

BOTTOMLAND HARDWOOD GUIDEBOOK:

The Decision Making Process,
Design, Management and
Monitoring of GTR's.

Prepared for:

The Environmental Protection Agency
1445 Ross Avenue
Dallas TX 75202

Prepared by:

Sammy King
U.S. Geological Survey
National Wetlands Research Center
700 Cajundome Blvd.
Lafayette LA 70506

and

Leigh Fredrickson
University of Missouri
Gaylord Memorial Laboratory
Route 1 Box 185
Puxico MO 63960

November 1998

INTRODUCTION

Bottomland hardwood forests (BLH) are distributed along rivers and streams throughout the central and southern United States. These wetlands are valuable habitat for wintering waterfowl, breeding and migrant waterbirds and songbirds as well as other species of wildlife. In addition, BLH improve water quality, attenuate flood peaks, and provide a valuable source of timber. Many habitats are available in these systems because the undulating topography common in riverine systems and variable precipitation cycles create diverse surface hydrology where timing, depth and duration of flooding is dynamic within and among years. This variation in hydrology controls conditions influencing plant species composition.

Greentree reservoirs (GTRs) are stands of bottomland hardwood forests that are typically equipped with levees and water-control structures and flooded during the dormant season to provide mast and invertebrates for wintering waterfowl. Although early studies indicated that GTR management was not detrimental to BLH stands, more recent studies have indicated that shifts in species composition from less water-tolerant to more water-tolerant species may

occur. In some instances, the changes in species composition may be subtle and slow. In others, changes may be very rapid and occur within 2-3 years.

Successful GTR management is not an accident. Successful manipulations are labor intensive, expensive and require the knowledge and appreciation of bottomland hardwood system dynamics. All successful GTR projects must include the following: 1) a decision process on determining whether to create a GTR; 2) proper site selection; 3) proper design; 4) a well-conceived management plan; and 5) an ecologically-based monitoring program designed to identify potential ecosystem stresses resulting from manipulations. Failure in any of these five components will assuredly result in serious consequences for the integrity of these systems.

The objectives of this handbook are to provide resource managers and other interested parties a step-by-step evaluation of GTR management projects. Scientific literature is cited when possible, however, some of the suggestions are based upon expert opinion and generally accepted beliefs within the scientific and resource management community.

PHASE I---DECISION MAKING PROCESS

The decision on whether or not to create a GTR on a given site should not be taken lightly. This decision should be based upon the objectives of the GTR. Assuming the objectives are legally, ethically, and ecologically feasible and acceptable, then the decision must be made as to whether or not the site and proposed management activities will effectively accomplish these objectives. In many instances, GTRs have failed to meet stated objectives due to poor site selection, poor design, improper management, lack of personnel, limited operational budgets, or all of the above. Many of these errors and other financially and ecologically costly mistakes can be eliminated in the decision-making process.

STATEMENT OF OBJECTIVES

Well-defined habitat based objectives are essential to evaluate site selection and management success. Habitat management objectives should be concise, measurable, and preferably quantitative. Writing and ranking objective statements forces potential managers to define the resources most important to their management area. Furthermore, well-written objectives are 1) achievable, 2) measurable, 3) repeatable, 4) understandable, 5) reasonable, 6) ethical, and 7) clearly defined in terms of time and location. All objectives should contain five major elements: WHO, WHAT, WHERE, WHEN, and WHY. An example of a well-written objective is illustrated below:

The Duck Club of America will provide shallow, temporarily flooded native bottomland hardwood habitat (what) of 0-45 acres (depending upon year and stage of flood management cycle) of the Club's property (where) during December-February in 1999-2005 (when) for the long-term benefit of wintering waterfowl populations.

Based upon the above objective, the manager has stated that: 1) the impoundment will be shallowly flooded during a specified time period; 2) a dynamic flooding pattern (see below) that will flood variable acreage annually will be implemented; and 3) management will be for the long-term benefit of waterfowl populations (e.g.,

short-term intensive management that degrades the habitat would not be acceptable). These objectives provide a means of assessing management success.

Is there a permanent commitment and adequate financial and technical resources to construct, manage, and maintain the GTR?

GTR management is an expensive, labor-intensive, and permanent commitment. Properly designed GTRs have an infrastructure (system of levees, water-control structures, as well as water supply and drainage potential to emulate natural hydrology) that is costly to construct and maintain. Generally, heavy equipment is required and adequate water-control structures are expensive. Personnel costs are high because they require constant oversight to ensure the immediate alleviation of any problems. Although damages associated with improper GTR design and management may be visible in less than 2 years, more than 60 years may be required for a system to recover. Therefore, a commitment to proper GTR management is required which is immediate and permanent. The GTR should not be constructed if the financial resources to construct *and maintain* the GTR are not available or if there is not a commitment to have a qualified individual to manage the GTR in perpetuity.

Does the stand flood naturally?

An evaluation of site hydrology is a crucial step in determining site suitability as well as the development of site design and management. Drainage patterns of the proposed impoundment area must be understood before the impoundment is constructed. Ideally, an evaluation of the hydrology and drainage patterns of a given site also should include subsurface water flows. Because flooding patterns of bottomland hardwood systems are dynamic, multiple years of data may be necessary to fully understand the hydrology of any given site. This step is extremely important as insufficient or incorrect hydrologic information can lead to poor decisions

on site selection and design and result in irreversible impacts to bottomland hardwood resources.

The objectives of most GTRs are to enhance waterfowl habitat by providing foraging opportunities on mast and invertebrates for wintering waterfowl. The conceptual idea of GTRs is to provide a more predictable habitat where food resources attract enough waterfowl to produce predictable hunting opportunities. In practice, however, prolonged GTR management often produces shifts in tree composition from less water-tolerant but more desirable species for waterfowl (e.g., willow oak, Nuttall oak, cherrybark oak) to more water-tolerant but less desirable species for waterfowl (e.g., overcup oak, water elm). In fact, tree mortality and lack of regeneration were the top two concerns of GTR managers in a 1989 survey.

If the objective of a GTR is to enhance long-term waterfowl habitat quality by providing foraging opportunities on mast and invertebrates for waterfowl, then a shift in tree species composition from less water-tolerant but more desirable species for waterfowl to more water-tolerant but less desirable species for waterfowl would result in a failure to meet the stated objectives. Therefore, the best management scheme for *natural flooding* stands is to protect the site from any hydrologic perturbations that would compromise natural processes. Any modification of natural flooding patterns can result in tree mortality and/or shifts in species composition that result in lower quality habitat for wintering waterfowl.

The difficulty is defining *natural flooding*. The hydrology of most bottomland hardwood forests has been altered to some degree. GTRs can potentially be effective restoration and enhancement strategies in areas where overbank flooding seldom or never occurs due to drainage ditches, channelization, dams, or levees. Under these circumstances, GTRs or management strategies similar to GTRs, could provide tremendous benefits to not only waterfowl but also to numerous other plant and animal species. Sites that flood frequently are not desirable areas for GTRs because foraging opportunities are already present and any additional flooding could increase tree mortality and degrade waterfowl habitat. In short, if the site already provides the functions and values that GTRs are supposed to provide then the site

should be protected from development or changes in hydrology.

Is there suitable topography and soils for establishing a GTR?

A site with suitable topography for establishing a GTR is flat or with a slope less than 1%. Soils should have low permeability to inhibit subsurface drainage and allow for maintenance of proper water levels. Soils that are predominantly clay and/or have restrictive horizons are ideal for proper water-level control.

Detailed topographic surveys of the site should be an absolute prerequisite during the site evaluation phase. These surveys will not only determine whether or not the site is suitable, but also will be heavily utilized in the design phase for the placement of water-control structures and if applicable, levees. For example, if the site has a ridge and swale topography variation in elevation for each swale in relation to the point of water supply and discharge is critical information that must be determined (Fig. 1).

Are conditions suitable for adequate water discharge?

The infrastructure and management strategy to assure the required supply and discharge of water are critical components of GTR development and management. Successful GTR management requires the potential to discharge an adequate amount of water whenever necessary to protect forest resources. Thus, concern for effective drainage must be addressed first. Efficient and timely discharge of water requires correct placement and size of water-control structures in relation to topography, an understanding of water-level regimes in the drainage system, and recognition of any legal restrictions on the timing and amount of discharge.

Proper siting of water-control structures are discussed in detail under the heading Phase IIC, but in the site selection phase a detailed understanding of site topography is necessary to evaluate the suitability of a given site for a GTR. Sites that have very prominent ridge and swale topography may be unsuitable for GTRs, because the ridges can result in excessive ponding and prevent efficient drainage without a prohibitive number of water-control structures (Fig. 1).

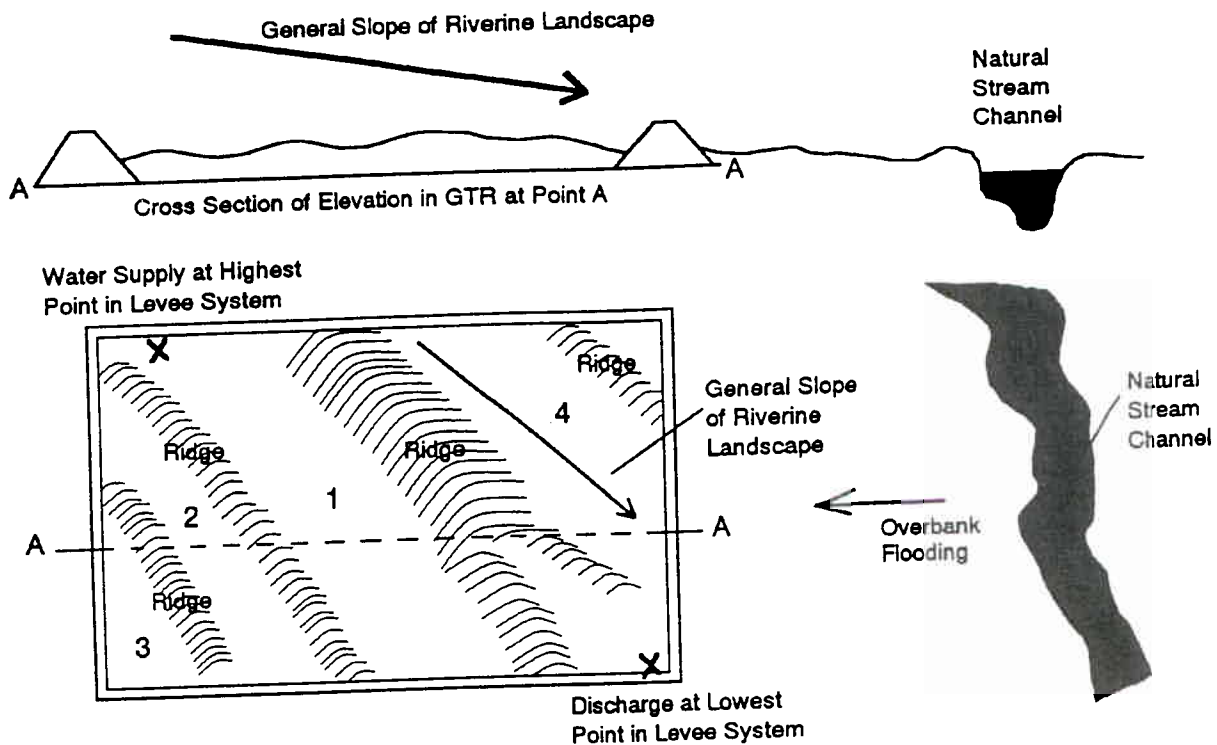


Figure 1. Ridge and swale topography within floodplains are characteristic of sites with greentree reservoir developments. See Figure 2 for the implications associated with GTR water-level management on sites with this topography.

It is also important to understand water level regimes in the drainage system to ensure that water can be drained when needed to prevent excessive flooding of the stand. Areas that are flooded during late winter/early spring either naturally (including beaver problems) or because of man-made alterations (e.g., dams, agricultural development, flood control) are generally not good sites for GTRs because flooding already occurs during the management period and flood water removal at the beginning of the growing season will be hampered by high water levels outside the GTR (Fig 2.). Obviously, virtually all BLH sites may experience beaver problems; however, serious consideration should be given to the time and financial commitment necessary to control beaver populations at a proposed site. If the commitment seems excessive for the available resources, then the site should be eliminated from further consideration.

Finally, any legal restrictions on timing and amount of discharge should be investigated during the site selection phase. A site that cannot be drained "at will" during winter and spring

is not suitable for GTR management as this capability is a necessity to prevent damage to the forest from water-management practices.

Is a dependable and adequate water supply present?

A dependable and adequate water supply is necessary for proper GTR management. Potential water sources include: storage reservoirs, irrigation projects, streams, rivers, lakes, wells, and rainfall. Storage reservoirs, from which water can be released by gravity flow, are cost effective because they provide a dependable water supply that can be easily regulated with water-control structures. Rainfall is the most economical means of flooding a GTR, but rainfall is the least dependable because precipitation is highly variable among seasons and years. An advantage of the latter approach, however, is that it results in a more natural flooding pattern because water availability is driven by natural climatic patterns and can potentially reduce many problems associated with intensively managed GTRs.

