FORESTS AND FLOODING WITH SPECIAL REFERENCE TO THE WHITE RIVER AND OUACHITA RIVER BASINS, ARKANSAS

U.S. GEOLOGICAL SURVEY

WATER-RESOURCES INVESTIGATIONS
OPEN-FILE REPORT 79-68

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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By M. S. Bedinger

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Lakewood, Colorado
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UNITED STATES DEPARTMENT OF THE INTERIOR

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RIVER AND OUACHITA RIVER

BASINS, ARKANSAS

By M. S. Bedinger

Abstract

The observed response of trees to hydrologic stress and distribution of trees in relation to habitat indicate that flooding, ground-water level, soil moisture, soil factors, and drainage characteristics exert a strong influence on bottomland forest species distribution. The dominant hydrologic factor influencing the distribution of bottomland tree species is flooding. Individual tree species are distributed as a function of frequency and duration of flooding. In the lower White and Ouachita River basins, the flood plains consist of a series of terraces, progressively higher terraces having less frequent flooding and less duration of flooding, and a significantly different composition of forest tree species. The sites studied can be divided into four basic groups and several subgroups on the basis of flood characteristics. On Group I (water hickory-overcup oak) sites, flooded near annually 32-40 percent of the time, the dominant species are water hickory and overcup oak. On Group II (nuttall oak) sites, flooded near annually 10-21 percent of the time, a more varied flora exists including nuttall oak, willow oak, sweetgum, southern hackberry, and American elm. The third group (Group III or shagbark hickory-southern red oak) of sites is flooded at intervals from 2 to 12 years. This group includes southern red oak, shagbark hickory, and black gum. The presence of blackjack oak in addition to Group III species marks Group IV (not flooded in historic time).

In the Ouachita River valley a subgroup of Group II is represented by sites flooded annually or near annually, but for durations of less than 9 percent of the time. The species makeup of these sites, designated Group IIA, has characteristics of Group I, Group II, and Group III.

Introduction

Hydrologic Factor and Forest Species

Water is by far the dominant environmental factor influencing the distribution of tree species in the flood plain.

One of the most useful methods in describing the hydrologic conditions in relation to vegetation distribution is the concept of the "moisture gradient" introduced by Whittaker (1956). Whittaker described the position of a site within the moisture gradient according to a qualitative measure of the relative moisture available. Moisture gradients in the Great Smoky Mountains of Tennessee and Virginia (Whittaker, 1956) and Santa Catalina Mountains, Arizona (Whittaker and Niering, 1965), were found to be related to elevation and topographic position (i.e., ravines, draws, canyon bottoms, lower slopes, and open slopes). Upon open slopes, the position of a site on moisture gradient is related to aspect with respect to compass direction. It is apparent that the range in moisture along the profiles studied by Whittaker is vastly greater than the range in moisture in flood plains in the United States east of the 95th meridian. The sites considered in this report are within the mesic zone of the moisture gradient considered by Whittaker. Nevertheless, the moisture gradient in flood plains, as measured by flood frequency and duration, is sufficiently broad to harbor the full range of a large number of species.

Utilizing the concept of moisture gradients as developed by Whittaker (1956, p. 43) is appropriate to the plant distribution in flood plains. That is, species populations are variously distributed along gradients, each according to its own physiology and genetic pattern. The distribution of a species can be defined in terms of population distributions along moisture gradients. The validity of this thesis with respect to distribution in the mesic, supermesic, and hydric range of the moisture gradient, which could be called the "flooding gradient" is substantiated by many studies including those of Brown (1943), Lindsey, Petty, Sterling, and Van Asdall (1961), Hall and Smith (1955), Franz and Bazzaz (1977), Bedinger (1971) and the present study.

In the botanical literature of flood plains, site descriptions are commonly referenced to features such as first bottoms, second bottoms or terraces, uplands, riverfront, swamps, poorly drained flats, well-drained flats, and sloughs. A hydrologic relation in each of these habitats is implied if not explicitly expressed. Turner (1937) describes rather completely the forest habitats of Arkansas. Turner divides first bottoms into two types, (1) very wet; wholly or intermittently submerged, and (2) submerged only during flooding. Type 2 is in turn subdivided into (a) poorly drained sites, and (b) better drained sites. Second bottoms or terraces were divided by Turner into three categories, (1) sites with poor drainage, (2) sites with intermediate drainage, and (3) sites with fair to good drainage. Turner divides small- and medium- sized flood plains into sites of fair to good drainage and sites of poor to fair drainage. Moore's (1972) classification of flood-plain habitats in Arkansas generally follows that of Turner (1937).

Studies of plant distributions have commonly recognized the relationship between hydrologic factors, particularly flooding, and plant species. An early study by Nichols (1916) in the Connecticut River valley recognized the progressive development of the flood-plain levels, the gradation from hydrophytic to mesophytic conditions and the concomitant change in vegetation. Distinct differences in plant assemblages were noted by Illichevsky (1933) on terrace levels subject to periodic flooding as contrasted with levels above flood stage. Stratification of plant species related to height above the river and decreasing flood frequency was pointed out in the Raritan River, New Jersey flood plain by Buell and Wistendahl (1955) and Wistendahl (1958). Brown (1943) found that vegetation zones on the margin of Catahoula Lake, Louisiana, correlate closely with lake levels.

Shelford (1954) treated the in-channel and flood-plain environment as a dynamic continuum and characterized the plant and animal life associated with the geomorphic development in the Mississippi River valley from New Madrid, Missouri, to Tipton, Tennessee. By the use of historic maps, river charts, other records, and tree-age data, he attempted to determine the time duration of various stages of geomorphic development--the age of deposits that trees are growing on and the height of the deposits above mean low water.

A number of studies reported in the literature demonstrate the application of studies of vegetation in interpreting hydrology. Wolman (1971) suggests relating plant assemblages with flood frequency as a technique for mapping flood plains. The author (Bedinger, 1971) previously described plant associations along the White River, Arkansas, and related species distributions to flood frequency and duration. He pointed out the potential of mapping tree species as an aid in flood-plain mapping and in extending stream-stage data from gaged points on streams.

Other uses of trees as aids in hydrologic interpretation include those employed by Sigafoos (1964) and by Hack and Goodlett (1960) in dating notable hydrologic events such as distinctive floods, ice-thrust deformation and sedimentation events. Tree-ring cores have been of value in reconstructing flood histories of ungaged watersheds (Stockton and Loring, 1976), and reconstruction of long-term lake level changes (Stockton and Fritts, 1973).

Studies in the western United States have established tree-ring techniques as a valuable tool in reconstructing climatic variations (Schulman, 1956, Fritts, 1963). Recent work by Cook and Jacoby (1977) and by Phipps, Ierley, and Baker (1979) has demonstrated the potential of tree rings in reconstruction of hydrologic and climatic changes in eastern United States forests.

Purpose of Study

The purposes of this study were to review the literature on the relation of flooding and tree species and to determine quantitatively the distribution of tree species in relation to flooding in the lower White River and Ouachita River valleys, Arkansas. The literature is extensive and the search here indicated is not exhaustive, but is believed to represent the present state of knowledge. The reviews are included as a means of providing some insight into the cause-effect relation between flooding and tree distribution and relative tolerance of bottomland species.

Response of Forest Species to Hydrologic Stress

The observed physiological response of tree species to hydrologic stress and distribution of trees in relation to hydrologic habitat suggest that flooding, ground-water level, soil moisture, soil factors, and drainage characteristics exert a strong influence on bottomland forest-species distribution.

