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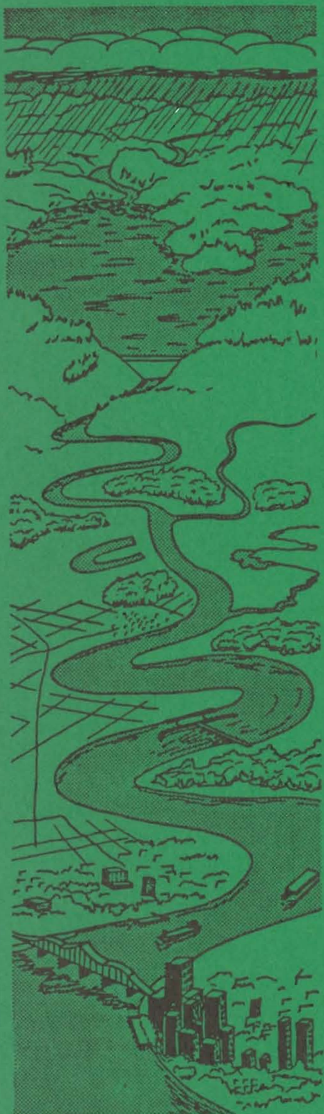

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ENVIRONMENTAL FEATURES FOR STREAMSIDE LEVEE PROJECTS

by

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

This study provides designers of levee projects with guidance for incorporating environmental enhancement features into project design and maintenance. Forty-six environmental features were identified by information review as having potential to improve fish and wildlife habitat, recreational use, and esthetic qualities of lands and water associated with levee projects. Information was obtained from review of scientific literature and planning documents as well as contact with US Army Corps of Engineers personnel and site visits to selected completed levee projects. (Continued)

PREFACE

This report was sponsored by the Office, Chief of Engineers (OCE), US Army, as part of the Environmental and Water Quality Operational Studies (EWQOS) Work Unit VIB entitled "Design and Construction Techniques for Waterway Projects to Attain Environmental Water Quality Objectives." The OCE Technical Monitors for EWQOS were Mr. Earl Eiker, Dr. John Bushman, and Mr. James L. Gottesman.

This study was conducted under Contract No. DACW39-82-C-0027 between the Center for Natural Areas (CNA) and the US Army Engineer Waterways Experiment Station (WES). The contract was administered by Mr. F. Douglas Shields, Jr., Environmental Laboratory (EL), under the general supervision of Dr. John Harrison, Chief, EL. Program Manager of EWQOS was Dr. Jerome L. Mahloch, EL.

In addition to the authors, several individuals provided valuable technical and professional services to the study. Several individuals from the consulting engineering firm of Waldemer S. Nelson and Company, under the direction of Mr. Mervin Morehisor, provided technical review and supplementary material for the report. Ms. Debra Romanella, working through CNA, greatly assisted through her efforts of information collection and review. Mr. Just Mueller, working through the professional landscape architecture firm of Mitchell-DeWan Associates, performed a similar function. Graphics and illustrations for the report were prepared by Mr. William C. Reed, CNA.

Individuals too numerous to mention from a variety of US Army Corps of Engineers (CE) Districts and Divisions and WES graciously gave of their time to provide information and/or review for early products of the study. Divisions that provided information for the study included Lower Mississippi Valley, New England, and Southwestern. Districts included Vicksburg, Rock Island, Huntington, Los Angeles, Sacramento, Walla Walla, San Francisco, Omaha, St. Louis, Jacksonville, New Orleans, Memphis, Portland, Seattle, St. Paul, Philadelphia, Chicago, Norfolk, Baltimore, Kansas City, Alaska, and New York.

Special acknowledgment is due several CE District offices for

CONTENTS

ENVIRONMENTAL FEATURES FOR STREAMSIDE LEVEE PROJECTS

PART I: INTRODUCTION

Background

1. The US Army Corps of Engineers (CE) is committed to implementing the National Environmental Policy Act (NEPA) and other environmental statutes, regulations, and executive orders. The CE has issued several documents that contain general environmental guidelines and policies (see Shields and Palermo (1982) for a review). Specific design guidance to implement these guidelines and policies is still needed. The CE is currently conducting the Environmental and Water Quality Operational Studies (EWQOS) research program to address high-priority environmental problems. Part of this program will provide environmental design and construction guidance for specific types of waterway projects. This guidance will be used by CE field offices to implement Federal and CE environmental policies.

2. Environmental guidelines for four main types of projects have been produced under EWQOS: flood-control channels (Shields 1982, Nunnally and Shields 1985), river training dikes (Burch et al. 1984), streambank protection (Henderson and Shields 1984), and levees. Background information is available from Thackston and Sneed (1982) and Shields and Palermo (1982). These project categories were set up in an arbitrary fashion to facilitate information collection and review, and there is some overlap (Shields and Palermo (1982) and Thackston and Sneed (1982), for example, contain limited information on levees).

Engineering Overview

3. A levee is an embankment whose primary purpose is to furnish flood protection from seasonal high water and which is therefore subject to water loading for periods of only a few days or weeks a year (US Army,

adding extra material needed to reduce seepage or slope instability. Levees may or may not have berms, depending on design. Access roads are commonly placed on levee crowns to enable inspection, repair, maintenance, and flood fights in the most efficient manner possible.

6. A major consideration in levee design is the quality of the foundation and embankment materials. Since flood protection for specific areas is the main objective in determining levee locations, foundation materials are often less than ideal from a structural standpoint. Foundation materials are examined to determine their potential for subsidence and underseepage. Significant quantities of material are required for levee embankment construction, and it is usually taken from the most convenient possible source in order to minimize cost. Therefore, embankment materials are often of less than optimum quality, and may be prone to seepage, erosion, and slope instability.

7. Levee failure during high water can occur without warning, and thus constitutes a threat to both property and life. Therefore, it is important to ensure levee integrity. Potential failure mechanisms include seepage, erosion, slope instability, and overtopping. Seepage occurs through or under the levee; once it begins, seeping water can easily and rapidly create ever larger pathways, until the structure fails. Erosion is caused by flood flow of sufficient velocity and quantity to change the location of soil particles. Slope instability occurs when the shear strength of embankment and/or foundation soils is exceeded. It is often caused by seepage patterns which develop excessive pore pressures in the embankment. Overtopping refers to water passing over the top of the levee. If overtopping occurs in sufficient amounts and for sufficient duration, the levee may be breached due to a washout. Small amounts of overtopping or simply a condition of zero freeboard can also lead to failure by causing seepage patterns to develop on the landside face of the levee.

8. Due to the need to maintain levee integrity, ongoing practices of inspection, maintenance, and flood fighting are prescribed. During inspection, potential seepage areas, location of hazardous vegetation, animal burrows, and sites of active erosion are noted. Maintenance

Resource Programs; these regulations include specific options for taking actions to preserve or enhance critical habitat for fish and wildlife, maintain or enhance water quality, improve streamflows, preserve and restore certain cultural resources, and preserve or create wetlands. CE environmental responsibilities are also outlined in the Digest of Water Resource Policies (US Army, Office, Chief of Engineers 1983). Despite the existence of the aforementioned regulations, the dominant factor controlling the inclusion of many types of environmental features is the authorizing legislation. In some cases, Federal legislation authorizing a project will include authorization of specific environmental features.

OCE approval

12. Different types of environmental features used on CE projects require various levels of approval and different cost-sharing arrangements. Advance approval from the Office, Chief of Engineers, is not required for measures implemented on lands required for project development; features that are required to complete or more fully develop proposed environmental quality measures partly on lands, including mitigation lands, required for water resource development; and features that are more cost effective to implement or manage when directly integrated with the implementation or management of the water resource development (US Army, Office, Chief of Engineers 1980a). Other measures require approval that is based on the (a) level of significance of the environmental quality resource, (b) proximity to proposed development, (c) acceptability and support for CE implementation, (d) certainty of pending loss or significant degradation of the environmental quality resource in the absence of the proposed development, (e) assigned missions of other agencies, and (f) cost effectiveness.

Cost sharing

13. If cost sharing is needed to implement environmental features, project planning must include the development of a letter of intent between the CE and non-Federal interests to meet certain conditions for cost sharing and to obligate the non-Federal interest to operation and maintenance of the environmental features (US Army, Office, Chief of Engineers 1983). For fish and wildlife enhancement, the

Inspection and maintenance

16. Finally, numerous guidelines have been promulgated for inspection and maintenance. Inspections occur immediately prior to the beginning of flood season, immediately after each major high-water period, continuously during flood periods, and otherwise at intervals not to exceed 90 days (33 CFR 208). Routine inspections concentrate on identifying areas of undesirable vegetation; encroachment of buildings, structures, and storage or refuse dumps along the levee; animal burrows; overgrazing; rutting of the crown; settlement of levees; and potentially damaging tree roots, cracks, spalling, and lateral movement of floodwalls (US Army, Office, Chief of Engineers 1967, 1968). Utility pipe crossings through or over the levee are inspected for leaks, piping, and corrosion that could compromise the integrity of the structure. Although not presently a common practice, routine levee inspections could include inspection of environmental features and procedures to determine compliance with provisions of the project plans and environmental impact statements. Inspections during flooding seek to identify sand boils and other irregularities such as caving, scour, and erosion.

17. Maintenance consists of the removal of undesirable vegetation, replanting and management of desirable vegetation, the control of unwanted animals, filling of animal burrows, and repair of damaged or eroded areas (US Army, Office, Chief of Engineers 1967, 1968). Both maintenance and inspection activities include checking stockpiles of materials required during flood emergencies (33 CFR 208).

Purpose and Scope

18. This document's purpose is to provide CE personnel working on levee projects and local sponsors with guidelines for incorporating environmental features into all phases of levee and floodwall projects. Environmental features are defined as measures that enhance aesthetics, fish and wildlife, and/or recreational resources. Measures that have to do with cultural resources are also recognized as environmental features, but receive only limited treatment herein. Although national in

use; basic components of the proposed levee design; and condition of the existing aesthetic, recreational, and ecological resources in the project area. When planning and design documents are available, they normally provide most of this information.

21. With information on the project setting, sections in this document entitled "Purposes" and "Limitations" can be used to generate a list of potentially applicable features. "Purposes" sections enable the reader to identify what resources are enhanced by the feature and thereby cross-reference environmental objectives of the project with the feature; "Limitations" discussions give the reader an idea of what conditions do not lend themselves to incorporation of specific features. Matrices provided in Appendix C allow rapid referencing of environmental features to both appropriate settings and site-specific limitations. Finally, information on the degree to which features have been used in projects successfully is provided in the "Performance" sections.

22. This report is structured so that its different parts can be used at different stages of project development. If a levee is being planned, for example, all parts of the report are applicable but Part II is especially useful since it contains features that can be incorporated as a part of locating and determining the optimum size of the levee. All other parts (III, IV, V) are useful for both projects being planned and completed projects. If the project has already been built, study of the general design memorandum and supporting documents would assist in further clarifying environmental objectives and potential site constraints. Levee enlargements are similar to both planned and existing projects.

23. Information in the "Description" sections is provided to assist users in developing specific designs and consists of sets of instructions on how to implement each. Finally, users can avail themselves of "Costs" sections that were generated from general design memoranda estimates and contract estimates for planned and existing CE levee projects as well as from the scientific literature. Unless otherwise noted, all costs were converted to 1981 dollars using the construction cost index (Anonymous 1982). If more information is desired, sources

PART II: ENVIRONMENTAL CONSIDERATIONS FOR GENERAL DESIGN

24. Environmental features discussed in this chapter address design decisions required for any levee project. These decisions include choosing sites for the levee and associated facilities, determining the proper size of the levee and related structures, and conducting general construction operations. National policy presently dictates that the Corps' decision to recommend a particular project plan normally be based on maximization of national economic benefits. Alternative plans may also be recommended with sufficient justification. This chapter may be used to incorporate environmental considerations into these basic decisions.

Avoidance of Ecologically Sensitive Areas

Purposes

25. Avoidance of ecologically sensitive areas is accomplished for two basic objectives: (a) prevention of loss of wildlife habitat, especially in agricultural or urban areas where habitat is limited and (b) preservation of biologically unique areas.

Description

26. Stream valleys commonly exhibit a wealth of ecologically significant sites such as bottomland hardwood forests and other types of riparian wildlife habitat. Other significant areas (Hynson et al. 1982) often targeted for protection are raptor and/or colonial wading bird nesting sites; big game wintering and migration areas; habitats or rare, threatened, or endangered animals and plants; shorebird roosts; areas with large concentrations of snags or overmature timber essential to many wildlife species; and areas designated by government agencies as important for ecological, scientific, recreational, or cultural purposes.

27. Often, ecologically valuable sites, especially wetlands, are undesirable for levee construction because of the presence of poor foundation materials, lack of convenient supply of suitable embankment

31. For unique areas, some supplementary features may be appropriate. These include land acquisition (paragraphs 290-298) and controlling access (paragraphs 358-365).

Performance

32. The direct effects of levee construction--land use change and habitat destruction--are reduced by entirely avoiding ecologically sensitive areas, although indirect effects such as hydrologic separation will persist. These sensitive areas make significant contributions to environmental quality by providing valuable wildlife habitats. Avoidance of sensitive areas helps to ensure a richer overall diversity of fauna and flora. Habitat preservation is the most effective way to ensure that populations of fish and wildlife remain viable.

33. Based on interviews with a variety of CE environmental branch personnel at the District level, avoidance of ecologically sensitive areas is a technique routinely employed with success. Many of these personnel indicated to the study team that many, if not most, of their potential environmental conflicts were resolved in this manner.

34. A variety of planning and design documents for CE and US Department of Agriculture Soil Conservation Service (USDASCS) flood protection projects also indicate that the avoidance of sensitive areas is a commonly used technique. For example, plans for a levee on the Missouri River (US Army Engineer District, Omaha 1976) called for existing private levees to be preserved because those areas contained extremely valuable wildlife habitat. Likewise, works were to be designed to disturb existing natural features as little as possible for a project in Monticello, Iowa (US Army Engineer District, Rock Island 1974a). Likewise, projects along the Sweetwater River (US Army Engineer District, Los Angeles 1982) and the San Luis Rey River (US Army Engineer District, Los Angeles 1981) in California and in the Wyoming Valley of Pennsylvania (US Army Engineer District, Baltimore 1981) proposed avoiding locating structures within wetlands. Within the Sacramento District (US Army Engineer District, Baltimore 1981) proposed avoiding locating structures within wetlands. Within the Sacramento District (US Army Engineer District, Sacramento 1980), borrow pits for one project were to

alternatives for levee alignment. Such changes in overall length will be reflected in overall project costs. Likewise, variations in levee alignment may result in base elevations that are lower than optimal design. This will increase the amount of clearing and grubbing required as well as the amount of material that must be obtained and placed; thus, overall amounts of area disturbed and project costs may be increased. As noted in paragraph 24, current policy is to select a plan for a project that maximizes national economic benefits (the National Economic Development, or NED, plan) while complying with environmental laws and regulations. Alternative levee alignments based on environmental considerations may not meet these criteria. However, plans other than the NED plan may be recommended if appropriate justification is presented. An example of such justification might include preservation of an environmental amenity (say a view or a scene) prized by the local community.

39. If wetlands are preserved on the landside of the levee, careful and continual examination of foundation materials may be needed to ensure that seepage does not develop through the levee and into the wetland. Where questionable soil exists, a buffer zone between the landside toe and the wetland may be appropriate to permit locating and treating seepage should it occur.

40. Changes in levee alignment to avoid sensitive areas could produce changes in flood-flow velocity depending on the extent that the cross section of flow is changed. Deposition may occur in foreshore wetlands if velocity reduction occurs, or revetment may be necessary if velocity increases sufficiently to cause erosion.

41. Levee construction may result in alterations in the biological system such that values of sensitive areas identified for protection would be lost in any event. Perhaps the most important of such effects is the alteration of flooding regimes which causes areas riverward of the levee to become wetter than their historical norm, while landside sites become drier than preproject conditions and mesic sites all but disappear (Shields and Palermo 1982). Specific implications of flooding regime modifications on various habitat types have been discussed in

46. Determination of which trees or groups of trees to preserve occurs during the design stage of project development. Unique specimens (Figure 3) including old trees, unusual species, uniquely sized or shaped trees, and trees with special wildlife value for food, resting,

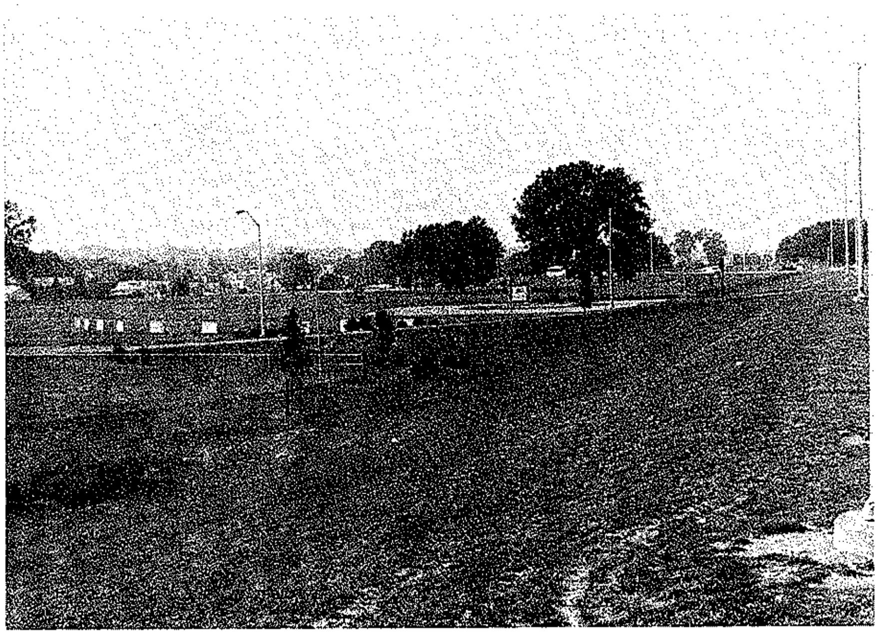

Figure 3. Several large, uniquely shaped trees preserved on the landside of the Clinton, Iowa, levee

and nesting deserve special attention for both aesthetic and ecological considerations as candidates for preservation. At the same time, the biological potential for these trees' survival is assessed, so that only trees that can be expected to live are retained.

47. In addition to consideration of individual specimens, blocks of trees (Figure 4) can be identified for preservation for both visual and wildlife habitat considerations. A block of trees can serve as a screen to break up the long, monotonous, and unnatural appearance of a levee. Blocks of trees to screen the levee are most appropriate in areas where visual contact with the levee would otherwise be at a maximum. Tree screens with irregular boundaries create a higher degree of visual diversity than do uniform shapes. The value of stands of trees

are commonly used to stress and to enforce the need to preserve the identified specimens or blocks of trees.

50. During construction, activities that cause permanent damage to trees identified for protection should be avoided. Vulnerability of trees to permanent damage varies with the species, size, and health of the individual specimens. For example, young willows and cottonwoods can often survive having significant amounts of material dumped directly on them, while other species are adversely affected by the root damage and soil compaction resulting from operating equipment within the drip line. Scarring of trees by machinery should be avoided.

51. Following construction, a variety of maintenance and management techniques may or may not be appropriate depending on site conditions. Pruning, insect/disease control, fertilization, and irrigation all may be options. In foreshore areas where high water velocities can be expected to destroy trees identified for protection, low bank protection may be appropriate.

Performance

52. At least two completed projects within CE's Rock Island District, Waterloo and Evansdale (US Army Engineer District, Rock Island 1970), exhibit careful attention to preserving trees that existed on project sites prior to construction. In both cases trees survived, no apparent structural damage to levees occurred, and residents were pleased with CE's ability to preserve local resources. In addition, tree preservation was to be an integral part of Rock Island District activities along the West Fork of the Des Moines River (US Army Engineer District, Rock Island 1971) and for an SCS project on the eastern shore of Maryland (USDASCS State Office, Maryland 1973).

53. Mitigation efforts seldom provide the same resource value as the existing trees. A good example is the Monroe floodwall project in Monroe, Louisiana (Vicksburg District). A large, old pecan tree with historical significance was growing on the proposed floodwall site. Because its roots were firmly entrenched in the only available foundation location, the tree had to be removed. The expensive array of concrete

a large portion of the embankment/foundation to be lost due to uprooting. This in turn could lead to a slope stability failure or seepage failure. Third, trees can hinder inspection if lower limbs are not periodically pruned; also they can obstruct flood fighting.

56. The ability of preserved trees to survive under altered conditions may limit the applicability of tree preservation with certain species under specific conditions. If other trees are removed in the immediate vicinity of the trees to be protected, the preserved trees will realize increased exposure to sunscald and/or windthrow. Construction-caused root damage and soil compaction may further limit survival. Finally, alterations in flooding and salinity regimes inherent in levee projects can limit the survival of protected trees.

Costs

57. Increased design effort is required to determine which trees are to be protected. Additional construction costs may be required, since access routes may be complicated by preserved trees. The increase in costs depends on how many trees are preserved and their location relative to construction operations. On the other hand, preservation of existing vegetation reduces the need for revegetation once the project is completed.

Future Land Use Considerations

Purpose

58. This measure can be implemented to prevent residential, industrial, and commercial development at the landside toe of the levee. Such provision protects the levee from activities that may threaten its stability, allows for adequate space for levee enlargement or modification, creates open space amenable to recreational or wildlife use, and provides adequate space for levee operation and maintenance.

Description

59. Implementation of controls that consider future land use can be accomplished either by the CE or by the local sponsor. Alternatives include acquisition (as discussed in section "Land Acquisition," para-

Chief of Engineers 1968), the CE has some authority to regulate land use on and around levees. This regulation states:

> Care should be taken to ensure that the levees are not encroached upon. Buildings, structures, and storage of miscellaneous materials or equipment should not be permitted on the levee. Refuse dumps are an item of frequent concern and should not be permitted.

Performance

62. Land use controls allow future land use changes and provide a buffer strip between the levee and developed land uses. Such a buffer zone facilitates future levee modifications. Overbuilding or other enhancement activities can be funded over time to reduce the initial cost component of project funding.

63. Most of the Mississippi River levees are located adjacent to agricultural land, which contains no building that would interfere with future modification. Further, it is common to find urban levees, such as those in Lewiston, Idaho, and Clinton, Iowa, at which the areas adjacent to the landside toe are used as parks. In both the Lewiston and Clinton examples, these parks are heavily used.

64. In other locations, such as some urban areas along the Sacramento River, land values have fostered development adjacent to landside toes of levees. Such development has made access for flood fight operations more difficult and has almost eliminated the possibility of modifying the levee at a future time.

Limitations

65. Existing use of the project site prior to levee development has perhaps the greatest impact on the ability to control land use adjacent to the levee. If the area has already been developed, such regulation is much more difficult.

66. Local sponsors can be expected to resist land use control if it requires significant and continual expenditures for monitoring and enforcement. Likewise, owners of the lands under question are likely to resist if the controls interfere with their prior plans to develop lands, or if recreational use creates trespassing problems when users of

the area attempt to access public lands over private lands.

67. Conflicts may also occur over what types of uses are appropriate to the zoned area. For example, if recreation is the prime dedicated use of the land, utilities within the zone may adversely affect recreational value by drawing attention to man-made structures.

Costs

68. Costs of land use regulation vary considerably among sites. Costs consist of enforcement and monitoring costs borne by the local sponsor and/or the CE, which are very difficult to quantify. Property owners bear costs of decreased land values since some uses are precluded. The section "Land Acquisition" (paragraphs 290-298) discusses costs if control is assumed through purchasing lands and/or land rights rather than by land use regulation.

Alignment to Increase Riverside Land Area

Purposes

69. Levee alignments may be set back a distance from the channel to permit natural erosion and deposition processes. Moreover, the measure allows preservation of riparian and bottomland wildlife habitats and enables the development of sites for river-related recreational facilities.

Description

70. Set-back levees are officially defined as "levees that are built landward of existing levees, usually because the existing levees have suffered distress, or are in some way being endangered, as by river migration" (US Army, Office, Chief of Engineers 1978). For this discussion, however, a set-back levee will refer to any levee or floodwall that has an area of land (foreshore or batture) between the riverward toe of the structure and the top of the riverbank at normal stages.