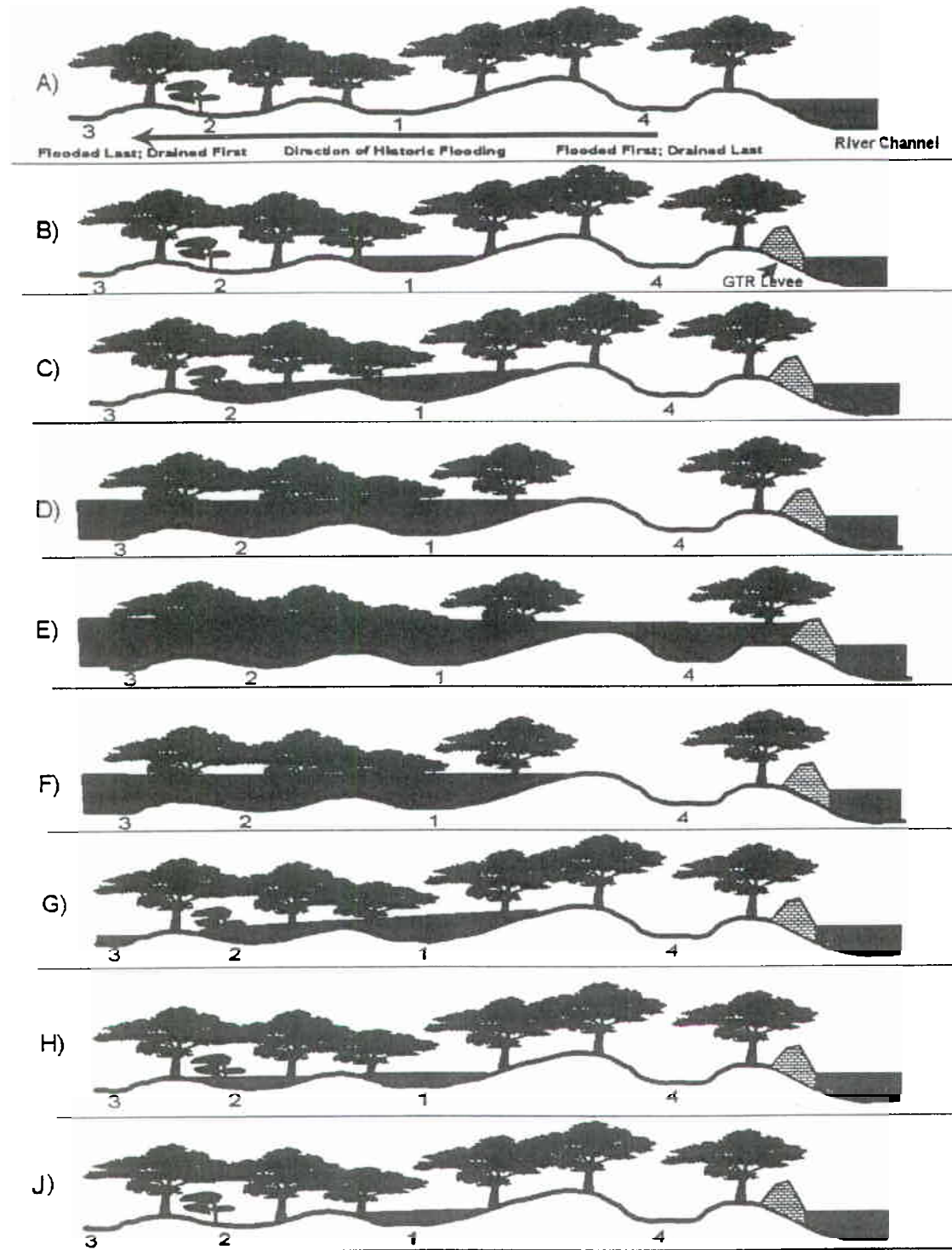
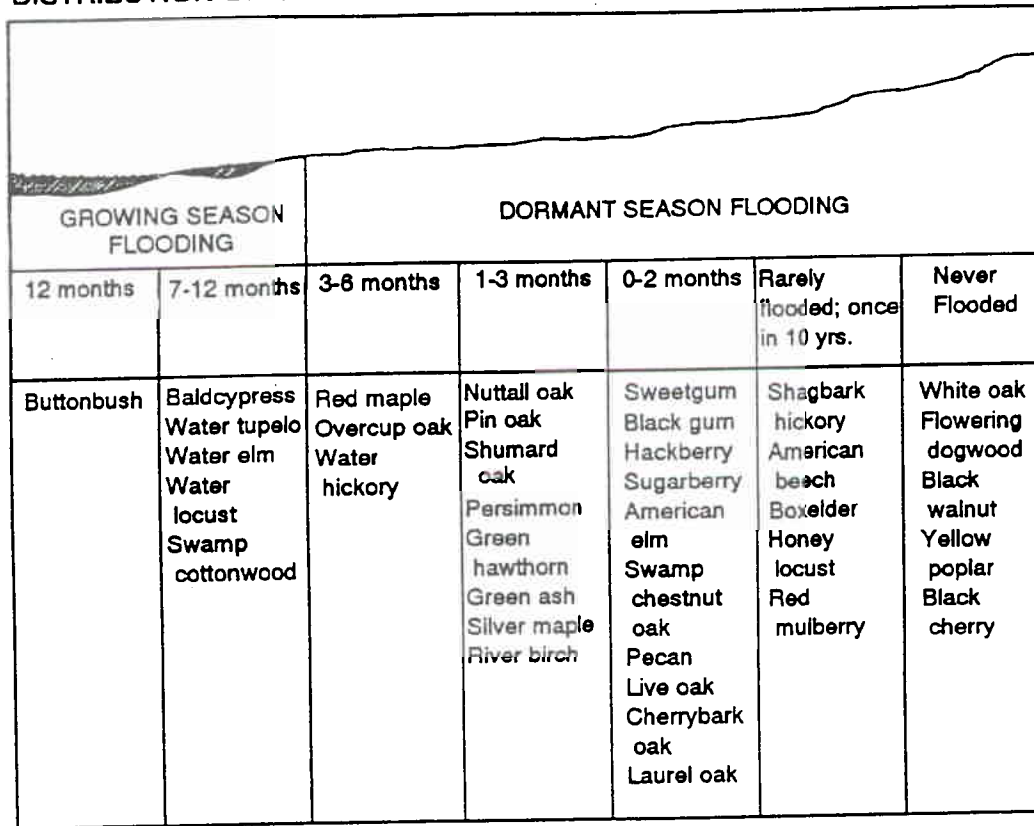


Figure 2. Effects of ridge and swale topography on natural overbank (A) and managed (B-J) flooding patterns. The water-intake structure is located at the upper end of the swale 1; the water release structure is located at the lowest point of the impoundment which is at the lower end of the swale 4 (see Fig. 1). Construction of levees and the water-control structures alters natural patterns of overbank flooding. Prior to levee construction swale 4 floods first and for the longest duration (A). After GTR construction, swale 1 is flooded first (B) and for the longest duration, followed by swales 2 (C) and 3 (D). The water-control structure is located at the end of swale 4, thus the drawdown is apparent in periods; these swales drain last (G-J). Note: We do not recommend placing levees adjacent to the river channel; this was for illustrative purposes only.

DISTRIBUTION OF BOTTOMLAND TREES ALONG A FLOODING GRADIENT



GROWING SEASON FLOODING		DORMANT SEASON FLOODING				
12 months	7-12 months	3-6 months	1-3 months	0-2 months	Rarely flooded; once in 10 yrs.	Never Flooded
Buttonbush	Baldcypress Water tupelo Water elm Water locust Swamp cottonwood	Red maple Overcup oak Water hickory	Nuttall oak Pin oak Shumard oak Persimmon Green hawthorn Green ash Silver maple River birch	Sweetgum Black gum Hackberry Sugarberry American elm Swamp chestnut oak Pecan Live oak Cherrybark oak Laurel oak	Shagbark hickory American beech Boxelder Honey locust Red mulberry	White oak Flowering dogwood Black walnut Yellow poplar Black cherry

Figure 3. Distribution of bottomland trees along a flooding gradient. Understanding the tolerance of trees to flooding during the growing and dormant season is critical in making decisions related to management and restoration. Trees must NEVER be flooded for a longer period than is indicated. Even then, the best success to assure long-term viability of the forest requires variation in the depth and duration of flooding within and among years. In no case should trees be planted on sites where the hydroperiod is longer than the range for the species.

Permanent streams provide a dependable water supply via diversion or pumping. The costs of water control structures, pumps, and diversion ditches are high. Pumping water from wells, streams, rivers, or lakes allows more complete water-control, but pumping is the least economical method of flooding GTRs because of high operational costs for fuel and maintenance of pumps. Sand in subsurface waters tend to reduce pumping efficiency. In some cases, discharges are reduced by half or more in as little as 5 years. Some streams or lakes in agricultural areas have high levels of herbicides or pesticides and are not desirable for use.

Is the vegetation suitable for GTR management?

Vegetation of the potential impoundment site should be evaluated to ensure that it is capable

of meeting the impoundment's objectives. For instance, if the objective of a GTR is to enhance long-term waterfowl habitat quality by providing foraging opportunities on mast and invertebrates for wintering waterfowl, then the impoundment should have a fairly strong component of bottomland oaks (Table 1). If the objectives of the impoundment are to restore functions typical of natural BLH systems, then other bottomland vegetative communities can be considered. However, in the latter case, the timing, depth, and duration of flooding, as well as the design of the impoundment may need to be dramatically different from impoundments designed as GTRs. Finally, sites with vegetation that is intolerant of flooding should never be considered suitable for a GTR (Fig. 3).

Table 1. Shade and water tolerance ratings for several tree species commonly found in or near bottomland hardwood forests. Waterlogging ratings were derived from Hook (1984). Shade-tolerance ratings were derived from Meadows and Stanturf (1997).

Scientific Name	Common Name	Waterlogging Tolerance	Shade Tolerance
<i>Taxodium distichum</i>	Baldcypress	Tolerant	Moderately Intolerant
<i>Nyssa aquatica</i>	Water Tupelo	Tolerant	Moderately Tolerant
<i>Carya aquatica</i>	Water Hickory	Moderately Tolerant	Not Listed
<i>Gleditsia aquatica</i>	Water Locust	Moderately Tolerant	Intolerant
<i>Acer negundo</i>	Boxelder	Moderately Tolerant	Moderately Tolerant
<i>Acer rubrum</i>	Red Maple	Moderately Tolerant	Tolerant
<i>Acer saccharinum</i>	Silver Maple	Moderately Tolerant	Not Listed
<i>Betula nigra</i>	River Birch	Moderately Tolerant	Intolerant
<i>Crataegus spp.</i>	Hawthorn	Moderately Tolerant	Moderately Intolerant
<i>Diospyros virginiana</i>	Persimmon	Moderately Tolerant	Very Tolerant
<i>Fraxinus pennsylvanica</i>	Green Ash	Moderately Tolerant	Moderately tolerant
<i>Gleditsia triacanthos</i>	Honeylocust	Moderately Tolerant	Intolerant
<i>Liquidambar styraciflua</i>	Sweetgum	Moderately Tolerant	Intolerant
<i>Platanus occidentalis</i>	American Sycamore	Moderately Tolerant	Intolerant
<i>Populus deltoides</i>	Eastern Cottonwood	Weakly - Moderately Tolerant	Very Intolerant
<i>Quercus lyrata</i>	Overcup Oak	Moderately Tolerant	Moderately Tolerant
<i>Quercus nuttalli</i>	Nuttall Oak	Moderately Tolerant	Intolerant
<i>Quercus palustris</i>	Pin Oak	Moderately Tolerant	Not Listed
<i>Quercus phellos</i>	Willow Oak	Weakly - Moderately Tolerant	Intolerant
<i>Ulmus americana</i>	American Elm	Moderately Tolerant	Moderately Tolerant
<i>Carya illinoensis</i>	Pecan	Weakly Tolerant	Moderately Intolerant
<i>Carya laciniosa</i>	Shellbark Hickory	Weakly Tolerant	Not Listed
<i>Celtis laevigata</i>	Sugarberry	Moderately Tolerant	Very Tolerant
<i>Celtis occidentalis</i>	Hackberry	Moderately Tolerant - Intolerant	Not Listed
<i>Juglans nigra</i>	Black Walnut	Weakly Tolerant	Not Listed
<i>Morus rubra</i>	Red Mulberry	Weakly Tolerant - Intolerant	Very Tolerant
<i>Nyssa sylvatica</i>	Black Gum	Weakly Tolerant	Not Listed
<i>Quercus laurifolia</i>	Laurel Oak	Moderately - Weakly Intolerant	Moderately Intolerant
<i>Quercus michauxii</i>	Swamp Chestnut Oak	Weakly Tolerant	Moderately Intolerant
<i>Quercus shumardii</i>	Shumard Oak	Weakly Tolerant	Intolerant
<i>Quercus virginiana</i>	Live Oak	Weakly Tolerant	Not Listed
<i>Cornus florida</i>	Flowering Dogwood	Intolerant	Not Listed
<i>Fagus grandifolia</i>	American Beech	Intolerant	Very Tolerant
<i>Liriodendron tulipifera</i>	Yellow Poplar	Intolerant	Very Intolerant
<i>Prunus serotina</i>	Black Cherry	Intolerant	Not Listed
<i>Quercus alba</i>	White Oak	Intolerant - Weakly Tolerant	Moderately Intolerant

Is the GTR properly positioned in the floodplain?

