoe, cussing us in mink, I am sure. Fish were jumping everywhere. We saw largemouth bass, chain pickerel, carp, buffalo, gar and crappie.

After about a mile, the marsh began to narrow and the river picked up its historical meanders. From this point on the river flowed through a forest of oak and hickory trees. Huge sentinel cypress trees stood along and in the river to mark our passage. These huge trees have special significance. They stood when the river flowed in these same meanders before man took the river and put it in a ditch. These same trees saw the river taken away and now witness its rebirth.

The Obion River flowed in this fashion for several miles before dumping back into the Obion Ditch. At the confluence of the Obion River and the Obion Ditch, one might be surprised it was ever a ditch or canal. The canal was excavated during the turn of the century and has not been touched since. Its banks are tree lined and the trees completely canopy the old canal. The canoeist is reminded it is a canal by the occasional, huge, eroded ditch that enters the canal from time to time. They can usually be spotted well before actually seeing the ditch by the soil and silt islands that protrude into the canal from the mouth of every ditch.

As we canoed down the canal we discussed and marvelled at nature's ability to heal itself if given the chance. The formation of the vast marshes, the recapturing of the river's meanders and even the old canal, all point to this. This commentary abruptly ended at the next bridge, which happened to be our take out point as well. The Obion Forked Deer Basin Authority had recently "worked" the Obion River downstream of the bridge. Every tree had been stripped from the Obion River's bank for as far as the eye could see. Most of the trees and other river stabilizing items had been yanked out of the river. The river banks were also presumably sprayed with herbicide, as well. The Obion Ditch stretched downstream as far as the eye could see - a lifeless, naked, dead ditch.

Is this the fate of the 13,000 acres of wilderness we had just traversed? The Obion Forked Deer Basin Authority plans to re-dredge the ditch and drain the entire site, if possible. The canoe trail will allow people to enjoy and understand the area. Hopefully, this understanding will lead to a public call to stop the senseless waste of State tax dollars to drain productive wetlands.

The Governor could stop this project with one stroke of a pen if enough people call and write. Call (615) 741-2001 or write Gov. McWherter at the State Capitol, Nashville, TN 37219.

Channel clash

State tries to lessen drainage damage

CONCERNED state officials are continuing to discourage environmentally damaging stream channelization as a method of draining huge areas of West Tennessee.

In a decision announced this week, the Department of Environment and Conservation cleared the way for removal of blockages in the Obion-Forked Deer River Basin. The department insisted, however, that most of the water be carried by old river channels rather than by the wide, straight, erosion-prone ditches that were gouged out years ago by the Corps of Engineers.

This approach will be welcomed by those who favor clearing and maintaining natural river channels rather than spending millions to dredge gaping chutes that cause erosion and pull clogging sediment and agricultural chemicals into streams by deepening river beds and speeding the flow of water.

Such "channelization," practiced for years by the Memphis District Corps of Engineers, also drains valuable wetlands that act as a natural sponge to soak up flood water, filter groundwater supplies and provide wildlife habitat.

Not so happy about the state's decision may be the Obion-Forked Deer Basin Authority, which had sought clearance to remove the river blockages. The authority favors use of channelized streams as the main drainage channels, with older river channels used only to handle overflow in times of high water. The authority may appeal.

The controversy was the latest battle between opponents and proponents of channelization. The huge West Tennessee Tributaries Project, which was intended to improve drainage in the Obion-Forked Deer Basin by channelization, was virtually shut down by legal challenges over damage to wetlands and erosion-prone land in the basin.

Even opponents of channelization agree that some blockages in the complex river system that drains much of West Tennessee need to be removed. However, they prefer stream removal guidelines followed by the U.S. Fish and Wildlife Service and other state and federal agencies.

The state Department of Environment and Conservation also conditionally approved removal of blockages on the Tuscumbia River near the Tennessee-Mississippi border, with the same preference for use of old river channels. Tennessee officials have insisted on changes in a Tuscumbia drainage proposal sought by Mississippi. The original proposal, state officials said, would have adverse effects on the Hatchie River, last major non-channelized river in West Tennessee and part of the state's scenic rivers system.