71. Implementation of the set-back levee concept occurs during initial levee alignment. Prior to alignment layout, information on the past meandering behavior of the river is used to determine a distance from the river that would be safe from riverbed migration. A habitat

map of the site can be used to chart the location of valuable areas that may be preserved by locating the levee landward of them. Analysis of land use patterns along the riverbank provides information on how much space is available for a foreshore or battured area. In addition, space requirements for foreshore recreational facilities (discussed in section "Uses for Periodically Flooded Areas," paragraphs 424-435) can be considered and the levee aligned accordingly.

Performance

72. From an engineering perspective, a set-back levee as defined for this discussion (see paragraph 70) offers several advantages over an alignment that locates the levee near the main channel. Since the levee does not have to follow the meandering channel, it can be shorter. Levee height will also be significantly less due to the changes in the floodway cross section. The net result will be a levee system that is much less costly to construct and maintain. A second advantage is reduced erosion. The impact of channel alignment on erosion has been studied recently by the Sacramento District (US Army Engineer District, Sacramento 1982); this study concluded that erosion is a function of discharge and the erosion potential of a given site. Erosion potential, in turn, depends upon the location of the thalweg and the radius of channel curvature, among other things. Russell (1967) has also noted the severity of erosion conditions that occur at bends. Setting back levees produces systems that have large radius bends and long straight reaches. This type of system should have fewer erosion problems and a lower risk of erosion-related levee failure. Finally, the reason for placing levees immediately adjacent to the main channel is often to convert floodplain areas to agricultural use. Placing the levees close to the main channel is often counterproductive to this goal, however, as a narrow levee system requires high water surface elevations for prolonged periods to discharge flood runoff, particularly seasonal floods that are often related to snowmelt runoff. This combination produces seepage and ground-water table elevations on the landside, which prevent use of the land for agricultural purposes during the flood season. Thus, the land

is indirectly lost to flooding in spite of the levee and the lack of direct flooding.

73. A good deal of biological opinion and evidence also suggests that implementation of the set-back levee concept does much to conserve wildlife habitat. For example, Fredrickson (1979) expressed a preference for levees over channel modification as a flood protection mechanism, because riparian and wetland areas are preserved. Heavy white-tailed deer use of foreshore areas is documented by a variety of authors (Murphy and Noble 1972, Zwank et al. 1979, and Wigley et al. 1980). Likewise, rich songbird (Dickson 1978a and 1978b) and turkey populations (Dickson, Adams, and Hanley 1978) are routinely noted in battured lands. Waterfowl (Fredrickson 1978, 1979) utilize floodplain wetlands within battured areas heavily, as do colonial wading birds and furbearers.

74. In contrast, levees that are constructed directly on riverbanks (Figure 7) commonly cause a number of undesirable effects for wildlife. First, historical floodplain wetlands become isolated from the river and thus may dry out or exhibit degraded water quality. Second, since operation and maintenance requirements for levees normally state that they be covered with either short grass or riprap, productive riparian wildlife habitats are transformed into sterile, monotypic

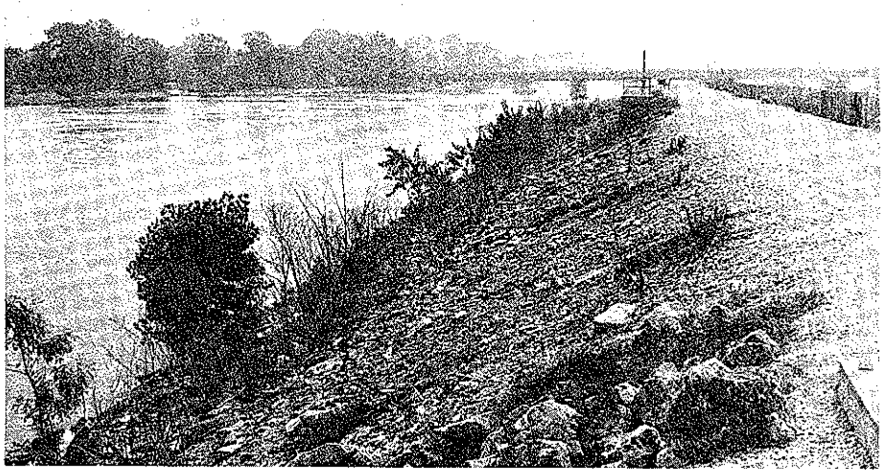

Figure 7. Levee set on riverbank, illustrating loss of riparian habitat

systems (Hurst, Hehnke, and Goude 1980). Finally, the levee's effect of drying on the landside will foster more intensive land use there, and thus will reduce the amount of available wildlife habitat. Thus, for some project locales, setting the levee back will discourage intensive land use on the riverside and encourage wildlife habitat development there.

75. Set-back levees provide a more natural visual setting for recreationists, in addition to allowing space for such activities. Recreational use of foreshore areas is commonly high, as evidenced by a variety of completed CE levee projects. Within the Sacramento District, a variety of boat ramps and regional parks receive heavy use. In the Vicksburg District, a public campsite and picnic area exists in the Point Lookout/Willow Point area, while a variety of private enterprises operate boat ramps and hunting clubs within battured lands. On projects in the Rock Island District near Waterloo, Ill., and Evansdale, Iowa, walkways and foreshore areas on the riverside of floodwalls are used extensively for fishing and sightseeing. At Fulton, Iowa, a simple boat ramp and unorganized open space area are used by the public for fishing, picnicking, and boating.

Limitations

76. On rivers with extensive floodplains, it may be impractical to set levees back far enough to include the entire floodplain. River stability may be increased or decreased by setting levees back from old, unstable levees, and the complexity of river processes makes this difficult to predict. Further, set-back levees are not practical where suitable foundation materials are unavailable.

77. Preproject land use also influences the practicality of set-back levees. Where existing residential, commercial, or industrial lands or municipal facilities (streets, sewers, water supply lines, etc.) extend to the riverbank, space for a foreshore area is not available. Moreover, resistance from agricultural interests occurs if the development of a set-back levee would remove their land from agricultural production. However, agricultural developments such as the increase of farming of water-tolerant soybean varieties have made

farming within foreshore areas more practical.

78. From a wildlife standpoint, habitat within the foreshore area will not remain preserved in its preproject state but will respond to changes caused by levee development. Most notably, a variety of authors (Fredrickson 1978; Whitlow and Harris 1979; Klimas, Martin, and Teaford 1981; Shields and Palermo 1982) noted that deeper, swifter flows can be expected in leveed foreshore areas than in unrestrained, natural flood-plains. Such alteration can cause a slow evolution of vegetational species composition on the wetter side. Species such as the oaks and hickories may give way to willows, cottonwoods, and silver maples, and understory species can be adversely affected. Such changes are not necessarily positive or negative to wildlife, but species composition of wildlife can be expected to change with species composition of vegetation.

79. From an aesthetic viewpoint, visual contact with the river will be reduced unless access is provided to the foreshore area. The greater the distance between the levee and the river, the less willing potential users of the river will be to travel to the riverbank. However, if strategically located access points are provided, set-back levees are desirable for boaters since the levees are less visible from the water.

Costs

80. A variety of cost factors exist which make it impractical to estimate set-back levee costs at the generic level. These factors need to be considered at the project level to determine an accurate estimate.

a. As noted earlier, the set-back levee will probably be shorter than a levee directly on the riverbank. This factor tends to reduce the relative cost of a set-back levee.

b. In some cases a set-back levee embankment is lower than a levee on the riverbank, requiring less borrow, a narrower right-of-way, and less construction effort. However, if the set-back levee were to be located in an area of poorer foundation materials or where borrow is more difficult to obtain than a levee on the riverbank, overall costs for a set-back levee would be increased. In addition, along rivers with sizable natural levees, streambank levees may have to be higher.

c. A set-back levee may experience less frequent hydraulic loading than a levee on the riverbank and will be less prone to erosion. Burrowing mammals that use aquatic habitats, including beaver, muskrat, and nutria, are less likely to adversely affect the structural integrity of a set-back levee unless there are riverside borrow pits at the toe. Thus, maintenance costs might be reduced.

d. However, a set-back may make foreshore areas unusable for commercial, residential, or industrial purposes and limit use for agricultural purposes. Project sponsors may have to buy foreshore areas or compensate landowners for their loss of ability to use foreshore areas. Land costs commonly are extremely significant in project budgets and could outweigh all the factors discussed above.

Minimization of Cleared Areas

Purposes

81. Existing wildlife habitat and aesthetic features may be preserved. Construction-related erosion and sedimentation problems can be reduced by maintaining a vegetative protective cover over as much of the project area as possible. The feature reduces the necessity to revegetate areas after construction. Finally, the minimization of cleared areas will help ensure preservation of a buffer zone of vegetation to screen levees from both sides.

Description

82. Levee construction requires land clearing for foundation preparation, construction equipment access and maneuvering, and stockpiling topsoil while the embankment is constructed. Clearing may also be required for excavated material disposal areas.

83. The extent of foundation preparation depends upon the width of the levee base. Base width is designed based on the friction angle of material used for embankment material, among other factors (US Army, Office, Chief of Engineers 1978). Using naturally high features upon which to align the levee will also minimize base width. When foundation soils have low bearing capacity, preconsolidation may be used to keep base width to a minimum. Staged embankment raising may be used to permit poor foundation soils to consolidate. Poor foundation soils may

also be removed and replaced with higher quality materials.

84. Construction-related clearing can be minimized by identifying those portions of the project that are least critical and arranging access, stockpile sites, and construction yards in these areas. Contracts can require that special equipment be used in critical areas to minimize necessary clearing. The contract may include a schedule of financial penalties for damages to vegetation outside acceptable clearing limits.

Performance

85. Minimization of cleared areas is a widely accepted technique for environmental preservation, as evidenced by the frequency with which it is proposed in planning documents. CE planning documents for the Sun River (US Army Engineer District, Omaha 1979), Merced County streams (US Army Engineer District, Sacramento 1980), and the San Luis Rey River (US Army Engineer District, Los Angeles 1981) all specifically describe provisions for ensuring that cleared areas will be kept to a minimum. The USDASCS has incorporated provisions to minimize cleared areas on levee projects in Maryland (USDASCS State Office, Maryland 1973) and New York (USDASCS State Office, New York 1980).

86. The principle of keeping cleared areas to a minimum is supported from the perspective of controlling nonpoint source pollution by the US Environmental Protection Agency (EPA) (Hopkins et al. 1973), the USDASCS (1977), and the USDI Fish and Wildlife Service (Hynson et al. 1982). Most states also incorporate this principle into their programs for nonpoint pollution control.

Limitations

87. Clearing in and around the foundation structure should be sufficient to ensure levee integrity. CE regulations (US Army, Office, Chief of Engineers 1978) specify that clearing of aboveground materials must be complete within both the levee and the berm foundation area. Grubbing (removal of specific objects) must be accomplished to a depth of 3 ft below ground in the levee foundation. Stripping is subsequently accomplished within the levee foundation proper (excluding berms beyond levee toes) to remove low-growing vegetation and organic topsoil.

88. Both availability and quality of foundation and embankment materials will determine the width of foundation clearing necessary. Extensive clearing may be unavoidable in areas where poor foundation materials must be replaced or consolidated prior to construction. Foundation stratification may exist, and thus an additional berm area would be required to prevent seepage. When levees must be constructed of low friction angle materials, a flat slope and thus a wide base will be required. Finally, the higher the levee will be, the wider the foundation will need to be and the more area will need to be cleared to obtain borrow.

89. If floodways are left uncleared, the floodway will offer greater resistance to floodwater passage and a larger channel cross section will be required. This in turn will cause higher water surface elevations during flooding. Although this may be a negative effect onsite, positive effects would occur by slowing erosion and providing for deposition of nutrient-rich sediment.

90. Although using a minimum foundation width and embankment size reduces clearing requirements, it also may eliminate the potential for aesthetic or wildlife-related vegetation to be planted or develop on the finished levee (paragraphs 92-104). Possibilities for shaping the levee irregularly to provide visual diversity (discussed in paragraph 94) will also be more limited. Moreover, clearing may be environmentally desirable in some instances to open up vistas to water features or distant mountains, or to set back natural succession to provide a diversity of wildlife habitat. Some degree of clearing is necessary to provide not only construction equipment access, but also access for flood fighting once the levee is operational.

Costs

91. Construction costs may be increased by having to work around uncleared areas. However, by retaining natural vegetation, revegetation costs will be reduced.

Overbuilt Levees

Purposes

92. Overbuilt levees offer opportunities for both aesthetic development and wildlife habitat enhancement. Limitations on embankment vegetation are less stringent than for standard-sized levees, and overbuilt areas may be shaped to conform to the natural surrounding landforms.

Description

93. Engineer Manual (EM) 1110-2-301 (US Army, Office, Chief of Engineers 1972a) defines an overbuilt levee as one that has a larger cross section than required to meet all engineering considerations. These considerations are discussed in detail in EM 1110-2-1913 (US Army, Office, Chief of Engineers 1978). Basic considerations include stability of both foundation and embankment materials as well as ability to operate maintenance equipment on levee slopes. A 1V:2H slope is considered the steepest slope practicable for the machine placement of riprap, while a 1V:2.5H is the maximum slope that can be conveniently traversed with conventional mowing equipment.

94. Overbuilding involves placing excess material in order to vary the levee cross section (Figure 8) or height. In both cases, the minimum embankment size is kept constant, and overbuilt areas are added to reduce the uniform, straight-line appearance of the conventional section. In some cases, the levee crown may be widened to provide space for recreational facilities that are discussed subsequently in Part IV. Overbuilding can also be used to smooth transitional areas, such as the break in grade between the crown and the side slopes and the area at the toe of the levee, by constructing transitional curves and irregularities. Regional landforms should be considered when designing overbuilt sections for aesthetic purposes. For example, a 1:4 slope can look just as artificial as a 1:2.5 slope, and undulating heights can also appear as artificial as constant heights if they are too uniformly spaced.

95. A second approach for overbuilding levees incorporates provisions to allow vegetation, for both wildlife and aesthetic enhancement

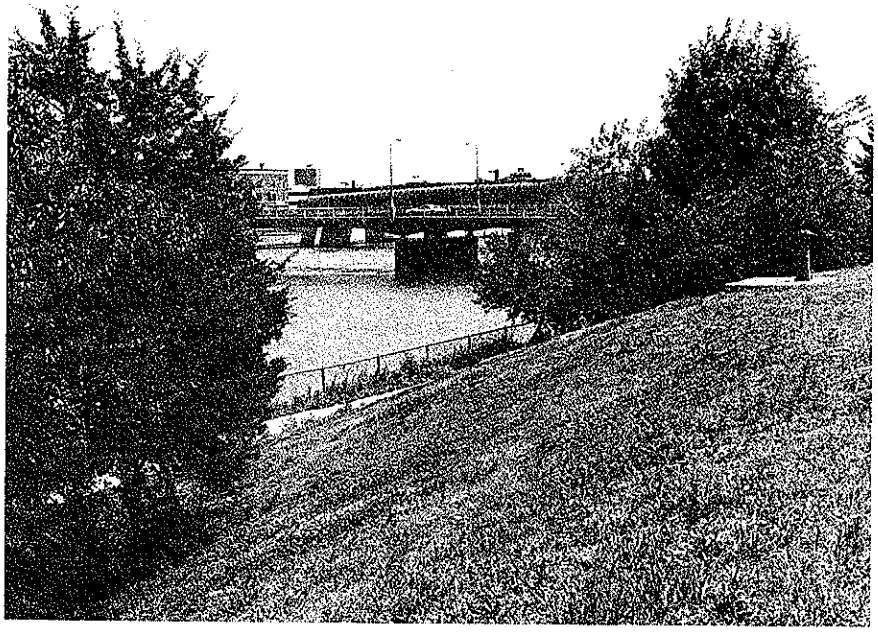

Figure 8. Undulating slope of levee creates visual diversity

(discussed in subsequent sections on wildlife seeding and planting, paragraphs 317-347; aesthetic plantings, paragraphs 410-423; and various maintenance options for vegetation management, paragraphs 496-577), that otherwise would threaten the structural integrity of a standard levee. Using this approach, the cross section of the levee consists of three parts: a basic structure, a root-free zone, and an overbuilt zone (Figure 9). The basic structures is that portion of the levee required to prevent floodwaters from breaching the levee. The root-free zone is a space that is free from roots of plants growing on the levee and thus free from threat from root-caused seepage and from uprooting of trees by wind or floods. The overbuilt zone is a space where roots would be acceptable and not cause a threat to the levee. Guidelines (US Army, Office, Chief of Engineers 1978) specify root-free zones should be at least 3 ft thick. Precision of the optimum depth of the root-free zone might be increased by estimating the depth of root penetration of vegetation to be planted and/or expected given local and regional natural

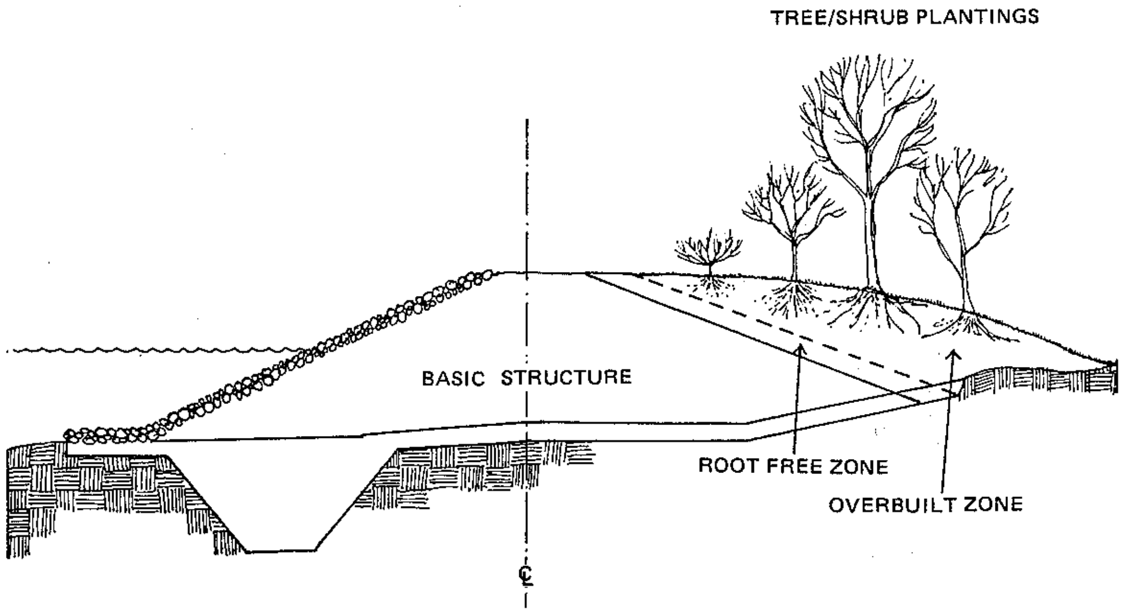

Figure 9. Cross section of an overbuilt levee

succession patterns. A positive cutoff barrier can be used to ensure roots do not penetrate the root-free zone.

Performance

96. Nolan (1981) described the use of overbuilt levees as the only way to permit some forms of brush and trees on levees. The enlarged cross section reduces the risks of seepage and slope instability in many instances. Moreover, where sufficient oversizing occurs, maintenance in the form of vegetation management can be reduced or eliminated. Overbuilt sections have been used or proposed in a number of instances to provide vegetative diversity.

97. An overbuilt zone was incorporated into a CE project levee on Alameda Creek, Calif., and enabled provision for a "no-mow" zone on the riverside of the levee and landscape plantings at various locations on the structures (US Army Engineer District, San Francisco 1969; Osmundson 1980). Although opinions differ regarding the overall success of the project (planted vegetation did not survive), it is agreed that the use of overbuilding eliminated risks to the structural integrity of the levee from both planted and natural vegetation.

98. The Evansdale, Iowa, project (Figure 8) is another example of an existing overbuilt levee. Overbuilding was used successfully at this project both to promote visual diversity and to permit landscape plantings.

99. Planning documents for yet-to-be-completed projects indicate the concept of overbuilt levees is becoming more popular. Overbuilt levee sections are part of plans for the Tijuana River (US Army Engineer District, Los Angeles 1977), the Little Calumet River (US Army Engineer District, Chicago 1982), and the west levee on the canal section of the Tennessee-Tombigbee Waterway (US Army Engineer Districts, Mobile and Nashville 1982). The Tennessee-Tombigbee overbuilt levee is composed of material excavated from the canal (paragraphs 276-279).

Limitations

100. The ability to incorporate overbuilding into project design depends upon the authorizing language and the availability of funds. Overbuilding is also dependent upon the availability of foundation and borrow materials that are stable and available in quantities sufficient to complete the project. CE guidance (US Army, Office, Chief of Engineers 1978) notes that overbuilding may increase stability problems due to settling after construction, and thus it is especially important for levee materials and foundations to be suitable.

101. Overbuilt levees require more land than standard levees, both for actual siting and for obtaining borrow in sufficient quantity. Thus, clearing requirements are increased and more area must be diverted from other land uses. Land requirements constrain implementation more in developed areas than in undeveloped ones. The use of high-quality materials can reduce the minimum section and thus reduce land requirements.

102. Depending on the degree to which the levee is overbuilt, maintenance requirements may either be increased or decreased. For example, the Alameda Creek experience of overbuilding levees to allow natural vegetative growth eventually resulted in the need for extensive and regular hand-cutting of brush to maintain channel capacity. On the other hand, plans for the levee along the Tennessee-Tombigbee Waterway

(US Army Engineer Districts, Mobile and Nashville 1982) call for the levee to be so large that natural succession can proceed normally so no vegetation control will be needed. The levee will be seeded to grass to prevent initial erosion. However, expect for areas critical from an engineering standpoint, the levee will be allowed to revegetate naturally. Critical areas are to be monitored for 5 years and may be allowed to revegetate naturally at that time if no seepage problems develop.

Costs

103. Land, labor, and materials costs are higher for overbuilt levees than for standard-sized levees. Such costs are extremely variable between sites and are dependent on real estate values, the availability of borrow, and labor rates. CE guidance (US Army, Office, Chief of Engineers 1978) suggests that riverside overbuilt sections are generally less expensive than landside overbuilt sections; this is true because land values are commonly higher on the landside than on the riverside and because the riverside slope is usually steeper than the landside slope and therefore less material is required for overbuilding. In some cases overbuilt sections are required to allow a public roadway on the levee crown. In other cases, overbuilt levees provide an opportunity for use of excess excavated material. In these types of situations, additional vegetation could be allowed without additional expenditures solely for vegetation.

104. As an example of additional costs associated with overbuilt levees, planning estimates for the Calumet River levee project (US Army Engineer District, Chicago 1982) included an overbuilt levee 28,000 lin ft in length with a total of 1,000 sq ft of cross-sectional area in a typical cross section. The cost included 155 acres of clearing and grubbing ($1,200) in addition to that for a standard section. Additional embankment material included 158,000 cu yd of fill priced at $8.40/cu yd.

Overdesigning Drainage Ditches

Purpose

105. The overdesign of drainage ditches serves to reduce the need for frequent clearing and/or mowing of drainage ditches and thus increases their potential for wildlife habitat and aesthetically pleasing vegetation.

Description

106. Oversizing ditches and minor drainage channels will reduce the frequency of vegetation control and sediment removal required in these areas. Channel sizes are designed based on high values for Manning's friction factor. Friction factors are selected assuming that the ditches will become occupied by vegetation. Additional width and depth are added to allow for storage of deposited sediment. Structural nonpoint pollution controls, including sediment check dams and filter strips, can be used to reduce sediment that enters the ditches.

Performance

107. Vegetation in oversized drainage ditches can be allowed to undergo at least the earlier periods of natural succession and thus provide wildlife habitat. Maintenance requirements are reduced over the long term.

108. On such drainage ditch on the Lewiston, Idaho, levee has been allowed to vegetate naturally, without control of plants in or adjacent to it. This area, as described by onsite managers, has proved to be one of the more productive sites for wildlife along the levee. Even though it is in an urban setting, a wide variety of songbird species, ring-necked pheasants, and Hungarian partridge have been observed using the area.

Limitations

109. Adequate oversizing may not be possible in developed or agricultural areas where runoff characteristics have already been adversely affected by land-use patterns. Agricultural areas commonly exhibit runoff waters highly laden with sediment, while developed areas sometimes experience dramatic increases in peak flows due to the

increased amount of area covered by impervious materials such as asphalt and concrete.

