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**US Army Corps  
of Engineers**  
Mississippi River  
Commission

# ENVIRONMENTAL DESIGN CONSIDERATIONS FOR MAIN STEM LEVEE BORROW AREAS ALONG THE LOWER MISSISSIPPI RIVER

LOWER MISSISSIPPI RIVER ENVIRONMENTAL PROGRAM  
REPORT 4  
APRIL 1986



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measures and more complex, costly measures are identified and discussed. Environmental measures discussed include borrow pit size, depth, shape, and vegetation and cover for both fish and wildlife. A review of the literature relating to the ecological characteristics of borrow pits and similar water bodies is presented.

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PREFACE

The Lower Mississippi River Environmental Program (LMREP) is being conducted by the Mississippi River Commission, US Army Corps of Engineers. It is a comprehensive program of environmental studies of the leveed floodplain of the Lower Mississippi River and navigation and flood control aspects of the Mississippi River and Tributaries Project. Objectives of the program are to provide environmental inventory data, to identify environmentally important parameters associated with navigation and flood control features of the project, and to present these as environmental design criteria.

One component of the LMREP is the Levee Borrow Pit Investigation. This report presents environmental design considerations for levee borrow areas associated with the main stem levees along the Lower Mississippi River and is the final product of the investigation. Other components of the investigation addressed fisheries, wildlife, and physical and hydrologic aspects of levee borrow areas.

The report was prepared by Larry R. Aggus and Gene R. Ploskey, Aquatic Ecosystem Analysts, PO Box 4188, Fayetteville, Arkansas. Mr. Jerry E. Scott, US Army Engineer District, Vicksburg, was the Project Officer, and Mr. Stephen P. Cobb, Mississippi River Commission (MRC), was the Program Manager for the LMREP. The work was sponsored by the Engineering Division, MRC, and was conducted by Planning Division, MRC, under the direction of the President of the Mississippi River Commission, BG Thomas Sands, CE.

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## LOWER MISSISSIPPI RIVER ENVIRONMENTAL PROGRAM

### Environmental Design Considerations for Main Stem Levee Borrow Areas Along the Lower Mississippi River

#### PART I: INTRODUCTION

##### Purpose and Scope

1. The purpose of this report is to identify environmental design considerations that could be used, where practicable, in the design and construction of levee borrow areas along the main stem levee system of the Lower Mississippi River. The report is primarily for use by US Army Engineer District and Division Planning and Engineering personnel involved in the planning and design of Mississippi River Levees. The environmental design considerations outlined represent possible refinements in the procedures used to evaluate environmental quality factors during the formulation of plans and specifications for specific levee work items and in no way are intended to be a departure in policy with respect to design and construction of levees and borrow pits. Environmental design features being considered for a particular levee item will be coordinated with the levee board and resource management agencies in the customary manner, and will be subject to various engineering, legal, regulatory, and project authority constraints. The intent of this report is to identify those physical features of levee borrow areas that are environmentally important and present them as environmental design considerations.

2. Environmental design considerations for excavation of levee borrow pits were developed as part of the Mississippi River Commission's Lower Mississippi River Environmental Program. Field investigations were made of fish and wildlife and of physical and hydrologic characteristics of selected

riverside levee borrow pits along the river from southern Missouri to southern Louisiana to collect data for formulation of environmental design considerations. In addition, historical data were obtained from an extensive review of the technical literature pertaining to fishery and wildlife management in environments and situations relevant to levee borrow pits. These environmental data were combined with engineering design criteria to develop environmental design considerations.

3. The following synopsis is presented to assist users in finding specific information within this report. The remainder of the introduction provides background information on the Lower Mississippi River, its levee system, and borrow pits. Part II describes factors that significantly influence the design and excavation of borrow pits and their value for fish, wildlife, and recreation. Part III is a synthesis of literature outlining a range of borrow pit characteristics that are most conducive to the production of fish and wildlife. Part IV provides an overview of borrow pit planning procedures to enhance fish, wildlife, or recreational values. Part V addresses two levels of environmental design considerations: (a) routine considerations, those that could be implemented during levee construction at minimal cost, and (b) complex considerations, those that could significantly improve fish, wildlife, or recreational resources, but might substantially increase cost. Appendix A summarizes an in-depth literature review concerning the effects of borrow pit characteristics on fish and wildlife communities.

## Background

### The River and Levee System

4. The Lower Mississippi River is an alluvial river system. Its floodplain encompasses some 24.5 million acres of fertile land in Arkansas, Louisiana, Kentucky, Mississippi, Missouri, and Tennessee (MacDonald et al., 1979). Seasonal flooding and periodic major floods historically have been deterrents to agricultural development and human habitation of the basin.

Man's attempts to contain the river with levees date back more than two centuries. However, early efforts were hampered by periodic devastating floods and a lack of coordination among the many small groups involved in these efforts. The Mississippi River Commission was established by Congress in 1879 to coordinate flood control activities in the Mississippi River Valley. The devastating flood of 1927 prompted Congress to pass the Flood Control Act of 1928, which authorized the US Army Corps of Engineers to undertake construction activities for flood control. Most of the existing levee system has been constructed or upgraded under this authority.

5. The main stem levee system of the Lower Mississippi River consists of 2,202.2 miles of authorized levees. These include 1,608.3 miles along the Lower Mississippi River, 449.2 miles along the Atchafalaya River, 59.2 miles on the Red River, and 85.4 miles on the Lower Arkansas River. Currently, 2,195 miles of levees are in place (Cobb et al., 1984). However, the flood of 1973 indicated the need to raise about 480 miles of main stem levees to meet refined peak flow-line estimates. Extensive construction activity is under way to bring these sections up to design level and grade, which will create a significant number of new borrow pits.

#### Borrow Pits

6. Borrow material for levee construction is obtained almost entirely from the river side of the levee. When possible, materials are excavated near the base and parallel to the levee. This produces a series of shallow depressions or pits which form a chain of temporary and permanent water bodies along the length of the main stem levees (Cobb et al., 1984). In 1973, the combined surface area of levee borrow pits less than 20 acres in size was estimated at 44,700 acres. Of these, 10,600 acres (23.7 percent) were permanent bodies of water, whereas the remaining 34,100 acres of pits contained water seasonally. The total acreage is a conservative estimate, inasmuch as many borrow pits exceed 20 acres in size. Cobb et al. (1984) estimated that the area of permanent and intermittent borrow pits accounted for about 42.5 percent of the combined surface area of abandoned channel

lakes, oxbow lakes, and other floodplain water bodies in a 60-mile reach of the river (river miles 480 to 520, Above Head of Passes).

7. Borrow areas provide valuable habitat for fish and wildlife. The pits vary in size, shape, depth, and duration of flooding, as a result of location and engineering requirements. The diversity of borrow pits and the variety of surrounding vegetation provide habitat for a diverse biota. Incorporation of environmental considerations could improve future and existing borrow pit habitat.

8. Borrow pits along levees in the upper Midwest have been developed for a variety of recreational uses such as ice skating, picnicking, fishing, hunting, boating, and swimming (see US Army Engineer District, Rock Island, 1970, 1974; US Army Engineer District, Omaha, 1976, 1979). Some borrow pits along the Lower Mississippi River are commonly used for hunting, fishing, bird watching, and other outdoor activities but are typically subject to private landowner jurisdiction.

## PART II: OVERRIDING FACTORS AND CONSTRAINTS

9. Factors identified as having an overriding influence on the location, design, and excavation of levee borrow pits and the value of pits for fish and wildlife include: (a) the availability and distribution of usable borrow materials, (b) the average duration of flooding, and (c) the dominant vegetation communities in the floodplain near proposed excavation sites. Although each factor limits the potential of a particular site for certain fish and wildlife uses, a variety of opportunities are afforded when the factors are viewed collectively. They also set constraints on potential fish and wildlife use that cannot be easily negated through design modifications. When identified prior to excavation, these factors can help design engineers and planners decide what environmental considerations, if any, are appropriate for a specific borrow area.

10. Levee borrow sites are selected on the basis of location and availability of acceptable borrow material, depth of ground water, depth of permeable layers, and environmental considerations (US Army Corps of Engineers, 1978). The depth of suitable borrow material influences the depth and size of individual pits. The most economical procedure has been to dig long, shallow, rectangular pits adjacent and parallel to the levee alignment and to separate them with a series of unexcavated traverses at 1,000-foot intervals to provide access across borrow pits and to reduce erosion (Shields and Palermo, 1982). If engineering constraints require shallow excavation, a pit probably will dry up seasonally, and environmental considerations for fish should be supplanted with those for wildlife. Many species of birds and mammals benefit from shallow ephemeral pools. Borrow sites with deep layers of suitable borrow material can be excavated to provide a permanent pool for both fish and wildlife. Underseepage is a major consideration in levee design and construction. Underseepage can raise hydrostatic pressure beneath the levee and cause piping and sand boils. Berms of varying width are often used to control underseepage and may influence the size and location of borrow pits.

11. The average annual duration of flooding influences the distribution and abundance of many benthic invertebrate, fish, and wildlife species. Cobb et al. (1984) and Buglewicz (1985) used the controlling elevation of borrow pits and historical river stages to estimate annual duration of flooding. Controlling elevation is the elevation at which the river would begin to flow into a borrow pit. When determined during early planning activities, average duration of flooding provides the design engineer and environmental planner with insight to the relative value of a borrow area for fish or wildlife. Generally, borrow pits flooded less than 30 days annually are most valuable for wildlife (Environmental Laboratory (EL), 1985). Those flooded 90 or more days annually should support the highest standing crops of fish and benthic invertebrates. Cobb et al. (1984) found a positive correlation between annual days of flooding and fish standing crop. The average annual duration of flooding in 25 borrow pits was 81 days, but ranged from 24 to 117 days.

12. Dominant plant communities in nearby areas also influence the probability of wildlife use at a particular borrow site (EL, 1985), although many species of birds and mammals of the Lower Mississippi River exhibit broad habitat tolerances and will occur in most locations. A subjective examination of habitat types enables an engineer or resource planner to judge the likelihood of wildlife use and identify probable land uses following construction. For example, a shallow borrow site in an intensively farmed area is likely to be drained and planted in crops or heavily grazed following excavation. The potential value of such a site for fish and wildlife improvements is marginal and further consideration of environmental measures would not be warranted. By contrast, a borrow site in a stand of bottomland hardwoods, mixed trees and open land, or pasture with low agricultural use may warrant efforts to protect or improve fish and wildlife resources.

### PART III: OPTIMAL CONDITIONS

13. Optimal conditions for fish, fishing, and wildlife (Table 1) were identified during a review of literature on borrow pits and ponds (Appendix A). An optimum range of values for each characteristic had to be selected subjectively because of the diversity of habitat requirements of fish and wildlife species.

14. Optimal conditions described in Table 1 and below are suggested without regard to the many engineering and legal constraints encountered in constructing borrow pits. The characteristics are presented to serve as a model of an ideal condition, although site-specific conditions may make it impractical to attain all of these characteristics.

15. Optimal conditions for fish, fishing, and wildlife overlap. For example, borrow pits excavated deep enough to create a year-round supply of water benefit all three uses. There is overlap in optimal maximum and mean depths of pools and in shoreline shape, surface area, bottom topography, and grazing intensity (Table 1).