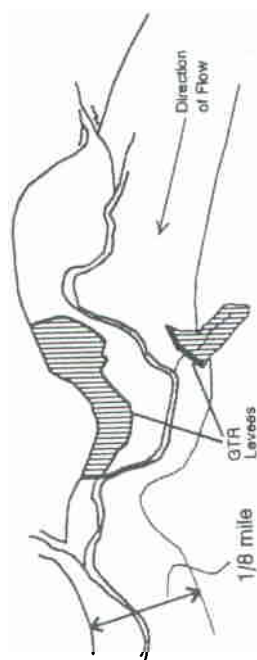
Proper site selection for GTRs also includes the proper positioning of the GTR within the floodplain (Fig. 4). Proper positioning of the GTR depends upon the major geomorphic, topographic and other structural and hydrological features of the floodplain. For small floodplain systems, GTRs should be positioned

to minimize the blockage of flow by levees and water-control structures. In some instances, GTRs have been designed so that they block the entire flow of the stream system. This can be disastrous because floodwaters forced into areas outside of the floodplain can kill flood-intolerant vegetation, prolong flooding in sites with historic short duration flooding, and/or cause severe damage to water-control structures and

PREFERRED SITE SELECTION

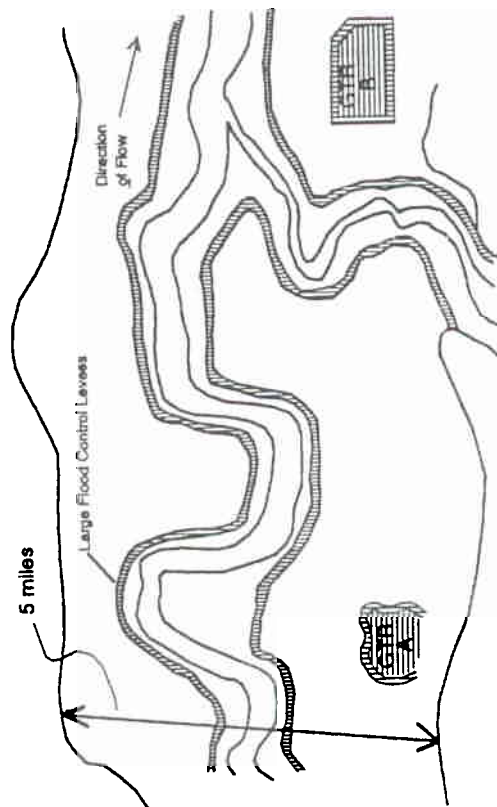
SMALL FLOODPLAIN - INTERMITTENT STREAM

SMALL LEVEES PARALLEL TO DRAINAGE SYSTEM OR ON SMALL DRAINAGES
INCREASE POTENTIAL FOR EFFECTIVE WATER LEVEL MANAGEMENT



LARGE FLOODPLAIN - MAJOR RIVER

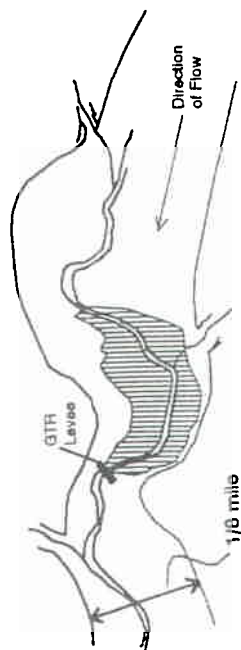
PLACEMENT OF LEVEES AT HIGHER ELEVATION ON THE FLOODPLAIN
INCREASE POTENTIAL FOR EFFECTIVE WATER LEVEL MANAGEMENT



POOR SITE SELECTION

SMALL FLOODPLAIN - INTERMITTENT STREAM

LARGE LEVEE BLOCKS THE ENTIRE FLOW IN THE DRAINAGE;
HIGH TREE MORTALITY WILL OCCUR



LARGE FLOODPLAIN - MAJOR RIVER

PROXIMITY TO RIVER COMPROMISES POTENTIAL TO DRAIN
IMPOUNDMENT AT ANY TIME

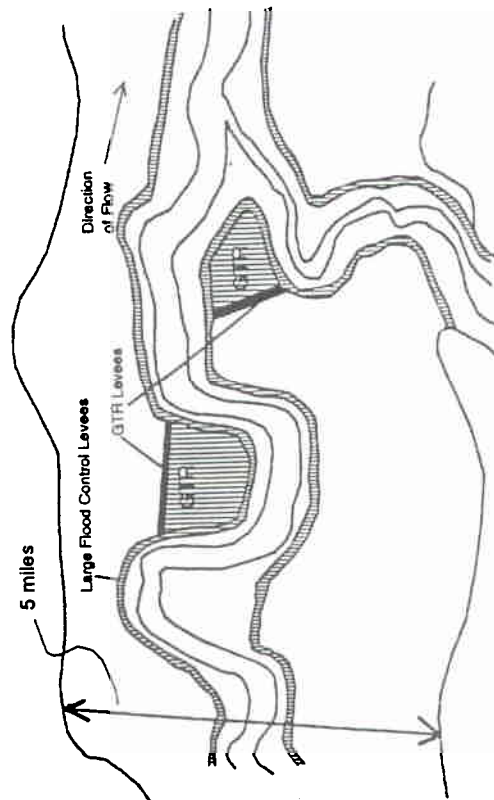


Figure. 4. Site selection for greentree reservoirs in large and small floodplains.

levees. Vegetation damage also can occur without completely blocking the drainage. In some instances, large sections of one of side of the floodplain have been blocked by levee systems which can have somewhat similar results to complete blockage of the floodplain. Therefore, GTRs in small floodplain systems should be situated so that they allow adequate water discharge from the river system.

In large floodplain systems, the principal concern of GTR position is to ensure that water discharge will not be detrimentally affected by floodwaters within the river/floodplain. Regardless of the size of the floodplain, GTRs should not be placed immediately next to the river system or to the flood control levees. GTRs should be positioned at slightly higher elevations to ensure that appropriate drainage is possible during moderately high waters. This does not mean that GTRs should be built in areas of flood-intolerant vegetation. It does mean, however, that if flood-tolerant vegetation (e.g., baldcypress, overcup oak) sharply grades into flood-intolerant vegetation then the site may not be suitable for a GTR. This type of situation may occur where the floodplain is constricted by bluffs and/or high terraces.

What are the potential impacts to other species of wildlife?

As with any management strategy, successful GTR management simultaneously provides benefits to one group of organisms while being detrimental to others. The effects to other wildlife can result from design features affecting dispersal or may be a direct or indirect response to flooding regimes. A GTR on the White River, AR, had a paucity of shrub-dependent songbirds because GTR management had decreased the shrub layer. Similarly, GTRs could potentially have a negative impact on some amphibians and fishes that are not adapted to the unnatural flooding schedule of GTRs. Foremost among these problems are breeding sites for amphibians such as salamanders, frogs, and toads. The best breeding sites for these groups are small isolated pools where access by fish is limited. When water management interconnects these small pools with surface flooding, fish often have access to the entire floodplain and compromise the breeding success of amphibians. In many instances, these impacts are not of concern because their overall impact is considered minor due to the quantity and quality of surrounding habitat or other overriding factors. However, if endangered species are involved, or if management objectives are to manage for multiple species of wildlife, then the potential management conflicts should be considered carefully in the decision-making process.

PHASE II—GTR DESIGN

Assuming that the above requirements have been met, the next phase in successful GTR management is a well-conceived design. Poorly designed impoundments can override the best devised management practices and render even the most dedicated and creative managers ineffective. The design of the impoundment should be based upon the objectives of the GTR and the topographic and hydrologic conditions of the site. For purposes of this guidebook, we will assume that the objective is to provide shallow, temporarily flooded native bottomland hardwood habitat using a dynamic flooding regime for the long-term benefit of wintering waterfowl populations. The design of impoundments to enhance other functions and values of bottomland hardwood communities may be different.

A) Are levees necessary?

Intuitively, it would seem that to answer this question you must first know the size, topography, hydrology, and number of impoundments before this decision can be made. However, this can also be reversed. The size and number of impoundments can be determined by the presence/absence and size of the levee system. We emphasize the latter approach because past results have indicated that impoundments that are under-designed (e.g., small or no levee systems) are less likely to have design-induced damage to trees than impoundments that are over-designed (e.g., large levee systems). Levee systems generally require removal of trees for levee construction and induce further damage by: (1) inhibiting subsurface water flows under the levee and causing a rise in the water table thereby killing trees; and (2) by increasing ponding of water and death of trees, particularly if a deep borrow ditch is located on the inside of the impoundment (also note that this presents a danger to hunters when the impoundment is flooded).

We recommend, therefore, that careful consideration be given to the decision whether or not to create a levee, and if needed, the size of the levee necessary to meet management objectives. Because water depths greater than 18 inches are poor waterfowl foraging areas, large levees that hold 3 or more feet of water are

generally not necessary or efficient and can increase the probability of widespread tree mortality. If large topographic differences exist in an impoundment, a GTR should not be developed. The large topographic differences across the impoundment and hence the purported need for large levees could possibly be alleviated by constructing small levees to create multiple impoundments with much less topographical relief (also see multiple impoundments versus single impoundments). An even more desirable alternative at some sites is to plug a small drainage (ephemeral streams) with a stop-log structure and allow the area to flood via rainfall and sheetflow. This is a much less intensive flooding strategy and has proven successful in areas where intensively designed impoundments have failed.

B) What are the recommended maximum and minimum sizes of GTRs? What are the advantages of a multiple-impoundment design versus a single-impoundment design?

The actual presence and size of a GTR and, when appropriate, whether a single or multiple impoundment strategy should be implemented, must be based upon careful, detailed examinations of the hydrologic and topographic features of the site. In general, however, GTRs should be between 20–100 acres in size. Some small impoundments of 1–2 acres often provide adequate resources for breeding wood ducks, but if levee systems are required this will likely cause more detriment to the system from forest disruption than benefits gained from GTR management. Small-impoundment strategies generally work best when small drainages are plugged with a stop-log structure. Impoundments greater than 100 acres generally have problems with efficient water-level control because of topographic variation and the volume of water that must be moved from the system. Furthermore, extensive forest disruption can occur from the construction of the levee system. Impoundments should not exceed 500 acres.

There are advantages to both single- and multiple-impoundment strategies (Table 2), although as noted above the site may be unsuitable for either design. The advantages of a

Table 2. The advantages and disadvantages of multiple and single impoundment GTR strategies. The advantages of one strategy become the disadvantages of the other strategy. Either strategy or both may be inappropriate for a given site.

GTR Strategy	Advantages	Disadvantages
Multiple Impoundments	Levees can be smaller thereby reducing potential impacts of levees on hydrology	Greater number of trees removed for levee construction
	Allow for more precise water-level control	Increased forest fragmentation
	Provide more water-management options	Higher levee maintenance costs
	Increase opportunity to emulate natural hydrological regimes	More water-control structures More detailed elevation data needed More complex water-management strategies
Single Impoundment	Fewer trees removed for levee construction	Less water-level control
	Less forest fragmentation	Limits water-management options
	Lower levee maintenance costs	Less opportunity to emulate natural hydrological regimes
	Fewer water-control structures	

multiple-impoundment system are that: (1) levees can often be smaller thereby reducing potential impacts of large levees; (2) they can allow for more precise water-level control; and (3) they provide more water-management options (e.g., timing of flooding and drawdowns) and increase the opportunity to emulate the dynamics of natural hydrological regimes. For example, a multiple impoundment approach increases the opportunity to leave one or more impoundments dry for an extended period to promote forest regeneration. This approach can provide the necessary means to manage impoundments less intensively while still having ample hunting opportunities.