110. The measure is most appropriate where the natural topography of the area permits ditch and culvert gradients high enough to be at least somewhat self cleaning. Overdesigning commonly results in lowered flow velocity within the drainage ditches, which in turn fosters sediment deposition; thus, sediment could be more of a problem in overdesigning ditches than in ones that are sized using a more standard practice. Obtaining higher gradients in ditches and related structures may be somewhat difficult, especially since land adjacent to levees is typically flat.

111. From a structural standpoint, the deeper a drainage ditch adjacent to a levee is, the more likely that problems with seepage and slope stability will develop. A drawback to overdesign of drainage ditches from a recreational standpoint is the increased difficulty for users to cross the ditch and thus access the levee or the river. Special access routes to the levee may have to be installed to resolve this issue.

Costs

112. Construction costs should increase and maintenance requirements should decrease when drainage ditches are oversized.

Planning and Design for Erosion and Water Quality Control During Construction

Purposes

113. Techniques identified in this section may be used to minimize soil loss at levee construction sites as well as to prevent entry of sediment, oil, gasoline, and other chemicals used during construction into adjacent waters.

Description

114. Sources of information. A number of references are available which describe methods for controlling erosion, sedimentation, and other environmental impacts of construction activities. Only basic

principles and sources of additional information will be given here. USDI Bureau of Reclamation (no data(a)) provides basic information, in booklet form, for construction contractors. Basic references on erosion control methods include Hopkins et al. (1973), USDASCS (1977), White and Franks (1978), and Thronson (1979). Rekas and Kirk (1978) discuss erosion control for rangelands. The Task Committee for Preparation of Manual on Sedimentation (1969) presents design criteria for terraces, diversion channels, and grass-lined waterways. In addition, more than 20 of the States have published erosion control handbooks; Amimoto (1978) and Becker and Mills (1972) are examples of these.

115. Site plan. The first step in formulating an erosion control plan for a levee construction site is the identification of areas which, due to steep slopes, unstable soils, inadequate vegetation density, insufficient drainage, etc., have high erosion potential. Once these areas are identified, measures can be selected to eliminate or at least reduce erosion during construction.

116. Techniques. Construction site erosion prevention techniques include runoff control, mechanical sediment control, establishment of grass filter strips, placement of various types of temporary mulches, chemical treatment of exposed soils, and the use of sediment basins. Temporary mulching with woodchip or straw mulch is one technique that is often used with good results. Grass filter strips appear to offer promise; however, actual full-scale experience is limited. Chemical treatment is highly dependent on soil characteristics and is therefore site specific. Erosion and sedimentation can usually be significantly reduced by scheduling construction during normally dry seasons, exposing areas to construction for only the minimum time needed to actually complete these activities, and by avoiding stream fording, subaqueous construction, and amphibious operations.

117. Runoff control. In many cases, the most effective control of erosion is the control of runoff. Curbs, dikes, gutters, drop inlets, and drainage channels are effective in diverting overland flow away from sensitive areas and for concentrating and directing flow to treatment areas. Water bars and infiltration trenches are used to

reduce the rates of runoff by encouraging infiltration. Stormwater retention basins are used to hold runoff and to allow suspended sediment to settle from the runoff.

118. Sediment retention. Filter berms, sediment barriers, filter fences, and vegetation strips are used predominantly to retain sediment onsite by removing coarse and medium-sized sediment from runoff. Filter berms are often used across roadways to filter runoff without disrupting traffic. Vegetation strips (often grass) function as small sediment traps. Mechanical stabilization is generally used to stabilize and protect excessively steep slopes that often occur during cut-and-fill operations in highway, bridge, and dam construction. Mechanical stabilization can be used to temporarily stabilize slopes while slopes are being revegetated. Curbs and dikes for bench construction and breast walls are used as retaining walls to stabilize the slope toe, to reduce slope slide, and to prevent undercutting.

119. Revegetation. Revegetation of construction sites during and after construction is the most effective way of permanently controlling erosion. Many erosion control techniques are intended also to expedite revegetation. Planting and seeding for wildlife and aesthetics are discussed in greater detail below. Revegetation is generally accomplished one of three ways: planting, seeding, or staking. Seeding is often used to revegetate sloping areas; seeds can be placed by drilling, manual application, and hydroseeding and in conjunction with hydromulching. Staking with plants such as willow, dogwood, and alder is often effective in providing a quick, inexpensive method of revegetation. Stakes about 6 to 8 in. long are driven into the ground at a density of about four per square yard for best results. The EPA (1975) has a manual on establishing vegetation on low-productivity soils at construction sites.

120. Mulching. Various mulching techniques are used in erosion control, such as use of straw, woodchip, or stone mulches; use of mulch nets and blankets; and hydromulching. Primarily, mulching is used to reduce the impact of rainfall on bare soil, to retain soil moisture, to reduce runoff, and often to protect seeded slopes.

121. Sediment basins. Sediment may be removed from construction site runoff by constructing sediment removal basins. The design of sediment removal basins is as much an art as it is a science. Sediment removal basins are most effective on coarse-grained soils; whereas, physical/chemical treatment is most effective on fine-grained soils including clays. Several investigators including Nawrocki and Pietrzak (1976) and Ripken, Killen, and Gulliver (1977) address the problem of removal of fine-grained material from construction site runoff.

Performance

122. The guidance documents and principles cited above are drawn from policies of various Government agencies. The principles discussed have been widely implemented and tested. Several of the methods mentioned above, while not extensively researched on a formal basis, are based on sound concepts and have been widely practiced for a long period of time. For example, timing construction and erosion control techniques to avoid wet seasons and to limit the amount of bare ground at any one time significantly reduces the potential for runoff to occur from bared areas. Runoff controls operate to reduce erosion by preventing overland flow from ever reaching sensitive areas as well as diffusing and slowing (thus dissipating the energy of) runoff water. Heede (1978) demonstrated that controlling runoff effectively reversed trends of gully development in eroding watersheds.

123. Other methods discussed above have been extensively documented. For example, the value of vegetation as a filter for sediment-laden waters has been documented by several authors (Trimble and Sartz 1957, Packer 1967) in order to develop buffer strip guidelines for roads. Data presented by Hopkins et al. (1973) indicate that planted vegetation can reduce soil loss from construction sites by 90-100 percent, while numerous other studies (e.g. Musgrave 1947; Reinhart, Eshner, and Trimble (1963); Striffler 1964; and Gessel and Cole 1965) show the value of vegetation in holding soil onsite and dissipating the erosive energy of raindrops and overland flows. Hopkins et al. (1973) also provided data indicating that various forms of mulching reduced soil loss in Fairfax County, Va., 90-98 percent. Further data on the

efficacy of various mulches is provided by Borst and Woodburn (1942); Goss, Blanchard, and Belton (1970); and Meyer, Johnson, and Foster (1972). Detention or retention basins are discussed by Hopkins et al. (1973), Traver (1980), and Poertner (1981).

Limitations

124. Water pollution control at construction sites is best accomplished by using a variety of specific measures that are organized into a system of synergistically acting techniques. Such systems are most effective when they are tailored to the specific nature of the construction site.

Costs

125. Costs vary widely depending on site conditions and the specific techniques employed. Scheduling construction to coincide with naturally dry seasons may or may not represent a cost, depending on cash flow and institutional factors. Likewise, efforts to protect bare areas as soon as possible and to avoid subaqueous and amphibious activities may make construction slightly more inefficient. However, not implementing these types of measures may result in higher costs for repair of erosion damage to newly constructed slopes and for removal of sediment deposits. Required combinations of structural erosion controls will differ widely between sites; thus, costs will range considerably. Thronson (1973) presents cost information for some 25 commonly used erosion and sediment control measures. Costs for vegetative stabilization will be analogous to those discussed subsequently for wildlife (paragraphs 345-347) and aesthetic (paragraphs 422-423) plant propagation.

Avoidance of Loss or Disruption to Cultural Resources

Purpose

126. Avoidance of loss or disruption to cultural resources is necessary to prevent destruction or loss of significant physical cultural resources--tangible evidence and artifacts of prior culture. Table 1 summarizes major Federal legislation relevant to preservation of

Table 1

Cultural Resources Legislation

Legislation	Policy	Applicability
1906 Antiquities Act	Protected historic or prehistoric ruins on public lands from destruction (through penalties).	Authorized the President to set aside historic places, landmarks, structures and lands of significant scientific, natural, and scenic value.
1935 Historic Sites Act	Made a national policy of preservation for public use of historic sites, buildings, and objects of national significance.	The Secretary of Interior was empowered to survey, document, acquire, and preserve archaeological and historical sites. The National Park Service was given responsibility for supervision of the nation's historic preservation effort.
1949 Establishment of National Trust for Historic Preservation	The National Trust was authorized to receive buildings, and objects significant in American history and culture and administer the properties.	The National Trust was established to manage and acquire properties.
1966 National Historic Preservation Act (NHPA)	Preservation efforts were expanded to sites of state and local significance.	The National Register of Historic Places was established. The purpose of the National Register was to include "sites, structures, and the like which are significant in American history, architecture, archaeology, and culture, and to encourage local, regional and national interest in the protection of such properties.

(Continued)

Table 1 (Continued)

Legislation	Policy	Applicability
1966 National Historic Preservation Act (NHPA) (Cont.)		Grants to states were provided for comprehensive surveys of eligible properties. Advisory Council on Historic Preservation was established to advise the President and Congress on historic preservation. Established procedures for nomination of state and local sites and properties to the National Register. (State Historic Preservation Officer and state review boards recommend nomination to the Keeper of the National Register.) Grants are provided to local governments and public groups for historic and architectural preservation and for local surveys of properties.
1969 National Environmental Policy Act	Made a national policy of protection and enhancement of environmental resources.	An assessment of impact to cultural resources was required for major Federal actions affecting the environment.
1974 Archaeological and Historical Preservation Act	Extended protection requirements for artifacts and information to Federally assisted or Federally licensed projects (e.g. wastewater treatment plant grants). This law authorizes up to	This Act requires that requests for Federal grants, loans, or other assistance be examined to see if cultural resources will be affected.

(Continued)

Table 1 (Concluded)

Legislation	Policy	Applicability
	1 percent of the Federal cost for recovery of data.	
1979 Archaeological Resources Protection Act (ARPA)	Prohibits removal of archaeological resources from public lands or Indian lands without Federal or Indian permission.	
1980 Amendments to the Historic Preservation Act of 1966	Sets up the process for the state certification of local historic preservation programs, along with responsibilities of the State Historic Preservation Officer.	This required the Sec. of the Interior establish criteria for properties to be included, removed, and determinations of eligibility for the National Register.
	Established responsibilities of Federal agencies to administer the cultural resources under their jurisdiction.	Artifacts and associated information is to be deposited in institutions with long-term curatorial capabilities. Advisory Council is responsible for guidelines for Federal agencies for preservation of properties in Federal control or ownership.

cultural resources. Some states have significant cultural resource legislation as well.

Description

127. It is not unusual for cultural resources to be concentrated along rivers where streamside levees and borrow pits are to be placed. Cultural resources within a project area are usually identified and evaluated during planning stages of a project. Guidance for such identification and evaluation is given in Chapter 3 of ER 1105-2-50 and Engineer Pamphlet (EP) 1105-2-55 (US Army, Office, Chief of Engineers, 1982b, c). If significant environmental resources are identified within the project area, and if project construction and/or operation is likely to cause adverse impacts, mitigation may be called for. Avoidance of project effects is the preferred form of mitigation (ER 1105-2-50). Mitigation can involve project relocation, protection of the resources present, or salvage excavation of the site. The state of knowledge regarding protection of resources (without removal) is poorly developed at present. Thorne (1984) provides a review of techniques useful for stabilizing sites against erosion and disturbance by vandals. Techniques described include riprapping, earth burial, use of filter fabric, vegetation, and signs. The effectiveness of various types of preservation techniques is a question that awaits further research. In some cases, a site might be protected by incorporation of the site into the levee embankment. Although erosion and vandalism would thus be controlled, effects of compaction and changes in flood stage and duration on the buried resources remain uncertain. Garfinkel and Lister (1983) describe effects of high embankment construction on Native American artifacts.

Limitations

128. The ability to avoid prehistoric and historic sites and structures depends on their number, size, and location and on the availability of alternative levee alignments. When cultural resource sites are numerous and alternatives are scarce, priorities may have to be established based on site significance--the potential of a site to provide meaningful scientific data concerning the history and prehistory of a region. Stabilization techniques involving erosion control structures

generally will require some type of maintenance. In some cases, the use of warning signs may attract rather than deter vandalism. Salvage excavation requires scheduling prior to most construction activities, and materials recovered must be analyzed, documented, and curated. In some cases current state-of-the-art salvage techniques may be inadequate to exhaust the data potential of a site.

Costs

129. The cost of avoiding loss or disruption to cultural resources will vary from project to project. Site stabilization usually will require ongoing maintenance expenditure; site salvage will involve ongoing expenditure for curation if no existing repository accepts the artifacts. Construction costs may be increased if alternative levee alignments are needed. Alternate alignments may have different costs for real estate, borrow excavation, and hauling.

PART III: ENVIRONMENTAL FEATURES FOR FISH AND WILDLIFE

130. This part provides discussions of features for creation or restoration of ponds, wetlands, and upland habitats to benefit fish and wildlife resources on levee project sites. Wetland or pond development includes (a) basic considerations for design of borrow pits and interior collection ponds and (b) "optional" features including water control structures, artificial islands, fish shelters, fish stocking, and marsh vegetation establishment. Upland development features include beneficial uses for dredged or excavated materials, land acquisition, artificial nesting and perching structures, seeding and planting for wildlife, wildlife brush piles, controlled access to wildlife areas, and wildlife fence designs.

Wildlife Considerations for Borrow Pit Design

Purpose

131. Borrow pits may be designed to develop excellent wetland wildlife habitat. The extent to which environmental features are included in borrow pit design can depend on whether or not the area is open to public access. Provisions for borrow areas are often a local interest responsibility; some local interest organizations, under State law, are authorized to furnish only limited rights. Generally, title to lands obtained for borrow revert to the landowner who has the right to use these lands in any way he sees fit as long as it is not detrimental to the flood protection afforded by the levee.

Description

132. Often the most convenient locations to obtain embankment materials for construction are foreshore areas. When construction is completed, these borrow pits naturally fill with water and become artificial wetlands or ponds (Figure 10). Well-designed pits can become highly productive wildlife habitats, and thus can be considered as sites for habitat improvement and fish and wildlife management (Figure 11).

Figure 10. Levee borrow pits often become valuable wetland wildlife habitat

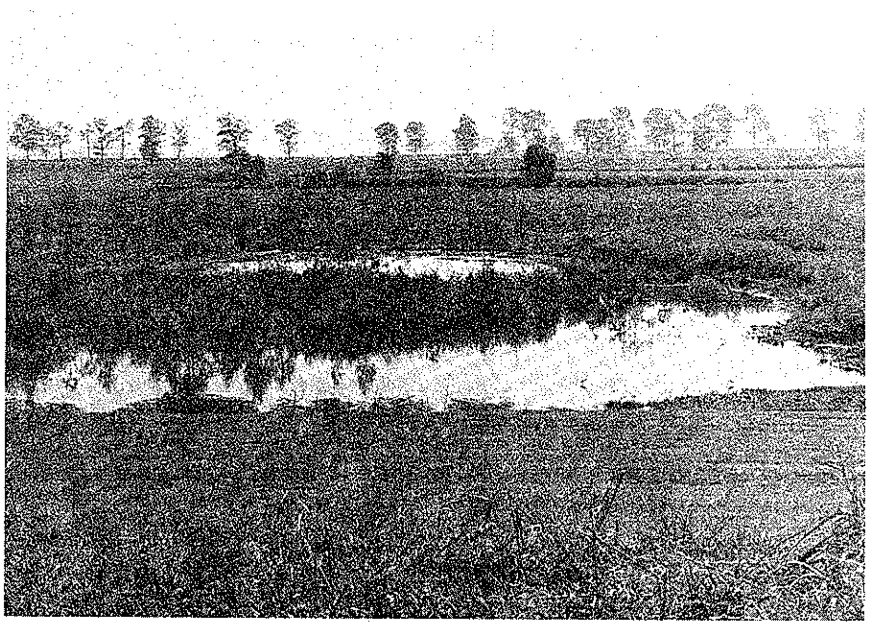

Figure 11. Borrow pit extensively used by wading birds

The Atlantic Waterfowl Council (1972) provides a basic guide for the creation of artificial wetlands.

133. Considerable study on a variety of similar artificial and natural wetlands consistently revealed that wildlife diversity and productivity are more strongly related to wetland size and the ratio between vegetation and open water than to any other characteristics. For example, a study of artificial flood protection lakes in Texas (Hobaugh and Teer 1981) used multiple stepwise regression to compare a variety of habitat variables to waterfowl densities and found the two most important to be surface area and the vegetation/open water ratio. Flake, Peterson, and Tucker (1977) found analagous results in a similar study for nesting waterfowl in South Dakota stock ponds. Preliminary results for selected levee borrow pits in the CE's Lower Mississippi Valley Division (LMVD) show the same two variables to be important (Landin 1984). Heusmann (1969) found a similar relationship in Massachusetts highway borrow pits.

134. Generally, a simple positive relationship exists between wetland size and wildlife productivity. All the studies cited above concluded that the larger the wetland size, the more productive for wildlife it is. Smith (1953) also came to this conclusion studying waterfowl production in artificial reservoirs in Montana. In British gravel pits, Catchpole and Tydeman (1975) found a slight tendency for bird species diversity to increase with pit size. Evrard (1975) likewise found waterfowl use to be heavier in larger artificial ponds in Wisconsin. General recommendations for waterfowl brood ponds commonly suggest a minimum size of 1-1.5 acres (Hamor, Uhlig, and Compton 1968; Lokemoen 1973) with no maximum size.

135. However, larger borrow pits may be counterproductive to wildlife in selected instances. In some cases, larger borrow pits may require destruction of scarce habitat to create relatively abundant open water. For example, areas of productive woody riparian or bottomland hardwoods could represent more important habitats in certain areas, especially if they are rare, while other wetland habitats similar to borrow pits are abundant.

136. Moreover, when consideration is given to providing waterfowl breeding and nesting habitat, a series of smaller, but more frequent wetlands could result in higher nest densities for the overall area than one large wetland. Derrickson (1979) showed that most waterfowl species seek isolation during some part of the nesting season, while Heusmann (1969) commented on the need for breeding ducks to be visually isolated from other breeding ducks. Smaller, but more numerous wetlands would provide a higher degree of visual isolation; thus, pair territories would not have to be as large and overall nest densities could be increased.

137. Most authors report vegetation/open water ratios in artificial wetlands to be optimal at 1:1 (Heusmann 1969; Flake, Peterson, and Tucker 1977; Hobaugh and Teer 1981; Kaminski and Prince 1981) to 2:1 (Yoakum et al. 1980). While this recommendation is admittedly based predominantly on data gained from dabbling duck habitat studies, its implementation would also provide a diversity of habitats, some or all of them for other wildlife species as well. As diversity of habitats is achieved, a diversity of species can also be achieved.

138. To a large degree, vegetation/open water ratio objectives can be achieved by excavating borrow pits with a variety of depths. Depths of 6-24 in. foster aquatic vegetation, while depths of 3-10 ft or more discourage it. Optimal feeding depth for many species of dabbling ducks is 12-18 in. (Chabrek 1979). However, some aquatic species can grow in depths of over 6 ft, so that too much vegetation is as likely to be a problem as too little. In order to obtain maximum vegetation/open water interspersion, gradual slopes (Hamor, Uhlig, and Compton 1968; Leedy, Maestro, and Franklin 1978) or the combination of gradual and steep slopes is preferred, as well as variation in the bottom topography of the borrow pit over its entire area. If several artificial wetlands are constructed near each other, excavating each at a different depth would promote habitat diversity and thus benefit waterfowl and other wildlife (Keith 1961). If fish preying on young ducklings is potentially a problem and the prime objective is waterfowl management, the

pit should be designed less than 5 ft deep to discourage fish populations.

139. Shoreline index (the ratio between the wetland's surface area and perimeter; a high shoreline index is represented by an irregularly shaped wetland) has also been shown to be positively related to waterfowl use for some species (Mack and Flake 1980), and high shoreline index values can provide nesting waterfowl with needed visual isolation (Heusmann 1969). Moreover, terrestrial species are benefitted by high shoreline index values through increased edge. Thus, irregularly shaped borrow pits would seem to offer greater wildlife productivity than uniformly shaped pits.

140. Quality and quantity of water are additional considerations when evaluating potential borrow pit productivity. Barstow (1957) noted a preference in Oklahoma for waterfowl to select clear farm ponds over turbid ones, while Heusmann (1969) found that acidity adversely affected wetland wildlife productivity in Massachusetts. The ability of artificial wetlands to contain water on a permanent basis was cited as an important consideration for artificial ponds in Minnesota (Uhlig 1963) and as a positive trait for borrow pits in LMVD (Landin 1984). Other studies in North Dakota (Stewart and Kantrud 1973, Kantrud and Stewart 1977) indicate that periodic drying of wetlands can be beneficial to overall productivity, and seasonal water fluctuations have been well researched and used as management in other areas. Perhaps the most important consideration is the assurance that water would be available during periods when high wildlife use is desired and that diversity of depth exists to provide some water during all seasons.

141. Location of borrow pits relative to human disturbance may also affect wildlife productivity. While location away from human disturbance and access can lead to increases in species diversity (Landin 1984), artificial wetlands in urban areas, such as those associated with the Lewiston, Idaho, levee and those studied by Harris, Ladowski, and Worden (1981) can still provide productive wildlife habitats. Chabrek (1979) noted that in many cases, wintering waterfowl were attracted to wetlands adjacent to agricultural areas where waste crops served as

abundant food sources. Thus, isolated borrow pit wetlands can serve a valuable purpose by providing habitat for species adversely affected by disturbance, while other pits can serve to provide the public with convenient potential to interact with wildlife.

142. A number of the features described below can be used to further improve borrow pits for wildlife. These include flushing (paragraphs 187-199), water control structures (paragraphs 212-227), artificial islands (paragraphs 228-242), marsh vegetation establishment (paragraphs 266-275), and controlled access (paragraphs 358-365).

Performance

143. Several studies have documented the value of borrow pits and similar artificial wetlands to wildlife. Based on a study in North Dakota, Rossiter (1980) concluded that highway gravel pits were roughly equivalent to natural wetlands for waterfowl production. Ruwaldt, Flake and Gates (1979) hypothesized that because of more stable water levels, artificial wetlands in South Dakota produced more waterfowl than natural ponds. In a British study, Harrison (1970) found old borrow pits had the highest diversity of nesting waterfowl in the region, and species diversity of all birds was increased by the existence of the borrow pit wetlands. On the Patuxent Wildlife Research Center in Maryland, the creation of borrow pits and other artificial wetlands resulted in the use of the area by 60 species of shore birds, marsh birds, and waterfowl that had never used the area before (Uhler 1964). In Florida, Wenner and Marion (1981) discovered that wetlands artificially created by excavation for phosphate mining had a high potential for wood duck production. Chabrek (1979) noted that artificial wetlands of all types are becoming extremely significant habitats for wintering dabbling ducks in the South. Both Brumsted and Hewitt (1952) and Benson and Foley (1956) found high wildlife use of artificial marshes in New York, while Spencer (1968) determined that waterfowl production on Maine marshes was higher on artificial areas than on natural areas because water levels were more stable.

144. Admittedly, data documenting borrow pit and similar artificial wetland values to waterfowl are much more extensive than research

concentrating on borrow pit values to other species. However, preliminary results of a levee borrow pit study in LMVD (Landin 1984) showed these areas to be highly productive for other species as well. Values of artificial ponds to upland wildlife have been further documented by Greenwall (1948), while Catchpole and Tydeman (1975) noted an increase in overall bird species diversity caused by borrow pits in England.