The literature describing various hydrologically related factors to forest-species distribution can be generally divided into (1) reports of laboratory studies describing the response of seeds on seedlings of forest species to controlled hydrologic stress, (2) reports of field studies describing the response of forest species to drastic changes in hydrologic environment such as impoundment.

Laboratory Studies

Numerous laboratory experiments have been made to observe the response of seedlings and seeds of forest species under controlled hydrologic conditions. Tree seeds may be subject to prolonged submergence and viability of seed after periods of submergence can control the germination of various species on a given site. Experiments with controlled flooding have been made with seeds of relatively few species: Baldcypress showed unimpaired viability after 7 weeks submergence but seeds failed to germinate after 14 months and 21 months submergence (Applequist, 1959). Demaree (1933) reported that a few baldcypress germinated after 30 months submergence. Water tupelo demonstrated good viability after submergence of 7 months (Shunk, 1939), 12 months (Briscoe, 1957) and 14 months (Applequist, 1959), but seed failed to germinate after 21 months of submergence (Applequist, 1959). Seeds of blackgum showed less tolerance to submergence than water tupelo (Briscoe, 1957). This relative tolerance was observed in the field by Bedinger (1971) where blackgum was observed on higher sites flooded less than 4 percent of the time.

Studies of germination of cherrybark oak and nuttall oak acorns after submergence indicate that flood frequency and duration are the environmental factors having the greatest effect on the distribution of species (Briscoe, 1961). Nuttall oak acorns showed no significant decrease in germination after submergence for periods up to 34 days; germination of cherrybark oak acorns was significantly lowered by 34-day submersion (Briscoe, 1961). In the White River bottoms cherrybark oak is a common species in sites flooded at frequencies of 2 years or less frequent for durations of 4 percent or less whereas nuttall oak is common on sites flooded at frequencies of 2 years or more frequent for durations greater than 4 percent of the time (Bedinger, 1971)

The effect of flooding on seedling roots is generally to produce stunted growth or death, but bottomland species react with variable tolerance to root submersion (McDermott, 1954; Hosner and Boyce, 1962; Hook and Brown, 1973; Hunt, 1951). The relative recovery from stunting may be indicative of a species tolerance to flooding and a significant factor in species composition of bottomland sites. Bottomland hardwood species also show selective tolerance to complete submergence of seedlings. Hosner (1958) and McAlpine (1961) found that the survival and mortality rate of plants varied with species and different periods of flooding. Selective survival to flooding is a primary mechanism that controls stratification of species in relation to flooding characteristics of at least the lower bottomlands.

The ability of a tree to survive under flooding conditions is related to special metabolic and anatomical adaptations in response to soil anaerobiosis (Gill, 1970). Many observations have been made on root structure and hypotheses formulated to account for the survival of species under flooding (Bryant, 1934; Kramer, 1951; Yeager, 1949; Hosner and Boyce, 1962; Jackson, 1955; Hook and others, 1970). The most powerful argument that metabolic, rather than morphologic, adaptations enhance survival of some species under flooding conditions is that tolerances to flooding vary widely among species that show similar morphologies (Gill, 1970). Metabolic adaptations have been studied by several investigators, among them Crawford (1967), Crawford and McMannon (1968), Crawford and Tyler (1969), and Hook, Brown, and Kormanik (1971).

Field Studies

Observations of the response of trees on the margins of man-made surface-water impoundments provide information on tolerance of trees to flooding. Tolerance of large trees to flooding is generally greater than that of seeds and seedlings. Studies generally report response of trees greater than 3 in. DBH (diameter at breast height 4½ ft.) to flooding and are useful in establishing tolerance of tree species. However, tolerances of large trees are of limited value in interpreting establishment of tree-species distribution under natural conditions.

An excellent review of the literature on the flooding tolerance of woody species was made by Gill (1970). Gill summarizes (1) the effects of flooding, (2) factors that determine survival of trees under flooding, and (3) the mechanisms of flood tolerance.

Gill classifies survival factors influencing recovery from floods as species, differentiating between interspecific and intraspecific factors, soil factors, and timing and duration of flooding. Gill's review reflects the fact that most flooding tolerance work has been done (1) with seedlings in the laboratory or (2) by observations of response of trees to flooding around man-made impoundments. Durations of flooding for most species are only critical when flooding occurs in the growing season. Flooding in the dormant season has little or no effect, regardless of duration. The sensitivity of tree species to duration of flooding during the growing season varies interspecifically and has been used as a measure of flood tolerance (Hosner, 1958).

An unusually well documented history of flood-duration tolerance of forest species is afforded by the work of Hall and Smith (1955). These investigators related the survival of forest species to the duration of growing season inundation on the margin of Kentucky Lake, Tennessee. All woody species were killed within the area that was flooded more than 54 percent of the growing season. Very high mortality was observed in the area that was flooded from 41 to 54 percent of the growing season. Of the species examined water elm, black willow, and overcup oak were the three species most tolerant of flooding; black cherry and flowering dogwood were the least tolerant. The data of Hall and Smith (1955) show that established trees (greater than 3 in. DBH) can survive growing season flood durations exceeding flood durations of sites on which they occur naturally. For example, sweetgum retained healthy growth on sites flooded 34.3 percent of the growing season, but, in the White River valley (Bedinger, 1971) sweetgum does not occur naturally on sites flooded greater than 21 percent of the time. Similar contrasts can be shown for many other species. Whereas established plants survived when flooded, the study by Hall and Smith shows that with exception of the willow, naturally established seedlings of most species cannot survive submergence during the growing season.

The effect of artificial flooding of hardwood species to depths as great as 90 cm has been observed by Broadfoot (1958, 1960, 1967). Broadfoot (1960) has shown that flood-tolerant species, nuttall oak, green ash, sweetgum, and overcup oak are not only tolerant to continuous flooding, but most individual trees show accelerated growth during the first 2 years of continuous impoundment. In contrast, most trees of a less flood tolerant species, southern red oak, died by the end of the 2d year of continuous flooding. In response to flooding during the winter, spring, and summer until July 1 for successive years, Broadfoot (1967) found that growth of hardwood species significantly increased compared with species growing on unflooded sites. The experiments of Broadfoot cited previously provide insight to the observed distribution of hardwood species. Similarly, observations on the intolerance of seedlings to flooding during the growing season, and observations of the intolerance to drought of flood-tolerant species (Putnam and others, 1960) provide evidence of the wide range of hydrologic factors that influence the distribution of bottomland tree species.

The mortality of 32 species of trees caused by high water levels in 1973 of two reservoirs in Illinois was studied by Bell and Johnson (1974). The species spanned a wide range in flood tolerance, including several species rarely found in flood plains.

The effects of several years impoundment on the upper Mississippi River was reported by Green (1947) and Yeager (1949). Green (1947) found no species survived 4 years of constant flooding. The trees involved were bottomland species generally associated with flood frequencies more often than 10 years and many of the species are common on sites flooded annually. Green observed that submergence of the root crown, regardless of depth, produced mortality in most woody species -- willow, birch, cottonwood, silver maple, elm, hackberry, red oak, bur oak, swamp white oak, pin oak, alder, and green ash. Species which survived permanent root crown submergence were deciduous holly, swamp privet, button bush, and red osier dogwood; all of these species were hardy after 4 to 7 years. Generally, where root crowns were not permanently flooded, the bottomland species survived.

