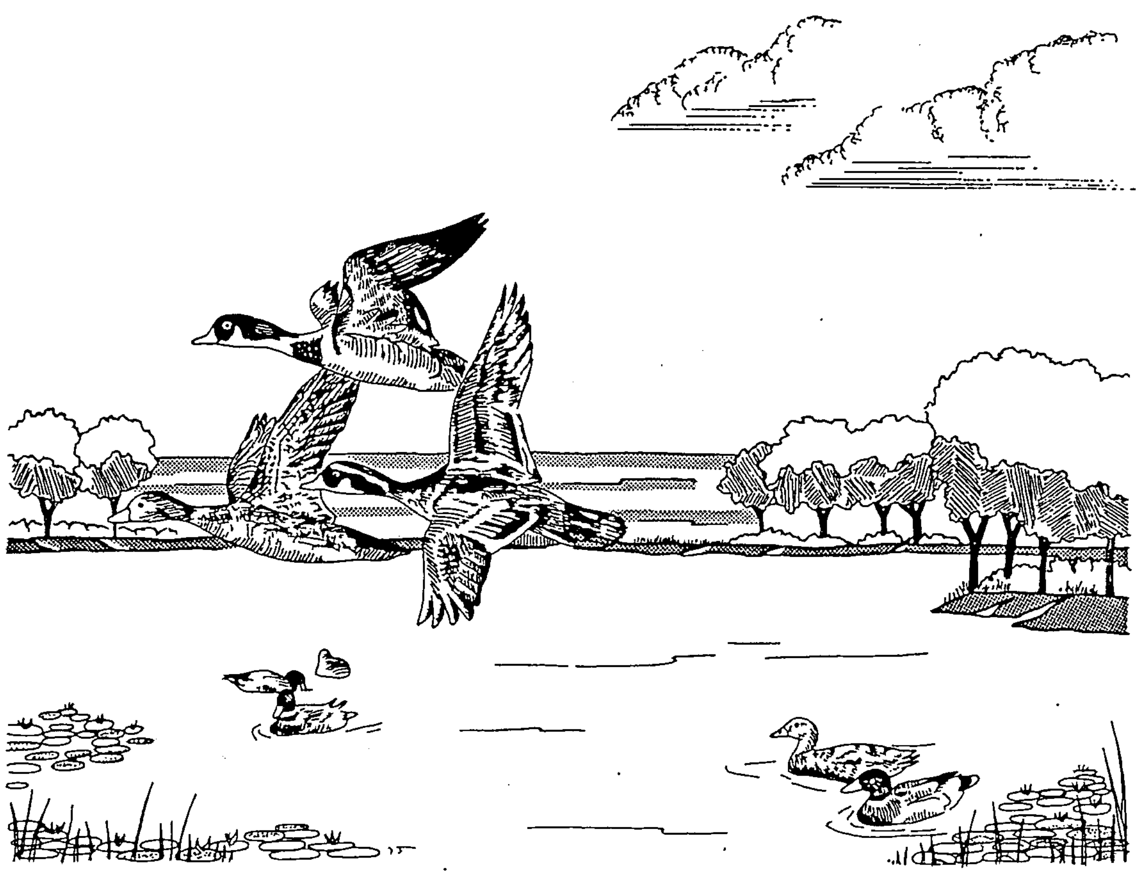
NEC – 87/04
DECEMBER 1986

WATER MANAGEMENT ALTERNATIVES AT REELFOOT LAKE: RESULTS OF A WORKSHOP



Fish and Wildlife Service

U.S. Department of the Interior

Pulliam

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FISH AND WILDLIFE SERVICE
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December 12, 1986

Memorandum

To: Recipients of the Reelfoot Lake Workshop Report

From: Regional Director, FWS, Atlanta, GA (PC)

Subject: Final Workshop Report

We are pleased to provide you with this copy of the Final Reelfoot Lake Workshop Report. This report is the result of discussions held in Memphis, Tennessee, during the week of August 25-29, 1986. The workshop was conducted by the National Ecology Center, a division of the U.S. Fish and Wildlife Service.

The workshop facilitators and the participants are commended for the cooperation and dedication they have shown while seeking solutions to the problems at Reelfoot Lake. This report provides an excellent base from which the Service can begin developing an Environmental Impact Statement on alternative water management programs for the lake.

Even though this report represents the culmination of the workshop process, we would still appreciate receiving any new ideas or information you may have on Reelfoot Lake. Any subsequent correspondence should be addressed to the Reelfoot Lake EIS Coordinator at the address shown above.

Once again, thank you for your assistance in defining the problems associated with Reelfoot Lake and in formulating alternative solutions to those problems.

James W. Pulliam, Jr.

Attachment

NEC-87/04
December 1986

WATER MANAGEMENT ALTERNATIVES AT REELFOOT LAKE: RESULTS OF A WORKSHOP

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Results of a Workshop Sponsored by
Region 4
and
Reelfoot National Wildlife Refuge
U.S. Fish and Wildlife Service

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DISCLAIMER

This report is a synthesis by the authors of the results of a workshop. As such, the opinions and recommendations expressed are those of the authors and do not necessarily reflect the views of the U.S. Fish and Wildlife Service nor of any of the other agencies represented by the workshop participants. Similarly, mention of trade names does not constitute endorsement or recommendation for use by the Federal Government or by any other agency.

This report should be cited as:

Roelle, J., A. Farmer, D. Hamilton, S. Williamson, and W. Seitz. 1986. Water management alternatives at Reelfoot Lake: results of a workshop. U.S. Fish Wildl. Serv., National Ecology Center, Fort Collins, CO. NEC-87/04. 104 pp.

EXECUTIVE SUMMARY

On August 24-29, 1986, the U.S. Fish and Wildlife Service sponsored a workshop concerning resource management issues at Reelfoot Lake, Tennessee. The objectives of the workshop were to:

(1) develop alternative water management strategies for Reelfoot Lake; and

(2) assess the probable consequences of those alternatives on the resources at Reelfoot.

The workshop was attended by approximately 40 scientists and managers familiar with Reelfoot Lake or with similar ecological situations. The authors of this report facilitated the workshop sessions and recorded discussions and conclusions.

Following a 1-day field trip to Reelfoot Lake, the workshop convened in Memphis, Tennessee. Participants were divided into five working groups (hydrology and sedimentation, aquatic ecology, fish, nonaquatic vegetation, and wildlife) representing general resources of concern. Each of these workgroups was first asked to:

(1) identify the resources that they would consider and the criteria that would be used to evaluate the impacts of alternative management strategies;

(2) define what they believed to be appropriate objectives for those resources; and

(3) develop a preferred management strategy for achieving those objectives.

Following these discussions, the authors of this report and interested participants met to consolidate these preferred strategies and several management alternatives proposed elsewhere into a set for all of the workgroups to use in analyzing impacts. The six alternatives chosen were:

(1) continuation of current management (i.e., maintaining lake level as close as possible to 282.2 ft msl and continuing present forest and wildlife management programs);

(2) a drawdown to expose about 50% of the lake bed to drying, in an effort to consolidate soft sediments and improve water quality and the fishery;

(3) a drawdown in combination with excavation of sediments from certain critical areas;

(4) a watershed treatment alternative designed to reduce sediment inputs to the lake;

(5) a water fluctuation alternative, which would allow lake levels to rise and fall over a greater range in response to the natural moisture regime; and

(6) an alternative involving implementation of a State law recently enacted by the Tennessee legislature (i.e., using the existing control structure to release water only when the lake surface elevation exceeds 283.6 ft msl).

In addition, the Hydrology and Sedimentation Workgroup briefly considered dredging and flushing as ways of dealing with in-lake sediments and nutrients.

There was general agreement among workshop participants that control of sediment input and deposition is the ultimate key to prolonging the life of Reelfoot Lake. Unless this problem is solved, any beneficial effects of other management actions will be temporary at best. As formulated at the workshop, the watershed treatment alternative, which was designed to control sediment input to the lake, consisted of three activities:

(1) acquisition, through fee title or easement, and revegetation of highly erodible areas in the hills east of the lake;

(2) construction of a large sediment retention basin near the mouth of Reelfoot Creek; and

(3) acquisition of the floodplain of Reelfoot Creek below the sediment retention basin and restoration of a natural, meandering, vegetated stream course.

There was nearly unanimous agreement that this would be a highly desirable alternative. Acquisition and revegetation of highly erodible lands would do much to control sediment at its source. Other mechanisms for accomplishing this (e.g., zoning restrictions, continuation of current economic incentives to farmers to institute better soil conservation practices) were also discussed, but were generally judged to be inferior to acquisition. In particular, the current incentive program for farmers has apparently been relatively ineffective.

A large sediment retention basin would probably be effective in trapping any sediment load that still remained after implementing an acquisition program. The feasibility of building such a structure could not be adequately evaluated with information available at the workshop; however, at least several participants thought additional study of this possibility would be warranted. Depending on the success of other programs to control sediment at its source, such a structure might not even be necessary.

Acquisition and restoration of a natural stream course on the floodplain of Reelfoot Creek would limit the amount of sediment picked up by the stream before reaching Reelfoot Lake. This was viewed as a critical aspect of any sediment control alternative; the effectiveness of the sediment control structures already constructed east of the lake has been questioned because the streams tend to regain a high sediment load in channelized downstream reaches.

As formulated at the workshop, the watershed treatment alternative pertained only to Reelfoot Creek. While this creek carries a high proportion of the total sediment load generated in the watershed surrounding Reelfoot Lake, recent studies have shown that other sediment sources are also significant. These include Indian Creek, Bayou du Chien, and a number of small natural drains and ditches that have been channelized for agricultural purposes. In particular, agricultural fields north and west of the lake may be an important source of both water and sediment at times when the water level in the Mississippi River is higher than that of Reelfoot Lake. An effective sediment control program will eventually have to address all of these sources.

Even the most effective sediment control program would do little to solve the problem of the soft sediment layer that has already accumulated on the bottom of the lake. This layer is thought to be a serious detriment to the fishery of Reelfoot Lake, both in terms of limiting spawning sites and preventing development of desirable benthic communities. Three alternatives for solving this problem were considered at the workshop; flushing, dredging, and drawing down the lake to expose bottom sediments to drying. Flushing and dredging were discussed in detail only by the Hydrology and Sedimentation Workgroup. Flushing would involve developing an alternate source of water to try to move accumulated sediments out of the lake. Generally, workgroup members believed that it would be impossible to generate water velocities high enough to move significant amounts of sediment. However, flushing might be effective in removing nutrients. Dredging was also judged to be infeasible, at least for the entire lake, because of high costs; technical problems associated with operating a dredge around stumps, logs, and other organic debris; and the difficulty of disposing of spoil material.

The drawdown alternative was discussed and evaluated by all of the workgroups. The purpose of this strategy would be to expose about 50% of the lake bed to drying by the sun, thus consolidating and oxidizing existing sediment, enhancing water quality, stimulating the growth of desirable benthic communities, and improving the quality of the fishery. The general consensus among workshop participants was that a drawdown is worth trying. The best available evidence, both from similar drawdowns in Louisiana and Florida and from work with disposal of dredge spoil, indicates that sediments would consolidate and not resuspend when the lake was refilled, assuming that sufficient drying occurred. Furthermore, experience in Florida and Louisiana indicates that such a strategy can result in significant benefits in terms of water quality, benthic communities, and the fishery.

However, a drawdown has never been implemented in Tennessee and significant questions regarding potential effectiveness remain.

(1) Drawdowns in Louisiana and Florida are usually implemented in fall or late winter, respectively. The extent to which the impacts from a summer drawdown, such as discussed for Reelfoot Lake, would differ is unknown.

(2) In Louisiana and Florida, a drying period of about 90 days is sufficient to produce adequate consolidation of sediments. The drying time suggested for Reelfoot Lake (120 days) is only an estimate. The extent of drying would depend on a number of unknown factors, including specific climatic conditions during the drawdown and the spatial extent and volume of groundwater inputs to the lake.

(3) As discussed at the workshop, the lake would be drawn down 5.8 ft between about June 1 and July 15. Allowing for 120 days of drying, refilling could begin about November 15. However, the Aquatic Ecology Workgroup questioned whether a drawdown of 5.8 ft could be accomplished in 45 days with the existing control structure. An earlier date for starting the drawdown would impact fish spawning and waterfowl broodrearing, while a later date to start refilling would likely impact early migrating waterfowl.

(4) Sowing ryegrass or millet on the exposed lake bed was suggested as a means of preventing establishment of less desirable vegetation, eliminating unsightly mud flats, and providing food for waterfowl after reflooding. This technique is used effectively in Louisiana and Florida. However, in dredge spoil disposal work, seeding is no longer recommended because vegetation inhibits drying of the substrate. The desirability and effectiveness of this technique under the particular situation that exists at Reelfoot are unknown.

In addition to the above uncertainties, a drawdown would probably have some negative impacts.

(1) The fishable area of the lake would be reduced during the drawdown. This, along with potential fish kills, noxious odors, and possibly unsightly mudflats, would perhaps have adverse effects on the tourism industry. These impacts could be partially offset by certain management techniques (e.g., sowing vegetation on exposed mudflats) and by the fact that a drawdown would allow easy, less expensive repair of facilities such as docks and boat ramps.

(2) During the drawdown, some wildlife species (e.g., reptiles and amphibians, marsh birds, wood ducks) would be negatively impacted. In the fall following the drawdown, early migrating waterfowl would also be impacted by lower water levels. Impacts on early migrating waterfowl, however, could be mitigated by developing additional capabilities to provide open water and food (e.g., moist soil units). Later migrating waterfowl would benefit from flooding of ryegrass or millet planted during the drawdown.

(3) In the spring following a drawdown, corn production on the Refuge would be impaired if the water level was allowed to stay at 283.2 ft msl until June 1. This would in turn mean a reduced food supply for waterfowl in the following fall. Again, however, this impact could be offset by purchasing additional agricultural lands at higher elevations.

Despite these uncertainties and possible negative impacts, participants generally believed that the potential benefits are substantial and that such a strategy is worth trying. They pointed out, however, that a drawdown at Reelfoot should be viewed as an experiment and that managers should be given considerable latitude to respond to specific conditions that may arise during implementation.

Participants, particularly those in the Fish Workgroup, also identified a number of actions that should be taken in concert with a drawdown. These included: implementation of a rough fish removal program while the lake is drawn down; exclusion of crappie from the commercial harvest during the drawdown; cleaning existing channels; dredging or excavating necessary drainage ditches to ensure proper drying; marking cleared channels and stump fields; and mapping the topography of the lake bed. In addition, members of the Hydrology and Sedimentation Workgroup suggested that it might be desirable to excavate dried sediments from certain critical areas. While excavation might have some minor negative impacts (e.g., physical structure for fish spawning would be reduced somewhat), benefits in terms of improved access and increased sediment retention capacity would probably be more significant.

Benefits from a drawdown would not be permanent, particularly if sediment inputs to the lake continue at their current rate. The best available evidence, again from Louisiana and Florida, indicates that drawdowns would be required on the order of every 6-10 years. The exact interval cannot be predicted for Reelfoot; members of the Fish Workgroup suggested several factors that should be monitored to determine the need to repeat the action. In addition, they suggested that a water fluctuation strategy, designed to mimic more closely the water levels that would occur in a natural, unregulated situation, would help to extend the interval between required drawdowns.

In the water fluctuation alternative, water levels would be allowed to rise naturally through the winter and would then be held relatively constant through March, April, and May to allow fish to complete their spawning activities. In naturally wet years, this level might be 284.0 ft msl; in dry years it might be only 282.0 ft msl. Following fish spawning, water levels would be drawn down a minimum of 2 ft. Occasionally, water levels might be drawn down earlier than June 1 if it was desirable to eliminate a particular year class of fish. Members of the Fish Workgroup believed that this strategy would improve fish spawning, consolidate and oxidize some organic sediment around the lake margin, and generally promote development of a more natural ecosystem.

This alternative would likely not have major impacts on hydrology and sedimentation. From the aquatic ecology perspective, it would probably be beneficial in enhancing water quality, reducing nutrient concentrations, and controlling emergent and submergent vegetation. Cutgrass and swamp loosestrife might tend to become established on exposed areas, but these species could probably be controlled with periodic flooding and herbicides. However, it is less clear that this alternative would be acceptable from the perspective of forested wetlands and wildlife.

The problem with respect to these resources concerns the timing of fluctuations. In general, water levels above 282.2 ft msl after March 1 would reduce corn production on the Refuge and thus impair the ability of the Refuge to meet its objective for wintering waterfowl. In principle, water level fluctuation was viewed as desirable from the perspective of forested wetlands. However, it was recommended that, with occasional exceptions (perhaps 1 year in 4), water levels should be at or below 282.2 ft msl by May 1 to avoid stress on bottomland hardwoods. Thus, the conditions most desirable for wildlife and forested wetlands would be inconsistent with those most desirable for fish, except in relatively dry years.

This potential conflict could be alleviated to some extent by acquiring and developing additional lands for waterfowl food production. The plan suggested by the Nonaquatic Vegetation Workgroup would require a total of 800 acres of agricultural land at 284.0 ft msl or higher, about half of which would have to be acquired in fee title or easement from private sources. In any year, 400 acres of this higher ground would be seeded to corn and 400 acres to green browse. Lower areas, some of which are presently used for soybean production, would be converted to moist soil units (600-800 acres) and greentree areas (600 acres). The moist soil units would provide food resources for waterfowl immediately; greentree areas would not produce mast for about 30 years. In the short term, development of these areas would alleviate the conflicts between fish spawning and waterfowl food production. However, implementation of the water fluctuation alternative as proposed at the workshop would still stress bottomland hardwoods. The extent of mortality that would result, if any, is unknown. In the long term, distribution of the species associations in the bottomland hardwood forest would change in response to the new water management regime. Additional land currently in agricultural production could be used to mitigate losses of forested wetlands if that land was used for bottomland vegetation.

The water management strategy contained in a State law recently enacted by Tennessee was generally perceived as the poorest of the alternatives analyzed at the workshop. While this strategy would have some short-term benefits, such as increasing fishable area and allowing some fluctuation in lake level, there would also be several negative impacts, including those on wildlife and forested wetlands described above for the water fluctuation alternative. In addition, the State law alternative would significantly increase the potential for flooding of areas surrounding the lake and for failure of the existing control structure. Furthermore, any benefits of this alternative would be relatively short-lived, because it does not address any of the real causes of problems at Reelfoot. In a few years (perhaps 20-30?), conditions in the lake would be very similar to those that currently exist.

In addition to analyzing these management alternatives, participants at the workshop suggested a variety of research and monitoring activities that should be initiated. While there was considerable variation in these suggestions, two general points were made. First, a successful monitoring program must be in place before any new water management strategy is implemented and must continue both during and after implementation. Information from such a program will be of little use unless it covers all three of these phases. Second, the monitoring program should be developed around a standardized scheme for stratification of sampling so that results from different studies can be related.

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FIGURES

TABLES

ACKNOWLEDGMENTS

This report summarizes the results of a workshop held August 24-29, 1986, at Reelfoot Lake and Memphis, Tennessee. The following individuals participated in the workshop.

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These individuals provided the majority of the ideas and information contained in this report and the authors are grateful for those contributions. However, errors of fact or interpretation are the fault of the authors and should not be attributed to any of the participants nor the agencies they represent. In particular we note that Sherwood McIntyre, Jim Naney, and Clarence Robbins, in keeping with the policies of their agencies, contributed technical information but did not participate in the development or ranking of management alternatives.

The authors are especially indebted to the following individuals: James Pulliam, Harold Benson, and their staff for providing us with the opportunity to conduct the workshop; Wendell Crews, Paul Brown, and their respective staffs for their hospitality and logistic arrangements at Reelfoot Lake; and Don Orr for meeting arrangements in Memphis.

INTRODUCTION

The introductory material that follows is intended to provide a brief overview of Reelfoot Lake and the context in which the workshop described in this report was conducted. It is not meant to be a comprehensive treatment. Much of the material in this section was taken from Smith and Pitts (1982), Talley et al. (1984), and Tennessee Wildlife Resources Agency (1985), which should be consulted for additional details.