145. Riverside levee borrow pits are extremely common in LMVD, and are extensively used for hunting and fishing. In addition, several other CE projects have incorporated marsh development by obtaining borrow from existing natural wetlands that have become too shallow to be productive. A variety of techniques have been proposed and/or implemented on several CE levee projects. For example, 9.6 acres of upland habitat was to be converted to marsh through excavating an area adjoining an existing marsh on a levee project on the Sweetwater River (US Army Engineer District, Los Angeles 1982). Land shaping and excavation were to be used to create 25 acres of marsh, while 6 acres would be created by constructing dikes and water control structures in Merced County, California (US Army Engineer District, Sacramento 1980). Other wetland creation is proposed for the Little Calumet River (US Army Engineer District, Chicago 1982), while dredging was used to create productive wetlands from shallow, wet areas in Fulton, Ill., and Evansdale, Iowa (Figure 12).

146. As discussed in the previous section, research results on the characteristics of artificial wetlands that make them productive for wildlife are extensive and generally quite consistent. Variability does exist, however, and can be attributed to differences in habitat requirements of wildlife species under investigation, as well as to regional differences. Thus, biologists with local expertise should assist in the development of species habitat management objectives and in completing the finer elements of project design.

Limitations

147. Flooding of riverside borrow pits is conducive to wildlife habitat, but riverside pits are much more likely to eliminate bottomland hardwoods and other productive riparian habitat. Official CE guidance

Figure 12. Attractive pond restored from an unproductive marsh by dredging and using the material as borrow

(US Army, Office, Chief of Engineers 1978) recommends riverside borrow pits over landside pits.

148. When the leveed stream is the water source, riverside borrow pits can be subjected to extreme depth fluctuations that vary with river stage. Pit water quality will also be predominantly influenced by river water quality. In these cases, the deeper the borrow pits are, the more likely they will have water in them during low river stages. Further, riverside pits can suffer significant alteration through erosion and sedimentation during flood events. As a result, CE guidance (US Army, Office, Chief of Engineers 1978) suggests that slopes of upstream and downstream ends of pits should be flat enough to avoid erosion when subjected to flows at high river stages.

149. Where the source of water for the pit is surface runoff or ground water rather than the river, the soil and geological chemistry of the immediate vicinity will control water quality and thus wetland productivity. In Massachusetts studies, for example, alkalinity of watershed soils was strongly related to alkalinity of waters in borrow pit

wetlands. Water alkalinities in turn were strongly related to overall wetland productivity (Heusman 1969; Shuldiner, Cope, and Newton 1979). Moreover, a thorough analysis of whether sufficient water is available to fill the pit is needed (Wiedeman 1962, Yoakum et al. 1980). Finally, upland pits often do not have outlets and are thus more likely to serve as nutrient traps and experience more rapid eutrophication than pits that do have outlets.

150. Borrow pits can sometimes become too attractive to wildlife. For example, Harris, Ladowski, and Worden (1981) documented an instance where an urban reservoir that was extremely attractive to waterrowl became subject to degraded water quality from duck excrement. A second example is the CE levee project in Lewiston, Idaho, where dense concentrations of wintering waterfowl on interior drainage ponds have raised concern among some citizens because of water quality issues. Concentrated wildlife populations may also be more susceptible to disease. On the other hand, overpopulation by wildlife has not been a problem on Mississippi River levee borrow pits.

151. In developing optimum designs for borrow pits, conflicts may occur between management objectives. For example, diving ducks prefer deeper water than dabbling ducks; and many shorebirds are attracted to unvegetated flats, while waterfowl are attracted to vegetated areas. Fish may require deeper water than wildlife (paragraph 158) and could reduce production of some water bird populations while providing valuable ecological and recreational resources. This point further emphasizes the need to provide diversity within borrow pit designs and to clarify management objectives early in project design.

152. Values of individual borrow pits to wildlife may not remain constant over time. Natural processes including eutrophication, sedimentation, and changes in vegetation often cause successional patterns that influence wildlife productivity. For example, with sedimentation, a deep pit can become shallow, either benefitting wildlife by creating shallow water areas or harming habitat values by reducing water areas. Eutrophication in its early stages will provide beneficial aquatic vegetation with high diversity, while in later stages it can cause monotypic

habitat areas. Thus, longevity of the pit is a factor in developing design recommendations.

153. Engineering and land use factors can influence the feasibility of developing borrow pits for wildlife. The ability to conform to basic guidelines for size, shape, and depth will depend upon the adequacy of borrow supply of suitable quality for use as embankment material and its location in the project area. Further, structural integrity of the levee may limit pit depth, because depths great enough to create seepage under the levee are not allowed (US Army, Office, Chief of Engineers 1978). Pits with uniform sizes and shapes are easier to construct with large equipment than pits with irregular bottom topographies and shoreline shapes. Finally, dedication of borrow areas will remove them from agricultural, commercial, or residential use, and thus could be opposed by local residents.

Costs

154. Historically, borrow pit locations and configurations have been determined based primarily on engineering rather than biological concerns. Even though many borrow pits do benefit wildlife, no extra costs have been incurred. However, one cost estimate has been generated comparing "environmentally enhanced" borrow pits versus a conventional design (US Army Engineer District, Vicksburg 1980). Five pits encompassing 15 acres were considered, and basic excavation costs for borrow of "conventional" and "environmentally enhanced" pits were identical; however, the "environmentally enhanced" design called for an additional $13,097 to be spent on "dressing and turfing." This cost item included extra effort by the contractor and CE inspectors to ensure that final grades of the structure met environmental design criteria. On the other hand, two levee projects in the Omaha District (US Army Engineer District, Omaha 1976, 1980) also incorporated environmentally enhanced borrow pits, but no additional costs were included in the estimate because planners decided that there would be no additional effort required to grade and shape the pits.

155. Several cost factors do exist, however, and should be kept in mind during project development. First, if borrow suitable for

embankment material is left in the pit to meet wildlife objectives, the cost of alternative borrowing needed to obtain sufficient embankment material represents a cost of the environmental feature. Second, construction costs may be increased. While less effort is required to excavate shallow pits than deep pits, it is more difficult to excavate irregular slopes and bottom topographies than regular ones.

Fishery Considerations for Borrow Pit Design

Purposes

156. Techniques described in this section may be used to develop borrow areas into fish ponds that provide ecologic diversity and recreational opportunity.

Description

157. While only a limited amount of data collected directly from levee borrow pits are available to develop design considerations to improve fishery potential, a significant amount of information has been developed for other artificial ponds, including gravel pit ponds, farm ponds, and reservoirs. Such information has been summarized by Moulton (1970), Bennett (1971), Jenkins and Morais (1971), and Noble et al. (1979). A study of fishery habitat characteristics of LMVD borrow pits is nearing completion through cooperative efforts by the US Army Engineer Waterways Experiment Station (WES) and LMVD. The results of that study, when available, will enable refinement of the initial guidance presented below.

158. Depths. Although a wide array of factors influence fish productivity in artificial ponds, perhaps the most important characteristic is depth. In more northern climes where ponds routinely freeze over during the winter, depths of at least 7-16 ft are needed to prevent winterkill (Brown and Thoreson 1952), Krumholz 1952, Meehan 1952, and Rawson and Ruttan 1952). Waters must be deep enough to contain a volume of oxygen to last through periods of snow and ice cover. In all locations, the presence of deeper water areas benefits fish productivity by discouraging extensive aquatic vegetation that chokes out open water

areas (Davison 1943, Swingle 1952). Deeper areas in most ponds also serve to provide cooler water temperatures in summer (Swingle 1952) and are a source of water during all seasons in those riverside pits that have water levels that fluctuate widely with the river stage. Further, deeper pits provide volume for sedimentation to occur, thus increasing the longevity of the pit as a productive fishery.

159. On the other hand, deeper waters in southern States often become anaerobic in late summer, and are thus of little value to fish. Moreover, shallow and heavily vegetated borrow pits that are only seasonally flooded but are directly connected to the river have been shown to have considerable value as spawning and nursery sites for riverine fisheries (Hall 1974).

160. A borrow pit feature often used to provide both shallow and deep water involves a steep dropoff at the bank to a depth of 18-24 in. (Figure 13, Leedy, Maestro, and Franklin 1978; Leedy, Franklin, and Maestro 1981). This depth is maintained for some distance from shore, at which point a second steep dropoff occurs to the design maximum depth of the pond. Such a design provides for shallow-water areas for

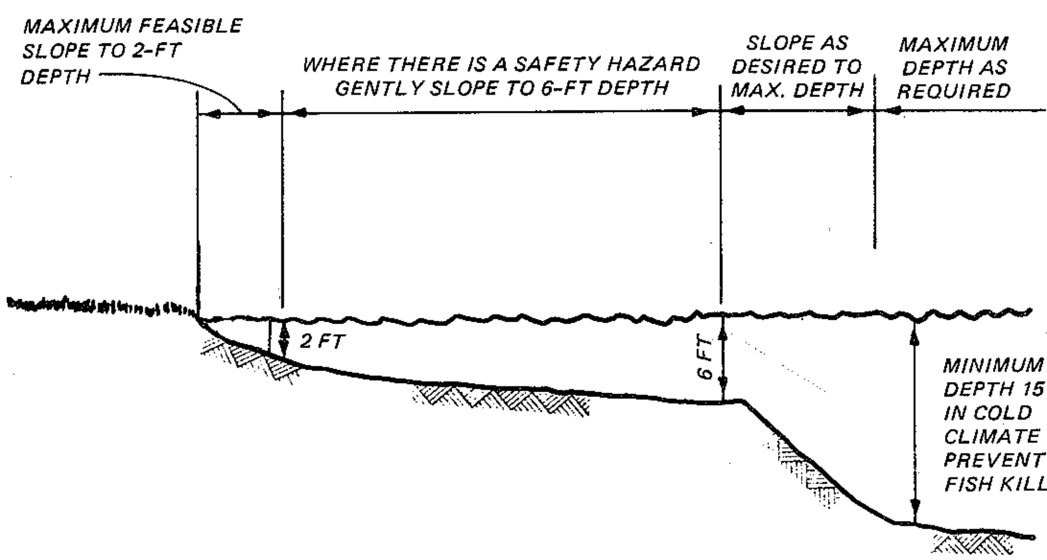

Figure 13. Cross section of artificial pond or borrow pit showing design for diversity of depths (adapted Leedy, Maestro, and Franklin 1978)

spawning and nursery habitat and reduces the hazards of children drowning while fishing, but still allows for needed deepwater areas.

161. Size. Pit size is also a consideration when designing borrow pits to provide fishery resources. While pit size probably has little effect on overall productivity, smaller borrow pit ponds are much more likely to develop imbalances in fish populations than larger ponds. As a result, a variety of authors recommend 2 acres as a minimum size for farm ponds (Brown and Thoreson 1952, Meehan 1952).

162. Shape. Pit shape is a consideration for the fishery, as well as influencing recreational use and aesthetic value of the pit. An irregular shape that provides more shoreline length increases the productive littoral zone and provides more fishing access. It also provides more visual diversity than a regularly shaped pit.

163. Access. Providing for intensive fishing pressure by locating the pit conveniently to the public can improve the fishery, if fishing pressure is directed at species that would otherwise become overpopulated. Bennett (1945) showed that increased fishing pressure in a small artificial pond in Illinois actually improved the fishery. A common problem in smaller artificial ponds is the development of large numbers of stunted and/or undesirable fish (Tarzwell 1940, Swingle 1956, von Geldern 1966). Therefore, providing access to foster sport fish harvest often facilitates the maintenance of desirable population levels.

164. Water source. Whatever the pit's source of water, it should be sufficient in quality and quantity to sustain fish populations throughout the year. Options for water supply include the leveed stream, ground water, and surface water. Water temperatures can often be limiting factors in small ponds, and thus should be within tolerance limits of the species of fish expected or being managed (Swingle 1952). Fish survival and productivity is commonly higher in neutral to slightly alkaline waters than in acid waters (Moulton 1970). Likewise, waters overly laden with sediment, nutrients, or pollutants are not conducive to productive fish populations.

165. Since many riverside borrow pits are hydraulically connected

to the river, both water quality and water quantity are often functions of the frequency and duration of water exchange between the pit and the river. Pit flooding is dependent on the elevation of the pit relative to the river, the distance between the pit and the river, and whether designs for flushing (paragraphs 187-199) have been incorporated. Features discussed below which may benefit fishery resources in borrow pits include water control structures (paragraphs 212-227), fish shelters (paragraph 243-252), and fish stocking (paragraphs 253-265).

Performance

166. Lower Mississippi River levee borrow pits support extensive recreational fishing (Figure 14). An ongoing study of 25 of these pits by WES and LMVD found fish standing crop biomass to vary from 50-3200 lb/acre. All but three of the pits sampled were flooded during the prior spring. Earlier research discussed by Bennett (1971) also proved that levee borrow pits can be productive fisheries. Additional examples of levee borrow pits that support recreational fishing are the levee projects in the Rock Island District on the sites of Waterloo and Clinton, Iowa. Work by Bennett and Childers (1972) demonstrated that ponds created from gravel borrow pits can supply long-term fishery benefits. Similar ponds were researched by Moulton (1970) and also found to be productive for fisheries. Lipsey (1980) and Lipsey and Malcolm

Figure 14. Borrow pits can be productive fisheries

(1981) discovered that gravel borrow pits provide a variety of food chain organisms. However, research on gravel pits may not be totally applicable to levee borrow pits for two reasons. First, gravel pit water commonly comes from ground water and surface water, while levee borrow pits commonly receive their water from the leveed stream. Second, bottom material differs in both physical and chemical characteristics from gravel pits and levee borrow pits.

167. While very little research has been accomplished to develop design considerations for fishery borrow pits, detailed guidelines have been developed for farm ponds. In addition to the papers cited above, work has also been done by Barnickol and Campbell (1952), Carlander (1952), and Compton (1952). Both farm ponds and borrow pits are small artificial lakes, often created by excavation. They differ in these two ways: (a) borrow pits are usually either continuously or intermittently connected to the leveed stream, while farm ponds are not and (b) farm ponds are usually created by impoundment rather than by excavation. Transfer of information from literature dealing with farm ponds should be done with great care if the borrow pit is frequently connected to the leveed stream, as this connection may overshadow all other factors.

Limitations

168. As stated earlier, ponds must normally be permanently filled with good-quality water to be of use as productive fisheries (Bennett 1971). Thus, site-specific determination for each borrow pit is needed to determine whether adequate water will enter the pond via the leveed stream, ground water, or surface sources.

169. Engineering considerations for fishery borrow pit design are quite similar to those discussed previously for wildlife borrow pits (paragraphs 147-153). They include: (a) whether or not natural borrow deposits are of sizes and shapes that lend themselves to fishery development, (b) the degree to which riverside borrow pits are protected from erosion damage and sedimentation during flooding, and (c) the possibility of threatening levee integrity with deep pits that foster underseepage problems.

170. A variety of physical and ecological changes can occur as

artificial ponds age. These changes can affect fish productivity. Commonly, artificial ponds exhibit 3-10 years of increasing productivity, followed by a decline. As noted earlier, imbalances in fish populations develop easily and reduce the availability of game fish in sizes preferred by anglers. Continual input of nutrients fosters eutrophication and the development of dense stands of aquatic vegetation, while sedimentation tends to develop extremely shallow depths or even dry ground. While some of these actions can be reduced in magnitude through proper design and management, maintenance activities including pond reclamation, weed control, and dredging may be necessary to ensure borrow pit productivity over the long term.

Costs

171. Cost considerations are essentially analagous to those provided in the previous section on wildlife borrow pit design (paragraphs 154 and 155). As in the case of wildlife borrow pits, most past work of this nature has occurred incidentally to project development, so that cost comparisons between environmentally enhanced borrow pits and conventional borrow pits are generally not available.

172. Cost of alternate borrow materials is a factor if material otherwise suitable for the levee embankment is left in the pit for environmental reasons. Further, if additional material not used in the levee embankment is removed from the pit to create favorable pond sizes and depths, construction costs for excavation and disposal would be factors in the overall budget. Additionally, land would have to be made available for this disposal and would represent a cost.

173. Generally, it is more expensive to excavate a deeper pit rather than a shallower one. Development of irregular shorelines is also more expensive and time consuming than shaping borrow pits with uniform dimensions.

174. Fish stocking, discussed in paragraphs 253-265, may represent an additional cost if the pit is geographically isolated to prevent immigration from natural sources. Maintenance costs may involve dredging and weed control, as well as chemical application for reclamation and plant control.

Interior Drainage Collection Ponds

Purpose

175. Interior drainage collection ponds may be used as fish ponds or wildlife wetlands. Thus, they provide a valuable means of using areas with a high potential for flooding.

Description

176. Interior drainage structures are located on the landsides of levees. They function to collect landside stormwater runoff and direct it through the levee and into the river in a manner that does not compromise the structural integrity of the levee. Although in most cases they are designed to be dry during nonstorm conditions, they can be designed to hold water on a permanent basis (Figure 15) when the threat of seepage is minimal.

177. Most interior drainage ponds discharge into the leveed stream through culverts with flap gates. Some of these structures are equipped with pumping stations to assist in moving water to the river. Outflow structures may be designed or operated in such a way that water

Figure 15. Interior drainage collection pond beside levee in Lewiston, Idaho

is impounded permanently in the collection pond. Fish screens may be attached to the outflow pipe if the collection pond contains species not native to the river system. Water can be also confined to the collection pond by (a) excavating the area to the desired depth or (b) diking the circumference of the area. Size, shape, and depth considerations are analagous to those previously discussed for development of fish and wildlife habitat in borrow pits.

178. The prime consideration in design of wet interior collection ponds is maintaining the structural integrity of the levee, which can be compromised by permanent standing water on the landside. Problems include possible sloughing of the landside slope, seepage, and reduced ability to detect seepage problems when they occur. Thus, it is important to determine whether the water permanently impounded in the interior drainage pond constitutes a threat to the levee, given the foundation and embankment materials at the site. Where advanced levee designs are used, such as a provision for an impervious core and fill materials on the landside that are stable when wet, threat to levee integrity is substantially reduced.

Performance

179. Levees in the vicinity of Lewiston, Idaho (US Army Engineer District, Walla Walla 1970; Osmundson and Associates 1972) have associated with them 9 acres of interior drainage ponds that are used extensively by the local populace for fishing. Although rough fish have been a problem, some 4- to 5-lb largemouth bass have been caught from them. These ponds also serve as concentration and resting areas for migrating and wintering waterfowl numbering in the thousands. A few domestic ducks and tame mallards also nest there. Because this levee has an advanced impervious core design, there has been no evidence of the ponds causing stability problems on the levee even after several years of operation.

180. A wet interior drainage collection marsh was proposed for an SCS levee project (USDASCS State Office, Michigan 1975). Although the project was never completed and thus the design never tested, SCS personnel felt the interior collection marsh would not have threatened the

levee since only a shallow depth would be impounded and because levee materials would be very stable. Wet interior ponding areas have also been incorporated into various Rock Island District designs* including Evansdale, Iowa (US Army Engineer District, Rock Island 1970), and Monticello, Iowa (US Army Engineer District, Rock Island 1974a).

Limitations

181. Significant limitations include potential problems with seepage and levee stability. Moreover, the measure is more applicable where small interior drainage watersheds are involved, since impounded water on the landside adds risk to levee integrity.

182. Water is usually supplied to interior drainage collection ponds in short, erratically spaced periods. Amounts and periods of water supply will vary with amount and timing of precipitation, area drained by the collection ponds, and soils of the drained area. Moreover, the water source is commonly surface runoff that can be laden with sediment, nutrients, and chemical pollutants, at least in developed areas. Algal blooms, high temperatures, and other water quality types of degradation can be problems. On the Lewiston, Idaho, levee, these issues were resolved by flushing the pond (paragraphs 189-192) with water from the river. These water quality problems tend to be less severe in climates with uniform rainfall distributions.

183. Although fish screens will reduce the likelihood of unwanted fish introductions either to the river or to the pond, such problems could still develop. Fish screens could become inoperative, and fishermen are quite likely to transfer their catch from one body of water to the other. Thus, all subsequent fish stocking plans should consider the potential of stocked species populating adjacent areas.

184. When interior drainage areas are not permanently ponded, they can be utilized for various recreational facilities (paragraphs 424-435) or for agriculture. A wet design would not necessarily preempt

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* Personal Communication, 1 July 1982, F. Collins, Chief, Environmental Branch, US Army Engineer District, Rock Island, Clock Tower Building, Rock Island, Ill.

other recreational uses, but would dedicate at least a portion of the space solely for a pond. Agricultural use would be preempted.

Costs

185. Levee design features that facilitate incorporation of wet interior drainage collection ponds can be quite expensive, while the ponds themselves are not. For example, the features that facilitate the interior drainage pond on the Lewiston levee project include an embankment design with an impervious core of bentonite clay surrounded by gravel fill, which prevents structural and seepage problems due to the ponds but is extremely expensive. Pumping stations to move pond water to the river are also included. However, the nature of the project setting is such that the embankment design and pumping stations would have been required whether or not the interior drainage ponds were wet or dry, and thus actual pond cost included only excavation and landscaping. Likewise, when such a design can be incorporated simply by modifying the level of the outlet between the drainage structure and the river, costs for construction are minimal. Thus, this measure is most cost-effective when the site and the project design incorporate features that lend themselves to developing interior collection ponds.

186. Maintenance may involve weed, algae, and insect control, as well as dredging, operating facilities to flush the ponds (paragraphs 197-199), and fish stocking (paragraphs 264-265).

Flushing Artificial Ponds and Wetlands

Purposes

187. There are several reasons for incorporating provisions for water exchange into and out of borrow pits, interior collection ponds, and other wetlands within the project area. First, with such exchange the pond can be used to augment riverine fish habitat. Second, the flushing serves to maintain high water quality in the pond and thus improve habitats for fish and wildlife. Third, it makes pond fishery population imbalances less likely.

Description

188. The simplest method to facilitate flushing in riverside borrow pits that are developed as ponds or wetlands is to locate them along drainage ditches, streams, or other small watercourses that exist in the project area (Figure 16). Such a design was proposed for a Lower Mississippi River levee project (US Army Engineer District, Vicksburg 1980). If natural drainageways do not exist, in some cases ditches may be excavated.

189. A more advanced system of flushing exists for interior drainage ponds on the Lewiston, Idaho, levee (US Army Engineer District, Walla Walla 1970). A siphon through the levee transports water into the first of a chain of interior collection ponds. This water circulates through all of the ponds and eventually returns to the river via a pumping station (Figure 17) that, although initially planned to operate only during storm periods, now operates continuously. Using this system, complete exchange of the water in Lewiston levee interior drainage ponds occurs daily.

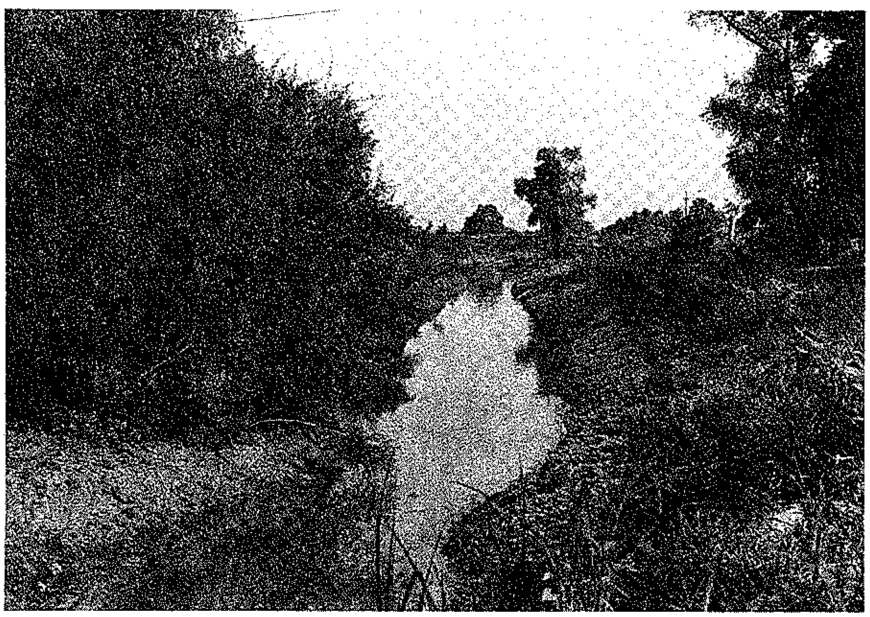

Figure 16. Onsite drainage ditches can be used to facilitate flushing of borrow pits

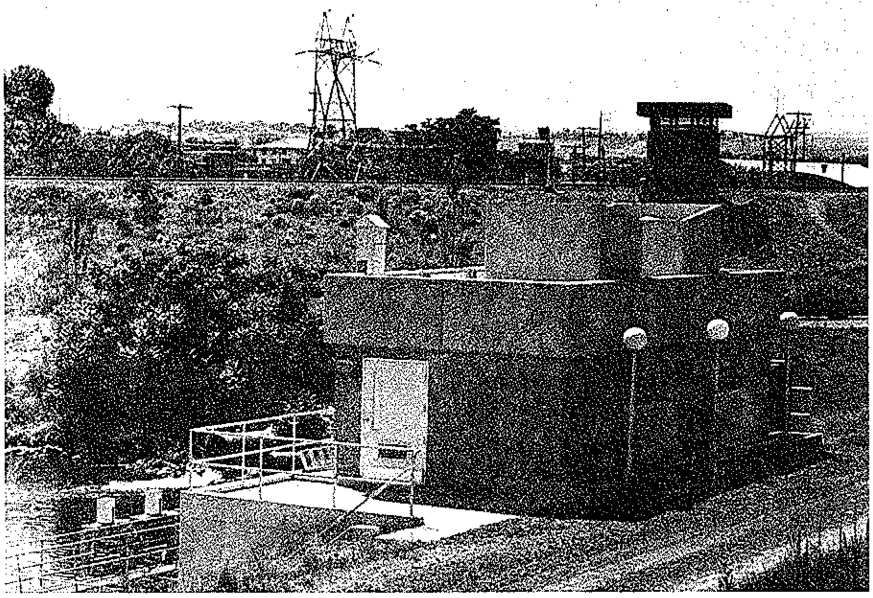

Figure 17. Pumping station on the Lewiston, Idaho, levee providing flushing for interior drainage collection ponds

190. The EPA (1980) and Welch (1981) recommend flushing rates that would exchange the entire volume of water once every 2 or 3 weeks, or the time that algal blooms require to develop. If the flushing rate is too great, however, the pond's productivity is reduced since the phytoplankton populations are unable to develop.