16. The strongest divergence in requirements for fish, fishing, and wildlife is in the number of days of flooding, the development of ephemeral pools during drought, side slopes, vegetation, and brush piles (Table 1). Positive correlations between days of flooding and the biomass of fish, including that of suckers, cyprinids (including common carp), crappies, catfishes, freshwater drum, and paddlefish (Cobb et al., 1984), suggest that fishing would be best at pits that remain flooded the longest each year (hence, >90 days, Table 1). By contrast, the Environmental Laboratory (1985) concluded that optimum borrow pit habitats for wildlife were those flooded less than 1 month. Borrow pits that dry up seasonally eliminate fish and fishing. By contrast, many species of wildlife benefit from an ephemeral pool. While the loss of fish in dried pools can be construed as a negative impact, it has minimal effect on fish communities of the Lower Mississippi River. Most ephemeral pits are flooded every year and trap fish. They can have a significant positive effect on fishing and foraging of water birds and

Table 1

## Optimal Borrow Pit Conditions for Fish, Fishing, and Wildlife\*

Characteristic	Fish		Fishing		Wildlife	
	Optimal Conditions	Paragraphs	Optimal Conditions	Paragraphs	Optimal Conditions	Paragraphs
Days of flooding	≥ 90 days	11,19,25; A = 2-12	≥90 days	11,19,25; A = 2-12	≤30 days	11,19,25; A = 2,13-16
Perennial pool	critical for survival	19,26; A = 20-22	critical only for year-round fishing	19,26; A = 20-22	beneficial to most species	27,28,37; A = 17-19, 27-30
Ephemeral pool	detrimental	16; A = 20	detrimental only when dry; water-level recession concentrates fish	16; A = 20	benefits some species such as shorebirds or wading birds	16,27; A = 30
Depth						
Maximum, feet	7-10	25,37;	7-10	25,37;	5-10**	27,37;
Mean, feet	≥3	A = 17-26	≥3	A = 17-26	2-4	A = 27-32
Bottom topography	smooth or variable	38-39; A = 45,46	smooth or variable	38-39	variable with islands	38-41; A = 33-38,53
Bottom slopes	gradual; down to the maximum depth near the river side of the pit (25H:1V)	26; A = 46	gradual; down to the maximum depth near the river side of the pit	26	gradual; down to the maximum depth near the river side of the pit	27; A = 52
Side slopes	3 or 4H:1V with some gradual (≤10:1) on upstream or downstream ends	26; A = 42-46	3 or 4H:1V with some gradual (≤10:1) upstream and downstream ends	26; A = 42-46	variable slopes; some gradual (<20H:1V) and some steep (≥4H:1V)	27,41; A = 52
Shoreline shape	irrelevant in most cases; gently curving, sinuous, or long and narrow pits would benefit sunfishes	28,38-41; A = 47	irregular with peninsulas and traverses to allow most areas to be fished from shore	28,38-41; A = 47	sinuous or irregular with traverses, peninsulas, and islands	28,38-41; A = 33-38, 52,53

(Continued)

\* Paragraph numbers refer to discussions in the main body of this report or in Appendix A (when prefaced by A = ).

\*\* Variation among nearby pits is desirable.

Table 1 (Concluded)

Characteristic	Fish		Fishing		Wildlife	
	Optimal Conditions	Paragraphs	Optimal Conditions	Paragraphs	Optimal Conditions	Paragraphs
Surface area	>10 acres to retain water	36; A = 39-41	10-25* acres to support public fishing	36; A = 39-41	>30 acres** but minimal in areas of bottomland hardwood forests	36; A = 49-51
Vegetation	ground cover to minimize erosion and some trees to provide shade and allochthonous leaf litter	29-31, 42,43; A = 55, 56,70	low ground cover with open areas around shore and trees for shade	29-31, 42,43; A = 55, 56,70	multilayered** woody and herbaceous vegetation down to the water's edge on the river side; moderate to open areas on levee side and between pits	29-31,42, A = 60-66,70
Grazing	light	12; A = 70	light to moderate or none when areas will be mowed occasionally	12; A = 70	none or minimal to facilitate erosion control and development of emergent vegetation	12; A = 66,70
Cover such as brush piles or root balls	located in the deepest area of pits with a maximum depth $\geq$ 7 feet and a minimum pool depth of 4 feet; covering no more than 0.5% of total pit area	33,44-48; A = 55-59	same as for fish	33,44-48; A = 55-59	located around pits on riverside right-of-way in areas of low agricultural use; anchored in areas with high-velocity flood flows	33,49,50; A = 67

\* Desirable surface areas depend in part on pit shape; large pits should be shaped so that most areas are fishable from shore.

\*\* Variation among nearby pits is desirable.

mammals as they dry up. A preponderance of steep side slopes (from 3 to 4H:1V) in borrow pits would be of greater benefit to fish and fishing than to wildlife. Borrow pit fishing is conducted from both the shore and boats. Gradual slopes and associated shallow areas are difficult to fish from shore, contain lower standing crops of harvestable-size fish than deeper areas, and may support aquatic plants detrimental to the production of harvestable sport fishes and fishing. For example, aquatic plants often overprotect young fish from predators such as largemouth bass and thereby limit predator foraging efficiency and growth. An overprotection of young sunfishes from predators can result in stunting of sunfish populations and intensive predation by sunfish on eggs in nests of other Centrarchids. Shallows with an abundance of aquatic plants are difficult for the average angler to fish. Many species of wildlife forage in shallow waters on aquatic plants or associated invertebrates and therefore benefit from gradual slopes and aquatic plant development.

17. Terrestrial vegetation requirements for the three uses of borrow pits are a matter of vegetation type and density rather than presence or absence. The universal requirement for vegetation is for erosion control, hence the need for ground cover such as bermuda grass or native herbaceous vegetation around pit margins (Table 1). Aquatic organisms benefit from the presence of a few trees around pits, because trees contribute leaf litter commonly consumed by invertebrates (Webster and Simmons, 1978). Trees also provide shade that might moderate high water temperatures in shallows. Fishing requires open areas around borrow pit margins, but some trees would be desirable for shade and aesthetics. Wildlife benefit from some vegetation in the form of multilayered woody and herbaceous species down to the water's edge. Tall and intermediate trees provide perching and nesting sites, as do shrubs, and vegetation to the water's edge provides protective cover for many species of mammals and birds. Trees with cavities are important for cavity-nesting birds such as woodpeckers and wood ducks. Because of the nature of borrow pit excavation, too much clearing of trees and shrubs is more likely to be a problem than too little clearing.

18. Brush piles improve habitat for both fish and wildlife. Fish attractors should be placed in the deeper areas of borrow pits, and wildlife attractors should be located on the land along the riverward margins of pits. Brush piles for fish and wildlife should be anchored to prevent them from being transported from areas that have high-velocity flows during flooding.

19. Many of the optimal conditions of borrow pits for fish and fishing (Table 1) are supported by the findings of Cobb et al. (1984). Other desirable characteristics in Table 1 are supported by observations in ponds (Appendix A). According to Cobb et al. (1984), borrow pits that flood longer annually, are deeper, and have a more sinuous shoreline support the greatest number of species, highest population densities, and greatest standing stocks of fishes and benthic macroinvertebrates.

20. Observations (outlined below) made by the Environmental Laboratory (1985) provide support for most of the desirable borrow pit characteristics for wildlife listed in Table 1. Because they provided more habitat diversity than shallow pits, borrow pits >6 feet deep and moderately grazed were almost as well suited for mammals as they were for birds. An optimal borrow pit was described as one with the following features: (a) flooding less than 1 month per year, (b) depths adequate to maintain a permanent pool during drought but having both shallow and deep water, (c) at least 30 acres of surface area, and (d) situated in mixed bottomland hardwood forest with vine and herbaceous vegetation.

#### PART IV: INTEGRATED PLANNING

21. Integration of fish, wildlife, and engineering considerations serves two important functions for design engineers and environmental planners. First, it offers a mechanism to optimize use of individual borrow areas based on design characteristics of the borrow pit and vegetation in the surrounding floodplain. Second, by considering fish and wildlife resources within extended levee reaches, integrated planning can help District and Division staffs identify areas that may warrant special environmental consideration.

22. Basic data must be collected during early planning so that appropriate environmental design features for fish and wildlife can be selected. These data include the volume of borrow material required, the depth of suitable materials, average annual duration of flooding, floodplain vegetation, surrounding land use, and proximity to ecologically sensitive areas. For example, preliminary boring and topographic data are typically collected for design purposes and for determining the depth of available borrow material and controlling elevation of a proposed borrow pit. The depth of suitable borrow material and amount needed will largely determine borrow pit size and depth. Size and depth, in turn, determine whether a pit will hold water all year. The annual duration of flooding can be estimated using hydrologic analyses. Aerial photographs and visits to proposed sites will aid in the identification of major vegetation types, land use practices, and environmentally sensitive areas such as rookeries of wading birds.

23. The basic data outlined above and the general characteristics of a proposed site should be examined carefully to identify a practical level of consideration for fish and wildlife. Figure 1 outlines procedures to aid the design engineer and environmental planner in selecting the appropriate level of environmental consideration for a particular borrow site. The user is then directed to specific sections of this report for detailed recommendations. While design considerations are divided into routine and complex measures, combinations of these should be evaluated on a site-specific basis during formulation of design recommendations.

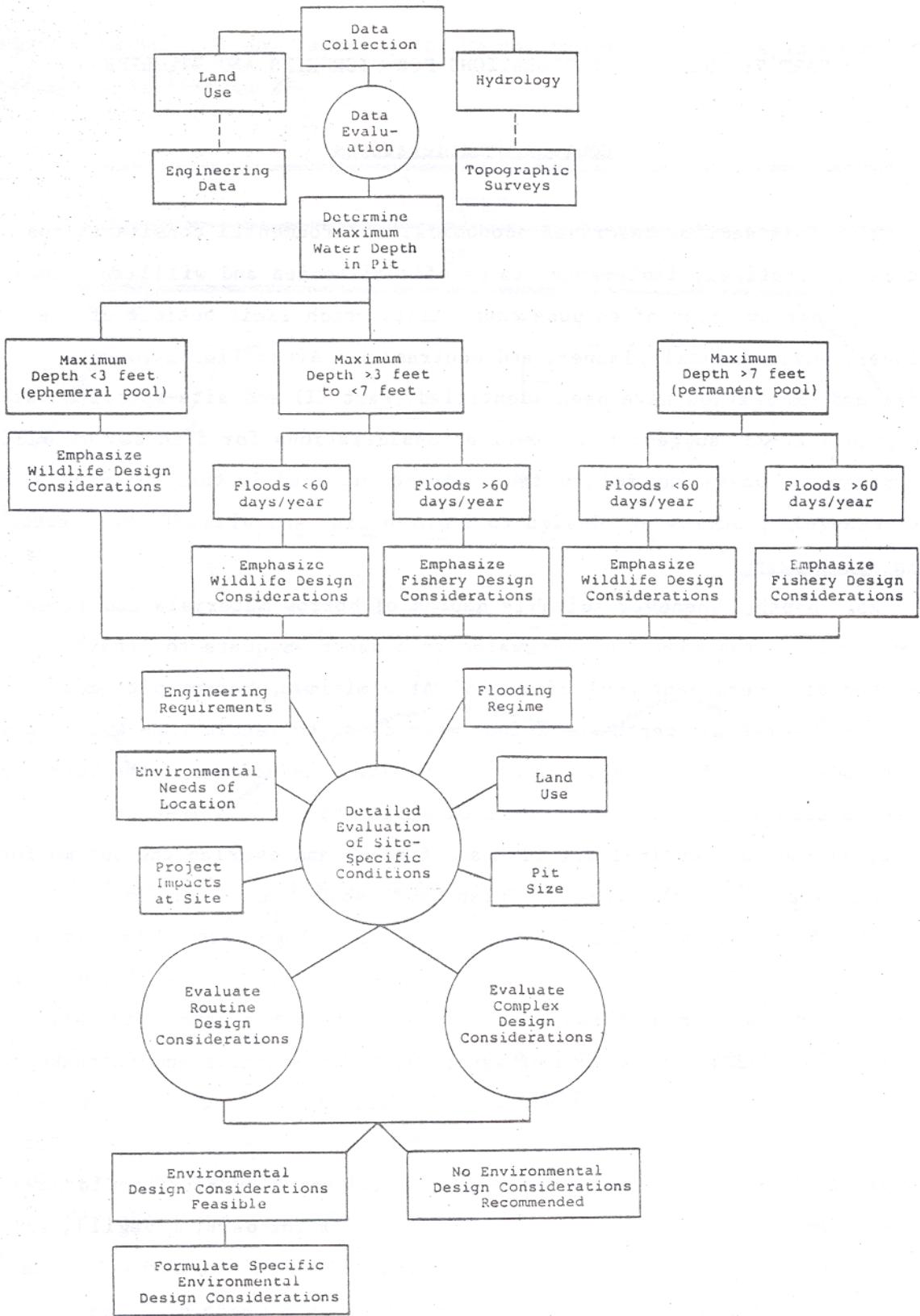


Figure 1. Flowchart for determining appropriate fish, wildlife, and recreational considerations for proposed borrow pits

## PART V: DESIGN CONSIDERATIONS FOR FISHERIES AND WILDLIFE

### Routine Considerations

24. This section describes economical environmental considerations that can be routinely implemented to benefit fisheries and wildlife. Individually, borrow sites often pose constraints which limit options of the engineer, environmental planner, and contractor. After limitations to design and excavation have been identified (Part II) and site-specific data (paragraphs 22-23) suggest that routine considerations for fish and wildlife are warranted, users may follow the guidance outlined in this section to make minor changes in borrow pit design to improve fish and wildlife resources.

#### Basin Morphometry

25. Depth. Whenever suitable depths of borrow materials and ground water permit, sites should be excavated to a depth adequate to permit the formation of a permanent pool of water. At a minimum, borrow pits must exceed 4-foot maximum depth and 2-foot mean depth to retain some water during dry periods. Mean depth is obtained by dividing the volume of the borrow pit by the surface area of the pit. Maximum depths of 7 to 10 feet are recommended, as they are optimal for fish and fishing and overlap the optima for wildlife (4 to 10 feet). Ideally, mean depth should exceed 3 feet.