Yeager (1949) found practically complete mortality of trees flooded for 8 years. The harmful effect of a water table raised to the land surface was clearly discernible, but mortality for each species was less than from surface flooding. On land not flooded, but subjected to a 3-foot rise in water table, only pin oak showed conspicuous reaction -- mortality of this species reached 28.2 percent. Losses of elm and maple were much lower, and white oak, pecan, cottonwood, and several other trees and shrubs were unaffected by the higher water level.

Initial inundation of from 7 to 100 days at Keystone and Oolagah reservoirs (Oklahoma) most severely affected vegetation within a zone 10 feet above normal pool stage. Mortality was highest among oak and hickory and was lower with hackberry, pecan, elm, green ash, sycamore, cottonwood, and willows (Harris, 1975).

The results of planting of flood-tolerant species of trees along margins of fluctuating reservoirs were reported by Silker (1948). The report summarizes the response of baldcypress, tupelo, sweetgum, green ash, water oak, willow oak, southern white cedar, and sycamore.

Most studies of the response of tree species to changes in flooding are related to decrease in flood frequency and increase in flood duration. The resulting flooding characteristics are often not typical of natural conditions. For example, under artificial increase in flooding, the flooding period often occurs during the growing season or, indeed, during the entire year.

A few studies have reported the effects of decreased flooding. There are probably many opportunities to observe such effects, but the results are not so dramatic or obvious as stress due to increase in flooding. Periodic flooding of a stretch of the valley of the Missouri River in North Dakota has been eliminated or greatly reduced by flood-control measures. Data collected by Burgess, Johnson, and Keammerer (1973) indicate that flood reduction has led to decreased tree growth and decline in tree reproduction.

In contrast effects of lowering of shallow water tables by drainage ditches on tree species indicate an increase in growth and vigor (Payandeh, 1973). Phipps and others (1979) examined growth responses of loblolly pine growing in an area of near soil surface-water table where water levels had been lowered slightly by ditching. They found rapid increases in growth rate following ditching and then a gradual, several-year decrease (of growth rates) to pre-ditching rates. It was felt that the slight lowering of the near surface-water table allowed what they termed "root release," resulting in a growth response analogous to that typically associated with crown release following lumbering.

Forest Simulation Models

Simulation modeling of ecosystems is a young, but promising discipline. Early ecosystems models made possible by analog and digital computers, were those of Odum (1960), Olson (1963), and Garfinkel (1962). A recent paper by Wiegert (1975) reviews in depth the present state of ecosystems simulation. Early models included few designed for forested ecosystems.

A forest simulation model, SWAMP, has been constructed by Phipps (1979) to simulate the effects of hydrologic conditions -- flood frequency and depth to water table -- on flood plain forest-vegetation dynamics. The model is based on data from the lower White River valley, Arkansas (Bedinger, 1971). The model simulates the growth of each individual on a 20- by 20-meter plot, taking into account effects of flooding, depth to water table, shade tolerance, overtopping, crowding, and probability of death and reproduction. Potential applications include simulation of timber and mast production under various conditions of drought, flood control, drainage, and lumbering.

Franz and Bazzaz (1977) modeled the distribution of bottomland species as a function of flood-stage probability. These investigators modeled the distribution of each species by a normal density function related to elevation of each specimen in the sample. These investigators predicted the change in bottomland-species distribution due to a change in flood-stage probability caused by impoundment of the stream.

Forest simulation models hold a twofold promise in advancing the knowledge of forest ecosystems. At present (1978) digital models are highly simplified. The simplifications are not based on limitations of mathematics or computer capabilities, but reflect the imperfect and incomplete knowledge of the forest ecosystem. The discipline of attempting to express mathematically the flow of matter and energy in a forest ecosystem will expose inadequacies of ecosystem understanding and force the ecologist to define more precisely the processes and interactions to be simulated. The models thus designed will in turn be used to simulate the forest ecosystem and serve as a mechanism to test multiple interactive hypotheses. Thus, the first advantage of simulation modeling is improved ecosystem insight. The second is the application to real world problems afforded by reliable predictable models of forest ecosystems.

Distribution of Forest Species in the Lower White and Ouachita River Basins

The forest vegetation of the lower White River and lower Ouachita River valleys in Arkansas is broadly classified by Kuchler (1967) as a southern flood-plain forest, with oak, gum, and cypress predominating. The flood plains of the lower White and lower Ouachita River valleys of the Coastal Plain are part of the southern hardwood territory described by Putnam and Bull (1932), Putnam (1951), and Putnam, Fernival, and McKnight (1960). The southern hardwoods principally occupy the alluvial bottoms, stream channels, and swamps in the Atlantic and Gulf Coast Plains of Fenneman (1938) in the area extending from Texas to Virginia. From 1915 to 1960 this region supplied about 45 percent of the national production of hardwood sawtimber, and the prognosis was made by Putnam, Fernival, and McKnight (1960) that the region would continue to produce this amount indefinitely. This prognosis, however, is in jeopardy because of large-scale clearing of forests for agriculture. Between 1959 and 1969, forest land in 21 Arkansas counties in the Mississippi, Arkansas, and White River flood plains decreased by almost 1.3 million acres, or 39 percent (Hedlund, 1971). This rate of clearing was nearly three times faster than that occurring from 1935 to 1959 when 1.1 million acres of forest were removed. Decline in acres of forest land is expected to continue, though at a decreased rate.

The valleys can be divided topographically into a series of terraces, each terrace level in the bottomland representing a former first bottom of the flood plain. The first bottom upstream from the stream channel is marked by the first areally-extensive plain that is flooded when the stream tops its banks and spreads out beyond its channel. The bottomland of the White and Ouachita Rivers is naturally forested. The bottomland soils are medium- to fine-grained silts and clays and are slowly to moderately permeable.

The hydrologic environment of the lower levels of the White River and Ouachita River flood plains could be described as extreme or rigorous. The lower flood-plain levels or first bottoms are naturally flooded each year about 40 percent of the time -- a much longer duration than most smaller flood plains in the Coastal Plain of Arkansas. Flooding generally occurs in winter and spring. The floodwaters generally recede in late spring or early summer, followed by flow below bankful stage until late fall or winter. Sucessively higher levels are flooded less frequently. Frequency of flooding ranged from annually to 12.5 years in the sites studied. Unflooded sites were also studied for reference.

Methods of Study

In the lower Ouachita and lower White River basins 47 flood plain sites were studied with regard to flood frequency and duration and species composition of the forest. The sites are all in the Coastal Plain province (Fenneman, 1938). The sites in the White River basin are in the Mississipi Alluvial Plain; the sites in the Ouachita River basin are in the West Gulf Coastal Plain (fig. 1).

Sites were selected to include the range of flooding in the valleys. The areas for study of forest vegetation were practically limited to large forested tracts in which the natural forest has not been obliterated by timber operations or cleared for agriculture. The sites in the White River valley for this study were centered in two areas: (1) the White River National Wildlife Refuge, near the mouth of the White River, and (2) the Hurricane Lake Public Hunting Area, near August, Arkansas (fig. 2). In the Ouachita River valley, large timbered tracts were present in public hunting areas, timber-company lands, and on some private lands (fig. 3). Timber management in these areas may have altered the natural percentages of the

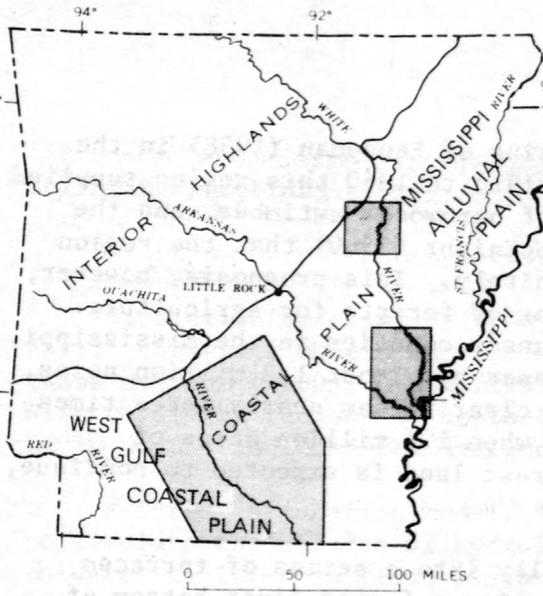

Figure 1.--Index map of Arkansas, showing study areas (shaded) in the White River and Ouachita River Basins.