ONE OF THE hottest environmental issues debated in the Tennessee General Assembly this year was over wetlands. After heavy lobbying by the Tennessee Farm Bureau, lawmakers agreed to relax regulations and let landowners drain swampy property as long as it had been farmed any time since 1970. Permits became a mere formality in such cases, which weakens efforts to protect the environment and landowners upstream and downstream from the area being drained.

Protecting wetlands also has become a national issue. The Bush administration has vowed to follow a "no net loss" of wetlands policy, but the President's Cabinet-level Council on Competitiveness, chaired by Vice President Dan Quayle, is considering regulatory changes that could muddy the water, figuratively and literally.

It is important that states and the federal government take a firm, yet reasonable approach to the potential damage from drainage projects. Tennessee is trying to do that in the latest Obion-Forked Deer and Tuscumbia River decisions.

A barrier to growth

2-12-1992 SECTION B

EPA, corps set up rules for draining Obion basin

By Tom Charlier
The Commercial Appeal

Federal officials have endorsed a compromise plan that sets strict guidelines on efforts to drain thousands of acres of open marsh and flooded timber land in rural West Tennessee.

The approval by the U.S. Environmental Protection Agency and the Corps of Engineers means a regional drainage authority will be able to clear four immense blockages in the Obion and Forked Deer river systems in Carroll, Henderson and Madison counties.

The Clean Water Act permit for the project, however, outlines an unusual set of "enforceable conditions" for the work. Wherever possible, artificial drainage canals must be abandoned in favor of natural river channels, and all work is subject to review by a task force to be drawn from state and federal environmental agencies.

The flood control proposal by the Obion-Forked Deer Basin Authority has been among the most intensely scrutinized in recent years. It is unusual because it involves an area where rivers that decades ago were straightened and diverted to accelerate drainage have begun to revert to their natural courses.

The main focus has been a 13,000-acre marsh between Trezevant and McKenzie along the South Fork of the Obion River. The area once supported towering hardwood trees, but they were killed by flooding as an artificial canal became silted-in and the river backed up into its natural channel.

During months of review, state water quality officials worked to strike an uneasy balance. Some landowners wanted the artificial channels reopened to protect timber, while environmentalists said it's too late to save the trees and the marsh has value in its own right.

The plan the officials came up with contains four major points:

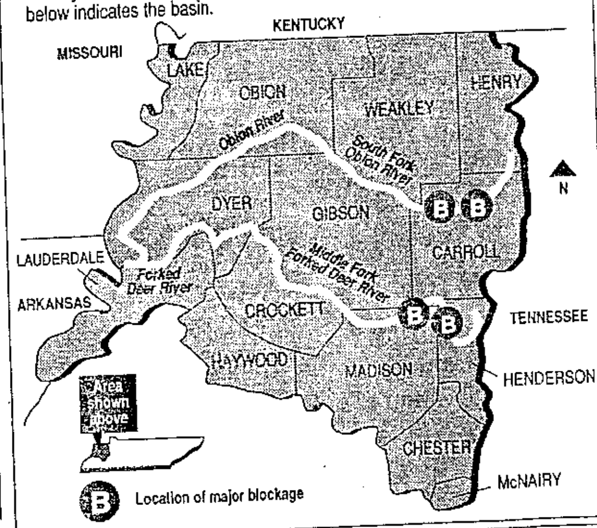
- The natural timetable of flooding is to be re-established by diverting water into original meandering channels of rivers "to the maximum extent possible."
- State and federal agencies will be authorized to form a task force that can review the basin

Please see DRAIN, Page B2

By Deborah D. Young

Drainage Plans

The Obion-Forked Deer Basin Authority won conditional approval to dredge for major river blockages blamed for flooding problems. The shaded area below indicates the basin.



From Page B1

Drain

authority's plans and suggest alternatives.

- Small dams should be built to hold water in the natural channels during low flows and release it into the artificial canals only during heavy floods.
- Areas of special ecological importance, such as heron rookeries, should be preserved.

In a letter to the corps last month, the EPA, which can veto drainage work, endorsed the compromise plan.