26. Basin and shoreline shapes. Shoreline slopes should be variable but with slopes of from 3 to 4H:1V on the leveeward and riverward sides of the pit. Steep slopes at these locations increase basin concavity, which will provide a substantial area of water during dry periods and increase the productivity of benthic invertebrates and fish. A slope of 4:1 is gradual enough for wildlife and livestock to traverse and can be safely mowed, if necessary. Upstream and downstream ends of pits and traverses should have slopes of about 10:1 to provide ample shallow area for bass, bluegill, and other sunfishes to spawn and for wading birds and shoreline birds to feed. The bottom slope should be about 25:1, beginning at a depth of 3 feet

along the levee side and tapering to the maximum attainable depth near the riverward side (Figure 2).

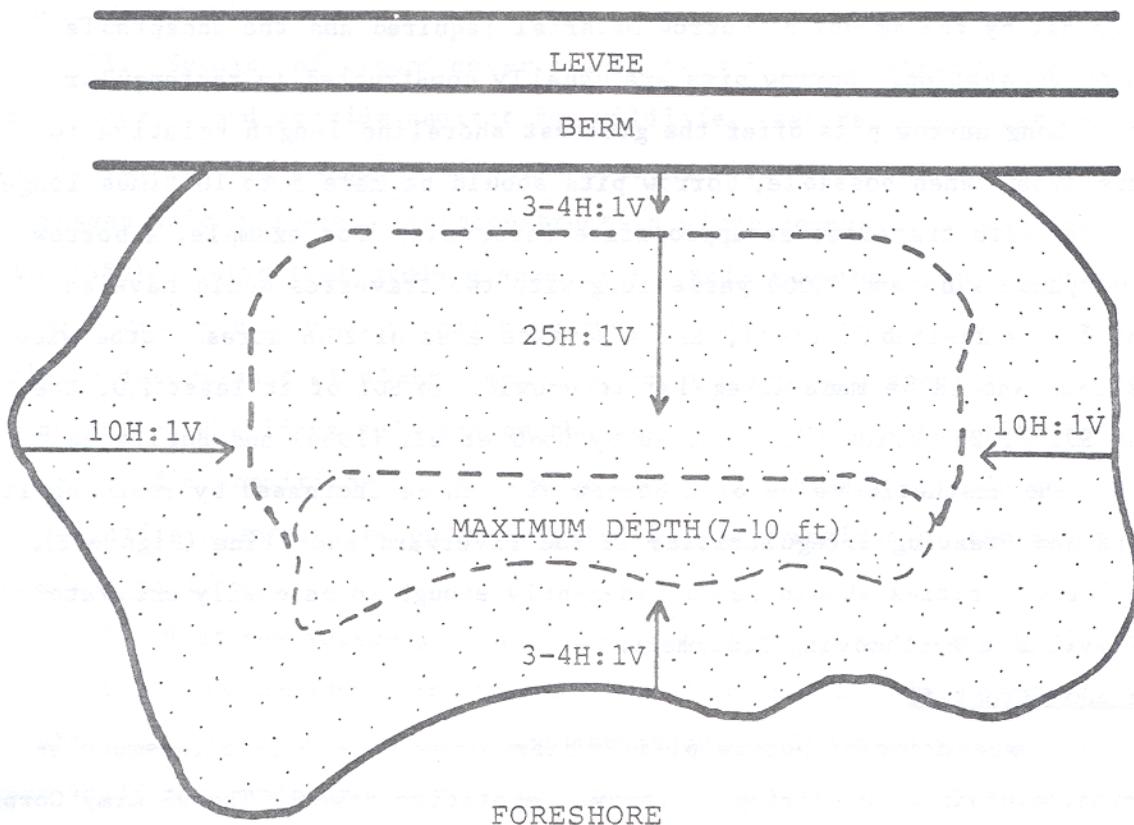


Figure 2. Diagram of a borrow pit, indicating optimal side and bottom slopes and maximum depth

27. Wildlife considerations should be emphasized at shallow borrow pits with maximum depths  $\leq 3$  feet. The basin shape should be similar to that proposed for deep borrow pits (see Figure 2), with side slopes of 4:1 along the levee and river sides but 20:1 along the ends of the pit and upstream and downstream from traverses. The goal is to increase habitat for shorebirds and wading birds. The bottom slope should be 25:1, beginning at a depth of 1.5 feet along the levee side and sloping toward the river side.

28. Design features that increase the length of shoreline relative to surface area (shoreline development index, SDI) benefit fisheries and wildlife by increasing the amount of nearshore area. Ultimately, borrow pit size will be set by the amount of borrow material required and the acceptable depth of excavation. Borrow pits are usually constructed in rectangular shapes. Long narrow pits offer the greatest shoreline length relative to surface area. When possible, borrow pits should be made 5 to 10 times longer than wide, with traverses at appropriate intervals. For example, a borrow pit 100 yards wide and 1,000 yards long with two traverses would have an SDI of 2.3, a desirable level, and a surface area of 20.6 acres. Otherwise, shorelines should be made irregular to provide an SDI of at least 2.0, the median SDI of 25 borrow pits studied by Cobb et al. (1984) and Buglewicz (1985). The aesthetic value of a borrow pit can be increased by rounding its corners and creating irregularities in the riverward shoreline (Figure 2). These irregularities should be curved gently enough to be easily excavated with available earthmoving equipment.

#### Cover and Structure

29. Excavation of borrow pits is disruptive to wildlife inasmuch as clearing, grubbing, and stripping remove vegetative cover. The US Army Corps of Engineers (1978) recommends minimizing impacts of construction activities on vegetation. For example, leaving existing woody and brushy vegetation in areas of shallow or poor-quality borrow material provides edge and cover that increase fish, wildlife, and aesthetic values.

30. Whenever possible, trees should be left standing along the fore-shore margin and ends of a borrow pit. Natural revegetation of small herbaceous plants and shrubs occurs within 1 or 2 years. However, trees require many years to attain a size large enough to provide cover or shade and nesting, roosting, or denning sites for wildlife. Mature trees left standing along the riverward margin of the borrow pit increase habitat diversity and suitability at minimal project cost. Tall trees and mast-, berry-, or fruit-producing species should be selectively retained because of their special value for wildlife. Trees with cavities are particularly important as they

may furnish den or nest sites. Where they exist, two or three cavity trees or dead snags per acre should be retained in locations where they will not impede excavation.

31. Seeding of ground cover immediately after construction will minimize erosion and provide habitat for wildlife. Natural revegetation is rapid, but seeding mixtures of plant species with high food and cover value increases wildlife use of postconstruction plant communities (see Yoakum et al., 1980). Herbs that produce seed in a single growing season should be established as a part of normal construction activities. Flooding is a primary determinant of plant community composition, and species of plants to be seeded should be selected on the basis of their adaptability to site-specific conditions. Fredrickson and Taylor (1982) provide guidance on selecting plants based on anticipated flooding regimes of the Lower Mississippi River.

32. Most new borrow pits have relatively shallow, smooth basins that afford only limited cover or structure for fish or wildlife. Irregularities in shoreline provide some cover and structure. Islands or peninsulas formed when shallow or undesirable fill materials are encountered also are of value to fish and wildlife. These areas should not be disturbed during borrow pit excavation.

33. Brush provides an efficient way of concentrating fish and providing cover for wildlife. For fish, some trees or root balls could be saved during excavation and pushed into the deeper part of pits to provide cover. Deeper pits ( $\geq 7$  feet deep) are best suited for fish attractors. These may need to be anchored in areas where flood flows could float them out of the pit. Brush shelters should not exceed 0.1 percent of the borrow pit area, and brush piles could be left on nonaccess margins of pits to provide cover for wildlife. Brush piles for wildlife can be circular (15 to 25 feet in diameter) or rectangular (25 to 50 feet long by 10 to 15 feet wide). They should be placed at a density of not more than one structure per 2.5 acres. The structures should not impair access and should be constructed only in relatively open areas.

### Complex Considerations

34. Complex design considerations are intended to substantially improve fish, wildlife, and recreational resources but at additional cost of levee construction. Complex design considerations that are marginally feasible or highly site-specific will be mentioned briefly with accompanying references, whereas considerations that may have broader application will be discussed in more detail.

#### Basin Morphometry

35. Borrow pit basin morphometry can be modified to benefit fish and wildlife more extensively than the routine considerations outlined earlier. Shaping shorelines and modifying bottom topography have more potential than do modifying basin slopes or water depth. Side and bottom slopes outlined earlier (paragraphs 26 and 27) cannot be improved upon and are also recommended as complex design considerations. Except for environmental management strategies for long sections of levees and island construction, routine guidance on depth (paragraph 25) also is recommended for complex designs.

36. In general, borrow pits with large surface areas are better for fish (>10 acres), fishing (>10 to 25 acres), and wildlife (>30 acres) than those with surface areas <10 acres, if water depths are adequate. In some cases, however, limited depths of suitable borrow materials will result in excavation of large shallow borrow pits. Excavation of wide, shallow pits and associated longer haul distances for borrow material and potential increased right-of-way needs are often required to improve control of underseepage, hydraulic performance, and environmental conditions under certain foundation conditions (US Army Corps of Engineers, 1978).

37. Depth. In areas where long reaches of the main-line levees are being raised or modified, special efforts should be made to excavate at least one deep borrow pit that will have a permanent pool (see paragraph 25) for every mile of levee, especially where construction results in most pits being shallow ( $\leq 3$  feet deep) due to engineering constraints. Permanent pools in borrow pits are most valuable in areas where permanent standing water is

limited. A single perennial borrow pit pool in a 1-mile section of levee will have value for most wildlife. Although costs of special efforts to obtain a single permanent pool may be high, the benefits to wildlife can be ascribed to a much larger area than the pit itself. When depths are not limited by geological features, all pits should be excavated to depths of 7 to 10 feet (the optimum range) or deeper (see paragraph 25).

38. Basin and shoreline shapes. Borrow pits with irregular shorelines tend to be of more value for recreation, fisheries, and wildlife than rectangular pits. Extremely convoluted shorelines will not necessarily increase the aquatic productivity (see Appendix A, paragraph 48) and may be detrimental in areas subjected to strong flow during floods because of the resulting erosion. Highly irregular shorelines may substantially increase excavation costs if curvatures require special maneuvers of equipment. Aesthetically, gently curving shorelines can make a typical borrow pit seem more like a pond or lake than a remnant of excavation. Fisheries benefit from an irregular shoreline (SDI = 2.0-3.4) because it improves aesthetic qualities and permits anglers to fish more of the borrow pit surface area from shore. However, it is recognized that much borrow pit fishing is from boats and that efforts to increase shoreline relative length for this purpose may not be justifiable in all instances. Wildlife benefits arise primarily from the diversity of habitat (edge) that can be created by an irregular shoreline. Edge results from the border between two different habitats (Yoakum et al., 1980), and benefits are derived from edge formed when water, land, forest, shrubs, open fields, or levees border one another.