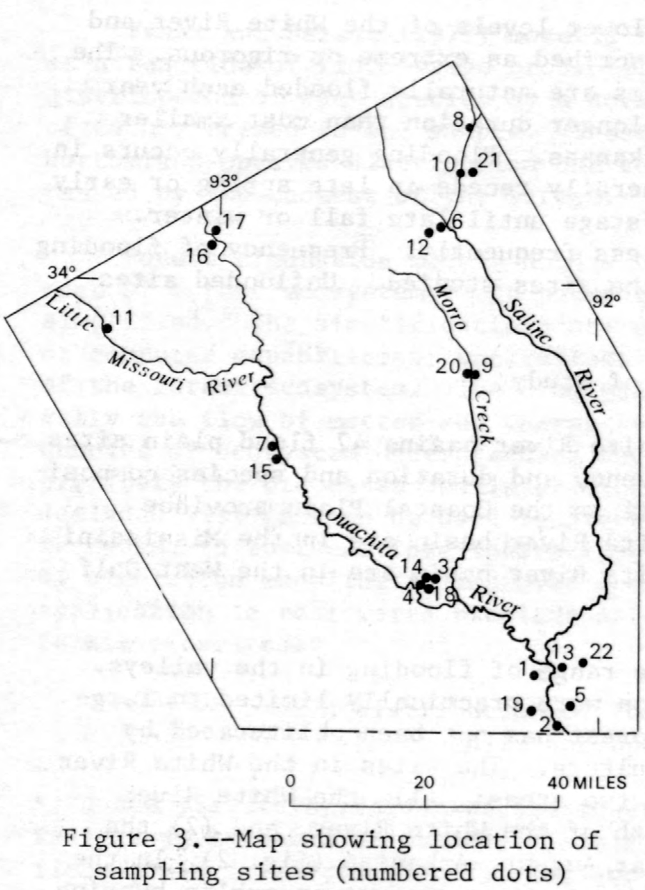

Figure 3.--Map showing location of sampling sites (numbered dots) in the Ouachita River Basin.

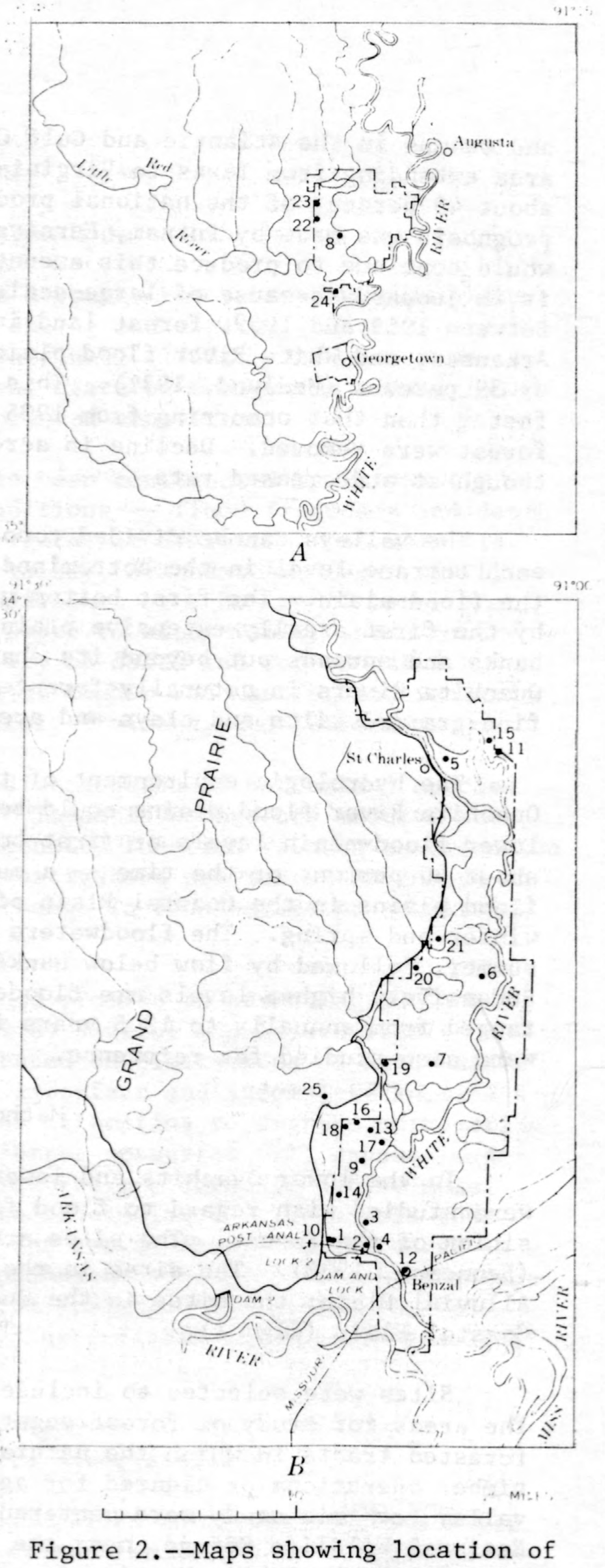

Figure 2.--Maps showing location of sampling sites (numbered dots) in the White River Basin A, sites in the Hurricane Lake Public Hunting Area; B, sites in and near the White River National Wildlife Refuge.

forest species, but it is not believed that the species makeup has been changed. Each site is relatively level and homogeneous in habitat. Local drainage courses and depressions were avoided. Within each of 47 sites, 50 pairs of trees (100 trees) were selected, each tree at least 4 inches DBH. This sampling procedure is the random-pairs method of Cottam and Curtis as described by Phillips, (1959).

Specimens of most of the forest species were collected during the fall of 1970 and 1971 and were deposited in the herbariums of the University of Arkansas at Little Rock, Arkansas, and the University of Arkansas at Fayetteville, Arkansas.

Regulation of Streamflows

Flood characteristics of study sites are based on stream-gaging records of the U.S. Geological Survey and the U.S. Army Corps of Engineers. Flood characteristics at established gaging stations were determined and used for nearby sites. Flood characteristics for study sites between stations were based on gaging-station characteristics, river gradient, and the proportionate distance between stations.

The period of applicable stream-stage record at the stations varied from 9 to 40 years. The construction of dams in the basins has modified the flood characteristics on the main stems and some tributaries. Flows on the White River were not significantly affected until 1952 (Bedinger, 1971). Records for stations on the White River used in the flood analysis began in 1934, at St. Charles, Arkansas; 1939, at Augusta Arkansas; and 1937, at Benzal, Arkansas (locations are shown in fig. 2). The period of record through 1951 was used in the analysis of flood characteristics in order to characterize conditions most representative of natural, preregulated flow.