ORIGIN AND LOCATION OF REELFOOT LAKE

Reelfoot Lake was created by the New Madrid earthquakes of 1811-1812 (Smith and Pitts 1982). It is located in Lake and Obion Counties of western Tennessee on the floodplain of the Mississippi River (Figure 1). At normal pool, which is considered to be 282.2 ft mean sea level (msl), the surface area of the lake is about 15,500 acres (Tennessee Wildlife Resources Agency 1985), though this area changes 2,000-4,000 acres for each foot of change in surface elevation (Talley et al. 1984). The total drainage area of the lake is approximately 153,000 acres (Smith and Pitts 1982). Most of the watershed (about 100,000 acres) lies in Obion County; an additional 15,000 acres are in Lake County, and 38,000 acres lie to the north in Fulton County, Kentucky. While the lake itself is on the Mississippi floodplain, a significant proportion of the watershed is composed of hills east of the lake with fertile but highly erodible loess soils.

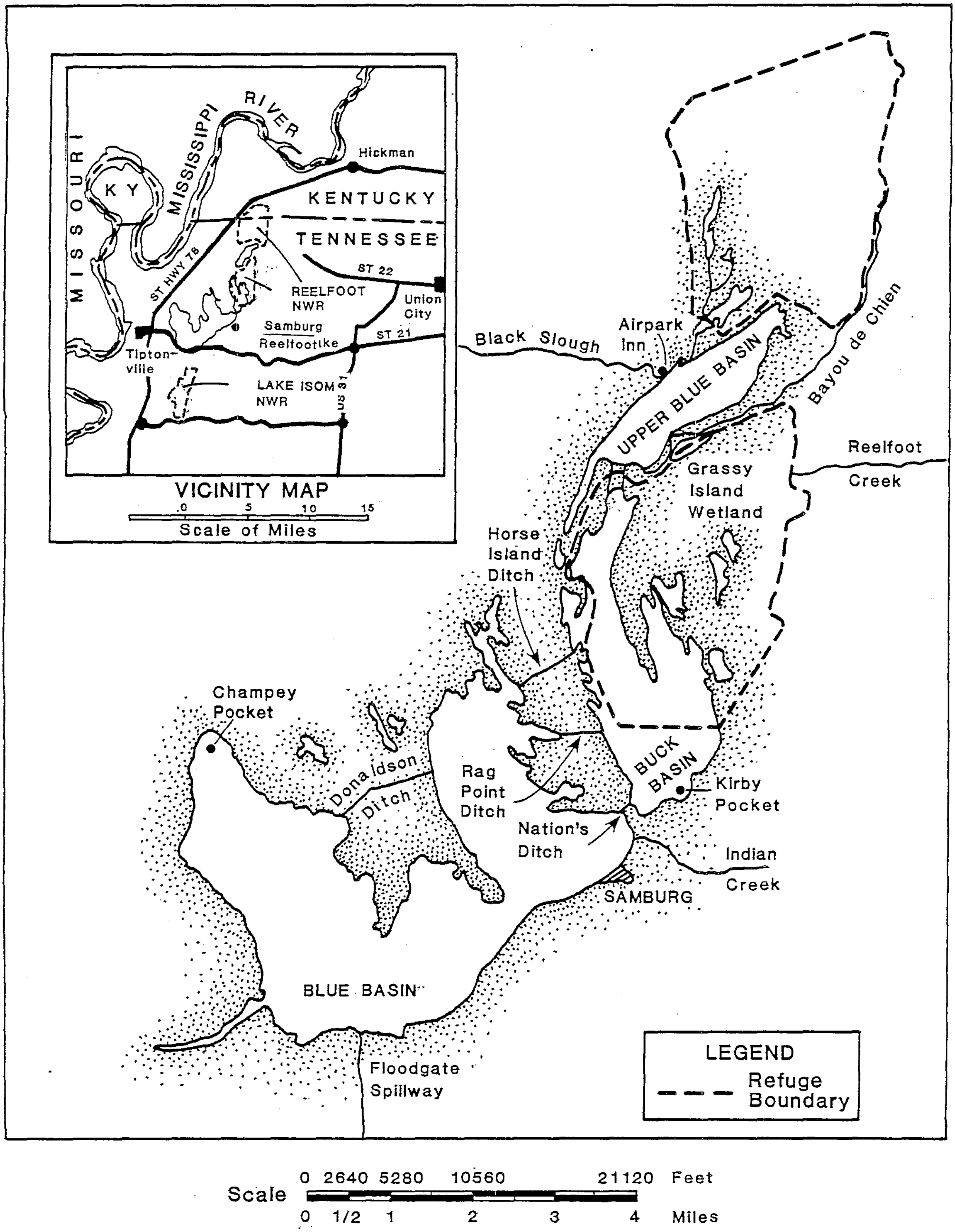

Figure 1. Map of Reelfoot Lake and vicinity.

ADMINISTRATION

Reelfoot Lake itself and considerable lands surrounding it are publicly owned. The Tennessee Wildlife Resources Agency (TWRA) is the State agency with primary responsibility for management of the lake. The publicly owned area consists of about 26,500 acres. TWRA and the Tennessee Department of Conservation (Reelfoot Lake State Park) administer approximately 24,400 acres in Tennessee, of which about 7,900 acres are leased to the U.S. Fish and Wildlife Service (Service) for Reelfoot National Wildlife Refuge (Refuge) under the terms of a 75-year agreement that was signed in 1941. The Service also holds title to an additional 500 acres in Tennessee and 2,100 acres in Kentucky. The publicly owned area is composed of approximately 9,600 acres of open water, 15,400 acres of vegetated wetlands, and 1,500 acres of developed land, agricultural land, and upland (Talley et al. 1984).

WATER CONTROL

For a little over a century after its formation, Reelfoot was subjected to flood flows from the Mississippi, which sometimes raised the lake as much as 10-12 ft above its normal level (Talley et al. 1984). Between 1910 and 1920, a levee was constructed north and west of the lake along the east bank of the Mississippi from Hickman, Kentucky, to Tiptonville, Tennessee (Smith and Pitts 1982). This levee effectively isolated Reelfoot from the flood flows of the Mississippi. In 1917, a levee, spillway, and outlet ditch were constructed at the south end of the lake to stabilize water levels. The spillway was rebuilt in 1931 at its present elevation of 282.2 ft msl. The lease agreement signed in 1941 gave the Service responsibility for operating the spillway. Since that time the basic strategy has been to maintain lake levels as close to 282.2 ft msl as possible, opening the spillway gates when the lake is above this level and closing them when it is below. Normal seasonal variations have been less than 1.5 ft above and below 282.2 ft msl (Talley et al. 1984).

TROPHIC STATUS

Like most floodplain lakes in similar situations, Reelfoot is relatively shallow and very fertile (Smith and Pitts 1982). Consequently, the lake and surrounding wetlands support abundant fish and wildlife populations. These resources provide opportunities for sport fishing, commercial fishing, hunting, and trapping, as well as nonconsumptive uses such as boating, birdwatching, and photography. The lake is an important part of the culture and history of the area and contributes significantly to the local economy, both through direct harvest of resources and through the recreation and tourism industries.

Lakes such as Reelfoot typically undergo an aging process known as eutrophication. The highly fertile, shallow waters allow rapid growth of aquatic macrophytes and phytoplankton. As these organisms die, organic matter accumulates on the lake bottom, along with inorganic sediments that may be contributed by the surrounding watershed. Gradually, the lake fills and vegetation changes through a series of stages including submergent aquatics, floating aquatics, emergents, shrub swamp, and floodplain forest. Thus, the very characteristics that are responsible for the abundant resources of a lake such as Reelfoot also contribute to its gradual demise.

The eutrophication process is a natural one for fertile, shallow lakes. However, there is concern that certain human activities may be accelerating the process at Reelfoot. Agricultural practices on the highly erodible loess soils in the hills east of the lake contribute significantly to erosion. Large volumes of inorganic sediment, as well as agricultural nutrients (fertilizers), are delivered to the lake every year. Also, past water level management may have contributed to rapid eutrophication.

As noted above, the lake has generally been managed for stable water levels for the last 45 years. While there have been seasonal variations, fluctuations are generally more pronounced in unregulated situations. Larger fluctuations are believed to help slow the eutrophication process by controlling the growth of aquatic vegetation, allowing periodic consolidation of sediments through drying, and promoting aeration of sediments and hence oxidation of organic materials. Stable water levels, on the other hand, tend to promote accumulation of soft sediments, which may reach several feet in thickness, on the bottom of the lake.

The net result of these processes is that the character of Reelfoot Lake is changing in ways that many people view as undesirable. Sediments, aquatic macrophytes, and organic debris are filling channels, thus impeding circulation and making access difficult for fishermen and other users. TWRA is particularly concerned about the quality of the fishery. Trends since 1952 indicate declining catch rates for some species of sport fish, declining weights for others, and an increase in the proportion of rough fish in the total fish biomass (Tennessee Wildlife Resources Agency 1985). These trends in the fishery are believed to be at least in part a result of the accumulation of a bottom layer of soft sediment, which inhibits production of food organisms and is unsuitable spawning substrate.

MANAGEMENT RESPONSES

These problems have been recognized for some time at Reelfoot and efforts to solve some of them are not new. For example, in 1960 a project was begun on Reelfoot and Indian Creeks, two of the major tributaries to the lake, to construct a series of sediment retention ponds. Fourteen impoundments were originally planned and six were completed as of 1984 (Talley et al. 1984). A Rural Clean Water Program, authorized in 1979, provides economic incentives to farmers for implementing erosion control conservation practices in the Reelfoot watershed. A sewage system recently completed for communities around the lake should reduce nutrient inputs.

In addition to these programs, in 1985 TWRA proposed and initiated a major manipulation of lake levels designed to directly address the problem of unconsolidated bottom sediments and the declining quality of the fishery. The original proposal was to draw the lake level down approximately 5.8 ft during the summer, thus exposing about 50% of the lake bottom to drying by the sun

(Tennessee Wildlife Resources Agency 1985). This technique is used in other locations (e.g., Louisiana and Florida) to control dense growth of aquatic macrophytes, consolidate sediments, and stimulate the growth of desirable aquatic vegetation. Lake level would have been held down until about November 1, at which time refilling would have started. Under normal climatic conditions, it was estimated that normal pool level would have been reached in 2-3 months. In subsequent years, the proposal called for lake level fluctuations wider than those that have occurred historically, with periodic major drawdowns (perhaps every 7-10 years) as required to control aquatic vegetation and consolidate sediments.

The Service agreed to this proposal and gave control of the spillway to TWRA, which began a drawdown in May 1985. Shortly thereafter, a group of citizens, concerned with the potential impacts of such a program on many of the resources at Reelfoot, sought a court order to halt the drawdown. They reasoned that such a program, by virtue of the Service having had responsibility for operating the spillway since 1941, constituted a major Federal action signficantly affecting the quality of the human environment and thus required preparation of an Environmental Impact Statement (EIS) under the terms of the National Environmental Policy Act (NEPA) of 1969 (42 U.S.C. 4321 et seq.). A U.S. District Court, finding for the plaintiffs, issued a preliminary injunction halting the drawdown and directed the Service to prepare an EIS prior to implementation of any drawdown strategy. The decision of the District Court was appealed by TWRA and upheld by the Sixth U.S. Circuit Court of Appeals.

THE WORKSHOP

The Service decided that, prior to initiating the EIS process, it would be highly desirable to take a broad look at management alternatives for Reelfoot Lake, particularly those involving water manipulation. A workshop format was chosen for accomplishing this task, and a group of approximately 40 scientists and managers familiar with Reelfoot Lake or similar ecological situations was assembled. The authors of this document, based on previous experience with similar projects, were asked to develop an approach for conducting the workshop, facilitate the workshop sessions, record the results and discussions, and prepare a report describing the proceedings.

Objectives

Broadly speaking, the objectives of the workshop were to:

(1) develop alternative water management strategies for Reelfoot Lake; and

(2) assess the probable consequences of those alternatives on the resources at Reelfoot.

In the course of accomplishing these objectives, participants also devoted considerable time to discussing other management options (i.e., those *not* involving water manipulation), as well as research and monitoring needs.

Approach

The workshop began with a 1-day field trip to Reelfoot, during which participants had an opportunity to familiarize themselves with the area and some of the management problems and opportunities. Following the field trip, participants traveled to Memphis, Tennessee, where the remainder of the workshop was conducted.

In order to make efficient use of the expertise available, participants were divided into five working groups. These included hydrology and sedimentation, aquatic ecology, fish, nonaquatic vegetation, and birds. The Bird Workgroup subsequently broadened its area of consideration to include several other types of fauna, and is hereafter referred to as the Wildlife Workgroup. For most of the workshop, these small workgroups met separately to allow focused discussion on specific topics. Occasional plenary sessions were held to allow communication and discussion among the workgroups.

The first part of the workshop was devoted to developing a set of management alternatives for further analysis. Each of the workgroups was asked to:

(1) identify the resources or ecosystem components to be considered by the workgroup (i.e., it was realized at the outset that dividing lines between the various groups were not completely clear) and the criteria or variables that should be used in assessing the effects of management alternatives on those resources;

(2) define appropriate objectives for those resources; and

(3) develop a preferred management strategy for achieving the objectives.

Once these tasks were accomplished, the authors of this report, the sponsors of the workshop, and interested participants met to consolidate the list of alternatives into a single set to be analyzed by all of the workgroups. Alternatives not suggested by the workgroups, but perceived as necessary from the perspective of the NEPA process, were also considered. The workgroups then devoted the remainder of the workshop to analyzing the probable consequences of this set of alternatives for the resources of interest [as reflected in the evaluation criteria mentioned in (1), above] and discussing additional research and monitoring needs. During the final plenary session, a member of each workgroup gave a short presentation summarizing the results of their discussions.

Relationship to the NEPA Process

We emphasize that this workshop was not designed to satisfy the requirements of NEPA related to scoping and public participation. Rather, it was viewed as a precursor to the formal EIS process, designed to identify promising management alternatives, ways of evaluating them, and their probable consequences. We hope, however, that the workshop results will be useful to the Service in preparing an EIS, and also to TWRA, which has been directed by the Tennessee legislature to prepare a 50-year management plan for Reelfoot Lake.

INITIAL WORKGROUP DISCUSSIONS

As noted above, the first tasks that the workgroups were asked to undertake were to: (1) identify the resources or ecosystem components that they would consider and the criteria or variables that would be used to evaluate the probable impacts of various management alternatives; (2) define what they believed to be appropriate objectives for those resources; and (3) develop a preferred management strategy for achieving those objectives. The results of those discussions are summarized in the following section. In each case, a brief description of the current status and management of the resources of interest is also included.

HYDROLOGY AND SEDIMENTATION WORKGROUP

Resources Considered and Evaluation Criteria

Workgroup members assumed that their charge was to consider hydrologic and sedimentation processes as they affect Reelfoot Lake and how management alternatives might impact those processes. It was assumed that water quality considerations would be addressed by the Aquatic Ecology Workgroup; however, it was often difficult to ignore water quality completely because many water quality variables are directly impacted by hydrologic and sedimentation processes. Evaluation criteria related to these processes included: sediment input to the lake, sediment deposition and redistribution within the lake, consolidation of existing lake sediments, removal of existing lake sediments, vertical and interbasin water circulation patterns within the lake, groundwater levels, inflows to the lake, and outflows from the lake. Flooding potential and safety of the control structure were also discussed in some cases.

Current Status and Management

Hydrology. The following general discussion of the hydrology of Reelfoot Lake is taken largely from Robbins (1985) and Robbins et al. (1985). These sources should be consulted for additional detail.

Climatologically, Reelfoot Lake is characterized by relatively wet winters and springs with somewhat drier summers and falls. The 30-year (1951-1980) standard normal monthly rainfall at Samburg, Tennessee, ranged from a high of 5.05 inches in March to a low of 2.55 inches in October. Annual variability, however, was high. In October 1984, for example, the total precipitation was 9.89 inches. Average monthly pan evaporation from 1977 to 1984, calculated from observations at Jackson and Martin, Tennessee, ranged from a low of 0.52 inches in January to a high of 5.71 inches in June. In an average year, precipitation probably exceeds pan evaporation by about 10 inches.

Reelfoot Lake has three major tributaries: Reelfoot Creek, Indian Creek, and Bayou du Chien (also known as Running Slough in Kentucky). These streams drain approximately 46%, 3%, and 5%, respectively, of the total drainage area of 153,000 acres. Of these streams, only Reelfoot Creek has been gaged for any extended period of time (1951-1973). During this period, discharge from Reelfoot Creek ranged from 0-16,600 cubic feet per second (cfs), with a mean of 116 cfs (Talley et al. 1984). This represents an average volume of about 84,000 acre-ft annually. For a 4-month period (September-December 1984) when all three streams were gaged, Reelfoot Creek accounted for about 48% of the total surface inflow, including inflows calculated for the ungaged portion of the watershed. About 37% of the ungaged area lies in the Mississippi River floodplain. During the period December-May, the water-surface elevation of the Mississippi is typically 10-20 ft higher than the surface elevation of Reelfoot Lake. Seepage from the river to the lake during this time thus accounts for a significant fraction of the total inflow. Runoff from the remaining 63% of the ungaged area is probably similar to that from the area drained by the main tributaries.

Groundwater relationships affecting Reelfoot Lake are largely unknown from empirical data, but have been estimated for the period May-December 1984 as the residual in a water balance calculation. These values ranged from a net monthly inflow (to the lake) of 10,330 acre-ft to a net monthly outflow of 4,370 acre-ft. In general, Reelfoot Lake is well-connected to an alluvial aquifer that ranges from 100 to 200 ft in thickness. The basic pattern of groundwater movement is from the bluffs on the east side of the lake toward the Mississippi. However, when the water surface elevation of the Mississippi is higher than the adjacent water table, the river can contribute to groundwater recharge, and thus to Reelfoot Lake itself. At lower river stages, Reelfoot may discharge water to the alluvial aquifer.

At normal pool (282.2 ft msl), the lake itself occupies about 15,500 acres, has a volume of about 80,300 acre-ft, and a mean depth of about 5.2 ft (Robbins 1985). At this stage, average annual surface inflows and net precipitation amount to something over two times the volume of the lake. Since 1940, the lake level has been regulated as close to 282.2 ft msl as possible. A staff gage was maintained at the spillway from 1940 to 1970. A continuous water surface elevation recording device located west of the spillway has been operated since 1970. Gage data from the period 1970 to 1983 indicate that a lake level of 282.3 ft msl has been equaled or exceeded 50% of the time. An elevation of 283.0 ft msl has been exceeded about 5% of the time and an elevation of 280.7 ft msl has been exceeded 99.98% of the time. The highest known lake elevation (from surveying water marks) was 287.22 ft msl in January of 1937. The minimum elevation, 279.59 ft msl, was recorded on November 20-21, 1953.

Surface outflow from the lake is from a single channel, Running Reelfoot Bayou, which receives water from the spillway. Flow of water in this channel is thus largely a function of how the control structure is operated. The channel has a capacity of approximately 1,800 cfs and is relatively stable due to vegetation on the banks.

Sedimentation. Sedimentation has long been a concern at Reelfoot Lake. A recent cooperative study by the Tennessee Office of Water Management and the Water Quality and Watershed Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, has attempted to develop an understanding of sedimentation processes. Reports describing the results of these studies (Denton 1986; McIntyre et al. 1986) should be consulted for details beyond those incorporated in this brief summary.

Sedimentation rates at Reelfoot have varied both spatially and temporally (Table 1). On average, since 1954, Upper Blue Basin has experienced the greatest sediment deposition and Blue Basin the least. Upper Blue Basin also appears to have experienced the largest increase in rate of deposition in recent years. Since 1885, mean water depths in Blue Basin, Buck Basin, and Upper Blue Basin have been reduced by an average of 2.3, 3.0, and 3.3 ft, respectively (Table 2). However, deposition rates vary greatly at different locations. Some sites in the Blue Basin have experienced little or no deposition in the past 100 years.

While not its primary purpose, the study described above also contributed some information relevant to an understanding of sediment sources at Reelfoot Lake. Previous studies estimated that Reelfoot Creek delivered as much as 85% of the total annual load of 619 acre-ft of sediment to the lake. The current study, however, demonstrated that much of the sediment transported by Reelfoot Creek is trapped by Grassy Island Wetland and never reaches the open water areas of the lake. Thus, small watersheds east of the lake and agricultural fields north and west of the lake may be more important sources of sediment than once believed. Using a comparative analysis of particle size distribution, McIntyre et al. (1986) also demonstrated that agricultural channelization of streams is an important contributor to the rate of sedimentation.