39. The most efficient method of increasing shoreline irregularity for fisheries and wildlife, without jeopardizing shore stability, is to round otherwise square corners of pits during excavation and design peninsulas or islands (Figures 3 and 4). Traditional traverses are valuable because they are similar to peninsulas and provide visual isolation between pool segments when water levels are low. They also facilitate movement of anglers, landowners, and wildlife across long borrow pits. A single large peninsula with a bifurcate point may increase (a) the amount of shoreline of a borrow pit

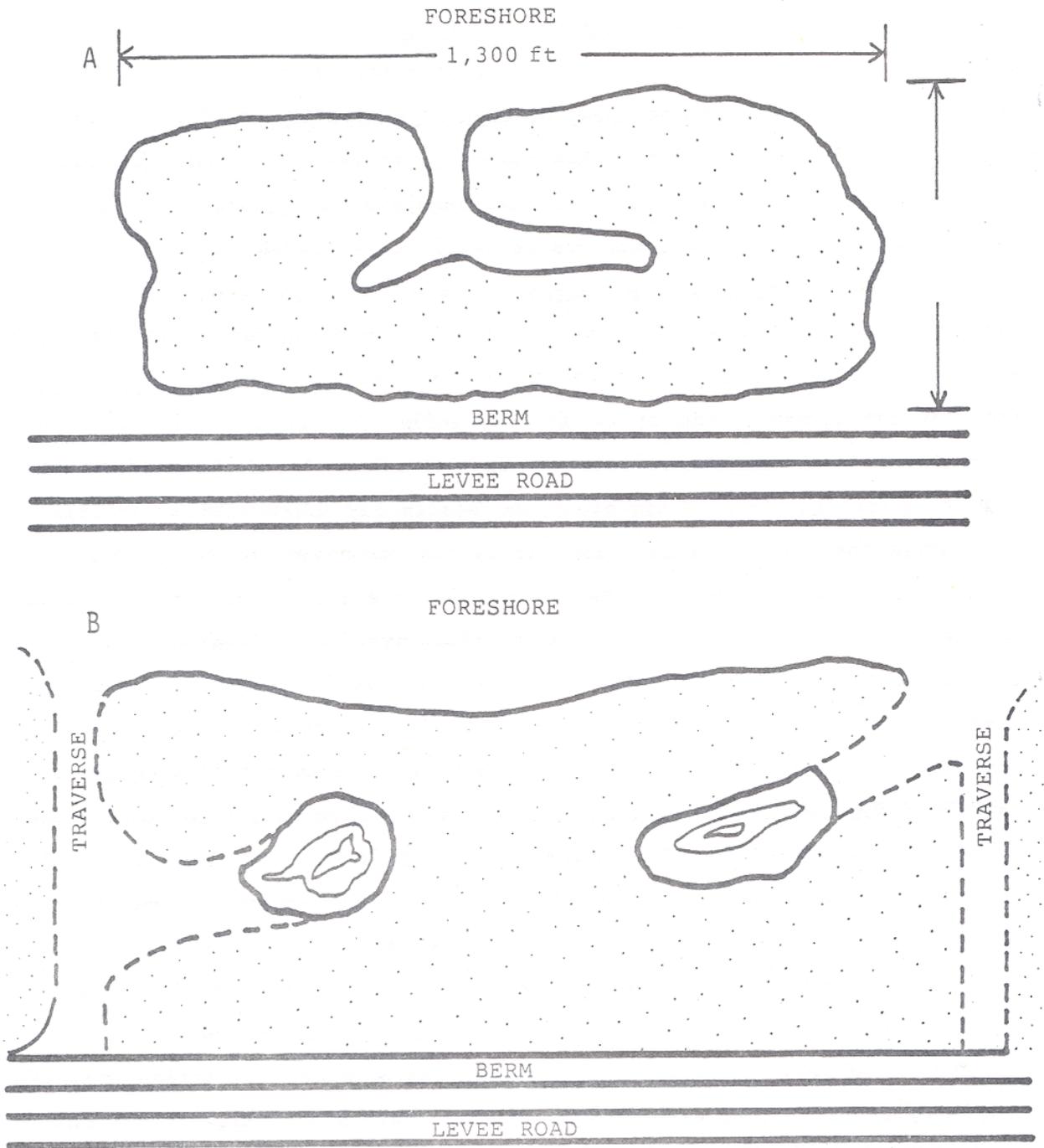


Figure 3. Plan view A illustrates a single forked peninsula that increases shoreline length by about 30 percent. Plan view B illustrates two peninsulas with elevated points that originate from traverses. This design results in peninsulas at normal water levels and islands when water levels are high. It should partially deflect floodwaters away from the levee.

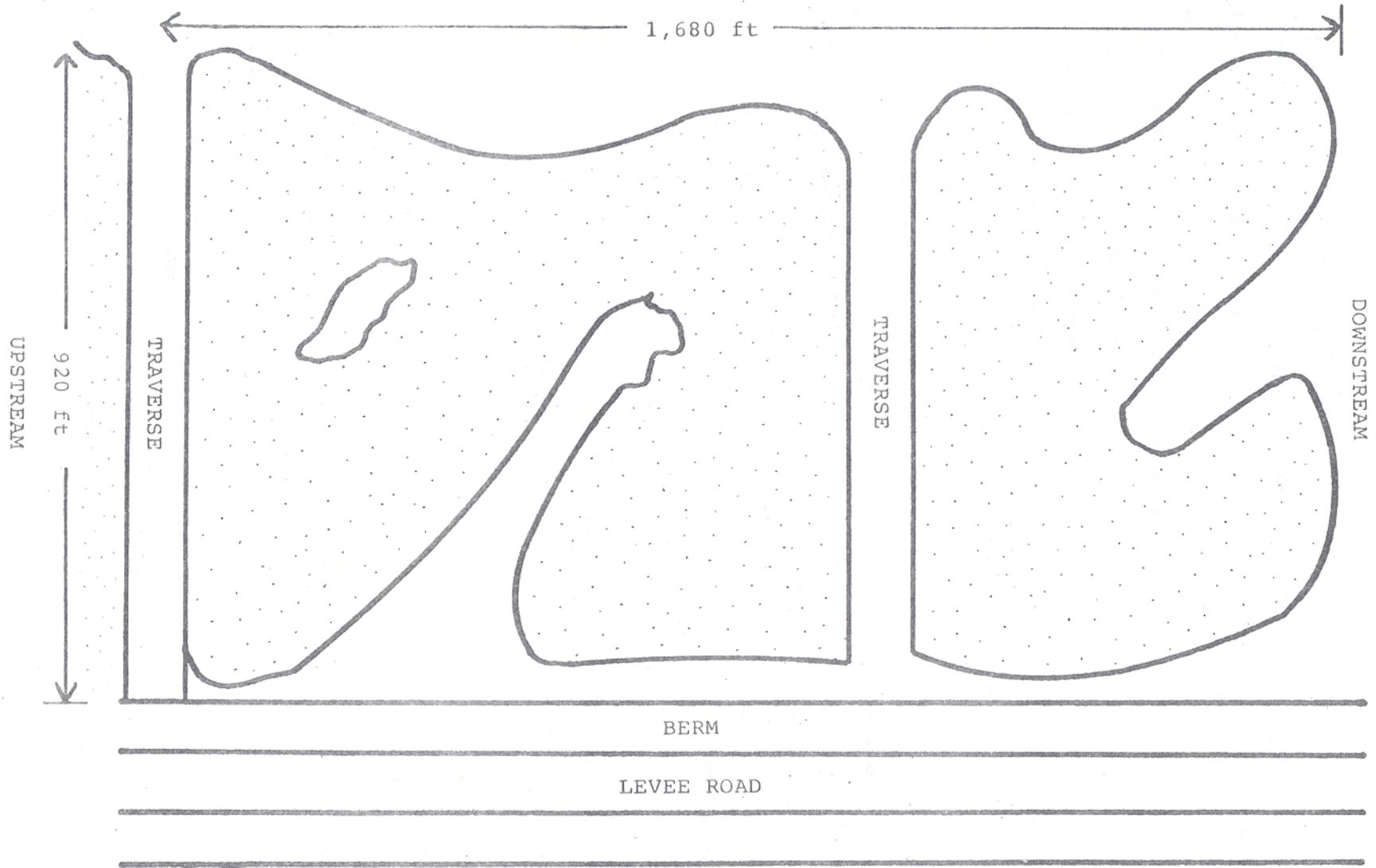


Figure 4. Orientation of islands and peninsulas to limit deflection of floodwaters into the levee and impediments to hauling borrow material to the levee during construction

by 30 percent (Figure 3A), (b) the visual segregation of parts of the pit, and (c) the ability of anglers to fish more surface area from shore. With the peninsula facing the levee side of a pit, hauling of borrow materials to the levee would not be greatly impeded.

40. Peninsulas and islands in pits located near the river where floodwaters may develop measurable flow should be oriented to deflect flowing water away from the levee (Figures 3B and 4). Less caution is needed in borrow pits 0.5 mile or more from the river, especially those with a forest buffer between them and the river. Peninsulas and islands oriented to deflect flows away from levees (Figure 4) should not impede efforts to haul borrow materials to the levee as much as peninsulas or islands oriented parallel to the levee.

41. To be stable, peninsulas and islands should have side slopes of about 4:1 and a width of at least 30 feet when the borrow pit basin is full of water. Their surfaces should be raised 2 feet above the bank-full elevation to ensure that they will not be submerged when pits are full of water. Side slopes of 4:1 will allow fishermen to fish from edges and provide wildlife with easy access to and from the water. With a width of 30 feet, these features should withstand annual flooding and afford ample room for anglers or wildlife. A peninsula originating from a traverse need only be raised above the elevation of the traverse at its point (Figure 3B). During construction, excavation equipment can move over the neck of such peninsulas to haul materials to the levee. When flooded, peninsulas originating from traverses will form islands; they will be continuous with the traverse when water levels are low. Islands and peninsulas are not expensive to construct (see Appendix A, paragraph 38); however, more rights-of-way may be required to make up for the borrow material that must be left in the pit to form these features. They have high value for aesthetics, fisheries, and wildlife and are recommended for all borrow pits, including those warranting only routine considerations, when they are at least 7 feet deep.

## Cover and Structure

42. Planting and seeding. Vegetative ground cover should be established immediately following construction to control erosion. Seeding also improves habitat for wildlife and enhances aesthetic values. Natural revegetation will usually occur rapidly; however, the quality of vegetative cover at construction sites is improved for wildlife when mixtures of herbs, grasses, shrubs, and hardwoods are planted. Plantings of trees may be desired to increase visual isolation and aesthetics in areas surrounding borrow pits. Routine revegetation of areas subject to erosion can benefit wildlife at little increase in project cost if mixtures of grasses and herbaceous plants of high food value are seeded.

43. Survival of plants selected for seeding is enhanced when they are well adapted to the annual flooding cycle at a specific site. Therefore, planting recommendations should be made by a wildlife planning specialist with consideration of soils, duration of flooding, vegetative communities in the surrounding area, anticipated land use, and physical characteristics of the borrow site.

44. Shelters. Borrow pits with maximum depths  $\geq 7$  feet are most suitable for the addition of brush or artificial shelters to attract sport fish. These shelters can be made from natural or artificial materials cabled together and anchored to withstand flood flows. They represent a one-time project investment and should be installed after excavation is complete.

45. Shelters can be fabricated from a variety of materials, but brush and hardwood logs are easiest and least expensive to obtain. Brush or logs can often be obtained during clearing activities. These can be stacked, cabled, and anchored at selected locations to provide artificial shelters. Cabling may be necessary to prevent woody materials that dry out during drought from floating away when the area floods. Logs can also be tied together to form a variety of configurations, then weighted and anchored in designated locations. A large pole driven into the pit bottom with brush or tires attached around its base forms a permanent structure.

46. A relatively small area of shelter (about 0.1 percent of the pit area) will attract sport fish and improve fishing. This represents one structure 20 feet long, 10 feet wide, and 3 to 4 feet high for each 5 surface acres of water. Shelters should be placed in deep water near the river side of the pit so that they remain submerged during periods of low water. They should be identified with a pole driven into the bottom at the site, as described in the previous paragraph. The pole would also provide a tie-up for anglers in small boats.

47. Shelters should last many years with proper selection of materials. Hardwoods such as oak will decay more slowly than softer woods such as black willow or sycamore. Selection of larger diameter wood also results in a slower rate of decomposition. Woody materials that are permanently covered with water last much longer than those exposed to the air every year.

48. The cost of constructing brush shelters can vary significantly, depending on the type of material used and the size and location of the structure. By using woody materials obtained at the construction site, costs would arise primarily from the labor and materials required to anchor the structures. Some labor would be required to dispose of cleared vegetation if it were not used to construct brush shelters.

49. Wildlife brush shelters provide protection for a variety of small game and nongame species. However, they appear to have only limited application for borrow areas. Brush piles constructed for wildlife should be placed on the river side of borrow pits. If these areas will be exposed to high-velocity flows during flooding, shelters should be securely anchored and cabled. Their use should be restricted to areas where natural cover is limited. These structures should be of the size and density recommended in paragraph 33.

50. Vegetative cover for islands should consist of a multilayered canopy of trees, shrubs, and seed-producing plants or ground cover, because islands are well suited as habitat for nongame birds. They also are valuable for animals such as beavers and turtles. Where islands are constructed, ground cover should be established by seeding mixtures of grasses, forbs,

and shrubs. Trees with high potential wildlife value should be planted at a density of one tree per 100 square feet to augment natural seeding and accelerate the development of a tree canopy by several years. Planting should take place as soon as construction has been completed.

#### Recreation Development

51. Development of recreation facilities at selected levee borrow pits is a possibility along the Lower Mississippi River. Construction of recreation facilities such as boat ramps would have to be cost-shared by the local project sponsor, who would also have to acquire fee title to needed lands. Recommended recreation facilities would have to be justified and the cost-sharing agreement approved under Federal rules and regulations for such projects. Given these constraints, therefore, development of recreation facilities at levee borrow pits would be rare.