The conditions "will serve to adequately protect and partially restore the ecological and hydrological integrity of the Obion-Forked Deer riverine system," said the letter from W. Ray Cunningham, director of EPA's water management division in Atlanta.

The corps and the basin authority have agreed to the conditions, as well.

Basin authority director J. Richard Swaim said work will begin once the state General Assembly provides funding. The project accounts for part of the agency's proposed capital budget of $2 million.

Swaim said the river work is urgently needed to halt the flooding of hardwoods and other damage. "Every year the situation gets a little worse," he said.

Although the task force hasn't been named yet, Robert Baker, an environmental specialist with the state Division of Water Pollution Control, said the group will bring a "different perspective" to the project.

"Hopefully, things that may not have been looked at before will be looked at more closely," he said.

W. Tenn.'s anti-flood river plan backfiring, study says

By Tom Charlier
The Commercial Appeal

The West Tennessee Tributaries project, the ambitious flood-control effort that has cost taxpayers $43.5 million, has resulted in more, not less, flooding for many farmers and communities, a newly published study contends.

Drawing on federal data to create before-and-after comparisons, two University of Alabama researchers concluded that the "channelization" of the Obion River more than doubled the frequency of floods that pour down the lower reaches of the river during growing season.

However, the findings by David Shankman and Thomas Bryan Pugh of the university's geography department were challenged by the Corps of Engineers, which constructed the project. "Our position is that it alleviated the flooding," said Jim Reeder, the corps' manager for the project.

The study, published in the academic journal Wetlands, could inflame debate over the long-controversial tributaries project, which is only 40 percent complete. After years of litigation and regulatory problems, the corps withdrew from the project in 1989, but last year Gov. Ned McWherter asked federal officials to consider reviving it in an "environmentally sound" manner.

The study by the Alabama researchers focused on the Obion, which flows into the Mississippi about 60 miles north of Memphis. As part of the tributaries project, the Obion was channelized during the 1960s at a cost of about $12 million.

Channelization involves scooping out a river channel to make it wider, straighter and deeper so floodwaters can drain from a watershed more quickly. The process, used from the early part of this century through the 1960s, has been criticized by environmentalists, who say it destroys wetlands and sterilizes streams.

The tributaries project, authorized by Congress in 1948, envisioned channel work along 225 miles of the Obion and Forked Deer river systems. If the project were reactivated, it would cost at least $85 million to complete, according to corps figures.

In their study, Shankman and Pugh steered clear of environmental issues and set out to determine whether channelization accomplished what it was supposed to: reducing floods. Using the corps' data, they compared river flows with corresponding rainfall events during a 10-year period before the channelization and a 10-year period afterward.

They found that the increased water velocity resulting from the channel work effectively decreased flooding in the upper portions of the Obion. However, the quicker flows sent water converging on downriver areas far faster than the channel could accommodate, resulting in higher "peak discharges" and increased flood frequency, the study said.

During the 10-year period before channelization, floods struck during the May-to-October growing season an average of 0.5 times per year. During the periods afterward, fields were inundated an average 1.2 times per year, an increase of 140 percent.

The channelization did reduce the average duration of floods from 3.3 to 1.3 days, the researchers found. However, they said, brief and intense floods can still cause severe damage to agriculture, the protection of which was one of the main justifications for the tributaries project.

The study follows recent reports by U.S. Geological Survey officials and other researchers pointing out problems associated with channelization. They found that the channel work causes increased erosion and sedimentation along streams, causing blockages and further aggravating the flooding problems.

The study findings have found support among some local officials in communities along the Obion and environmentalists.

Glen Parnell, mayor of the town of Obion, located along the lower portion of the river, said the study jibes with his observation that flooding has worsened dramatically in the 49 years he's lived in the area.

"As they went further on up (the river) with channelization, it just got worse," he said. "Channelization hasn't worked up here."

Parnell said flooding has gotten so bad in recent years that Obion is trying to get help from the National Guard in building a levee to protect the town.

Norris Cranford, Obion County executive, also said flooding has worsened substantially in recent years, although he's not sure how much of it can be attributed to channelization.

"We used to go years without anyone getting flooded out of their homes," he said. "We get a pretty good rain now and we get people flooded in Obion, Rives and Bogota."