Table 1. Sedimentation rates (cm/yr) at Reelfoot Lake (after Denton 1986).

Location	Average annual rate of deposition since 1954	Average annual rate of deposition since 1885	Maximum rate of deposition since 1954[a]	Maximum rate of deposition since 1885[a]
Blue Basin	0.9	0.9	2.4	2.0
Buck Basin	1.1	0.9	2.1	1.5
Upper Blue Basin	1.9	1.1	3.3	1.7

[a]Refers to maximum deposition rates for the sites sampled.

Table 2. Water depths (ft) at Reelfoot Lake (after Denton 1986).

Location	Current average depth[a]	Estimated historic average depth	Current maximum depth	Estimated historic maximum depth
Blue Basin	8.2	10.5	15.7	20.6
Buck Basin	5.9	8.9	7.8	11.5
Upper Blue Basin	5.6	8.9	9.8	14.3

[a]Depths reported here are averages for those locations that were sampled (G. Denton, Tennessee Department of Health and Environment; pers. comm.). Robbins (1985) estimated the average depth of the entire lake to be 5.2 ft.

Efforts to reduce sediment inputs to Reelfoot have focused largely on agricultural lands in the hills east of the lake. The Reelfoot-Indian Creek Watershed Project, which was initiated in 1960, called for construction of 14 sediment retention dams. As of 1984, six of these had been constructed. A Rural Clean Water Program initiated in 1979 provides economic incentives to farmers to institute erosion control practices. The overall value of these programs has been debated, however, both because economic incentives have not been sufficient to stimulate large changes in agricultural practices and because channelization of streams below sediment retention structures has limited their effectiveness.

Objectives

Workgroup members, while understanding the need for stated objectives as a framework for the evaluation of management alternatives, believed that such objectives should be stated in terms related to the biological resources of Reelfoot Lake and their use by humans, rather than in terms related to hydrology and sedimentation. That is, hydrologic and sedimentation processes should be viewed as good or bad to the extent that they promote or prohibit achievement of other objectives. For example, the current water management regime is neither good nor bad from a hydrologic perspective; rather, its relative merit depends on its impacts on other resources, such as vegetation, fish, and wildlife.

With this perspective in mind, workgroup members assumed that the overall management goal at Reelfoot Lake is to maintain or enhance the ability of the area to support current wildlife populations, fish populations, and recreational uses. Achieving this goal will likely require that two objectives be met with respect to hydrology and sedimentation:

(1) development of mechanisms for better controlling the amount, character, and timing of sediment input and deposition; and

(2) development of mechanisms for better controlling the amount, quality, and timing of inflows and outflows.

Workgroup discussions then turned to alternate methods for achieving these objectives in support of the overall management goal.

Preferred Management

In attempting to develop a preferred management alternative, potential actions were divided into those related primarily to sediment control and those related primarily to water supply and manipulation of water levels. Sediment control alternatives were further subdivided into those pertaining to on-field sediment sources, those pertaining to transport and delivery systems, and those pertaining to treatment of sediments already in the lake.

Sediment control. The workgroup focused the majority of its attention on mechanisms for sediment control, because there was unanimous agreement that excessive sedimentation is the ultimate problem at Reelfoot Lake and that other management actions are likely to be ineffective in the long run unless this fundamental problem is also addressed.

Of the alternatives that were discussed for on-field control of erosion, purchase of agricultural lands that contribute significant sediment load to the lake was considered most likely to achieve the desired result. These lands would either be converted to cover crops with greater ability to stabilize the soil or would be allowed to revert to natural vegetation. While the cost of purchase would likely be relatively high, and there would probably be some resistance to further expansion of public holdings, the benefits would be significant and lasting. In addition to erosion control, there might also be substantial benefits in terms of wildlife production and recreational use. Such a program would undoubtedly focus on highly erodible areas in the hills east of the lake; however, it would also have to consider recent evidence suggesting that sediment contribution from lands north and west of the lake is significant. Controlling erosion in the hills alone, for example, is not likely to reduce sediment input to the Upper Blue Basin.

The second best alternative for controlling on-field erosion was thought to be zoning restrictions that would regulate land use based on erosion potential. While such an approach could potentially be effective, implementation might be difficult due to resistance to government controls on agriculture. It would also be less "permanent" than land acquisition in the sense that it could be reversed by future regulatory changes.

The poorest of the alternatives for control of on-field erosion was judged to be further efforts to stimulate use of best management practices. This judgement was based largely on the perception that the current program has achieved little thus far. However, lack of results to date may only mean that economic incentives to farmers have been insufficient.

There was also agreement among workgroup members that none of these approaches for controlling on-field erosion would be very effective without concurrent changes in transport and delivery systems. Of the alternatives considered, restoration of channels to their natural configuration was judged to be most desirable. This would involve restoring meandering channels, reducing side slopes, and revegetating banks and adjacent lands, in order to reduce both velocity and sediment carrying capacity of water moving toward the lake. Suspended sediments would tend to settle out as water slowed down, and scouring of sediment from the channel itself would also be reduced. Land acquisition in the form of fee title purchase or easements would likely be required. First priority for such a program would probably be Reelfoot Creek, followed by Bayou de Chien and ditched agricultural lands surrounding the lake (e.g., the area near Kirby Pocket).

Construction of additional siltation basins around the lake was judged to be the second best alternative for controlling transport and delivery of sediment. Workgroup members emphasized, however, that the effectiveness of these basins is greatly diminished if water that is released has an opportunity to pick up additional sediment. For this reason, structures close to the lake (e.g., the one presently under construction on Indian Creek) are likely to be more effective and safer than those at elevations higher in the watershed.

Channelization of streams below structures is also an important factor in this regard. Instream structures designed to reduce water velocity might be of some use, but eliminating channelization is the only real solution.

In particular, workgroup members believed that there is some possibility that a large (surface area of several thousand acres) sedimentation basin might be constructed on Reelfoot Creek and that this possibility should be explored further. A structure of this size would have a long active life that could be extended by stabilization of agricultural areas upstream. In addition, it would provide some water delivery capability that might be useful in combination with other management alternatives.

In the view of workgroup members, diversion of sediment-bearing streams around the lake is the least desirable alternative related to transport and delivery. Such an alternative would be expensive and would require development of an auxiliary water supply. In addition, a diversion channel might tap the alluvial aquifer and thus disrupt groundwater relationships with the lake. There is also potential for creating downstream sedimentation problems with this alternative.

A drawdown to allow drying and consolidation of sediments, in combination with excavation of sediments from critical areas, was judged by workgroup members to be the best alternative for dealing with material already deposited in the lake. While there are some questions concerning how well this approach might work at Reelfoot, experience with similar techniques in Louisiana and Florida and with disposal of dredged material indicates that there is a reasonable probability of success. Additional detail on this option can be found in a later section entitled ANALYSIS OF PROBABLE IMPACTS.

Other alternatives considered for treating the in-lake sediment problem included flushing, dredging, and mechanical removal of aquatic vegetation. All of these were judged to be less desirable than the drawdown and excavation approach. Flushing, using water either from upstream sources within the watershed, wells, or the Mississippi River, was believed to be infeasible due to the difficulty of developing sufficient water velocities to move existing sediments. Flushing might, however, be useful in removing nutrients. Dredging, while perhaps not impossible, would also be extremely difficult. A dedicated disposal site would be required, and the large amount of organic debris (stumps, logs) in the lake would make it hard to maneuver a dredge. Cost would also likely be prohibitive for the entire lake, though perhaps not for smaller critical areas. Removal of aquatic vegetation would have the virtues of reducing the organic matter contribution to the sediment and perhaps decreasing deposition somewhat by increasing water movement. However, this approach would do nothing to help consolidate existing sediment and would likely be very costly and time consuming.

Water supply and water level manipulation. The workgroup considered a number of actions that might be taken to increase water supply or provide better control over water levels, including: constructing upstream reservoirs; developing structures to divert incoming flows as desired (e.g., during times when sediment loads are high); groundwater pumping; reestablishing a surface connection with the Mississippi River; improving the existing control structure by increasing the height, enlarging the capacity, and providing a multilevel outlet; maintaining a higher pool level in spring and thus a higher level throughout the summer; cleaning existing channels to improve water circulation; and dredging new channels to improve circulation. These alternatives were discussed in much less detail than sediment control alternatives, because it was less clear that a supplemental water supply or greater ability to manipulate water levels would contribute to achievement of some other objectives.

In general, workgroup members felt that actions providing some measure of sediment control in addition to water control capabilities are likely to be preferred. Thus, a reservoir providing some sediment retention on Reelfoot Creek is likely to be more desirable than development of a groundwater supply or reestablishing a surface connection with the Mississippi River, other things (e.g., cost) being equal. The existing control structure at the lower end of the lake is known to be deteriorating and may have to be replaced for safety reasons. Providing additional manipulation capability (e.g., enlarging the capacity of the spillway and outlet channel so that a drawdown, if desired, could be accomplished more quickly) might be logical if the structure is replaced. However, decisions of this nature should be based on the extent to which they would allow accomplishment of other objectives, rather than just the extent to which they would provide hydrologic control. Similarly, a higher control structure, which might allow maintenance of higher pool levels, should be considered only if it allows other objectives (e.g., better access for fishermen) to be achieved. Finally, it is unlikely that cleaning existing channels would improve water circulation substantially, though, again, cleaning might be justifiable on the basis of improving access.

Additional discussion of some of these potential actions can be found in the section entitled ANALYSIS OF PROBABLE IMPACTS.

Combinations of actions. On the basis of these discussions the workgroup concluded that the preferred management alternative is a combination of various actions to address various parts of the overall problem. These include:

(1) purchase of lands that are contributing sediment to Reelfoot Lake and reestablishment of vegetation capable of stabilizing soils;

(2) purchase of lands along major conveyance channels and reestablishment of natural streamflow patterns and vegetation;

(3) exploration of the possibility of constructing a large sediment retention basin near the mouth of Reelfoot Creek;

(4) drawdown of the lake to allow drying and consolidation of existing sediments; and

(5) excavation of dried material from certain critical areas to provide additional sediment retention capacity and improve access.

It must be remembered, however, that the perceived desirability of these actions is based on the assumed goal of maintaining or enhancing the ability of the lake to support fish, wildlife, and human use, rather than on any objectives related to hydrology and sedimentation per se.

Resources Considered and Evaluation Criteria

The Aquatic Ecology Workgroup was responsible for: (1) characterizing the current eutrophic (or hypereutrophic) status of Reelfoot Lake in terms of its water quality, nutrient concentrations and cycling, benthic and planktonic communities, and nonwoody vegetation; and (2) assessing the consequences of various management actions on these lake characteristics. Water quality variables that were used to evaluate trophic status and management consequences included dissolved oxygen, chlorophyll, and inorganic suspended particulates. The primary nutrients of concern were nitrogen and phosphorus. While there are many forms of these nutrients that could have been discussed, the workgroup decided to focus on total nitrogen and total phosphorus. Very little work has been done on the taxonomy and density of plankton and benthos in Reelfoot Lake. As a result, general changes in energy pathways were used as evaluation criteria; that is, changes in the diversity and components of the phytoplankton, zooplankton, and benthic communities. Finally, nonwoody vegetation was interpreted as vegetation in the palustrine-aquatic bed and palustrine-emergent wetland types of Cowardin et al. (1979). Workgroup discussions focused on several groups of "undesirable" vascular plants in Reelfoot. Submergent vegetation was represented by coontail (Ceratophyllum demersum) and curly-leaf pondweed (Potamogeton crispus). Spatterdock (Nuphar advena) and lotus (Nelumbo lutea) were used to characterize seasonally emergent/nonpersistent vegetation. The emergent/persistent vegetation group included cutgrass (Zizaniopsis miliacea), southern smartweed (Polygonum densiflorum), and swamp loosestrife (Decodon verticillatus). While swamp loosestrife is actually a woody shrub in the scrub-shrub wetland type (which was considered by the Nonaquatic Vegetation Workgroup), it was discussed by the Aquatic Ecology Workgroup because of its low, dense growth form and its designation by some as another "undesirable" species.

Current Status and Management

The U.S. Environmental Protection Agency (1976) has classified Reelfoot Lake as hypereutrophic based on several water quality and nutrient variables. Unless noted otherwise, information presented below on current conditions in the lake is from Smith and Pitts (1982) and Tennessee Wildlife Resources Agency (1985).

The eutrophication process. In classical limnology, eutrophication (nutrient accumulation in an aquatic ecosystem) is considered a natural aging process of lakes. This aging process is due, in part, to silt carried by inflowing water that progressively fills the lake basin. In addition, nutrients carried into the lake from the surrounding watershed stimulate productivity of phytoplankton and aquatic macrophytes. These changes in sedimentation and productivity at the base of the food chain cause major changes in the lake ecosystem. Increased phytoplankton concentrations and suspended particulates reduce light penetration and restrict biological productivity to surface waters. As organic debris accumulates on the bottom, decomposition may deplete dissolved oxygen in bottom sediments and deep water. Oxygen levels can be depressed further diurnally due to nighttime respiration. Oxygen depletion can, in turn, cause occasional fish kills as well as changes in benthic and planktonic communities, including: a general reduction in the number and diversity of chironomids and other benthic animals (e.g., molluscs, crustaceans) and a concurrent increase in oligochaete worms; a shift to dominance by blue-green algae in the water column and epiphytic algae in the littoral zone; and a change in the zooplankton community that feeds on these algae. These changes in energy pathways, and associated water quality changes, may cause shifts in the fish community in the lake and waterfowl populations using the lake. As the lake basin continues to fill, the resulting shallowness speeds the cycling of available nutrients and further increases productivity. A succession of plants results, progressing from submergents, such as coontail and curly-leaf pondweed, to floating aquatics, such as spatterdock and lotus, to emergents, such as cutgrass and smartweed, to woody species, such as swamp loosestrife and cypress, to a floodplain forest, and eventually to an upland forest. As this succession proceeds, dense plant growth can interfere with boating, fishing, and other recreational uses of a lake.

The process of eutrophication is generally relatively slow, extending over centuries or millennia. However, the influence of humans in a lake basin or watershed (e.g., agricultural practices, development, dumping or seepage of raw sewage, recreational use) can greatly accelerate this process. This accelerated enrichment has been termed cultural eutrophication and has been attributed largely to additional nitrates and phosphates added to a lake. While cultural eutrophication is occurring at Reelfoot Lake, there is evidence from other parts of the country (e.g., Lake Washington, Lake Erie) that this process can be arrested and even reversed.

Water quality status. [Note: The Office Water Management, Tennessee Department of Health and Environment, is in the process of analyzing additional water quality data for Reelfoot Lake. Their report, when completed, should be consulted for the most recent information.] While dissolved oxygen concentrations in Reelfoot Lake vary depending on water column depth and presence or absence of submerged and surface vegetation, summer diurnal fluctuations may range from about 15 mg/l in the evening down to 2-3 mg/l in the early morning. Fluctuations are less pronounced in the winter. The State water quality standard for dissolved oxygen is a minimum of 5 mg/l.

The only published records of chlorophyll-a measurements in Reelfoot Lake show a range from 16.2 μg/l in May to 210 μg/l in August. The U.S. Environmental Protection Agency's Clean Lakes Program Guidance Manual [cited in Tennessee Department of Health and Environment (1984)] considers lakes eutrophic if chlorophyll-a is greater than 6-10 μg/l; concentrations in excess of 200-250 μg/l indicate a high potential for fish kills. The only determinations of suspended particulates were made by the Tennessee Division of Water Quality Control. Their samples showed a range in suspended material from 10.5 to 50.0 mg/l (oven-dry weight) with 10.1% to 52.4% organic matter. It is not known what fraction of this material is the result of resuspension.

Nutrient status. In classifying Reelfoot Lake as hypereutrophic, the U.S. Environmental Protection Agency (1976) suggested that productivity is nitrogen-limited. In terms of nutrient concentrations, Wetzel (1975) characterizes eutrophic lakes as those having average epilimnetic concentrations of inorganic nitrogen between 0.5 and 1.5 ppm, organic nitrogen between 0.7 and 1.2 ppm, and total phosphorus between 0.03 and 0.1 ppm. Lakes having nitrogen and phosphorus concentrations exceeding these values are characterized by Wetzel (1975) as hypereutrophic. Monthly sampling by Smith and Sherriff (unpublished) at seven sites in Reelfoot Lake showed a range in total phosphorus of 0.008 to 2.3 ppm, with most values between 0.1 and 0.7 ppm. The U.S. Environmental Protection Agency's Clean Lakes Program Guidance Manual considers lakes eutrophic when total phosphorus (winter) exceeds 0.02 to 0.03 ppm; data from the Upper Buck Basin of Reelfoot (Tennessee Department of Health and Environment 1984) indicated a mean total phosphorus concentration (winter) of 0.02 ppm. Very few data on nitrogen concentrations are available for Reelfoot Lake. The Clean Lakes Study in 1983 (Tennessee Department of Health and Environment 1984) showed organic nitrogen ranging from 0.71 ppm in the fall and winter to 0.99 ppm during the summer. Sampling by Smith and Sherriff (unpublished) indicated the importance of Reelfoot Creek as a source for both nitrogen and phosphorus.

Nonwoody vegetation status. Dense stands of nonwoody plants in Reelfoot Lake interfere with boating and fishing, reduce dissolved oxygen concentrations, inhibit circulation, and crowd out plants considered to be important sources of food for fish and waterfowl. Problems associated with aquatic macrophytes have been described by Smith and Pitts (1982) and Tennessee Wildlife Resources Agency (1985), but the growth and spread of these plants has not been quantified.

Plankton and benthos status. Very few studies have been conducted on phytoplankton, zooplankton, and benthos in Reelfoot Lake; most of these studies were more descriptive than quantitative. The most thorough treatment of phytoplankton was done by Hiatt et al. (1978); no studies of seasonal population dynamics or in situ phytoplankton productivity have been conducted. Zooplankton were most recently characterized by Hoff (1943, 1944). He reported finding 33 species of cladocera, six of ostracods, nine of copepods, two of amphipods, two of isopods, and one of shrimp. Benthic studies are currently being conducted by the University of Tennessee - Martin. An earlier (1974) series of dredge samples (Smith, unpublished) yielded 905 chironomids, 75 oligochaetes, 65 leeches, 11 beetle larvae, and 11 isopods per square meter.

Current management. Past developments (e.g., levees, spillways, radial gates) and current management have eliminated the natural water level fluctuations in Reelfoot Lake that periodically oxidized organic sediments and reestablished earlier successional communities. This stabilization, in conjunction with agricultural practices in the watershed, has greatly accelerated the eutrophication process in Reelfoot Lake.

Objectives

Any management actions that reduce nutrient concentrations will help slow the eutrophication process and thereby improve water quality, gamefish populations, waterfowl use, and recreational enjoyment of Reelfoot Lake. As such, the primary management objective, from the standpoint of the Aquatic Ecology Workgroup, should be to reduce the watershed loadings and in-pool concentrations of nitrogen and phosphorus. This will allow secondary objectives to be met, including: flattening the diurnal dissolved oxygen curve and meeting State dissolved oxygen standards; reducing productivity; increasing the diversity of benthic and planktonic organisms; and increasing the diversity of nonwoody vegetation while decreasing dense, "noxious" vegetation.

Preferred Management

The primary causes of eutrophication in Reelfoot Lake are the sediment and nutrient inputs from the watershed. Therefore, the most important management actions to consider are those that would reduce these inputs. While watershed treatments would eventually result in decreased productivity in Reelfoot Lake, this decrease would occur very slowly because of the high concentrations and large pools of nutrients already in the lake. Therefore, management actions in the lake basin should be implemented in conjunction with watershed treatments to reduce nutrient levels more quickly and arrest or reverse the eutrophication process.

Watershed treatment. A variety of management actions should be implemented as part of the preferred alternative to reduce sediment and nutrient inputs from the watershed. Promoting better soil conservation practices on lands in agriculture or silviculture is essential; however, past Federal incentives have not been very effective in accomplishing this. Soil loss zoning or acquisition of the most erodible lands by the State will probably be required.