191. In most cases, the most convenient water source will be the leveed stream. Tributaries, artesian wells, and domestic water inputs may be suitable sources in selected instances.

Performance

192. Flushing is currently being used with success on the Lewiston levee. Before instituting a system of circulating river water through interior drainage ponds, unsightly algal blooms that gave off objectionable odors were common. Now that regular flushing occurs, few algal blooms ever develop.

193. Studies in Fountain City Bay have also documented the value of flushing (Fremling et al. no date). The area is a large (5,150-acre) backwater consisting of bays, marshes, and running sloughs on the Wisconsin side of the Mississippi River between river miles 733.4 and 741.

In this case, flushing was created by partially closing a breach in a natural levee that provided heavily sediment-laden waters, providing three gated culverts each capable of 100-cfs flows through a navigational dike that had previously blocked the inlet, and installing/maintaining a trash rack on another culvert already existing through the dike. Harvest of game fish in the Bay has steadily improved since installation of these features. While the authors felt it was too soon to evaluate changes in wildlife populations, they further concluded that aquatic vegetation, although slightly altered, has not been negatively affected.

Limitations

194. Steep topography and rocky soils make excavation for drainageways more difficult and costly, while the lack of naturally existing drainageways makes such activities necessary. Drainageways also may require shaping, vegetative stabilization, or riprap to protect them from erosive flows during flooding. Since a nearby, convenient source of water should exist, riverside ponds are more amenable to this technique than landside locations because the river can more easily be used than other sources for water. Moreover, the use of domestic water sources may conflict with community needs.

195. Where direct connections between ponds and the river exist, stocking of nonnative fish species may be precluded in order to protect the river system as a whole from potentially undesirable introductions. Although Bennett (1971) reported that infrequent flooding could rectify fish populations in ponds, too frequent flushing by major floods could result in unstable fish populations.

196. Flushing is undesirable in instances where pond water quality is higher than river water quality. Moreover, highly sediment-laden river water, if used for flushing, could result in faster filling of the pond with sediment.

Costs

197. No additional cost was included in the Willow Point/Point Lookout (US Army Engineer District, Vicksburg 1980) comparison of constructing borrow pits along a preexisting drainageway versus locating

them without considering the drainageway.

198. However, the complex system on the Lewiston levee involved significant costs. Although 1973 contract estimates for the pumping station listed a cost of $280,000, this figure is somewhat misleading since the pumping station would have been constructed whether or not periodic flushing was used. Siphons were estimated to range from $34,000-$59,000. Since some siphons are used for flushing the drainage ponds while others are used to obtain water for irrigation, the number of siphons as well as their cost for the flushing system are extremely difficult to further quantify.

199. Operation and maintenance costs likewise can range tremendously, depending on whether the system operates with gravity in existing drainageways, or whether pumps are used.

Freshwater Diversions

Purposes

200. Freshwater diversions directly improve water quality conditions, especially salinity, in estuaries and marshes that are cut off by levees from freshwater inflow. For the most part, this feature has received the greatest amount of use in the New Orleans District, where the interface between riverine and estuarine systems is extensive. However, it is closely related to flushing, which was discussed in the previous section (paragraphs 187-199). Secondary objectives include marsh restoration, creation of habitat for waterfowl and other wildlife, and the reduction of erosion of marshes and barrier islands.

Description

201. The construction of flood protection and hurricane protection levees has had severe impacts on the adjacent wetlands in the New Orleans District. Eliminating natural overbank flooding of these wetlands has reduced the net inputs of freshwater and sediment into the marshes. This has resulted in increasing marsh salinities and has increased oyster mortality due to predation and disease (Pollard 1973; van Sickle et al. 1976). The increased salinity has sometimes killed

the native vegetation and thus accelerated rates of erosion. This erosion, combined with the reduced inputs of sediment into the marshes, has caused rapid land loss in the marshes and barrier islands (Gagliano et al. 1970a, 1970b; Gagliano 1973; Morgan 1973; Adams et al. 1978). Elimination of the flooding has cut off the flow of nutrient-rich river water into the marshes (Ho and Barrett 1975), and the construction of hurricane protection levees has prevented the transport of nutrient-rich detritus from the marshes into the estuaries. Detritus is the basis of the estuarine food web (Darnell 1961; Day, Smith, and Hopkinson 1973; Odum and Zieman 1973).

202. Freshwater diversion has been proposed as a solution to many of these problems. Controlled diversions can be used to reduce salinities to historic levels, to help rebuild deteriorating marsh and barrier islands, and to restore the fish and wildlife resources of the marsh and estuaries.

203. Since the basic concept involves making a path for river water over or through the levee from and into natural marshes on the landside, techniques similar to the ones described previously to provide flushing of artificial wetlands can be used to implement freshwater diversions. Control structures using gravity feed, but durable enough to withstand floods, are installed in the levee and are opened and closed as needed to manage water levels in the wetlands. If necessary, pumping stations can be added if natural flows are not capable of carrying enough water to landside wetlands. The most common structure proposed is a box culvert with a vertical lift gate, but other devices such as siphons are sometimes used.

204. Management decisions include determining the amount and timing of flows into and out of the managed wetland. If seasonal water quality data are available for the wetland prior to levee construction, they can be used to determine the amount and timing of water to be diverted. Otherwise, a nearby wetland that meets desired management objectives can be modeled to determine amounts and timing of freshwater diversion.

Performance

205. Freshwater diversions increase the recreational potential of landside wetlands for hunting and fishing and offer substantial economic benefits to the fisheries and allied industries. For example, the State of Louisiana has operated a small-scale freshwater diversion project in Plaquemines Parish for a number of years. As a result, the affected wetland has experienced a substantial increase in the oyster harvest. The commercial oyster harvest for Breton Sound in 1970 was 580,000 lb. This harvest increased in the 1974-75 season to 1,508,277 lb and to 4,158,275 lb in the 1975-76 season (US Army Engineer District, New Orleans 1982).

Limitations

206. The New Orleans District (1982) described several physical site factors that may limit implementation of freshwater diversions. Soil/geological concerns include potential erosion, settlement, seepage, and liquefaction failure; thus, foundation and embankment materials need to be as sound as possible. Preferred sites are locations where connections to the freshwater source currently exist or previously existed in order to minimize the length of conveyance channels for economic and environmental reasons.

207. The most beneficial diversion sites are ones that will (a) have the greatest natural dispersion, (b) affect the largest marsh area, (c) have the slowest runoff rate, and (d) have the longest detention time. A water source that is free from industrial, municipal, thermal, or sediment pollution is needed in order for the feature to result in water quality improvement.

208. Both design and management practices associated with specific diversion structures will depend on the water balance requirements of the area and on the specific wildlife and fisheries management objectives chosen. Since different fish and wildlife species have different water quality and salinity requirements, a decision to increase the habitat preferred by some species may have adverse effects on others. Authorities on the local ecosystem and species should be consulted to determine the exact nature of these tradeoffs.

209. Construction of diversion structures is most feasible in sparsely developed areas where business and residential dislocations would be minimized. Some short-term aesthetic impacts may occur during construction but will not be carried over into the long term.

210. Planning documents for proposed diversion structures in Louisiana (US Army Engineer District, New Orleans 1982) stated that major structural repairs would be required every 15 years. These major repairs would include dewatering the structure, replacing or repairing valves, painting and repair of machinery, and repair of electrical systems. Annual maintenance activities include dredging in adjacent inlets and outlets, use of electrical power for pumps, and minor repairs. Project plans also recommended ongoing biological monitoring to evaluate biological productivity and the biological effects of the diversion.

Costs

211. Costs of diversion structures vary widely depending on the size of the diversion, type of structure (gravity flow, inverted siphon, or pump station), and support operations such as operational and biological monitoring programs. The cost for construction of a box culvert structure designed for 6,600 cfs for Breton Sound, La., was estimated at $15 million, while a similar but larger structure (10,000 cfs) for Barataria Sound, La., was estimated at $32 million (US Army Engineer District, New Orleans 1982). Major maintenance costs were estimated at $250,000 every 15 years for the Breton Sound structure.

Water Control Structures

Purpose

212. Water control structures may be built to manipulate water levels in borrow pits and other artificial wetlands for fish and wildlife management.

Description

213. Water control structures are possible where (a) an adequate and stable source of inflow can be obtained and (b) existing drainage occurs from the site of the artificial wetland to enable drawdown (Uhler

1956). Because of the need for elevational gradients for gravity drainage, marshes and ponds created by impoundment (dikes or dams) are generally more suitable for incorporation of water control structures than are wetlands created by excavation, such as borrow pits. However, where drainage already exists at the site of a planned excavated wetland or borrow pit, incorporation of water control capability may be possible. Sites with perennial streams or drainage ditches flowing through them are especially well adapted for this type of feature (Rudolph and Hunter 1964).

214. Designs for water control can range from simple to extremely complex. At the simplest level is the stop log structure (Figure 18) where water level is manipulated by placing or removing preservative-treated wooden boards in or out of the spillway. Procedures for designing and constructing simple structures are outlined in detail by the Atlantic Waterfowl Council (1972). The most important site-specific consideration is to ensure that structures have adequate capacity to pass flows associated with the heaviest precipitation expected during drawdown periods (Uhler 1956).

215. More complex systems include pumps, upstream reservoirs for water supply, and/or advanced designs for dams and drawdown valves. As design complexity increases, so do costs and risks of economic losses due to flood damages.

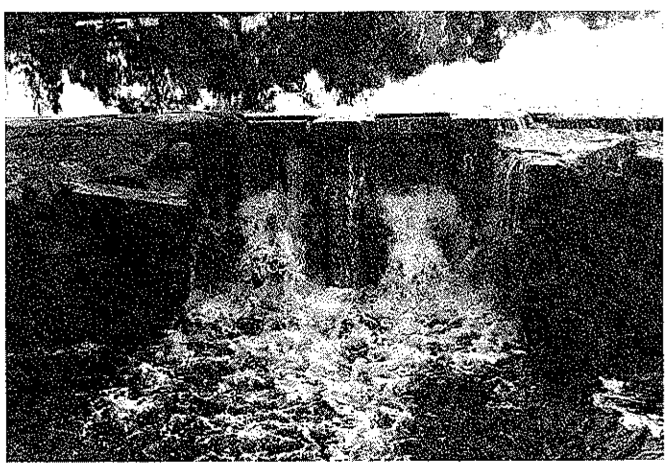

Figure 18. Simple stop log water control structure

216. Management goals are basically twofold: (a) to provide a source of water during fish and wildlife use periods and (b) to manage the aquatic vegetation of the wetland. Although goals often conflict with each other, they can be obtained by (a) consideration of frequency, dates, and durations of flooding and drawdown and (b) determination of the optimum level of flooding and drawdown. For biological reasons, such determinations are necessarily site specific.

217. For example, distinct differences in the timing of flooding to foster waterfowl habitat are evident. In the more southern states that have significant wintering waterfowl populations, fall and winter flooding (Givens and Atkeson 1957, Rudolph and Hunter 1964, Landers et al. 1976) is desired to make food and cover sources available to ducks. In this region, spring flooding would kill many desired plant species. On the other hand, in northern areas (Keith 1961, Krull 1969, Schroeder et al. 1976, Kaminiski and Prince 1981) early spring and early summer flooding is desired to produce nesting and brooding habitat. Winter drawdown is often used to prevent destruction by ice of residual cover used for nesting. Meeks (1969) showed that wetland vegetation can markedly change depending on the date of drawdown, and thus recommended a May drawdown for specific Ohio wetlands. Summer drawdown is a most common practice in order to stimulate aquatic vegetation (Griffith 1948, Brumsted and Hewitt 1952). Water management prescriptions can also range from biennial drawdowns (Uhler 1956) to several cycles of drawdown/flooding annually (Nelson, Horak, and Olson 1978). Harris and Marshall (1963) recommended at least one drawdown every 5 years for waterfowl management in northern marshes.

218. In addition, timing of flooding will be influenced by the desired species to be managed. Rundle and Fredrickson (1981) determined that rails and shorebirds in Missouri respond better to earlier fall flooding than that commonly prescribed for waterfowl. Specialized problems, such as the control of botulism outbreaks, require yet another drawdown schedule (Sperry 1947).

219. Level of drawdown or flooding has a marked influence on results of management. For fishery management, Bennett (1954) noted that

a drawdown that is too low creates an imbalance in bass/bluegill populations, while drawdown to the right level would actually enhance the balance between species. For the management of waterfowl in southern impoundments, Landers et al. (1976) described two management practices, each producing different results. Drawdowns to saturated soil condition favored smartweed, while drawdowns to dry soil fostered panic grass.

Performance

220. Wentz (1981) described water control as one of the best management tools available for wetland wildlife habitat management. Landers et al. (1976) noted that South Carolina marshes with managed water levels attracted more waterfowl than unmanaged marshes. While Bellrose and Brown (1941) found muskrat densities per acre of emergent vegetation to be higher in areas that had stable water levels when compared to semistable and widely fluctuating levels, they further noted that semistable (managed) water levels promoted emergent vegetation, and thus muskrat habitat. Muskrat densities were higher for lakes and wetlands that had semistable levels; this was true because stable lakes had much larger fractions of open water, unusable as muskrat habitat. Widely fluctuating water levels, on the other hand, were not extensively used by muskrats. Taylor (1978) found that seasonally flooded impoundments contain great quantities of both plant and animal foods. McQuilken and Musbach (1977) found that more sound acorns were found on seasonally flooded bottomland hardwoods (greentree reservoirs) than on adjacent unflooded areas.

221. Because of the need for a stable source of inflow and a gravity drainage at the outlet, water control structures have not been widely used in levee borrow pits. However, a water control structure was proposed for a project in the Vicksburg District (US Army Engineer District, Vicksburg 1980).

Limitations

222. As stated earlier, the primary limitation to constructing water control structures is the need for gravity drainage at the wetland outlet to enable drawdown. Often the flat topography surrounding riverside borrow pits makes drainage from pits very difficult. Moreover,

water supply and quality can be problematic, especially where water is not conveniently available from the river and/or flooding is desired during naturally dry periods. Artificial water control may be impossible for borrow pits with water levels that fluctuate widely with river stage. Determination of the feasibility of a water control structure should be possible using data available or obtainable through levee design studies.

223. Biological limitations include the potential for pest problems and the need to determine what species are being managed in order to develop prescriptions for optimum timing and water levels. Beavers have been known to dam on water control structures, making them inoperative (Rundle and Fredrickson 1981). Further, water control management that fosters beavers, muskrats, and other burrowing mammals may compromise the integrity of the levee if the managed wetland is located adjacent to the levee toe. Frequent inspections, destruction of beaver dams, and/or trapping thus may be required. Rundle and Fredrickson (1981) showed that water manipulation for waterfowl did not necessarily benefit other species, while Fredrickson (1979, 1980) and Harris and Marshall (1963) found that undesirable vegetative changes were possible in wetlands even with water management activities.

224. Water control structures could be seriously damaged or destroyed if they are located on the riverside areas and thus must withstand heavy floods. Moreover, operational plans for riverside pits may be disrupted by flooding. Periodic repair of structures, as well as routine operations to manage water levels, will add to operation and maintenance costs.

225. From an aesthetic standpoint, water level fluctuations, especially drawdowns, can adversely affect visual perception of the area. Exposed mudflats are often looked on as unattractive and can emit unpleasant odors.

Costs

226. A proposed project in the Vicksburg District included two water control structures on a series of five borrow pits at a total estimated cost of $13,800. As stated earlier, costs can be expected to

vary widely depending on the complexity of the design.

227. Costs of management include those for transportation and labor and materials costs for maintenance and for structure operation (Rundle and Fredrickson 1981). These costs have been documented on the USDI Fish and Wildlife Service's National Wildlife Refuge System to range from $0.92 to $9.60 per acre of managed wetlands per year. Management costs are dependent on the travel distances required to access the facility, the number of times annually that water levels will be altered, and the sophistication of the water control system.

Artificial Islands

Purpose

228. Artificial islands can be incorporated into artificial wetland design to increase productivity for waterfowl and other bird populations, primarily by increasing nesting and loafing areas as well as reducing losses to predation. Additionally, artificial islands created by excavation or fill can be used to create habitat for beaver, muskrat, and nutria populations without compromising the structural integrity of the levee.

Description

229. Islands may be created in four basic ways: (a) constructing and installing floating platforms; (b) placing excess material generated during construction or other fill in mounds (Figure 19); (c) flooding low portions of existing peninsulas, either by raising water levels in the basin or by cutting through isthmuses; and (d) leaving a portion of a borrow pit unexcavated so that it becomes an island when the pit fills with water (trees may be preserved on such islands).

230. Construction and use of floating islands in Arizona is described by Fager and York (1975). The islands are made from styrofoam and planted with emergent vegetation from the pond site. Holes are drilled through the styrofoam so that water seeps into the rooting zone of the plants. Each island has a covered nesting enclosure and an open loafing area. Dimensions of the islands ranged from 4 by 4 ft to 4 by

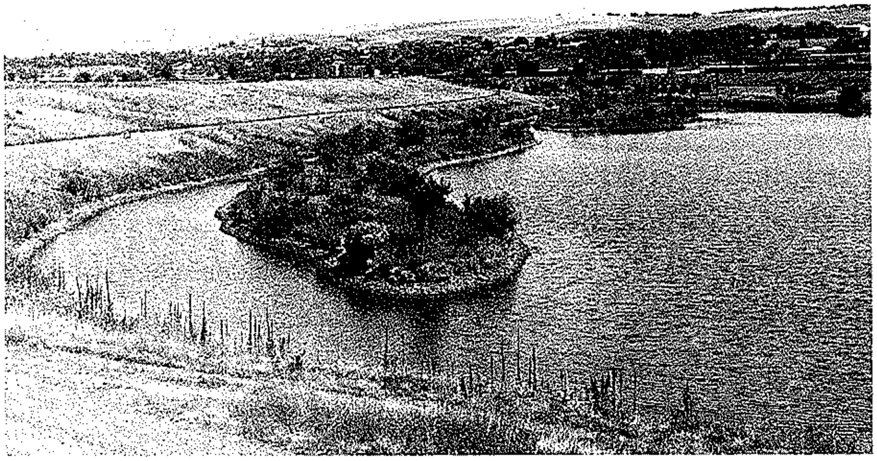

Figure 19. Artificial islands add habitat and visual diversity to borrow pits and other aquatic areas. Although the island shown here is in an urban area and was landscaped for aesthetics, extensive use by waterfowl for nesting and loafing was observed

8 ft and were 4 in. thick. A nesting square 2 by 2 ft by 2 in. thick was placed in the center of each platform. Styrofoam was partly covered with chicken wire, soil, and brush. The entire platform was framed by 8-in.-wide logs and anchored with a rope and a 25- to 30-lb rock. An alternate design specifically for Canada geese is given by Will and Crawford (1970).

231. Islands created by excavation or fill can be created using dredges, bulldozers, draglines, or similar equipment. Coarse aggregates for base provide stability, while finer materials on the surface allow for the establishment of vegetation. Normally, vegetation will establish itself naturally, but planting may be advisable for some soils (see discussion on wildlife seeding and planting, paragraphs 317-347), and watering could be appropriate in arid climates (Giroux 1981a). If the primary objective is enhancement of nesting cover for the prairie duck complex, vegetation should not be allowed to grow densely on the island except on its windward side (Giroux 1981a). Periodic burning or mechanical scarification may be desirable (Duebbert 1982). To further minimize erosion at sensitive sites, islands may be situated along the lee shore of the basin and oriented parallel to prevailing winds and

currents that would occur during flooding.

232. Optimum sizes for artificial islands for waterfowl nesting range from 0.1 to 0.5 acre (Hammond and Mann 1956; Johnson, Woodward, and Kirsch 1978; and Giroux 1981a). Although smaller islands would not provide as great benefits for nesting, they do serve as valuable resting and loafing sites. Larger islands would be more conducive to supporting mammalian predators, which could reduce waterfowl productivity. On the other hand, the large islands can be expected to exhibit increased species diversity for other wildlife.

233. Separation of the island from the mainland as far as possible will serve to further discourage predators from destroying nests (Duebbert 1982). Depths of water between the island and the mainland that exceed 30 in. also will reduce accessibility of the island to predators. Although clustering islands will make them less erodible, it can increase their attactiveness to waterfowl predators (Sherwood 1968), and thus separations of a least 100 yd are beneficial between islands. This may be impractical in many small borrow pit wetlands.

234. While island shapes are not critical to wildlife diversity, rectangular or irregular islands will provide proportionately more beneficial edge than round or square islands. Moreover, irregularly shaped islands add to the visual diversity of the site.

Performance

235. Artificial islands of all types have been tested and proven effective in a number of locations, not only for concentrating waterfowl but also for increasing their productivity (Hammond and Mann 1956; Noble et al. 1979; Giroux 1981a, 1981b; Duebbert 1982). They also may benefit loons (McIntyre and Mathison 1977) and colonial water birds, especially ground-nesters, if suitable natural sites are lacking. In some areas (e.g. the Upper Mississippi River), use of dredged material islands by such species appears negligible (Environmental Laboratory 1978). Nevertheless, they may be vital as shorebird roosting sites (Fager and York 1975) and may host populations of nongame birds that are more diverse and dense than those found on upland sites (Giroux 1981a, 1981b). Management of islands developed or enlarged by dredged material placement

is a common practice by the CE along the Snake and Columbia Rivers in Oregon and Washington. Several of these islands are planted with grass/legume mixtures and are managed specifically for goose nesting.

236. Artificial islands created with fill in the Lewiston, Idaho, levee interior drainage collection ponds are used heavily by resident, migrating, and wintering waterfowl. These islands provide both protection from predators and isolation from human disturbance. Borrow pit islands in the Lower Mississippi Valley provide habitat for a wide variety of species other than waterfowl, including nongame birds and denning furbearers.*

237. Artificial islands have been proposed for number of other CE levee projects. These include the Santa Ana River (US Army Engineer District, Los Angeles 1980), the Sweetwater River (US Army Engineer District, Los Angeles 1982), flood protection for Davenport, Iowa (US Army Engineer District, Rock Island 1976), and the Little Calumet River (US Army Engineer District, Chicago 1982).

Limitations

238. Islands are most appropriate in larger artificial wetlands. For example, Giroux (1981a) recommended a minimum wetland width of 600 ft for an island to be worthwhile. Wetland depth should exceed 30 in. in order for islands to provide protection from predators.