The disadvantages of a multiple-impoundment system are that they require a more extensive levee system and more water-control structures than a single, large impoundment (please also see Water Discharge Outlets below). A more extensive levee system requires removal of more trees for levee construction. Tree removal not only reduces the number of mast-producing trees, but the fragmentation of the forest affects habitat quality for other species of wildlife (please see Levee Construction below). In addition, maintenance costs may be higher for repair of extensive levee systems. The latter concern, however, is quite possibly a tradeoff because levee repair takes less time than the time required to recover from ecological damage to a bottomland hardwood forest! A

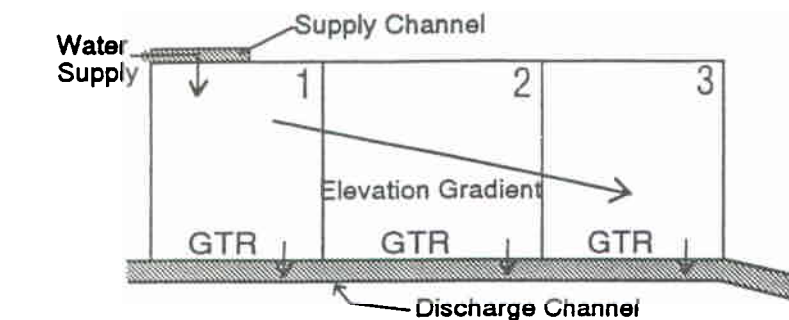
multiple impoundment approach will require more detailed elevation data because of the need to understand drainage dynamics within individual impoundments. This information should be available, however, assuming the site selection process was completed correctly.

The advantages of a single unit are basically the opposite of the disadvantages of a multiple-impoundment unit. The primary disadvantage of a single unit is that it limits water-management options. This is a critical consideration as prolonged annual flooding can lead to detrimental changes in habitat quality for numerous species. The advantages of a single GTR impoundment should be weighed very carefully against the disadvantages of reduced water-management options.

C) Where should water-control structures and water-discharge outlets be placed? How should water-discharge outlets be designed?

Before the location of levees is decided upon, the location of water-control structures and drainage requirements is essential to assure proper water-level management. Much of the damage to trees in GTRs is related to prolonged and/or deep flooding that is often a result of too few or improperly placed water-control structures and/or improperly designed water-discharge outlets (Fig. 5). Successful GTR management necessitates that water be dis-

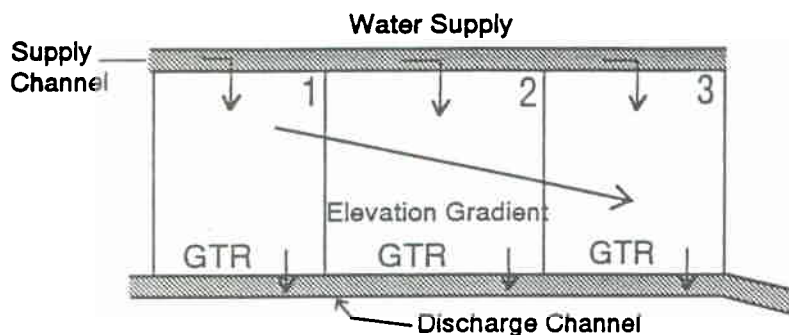
WATER CONTROL FOR GTR



GRAVITY FLOW SYSTEM

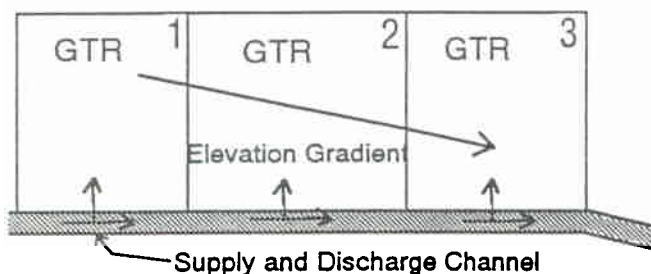
POOR DESIGN

Independent drainage
Units 2 & 3 cannot be
flooded independently



GOOD DESIGN

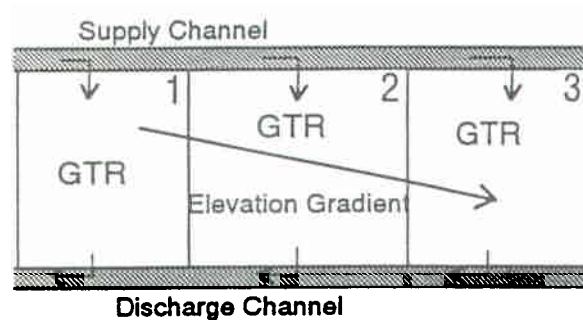
Independent supply
Independent drainage



PUMP SYSTEM

POOR DESIGN

Water Supply and
discharge through
same structure



GOOD DESIGN

Water supply at high end
Water discharge at low end

Figure 5. Common designs for water supply and discharge in GTR's. Poor designs lack the potential for independent control of water within an impoundment.

charged effectively in a timely manner. Thus, the placement of water-control structures should be based on detailed analysis of topographic maps and drainage patterns. Furthermore, each

unit should be drained independently and the discharge ditches must be adequate to permit transfer of water from all impoundments.

The placement of a single water-control structure at the lowest point of the impoundment does not ensure complete drainage of the impoundment. Ridge and swale topography is common in many GTRs. Ridge and swale topography can often produce a slight ridge (≥ 0.5 feet) that separates various sections of the GTR (Fig. 1). These ridges can be less than a foot higher in elevation from the surrounding area but can prevent complete drainage of the impoundment by a single water-control structure. Ponding water can increase stress of trees, and particularly regeneration, therefore impeded drainage is not a desirable situation. Detailed topographic surveys and pre-impoundment observations of drainage patterns can identify potential drainage problems. This information can then be used to develop well-conceived designs that can alleviate some drainage problems. As noted above, multiple water-control structures may be necessary to alleviate the problem. Constructing drainage ditches within the impoundment to alleviate the problem is not a desirable alternative because ditches cause additional hydrologic modifications, destroy trees, create hazards for hunters, and require periodic dredging.

Emergency spillways also should be constructed in the levees of all impoundments. These spillways are important during flood events and can prevent excessive damage to water-control structures and levee systems. Emergency spillways should be rip-rapped and in some cases, the rip-rap should be grouted.

Discharge ditches exiting the impoundment should be large enough to transport water effectively. Ditches should be kept free of debris and vegetation. Caution is suggested when developing the drainage system to assure that the clay pan is not opened directly to the groundwater table. Such errors in development in the past have been very costly and may preclude effective management on the entire area. As a safety note, water discharge areas should be well-marked to prevent accidents.

D) What type(s) of water-control structure should be used?

Permanent water-control structures are essential for successful GTR management. Stoplog water-control structures provide effective water regulation and are essential if natural hydrological regimes are to be emulated. In

areas of beaver activity, beaver-pond levelers may be necessary.

A typical stoplog structure is composed of corrugated, galvanized steel or PVC drain pipe running through the levee, connected to a system allowing regulation of water levels (Fig. 6). The control system might be a concrete box, a metal frame, a round or half-round galvanized steel box, or a prefabricated PVC box. Stoplogs are inserted between grooved recesses in the concrete, PVC or galvanized steel box and should be of several different widths to enable water-level changes as small as one inch. For longevity, galvanized steel pipe should be treated with a water repellant tar. In some instances, the extra expense of aluminum structures is worth the additional expense. Recently, some companies have fabricated PVC culvert and stoplog structures. These are usually less expensive but are more easily damaged by vandals and freezing.

Appropriate changes in water levels are made by selecting a combination of appropriately sized stoplogs. If stoplogs are sized and numbered, water-level changes can be made quickly and accurately. Redwood or treated lumber is suitable material. Ducks Unlimited has developed a system of metal stoplogs that seal well and can be modified to make their addition or removal easier. Furthermore, the weight of the metal allows stoplogs of different heights to be interchanged easily without being wedged into place. If seepage occurs between the stoplogs, dumping sawdust or straw just above the stoplog structure usually stops leakage quickly.

E) Where should levees be placed? How large should they be? How should they be constructed?

Levees should be placed on contours, and when possible, utilize existing dikes, roadways, pipelines, or other disturbed areas to prevent habitat fragmentation. Contour levees take advantage of natural changes in topography and provide maximum areas of flooding with optimum water depths. Contour levees also have the potential to facilitate multiple impoundment management (please see Multiple Impoundments above) that can be managed independently for waterfowl with greater potential to emulate natural hydrological regimes. Pre-

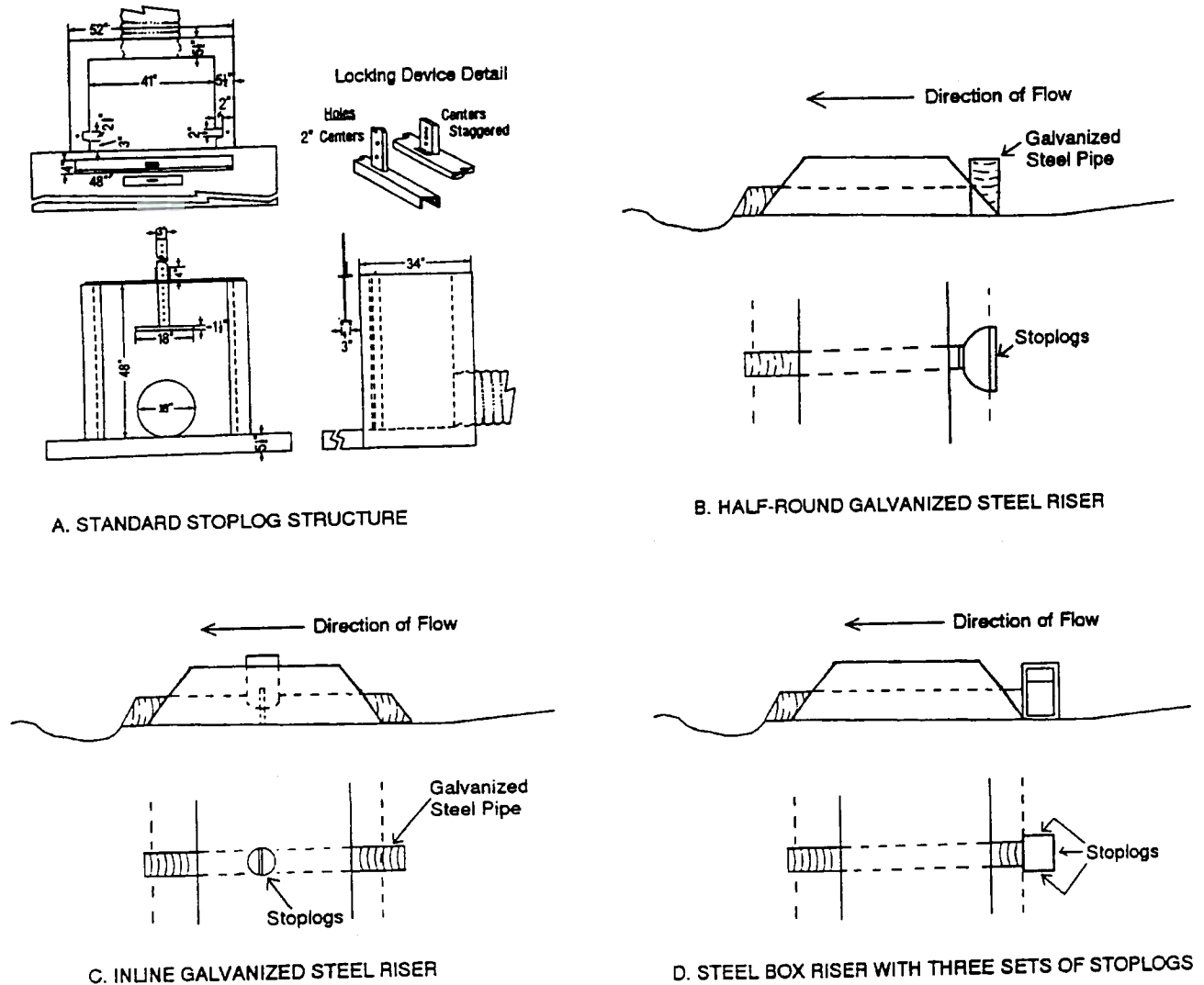


Figure 6. Examples of cost effective stoplog water-control structures. Size of structure is dependent on area to be drained.

impoundment elevation data are essential in proper placement of levees.

The height and width of levees depends on topography, depth of flooding and size of the impoundment. Usually, the maximum height of the levee should be 12-18 inches above maximum water depth. Large levees should not be justified based upon irregular topography as this condition is indicative of a site that is not suitable for a GTR. Furthermore, the size of the reservoir should be reduced if large levees would be needed to support water management.

In areas that receive substantial backwater or flash flooding as well as managed flooding, a low levee that is submerged quickly and

uniformly is damaged less than a large protective levee. Therefore, levees should be no more than 3 feet tall and should have a crown appropriate for the size of the impoundment, and goals and objectives for management. Smaller levees suitable for 4-wheelers may be adequate on some sites but levee maintenance and control of burrowing animals may be more difficult with smaller levees. For long-term maintenance efficiency, a crown width of 10 feet supports large mowing equipment and deters burrowing activity by beaver, muskrats, or other animals. Side slopes must be at least 3:1, but 4:1 or 5:1 is better. The compromise with more gradual slopes is that a greater area of forest is dis-

rupted, but the loss may be justified to reduce maintenance costs caused by burrowing mammals.

