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RESULTS OF A WORKSHOP CONCERNING IMPACTS OF VARIOUS ACTIVITIES ON THE FUNCTIONS OF BOTTOMLAND HARDWOODS

Fish and Wildlife Service

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RESULTS OF A WORKSHOP CONCERNING IMPACTS OF VARIOUS ACTIVITIES ON THE FUNCTIONS OF BOTTOMLAND HARDWOODS

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INTRODUCTION

Under Section 404 of the Clean Water Act, the U.S. Environmental Protection Agency (EPA) has regulatory responsibilities related to the discharge of dredged or fill material into the Nation's waters. In addition to its advisory role in the U.S. Army Corps of Engineers' permit program, EPA has a number of specific authorities, including formulation of the Section 404(b)(1) guidelines, use of Section 404(c) to prohibit disposal at particular sites, and enforcement actions for unauthorized discharges. A number of recent court cases focus on the geographic scope of Section 404 jurisdiction in potential bottomland hardwood (BLH) wetlands and the nature of landclearing activities in these areas that require a permit under Section 404. Accordingly, EPA needs to establish the scientific basis for implementing its responsibilities under Section 404 in bottomland hardwoods.

EPA is approaching this task through a series of workshops designed to provide current scientific information on bottomland hardwoods and to organize that information in a manner pertinent to key policy questions. The first two workshops in the series were originally conceived as technically oriented meetings that would provide the information necessary to develop policy options at the third workshop. More specifically, the first workshop was designed to examine a zonation concept[1] as a means of characterizing different BLH communities and describing variations in their functions along a soil moisture gradient. The second workshop was perceived as an attempt to evaluate the impacts of various activities on those functions.

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[1]Clark, J.R., and J. Benforado, eds. 1981. Wetlands of bottomland hardwood forests. Elsevier Scientific, New York. 401 pp.

However, one conclusion of the first workshop, which was held in December 1984 in St. Francisville, Louisiana, was that the zonation approach does not describe the variability in the functions performed by BLH ecosystems sufficiently well to allow its use as the sole basis for developing a regulatory framework.[2] That is, factors other than zone were considered critical for an effective characterization of the structure and functions of bottomland hardwoods.

The approach to the second workshop, the results of which are described in this report, was therefore modified in response to the conclusions from the first workshop. The focus of the second workshop remained an analysis of the impacts of various activities on the functions of BLH ecosystems. However, as a prerequisite to this analysis, participants were also asked to develop a list of characteristics that determine the extent to which BLH sites perform the important functions.

The workshop was organized such that alternating plenary and workgroup sessions allowed ample time for communication while still maintaining a focus on the overall goal. In the initial session, various individuals gave presentations concerning methodologies for evaluating the functions performed by wetlands, factors influencing the conversion of BLH forests to other uses, and the impacts of conversion activities. These were followed by a series of case study presentations designed to familiarize participants with the kinds of issues that are dealt with in the Section 404 program. These presentations are cited in this report as (author, workshop presentation).

At the conclusion of these presentations, participants were divided into six workgroups to examine the functions of BLH ecosystems in the areas of hydrology, water quality, fisheries, wildlife, ecosystem processes, and culture/recreation/economics. Each workgroup was asked to undertake the following tasks.

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[2]Roelle, J.E., G.T. Auble, D.B. Hamilton, R.L. Johnson, and C.A. Segelquist, eds. 1987. Results of a workshop concerning ecological zonation in bottomland hardwoods. U.S. Fish Wildl. Serv., National Ecology Center, Ft. Collins, CO. NEC-87/14. 141 pp.

1. Develop a list of functions performed by BLH ecosystems from the perspective of the workgroup's expertise and area of responsibility.

2. Identify those activities (e.g., impoundment construction, conversion to soybean farming) that impact the major functions (e.g., sediment retention, detrital export) performed by BLH ecosystems.

3. Develop a list of characteristics that determine the extent to which a BLH site performs each function and describe the relationship of each characteristic to the function.

4. Develop, with supporting evidence where possible, an analysis of the impact of each activity (Task 2) on each characteristic (Task 3) and on each function as a whole.

Upon completion of Task 2, in an effort to provide some uniformity in the analyses by the various workgroups, EPA personnel and several participants met and compiled a complete list of all of the activities identified as having significant impacts in bottomland hardwoods (Table 1). From this list the group derived a set of seven activities, and a number of specific actions associated with each, for analysis by the workgroups (Table 2). These activities were selected on the basis of their perceived importance in BLH ecosystems and their interest from the perspective of EPA. Each workgroup was also encouraged to add any activities of particular importance from its perspective.

The workgroup reports that follow document the results of discussion concerning the above tasks. The WORKSHOP SUMMARY attempts to summarize these workgroup results, discuss availability of information, and identify some problems that must be addressed prior to the third workshop in this series.

Table 1. Activities identified as having significant impacts in bottomland hardwoods.

Landclearing	Clearcutting
Leveling	Thinning
Channelization	Selection harvesting
Canalization	Burning
Tiling	Depredation control
Ditching	Impoundment construction
Pumping	Bank stabilization
Dredging and filling	Diversion construction
Fertilizing	Highway construction
Applying pesticides	Utility right-of-way clearing
Chemical conditioning	Refuse disposal
Discing	Sewage disposal
Plowing	Drilling mud disposal
Planting	Hazardous waste disposal
Farm road construction	Mining
Irrigation	Oil and gas exploration and production

Table 2. General activities and associated specific actions chosen for analysis by all workgroups.

Activity	Actions	
Conversion to rice	Landclearing Leveling Levee construction Flooding	Drainage or drying Fertilization Pesticide application Seed bed preparation
Conversion to soybeans	Landclearing Leveling Ditching	Fertilization Pesticide application Seed bed preparation
Impoundment construction (upstream of site, on-site, downstream of site)	Landclearing (on-site) Dredging	Filling
Channelization	Trapezoidal cut Landclearing (both sides)	Dredging Filling
Levee construction (e.g., a mainline river levee)	Landclearing Dredging	Filling
Conversion to pine plantation	Clearcutting Landclearing Site preparation	Ditching Herbicide application Pesticide application
Conversion to aquaculture	Landclearing Leveling Levee construction	Ditching Irrigation

HYDROLOGY WORKGROUP REPORT

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David Hamilton (Recorder)

INTRODUCTION

Natural functions attributed to bottomland hardwood (BLH) ecosystems result from, or are strongly influenced by, hydrology (Conner and Day 1976; Carter et al. 1979; Wharton 1980; Bedinger 1981; Gosselink et al. 1981). Bottomland hardwoods provide flood storage and modify storm flows (Wharton 1970; Novitzki 1979). While some BLH areas serve as ground water recharge sites (Littlejohn 1977), most discharge ground water. Modifications of these functions in turn influence the extent to which the BLH site and downstream sites modify water quality, the vegetation that is present and its ability to reproduce, the habitat value for wildlife and fish, and the economic and recreational opportunities available.

The approach used by the Hydrology Workgroup to determine impacts of various activities on BLH site characteristics and thus on the hydrologic regime is presented in Figure 1. First, three primary hydrologic functions that bottomland hardwoods perform were identified: flood storage, reduction of flow velocity, and ground water discharge modification. Next, characteristics that influence the extent to which a particular site performs each function were identified. The impacts of various activities on each characteristic were determined and then aggregated into an impact on each function as a whole. Finally, impacts on the flood storage, velocity reduction, and ground water discharge modification functions were integrated to determine the overall impacts to on-site and downstream hydrologic regimes.

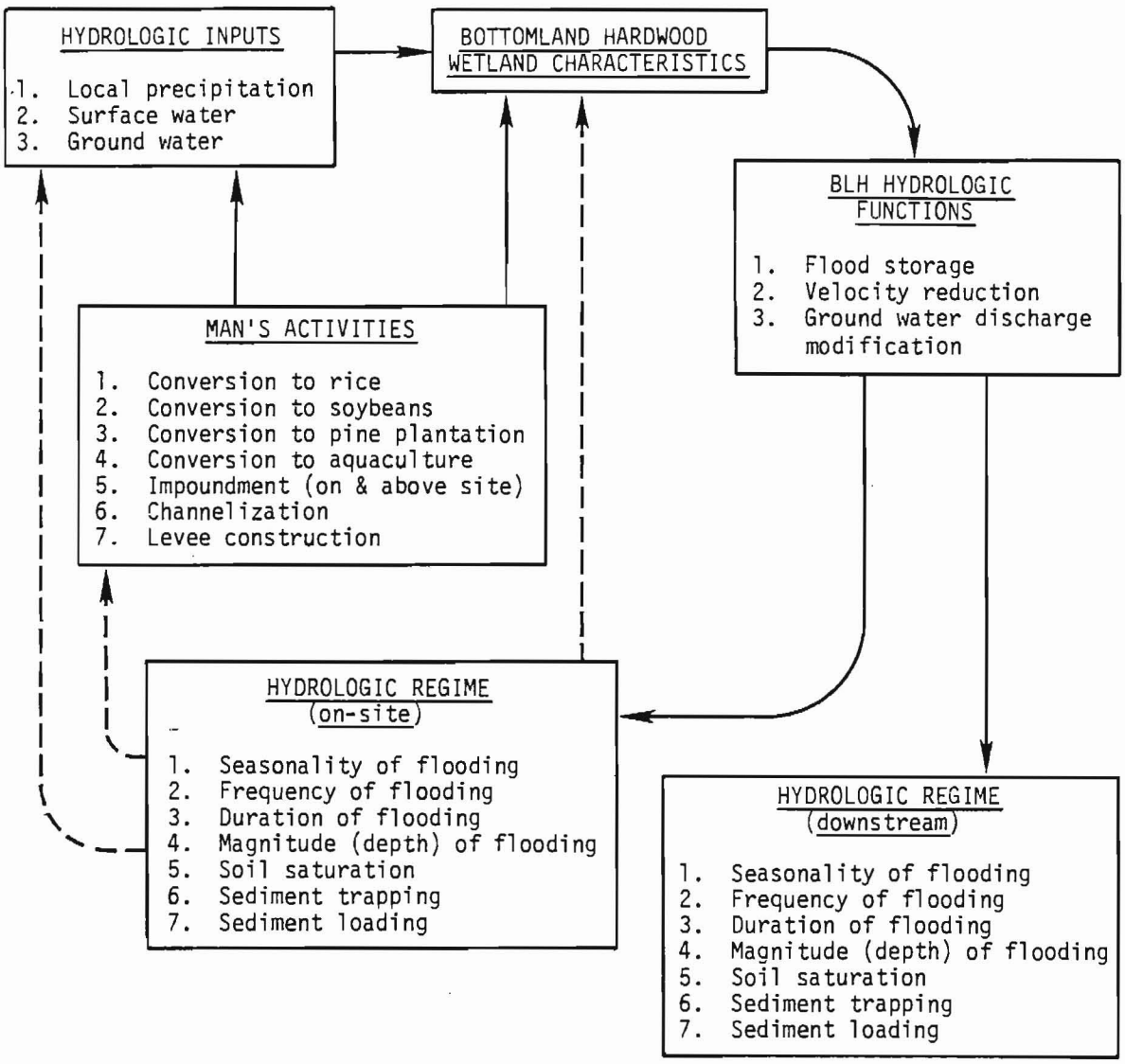

Figure 1. Conceptual model of the influence of man's activities on BLH hydrologic functions.

ANALYSIS OF IMPACTS

FLOOD STORAGE CAPACITY

Flood storage capacity is simply the volume of space available to hold water. In a reservoir this space lies between the current water level and the potential flood pool. In the case of land surfaces it includes that volume of soil porosity that can be filled upon inundation plus the volume of space between the ground surface and flood stage (level). The relationship between flood storage (an instantaneous measure) and the ability of an area to reduce flood peaks and volumes is important to note. The former is strictly a function of the volume of space available while the latter is a function of flood storage in addition to the rate of flow into, through, and from any particular site.

The flood storage capacity provided by a bottomland hardwood system is dependent on the following site characteristics: surface area of active floodplain, vegetation cover, ground surface roughness, elevation, slope, detention storage, and soil saturation. The impacts of various activities on these characteristics and the overall impact on the flood storage function are presented in Table 3.

Surface Area of Active Floodplain

The most important characteristic of a BLH site affecting flood storage capacity is the surface area of the active floodplain. For a given site elevation and slope, a larger floodplain area temporarily stores more flood waters. Activities that involve construction of levees negatively impact flood storage by precluding flood flows from the area behind or within the levees. Large mainline levees remove a BLH site from the active floodplain during all but the most severe flood events. Moderate (3 to 4 ft) levees associated with aquaculture negatively impact storage for average floods but would be overtopped during severe floods. The small levees associated with

Table 3. Impacts of various activities on flood storage as mediated through certain characteristics that contribute to the performance of this function.

Function: flood storage capacity

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U	I-O	I-D	C	L	P	A
Surface area of active floodplain[3]	+	0	0	0	-	0	0	-	0	-
Vegetation cover[3]	-	+	+	-	NA	0	+	+	+0	+
Ground surface roughness	+	-	0	0	NA	0	0	0	0	0
Elevation of site	-	-	0	0	-	0	0	-	0	-
Slope	-	0	0	0	NA	0	0	0	0	0
Detention storage	+	-	-	-	NA	0	0	-	0	0
Soil saturation	-	-	+	0	NA	+-	+	+	+	-
Overall impact on flood storage capacity		-	+	0	-	0	+	-	+0	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts either spatially or temporally. NA means not applicable. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Primary characteristics that contribute to the performance of the function.

would be overtopped during severe floods. The small levees associated with rice farming have a negligible impact because they would be overtopped by almost all flood events. Construction of a flood control impoundment, in one sense, reduces flood storage of a BLH site by partially filling it with the conservation pool. However, the structure allows flood waters to be held on-site as long as needed, thus increasing the flood storage capability of the area behind the structure. Because the old BLH site is inundated by the conservation pool, impacts of on-site impoundments on most other characteristics were assumed not applicable.

Vegetation Cover

Flood storage capacity is reduced by the volume of above-ground biomass. Activities that clear bottomland hardwood forests and replace them with open or agricultural areas (e.g., conversion to rice, soybeans, or aquaculture; clearing associated with channelization) therefore result in a slight increase in flood storage. Clearing associated with conversion to a pine plantation initially increases flood storage somewhat; however, by year 15 in a pulpwood rotation and year 30 in a sawwood rotation, the biomass will return to levels approximating those of bottomland hardwoods. Clearing associated with levee construction has a negligible effect on flood storage for two reasons; first, the area cleared is fairly small and second, the levee removes the site from the active floodplain except during extreme flood events.

Ground Surface Roughness

The volume of microtopographic irregularities in a bottomland hardwood contribute marginally to flood water storage. Rice farming requires relatively precise leveling of sites for optimum water control and therefore negatively impacts this site characteristic. All other activities involve minimal or no leveling and thus have no measurable effect on ground surface roughness and associated flood storage.

Site Elevation

Site elevation refers to the height of the ground surface of a site relative to some reference such as mean sea level or average river stage. Activities that impound water on a site effectively increase the site elevation and thus reduce flood storage capacity. Rice farming levees generally impound less than a foot of water from March to August each year, aquaculture levees typically impound several feet of water for most of the year, and on-site flood control structures can impound a variable depth conservation pool through the entire year. Construction of a mainline levee has a minimal impact on actual site elevation; however, it raises the effective elevation at which flood waters enter a site and thus has a negative impact on flood storage.

Slope

Slope refers to the grade or "tilt" of a bottomland hardwood site along a path perpendicular to the stream channel. A low slope allows flood waters to spread out to a greater degree and thus provides more flood storage than a site with a steep slope (either toward or away from the stream channel).

The only activity that affects the slope of a site is conversion to rice. However, the associated leveling has no net impact on flood storage capacity because the high end of the slope is lowered by depositing the dirt at the low end of the slope (Fig. 2).

Detention Storage

Detention storage is the volume of major depressions on a site (e.g., oxbows) that temporarily hold water following the recession of a flood. The stored water eventually flows out through backwater swamps, evaporates, or percolates through the soil.

Figure 2. Cross-sectional representation of leveling associated with conversion to rice farming.

Agricultural conversions to rice or soybeans are not generally considered for sites that require filling of major depressions. Therefore, most agricultural conversions were assumed to have no impact on detention storage. Channelization can greatly increase detention storage if connections to the old channel are blocked; however, these connections are typically left open so that flood waters filling them drain out as the flood recedes. Construction of mainline levees increases detention storage of precipitation and overland flow from surrounding uplands and increases detention storage during extreme flooding events. However, the levees prevent average over-bank flooding from entering the site in most years and thus were assumed to have an overall negative impact on the actual detention storage.

Soil Saturation

The volume of water that can be stored in soil pores is determined by the available (air-filled) porosity at the time of flooding and the rate of movement of surface water into the soil system. The rate of movement is a function of the soil's infiltration rate and percolation rate. Thus, dry, porous soils provide more storage than saturated or dense soils.

Activities that impound surface water (e.g., rice farming, aquaculture) result in saturated soil profiles and thus the loss of this storage capacity. Activities that involve draining a bottomland hardwood site (e.g., conversion to soybeans, channelization, conversion to pine plantation) or that reduce the extent or duration of flows across the site (e.g., levee construction, flood control impoundment upstream) result in drier soils and more storage capacity.

Overall Impact on Flood Storage

Construction of large mainline levees causes a significant reduction in flood storage capacity because it removes a bottomland hardwood site from the active floodplain for all but a few extreme flood events. The reduction associated with a conversion to aquaculture is less severe primarily because the impounding levees are lower. Conversion to rice farming results in a very small reduction in flood storage capacity due to field leveling and maintaining saturated soils through most of the growing season. On-site impoundments reduce the flood storage capacity of a site by filling it with a conservation pool of water; however, the structure allows water to be impounded deeper and held longer thus increasing overall flood control. Conversion to soybeans, channelization, and conversion to pine plantation all result in a slight increase in flood storage capacity due to associated draining and initial vegetation removal. Subsequent tree growth in pine plantations will offset the initial increase in flood storage by years 7 to 15 in a pulpwood rotation and beyond year 30 in a sawlog rotation.

VELOCITY REDUCTION

Another aspect of flood storage involves the extent to which flows are delayed or slowed as they flow through a bottomland hardwood site. The most important site characteristics influencing the reduction of flood flow velocities include the surface area of the active floodplain, vegetation cover, ground surface roughness, the shape of the site, stream sinuosity, and the amount of debris on the site. Less important characteristics include the slope of the site and the extent of internal drainage channels. The impacts of various activities on these characteristics and the overall impact on the velocity reduction function are presented in Table 4. Effects of an on-site impoundment were considered not applicable because flow velocities would be controlled by the impounding structure, not by characteristics of the site.

Surface Area of Active Floodplain

When flood waters overtop stream banks they spread out over the adjacent floodplain and their velocity is reduced. The greater the extent of spreading, the greater the velocity reduction. The only activities that affect the size of the active floodplain are those that involve moderate to large levees. The 3- to 4-ft levees associated with aquaculture prevent average floods from spreading into the floodplain and thus negatively impact the function. Large mainline levees remove a BLH site from the active floodplain for all but the most extreme floods and thereby negatively affect velocity reduction in most years.

Vegetation Cover

The extent to which flood waters are impeded as they flow through a bottomland hardwood site is directly related to the density of vegetation present. Vegetation density is a function of the type of vegetation (e.g., densely planted pine trees typically provide more surface area and thus more resistance to flow than hardwoods), the stem density and sizes, and the vertical structure of the plant community. Thus, a pulpwood pine plantation

Table 4. Impacts of various activities on velocity reduction as mediated through certain characteristics that contribute to the performance of this function.

Function: velocity reduction										
Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U	I-O	I-D	C	L	P	A
Surface area of active floodplain[3]	+	0	0	0	NA	0	0	-	0	-
Vegetation cover[3]	+	-	-	0	NA	0	-	0	-+0	-
Ground surface roughness[3]	+	-	-	0	NA	0	0	0	+	0
Width/length ratio[3]	+	0	0	0	NA	0	0	0	0	0
Sinuosity[3]	+	0	0	0	NA	0	-	0	0	0
Debris[3]	+	-	-	0	NA	0	0	0	-	-
Slope	-	+	0	0	NA	0	0	0	0	0
Internal drainage	-	+	-	0	NA	0	-	0	-	+
Overall impact on velocity reduction		-	-	0	n/a	0	-	-	-+0	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts either spatially or temporally. NA means not applicable. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Primary characteristics that contribute to the performance of the function.

(e.g., loblolly or slash pine) retards flow more than a cypress-tupelo swamp, which retards flow more than a field of soybeans. All activities that involve landclearing (conversion to rice, conversion to soybeans, channelization, conversion to aquaculture, conversion to pine plantation) result in a decline in the ability of a site to reduce flood flow velocities. The dense growth that occurs in the first 7 to 15 years of a pine plantation (600-900 stems/acre) results in a gradual net increase in the velocity reduction by that site (Fig. 3) following clearing. If the site is managed for pulpwood, clearing at about year 15 would again negatively impact the function. If the site is managed for sawlogs, periodic thinnings over the longer rotation period would gradually reduce the ability of the site to retard flood flows to levels approximating those provided by natural bottomland hardwoods.

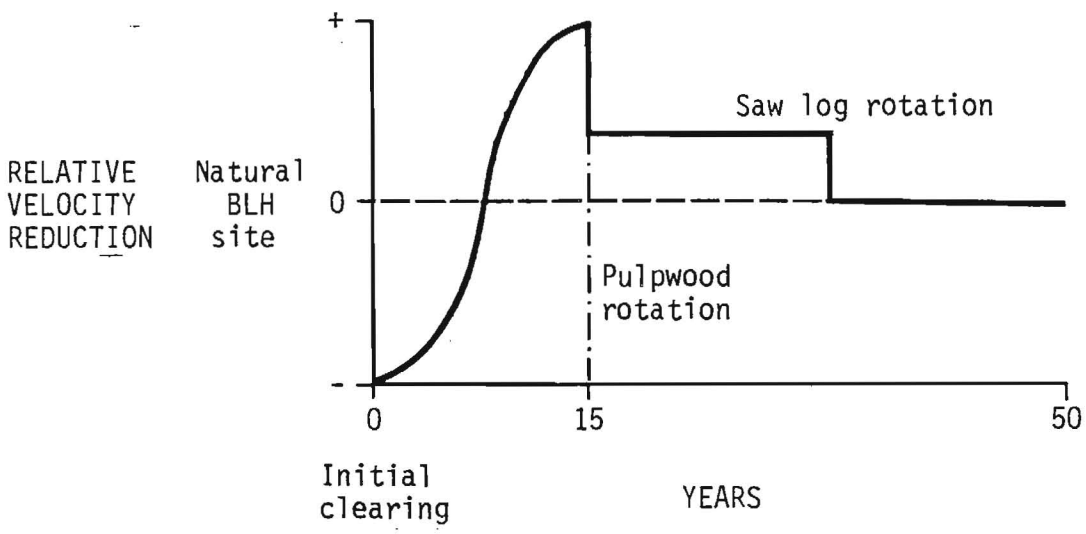

Figure 3. Changes in flood flow velocity reduction through a pine plantation rotation cycle.

Ground Surface Roughness

A bottomland hardwood site with surface irregularities causes additional turbulence in waters flowing over the site and thus slows them down to some extent. Conversely, very smooth sites allow water to pass through relatively unimpeded. The leveling associated with conversion to rice farming, and to a lesser extent conversion to soybeans, therefore reduces the ability of the site to retard flood flows. However, this reduction is probably minimal when compared to the impacts from associated vegetation clearing and removal of debris. The only other activity that affects surface roughness is conversion to pine plantations. Site preparation typically entails development of a series of ridges and furrows. The ridges provide a slightly higher, and therefore drier, location to plant seedlings, while the furrows provide drainage. Although the ridges and furrows tend to degrade through time, they provide additional surface roughness and thereby help to reduce flow velocity slightly.

Width/Length Ratio

The shape of a bottomland hardwood site can influence the extent to which flood waters are retarded. Sites that are wider (along a path perpendicular to the stream channel) provide a greater opportunity for flood waters to spread out than sites of the same size that run in a narrow band along the stream channel. This characteristic would be important to consider when comparing the relative velocity reduction potential of two BLH sites; however, it is not affected by any of the activities considered.

Stream Sinuosity

Stream sinuosity refers to the extent of meandering of a stream channel. Highly sinuous channels tend to slow down stream flows while straight channels allow water to flow relatively unimpeded. Channelization and associated debris removal therefore have a major impact on the ability of a bottomland hardwood site to slow stream flow. None of the other activities affect stream sinuosity.

Debris

A bottomland hardwood site typically contains an accumulation of fallen trees, broken limbs, and racks of leaf and stem parts. This debris increases the overall roughness of the site and helps to impede flood flows. Extreme accumulations of debris can block stream channels or impound water in a portion of a BLH site. All activities that involve landclearing (conversion to rice, soybeans, pine plantation, or aquaculture) therefore reduce the ability of the site to retard flood flows.

Slope

The slope of a site (along a path perpendicular to the stream channel) interacts with surface area and the shape of the site to determine the extent to which flood waters can spread out. A gentle slope allows more spreading and thus a greater reduction in velocity. The precise leveling associated with a conversion to rice farming can, therefore, have a small positive impact on the velocity reduction function.

Internal Drainage

The network of natural sloughs and small collector channels interspersed within a bottomland hardwood site provides some degree of drainage. Sites with extensive networks allow water to drain quickly and therefore provide less retardation of flood waters than sites with minimal internal drainage.

Conversion to rice or aquaculture involves construction of low to moderate size levees to impound water. Flood waters that overtop the levees are therefore impounded temporarily and their velocities are reduced (a positive impact on the function). The improved site drainage associated with channelization or conversion to soybeans or pine plantation reduces the ability of a site to retard flood waters.

Overall Impact on Velocity Reduction

Activities that isolate a bottomland hardwood site from the active floodplain (construction of mainline levees, conversion to aquaculture) eliminate the potential of the site to retard flood flows in most years. Activities that improve site drainage (conversion to soybeans or pine plantation, channelization) or remove vegetation (conversion to agriculture, silviculture, aquaculture, or channelization) reduce the potential of the site to retard flood flows. In the case of pine plantation conversion, the dense growth of pines following clearing subsequently results in a net increase in velocity reduction potential, but thinnings after year 15 eventually reduce this potential to a level approximating that of a mature bottomland hardwood forest.

GROUND WATER DISCHARGE MODIFICATION

The limited information concerning ground water exchange relationships of wetlands (including bottomland hardwoods) is contradictory. Many investigators have considered ground water recharge (movement of surface water into the ground water system) to dominate in wetland areas. However, recent studies suggest that wetlands are more typically ground water discharge (movement of ground water into the surface water system) areas.

Under normal (undisturbed) conditions, the ground water system is in equilibrium, and recharge to the system equals discharge from the system (Fig. 4). Recharge typically occurs as infiltration through permeable upland soils, and discharge is to lakes, streams, wetlands, and plant transpiration. More water will be stored in the ground water system (Fig. 5) if either recharge increases (Fig. 5a) or discharge decreases (Fig. 5b). Less water will be stored in the ground water system (Fig. 6) if either recharge decreases (Fig. 6a) or discharge increases (Fig. 6b).

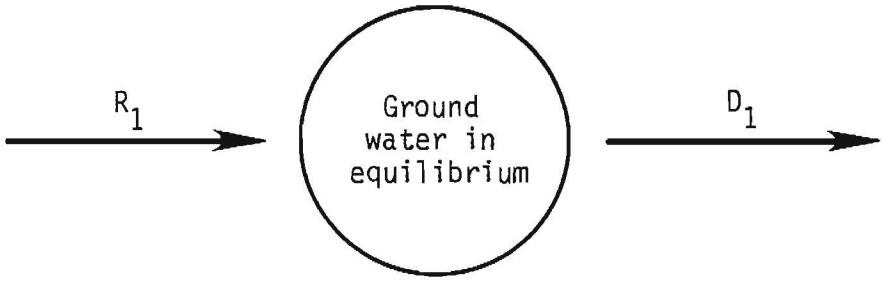

Figure 4. Ground water discharge and recharge relationship with the ground water supply in equilibrium at time 1.