239. Erosion can be a problem on those islands created by fill or by excavation around natural sites, and some shore protection may be needed. Strong winds, waves, and high-velocity flows will exacerbate any island erosion problems on areas created by excavation or fill, so that sites having these features should be avoided. High-velocity flows may also cause floating platforms to break free and obstruct water passage further downstream. Floating platforms should therefore be small enough to pass under downstream bridges.

240. If seasonal water level fluctuations in the artificial islands are extreme, the islands may not be effective. Moreover, winter

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* Personal Communication, 1982, M. C. Landin, Wildlife Biologist, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

ice cover may increase the need for maintenance.

241. If island construction by fill occurs as a separate activity, a dredge and fill permit may be required under Section 404 of the Clean Water Act. Such activities would entail placement of fill within waters of the United States. If an island is constructed, it could replace otherwise productive wetland habitat; thus, the request for a permit could be met with resistance.

Costs

242. Costs of island construction from fill were previously documented by Hammond and Mann (1956) to range from $52 to $177. The Atlantic Waterfowl Council (1972) also described project costs as $81-$202 per island depending on site conditions.

Fishery Shelters in Borrow Pits

Purpose

243. Fishery shelters constructed in borrow pits can enhance fish populations by providing cover and shading and occasional spawning and feeding sites. This may be particularly important as a temporary measure for providing cover during the period when riparian vegetation is removed and before it becomes reestablished.

Description

244. Artificial fishery shelters (Figure 20) can consist of wood or other vegetation assembled in a symmetrical manner, unassembled woody vegetation simply gathered together in clumps, or other materials such as tires tied together and sunk to the bottom of artificial ponds and borrow pits (Nelson, Horak, and Olson 1978). Vegetation may consist of woody debris cleared from the bottom of the pit during construction, or may originate from adjacent shoreline or upland areas.

245. Constructed brush shelters require more effort but may be more durable and effective. Durable woods such as oak and cedar, rather than alder and willow, may be bound together in alternating layers. Weights may not be required to sink and anchor the structures, depending on the type of wood used. They will persist longer if placed below the

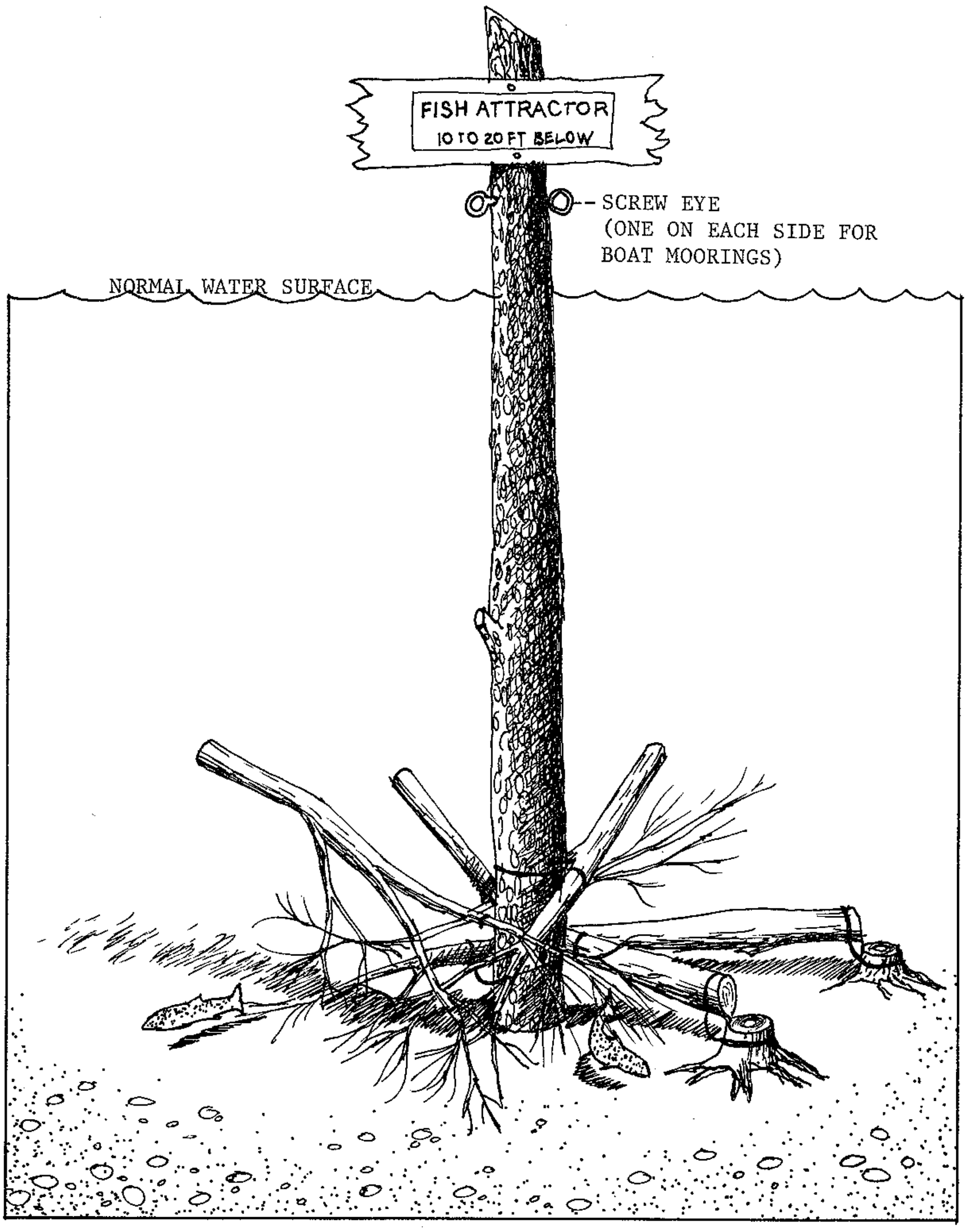

Figure 20. One type of brush shelter

mean low water level. Many configurations have been used; dimensions of 10 by 10 ft by 18 in. are common. On ponds that freeze over, shelters may be easily placed in deepwater areas by placing them on the ice in winter. In other areas, placement by boat may be necessary.

Performance

246. Fish shelters installed in 1937 were evaluated by Thomas, Legault, and Carpenter (1968) and found to be still concentrating fish after a 30-year period in Douglas Lake, Mich. Other research by Prince and Maughan (1978) and Swales and O'Hara (1980) also demonstrated the value of artificially created fishery shelters. Commonly, private fisherman construct shelters in "secret" locations and thus guarantee themselves good, undisturbed fishing. However, fishery shelters have not been incorporated into any levee project design that was studied during this research effort.

Limitations

247. If shelters are not firmly anchored or if they are located in areas where flood flows are strong, they may be dislodged during floods, and wash down to bridges, culverts, and other water outlet structures. There, they may create dams that aggravate flooding and erosion problems. Shelters are most suitable in landside ponds, but are practical in riverside locations that are sheltered from high-flow velocities during flooding.

248. Durability of fishery shelters will be reduced by repeated wet-dry seasons that will hasten chemical decomposition. If placed in areas of severe anchor ice, their destruction is also hastened by alternate freezing and thawing.

249. Byproducts of decomposition may cause water quality impairment. Decay of wood/brush shelters may cause localized excessive biochemical oxygen demand and thus stressful oxygen conditions.

250. Shelters placed on already productive natural vegetation may constitute a loss of valuable habitat. Moreover, by creating cover for forage fish, shelters may exacerbate population imbalances by making forage fish unavailable to predators.

251. Some anglers can be expected to exhibit some frustration at

having their lines ensnared by artificial fish shelters. Where their tops could be exposed by water level fluctuations, adverse visual impact could occur.

Costs

252. Nelson, Horak, and Olson (1978) reported costs for two brush shelter projects associated with reservoir projects to range from $34 to $137 for construction of each shelter. Maintenance costs ranged $5.50-6.90 per year per shelter.

Fish Stocking

Purposes

253. Stocking can be used to establish or augment fish populations of commercial or sport value and thus add to the recreational value of borrow pits and other artificial wetlands constructed as a result of levee projects. Further, stocking can be used to restore the balance of some fish populations and to control pest insects and vegetation.

Description

254. Borrow pits or other artificial ponds that do not have means for fish to populate them by immigration through natural inlets or outlets or through passageways that occur during floods must be stocked with fish in order to have viable populations. Fish may be imported as hatchery stock or, less commonly, from natural populations nearby. The species stocked should be chosen with care by biologists familiar with the regional setting as well as with temperatures and water quality conditions expected in the newly created ponds. For recreational fisheries, mixtures of prey species and predator species are stocked simultaneously. A variety of combinations (Table 2) have been developed at the State level in order to provide relatively standard recommendations.

255. A few selected species have also been used for control of undesirable insects and plants. For example, Childers and Bennett (1967) determined that mouthbrooders can effectively control algae in some ponds prone to algal blooms. Plans currently exist for stocking

Table 2

Selected Examples of Regional Fish Stocking Prescriptions*

Species	Rate No./acre	Size/Age	Habitat	State/ Region	References
Largemouth bass/ bluegill	1 1-15	Fingerling	Ponds	Alabama	Swingle and Smith (1943)
Largemouth bass/ bluegill	100 1,500	Fingerling	Fertilized ponds	Alabama	Swingle (1952) Meehan (1952)
Largemouth bass/ bluegill	30 400	Fingerling	Unfertilized ponds	Alabama	Swingle (1952)
Largemouth bass/ bluegill	200-400 200-400	Fingerling	Ponds	Illinois	Brown (1950) Durham (1949)
Largemouth bass/ bluegill	200 30	Fry and adult	Ponds	Kentucky	Clark (1952)
Largemouth bass/ bluegill**	2-10 100	Adult and small	Ponds	General	Bennett (1971)
Largemouth bass/ bluegill	100 10	Fingerling and adult	Ponds	Michigan	Ball (1952)
Largemouth bass/ bluegill/ redear sunfish	100 1,000 500	Fingerling	Fertilized ponds	Southeast	Swingle (1952)
Largemouth bass/ redear sunfish	100 100	Fingerling	Ponds	Indiana	Krumholz (1950)
Rock bass	200	Fingerling	Ponds	Indiana	Krumholz (1950)
Channel catfish	200	Fingerling	Ponds	Indiana	Krumholz (1950)
Hybrid sunfish	200	Fingerling	Ponds	Indiana	Krumholz (1950)

* Fish stocking times and size of fingerlings are important considerations. Check with local authorities (e.g. fishery agencies) for appropriate stocking procedures.

** Added after first year.

this species into interior collection ponds along the Lewiston, Idaho, levee to see if algae can be controlled there. Additionally, introduction of the mosquitofish has proven to be successful in some situations to control mosquitoes.

256. Consideration should be given to expected harvest rates of predator and prey species, along with the life history requirements of the species to be stocked. Temperature and oxygen requirements are most important, along with special requirements for spawning and nursery habitat.

257. Most warmwater species are stocked only once, and then natural reproduction is allowed to maintain fish populations within the pond. Coldwater species often require annual stocking, since suitable spawning areas are often not available in artificial ponds and summer temperatures often are warmer than these species' tolerance levels. Thus, coldwater fish stocking is often considered as a "put-and-take" operation, and stocking levels are determined by estimating fishing pressure so that the bulk of the fish will be harvested before temperatures become too warm. Assistance is commonly available from the State fish and wildlife agency in both developing optimal stocking prescriptions and acquiring the needed fish.

Performance

258. Stocking is probably the oldest and most widely accepted fish management tool. Stocking is usually effective under the following conditions:

- a. The species are adapted to the region's climate.
- b. A satisfactory predator-prey ratio is established.
- c. Immigration and emigration of fish are controlled or at least understood, and undesirable species are excluded.
- d. The borrow pit is sufficiently fertile.
- e. Spawning sites and cover are adequate within the borrow pit.
- f. The stocked fish are free of diseases and acclimated prior to stocking.
- g. Harvest rates are satisfactory.
- h. Stocking is done at the proper season.

259. Bennett and Childers (1972) described a successful stocking program in a borrow pit in Illinois, which resulted in favorable fishing for at least 13 years. At the State level, stocking is a routine practice.

Limitations

260. The most important concern with stocking is the potential for introducing an undesired fish species, parasite, or disease into an entire watershed. To prevent this from happening, either stocked species should be compatible with the naturally occurring species of the watershed, or the artificial pond should be located and/or designed such that no opportunity exists for stocked fish to emigrate.

261. Stocked ponds commonly exhibit population imbalances created by overharvesting of predator species, underharvesting of prey species, and extremely high fecundity of prey species. Bass/bluegill combinations, for example, often develop very high populations of stunted bluegills, while bass populations become depressed.

262. As stated earlier, in order to survive, stocked fish must be adaptable to water conditions at the site. Temperature, oxygen, and the existence of pollutants all can limit the ability of stocked fish to survive and grow to catchable size.

263. Species not desired by anglers can become established in stocked ponds and outcompete desired species for food. Such species become established either through immigration or through the use of live fish as bait. In such instances, pond reclamation may be required in order to remove these fish before developing a new population through restocking.

Costs

264. Nelson, Horak, and Olson (1978) reported actual costs for four hatcheries to range from \$0.55-\$2.60/lb of fish released. Two other hatcheries had costs of \$0.003 and \$0.014 per egg or fry produced. Transportation costs included operating costs of \$1.90 per mile (assuming 20,000 miles annually).

265. If provisions for stocking borrow pits would require construction of a hatchery to produce fish, project costs could be

exorbitant. Fortunately, many States offer to sell fish or to provide fish free of charge for stocking.

Marsh Vegetation Establishment

Purposes

266. Both biological and physical values of wetlands are enhanced through marsh vegetation establishment. Vegetation serves to trap sediment, cycle nutrients, stabilize shorelines, support fishery food chains, and create a natural edge appearance. Vegetation may also be chosen to provide food and cover for waterfowl and other wildlife.

Description

267. Emergent or aquatic vegetation can be established by seeding or by the use of sprigs, tubers, or plugs either in existing basins or in artificially excavated areas such as borrow pits. Substrate preparation may be required. Since most noneroding lacustrine sites with water depths less than 7 ft will eventually become naturally vegetated, attempts at artificial establishment are usually appropriate only where severe erosion or invasion by undesirable plants will occur before natural establishment. Natural establishment can be hastened by manipulating water levels (paragraphs 217 and 220).

268. Most of the common aquatic plants have been used for vegetation establishment. Those most often planted for waterfowl include pondweed, smartweed, duck potato, spike sedges, duckweeds, coontail, flat sedges, bulrushes, and various wetland grasses (Pirnie 1935, Bellrose and Anderson 1943, Givens and Atkeson 1952, O'Neill 1972, Anderson and Low 1976, George and Young 1977). A variety of detailed guides are available that describe methods for species selection and propagation, including Kadlec and Wentz (1974), Garbisch (1977, 1980), and Environmental Laboratory (1978). When choosing plants for potential marsh vegetation establishment, consideration of soil, water, and climatic conditions is needed to ensure survival of the plants on the site, while plant characteristic variables determine plant values to fish and wildlife.

Performance

269. A number of case studies document successful wetland plant establishment projects and the value of wetland plantings to fish and wildlife. These studies include, but are not limited to Hewitt (1942); Emerson (1961); Reed and Heath (1974); Woodhouse, Seneca, and Broome (1976); Barko et al. (1977); Clairain et al. (1978); Cole (1978); Crawford and Edwards (1978); Heilman et al. (1978); Kruczynski, Huffman, and Vincent (1978); Morris et al. (1978); Reimold, Hardisky, and Adams (1978); and Webb et al. (1978). Wetland plant values to wildlife are summarized by Adamus (in press), while the importance of wetland plants in controlling erosion is discussed by Allen (1979).

Limitations

270. A variety of physical site factors influence the survival of artificially propagated marsh vegetation. Fine substrates generally support wetland plants better than very coarse substrates, although several species do exist that are specifically adapted to sands. Slope of the substrate is also a factor for plant survival since steep slopes are more prone to erosion. Slopes of less than 3:1 are most conducive to wetland plant survival. Sites susceptible to severe scouring, prolonged desiccation, woody plant invasion, and severe anchor ice provide more limited opportunity than sites not subjected to these conditions.

271. Water quality factors also influence the ability of plants to survive. High salinities or low pH may restrict the variety of plants that can become established. Alkalinities greater than 25 mg/ℓ $CaCO_3$ and moderate nutrient concentrations will encourage establishment.

272. Some wetland planting failures are due to choice of improper plant species, poor quality stock, incorrect timing of planting, sloppy planting techniques, vandalism, and poor handling and transportation of plant material. Protection from grazing is sometimes necessary during initial establishment.

Costs

273. Costs of marsh plant establishment can vary widely with regional differences, plant species selected, collection and planting techniques, skill of personnel, and other factors. However, the

Environmental Laboratory (1978) gives general estimates for a variety of cost factors inherent in marsh vegetation establishment.

274. Labor varies with the type of planting technique employed. Transplants and sprigs require 40-80 man-hours per acre, while rhizomes, tubers, and rootstocks require 40-60 man-hours per acre. Seed plantings require 4-16 man-hours per acre.

275. Use of a bulldozer for sloping and general shaping would cost $38-$95 per acre. Tractor and disk operation runs $5.10-$17.80 per acre per trip over the site; often two trips are needed to satisfactorily prepare the seedbed. Fertilizer commonly averages $7.60 per 100 lb, while lime costs $11.50-$17.80 per ton.

Beneficial Uses for Dredged or Excavated Material

Purpose

276. Dredged or excavated materials may be used to develop fish and wildlife habitat and visual diversity. Construction costs may be reduced by utilizing the materials onsite since hauling and disposal requirements are reduced.

Description

277. Excess material most commonly becomes available when it must be removed to reach suitable material for levee construction. For example, foundation materials that have low load-bearing potential or high seepage potential are commonly removed prior to levee construction. Moreover, embankment materials often occur in layers, with the first layer being either of insufficient quality or inadequate quantity to use as borrow. Thus, it must be excavated from the site in order to reach material that is to be used for levee construction.

278. One alternative for excess material use is the creation of artificial islands in borrow pits, ponds, and wetlands. This option was discussed in paragraphs 228-242.

279. A second alternative is thin spreading of material on the banks of borrow pits or in foreshore areas associated with the levee (Figure 21). If the excavated material is fertile, it can produce a

Figure 21. Excess dredged material was deposited in thin layers on this foreshore site in Fulton, Ill., and will be planted to vegetation valuable as wildlife habitat

lush growth of vegetation that will provide shading for borrow pit ponds. Moreover, thin spreading will slightly raise the elevation of foreshore areas so that less flood-tolerant species can be used. Specific recommendations for developing upland habitats for wildlife from dredged material are provided by Hunt et al. (1978) and Walsh and Malkasian (1978).

280. If material is suitable for a low dike or earthen dam, ponds or wetlands can be created and serve as valuable wildlife habitat. Wetlands created by impoundment are more amenable to management through water control (paragraph 213) than those created by excavation.

281. Another option involves placing the excess material in mounds. Such placement is used to add diversity to an otherwise flat topography (Figure 22). Additionally, mounds that are placed on windward sites of borrow pits can shelter waterfowl and other wildlife during high winds, and mounds generally can serve as wildlife retreats during rapidly rising floodwaters (Grizzel and Vogan 1973).

282. The best height for material placement depends on resource

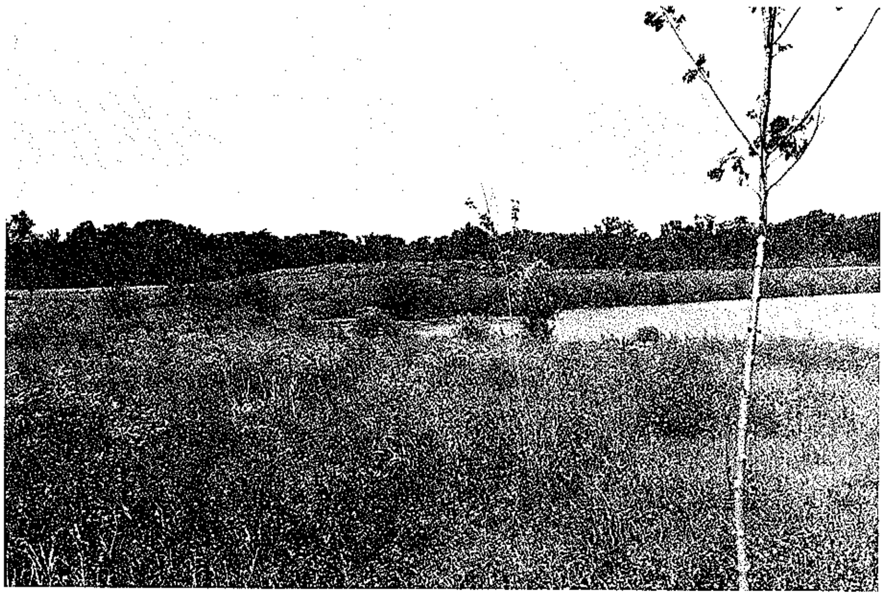

Figure 22. Mound in the background created from excavated material now provides visual diversity to borrow pit site

management objectives. If the material is to be farmed or is likely to be an eyesore, it is normally smoothed out in layers only a few inches thick. Alternatively, the mound concept is appropriate where visual diversity or higher land would benefit habitat and aesthetic considerations. If the mound concept is used, gentle and asymmetrical shapes, along with transitional grading to blend the mounds into the landscape, are used to provide a positive visual effect. In order to minimize adverse effects of material placement on vegetation, Grizzel and Vogan (1973) recommended that material not be placed within 20 ft of the base of existing trees.

Performance

283. A variety of research projects through the CE Dredged Material Research Program (DMRP) (US Army Engineer Waterways Experiment Station 1980) documented that the use of dredged or excavated material can provide substantial benefits to fish and wildlife. These results have been compiled into a variety of synthesis and summary documents, including Environmental Laboratory (1978); Hunt et al. (1978); Lunz, Diaz, and Cole (1978); Smith (1978); Soots and Landin (1978); and Walsh and

Malkasian (1978). The value of artificial islands as a potential method of disposal for excess material was discussed in paragraphs 228-242, while a successful example of using dredged materials to create shallow marshes is described by Reed (1976).

284. Two examples of beneficial uses for dredged or excavated material occur within the Rock Island District. The first is on the Fulton, Ill., project, where thin spreading of surplus material in the foreshore is being used to raise elevations enough to support planted stands of pin oak. During the period of research for this report, the material had been spread, but planting had not yet been accomplished. The second example involves the Evansdale, Iowa, project where unwanted debris was shaped into a mound on the edge of a borrow pit. This effort was the idea of the construction contractor, and he received a commendation for adding to visual diversity of the area while at the same time reducing construction costs.

285. The Sacramento District also provides an example of the successful beneficial use of excess material. Brennan Island State Park on the Sacramento River is a large area where dredged materials are used to develop landforms which buffer areas of different interest (camping, RVs, boating, swimming, and sports) from each other and control noise. An endangered plant species (Antioch dune evening-primrose) has been transplanted and is thriving on the dredged material.

<u>Limitations</u>

286. Sites must be available and planned into the overall design and alignment of the levee. These sites should not contain existing valuable wildlife habitat features. Sites that have steep slopes or are subject to severe erosion are poorly adapted to applications of beneficial use techniques. Vegetative erosion protection and possibly mulching are needed at most sites for this measure to be successful.

287. Dredged or excavated materials used should be excess material generated from construction. They should be free from contamination by industrial or municipal pollutants (Gosselink et al. 1971) that would release undesirable constituents. Although sterile soils will be more difficult to revegetate than fertile materials, plants adapted to

sterile sands do exist and can be used for planting if needed.

288. Construction of small dikes or dams to create wetlands or ponds is limited to situations where excess materials are relatively impervious and stable when wet. Normally, this is the material chosen for use in the levee; however, it sometimes occurs in insufficient quantity, as in the case of several sites in the Rock Island District. At these sites, silts overlay sands but do not exist in sufficient quantity with which to construct levees; thus, levees are commonly constructed from the sands.

Costs

289. In both the Fulton, Ill., and Evansdale, Iowa, projects, overall project costs were reduced through developing beneficial uses for excess material. Alternative methods of disposal would have required extensive hauling, diked disposal areas, and other more costly measures. Additional cost data are available from WES through the Dredging Operations and Technical Support (DOTS) Program.