Borrow areas for the levees can be located outside the levee or offsite. The advantages of locating the borrow area outside rather than inside the levee includes: 1) reduced pumping costs, 2) less desirable habitat to attract beavers within the GTR, 3) desirable deepwater habitat for diving waterfowl, wading birds, and other wildlife that does not influence tree mortality within the GTR, and 4) safety concerns for hunters and other users. Safe access to GTRs with borrow areas inside the levee requires bridges or other crossings. Borrow areas should not be located inside the levee system because the lip of the borrow ditch hampers the ability to control water levels and because of the danger to hunters. Furthermore, the ponding of water and subsurface water flow disruption can result in additional tree stress and mortality in the impoundment even in the absence of artificial flooding. Offsite borrow-areas are often advantageous because they limit additional disturbance to the wetland and result in safer access

to the GTR. *Levee construction should always occur during dry periods, regardless of where the borrow area is located.*

Mortality of a significant number of large trees in GTRs because of hydrologic modifications causes additional changes in hydrology related to evapotranspiration (ET). ET from a large oak may be equivalent to 100 gals/tree/day. Changes on a large scale may be equivalent to a 1 inch decrease in evapotranspiration for every 10% decline in forest cover. Thus if tree mortality reaches 50%, the impact is equivalent to a 5 inch increase in rainfall. This change may be great enough to cause more mortality or to compromise the establishment of replacement trees.

To further prevent wetland degradation during levee construction, steps should be taken to minimize erosion and water quality impacts. Appropriate steps may include use of silt fences, silt barriers, erosion blankets, or other suitable alternatives to reduce erosion and sediment discharge into adjacent waterways. Disturbed surfaces should be permanently stabilized as soon as possible.

PHASE III—WELL-CONCEIVED MANAGEMENT PLAN

A well-conceived GTR management plan should address both water and timber management. The timing, depth, and duration of flooding within and among years determines the plant species composition on a site and defines the functional ability of a given BLH system. Historically, water-management regimes in GTRs have been similar within and among years (Fig. 7). Light availability is also a major constraint on plant species composition and regeneration; therefore, providing ample light for the desired plant species will affect the habitat composition and quality on any given site.

Water Management

In general, successful water management plans incorporate two broad sets of principles: 1) flooding and drawdown techniques; and 2) sound flood strategies within and among years. For clarity, we will discuss the former first, but under the realization that regardless of whether or not the flooding and drawdown techniques are implemented, the impoundment will fail if the flood strategies within and among years are not well conceived and effectively implemented. The development of a well-conceived water management plan that is based on the best scientific knowledge is among the most important factors to assure success. In more than one instance, water management of GTRs has become a political issue. Well-conceived, biologically defensible objectives and water management plans are often needed to ensure management that provides long-term benefits to waterfowl populations in the face of political adversity.

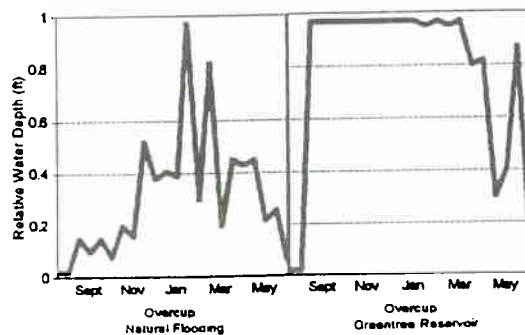


Figure 7. Dormant season water levels on an overcup oak site with natural compared to greentree reservoir flooding.

Flooding and drawdown techniques—The maximum depth at any point in an impoundment should be 18 inches. Dabbling ducks, such as mallards and wood ducks, cannot effectively forage in areas flooded greater than 18 inches; optimum water depths are 4–10 inches. Furthermore, water depths greater than 18 inches also will likely submerge seedlings and thereby decrease regeneration opportunities and reduce invertebrate response. The best strategies are those which optimize the ideal depths of 4 to 10 inches by gradually increasing or decreasing water levels.

Flooding and drawdowns should be initiated no sooner than 15 November and possibly later in coastal states. Common management advice suggests that GTRs can be flooded as soon as the trees lose their leaves; however, many bottomland hardwood experts believe that root activity may not cease for a few to several weeks after the trees lose their leaves. Therefore, early flooding may inhibit carbohydrate storage and affect long-term tree productivity and survival. Currently, root activity and carbohydrate storage admittedly are poorly understood, but limited evidence and personal observations suggest that a conservative approach is justified.

Drawdowns should be completed before 1 March in the South (e.g., Louisiana, Arkansas) and by 1 May in the North (e.g., New York, Minnesota). In more southern states and in warm winters, earlier drawdowns may also be justified to prevent tree stress. Drawdowns should be initiated with plenty of time to ensure that a slow gradual drawdown, that may be interrupted by rain and natural flooding, will completely drain the impoundment by the target date. These drawdowns will not only minimize tree stress but also will prevent shifts in invertebrate communities to those more indicative of permanent flooding.

Flooding and drawdowns should occur slowly to create a band of high concentrations of invertebrates and mast (i.e., a feather edge) (Fig. 8) for waterfowl. Slow, partial drawdowns should also occur during periods of peak waterfowl abundance to concentrate macroinvertebrates for waterfowl consumption. These slow drawdowns also facilitate nutrient cycling and prevent excessive losses of valuable nutrients

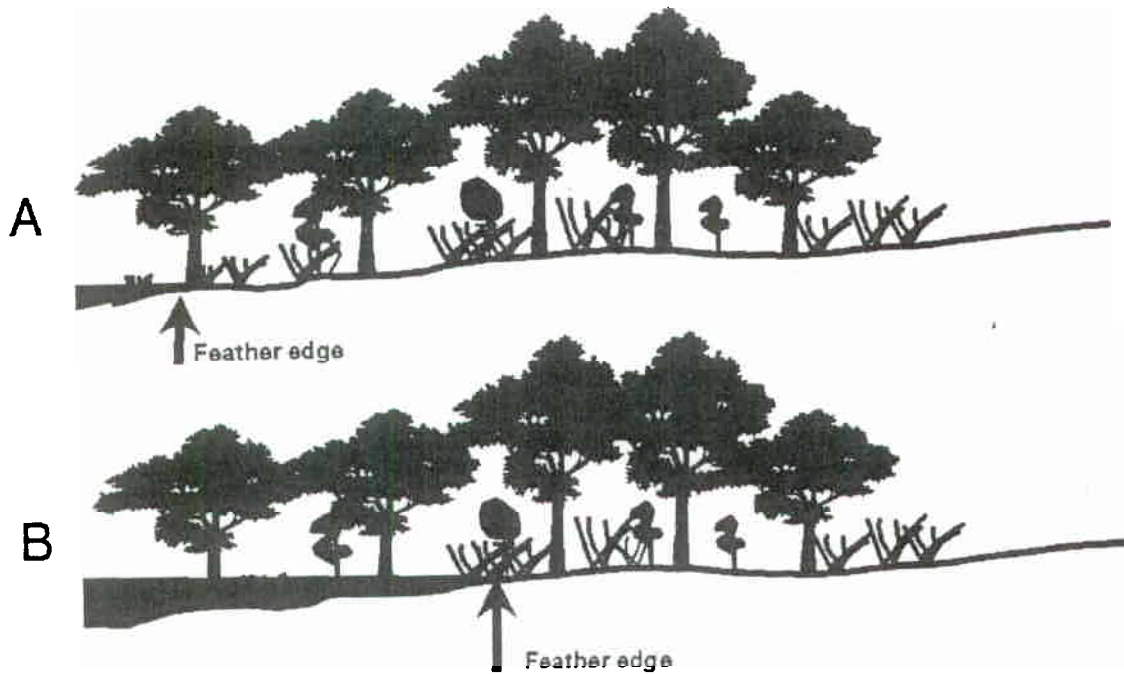


Figure 8. The feather edge effect associated with flooding regimes in bottomland hardwood systems. As water floods from Condition A to Condition B, terrestrial invertebrates, acorns and other plant foods become available along the flooding front. In contrast, when water recedes from Condition B to A, aquatic invertebrates are concentrated in the shallow water at the edge of the inundation zone. Maintaining constant water depth for a prolonged period of time or water depths > 18 inches create lower quality foraging opportunities.

from the GTR. Additional information on when to initiate drawdowns is provided in the next section.

Flood strategies within and among years— Functions and processes of BLH systems are driven by the timing, depth, and duration of

flooding within and among years (Fig. 9a). Flooding patterns that are common in BLH systems within a given year, may be atypical if repeated among years. For instance, flooding from November to March may occur in any given year within most BLH systems. However,

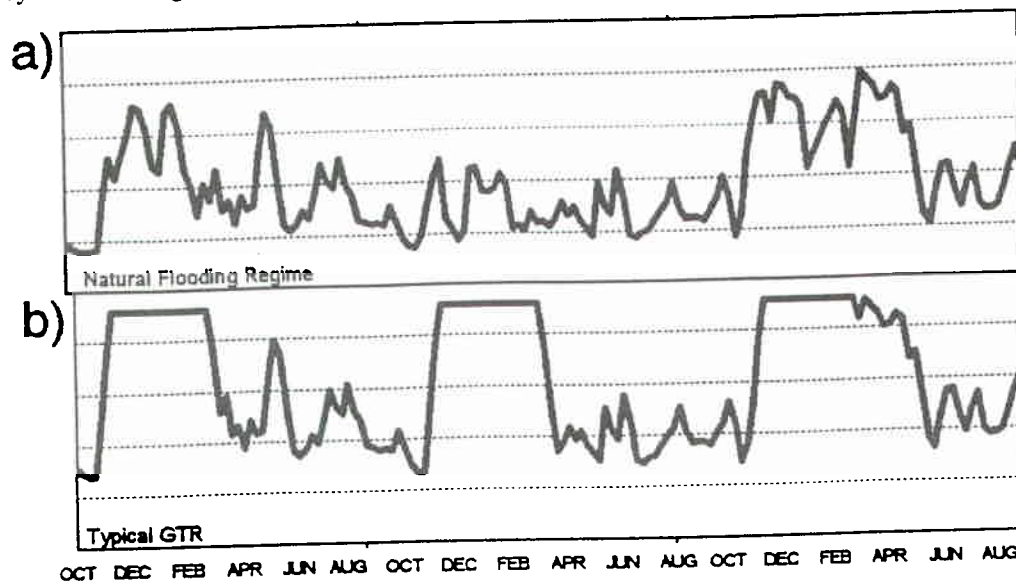


Figure 9. Comparison of a natural flooding regime to that of a typical GTR over a 3 year period (a) and within the same year (b). Note the variability both among years (a) and within years (b).

this pattern of flooding from November to March is likely to occur only once every 3-7 yrs or more and very unlikely on an annual basis. A consistent flooding pattern in relation to time, duration and depth is atypical of BLH systems (Fig. 9b). Thus management with consistent patterns of flooding affect the integrity of the system and the quality of waterfowl habitat for several generations. Therefore, water management plans must be variable within and among years and have the flexibility to adapt to changing environmental conditions (Fig 9a).

Changing environmental conditions can be either biotic (e.g., trees, seedlings, invertebrates) or abiotic (e.g., flooding and drought). Stressed trees, as evidenced by canopy loss, thinning, or yellowing of leaves, should not be flooded until trees recover. Furthermore, for successful regeneration, the impoundment should not be flooded for prolonged periods following heavy mast years and during the first few years of seedling establishment. It is not necessary to encourage regeneration every year, but stand regeneration should be a part of the long-term strategy for successful GTR management (see Timber Management below).

Managers should also account for natural rainfall and flooding events during the planning and implementation of water-management schemes. Habitats that are artificially flooded to their maximum depth early in the winter, can become poor habitat for waterfowl if rainfall and/or natural flooding increases the water depth. Heavy rainfall can not only increase the water depth in the GTR, but it can also prevent its efficient drainage because of high water levels outside the impoundment. This may be of particular importance with late winter/early spring floods as it can prolong flooding well into the growing season. Therefore, water-management plans, should be flexible enough to allow some additional flooding of the impoundment by natural flooding events. For example it would be wise to flood the impoundment to 3-4" below the target level and allow natural flooding events to increase the water levels to optimum depths. If sufficient rainfall does not occur during a given amount of time, then additional artificial flooding can precede until the impoundment is at the target level. As noted above, drawdowns should be initiated with plenty of time to ensure that a slow gradual drawdown, that may be interrupted by rain and natural flooding, will com-

pletely drain the impoundment by the target date.

The most successful GTR management plans are those that most closely emulate the natural variability within a given system. Several common strategies that have been mentioned in the literature and/or have been implemented on various refuges or WMA's have weaknesses worthy of discussion. The intent of this discussion is to stimulate thinking that links wetland concepts with the constraints and opportunities associated with management of new and existing GTRs.