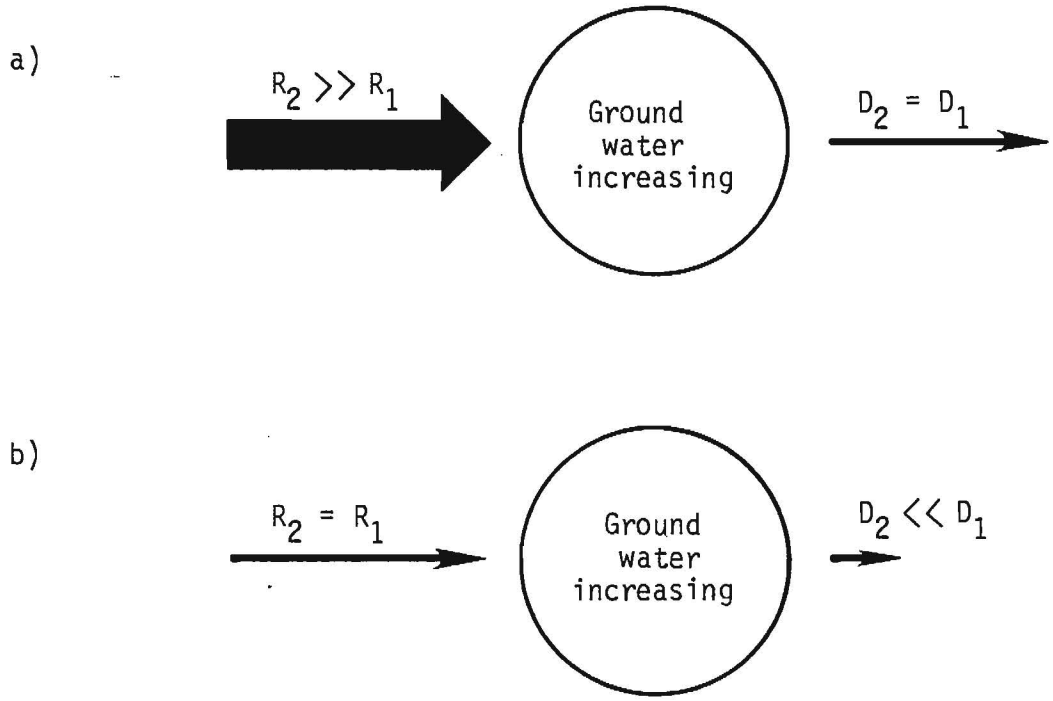

Figure 5. Ground water discharge and recharge relationships resulting in an increase in ground water supply from time 1 to time 2.

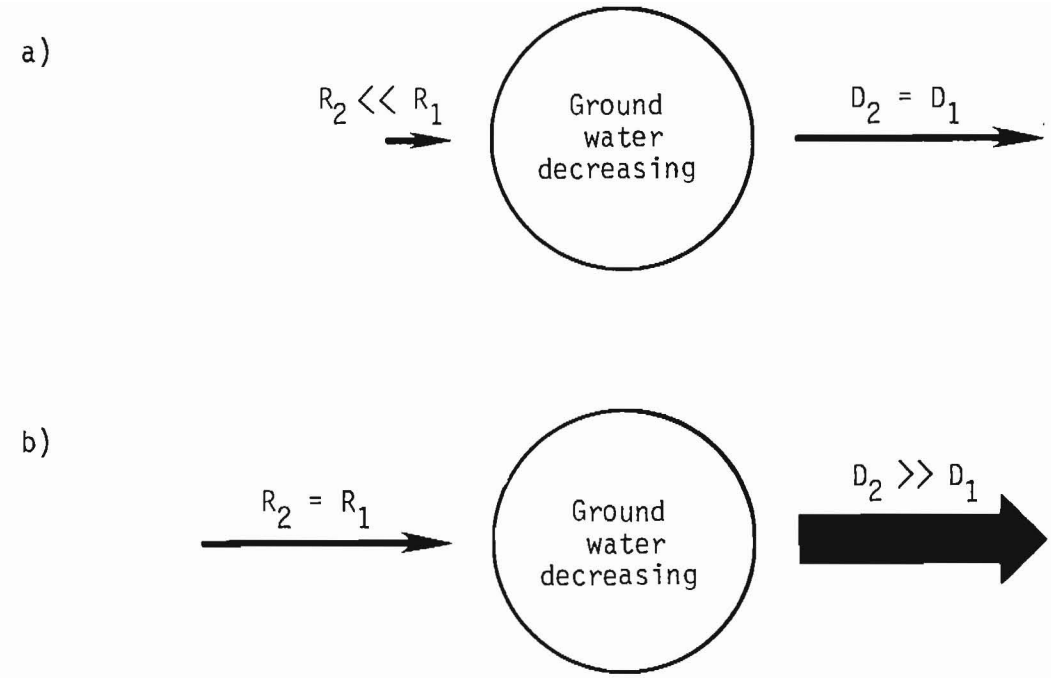

Figure 6. Ground water discharge and recharge relationships resulting in a decrease in ground water water supply from time 1 to time 2.

Saturated conditions, flat hydraulic gradients, and accumulating organic soils in bottomland hardwood sites tend to inhibit (reduce) ground water discharge. The extent of ground water discharge reduction is dependent upon the following characteristics: hydraulic gradient, soil permeability, infiltration rate, detention storage, and evapotranspiration. The impacts of various activities on these characteristics and the overall impact on ground water discharge are presented in Table 5.

Hydraulic Gradient

Hydraulic gradient is the primary site characteristic influencing the rate at which ground water-surface water exchanges occur. If permeability remains constant, ground water flow is proportional to the slope of the water

Table 5. Impacts of various activities on ground water discharge modification as mediated through certain characteristics that contribute to the performance of this function.

Function: ground water discharge modification

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U	I-O	I-D	C	L	P	A
Hydraulic gradient[3]	+	-	+	0	-	+	-	-	+	-
Infiltration rate	+	-	-	0	0	0	0	0	-	0
Soil permeability	-	0	0	0	0	0	0	0	0	0
Detention storage	-	-	+	0	0	0	0	0	+	0
Evapotranspiration	-	?	?	?	?	?	?	?	?	?
Overall impact on ground water discharge modification		-	+	0	-	+	-	-	+	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts either spatially or temporally. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Primary characteristics that contribute to the performance of the function.

table (hydraulic gradient) normal to the river. Activities that increase the wetness of the site (i.e., activities that impound water, raise the river stage, or decrease evapotranspiration) will flatten or reverse the hydraulic gradient and therefore decrease ground water discharge to the river. Conversely, activities that reduce the wetness of the site (i.e., activities that drain the site, lower river stage, increase evapotranspiration, or pump ground water from wells on or near the site) will positively increase the gradient and therefore increase discharge.

Rice farming, aquaculture, and on-site flood control structures impound water on a site, thereby reducing ground water discharge. Mainline levees isolate bottomland hardwoods from the active floodplain, preventing river flow from spreading out over the site. Since water cannot spread out as much, the river stage increases. This flattens the hydraulic gradient and reduces discharge. If river stage increases greatly during a flood, the hydraulic gradient can be reversed, causing artesian effects on the site. Conversion to soybeans or pine plantation typically involves ditching and draining; therefore ground water discharge increases. Flood control impoundments result in lower flows (river stages) downstream and consequently an increase in discharge at downstream sites. Channelization flattens the hydraulic gradient (Fig. 7), thereby reducing ground water discharge.

Infiltration Rate

Water falling or flowing on the soil surface is absorbed into the soil and gradually moves into subsurface layers. The volume of water infiltrating per unit area per unit time is the infiltration rate. This rate is dependent on antecedent soil water conditions, soil texture and structure, and uniformity of the soil profile. Sandy or gravelly soils allow rapid infiltration, whereas clays or tightly compacted organic soils impede infiltration. Infiltration through all of these soils is reduced if the surface layers are compacted. Infiltration rate also varies with time; it is high in the early stages of infiltration, then asymptotically decreases toward a steady-state rate that depends on the soil characteristics mentioned above. The characteristics that

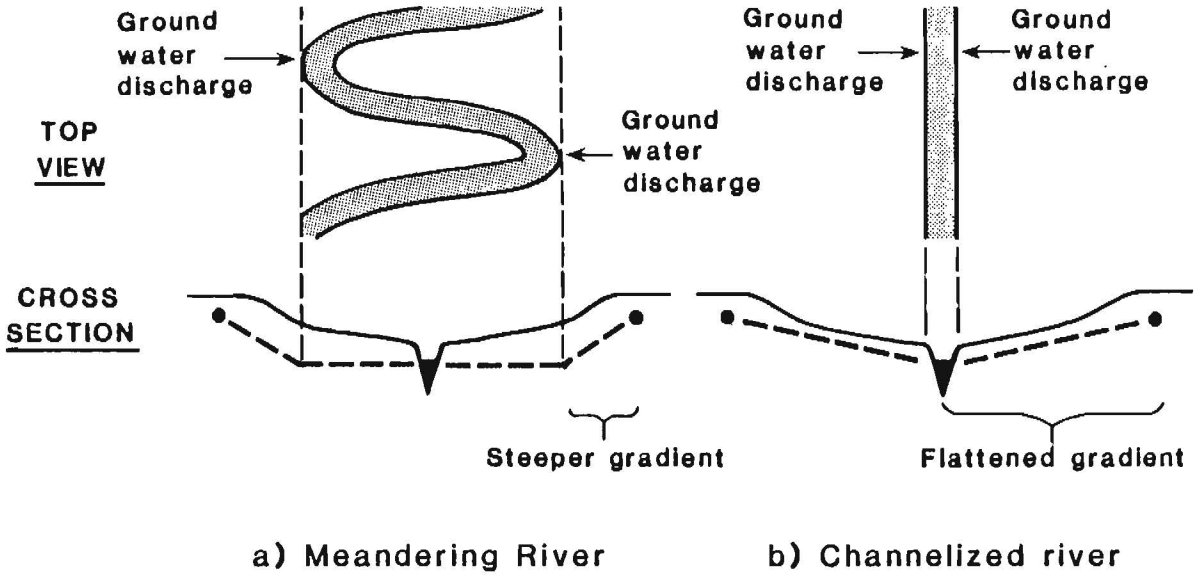

Figure 7. Effect of channelization on hydraulic gradient.

control infiltration of surface water into the soil also control the rate at which ground water can be discharged to surface water. Thus, low infiltration rates imply low ground water discharge rates.

Activities that add fine-grained sediments (i.e., activities that improve sediment trapping), enhance the accumulation of organic soils (i.e., activities that increase the duration of flooding or soil saturation), or compact the soil surface result in reduced infiltration rates. Conversion to agriculture (rice, soybeans) or pine plantation involves site preparations that compact the soil to varying degrees. The extent of compaction is highly dependent on the soil type, the operator, and the season in which site preparation is conducted.

Soil Permeability

The permeability of aquifer materials and surficial deposits determine the rate of ground water flow for a given hydraulic gradient. Ground water flow is rapid in sandy and gravelly materials and very slow in fine-grained alluvial deposits, decomposed organic materials, and clays. None of the activities affect this characteristic.

Detention Storage

Depressions in a bottomland hardwood site that retain water after floods recede may either allow water to recharge into the underlying soils or inhibit ground water from discharging upward by flattening the hydraulic gradient. In either case, the net effect is an increase in ground water supplies. Therefore, any activity that reduces detention storage will increase ground water discharge. Site preparations associated with a conversion to soybeans or pine plantation have this effect. The low levees constructed for rice farming serve to increase detention storage and decrease ground water discharge.

Evapotranspiration

Evaporation from open water or the soil system and transpiration by plants are important mechanisms that discharge near-surface ground water. Any activity that increases evapotranspiration will therefore increase ground water discharge. However, results of recent studies are somewhat contradictory concerning the net effect of vegetation clearing or conversion to agriculture. Bottomland hardwood forests may have high transpiration losses but the microclimate they produce minimizes evaporation. Clearing these forests or converting them to agricultural fields reduces transpiration but increases evaporation. The relative changes in transpiration and evaporation resulting from various activities could not be assessed at the workshop.

Overall Impact on Ground Water Discharge Modification

Hydraulic gradient is the dominant characteristic determining ground water discharge. The overall impact of each activity is therefore the same as the impact associated with hydraulic gradient. Thus, on-site impoundments, levees, channelization, and conversion to rice or aquaculture flatten the gradient and decrease discharge, while conversion to soybeans or pine plantation and construction of upstream impoundments increase the gradient and discharge.

IMPACT ON HYDROLOGIC REGIME

Flood flow moderation is the process through which peak flows that enter a bottomland hardwood site are delayed in their downslope journey. This moderation is the combined result of the flood storage, velocity reduction, and ground water discharge/recharge functions discussed previously. Flood desynchronization is the process through which simultaneous storage of peak flows in several basins within a watershed and their gradual release in a nonsimultaneous manner results in lower but more persistent downstream flows (Adamus and Stockwell 1983). Impacts of various activities on the hydrologic regime, and associated sedimentation characteristics, within a basin are discussed below. Impacts of activities on flood desynchronization are highly dependent on the configuration of basins within a watershed and must be evaluated on a site-specific basis.

On-Site Impacts

The impacts of various activities on the on-site hydrologic regime are presented in Table 6. Activities that involve impounding surface water (conversion to rice or aquaculture, on-site flood control structure) alter the seasonality of flooding and increase "flood" frequency and duration over the natural flooding regime. Rice fields are flooded with several inches of water from March to August, aquaculture ponds are flooded with several feet of water

Table 6. Impacts of various activities on the on-site hydrologic regime resulting from the combined modification of flood storage, velocity reduction, and ground water discharge.

Hydrologic parameter	Activity[1]						
	R	S	I	C	L	P	A
Seasonality of flooding	y	n	y	n	y	n	y
Flood frequency	+	0	+	-	-	-0	+
Flood duration	+	-	+	-	-	-0	+
Flood magnitude (depth)	-	-	+	-	-	-0	-
Soil saturation	+	-	+	-	-	-	+
Sediment trapping	-	-	+	-	-	-+	-
Sediment loading	+	+	-	+	+	+-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts either spatially or temporally. R = conversion of site to rice, S = conversion of site to soybeans, I = impacts from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

almost year round, and flood control structures impound pools that vary in depth through the year. The depths of flooding for rice and aquaculture were considered less than the average depth of natural flooding, while the depth of conservation pools was assumed to be greater than that associated with natural flooding. Activities that involve isolation of a bottomland hardwood site from the active floodplain in most years (e.g., mainline levee construction) or that involve improved drainage (e.g., channelization, conversion to pine plantation or soybeans) cause a decrease in flood frequency, duration, and magnitude on-site. The decrease resulting from conversion to pine plantation is temporary; a more typical flooding regime occurs as the pine plantation matures.

The various activities, and the associated changes in flooding characteristics, also cause changes in soil saturation and in the sediment load carried in stream flow. Soil saturation changes are the same as those for flood frequency and duration. The sediment load is determined by the tendency of the site to trap sediments versus its tendency to have sediments scoured from it. Activities that reduce vegetation structure (conversion to agriculture, silviculture, or aquaculture) or prevent flow through the site (construction of mainline levees, channelization) reduce the ability of the site to trap sediments. Construction of a flood control structure greatly increases sediment trapping as waters are slowed or impounded behind the structure. Activities that remove vegetation (conversion to agriculture or silviculture) or result in unprotected banks (channelization, construction of mainline levees) result in increased sediment loading. Activities that impound at least several feet of water (on-site impoundment, conversion to aquaculture) reduce sediment loss.

Downstream Impacts

The only activity that affects the seasonality of downstream flooding is construction of a flood control impoundment (Table 7). It was assumed that such impoundments would decrease the frequency, duration, and magnitude of floods downstream. As a result, soils at downstream sites are saturated less often. Since much of a stream's sediment load settles out behind a flood control structure, downstream sites have less "opportunity" to trap sediments. The net effect of an impoundment on sediment loading at downstream sites could not be determined. Water released from the structure will have a lower sediment load because of settling in the impoundment. This clearer water has a greater capacity to pick up sediment and will therefore result in more scouring. However, regulation of flood flows will reduce the frequency and severity with which downstream sites are scoured.

Table 7. Impacts of various activities on the donwstream hydrologic regime resulting from the combined modification of flood storage, velocity reduction, and ground water discharge.

Hydrologic parameter	Activity[1]						
	R	S	I	C	L	P	A
Seasonality of flooding	n	n	y	n	n	n	n
Flood frequency	+	+	-	+	+	+0	+
Flood duration	+	+	-	+	+	+0	+
Flood magnitude (depth)	+	+	-	+	+	+0	+
Soil saturation	+	+	-	+	+	+	+
Sediment trapping	+	+	-	+	+	+-	+
Sediment loading	-	-	+	-	-	-+	0

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts either spatially or temporally. R = conversion of site to rice, S = conversion of site to soybeans, I = impacts from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

All other activities result in an increase in flood frequency, duration, and magnitude and therefore soil saturation. These activities cause flood waters to move through a site faster (negative impacts on velocity reduction in Table 4) which results in those waters "stacking up" downstream. The increases in velocity are sufficient to counteract the small increases in flood storage (Table 3) associated with conversion to soybeans, conversion to pine plantation, and channelization. The initial effects of conversion to pine plantation are eventually negated as the pine plantation matures. Sediment trapping downstream was assumed to increase as a result of the increase in flood duration. Sediment loading from downstream sites was assumed

to decrease because of the increased loadings upstream at the site of the activity (Table 6). Increased loads from upstream reduce the capacity of the water to carry sediments, which results in less scouring downstream.

Significance of Hydrologic Regime Modifications

Several factors must be considered when evaluating the significance of bottomland hardwoods for modifying hydrologic regimes (Adamus and Stockwell 1983). First, although wetland basins not already filled can provide some flood storage, these areas can quickly become saturated and filled to capacity. Second, bottomland hardwood sites in headwater areas have less "opportunity" to store flood waters than similar sites lower in the drainage basin. Third, the configuration of the stream network and associated BLH sites determines the effect of bottomland hardwoods on flood desynchronization. For example, a number of comparisons of watersheds with wetlands drained versus undrained strongly suggested the importance of wetlands for desynchronizing flood peak flows (Moore and Larson 1979; Novitzki 1979; Brun et al. 1981). However, a study in a lowland portion of a watershed with extensive forested wetlands suggested that flooding was more severe and flashy than in a watershed with less wetland acreage (Young and Klawitter 1968). Fourth, downstream hydrologic changes resulting from site modifications are likely to be small unless the project area is large relative to the source area of flood waters. However, while small projects may not have much effect individually, the cumulative impact of many such projects in a drainage basin could significantly alter the downstream hydrologic regime. Finally, while the consequences of slightly flooding a number of small sites is usually proportionately less than if flows are combined and their cumulative impact occurs downstream, the economic consequences of natural flood moderation are dependent on the size and frequency of flooding expected, the size and location of bottomland hardwoods in the basin, and the proximity and type of dwellings or developments along the river. For example, a reduction of more than 1% of a hydrograph peak might be significant in many areas of Vermont (E. Swanson, Vermont Department of Water Resources, pers. comm., 1982 - cited by Adamus and Stockwell 1983). On the

other hand, Clark and Clark (1979) indicate that few wetland watersheds or individual wetland sites are capable of desynchronizing the severe flood flows (e.g., 50- or 100-year probability) that cause most property damage.

SUMMARY

Natural functions attributed to bottomland hardwood ecosystems result from, or are strongly influenced by, hydrology. Bottomland hardwoods provide flood storage and modify storm flows. While some BLH areas serve as ground water recharge sites, most are groundwater discharge areas.

Activities that remove portions of the active floodplain (e.g., levee construction, conversion to aquaculture) are most detrimental in terms of flood water storage. Activities that affect other characteristics related to flood storage (e.g., surface roughness, vegetation cover, soil saturation) have only a very minor impact on this function. Activities that reduce the resistance to water flow (e.g., land clearing and leveling associated with agricultural conversion, channelization) or that reduce the area over which waters can spread (e.g., levee construction) impair the ability of a BLH site to reduce flood flow velocity. Activities that decrease infiltration rate (e.g., trapping of find-grained sediments, accumulation of organic matter) or that decrease the hydraulic gradient by raising the river stage (e.g., levee construction), impounding water (e.g., rice or aquaculture), or decreasing evapotranspiration (e.g., land clearing) cause a decrease in ground water discharge.

Alterations of the flood storage, velocity reduction, and ground water discharge modification functions of a BLH site interact to modify the on-site and downstream hydrologic regime (e.g., frequency, duration, and magnitude of flooding; sediment load). The on-site changes in hydrologic regime can be substantial when the area is cleared (e.g., conversion to agriculture), drained (e.g., channelization), purposely flooded for much of the growing season (e.g., conversion to rice or aquaculture), or removed from the active

floodplain (e.g., levee construction). The downstream changes are likely to be small unless the project area is large relative to the source area of flood waters. However, while small projects may not have much effect individually, the cumulative impact of many such projects in a drainage basin could significantly alter the downstream hydrologic regime. Flood control impoundments generally decrease flood frequency, duration, and magnitude and augment low flows. In addition, they tend to trap sediments, thereby reducing downstream sediment loads. All other activities discussed reduce flood storage and/or increase the speed with which flood waters move through a site. As a result, water tends to "stack up" downstream causing an increase in flood frequency, duration, and magnitude within the same stream course or basin. The extent to which a bottomland hardwood site, or modifications of the site, serve to desynchronize or synchronize flood peaks in a watershed is highly dependent on the position of the site within a basin and the configuration of basins in the watershed. As a result, no general conclusion can be drawn concerning the benefit of bottomland hardwoods in desynchronizing flood peaks.

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WATER QUALITY WORKGROUP REPORT

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INTRODUCTION

Hardwood bottomlands, forested floodplains of southeastern rivers, or as they were identified at this workshop, bottomland hardwood (BLH) ecosystems, provide a number of water quality functions. Because of the relatively level topography and the surface roughness of the floodplain, conditions are favorable for removal of suspended sediment, both organic materials and mineral matter, from the water that moves through the bottomland. The low flow rate of the water and the high surface activity of the organic matter and clay are major factors in the removal of suspended sediment. These same soil properties cause a high biological activity that results in a much higher breakdown of biodegradable toxic substances than occurs in most upland soils. Nonbiodegradable toxic substances that are removed from flood waters are likely to be less available due to burial in sediments.

Bottomland hardwoods also perform important nutrient transformations that improve water quality. Nitrogen and phosphate, the nutrients most often implicated in eutrophication, undergo significant reactions after entering a bottomland area that often decrease their concentrations before flowing out of the bottomland. One of these effects is plant uptake, which results in either permanent or temporary removal from the water. Nitrogen can undergo immobilization, conversion from soluble inorganic forms to reusable organic form, or nitrification-denitrification reactions that remove it from the water column. Bottomland soils are very reactive with phosphate and readily remove it from the water by adsorption and precipitation.

Bottomland hardwoods have unique erosion control capabilities. Since erosion is largely dependent on the velocity of moving water, the low gradient of bottomlands reduces the flow rate to values that are generally too low to dislodge soil particles. The surface roughness of the soil and the binding effect of plant roots also lower the erosion potential. Sediment-laden waters running into the bottomland from adjacent uplands deposit most of their sediment load into the densely vegetated, low gradient floodplain, thus preventing sediment from reaching the stream.

ANALYSIS OF IMPACTS

SEDIMENT RETENTION

Sediment-laden waters originating from overbank flooding and/or from adjacent uplands are filtered by BLH forests. The amount of sediment removed from water flowing through these bottomland forests is dependent upon certain characteristics such as slope of the floodplain, extent of ponding, density of the vegetation, and velocity of the overland flow (Table 8). Developmental activities that alter these characteristics have various impacts on the ability of the floodplain to perform this filtering function. The following discussion indicates how selected developmental activities affect these characteristics and impact the sediment retention function of BLH ecosystems.

Size of Tract

A large floodplain provides more area for water to spread over during overbank flooding from streams and from overland flow from adjacent uplands; thus, a large floodplain provides more area for sediment trapping than a small one. While the area of effective filtration may be reduced by developmental activities, the overall size of the floodplain is not reduced by development. Thus, no impacts were recorded for this characteristic as a direct consequence of development and this characteristic was dropped from consideration in subsequent analyses by the Water Quality Workgroup.

Table 8. Impacts of various activities on sediment retention as mediated through certain characteristics that contribute to the performance of this function.

Function: sediment retention

Characteristic	Relationship of characteristic to function[2]	Activity[1] R	S	I-U[3]	I-O[3]	I-D	C	L	P	A
Size of tract	+	0	0			0	0	0	0	0
Cross-sectional slope of tract	-	-	-			0	0	0	0	-
Proximity to stream	+	0	0			0	0	0	0	0
Extent of natural ponding	+	-	-			-	-	-	-	-
Ground surface roughness	+	-	-			0	0	0	0	-
Density of understory	+	-	-			+	+	+	+	-
Density of overstory	+	-	-			0	0	0	-	-
Water velocity on tract	-	-	-			+	-	-	-	-
Duration of flooding	+	-	-			-	-	-	-	-
Frequency of flooding	+	-	-			-	-	-	-	-
Sediment load from stream to tract	+	-	-			-	-	-	-	-
Upland sediment input to tract	+	-	-			0	0	0	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream from an impoundment and from an impoundment on-site were not discussed.

Cross-sectional Slope of Tract

A floodplain with a steep gradient is much less effective in trapping sediment than a floodplain with a low gradient. Conversion of bottomland hardwoods to soybeans results in an increased slope as the result of land forming activities to increase drainage and thereby adversely impacts the ability of the area to retain sediment. Conversion to rice and aquaculture also results in a reduction in the sediment trapping function of an area by the construction of levees and drainage ditches that keep natural floodwaters off the tract and/or direct flood waters through or around the tract. The impacts of channelization, levee construction, conversion to pine plantations, or the impacts of construction and operation of upstream impoundments have little effect on the cross-sectional slope of the tract and subsequent impacts on sediment retention related to this characteristic.

Proximity of Tract to Stream

Areas near streams are usually much more effective in trapping sediments from overbank flooding than areas farther away. Thus, natural levees usually form next to streams during overbank floods as velocity of flood waters quickly diminishes and heavy particles are deposited. While development activities affect the extent of overbank flooding and the amount of sediment that is deposited near the stream, they seldom change the location of the tract relative to the stream except during major stream realignment. Thus, the impacts of development on this characteristic were dropped from further consideration.

Extent of Natural Ponding on Tract

Ponding of sediment laden waters results in sediment retention as water evaporates and/or sediment is deposited. All development activities considered in this analysis result in reduced ponding and sediment retention. Conversions to soybeans, rice, pine, or aquaculture require land forming and drainage that

reduce natural ponding. Levee construction, channelization, and the effect of impoundments constructed upstream all reduce the extent of overbank flooding and thereby reduce ponding and sediment retention.

Ground Surface Roughness on Tract

Ground surface roughness (e.g., irregularities in the soil, fallen logs, stumps, other debris) reduces the velocity of flowing water, which in turn results in increased sediment deposition and retention during overbank flooding and overland flows in bottomland hardwoods. Conversion of bottomland hardwoods to soybeans, rice, or aquaculture eliminates most of this surface roughness and decreases the ability of the floodplain to trap sediments. Channelization or conversion to pine results in a temporary reduction in surface roughness and decreased sediment retention. However, long-term effects on surface roughness and impacts on deposition are minor. Levee construction also results in a short term reduction in ground surface roughness and reduced sediment trapping. However, a more severe impact resulting from levee construction or channelization has to do with the reduction in flooding, which effectively prevents sediment from being trapped in the floodplain.

Density of Understory on Tract

Understory vegetation acts in much the same way as ground surface roughness in reducing water velocity and increasing the sediment retention function of bottomland hardwoods. However, impacts resulting from developmental activities are different. Clearing bottomland hardwoods and converting to soybeans, rice, or aquaculture result in complete elimination of understory vegetation and a substantial reduction in the sediment trapping efficiency of floodplains. On the other hand, density of understory vegetation may actually be increased downstream from impoundments or by conversion to pine, channelization, or levee construction. This occurs because the reduction in flooding that results from the developmental activities actually enhances the growth of intolerant understory vegetation. The consequence of this increased vegetation is an understory with more potential for sediment trapping than in the original

BLH forest. However, the positive impacts resulting from these activities may be offset by a reduction in the duration and frequency of flooding, which is discussed later.

Density of Overstory Basal Area

Stems of trees, large shrubs, and vines also contribute to the roughness that reduces the velocity of flowing waters and contributes to the sediment trapping efficiency of BLH forests. As with the understory, clearing and converting bottomland hardwoods to soybeans, rice, or aquaculture eliminate all larger woody stems and decrease the potential for the floodplain to trap sediment. Clearing and converting to short rotation pines also results in lower tree basal area over time and a reduced potential for sediment trapping. However, channelization, levee construction and maintenance, or construction and operation of an impoundment upstream have minimal effects on tree basal area and little direct effect on the potential of bottomland hardwoods for trapping sediment, the effects of reduced flooding notwithstanding.

Duration of Flooding on Tract

The longer a floodplain is inundated by flood waters, the greater the potential for trapping sediment. Thus, any activity that reduces the duration of flooding adversely impacts the ability of the area to trap sediment. All of the activities considered result in reduced flooding and thus reduced sediment trapping.

Frequency of Flooding on Tract

Just as the duration of flooding is positively related to sediment retention, so is the frequency of flooding. Each new flood brings in a new load of sediment to the floodplain. The consequences of development on this characteristic are similar to those for the duration of flooding and the impacts of all development activities on the sediment retention function are negative. Development tends to reduce the frequency of flooding and decrease the ability of the area to trap sediment.