Land Acquisition

Purpose

290. Land acquisition provides the opportunity for scientifically sound fish and wildlife management in designated areas. It is often used as mitigation to "replace" direct habitat loss.

Description

291. Steps in arranging acquisitions generally include (a) site survey, (b) setting of priorities, (c) preliminary negotiations, (d) land appraisal, (e) impact statement preparation, (f) final negotiations, and (g) closing. Issues involved with land acquisition include how to determine what and how much land should be acquired, as well as the choice of what method of acquisition is most appropriate to provide the greatest degree of protection at the lowest cost.

292. A number of methods are available to assist in planning the amount of land and the habitat types most appropriate for acquisition for specific projects. Perhaps the two most common are the Habitat

Evaluation Procedure (HEP) and Habitat Evaluation System (HES). Both processes involve ranking the value of the area lost and the amount of land lost to project development, then combining the two variables into a single value. Land is acquired to equal the value of the land lost. With any land acquisition scheme, unique or especially threatened habitat types receive special attention.

293. A variety of acquisition alternatives are available (Anonymous 1979; USDI Bureau of Reclamation, no data (b)). These include fee-simple acquisition in fee with retention of a life estate or lesser estate, easement, and purchase of development rights other than easements. Fee-simple acquisition involves outright purchase of sole ownership. It is usually the easiest and least complicated, but also the most expensive. Acquisition of land through estate provides the landowner with the right to use the land throughout his/her life, but wills it to the Government upon his/her death; such arrangements can be acquired at lower cost and can be used by the landowner as a tax advantage. Easements or development rights can be used to permit or prohibit certain specific uses.

Performance

294. At times, acquisition is the only method by which to preserve especially unique habitats. It has become a routine element of mitigation activities in project plans since the passage of NEPA. For example, proposed CE levee projects on the Santa Ana River (US Army Engineer District, Los Angeles 1980), the Sweetwater River (US Army Engineer District, Los Angeles 1982), and the San Luis Rey River (US Army Engineer District, Los Angeles 1981) all include some form of land acquisition as mitigation for the projects. Land acquisition efforts were also included in a levee project in Davenport, Iowa (US Army Engineer District, Rock Island 1976). Such efforts commonly enable either preservation or scientific management to occur.

Limitations

295. A number of sociological and legal obstacles exist to acquiring land as a part of levee projects. First, such efforts may meet extreme resistance from local landowners and residents who wish to

retain ownership of their land. Second, purchase may not be possible because there may be no land available for purchase or because the boundaries are so fragmented that the legal burden is too great. Moreover, purchases can be contested in court by State and local governments. CE policy requires that specific Congressional authorization be provided for acquisition of land for mitigation or enhancement of fish and wildlife resources (US Army, Office, Chief of Engineers 1983). Additional factors unique to levee projects are discussed in paragraph 127.

296. A variety of authors described a number of instances where land acquisition plans were not possible to implement. For example, Broach (1979) noted that delays in acquisition have resulted in mitigation lands being developed before they could be obtained and preserved. Broach recommended that acquisition should occur prior to or simultaneously with acquisition of land for project works, with allowance for obtaining a small additional percentage of the total land after construction in case unexpected impacts occur. Moreover, Rappoport, Mitchell, and Nagg (1977) felt that if acquisition is based on finding willing sellers, the resultant parcel may be too fragmented to be a coherent management unit or of unsatisfactory quality as replacement, or it may take too long to acquire.

297. Local resistance sometimes seriously interferes with land acquisition. Gard (1979) noted that for activities in the Lower Mississippi Valley, only 36,600 acres (20 percent of a planned 183,000 acres) had been actually acquired and placed under management as of 1979. Resistance came from landowners, States, and other Federal agencies.

Costs

298. Land acquisition costs may be divided into initial costs and long-term management costs. Costs of initial land purchase can vary considerably, depending on the region and the local land use pattern. However, acquisition generally is a very expensive option for habitat improvement. For example, on the Sweetwater River in California, 1 acre of marsh was estimated to cost $5,000 (US Army Engineer District, Los Angeles 1982). Long-term management costs vary depending on the

management actions undertaken. Management costs for a 92-acre marsh on the Santa Ana River were estimated at $11,000 annually (US Army Engineer District, Los Angeles 1980). This estimate involved cost sharing (half time) for the salary of a State or Federal biologist to conduct biological monitoring and to inspect water control structures to ensure they were being operated according to prescribed methods.

Artificial Nesting and Perching Structures

Purposes

299. Nest boxes and similar structures may increase wildlife productivity in areas that are generally suitable habitat but lack snags, hollow trees, or perching sites necessary for bird nesting or perching. In treeless areas, perching structures can facilitate raptor predation on burrowing mammals such as ground squirrels.

Description

300. A variety of nesting structures have been developed to provide habitat for a number of species (Table 3). Types of structures include, but are not limited to, wood duck nesting boxes, passerine nesting boxes, gray squirrel nesting structures, purple martin and tree swallow boxes, waterfowl nesting baskets, and elevated platforms for water birds and raptors. A good general guide to the construction, application, and protection of nesting structures is provided in the Wildlife Resources Management Manual (US Army Engineer Waterways Experiment Station, in preparation), Part 5.2, Nesting and Roosting Structures.

301. Perhaps the most often used and well researched structure is the wood duck nesting box (Figure 23). Yoakum et al. (1980) provided plans for both a wooden design and a metal design. Although wood ducks seem to select wooden boxes over metal boxes, the metal boxes usually exhibit a higher nest success rate. The wooden design is 24 in. tall, 12 in. wide, and 12 in. deep. The top is removable to facilitate cleaning, while the entry hole is an oval measuring 4 by 3 in. Rough-cut lumber is preferred to smooth lumber in order to give ducklings a surface with friction to help them exit. Metal houses are cylindrical,

Table 3

Dimensions and Mounting Heights of Nesting Boxes (Yoakum et al. 1980, Courtesy of the Wildlife Society)

Species	Floor of Cavity, in.	Depth of Cavity, in.	Entrance Above Floor, in.	Diameter of Entrance, in.	Height Above Ground,* ft
Bluebird	5 × 5	8	6	1.25	5-10
Robin	6 × 8	8	**	**	6-15
Chickadee	4 × 4	8-10	6-8	1.12	6-15
Titmouse	4 × 4	8-10	6-8	1.25	6-15
Nuthatch	4 × 4	8-10	6-8	1.25	12-20
House wren	4 × 4	6-8	1-6	1-1.25	6-10
Bewick's wren	4 × 4	6-8	1-6	1-1.25	6-10
Carolina wren	4 × 4	6-8	1-6	1.50	6-10
Violet-green swallow	5 × 5	6	1-5	1.50	10-15
Tree swallow	5 × 5	6	1-5	1.50	10-15
Barn swallow	6 × 6	6	**	**	8-12
Purple martin	6 × 6	6	1	2.50	15-20
Prothonotary warbler	6 × 6	6	4	1.50	2-4
Starling	6 × 6	16-18	14-16	2	10-25
Phoebe	6 × 6	6	**	**	8-12
Crested flycatcher	6 × 6	8-10	6-8	2	8-20
Flicker	7 × 7	16-18	14-16	2.50	6-20
Golden-fronted woodpecker	6 × 6	12-15	9-12	2	12-20
Red-headed woodpecker	6 × 6	12-15	9-12	2	12-20
Downy woodpecker	4 × 4	9-12	6-8	1.25	6-20
Hairy woodpecker	6 × 6	12-15	9-12	1.50	12-20
Screech owl	8 × 8	12-15	9-12	3	10-30
Saw-whet owl	6 × 6	10-12	8-10	2.50	12-20
Barn owl	10 × 18	15-18	4	6	12-18
Sparrow hawk	8 × 8	12-15	9-12	3	10-30
Wood duck	10 × 18	10-24	12-16	4	10-20

* Many experiments show that boxes at moderate heights mostly within reach of a man on the ground are readily accepted by many birds.

** One or more sides open.

Figure 23. Wood duck nesting box

12 in. in diameter, and 24 in. long. They are topped by cones that are 12 in. in diameter and 15 in. high. Openings are oval shaped, 3 in. by 4 in. All boxes are lined with sawdust, wood chips, or shavings to form a nest base. Placement on poles over water seems to attract ducks more than placement on land. Densities of 2-3 boxes per acre appear to be optimum. Keran (1978) further discussed options for placement of wood duck boxes.

302. Various modifications of the basic wood duck nesting box have been used in order to resolve problems associated with predation and interspecific competition. Use of horizontally, rather than vertically, placed cylinders were recommended by McGilvery and Uhler (1971) and Heusmann, Blandin, and Turner (1977) in order to deter use by starlings. Grabill (1977) accomplished the same objective by installing a second, smaller box on the side of the wood duck box. Starlings would choose the smaller box rather than the larger box and would prevent other starlings from nesting in the larger box. Both Cronan (1957) and Eaton (1966) recommended guards on wood duck nesting boxes to protect them from raccoon predation. Griffith and Fendley (1981) designed a wood duck nesting box from a 5-gal plastic bucket as a cost-saving

measure. Minnesota Waterfowl Co. sells a plastic wood duck box made by Phillips Petroleum for about $20. It is almost predator proof.

303. Smaller boxes provide nests for a variety of cavity nesting birds including tree swallows, chickadees, and house wrens (Cook 1947), but have been most often erected as a tool to reverse recent trends in bluebird population declines (Yoakum et al. 1980). These boxes are constructed of wood, 14 by 6.5 by 5 in., and have a pivoting side that is used for cleaning. A 1.5-in. circular hole is provided for entry. When used for bluebirds, boxes are placed 3-4 ft off the ground in habitat consisting of open areas with scattered trees. Spacing boxes at least 100 yd apart reduces territorial fighting. When used for tree swallows, boxes are placed around ponds or marsh areas, spaced 30-40 yd apart, and located 4-9 ft above the ground. Yoakum et al. (1980) provided a number of alternative designs for these structures.

304. Both wooden (Barkalow and Soots 1965) and tire (Burger 1969) structures have been designed for gray squirrels, and wooden squirrel boxes meet the design requirements for kestrels (Hammerstrom, Herstrom, and Hart (1973) and screech owls. Designs for these structures along with instructions for assembly are provided by Yoakum et al. (1980). Sanderson (1975) described optimal habitat for squirrel nesting boxes as hardwood stands 30-60 years of age that lack natural cavities but produce high mast yields. Spacing of 2-3 per acre provides for maximum density and utilization.

305. Purple martin structures house colonies rather than single families of birds. As such, they have a number of entrances that usually measure 2.5 in. in diameter. Each "room" is 6 by 6 by 6 in., and the house itself is located 15-20 ft above ground. Competition for nest boxes can be severe among purple martins, starlings, and house sparrows, and thus opening and closing of the entrance holes timed to coincide with the purple martin nesting season is sometimes required to ensure that pest species will not unsurp the box.

306. Conical nest structures made from chicken wire or hardwear cloth increase nest site availability for ground-nesting ducks (Cowardin, Cummings, and Reed 1967; Bishop and Barratt 1970; Doty and

Lee 1974; Doty, Lee, and Kruse 1975; and Doty 1979). Elevated and/or floating structures and waterfowl (Brenner and Mondok 1979), geese (Craighead and Stockstad 1961, Will and Crawford 1970, Fielder 1979), and California quail (MacGregor 1950) reduce threats from predation.

307. Hall, Howard, and Marsh (1981) developed artificial perching structures for raptors with the intent of stimulating predation on rodent pests. A pine block (2 by 2 by 18 in., rounded on the edges) was bolted perpendicular on one end to a 16-ft pipe that consisted of sections that could be screwed together. To install the structure, a fencepost was driven into the ground and the perch attached to the post with bailing wire.

Performance

308. The values of wood duck boxes (Hawkins and Bellrose 1941; McLaughlin and Grice 1952; Klein 1955; Burger and Webster 1964; Strange, Cunningham, and Geortz 1971; Doty and Kruse 1972; McComb and Noble 1981a, 1981b; and Wenner and Marion 1981) are consistently documented through a number of studies. Likewise, Zeleny (1977) reported extremely high use and productivity from bluebird nesting boxes. Squirrel nest boxes have been documented to be effective in areas where natural tree cavities are in short supply (Barkalow and Soots 1965, Burger 1969, Nixon 1979), while the authors cited above, who tested waterfowl nesting cones (see paragraph 306) and elevated platforms, found them to be effective at reducing predation and occasionally increasing productivity.

309. Hall, Howard, and Marsh (1981) found that artificial perches were readily accepted by raptors in California, and several of these raptors were observed capturing pest rodents. The authors concluded that the use of artificial perches appeared promising for developing biological rodent control efforts.

310. Purple martin houses were erected in a local park adjacent to a levee borrow pit pond by the local sponsor for a CE levee project in Evansdale, Iowa. Purple martins and tree swallows were using these boxes. In addition, personnel from the Seattle District reported the use of wood duck boxes in a number of instances. Wood duck boxes are

also routinely incorporated into the design of levees and levee repair work in the Portland District.

Limitations

311. Biologically, both competition from unwanted species and predation cause difficulties in some management efforts using artificial nesting structures. Frank (1948), for example, found wood duck nest box usage in Connecticut to be limited because the boxes were taken over by other species including squirrels, wasps, and hornets. Unless protected, nests in boxes can be threatened by raccoons, snakes, and other predators (Yoakum et al. 1980). Tardell and Doerr (1982) reported that black bear predation was a serious problem for some North Carolina bluebird nest boxes where nests, birds, and the boxes themselves were destroyed. Jones and Leopold (1967) discovered intraspecific competition to be a problem in one wood duck nesting box project.

312. If structures are located in foreshore areas, they could be susceptible to flooding. Boxes could be destroyed by floods and thus result in a lost investment. If flooding occurred during the nesting season, nests could be lost. Finally, boxes and structures washed away by floods could become unwanted debris downstream.

313. Nest boxes or other habitat structures placed in recreation areas or other human activity areas could be subjected to vandalism. Some types of structures, such as tires for squirrel denning, could have negative visual impacts.

314. Boxes and other structures are useful only in areas where food and cover resources are otherwise suitable for the species being managed. For example, both Sanderson (1975) and Nixon (1979) noted that squirrel boxes are most appropriate in young hardwood stands where mast is plentiful but natural cavities are not. Likewise, Keran (1978) provided specific habitat recommendations for wood duck nesting boxes.

315. In many instances, annual maintenance and cleaning will be needed to ensure long-term productivity. Standard designs for wooden wood duck nesting boxes and bluebird nesting boxes include doors for box cleaning.

Costs

316. The US Army Engineer District, Chicago (1982), estimated the cost of materials for wood duck nesting boxes as $1.05-$1.24 per box, based on actual project data published in the scientific literature. Construction requires 0.25-2 man-hours per box. Installation labor costs are highly variable. If it is assumed that boxes would be fully occupied for 5 years and there were no predation, each wood duck produced would cost $0.15.

Seeding and Planting for Wildlife

Purposes

317. Establishing vegetation for wildlife enables development of food and/or cover that attracts desired wildlife species to the project site. Vegetation for wildlife also reduces soil erosion.

Description

318. Plant establishment for wildlife includes seedbed preparation, fertilizing, liming, planting or seeding, control of competing vegetation, irrigation, and any other measures needed to ensure the survival of the planted vegetation. After vegetation is established, a number of alternatives may be pursued (paragraphs 496-577) to foster valuable wildlife habitat types. Selection of plant species and arrangement during the design process are critical to making revegetated areas attractive to wildlife.

319. Plant survivability. In order to maximize plant survival, species adaptation to project site conditions should be considered. Species that are adapted to climatic, soil, and topographic features of the site may be identified by preconstruction site survey. Inventories of plants inhabiting similar previously disturbed sites may provide information on species survivability.

320. General rules of thumb for wildlife plantings (Yoakum et al. 1980) include using mixtures rather than single-species plantings wherever possible in order to ensure that at least some species survive. Native species will usually adapt to the site better than exotic

species, and perennial species usually exhibit greater long-term survival rates than annual species.

321. Many reports are available which provide information on developing planting prescriptions to maximize plant survival. At the State level, the USDASCS produces and routinely updates portions of its Technical Guide, which provides prescriptions and techniques for critical-area planting that are keyed to specific site conditions. Parsons (1963), Seibert (1968), and Allen et al. (1978) provide procedural guides for establishing vegetation along riverbanks for erosion control, while Edminster (1950) describes criteria for species selection and discusses appropriate species for riparian and upland woody plantings in the Northeast United States. Hafenrichter et al. (1968) discuss appropriate species and planting techniques for grass and legume species in the Pacific Northwest and Great Basin States, and Duebbert et al. (1981) give comprehensive guidelines and instructions for the establishment of seeded grasslands in the prairie pothole region. Nord and Green (1977) discuss plant selection and procedures for use in the California Mediterranean ecosystem. Vallentine (1971) gives planting guidelines generally applicable to the Western States, while Plummer, Christensen, and Monsen (1968) deal with specific recommendations for Utah.

322. The CE has developed several guides for choosing plant species and establishment techniques. Ocean Data Systems, Inc., Coastal Zone Resources Division (1978), covers 250 selected plant species and discusses wildlife value, regional applicability, establishment procedures, and geographic distribution. This handbook is specifically directed at dredged material disposal sites, but is somewhat applicable to levees since (a) highly disturbed sites are common to both levee projects and dredged material disposal areas and (b) levees are frequently constructed from dredged material. However, the handbook does not evaluate species relative to risks to levee integrity. Other CE guidance documents have been developed by Environmental Laboratory (1978), Hunt et al. (1978), Smith (1978), and Soots and Landin (1978). MacClanahan et al. (1975) listed plants that showed an acceptable survival rate on 1966 Sacramento River levee plantings.

323. Plantings in levee foreshore areas will be subjected to partial and complete inundation at various frequencies. Riverside plantings must therefore have a certain degree of flood tolerance to survive. A number of authors dealt with synthesizing data enabling choice of plant species that are more tolerant of floods. For example, a series of documents by the USDI Fish and Wildlife Service (Teskey and Hinckley 1977a, 1977b, 1977c, 1978a, 1978b, 1978c; Walters, Teskey and Hinckley 1980a, 1980b; Chapman et al. 1982; Lee and Hinckley 1982) give regional rankings of plant species regarding their flood tolerance. Likewise, Whitlow and Harris (1979); the US Army, Office, Chief of Engineers (1980b); and Klimas, Martin, and Teaford (1981) developed information on the flood tolerance of various plant species for the CE.

324. Plant value. In addition to survivability, the second major consideration for wildlife plantings is the value of the plant species to wildlife. Plants become useful to wildlife if they provide desired species with food, cover, or both (Figure 24).

325. Martin, Zim, and Nelson (1951) is a basic guide to the wildlife food value of plants. Leedy, Maestro, and Franklin (1978) and

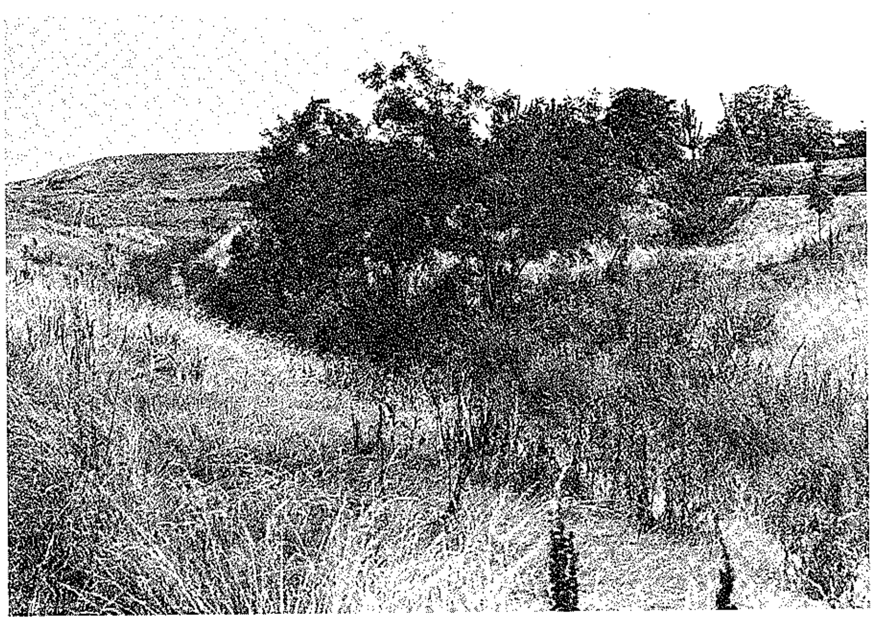

Figure 24. Area of a drainage ditch on the Lewiston, Idaho, levee used to foster plants that provide quality wildlife habitat

Yoakum et al. (1980) provide plant lists ranked in order of preference as general wildlife food sources. However, regional studies along with the personal experience of biologists with expertise in the locality are invaluable in determining which plant species provide quality sources of wildlife food. Generally preferred types of plants include mast-producing trees, edible seed or berry-producing shrubs, and large seeded grasses and legumes. Succulent forbs provide valuable food sources also but can be overutilized by wildlife with the ultimate result of planting failure (Dryness 1975). When developing plant prescriptions, it is often justifiable to give preferential treatment to species that provide food in the winter, when natural food sources are limited. The use of multispecies plantings can provide a variety of food sources that are available during different seasons.

326. Different wildlife species have different plant cover preferences. Tall grasses provide valuable nesting and escape cover for a variety of waterfowl (Duebbert and Lokemoen 1976, Duebbert et al. 1981), pheasants (Joselyn and Tate 1972, Snyder 1974, George et al. 1979), other ground-nesting birds, and small mammals. Various authors (Greenwall 1948; Anderson and Ohmart 1979; Lines, Carlson, and Corthell 1979; Robel and Browning 1981; and Yahner 1982) noted the value of shrub plantings in promoting overall species diversity and providing critical sources of winter cover. If used as winter cover, many-branched shrubs produce more and higher quality cover than single-branched species. Tree plantings provide good cover for a number of species. A variety of wildlife, including cavity-nesting birds and others, are dependent on woodlands for their survival.

327. Unfortunately, several plant species that provide poor wildlife food value and limited wildlife cover are used extensively for planting on levees and other disturbed areas. These species do rate very high in their ability to cover erosion and thus are sometimes necessary on steeply sloped disturbed areas, such as levees. However, where they are not needed for erosion control, more beneficial wildlife plants could be substituted. One example is tall fescue, which has been shown to be a very poor food source for deer (Probasco and Bjugsted

1978) and generally does not foster a variety of wildlife species. Other examples include coastal bermuda grass and crested wheatgrass. Often these species, through forming very dense sod mats, prevent natural succession to more beneficial wildlife plants.

328. Some plant communities are becoming increasingly rare due to agricultural and urban development, but they still have important value for the wildlife associations they support. Examples include the bottomland hardwoods of the Midwest and South, willow/cottonwood riparian areas of the West, and native prairie grass of the Midwest and West. If there is sufficient land area associated with a levee project, consideration should be given to plantings of these rare communities.

329. A number of project plans for various CE levee projects (US Army Engineer District, Huntington 1980; US Army Engineer District, Los Angeles 1977, 1980, 1982; US Army Engineer District, Omaha 1975, 1976, 1979, 1980b; US Army Engineer District, San Francisco 1969; US Army Engineer District, Vicksburg 1980) illustrate the variety of options available for planting schemes for levee projects. In most cases, these plans incorporated several of the basin premises stated above, including (a) choosing species that are adaptable to the site, (b) promoting as diverse a group of plant species as possible for a variety of food and cover values, (c) favoring rare types, and (d) choosing species that have value as wildlife food or cover.

Performance

330. Where plantings have survived, their value to wildlife consistently proves to be excellent. However, survival of plantings often is a major factor limiting their usefulness (Yoakum et al. 1980). For example, grass and grass/legume mixture plantings have been tested extensively to determine their value as waterfowl and upland game bird nesting habitat. Plantings increased waterfowl and/or upland game bird productivity in Iowa (George et al. 1979), Illinois (Joselyn, Warnock, and Etter 1968; Joselyn and Tate 1972), Colorado (Snyder 1974), Wisconsin (Frank and Woehler 1969), Maryland (Burger and Linduska 1967), and the Dakotas (Duebbert and Lokemoen 1976, Duebbert et al. 1981). Although recommended species, mixtures, and seeding rates varied between

studies due to climate, soils, and management objectives, mixtures of grasses and legumes were preferred over pure grass stands in all studies except those in Iowa. The legumes were included because they serve as valuable wildlife food and they fix nitrogen and thus improve grass survival. Legumes were not included in the Iowa recommendations (George et al. 1979) because their presence encourages landowners to conduct haying operations early in the season and thus excessively disturb nesting birds.