The findings come as little surprise, said Chester McConnell, a field representative of the Wildlife Management Institute and longtime opponent of channelization.

"It proved for the Obion-Forked Deer river systems what had already been proven in similar circumstances for numerous other river systems over the past 25-30 years," he said.

McConnell said channelization "is always going to decrease (flooding) upstream and it's always going to increase it downstream, and you don't need any data to show that."

However, the corps' Reeder disputed the conclusion that the tributaries work has heightened flood dangers. Although he hasn't reviewed the study in detail, Reeder said it's difficult to draw comparisons of conditions before and after channelization.

There are lots of variables in how rainfall affects river flows, he said. Also, in the time since the channelization, there have been other changes — such as increased urban development and construction of levees by farmers — that could be aggravating the flooding problem, he said.

Reeder said sediment buildups have been a problem on the lower Obion and elsewhere. But still, the flooding threat along the river is considerably less than it would be if the project had not been constructed, he said.

"We still believe, even though things have changed out there, that it is providing for flood control," he said.

Reeder said the corps, while designing such flood-control projects, anticipates the greater flows from upriver and "we size the channel downstream accordingly."

The tributaries plan also was defended by J. Richard Swaim, director of the Obion-Forked Deer Basin Authority, the state agency that sponsored the project.

Swaim declined comment on the study because he hadn't seen it. But he said, "There's no question that the West Tennessee Tribs (project) has contributed to a reduction in the flood frequence and flood peaks."

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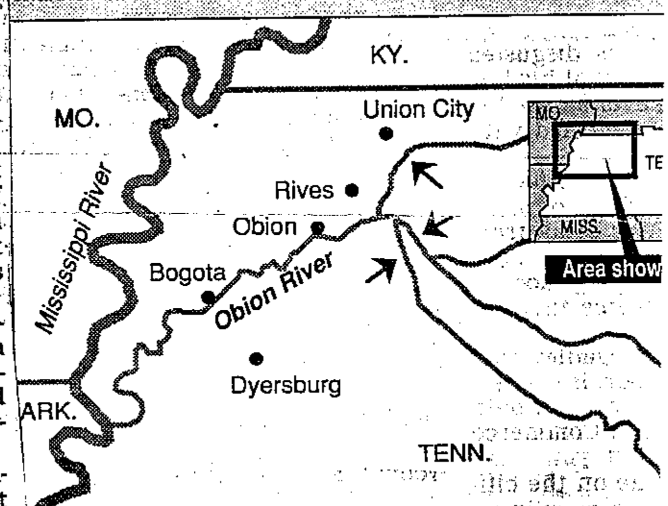
Flooding Dilemma

A new study by two University of Alabama researchers concludes th
1960s channelization of the Obion River as part of the West Tennes
Tributaries flood-control project actually has worsened flooding alon
portions of the river. Shown by arrows are the upper limits of where
channelization work was conducted.



Tenn. marsh shapes arena for test of wetlands policy

By Tom Charlier
The Commercial Appeal

TREZEVANT, Tenn. — Deep in the wilds of Carroll County, an eerie marsh wrapped in lily pads and studded with the trunks of long-dead trees is about to become a proving ground for state policies governing wetlands.

The Department of Environment and Conservation this week is expected to rule on plans to dredge a portion of the South Fork of the Obion River here, as well as five miles of other silted streams in Carroll, Henderson and Madison counties.

In the politically charged arena of wetlands management, the projects pose state officials with a particularly difficult decision: Should artificial drainage patterns critical to farmers be maintained, or should nature now be allowed to take its course?

The decision, however it goes, won't please all the government agencies, interest groups, landowners and sportsmen who have been vigorously debating it. At stake could be a new course for Tennessee's ever-changing wetlands policies.

The dredging proposal is advanced by the Obion-Forked Deer Basin Authority, a Jackson-based state agency geared toward flood-control work.

In September 1985, it received approval to dredge 742,400 cubic yards of silt — enough to fill nearly 50,000 dump trucks — from six blockages.

However, because of delays in getting needed easements from property owners, the authority was able to clear only two blockages by the time the five-year permit expired.