Water Velocity on Tract

The amount of sediment that is trapped by BLH forests during overbank flooding and overland flow from adjacent uplands is directly related to the velocity of the water in which the sediment is suspended. Thus, activities that change the velocity of flow across riverine floodplains impact the sediment retention function. Conversion of BLH ecosystems to soybean farming usually requires clearing and drainage, which result in increased velocity of flows and reduced sediment trapping. Clearing and conversion to rice or aquaculture also result in increased water velocity for those occasions when flooding occurs; however, levees and drainage also reduce overbank flooding to the extent that the floodplain no longer functions effectively in trapping sediment. The effects of the construction and operation of impoundments may serve to reduce the velocity of overbank floods and increase the potential for sediment trapping, but frequency of overbank flooding is also reduced and the impoundment traps sediment upstream. Conversion to pine results in more rapid drainage of the area and reduced sediment trapping. Channelization or levee construction moves water more rapidly through the area and reduces sediment trapping efficiency of the floodplain.

Sediment Load in Stream

The more sediment there is in the stream that serves as a source of overbank flooding, the more sediment that is available for retention in the floodplain. Developmental activities in the floodplain increase soil erosion and sediment loads in the stream, but these same development activities also increase the rate of runoff, decrease frequency and duration of flooding, and reduce roughness of the ground surface. The net impact on sediment retention is therefore negative.

Upland Sediment Input to Tract

The higher the levels of sediment in overland flows originating from the uplands, the greater the level of sediment retention that can be expected when

this water flows through the floodplain. Thus, given a constant level of sediment from the upland, developmental activities may increase or decrease sediment retention. Clearing and conversion to pine, soybeans, rice, or aquaculture usually require some drainage, diversion, or levee construction to keep water off the land. Thus, all these activities reduce the sediment trapping effectiveness of the floodplain. Channelization, levee construction, or impoundments that are constructed upstream do not affect the flow of water from the adjacent uplands or across the floodplain.

Overall Impact of Development on the Sediment Retention Function

The overall effect of development on the sediment retention function of bottomland hardwoods is negative. The primary reason for this is that all developmental activities in some way eliminate or reduce the opportunity for sediment laden floodwaters originating from the stream or adjacent uplands to pass over the floodplain. Obviously, a floodplain that is not flooded performs no sediment trapping.

Developed floodplains that are, in fact, occasionally flooded despite preventative efforts, are no longer as effective in trapping sediments as undisturbed BLH sites. This is because the roughness that exists in the form of uneven soil surfaces, stumps, fallen logs, litter, and various layers of vegetation in the undisturbed BLH forest are normally eliminated by development.

The consequence of development on the sediment trapping function in forested floodplains is that more sediment is carried downstream where it contributes to reduced water quality.

EROSION CONTROL

Generally, the factors that affect sedimentation, as discussed above, also are important in controlling erosion, with the two effects inversely related (Table 9). For this reason, erosion from natural BLH forests is

Table 9. Impacts of various activities on erosion control mediated through certain characteristics that contribute to the performance of this function.

Function: erosion control										
Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O[3]	I-D	C	L	P	A
Cross-sectional slope of tract	-	+	-			0	0	0	0	+
Extent of natural ponding	+	-	-			-	-	-	-	-
Ground surface roughness	+	-	-			0	0	0	0	-
Density of understory	+	-	-			+	+	+	+	-
Density of overstory	+	-	-			0	0	0	-	-
Water velocity	-	-	-			+	+	+	-	
Duration of flooding	-	+	+			+	+	+	+	
Frequency of flooding	-	+	+			+	+	+	+	+
Upland runoff	-	+	+			0	0	0	+	+
Percent clay in soil	+	0	0			0	0	0	0	0
Soil organic matter content	+	-	-			-	-	-	-	-
Soil disturbance	-	-	-			0	-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream from an impoundment and from an impoundment on-site were not discussed.

generally very low because of the very low gradient and the dense vegetation cover. Erosion from overbank flooding is minimal because water moves very slowly across the floodplain and the ground and vegetative surface roughness further impede water flow. The soil is also protected by the litter on the surface and the dense root structure of the vegetation. Precipitation driven erosion is also minimized by the dense overstory and understory vegetation that reduce the erosive force of the falling rain and by the same features that contribute to erosion control from overbank flooding.

Cross-sectional Slope of Tract

The gentle cross-sectional slope of BLH sites keeps the velocity of water flowing across the bottom very slow, thus providing little energy for erosion. Two of the development activities examined in this exercise, conversion to rice and aquaculture, reduce the cross-sectional gradient of the floodplain even further and have a positive impact on soil erosion for this characteristic. Conversion to soybeans probably results in steeper gradients as the result of drainage activities. However, channelization, levee construction, conversion to pine, or the construction and operation of upstream impoundments probably has a very minimal impact on slope and soil erosion.

Extent of Natural Ponding

Natural ponding contributes to lower erosion by slowing or eliminating overland flows. All developmental activities result in reduced ponding and reduced erosion control.

Ground Surface Roughness

Ground surface roughness reduces the velocity of flowing water and thereby contributes to erosion control. Conversions to rice, soybeans, or aquaculture all reduce ground surface roughness and contribute to increased soil erosion. Developmental activities (such as channelization, levee construction, conversion to pine, or upstream impoundment construction and operation) that

disturb the surface area only slightly or disturb only a relative small percent of the total area do not greatly affect ground surface roughness.

Density of Understory

A dense understory provides roughness that slows water velocity and roots that bind the soil, thus preventing soil erosion. Conversions of BLH sites to soybeans, rice, or aquaculture remove the understory and increase soil erosion. Conversion to pine, channelization, upstream impoundment construction and operation, or levee construction protects intolerant vegetation in the understory from flood related mortality and thus increases understory vegetation density and reduces soil erosion.

Density of Overstory

The trunks of overstory trees provide an additional element of roughness that reduces velocity of running water and contributes to erosion control. The overstory canopy also contributes to a reduction in the erosive force of rain drops falling on the forest floor. Clearing and conversion of BLH areas to rice, soybeans, or aquaculture eliminate all overstory trees and as a consequence erosion is increased. Converting to pine also eliminates BLH timber and increases soil erosion, but the impact is much less severe than in agricultural conversion because pines provide a similar level of protection as BLH forests as they mature. Those developmental activities that do not require large scale clearing (e.g., impoundment construction, channelization, or levee construction) have little long-term effect on this characteristic.

Water Velocity on Tract

Soil erosion is directly related to the velocity of the water flowing over the soil surface. Clearing and conversion to crops or aquaculture increase the velocity of flood water and thus may increase soil erosion. Construction of levees, channelization, or construction and operation of upstream impoundments all result in less overbank flooding and an increased

understory density that reduces the velocity of water on the floodplain and also reduces the potential for soil erosion. The increase in understory vegetation in pine plantations also contributes to a reduction in floodwater velocity and more erosion control.

Duration and Frequency of Flooding

These two characteristics function in a similar manner in soil erosion and developmental impacts are also the same. Saturated soils are generally more erodible than dry soils and the longer and more frequently that BLH areas are flooded, the greater the potential for soil erosion. All developmental activities considered in the water quality analyses contribute to a reduction in the duration and frequency of flooding, because the activities considered include features designed to keep flood waters off the floodplain. Thus, considering these characteristics alone, all developmental activities reduce the potential for soil erosion related to duration and frequency of flooding.

Upland Runoff to Tract

The more water that flows into and across the BLH floodplain, the higher the potential for increased soil erosion. Conversion of BLH forests to pine, soybeans, rice, or aquaculture all have features that direct upland runoff through or around the tract being developed; thus, overland flows are reduced and so is soil erosion. Construction and operation of upstream impoundments, channelization, and levee construction do not directly affect upland flows and have no consequences on this characteristic.

Percent Clay in Soil

Soils with high clay contents are less erodible than other soils. While this characteristic is very important in determining the erodibility of the soil, none of the developmental activities considered change the clay content of the soil. Thus, development has no effect on this characteristic or its role in soil erosion.

Percent Organic Matter in Soil

Soils with high organic matter contents are less prone to erosion than soils with little organic matter. Clearing and converting BLH to crops and aquaculture reduce the organic matter content of the soil and contribute to increased erosion. Other activities (pine culture, construction and operation of upstream impoundments, channelization, or levee construction) result in increased vegetative cover and higher levels of organic matter in soils, which increase the ability of the site to control erosion.

Soil Disturbance

All activities that result in the disturbance of soil on a repeated basis have a large negative impact on soil erosion and water quality of the receiving stream. Thus, clearing and conversion to rice and soybeans have a very serious impact on soil erosion. Aquaculture has a lesser impact because the disturbance is less frequent. Conversion to pine has a short-term impact during clearing and harvesting, but no impact during the growth stages. Levee construction has a short-term negative impact. Channelization has a very severe short-term impact and may also have a long-term adverse effect if channels are not stabilized. There is little or no disturbance of the soil as a result of construction and operation of upstream impoundments.

Overall Impact of Activities on Soil Erosion

Activities, such as conversion to soybeans, that require the clearing of BLH forests and repeated disturbance of the soil have a very severe adverse impact on soil erosion, more so than other activities. Clearing and conversion to rice also have the potential for increased soil erosion, but levees and contour farming reduce this impact to some extent. Aquaculture does not result in impacts as severe as rice farming because soil disturbance is not repeated so often.

Channelization and levee construction also contribute to greatly increased soil erosion, but these results are usually localized and temporary. Channelization may result in increased streambank erosion requiring some form of stabilization, but erosion on the adjacent floodplain may actually be reduced as flood waters are confined to the channel. The effects of construction and operation of upstream impoundments on soil erosion are generally negligible or positive as there is no disturbance of the floodplain and overbank flooding is reduced. Finally, conversion to pine results in intermittent periods of soil disturbance when trees are harvested and planted, but the overall consequence of conversion to pine is generally minimal.

NUTRIENT RETENTION AND TRANSFORMATION

Because of the level topography, surface roughness, and high organic matter and clay content of their soils, BLH ecosystems have a unique ability to trap nutrients by adsorption or precipitation and to transform nutrients from soluble to insoluble and/or gaseous forms. Nutrient retention and transformation functions are closely linked to the sediment trapping function discussed earlier and major developmental impacts are also similar (Table 10).

Cross-sectional Slope of Tract

Just as BLH ecosystems with gentle cross-sectional gradients are effective in trapping sediments, they are also effective in trapping and transforming nutrients. The same impacts occur with developmental activities on BLH sites for nutrients as for sediment. Activities that increase the slope and/or disturb the soil, such as conversion to soybeans, rice, and aquaculture, generally result in negative impacts on nutrient retention and transformation. Other activities have little or no effect on how hardwood bottomlands perform this function.

Table 10. Impacts of various activities on nutrient retention and transformation as mediated through certain characteristics that contribute to the performance of this function.

Function: nutrient retention and transformation

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O[3]	I-D	C	L	P	A
Cross-sectional slope of tract	-	-	-			0	0	0	0	-
Extent of natural ponding	+	-	-			-	-	-	-	-
Ground surface roughness	+	-	-			0	0	0	-	-
Density of understory	+	-	-			+	+	+	+	-
Density of overstory	+	-	-			0	0	0	-	-
Water velocity on tract	-	-	-			+	+	+	-	-
Duration of flooding	+	-	-			-	-	-	-	-
Frequency of flooding	+	-	-			-	-	-	-	-
Upland runoff	+	-	-			0	0	0	-	-
Percent clay in soil	+	0	0			0	0	0	0	0
Soil organic matter content	+	-	-			-	-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream from an impoundment and from an impoundment on-site were not discussed.

Extent of Natural Ponding

Ponding provides excellent opportunities for nutrient trapping and transformation. In fact, some ponds may actually become nutrient sinks. All developmental activities considered by the Water Quality Workgroup reduce natural ponding and usually adversely impact the ability of BLH to retain and transform nutrients.

Ground Surface Roughness

As for sediment, a rough-surfaced floodplain contributes to reduced water velocities and increased nutrient retention and transformation. Conversions to soybeans, rice, pine, or aquaculture all reduce ground surface roughness, increase the velocity of flood waters, and reduce the effectiveness of the floodplain in trapping and transforming nutrients. Activities that do not disturb the surface do not affect these functional attributes.

Density of the Understory

Understory vegetation slows the velocity of flood waters and increases the nutrient-trapping and transformation efficiency of BLH ecosystems. Understory vegetation also takes up a considerable amount of nutrients in growth processes. Conversion activities that eliminate the understory vegetation have adverse impacts on nutrient retention and transformation. Activities that stimulate the development of a more dense understory have a potential positive relationship to nutrient retention and transformation. However, these same activities also eliminate the natural flooding regimes that may be required for a BLH tract to actually perform this function.

Density of the Overstory Basal Area

The additional roughness provided by trunks of overstory trees decreases flood water velocity and increases sedimentation and nutrient retention and

transformation. Clearing associated with conversion to rice, aquaculture, soybeans, or pine eliminates BLH timber and reduces the ability of the floodplain to retain and transform nutrients.

Water Velocity on Tract

This characteristic is closely linked to each of the previously discussed characteristics, and, as previously described, the velocity of flood waters flowing over the floodplain is inversely related to the ability of the tract to trap and transform nutrients. Thus, activities that involve clearing increase water velocity and adversely impact nutrient retention and transformation. Channelization and levees keep water off the site and reduce water velocity and potentially increase sediment and nutrient trapping, but these activities also eliminate the source of nutrients carried by flood water.

Duration and Frequency of Flooding

The more often and longer they are flooded under natural conditions, the more effective BLH areas are in trapping and transforming nutrients. Flood waters carry nutrients; thus, each time the area is flooded a new load of nutrients is brought into the floodplain. In this analysis, all activities considered result in reduced duration and frequency of flooding and similar reductions in nutrient retention and transformation.

Upland Runoff

Nutrients are also added to the floodplain from adjacent uplands. Thus upland runoff contributes to the nutrient loading of the BLH forest. Developmental activities, such as conversion to soybeans, rice, pine, or aquaculture, divert upland runoff through ditches and levees so that overland flow is eliminated. This has a negative impact on nutrient retention and transformation.

Percent Clay in Soil

Clay particles are very reactive and tend to bind nutrients through adsorption, thus improving retention in BLH sites. Although developmental activities disturb the soil, they do not alter the amount of clay in the soil and thus have no measurable impact on the ability of the soil to trap and transform nutrients.

Soil Organic Matter Content

A high percent of organic matter increases the effectiveness of soils in retaining and transforming nutrients. Organic matter tends to accumulate in wet soils; thus, BLH soils are usually very high in organic matter content. Development activities that reduce soil moisture content and increase aeration tend to reduce the organic matter content of the soil. All of the activities considered in this analysis tend to reduce soil saturation and thus negatively impact this characteristic and the ability of the soil to retain and transform nutrients.

Overall Impact of Activities on Nutrient Retention and Transformation

The overall impact of developmental activities on the role that BLH forests play in nutrient retention and transformation is negative. The severity of the impact depends primarily on the degree to which the flooding regime is modified and the vegetative cover is altered. Flood control activities, including channelization, and impoundment and levee construction, are generally required for any development of BLH sites. These activities alone have severe consequences on nutrient retention and transformation by modifying flood flows, soil saturation, organic matter content, and the extent of ponding. However, it is seldom that development stops at this level. Usually, clearing and conversion of native vegetation to an agriculture crop, aquaculture, or some other land use follow, or occasionally precede, flood control. These activities require additional flood control and land disturbance that further degrade the ability of the area to perform nutrient retention or

transformation functions. Results of development include passage of nutrient-laden water downstream and may also include additions of agricultural fertilizer that further degrade water quality.

CONTAMINANT RETENTION AND TRANSFORMATION

The same features of BLH systems that are important in sediment trapping and in nutrient retention and transformation are important in contaminant retention and transformation (Table 11). Biodegradable contaminants are often transformed to nontoxic forms as a result of the biological reaction associated with BLH soil properties. Nondegradable contaminants may be bound and/or deposited with sediment. Many of the impacts that result from developmental activities are also similar.

Cross-sectional Slope of Tract

The gentle slope of BLH sites that facilitates sediment retention also facilitates the retention and subsequent transformation of contaminants. As with sediment retention, conversions to soybeans, rice, or aquaculture modify the slope and reduce the effectiveness of the area in retaining and transforming contaminants. Other activities that do not directly affect the slope of the floodplain (e.g., channelization, upstream impoundment construction and operation, levee construction) do not directly affect the floodplain gradient or impact contaminant retention and transformation, but these activities may have other consequences that are reflected in other characteristics such as flooding frequency and duration.

Extent of Natural Ponding on Tract

Natural ponds serve as depositional areas for sediment and associated contaminants. Because of the high levels of clay and organic material and the repeated wetting and drying cycles, these areas are effective in trapping and transforming contaminants and improving water quality. Since all developmental

Table 11. Impacts of various activities on contaminant retention and transformation as mediated through certain characteristics that contribute to the performance of this function.

Function: contaminant retention and transformation

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O[3]	I-D	C	L	P	A
Cross-sectional slope of tract	-	-	-			0	0	0	0	-
Extent of natural ponding	+	-	-			-	-	-	-	-
Ground surface roughness	+	-	-			0	0	0	-	-
Density of understory	+	-	-			+	+	+	+	-
Density of overstory	+	-	-			0	0	0	-	-
Water velocity on tract	-	-	-			+	+	+	-	-
Duration of flooding	+	-	-			-	-	-	-	-
Consequence of flooding	+	-	-			-	-	-	-	-
Upland runoff	+	-	-			0	0	0	-	-
Percent clay in soil	+	0	0			0	0	0	0	0
Soil organic matter content	+	-	-			-	-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream from an impoundment and from an impoundment on-site were not discussed.

activities examined eliminate ponding to some degree, either by alteration in flooding or physical modification of the landscape, all activities have a negative effect on this water quality function.

Ground Surface Roughness

Ground surface roughness contributes to a slowing of overbank and overland flood flows and increases sediment and contaminant deposition. Physical alterations of the floodplain by conversion activities associated with soybeans, rice, pine, or aquaculture eliminate surface roughness and adversely impact retention and transformation of contaminants. Construction and operation of upstream impoundments, channelization, or levee construction does not directly affect ground surface roughness or affect contaminant deposition and transformation by this means. However, these latter activities may affect the contaminant functions through other means.

Density of Understory Vegetation

Through its effect on water velocity, understory vegetation facilitates deposition of sediment and associated contaminants. Conversion activities adversely affect the ability of understory vegetation to trap contaminants and adversely impact the contaminant retention and transformation function of BLH ecosystems. Protection of the floodplain from overbank flooding often results in a more dense understory vegetation and an increased potential for sediment and contaminant retention; however, this potential may not be realized if contaminant laden flood waters are restricted from the floodplain.

Density of Overstory Basal Areas

Tree density on BLH areas contributes to roughness and to reduced water velocities during flooding. Conversions to soybeans, rice, aquaculture, or pine eliminate BLH timber and negatively impact the ability of the area to trap and transform contaminants. Channelization, levee construction, or

impoundment effects downstream do not directly affect BLH forests or contaminant retention and transformation, but may have an effect through some other means.

Water Velocity on Tract

Slow-moving waters increase sediment and contaminant deposition. Conversion activities for rice, soybeans, acquaculture, or pine all tend to speed water flow through various drainage modifications and by clearing vegetation; thus, these activities decrease the ability of the site to trap and transform contaminants. Construction of upstream impoundments, channelization, or levee construction all reduce flood flows and/or keep more water in channels, thereby reducing velocities of water on the floodplain and theoretically increasing contaminant retention. However, the restriction of flooding may negate this positive impact.

Duration and Frequency of Flooding

These two characteristics have the same basic effects on contaminant retention and transformation. The longer and the more frequently an area is flooded, the more contaminants that can be moved into the floodplain, trapped, and transformed. All developmental activities considered in this exercise reduce both the duration and frequency of flooding. Thus, all activities have a negative impact on contaminant retention and transformation.

Upland Runoff

Contaminants from the upland are often trapped by BLH forests. When drainage patterns are altered for conversion of BLH sites to rice, soybeans, pine, or aquaculture, contaminants are no longer trapped but are often shunted quickly and directly to the stream, thus adversely impacting water quality downstream.

Percent Clay in Soil

The clay contents of soils are very important in contaminant retention and transformation, but are not altered by development.

Soil Organic Matter Content

Soil organic matter content is high in BLH areas and is very important in trapping and transforming contaminants. When an area is drained or protected from flooding, organic matter tends to oxidize and as organic matter is depleted from the soil, the contaminant retention and transformation function is negatively impacted. All activities considered have an adverse effect on organic matter in the soil and, consequently, an adverse impact on the retention and transformation of contaminants.

Overall Impacts on the Contaminant Retention and Transformation

In general, developmental activities have an adverse impact on the capability of floodplains to retain and transform contaminants. As for nutrients, the ability of a BLH site to trap and transform contaminants from a toxic to a nontoxic form is related to natural overbank flooding and the presence of natural BLH vegetation. Developmental activities almost always involve flood control followed by landclearing and/or cultivation or some other change in land use practice. Thus, it is impossible for functions that are dependent upon natural conditions to be maintained. Furthermore, many cultural activities implemented on BLH areas following clearing require use of pesticides or other chemicals in one form or another to control weeds or insects or prepare crops for harvest. These chemicals are a form of contaminant that further exacerbates the negative impact of development on water quality, with the ultimate consequence being a deterioration of downstream water quality.

SUMMARY

Water quality functions of BLH ecosystems are adversely impacted by almost all developmental activities, since undeveloped hardwood bottomlands are probably nature's best improvers of water quality. While direct effects of some developmental activities may be minimal for certain water quality functions, or may in fact have positive values (e.g., erosion control as related to upstream impoundment, channelization, and levee construction), follow-up or indirect effects are apparently negative without exception. Using erosion control as an example, protection of BLH sites from flooding almost always results in conversion activities that require clearing of native vegetation, elimination of surface roughness, repeated soil disturbance, and elimination of natural ponding. All of these effects contribute to increased soil erosion and corresponding deterioration of water quality.

Since all water quality functions described for BLH sites require that the floodplain be regularly flooded and that native vegetation be maintained in an undisturbed condition, any activity that results in flood control or conversion of bottomland hardwoods will have a negative impact on the water quality of the BLH ecosystem. This may result in a negative impact on water quality if protective measures are not included in the activity.

FISHERIES WORKGROUP REPORT

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INTRODUCTION

Bottomland hardwood (BLH) ecosystems provide vital habitat for freshwater organisms. The Fisheries Workgroup structured the analysis of the habitat function according to values to finfish and shellfish (particularly crawfish). Throughout the analysis, impacts on both adult and young-of-the-year were considered. Also implied was consideration of the impacts of all activities on food (e.g., invertebrates for fish), cover and living space, reproduction, nursery sites, and water quality. The workgroup assumed that the analysis would encompass the first five BLH zones (Clark and Benforado 1981), including the mainstem channel.

In addition to the seven prescribed activities, the impacts of oil and gas development on finfish and shellfish habitat were examined. Oil and gas development in bottomland hardwoods includes those activities associated with access to drilling sites, disposal of pollutants (e.g., drilling muds and brine), and transport of the product. Access to drilling sites includes dredging of canals, deposition of dredged materials adjacent to canals, and construction of roads through filling and ditching. Disposal of pollutants is either into holding ponds or directly into waterways. The transport of products via pipeline requires clearing, dredging, and filling.

ANALYSIS OF IMPACTS

FINFISH HABITAT

Nine characteristics were evaluated for eight activities. The characteristics are areal/stage relationship, natural floodplain vegetation, gentle topography, stream sinuosity, snags and instream cover, access to permanent water, presence of toxics, oxygen level, and sedimentation. Table 12 presents the impacts of the activities on these characteristics.

Areal-Stage Relationship

The largest yields of finfish tend to be supported by those BLH areas where flooding occurs for the longest time (and during a season critical to fish) and over the largest area of floodplain. The seasonal duration of flooding is difficult to determine precisely and varies greatly from year to year, but a general idea may be gained from interviewing knowledgable local citizens. Existing gage data generally report only the mainstem conditions rather than flooding duration in seasonally flooded zones. During unflooded conditions, the areal extent (acreage) of flooding may be determined by presence of water marks, drift lines, discolored leaf litter, and sediment deposits on vegetation; examination of aerial photos and topographic contour maps (paired with stream gage data); and interviews with local sources. The flooded area may be delineated and planimetered from these data. The absence of a positive indicator of flooding from any of these items should not be assumed to be conclusive evidence of lack of flooding.

The ratio of mainstem acreage (or volume) to flooded acreage (or volume) during various frequency floods is one parameter used to measure the areal/stage relationship. The workgroup believed that data are insufficient to indicate whether a 1:1 ratio of these habitats, or any other ratio, is significant to fisheries.

Table 12. Impacts of various activities on habitat for finfish as mediated through certain characteristics that contribute to the performance of this function.

Function: habitat for finfish											
Characteristic	Relationship of characteristic to function[2]	Activity[1]									
		R	S	I-U	I-O	I-D	C	L	P	A	O
Areal/stage relationship	+	-	-	0	-	-	-	-	-	-	-
Natural floodplain vegetation	+	-	-	0	-	-	-	-	-	-	-
Gentle topography	+	-	-	0	0	0	-	-	-	-	-
Stream sinuosity	+	0	0	0	-	-	-	0	0	0	-
Snags and instream cover	+	-	0	0	-	-	-	0	0	0	-
Access to permanent water	+	-	0	-	+	-	-	-	-	-	-
Presence of toxics	-	-	-	0	-	0	-	0	-	0	-
Oxygen level	+	-	-	0	+	-	-	-	0	0	-
Sedimentation	-	-	-	0	0	-	-	-	-	0	-
Overall impact on habitat for finfish		-	-	-	-	-	-	-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture, O = oil and gas development on-site.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

In the impact analysis it was assumed that an adverse impact on areal/stage relationship is one that reduces the extent or duration of overbank flooding, or alters the season of its occurrence. A positive impact results from an activity that increases the extent or duration of overbank flooding. No impact results from an activity having no effect on the natural flood regime.

Except for the impacts upstream from an impoundment, the activities were judged to reduce areal/stage relationships and thus impair finfish habitat. Conversion to rice, channelization of stream adjacent to site, levee construction on-site, and aquaculture (through the construction of levees or berms) reduce the area to be flooded and thus reduce available area for the production of food, cover, and reproduction sites for fish. The areal/stage relationship is diminished by conversion to soybeans due to landclearing, leveling, and ditching, which result in improved drainage and shorter duration of flooding. Conversion to pine plantations also reduces flooding events through increased drainage (ditching) and blockage of sheet flow by road construction. Although an impoundment on-site floods a larger acreage than normally occurred in the BLH area, the water level fluctuations are not seasonal. Thus, the floodplain fishery is converted to a lake fishery. Finfish habitat is adversely affected by the construction of a dam upstream due to the alteration of the natural areal/stage relationship in a controlled tailwater volume. The result is a loss of spawning and nursery habitat in a reduced floodplain. Oil and gas development reduces areal/stage relationships by the construction of canals, ditches, and roadways.

Natural Floodplain Vegetation

The largest yields of finfish tend to be supported by those BLH areas where vegetation has not been altered by man. Under such conditions, diversity of vegetational layers, species richness, and annual leaf-fall are at their maximum, and availability of both terrestrial and aquatic invertebrates is consequently highest. Also, flood flows may be retarded by vegetation on the

floodplain and detrital material may be transported to the channel and downstream areas. Diversity of vegetation conditions is easily recognized by individuals with local knowledge of typical species and their usual densities within each zone. Specific parameters, such as vertical layer structure and canopy closure, may be measured. However, the workgroup identified no criteria for these parameters nor rapid methods for their assessment.

In the impact analysis, the group assumed that any deviation from natural conditions would constitute an adverse effect, while preservation of natural conditions would constitute no effect.

Natural floodplain vegetation is affected by conversion to rice, soybeans, and pine plantations; impoundment on site; and aquaculture through the removal of all vegetation by landclearing. Although flood waters can still reach the converted agricultural fields and pine plantations, the resulting vegetation and detrital material are not as valuable to finfish. BLH areas downstream from an impoundment are impacted by the leveling of seasonal flows from the dam. The natural flows are critical to the fertilization and hydrologic environment of the natural floodplain vegetation. Thus, the altered flows can alter species composition of natural vegetation to more of an upland vegetation. The result is the elimination of crawfish and finfish habitat.

Likewise, channelization and oil and gas development reduce and alter the flooding of BLH areas, resulting in drier conditions that are favorable to more mesic species. Backswamp areas on the protected side of levee systems or areas that have undergone ditching result in plant community changes due to spatial and temporal changes in flooding. Thus, the supply and extent of dissolved and particulate organic matter is lessened, which reduces the food base for finfish populations. Again, BLH areas upstream from impoundments would not affect this characteristic.