The flood characteristics of several tributaries in the Ouachita River basin are negligibly affected by regulation. These tributaries include Hurricane Creek near Sheridan, Hurricane Creek below Sheridan, and Moro Creek near Fordyce, (locations are shown in fig 3). Diversions for water supply are made from an upstream tributary of the Saline River and a small diversion from the main stem is made upstream from the stream-gaging station near Sheridan. These diversions are assumed to have negligible effect on flood characteristics at the study sites on the Saline River. Flows on the Ouachita River have been regulated by Lake Catherine since 1925 and by Lake Hamilton since 1932, beginning before most of the stream-gaging stations on the Ouachita River were established. These reservoirs are relatively small, were constructed for hydroelectric generation, and are assumed to have little effect on flood characteristics of the study sites. Flows at study sites on the Ouachita River and Little Missouri River have been regulated since 1949 by Lake Greeson. Further regulation of the Ouachita River was effected by Lake Ouachita on the Ouachita River since 1952 and De Gray Lake on the Caddo River since 1969. Records through 1949 for the following stations have been used: Little Missouri River at Boughton, Arkansas, Ouachita River at Camden, Arkansas, Ouachita River at Lock and Dam 8, near Calion, Arkansas, Ouachita River at Arkadelphia, Arkansas, and the Ouachita River near Felsenthal, Arkansas.

The number of years of record used in describing the flood frequency and flood duration at each study site is given in tables 2 and 3 (p. 25 and 27). The flood frequency is computed from the annual flood series (Dalrymple, 1960). The flood duration is computed as the percentage of the number of days the site was inundated during the period of record.

For the present study, only forest trees 4 inches DBH, and presumed to have been established prior to significant regulation of flow, were sampled.

Flooding Characteristics of Study Sites

The frequency of flooding of the sites studied ranges from annually to once in 12.5 years (fig. 4). Three sites with no historic record of flooding were studied for comparison. The duration of flooding varies greatly. Within the group of sites flooded annually (recurrence of 1.0 year) the duration of flooding ranges from 6 to 40 percent of the time. Flood duration of sites flooded annually is directly related to the drainage area of the stream basin upstream from the site. For example, all sites in the White River basin and the two sites in the Ouachita River basin flooded annually have flood durations of from 18 to 40 percent. Other sites flooded annually in the Ouachita River basin show a decrease in flood duration with decrease in drainage area of the stream upstream from the site. Sites on streams having drainage areas from 5,000 to 7,000 mi^2 have flood durations from 10 to 18 percent; a site on a stream having a drainage area of 1,000 to 2,500 mi^2 has a flood duration of 12 percent; sites on streams having drainage areas less than 300 mi^2 have flood durations of 5 to 7 percent. Higher flood plains (flooded less frequently) show a similar decrease in flood duration with a decrease in drainage area.

Flooding Environment of Forest Species

The species distribution of flood plains is related to habitat, particularly to the hydrologic factors of the habitat. Local features related to hydrology, that is, oxbow lakes, streambanks, river sandbars, bayous, and others, are associated with certain species, such as cottonwood, willow, cypress, sycamore, and water tupelo (table 1). Though these species are present in the White River flood plain, they are species of special environments and are a small part of the flood-plain vegetation as a whole. The present study related hydrologic factors to the species of broad, generally homogeneous habitats in the flood plain rather than to the species of the special or forest-edge habitat.

White River Basin

The trees of the sites sampled in the White River basin can be grouped into four broad categories. The flood characteristics of the sites in each category can be correspondingly grouped. The sites in the first group (Group I) are flooded annually, with the average duration of flooding ranging from 29 to 40 percent of the time. The sites in the second group (Group II) are flooded from 10 to 21 percent of the time. The second group is inundated

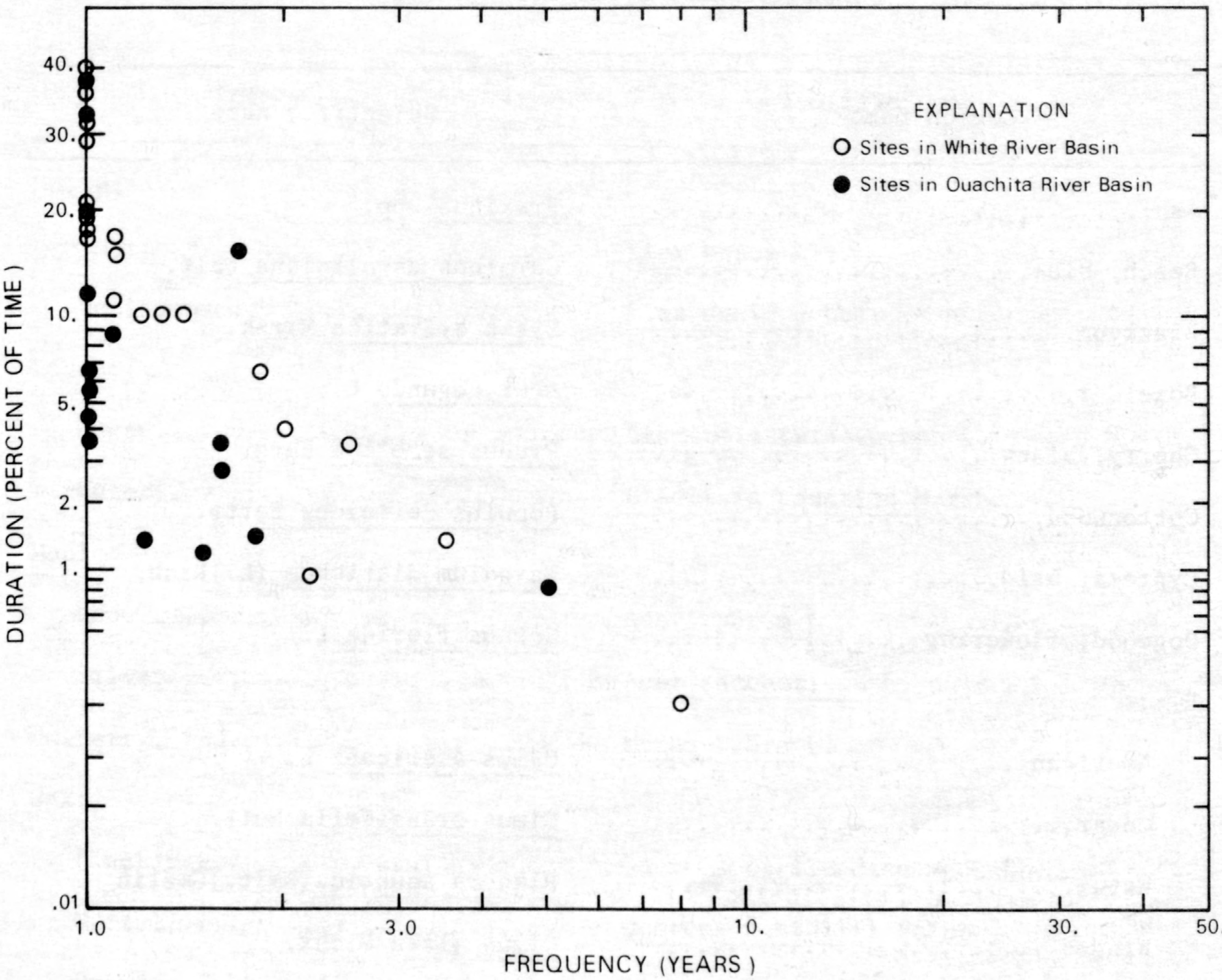

Figure 4.--Frequency and duration of flooding of study sites.