By far the most common, yet most detrimental, approach is to flood the GTR to full pool on an annual basis for a specific time period (Fig. 7). Flooding on an annual basis, particularly to full-pool level, does not emulate natural flooding patterns among years. If this management scheme is enacted for a prolonged period of time, increased tree mortality and decreased regeneration of the less water-tolerant but more desirable trees for waterfowl will occur. Furthermore, annual flooding at the same time, depth, and duration among years, can also alter tree and shrub composition, thereby degrading overall habitat quality for waterfowl and other wildlife species.

An alternative to flooding on an annual basis is to flood the impoundment for a specified number of years and then not artificially flood the impoundment for a year. This strategy is better than the first, but is flawed because the dynamic fluctuations among years is compromised and considerations for state of tree stress and regeneration is ignored (i.e., no flexibility). As mentioned previously, flooding to full-pool level may occur naturally in BLH systems, yet to occur with regularity during the same time periods in consecutive years is very uncommon. Furthermore, management schemes should involve assessing tree stress and regeneration on an annual basis before the decision is made to flood an impoundment.

So how can strategies be developed that more closely emulate historic flooding patterns? The most defensible method would be to evaluate long-term (20 years or more) river stage and rainfall data. Are cycles evident? For example, in Missouri 70 years of records suggest peak flood years occurred every 7 years with drier years in between. A 7-yr flood management cycle was developed in which year 1 received no

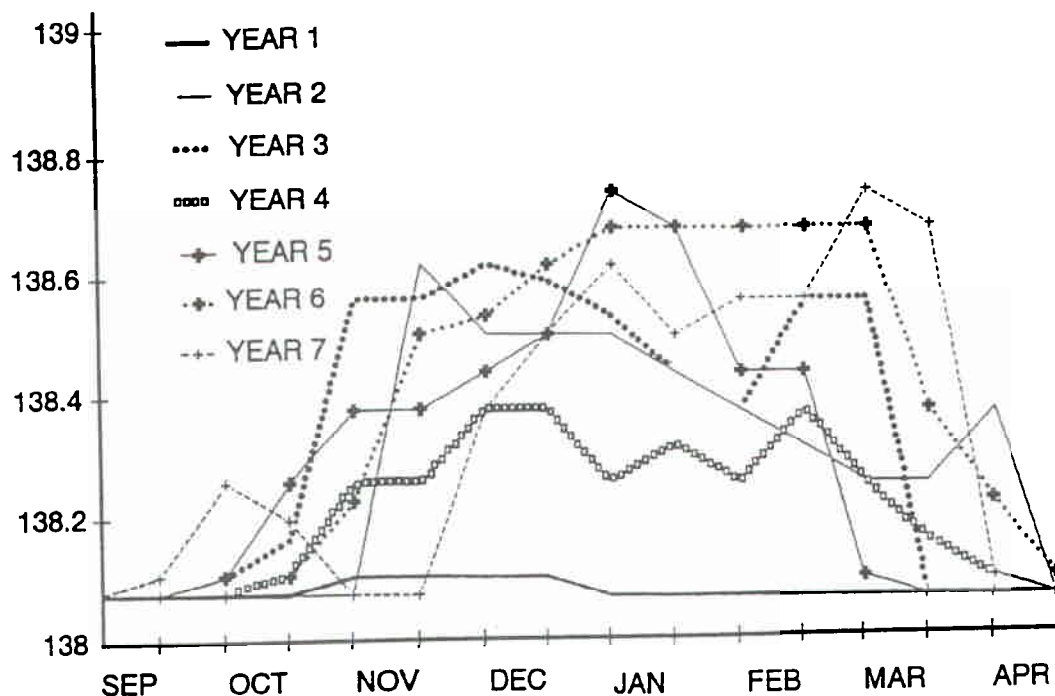


Figure 10. A conceptual 7-year water-level management plan for a greentree reservoir that emulates within and among year variations in the natural hydrologic regime. Managers were allowed to flood impoundments less intensively and with multiple drawdowns but never allowed to purposely flood impoundments more intensively. Occasionally, natural rainfall extended flooding longer than planned which indicates the need for efficient water drainage and constant oversight of GTR's.

flooding, with successively wetter years up to full pool at year 7 (Fig. 10). The cycle was then repeated. The management scheme also involved careful annual monitoring for tree stress and regeneration, to ensure that the management plan was not negatively impacting the system. The manager had the flexibility to terminate flooding at any point in time.

In some situations, long-term hydrologic and rainfall data may not be available for a given site. A 7-yr flooding/drawdown cycle may be appropriate. The key to success, however, is that the site can receive less flooding than called for under the management plan but more flooding should never occur. Also, if the trees are showing any signs of stress, the impoundment should not receive artificial flooding until trees recover.

In summary, the best water-management plans for GTRs are those that are developed based upon historic flooding patterns. These water-management plans should, however, have the flexibility to reduce flooding at any given time to prevent tree stress or mortality or to en-

courage regeneration. Impoundments should not be flooded more intensively by altering the depth, duration or frequency than called for in the plan. The second best approach would be to flood the impoundments for 2 years and have a 1-yr drawdown, or to flood the impoundment 1 in 3 yrs. If this approach is used, the impoundment should not be flooded to full level during every flood year. Some annual variation in the amount of flooding should be incorporated into the plan. Finally, the worst scenario is to flood the impoundment to full level year after year. This plan will undoubtedly lead to tree mortality and/or a shift to a more water tolerant plant community that is of lesser value to waterfowl.

Timber Management

A good GTR management plan should have well-defined goals that identify the targeted future condition of the forest. A considerable body of literature exists on the silvicultural practices necessary to regenerate BLH stands; however,

very few studies have been conducted that consider the importance of the timing, depth, and duration of flooding prior to and following timber harvest on the composition and abundance of regeneration.

A forest with a diverse tree species composition and stand structure (i.e., tree diameter sizes and shrub component) will provide the greatest overall long-term benefits to waterfowl and other species of wildlife. Many tree and shrub species produce seeds and fruits that are used by waterfowl and songbirds. Species such as black gum, baldcypress, and sycamore are good cavity producing trees that provide nesting sites for wood ducks, and other cavity nesting wildlife as well as roosting by bats. Furthermore, litterfall from a variety of species is essential for the maintenance of quality invertebrate communities and efficient nutrient-cycling processes. Management strategies that adversely affect nutrient-cycling processes can decrease the long-term productivity of the forest, thereby resulting in lower long-term habitat quality.

Timber-management strategies in GTRs should target a diverse plant community but should also attempt to maintain a strong oak component. Oaks that produce small acorns, such as pin oak, water oak, and willow oak among others, are more desirable for waterfowl than overcup oak because they produce mast that can be consumed easily. The larger acorn of the more water tolerant overcup oak is seldom consumed by waterfowl.

Several harvesting strategies are available for regenerating bottomland hardwood systems. Factors for consideration include the target composition of the plant community, direct impacts to other species of wildlife, and indirect impacts to other species of wildlife through habitat fragmentation and altered forest composition and structure.

In the absence of timber management or other forms of major disturbance, plant communities will gradually shift to a community with a greater component of shade-tolerant species. In bottomland hardwood forests, these may include american elm, hackberry/sugarberry, and red maple all of which are valuable for a variety of species of wildlife. The amount of time necessary for this shift to occur, however, is poorly understood and is likely a result of past timber-management practices, flood conditions, site characteristics, and disturbance history.

Oaks are a shade-intolerant group (Table 1); therefore, active management is necessary to maintain a strong component of bottomland oaks. Abundant advanced regeneration (i.e., established seedlings) should be released with openings of 0.25 acres or larger to provide adequate light conditions for growth and survival of oaks. To encourage regeneration, the impoundment should not be artificially flooded during a heavy mast year and for 2-3 years thereafter to allow for germination and seedling establishment.

All forests have openings resulting from natural processes such as age-related mortality, storms and fires. The area of such openings varies from 5 to 12% in subtropic systems where the forest is unevenly aged. On an annual basis in BLH forests, approximately 0.5 - 3% of the forest consists of newly formed openings with younger stands resulting in fewer canopy openings. An assessment of this condition is important before silviculture practices are implemented. Openings that are too large or too numerous can reduce overall habitat quality for waterfowl and other wildlife. Managers must also consider that openings created by timber management are additive to natural processes. In other words, natural openings will be created on 0.5-3% of the non-harvested area annually which is in addition to the percentage of the area subjected to managed openings.

Single-tree openings, group selection, shelterwoods, and clearcuts are all timber-management practices that may be appropriate if the number or size of openings is inadequate, stand composition/structure is poor, or regeneration must be encouraged. Meadows and Stanturf (1997) provide the most recent overview of silvicultural systems in bottomland hardwood forests and their paper should be reviewed for more detailed information on various silvicultural systems. However, their paper is based upon the assumption that economic returns are the primary objective; thus the strengths and weaknesses of each silvicultural strategy to wildlife communities are not a focal point of the paper. In fact, species that are listed as undesirable for timber production are actually highly desirable components of wildlife habitat. Coates and Burton (1997) provide an alternative approach to timber management that more closely emulates natural disturbance patterns.

The direct impacts of these various silvicultural practices on wildlife communities are poorly understood and the indirect impacts on wildlife communities have seldom even been considered. Of major concern is the effect of timber-management practices on habitat fragmentation. The majority of BLH systems are already highly fragmented, particularly in the Lower Mississippi River Alluvial Valley. Habitat fragmentation can adversely affect reproduction and survival of a variety of wildlife species as well as affect long-term plant succession. Considerable research is needed to quantify the relationships between timber-management and habitat-fragmentation issues, but regardless, the decision to use a particular timber-management practice should explicitly consider landscape level fragmentation issues.

Finally, simply removing more water-tolerant trees or saplings (e.g., overcup oak) will not ensure that less water-tolerant species will increase in dominance even if these areas are underplanted with seedlings of the less water-tolerant species. In fact, this type of practice can lead to widespread degradation of habitat quality. Overcup oak communities should not be considered undesirable as they provide important habitat for a variety of wildlife species including waterfowl along a specific portion of the flood gradient. A shift to overcup oak from less water-tolerant species, however, should alert managers to a potential water-management problem. Overcup oak and other water-tolerant communities become established largely because hydrological conditions favor their establishment. Therefore, timber-management practices to improve stand composition will not be successful without addressing water-management problems.

Beavers

Historically, beavers played an important role in bottomland hardwood systems. Dams along small drainages changed local hydrology that controlled the distribution and composition of vegetation. Less water-tolerant vegetation was eliminated and more water-tolerant vegetation dominated these sites with changed hydrology. Natural drawdowns in summer resulting from evapotranspiration created mudflats where annual herbaceous vegetation and more water-tolerant trees became established. Seed producing annuals within beaver impoundments often

produced important food resources for migrant waterfowl. These changes on a small scale within the immense extent of bottomland hardwoods added plant and animal biodiversity to the system. Unfortunately, today beaver activity is more problematic because man-made structures in combination with a greatly reduced area of BLH habitat often result in habitat changes or degradation in these increasingly scarce wetland forests.

Beaver activity has the potential to compromise management of bottomland hardwood forests because of their behavioral response to the sound of running water and their need to create water of sufficient depth for their activities. The potential for beavers to build dams are enhanced by man-made structures such as roadways, railroad grades, spoil banks and levees. These structures provide a substantial starting point for beaver dam construction and desirable sites for denning. Man-made structures provide beavers more opportunities to impound water on sites where there was little potential to build dams historically. Because many of these man-made structures are extensive and already impede water movement over significant areas of remnant forests, beavers have the potential to significantly impact plant composition and condition of plants in forest fragments. The sound of water movement through water-control structures attracts beavers and stimulates them to stop the flow. Thus, inlets and outlets associated with water-control structures are often plugged within hours of water-level manipulations. Activities by beavers often compromise drainage of an impoundment. If water remains impounded or if there is a change in rate of discharge, the vigor or survival of less water-tolerant vegetation is compromised and a change in forest composition may occur.

Control of beaver activity requires either elimination of the problem animals or creating conditions that reduce the effects of their activities. Elimination of problem animals can best be achieved by trapping or shooting the specific animals causing the problem at the site of high activity. Because activity often is highest just before and after dawn or dusk, the problem animals can be identified and eliminated at the point of activity. Keeping local beaver populations low through annual trapping programs also is of some benefit, but on large areas there

is little likelihood that enough animals can be trapped to significantly reduce the problem.