A buffer zone in the primary floodplain of Reelfoot Creek should be acquired. Once acquired, the buffer zone should be converted, or allowed to revert, to hardwood forests, and the stream should be allowed to cut a meandering channel. This would slow water runoff from surrounding lands and allow much of the sediment and associated nutrients to settle out before entering Reelfoot Lake.

Drainage ditches also contribute sediment and nutrients to the lake. The ditches of most concern are the ones in Kentucky that feed into Bayou du Chien and the ones in Tennessee on the west side of the lake. These ditches should be cleaned, diverted, or run through filtration zones (e.g., marsh vegetation). Also, there should be no cutting of new ditches. Finally, gravel mining at the base of the bluffs should be stopped.

In-basin treatment. A number of in-basin management actions were discussed but not included in the Aquatic Ecology Workgroup's preferred alternative because they were judged to be infeasible or only minimally effective. For example, from an aquatic ecology perspective, the optimum action would be to breach the mainline levee along the Mississippi River and thereby reestablish the hydrologic regime under which the lake developed. Another alternative would be to install a whole-lake aeration system. While this would improve dissolved oxygen concentrations, it would not address the underlying cause of eutrophication. It would probably also be prohibitively expensive. Diverting

Reelfoot and Indian Creeks and using Mississippi River water or groundwater as an alternative supply was also discussed. This alternative was rejected because of cost considerations and because of concerns about the quantity and quality of river water and groundwater that would be available when needed. Another alternative would be to "filter" all incoming water through marsh vegetation. Initial studies from the University of Florida indicate that such a flow-through system would filter out many of the suspended solids but would not significantly reduce nitrogen and phosphorus inputs; isolated cypress heads (or the equivalent) with very little water flow would be required to remove nitrogen and phosphorus. This suggestion was not included in the preferred alternative because of lack of information; however, the Aquatic Ecology Workgroup felt that this idea should be studied in more detail to determine its effectiveness, acres and vegetation species required, and need for periodic harvest and removal of the vegetation. A final suggestion that was not incorporated into the preferred alternative was to subdivide the lake with levees and use both the Upper Blue Basin and Buck Basin as combination moist soil units and sediment catchments, and manage the lower part of the lake for fish and recreation. The moist soil portions of the upper basins might have to be "hayed" every few years and other portions of the upper basins excavated periodically to remove accumulated nutrients and sediment. This should be considered only as a last resort because of the large amount of habitat that would have to be "sacrificed" for catchment basins.

The preferred alternative for in-basin treatment consists of a drastic drawdown followed in subsequent years by water level fluctuations more typical of the historic (i.e., prior to construction of the control structure) hydrologic regime. The drawdown would consolidate surficial sediments and decrease the organic content of those sediments. This, in turn, would lead to decreased resuspension and associated internal nutrient cycling, thereby decreasing the excessive productivity of the lake. The drawdown and consolidation would also increase the numbers and diversity of benthic organisms and would partially shift the plant community (submergents and nonwoody emergents) to an earlier successional stage. A drawdown should be viewed initially as experimental. While there is a reasonable body of experience on drawdowns in Florida and cannot be predicted with certainty. Such drawdowns would likely be required periodically, but the time between drawdowns is not known and would depend, in part, on the implementation and success of watershed management actions to control sediment inputs. Water level fluctuations in the intervening years would prolong the benefits achieved by the drawdowns.

From a water quality perspective, a complete drawdown to expose the entire lake bed to drying would be preferable. However, this is not likely to be acceptable from the point of view of other resources and users of the lake, and could not be accomplished with the present control structure. A drawdown of 5.8 ft (to a pool level of 276.4 ft msl) should be possible with the present structure. This would expose 40% to 60% of the lake bed, which would probably result in significant benefits from the point of view of aquatic ecology. A 3-ft drawdown, which could be accomplished under the current lease agreement, would have very limited benefits.

The drying period should be 120 days, measured from the time when the drawdown is completed. The ideal period would be June through September; however, the period July through October would be acceptable. If the lake level can be reduced 0.1 ft/day with the present control structure, as some observations suggest, a drawdown would have to be initiated about May 1 to achieve complete drawdown by July 1 and allow 120 days for drying. This timing would likely have severe impacts on fish spawning and waterfowl brood-rearing. However, members of the Aquatic Ecology Workgroup believed that the average sustained rate of drawdown that could be achieved might be closer to 0.05 ft/day. This would imply initiating the drawdown about March 1, which would further increase the severity of the impacts to fish and waterfowl.

Capability for a faster drawdown would alleviate many of these potential problems. Experience in Florida and Louisiana suggests that a rate of about 4 inches/day is desirable. At this rate, a drawdown of 5.8 ft could be accomplished in about 18 days; 120 days of drying could thus be achieved by control structure leaks and may have to be replaced in the near future for safety reasons, any new structure should be designed to allow an increased rate of drawdown, even if that capability cannot be exercised under current State law and lease agreements.

Several actions should be taken as the drawdown is occurring. Existing ditches should be cleaned to facilitate draining. In addition, some new channels may have to be "cut" (with the cookie cutter or perhaps by simply running an airboat through the area a few times) to drain isolated pockets as they become evident. Prior to a drawdown, germination studies should be conducted to investigate the presence of a natural seedbank in lake sediments. If the natural seedbank is inadequate or has an undesirable species composition, millet (Echinochloa spp.) or ryegrass (Elymus spp.) should be seeded; this can be easily accomplished by aerial seeding or by throwing seed behind an airboat. As the drawdown occurs and during drying, the millet or ryegrass may compete with less desirable plants, and help compact and hold sediments through root growth. There is also some possibility that millet or ryegrass would increase evapotranspiration and help dry sediments. However, evidence from dredge spoil disposal work indicates that presence of vegetation actually inhibits drying. As the lake refloods, these plants may help drop solids out of incoming water, stimulate a zooplankton bloom to help control algae populations, provide structure and invertebrates for fish, and provide food for waterfowl. Use of ryegrass would be better for fish, but millet would be better for waterfowl. Some natural reseeding would likely occur as water levels are fluctuated in subsequent years.

While the drawdown and subsequent reflooding would help control some of the noxious nonwoody plants, they would not provide total control. Some selective herbicide use would probably be required to obtain the desired level of noxious plant control. As an example, following a drawdown in Lake Tohopekaliga, selected herbicide use was required to obtain desired vegetation control and consequent improvement in fish and waterfowl habitat (V. Williams, Florida Game and Fresh Water Fish Commission; pers. comm.).

to mimic the historical variability in lake level and prolong the time between required drastic drawdowns. The water level fluctuations would help maintain consolidation of sediments in the lake periphery and would provide some plant control by maintaining vegetation in the littoral zone in an early successional stage. As a starting point, the water management regime might try to produce a 2-ft variation in water level each year. However, this should not be the same 2-ft variation each year; rather, it should occur within an overall range of about 4 ft (e.g., 280.0 to 284.0 ft msl) depending on weather conditions (Figure 2). Thus, in dry years, the lake might fluctuate from 280.0 ft msl to 282.0 ft msl, whereas in wet years it might fluctuate from 282.0 ft msl to 284.0 ft msl. Water quality, vegetation, fish populations, and waterfowl use should be monitored to refine this initial water management regime as needed.

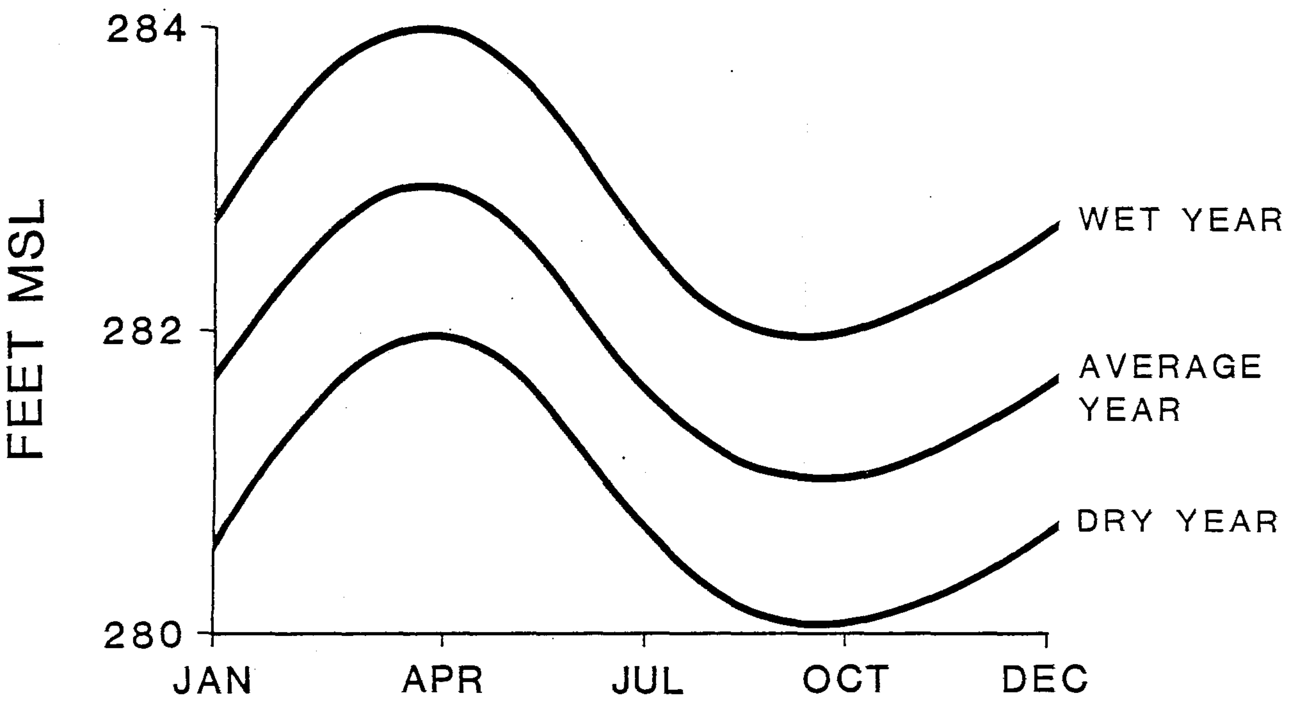

Figure 2. Suggested water management regime following a drastic drawdown.

The Fish Workgroup focused its attention on the fishery resources of Reelfoot Lake and how those resources might be impacted by various management alternatives. For purposes of assessing impacts, the important fish species at Reelfoot were grouped into five categories (Table 3): those taken in the sport fishery, those taken in the commercial fishery, those that provide a forage base, those that are considered rough fish, and white amur. Several species occur in more than one of these general groups (e.g., crappie are taken in both the sport and commercial harvests). Rare species were not considered explicitly due to lack of information; most rare species would likely fall in the forage fish category.

Overall assessments of impacts on these general groups were developed by considering how a particular alternative would affect a variety of more specific factors, including spawning habitat, cover, available forage, sedimentation, water quality (e.g., turbidity, dissolved oxygen, pH), number and size of fish in the standing stock and in the harvest, and catch rates. Specific impacts on individual species were noted when possible. In addition, the various alternatives were also evaluated with respect to their impacts on fish habitat generally, access (both in the sense of the number of access points around the lake and ease of movement between parts of the lake), and the resort or tourism industry in general.

Current Status and Management

As has been noted in previous sections, over the past 40-50 years Reelfoot Lake has been characterized by relatively stable water levels and high inputs of sediment, nutrients, and agricultural chemicals. At least in part as a result of these conditions, a layer of soft sediment as much as 6 ft in depth (Denton 1986) has formed over major portions of the lake bed. This layer is species are listed in order of relative importance as perceived by workgroup members.

Common name	Scientific name
Sport fish	
1. Black crappie	*Pomoxis nigromaculatus*
White crappie	*Pomoxis annularis*
2. Bluegill	*Lepomis macrochirus*
3. Largemouth bass	*Micropterus salmoides*
4. Channel catfish	*Ictalurus punctatus*
5. Yellow bass	*Morone mississippiensis*
6. Redear sunfish[a]	*Lepomis microlophus*
7. Other sunfish[a]	*Lepomis* spp.
Commercial fish[b]	
1. Black crappie	*Pomoxis nigromaculatus*
White crappie	*Pomoxis annularis*
2. Channel catfish	*Ictalurus punctatus*
3. Buffalo	*Ictiobus* spp.
4. Carp	*Cyprinus carpio*
5. Yellow bass	*Morone mississippiensis*
6. Freshwater drum	*Aplodinotus grunniens*
7. Flathead catfish[a]	*Pylodictis olivaris*
Other catfish	Ictaluridae
Forage fish	
1. Immature individuals of species listed as sport, commercial, and rough fish	
2. Golden shiner	*Notemigonus crysoleucas*
Brook silversides	*Labidesthes sicculus*
Gambusia	*Gambusia* spp.
Threadfin shad	*Dorosoma pentenense*
Other minnows	Cyprinodontidae
Mississippi silversides	*Menidia beryllina*

Rough fish	
1. Bowfin	*Amia calva*
2. Gizzard shad	*Dorosoma cepedianum*
3. Freshwater drum	*Aplodinotus grunniens*
4. Yellow bass	*Morone mississippiensis*
5. Spotted gar	*Lepisosteus oculatus*
Other gar	*Lepisosteus* spp.
6. Carp	*Cyprinus carpio*
Other	
1. White amur	*Ctenopharyngodon idella*

[a]Not considered by Fish Workgroup, but listed by Tennessee Wildlife Resources Agency (1985).

[b]There is also a commercial harvest of turtles at Reelfoot Lake, but this resource was not considered in any detail.

low in dissolved oxygen and inhibits production of plants and invertebrates that are important for spawning and foraging of desirable fish species. Soft sediment also alters normal nutrient cycles, resulting in poor water quality and rapid growth of noxious aquatic macrophytes and blue-green algae. Growth of aquatic macrophytes in shallow water around the periphery of the lake further reduces the amount of suitable spawning habitat and the forage base for desirable fish, and impairs movement of boats. This, combined with a shortage of public access points for boat launching and bank·fishing, limits recreational opportunities.

The net result of these conditions has been what some perceive to be a decline in the quality of the fishery at Reelfoot Lake, as evidenced by the following.

for crappie, however, is about three times the Statewide average.

(2) Recruitment of largemouth bass is low, as reflected in a catch rate of 0.196 fish/hr, compared to a Statewide average of 0.391 fish/hr. Recruitment of yellow bass and crappie is good, however.

(3) Species composition in the lake has generally shifted toward rough fish and away from sport, commercial, and forage fish.

Current management of the fishery resource at Reelfoot involves a number of different activities. In addition to normal sport fishing seasons and limits, white and black crappie are taken in a commercial harvest from mid-October through mid-March. Net mesh size is regulated to control species composition and size of fish in the catch. The general purpose of this harvest is to reduce competition among crappie and thus promote growth of larger fish for the sport fishery. Standing stocks and catch of the various fish species are monitored through cove rotenone sampling, electrofishing, creel surveys, and collection of data from commercial fish landings.

In 1983, 30,000 white amur were stocked in Reelfoot Lake to control growth of certain aquatic plants, such as curly-leaf pondweed. Staff members from the University of Tennessee - Martin are presently evaluating the effects of this program. Metabolic rates, and hence foraging rates, of white amur change dramatically as they increase in size. It is likely that the fish stocked in 1983 are now too large to be effective in controlling aquatic vegetation. Depending on the outcome of the study mentioned above, it may be desirable to repeat this stocking program in the future.

A mechanical device known as a "cookie cutter" is used to open access lanes through dense aquatic vegetation.

The State of Tennessee has initiated a program to acquire additional lands around the periphery of the lake. The purpose of this program is to reduce impacts to private landholders should higher water levels be desirable in managing the lake.

sediment inputs.

Objectives

Fish Workgroup members felt that one of the overall goals of management at Reelfoot Lake should be to improve the quality of fish habitat, preferably through strategies that retard or set back natural succession. They recognized the critical importance of management strategies to reduce sedimentation and improve water quality in accomplishing this goal, but left detailed discussion of such strategies to other workgroups.

With specific reference to the fisheries at Reelfoot Lake, the workgroup established the following objectives:

(1) improve the quality of the sport fishery for crappie, where quality is measured in terms of average weight of fish harvested;

(2) improve the quality of the sport fishery for largemouth bass, where quality is defined in terms of catch rate;

(3) increase the proportions of sport, commercial, and forage fish in the standing crop;

(4) maintain the quality of the sport fishery for bluegill, where quality is defined in terms of size and catch rate; and

(5) improve access to the lake and within the lake for fishing and other recreation.

Preferred Management

Members of the Fish Workgroup developed two alternatives to address the problems and achieve the objectives described above. They felt that the best strategy would be to implement the two alternatives in sequence; however, either alternative could potentially be implemented without the other.

to drying by the sun. During the drying process, bottom sediments would compact and undergo permanent changes in physical structure, thus preventing their resuspension upon refilling the lake. Compaction would also deepen the lake somewhat, but how much is not clear.

This alternative would be implemented in two phases. Phase I would consist of the drawdown itself, which would begin about June 1. Initiating a drawdown earlier than June 1 would probably interfere with spawning activities of some fish. With the present control structure, it is estimated that lake level could be dropped about 5.8 ft below normal pool (i.e., to 276.4 ft msl), which would expose about 50% of the lake bed. Empirical observations indicate that, at least for some combinations of head and water volume (i.e., at some points on the elevation-volume curve), the lake surface elevation can be reduced 0.1 ft/day. At this rate, the drawdown should be complete by about mid-July. Best estimates are that the drying period should be about 120 days and, thus, that it should be possible to begin refilling the lake about November 1. [Note: This interpretation of the drawdown rate that could be achieved with the existing control structure and the length of the drying period is somewhat different from that of the Aquatic Ecology Workgroup members. Also, the starting and ending dates must be interpreted generally. Strictly speaking, a drawdown of 5.8 ft at a rate of 0.1 ft/day would require 58 days or from June 1 to July 28. This would also mean that refilling could not start until November 28 if the entire exposed lake bed was allowed to dry for 120 days.]

Phase II would constitute the period from November 1 to June 1. The lake would be refilled as rapidly as possible to an elevation of 283.2 ft msl and held at that level until June 1. The additional 1 ft above normal pool would increase the fishable area (i.e., area with water at least 3 ft deep) by about 22% and would also provide additional spawning sites. In a year of normal precipitation, it should be possible to fill the lake to 283.2 ft msl by about precipitation.

The workgroup also identified several other management actions that should be implemented in concert with drawdown and refilling. These include:

(1) implementing a rough fish removal program when the lake is completely drawn down;

(2) excluding crappie from the commercial catch during Phase II;

(3) sowing vegetation such as annual ryegrass or millet on the exposed lake bed;

(4) improving fishing access by deepening existing channels and perhaps constructing some new ones;

(5) marking cleared channels and stump fields; and

(6) mapping stump fields and the topography of the lake bed.

In addition, workgroup members felt that the desirability of introducing largemouth bass brood stock and of using herbicides to control certain problem plants (e.g., southern smartweed, cutgrass, and swamp loosestrife) should be investigated.

In order to maintain the quality of the fishery at Reelfoot, the drawdown alternative would have to be repeated periodically. Experience in Louisiana and Florida indicates a minimum frequency of once every 6 years. However, this is not a hard and fast rule, and specific decisions about future drawdowns should be based on monitoring. Specifically, additional drawdowns should be considered when:

(1) submergent vegetation becomes extremely dense;

(2) the standing crop of gizzard shad is 60% or more of the total standing crop;

(3) the number of harvestable largemouth bass (i.e., those 10 inches or more in length) declines to 10 or less per acre (numbers in the range of 40 to 60 per acre may be achieved within 2 years of a drawdown); and

In general, the workgroup felt that monitoring should be focused on largemouth bass and possibly redear sunfish. Again, however, there are no hard and fast rules, and decisions will have to be made based on combinations of several variables.

Alternative B - dynamic water level management. The workgroup felt that many of the problems with the fishery resource at Reelfoot Lake are at least in part a result of the relatively stable water management regime. The second preferred management alternative involves dynamic water level management. The workgroup felt that the best strategy would be to implement this alternative following a drawdown; however, it could also be used alone.