Table 1.--Common and scientific names of trees in the lower White River and Ouachita River basins, Arkansas

[Nomenclature from Moore (1972)]

Common name	Scientific name
Ash	Fraxinus spp.
Beech, blue	Carpinus caroliniana Walt.
Blackgum	Nyssa sylvatica Marsh.
Boxelder	Acer negundo L.
Cherry, black	Prunus serotina Ehrh.
Cottonwood	Populus deltoides Bartr.
Cypress, bald	Taxodium distichum (L.)Rich
Dogwood, flowering	Cornus florida L.
Elm:	
American	Ulmus americana L.
Cedar	Ulmus crassifolia Nutt.
Water	Planera aquatica(Walt.)Gmelin
Winged	Ulmus alata Michx.
Hackberry, southern	Celtis laevigata Willd.
Hawthorn	Crataegus spp.
Hickory:	
Bitternut	Carya cordimormis(Wang.)K.Koch
Mockernut	Carya tomentosa Nutt.
Shagbark	Carya ovata(Mill.)K.Koch
Shellbark	Carya laciniosa(Michx.f.)Loud.
Water	Carya aquatica(Michx.f.)Nutt.

Table 1.--Common and scientific names of trees in the lower White River and Ouachita River basins, Arkansas--Continued.

[Nomenclature from Moore (1972)]

Common name	Scientific name
Holly:	
American......................	*Ilex opaca* Alt.
Deciduous.....................	*Ilex decidua* Walt.
Locust:	
Honey.........................	*Gleditsia triacanthos* L.
Water.........................	*Gleditsia aquatica* Marsh.
Maple:	
Red...........................	*Acer rubrum* L.
Silver........................	*Acer saccharinum* L.
Mulberry, red.....................	*Morus rubra* L.
Oak:	
Blackjack.....................	*Quercus marilandica* Muenchh.
Nuttall.......................	*Quercus nuttallii* Palmer.
Overcup.......................	*Quercus lyrata* Walt.
Pin...........................	*Quercus palustris* Muenchh.
Post..........................	*Quercus stellata* Wang.
Shumard.......................	*Quercus shumardii* Buckl.
Southern red (cherry bark).....	*Quercus falcata* var. *pagodaefolia* Ell.
Water.........................	*Quercus nigra* L.
White.........................	*Quercus alba* L.
Willow........................	*Quercus phellos* L.

Table 1.--Common and scientific names of trees in the lower White River and Ouachita River basins, Arkansas--Continued.

[Nomenclature from Moore (1972)]

Common name	Scientific name
Pecan, sweet	Carya illinoensis(Wang.)K.Koch
Persimmon	Diospyros virginiana L.
Pine:	
Loblolly	Pinus taeda L.
Shortleaf	Pinus echinata Mill.
Privet, swamp	Forestiera acuminata(Michx.)Poir.
Redbay	Persia borbonia(L.)Spreng.
Redbud	Cercis canadensis L.
Sweetgum	Liquidambar styraciflua L.
Sycamore	Platanus occidentalis L.
Willow	Salix spp.

during most years. Sites in the third group (Group III) are flooded on an average of from once in 2 years to once in 8 years. A fourth category (Group IV) includes one site on the Grand Prairie terrace that had not been flooded during historic times. A summary of the distribution of selected forest species with respect to flooding is given in table 2.

The forest of Group I (29-40 percent duration of inundation) is referred to as the water hickory-overcup oak group, and is composed primarily of six species. Water hickory and overcup oak are major species; southern hackberry, water locust, water elm, and swamp privet are minor species. On some sites, southern hackberry is a major species. On the lower sites in this group, these six species, and an occasional baldcypress, may compose the entire forest.

On the highest site of Group I a more varied flora may be found -- the additional species including American elm, cedar elm, persimmon, red maple, silver maple, and blue beech. Two other species, nuttall oak and ash, are present in the higher sites of Group I. These species become conspicuous in the Group II sites (inundated 10-21 percent of the time).

Forests of the Group II sites (inundated 10-21 percent of the time), referred to as the nuttall oak group, are persistently more varied in species composition than the Group I. The major species are overcup oak, nuttall oak, southern hackberry, ash, and water hickory. Willow oak and sweetgum are present on most of these sites and are commonly conspicuous. Swamp privet is present on some of the lower sites in this group. Water locust is rare in this group of sites, having been replaced by honey locust. Hawthorn and persimmon, though minor species, are present in almost all sites of the group and reach their greatest abundance in the nuttall oak group.

Group III sites (flooded at intervals of 2-8 years) are referred to as the shagbark hickory-southern red oak group because these species are major constituents and persist throughout the group. Bitternut hickory and black gum are found on higher sites of this group. The shagbark hickory-southern red oak group is also characterized by the paucity of several species conspicuous in lower sites. Water hickory is absent, and nuttall oak and overcup oak are found only on the lower sites of Group III. Several minor species, cedar elm, red maple, and blue beech, are sparingly present on the lower sites in the group. Among the species present on higher sites in this group are white oak, shumard oak, post oak, and pin oak.

In addition to species of Group III a single species, blackjack oak, that is not found on lower sites is present in the Group IV (not flooded in historic times).

Ouachita River Basin

The major differences in hydrologic environment between the White River and Ouachita River sites are reflected in differences in the forest species. Group I of the White River basin is present in the Ouachita River in the same habitat -- sites flooded annually 32 to 40 percent of the time. Here, water hickory and overcup oak are dominant species. In the two sites studied in the Ouachita River basin, southern hackberry and water elm are absent; and willow oak is present.

Group II of the White River basin is represented in sites at John Mack Slough, Yellow Bluff, CD Siding and Lisenbey Deer Club. The lack of predominance of nuttall oak may be attributed to local conditions: poor drainage at John Mack Slough and timber cutting at Yellow Bluff. Other differences between this group in the two basins are minor -- such as presence of southern red oak on one Ouachita River site.

Group III is represented at eight sites. These sites are flooded within the range of 1.83 to 12.5 years of frequency and from 0.9 to 9.8 percent duration. As in the White River basin, southern red oak is a prominent species, and the flood tolerant species water hickory, overcup oak, and nuttall oak are absent. The paucity of mockernut hickory reflects the general scarcity of this species in the Ouachita River basin. Loblolly pine is conspicuous on these sites.

Group IV in the Ouachita basin, those sites not flooded in historic time, is characterized by northern red oak (rather than blackjack oak are in the White River basin) and the absence of flood-tolerant species.

In addition to the four groups of environments sampled in the White River basin, there are habitats having less duration of flooding for a given frequency. One group, here called Group IIA, is flooded near annually (1.04 to 1.26 years frequency) for durations ranging from 1.4 to 8.6 percent. This group has characteristics of Group I, represented by overcup oak, Group II, represented by American elm, and overcup oak; and Group III, represented by Southern red oak and mockernut hickory. Flood-tolerant species water hickory is absent and nuttall oak is not common.

Complementary Species

Several species could be arranged in pairs with mutually exclusive distributions -- one species occurring on sites flooded more frequently for longer duration than the sites on which the complement species occurs. Such pairs of species are here called complementary species. Among these deciduous holly and American holly were not observed occurring in the same sites in the Ouachita River basin, but they occurred separately on all but eight of 22 sites.