Gentle Topography

The largest yields of finfish tend to be supported by those BLH areas where the topography is gentle and mildly complex. Such an area would have an average gradient from the mainstem up through zone 5 that is very slight, but complex both vertically and horizontally in the sense of having small mounds, mild undulations, and backwaters. Gentle, complex topography is important because it allows water to be trapped for longer periods over a wider area with a greater edge effect between upland and flooded soils. However, specific criteria for this characteristic were not identified. Adverse impacts were assumed to be those associated with leveling of the irregularities in the topography or creation of other unnatural conditions (e.g., steep mounds).

Topography is affected by most activities through leveling and/or levee or berm construction. Levees drastically reduce the area of shallow water during flood events and it is in these shallow areas where the maximum production of finfish and shellfish occurs in BLH forests. However, impoundments were judged to have an insignificant effect on topography.

Stream Sinuosity

BLH areas adjacent to permanent water channels that are highly meandering or sinuous in shape tend to support the largest yields of finfish. Sinuosity is important because it reflects the availability of cover for finfish inhabiting the mainstem during seasons when the floodplain is dry. Recent topographic maps or aerial photos can be used to measure sinuosity by determining the ratio of direct distance to thalweg distance between two stream points. Specific criteria relating to quality of the fishery were not developed. Adverse impacts were assumed to be those resulting in straightening of the main channel, and positive impacts to be those resulting in an increase in its sinuosity.

Only four activities affect stream sinuosity. Impoundments on-site totally inundate the channel and remove meandering characteristics. Stream channels associated with BLH areas downstream from impoundments are typically straightened either mechanically or because seasonal fluctuations are reduced. The result is that main channel finfish habitat contains less cover on a year-round basis. Although habitat space may be somewhat greater during the normal dry season, this does not compensate for loss of cover typically associated with channel meandering.

Snags and Instream Cover

A direct relationship exists between finfish yields and BLH areas where the floodplain and especially the mainstem have moderate accumulations of large organic debris (e.g., tree trunks and roots). Snags in the channel provide cover for finfish as well as serving as a stable substrate for high densities of invertebrate food organisms. Site visits would be required to determine the occurrence of snags. Adverse impacts result from removal of instream cover, while positive impacts occur when instream cover is increased.

BLH areas downstream from impoundments receive lower peak seasonal flows. This reduces the opportunity for woody debris to be washed out of the floodplain and into the channel. Moreover, the dam physically cuts off the supply of large debris from upstream areas. Thus, the reduced instream cover in this tailwater area can adversely affect finfish. Snags and instream cover are totally inundated by an impoundment on-site and are unavailable because of seasonal stratification. Channelization removes snags and other debris.

Access to Permanent Water

The largest yields of finfish tend to be supported by those BLH areas that are connnected directly (i.e., a "water bridge" is present) to the main channel during flooding. Such water bridges are essential because they allow adult fish to have access during flooding to fertile floodplain areas, which

are critical sites for reproduction, food, and cover. At the same time, presence of water bridges allows fish to follow receding floodwaters back into the main channel.

The presence of water bridges acts as a modifier of the areal/stage relationship; i.e., when calculating a ratio of mainstem acreage to floodplain acreage, only those parts of the floodplain that would be accessible to fish during flooding should be considered. Such accessible areas may be identified by use of topographic maps; field inspections during flooding; interviews with knowledgeable sources; or by scour marks on the forest floor, relative lack of leaf litter build-up, or presence of adventitious (above-ground) roots on trees. Absence of any of these indicators should not be taken as prima facie evidence of lack of a water bridge. On the other hand, water marks and discolored leaves do not necessarily indicate presence of a water bridge, as their appearance may be due to dried-out precipitation pools or water table highs.

An adverse impact was judged to occur when fish ingress or egress is blocked from the floodplain, and a positive impact when a greater acreage is accessible to fish.

The construction of levees negatively affects access to permanent water. The levees act as a barrier to finfish movement and may prevent the retreat of finfish to permanent water areas as the floodwaters recede. BLH areas downstream from impoundments receive reduced peak seasonal flows, which prohibit finfish from getting into many floodplain areas needed for feeding and spawning. On-site impoundments make some backwater areas accessible that previously were not, and the acreage of permanent water is obviously enlarged. However, dams physically restrict natural dispersal upstream and downstream, so finfish populations can suffer.

Presence of Toxins

Small finfish yields tend to be supported by those BLH areas where fish are exposed to excessive levels of toxic substances or conditions, such as certain pesticides, heavy metals, acidity, brine, and oil. These may be directly toxic or they may indirectly affect fish through impacts on food and vegetative cover. The upper zones of BLH areas are especially vulnerable to pesticide runoff. To assess the occurrence of toxics, field staff would begin by reviewing location of point sources and crop fields.

The Fisheries Workgroup assumed that an adverse impact would result from any increase in toxic substances within an environment where fish might be exposed. For activities that caused no change in natural background levels, a "0" rating was assigned.

Pesticides, herbicides, and fertilizers are used on agricultural fields and pine plantations. Therefore, toxics increase in kinds and quantity due to these activities and result in a negative impact to fish habitat. Also, on pine plantations the decomposition of pine needles acidifies the soil, reduces bacterial action, and can produce a medium too acidic for other lower forms of life that are found in the food chain of fishes. Impoundments on-site concentrate sediment with attached toxic substances. Under certain mixing conditions, the substances can be mobilized within the impoundment. Spoil disposal from oil and gas development negatively influences the amount of spawning and nursery habitat as well as the quality of available food.

Oxygen Levels

BLH areas where dissolved oxygen (DO) levels in the water column and sediment are adequate tend to be associated with large yields of fishes. Although specific criteria were not assigned, it was assumed that levels of approximately 3 mg/ℓ are adequate. The workgroup assumed that an adverse impact would result from any decrease in dissolved oxygen levels and that a

positive impact would result from increases in dissolved oxygen levels up to about 4 mg/ℓ, beyond which DO assumes less importance as a limiting factor to BLH fishes.

Conversions to rice and soybeans lower oxygen levels by increased water runoff of higher temperatures and lower oxygen detention potential. Oxygen levels within an on-site impoundment are, in most cases, less stressful than the levels that previously existed in backwaters. Channelization and levees alter and reduce the exchange of water between the BLH area and main channel. Because of the decomposition of plant litter on the forest floor during flood events, areas devoid of water movement may have significantly lower oxygen contents, making those areas less suitable habitat for finfishes.

Sedimentation

Where levels of suspended sediment are high or the depth of annually deposited sediment is excessive, yields of fishes in BLH areas are small. Suspended sediment's direct adverse effects on fish are well known, although moderate turbidity may provide protective cover from predators in the case of some young fish. The role of deposited sediment is less certain. Excessive deposited sediment may destroy invertebrate foods and smother vegetation vital as cover, while moderate amounts may essentially fertilize the floodplain vegetation, ultimately providing better cover.

An increase in sediment was assumed to result more often in an adverse impact than in a positive one. Conversely, a positive impact would be any effect that results in reduced levels of incoming sediment.

Sediments increase from conversion to rice, soybeans, and pine plantations through landclearing, leveling, seedbed preparation, and drainage. Although impoundments upstream of BLH areas reduce turbidity in the tailwaters, the predominant effect on finfish is adverse due to reduced peak seasonal flows. Seasonal flows normally fertilize backwater areas with moderate amounts of sediment. Channelization causes bank erosion and deposition of sediment

downstream. Levees prevent the export of sediments (and associated nutrients) from main channel areas to the forest floor, which over time may reduce primary productivity and decrease the food base for finfish.

SHELLFISH HABITAT

Six characteristics of shellfish habitat were evaluated for eight activities. The characteristics are areal/stage relationship, natural floodplain vegetation, gentle topography, presence of toxics, oxygen level, and sedimentation. Table 13 summarizes the relationships between activities, characteristics, and the shellfish habitat function. The Fisheries Workgroup concluded that the impacts on the function from the relationship of the activities and characteristics are similar to those described above for finfish.

CUMULATIVE IMPACTS

During the analyses of the eight perturbations identified for evaluation, the Fisheries Workgroup realized that single development activities seldom occur in isolation. For example, the acreage of soybean production present in the Lower Mississippi Valley would be substantially lower today without the massive flood control efforts of the Federal Government.

Flood control projects offer a degree of floodplain protection locally, increase flood problems downstream, and induce additional flood control measures to control the downstream problems. Through this process, an expectation is spawned and cultivated among the public that flood protection will be provided simply because it was provided upstream. This expectation, in addition to Federal financial subsidies, encourages landowners to convert valuable BLH wetlands to farmland. When crop damage occurs as a result of flooding, levee construction, channelization, or upstream impoundments appear justified. A technique for illustrating this contention is to use a basin case history.

Table 13. Impacts of various activities on habitat for shellfish as mediated through certain characteristics that contribute to the performance of this function.

Function: habitat for shellfish

Characteristic	Relationship of characteristic to function[2]	Activity[1] R	S	I-U	I-O	I-D	C	L	P	A	O
Areal/stage relationship	+	-	-	0	-	-	-	-	-	-	-
Natural floodplain vegetation	+	-	-	0	-	-	-	-	-	-	-
Gentle topography	+	-	-	0	0	0	-	-	-	-	-
Presence of toxics	-	-	-	0	-	0	-	0	-	0	-
Oxygen level	+	-	-	0	+	-	-	-	0	0	-
Sedimentation	-	-	-	0	-	-	-	-	-	0	-
Overall impact on habitat for shellfish		-	-	0	-	-	-	-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upsteam from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture, O = oil and gas development on-site.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

The Yazoo Basin is located in the northwestern portion of Mississippi and is composed of approximately 4 million acres of delta (old Mississippi River floodplain) and 4½ million acres of hill area. When J.J. Audubon visited this delta in its predevelopment days, he was explicit in his accounts of streams filled with fishes and covered with ducks and geese (U.S. Fish and Wildlife Service 1979).

Flood control in the area began with private construction of levees along the Mississippi River. After the great floods of 1927 and 1928, the Federal Government become involved in major flood control efforts for the first time (for an in-depth discussion see McCabe et al. 1982). Federal action began with the construction of flood control reservoirs by the Corps of Engineers and small retention reservoirs by the Soil Conservation Service, both in the hill area to control headwater flooding. With these efforts came increased conversion of tributary floodplains to agriculture and the resultant need for additional protection in the form of levees and channelization.

These flood control measures allowed the waters of the hill region to move quickly down to the delta region with larger volumes and flows than historically existed. This resulted in a series of flood control actions that would culminate in more than one billion dollars in Federal expenditures. Levees and channel improvements were accomplished on the Coldwater, Tallahatchie, Yalobusha, and Yazoo Rivers in the upper region of the delta. These actions to protect property and crops from flooding also made it possible to convert massive BLH areas once believed to be too wet to regularly sustain crops. When this occurred, on-farm drainage of the cleared areas overloaded the downstream capabilities to contain the flows within channels. Thus, additional actions were performed to channelize, levee, and build over-land canals to move the floodwaters to the lower portion of the delta more expeditiously.

The pattern of Federal flood control measures moving down the Basin was well recognized by landowners as they "waited their turn." Extensive areas of productive BLH wetlands were converted to marginal farmlands with the expectation that flood control measures would upgrade them to prime farmlands.

The same process of pushing the once stored floodwaters downstream occurred as had occurred in the upper reaches of the Basin. By the late 1970's, the only area in the Yazoo Delta that had not received major flood control, and the ensuing devastation of the BLH resources, was the area just above Vicksburg known as the "Backwater Area". It was so named because, before construction of the Yazoo Backwater Levee, the Mississippi River regularly flooded the area during spring flows. With creation of the backwater levee, the entire Yazoo Delta became "ring leveed" by the hill area to the east, mainline Mississippi River levees to the west, and the backwater levee connecting the two at the southern tip of the Delta.

The vast majority of these flood control measures were justified by "agricultural intensification" on areas previously supporting BLH wetlands. Not only were these valuable wetlands lost, but they were replaced by farmland that exhibited 10 to 20 times the previous erosion rate, with extremely high concentrations of agricultural chemicals. In the 1960's, pesticide input into natural waters forced the closing of lakes, such as Mossy and Wolf, in the central Yazoo Delta, to fishing. These chemically "hot" water bodies were, unfortunately, not the exception but the rule. Analyses of the pesticide concentrations in fish flesh at the outfall stream (Yazoo River) of the Delta revealed agri-chemicals in concentrations 320 times the accepted EPA level. Because of loss of BLH habitat, extremely high erosion rates after conversion (up to 20 tons/acre/year), and dangerous levels of pesticides, only 20% of the Yazoo Basin stream area is capable of sustaining a fish population today (U.S. Fish and Wildlife Service 1979).

While more than one billion Federal dollars have been spent in the Yazoo Basin for "flood control," little has been spent solely for fish and wildlife conservation. Indeed, no consideration has ever been given to the cumulative and self-perpetuating effects of impoundments, levees, channelization, soybeans, rice production, aquaculture, and oil and gas development in the Yazoo Delta. Yet, the overall effects of all perturbations considered in this workshop have eliminated 80% of the stream habitat and 90% of the spawning and nursery habitat for Yazoo Delta fishes. The individual impacts of any of the

perturbations analyzed above are certainly important. However, without full consideration of those forces that cause the perturbations and other associated activities, the extent of long-term fisheries impacts cannot be determined. The Fisheries Workgroup believes it is a primary responsibility of the Section 404 permit program to ensure that these cumulative impacts are fully considered.

SUMMARY

Freshwater organisms are provided vital habitat in bottomland hardwoods. The Fisheries Workgroup determined that the most important values are represented by finfish habitat and shellfish habitat. Finfish habitat was evaluated by examining the effect of eight activities on nine characteristics; shellfish habitat was assessed on the basis of the effects of the same activities on a subset of six of the nine characteristics. In addition to the seven prescribed activities, the impact of oil and gas development was evaluated. Characteristics evaluated for finfish and shellfish habitat were areal/stage relationships, natural floodplain vegetation, gentle topography, presence of toxics, oxygen level, and sedimentation. For finfish habitat, stream sinuosity, snags and instream cover, and accessibility to permanent water were also assessed.

In general, the activities impair the finfish and shellfish habitat functions, although the functions of BLH areas upstream from impoundments are uneffected. Characteristics impaired most often are areal/stage relationship, natural floodplain vegetation, gentle topography, and sedimentation. Impairment is primarily due to landclearing and hydrologic modifications. Oil and gas development on-site, conversion to rice, conversion to soybeans, and channelization of stream adjacent to site impair the functions through effects on most of the characteristics.

During the analysis of the eight perturbations identified for evaluation, the workgroup realized that very seldom does a single development activity

occur without one or more associated development activites. The Fisheries Workgroup believes that the acreage of soybean production and other development present in the Lower Mississippi Valley would be substantially lower today without the massive flood control efforts of the Federal Government. Indeed, little, if any, consideration has been given to cumulative and self-perpetuating effects of impoundments, levees, channelization, soybean production, rice production, aquaculture, and oil and gas development. Yet, it has been the overall effects of all perturbations considered in this workshop that have eliminated much of the stream, spawning, and nursery habitat for Lower Mississippi Valley fishes. The individual impacts of the previously mentioned perturbations are certainly important. However, without full consideration of those forces that cause these perturbations and other induced activities, the extent of long-term fisheries impacts cannot be determined. The Fisheries Workgroup believes it is a primary responsibility of the administrators of the Section 404 permit program to ensure that these cumulative impacts are fully considered.

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WILDLIFE WORKGROUP REPORT

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INTRODUCTION

The charge to the Wildlife Workgroup was to identify a set of characteristics useful in evaluating the extent to which bottomland hardwood (BLH) ecosystems perform a wildlife support function and to evaluate the impact of various developmental activities on those characteristics and hence on the wildlife support function itself. Initial discussions in the workgroup focused on defining the wildlife support function in a manner that would facilitate such an analysis of impacts. Three basic approaches were examined.

1. Consider wildlife support as a single function and attempt to identify characteristics indicative of sites that, overall, provide high quality wildlife habitat.

2. Consider support of individual, representative species or species groups as separate functions and attempt to identify characteristics indicative of sites that meet the life requisites of those species or groups.

3. Consider individual habitat requirements (e.g., tree cavities for nesting) as separate functions and attempt to identify characteristics of sites that meet those requirements.

After considerable discussion, most workgroup members felt that the second approach was preferable because: (1) it is a common way of thinking about wildlife habitat; (2) it could be accomplished, at least for a few species or groups, in the time available at the workshop; and (3) it would be the easiest to explain and defend to decisionmakers. Following this decision,

five species or species groups were chosen for consideration: wood ducks (Aix sponsa), wintering dabbling ducks (excluding wood ducks), black bear (Ursus americanus), white-tailed deer (Odocoileus virginianus), and migrating passerine birds (i.e., those in passage between wintering and breeding habitats). These species or groups of similar species were chosen subjectively, but with several general criteria in mind, including importance to management agencies, seasonality of use of BLH ecosystems, and diversity of habitat requirements. It is obvious, however, that no set of five species or groups can represent the full range of habitat requirements of all wildlife species. Results of the analyses that follow would vary depending on the species or groups selected.

For each species, six life requisites or habitat components were considered: food, reproductive sites, escape cover, resting areas, migration habitat, and movement corridors. Depending on the species or group, movement corridors were considered from several perspectives, including repopulation of vacant areas, maintenance of genetic interchange between population centers, and movement between areas meeting other needs. In the tables that follow, these life requisites are listed as the characteristics that determine the importance or value of a site. Specific examples of resources or conditions that fulfill the life requisites, as well as ways in which they might be measured or estimated in the field, are given in the accompanying text. These examples were arrived at on the basis of general knowledge of workgroup members, without specific reference to the large body of literature that exists. Habitat requirements for many species have been usefully summarized in connection with evaluation methodologies such as the Habitat Evaluation System developed by the U.S. Army Corps of Engineers (1980) and the Habitat Evaluation Procedures developed by the U.S. Fish and Wildlife Service (1980). Such references would be of great value in constructing a more detailed list of habitat components and in identifying ways of estimating their availability or importance to wildlife.

ANALYSIS OF IMPACTS

HABITAT FOR WOOD DUCKS

Food

Wood ducks feed primarily on a variety of natural materials including hard mast [e.g., acorns of pin oak (Quercus palustris), water oak (Q. nigra), Nuttall oak (Q. nuttalli), and willow oak (Q. phellos)], invertebrates, weed seeds [e.g., smartweed (Polygonum spp.)], aquatic tubers [e.g., river bulrush (Scirpus fluviatilis)], and other fruits [e.g., persimmon (Diospyros virginiana) drupes]. Waste agricultural grains (e.g., soybeans and rice) provide a secondary food source, particularly if they are located near BLH forests. To be available to wood ducks, these foods must be located in shallowly (less than 18 inches) flooded areas. Invertebrates are particularly important for breeding adults in late winter and early spring in shallowly flooded areas and for broods in summer in more permanent marshes, ponds, and sloughs close to nesting habitats.

Each of the activities considered was judged to have an overall negative impact on food resources for wood ducks, largely due to the destruction of natural vegetation (Table 14). Possible exceptions to this general conclusion include the following. Waste grains can partially offset the loss of natural foods if the fields are flooded and located near BLH forests. Depending on a variety of factors such as topography and operating practices, the upper ends and margins of impoundments can sometimes be managed for vegetation that provides useful feeding habitat for wood ducks. Habitat losses may also be offset to some extent by the fact that impoundments sometimes raise the local water table and thus increase off-site flooding. Channelization and levee construction projects can affect wildlife habitat in general, and wood duck habitat in particular, in three ways: direct impacts (e.g., vegetation clearing) associated with channelizing the stream or building the levee; alterations in the flooding regime of adjacent sites; and induced clearing,

Table 14. Impacts of various activities on habitat for wood ducks as mediated through certain characteristics that contribute to the performance of this function.

Function: habitat for wood ducks										
Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O	I-D[3]	C	L	P	A
Food	+	-	-		-		-	-	-	-
Reproductive sites	+	-	-		-		-	-	-	-
Escape cover	+	-	-		-		-	-	-	-
Resting areas	+	-	-		-		-	-	-	-
Movement corridors between habitats[4]	+	-	-		0		0	0	-	0
Migration habitat	+	-	-		+		-	-	-	+
Overall impact on habitat for wood ducks		-	-		-		-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream and downstream from an impoundment were not discussed.

[4]For example, movements between reproductive sites and brood-rearing habitat.

for agricultural purposes, of lands where flooding frequency and duration are reduced. While the effects of such projects are highly site specific (i.e., additional landclearing does not always occur), the three types of impacts are stated roughly in order of increasing importance. However, levees constructed as part of a floodway may benefit wood ducks by ponding water between the levees, so long as natural vegetation is not removed. Finally, aquacultural conversions involving catfish ponds generally impact food for wood ducks negatively. On the other hand, conversions to crawfish farms often involve shallower ponds that can provide some food.

Reproductive Sites

Wood ducks use cavities in trees over or near water for nesting. Reproductive success is also importantly influenced by the presence of suitable brood habitat (permanently or semipermanently flooded swamps, ponds, and sloughs) in proximity to the nest site. In addition, site fidelity is an important aspect of wood duck nesting ecology.

To the extent that they remove large trees that contain potential nesting cavities, all of the activities were judged to affect wood duck reproductive sites negatively. Possible exceptions include impoundments where nest boxes are installed as mitigation, unmaintained channelization projects (e.g., instances where beavers are allowed to dam tributary streams and cause ponding on the landward side of the berm) that may provide both nest sites and brood habitat, and crawfish ponds where some or all of the natural vegetation is left on the site.

Escape Cover

Wood ducks use expanses of flooded timber or shrub-scrub as escape cover. Water depth is not particularly important, but denser vegetation is generally more useful. Removal of natural vegetation for any of the activities thus impacts this characteristic negatively. Possible exceptions include all of those noted above for reproductive sites.

Resting Areas

Wood ducks use similar areas for escape cover and resting. Impacts and exceptions are similar to those noted above for escape cover.

Movement Corridors

Watercourses and their forested borders provide important corridors for movement of wood ducks between habitats. Movements of young from the nest site to brood habitat are especially important. Activities that maintain or create aquatic habitats (e.g., impoundment construction, channelization, levee construction, conversion to aquaculture) were judged not to impact movement corridors significantly, while activities that disrupt aquatic habitats were judged to have negative impacts.

Migration Habitat

Habitats used by wood ducks for long distance migrations are those that provide necessary food, escape cover, and resting areas and are in close proximity to flyway corridors. Activities that create open water that can be used for resting during migration (e.g., impoundment construction, conversion to aquaculture) may thus create some migration habitat. However, this was not judged to be a significant benefit, because migration patterns are usually well established prior to development and also because open water areas are already abundant. Other activities that remove natural vegetation and thus interrupt the continuity of forested watercourses were judged to have a negative impact on migration habitat.

Overall Impact

Based on the analysis described above, each of the activities was judged to have an overall negative impact on habitat for wood ducks.

HABITAT FOR WINTERING DABBLING DUCKS

Food

Wintering dabbling ducks utilize a variety of foods including hard mast (e.g., acorns of pin oak, water oak, willow oak), waste agricultural grains (e.g., corn, soybeans, rice), invertebrates found in leaf litter or crop residue, weed seeds, and aquatic tubers. Such foods ordinarily must be shallowly flooded to be attractive to dabbling ducks. Invertebrates are particularly important for potential breeders during late winter and early spring.

To the extent that they remove natural vegetation and/or reduce the frequency and duration of flooding, all of the activities were judged to negatively impact food for wintering dabbling ducks (Table 15). Possible exceptions include those noted above for wood ducks.

Escape Cover

Flooded forests and shrub-scrub provide important escape cover for wintering dabbling ducks. Water depth is not critical, but denser vegetation generally provides better cover. Because all of the activities generally involve removing vegetation and/or reducing the frequency and duration of flooding, they were judged to impact escape cover negatively. Possible exceptions include the upper ends and margins of impoundments (if managed properly), levees used in creating floodways, and aquacultural conversions where the natural vegetation is left in place.

Resting Areas

In addition to the kinds of areas listed for escape cover, dabbling ducks also use open water for resting. Activities that create reliable winter water (e.g., impoundment construction, conversion to aquaculture) may therefore create resting areas. However, this was not judged to be a very important

Table 15. Impacts of various activities on habitat for wintering dabbling ducks as mediated through certain characteristics that contribute to the performance of this function.

Function: habitat for wintering dabbling ducks

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O	I-D[3]	C	L	P	A
Food	+	-	-		-		-	-	-	-
Escape cover	+	-	-		-		-	-	-	-
Resting areas	+	-	-		+		-	-	-	+
Migration habitat	+	-	-		+		-	-	-	+
Overall impact on habitat for wintering dabbling ducks		-	-		-		-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream and downstream from an impoundment were not discussed.

factor, because resting habitat is probably not in short supply. Other activities that reduce the frequency and duration of flooding and/or remove natural vegetation probably have a negative impact on resting areas. Possible exceptions include those noted above for escape cover.

Migration Habitat

Suitable migration habitat for dabbling ducks is comprised of sites that provide adequate food, escape cover, and resting areas in proximity to flyway corridors. Impacts of the activities on migration habitat are thus similar to those described above. Open water areas created by impoundments and aquacultural conversions may be a positive impact, but this was not judged to be particularly important because open water for resting is already relatively abundant. Removal of natural vegetation and reductions in the frequency and duration of flooding caused by the other activities have a negative impact on migration habitat.

Overall Impact

Based on the above analyses, it was judged that all of the activities, in general, have a negative impact on habitat for wintering dabbling ducks.

HABITAT FOR BLACK BEARS

Food

Black bears are omnivorous, utilizing a variety of foods including nuts, berries, crawfish, fish, small mammals, and carrion. Their food habits may vary considerably at different locations and at different times of the year. It is therefore difficult to identify particular characteristics that would provide an index of the quality of food available for black bears. The total area of contiguous habitat may be among the most important factors determining food supply, as well as other life requisites.

It was therefore judged that any activity that removes native vegetation and thus potentially interrupts continuity of the habitat probably has a negative impact on the food available to black bears (Table 16). Impacts of channelization and levee construction are probably less severe, provided that they are not followed by additional landclearing.

Reproductive Sites

Black bears require large, unflooded cavities for denning. To the extent that they remove large trees that may provide such cavities, all the activities impact black bear reproductive sites negatively.

Escape Cover

Preferred escape cover for black bears consists of thick swamps interspersed with areas of higher ground. Any area of dense vegetation can be used, however, as can open water. Impoundment construction and conversion to pine plantation were therefore judged to have no impact on escape cover. The other activities were judged to impact escape cover negatively, either through removal of natural vegetation, reductions in the frequency and duration of flooding, or both. A possible exception is levee construction to create floodways in which the natural vegetation is maintained.

Movement Corridors

Black bears are wide-ranging animals with large home ranges. Corridors that allow movement between areas that can satisfy their other life requirements are thus important in areas where large blocks of contiguous habitat do not exist. Vegetated corridors connecting upland forests with BLH sites may be particularly important because the uplands can provide additional denning sites and alternate food sources.

Table 16. Impacts of various activities on habitat for black bear as mediated through certain characteristics that contribute to the performance of this function.

Function: habitat for black bear										
Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O	I-D[3]	C	L	P	A
Food	+	-	-		-		-	-	-	-
Reproductive sites	+	-	-		-		-	-	-	-
Escape cover	+	-	-		0		-	-	0	-
Movement corridors[4]	+	-	-		-		-	-	0	-
Overall impact on habitat for black bear		-	-		-		-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream and downstream from an impoundment were not discussed.

[4]For black bear, movement corridors are probably most important in allowing access to various life requirements (e.g., movements between different food sources). They may also allow exchange of genetic material and repopulation of areas where the endemic population has been extirpated.

The impact of various activities on movement corridors is thus extremely dependent on the exact location of such activities. However, it was the opinion of the group that all of the activities except conversion to pine plantation generally impact movement corridors negatively. Pine plantations were judged to provide suitable movement corridors due to the presence of adequate vegetation.

Overall Impact

Based on the above analysis, all of the activities were judged to have a negative impact on black bear habitat.

WHITE-TAILED DEER HABITAT

Food

White-tailed deer utilize a variety of foods including hard mast (e.g., acorns); soft mast [e.g., fruits of persimmon, hawthorn (*Crataegus* spp.), American beautyberry (*Callicarpa americana*), and deciduous holly (*Ilex decidua*)]; grasses, forbs, herbs, vines, and shrubs common in forested habitats; and agricultural crops (e.g., soybeans, corn, wheat).