#### Landside Borrow Pits

52. Opportunities for managing borrow pits to improve fish and wildlife resources are sometimes better for pits on the land side than on the river side of levees because riverine flooding does occur. One major problem with landside borrow pits, however, is the influx of poor-quality water, especially in agricultural areas. Management possibilities for fisheries include eradication of undesirable species, stocking of desirable species, and water-level manipulation. Possibilities for wildlife include creating artificial marshes that can be flooded at appropriate times to attract waterfowl or shore, water, or wading birds. In addition, prevention of annual flooding can benefit populations of small ground-dwelling mammals and the nesting success of perching birds (Fredrickson, 1979; EL, 1985).

#### Water-Control Structures

53. Water-control structures could improve riverside borrow pit habitat for fish and wildlife by maintaining water levels during low-flow dry periods of the year. However, these structures are impractical for most sites, as few borrow pits have a dependable source of ground water or a watershed of sufficient size to maintain water levels through summer and fall or to refill a pit if it were drained for management purposes during these

seasons (Hynson et al., 1985). A dependable water source (watershed or ground water) that exceeds expected losses to evaporation and seepage is needed.

54. Unless water can be pumped from a nearby source and water levels manipulated (a common practice on wildlife refuges, see Fredrickson and Taylor, 1982), water-control structures should be considered only for borrow pits with 3 to 5 acres of watershed for every acre-foot of water capacity (Soil Conservation Service, 1971, 1973). For example, a 20-acre borrow pit with a mean depth of 4 feet (volume = ca. 80 acre-feet) should have a watershed of from 240 to 400 acres. Sites suitable for water-control structures will be few, but they might be found in a broad drainageway or at a low point in a natural depression. A site survey would be required to assess the size of the watershed relative to the volume of a proposed borrow pit. If a proposed borrow pit has a sufficient watershed and elevational gradient for drainage or a dependable ground-water source, as well as the potential for water-level management, several useful references for further information include the Soil Conservation Service (1971), Atlantic Waterfowl Council (1972), Yoakum et al. (1980), and Hynson et al. (1985).

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## APPENDIX A: LITERATURE REVIEW OF ENVIRONMENTAL CONSIDERATIONS

1. The 44,700 acres of borrow pits within the leveed floodplain of the Lower Mississippi River represent a large but dispersed aquatic resource. Borrow pits occur in a chain stretching along the base of 1,600 miles of main-line levees in six states and about 48 counties or parishes. Because of the diversity of flooding regimes and habitat among borrow pits, they present many different problems as well as opportunities for fish and wild-life enhancement.

### Flooding

2. Seasonal flooding and dewatering of the floodplain is the dominant factor influencing the structure and production of plant and animal communities along the Lower Mississippi River. Short- and long-term water cycles play a major role (Fredrickson, 1980). The importance of seasonal flooding to the maintenance of biological communities of the Lower Mississippi River floodplain was recognized by Viosca (1927). He linked overbank flooding to major population changes in animals such as muskrats and fish. He observed intensive spawning and feeding by adult and young fish during years of significant flooding. He recognized that seasonal reductions in river stages concentrated aquatic production back into the main river channel and other aquatic habitats on the floodplain and provided food for many animals, including man.

### Fish and Fisheries

3. Most species of fish inhabiting the channel and floodplain habitats of the Lower Mississippi River have evolved life history strategies closely tied to the annual cycle of flooding. Most riverine species move from the main channel onto the floodplain during overbank flow to spawn and feed. Young fishes use the inundated floodplain for nursery habitat. As floodwaters recede, fish are concentrated first in low-lying areas of the

floodplain and finally back into the main channel. Many are retained in floodplain borrow pits and lakes (Guillory, 1979).

4. Year class strength of most important sport and commercial fishes of the Lower Mississippi River depends upon the amount and duration of overbank flooding. Bryan and Conners (1980) and Pennington et al. (1983) demonstrated that peak abundance of larvae of many important species occurs from April through June. Average river stages are highest from March through May (US Army Engineer District, Vicksburg, 1976), and overbank flooding occurs in most years, although the amount and duration vary greatly from year to year. Bryan and Conners (1980) postulated that even minimal overbank flooding is beneficial. However, the strongest year classes of fish occur during years of prolonged overbank flooding (Wood, 1951; Cobb et al., 1984).

5. Several species of fish can reproduce in borrow pits, but spawning success is highly variable and probably of limited importance in the long-term maintenance of fish populations. Centrarchids (sunfishes, crappies, and largemouth bass) and clupeids (gizzard and threadfin shad) are well adapted to spawn in borrow pits after floodwaters recede. However, Hall (1974) suggested that the inundated floodplain provided the primary spawning and nursery habitat for these species. Using rotenone samples, Cobb et al. (1984) found that most fish assemblages in borrow pits were dominated numerically by Age I or older fish. This finding suggests either that reproduction and recruitment were limited or that young fish produced in borrow pits were preyed upon heavily because samples of fish collected with rotenone usually contain a much higher numerical percentage of young-of-year than older fish (Hayne et al., 1968; Jenkins and Morais, 1976).

6. The size distributions and growth of fish in borrow pits are comparable to those of fish in major riverine habitats of the Lower Mississippi River. This comparability suggests that borrow pits are populated to a large extent by fish which move from the Mississippi River into the floodplain during flooding and become trapped as waters recede. Size-distribution data on fishes of the Lower Mississippi River are limited, but mean weights of several species collected by netting from the mouth of the Missouri River to

Caruthersville, Missouri, during the period 1944-46 (Barnickol and Starrett, 1951) were very similar to the average sizes of fish reported by Cobb et al. (1984) (see Table A1).

7. As with other floodplain lakes, borrow pits provide valuable habitat for fish on the floodplain. These habitats will become increasingly important in a heavily managed navigation and flood control system such as the Lower Mississippi River, because floodplain lakes will gradually fill in with sediment while few new ones are formed (Ellis et al., 1979).

8. Borrow pits support large standing crops of fish and are among the more productive aquatic habitats of the floodplain. Cobb et al. (1984) reported an average fish standing crop of 595 pounds per acre during their 1981 sampling of populations in 25 levee borrow pits. Standing crops ranged from 51 to 3,199 pounds/acre. On average they compared favorably with previously reported standing crops in floodplain lakes (Lambou, 1960; Lambou and Geagan, 1961). The standing crop of fish in borrow pits is high compared with that of fish in landside lakes that are not subjected to annual riverine flooding (Lambou, 1960).

9. Natural restocking of fish takes place each time a borrow pit is inundated, and borrow pits which flood longer generally contain higher standing crops of fish. Stocking of prey or sport fishes is therefore of limited value for manipulating fish populations in borrow pits. Flooding for only a few days is sufficient to permit recolonization of floodplain pools (Guillory, 1979). Cobb et al. (1984) found that all borrow pits sampled during their investigation contained fish, even pits that dried up annually. They also reported significant positive correlations between the average annual duration of flooding and the total standing crop (biomass) of fish, including that of several important forage, commercial, and sport species. During flooding, fish disperse throughout the floodplain but are funneled back through natural depressions or drainageways as water levels recede. Borrow pits located in these low areas trap more fish than ones at slightly higher elevations because they remain open to the river (flood) longer and act as the catchment for large areas of floodplain.

Table A1

Comparison of Mean Weights (in Pounds) of Selected Commercial and Sport Fishes Collected from Mainstream Habitats of the Lower Mississippi River by Netting Near Caruthersville, Missouri (Barnickol and Starrett, 1951) and by Rotenone Sampling in Borrow Pits During 1981 (Cobb et al., 1984)

<u>Species or Group</u>	<u>Mainstream</u>	<u>Borrow Pits</u>
Paddlefish	2.17	4.06
Longnose gar	2.08	1.48
Shortnose gar	0.93	0.83
Bowfin	2.95	3.02
Common carp (less young-of-year)	2.04	2.09 *
Carp suckers	1.11	0.82
Smallmouth buffalo	1.25	1.42
Bigmouth buffalo	2.15	2.53
Black buffalo	3.89	3.43
Blue catfish	0.57	0.69
Channel catfish	0.75	0.23
Flathead catfish	2.77	6.83
White bass	0.51	0.44
Largemouth bass	1.12	0.25
White crappie	0.29	0.05
Black crappie	0.37	0.10
Freshwater drum	0.57	0.29

\* Data from Borrow Pit 3 of Cobb et al. were excluded since the mean weight of carp in this sample (0.0008 lb) was considered a possible anomaly.

10. The average annual duration of borrow-pit flooding can be predicted with reasonable accuracy from the controlling elevation at which a borrow pit is cut off from the river and historical river stages near that site. Buglewicz (1985) reported that the average duration of flooding for 25 main stem borrow pits ranged from 24 to 117 days annually. Duration of flooding was negatively related to controlling elevation, and pits located in the lower reaches of the study area generally had lower controlling elevations.

11. Angler use and harvest in borrow pits of the Lower Mississippi River have not been quantified with creel surveys. However, several authors (Cobb et al., 1984; EL, 1985; and others) have reported extensive angler use of borrow pits along the Lower Mississippi River. Cobb et al. (1984) estimated that about 200,000 angler days of fishing per year could be sustained at existing perennial borrow pools. This estimate probably would be higher if angling at the ephemeral borrow pits had been considered. Ephemeral pits may provide good fishing before they dry up.

12. Because of the annual cycle of flooding, most borrow pits support large populations of commercial fish. These populations are largely under-exploited. Cobb et al. (1984) reported an average of 288 pounds per acre of commercial species (catfishes, suckers, buffalofishes, and carp) in levee borrow pits. Using only those pits retaining water all year, the authors projected a potential annual harvest of 2.7 million pounds of commercial fish with a market value of \$1.5 million. Inclusion of potential catches from ephemeral borrow pits (ca. 34,100 acres) before they dry out would significantly increase these projections.

#### Wildlife

13. Both the extent and duration of overbank flooding influence the distribution of wildlife in the leveed floodplain and wildlife use of borrow pits. Seasonal flooding temporarily displaces many species to habitats at higher elevations. During extreme flooding, animals may be forced to the land side of levees, where cover and food supplies may differ significantly from those within the leveed floodplain (EL, 1985). The average duration of

annual flooding also influences land use and the composition of plant communities on the floodplain. It therefore determines the suitability of habitats for many wildlife species. Areas that flood only briefly each year are sometimes farmed and often used for pasture. The species composition of bottomland and mixed hardwood forest communities also varies depending on average duration of flooding (Huffman, 1980; Conner et al., 1981; Klimas et al., 1981; and others).

14. Most species of mammals living in the leveed floodplain do not depend on borrow pit habitats for survival. During a 2-year study of borrow pits along the Lower Mississippi River, 23 wild species were observed (EL, 1985). However, only seven of these (beaver, muskrat, nutria, raccoon, river otter, rice rat, and mink) required standing-water habitat. These species were well adapted to seasonal flooding and dewatering of borrow areas and moved to different locations when hydrologic conditions changed. Overall, borrow pits that were flooded less than 1 month each year provided the best habitat for mammals.

15. The use of borrow pits by birds is also influenced by the extent and duration of flooding. However, few generalizations apply to all species of birds because collectively they are very well adapted to the range of habitats in the floodplain. Virtually all patterns of flooding benefit or harm some avian species. For example, borrow pits flooded for comparatively long periods of time receive less use by birds that nest or feed on the ground or in shrubs or snags. Conversely, water birds, wading birds, and shore birds may be more numerous at these sites.

16. The annual cycle of flooding in borrow pits of the Lower Mississippi River does not consistently create the habitat needed to attract large numbers of waterfowl. Although Hynson et al. (1985) considered waterfowl management an important feature of borrow pits and the floodplain of the Lower Mississippi River is valuable migratory and wintering habitat for waterfowl, the Environmental Laboratory (1985) found only limited use of Lower Mississippi River borrow pits by migrating and wintering populations. Wood duck use was also limited by fluctuating water depths and an absence of

cover, food, and nesting cavities in and around pits. For borrow pits of the Lower Mississippi River to be highly attractive to migrating waterfowl, water levels must be lowered during the growing season to develop appropriate food and cover, but the pits must be flooded in fall to attract waterfowl during migration (Chabreck, 1979; Fredrickson and Taylor, 1982). This inability to regulate water levels in borrow pits makes management for waterfowl very difficult. Flooding of borrow pits to optimize waterfowl use would require unusual flooding patterns or seasonal pumping of water into borrow pits.

#### Borrow Pit Depth

17. Water depth is one of the most important environmental factors affecting fish and wildlife use of borrow pits, as it affects the quality and availability of water during dry periods of the year. The provision of a permanent supply of water is crucial to the survival of fish communities and is important to many species of wildlife (e.g., water birds, waterfowl, beaver, and muskrats). Borrow pits are vulnerable to drying out because most are refilled by flooding only once a year. Pits lose water to evaporation, seepage, and drainage, and few have a watershed of sufficient size to maintain water levels with surface runoff. As a result, shallow pits tend to dry out while deeper pits provide a perennial pool with substantial seasonal fluctuation in water level.