Now, as the authority seeks reauthorization for the work, a phalanx of opponents has formed to make sure the decision is anything but routine.

Their concerns center on Jarrell Bottoms, a 13,000-acre marsh on the Obion's south fork about 100 miles northeast of Memphis.

Once the site of a dense hardwood forest, the 1½-mile-wide floodplain gradually became inundated after a blockage formed in the canal that was dug some 70 years ago so crops could be planted. Critics contend the straight artificial channels are destined to become clogged because they can't accommodate a river's natural meandering tendencies.

In Jarrell Bottoms, the flows that were backed up from the

Please see SWAMP, Page A10

blockage have spilled into the original, meandering river channel. Beginning about 20 years ago, the rising water killed the valuable hardwoods and flooded the cropland while creating an open marsh reminiscent of Florida's Everglades.

Opponents to the dredging say that while it's a shame the hardwoods were killed, the new ecosystem that has formed here shouldn't be destroyed.

Jackson businessman Lee Fite, whose family owns 300 acres in the area of the marsh, is among those fighting the projects.

"We bought the land as it is, and we'd like to maintain it like that," he said. "It's an absolutely pristine wetland."

Fite and other opponents contend the transformed marsh is rich in wildlife and plant diversity. Sierra Club official Larry J. Smith said it contains the floating mats of vegetation usually seen only in coastal areas.

Fishermen nearly always can be seen scouring the bottoms for crappie, bream and catfish, and during the winter hunters find an abundance of waterfowl.

In a letter to federal officials, longtime wetlands advocate Chester McConnell commented, "It continues to surprise me how nature can create such an area as a result of man's misuse of land and waters."

Supporters of the projects, however, say the work not only will reduce flooding but will bring enormous ecological benefits to the bottoms. The dredging would allow for a more natural ebb-and-flow scheme, which would result in better-quality water for fish and other animals, said basin authority director J. Richard Swaim.

He said the projects will provide for more flexibility in managing water levels. Landowners, for instance, could install water-control structures to create reservoirs, Swaim said.

Some sportsmen say they would welcome the dredging.

"It looks to me like it ought to have been done long ago, as big a mess as it is," said lifelong area resident Evester Adkisson, 70, as he fished last week.

As he prepared for an afternoon on the water, Bobby Sawyer of McKenzie voiced complaints about current conditions. "When you get a lot of rain, the water gets real bad," he said.

Sawyer's fishing partner, Ricky Beadles, said members of his family currently have "a lot of good land underwater."

The reauthorization issue has prompted verbal sparring between the U.S. Environmental Protection Agency and the Corps of Engineers, which will likely issue the final permit should state Department of Environment and Conservation officials give their approval.

Corps officials contended that the basin authority should get fast-track approval since it already had received a permit. But EPA said that new circumstances have arisen — such as President Bush's goal of no net wetland loss — requiring a fresh look at the issue.

Tom Welborn, chief of the wetlands regulatory unit in EPA's Atlanta office, said the corps is "pushing" the project by allowing only a brief public comment period. He also cited a June 13 letter in which the corps told state officials their decision-making powers would be "waived" if they didn't rule on the projects by July 5.

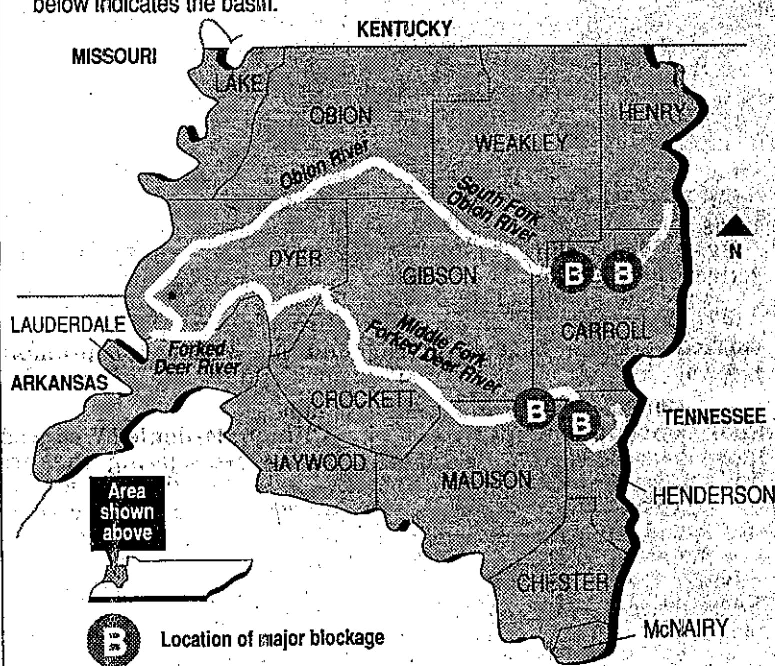
Larry Watson, the corps' chief of regulatory functions in Memphis, denied that his office is giving special treatment to the projects. "We're not trying to push it through," he said.