Activities that lead to standing water on the land surface (e.g., conversion to rice, impoundment construction, conversion to aquaculture) were judged to have generally negative impacts (Table 17). While the impact of conversion to soybeans is negative in most cases, soybeans interspersed in BLH forests might actually improve food availability for deer in some locations. Similarly, levee construction and channelization were judged to be negative in most cases, largely due to the possibility of induced landclearing. However, creation of edges and reductions in the frequency and duration of flooding might improve browse and mast production under certain circumstances if there is no landclearing. Finally, workgroup members were unwilling to generalize about the effects of conversion to pine plantation because of the high degree

Table 17. Impacts of various activities on habitat for white-tailed deer as mediated through certain characteristics that contribute to the performance of this function.

Function: habitat for white-tailed deer

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O	I-D[3]	C	L	P	A
Food	+	-	-		-		-	-	?	-
Reproductive sites	+	-	-		-		-	-	?	-
Escape cover	+	-	-		-		-	-	0	-
Resting areas	+	-	-		-		-	-	0	-
Movement corridors between habitats[4]	+	-	-		-		-	-	0	-
Overall impact on habitat for white-tailed deer		-	-		-		-	-	?	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream and downstream from an impoundment were not discussed.

[4]Movement corridors serve to allow access to different required habitats, repopulation of areas where the endemic population has been extirpated, and exchange of genetic material.

of variability associated with factors such as the exact type of vegetation being replaced and the management practices used in the newly created plantations.

Reproductive Sites

Reproductive sites for white-tailed deer are generally characterized by dense understory and ground cover vegetation in proximity to food sources. Sites used typically include forest edges, overgrown openings, thickets, windthrows, and cut-over areas.

Activities that remove understory and ground cover vegetation (conversion to rice, conversion to soybeans, impoundment construction) were thus judged to impact reproductive sites for white-tailed deer negatively. Channelization and levee construction were also assumed to impact reproductive sites negatively in the general case, but it should be noted that reductions in the frequency and duration of flooding at some locations could actually improve their suitability as reproductive sites. The impacts of conversion to pine plantations were again considered to be too variable to characterize in a general way.

Escape Cover

Escape cover for white-tailed deer is similar to reproductive sites, with the exception that shallow water (e.g., beaver impoundments, swamps, slack water areas) is also important. Impacts of the various activities were thus assumed to be similar to those on reproductive sites, with the exception that pine plantations were assumed to provide useful escape cover under most circumstances.

Resting Areas

Characteristics of resting areas and the impacts of the activities on those areas were judged to be very similar to those described for escape cover.

Movement Corridors

Movement corridors for white-tailed deer are probably most important in allowing animals to move between habitats to meet their life requisites. They may also allow repopulation of vacant areas and exchange of genetic material between populations.

White-tailed deer can probably use nearly any vegetated corridor for movement. However, wider bands of dense vegetation are probably preferred. Impacts of the activities were thus judged to be similar to those on escape cover.

Overall Impact

The above analysis indicates that most of the activities would tend to impact white-tailed deer habitat negatively. The impacts of conversion to pine plantation were judged to be too site-specific and variable to make a general statement.

MIGRATING PASSERINE BIRDS

Food

Migrating passerines are a diverse group of species whose foods and feeding habits vary widely. Vertical and horizontal diversity of the vegetation and size of the tract seemed to be the only two parameters that might be used to evaluate the suitability of a site for providing food for these birds as a group.

Workgroup members judged that, in the general case, all of the activities would tend to reduce vegetation availability and diversity and thus negatively impact food for migrating passerines (Table 18). In particular cases, however, assuming that they are not followed by landclearing, activities such as

Table 18. Impacts of various activities on habitat for migrating passerine birds as mediated through certain characteristics that contribute to the performance of this function.

Function: habitat for migrating passerines

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U[3]	I-O	I-D[3]	C	L	P	A
Food	+	-	-		-		-	-	-	-
Escape cover	+	-	-		-		-	-	-	-
Resting areas	+	-	-		-		-	-	-	-
Migration habitat	+	-	-		-		-	-	-	-
Overall impact on habitat for migrating passerines		-	-		-		-	-	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

[3]Impacts upstream and downstream from an impoundment were not discussed.

channelization and levee construction might increase vegetation diversity by creating openings and edges. Similarly, small pine plantations interspersed in BLH forests might increase vegetation diversity and thus improve the food supply for migrating passerines.

Escape Cover

Again, given the diversity of passerine species, tract size and vegetation diversity were judged to be the only useful indicators of the utility of a site for escape cover. Impacts of the activities on escape cover were judged to be similar to those on food supplies.

Resting Areas

Habitat requirements and impacts were assumed to be similar to those for food and escape cover.

Migration Habitat

In addition to vegetation diversity and tract size, the suitability of a site as migration habitat can be affected by the presence of man-made structures (e.g., television towers can be a significant source of mortality), proximity to migration corridors, and distance to other suitable tracts. BLH forests along the Gulf Coast may be particularly important resting areas for migrants crossing the Gulf of Mexico.

Impacts of the activities on migration habitat were judged to be generally negative because of reductions in tract size and vegetation diversity. Again, however, levee construction, channelization, and conversion to pine plantation might actually increase vegetation diversity under certain circumstances. Furthermore, location of a site within a flyway corridor and its relationship to other suitable tracts may be important determinants of the impacts of these activities on migration habitat.

Overall Impact

Based on the above analysis, workgroup members judged that the overall impact of each of the activities on migrating passerines is negative. However, the magnitude of such impacts is highly site-specific and highly dependent on the individual species being considered.

SUMMARY

With regard to impacts of the various activities, the analysis above allows the following general conclusions.

1. Analyses of this kind are dependent on the species or species groups chosen. While an effort was made to select species that utilize BLH ecosystems to satisfy a range of habitat requirements, an analysis based on other species would be expected to vary.

2. It appears that all of the activities examined have generally negative impacts on habitats of the species that were considered. Under a few circumstances, however, any of the activities may have a positive impact on the habitat of some species.

3. Whether the site-specific and species-specific impacts are positive or negative depends on a variety of factors including: the type of habitat that is being replaced or altered; the geographic location of the site; the geographic extent of the activity; the specific purpose of the activity (e.g., flood control impoundments versus hydroelectric impoundments); habitat conditions in the surrounding area; construction techniques and future management of the site; and specific wildlife management objectives for the area.

4. For many kinds of activities (e.g., channelization, levee construction), the direct impacts are far less important than secondary effects such as alterations in the flooding regime and induced landclearing.

5. Finally, and perhaps most important, even though the site-specific impacts of an activity can be positive in some cases, the cumulative impacts of many replications of that activity are likely to be negative for wildlife species that utilize BLH ecosystems.

Based on discussions in the workgroup, members identified the following characteristics as being indicative of BLH areas that would be particularly important in performing a wildlife support function.

1. Large blocks of contiguous habitat. In addition to providing diverse habitats for smaller species, large blocks of BLH forests may be important in providing for the needs of large, mobile species.

2. Forested corridors connecting other habitat blocks, particularly those along watercourses and those connecting upland forests with BLH forests. Movements between blocks of habitat are important for several reasons, including repopulating vacant areas, exchanging genetic material, and allowing larger, mobile species access to a variety of resources. Many species tend to follow watercourses in these movements. Corridors connecting bottomlands to upland forests may be important as escape routes during floods and in providing alternate food sources.

3. Tracts along the Gulf Coast. Such tracts may be particularly important to birds that migrate across the Gulf of Mexico.

4. Tracts immediately outside mainline levees and floodways. Such tracts may provide important escape habitat during flood situations.

5. Tracts with high diversity, in the sense of interspersion of forest types, vertical vegetation structure, and flooding regime. Such tracts have the highest probability of meeting the needs of a variety of wildlife species.

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ECOSYSTEM PROCESSES WORKGROUP REPORT

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INTRODUCTION

From the ecosystem perspective it is important to distinguish between impacts of development activities on the actual site involved and those that occur over a larger area as a result of the completion of many small projects over a period of time. For convenience we will refer to the proposed development site as the "project site" and to the larger surrounding area as the "watershed" or "basin," understanding that the size of the larger area may vary and that these terms are used for convenience. In this section, we address the impact of several different kinds of human activity on both the project site (site-specific effects), and on a watershed (cumulative effects). Although the watershed is considered as the basic unit of landscape in the cumulative analysis, it should be recognized that watersheds vary enormously in size, and that for some processes the scale may need to be even larger.

The workgroup focused on cumulative impacts. The modification of a small forest site often has little measurable impact on the whole basin. However, development of many small sites profoundly changes the basin. Therefore, the following analysis emphasizes ecosystem characteristics that measure the integrity of the whole forest. Some may also apply to individual sites, but many make sense only in the context of large, diverse areas. The analyses include site-specific effects where they may be important.

For each function discussed, several characteristics were identified that might serve as measurable indicators of the performance of the function, or that were judged to determine the performance of the function. These characteristics were then evaluated in terms of how they are impacted by typical development activities in bottomland hardwood (BLH) ecosystems. For several cumulative impacts, we then developed examples of how critical levels of ecosystem function could be determined, in order to set reasonable limits to development. Finally, activities were ranked and grouped according to their general importance along the dimensions of intensity, spatial extent, and permanence.

ANALYSIS OF IMPACTS

MAINTENANCE OF NATURAL BIOTIC DIVERSITY

The maintenance of natural, or native, biotic diversity is specifically mandated by several pieces of Federal and State legislation (e.g., the Endangered Species Act of 1973). Numerous species of native flora and fauna are either endemic to BLH forests or depend on these ecosystems for one or more of their survival needs at various seasons or life stages. This section focuses on terrestrial species, although much of the discussion is also relevant to aquatic species. Strong distinctions must be drawn between native "flora" and "vegetation" and between native "fauna" and "wildlife." The terms "flora" and "fauna" refer to the assemblages of species that are native to an area, characterize it as a biotic community type (a biotope), and allow it to be distinguished from surrounding community types. In cases where there are no unique or endemic species, the comparative abundance of different species can easily serve as a distinguishing characteristic (e.g., a cutgrass marsh that includes a few willows and buttonbush is a different community than a willow forest swamp that contains sparse cutgrass in the understory). By contrast the terms "vegetation" and "wildlife" do not distinguish between native and alien species. Thus a community that supports 20 exotic species

but has lost two native species might be viewed as having increased overall species diversity, but would have decreased native biotic diversity.

Large, continuous tracts of BLH forest (characterized by effective size or area of various community types, breadth, and linear continuity) are critically important to the maintenance of natural biotic diversity for at least the following reasons.

1. They provide a diverse array of sites (i.e., ecological diversity) that support a full set of stenotopic species (e.g., several species of oaks, orchids, and certain warblers).

2. They maintain natural patch-dynamic processes whereby shade-intolerant species can occur in all life stages. These patch dynamics are especially important in producing regeneration sites in close proximity to unperturbed stands with mature, seed-bearing individuals.

3. They facilitate maintenance of the full gamut of within-species genetic diversity, including clines, ecotypes, demes, chromosomal heterozygosity, and allelic polymorphism.

4. They allow wide ranging, ground-based, terrestrial organisms to occur in populations with numbers sufficiently large to forestall or prevent inbreeding, regional extirpation, or extinction.

5. They facilitate the occurrence of faunal and floral assemblages that have community and trophic integrity and thus minimize management and conservation costs.

Impacts of various activities on maintenance of natural biotic diversity are summarized by a number of measurable characteristics at the cumulative level in Table 19 and at the site-specific level in Table 20.

Cumulative Level

Native species richness. This is a measurable indicator of the degree to which the function of maintenance of natural biotic diversity is being performed. Again, it is important to note that occurrence of native species,

Table 19. Impacts of various activities on maintenance of natural biotic diversity at the cumulative level, as indicated by characteristics related to the performance of this function.

Function: maintenance of natural biotic diversity, cumulative level

Characteristic	Relationship of characteristic to function[2]	Activity[1]							
		R	S	I	C	L	P	A	G
Native species richness	+	-	-	-	-	-	-	-	-
Effective size	+	-	-	-	-	-	-	-	0
Breadth	+	-	-	-0	-0	-0	-	-	0
Linear continuity	+	-	-	-	-	-	-	-	-0
Percent of regional landscape	+	-	-	-	-	-0	-	-	0
Ecological heterogeneity	-+	-+	-+	-+	-+	-+	-+	-+	-+

[1]A plus indicates that the function is enhanced by the activity. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on initial conditions, multiple causal pathways, or interactions. R = conversion of site to rice, S = conversion of site to soybeans, I = impoundment impacts in general, C = channelization impacts in general, L = levee construction impacts in general, P = conversion of site to pine plantation, A = conversion of site to aquaculture, and G = conversion of site to greentree reservoir.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation. A combination of signs indicates that the relationship differs depending on initial conditions, regional context, or interactions.

Table 20. Impacts of various activities on maintenance of natural biotic diversity at the site-specific level, as indicated by certain characteristics that are related to the performance of this function.

Function: maintenance of natural biotic diversity, site-specific level

Characteristic	Relationship of characteristic to function[2]	Activity[1]							
		R	S	I	C	L	P	A	G
Number and area of different community types and ecological zones	-+	-	-	-+	-+	-+	-	-0	-0
Edge between community types	-+	-	-	-+	-+	-+	-	-0	-0
Structural diversity of vegetation (within stand)	+	-	-	-	-+	-+	-	-	-
Mast production and diversity	+	-	-	-	-+	-+	-	-	-+
Nesting and escape cover (within stand)	+	-	-	-	-+	-+	-	-	-+

[1]A plus indicates that the function is enhanced by the activity. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on initial conditions, multiple causal pathways, or interactions. R = conversion of site to rice, S = conversion of site to soybeans, I = impoundment impacts in general, C = channelization impacts in general, L = levee construction impacts in general, P = conversion of site to pine plantation, A = conversion of site to aquaculture, and G = conversion of site to greentree reservoir.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation. A combination of signs indicates that the relationship differs depending on initial conditions, regional context, or interactions.

including genetic variants, is quite different from total species richness including naturalized, alien, introduced, and escaped species. All development activities were considered to reduce native species richness, although overall species diversity may increase in cases where the landscape context is such that the community shifts caused by the development activities contribute to overall ecological heterogeneity.

Effective size. Effective size measures the extent of BLH tracts relative to species' habitat requirements. All development activities have a negative impact to the extent that they fragment the landscape, resulting in smaller continuous tracts of BLH habitat. In the case of properly managed greentree reservoirs or, in some cases, downstream from an impoundment (if the change in hydrologic regime is small), the impact may be negligible.

Breadth. The full set of ecological zones, I through V, (Clark and Benforado 1981; Roelle et al. 1987) is needed to support the full gamut of BLH species. The BLH forests of higher elevational zones provide refugia for terrestrial species during floods, slightly lower elevational zones provide shallow inundated areas for aquatic species during the same events, and adjacent streams provide year-round habitat for migratory fish and shellfish. Development activities negatively impact this characteristic to the extent that they eliminate the natural range of environments and/or native vegetation in various elevational zones.

Linear continuity. Aquatic ecosystem function depends on upstream and downstream linkages, providing transport of water-borne materials and access for aquatic organisms. Many terrestrial organisms also require movement and dispersal corridors. All activities have a negative impact on this characteristic to the extent that they fragment and interrupt continuous tracts of BLH forest.

Percentage of regional landscape. As the percentage of BLH forest in the regional landscape declines, the integrity of remaining patches of BLH forest is reduced. Remaining patches are increasingly vulnerable to complete change

by meteorological and climatic perturbations and to invasion by weedy species. At some point, patches drop below critical values for the support of "interior" or stenotopic species. All activities have a negative impact to the extent that they result in a conversion of natural BLH forest. For greentree reservoirs this impact may be negligible because the changes in vegetative composition are minimal if the greentree reservoir is properly operated. In some cases (e.g., levee construction), the direct conversion may be negligible with a larger potential for indirect effect through modification of the hydrologic regime upstream and/or downstream.

Ecological Heterogeneity. Natural bottomland landscapes consist of elevational gradients and discontinuities with consequent diversity of vegetative communities, or biotopes, that contribute to the maintenance of species diversity. Activities that involve the introduction of anthropogenic structures and "communities" may increase ecological heterogeneity up to the point where these features become dominant in the landscape. However, the resulting increase in overall ecological diversity may have mixed, or negative, impacts on the native biotic diversity by enhancing certain species and eliminating other "interior" or stenotopic species. Thus, the impact of activities on biotic diversity depends both on the landscape context (i.e., are rare biotopes being added with a loss of common biotopes or are common biotopes being added with a loss of rare biotopes), and on the species being considered (increased heterogeneity of biotopes enhancing habitat for edge-preferring species and decreasing habitat for certain stenotopic or "interior" species).

Site-specific Level

The workgroup also identified characteristics that would be especially useful in assessing maintenance of natural biotic diversity on a specific site containing one or more relatively homogeneous stands. Although the site-specific level was discussed separately at the workshop, there is considerable overlap with the cumulative level in the characteristics identified, reflecting the gradation of scale in both floral and faunal structure as one goes from a relatively homogeneous stand or site to a complex of sites or stands to a

regional landscape. One convenient framework for this gradation in components of biotic diversity is the distinction between within-stand or habitat (α) diversity, between-habitat or community (β) diversity, and among-habitat or landscape (γ) diversity. In a site-specific assessment, the focus is on characteristics reflecting the within-habitat and, perhaps, the between-habitat components.

Number and area of community types and ecological zones. The presence of multiple vegetative communities and hydrologic conditions tends to increase the overall biotic diversity of a site. This effect may be counterbalanced or outweighed by the need for continuous tracts of critical size in order to support certain stenotopic species. Despite the mixed effects on different types of species, contextual complexities, and equivocal relationships, the simple cases of complete conversion of a site from a subtly varying complex of BLH communities to an essential monoculture (e.g., soybeans, rice, or pine) negatively impact the maintenance of natural biotic diversity on that site. Aquaculture involving clearing and dedicated impoundments also has a negative effect, although aquaculture without landclearing and greentree reservoirs may have more neutral overall impacts. The impacts of channelization, levee construction, and impoundment are more equivocal in that the tradeoff between the new communities created versus the simplification of natural variation in hydrologic conditions is less clear.

Edge between community types. The amount of edge between community types, although certainly related to the number and area of community types, is a slightly different measure incorporating additional aspects of the site's spatial mosaic. An increase in the amount of edge has both positive and negative effects on biotic diversity of the overall site. Some species respond very positively to edge, whereas when edge is gained by fragmenting large, continuous stands the resulting small patches may not be able to support other "interior" or stenotopic species. Overall, the relationships of the various activities to edge are similar to the effects on the number and area of community types.

Structural diversity of vegetation (within stand). Each stand or vegetative community on a site is further composed of a number of vegetative layers. Numerous measures of this structural diversity are available (e.g., foliage height diversity) and have been correlated with faunal diversity (especially for birds). Replacement of natural BLH communities with other vegetative communities tends to strongly reduce this structural diversity. Channelization and levee construction may, in some cases, increase this structural diversity if they only produce a shift in the type of BLH community due to a change in hydrologic regime (e.g., a zone II cypress-tupelo community to a slightly drier community with better developed understory vegetation).

Mast production and diversity. Many aspects of net primary production and organic matter processing are relevant to the maintenance of biotic diversity on a site. Practically, mast production and diversity (in type and time) is a very important characteristic for wildlife. Activities involving conversion to a completely different vegetative community strongly reduce this production and diversity, whereas hydrologic modifications producing a shift between types of bottomland hardwood vegetation may result in either increases or decreases. Greentree reservoirs probably have negligible impact on overall production, although diversity may be somewhat reduced.

Nesting and escape cover. Snags, logs, and butt cavities are important characteristics of overall structural diversity that are often not included in measures of the vegetative layers. Landclearing virtually eliminates this structure, whereas hydrologic modifications may have either positive or negative effects.

FOOD CHAIN SUPPORT

The function of food chain support was discussed at both the cumulative and site-specific levels. The only substantive difference, however, was the importance of the landscape mosaic as a characteristic at the cumulative level. Thus, both levels of analysis are combined for this function (Table 21).

Table 21. Impacts of various activities on food chain support as indicated by certain characteristics related to performance of this function.

Function: food chain support									
Characteristic	Relationship of characteristic to function[2]	Activity[1]							
		R	S	I	C	L	P	A	G
Net primary production									
Quantity	+	+	+	-+	-+	-+	0+	-	-0
Quality	+	-	-	-	-	-	-	-	-0
Organic matter processing	+	-	-	-	-	-	-	-	-0
Access/transport vectors	+	-	-	-	-	-	-	-	-0
Landscape mosaic	+	-+	-+	-+	-+	-+	-+	-+	-+

[1]A plus indicates that the function is enhanced due to the activity. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on initial conditions, multiple causal pathways, or interactions. R = conversion of site to rice, S = conversion of site to soybeans, I = impoundment impacts in general, C = channelization impacts in general, L = levee construction impacts in general, P = conversion of site to pine plantation, A = conversion of site to aquaculture, and G = conversion of site to greentree reservoir.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation. A combination of signs indicates that the relationship differs depending on initial conditions, regional context, or interactions.

Net Primary Production

Three aspects of net primary production are relevant: the quantity per unit area (e.g., production in units of carbon or energy/area), the total net production (area times production/area), and the quality of that production in terms of its organic composition, location, and timing. While quantity/area and quality can be site-specific, total production is cumulative, as is the quality in so much as it is modified by variation in timing and organic composition throughout the watershed. Generally, replacement of natural stands of bottomland hardwoods with other aquatic or terrestrial communities has a negative, overall impact on net primary production as it relates to support of natural food chains. Furthermore, this effect is cumulative. A large part of this overall effect is due to changes in the nature and timing of net primary production (e.g., from forest community to soybean field or to the water column of an impoundment), which may or may not be accompanied by reductions in the total amount of net primary production. For example, conversion to pine plantation or soybean agriculture with drainage may increase the quantity of net primary production at a site while substantially altering the distribution of that production among various components that serve as food items.

The situation is further complicated for hydrologic modifications (e.g., impoundment construction, levee construction, and channelization) that involve both direct, and generally limited, conversion of communities (e.g., forest to lake) and indirect, and much more pervasive, effects on forested sites through subtle modification of the hydrologic regime. These indirect effects may be mixed at different spatial locations as sites are shifted either away from or toward the intermediate flooding regime generally considered to be optimum for net primary production of natural bottomland hardwood communities. Properly operated greentree reservoirs should not significantly affect overstory net primary production, although there may be shifts (declines) in the understory and long-term shifts in the overstory if water is not managed effectively.

From a practical standpoint, net primary production for a specific site may be estimated from detailed knowledge of the stand composition (densities, sizes, and age distributions by species). Generally, net primary production in bottomland hardwoods is highest in sites with intermediate hydroperiods. Stand composition and hydrologic regime interact, however, and the optimum hydrologic regime is not the same across various communities (e.g., soybeans and pine plantations may require drainage for optimum net primary production).

Organic Matter Processing

In addition to providing a rich and diverse distribution of net primary production across types of organic components, locations, and times, natural BLH forests further transform organic matter by a variety of biotic and abiotic processes (e.g., conversion of Coarse Particulate Organic Matter to Fine Particulate Organic Matter). All development activities were judged to impair the performance of this processing function to the extent that they simplify the physical environment and the detrital assemblages.

Access/Transport Vectors

Flooding provides the medium both for transport of processed detrital material from BLH sites to downstream aquatic foodchains and for access of aquatic consumers (e.g., fish) to and from BLH sites. Flooding also drives terrestrial animals from lower, inundated sites to higher refuges, whereas subsequent drainage of the flooded sites opens them up again to exploitation by terrestrial animals. Site-specific impacts may block or open specific corridors, but often the more significant changes are a function of many individual site impacts, thus producing a cumulative problem. All of the development activities tend to disrupt the natural access and transport vectors by fragmenting the landscape and by interrupting and simplifying natural hydrologic patterns. This impact may be minimal in some cases, especially at specific sites; on the other hand, strategically placed activities may have severe impacts out of proportion to the size of the project site.

Landscape Mosaic

At a landscape level, the distribution and spatial configuration of various communities (natural and anthropogenic) is critical to the food chain support function for two reasons.

1. The species composing the food chains must be able to satisfy all life requisites (not just food) and thus may require certain distributions and configurations of vegetative communities in order to meet requirements such as cover or nesting habitat.

2. Many species utilize different communities at different times (e.g., as refugia during high or low water levels or as different food sources become available over time) and thus require certain distributions and interspersions of various community types.

The effect of various activities on this general characteristic is equivocal, depending in large part on whether the new communities created constitute a small or large fraction of the regional landscape. From a cumulative viewpoint, nearly all human activities simplify the natural landscape (e.g., monocultures, flooding large tracts, draining large tracts); however, in the early stages of development, activities such as forest clearing may actually increase the mosaic pattern.

STREAMFLOW MEDIATION

Bottomland sites are often subject to stream overflow from some combination of headwater and backwater flooding. The water stored on the floodplain does not drain as long as the river stage is as high as that of the floodplain waters. The stored water on the floodplain thus modifies river stage during times of peak flooding, and drains off after the peak has passed (Fig. 8). Consequently, the flood storage capacity of the bottomlands reduces downstream flood stages. When storage capacity is lost and water is confined to the river channels, downstream flood stages are increased. Furthermore, as the discharge relations of the river change, the channel may become unstable with consequent problems of scouring and filling (Belt 1975). The general function

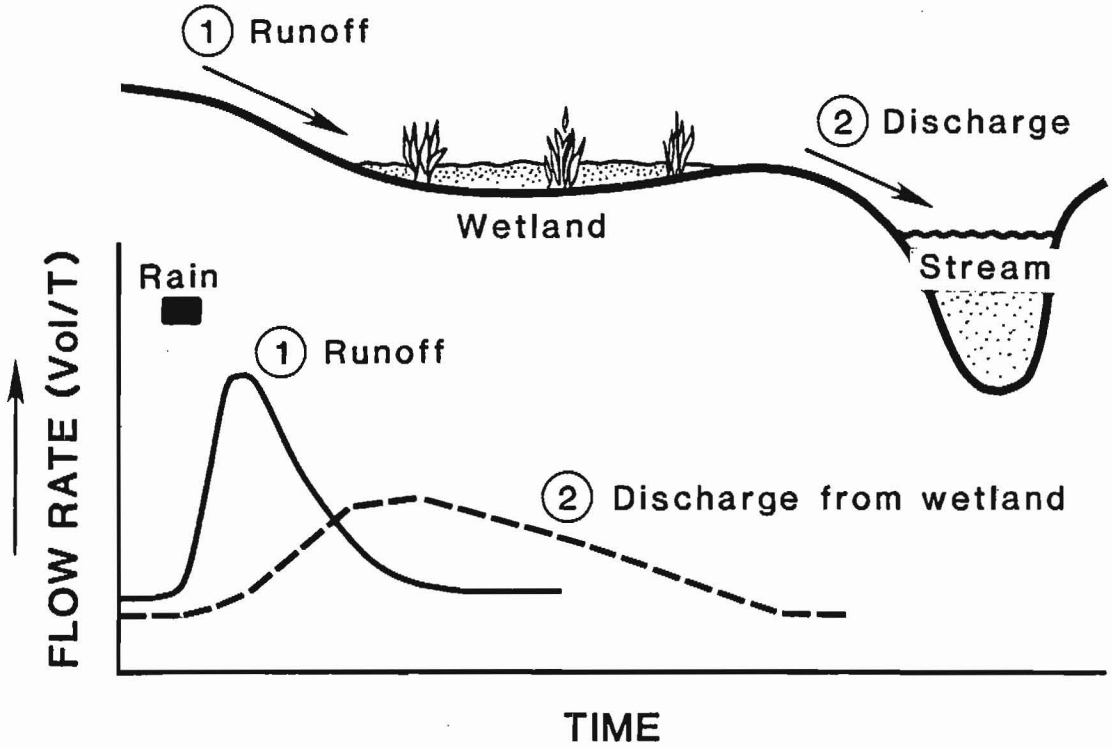

Figure 8. Generalized impact of wetland flood storage on timing of runoff.

of streamflow mediation by naturally flooding bottomlands thus may provide human values in the areas of channel stability and downstream flood protection. On a cumulative level, several characteristics are generally related to this streamflow mediation function (Table 22).

Percentage of Freely Flooding Area in Watershed

The freely flooding area is directly related to the natural flood storage capacity of the bottomland system. Activities (e.g., levee construction) that decrease this area reduce the streamflow mediation function to the extent that they "uncouple" water storage in these areas from river stage. Impoundments may have either positive or negative effects depending on their operation.

Table 22. Impacts of various activities on streamflow mediation as indicated by characteristics related to the performance of this function.

Function: streamflow mediation									
Characteristic	Relationship of characteristic to function[2]	Activity[1]							
		R	S	I	C	L	P	A	G
Percent of freely flooding area in watershed	+	-	0	-+	-0	-	0	-	-
Downstream flood stage/standard flood	-	0	0	+	-+	+	0	+	0
Hydrologic detention time	+	0+	-	+	-	-	-	0+	0+

[1]A plus indicates that the function is enhanced by the activity. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on initial conditions, multiple causal pathways, or interactions. R = conversion of site to rice, S = conversion of site to soybeans, I = impoundment impacts in general, C = channelization impacts in general, L = levee construction impacts in general, P = conversion of site to pine plantation, A = conversion of site to aquaculture, and G = conversion of site to greentree reservoir.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation. A combination of signs indicates that the relationship differs depending on initial conditions, regional context, or interactions.