18. Seepage of water is controlled to the extent that an adequate layer of impervious soil is left in the bottom of borrow pits to prevent underseepage or other levee stability problems (US Army Corps of Engineers, 1978). These practices are desirable for fish and wildlife because seepage from pits is reduced.

19. A large percentage of borrow pits are subject to seasonal dewatering. Borrow pits with a maximum depth  $\leq 3$  feet and a mean depth  $\leq 1.6$  feet may dry out completely during years or seasons of drought. Of the estimated 44,700 acres of borrow pits in the main stem levee system in 1973, only 10,600 acres (23.7 percent) were considered to be permanent standing

water (Ryckman et al., 1975). The remaining 34,100 acres contained water intermittently during the year. The 25 borrow pits studied by Cobb et al. (1984), Buglewicz (1985), and the Environmental Laboratory (1985) exhibited substantial recession of water levels during summer and fall of 1981, a period of low rainfall. Seven of the 25 pits studied became dry or nearly dry. Four borrow pits that had the greatest reductions in water levels had an average maximum depth at full pool of 3 feet and an average mean depth of only 1.6 feet (Buglewicz, 1985).

#### Fish and Fisheries

20. Provision of adequate depth to ensure a year-round pool of water in borrow pits is critical for sustaining fish populations and a year-round fishery. Although fish communities in shallow pits will be eliminated by drought, they may provide excellent fishing for humans and water birds as waters recede and concentrate fish. Two shallow borrow pits that dried up in 1981 (EL, 1985) and, presumably, in 1980 contained 600 and 3,200 pounds of fish per acre in 1980 (Cobb et al., 1984). As these shallow pits were drying up, fish were heavily preyed upon by water birds such as herons and egrets (EL, 1985). Fishermen had good catches of fish at one borrow pit and heavily fished another, both of which exhibited substantial reductions in water levels in summer and fall of 1981 (EL, 1985).

21. Pond manuals specify water depths designed to maximize production and protect fish from desiccation and winter kill. Viosca (1937) recommended a maximum depth of 4 to 5 feet for Louisiana ponds, claiming that maximum fish production occurred in waters  $\leq 4$  feet deep and that waters exceeding 6 feet in depth were not used extensively by fish. Edminster (1947), who explained that depths should be adequate to protect fish from prolonged ice cover and potential winter kill as well as from drought, recommended at least 6 feet of depth over one-fifth of a pond's area. Davison (1955) stated that 4 feet was an adequate depth in the South but that 6 feet was more appropriate. He advocated 8- to 10-foot maximum depths for ponds in the central United States. Grizzell (1967) recommended a minimum pool depth of at least 3 to 4 feet in Southern States and 6 feet north of Arkansas. For southern

Illinois, Lopinot (1972) suggested a maximum depth of 7 feet. Dillon et al. (1977) noted that depths of 3 to 4 feet were adequate to maximize fish production, although deeper water would be desirable if evaporation or freezing would be a problem. Similarly, in Louisiana's most recent pond manual, Summers (1984) recommended a depth sufficient to maintain a minimum of 4 feet of water over most of a pond during a prolonged drought (i.e., a maximum depth of 6 to 8 feet).

22. Levee borrow pits in the Lower Mississippi River should have a maximum depth of at least 7 feet and a mean depth  $\geq 3$  feet to support a year-round fishery. These depths are based on the premise that approximately 3 feet of water loss will occur in a dry year and the optimal depth for fish is 4 feet. The Soil Conservation Service (1971) recommended a depth of 6 to 7 feet for ponds in the Lower Mississippi River Valley. They advocated increasing the 6- to 7-foot depth if seepage is expected to exceed 3 inches per month. Their recommendation accounts for average rates of precipitation, evaporation, and seepage but not for effects of alluvial flooding on pit volume or for consumption of water by livestock and wildlife.

23. Historically, borrow pits have been constructed to catch river sediments and return excavated areas to their original state as soon as possible (US Army Corps of Engineers, 1978). However, if borrow pits are viewed as assets rather than as a remnant of levee construction, there are advantages in digging them as deep as possible. Although excavation costs may increase somewhat (Shields and Palermo, 1982), benefits include shorter hauling distances, a reduced need for clearing bottomland hardwoods or for acquiring additional rights-of-way, increased capacity for sediment retention, and improved fish and wildlife habitat.

24. Thermal stratification and hypolimnetic oxygen deficits may occur in borrow pits exceeding 5 feet in depth, especially if they are steep sided, have a small surface area, and are protected from prevailing winds by the levee or trees. However, unless the pits are exceptionally fertile or support high densities of aquatic plants, fish kills are unlikely to occur. Buglewicz (1985) found a weak thermal but strong oxygen stratification in

one borrow pit. This pit had mean and maximum depths of 7.2 and 17.7 feet, respectively. Its surface area was only 6.7 acres. Most of the 40 Kansas farm ponds studied by Tiemeier and Moorman (1957) had dissolved oxygen concentrations <4 ppm at depths exceeding 6 feet. Of the 84 dissolved oxygen measurements made at a depth of 6 feet, 29 percent were below 0.5 ppm. The likelihood that many Lower Mississippi River borrow pits stratify is indicated by the fact that dominant macroinvertebrates in the pits (phantom midges and tubificid worms) are highly tolerant of low dissolved oxygen concentrations (Cobb et al., 1984).

25. Excavation to minimize the amount of shallow area may benefit borrow pit fisheries. Pond construction experts commonly recommend minimizing the amount of area that will be <2 or 3 feet deep (Bennett, 1971; Dillon et al., 1977; Summers, 1984) to limit aquatic plant growth and enhance fishability. However, water-level fluctuations of the magnitude that occurs in most borrow pits would tend to discourage aquatic plant development.

26. The development of a harvesting basin could be extremely valuable for commercial fisheries in borrow pits. In a sense, most borrow pits act as harvesting basins because they concentrate fish in relatively small areas after floodwaters recede in spring or summer. Borrow pits often have gradual bottom slopes of 25H:1V on the riverward side of the pit. Harvesting basins as described by Grizzell (1967) for commercial ponds require a drawdown by release of water through a drain. Water would have to be pumped from excavated borrow pits, unless additional excavation and construction were undertaken to build water-control structures.

#### Wildlife

27. Depth influences the value of borrow pits as wildlife habitat, although some species are affected more directly than others. Pools created by borrow pits provide water and a diversity of habitat for many species. For example, 23 species of wild mammals and 186 species of birds were observed in and around Lower Mississippi River borrow pits (EL, 1985). However, few of these species are absolutely dependent on standing water. Only the aquatic or semiaquatic species require standing pools of water.

Most species may benefit from having borrow pits nearby but would still occur in the area if borrow pits were absent.

28. Where possible, it is important to provide depths adequate to ensure a year-round supply of water. Borrow pits excavated to a maximum depth of 5 or more feet and a mean depth of at least 3 feet should hold adequate water for wildlife all year. Maximum and mean depths of seven borrow pits that either dried or almost dried up in 1981 (EL, 1985) averaged 4.7 and 2.5 feet, respectively. The four pits with the greatest water-level reductions had an average maximum depth of 3 feet and a mean depth of 1.6 feet. Observations by the Environmental Laboratory (1985) provide justification for designing pits to hold some water year-round: optimal pit design was one with depths adequate to maintain some water during drought, as these pits afforded both shallow- and deep-water areas. In general, the best habitat for birds and mammals was provided by pits >6 feet deep. Although mammal species were slightly more abundant around shallow pits than deep ones, differences were not significant. Borrow pits 6 feet deep or deeper, which partially dried out and yet retained some standing water, were used most often by water birds, waterfowl, raptors, nonperching birds (e.g., woodpeckers and kingfishers), and perching birds. They also supported more species and more total nests. Only shorebirds used shallow pits that tended to dry up. Because permanent standing water in borrow pits usually did not exceed 10 feet in depth, all pits were shallow enough to provide the variable depths required by different animals. Water depth was not important to gulls or terns.

29. If 25 percent or more of the borrow pits adjacent to a reach of levee were deep enough to retain water all year, the loss of water from the remaining pits would be inconsequential to wildlife because of the availability of other pits nearby. Although one of four pits may dry up, the close proximity to a deeper permanent pit could reduce the vulnerability of water-dependent species to predators or desiccation.

30. An ephemeral pool can benefit wildlife by providing habitat variety. Most aquatic or semiaquatic species are capable of relocating to

permanent bodies of water. The Environmental Laboratory (1985) report mentioned beavers temporarily leaving ephemeral borrow pit pools when the pools dried up. As a shallow pit slowly dried out, its avian inhabitants would change from water birds such as anhingas and cormorants to waterfowl and wading birds, and finally to shorebirds that foraged on exposed mudflats. Hundreds of feeding herons, egrets, and ibises frequented drying pools where fish were trapped. Colonization of the pit bottom by wetland grasses and nutsedges provided wildlife food in the form of green leaves or seeds.

31. Perennial borrow pools also exhibited changes in use similar to those described for ephemeral pools in the previous paragraph. Mudflats exposed during periods of water-level recession attracted shorebirds, and shallower depths encouraged increased feeding by wading birds. Bird use also was high in large, deep borrow pits with diverse habitats created by islands, a series of connecting pools, and breached berms (EL, 1985).

32. Excavating borrow pits to a variety of different depths may greatly increase the diversity of wildlife by increasing the diversity of the habitat. Shallow areas <2 feet deep may encourage the development of aquatic vegetation, provided that water levels do not recede early in the year and the pits are not heavily grazed by cattle. An almost complete absence of aquatic plants were observed in borrow pits that were heavily grazed; depths of flooding, water flow, and cattle grazing were identified as limiting factors (EL, 1985). Deep waters (>3 feet) discourage aquatic plant development (Boyd, 1968; Summers, 1984) and can provide open water adjacent to vegetative cover. This increased edge and habitat diversity is important to many species of wildlife including ducks. Permanent water in deep borrow pits seldom supports aquatic plants, except for small floating species. Studies of northern wetlands indicate that ratios of 1:1 or 2:1 (ratio of vegetation to open-water areas) are most productive of waterfowl (Yoakum et al., 1980; Hobough and Teer, 1981; Kaminski and Prince, 1981). However, during 2 years of observations at 26 borrow pits along the Lower Mississippi River, the Environmental Laboratory (1985) noted that waterfowl use was low at all sites throughout the year and that few ducks nested in

borrow pits. Low use by ducks probably can be accounted for by water depth, water-level fluctuation (flooding), and a resultant lack of appropriate food and cover in Lower Mississippi River borrow pits. Use was mainly in winter and during migration.

33. Islands in borrow pits and wetlands are valuable for attracting wildlife because they provide safe resting sites and isolation. They are heavily used by birds, including waterfowl (Sherwood, 1968; Johnson et al., 1978; Giroux, 1981; Duebbert, 1982) in northern states, water birds (McIntyre and Mathison, 1977), shorebirds (Fager and York, 1975), songbirds, and raptors, as well as small mammals such as muskrats and beaver (Landin, 1980). Turtles and other reptiles also use islands. Populations of nongame birds may be more diverse and dense on islands than at upland sites (Giroux, 1981).

34. Islands are valuable additions to borrow pits of all sizes but are most practical for larger ones. Giroux (1981) concluded that a wetland pool should be at least 600 feet wide and 30 inches deep for an island to be worthwhile for waterfowl nesting. If borrow pit length and width were both 600 feet, a borrow pit would have to be about 10 acres for one 2-acre island. The 3-foot minimum depth, which was recommended to discourage predators from wading to islands with young waterfowl, is a good idea for borrow pits for another reason, i.e., because water levels commonly recede 3 feet during summer.

35. Small islands in borrow pits provide valuable resting areas as well as denning sites for furbearers (EL 1985). Johnson et al. (1978) and Giroux (1981) listed the optimal size for waterfowl islands as 0.1 to 0.5 acre. Staff of the Environmental Laboratory (1985) observed that large borrow pits usually had larger wooded islands that provided safe resting places and habitat for water birds and waterfowl, but few of these exceeded 1 acre in size.

36. Islands in borrow pits may consist of unexcavated areas that are left with vegetation, or they may be built up with additional materials. The former type would be less costly to develop, particularly if at the island site there was a thin blanket of impervious materials that would not be

excavated. Islands probably occur in large borrow pits for this reason. Adding borrow materials to elevate unexcavated islands would make them more vulnerable to erosion until vegetation was thoroughly established. Unvegetated islands should be seeded immediately after construction. Some knowledge of historical flooding regimes, including time of year, duration, and magnitude, would be invaluable in designing islands.