At EPA's request, the corps has extended the public comment period from 21 to 30 days — it now is set to end July 14. But it so far hasn't granted the Aug. 14 date EPA had sought.

Bill Duffel, assistant natural resources manager for in the Division of Water Pollution Control, said the state does plan to meet the Friday deadline for making a decision.

Drainage Plans

The Obion-Forked Deer Basin Authority is seeking reauthorization to dredge for major river blockages blamed for flooding problems. The shaded area below indicates the basin.

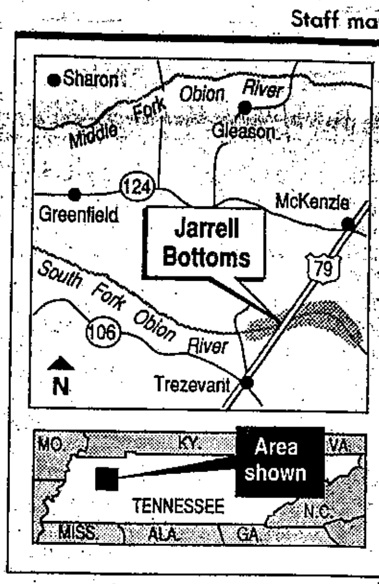


July 1, 1991 Commercial Appeal

Feb 11 1991

Changing drainage muddies the waters on forest vs. marsh

Staff map.



By Tom Charlier
The Commercial Appeal

TREZEVANT, Tenn. — On a brittle winter day, Peter James is steering a leaky johnboat into the current of a rain-bloated river, the hum of his engine penetrating forsaken Jarrell Bottoms.

In the late-afternoon sun, ice glazes the water's edge and silence wraps the cypress forest beyond. Amid the cold stillness, three deer are foraging for acorns, a raccoon scurries up a hollow tupelo tree and two mallards glide overhead.

"Just about everything that lives in Tennessee exists down in these bottoms," says Dean Griffith, James's frequent partner on fishing trips to the site.

Including controversy. Swamps such as this 10,000-acre marsh 100 miles northeast of Memphis are of particular interest to state leaders this year. Legislative and regulatory proposals would relax environmental rules and allow drainage of these kinds of areas.

Settling the issue will require officials to sort out disagreements over the ecological and flood-control benefits of different types of wetlands.

Jarrell Bottoms, parts of which are sometimes called Christmasville Bottoms and McKenzie Bottoms, is southwest of McKenzie in Carroll County, where the South Fork of the Obion River strays from an artificial canal and spreads into a broad flood plain.

In areas, the marsh opens like a sea, punctuated by dead tree masts and singular cypress and tupeloes. In other areas, the trees are thicker, and beaver

Please see MARSH, Page A10

CA

From Page A1

Marsh

lodges rise like haystacks at every turn.

It was not always like this. As recently as 20 years ago, the bottoms were much drier and thickly wooded with towering oaks and other hardwoods coveted by landowners and timber companies.

"I can remember driving along Highway 79 between Trezevant and McKenzie and, except at high noon, you were driving in shade because the timber grew up on either side of the road," said J. Richard Swaim, director of the Obion-Forked Deer Basin Authority.

The changes in the bottoms are common to West Tennessee, where networks of canals and levees, with erosion from farms, have drastically altered natural drainage patterns.