Design features of impoundments to preclude beavers or to restrict their activities are important. Levees with more gradual slopes (4:1 or greater) reduce burrowing activities. The design and placement of water-control structures, borrow ditches, and boat channels is critical if beaver activity is to be reduced at the point of water discharge. No strategy will be completely successful, but the level of success will be related to whether enough water is present in borrow ditches and boat channels to attract beavers, whether the sound of running water can be reduced, and/or whether the sound of running water can be separated from the animals either temporally or spatially as much as possible. One general strategy requires careful development for the supply, distribution, and control of water. For example, borrow areas or boat channels inside levees tend to retain enough water to attract beavers. Then beavers build dams to further improve habitat condi-

tions. Beaver dams within GTRs increase water levels which influence tree vigor and survival. Likewise, dams in the borrow areas or boat channels obstruct the flow of water during flooding or drawdowns. Other structural considerations to reduce beaver problems include in-line water-control structures because they increase the distance between the animal and the point of noise (Fig. 6). In-line control structures are placed in the middle of the levee so that the sound is muffled at the inlet. The outlet pipe must be situated so that the opening is always submerged, otherwise beavers are more likely to hear the sound because the pipe is only partially filled. In such cases, the animal can plug the opening or possibly travel through a partially filled pipe to the stoplog structure. A second strategy is to move the inlet away from the control structure and install enough perforated pipe below the water surface that the majority of the water can be drained before there is a great deal of sound. Box-type control structures are helpful sometimes (Fig. 11). Because box structures

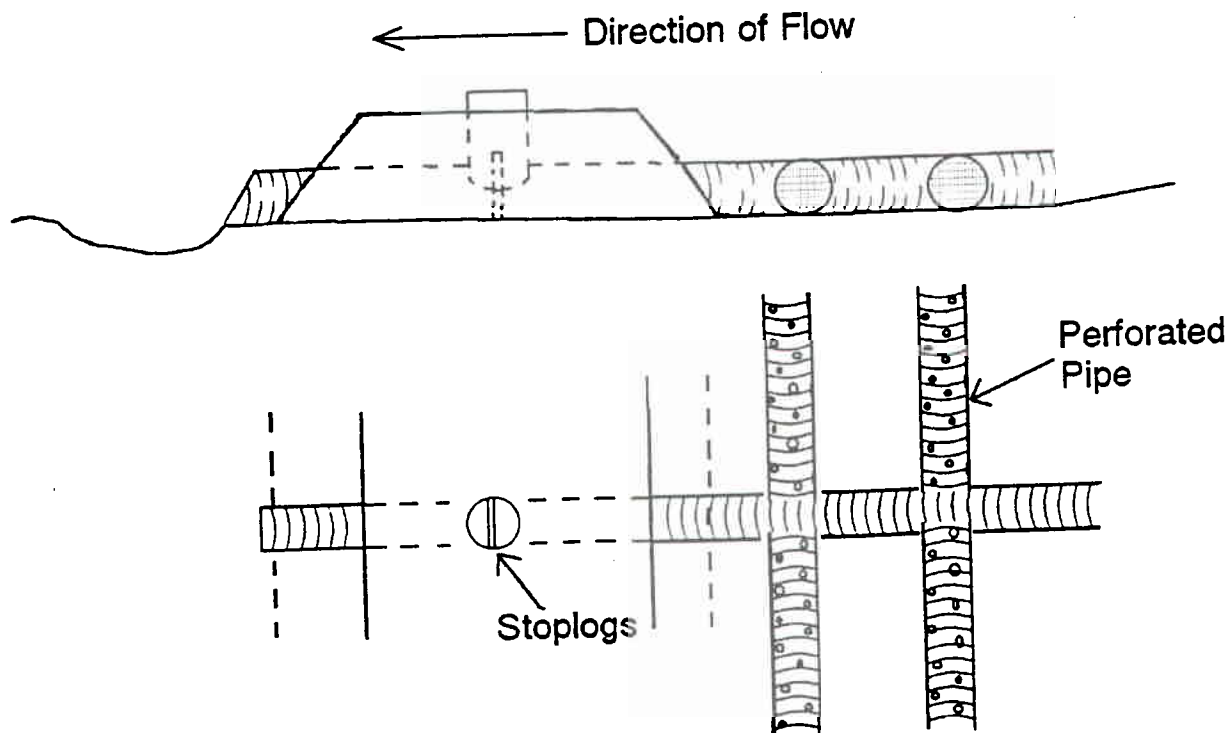


Figure 11. Conceptual design for water-control structure to restrict beaver activity that compromises water management.

have a greater area of stoplogs, beavers require more time to completely plug the structure (Fig. 6). When beavers build dams across borrow ditches or boat channels, the dams must be removed with heavy equipment or with explosives to facilitate drainage. In many cases explosives are the only option to remove dams when conditions are too wet or remote for the use of equipment.

A second suite of strategies relates to the operation of the GTRs. Beaver activity tends to be highest and most problematic when impoundments are being filled or drained because moving water creates noise. Most beaver activity occurs from dusk to dawn. By restricting

the discharge of water during the day, control structures are less likely to be plugged each night. Obviously only operating the control structures during the day requires more manpower during drawdowns because each control structure must be opened in the morning and closed in the afternoon. Foremost among management responsibilities during flooding and drawdowns are daily inspections to insure that water continues to flow. Thus, early morning inspections are most important to identify beaver activity that obstructed water movement during the previous night. These obstructions must be removed daily if water management is to continue in a timely manner.

PHASE IV—MONITORING

The monitoring phase is essential to evaluate the success of management activities, to make necessary adjustments to improve habitat management strategies, and to prevent damage to the integrity of the BLH forest. In essence, monitoring of GTRs can be conducted at 2 levels: (1) an evaluation of impoundment conditions to prevent ecological damage; and (2) an assessment of habitat quality through more intensive assessments of plant and animal communities. For purposes of this document, we will only address the former monitoring scheme.

Monitoring in GTRs is particularly critical because of the amount of damage that can occur in a short period if flooding extends into the growing season. An effective monitoring plan should assess water conditions, tree stress, regeneration conditions, and species composition

changes. Monitoring is not meant to be research; therefore, some of the limitations associated with research such as random samples do not necessarily apply. Systematic sampling is advantageous because there is the potential to assess general conditions throughout an impoundment. Plots should be established within representative plant communities, elevations, timber-management tracts, or other areas that may provide unique information about the impoundment or management activities. Plots should be replicated and if conditions warrant, other plots should be added to monitor problem areas. Several hydrologic and vegetation variables should be measured at varying time intervals (Table 3).

The overall plot should be at least 0.25 acres in size (Fig. 12).

Table 3. Overview of minimum and intensive sampling strategies for GTRs. GTR managers can use these methodologies to help prevent ecological damage to the GTR area. An assessment of habitat quality through more extensive and intensive sampling of plant and animal communities is not covered in this handbook but is recommended for land managers.

Strategy	Variable	Sampling scheme	Information	Frequency of sampling
Minimum	Overstory	Plots	DBH Species Composition Buttressing P/A Crown Class Stress Class	Pre-impoundment; every 7–10 yrs Pre-impoundment; annually
	Regeneration	Transects	Presence/Abundance and Composition	Pre-impoundment; annually in fall prior to flooding
	Water	Plots	Depth	Pre-impoundment; every 2 weeks in growing season first 2–3 yrs; minimum of monthly thereafter
Intensive	Overstory	Plots	DBH Species Buttressing P/A Crown Class Stress Class	Pre-impoundment; every 5 yrs Pre-impoundment; annually
	Shrubs/Saplings	Plots	DBH Species	Pre-impoundment; every 5 yrs
	Regeneration	Plots	Species Height (subsample)	Pre-impoundment; every 5 yrs
	Water	Plots	Depth	Pre-impoundment; every 2 weeks

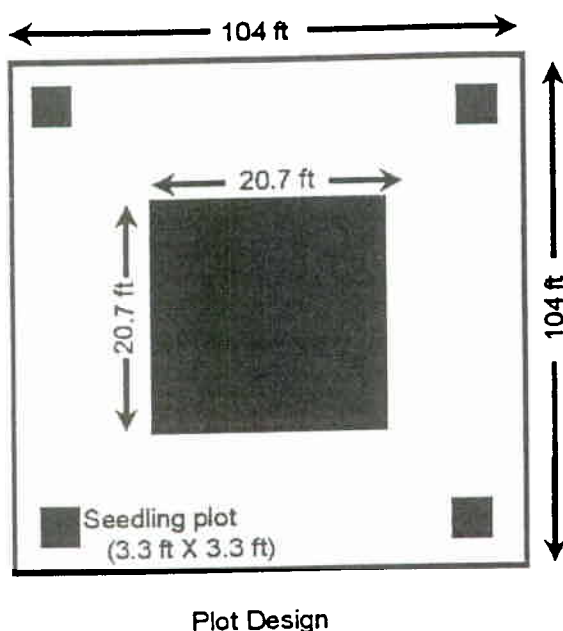


Figure. 12. Layout of an intensive monitoring plot. Minimum monitoring procedures should include the 104 ft. x 104 ft. overstory sampling plot.

As an absolute minimum, water depth, and the diameter, species, presence/absence of buttressing, and crown class of all trees (> 6.0 inches diameter-at-breast height {dbh}) should be measured and recorded. Water depths should be measured at the center of each whole plot every 2 weeks during the growing season for the first 2-3 years of management. Intensive sampling during the first few years is necessary to evaluate flooding patterns on the site and to identify potential drainage problems resulting from topography or beavers. If beavers are not a problem and topography is not limiting drainage, then water-level sampling can be moved to once per month.

The placement of numbered tags on all trees are helpful (Note: Aluminum nails should be used and 0.5" or more of the nails should be left on the outside of the tree to allow for tree growth. In subsequent samples the nails should be readjusted to allow for additional growth). Canopy condition must also be assessed based upon the coloration of leaves and mortality of branches within the crown. Some suggested crown stress classes are as follows: 1) none to 5% of crown dead; 2) 6 to 25% of crown dead; 3) 26 to 50% of crown dead; 4) 51 to 75% of crown dead; 5) 76 to 95% of crown dead; 6) 96 to 100% crown dead; and 7) tree is dead and most or all

branches have deteriorated and fallen. The presence, composition, and abundance of regeneration should be determined and incorporated into the annual water-management plan as described above. The minimum assessment of seed production and the abundance and composition of regeneration can be accomplished by establishing transects in the impoundment and traversing these in the fall (September). It is particularly important that the transects provide an overview of all communities, thus selection of transect location is a critical component of monitoring.

Additional vegetation data could be collected to provide a more thorough assessment of water-management activities on vegetation. This can be accomplished by establishing a 0.01 acre sub-plot centered within the whole plot. Five seedling plots (3.28 ft X 3.28 ft) should be placed in each corner and at the center of the whole plot. In each of the 0.01 acre subplots, the diameter and species of all saplings and shrubs (> 4.5 ft tall but < 6.0 in dbh) should be recorded. The species of all seedlings should be recorded in each of the seedling plots. This information will enhance the ability of managers to detect gradual, long-term shifts in vegetative communities at an early stage and allow for corrective actions in a timely manner. Early detection of problems with seedling and sapling abundance and composition can provide valuable insights into compositional changes and can prevent a degradation of habitat quality. For example, a total lack of seedlings or seedlings of only the most water-tolerant species suggests that either mast failure, germination, or establishment of the less water-tolerant species are occurring and water-management activities should be carefully scrutinized. Appropriate corrections should be made to prevent compositional shifts and/or mortality of less water-tolerant tree species.

Regardless of whether the minimum or intensive approach is used, all vegetation should be measured prior to construction of the GTR. Tree stress and a visual estimate of the abundance and composition of regeneration should be measured on an annual basis (Table 4). Annual water-management plans should carefully consider tree stress values. Impoundments should not be flooded if trees are stressed regardless of what the long-term water-management plan dictates.

Table 4. Indicators of flooding stress on bottomland trees and potential for recovery.