The essence of this strategy would be to ensure that water levels fluctuate at least 2 ft annually. In "wet" years, fluctuations might range from 284.0 ft msl sometime in the period November-May, to 282.0 ft msl or lower sometime in the period June-October. In dry years, the range might be 282.0 ft msl to 280.0 ft msl. Reductions in water level prior to June 1 would be avoided if at all possible to allow fish to complete their spawning activities under relatively stable conditions.

The workgroup also felt that periodic stocking of white amur to control submergent vegetation should be continued.

NONAQUATIC VEGETATION WORKGROUP

Resources Considered and Evaluation Criteria

Workgroup members decided that nonaquatic vegetation should be interpreted to mean palustrine forested wetland, palustrine scrub-shrub wetland, and annual vegetation (e.g., croplands, moist soil areas). Palustrine emergent vegetation (e.g., cutgrass, swamp loosestrife, smartweed) was left for consideration by the Aquatic Ecology Workgroup. Palustrine scrub-shrub at for the refuge (Stewart 1969) does not distinguish between young black willow stands (palustrine scrub-shrub wetlands) and mature stands (palustrine forested wetlands). The workgroup therefore considered all black willow to fall in the palustrine forested category. There is little or no true upland forest; the majority of forested acres occur at elevations between 280.0 ft msl and 285.0 ft msl.

For purposes of evaluating the impacts of various management alternatives, palustrine forested wetlands were divided into seven species associations based on the work of Stewart (1969). Proceeding generally from wetter to drier sites, these include:

(1) baldcypress (*Taxodium distichum*),

(2) black willow (*Salix nigra*),

(3) overcup oak (*Quercus lyrata*),

(4) sugarberry (*Celtis laevigata*) - American elm (*Ulmus americana*) - green ash (*Fraxinus pennsylvanica*),

(5) sweetgum (*Liquidambar styraciflua*) - Nuttall oak (*Quercus nuttallii*),

(6) sycamore (*Platanus occidentalis*) - pecan (*Carya illinoensis*) - American elm - cottonwood (*Populus deltoides*), and

(7) cherrybark oak (*Quercus falcata* var. *pagodaefolia*).

Division of palustrine forests into these species associations was considered necessary because they respond differently to various water regimes. In evaluating alternatives, both acreages [i.e., changes from those reported by Stewart (1969)] and species composition of these associations were considered (i.e., a positive impact might involve increasing the acreage of an association or improving species composition within an association). Changes in species composition were generally evaluated in the context of providing for the needs of wildlife. Additional, quantified measures of wildlife habitat values would be desirable, but were not developed by the workgroup.

Acreages of the species associations on Reelfoot National Wildlife Refuge as of 1969 are shown in Table 4. Similar data for the State Wildlife Management Area were not available at the workshop.

Table 4. Acreages of species associations on Reelfoot National Wildlife Refuge [after Stewart (1969)], not including the Lake Isom Unit.

Species association	Acres	Percent of forested area
Baldcypress	1,643	27
Black willow	1,352	22
Overcup oak	40	0.6
Sugarberry-American elm-green ash	2,068	33
Sweetgum-Nuttall oak	770	12
Sycamore-pecan-American elm-cottonwood	285	5
Cherrybark oak	19	0.3
Total	6,177	99.9

Current forest management on the Refuge consists of timber stand improvement and commercial harvest. Grazing and controlled burning are not allowed. Timber stand improvement is accomplished through selective thinning by chemical injection. The commercial harvest involves all-age management in even-age blocks, with a 96-year rotation. Oaks, pecans, and hickories (<u>Carya</u> spp.) are not taken in the commercial harvest; cypress is taken only rarely. Some small stands are set aside as old growth, but they represent a small part of the total acreage.

associations in favor of species that produce mast and cavities for wildlife (e.g, sycamore, pecan). Higher sites are managed for small blocks of water-intolerant oaks (e.g., cherrybark oak), but there are few suitable sites on the Refuge. State lands surrounding Reelfoot Lake are designated as a State Natural Area. Consequently, there is no active forest management and these forests are being allowed to convert to old growth.

Annual vegetation, in the form of moist soil areas and croplands, is found on the Refuge but not on the State Wildlife Management Area. In 1984, there was one field of less than 15 acres in moist soil production; its purpose was to provide food for wintering waterfowl. The number of acres in cropland varies somewhat from year to year. In 1985, there was a total of approximately 1,000 acres, about 75% of which was soybeans and the remainder corn. In the cooperative farming program, the farmers harvest the soybeans and leave the corn for use by the Refuge as wildlife food. Some of the soybean fields are aerially over-seeded with winter wheat to provide green browse for Canada geese (Branta canadensis). An additional 100 acres is marginal farmland; in any year, the driest part is farmed and the remainder produces natural annual vegetation.

Objectives

Management of forest lands can involve a variety of objectives related to factors such as wildlife habitat, aesthetics, and stand vigor. After considerable discussion of the alternatives, the workgroup agreed that the overall objective should be to manage for a diverse palustrine forested wetland. It is extremely important that the wetland character of these areas be recognized. At least 90% of the forested sites should be thought of as wetlands first and forests second.

Three subobjectives related to this overall objective were identified (no priority is implied by the order). First, management should be designed to as black willow. Third, management should promote growth of species that provide food (e.g., mast) and cover (e.g., nest cavities) for wildlife. This implies a lower proportion of forest in sugarberry, sweetgum, and sycamore, and a higher proportion in Nuttall oak, willow oak (Quercus phellos), and pin oak (Quercus palustris).

In terms of annual vegetation, the workgroup agreed that the overall objective should be to provide a diverse food base for wildlife in general, and waterfowl in particular, throughout the year. The food base should include high-energy foods (e.g., corn), protein-rich foods (e.g.., invertebrates), as well as vitamins and minerals. In order to determine the quantities of these resources required, the workgroup consulted with the Wildlife Workgroup as to their specific objectives. With respect to wintering waterfowl, these were to provide:

(1) winter habitat for 250,000 ducks (current levels are about 90,000), and

(2) winter habitat for 50,000 Canada geese (current levels are about 80,000).

The Nonaquatic Vegetation Workgroup estimated that these objectives could best be approached with a combination of 400 acres of corn, 400 acres of green browse, 600 acres of moist soil units, and 600 acres of greentree areas. Mallards (Anas platyrhynchos), which compose about 90% of the wintering duck population, would utilize the corn, moist soil units, and greentree areas. Wood ducks (Aix sponsa), which constitute the majority of the remaining 10% of the wintering ducks, would largely utilize the greentree areas. Geese would use the corn, green browse, and moist soil units. In addition, the workgroup believed that about 10% of Refuge forest lands should be devoted to old growth stands, which would provide a unique natural area that would be used by many species of birds and other wildlife.

In attempting to arrive at a preferred management alternative, the work-group first discussed general strategies and their likely consequences. These general strategies included: no management, current forest habitat management, current management plus dynamic water level management, and current management plus dynamic water level management and sediment control.

In order to estimate the impacts of these general strategies, the work-group members first discussed general trends in moisture regime that might be expected in the future. They concluded that in the short term (i.e., at least the next 30 years), the forest lands surrounding Reelfoot are likely to become wetter. In the long term, with continued sediment input and expiration of the Federal lease in 2016, forest lands are likely to become drier. Under the no management strategy, forest vegetation would be controlled largely by natural succession. Baldcypress acreage would likely not change in the short term, while increasing moisture would favor black willow and overcup oak (Table 5). Other forest species associations would likely decrease. Changes in acreages of moist soil units and permanent agricultural land due to active management would not occur under this strategy.

Under the current forest habitat management program, acreages of overcup oak and cherrybark oak will probably increase somewhat, while acreages in other forest associations and land uses will likely remain stable. However, the current management program is improving the species composition of the sugarberry, sweetgum, and sycamore associations.

With dynamic water level management in addition to current forest habitat management, acreages could probably be shifted toward species more important for wildlife. Overcup oak and cherrybark oak would continue to be encouraged, and the species composition of the sugarberry, sweetgum, and sycamore associations would continue to improve. Under this strategy, higher water levels would probably make some of the current agricultural land unusable for farming; the best use of this land would probably be to convert it to moist soil units or greentree areas.

tree species associations, moist soil units, and permanent agricultural land for four general management strategies (0 = no change, + = increase, - = decrease).

Tree species association or land use	No management	Current management	Current management plus dynamic water level management[a]	Current management plus dynamic water level management and sediment control[a]
Baldcypress	0	0	0	0
Black willow	+	0	-	-
Overcup oak	+	+	+	+
Sugarberry-American elm-green ash	-	0[b]	0[b]	0[b]
Sweetgum-Nuttall oak	-	0[b]	0[b]	0[b]
Sycamore-pecan-American elm-cottonwood	-	0[b]	0[b]	0[b]
Cherrybark oak	-	+	+	+
Moist soil units	0	0	+	+
Permanent agricultural land	0	0	-	-

[a]Water level management increases ability to manage particular species (e.g., control black willow by flooding, encourage oaks by drying, encourage survival of baldcypress seedlings), age composition, and habitat quality.

[b]Current forest habitat management practices are improving species composition toward those more valuable for wildlife (e.g., oaks).

the long term, however, sediment control would prevent filling of the lake and allow management for a diverse palustrine forested wetland for a longer period of time.

On the basis of these general discussions, members of the Nonaquatic Vegetation Workgroup concluded that the most desirable management strategy would be a combination of several actions, including sediment control, dynamic water level management, land acquisition and development, and forest habitat management. They advocated use of forested riparian buffer strips as one useful method of sediment control, but left specification of additional sediment control actions to other workgroups and focused their attention on the remaining aspects of a preferred strategy.

Water management. The optimal water management strategy for forested wetlands would involve water level fluctuations approximating those in an unregulated situation, including short-duration pulses of high water. In the dormant season (December 1 - April 15), water would be allowed to rise as high as 283.2 ft msl. [Note: During the review process, F. Bowers (U.S. Fish and Wildlife Service; pers. comm.) suggested March 20 as a more reasonable date for the end of the dormant season.] Ideally, the surface elevation of the lake would then be reduced to 280.2 ft msl by May 1 and held there until the end of the growing season (about November 15), at which time lake level would again be allowed to rise. Workgroup members realized that the present control structure would not allow a 3-ft reduction in lake level in 15 days; however, they believed that this would be the optimal strategy for management of forested wetlands.

Land acquisition and development. The higher spring water levels suggested in this alternative would make some of the existing agricultural land on the Refuge too wet for planting and would thus reduce the amount of waterfowl food (corn) produced. To compensate for this, a program of land acquisition and development should be instituted. In fact, workgroup members felt that options for forested wetlands, allow the Refuge to produce a variety of high-quality waterfowl foods, and reduce dependency on a single crop (corn).

The acquisition and development program would involve purchase of an additional 400 acres of land at 284.0 ft msl or higher and contiguous with the Refuge. With this land and other areas currently available on the Refuge and State Wildlife Management Area, about 2,000 acres could be used for waterfowl food production. The higher ground would be used for corn (400 acres) and green browse (400 acres) in a rotation pattern. Lower areas would be used to develop at least 600 acres of moist soil units and 600 acres of greentree areas. Soybean production would be reduced.

Each of the small drainages around the lake should be evaluated with respect to its potential for developing moist soil units (first) and greentree areas (second). During the field trip to Reelfoot Lake, it appeared that at least 300 acres on the Refuge (at the north end of the lake) and 300 acres on the State Wildlife Management Area (south of the Airpark Inn) would be suitable for moist soil units. Impoundments on the upper fingers of the lake could also be considered for this purpose; however, dedicated moist soil units with independent water supply and drainage would be preferable. At least seven such units should be constructed. This would allow individual units to be managed for specific objectives (e.g., production of invertebrates for molting mallards) and would allow control of some woody species (e.g., black willow) through variations in the water regime and discing.

Remaining agricultural areas and fallow ground should be developed into about 600 acres of greentree areas. These areas should be as large as possible, but a minimum of 100 acres each, and should be configured based on topography and drainage. They should be planted with Nuttall oak, willow oak, and pin oak. These species must reach an age of about 30 years before they produce mast, but the areas would produce moist soil plants, in decreasing

If more than 2,000 acres are available, corn and browse should be maintained at a total of about 800 acres and the remaining area should be divided about evenly between moist soil units and greentree areas. Finally, some fraction of each of these types of areas (agricultural lands, moist soil units, and greentree areas) should always be closed to hunting to provide resting areas for waterfowl.

Forest habitat management. The present forest habitat management program (commercial harvest and timber stand improvement) should be continued on the Refuge and a similar program should be instituted on the State Wildlife Management Area. Trees that produce nesting cavities and mast should continue to be favored and approximately 10% of the forested area should be maintained in old growth.

Compromise alternatives. The water management regime described above would be optimal for forested wetlands; however, some modification of the details might be necessary in order to manage for other resources. Other dynamic water level management regimes would be acceptable, but somewhat less desirable, if they met the following constraints. [Note: In his review comments, F. Bowers, (U.S. Fish and Wildlife Service; pers. comm.) suggested substituting April 1 for May 1 and June 1 for July 1 in these constraints.]

(1) Between May 1 and November 15, water levels should not generally exceed 282.2 ft msl for more than a total of 14 days. This level should provide approximately 2 ft of well aerated soil for average sites in the sugarberry association.

(2) Between May 1 and November 15, water levels could be managed up to 283.2 ft msl approximately 1 year in 4 without substantial tree mortality, as long as these levels were not maintained past July 1. Water levels above 283.2 ft msl in the growing season should never result from active management, but might occur naturally.

harmed by water levels higher than this. High spring water levels, however, would reduce waterfowl food production as described above, unless land at higher elevations was put into corn production.

(4) Due to the relatively high water table, summer drying as a result of water level fluctuations would not impact forested wetlands so long as the lake is preserved and not allowed to turn into a braided stream.

WILDLIFE WORKGROUP

Resources, Objectives, and Management Activities

The Wildlife Workgroup was given the charge of identifying the key wildlife resources to consider in the development of management plans for Reelfoot Lake. The organizers of the workshop perceived that the principal concern was migratory birds; consequently, the group was given an initial charge of identifying important bird resources. However, it became obvious in the workgroup discussions that wildlife concerns include other species as well. The total list of wildlife resources identified by the workgroup is shown in Table 6.

Once the wildlife resources were identified, the group attempted to develop the specifications for a preferred management plan for Reelfoot Lake and associated habitats. This was done following a four-step process.

(1) Identify an evaluation criterion or performance measure for each wildlife resource. This simply was a statement of the units one would use to measure progress toward achieving management objectives.

(2) Describe the current status of each resource in terms of the performance measure.

(3) Establish a management objective for each resource in terms of the performance measure.

(4) Specify the management activities that would be implemented in order to achieve the established objectives for each resource.

established by the Wildlife Workgroup.

Resource	Performance measure	Current level	Objective level
Wintering ducks	Peak population	90,000	250,000
Wintering geese	Peak population	80,000	50,000
Wood duck (breeding)	Rate of use of nest boxes	335 boxes with >80% use	Increase natural cavities and nest boxes until rate of use of nest boxes is <80%
Bald eagle (wintering)	Use-days	20,000	≥ current level
Bald eagle (breeding)	Nesting pairs	0	12
Osprey (breeding)	Nesting pairs	3-4	8-10
Bottomland hardwood community	Acres	12,500	≥ current level
Wading birds	---[a]	---[b]	---[c]
Marsh birds	---[a]	---[b]	---[c]
Aquatic reptiles and amphibians	---[a]	---[b]	---[c]
Threatened, endangered, and other "listed" species	---[a]	---[b]	---[c]

[a] Performance measure was not identified.

[b] Current status was not well known or not identified.

[c] Objective was not identified.

no objective was established, either because the current status of the resource was unknown or because the resource constituted a diverse group of organisms for which a single objective statement was impossible to formulate (e.g., aquatic reptiles and amphibians).

The preferred plan from the wildlife perspective was developed by combining the activities that, in the judgement of the participants, would accomplish the objectives identified in Table 6. Management activities were defined separately for each resource by first identifying possible limiting factors and then specifying actions to alleviate those factors.

Wintering ducks. This resource was defined to consist principally of mallards and early fall migrants [e.g., gadwall (*Anas strepera*) and wigeon (*Mareca americana*)]. The current wintering population peaks at about 90,000 birds and the objective established was to manage the National Wildlife Refuge to provide a food base to support a peak winter population of at least 250,000 birds. This is consistent with the need for continuing emphasis on management of midcontinent winter waterfowl habitat as identified in the North American Waterfowl management plan (U.S. Fish and Wildlife Service and Canadian Wildlife Service 1986). In order to accomplish this objective, the following activities were proposed.

(1) Acquire an additional 400 acres of land suitable for growing corn, bringing the total Refuge land suitable for corn to 800 acres. About half of this new total, or 400 acres, would be planted to corn each year and the remainder would be rested to control Johnson grass.

(2) Develop 600-800 acres of moist soil areas in order to diversify the food supply. These areas would be located, in part, near the upper reaches of the lake to provide roosting and loafing areas for waterfowl.

(3) Provide 400 acres of green browse annually.

(4) Develop 600 acres of greentree areas.

(6) Increase production of desirable submerged aquatic plant species (e.g., Potamogeton spp.) primarily for early fall migrants such as gadwall and wigeon. Several activities were proposed to achieve this result, including: acquiring and stabilizing erodible lands in the Reelfoot and Indian Creek watersheds; removing white amur from the lake; and prohibiting further stocking of white amur.

Wintering geese. Presently, the peak winter population is about 80,000 Canada geese. The objective established was to reduce the peak numbers to about 50,000 birds by moving 30,000 birds to other refuges south of Reelfoot Lake. No specific management activities were identified for this objective. It was recognized that this would be accomplished largely by management in other parts of the flyway to make these areas more attractive to wintering geese in the long term. It was also recognized that increasing the food resource for wintering ducks on the Refuge would make it more difficult to achieve this objective because duck management would also benefit Canada geese.

Wood duck (breeding). The current status of wood duck production in the Reelfoot Lake area is not well known. The belief is that availability of nest cavities currently limits production. Both the Service and TWRA have established artificial nest boxes and continue to erect new boxes each year. Currently, about 335 nest boxes have been erected and their frequency of use is high; more than 80% are used by wood ducks each year. Because the number of wood ducks produced annually is not well known, it was difficult to establish an objective in terms of population numbers. The consensus was that the high frequency of use of existing nest boxes indicates that additional boxes would result in even higher production. Consequently, the performance measure for wood ducks was chosen to be the annual frequency of use of artificial nest boxes. The management objective was to continue to erect new nest boxes and to create natural cavities as long as the annual frequency of nest box use remains at least 80%. Specific activities recommended were:

(1) continue to erect nest boxes at some unspecified rate;

(3) continue the present raccoon hunting program on the Refuge as a means of controlling nest predators; and

(4) maintain the lake level at or above 281.2 ft msl through the first of July each year to ensure adequate broodrearing habitat (i.e., flooded emergents).

There was some discussion suggesting that wood duck management on the lake should be reevaluated in order to establish realistic management objectives in population terms.

Bald eagle (wintering). Currently, about 200 bald eagles (Haliaetus leucocephalus) spend about 100 days at Reelfoot Lake during the winter, for a total of about 20,000 eagle use-days. The objective established at the workshop was to maintain this amount of use over the long term. This would be accomplished through two activities. First, the workgroup felt that lake management to increase the abundance of forage fish and to preserve the abundant roost trees would contribute to the achievement of this objective. Second, during periods of lake freeze-up, bald eagles fly to the Mississippi River to feed, and protection of these areas was recommended. Feeding areas along the river should be protected by acquiring riparian lands in fee title or easement and by implementing zoning regulations to prohibit barges from tying up in key areas during the winter period.

Bald eagle (breeding). There has been no known eagle nesting at Reelfoot Lake in recent years (the last known nesting occurred in 1961). The objective established during the workshop was to increase the nesting population to 12 pairs. An eagle hacking program was initiated on TWRA lands in 1981 and, to date, 27 birds have been released into the wild. Continuation of the hacking program was the principal activity recommended to accomplish this management objective. Additionally, the Service and TWRA should initiate an inventory program to detect eagle nests and take steps to restrict human use and disturbance around newly established nests.