In the early 1970s, the canal initially dug 50 years earlier became clogged with sediment and debris. The blockage diverted the river into its natural flood plain and channel, where it has become "ponded," or perennially backed up, as a result of overall poor drainage.

The inundation killed the valuable hardwood trees, whose survival depended on their roots being dry during the summer.

Swaim and landowner groups across the state want to be able to partially drain such swamped-out areas. The sites still would be considered wetlands — flooded during the winter and spring — but the marsh ecosystem would be replaced with bottomland hardwoods.

Presently, state and federal water-pollution laws make it difficult for property owners to blast the drainage ditches needed to accomplish that.

But rules changes proposed by the state would give owners broad powers to drain land that has become inundated since 1977. This month, a bill supported by a farm-lobby group was introduced in the General Assembly proposing that the reference date be set at 1970.

"It's simply right to restore the land to its productive capacity," said Julius Johnson, director of public affairs for the Tennessee Farm Bureau, the largest landowners group in the state.

Supporters of change contend seasonally flooded bottomlands are preferable to constantly inundated marshes. The fluctuations provide a greater exchange of water, fostering lusher vegetation, cleaner streams, better wildlife habitat and improved flood control, they say.

"I think sites like the Jarrell Bottoms ought to be allowed to be drained, then let it ebb and flow," Swaim said. "You're certainly not destroying wetlands when you do that."

That position was tentatively supported in a recent report by the Tennessee Wildlife Resources Agency. In a draft management plan for a Dyer County wildlife area, the agency described constantly flooded swamps as "undesirable."

However, the plan has been criticized by some scientists within state government and is likely to be amended.

"You're going to find a lot of disagreement — even within this agency," said Dan Sherry, a TWRA fish and wildlife environmentalist, on the marsh-vs.-hardwood issue.

His personal opinion is, "it's a tradeoff," with each type of ecosystem offering advantages.

Officials with environmental groups believe the marshes should be left alone. It is too late to save the hardwoods, they say.

Betty Tabatabai, president of the Wolf River Conservancy in Memphis, has watched the bottoms become wetter since she first collected plant samples there as a biology graduate student in the early 1970s.

Ms. Tabatabai said she too lamented the loss of the hardwood trees but was heartened by the transformations she saw unfold.

"About 10 years later I started looking at it (the bottoms) with a new excitement. . . .

"Not all the trees were dead. The cypress were still alive and there was all this lush wetlands vegetation — it was a marsh."

Landowners, she said, understate the values of marshes. "They act like there's nothing but sterile water in these sites."

Environmentalists say Jarrell Bottoms contains a rich variety of plant and aquatic life. It even has rare floating mats of vegetation — usually seen only in Louisiana or the Florida Everglades, said Larry J. Smith, wetlands chairman for the state chapter of the Sierra Club.

Many local outdoorsmen regard the marsh as a treasure trove.

Duck blinds dot the marsh, and a string of decoys lie tangled in brush on the river bank. Static "limb lines" used to catch large catfish hang from many tree branches, and submerged stumps are known as prime bass and crappie hangouts.

The water bleeding in from the surrounding forests is crystal clear, darkened only by the occasional school of minnows.

Griffith and James, local furniture workers, regularly navigate the maze of sunken stumps, fallen limbs and tree masts to favored fishing sites.

"Even if the fish aren't hitting we like to come down here because you can see so much,"

From Page A1

Flags

ic details would have to be pro-

Shlenker has since put those

Memorandum For Record

Date: 29 July 2009

Subject: Phone conversation with Tennessee Wildlife Resources Agency (TWRA) regarding written scoping comments for the West Tennessee Tributaries Project

1. Mike Thron (U.S. Army Corps of Engineers) called Rob Todd (TWRA) on 29 July 2009 and inquired whether TWRA had sent any written scoping comments, as previously discussed.

2. Rob Todd stated that TWRA would not be providing written comments at this time and that TWRA felt there would be ample opportunities to comment later in the study process.

Mike Thron
West Tennessee Tributaries
Project Biologist & NEPA Coordinator
U.S. Army Corps of Engineers, Memphis District