Condition	Probable cause	Potential for recovery
Yellowing of leaves (Chlorosis)	Saturated soils and/or shallow flooding during the growing season	Good if flooding frequency and duration reduced. Do not flood for at least 2-3 years or longer if trees do not recover
Loss of flowering	Saturated soils and/or shallow flooding for extended period during dormant and growing season	Good if flooding frequency and duration reduced
Canopy thinning (fewer leaves produced)	Saturated soils and/or shallow flooding for part of the growing season for 2 or more years	Fair if flooding frequency and duration reduced. Do not flood for at least 2-3 years or longer if trees do not recover
Butt swelling on red oaks	Dormant season flooding at same depth, duration and timing for 10 or more years	Fair if flooding frequency, duration, and depth is changed to be dynamic within and among years
Tip die-back	Long-deep flooding in dormant season and extended flooding in 2 or more growing seasons	Fair when first noticed, but trees most likely have reduced vigor and will have increased mortality in next 5 to 7 years. Do not flood for at least 2-3 years or longer if trees do not recover
Large dead branches (2" or more in diameter)	Long-deep flooding in dormant season and well into and during the growing season	No reversal possible

SUGGESTED READING

- Allen, J. A. and H. E. Kennedy, Jr. 1989. Bottomland hardwood reforestation in the Lower Mississippi Valley. U.S. Fish and Wildlife Service, Slidell, LA, USA and U.S. Forest Service, Southern Forest Experiment Station, Stoneville, MS, USA.
- Allen, J. A., J. W. Teaford, E. C. Pendleton, and M. Brody. 1988. Evaluation of greentree reservoir management options in Arkansas. Transactions of the North American Wildlife and Natural Resources Conference 53:471-480.
- Batema, D. L., G. S. Henderson, and L. H. Fredrickson. 1985. Wetland invertebrate distribution in bottomland hardwoods as influenced by forest type and flooding regime. p. 196-202. In Proceedings of the Fifth Central Hardwoods Conference, University of Illinois, Urbana-Champaign, IL, USA.
- Bedinger, M. S. 1971. Forest species as indicators of flooding in the Lower White River Valley, Arkansas. U.S. Geological Survey Professional Paper 750-C:C248-C253.
- Briscoe, C. B. 1961. Germination of cherrybark and nuttall oak acorns following flooding. Ecology 42:430-431.
- Bullock, J. F. and D. H. Arner. 1985. Beaver damage to nonimpounded timber in Mississippi. Southern Journal of Applied Forestry 9:137-140.
- Chambers, J. L., K. Velupillai, S. Guddanti, H. Williams, S. Erwin, R. Pezeshki, and H. E. Kennedy, Jr. 1993. Root growth response of several bottomland oak species to flooding. Louisiana State University, School of Forestry Wildlife and Fisheries, Final Report, Cooperative Research Project 19-88-064.
- Christman, S. P. 1984. Breeding bird response to greentree reservoir management. Journal of Wildlife Management 48:1164-1172.
- Coates, K. D., and P. J. Burton. 1997. A gap-based approach for development of silvicultural systems to address ecosystem management objectives. Forest Ecology and Management 99:337-354.
- Crawford, C. S., L. M. Ellis, M. C. Molles, Jr., and H. M. Valett. 1996. The potential for implementing partial restoration of the Middle Rio Grande ecosystem. p. 93-98. In D. W. Shaw and D. M. Finch (technical coordinators) Desired Future Conditions for Southwestern Riparian Ecosystems: bringing interests and concerns together. U.S. Forest Service General Technical Report RM-GTR-272.
- DuBarry, A. P. 1963. Germination of bottomland tree seed immersed in water. Journal of Forestry 61:225-226.
- Ernst, J. P. and V. Brown. 1989. Conserving endangered species on southern forested wetlands. p. 135-145. In D. D. Hook and R. Lea (eds.) Proceedings of the Forested Wetlands of the Southern United States, Orlando, FL, USA, U.S. Forest Service General Technical Report SE-50.
- Francis, J. K. 1983. Acorn production and tree growth of Nuttall oak in a green-tree reservoir. U.S. Forest Service, Southern Forest Experiment Station, New Orleans, LA, USA. Research Note SO-289.
- Fredrickson, L. H. 1979. Floral and faunal changes in lowland hardwood forests in Missouri resulting from channelization, drainage, and impoundment. U. S. Fish and Wildlife Service, Biological Services Program, Washington, DC, USA. FWS/OBS-78/91.
- Fredrickson, L. H. 1997. Managing forested wetlands. Pages 147-177 in M. S. Boyce and A. Haney, eds. Ecosystem management: Applications for sustainable forest and wildlife resources. Yale University Press, New Haven, Connecticut.
- Fredrickson, L. H., and M. E. Heitmeyer. 1988. Wetland use of southern forested wetlands by waterfowl. Pages 307-343 in M. W. Weller, ed. Waterfowl in winter. University of Minnesota Press, Minneapolis.
- Fredrickson, L. H. and F. A. Reid. 1990. Impacts of hydrologic alteration on management of freshwater wetlands. p. 71-90. In J. M. Sweeney (ed.) Management of Dynamic Ecosystems. North Central Section, The Wildlife Society, West Lafayette, IN, USA.
- Fredrickson, L. H. and D. L. Batema. 1993. Greentree reservoir handbook. Gaylord Memorial Library, Wetland Management Series Number 1. University of Missouri, Columbia, School of Natural Resources, Gaylord Memorial Library, Puxico, MO, USA.
- Cresham, C. A. 1985. Clearcutting not enough for early establishment of desirable species in

- Santee River Swamp. *Southern Journal of Applied Forestry* 9:52-54.
- Gysel, L. W. 1956. Measurement of acorn crops. *Forest Science* 2:305-313.
- Hamel, P. B. 1989. Breeding bird populations on the Congaree Swamp National Monument, South Carolina. p. 617-628. *In* R. R. Sharitz and J. W. Gibbons (eds.) *Freshwater Wetlands and Wildlife*. CONF-8603101, U.S. Department of Energy Symposium Series No. 61, U.S. Department of Energy Office of Scientific and Technical Information, Oak Ridge, TN, USA.
- Harris, L. D. 1988. The faunal significance of fragmentation of southeastern bottomland forests. p. 126-134. *In* D. D. Hook and R. Lea (eds.) *Proceedings of the Forested Wetlands of the Southern United States*, Orlando, FL, USA. U.S. Forest Service General Technical Report SE-50.
- Harris, L. D. and T. E. O'Meara. 1989. Changes in southeastern bottomland forests and impacts on vertebrate fauna. p. 755-772. *In* R. R. Sharitz and J. W. Gibbons (eds.) *Freshwater Wetlands and Wildlife*, CONF-8603101, U.S. Department of Energy Symposium Series No. 61, U.S. Department of Energy Office of Scientific and Technical Information, Oak Ridge, TN, USA.
- Heitmeyer, M. E., L. H. Fredrickson, and G. F. Krause. 1991. Water relationships among wetland habitat types in the Mingo Swamp, Missouri. *Wetlands* 11:55-66.
- Hodges, J. D. 1994. The southern bottomland hardwood region and brown loam bluffs sub-region. p. 227-269. *In* J. W. Barrett (ed.) *Regional Silviculture of the United States*. 3rd ed. John Wiley and Sons, New York, NY, USA.
- Hosner, J. F. 1957. Effects of water upon the seed germination of six bottomland tree species. *Ecology* 39:371-373.
- Hubert, W. A. and J. N. Krull. 1973. Seasonal fluctuations of aquatic macroinvertebrates in Oakwood Bottoms Greentree Reservoir. *American Midland Naturalist* 90:177-185.
- Hunter, W. C., B. W. Anderson, and R. D. Ohmart. 1987. Avian community structure changes in a mature floodplain forest after extensive flooding. *Journal of Wildlife Management* 51:495-502.
- Johnson, R. L. 1975. Natural regeneration and development of Nuttall oak and associated species. U.S. Forest Service, New Orleans, LA, USA. Research Paper SO-104.
- Jones, R. H., R. R. Sharitz, P. M. Dixon, D. S. Segal, and R. L. Schneider. 1994. Woody plant regeneration in four floodplain forests. *Ecological Monographs* 64:345-367.
- Karr, B. L., G. L. Young, J. D. Hodges, B. D. Leopold, and R. M. Kaminski. 1990. Effect of flooding on greentree reservoirs. U.S. Department of Interior, Washington, DC, USA. Technical Completion Report G1571-03.
- King, S. L. 1995. Effects of flooding regimes on two impounded bottomland hardwood stands. *Wetlands* 15:272-284.
- King, S. L., and J. A. Allen. 1996. Plant succession and greentree reservoir management: Implications for management and restoration of bottomland hardwood wetlands. *Wetlands* 16:503-511.
- King, S. L. and W. E. Grant. 1996. A simulation model of the impacts of green-tree reservoir management on bottomland hardwood seedling growth and survival. *Ecological Modelling* 87:69-82.
- Klimas, C. V. 1988. River regulation effects on floodplain hydrology. p. 40-49. *In* D. D. Hook, W. H. McKee, Jr., H. K.
- Smith, J. Gregory, V. G. Burrell, Jr., M. R. DeVoe, R. E. Sojka, S. Gilbert, R. Banks, L. H. Stolzy, C. Brooks, T. D. Matthews, and T. H. Shear (eds.) *The Ecology and Management of Wetlands*. Volume 1: Ecology of Wetlands. Timber Press, Portland, OR, USA.
- Krull, J. N. 1969. Seasonal occurrence of macroinvertebrates in a green-tree reservoir. *New York Fish and Game Journal* 16:119-124.
- Larsen, H. S. 1963. Effects of soaking in water on acorn germination of four southern oaks. *Forest Science* 9:236-241.
- Malecki, R. A., J. R. Lassoie, E. Rieger, and T. Seamans. 1983. Effects of long-term artificial flooding on a northern bottomland hardwood community. *Forest Science* 29:535-544.
- Massey, B. J. 1998. *Wetlands Engineering Manual*. Southern Regional Office, Ducks Unlimited, Inc. 16pp.
- McQuilkin, R. A. and R. A. Musbach. 1977. Pin oak acorn production on greentree reservoirs in southeastern Missouri. *Journal of Wildlife Management* 41:218-225.
- Merz, R. W. and G. K. Brakhage. 1964. The management of pin oak in a duck shooting

- area. *Journal of Wildlife Management* 28:233-239.
- Meadows, J. S., and J. A. Stanturf. 1997. Silvicultural systems for bottomland hardwood forests. *Forest Ecology and Management* 90:127-140.
- Minckler, L. S. and R. E. McDermott. 1960. Pin oak acorn production and regeneration as affected by stand density, structure, and flooding. University of Missouri, Agricultural Experiment Station, Columbia, MO, USA. Research Bulletin 750.
- Mitsch, W. J. and J. G. Gosselink. 1993. *Wetlands*. 2nd ed. Van Nostrand Reinhold, New York, NY, USA.
- Moorhead, D. J., J. D. Hodges, and K. J. Reinecke. 1990. Silvicultural options for waterfowl management in bottomland hardwood stands and greentree reservoirs. p. 710-721. *In* Proceedings of the Sixth Biennial Southern Silvicultural Research Conference, U.S. Forest Service, Asheville, NC, USA. General Technical Report, SE-70.
- Reily, P. W. and W. C. Johnson. 1982. The effects of altered hydrological regime on tree growth along the Missouri River in North Dakota. *Canadian Journal of Botany* 60:2410-2423.
- Rudolph, R. R. and C. G. Hunter. 1964. Greentrees and greenheads. p. 611-618. *In* J. P. Linduska (ed.) *Waterfowl Tomorrow*. U.S. Department of Interior, Washington, DC, USA.
- Schlaegel, B. E. 1984. Long-term artificial annual flooding reduces nuttall oak bole growth. U.S. Forest Service, New Orleans, LA, USA. Research Note SO-309.
- Schneider, R. L., N. E. Martin, and R. R. Sharitz. 1989. Impact of dam operations on hydrology and associated floodplain forests of southeastern rivers. p. 1113-1121. *In* R. R. Sharitz and J. W. Gibbons (eds.) *Freshwater Wetlands and Wildlife*. U.S. Department of Energy Symposium Series 61, CONF-8603101, U.S. Department of Energy Office of Scientific and Technical Information, Oak Ridge, TN, USA.
- Shankman, D. 1993. Channel migration and vegetation patterns in the southeastern coastal plain. *Conservation Biology* 7:176-183.
- Streng, D. R., J. S. Glitzenstein, and P. A. Harcombe. 1989. Woody seedling dynamics in an east Texas floodplain forest. *Ecological Monographs* 59:177-204.
- Theriot, R. F. 1993. Flood tolerance of plant species in bottomland forests of the southeastern United States. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS, USA. Wetlands Research Program Technical Report WRP-DE-6.
- Toliver, J. R. and B. D. Jackson. 1989. Recommended silvicultural practices in southern wetland forests. p. 72-77. *In* D. D. Hook and R. Lea (eds.) *Proceedings of the Forested Wetlands of the Southern United States*, Orlando, FL, USA. U.S. Forest Service General Technical Report SE-50.
- Ward, J. V. and J. A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. *Regulated Rivers: Research and Management* 11:105-119.
- Weller, M. W. 1988. Bird use of an east Texas shrub wetland. *Wetlands* 8:145-158.
- Weller, M. W. 1989. Plant and water-level dynamics in an east Texas shrub-hardwood bottomland wetland. *Wetlands* 9:73-88.
- Wehrle, B. W., R. M. Kaminski, B. D. Leopold, and W. P. Smith. 1995. Aquatic invertebrate resources in Mississippi forested wetlands during winter. *Wildlife Society Bulletin* 23:774-783.
- Wharton, C. H., W. M. Kitchen, E. C. Pendleton, and T. W. Side. 1982. The ecology of bottomland hardwood swamps of the Southeast: a community profile. U.S. Fish and Wildlife Service Biological Services Program, Washington, DC, USA. FWS/OBS-81/37.
- White, D. C. 1985. Lowland hardwood wetland invertebrate community and production in Missouri. *Archiv Hydrobiologie* 103:509-533.
- Wigley, T. B. and T. H. Filer, Jr. 1989. Characteristics of greentree reservoirs: a survey of managers. *Wildlife Society Bulletin* 17:136-142.
- Young, G. L., B. L. Karr, B. D. Leopold, and J. D. Hodges. 1995. Effect of greentree reservoir management on Mississippi bottomland hardwoods. *Wildlife Society Bulletin* 23:525-531.