Certainly, flood control impoundments tend to decrease downstream flood stages. In contrast to naturally flooding bottomland hardwoods, however, the forest ecosystem is usually drowned out upstream from the impoundment structure. Also, the ability to control the time of discharge of impounded waters completely uncouples streamflow from natural flood events. Impoundments such as those utilized in rice or catfish production tend to reduce flood storage capacity by isolating and removing an area from the functioning floodplain, at least at certain river stages.

Downstream River Stage/Standard Flood

Downstream river stage is an off-site, cumulative impact index of bottomland streamflow mediation. Reducing storage capacity in a watershed increases the downstream stage for a given discharge (at flood levels). Furthermore, as floodplain storage decreases, the river becomes increasingly unstable in terms of scour and fill dynamics.

Hydrologic Detention Time

The detention time in days (stored volume/discharge rate) is an integrated index of the storage capacity and the discharge rate. An example of its use is given by Gosselink et al. (1981) who estimated crudely that for the lower Mississippi River the detention time has gone from about 60 days in the early part of the century to about 12 days today. While all the implications of this change are not known, it is possible to cite increased flood crests, increasingly unstable stream bottoms and flows (Belt 1975), and changes in sediment transport capacity (Keown et al. 1980).

In general, impoundments tend to increase the hydrologic detention time. However, the impoundments involved in greentree reservoirs, rice production, and aquaculture were judged to have minor impact on this characteristic because of their relatively shallow nature. Hydrologic modifications due to levee construction and channelization decrease the hydrologic detention time, as do conversions to soybeans and pine plantation involving minor drainage and decreased surface roughness.

WATER QUALITY: TRANSFORMING AND FILTERING

Results from the Ecosystem Processes Workgroup session at the St. Francisville workshop suggest that transformation and transport of materials from BLH ecosystems is an important function. The principle developed (Brinson et al. 1987) states that "BLH ecosystems are open systems that transform energy and materials derived from inflows. Hence, outflows from BLH ecosystems differ quantitatively and qualitatively from inflows." An important consequence of the transforming and filtering capacity of BLH wetlands is their ability to maintain and improve water quality. One way of describing various patches of the landscape is to characterize them according to various "soil loss types," reflecting a combination of cover, management practices, slope, and soil characteristics. Key chacteristics that influence the degree to which BLH ecosystems perform transformation and filtering functions are: (a) the percent of the watershed that exists in BLH forest versus other soil loss types (e.g., row cropped), and (b) the location and configuration of various soil loss types in the watershed (i.e., location and shape of buffer zones).

Specifically, Table 23 suggests that increasing the area of highly erodable soil (either individually or collectively) can result in degradation of water quality. Similarly, the location and configuration of various soil loss types within a watershed are critical in determining the fate (i.e., transformation or transport) of sediments, nutrients, organic matter, and contaminants. BLH ecosystems have been shown to act as effective buffers to protect water quality. Hence, perturbation of BLH ecosystems can have direct effects on water quality characteristics (e.g., Total Suspended Solids, Dissolved Oxygen, Total Orthophosphate, etc.) either by causing direct loading of adjacent waters from eroding bottomland soils, or by allowing untransformed or poorly filtered nutrients, organic matter, and contaminants to reach adjacent waters (see Richardson 1985). We suggest that the transforming capacity of BLH ecosystems is directly related to their condition and to the rate at which material is transferred through them. Perturbation of the natural structure

Table 23. Impacts of various activities on transforming and filtering functions (water quality) as indicated by characteristics related to the performance of this function.

Function: transforming and filtering (water quality)

Characteristic	Relationship of characteristic to function[2]	Activity[1] R	S	I	C	L	P	A	G
Percent of watershed in BLH versus other cover types	+	-	-	-+	-	-+	-	-0	0
Buffer configuration of BLH (% of stream bordered by BLH)	+	-	-	-+	-	-+	-	-0	0

[1]A plus indicates that the function is enhanced by the activity. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on initial conditions, multiple causal pathways, or interactions. R = conversion of site to rice, S = conversion of site to soybeans, I = impoundment impacts in general, C = channelization impacts in general, L = levee construction impacts in general, P = conversion of site to pine plantation, A = conversion of site to aquaculture, and G = conversion of site to greentree reservoir.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation. A combination of signs indicates that the relationship differs depending on initial conditions, regional context, or interactions.

of BLH ecosystems through various land use or water regulation activities has direct effects on their efficiency as filters and therefore their utility as wetlands that function to maintain or improve water quality.

Percentage of Watershed in BLH

Conversion of bottomland hardwoods to agricultural cover types generally converts these sites from net depositional environments for sediment to net sources of sediment and applied agricultural chemicals.

Impoundments can have positive impacts on water quality by serving as traps for many constituents (especially settleable material). Impoundments can also result in a net negative impact on the quality of water emanating from a watershed, given activities that are necessarily associated with construction of reservoirs (clearing, grading, dam construction, etc.) and inundation (for prolonged periods) of soils that were formerly only periodically inundated. For example, in the South Atlantic Coastal Plain, it is common that new reservoirs significantly impact the timing, rate, and duration of flood events, as well as the dissolved and suspended loads and temperature of waters released through spillways. Increased heavy metal concentrations and oxygen depleted waters are common, for example, downstream from dams with hypolimnetic release capabilities. Anaerobic waters exhibiting high concentrations of heavy metals are also common "on-site" (i.e., in the reservoir itself).

Levee construction that results in excluding water from BLH sites can have either positive or negative effects, depending on the specific location of the levee and the degree to which it limits the filtering capacity of a site at various stages of river discharge. Total exclusion of floodwaters from a BLH site yields a net negative effect very similar to the effect of channelization.

Aquacultural practices commonly include use of fertilizers and desynchronized detainment of waters on BLH sites. Hence, nutrient loading and a longer residence time of waters in developed ponds or impounded areas can result in overall decreases in water quality (e.g., increases in Total Suspended Solids and Total Dissolved Solids, usually higher water temps). In the best circumstances, aquacultural activities have no significant impacts.

Buffer Configuration of BLH Sites

Performance of water quality improvement by the transformation and filtering of constituents in water moving through BLH sites depends on the configuration of those BLH sites relative to water flow from source areas (either higher elevation sites or from the channel itself in the case of overbank flooding). Operationally, the magnitude of the buffering effect can be estimated by the percentage of streams bordered by BLH forest.

Since levee construction usually limits the extent of the floodplain (and hence of the transforming BLH ecosystem), the effect of levees is generally to degrade water quality. This is especially true if levees direct flow to the confined, unbuffered main channel areas and bypass areas where transformation and filtering could occur.

Impoundment of waters on BLH sites can result in positive or negative effects on the buffering capacity of the system. As noted above, impoundments can serve as traps for many constituents. However, if the impoundment is newly constructed and has not had sufficient time to purge itself of resuspended nutrients, organic matter, and contaminants, *in situ* and downstream effects on water quality will definitely be negative. On the other hand, if the impoundment is ephemeral, and especially if impoundment occurs in a relatively undisturbed BLH stand, net effects can be positive. However, given increased duration of flooding, this positive effect may decline to neutral or negative as the BLH wetland degrades in adjustment to the longer hydroperiod.

Aquacultural practices can have neutral or negative effects on the buffering capacity of BLH sites, depending on the specific location of the developed ponds or impoundments and on the management regime implemented on the site.

QUANTIFICATION OF CRITICAL VALUES FOR CUMULATIVE IMPACTS

The purpose of this section is to illustrate how basin-level characteristics might be used as a basis for assessing and controlling cumulative impacts, rather than to propose specific values or regulatory options. The basic approach is to identify an acceptable performance of each function on a regional or watershed level; associate values of measurable, regional characteristics with that acceptable level; and use those critical values, in some way, as limits to further change in the characteristic. This approach is easiest to apply in cases where:

(1) there are nonlinear or qualitative changes in the function associated with changes in the characteristic (e.g., extinction or extirpation of a species population as opposed to a "marginal" decrease in numbers); and

(2) the scientific understanding of a watershed-level ecological process is well developed (e.g., watershed hydrology and the rapidly developing fields of landscape ecology and biogeography).

Approaches to quantifying critical values are suggested below for the three functions of maintenance of natural biotic diversity, streamflow mediation, and water quality.

Maintenance of Natural Biotic Diversity

The total area of habitat (e.g., bottomland hardwoods) required to support a viable population of certain species in an area can be estimated by considering the area required per individual or pair (e.g., home range or breeding territory) and a minimum population size (perhaps 50 individuals). This approach works best with endemic species having strict ecological requirements (i.e., stenotopic species). Other "edge-preferring" species may increase in numbers due to the same landscape changes that force an interior species to extinction or extirpation (Fig. 9).

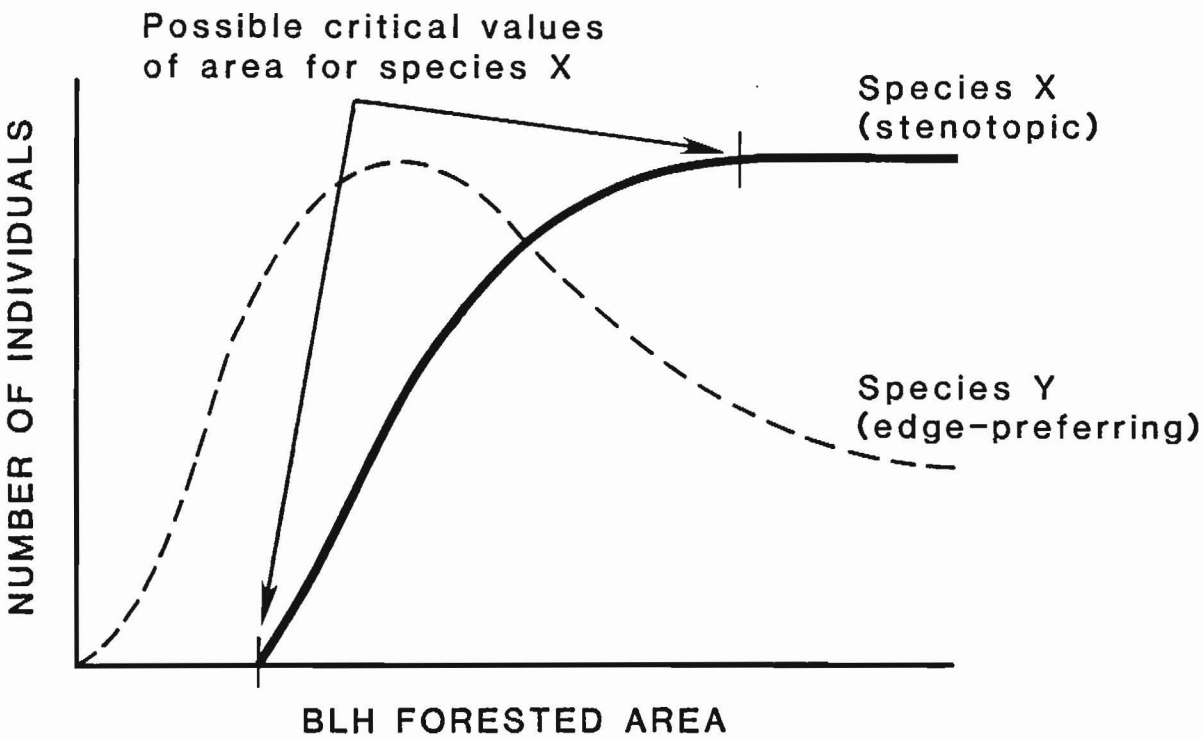

Figure 9. Generalized relationships of population sizes for stenotopic and "edge-preferring" species to BLH forested area.

Many plants and animals depend on continuous corridors of water or vegetation for dispersal and reestablishment. As these corridors become interrupted (linear continuity being lost), movement and dispersal are impaired and the value of resulting isolated patches declines. Harris (workshop presentation) presents some quantitative estimates of the required breadth of these corridors in terms of ecological zones of bottomland hardwoods in order to provide effective pathways for various species groups (Fig. 10).

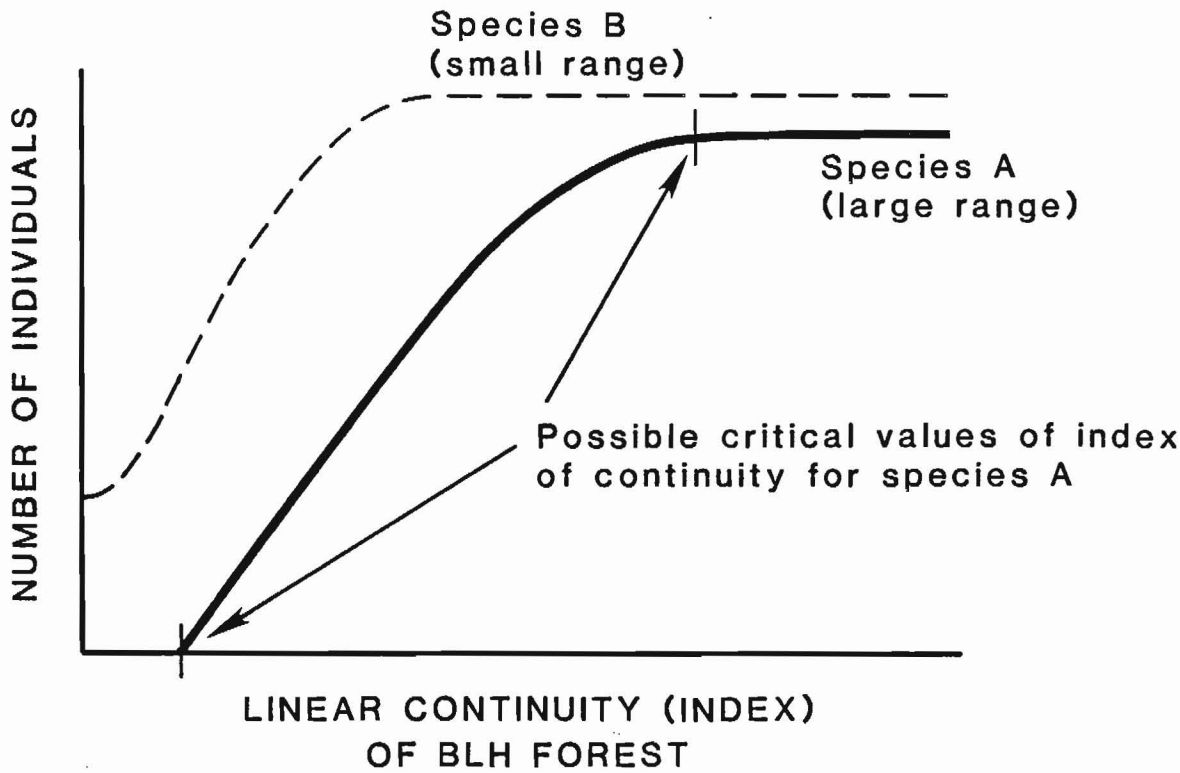

Figure 10. Generalized relationships of population sizes for species with small and large ranges to linear continuity (index) of BLH forest.

Streamflow Mediation

Downstream stage. Analysis of bottomland hardwood area versus downstream stage for representative floods (see Belt 1975) will show generally increased stage, for a given discharge, as bottomland hardwoods decrease. Increased stages translate to increased costs associated with higher levees or increased flooding downstream. Quantitative limits on bottomland hardwood conversion could be based on these costs versus benefits of conversion, or directly on some gross allowable increase in stage (U.S. Army Corps of Engineers 1972).

Flood storage modification. Storage volume versus discharge curves for different stream types may show characteristic detention rates. If these rates change appreciably, downstream flooding is increased, the stream becomes more unstable, and low river stages impede navigation. In a simulation model, Ogawa and Male (1983) (Fig. 11) showed how peak flow is expected to increase with loss of upstream wetlands. A quantitative limit might be formulated based on the percentage change in discharge.

Water Quality

The overall approach of working backward from acceptable cumulative standards to regulation of site-specific activities is well established in water quality regulation as a result of the passage of the Clean Water Act.

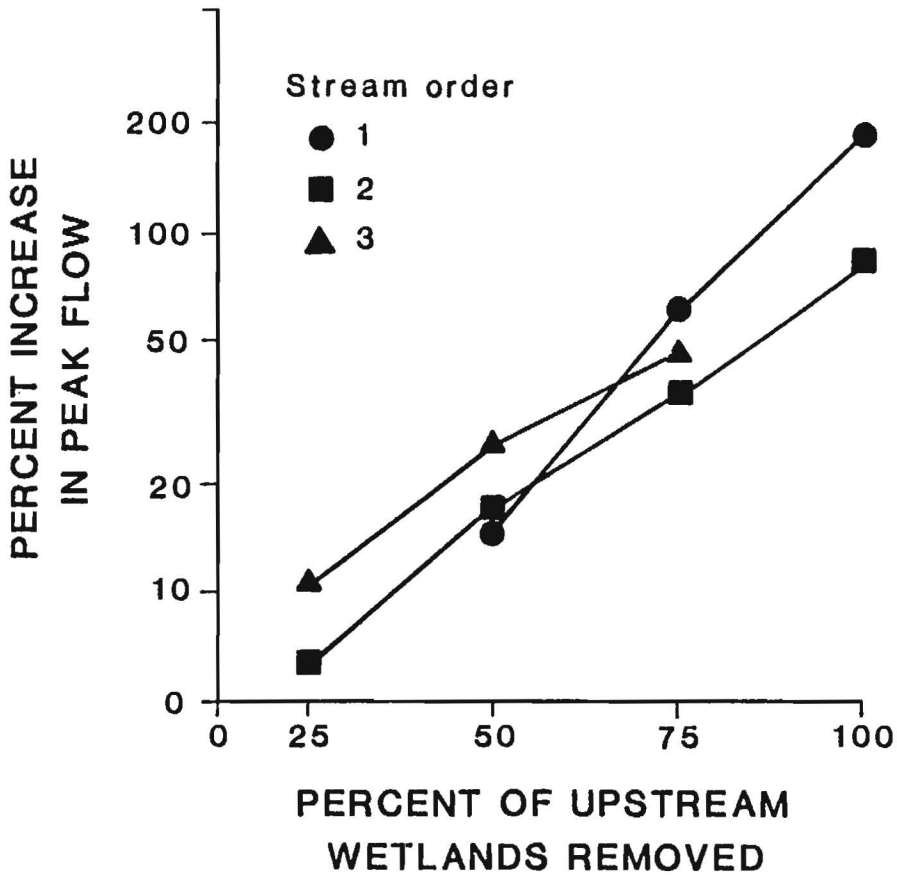

Figure 11. Results from hydrologic simulation model showing relationships between peak flood streamflow (130-yr flood) and wetland removal upstream (from Ogawa and Male 1983).

This approach could be extended to activities involving cover type conversions and hydrologic modifications by estimating yield or loading rates of sediment and agricultural chemicals from various cover types. Limits might also be set for bottomland hardwoods as buffer zones by considering their area and flooding characteristics in relationship to upslope runoff and overbank flooding from channels.

SUMMARY

The workgroup made a distinction between impacts of development activities on the local ecosystem (site-specific level) and those that occur over a larger area as a result of many individual development actions over time (cumulative level). Although the workgroup's interest and focus were primarily at the cumulative level, characteristics were also related to the site-specific ecosystem processes of food chain support and maintenance of natural biotic diversity, with attention to how these processes might be assessed in the context of an individual site. In fact, there was a considerable amount of overlap between the site-specific and cumulative levels, with the cumulative level primarily involving additional, synthetic measures of broad-scale landscape patterns. A considerable amount of complexity was identified in these relationships and in the relationships between development activities and the functions and characteristics. The complexity stems from interactions among characteristics (e.g., between community structure and hydrologic regime) and substantial variability across both sites and time.

Following the consideration of impacts of various activities on specific characteristics and functions, the workgroup subjectively ordered a set of nine activities on the following dimensions of general, cumulative impact:

(1) INTENSITY of the impact in the affected area;

(2) AREA affected, or spatial extent of the activity; and

(3) PERMANENCE, or the degree to which the activity involves lasting or irreversible changes.

The unweighted ranks are portrayed in Figure 12. Before discussing the results, it should be stressed that these are simple rankings and thus have some severe limitations. For example, the area dimension might be more properly quantified in terms of actual area measurements (e.g., square kilometers) to weight the relative differences more accurately.

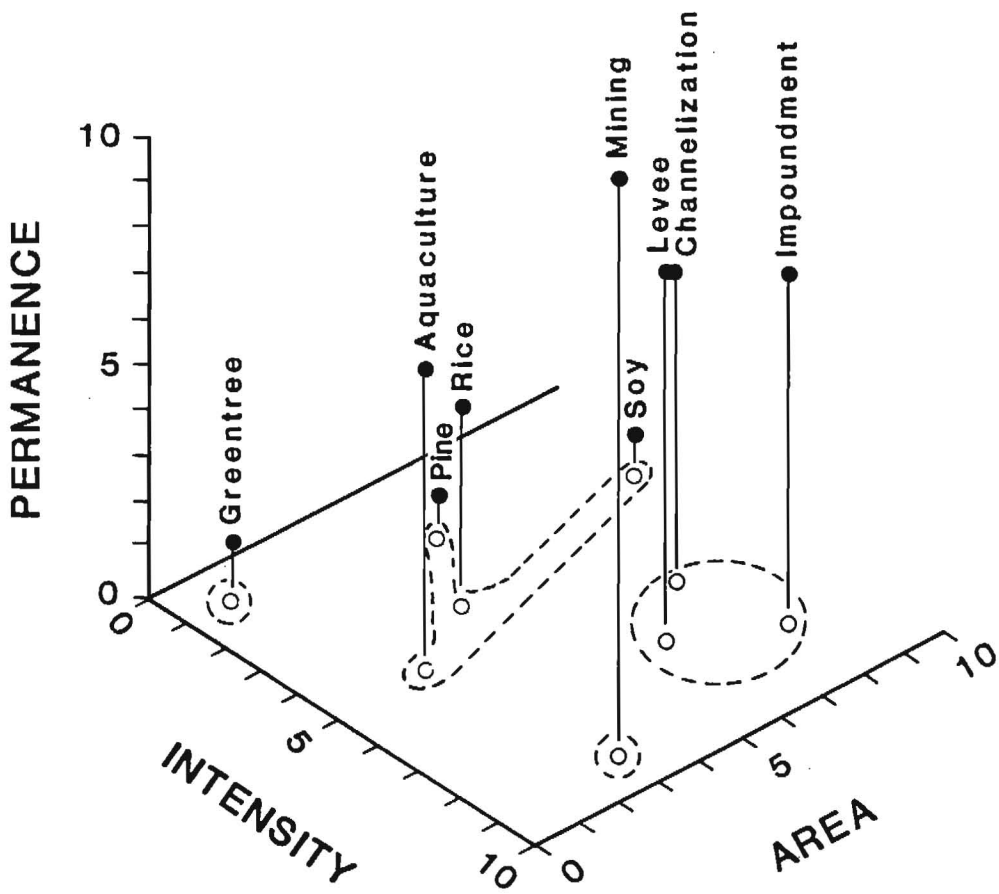

Figure 12. Simple ordination of activities by the importance of their cumulative impacts.

The activities can be considered in roughly four clusters.

1. Water resource development activities (impoundment construction, channelization, and levee construction) were judged to be very serious in terms of cumulative impacts because they combine relatively intense and pervasive impacts with a high degree of permanence.

2. Mining was ranked as very severe in terms of intensity and permanence, despite a relatively small areal extent. The mining activity considered here involved extraction of bulk material that was judged to constitute a major and permanent landform alteration. Petroleum and sulfer extraction have surface impacts that may also be severe. They are, however, more closely associated with 1 above (i.e., impoundment, channelization, and levee construction).

3. Conversion to soybean and rice agriculture, pine plantation, and aquaculture were grouped in a broad cluster of intermediate to low intensity and permanence. Conversion to soybeans was at an extreme edge of this cluster due to its large areal extent and conversion to pine plantation was at another edge due to its relatively low intensity (i.e., a woody vegetative community is maintained). These activities are similar in that they all involve primarily alteration of the vegetation with localized modification of the hydrologic regime. The aquaculture activity considered here was conceived as a relatively dedicated impoundment with landclearing, as might be typical of catfish farming, rather than a crawfish farming operation that might not involve landclearing.

4. Conversion to greentree reservoirs was judged as the least severe activity on all dimensions.

As a whole, the workgroup argued that there are important levels of analysis (e.g, watershed, regional landscape) above the site-specific ecosystem and, furthermore, that emerging scientific understanding of processes at these levels is sufficient to formulate regulation at these levels under the general heading of cumulative impacts. The basic approach would consist of the following.

1. Identifying "higher-level" functions and acceptable performance of those functions (e.g., maintenance of natural biotic diversity).

2. Identifying cumulative impact measures to quantify those functions. These would include both characteristics of the watershed or landscape that are causally related to performance of the functions (e.g., % of region in natural BLH forest) and "higher level" indices of performance itself (e.g., downstream hydrograph, natural species richness).

3. Identifying critical values of the cumulative impact measures.

4. Adopting differential regulation of activities based on the relationship between the current values of the cumulative impact measures and the critical values (e.g., regional limits).

Such an approach was outlined for several higher-level functions such as maintenance of natural biotic diversity and streamflow mediation. Observable characteristics and indices were proposed as cumulative measures and procedures were discussed for identifying critical values of those measures (e.g., using home range and minimum population size to determine critical values of regional habitat composition).

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CULTURAL/RECREATIONAL/ECONOMIC WORKGROUP REPORT

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INTRODUCTION

The Cultural/Recreational/Economic (CRE) Workgroup accepted a multifold charge at the workshop. First, the group identified certain characteristics of bottomland hardwood (BLH) ecosystems related to cultural, recreational, and historic functions. Second, the relationship between characteristics and functions was described. Third, the impacts of specified activities on BLH characteristics and functions were estimated. Fourth, alternative economic analysis techniques were discussed for use in analyzing the relative value of bottomland hardwoods in producing various "commodities and service flows" through the functions considered at the workshop.

ANALYSIS OF IMPACTS

The CRE Workgroup identified four functions of BLH ecosystems that may produce recreational and cultural commodities. These include sensory experience, recreation experience, information storage, and renewable harvesting. These four functions arise from the four values shown in Table 24. When combined with other inputs such as recreational equipment and personal time, the functions can produce the experiences and activities listed in the "uses" column of Table 24.

Table 24. Values functions, and potential uses of bottomland hardwoods.

Values	Functions	Uses
Aesthetic quality	Sensory experience	Boating Sight seeing
Recreation quality	Recreation experience	Boating Sight seeing Photography Wetland art Bird watching Canoeing, kayaking ATV use Sport fishing Sport hunting
Heritage	Information storage	Nature study Education, research Wetland art Photography Literary work Archeology/historic
Food, fish, fur fiber, timber	Renewable harvesting	Natural food gathering Commercial fishing Fur harvesting Herbaceous harvesting Timber and fiber harvesting

Characteristics that are important in assessing the performance of the four functions were identified to provide more measurable indicators of the impacts of various BLH development activities (Table 25). Activities that may impact the characteristics and functions are listed and summarized in Table 26. These activities were reported during a planning session at the workshop, and a set of activities was chosen for analysis with respect to all BLH functions considered at the workshop. Estimating the effects of these common activities on BLH characteristics and functions became the primary task of the CRE Workgroup. Results of that work are reported in the remainder of this section on analysis of impacts.

Table 25. Characteristics of cultural/recreational/economic functions performed by bottomland hardwoods.

Characteristic	Functions			
	Sensory experience	Recreation experience	Information storage	Renewable harvesting
Visual access	x			
Physical access	x	x		
Vegetation diversity	x			
Water quality	x	x		
Species richness	x			
Fauna	x			x
Flora	x			x
Water flow velocity		x		
Water depth minimum		x		
Stream pattern complexity		x		
Contiguity and size		x		
Historical/archeological			x	
Representative ecosystems			x	
Relict stands			x	
Existing documentation			x	
Presence of food species				x
Presence of finfish, shellfish				x
Presence of wildlife				x
Presence of fiber species				x

Table 26. Activities impacting the cultural/recreational/economic functions of bottomland hardwoods.