The management objective established by the Wildlife Workgroup was to increase this to about 8 to 10 nesting pairs, principally by erecting artificial nesting platforms and by restricting human use around active nests. Additionally, there was some discussion that water management to increase fish abundance might also help achieve the osprey objective, but it was not clear if fish abundance would ever be a limiting factor given the small number of ospreys.

Bottomland hardwood community. The workgroup recognized that there are many wildlife species that use bottomland hardwoods, and that it is desirable to consider these species in any management plan for Reelfoot Lake. However, it was difficult to establish a meaningful management objective. Several performance measures were discussed (e.g., area, species richness, stand condition), but there was no consensus on a strategy for managing this community. Currently, there are about 12,500 acres of bottomland hardwoods associated with Reelfoot Lake. These woodlands are managed with more than one strategy in mind. The Service tends to manage woodlands on the Refuge to achieve a diversity of age classes, whereas TWRA tends to manage their woodlands to maintain maximum acreage of old growth. The Wildlife Workgroup did not propose specific activities for this resource, but concluded that in no case should water management be allowed to reduce the area of bottomland hardwoods below the current 12,500 acres.

Other wildlife. Traditional management at Reelfoot Lake has concentrated on waterfowl. The Wildlife Workgroup recognized that management impacts the welfare of a broader array of species (e.g., wading birds, marsh birds, aquatic reptiles and amphibians, and particularly species other than the bald eagle and osprey that are recognized as endangered, threatened, or otherwise "listed"). These species must be considered in the development of future management plans for Reelfoot Lake. The Wildlife Workgroup was unable to state specific goals for management of these species because too little information exists concerning their current status. The workgroup felt strongly that management agencies at Reelfoot must devote resources to baseline integrated into future management of the lake.

Preferred Management

The preferred management strategy from the wildlife perspective is simply a combination of the activities identified for the individual resources. These actions are summarized in Table 7.

Two of these activities pertain to management of water levels at Reelfoot Lake. Development of moist soil units would ensure availability of open water and food for waterfowl if water levels are low in the fall, which would be the case if a drawdown were implemented. Holding the lake level at 281.2 ft msl or above until July 1 would ensure availability of suitable habitat for wood duck broods. However, workgroup members believed that these management actions for wildlife should be implemented regardless of the water management strategy chosen for Reelfoot Lake.

Table 7. Components of a preferred management strategy for wildlife at Reelfoot Lake.

	Component					
Resource	Land acquisition	Water level manipulation	Vegetation manipulation	Agricultural practices	Structures	Othe d
Wintering ducks	400 acres for corn	Implement moist soil management on 600-800 acres; develop 600 acres of greentree areas	Increase desirable submerged aquatics	Relax constraints on knocking down corn stalks	---	Red inp
Wintering geese	---	---	---	Plant 400 acres of green browse	---	
Wood duck (breeding)	---	Maintain lake level at 281.2 ft msl or above until July 1	Increase number of natural cavities through silviculture	---	Erect nest boxes	Ree obj con dat con
Bald eagle (wintering)	Riparian areas along Mississippi River	---	---	---	---	Zon bar win
Bald eagle (breeding)	---	---	---	---	---	Con pro lis aro
Osprey (breeding)	---	---	---	---	Erect nesting platforms	Est zon nes
Bottomland hardwood community	---	---	---	---	---	Dev tiv how gro des
Wading birds	---	---	---	---	---	Per inv pop
Marsh birds	---	---	---	---	---	Per inv pop
Aquatic reptiles and amphibians	---	---	---	---	---	Per inv pop ide nac
Threatened, endangered, and other "listed" species	---	---	---	---	---	Per lir mor tic app pro

WATER MANAGEMENT ALTERNATIVES

Following the initial workgroup discussions described above, the authors of this report met with Service personnel and other interested participants to select a set of management alternatives that all of the workgroups would use in assessing impacts. In making this selection, we considered not only those alternatives suggested by the workgroups, but also additional alternatives that might eventually have to be considered in the NEPA process. We focused on alternatives having major differences with respect to water management; water management is one of the fundamental issues at Reelfoot Lake because of its broad scale impacts on a variety of resources. We also considered alternatives involving management of sediment, again because of the overall importance of sediment management to the lake. This does not mean, however, that other management actions (e.g., land acquisition) are unimportant. Many actions not directly involving water and sediment will also be necessary in developing a successful management program at Reelfoot Lake. The alternatives selected for analysis are not all mutually exclusive. The best management plan for Reelfoot Lake may well involve combinations of two or more of the strategies discussed below.

ALTERNATIVE 1 - CONTINUE CURRENT MANAGEMENT

With this alternative, management would continue as in the past, both with respect to water levels and other programs. The surface elevation of the lake would continue to be maintained as close to 282.2 ft msl as possible; water would be released any time the lake is above 282.2 ft msl and the gates would be closed any time the lake is below that level. The forest habitat forests on the State Wildlife Management Area. The current program involving construction of sediment retention basins in the hills east of the lake would also continue.

ALTERNATIVE 2 - DRAWDOWN

The drawdown alternative would involve lowering the lake level 5.8 ft (from 282.2 ft msl to 276.4 ft msl) to expose approximately 50% of the lake bottom to drying by the sun. The principal objective would be consolidation of lake sediments and resulting improvements in fish habitat. The drawdown would start on June 1 and be completed by July 15. [Note: This drawdown schedule implies a rate somewhat greater than the observed rate of 0.1 ft/day.] A minimum of 120 days would be allowed for drying, thus allowing refilling to begin somewhere between November 1 and November 15. The lake would be refilled to 283.2 ft msl and held at that level until June 1 of the following year, at which time any of a number of other water management strategies might be followed. While the lake was drawn down, existing channels would be cleaned and new channels would be cut as necessary to ensure proper drainage and drying. Annual vegetation (e.g., annual ryegrass or millet) would be seeded on the exposed lake bed to prevent growth of less desirable vegetation and provide food for waterfowl. Small impoundments (200+ acres) would be constructed on the upper lake fingers to provide food for waterfowl arriving prior to the refilling of the lake. Drawdowns would be repeated as needed every 5 to 10 years; specific decisions concerning timing would be made on the basis of monitoring physical and biological conditions.

The drawdown alternative would be implemented as described above. In addition, dried sediment would be excavated from certain critical areas while the lake was drawn down. The purpose of excavation would be to increase water depth in certain areas where movement of boats is now difficult and also to provide additional sediment retention capacity. Actual identification of specific areas to be excavated might not be possible until a drawdown was underway; however, for purposes of the workshop, we assumed that excavation would occur in the critical areas of the Upper Blue Basin as identified by Denton (1986).

ALTERNATIVE 4 - WATERSHED TREATMENT

This alternative was included to try to get a sense of the relative importance of treating the sedimentation problem at its source. As stated for analysis at the workshop, three activities were included:

(1) acquisition (either in fee title or through easements) of highly erodible lands east of the lake and stabilization of the soils with vegetative cover;

(2) construction of a large (perhaps 10,000 surface acres) sediment retention reservoir near the mouth of Reelfoot Creek; and

(3) acquisition of the remainder of the floodplain of Reelfoot Creek, allowing the creek to reestablish its natural meandering pattern and revegetating with bottomland hardwoods.

ALTERNATIVE 5 - WATER LEVEL FLUCTUATION

The level of Reelfoot Lake would be managed more dynamically than in the past, depending on the natural moisture regime in a particular year. The intent would be to manage for at least a 2-ft fluctuation each year. In a wet year, this fluctuation might be from 284.0 ft msl to 282.0 ft msl or lower; in a dry year, the fluctuation might be from 282.0 ft msl to 280.0 ft msl. High

ALTERNATIVE 6 - STATE LAW

Under this alternative, which was described in a law recently enacted by the Tennessee legislature (Public Chapter No. 670, House Bill No. 1798, 1986), lake level would be managed much as it is now, but at a higher level. Gates on the control structure would be opened only when the lake surface elevation was above 283.6 ft msl; otherwise, they would remain closed. The lake would still drain over the control structure until the surface elevation reached 282.2 ft msl. The exact implications of this strategy for lake levels could not be determined at the workshop; however, it was generally felt that peak lake levels would be somewhat higher than in the past, while low levels would be similar to those observed in the past, but for shorter periods of time.

ANALYSIS OF PROBABLE IMPACTS

Each of the workgroups was asked to evaluate the impacts of the six water management alternatives described above on the evaluation criteria previously identified. The results of these evaluations are summarized in Tables 8-13. Discussion of the rationale for the entries in the tables can be found in the remainder of this section. The summary tables must be interpreted carefully, because each of the workgroups took a slightly different approach to the analysis.

to current management. Thus, ++ indicates a major beneficial change in a criterion (as compared to current management), rather than an increase in its absolute magnitude. Similarly, -- indicates a major detrimental change. A + indicates a minor beneficial change and a - indicates a minor detrimental change. Because the alternatives were evaluated with respect to current management, all entries under current management are 0.

Evaluation criteria	Alternative					
	Current management	Drawdown	Drawdown plus excavation	Watershed treatment	Water level fluctuation	State law
Sediment input	0	0	0	++	-	-
Sediment deposition	0	-	-	++	-	0
Sediment consolidation	0	++	++	0	0	0
Sediment removal	0	+	++	0	0	0
Water circulation	0	+	+	+	0	0
Groundwater table	0	0	0	0	0	0
Inflows	0	0	0	+	0	--
Outflows	0	0	0	+	0	--

on evaluation criteria identified by the Aquatic Ecology Workgroup. A 1 indicates a highly desirable alternative and a 6 indicates a very undesirable alternative.

Evaluation criteria	Alternative					
	Current management	Drawdown	Drawdown plus excavation	Watershed treatment	Water level fluctuation	State law
Water quality						
Dissolved oxygen	6	1	1	1	2	6
Chlorophyll	6	1	1	1	2	6
Suspended particulates	6	2	4	1	3	6
Nutrient concentrations[a]						
Total phosphorus	6	1	1	1	3	6
Total nitrogen	6	1	1	1	3	6
Vegetation control[b]						
Submergent	6	1	1	3	1	6
Seasonally emergent/ nonpersistent	6	1	1	3	1	6
Emergent/ persistent	6	1	1	3	1	6
Benthos and plankton						
Energy pathways	6	1	1	2	1	6

[a]The alternatives would influence concentrations of many forms of nitrogen and phosphorus; total nitrogen and total phosphorus were chosen as useful indicator variables.

[b]Only partial vegetation control can be accomplished with the alternatives considered; some use of selective herbicides will likely be required to obtain desired levels of vegetation control.

evaluation criteria identified by the Fish workgroup. A + indicates a positive impact, a - indicates a negative impact, and a 0 indicates no impact.

Evaluation criteria	Alternative					
	Current management	Drawdown	Drawdown plus excavation	Watershed treatment	Water level fluctuation	State law
Sport fish (size, catch rate)	-	+	+	+	+	-
Commerical fish (weight, landings)	-	+	+	+	+	-
Forage fish (standing crop)	-	+	+	+	+	-
Rough fish (standing crop)	+	-	-	+	+	+
White amur (standing crop)	0	-,0[a]	-,0[a]	0	0	0
Overall fish habitat	-	-/+[b]	-/+[b]	+	+	-
Access within lake	-	-/+[b]	-/+[b]	+	+	-
Access around lake	-	-/+[b]	-/+[b]	+	+	-
General tourism	-,0[a]	-/+[b]	-/+[b]	+	+	-,0[a]

[a]Marginally negative or mixed impacts (e.g., catch rate of crappie is good, but size is small).

[b]During the drawdown, net impact would be negative; following drawdown, consolidation, and refilling, net impact would be positive.

indicates an increase in acreage over the next 30 years, a – indicates a reduction in acreage, and a 0 indicates no change.

Evaluation criteria	Alternative					
	Current management	Drawdown	Drawdown plus excavation	Watershed treatment	Water level fluctuation	State law
Baldcypress	0	0	0	0	0	0
Black willow	0	–	–	0	–	–
Overcup oak	+	+	+	+	+	+
Sugarberry association	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Sweetgum association	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Sycamore association	0[a]	0[a]	0[a]	0[a]	0[a]	0[a]
Cherrybark oak	+	+	+	+	+	+
Moist soil units	0	0	0	0	+	+
Agricultural land	0	0	0	0	–	–

[a]Current forest management practices, which would likely continue under any water management regime, are improving species composition toward those more valuable for wildlife (e.g., oaks).

evaluation criteria identified by the wildlife workgroup. Alternatives were discussed in comparison to current management. Thus, a +3 indicates that an alternative would be much more desirable than current management and a -3 indicates that it would be much less desirable. Because the alternatives were evaluated with respect to current management, all entries under current management are 0. Entries before the diagonal indicate short-term impacts; those following the diagonal are long-term impacts.

Evaluation criteria	Alternative					
	Current management	Drawdown	Drawdown plus excavation	Watershed treatment	Water level fluctuation	State law
Wintering ducks	0/0	+1/+1	+1/+1	+1/+2	-2/-1	-3/-2
Wintering geese	0/0	+1/+1	+1/+1	+1/+2	-2/-1	-3/-2
Wood duck (breeding)	0/0	-1/+1	-1/+1	+1/+2	+1/0	+1/-1
Bald eagle (wintering)[a]	0/0	NL/NL	NL/NL	+1/+3	-1/-1	-1/0,-1
Bald eagle (breeding)[a]	0/0	NL/NL	NL/NL	+1/+3	-1/0	0/0
Osprey (breeding)	0/0	+1/+1	+1/+1	+1/+3	+1/0	0/0
Bottomland hardwood community	0/0	+2/0	+2/0	+1/0	-1,0/+1	-1/-2
Wading birds	0/0	+1/+1	+1/+1	0/+2	+1/+1	0/0
Marsh birds	0/0	-2/+1	-2/+1	-1/+2	+1/+1	+1/+1
Aquatic reptiles and amphibians	0/0	-1/0	-1/0	0/+2	+1/+1	+1/0
Threatened, endangered, and other "listed" species[b]	0/0	NR/NR	NR/NR	NR/+3	NR/NR	NR/NR

[a]NL for this criterion means not affected because food resources are not limiting.

[b]NR for this criterion means not rated due to lack of data or uncertainty of impacts.

wildlife. Entries represent the number of criteria impacted positively, impacted negatively, not impacted, or not rated, disregarding magnitude of the impact (Table 12). Entries before the diagonal indicate short-term impacts; those following the diagonal are long-term impacts. As in Table 12, all entries are in comparison to current management.

Impact category	Alternative: Current management	Drawdown	Drawdown plus excavation	Watershed treatment	Water level fluctuation	State law
Not impacted	0/0	2/4	2/4	2/1	0/3	3/4
Positively impacted	0/0	5/6	5/6	7/10	5/4	3/1
Negatively impacted	0/0	3/0	3/0	1/0	5/3	4/5
Not rated	0/0	1/1	1/1	1/0	1/1	1/1

Hydrology and Sedimentation

If there is no change in management regime in the future, sediment input and deposition rates at Reelfoot Lake will likely remain high. Construction of additional sediment retention basins that are now planned would undoubtedly result in sediment trapping; however, the effectiveness of these structures is questionable because water now tends to regain its sediment load in channelized reaches downstream. There would be no compaction or removal of sediments already present in the lake. Water circulation would remain poor and the groundwater table would continue to fluctuate in response to changes in river stage, lake level, and inputs from the hills east of the lake. Inflow and outflow patterns would not change significantly.

Aquatic Ecology

Water quality and nutrient concentrations. Extreme diurnal fluctuations in dissolved oxygen during the summer and fall would continue under current management. In addition, anaerobic conditions in bottom sediments and deep water due to decomposition and respiration would become more frequent. Periodic fish kills would be expected with these dissolved oxygen conditions. While dissolved oxygen concentrations under the ice in winter are not yet a problem, the potential exists for this problem to develop over the long term.

Chlorophyll-a concentrations would probably remain about the same under current management. The high present concentrations (approximately 200 to 230 µg/l) of chlorophyll-a indicate the potential for fish kills. Concentrations of suspended particulates would also remain about the same.

With continued input of nutrients from the watershed and continued internal nutrient loading from resuspension, nitrogen and phosphorus concentrations in the lake would remain near their current high levels.

persistent, seasonally emergent vegetation. Submergent vegetation would probably begin to increase in the near future as the white amur introduced in 1983 reach weights at which they switch to a maintenance diet and are thus no longer effective in controlling submergent vegetation.

Energy pathways. Under current management, phytoplankton productivity would remain high with a potential long-term shift in dominance from green to blue-green algae. Benthic diversity would remain low, with chironomids and oligochaetes predominating.

Fish

Habitat. Overall, continuation of current management would result in further degradation of fish habitat in Reelfoot Lake. High sediment inputs and accumulation of organic material on the lake bottom, along with poor water quality, would continue to prevent growth of benthic organisms desirable as fish food. These same factors would result in further encroachment of emergent vegetation, thus limiting availability of suitable spawning sites and reducing fishable area (i.e., area with water at least 3 ft deep).

Species composition. Continuation of current management would continue to favor rough fish over sport, commercial, and forage fish. Gizzard shad and yellow bass would continue to constitute a high proportion of the total fish biomass due to their ability to tolerate poorer water quality (in terms of pH, dissolved oxygen, and turbidity) and to reproduce under the conditions that presently exist. The probability of fish kills involving desirable species (sport, commercial, and forage fish) would increase. Sport and commercial fish species would be further impacted by declines in the forage fish that serve as a food base.

Sport and commercial fish. Generally, continuation of current management would tend to favor the commercial fishery over the sport fishery, although sport fishery. The commercial fishery is beneficial not only because it contributes to the local economy, but also because it reduces the total fish biomass in the lake (thus slowing the eutrophication process, at least in principle) and provides a source of food for bald eagles in the winter months. The quality of the sport fishery for bluegill (both size and catch rate are above the long-term Statewide averages) would likely be maintained.

While catch rates for crappie would remain high, their average size would continue to be small, which is viewed as especially undesirable for the sport fishery. Similarly, catch rates for largemouth bass would remain low, and redear sunfish, once an important component of the sport fishery, would continue to decline. Conflicts between sport and commercial fishermen (e.g., entanglement of fishing lines in commercial nets) would continue, as would costs of administering the commercial fishery program.

Access and tourism. Continued siltation and accumulation of organic matter on the lake bottom, and the resulting encroachment of aquatic macrophytes, would continue to reduce access for commercial fishing, sport fishing, and other forms of recreation. Reduced access for sport fishing and other forms of recreation would likely also impact the tourism industry negatively.

White amur. The impacts of continuing a white amur stocking program would probably be mixed. White amur now in the lake have apparently been effective in controlling submergent vegetation, which has increased the fishable area, increased the availability of forage fish to sport and commercial fish, and reduced the organic contribution to sediments in shallow areas. In addition, white amur contribute biomass to the commercial fishery.

On the other hand, removal of submergents has reduced the food supply for waterfowl. Removal of submergents, such as curly-leaf pondweed, has also reduced the amount of habitat for aquatic invertebrates and may eventually cause a shift in species composition toward invertebrate species that are a turbidity, because submergents tend to trap sediments during high winds and during the spring months when high precipitation occurs. Finally, as white amur increase in size, up to 50% of the forage that they take in remains unmetabolized and thus contributes to eutrophication when it is released.

Nonaquatic Vegetation

Current forest habitat management on the Refuge is intended to promote growth of oaks and improve species composition in the sugarberry, sweetgum, and sycamore associations toward those more valuable to wildlife. There is no active forest management on State lands; these forests are thus tending toward old growth.

In the short term, continuation of the current ineffective sediment and water management strategies would likely mean that the Refuge forest habitat management program would become less effective. While the total number of forested acres would not change in the near future, there would likely be a shift in species composition toward species more tolerant of sediment and water [e.g., baldcypress, willows, water elm (Planera aquatica), and buttonbush] and away from elm, ash, Nuttall oak, overcup oak, sugarberry, and pin oak. In the long term, the whole lake would fill with sediment and become a forested wetland.

Wildlife

In the short term, continuation of current management would not likely have significant impacts on wildlife. Reelfoot Lake would continue to support a diverse and productive wildlife community and the Refuge would continue to be an important area for wintering waterfowl, wintering eagles, and breeding wood ducks. In the long term, however, the ability of the Refuge and Reelfoot desirable species.