Two species, nuttall oak and loblolly pine, occurred on all but four of 22 sites in the Ouachita River basin, but both occurred on only one of these sites. Loblolly pine is the more common species on the drier sites. Either water elm or American elm occurred on all but three sites in the White River basin. At only one site did both species occur in common. Water elm occurred only on sites flooded more than 30 percent of the time. Water hickory occurred in the sites flooded 18 percent or more of the time in the Ouachita River basin and on sites flooded 10 percent or more of the time in the White River basin, whereas, its complementary species, mockernut hickory, occurred on drier sites. The two species were not observed to occur on the same site, one or the other was present on all but nine of the 47 total sites studied in both basins. In the White River basin either overcup oak or post oak occurred on all but one of the 25 sites, never occurring on the same site. In the Ouachita River basin these two species were present on all but two sites and occurred together on only three sites. Honey locust and water locust were not observed on the same sites. Water locust was present on each of the sites flooded 30 percent or more of the time in the White River basin and on one site flooded 37 percent of the time in the Ouachita River basin. Honey locust was observed on a wider range of sites -- from sites flooded 18 percent of the time to a site not flooded in historic time.

Conclusions

The present study demonstrates a definite relationship between the distribution of forest species and the frequency and duration of flooding. The relationship is sufficiently distinct to permit estimation of flood characteristics at a given site by evaluation of the forest-species composition. This relationship is of potential use to the hydrologist who may use forest species as criteria to transfer flooding parameters from gaging stations to ungaged reaches of streams.

The difference in forest associations, as a function of duration of flooding, is demonstrated by sites flooded annually. Sites flooded annually for durations of 20 to 40 percent of the time exhibit relatively few species, whereas sites flooded annually for less than 5 percent of the time exhibit a large number of species. Flood duration during the growing season is critical with regard to tolerance to flooding. Flooding during the dormant season is not critical.

The distribution of species in the flood plain is related to the differing physiological response of species to the hydrologic environment. Large established trees show much greater tolerance to flooding than seedlings. Research indicates a strong influence of hydrologic environment during early plant development, including the tolerance of seed to flooding, degree of root-zone saturation, and inundation of seedlings. It is the tolerance of seed and seedling in the early stage of development that largely controls the distribution of the species in relation to flooding. Each species is distributed along the flooding gradient according to the physiological response of the tree species to flooding. Plant succession in the flood plain is dependent upon the geomorphic evolution of the flood plain and the concomitant change in flood characteristics. A stable tree-species assemblage of forest type exists for each flooding environment. As the flood plain geomorphically evolves by periodic overbank flooding and deposition, or by downcutting of the stream, flood frequency and duration of a site slowly diminishes. This diminished flooding imposes a potential within the flood-plain environment for change in forest-species composition. This potential for change is a reflection of a diminished favorability of the environment for some species and the emergence of a more favorable environment for other species in the habitat or new species which can now become established.

The strong hydrologic-forest relationship suggests several lines of research to be taken in regard to forest management for recreation, timber, or other wetland values. For timber values, is the natural stratification optimal for timber production and quality? Can the species composition be manipulated by coordinating flood control and forest management practices to increase the timber production and quality?

Because the forest species makeup is strongly influenced by flooding, other questions of environmental concern are raised over the long-range effect of streamflow regulation on forest species in terms of growth rates, propagation, influence on species distribution, forest management practices, and wildlife management and habitat. The obvious result of a regulation would be a decrease in flood frequency and duration. Comparison of sites in the White River basin with those in the Ouachita River basin may provide some insight to this question. The lower sites in the Ouachita River basin are not as consistently flooded each year as determined from long-term streamflow records. The development of forest simulation models holds the promise of a mechanism for synthesizing data and hypotheses of forest development, testing those hypotheses, and emerging with models that can be used to predict effects of changed environments on forests.

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Table 2.--Distribution of forest species in relation to flooding in the lower White River basin, Arkansas

Group	Flood duration (percent of time)	Flood frequency (years)	Site (fig. 2.) Number	Name	Taxodium distichum	Planera aquatica	Gleditsia aquatica	Forestiera acuminata	Carya aquatica	Quercus lyrata	Quercus nuttallii	Celtis laevigata	Salix spp.	Fraxinus spp.	Crataegus spp.	Ulmus americana	Ulmus crassifolia	Gleditsia triacanthos	Acer rubrum	Quercus phellos	Liquidambar styraciflua	Diospyros virginiana	Ulmus alata	Carpinus caroliniana	Acer saccharinum	Populus deltoides	Platanus occidentalis	Ilex decidua	Quercus nigra	Morus rubra	Acer negundo	Carya tomentosa	Carya ovata	Quercus falcata	Nyssa sylvatica	Carya laciniosa	Cercis canadensis	Quercus alba	Quercus stellata	Quercus shumardii	Carya cordiformis	Quercus palustris	Cornus florida	Prunus serotina	Quercus marilandica
I	40	1.06	1	Flat Lake	--	9	28	14	18	15	--	16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
I	36	1.06	2	Wild Goose Bayou	--	3	19	9	30	34	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
I	33	1.06	3	Pickle Bar	1	4	11	10	17	52	--	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
I	32	1.06	4	Dam 1	--	3	7	18	24	37	--	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
I	29	1.06	5	St. Charles	1	1	2	5	4	10	13	34	--	10	1	4	1	--	1	--	--	7	--	1	1	1	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
I	33	1.06	6	Escronges Lake	1	10	12	7	14	44	--	4	1	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
I	32	1.06	7	Prairie Lake	3	1	4	10	13	47	3	9	--	10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	21	1.06	8	Glaise Creek	--	--	--	2	9	10	26	11	--	9	3	2	17	--	--	1	2	1	7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	19	1.06	9	Prairie Landing	--	--	--	--	10	23	20	7	--	4	3	3	3	--	1	8	10	8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	18	1.06	10	Arkansas Post Canal	--	--	--	6	6	16	14	35	--	5	1	10	--	1	--	--	--	5	1	--	--	--	--	--	--	---	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	17	1.12	11	Indian Bay	--	--	--	1	2	4	6	20	--	2	1	4	5	1	1	5	11	2	--	9	--	--	1	--	8	12	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	15	1.12	12	Benzal	--	--	--	3	5	17	12	26	--	9	3	--	--	--	--	6	10	6	--	--	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	15	1.12	13	Wolf Bayou	--	--	--	--	22	27	13	6	--	23	1	1	--	--	--	--	2	5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	11	1.19	14	Prosperous Bayou	--	--	--	--	6	7	19	6	--	10	1	8	1	--	5	9	23	5	--	--	--	--	--	--	--	--	--	--	--	---	--	--	--	--	--	--	--	--	--	--	--
II	10	1.33	15	Kelly Field	--	--	--	--	1	4	3	9	--	2	--	6	1	2	1	9	11	4	2	16	--	--	--	--	17	12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	10	1.46	16	East-West road	--	--	--	--	8	15	5	27	--	1	2	5	1	--	2	17	11	2	--	--	--	--	--	--	1	3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	10	1.27	17	Jacks Bay	--	--	--	--	1	2	10	24	--	3	2	8	9	--	--	25	5	6	1	--	--	--	--	--	3	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
III	4	2	18	Section 3	--	--	--	--	--	7	1	--	--	--	--	5	--	--	7	5	36	--	14	--	--	--	--	--	1	3	--	8	2	7	4	--	--	--	--	--	---	--	--	--	--
III	4	2	19	Hickory Ridge	--	--	--	--	--	8	1	15	--	7	2	9	6	--	--	22	1	1	18	1	--	--	--	--	5	3	--	--	--	1	--	--	--	--	--	--	---	--	--	--	--
III	3.5	2.5	20	Brair Ridge	1	--	--	--	--	--	--	4	--	1	--	5	--	--	--	9	25	2	4	2	--	--	---	1	5	4	--	--	10	14	2	6	5	--	--	--	--	--	--	--	--
III	1.4	3.5	21	Essex Bayou	--	--	--	--	--	--	--	--	--	2	--	3	--	--	--	19	2	1	26	--	--	--	--	--	--	--	--	--	5	23	--	3	--	5	10	1	--	--	--	--	--
III	0.2	8	22	Hurricane Lake	--	--	--	--	--	--	--	--	--	2	--	2	--	--	--	--	4	--	3	--	--	--	--	--	4	--	--	35	6	19	4	--	--	10	7	1	--	--	3	--	--
III	0.2	8	23	Picnic	--	--	--	--	--	--	--	--	--	2	--	--	--	--	--	4	7	--	9	--	--	--	--	--	--	1	--	5	11	24	4	--	--	5	13	--	8	--	5	2	--
III	0.2	8	24	Little Red River	--	--	--	--	--	--	--	--	--	2	--	5	--	--	--	13	1	1	5	--	--	--	--	--	--	--	--	5	4	43	--	--	--	7	2	7	1	4	--	--	--
IV			25	Bell Gully 1/	--	--	--	--	--	--	--	2	--	2	--	--	--	2	--	--	--	--	2	--	--	--	--	--	--	5	--	39	3	27	--	--	--	--	10	--	5	--	--	1	2