Activity	Comments
Renewable without transformation	
Commercial fishing	
Sport fishing	
Timber harvesting	
Water supply	
Hunting	
Fur harvest	
Recreation	
Leave it alone use	
Historical/archeological	
Preservation	
Asthetic/passive recreation	
Renewable with transformation	
Cropland	Require various combinations of clearing, brush control, draining, flood control, agricultural chemicals, impoundments, use of heavy machinery
Rice	
Other crops	
Aquaculture	
Silvicultural plantations	
Water resource development	
Includes flood control, impoundments, release schedules, channelization, levees, dredge/spoil areas	
Linear disruptions	
Powerline corridors	All require landclearing, landgrading and alteration, and chemical conditioning
Oil pipelines	
Coal slurry pipelines	
Water pipelines	
Highways and roads	
Drilling access	
Recreation trails	
Resource extraction	
Peat extraction	Removes resource
Oil and gas development	Subsidance
Borrow pits	Remove resources, change land level
Top soil, sand, gravel, phosphate, lignite coal	

Table 26. (Concluded)

Waste treatment and industrial processing	
Waste water treatment Cooling ponds Solid waste disposal Manufacturing and industrial operations Water-based transportation Waste water renovation	All remove surface cover and involve site preparation and some land-forming
Commercial/residential/military use	
Toxic Inert	Require removal of cover, site preparation, and possible filling
Summary of activities	
Removing cover Changing land contour Changing water regime Introducing foreign substances Natural harvesting Extracting materials (mining)	

SENSORY EXPERIENCE

The quality of sensory experiences in the landscape is related to a complex range of cultural, psychological, and environmental factors (Lee 1983). Sensory experiences in BLH involve nonconsumptive contacts between people and the environment. They depend on the physical, biological, and hydrological characteristics of the BLH ecosystem, the mode of experiencing it, perceptions of value by users, and the information gained by users. Newby (1971) described human perception of the environment as incorporating "the interaction of man's senses into a system whereby he is able to adapt to a world of constantly changing environmental conditions" (quoted in Lee 1983). Characteristics and activities shown in Table 27 are important in determining the quality of sensory experiences that may be produced by bottomland hardwoods and that may be impacted by various changes in land use. These characteristics include visual access, physical access, vegetative diversity, water quality, species diversity, fauna, and flora.

Visual Access

Visual access means that vistas are open to different environments. Four factors are identified by Lee (1983) as being important to visual preferences in the environments. Legibility involves the clarity or coherence of a scene, aiding in individual recognition of visual elements. Spatial definition primarily involves the arrangement of three-dimensional space within the visual array. It affects orientation and has a definite influence on individual perception and preference. Complexity involves the number and relative distribution of landscape elements. Finally, mystery concerns the promise of additional visual information and encourages an individual to enter a visual display in order to seek this additional visual data.

Table 27. Impacts of various activities on sensory experience as mediated through certain characteristics that contribute to the performance of this function.

Function: sensory experience										
Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U	I-O	I-D	C	L	P	A
Visual access	+-	-	-	0	-	0	-	+	-	-
Physical access	+-	-	-	0	-	0	+-	+-	+	-
Vegetation diversity	+	-	-	0	-	0	-	-+	-	-
Water quality	+	-	-	0	-	+	-+	0	0	-
Species richness	+	-	-	0	-	0	-	-+	-	-
Fauna	+	+-	+-	0	-	0	-+	-+	+-	-
Flora	+	-	-	0	-	0	-+	-+	+-	-
Overall impact on sensory experience		-	-	0	-	0	-	0	-	-

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on specific circumstances. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristics and the function. A minus indicates a negative correlation. A combination of signs indicates that the relationship may differ depending on specific circumstances.

As access to visual information increases, the sensory experience function of bottomland hardwoods also increases initially. The extent of this positive relationship is probably a long one, only turning negative when visitation demand enters the relationship. Then crowding, associated with the quality of visual access, may produce a negative impact on an individual's sensory experience.

All activities considered at the workshop were estimated to have a negative impact on sensory experience through visual access except water impoundments and levees (Table 27). Conversion to agricultural crops (rice or soybeans) destroys the natural scenic environment and conversion to pine plantations drastically changes the scenic environment. Channelization mars the environment and restricts visual access to views up and down the channelized stream. Aquaculture and on-site impoundments destroy the natural scenes, but there is no visual affect upstream or downstream unless the hydrologic regime is drastically altered. Only levees have a potential positive affect through visual access on sensory experiences. Levees can improve viewer elevation and increase visual access to more legible, spatially defined, and more complex environmental vistas, but can also block views if the observer is standing on either side of the levee.

Physical Access

Physical access indicates the degree of access to or within bottomland hardwoods by trail, road, or boat (Smardon 1983). Improved physical access has a positive effect on sensory experiences unless it becomes so convenient that individual enjoyment is impaired by crowding. Conversion of bottomland hardwoods to rice, soybeans, aquaculture, or on-site impoundments destroys the natural environments that create sensory experiences. Locations upstream or downstream of impoundments and aquaculture are little affected by these developments. Conversion to pine plantations improves access to surrounding bottomland hardwoods as well as to the new plantations themselves, while levees and channelization improve water-based access but may block foot access from one area to another.

Vegetation Diversity

Vegetation diversity generally interacts positively with sensory experience. This is especially true as variable height trees increase legibility, spatial definition, complexity, and mystery at wetland or water body edges. However, vegetation diversity may be inversely related to visual access if growth becomes too dense and pervasive to permit clear views of varied environmental vistas.

Conversion of bottomland hardwoods to rice, soybean production, pine plantations, aquaculture, and on-site impoundments drastically changes vegetation, resulting in severe reductions in sensory experience. Vegetation diversity is not affected upstream of an impoundment, and is not likely to be affected downstream unless drastic changes in the water regime are initiated. Vegetation diversity is reduced by channelization as flora outside the channel shifts to more mesic species and flora within the channel shifts to aquatic plants. Levees have a negative impact on vegetation diversity and thereby sensory perception at the exact location of the levee and may have either a positive or negative effect on lands influenced by the levee. Species mixes normally change as a result of a levee.

Water Quality

Sensory experiences of visitors to BLH resources are affected by the quality of water encountered during their stay. Threshold values for tactile, olfactory, and visual attributes of water are all important determinants of the sensory experience. Once the threshold levels have been achieved, further improvements in these water quality attributes go unnoticed.

Conversion of bottomland hardwoods to rice, soybeans, or aquaculture is likely to impinge negatively on sensory experiences through reductions in water quality caused by increased sediment loads and chemical concentrations.

The visual quality of water in shallow, windswept impoundments is likely to be reduced due to increased turbidity. Water quality upstream from an impoundment is likely to be unaffected and water downstream from an impoundment is likely to carry reduced sediment loads.

The quality of water in pine plantations that have been converted from bottomland hardwoods is expected to be unchanged because the land will still be forested after an initial period for stand establishment. Levees are also expected to be neutral in their effect on water quality, while channelization will have a negative effect in the short term due to increased turbidity and a positive effect later because of reductions in water stagnation.

Species Diversity

The quality of sensory experience is estimated to improve as animal species diversity increases. Diversity of species, and thereby the sensory experience, is drastically reduced when bottomland hardwoods are converted to rice, soybeans, aquaculture, and on-site impoundments, because the nature of land use and productivity is totally changed. Conversion to pine plantations also reduces species diversity through replacement of BLH habitat with a monoculture pine forest. Areas upstream and downstream from an impoundment are not likely to be affected.

Channelization reduces animal species diversity both in and outside the channel. Levees result in the elimination of many animal species at the levee site and changes in species mix in areas influenced by the levee. Whether species diversity increases or decreases in those areas is uncertain.

Fauna

A positive relationship is expected between total fauna and sensory experience throughout the relevant range of the production function. Aquaculture and on-site impoundments affect these relationships negatively. Potential changes in fauna upstream or downstream from impoundments are not expected to have noticeable effects on sensory experience.

Conversion of bottomland hardwoods to either rice or soybeans has a drastic effect on faunal species mix, but the effect on total fauna is uncertain. Conversion to pine forests also affects species mixes and total numbers in uncertain ways. Channelization causes reductions in fauna in the short run and a long-term shift in species, with uncertain implications for total populations in the long run. Animal populations are drastically reduced at levee sites and affected uncertainly in areas influenced by the levee.

Flora

Sensory experience is estimated to vary directly with vegetation growth. Conversion of bottomland hardwoods to rice, soybeans, aquaculture, or on-site impoundments results in drastic changes in plant species and reductions in flora. Conversion to pine forests is less severe and may result in species mix changes and either positive or negative changes in floral production. Areas upstream and downstream from impoundments are estimated to be unaffected. Near-term implications of channelization are expected to be drastic reductions in flora, with long-term effects uncertain. Vegetation under levees is at first destroyed, but the effect on land influenced by the levee may be either positive or negative.

Overall Impact

Unweighted tallies of the effects of activities on sensory experience through various relevant activities indicate that conversion of bottomland hardwoods to rice, soybeans, pine plantations, aquaculture, or on-site impoundments produces negative impacts. Channelization also has negative implications on sensory experience, with upstream and downstream impacts neutral. Only levees may have a positive effect on this function.

RECREATION EXPERIENCE

"Recreation is one of the largest sectors of the U.S. economy. Private expenditures on recreation goods and services account for more than 14% of personal consumption expenditures and 8% of total gross national product, according to Bever for the Third Nationwide Outdoor Recreation Plan" (quoted in Walsh 1986). Walsh also points out that private recreation expenditures exceeded expenditures on national defense or home construction in 1977. Outdoor recreation is an important and growing component of private recreation and preservation of remaining BLH forests for recreational use may be economically viable as well as ecologically sound. The challenge lies in correctly valuing the recreation experience function of bottomland hardwoods, because much of the recreational value is not established through consumer demand in well functioning markets.

This section of the CRE Workgroup Report estimates how characteristics of flow velocity, water depth minimum, stream sinuosity, physical access, contiguity and size, fauna and flora, and water quality affect the recreation experience function in bottomland hardwoods. Further, the impacts of various activities on recreation characteristics and functions are analyzed (Table 28). Characteristics chosen to analyze the performance of the recreation experience function lean heavily toward water-based recreation. This may be appropriate, because water plays such an important role in BLH ecosystems.

Water Flow Velocity

Recreational use of waterways for boating requires a minimum flow velocity that varies with the type of water craft being used. Once this threshold velocity is reached, the quality of the recreation experience remains fairly constant for a substantial range of flow velocities and then deteriorates as velocities become too high for safe navigation by various recreational water craft (R.C. Smardon, College of Environmental Science and Forestry, S.U.N.Y., Syracuse; unpubl.).

Table 28. Impacts of various activities on recreation experience as mediated through certain characteristics that contribute to the performance of this function.

Function: recreation experience

Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U	I-O	I-D	C	L	P	A
Water flow velocity	-	-	-	NA	0	0	+	0-	NA	-
Water depth minimum	+-	-	-	0	NA	+	+	0	0	NA
Stream pattern complexity	+-	-	-	0	-	+	-	0	0	NA
Physical access	+-	-+	-+	+	-	+	+	+	+	NA
Contiguity and size	+-	-+	-+	-	-	-	-	-	NA	-
Water quality	+	-	-	0	NA	I	-+	0	NA	-
Flora and fauna	+	-+	-+	-	-	-	-+	0-	+-	-
Overall impact on recreation experience	-	-	-	-	-	+	0	0	-	

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on specific circumstances. NA means not applicable. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation. A combination of signs indicates that the relationship may differ depending on specific circumstances.

Conversion of bottomland hardwoods to rice, soybeans, or aquaculture withdraws on-site land from recreational boating and is likely to reduce flows in adjacent streams. Water velocities on the stream side of a levee may increase, but not significantly, and velocities on the protected side of a levee are likely to decrease. Stream velocities at on-site impoundments obviously decrease, but the effect carried through to the recreation function was considered inconsequential. More consistent velocities downstream from the impoundment were also considered to have no effect on the function.

Streams and wet areas of bottomland hardwoods are not normally converted to pine plantations, so the stream velocity indicator is not applicable for that activity. Water velocity upstream from impoundments was also considered not applicable. Channelization, however, can provide increased stream flow velocity and improved access by larger recreational water craft.

Water Depth Minimum

Shallow waters physically and psychologically inhibit recreational boating and may preclude access to bottomland hardwoods by boat. Water depth required for access, launching, and navigation depends upon the type of water craft used.

Water depth is eliminated by conversion of BLH forests to rice or soybean farming. It is not applicable to pine plantation activities, because streams and wet areas cannot be converted to pine plantations successfully. While conversion to aquaculture and impoundments may increase water depth in some cases, these land uses are so different from bottomland hardwoods that varying water depths in this way was considered not applicable to a BLH recreation experience. Minimum depths of water upstream from impoundments are not affected, nor are water depths on the landward side of levees. Streams inside levees have sufficient minimum water depths for a greater part of the year than they had before levee construction. Channelization also increases water depth minimums, insuring a positive relationship between channelization and recreation experience acting through water depth changes.

Stream Pattern Complexity (Sinuosity)

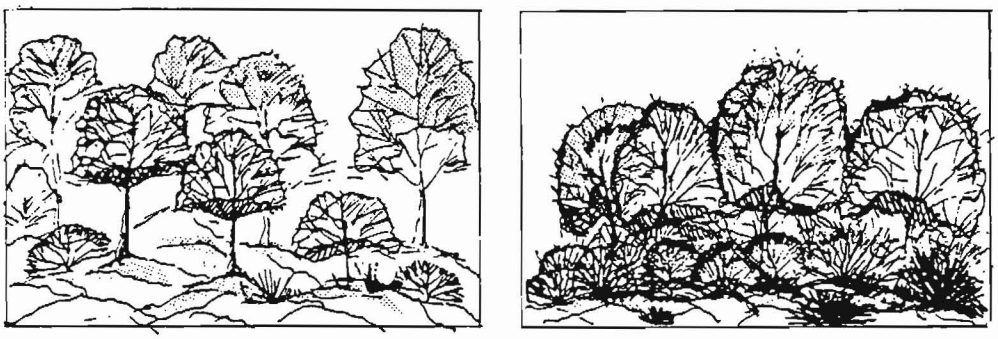
For a scene to evoke a positive visual response it must be both legible and complex. Legibility is related to an individual's ability to adapt or understand a visual experience; complexity is related to variation and surprise. Visual complexity has a positive effect on visual preference until the scene is no longer legible (Fig. 13). Finally, as complexity continues to increase, cognitive overload can result in feelings of chaos and way-finding problems. Interaction of these two attributes is an important determinant of recreational experience as a traveler encounters a series of views or "sequential glimpses" down a stream corridor (Lee 1983).

Conversion to rice, soybeans, aquaculture, or on-site impoundments eliminates most stream segments and straightens others. Channelization also has a strongly negative effect on recreation experience through reduced sinuosity of streams. Streams below impoundments have more stable flows and are somewhat less complex, while upstream areas are not affected by an impoundment. Levees are assumed to have no affect on recreational experience through changes in stream sinuosity.

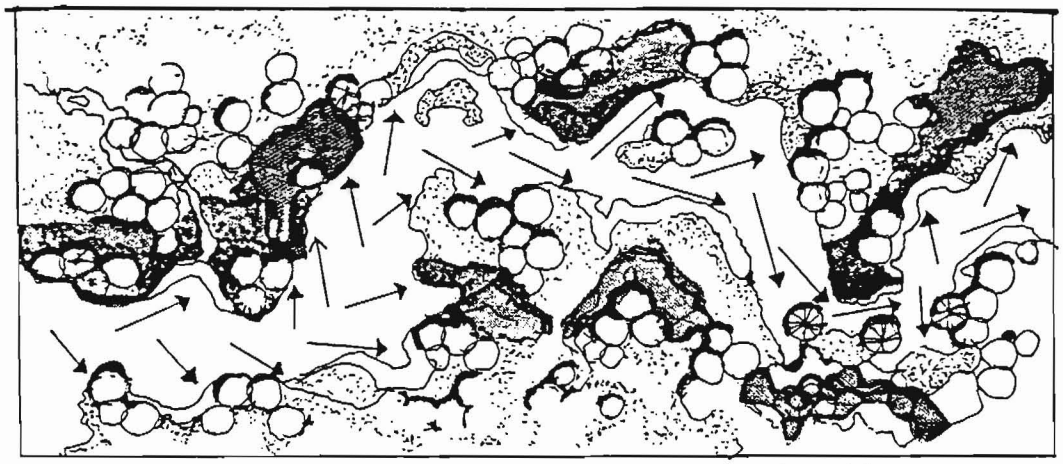
Physical Access

The collective enjoyment of people who visit recreation sites increases throughout substantial ranges of access functions. If access becomes so convenient that crowding of visitors becomes extreme, the relationship between further improvements in physical access and recreation experience may become negative.

On-site impoundments destroy bottomland hardwoods for recreation, as does conversion to aquaculture. Bottomland hardwoods upstream and downstream of impoundments, however, may offer improved recreation experiences because the impoundments may become new launching sites. Channelization and levees also improve recreational experience through increased access by boats. Land access is improved by conversion to pine plantations, rice, and soybeans.



Legible versus illegible vegetation.



A river traveler constantly receives important visual and spatial cues from the shoreline environment.

Figure 13. Legibility and sinuosity as determinants of the quality of recreation experience (from Lee 1983).

Access by water, however, is decreased when bottomland hardwoods are converted to rice or soybeans, resulting in potential reductions in water-based recreational experience.

Contiguity and Size

Recreation experience is positively correlated with wetland size up to a point. The relationship becomes negative as effective access becomes less practical. The size of a wetland can be effectively extended through contiguity between bodies of water providing boat passage ways.

Water impoundments destroy bottomland hardwoods on-site and interrupt stream contiguity between upstream and downstream locations, effecting a negative impact on recreation experience. Channelization affects recreation experience negatively by segmenting and dividing BLH wetlands, as do levees that break continuity and reduce the size of BLH areas.

Conversion of BLH forests to rice, soybeans, or aquaculture reduces tract size and interrupts contiguity, but conversion to pine plantations has no effect because plots are still timbered and natural wetlands are not converted.

Water Quality

Algae blooms may be sufficiently unsightly to discourage recreational use and chemical concentrations or high bacterial counts may pose a direct health hazard (Smardon, unpubl.). Once safe thresholds of water quality have been reached and no visual, tactile, or olfactory annoyances are noticed, further improvements in water quality go unnoticed and do not change recreation experience.

Conversion of BLH forests to rice, soybeans, or aquaculture may impair water quality during early stages through increased sediment and through all production phases by increased chemical concentrations. Water quality upstream from impoundments is unchanged, while on-site impoundments and downstream

impoundments affect water quality and recreation experience in uncertain ways. Chemicals and sediments may be trapped by the impoundment, improving water quality downstream. On the other hand, algae blooms, bacteria counts, and water temperature may be increased in the impoundment, decreasing water quality and recreation experience both in the impoundment and below it.

Channelization decreases water quality and thereby recreation experience during and shortly after development, but is likely to improve water quality and recreation thereafter by reducing stagnation. Levees were estimated to have no affect on water quality in the long run, as was conversion to pine plantations, because the land is still in timber. Short-term (construction period) effects of these two activities are negative because of increased sedimentation from construction work.

Flora and Fauna

Recreation experience varies directly with (is a positive function of) abundance of flora and fauna.

On-site impoundments and conversion to aquaculture produce drastic changes in plants and animals and have a negative effect on recreation experience. Communities downstream from impoundments change because of reductions in backwater flooding, with a resulting negative impact on recreation experience. Both upstream and downstream locations are isolated from each other, affecting recreation experience negatively through adverse impacts on large mammals.

Conversions to rice, soybeans, and pine plantations drastically change vegetation, but may either enhance or impair habitat depending upon species. This may result in either positive or negative effects on recreation experience. Channelization was estimated to have a negative impact on recreation experience through its short-term effects on flora and fauna and long-term species shifts that could be either positive or negative. Levees were judged to reduce flora and fauna, and thereby recreation experience on the land side, while leaving flora and fauna largely unchanged on the stream side of the levee.

Overall Impact

All except three of the activities considered at the workshop were estimated to produce negative effects on BLH recreation experience. Conversion of BLH ecosystems to rice or soybeans was estimated to have the strongest negative implications for recreation experience. Impoundments and conversions to aquaculture were judged to be less damaging to recreation experience, but were also estimated to have negative impacts.

Levees and pine plantations were judged to have no net affect on recreation experience in bottomland hardwoods when the positive implications from some characteristics are balanced against the negative and neutral impacts expected from other characteristics.

Only channelization may impact recreation experience in a positive way. Positive effects through enhanced waterflow velocity, greater water depth minimums, and improved access slightly outnumber the clearly negative impacts associated with impaired stream pattern complexity and reduced contiguity and size. Impacts on water quality, flora, and fauna may be either positive or negative, depending upon which species are being considered.

INFORMATION STORAGE

The information storage function of BLH ecosystems relates to the various attributes that are in themselves historic, are of historic or cultural significance, or have documented potential for future cultural and educational use including scientific research.

This function includes, by example, natural history. Explorations in the mid-Mississippi Valley reveal use of animals such as turtle, fish, waterfowl, beaver, and raccoon by early native Americans (Smith 1975). Cultural history also includes BLH ecosystems as a source of skins for clothing. Along the southern coast of Carolina, traders worked on agreements with Indians for

obtaining fur resources from the floodplains and swamps of the river systems in Georgia, Alabama, and Mississippi (Neiring 1978). There is also cultural history associated with logging of timber in southern river swamps.

Cultural and historical significance by association refers to BLH ecosystems that inspired or were the actual basis for art, literature, and music. Wetland art related to cultural history can be found in Elman (1972). Actual famous paintings of BLH forests include R.W. Meeker's (1829-1889) painting, Bayou Teche, of a river hardwood forest draped in spanish moss, and Muddy Alligators by John Singer Sargent (1856-1926). The literature heritage of wetlands in general is well treated by Fritzell (1978). Specific pieces of literature that relate to wetlands can be found in the works of Twain, Rolvaag, Faulkner, Hemingway, and Welty. Particular literary works that may relate to BLH ecosystems include Faulkner's The Bear and Twain's Huckleberry Finn. The musical heritage of BLH forests can be heard in such works as Ferde Grofe's Mississippi Suite and Frederick Delivo's Florida Suite.

Current and future potential informational uses of BLH forests include research on hydrology, biological productivity, nutrient cycling, diversity, and spatial patterns. The value of a particular site may be related to existing documentation of previous research. Specialized historical research such as palynology and archeology can be conducted only on sites with appropriate historical materials. Even more specialized are those sites that have rare or endangered species [e.g., the endangered Florida royal palm (Roystonea elata), an associate in cypress swamps].

One of the most promising potential uses of BLH forests is educational. As Neiring (1978) reminds us by example "the sight of a barred owl at midday, small alligators in floating water lettuce from the boardwalk in National Audubon Society's Corkscrew Cypress Swamp" can be very educational to the average person. Certain sites have high educational potential, especially if there are many species or features in close proximity to each other, or if they are close to educational institutions (Smardon 1975, 1978).

Presence of Historic/Archeologic Sites

The existence of historic/archeologic sites bears a strong positive relationship to the information storage function. No actions can be taken to "create" these sites, but the sites can be preserved. Many sites where artifacts such as arrowheads are abundant are located in higher BLH locations. Unfortunately, areas having high probabilities for containing these archeologic sites are also excellent sites for "borrowing" fill and construction materials.

Conversion of BLH forests to rice, soybeans, aquaculture, or on-site impoundments runs the risk of severe disturbance or covering of historic/archeologic sites, thereby impairing this function (Table 29). Locations upstream and downstream from impoundments are unaffected. Pine plantations may result either in the discovery and potential protection of historic/archeologic sites or their complete destruction if they are not discovered when BLH forests are converted to pines.

Channelization has a high probability of total disruption of historic/archeologic sites during construction. Levees are also likely to be totally destructive at the dredge or fill location. However, BLH forests protected from flooding by the levee may protect historic/archeologic sites while BLH forests on the water side of the levee are likely to have deeper, higher velocity water that may damage historic/archeologic sites.

Representative Ecosystems

Ecosystems that are representative of natural BLH forests are positively correlated with information storage. This characteristic is affected very negatively when bottomland hardwoods are converted to rice, soybeans, aquaculture, or on-site impoundments. BLH forests upstream and downstream are not likely to be changed. Conversion to pine plantations also destroys the representative ecosystems characteristic and replaces it with a monoculture. Channelization destroys some representative BLH ecosystems and segments other stands, affecting the function negatively. Bottomland hardwoods directly

Table 29. Impacts of various activities on information storage as mediated through certain characteristics that contribute to the performance of this function.

Function: information storage										
Characteristic	Relationship of characteristic to function[2]	Activity[1]								
		R	S	I-U	I-O	I-D	C	L	P	A
Historic/ archeological	+	-	-	0	-	0	-	--+	0-	-
Representative ecosystems	+	-	-	0	-	0	-	0--	-	-
Relict stands	+	-	-	0	-	0	-	0--	-	-
Existing documentation	+	NA	NA	NA	NA	NA	NA	NA	NA	NA
Overall impact on information storage	-	-	0	-	0	-	-	-	-	

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on specific circumstances. NA means not applicable. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

impacted by levees are destroyed as representative ecosystems, but land on the unprotected side of the levee remains unchanged because it continues to be flooded periodically. BLH forests protected by the levee are either unaffected or impacted negatively, depending upon the amount of change in the water regime caused by the levee.

Relict Stands

Relict stands either currently exist or they will not exist during the time period relevant to this analysis. When they do exist, relict stands have a very positive relationship to the information storage function. They are affected by activities exactly as representative systems are affected, for identical reasons, except that when relict stands are discovered during pine plantation conversion, they are more likely to be preserved.

Existing Documentation

Existing documentation consists of photographic materials, paintings, and literature that describe bottomland hardwoods for current visitors, vicarious observers, or intergenerational transfer. To the extent that it already exists, documentation is unaffected by any activity affecting bottomland hardwoods. However, BLH forests provide the opportunity for further documentation in the future. Any activity that interferes with natural BLH ecosystems has a negative effect on these future documentation opportunities.

Overall Impact

No activity considered during this analysis was estimated to have a net positive effect on information storage through characteristics identified and analyzed by the workgroups. In fact, only one positive relationship was found in the entire analysis (Table 29).

Conversion of bottomland hardwoods to rice, soybeans, aquaculture, or on-site impoundments, as well as channelization, were all assumed completely negative in their effects on the information storage function that can be provided by BLH ecosystems.

RENEWABLE HARVESTING

Renewable harvesting includes production from agricultural crops, aquaculture, and silviculture, as well as harvest from natural vegetation. It excludes mining and extraction of peat. Relationships between the renewable harvesting function, its characteristics, and specific activities are shown in Table 30.

Presence of Food Species

The presence of food species is positively correlated with the renewable harvesting function. Conversion of BLH forests to rice or soybeans dramatically increases the amount of renewable food that can be grown, even though it is a much different crop than the more "natural" one. This effects a positive change in the renewable harvesting function. Levees also have a positive effect because they improve access to foods. Conversion to pine plantations may have either a positive or negative impact depending upon the species being harvested.

Aquaculture and on-site impoundments place land under water and eliminate production of harvestable vegetation. Upstream and downstream production potential are likely to be largely unchanged. Channelization reduces renewable harvest through loss or displacement caused by the channel itself and by making some land more wet and other land more dry.

Table 30. Impacts of various activities on renewable harvesting as mediated through certain characteristics that contribute to the performance of this function.

Function: renewable harvesting										
	Relationship of characteristic	Activity[1]								
Characteristic	to function[2]	R	S	I-U	I-O	I-D	C	L	P	A
Presence of food species	+	+	+	0	-	0	-	+	+-	-
Presence of finfish, shellfish	+	-	-	0	+	0	-	+	NA	+
Presence of wildlife	+	-+	-+	0	+-	0	-	+	+-	+-
Presence of fiber species	+	-	-	0	-	0	+-	+	+	-
Overall impact on renewable harvesting	-	-	0	-	0	-	+	+	-	

[1]A plus indicates that the function is enhanced due to the impact of the activity on the characteristic. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on specific circumstances. NA means not applicable. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site, I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]A plus indicates a positive correlation between the characteristic and the function. A minus indicates a negative correlation.

Presence of Finfish and Shellfish

The presence of finfish and shellfish is positively correlated with food harvesting. Conversion of BLH forests to rice or soybean production eliminates these two groups of animals. Channelization is likely to reduce finfish and shellfish abundance also, especially in the short-term. The degree of impairment in the long-term depends upon management practices that may maintain or restore bank shading, instream riffles, pools, and segments of old channels.

On-site impoundments and conversions to aquaculture were estimated to increase shellfish and finfish production and thereby improve the renewable harvest function of bottomland hardwoods. Stream reaches upstream or downstream of impoundments are not likely to be significantly impacted.

Conversion to pine plantations does not occur on lands that are sufficiently wet to be of significant importance in finfish or shellfish production; this change in land use is therefore not applicable. Levees were estimated to increase harvest of finfish and shellfish through improved access.