ALTERNATIVE 2 - DRAWDOWN

Hydrology and Sedimentation

The major impact of this alternative would probably be on sediment consolidation. The best available evidence (from experience with similar management strategies in Louisiana and Florida and with disposal of dredged material) seems to indicate that exposed sediment would consolidate and not resuspend when the lake was refilled, provided that drying was sufficient. The success of this alternative would thus be highly dependent on climatic conditions after the lake was drawn down. Another unknown is the extent of groundwater inflows to the lake and their specific location with respect to areas where drying and consolidation of sediments are desired. Groundwater inflows could certainly prevent drying in some places. Another unresolved issue concerns planting vegetation on the exposed lake bed. This technique is apparently used successfully in Louisiana to prevent growth of less desirable species and provide food for waterfowl in the fall. However, seeding vegetation is no longer recommended in dredge spoil disposal work, because the vegetation inhibits drying of the substrate. It is not clear how these factors would balance out under the specific conditions that exist at Reelfoot Lake.

Other impacts of the drawdown alternative on variables relating to hydrology and sedimentation would likely be minor. There is potential for some sediment to be redistributed by rainfall and runoff while the lake bed is exposed. This was viewed as negative in the sense that it would tend to fill deeper parts of the lake. Minor positive impacts would include a small amount of sediment removal and perhaps small improvements in water circulation, due to cleaning of channels. Groundwater levels would probably be lowered somewhat during the drawdown, but would quickly rise again as the lake was refilled. Inflows and outflows would not change appreciably.

Members of the Aquatic Ecology Workgroup questioned one of the assumptions made in the description of this alternative provided at the workshop. In their view, it was not clear that the lake could be drawn down 5.8 ft in the period between June 1 and mid-July. However, for purposes of evaluating impacts, they accepted this assumption.

Water quality and nutrient concentrations. During the year of the drawdown, nutrient concentrations and suspended particulates in the remaining pool would likely increase due to resuspension. This might result in an algal bloom (increased chlorophyll); the magnitude of the bloom would be determined by the extent to which decreased light penetration due to particulates would offset effects of increased nutrients. Dissolved oxygen levels would likely deteriorate during the drawdown due primarily to resuspension and mixing of organic sediments into the aerobic zone.

For a few years following the drawdown, suspended particulates, nutrient concentrations, and productivity would be somewhat lower than currently, because consolidation of sediments during the drawdown would result in less resuspension. Also, seeding of millet or ryegrass during the drawdown would help settle out particulates from incoming water. The drawdown might also decrease productivity by stimulating zooplankton that would feed on phytoplankton and by stimulating germination of early successional wetland plants that would take up available nutrients.

Without simultaneous implementation of the watershed management alternative, suspended particulates, nutrients, and productivity would eventually (perhaps 3 to 5 years) return to predrawdown levels because watershed inputs would quickly overwhelm the decrease in resuspension due to consolidation.

Nonwoody vegetation. Persistent emergent vegetation would germinate during the drawdown. Newly germinated southern smartweed would likely dry out and die as the drawdown continued; however, some newly germinated cutgrass conditions. For the drawdown as described at the workshop, workgroup participants felt that lotus would not change in the short term, but might expand somewhat in the long term. Competition with millet or ryegrass, if these species were seeded, would have mixed effects on submerged vegetation; curly-leaf pondweed would increase in extent, coontail would remain about the same, and fanwort (*Cabomba caroliniana*) would decrease.

Energy pathways. Following a drawdown, reflooding of seeded millet or ryegrass would stimulate a zooplankton bloom, which might help reduce phytoplankton. Consolidation of bottom sediments in exposed areas would create conditions conducive to increased benthic diversity and numbers. A drawdown would also benefit vertebrates associated with littoral vegetation, stimulate periphyton communities, and promote growth of invertebrates more desirable to fish and waterfowl.

Fish

Habitat. Generally, members of the Fish Workgroup felt that the drawdown alternative would result in better fish habitat due to consolidation of bottom sediment, improvements in water quality, stimulation of more desirable benthic communities, and control of undesirable aquatic vegetation. These changes would promote better food supplies and increase the amount of suitable spawning habitat. In the season following the drawdown, however, spawning activities could be inhibited if climatic conditions prevented the lake from being refilled on schedule.

Species composition. A drawdown would tend to promote substrate conditions that favor sport fish, commercial fish, and forage fish over rough fish, particularly with respect to spawning. Spawning activity of desirable species would also be accelerated after the lake was refilled. Sport fish and commercial fish would benefit further from an increase in forage fish that

Sport fish and commercial fish. In addition to the benefits noted above, sport fish would probably experience an increase in growth rate following a drawdown, due to reduced competition. Channel catfish spawning activity and fingerling survival would probably increase due to reductions in hydrogen sulfide concentrations. Based on experience in Louisiana, there is little likelihood that desirable species would be lost through the spillway during a drawdown. This has been viewed as a potential problem by some individuals.

On the negative side, there is some possibility that commercial fishing during the low-water period would result in a reduction in the brood stock of largemouth bass, particularly if the current regulation allowing 3-inch mesh nets remained in effect. A 4-inch mesh regulation would reduce bass losses, but would also eliminate the catch of crappie. Introduction of additional brood stock following the drawdown could also be used to offset bass losses.

Access and tourism. While a drawdown might have some short-term negative impacts on access and tourism, it is likely that the long-term impacts would be very positive. There would undoubtedly be a reduction in fishable area during a drawdown. However, concentration of fish in the remaining pool would also tend to increase fishing success. Fish kills, which would be more likely during a drawdown, and exposed mudflats would cause noxious odors and unsightly conditions, especially in areas of high public use. However, a fish kill would also have beneficial aspects, because it would reduce total fish biomass, and planting vegetation on the exposed mudflats would tend to mitigate any visual impacts. There is also some possibility that a drawdown would damage public and private facilities around the lake. However, repair or improvement of these structures or others that are already damaged would be easier and less expensive when the lake was drawn down. Stump fields and travel lanes could also be easily marked and additional access facilities could be result in significant benefits in terms of access and tourism. Consolidation of the lake bottom, in combination with cleaning of channels and travel lanes, would make access for fishing and other forms of recreation easier. These factors, along with general improvement in the fishery, would make Reelfoot a more desirable place to visit.

White amur. Based on experience with drawdowns elsewhere, there is a strong possibility that white amur, unlike native fish, would escape from the lake over the spillway during a drawdown. However, this is not necessarily an important impact, because most of these fish are currently too large to be effective in controlling submergent vegetation.

Nonaquatic Vegetation

A drawdown would place some stress on baldcypress trees. [Note: In his review comments, L. Fredrickson (University of Missouri; pers. comm.) stated his belief that a drawdown would enhance vigor of baldcypress.] However, based on experience with drawdowns in other locations, this is not likely to be a significant problem. Potential problems for both baldcypress and bottomland hardwood forests could be further minimized by ensuring that the drawdown did not occur in the year of or the year following some natural stress, such as drought, insect defoliation, or disease. A drawdown following a flood would be acceptable and perhaps even desirable.

Moist soil units with independent water level controls would be preferable to impoundment of the upper lake fingers for providing waterfowl habitat during a drawdown. If subimpoundments were used, they should not be constructed in forested wetlands, because this resource is already in short supply throughout the bottomlands of the Mississippi floodplain.

be negatively impacted by low water levels in the fall. This impact could be offset by construction of impoundments on the upper lake fingers (or moist soil units as suggested by the Nonaquatic Vegetation Workgroup). There would also be increased potential for a botulism outbreak during a drawdown year.

Bald eagle foods would be more concentrated in the short term and, in principle, this could benefit bald eagles if there were no major fish kills during the drawdown and if commercial fishermen continued to throw rough fish overboard. However, this was not felt to be a significant impact, because it is not likely that eagles are currently limited by food supply. Ospreys and wading birds might also benefit from concentrated fish populations during the summer of a drawdown.

Wood ducks and marsh birds would be negatively impacted during the year of a drawdown. Wood ducks would be affected by loss of habitat for brood-rearing. Marsh birds would be impacted by separation of nesting areas (e.g., herbaceous wetland vegetation) from feeding areas (e.g., areas with remaining surface water).

Impacts of a drawdown on aquatic amphibians and reptiles and on threatened or endangered species other than eagles could not be assessed due to lack of baseline information. Potential impacts on these resources should be investigated more carefully before any management strategy is implemented.

In the long term, a drawdown would be positive for wildlife due to the increased longevity of the lake and surrounding wetlands.

material were left in the lake (e.g., to create islands), fishable area and be identical to those of Alternative 2, with the exception that there would be significant sediment removal. The workgroup estimated that excavation of the critical areas identified by Denton (1986) in the Upper Blue Basin to a depth of 3 ft would remove roughly 750,000 yd^3 of material. While this is a small amount relative to the total volume of the lake, at current average rates of deposition (about 1.9 cm per year in the Upper Blue Basin), these areas would require about 50 years to refill. This assumes, however, that excavation would not alter present deposition patterns. Excavation of these areas would thus provide significantly greater water depths for an extended period of time and thus possibly improve access for recreational use.

Aquatic Ecology

The effects of excavation following a drawdown would be only marginally different from those of a drawdown alone. One difference would be an additional improvement in suspended particulates because the excavation would be analogous to cleaning out a sediment trap. The other difference would be a very localized, short-term improvement in the benthic community at the excavation site.

Fish

Impacts of excavation after a drawdown would differ from those of a drawdown alone in only minor ways. Fishery resources might benefit due to removal of some nutrients from the lake, provision of areas that would serve to trap additional sediment, minor improvements in water circulation, and creation of some additional fishable areas. However, excavation would also remove some habitat structure from the lake. In addition, if the excavated

The sediment retention reservoir might also have some impacts on hydro-

Impacts would be very similar to those of a drawdown alone, assuming that excavated material was not deposited in forested wetlands. Depending on its physical properties, some of the excavated material might be useful in constructing moist soil units or leveling agricultural land.

Wildlife

Overall, the Wildlife Workgroup felt that the impacts of this alternative would be similar to those of the drawdown by itself. Excavation, however, might provide some additional benefits by extending the life of the lake ecosystem.

ALTERNATIVE 4 - WATERSHED TREATMENT

Hydrology and Sedimentation

The combination of activities specified in the watershed treatment alternative would likely result in significant decreases in sediment input and deposition. Acquisition and revegetation of highly erodible areas would control much of the sedimentation problem at its source. The sediment retention basin would trap a large fraction of any sediment that still remained in the stream, and acquisition and restoration of the floodplain below the retention structure would ensure that the stream did not pick up additional sediment. As described at the workshop, however, this alternative pertained largely to Reelfoot Creek. It must be remembered that other sources of sediment are significant. Also, this alternative by itself would not serve to consolidate or remove any sediment already in the lake.

certain locations. The groundwater table in the vicinity of the reservoir and on the floodplain below it would probably be raised, but this would not present any serious problems if the floodplain below the dam were acquired. Inflows to and outflows from Reelfoot would, of course, be dependent on the operating rules for the dam on the reservoir and the control structure at the outlet from the lake. Overall, the distribution of inflows and outflows would likely be somewhat smoother, with lower peaks and higher low points. There would also be some potential flood control benefits. Overall, these changes in inflows and outflows were viewed as positive because the dam would likely provide greater management control.

Aquatic Ecology

Water quality and nutrient concentrations. In the first few years following implementation of a watershed management alternative, there would be no noticeable change in productivity (as measured by chlorophyll) and dissolved oxygen concentrations. While watershed practices would decrease external nutrient loadings (the U.S. Environmental Protection Agency estimates that 60% of the nutrient loading for Reelfoot Lake is from tributaries), the existing nutrient concentrations and internal loadings from resuspension would keep productivity high and thereby maintain current dissolved oxygen levels and fluctuations. Over the long term, the internal loadings would exchange with the relatively clean incoming water and be flushed out of the lake. Eventually, nutrients in the lake would reach an equilibrium with the incoming water. The decrease in nutrient concentrations would decrease productivity (as measured by chlorophyll) and thus improve minimum dissolved oxygen concentrations. The time required to reach equilibrium and the improved dissolved oxygen levels cannot be determined unless nutrient budget studies are conducted.

across most of the lake.

Nonwoody vegetation. Both persistent emergent and nonpersistent seasonally emergent vegetation would continue to expand under a watershed management alternative, but at a slower rate than with current management, due to the decrease in sedimentation. The decrease in suspended particulates would increase the photic zone in the lake, resulting in an increase in submergent vegetation.

Energy pathways. There would be very little change in energy pathways in the first few years after initiation of a watershed management alternative. Over the long term, however, the decrease in nutrient loading (external and internal) and suspended particulates would decrease phytoplankton in the lake. These changes would also result in a greater diversity of immature insects (e.g., mayflies, chironomids, dragonflies) in vascular plant beds and in benthic communities, as well as an increase in the diversity of molluscs and crustaceans.

Fish

Control of sediment inputs as proposed in the watershed treatment alternative would prolong the life of Reelfoot Lake and therefore provide major benefits in terms of the fishery. Turbidity of the lake would be decreased, which would in turn benefit the entire aquatic ecosystem and the aesthetic qualities of the lake. A large reservoir on Reelfoot Creek would: provide additional fishing opportunities, particularly at times when Reelfoot Lake itself was drawn down; provide an additional source of water for refilling Reelfoot Lake following a drawdown; and provide a source of fish for restocking Reelfoot, should restocking be necessary. Without intensive management of the watershed above such a reservoir, however, problems similar to those *now being*

Impacts of this alternative on nonaquatic vegetation would be positive. Reduction in sediment inputs would prolong the life of the lake in general and areas such as Grassy Island Wetland in particular. Acquisition of the primary floodplain of Reelfoot Creek would provide an opportunity to reestablish bottomland vegetation and develop significant additional resources, including greentree areas and moist soil units.

Wildlife

The reduced rate of succession that would result from this alternative would mean relatively more open water and less emergent vegetation, as well as improvements in water quality. These changes would benefit wintering waterfowl by favoring production of preferred submergent vegetation. Fish production would also be enhanced and these fish would be available in open water areas; eagles, ospreys, and wading birds would thus benefit. In the short term, marsh birds would be negatively impacted due to the relatively (compared to continuing current management) smaller acreages of emergent wetlands. In the long term, however, marsh birds would benefit because the life of emergent wetlands would be extended due to increased longevity of the lake system as a whole. The wildlife community that uses the bottomland hardwood community would not be affected in the short term. In the long term, however, there would be fewer acres of bottomland hardwoods than would be expected if current management continued. Other wildlife species would likely benefit in the long run, because the life of the lake would be prolonged.

sediment input and deposition. If fluctuating water levels result in flooding of shoreline or agricultural fields that are not presently subject to flooding, additional sediment might be input to the lake. Similarly, falling water levels and precipitation on any exposed shoreline could have a tendency to move sediment toward deeper parts of the lake. Under certain circumstances (e.g., extremely heavy precipitation during low water periods) these impacts could be important. Under most conditions, however, they would likely be minor. There would be no sediment consolidation or removal as a result of this alternative.

Impacts on hydrologic variables would likely also be negligible. The water circulation pattern would not be significantly different from that which currently exists. The groundwater table in the vicinity of the lake would fluctuate with changes in lake level, but, overall, this was viewed as an insignificant change. Outflows would be dependent on operation of the control structure to achieve desired water levels; again, however, this was not viewed as a significant change. Finally, inflow patterns would be similar to those under current management.

Aquatic Ecology

Water quality and nutrient concentrations. There would be no appreciable change in dissolved oxygen in open water areas of Reelfoot Lake under a management regime of fluctuating water levels. There might, however, be a slight improvement in dissolved oxygen in shallow areas due to the periodic exposure and oxidation of sediments. Nutrient concentrations would decrease in shallow areas as a result of periodic oxidation of sediments as well as establishment of macrophytes and subsequent nutrient uptake. This, in turn, would result in ent emergent vegetation, such as cutgrass, nutgrass (Cyperus esculentus), various smartweeds, and swamp loosestrife, would become established in the fluctuation zone, thus increasing their areal extent over present conditions. Over the long term, these areas would likely be dominated by cutgrass and loosestrife. Selective herbicide use, and perhaps some moist soil management techniques, could be used to favor the more desirable species (e.g., swamp smartweed and nutgrass for waterfowl) in this zone. There should be no appreciable change in seasonally emergent vegetation (e.g., lotus, spatterdock) with fluctuating water levels. Rooted submergents in shallow areas would be periodically stressed by water level fluctuations, thus preventing them from becoming overly dense.

Energy pathways. In general, a management regime of fluctuating water levels would cause changes in energy pathways qualitatively similar to those of the drawdown alternative. Quantitatively, these changes would occur over a smaller area than with a drawdown, because less sediment would be exposed. However, the changes would last for a longer period of time because the fluctuations would occur periodically as opposed to only once in a single drawdown. As compared to the drawdown alternative, qualitative differences in energy pathways would include less dramatic changes in zooplankton and phytoplankton, but greater stimulation of periphyton.

Fish

From the fishery perspective, the principal benefit of the water fluctuation alternative would be to provide managers with some degree of control over the amount of suitable spawning habitat for various species of fish. Generally, the preferred method of implementing this alternative would be to allow the lake level to rise naturally during the winter and then to hold the

Other aspects of this alternative would also be of benefit to the fishery. There would be some consolidation and oxidation of exposed sediments during low water periods. This would improve water quality to some extent and would stimulate growth of zooplankton, aquatic invertebrates, and benthic organisms. These conditions, in turn, would tend to favor sport fish, commercial fish, and forage fish, thus improving the overall species composition in the lake. In addition, there would be an opportunity to plant desirable vegetation on exposed areas during low water, thus benefiting both fish and waterfowl.

Impacts of the water fluctuation alternative on access and fishing would be mixed. During years of high water, access would be improved and additional fishable area would be available. During years of low water, the reverse would be true. Encroachment of vegetation around the exposed edges of the lake would also reduce fishable area to some extent, but this vegetation could probably be controlled with herbicide.

White amur would probably be unaffected by the water fluctuation alternative.

Nonaquatic Vegetation

Water level fluctuations would be acceptable and desirable for palustrine forested wetlands, so long as certain stipulations were met. In any given year, water levels should not exceed 282.2 ft msl for more than a total of 14 days during the period May 1-November 15. This should provide approximately 2 ft of well aerated soil for the average sugarberry-elm-ash site during the

ALTERNATIVE 6 - STATE LAW

Hydrology and Sedimentation

The generally higher water levels that would result from this alternative oak were not flooded (approximately 285.0 ft msl). Holding water at low levels during the growing season would not be detrimental to forested wetlands.

In completing Table 11, members of the Nonaquatic Vegetation Workgroup assumed that the water fluctuation alternative would be implemented in a manner consistent with these constraints.

Wildlife

The water fluctuation alternative would have both beneficial and adverse effects on wildlife. Increased invertebrate production would provide additional food for wood duck broods, wading birds, marsh birds, aquatic reptiles, and other species of the bottomland community. If fish production increased as a result of this alternative, osprey and other fish-eating birds would also benefit.

The principal drawback of the water fluctuation alternative would be that it would conflict with Refuge management operations designed to benefit wintering waterfowl (production of corn and green browse). Lake levels above 282.2 ft msl on March 1, which would occur in many years under the water fluctuation alternative, can reduce corn production by as much as 50%. Corn is an important food source for wintering waterfowl. Wintering bald eagles might also be impacted negatively by this alternative, because ducks are used by eagles as a secondary food source. The degree to which this impact might be offset by increases in fish, which are the primary food of eagles, could not be determined. It is possible that these negative impacts could be mitigated by purchase of additional, higher areas for corn and green browse production.

Fish

Many of the impacts of this alternative on fish would be similar to those of continuing current management. The channel catfish and bluegill fisheries ... the catch rate for crappie would remain high. However likely be minor, however, relative to total current sediment input. Sediment deposition, consolidation, and removal would be unchanged.

With respect to hydrology, there is potential for major impacts on inflows and outflows. Higher lake levels would increase the surface area of the lake on which direct precipitation would fall, increase the area of saturated soils surrounding the lake, and reduce the flood storage capacity. All of these factors would increase the potential for severe flooding of areas around the lake. This was judged by workgroup members to be a significant potential impact. Higher lake levels would also increase the hydraulic head at the control structure and thus increase the potential for the structure to fail. Because the present control structure is known to be damaged, increased potential for failure was also judged to be a significant impact. Other hydrologic variables would probably not change significantly under this alternative. Water circulation patterns would remain as they are presently. The groundwater table would be elevated somewhat during high lake stages, but overall would not change dramatically.