1/ Not flooded in historic times

Table 3.--Distribution of forest species in relation to flooding in the lower Quachita River basin, Arkansas

Group	Flood duration (percent of time)	Flood frequency (years)	Site (fig. 3) Number	Name	Taxodium distichum	Planera aquatica	Gleditsia aquatica	Forestiera acuminata	Carya aquatica	Ilex decidua	Crataegus spp.	Quercus nuttallii	Quercus lyrata	Diospyros virginiana	Fraxinus spp.	Quercus phellos	Liquidambar styraciflua	Quercus nigra	Nyssa sylvatica	Carpinus caroliniana	Quercus stellata	Pinus taeda	Celtis laevigata	Ulmus americana	Ulmus alata	Morus rubra	Quercus michauxii	Quercus falcata	Carya tomentosa	Ilex opaca	Acer rubrum	Carya texana	Prunus spp.	Quercus alba	Persia borbonia	Platanus occidentalis	Fagus grandifolia	Carya ovata	Sassafras albidum	Gleditsia triacanthos	Carya illinoensis	Cornus florida	Prunus serotina	Pinus echinata	Quercus shumardii	Ostrya virginiana	Castanea ozarkensis	Aralia spinosa	Quercus rubra
I	37	1.1	1	Deep Slough	--	--	2	1	35	5	1	12	33	6	3	2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
I	33	1.1	2	Dam 6	--	--	--	--	62	--	--	15	5	3	--	14	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	19	1.09	3	John Mack Slough 4/	2	1	--	--	--	2	4	5	8	2	9	40	10	2	10	3	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	19	1.09	4	Yellow Bluff	--	2	--	--	13	--	1	2	2	2	6	1	10	13	3	33	--	--	1	1	5	2	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	17	1.83	5	C D Siding 1/	--	--	--	--	7	1	13	--	8	5	--	51	11	--	4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
II	13.4	1.03	6	Lisenbey Deer Club	--	--	--	--	--	--	--	--	2	--	1	2	18	8	1	42	--	--	1	1	3	--	1	6	3	11	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IIA	8.6	1.2	7	Ecore Fabre	1	1	--	--	--	--	--	2	3	--	2	7	20	23	3	24	--	--	--	6	1	--	--	3	--	2	1	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IIA	8.3	1.06	8	Hurrican Sheridan	--	--	--	--	--	1	--	--	1	--	--	1	26	3	1	22	--	--	--	2	--	2	3	7	5	11	2	--	--	8	1	1	3	--	--	--	--	--	--	--	--	--	--	--	--	--
IIA	8.0	1.04	9	Moro Creek	1	--	--	--	--	--	--	--	--	--	--	--	31	5	2	18	--	7	3	--	11	1	1	15	1	3	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
IIA	4.5	1.06	10	Hurrican Grapevine	--	--	--	--	--	--	--	--	1	--	3	1	25	9	5	35	--	--	--	3	1	1	3	5	3	3	--	--	--	--	--	1	--	1	--	--	--	--	--	--	--	--	--	--	--	--
IIA	3.7	1.11	11	Boughton 3/	--	--	--	--	--	--	--	3	4	--	9	18	4	1	1	3	--	--	16	15	9	5	--	4	2	--	--	2	--	--	1	--	--	1	1	1	--	--	--	--	--	--	--	--	--	--
IIA	1.4	1.26	12	West Farindale 1/	--	--	--	--	--	--	--	--	1	2	1	29	11	19	1	--	2	17	--	1	2	--	1	12	--	--	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
III	9.8	1.83	13	Marais Saline	--	--	--	--	--	--	4	--	--	--	--	2	13	4	4	--	13	60	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
III	6.4	2.0	14	Bangs Slough 3/	--	--	--	--	--	--	--	--	--	--	--	5	16	32	1	--	12	26	--	--	--	--	--	3	1	1	--	2	1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
III	3.5	1.71	15	Gravel pit 3/	--	--	--	--	--	--	--	1	1	--	2	2	5	28	--	20	--	--	8	5	4	--	1	13	1	6	--	--	--	--	--	1	--	--	--	1	1	--	--	--	--	--	--	--	--	--
III	2.8	1.71	16	Oak Grove Church 2/	--	--	--	--	--	--	1	2	14	--	--	19	16	2	6	2	8	--	--	--	5	--	--	16	1	--	1	--	--	4	--	--	--	1	--	--	--	2	--	--	--	--	--	--	--	--
III	1.4	2.0	17	Tupelo Creek	--	--	--	--	--	--	--	--	10	--	5	18	11	2	4	7	--	1	--	4	5	--	--	9	2	1	1	6	--	11	--	--	--	3	--	--	--	--	--	--	--	--	--	--	--	--
III	.9	2.4	18	Harvin Ridge 3/	--	--	--	--	--	--	--	--	--	--	--	6	16	6	1	4	1	47	--	1	2	1	--	7	--	--	2	--	--	2	--	--	--	--	--	--	--	--	--	--	--	4	--	--	--
III	1.1	5.5	19	Felsenthal	--	--	--	--	--	--	--	--	--	--	--	25	14	10	--	--	20	11	--	--	1	--	--	19	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
III	.03	12.5	20	Roadside park 1/	--	--	--	--	--	--	--	--	1	--	--	1	11	6	8	7	--	23	--	3	2	--	--	13	2	6	2	--	--	3	--	--	1	--	--	--	--	--	1	2	1	7	--	--	--
IV	--	--	21	Camp Creek 5/	--	--	--	--	--	--	--	--	--	--	1	1	17	3	8	10	--	1	--	--	1	1	4	11	5	15	6	2	--	6	--	--	1	--	1	--	--	1	--	--	--	1	1	1	2
IV	--	--	22	Levi Wilcoxson 5/	--	--	--	--	--	--	--	--	--	--	--	--	23	--	--	--	3	26	--	--	--	--	--	11	1	--	1	--	--	5	--	--	--	--	--	--	--	5	3	19	--	--	--	--	3

1/ Site has been logged 2/ Swale 3/ Natural levee, well drained 4/ Backswamp, poorly drained 5/ Not flooded in historic time

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