Presence of Wildlife

The presence of wildlife is positively related to renewable harvesting. Wildlife abundance and harvesting may be affected either positively or negatively by rice and soybean production, on-site impoundments, conversion to pine plantations, or conversion to aquaculture, depending upon the particular wildlife species being harvested. Habitats may be drastically changed by any of these activities, but food supplies can also be increased for some species. Impoundments and aquaculture may also improve habitat for some waterfowl.

Channelization disrupts habitat in the short-term and segments ranges in the long-term. Only levees have a clearly positive impact, through improved access, on renewable harvesting.

Streams below or above impoundments were assumed not to change significantly from the effects of the impoundment.

Presence of Fiber Species

Renewable harvesting is a positive function of the presence of fiber species. Conversion of BLH forests to pine plantations has a strong positive effect on fiber harvesting because yields per acre are improved. Levees can increase fiber harvest through improved access, while channelization is likely to reduce fiber harvest because of losses due to channelizing and clearing.

Conversion of BLH forests to rice, soybeans, on-site impoundments, or aquaculture destroys fiber production capabilities. It was assumed that downstream and upstream areas are unchanged by impoundments.

Overall Impacts

Levees have a clearly positive effect on renewable harvest by improving access. Conversion to pine plantations also has a modestly positive net effect on the renewable harvest function. All other activities have strong negative effects, with the exception that impacts upstream and downstream of an impoundment were assumed to be negligible.

SUMMARY

The CRE Workgroup interpreted its charge to include two separate activities. The first activity, which was dominant in terms of time allocated to the efforts, was the description of how certain characteristics of BLH forests relate to important BLH functions and how potential activities may impinge upon these characteristics and functions. The second activity was the exploration of means by which the information gathered in the first activity could be organized for presentation in an economic format. Only a brief

outline of this second activity is presented here with the expectation that the third workshop will pursue it in the detail necessary to create an operational procedure.

All except two of the impacts of the various activities on recreational and cultural functions were negative or neutral. Levee construction and conversion to pine plantations were estimated to have a net positive impact on the renewable harvesting function (Table 31).

Table 31. Summary of the net impacts of various activities on cultural/recreational/economic functions.[1]

	Functions			
Activities	Sensory experience	Recreation experience	Information storage	Renewable harvesting
Conversion to rice, soybeans	-	-	-	-
Conversion to pine plantations	-	0	-	+
Impoundments, aquaculture	- on-site 0 upstream 0 downstream	- on-site - upstream - downstream	- on-site 0 upstream 0 downstream	- on-site 0 upstream 0 downstream
Channelization	-	0	-	-
Levee construction	0	0	-	+

[1]The impact shown in each cell is a composite judgement of the CRE Workgroup based on individual weighting of the positive, negative, and neutral effects of the various activities on the characteristics. A plus indicates that the function is enhanced by the activity. A minus indicates that the function is impaired. A zero indicates no net effect.

From the perspective of analytical economics, the CRE Workgroup in the first activity was attempting to describe some "production functions" for bottomland hardwoods, with characteristics serving as resource inputs in the production process. The approach relates the potential for bottomland hardwoods to produce desirable service flows (i.e., recreation experience) to varying levels of resource inputs (e.g., physical access or vegetation diversity). In principle, the CRE Workgroup thus provided supply relationships. This was also true for the other workgroups. They described the levels of service flows or commodities (fisheries or wildlife for example) obtained from bottomland hardwoods with various modifications.

Description of the supply potential or capabilities of bottomland hardwoods is necessary, but not sufficient, to analyze aggregate human values of BLH functions, either relative to each other or relative to other functions of bottomland hardwoods that were not considered at the workshop (e.g., the benefits of conversion to cropland or shopping centers). The demand (i.e., marginal values) for various BLH commodities or functions must also be estimated if relative values are to be used in resource allocation decisions.

The second activity of the CRE Workgroup considered various valuation techniques that could be used to compare the relative values of bottomland hardwoods in producing alternative commodities. Economic markets, least cost replacement, and ordinal valuing techniques were all considered. Matching of valuation techniques with BLH service flows or commodities (functions) depends upon cost and availability of information, existence of real or pseudo markets, and temporal/spatial scale. Table 32 presents a preliminary matching of valuation techniques with BLH functions analyzed by the CRE Workgroup.

Table 32. Methods of estimating BLH "values", with examples.

Method	Examples
Least cost replacement	By item -- renewable harvest By service -- information storage
Market values	By market price -- recreation experience By comparable sales -- recreation experience By simulated price -- recreation experience, sensory experience Travel cost method Contingent value method Hedonic method
Ordinal valuing techniques	Information storage, heritage, culture, historic Unit-day values Delphi techniques Multiple objective processes

The capability to estimate the demand for various BLH functions or commodities is an important element of valuation not provided by descriptions of production processes alone; and the capability to perform relative valuation analyses seems important in the policy formulation stage scheduled to begin at the next workshop. The CRE Workgroup developed the following suggestions for performing relative valuations.

1. Develop a generic appraisal process that includes several levels of valuation, ranging from market prices and simulated prices, to intangible or nondollar valuations. These valuations may be organized into National and local accounts like those used in the principles and guidelines developed by the Water Resources Council.

2. Establish some hierarchy of characteristics that implies various levels of importance of bottomland hardwoods. The level of quantification required and the order of collecting information in suggestion 1 will depend upon these designations.

3. Collect professional primary data and review literature for the BLH systems of interest. This work should include human use values, functions, and proposed activities in bottomland hardwoods. Human use values can be divided into the components shown in Figure 14 for analytical purposes. Rigor and information costs should vary directly with the importance of the specific case and a dollar value may not be used in every case. Existing budget information should be used to make the appraisals whenever possible. The analysis and reference materials, including data sources and models, should be accessible and understandable to regulatory and higher level decisionmakers in addition to the analysts who are responsible for developing them. This "generic" information should include sufficient quantification and scientific credibility to establish its utility in the regulatory review process. It must be current, relevant, and testable in terms of reliability, validity, and sensitivity.

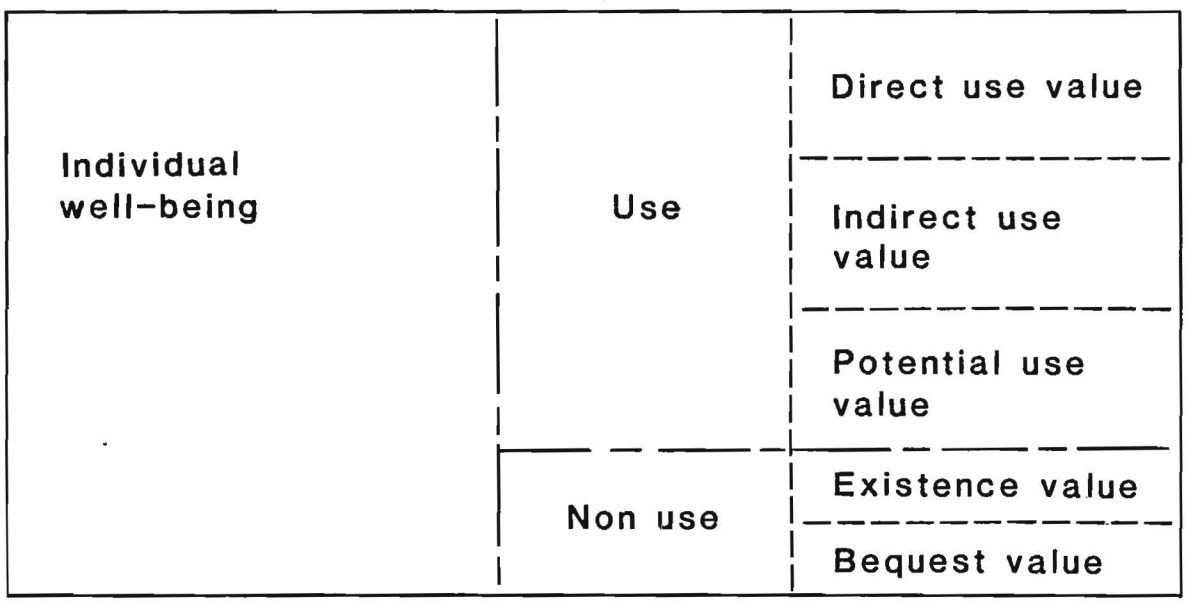


Figure 14. Components of economic value that contribute to individual well-being.

4. Other considerations:

   a. Recognize the difference between the regulatory process this system is being designed for and the project planning work of various agency planning teams.

   b. Be careful to not equate "leaving alone" with optimal biological management, even when managing natural resources for natural use objectives.

   c. Be careful to not force, or permit, use of information in some unintended way, like use of an inappropriate numerare or unit of measure.

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WORKSHOP SUMMARY

James Roelle

OBJECTIVES

Bottomland hardwood (BLH) wetlands are recognized as important natural resources because of the functions they perform and the values that people attribute to those functions. In many areas, significant losses of these wetlands are occurring to various development activities. The basic question being addressed in this series of workshops is how existing legislative and regulatory authorities can best be used to protect the functions performed by BLH wetlands and hence the values associated with those functions.

In the first workshop in the series, participants were asked to examine a zonation concept (Clark and Benforado 1981) as a means of characterizing variations in the functions performed by various types of BLH ecosystems. The responses from that workshop indicated that the zonation concept does not describe the variability in the functions performed sufficiently well to allow its use as the sole basis for developing a regulatory framework (Roelle et al. 1987). The extent to which functions are performed by a particular BLH site depends also on a broader spatial context and/or site-specific factors that are not adequately characterized by concomitant variations in hydrology, soils, and vegetation as described in the zonation concept.

With this response in mind, two objectives were established for the second workshop: identification of more specific characteristics that determine performance of functions; and analysis of the impacts of various activities on the functions. In an attempt to achieve some consistency in the way the workgroups approached these objectives, five basic questions were asked.

1. What are the functions performed by BLH ecosystems?

2. What are the most important activities that impact those functions?

3. What characteristics determine the extent to which the functions are performed by a particular BLH site?

4. How do various developmental activities affect these individual characteristics?

5. Considering the effects on individual characteristics, what is the overall impact of the activities on the functions?

These questions were posed in the context of a particular BLH site because many of the important regulatory decisions affecting bottomland hardwoods are made on a site-specific basis.

RESULTS

FUNCTIONS

The six workgroups identified a total of 23 functions performed by BLH ecosystems (Table 33). Some of these functions are obviously duplicative. For example, the streamflow mediation function as conceived by the Ecosystem Processes Workgroup is really the cumulative counterpart of two functions (flood storage and velocity reduction) considered at a more site-specific level by the Hydrology Workgroup. Similarly, the transforming and filtering function encompasses several more specific functions identified by the Water Quality Workgroup.

In addition, the total number of functions listed in Table 33 is the result of various degrees of lumping and splitting by the workgroups. For example, the Wildlife Workgroup specifically noted three different ways that the wildlife support function(s) might be conceived. Similar distinctions can

Table 33. Summary of BLH functions identified by the workgroups.

Workgroup	Functions
Hydrology	Flood storage Velocity reduction Ground water discharge modification
Water Quality	Sediment retention Erosion control Nutrient retention and transformation Contaminant retention and transformation
Fisheries	Habitat for finfish Habitat for shellfish
Wildlife[1]	Habitat for wood ducks Habitat for wintering dabbling ducks Habitat for black bear Habitat for white-tailed deer Habitat for migrating passerines
Ecosystem Processes	Maintenance of natural biotic diversity, cumulative level Maintenance of natural biotic diversity, site-specific level Food chain support Streamflow mediation Transforming and filtering (water quality)
Cultural/Recreational/ Economic	Sensory experience Recreation experience Information storage Renewable harvesting

[1]The functions identified by the Wildlife Workgroup were considered only as representative examples, as opposed to a comprehensive list.

be made concerning several other functions, including contaminant retention and transformation (a single function or a separate function for each contaminant?) and recreation experience (a single function or a separate function for each type of recreation?).

For these reasons, the total number of functions must be interpreted and used with some care. It would be inappropriate, for example, to sum the number of functions that depend on a particular characteristic as a measure of the importance of that characteristic. Nevertheless, the functions as listed in Table 33 do seem to cover, in some combination, all of the functions considered in other evaluation schemes (e.g., Adamus and Stockwell 1983).

ACTIVITIES

It is evident from Table 1 (see INTRODUCTION, page 4) that there are many activities that can impact the functions of BLH ecosystems and that these activities can and do occur in many different combinations. In an effort to achieve some consistency among the workgroups, seven activities [conversion to rice, conversion to soybeans, impoundment construction (upstream of site, on-site, and downstream of site), channelization, levee construction, conversion to pine plantation, and conversion to aquaculture] and specific actions associated with each were identified for analysis (Table 2; see INTRODUCTION, page 5). In addition, some of the workgroups added specific activities (e.g., oil and gas development, mining, greentree reservoir operation) perceived to be of particular importance.

While identification of these activities for analysis did achieve some of the desired consistency, considerable interpretation was still required on the part of participants. For example, the purpose of a particular activity can often influence its effects on BLH functions. The Wildlife Workgroup noted that mainline levees that prevent floodwaters from reaching forested sites may have far different impacts than floodway levees that store excess water in forested areas during high flows. In addition, the overall impact of many

activities (e.g., levee construction) is highly dependent on whether consideration is limited to the area actually disturbed during development, is extended to include the area where the flood regime is altered, or is further extended to include other activities (e.g., landclearing) that may be induced. The potential for such differences in interpretation must be kept in mind in comparing results across workgroups. The Water Quality Workgroup, for example, generally limited its considerations to direct effects, while noting the importance of indirect and induced effects.

CHARACTERISTICS

The workgroups were successful in identifying a variety of characteristics that are important in determing the extent to which the various functions are performed. Some characteristics, such as stream sinuosity, slope, surface roughness, and flooding frequency and duration, were identified, in one form or another, by several workgroups. Size of the BLH tract was also mentioned frequently, either alone or in combination with some other measure (e.g., areal/stage relationship, effective size relative to the requirements of a particular species). Furthermore, large, continuous tracts of BLH forest were identified by two workgroups (Wildlife, Ecosystem Processes) as potentially more important than the same area composed of small tracts for several reasons. These include: provision of a diverse array of sites that support a full set of species with narrow habitat requirements; maintenance of patch-dynamic processes whereby shade intolerant species can occur in all life stages; maintenance of genetic interchange and diversity; maintenance of biologically viable populations of large, terrestrial organisms; and maintenance of floral and faunal assemblages that have community and trophic integrity and are thus relatively easier to conserve and manage.

In contrast to these similarities, there were also significant points of divergence. A few characteristics were identified as being positively related to some functions and negatively related to others. For example, vegetation cover was indicated as positively related to velocity reduction and fishery habitat, but negatively related to flood storage. Other characteristics were judged to be related to the performance of a particular function, but not in a consistent way. The Ecosystem Processes Workgroup identified several characteristics that might be positively or negatively related to a particular function depending on factors such as initial conditions, regional context, and interactions. Similarly, the Cultural/Recreational/Economic Workgroup identified several characteristics that appear to be important only within certain ranges of values. These points will be extremely important if there is ever any attempt to use these kinds of characteristics as part of an assessment tool.

Finally, there was significant variability in the extent to which the workgroups were able to specify the important characteristics in terms of measurable parameters. In general, this appears to have been more difficult for those functions that are highly dependent on spatial context (e.g., ecological heterogeneity) and/or large numbers of interacting factors (e.g., water quality, presence of wildlife species). Measurable parameters corresponding to many of these characteristics could probably be identified given more time than was available at the workshop.

IMPACTS

With minor exceptions as noted above (i.e., cases where initial conditions, spatial context, interactions, and thresholds are important), the workgroups were able to describe the impacts of the various activities on the functions as mediated through individual characteristics (see tables in the workgroup reports). In addition, several of the workgroups provided an estimate of the net effect of each activity on each function, considering the impacts on all of the characteristics. Table 34 presents those net impacts, including my own interpretation for those cases where summary information was not provided by the workgroup.

Table 34. Summary of the impacts of various activities on the functions identified by the workgroups.

Function	Activity[1]								
	R	S	I-U	I-O	I-D	C	L	P	A
Hydrology									
Flood storage capacity	-	+	0	-	0	+	-	+0	-
Velocity reduction	-	-	0	NA	0	-	-	-+0	-
Ground water discharge modification	-	+	0	-	+	-	-	+	-
Water Quality[2]									
Sediment retention	-	-			-	-	-	-	-
Erosion control	-	-			0+	-	-	0	-0
Nutrient retention and transformation	-	-			-	-	-	-	-
Contaminant retention and transformation	-	-			-	-	-	-	-
Fisheries									
Finfish habitat	-	-	-	-	-	-	-	-	-
Shellfish habitat	-	-	0	-	-	-	-	-	-
Wildlife									
Wood duck habitat	-	-		-		-	-	-	-
Wintering dabbling duck habitat	-	-		-		-	-	-	-
Black bear habitat	-	-		-		-	-	-	-
White-tailed deer habitat	-	-		-		-	-	?	-
Migrating passerine habitat	-	-		-		-	-	-	-
Ecosystem Processes[2]									
Maintenance of natural biotic diversity, cumulative level	-	-		-		-	-	-	-
Maintenance of natural biotic diversity, site-specific level	-	-		-		-+	-+	-	-
Food chain support	-	-		-		-	-	-	-
Streamflow mediation	-	0		+		-	-	0	0+
Transforming and filtering	-	-		-+		-	-+	-	-0

Table 34. (Concluded)

Function	Activity[1]								
	R	S	I-U	I-O	I-D	C	L	P	A
Cultural/Recreational/Economic									
Sensory experience	-	-	0	-	0	-	+	-	-
Recreation experience	-	-	-	-	-	+	0	0	-
Information storage	-	-	0	-	0	-	-	-	-
Renewable harvesting	-	-	-	-	-	-	+	+	-

[1]A plus indicates that the function is enhanced by the activity. A minus indicates that the function is impaired. A zero indicates no impact. A combination of signs indicates differing impacts depending on initial conditions, multiple causal pathways, time since the activity was initiated, or interactions. NA means not applicable. R = conversion of site to rice, S = conversion of site to soybeans, I-U = impacts upstream from an impoundment, I-O = impacts from an impoundment on-site (except for the Ecosystem Processes Workgroup, where I-O indicates impoundment impacts in general), I-D = impacts downstream from an impoundment, C = channelization of stream adjacent to site, L = levee construction on-site, P = conversion of site to pine plantation, A = conversion of site to aquaculture.

[2]Workgroup did not summarize impacts. Entries in the table are the author's interpretation.

The Hydrology Workgroup identified development activities that remove portions of the active floodplain (e.g., levee construction) as being most detrimental to the flood storage and velocity reduction functions. In addition, activities that decrease resistance to water flow (e.g., landclearing and leveling) were judged to impair significantly the ability of BLH sites to reduce floodwater velocities. Similar conclusions were drawn by the Water Quality Workgroup regarding functions such as sediment retention, erosion control, and the retention and transformation of nutrients and contaminants. Performance of these functions depends importantly on water velocity (i.e., lower velocities allow settling of suspended sediments and reduce erosion rates), as well as surface area and contact time (i.e., water spread over larger areas for longer times provides greater opportunity for retention and transformation of nutrients and contaminants).

Conclusions from the Fisheries and Wildlife Workgroups were similar. Both workgroups identified the natural flooding regime, natural vegetation, and natural topography as important characteristics in the performance of the fish and wildlife support functions. Activities (e.g., conversion to agriculture, levee construction, and channelization) that disrupt these characteristics were judged to have the greatest impacts on these functions.

The Ecosystem Processes Workgroup conducted a simple ordination of the activities according to the importance of their cumulative impacts by subjectively ranking the activities along the dimensions of intensity of the impact, area impacted, and permanence of the impact. Viewed from this perspective, the activities appeared to fall into four clusters.

1. Water development activities, which were judged to be very serious because of a combination of relatively intense, pervasive, and permanent impacts.

2. Mining (an activity not considered by all of the workgroups), which was judged to be very severe in terms of intensity and permanence, less so in terms of areal extent.

3. Conversions to rice, soybeans, pine plantations, and aquaculture, which were judged to be of intermediate to low intensity and permanence, with conversion to soybeans the most detrimental because of its large areal extent.

4. Conversion to greentree reservoirs (another activity considered only by the Ecosystem Processes Workgroup), which was judged to be least severe along all of the dimensions.

Finally, nearly all of the activities were judged to have negative or neutral impacts on the cultural/recreational/economic functions. Possible exceptions that were noted include activities (e.g., levee construction) that may improve access and others (e.g., conversion to pine plantation) that may have a positive impact on renewable harvesting.

Thus, the vast majority of the entries in Table 34 indicate negative impacts, because, to a greater or lesser extent, all of the activities disrupt the natural vegetation and natural hydrologic (flooding) regime that are crucial to the performance of the functions. However, the entries in Table 34

should be interpreted as the general or most common case. It should be recognized that, under particular circumstances, almost any of the activities can have positive effects on at least some functions. Whether the impacts are positive or negative in a particular case is importantly dependent on factors such as the nature of the area being replaced or altered, geographic location and extent of the activity, the specific purpose of the activity, development techniques, and future management goals and approaches.

Despite the possibility that positive effects can occur in some circumstances, there was universal agreement among the workgroups that the cumulative impacts of development actions on the functions of BLH ecosystems are almost always negative. To the extent that the functions depend on natural vegetation and hydrology, and to the extent that development activities alter these components of the ecosystem, this is an inescapable conclusion. Perhaps the dominant theme of the entire workshop was that some method of relating cumulative impacts and the site-specific decisionmaking process must be found if the functions of BLH ecosystems are to be preserved. In addition, the Cultural/Recreational/Economic Workgroup was careful to point out that an objective analysis of the value of BLH ecosystems must consider the demand for the natural functions and also the potential value of alternative goods and services that BLH sites might provide.

APPLICABILITY

It appears, therefore, that a successful approach to more effective preservation of the functions of BLH ecosystems will have to deal with impacts at both the site-specific and cumulative levels. The focus of the workshop described in this report was the site-specific level, due to the fact that many of the important decisions in the current regulatory framework are made on a case-by-case basis.

Considerable progress was made in describing characteristics that are important to the performance of BLH functions at the site-specific level. These characteristics include many that attempt to address the issue of spatial context and are thus closely related to the question of cumulative impacts. Nevertheless, several questions remain. One of the most important of these concerns information availability. Decisions at the site-specific level must often be made when resources that can be devoted to gathering information are limited. Information availability will therefore be a critical factor in determining the applicability of the concepts discussed in this report.

Table 35 attempts to address the issue of information availability by grouping the characteristics identified by the workgroups into a series of categories related to information source. These categories include:

1. Position and dimensions--characteristics that can probably be estimated from basic geographic data.

2. Topography--characteristics that can probably be estimated from readily available topographic data.

3. Soils--characteristics that can probably be estimated (at least roughly) from soils maps and known characteristics of soil types.

4. Hydrology--characteristics that can probably be estimated from basic stream gage data.

5. Topography and hydrology--estimation of these characteristics will probably require a combination of topographic and hydrologic data. Note, however, that for some functions, stream gage data may not be sufficient information concerning hydrology.

6. General cover maps--evaluation of these characteristics will likely require fairly general, but perhaps broad-scale, cover maps.

7. Detailed cover maps--evaluation of these characteristics will likely require more detailed cover maps that distinguish, for example, between different types of BLH forest.

8. Site-visits--evaluation of these characteristics will probably require at least brief site visits though it may be possible to estimate some from known attributes of various cover types.

9. Detailed investigations--information on these characteristics will likely be obtained only through fairly detailed studies; again, however, rough estimates may be possible based on known properties of certain cover types.

Table 35. Characteristics identified by the workgruops categorized by information source.

Category of information and associated characteristics	Workgroup(s)[1]
Position and Dimensions	
Width/length ratio	H
Sinuosity	H, F
Size of tract	WQ, W
Proximity to stream	WQ
Proximity to flyway corridors	W
Proximity to Gulf coast	W
Proximity to mainline levees or floodways	W
Stream pattern complexity	CRE
Physical access (may also require ownership)	CRE
Topography	
Ground surface roughness	H, WQ
Elevation	H
Slope	H, WQ, F
Soils	
Infiltration rate	H
Permeability	H
Organic matter content	WQ
Clay content	WQ
Hydrology	
Downstream flood stage/standard flood	EP
Hydrologic detention time	EP
Waterflow velocity	CRE
Water depth minimum	CRE
Topography and hydrology	
Surface area of active floodplain	H
Detention storage	H
Internal drainage	H
Extent of natural ponding	WQ
Duration of flooding	WQ
Frequency of flooding	WQ
Areal/stage relationship	F
Access to permanent water	F
Shallowly flooded area	W
Access/transport vectors	EP
% of freely flooded area in watershed	EP

Table 35. (Continued)

Category of information and associated characteristics	Workgroup(s)[1]
General cover maps	
Natural floodplain vegetation	F
Forested watercourses	W
Open water	W
Area of contiguous forest	W
Vegetation corridors connecting BLH forests and uplands	W
% of regional landscape	EP
Effective size	EP
Landscape mosaic	EP
% of watershed in BLH forests	EP
Buffer configuration of BLH forests	EP
Linear continuity	EP
Contiguity and size	CRE
Detailed cover maps	
Interspersion of swamps and higher ground	W
Breadth	EP
Number and area of community types and zones	EP
Edge between community types	EP
Vegetative diversity	CRE
Site visits	
Vegetation cover (density)	H
Debris	H
Soil saturation	H
Density of understory	WQ, W
Density of overstory	WQ
Snags and instream cover	F
Sedimentation	F
Presence of weed seeds, fruits, aquatic tubers	W
Presence of tree cavities	W
Presence of large, unflooded, basal cavities	W
Presence of browse, forbes, grasses	W
Structural diversity of vegetation (within stand)	W, EP
Mast production and diversity	W, EP
Native species richness	EP
Nesting and escape cover	EP
Presence of food species	CRE
Presence of finfish, shellfish	CRE
Presence of wildlife	CRE
Presence of fiber species	CRE
Visual access	CRE
Animal species diversity	CRE
Flora	CRE
Fauna	CRE

Table 35. (Concluded)

Category of information and associated characteristics	Workgroup(s)[1]
Detailed investigations	
Evapotranspiration	H
Hydraulic gradient	H
Sediment input from stream	WQ
Sediment input from uplands	WQ
Upland runoff	WQ
Presence of toxics	F
Dissolved oxygen content	F
Net primary production	EP
Organic matter processing	EP
Water quality	CRE
Other	
Soil disturbance	WQ
Historical/archeological	CRE
Representative ecosystem	CRE
Relict stand	CRE
Existing documentation	CRE

[1]H = Hydrology, WQ = Water Quality, F = Fisheries, W = Wildlife, EP = Ecosystem Processes, CRE = Cultural/Recreational/Economic.

10. Other--a few characteristics that don't seem to fit well in any of the above categories.

In developing this table, it was necessary to translate the characteristics listed by the Wildlife Workgroup (e.g., escape cover for black bear) into more specific parameters (e.g., interspersion of swamps and higher ground) based on information presented in the narrative portion of the workgroup report.

In general, the difficulty of obtaining information related to the characteristics is likely to increase from the top to the bottom of the table. For example, information on topography is probably easier to obtain than information on a site-specific process such as sediment input from uplands. Thus, it appears that basic information on many of the characteristics should, at least in principle, be available for many sites. However, Table 35 does not adequately reflect two other steps that must be taken if the characteristics listed are to be used in making site-specific decisions. First, the basic data or information must be translated into a meaningful measure of performance. For example, topographic maps certainly contain information related to ground surface roughness. However, establishing a meaningful relationship between varying degrees of roughness and, say, the velocity reduction function may be very difficult. The workshop addressed only the direction of such relationships (i.e., positive or negative). And second, there must be a method for aggregating information concerning several characteristics into a single estimate of function. That is, the question of the relative importance of the various characteristics that pertain to a certain function must be addressed.

In addition, the workshop also made some progress toward effective consideration of impacts at the cumulative level. Several of the workgroups clearly identified cumulative impacts as an important, perhaps dominant, concern. Furthermore, as noted above, some of the characteristics identified as important at the site-specific level attempt to take into account spatial context, which is clearly an important factor in the issue of cumulative

impacts. Finally, the Ecosystem Processes Workgroup discussed in some detail a general approach for addressing the question of cumulative impacts. This approach involves the following steps:

1. Identifying "higher-level" functions (e.g., maintenance of biotic diversity) and acceptable levels of performance of those functions;

2. Identifying cumulative impact measures to quantify those functions, including both characteristics of broad spatial areas that are causally related to performance of the functions (e.g. percent of an area in BLH forest) and indices of performance (e.g., changes in a hydrograph as an index of the flood control function);

3. Identifying critical values of the cumulative impact measures; and

4. Adopting differential regulation of activities based on the relationship between the current values of the cumulative impact measures and the critical values (e.g., regional limits).

Consideration of this and other approaches for relating the issue of cumulative impacts to the site-specific decision process could well provide an interesting and fruitful framework for discussions at the third workshop in this series.

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