Aquatic Ecology

The Aquatic Ecology Workgroup assumed that the result of the State law alternative would be slightly higher average water levels with somewhat more water level fluctuation than under present management (but not nearly as much fluctuation as with the water fluctuation alternative). As such, the expected changes in water quality, nutrient concentrations, nonwoody vegetation, and energy pathways would be similar in nature, but lesser in extent, to those with the water fluctuation alternative.

Wildlife

The impacts of the State law alternative on wildlife were perceived as being very similar to those of the water fluctuation alternative. The major negative impact would be loss of corn and green browse production on the decline. Overall, the current unfavorable imbalance of rough fish to sport, commercial, and forage fish would be perpetuated.

In the short term, there would be an increase in fishable area, partially as a result of decreases in emergent vegetation, and boating access would improve. These conditions would be temporary, however. In perhaps 20-30 years the condition of the lake would be much as it is now, with siltation and accumulation of organic material continuing to degrade all fish habitat.

Nonaquatic Vegetation

Any water management strategy that establishes a normal pool level above 282.2 ft msl would alter the species composition, and eventually the acreage, of forested wetlands. Thus, the constraints listed under the water fluctuation alternative also apply here. A higher normal pool would also interfere with corn production on current agricultural lands on the Refuge. However, land acquisition could be used to establish new areas for bottomland hardwoods and agriculture, offset potential habitat losses, and meet management objectives. Without land acquisition, all species except the most water tolerant (baldcypress, black willow) would decrease as additional acreage was inundated.

result in significant mortality of trees in forested wetlands. This would, of course, negatively impact all of the species that currently use these habitats. In particular, wood ducks would be impacted by loss of tree cavities, which are currently thought to be in short supply.

(3) Additional work on groundwater relationships is needed to evaluate:

(a) the spatial extent and volume of groundwater seepage to the lake and potential for inhibiting drying of sediments during a drawdown;

(b) the rate of movement of subsurface soil water out of

Each of the workgroups was asked to discuss additional research and monitoring activities that should be conducted at Reelfoot Lake. The results of these discussions are summarized in the following section. The lists from the workgroups have been edited somewhat to eliminate duplication. Two overall themes deserve special note.

(1) In order to be useful, a monitoring program must be in place before any new water management strategy is implemented and must continue both during and after implementation. Information from such a program will be of little value unless it covers all three phases.

(2) The monitoring program should be developed around a standardized scheme for stratification of sampling so that the results from different studies can be related and used as a basis for better management planning. A simple example illustrating this need is the fact that it would be difficult to relate a fish kill in one location to water quality information collected elsewhere. A system of polygons presently being used by the U.S. Geological Survey in a thermal study of the lake may provide a useful starting point for developing such a stratification system.

HYDROLOGY AND SEDIMENTATION

Research and monitoring needs discussed by the Hydrology and Sedimentation Workgroup included the following.

(1) Current monitoring of hydrology and sedimentation should continue during and after implementation of any water management action.

(2) A study should be instituted to quantify oxidation of organic sediments under the various climatic conditions that might occur during a drawdown.

Nonwoody Vegetation

Current benthic biomass sampling studies should be continued. Sweep-net sampling should be initiated to characterize invertebrates associated with aquatic vegetation. Algae of the lake should be characterized both taxonomicthus on the groundwater table in the floodplain below.

(4) The effectiveness of existing sediment retention basins should be evaluated. Suspended sediment loads downstream have been examined, but little is known about inputs to these basins.

(5) Additional stability tests should be conducted on the existing control structure, especially if the State law alternative is to be implemented.

AQUATIC ECOLOGY

Water Quality and Nutrient Concentrations

A water quality monitoring network should be installed to characterize Reelfoot Lake with respect to dissolved oxygen, chlorophyll-a, nitrates, soluble reactive phosphorus, pH, transparency, turbidity, and suspended solids. Initially, such sampling should be done biweekly or monthly at two stations in each basin, at major inflows, and at the outlet. Nutrient budgets for both nitrogen and phosphorus would also be very useful in making future management decisions. Research studies to develop these budgets would involve measuring all major forms of nitrogen and phosphorus, including inputs, outputs, and exchanges between various parts of the ecosystem (e.g., between sediments and the water column), under various conditions over a period of time.

Drawdown

Prior to implementation of a drawdown (or any other management strategy), a sampling program should be implemented to determine abundance, food habits, vegetation establishment and survival. Germination studies should also be conducted to investigate the presence of a natural seedbank in lake sediments. Aerial photography should be used to quantify lake-wide changes in emergent, and perhaps submergent, vegetation. Color infrared photography at a scale of 1:12,000 is suggested. Photographic coverage every 5 years in December would be preferable for delineating persistent marsh and in May for delineating curly-leaf pondweed. Annual coverage in August would be preferable for all other nonwoody vegetation. Information from aerial photography would be even more useful if it could be related to elevations (and water depths) in the basin. One-foot contours are presently available up to an elvation of 283.0 ft msl; contours up to at least 285.0 ft msl would be desirable. Entry of topographic and vegetative cover information in a geographic information system would further enhance management analysis capabilities.

FISH

The Fish Workgroup members discussed research and monitoring needs in the context of their two preferred alternatives -- a drawdown for sediment consolidation followed by water level fluctuation. Under these alternatives, monitoring would be used both to evaluate the success of the program and to determine the need for additional management actions. However, many aspects of the suggested monitoring program would be useful no matter what management strategy is eventually chosen for Reelfoot Lake. Several parts of the monitoring program suggested by the Fish Workgroup were also mentioned by other workgroups; these are not repeated here.

(3) abundance and distribution of benthic organisms;

(4) abundance and distribution of aquatic macrophytes; and

(5) concentrations of chlorophyll-a and chlorophyll-b in the water column.

The Louisiana Department of Fisheries and Wildlife, for example, uses rotenone sampling of a 1-acre net enclosure, with a sampling frequency of about 1 acre for each 1,000 acres of lake surface. Whatever technique is chosen, specific effort should be devoted to ensuring that all habitats and all species in the lake are sampled. The monitoring program should also gather information on the sport catch, the commercial catch, and the fish population below the spillway.

In addition to these basic data on the fishery, a variety of other information should be collected as the lake is drawn down and refilled. Meteorological conditions should be monitored at several stations around the lake. Relationships between sediment type, consolidation, vegetation growth, and recolonization by benthic fauna should be used to document both present vegetation cover and regrowth of submergents and emergents as the lake is refilled. In addition, aerial photography taken at known lake levels should be used to verify existing bathymetric data. Finally, water quality conditions and the extent of any fish kills that occur during the drawdown should be documented..

Water Level Fluctuation

The Fish Workgroup suggested that, at a minimum, the following information should be collected annually:

(1) species composition, age distribution, weight, and growth rates of all sport, commercial, forage, and rough fish;

(2) distribution of fish species seasonally;

Aquatic Reptiles and Amphibians

Little is known about the current status of reptiles and amphibians at Reelfoot, although the lake has long been a popular location for herpetological

NONAQUATIC VEGETATION

Annual aerial photography should be used to measure changes in forested acreage and to monitor stress on bottomland hardwoods due to water level manipulations or sedimentation. Large format, stereo, color infrared photography taken in August at a scale from 1:6,000 to 1:12,000 would be suitable for this purpose. Stress, as indicated by tree color, die-back, and foliage loss, should also be monitored using ground transects. These transects should be run annually by a qualified forester and should extend from water's edge upslope through all forest associations. At least four transects should be located on the Refuge and two in State-owned forests; all should include permanent photo stations for individual trees. Soil water content should be measured with a neutron probe every 2 weeks during the growing season at a minimum of five stations for each 1-ft contour interval along the transects. Sediment deposition rates should also be monitored and surveys of regeneration should be conducted in any areas where die-offs occur.

WILDLIFE

Workgroup members felt that the following research and monitoring programs should be implemented under any management strategy for Reelfoot Lake.

Bald Eagles

Management of water levels in the lake could affect bald eagles by altering the species composition of fish. Several proposed water management strategies would attempt to reduce the relative abundance of rough fish, which triactylum)], occur in the lake. There is a need to collect data on these and other reptiles and amphibians, including the following specific information:

(1) baseline population data,

(2) locations of hibernacula, and

(3) population responses (e.g., turtle recruitment) to drawdowns or other water level manipulations.

<u>Wildlife Disease</u>

There is potential for outbreak of wildlife diseases (particularly botulism) during a drawdown. If a drawdown occurs, isolated pools should be monitored weekly to detect significant waterfowl mortality. Carcasses may be sent to the National Wildlife Health Center in Madison, Wisconsin, for diagnosis. To the extent possible, areas where mortality occurs should be flushed with fresh water; caracasses should be picked up daily and burned.

<u>Waterfowl</u>

Research should be initiated to examine competition for submerged aquatic vegetation (e.g., <u>Potamogeton</u>) between waterfowl and white amur.

Little is known about the current status of wood duck breeding populations at Reelfoot Lake or of how the nest box program relates to populations and production. The wood duck management program should be reevaluated to establish feasible production objectives. Information concerning the number of breeding adults in the population and recruitment rates from both artificial and natural cavities is essential for this purpose.

management objectives for eagles.

Other Wildlife

Several other groups of wildlife species were identified as being of special concern for management planning, but almost nothing is known about their current status. A program should be initiated to determine populations and monitor the impacts of any water management on marsh birds (especially gallinules and rails), wading birds (especially herons and egrets), and State and Federal threatened, endangered, or otherwise "listed" species.

Funding

Because current funds are fully allocated, additional funds will likely be necessary to meet these research and monitoring needs. The Wildlife Workgroup suggested that an interagency funding mechanism might be most appropriate.

participants thought additional study of this possibility would be warranted. Depending on the success of other programs to control sediment at its source, such a structure might not even be necessary.

There was general agreement among workshop participants that control of sediment input and deposition is the ultimate key to prolonging the life of Reelfoot Lake. Unless this problem is solved, any beneficial effects of other management actions will be temporary at best. As formulated at the workshop, the watershed treatment alternative, which was designed to control sediment input to the lake, consisted of three activities:

(1) acquisition, through fee title or easement, and revegetation of highly erodible areas in the hills east of the lake;

(2) construction of a large sediment retention basin near the mouth of Reelfoot Creek; and

(3) acquisition of the floodplain of Reelfoot Creek below the sediment retention basin and restoration of a natural, meandering, vegetated stream course.

There was nearly unanimous agreement that this would be a highly desirable alternative. Acquisition and revegetation of highly erodible lands would do much to control sediment at its source. Other mechanisms for accomplishing this (e.g., zoning restrictions, continuation of current economic incentives to farmers to institute better soil conservation practices) were also discussed, but were generally judged to be inferior to acquisition. In particular, the current incentive program for farmers has apparently been relatively ineffective.

A large sediment retention basin would probably be effective in trapping any sediment load that still remained after implementing an acquisition program. The feasibility of building such a structure could not be adequately evaluated with information available at the workshop; however, at least several

enough to move significant amounts of sediment. However, flushing might be effective in removing nutrients. Dredging was also judged to be infeasible, at least for the entire lake, because of high costs; technical problems associated with operating a dredge around stumps, logs, and other organic structures already constructed east of the lake has been questioned because the streams tend to regain a high sediment load in channelized downstream reaches.

As formulated at the workshop, the watershed treatment alternative pertained only to Reelfoot Creek. While this creek carries a high proportion of the total sediment load generated in the watershed surrounding Reelfoot Lake, recent studies have shown that other sediment sources are also significant. These include Indian Creek, Bayou du Chien, and a number of small natural drains and ditches that have been channelized for agricultural purposes. In particular, agricultural fields north and west of the lake may be an important source of both water and sediment at times when the water level in the Mississippi River is higher than that of Reelfoot Lake. An effective sediment control program will eventually have to address all of these sources.

Even the most effective sediment control program would do little to solve the problem of the soft sediment layer that has already accumulated on the bottom of the lake. This layer is thought to be a serious detriment to the fishery of Reelfoot Lake, both in terms of limiting spawning sites and preventing development of desirable benthic communities. Three alternatives for solving this problem were considered at the workshop; flushing, dredging, and drawing down the lake to expose bottom sediments to drying. Flushing and dredging were discussed in detail only by the Hydrology and Sedimentation Workgroup. Flushing would involve developing an alternate source of water to try to move accumulated sediments out of the lake. Generally, workgroup members believed that it would be impossible to generate water velocities high

(4) Sowing ryegrass or millet on the exposed lake bed was suggested as a means of preventing establishment of less desirable vegetation, eliminating unsightly mud flats, and providing food for waterfowl after reflooding. This technique is used effectively in Louisiana and Florida. However, in dredge spoil disposal work, seeding is no longer recommended because vegetation inhibits drying of the

groups. The purpose of this strategy would be to expose about 50% of the lake bed to drying by the sun, thus consolidating and oxidizing existing sediment, enhancing water quality, stimulating the growth of desirable benthic communities, and improving the quality of the fishery. The general consensus among workshop participants was that a drawdown is worth trying. The best available evidence, both from similar drawdowns in Louisiana and Florida and from work with disposal of dredge spoil, indicates that sediments would consolidate and not resuspend when the lake was refilled, assuming that sufficient drying occurred. Furthermore, experience in Florida and Louisiana indicates that such a strategy can result in significant benefits in terms of water quality, benthic communities, and the fishery.

However, a drawdown has never been implemented in Tennessee, and significant questions regarding potential effectiveness remain.

(1) Drawdowns in Louisiana and Florida are usually implemented in fall or late winter, respectively. The extent to which the impacts from a summer drawdown, such as discussed for Reelfoot Lake, would differ is unknown.

(2) In Louisiana and Florida, a drying period of about 90 days is sufficient to produce adequate consolidation of sediments. The drying time suggested for Reelfoot Lake (120 days) is only an estimate. The extent of drying would depend on a number of unknown factors, including specific climatic conditions during the drawdown and the spatial extent and volume of groundwater inputs to the lake.

(3) As discussed at the workshop, the lake would be drawn down 5.8 ft between about June 1 and July 15. Allowing for 120 days of drying, refilling could begin about November 15. However, the Aquatic Ecology Workgroup questioned whether a drawdown of 5.8 ft could be accomplished in 45 days with the existing control structure. An earlier date for starting the drawdown would impact fish spawning and waterfowl broodrearing, while a later date to start refilling would likely impact early migrating waterfowl.

drawn down; exclusion of crappie from the commercial harvest during the drawdown; cleaning existing channels; dredging or excavating necessary drainage ditches to ensure proper drying; marking cleared channels and stump fields;

some negative impacts:

(1) The fishable area of the lake would be reduced during the drawdown. This, along with potential fish kills, noxious odors, and possibly unsightly mudflats, would perhaps have adverse effects on the tourism industry. These impacts could be partially offset by certain management techniques (e.g., sowing vegetation on exposed mudflats) and by the fact that a drawdown would allow easy, less expensive repair of facilities such as docks and boat ramps.

(2) During the drawdown, some wildlife species (e.g., reptiles and amphibians, marsh birds, wood ducks) would be negatively impacted. In the fall following the drawdown, early migrating waterfowl would also be impacted by lower water levels. Impacts on early migrating waterfowl, however, could be mitigated by developing additional capabilities to provide open water and food (e.g., moist soil units). Later migrating waterfowl would benefit from flooding of ryegrass or millet planted during the drawdown.

(3) In the spring following a drawdown, corn production on the Refuge would be impaired if the water level was allowed to stay at 283.2 ft msl until June 1. This would in turn mean a reduced food supply for waterfowl in the following fall. Again, however, this impact could be offset by purchasing additional agricultural lands at higher elevations.

Despite these uncertainties and possible negative impacts, participants generally believed that the potential benefits are substantial and that such a strategy is worth trying. They pointed out, however, that a drawdown at Reelfoot should be viewed as an experiment and that managers should be given considerable latitude to respond to specific conditions that may arise during implementation.

Participants, particularly those in the Fish Workgroup, also identified a number of actions that should be taken in concert with a drawdown. These included: implementation of a rough fish removal program while the lake is

controlling emergent and submergent vegetation. Cutgrass and swamp loosestrife might tend to become established on exposed areas, but these species could probably be controlled with periodic flooding and herbicides. However, it is less clear that this alternative would be acceptable from the perspective of would be reduced somewhat), benefits in terms of improved access and increased sediment retention capacity would probably be more significant.

Benefits from a drawdown would not be permanent, particularly if sediment inputs to the lake continue at their current rate. The best available evidence, again from Louisiana and Florida, indicates that drawdowns would be required on the order of every 6-10 years. The exact interval cannot be predicted for Reelfoot; members of the Fish Workgroup suggested several factors that should be monitored to determine the need to repeat the action. In addition, they suggested that a water fluctuation strategy, designed to mimic more closely the water levels that would occur in a natural, unregulated situation, would help to extend the interval between required drawdowns.

In the water fluctuation alternative, water levels would be allowed to rise naturally through the winter and would then be held relatively constant through March, April, and May to allow fish to complete their spawning activities. In naturally wet years, this level might be 284.0 ft msl; in dry years it might be only 282.0 ft msl. Following fish spawning, water levels would be drawn down a minimum of 2 ft. Occasionally, water levels might be drawn down earlier than June 1 if it was desirable to eliminate a particular year class of fish. Members of the Fish Workgroup believed that this strategy would improve fish spawning, consolidate and oxidize some organic sediment around the lake margin, and generally promote development of a more natural ecosystem.

This alternative would likely not have major impacts on hydrology and sedimentation. From the aquatic ecology perspective, it would probably be beneficial in enhancing water quality, reducing nutrient concentrations, and

new water management regime. Additional land currently in agricultural production could be used to mitigate losses of forested wetlands if that land was used for bottomland vegetation.

reduce corn production on the Refuge and thus impair the ability of the Refuge to meet its objective for wintering waterfowl. In principle, water level fluctuation was viewed as desirable from the perspective of forested wetlands. However, it was recommended that, with occasional exceptions (perhaps 1 year in 4), water levels should be at or below 282.2 ft msl by May 1 to avoid stress on bottomland hardwoods. Thus, the conditions most desirable for wildlife and forested wetlands would be inconsistent with those most desirable for fish, except in relatively dry years.

This potential conflict could be alleviated to some extent by acquiring and developing additional lands for waterfowl food production. The plan suggested by the Nonaquatic Vegetation Workgroup would require a total of 800 acres of agricultural land at 284.0 ft msl or higher, about half of which would have to be acquired in fee title or easement from private sources. In any year, 400 acres of this higher ground would be seeded to corn and 400 acres to green browse. Lower areas, some of which are presently used for soybean production, would be converted to moist soil units (600-800 acres) and greentree areas (600 acres). The moist soil units would provide food resources for waterfowl immediately; greentree areas would not produce mast for about 30 years. In the short term, development of these areas would alleviate the conflicts between fish spawning and waterfowl food production. However, implementation of the water fluctuation alternative as proposed at the workshop would still stress bottomland hardwoods. The extent of mortality that would result, if any, is unknown. In the long term, distribution of the species associations in the bottomland hardwood forest would change in response to the benefits, such as increasing fishable area and allowing some fluctuation in lake level, there would also be several negative impacts, including those on wildlife and forested wetlands described above for the water fluctuation alternative. In addition, the State law alternative would significantly increase the potential for flooding of areas surrounding the lake and for failure of the existing control structure. Furthermore, any benefits of this alternative would be relatively short-lived, because it does not address any of the real causes of problems at Reelfoot. In a few years (perhaps 20-30?), conditions in the lake would be very similar to those that currently exist.

In addition to analyzing these management alternatives, participants at the workshop suggested a variety of research and monitoring activities that should be initiated. While there was considerable variation in these suggestions, two general points were made. First, a successful monitoring program must be in place before any new water management strategy is implemented and must continue both during and after implementation. Information from such a program will be of little use unless it covers all three of these phases. Second, the monitoring program should be developed around a standardized scheme for stratification of sampling so that results from different studies can be related.

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