37. Slopes of an island's sides should be gradual enough for wildlife to gain access to and from the water, i.e., 4:1 to 5:1. The Soil Conservation Service (1971) recommended slopes of 4:1 for livestock. Very gradual slopes are undesirable because receding water levels will make islands accessible to predators or humans when peninsulas are exposed.

38. Costs associated with island or peninsula construction vary with the construction method used and site-specific conditions. Costs, in 1981 dollars, for constructing optimal sized islands of 0.1 to 0.5 acre ranged from \$52 to \$177 per island (Hynson et al., 1985). The basic cost of constructing a peninsula or island (30 feet wide, with 4:1 slopes, raised 2 feet above the controlling elevation) is about \$7 per yard of length. Assumptions in this estimate are as follows: (a) there is no significant cost for not excavating material that will form islands or peninsulas, (b) 5.8 cubic yards of borrow material per linear yard of length must be hauled onto islands or peninsulas to raise them 2 feet above the controlling elevation, and (c) the cost of hauling is \$1.20 per cubic yard--the unit cost of hauling borrow to form a berm (US Army Engineer District, Vicksburg, 1980). A 50-yard-long peninsula or island with the above dimensions would have had a basic cost of approximately \$350 in 1980. Assuming that the area of this peninsula 3 feet below the controlling elevation would be 900 square yards  $[(4 + 10 + 4) \times 50 \text{ yards}]$ , about 0.20 acre of additional right-of-way would be required to meet additional borrow needs. Using \$900 per acre as an estimate of the unit cost of riverward lands (US Army Engineer District, Vicksburg, 1980), the additional cost of right-of-way would be about \$180, bringing the total cost to \$530 for one 50-yard-long peninsula or island. This cost estimate would be substantially less if a significant portion of

the material in the peninsula or island were unsuitable as borrow and would not be excavated.

### Basin Size, Slope, and Shape

#### Fish and Fisheries

39. The surface area of most levee borrow pits is adequate to support fishing. The mean and median surface areas of 25 main stem borrow pits sampled by Cobb et al. (1984) and Buglewicz (1985) were 20 and 13.9 acres, respectively, and the range was from 3.3 to 53.4 acres. Minimum sizes of ponds have been established on the basis of anticipated fishing pressure (Edminster, 1947). Most researchers set 0.4 acre as a minimum for a single-family pond, with 1 to 2 acres being ideal (Edminster, 1947; Summers, 1963; Soil Conservation Service, 1971). Bennett (1971) concluded that ponds <1 acre were unsatisfactory for fishing. Summers (1984) concluded that ponds used for watering livestock and fishing should be from 3 to 5 acres. Ponds open to the public should be at least 5 acres according to the Soil Conservation Service (1973). Highway borrow pits in Illinois are considered most valuable for public fishing when they exceed 25 acres (Lopinot et al., 1973). Although the standing crop of fish per acre is not related to the size of ponds (Carlander, 1955; Jenkins, 1958; Turner, 1960) or borrow pits (Cobb et al., 1984), larger surface areas of suitable depth provide a proportionally larger fishery resource. For example, at an average standing crop of 595 pounds/acre (Cobb et al., 1984), a 25-acre pit could support 14,875 pounds of fish, as opposed to only 5,950 pounds in a 10-acre pit.

40. The current practice of excavating separate borrow pits ranging from about 3 to 50 acres is compatible with fishery needs. Experience has shown that several isolated gravel-pit ponds are more easily fished and managed for fishing than a single large pit (Bennett, 1971). However, river-side borrow pits are rarely managed for fishing, nor are they particularly conducive to fishery management because of annual flooding.

41. If larger borrow pits were desired to provide fishing opportunities, new pits might be made continuous with old ones. Some advantages include creation of a larger trap for fish and reduced requirements for clearing, hauling, and rights-of-way acquisition. Large continuous pits also would provide more area for fish and wildlife. A major disadvantage may be that open-water areas of large borrow pits cannot be fished effectively from shore. However, the effectiveness of shore fishing is as much a function of basin slope and shoreline shape as it is of surface area. In addition, much of the fishing in borrow pits is conducted from boats.

42. To enhance pond fisheries, basin slopes usually are designed to limit aquatic plant development and to make waters as fishable as possible. Aquatic vegetation is more likely to become established on gradual slopes <2 to 3 feet deep. Anglers benefit from having relatively deep water close to shore, as shallow waters rarely provide suitable habitat for harvestable fish. Therefore, the most commonly recommended slope for pond sides is steep, i.e., 3:1 (Viosca, 1937; Edminster, 1947; Grizzell, 1967; Gabelhouse et al., 1982). Occasionally the 3:1 slope is specified to a particular depth, such as 3 feet (Soil Conservation Service, 1971) or 6 feet (Lopinot et al., 1973). Slopes of 2:1 or steeper can be maintained only with clay soils (Edminster, 1947) and can be unstable or too steep for angler safety. Lopinot et al. (1973) recommended slopes of no more than 6:1 above maximum pool elevations to minimize erosion and allow easy access to the water edge. Slopes  $\leq 4:1$  also can be mowed safely.

43. Occasionally, gradual slopes are recommended to provide spawning habitat for fish. Spawning of sunfishes undoubtedly plays an important role in providing prey for sport fishes in pits where forage-size fishes are seldom abundant (see Cobb et al., 1984). Leedy et al. (1978) proposed leaving a terraced shelf around the 18- to 24-inch depth contour below maximum pool elevation. This design was to provide shallow water near shore for fish spawning and public safety. However, unless such a shelf is constructed at least 3 feet below the controlling elevation of a levee borrow pit, it is apt to be dewatered in summer when lepidomid sunfishes such as bluegills are

still spawning. Spawning of largemouth bass and crappies normally ends by early June.

44. A range of side slopes from 3:1 to 10:1 would provide areas for anglers to fish (steeper slopes) and centrarchids to spawn (gradual slopes). The advantage of steep slopes to anglers is that they can readily fish deep waters from shore. The density and biomass of fish (large fish in particular) in 25 borrow pits were significantly higher on the deeper side of pits (opposite the levee) than on the shallow levee side (Cobb et al., 1984). Gradual slopes of 6:1 or 10:1, as are often proposed for the downstream ends of traverses (US Army Corps of Engineers, 1978), would provide centrarchid spawning habitat at a wide range of water levels.

45. The value of specifically designing pits to provide spawning habitat may be questionable, inasmuch as centrarchids are capable of spawning at a wide range of depths encompassing most of the depths in Lower Mississippi River borrow pits. For example, bluegills have been observed to nest at depths of 8.2 to 10.8 feet (Swingle and Smith, 1943), although nests are commonly found at depths ranging from 0.5 to 4 feet. Largemouth bass nests are usually built at depths of 4 to 6 feet (e.g., see Jester, 1971), although they have been observed to nest at depths ranging from 6 inches to 18 feet (Heidinger, 1975). In addition, even the deepest borrow pits have substantial areas of water at suitable depths for centrarchid spawning (based on data of Buglewicz, 1985, and Cobb et al., 1984). About 76 percent of the 25 pits studied had mean depths <4 feet.

46. Relatively steep sides and a flat, gradually sloping bottom in a borrow pit also may be beneficial to certain species of benthos. The density of the most abundant benthic invertebrate (the phantom midge) in 25 borrow pits was positively correlated with a volume development index [ $3 \times (\text{mean depth}/\text{maximum depth})$ ] as was the diversity of all benthos (Cobb et al., 1984). A high volume development index ( $>1$ ) indicates that the basin shape is concave, whereas an index  $<1$  indicates that the basin shape is convex. A maximum index of 3 would be obtained in a cylinder, where mean and maximum depths are equal and the sides are vertical. The relation between phantom

midge density and volume development is not surprising. The phantom midge inhabits the deepest bottom areas during the day to avoid fish predation and migrates into the water column at night to feed on zooplankters. Thus, it benefits by having more deep bottom area relative to surface area. Its high tolerance of low-oxygen tension, need to avoid predators, and ability to exploit the water column would reduce the value of nearshore shallow waters. Another reason steeply sloped sides may be advantageous to benthos is that receding water levels expose substantially less benthic habitat per unit change in elevation than they would over a very gradual slope. In Lake Francis Case, South Dakota, Benson and Hudson (1975) found that densities of benthos were five times higher on substrates that were not dewatered in the previous year than they were when the same substrates had been exposed the year before.

47. A concern in shaping borrow pits for fisheries is to avoid highly rectangular pits and those that cannot be fished effectively from shore. The shape of borrow pits is more important for aesthetics and fishermen than it is for fish. Although straight-line rectangular shapes are the easiest to excavate, they do not have the aesthetic qualities of pits with more curved shorelines. Lopinot et al. (1973) recommended blending the pit elevation contour into existing contours or at least gently curving it into irregular shapes. Abrupt corners are the most visually obvious indicator of a man-made pool. The value of fisheries can be enhanced by slight changes in size or shape during excavation (Leedy et al., 1981). Irregular but gently curved shorelines, occasionally with peninsulas, provide anglers with a variety of vantage points for shore fishing, the primary fishery of borrow pits. Traverses (US Army Corps of Engineers, 1978) are valuable for fisheries because they provide additional fishing sites and allow anglers access to the deeper side of pits near the foreshore where more and larger fish apparently congregate (Cobb et al., 1984). Relatively long and narrow pits allow shore anglers to fish a larger percentage of the area. By contrast, large pits approaching square or circular shapes leave a large proportion of the pool unfishable from shore.

48. The number and biomass of sunfishes (Lepomis spp.) in 25 levee borrow pits were highly correlated with a shoreline development index (Cobb et al., 1984). The index is a comparative value relating shoreline length to the circumference of a circle with the same surface area. Values of the index range from 1 for circular lakes to over 30 in dendritic reservoirs such as Cumberland Lake, Kentucky (34.5). In 25 borrow pits, the index ranged from 1.2 to 3.4 (Cobb et al., 1984), reflecting the amount of shoreline and supposedly shallow nearshore "littoral area" relative to surface area. The index can be misleading in that long, narrow borrow pits tend to have the highest index. The entire area of shallow circular pits would be comparable to littoral area. Bergstrom et al. (1971) suggested leaving about one-third of highway borrow pits less than 3 feet deep as an alternative to creating irregular-shaped shorelines for aquatic organisms.

#### Wildlife

49. The diversity of wildlife tends to be positively correlated with the size of borrow pits, as it is in wetlands and ponds. The tendency appears to be particularly true in the case of waterfowl (Catchpole and Tydeman, 1975; Evrard, 1975; Flake et al., 1977; Hobough and Teer, 1981). The study by the Environmental Laboratory (1985) found that borrow pit size was positively associated with both the number and variety of mammals observed at pits over 2 years. Pits >30 acres attracted more species of mammals in larger numbers than smaller pits. Only nutria occurred in higher numbers in pools <10 acres. For all groups of birds except shorebirds, higher numbers were observed at borrow pits larger than 30 acres.

50. Ultimately, the need for borrow materials will dictate borrow pit size, but efforts should be made to minimize unnecessary clearing of bottomland hardwoods. Bottomland hardwood forests are extremely valuable habitat for wildlife (Fredrickson, 1978, 1980) and are becoming increasingly scarce as farmlands are developed (MacDonald et al., 1979). Advantages of limiting excavation area at sites with bottomland hardwoods include protection of levees from flood currents with a buffer of trees, improved aesthetic values, and retention of optimum habitat for many species of wildlife and fish.

51. Some studies have suggested that a series of small wetland areas might be more productive for birds than a single large wetland. For waterfowl nesting, visual isolation among nesting pairs would be increased in a series of small pools (Derrickson, 1979). However, the low use of Lower Mississippi River borrow pits for wood duck nesting (EL, 1985) makes this suggestion seem irrelevant. Nevertheless, other animals would benefit from increased visual isolation and habitat diversity (e.g., woodpeckers and warblers). Fredrickson and Taylor (1982) concluded that a group of small impoundments provides more flexibility than a single large one because features used to attract one group of wildlife do not preclude attracting another group to an adjacent area.

52. Pits excavated to create a variety of basin slopes are most desirable for wildlife. Gradual slopes, as recommended for the upstream and downstream ends of riverside pits (US Army Corps of Engineers, 1978), benefit wading birds and mammals when inundated and shorebirds when exposed. Fredrickson and Taylor (1982) listed amphibians, dabbling ducks, shorebirds, and raccoons as examples of animals attracted to mudflats. Dabbling ducks also prefer shallow areas 12 to 18 inches deep (Chabreck, 1979). Gradual bottom slopes provide more area in this depth range than steeper slopes. Having gradual and steep slopes in the same pit may help to develop a good ratio of aquatic vegetation to open-water area. Such diversity and edge in turn improve wildlife habitat. Gradual slopes on upstream and downstream ends of a pit also are desirable to provide mammals and birds with safe access to water in summer and fall after water levels have receded. Steep slopes (2:1 or 3:1) to deep water may limit development of aquatic vegetation, thereby providing open-water habitat. Having deep water near a steep bank may provide a refuge from predators for fish and swimming birds and mammals. Beavers and muskrats often burrow into steep banks of islands or pit sides to make dens (Fredrickson and Taylor, 1982; EL, 1985).

53. Irregularly shaped pools or wetlands generally provide the best habitat for wildlife because of the amount and diversity of edge created.

Waterfowl use has been positively correlated with shoreline indices indicative of the irregularity of wetland shape (Mack and Flake, 1980). Islands may significantly increase the amount of shoreline relative to surface area.

#### Structure and Cover

54. Structural complexity of aquatic and terrestrial habitats is extremely important in determining the kinds and abundance of fish and wild-life species that will inhabit an area. Schnick et al. (1982) defined structure as "irregularities of substrate or relief, either artificial or natural, living or non-living, which are concave or convex." Structure can be created by natural vegetation, the addition of natural or man-made materials, or excavation of irregularities in the land. Cover refers collectively to those features which provide natural shelter and protection for animals.

#### Fish and Fisheries

55. Cover in the form of vegetation or other natural or man-made materials concentrates fish, provides spawning habitat and shelter for certain species, and a surface for the attachment of fish-food organisms (Prince et al., 1975). It provides escape cover for small fish and thereby influences predator-prey interactions (Schnick et al., 1982). The flooding of terrestrial vegetation around lake margins has been linked to increased survival of juvenile sport fishes such as largemouth bass (von Geldern, 1971; Aggus and Elliott, 1975; and others). Although the presence of vegetation is beneficial, a veritable jungle impedes fishability, particularly from shore. Some grazing or mowing of herbaceous plants is therefore beneficial for fishing.

56. Several important sport, commercial, and prey fishes common to borrow pits are concentrated by cover. Under favorable conditions, the increased biomass of fish near cover can be spectacular. Pierce and Hooper (1979) compared the biomass of fish collected from two 1-acre brush shelters with that from nonsheltered areas during the 1978 rotenone sampling of the

210-acre Crooked Creek arm of Barkley Lake, Kentucky. Sport fishes and their ratios of biomass in sheltered versus nonsheltered areas were as follows: largemouth bass, 7:1; bluegill, 18:1; white crappie, 12:1; and channel catfish, 5:1. Total fish standing crop was 2,157 pounds/acre in sheltered areas and 884 pounds/acre in the remainder of the arm. Willis and Jones (1984) also reported significantly higher standing crops of sunfishes, crappies, largemouth bass, freshwater drum, buffalofishes, and river carpsuckers in timbered than in nontimbered coves in seven Kansas reservoirs. Standing crops of white bass, gizzard shad, and walleye (open-water species) did not differ significantly among timbered and nontimbered coves.

57. Concentrating fish with natural or artificial cover may also attract anglers and increase harvest at these locations. Ploskey (1985) reviewed previous studies on angling pressure and harvest of sport fish near cover in North American reservoirs and documented many instances where natural or artificial shelters or standing timber concentrated anglers. While this resulted in an increased harvest near the sites because of greater use by anglers, catch rates frequently did not differ significantly from those in nearby areas which contained no cover. Increased harvests, particularly of centrarchids, were associated with the congregation of fish and anglers in areas with cover.

58. The total quantity of cover present in a body of water determines its value for influencing predator-prey interactions and concentrating fish. Crowder and Cooper (1979) and Savino and Stein (1982) demonstrated that intermediate levels of cover in the form of submerged vegetation or artificial materials optimized fish production. Too little or excessive amounts of cover produced suboptimal foraging conditions. Similarly, the quantity of cover influences its value in concentrating fish. Jenkins (1970) suggested that large quantities of cover diminished the concentration of fish at specific locations in reservoirs, whereas cover placed in otherwise bare areas was highly effective in concentrating fish. During the Lake Barkley study, only about 2 acres (0.9 percent) of the 210-acre Crooked Creek area contained shelters (Pierce and Hooper, 1979). Wilbur (1974) also recommended very

small areas of brush (0.01 percent of the total area) in lakes larger than about 1,000 acres. The US Army Engineer District, Mobile, has recently established areas of natural cover equal to about 1 percent of the total lake acreage of the Tennessee-Tombigbee Waterway. However, the approach has been only moderately successful to date, as extensive areas of natural vegetation in the recently formed impoundments provided an abundance of cover (Sims, 1982; Timmons and Garrett, 1985).

59. Man-made structures of brush or artificial materials could have considerable environmental value for fish if they were placed in a pit during construction. Borrow pits are usually relatively smooth, shallow depressions that afford minimal cover for fish. Large seasonal fluctuations in water level are conducive to the development of terrestrial vegetation within the fluctuation zone. Depending on the season when construction occurs, vegetative regrowth begins around the margins of new pits soon after construction activities cease. The types and rate of vegetative regrowth at any particular borrow pit are determined by the surrounding vegetation, seeding practices, and the duration and seasonal pattern of flooding, as modified by the combined effects of grazing and other agricultural activities. After grasses are well established, some grazing or mowing of pit margins would increase fishability for shore anglers. Natural woody materials such as hardwood trees or root balls pushed into the deepest areas of new borrow pits would provide cover for fish; above-water portions would provide resting sites for turtles and some species of birds, and snags could be used by cavity-nesting birds. Woody materials may require anchoring to keep them from drying out during periods of low water and then floating away when the pit refloods. A relatively small number of hardwoods such as oak, maple, or hickory trees would provide an immediate source of cover that could last for years. However, use of hardwoods should be limited to pits that would provide permanent pools.

#### Wildlife

60. The use of cover for creating diversity in borrow pit habitats is important for wildlife. The quality and quantity of cover determine the

presence and abundance of many wildlife species. Wildlife cover can include a variety of features such as ditches, ground burrows, or brush; however, it is primarily terrestrial plant communities that determine habitat suitability for wildlife. Plant communities provide escape cover and protection from inclement weather (Yoakum et al., 1980), as well as sites for feeding, nesting, and roosting.

61. Compared to mammals, the avian fauna of the Lower Mississippi River is extremely diverse, and some species will be well adapted to most of the major vegetative assemblages surrounding borrow pits. Specific environmental considerations may therefore apply only to certain species, and it should be recognized that actions benefitting one species may be detrimental to others.

62. Construction activities are usually limited to the area immediately surrounding a borrow site, and actions to improve wildlife habitat involve the "edge" or margin between the borrow pit and the surrounding floodplain. Many wildlife species utilize areas where two habitats meet (Yoakum et al., 1980). These areas may support communities of plants and animals not found in other locations. Cavity-nesting birds have been found to be the most common nesting forms near borrow pits because snag habitat was abundant around the margins of existing borrow pits (EL, 1985). Other forms such as the prothonotary warbler nest in cavities over water, and red-winged blackbirds use button bushes for nesting (Fredrickson, 1978). Summer residents of borrow pits such as herons and egrets are closely associated with foraging sites. Borrow pits that provide good feeding habitat for these forms have greater potential environmental value if they also provide large trees for roosting and nesting habitat around the margin.

63. Bird habitat can be improved by having a mixture of mature trees and understory vegetation in the fluctuation zone and around the margins of borrow pits, particularly if they provide vertical diversity. Large trees provide nesting sites for some species of songbirds and perches for water birds and shorebirds (EL, 1977; Fredrickson, 1978). A mixed understory of shrubs and herbaceous plants affords isolation, protection, and nesting

sites for many passerine and upland species (Landin, 1979). Seasonal fluctuations in water levels and annual variations in the extent and duration of flooding keep the understory in early stages of succession and encourage the production of seed-bearing plants, which are valuable food sources for many species of wildlife.

64. Many species of woody plants will colonize the margins of new borrow sites when construction is completed, but it takes several years for trees to grow large enough to benefit wildlife. When present, large trees should be left standing around the margin of new borrow pits to provide a partial canopy. The most valuable species are those with high food value for wildlife, i.e., trees that produce berries, fruits, or nuts. Retention of a limited number of trees with cavities provides cavity-nesting sites or dens for some wildlife. Two to four den trees per acre is adequate (Yoakum et al., 1980).

65. Selective seeding or planting of borrow pit construction sites can speed revegetation, reduce erosion, and encourage the development of plant species with high food and cover value for wildlife. Flood tolerance is a primary consideration for establishing vegetation within the leveed floodplain, and native species common to a particular flooding regime should be planted whenever possible. Yoakum et al. (1980) recommended planting mixtures of native plants to ensure that at least some species would survive. They also recognized that perennial species had a greater long-term value than annual forms. To maximize plant survival, Hynson et al. (1985) recognized that plants should be matched to a particular set of environmental conditions and suggested identifying plant species adapted to a specific set of climatic, soil, and topographic features during preconstruction site surveys. This effort should include consultation with a wildlife planning specialist to ensure selection of species of high wildlife value. Flood tolerances of many plant species common to the Lower Mississippi River floodplain have been summarized by Whitlow and Harris (1979), Klimas et al. (1981), and Fredrickson and Taylor (1982).

66. Intensive cattle grazing is generally considered to be detrimental to the development of shoreline vegetation around borrow pits. Cattle feed extensively on seed plants growing in the fluctuation zone. Almost without exception, manuals for farm-pond construction recommend fencing livestock away from water (Soil Conservation Service, 1971; Gabelhouse et al., 1982; and others). Hoffman and Stanley (1978) recommended restrictive grazing of cattle in the fluctuation zones of Lakes Oahe and Sakakawea on the Upper Missouri River as a means of enhancing habitat for fish and wildlife. Although cattle grazing may have some negative impacts on fish and wildlife resources, it does help to minimize overgrowth of vegetation that can impede access by fishermen.

67. Brush piles made from woody materials removed during borrow pit excavation provide good cover for many small species of wildlife. Placed on the river side of newly excavated borrow areas, these materials could provide concealment from predators, nesting and rearing sites, and protection from inclement weather for many small animals (Yoakum et al., 1980).

68. Brush shelters pose some engineering problems, as they are subject to being dislodged during flooding and can present problems of erosion or damage by animals if they are located at the toe of the levee (Hynson et al., 1985). Care should be taken in site selection so that these structures do not obstruct access. Brush piles are most beneficial in areas of relatively sparse cover. Yoakum et al. (1980) recommended that brush piles be used as a by-product of other land treatments involving clearing. They should be small enough so as not to restrict movements of large mammals. For small animals, brush piles can be rectangular (25 to 50 feet long by 10 to 15 feet wide) or circular (10 to 15 feet in diameter) and 3 to 4 feet high. As with brush shelters for fish, brush piles constructed to benefit wildlife should be placed at wide intervals. One structure for each 2.5 acres of land is recommended (Yoakum et al., 1980). In areas subject to high-velocity flows during flooding, these structures need to be anchored.

## Erosion Control and Sedimentation

69. Sedimentation will alter fish and wildlife habitat, but it is a natural process over which man has little control. Changes associated with long-term sedimentation are likely to include increased development of aquatic plant life, degraded habitats for fish and wildlife that prefer deeper waters (e.g., beaver, cormorants, anhingas), and improved habitat for wildlife preferring shallow pools (e.g., amphibians, some small mammals, shorebirds, wading birds). Deeper excavation can prolong pit longevity. Further investigation is needed to determine rates and impacts of sedimentation in borrow pits.

70. The small grass-covered watersheds of most borrow pits are unlikely sources of suspended colloidal material unless the levees or other watershed areas are left barren. Pond experts and the US Army Corps of Engineers (1978) have long recognized the importance of seeding pond or borrow areas with herbaceous vegetation immediately after construction activities cease. Herbaceous vegetation reduces erosion, and, when flooded, decays and precipitates colloidal clay particles (Irwin, 1945). Most pond construction experts emphasize the importance of fencing livestock out of pond areas to reduce erosion (e.g., see Summers, 1963, 1984; Soil Conservation Service, 1971, 1973; Lopinot, 1972; Gabelhouse et al., 1982). Fencing is beneficial as it reduces damage to fish and wildlife habitat. Erosion and turbidity reduce aquatic productivity by decreasing photosynthesis; trampled and overgrazed vegetation is of little value to wildlife. Another important reason for fencing is to protect the health of livestock that will foul their own drinking water.