331. Atkeson and Givens (1953, 1954) reported the establishment of hayfields as a routinely used tool in Southeastern wildlife management, other public lands, and club lands in order to provide browse for geese. Recommended species for this purpose included alfalfa, crimson clover, white-Dutch clover, Ladino clover, tall fescue, redtop, and orchardgrass. Landin* observed extensive planting of wheat and rye for winter food for deer, geese, and turkeys by private hunting clubs in the batture of the Lower Mississippi River. Schimke, Green, and Heavilin (1970) found grass plantings in California greatly reduce threats of brush fires, while Davis, Ito, and Zwanch (1967) documented very good adaptibility for four species and/or varieties of grass (coastal bermuda, creeping wildrye, tifgreen bermuda, and tifway bermuda), and good adaptability for one grass (Kikuyu grass) and one forb (matgrass) on Sacramento River levees.

332. Likewise, a number of authors researched the value of planted woody vegetation to wildlife. Robel and Browning (1981) evaluated nongame bird use for 33 species of woody shrub plantings in Kansas. They found that 50 percent of all bird usage was concentrated in four species: thornless multiflora rose, a multiflora rose hybrid, cardinal autumn olive, and manchu cherry. Other significantly used plants were smooth prairie rose, sargent crabapple, silver buffaloberry, Russian-olive, skunkbush sumac, redosier dogwood, red tatarian honeysuckle, western chokecherry, cotoneaster, and amur honeysuckle. The authors

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* Personal Communication, 1983, M. C. Landin, Wildlife Biologist, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

found that woody plantings were generally useful tools in the development of nongame wildlife habitat.

333. In another study of woody plantings in Minnesota, Yahner (1982) concluded that in intensively farmed areas, woody plantings constituted a limited but very important habitat type. He found vertical diversity to be an important variable and recommended plantings that would provide bird habitat at a variety of levels (ground, midstory, and overstory) because it would allow for a higher species diversity. Out of 13 genera tested, 5 (spruce, elm, honeysuckle, aspen, and maple) were found especially attractive to birds. Such woody shelterbelt plantings were also found to be highly valuable to nongame birds in South Dakota (Emmerich and Vohs 1982).

334. Anderson and Ohmart (1979) obtained good survival and growth from woody riparian plantings in desert areas of Arizona and California. Moreover, they noted marked increases in bird densities and species numbers within 1 year after revegetation. Further, Greenwall (1948) in Missouri discovered that woody plantings around farm ponds significantly added to pond use by wildlife when all the plants survived. However, plant survival in Greenwall's study was not good. In Maryland, shrub hedges of multifora rose greatly increased quail populations (Burger and Linduska 1967).

335. Allen et al. (1978) reported results of planting nine upland plant species (trees, shrubs, and grasses) at a dredged material disposal site in the Galveston Bay, Tex., area. Good survival was obtained from live oak, wax myrtle, winged sumac, bitter panic grass, and coastal bermuda grass. Plant survival and growth were heavily dependent on wetness of the experimental sites. Wildlife use increased as the vegetation developed. In followup studies at this site, invasion and colonization by native species have been observed. Although successional change have affected the survival of the original plantings, the site remains completely vegetated (Landin 1982).

336. Clairain et al. (1978) reported on revegetation of a dredged material disposal site on Miller Sands Island in the Columbia River in Oregon. Initial success was high with grass/legume mixtures, but

further growth was poor due to the nutrient-poor, sandy substrate. Although planted meadows were more attractive to feeding geese and nesting mallards than control sites, overall avian species diversity was lower than in control areas that were evolving into woody vegetation types. Followup studies of this site have revealed that this phenomenon is continuing.*

Limitations

337. Biologically, the most important limitations involve the ability of planted vegetation to survive the often harsh conditions associated with levee projects. The natural soil structure is often destroyed during construction, and fertilization and/or replacement of topsoil is often required for plant survival. Moreover, different areas of the levee project site have vastly different flooding and moisture regimes. On the slopes and crown, droughty conditions are common, while floods can be expected in the foreshore area. Because of the wide range of conditions and the harsh nature of the site, many plantings in California have been unsuccessful (Davis, Ito, and Zwanch 1967).

338. A number of considerations limit the feasibility of planting or otherwise fostering vegetation on or adjacent to levees. First, lush vegetation can reduce the ability of maintenance personnel to efficiently conduct periodic inspections. Second, deeply penetrating roots may create seepage pathways through the levee embankment. Third, slope instability and erosion could result if large plants were uprooted during flood flows. Finally, extensive large vegetation can decrease the hydraulic capacity of small leveed channels.

339. As a result of the above considerations, CE guidance specifies a number of constraints on levee vegetation. On the levee itself, maintenance standards (US Army, Office, Chief of Engineers 1968) recommend dense, sod-forming grass 2-12 in. high substantially free of weeds for the levee embankment. Although landscape plantings are permitted on overbuilt levees (US Army, Office, Chief of Engineers 1972a), a

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* Personal Communication, 1983, M. C. Landin, Wildlife Biologist, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

root-free zone at least 3 ft thick must be maintained between the deepest expected root penetration and the face of the basic project structures (see paragraphs 92-104 for a discussion of overbuilt levees). Moreover, plantings cannot encroach upon seepage drains, toe drains, pressure relief walls, and other special devices for handling drainage through, around, or beneath the structure. Planting schemes must permit inspection of structures from moving vehicles, and the plants themselves should be as maintenance free as possible.

340. Engineering considerations for levee plantings vary somewhat depending on location of the plants. Plantings in the foreshore or battured area probably are least restricted by engineering concerns. Foreshore vegetation should not significantly reduce flood-flow capacity and must be flood tolerant.

341. Restrictions on vegetation on the riverside slope and crown plantings are aimed at preventing root-caused seepage and damage to the levee when trees are uprooted during floods. Additionally, periodic inspection of the embankment for erosion and burrowing mammal holes is required. However, riverside slope inspection is generally not accomplished when the slope is submerged during floods, and thus inspectability is slightly less important for the riverside than for the landside.

342. Inspectability is the basis for the landside slope vegetation restrictions, especially where the levee is made of less than optimal materials. The potential for root-caused seepage is also a significant concern. Dense sod on pervious levees with natural seepage problems is thought to exacerbate erosion concerns, since large mats of sod can be forced from the levee as water pressure builds within the levee. Inspection may or may not be required on the landside area adjacent to the levee, depending on the degree to which underseepage problems are anticipated.

343. The invasion and spread of undesirable plant species may be a problem and could require expensive control programs. Perhaps the most dramatic example of this is multiflora rose, which has consistently been found to have exceptionally high wildlife value and has been routinely recommended for wildlife plantings for quite some time. However,

it has spread to the point that in some locations extensive control efforts are being demanded or undertaken by local residents. For example, the State of Iowa recently instituted such a program. Thus, unless exotic species demonstrate overwhelming survival and wildlife value, and have a minimum risk of spreading, they should be avoided in wildlife plantings.

344. Finally, wildlife plantings have the potential for attracting undesirable as well as desirable wildlife to project sites. Burrowing mammals, including ground squirrels, beaver, muskrat, and nutria, are of utmost concern, particularly in Western States since their burrows in levees may create pathways for water passage. Wildlife plantings on levees should not be species that attract these animals. Such species may be allowed in adjacent areas where they will do no harm. Planting schemes and vegetation management plans should permit inspection of the levee for burrows.

Costs

345. Cost data for wildlife plantings are available from a number of sources, including the USDASCS, the USDI Fish and Wildlife Service, and State resource management agencies. Costs can be expected to vary considerably depending on the species being planted, the density of plants, and the extent of supplementary activities (weeding, fertilizing, irrigating, preparing the seedbed) required to ensure plant survival.

346. Lines, Carlson, and Corthell (1979) summarized project costs for USDASCS streambank restoration work in Oregon. Shrub plantings averaged $1.75 per foot of stream of $7,060 per acre of area planted. Grass plantings averaged $635-$870 per acre, while mixed grass/woody plantings were $1,480-$2,470 per acre. Nelson, Horak, and Olson (1978) listed project costs for wildlife plantings associated with reservoir projects to range from $36-$245 per acre, and $0-$73 per acre per year was required for maintenance.

347. Moreover, costs will vary depending on the source of stock and the labor used for planting. Costs can be reduced by using free sources of planting stock, such as the USDASCS, rather than commercial

sources, and by using volunteer labor where possible, such as Boy Scout troops, rather than paid labor.

Wildlife Brush Piles

Purpose

348. Brush piles provide resting and escape cover for small game and nongame wildlife. Where natural cover is limited, brush piles may be constructed to be used by wildlife until natural vegetation becomes established.

Description

349. Brush piles are constructed by stacking logs, slash, and stumps in designated areas (Figure 25) (Yoakum et al. 1980; US Army Engineer Waterways Experiment Station, in preparation). For levee work, such piles are best made on the landside of stands of trees in the foreshore area so that the piles are protected from high-velocity flows during floods. Brush piles may also be built on the landside of levees if they do not interfere with other uses. Anchoring the piles with stakes,

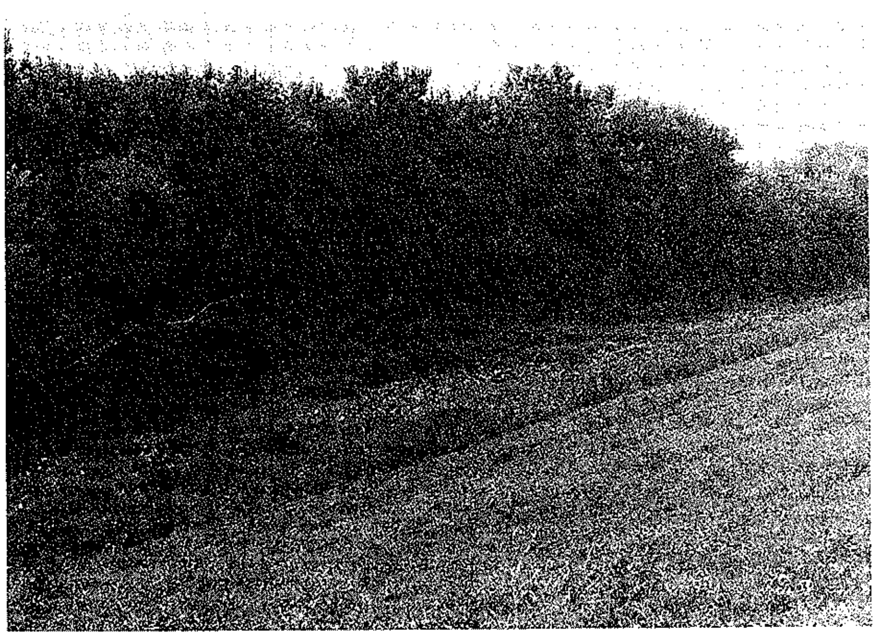

Figure 25. Organic debris used to create brush piles on the riverside of the Fulton, Ill., levee

planted woody vegetation, or other methods may be desirable if high, swift flood flows are anticipated.

350. Brush should be located far enough away from the levee so as not to attract burrowing mammals to the levee toe or to interfere with inspection. Long windrow brush piles are usually undesirable in areas that support big game movements.

351. Yoakum et al. (1980) described design dimensions and construction methods for brush piles for various wildlife species. For quail, brush piles should be about 5-6 ft in diameter and about 3 ft high. They should be located within 200 ft of each escape cover. For rabbits, dimensions of 25-50 ft long, 55 ft wide, and 4 ft high are optimal. If rocks or heavy limbs are used to support brush piles at least 6 in. above ground, decomposition will be retarded. Quail brush piles should have about a foot of clearance at ground level.

Performance

352. Brush piles have been a standard, recommended wildlife management practice for over 50 years (Leopold 1933, Yoakum et al. 1980). Where cover is limiting, they provide excellent escape areas for rabbits, quail, pheasants, other small game, and nongame species. They are recommended as standard practices by the USDA Forest Service (1969) and the USDASCS (1977). Benefits provided by brush piles include concealment and protection from predators and from the elements, and provision of a medium for seed germination and plant growth.

353. Debris disposal for the recently constructed Fulton, Ill., levee project in the Rock Island District involved the creation of brush piles. Since these brush piles have been in existence for only a short time, it is too soon to tell how effective they are in attracting wildlife, or whether they cause any problems. Brush piles were also proposed as a wildlife enhancement technique for a USDASCS levee project in Michigan (USDASCS State Office, Michigan 1969)

Limitations

354. Limitations based on engineering concerns are twofold. First, anchored riverside brush piles could wash away and become unwanted debris. Second, if piles are located too close to the toe of the

levee, they could attract unwanted mammals, interfere with inspection, or cause erosion if washed into the levee during a flood.

355. From a wildlife perspective, the major limitation of brush piles is the barriers to big game they may create. Western studies (Lyon 1976, Lyon and Basile 1979, Lyon and Jenson 1980) showed that windrows over 1.5 ft tall are avoided by mule deer and elk. Thus, brush piles located on big game movement corridors could alter patterns of migration.

356. Aesthetically, brush piles could have an adverse effect and could block human access to recreational sites. The use of brush piles is therefore most suitable in sparsely populated areas. They are usually not suitable for urban areas or adjacent to heavily used greenbelt areas.

Costs

357. The only levee project found where brush piles were used for wildlife habitat was the Fulton, Ill., project. Alternatives for brush and slash disposal consisted of extensive hauling, burying, or burning. Piling the debris into designated areas had the lowest cost of all the options available.

Controlled Access to Wildlife Areas

Purpose

358. Sensitive wildlife species may be protected from human disturbance by controlling access to important habitat areas. Examples of such sensitive areas and/or species include endangered species habitats, sites used by rare or important species for nesting and/or brood rearing, and big game wintering areas.

Description

359. Controlled access can be implemented concurrently with avoiding activities in sensitive areas, which was discussed in Part II (paragraphs 25-43). After sensitive areas have been identified, they may be used as control points in the location of access roads and recreational trails, so that such facilities do not directly encroach upon

sensitive areas or provide the public with ready access to them. More complex measures include fencing and posting signs around sensitive areas, as well as patrolling and enforcing posted boundaries.

Performance

360. From preliminary analysis of 1 year's observations at 25 selected Lower Mississippi River borrow pits, Landin (1984) found that the borrow pits less frequently visited by people supported more wildlife species. Keith (1961) concluded that overuse of artificially created wildlife marshes interfered with nesting and brooding activities of waterfowl. Steenhof (1978) documented disturbance effects on eagles, while Burger (1981) showed that water birds were sensitive to human activity. He found that larger and nonresident species were most sensitive to disturbance and that increasing levels of disturbance were caused by people on horseback, in vehicles, walking slowly, and jogging. Controlled access is widely practiced by private hunting clubs and some Government refuge and game management areas.

361. Two projects in the Los Angeles District (US Army Engineer District, Los Angeles 1980, 1982) and one project in the Rock Island District (US Army Engineer District, Rock Island 1976) proposed facility-siting actions to provide buffer zones for sensitive wildlife areas. The same Los Angeles District projects also proposed fencing for selected significant wildlife marshes.

Limitations

362. Alternative land uses for agricultural, residential, commercial, and recreational purposes will be preempted if access is controlled for wildlife management purposes. From a recreational standpoint, users will have less of an opportunity to interact with wildlife.

363. Limiting or eliminating access is sometimes very difficult. Those who really desire to enter a restricted area can be very resourceful in gaining entry.

Costs

364. If controlling access is limited to just locating facilities to avoid sensitive areas, costs would generally be low except for

compensation required for preempting other land uses (see paragraph 298 above).

365. Moderate levels of expenditure would be required for structural measures such as fencing and signs. If patrolling is involved, labor costs can be high and represent an ongoing commitment.

Fencing Designs to Enable or Discourage Wildlife Passage

Purposes

366. Where levee project lands require isolation from human or livestock disturbance, properly designed fences can exclude people and livestock, yet allow big game movement. Other fence designs can be used to exclude wildlife from newly vegetated areas, overused sites, or locations that are otherwise sensitive to wildlife-caused damage.

Description

367. Efforts to control human access (paragraphs 358-365) or to regulate grazing (paragraphs 525-547) may require the use of fences in the levee project area. Such fences, if not properly designed and constructed, could also block important movements of big game. Other areas that have been recently disturbed by construction or are overutilized by wildlife, however, may require that big game be excluded so that vegetation can become established in order to protect the site from erosion and slope stability concerns. Yoakum et al. (1980) provide designs for both types of fences.

368. Most research on fence passage of big game has been concentrated on the pronghorn antelope and the mule deer of the Western States. Since antelope tend to go under wire while deer jump over fences, designs for these two species are necessarily different. In the East, white-tailed deer jump fences only when they cannot go under or through them.

369. Antelope. For antelope, three designs are recommended, depending upon whether the range or pastures are used for cattle, sheep, or both. In all cases, a combination of barbed and smooth wire is recommended over net or woven wire.

a. Cattle ranges can be fenced with three strands of wire: the bottom (smooth wire only) spaced 16 in. above the ground, the second wire (barbed), 11 in. above that, and the third (also barbed) 11 in. above that, for a total fence height of 38 in.

b. Sheep ranges have four strands of wire, the first a smooth wire 10 in. above ground. Above that, three strands of barbed wire are spaced 7 in. apart.

c. Sheep/cattle ranges have four strands of wire, the first a smooth wire 10 in. above ground. The remaining three (barbed) are spaced 9 in. apart.

d. In addition, a device known as an "antelope-pass" has been designed for Western fenced rangelands. It is designed to replace a cattleguard to enable passage of antelope fawns. Designs and proper locations for placement are described by Yoakum et al. (1980).

370. Deer. Fences designed for deer passage differ from antelope fences in that the top wire rather than the bottom one is smooth, and stays between fenceposts are preferred. A three-wire design is recommended, the bottom one 16 in. above the ground, with the remaining two spaced at 10-in. intervals.

371. Big game. In contrast, woven wire is preferred where the management objective is to keep deer from entering sensitive areas. Heights of 6 ft on upright fences are usually adequate to discourage deer entry, although heights of 8 ft are sometimes necessary. As an alternative to the taller design that is less costly, woven wire can be placed to a height of 6 ft, followed by four strands of smooth wire spaced 4 in. apart. Alternative deer-proof fences described by Yoakum et al. (1980) include an overhanging or standing design and an electrified fence.

Performance

372. Blocking of game movement has been a significant adverse effect of development in the Western States and has been hypothesized as a major cause of big game population declines. Although livestock-containing fences high enough off the ground for an antelope to crawl under have been well researched and are usually effective for containing cattle, there is still disagreement about the designs for sheep: fences low enough to contain sheep are too low to permit antelope passage. Un-

fortunately, few of the designs for antelope passes have been tested under range conditions. Fences designed to constrain cattle but permit deer movement have been tested for several years in Nevada, while designs to constrain deer have proven effective in Colorado, California, and Virginia.

Limitations

373. Designs that permit big game passage are also effective at controlling livestock, but they may or may not successfully limit human entry. Although the fences may have some psychological effect, they would not restrict anyone determined to enter fenced areas.

374. Fencing might constrain flood fighting or maintenance operations. If located on the foreshore, they could be destroyed by floods. Fences that are designed to exclude livestock from the levee and foreshore may be opposed by landowners, if the landowners plan grazing in the area.

PART IV: ENVIRONMENTAL FEATURES FOR RECREATION AND AESTHETICS

Basic Requirements

375. The following discussions identify features that are designed to facilitate use of the levee and associated areas for public recreation or to enhance the appearance of the levee and related structures. Virtually all of the features described have some common limitations, unless otherwise stated.

a. First, the success of all recreational facilities is dependent on public demand for individual developments. Regional recreational plans and input from the public during the project development process are quite valuable in determining which features are desired and would be attractive.

b. Publicly controlled land is required for recreational development. The public must be able to utilize the site without fear of trespass. Moreover, they must be able to access the site over publicly controlled rights-of-way.

c. Recreational and aesthetic sites that receive heavy public use can be prone to vandalism. Designs and elements of features that make them vandal-proof or reduce costs to the point that replacement is not a significant problem may be warranted.

d. Lighting of facilities for night use may or may not be appropriate depending upon local land use and circulation patterns, anticipated usage, surveillance possibilities, other lighted areas, available power sources, and community attitude.

CE Policy and Guidance

376. EP 1165-2-1 (US Army, Office, Chief of Engineers 1983) provides a digest of CE policy regarding recreation developments. Construction costs for recreational facilities included in CE levee projects are normally cost shared on a 50:50 basis between the Federal Government and the local sponsor. The local sponsor also provides

lands, easements, rights-of-way, relocations, operation, and maintenance.

377. ER 1105-2-20 (US Army, Office, Chief of Engineers 1982a) limits the types of recreation facilities eligible for cost sharing in conjunction with CE projects. Permitted facilities include man-made improvements to facilitate public use and enjoyment of project resources and include access roads and parking areas; picnic areas and campgrounds; beaches and bathhouses; playgrounds and game fields; boat launching, temporary mooring facilities, and sport fishing; snowmobile, horseback riding, and bicycle trails; and similar improvements for use of the general public. These facilities are not ordinarily provided by private enterprise or on a commercial or self-liquidating basis. ER 1105-2-20 identifies certain types of recreation facilities, although they might be appropriate for a project, as ineligible for Corps participation. In addition to revenue-producing facilities such as motels, retail establishments, stables, etc., the following items are ineligible for inclusion in levee projects:

a. Decorative fountains and statuary.

b. Decorative lakes or ponds for recreation or aesthetic reasons only.

c. Elaborate playground equipment such as spray pads or wood and stone replicas of forts, castles, etc.

d. Decorative promenades.

e. Bleachers and dugouts.

f. Courts, except for general, all-purpose areas.

g. Golf courses.

h. Clubhouses.

i. Swimming pools.

j. Chairlifts.

k. Administrative buildings.

l. Visitor centers.

m. Amphitheaters.

n. Exhibit halls.

o. Shower buildings.

Appendix D of ER 1120-2-400 (US Army, Office, Chief of Engineers 1976) contains a checklist of facilities that may be provided in recreation developments.

378. Other CE guidance documents include EM 1110-2-400 (US Army, Office, Chief of Engineers 1971b), ER 1110-2-400 (US Army, Office, Chief of Engineers 1972b), and ER 1130-2-400 (US Army, Office, Chief of Engineers 1971a). EM 1110-2-400 gives definitions of recreation terms and general criteria for several types of facilities including signs; interpretive features; overlooks; boating, swimming, camping, and picnic areas; roads, trails, fishing, hunting, and nature areas; landscape plantings; utilities; and support facilities. ER 1110-2-400 gives basic principles controlling layout and design of recreation areas, with emphasis on basic elements such as roads, water supply, utilities, landscaping, etc. ER 1130-2-400 is a collection of information on CE policy regarding management of recreation areas. Nunnally and Shields (1985) discuss recreational features appropriate for CE flood control channel projects.

Recreational and Aesthetic Aspects of Borrow Pit Design

Purposes

379. Borrow pits can be designed to enhance recreational opportunities and can also be designed to be visually attractive and harmonious with the surrounding area.

Description

380. Borrow pits can be used for fishing, hunting, swimming, ice-skating, boating, and other activities. For fishing, hunting, and/or nonconsumptive wildlife use, borrow pits should be designed and constructed using the guidelines presented in Part III.

381. Safety considerations can be incorporated into borrow pit design. Leedy, Maestro, and Franklin (1978) and Leedy, Franklin, and Maestro (1981) recommend sloping and shaping the shoreline of fishing ponds to prevent children from drowning. A 2-ft-deep "shelf" or shallow area is constructed around the perimeter of the pit. The shelf

should be wide enough to prevent anyone accidently falling in from entering deep water (10-12 ft).

382. A final consideration for borrow pits used for recreational fishing involves the amount of shoreline available to fishing compared with overall pit area. Irregular, oblong, or rectangular shapes provide proportionately more sites for shoreline fishing than do round or square shapes.

383. Where water quality permits contact recreation, swimming facilities may be provided to increase recreational use. Such facilities consist of a gradual slope of the borrow pit edge to a safe depth of 4-5 ft, markers to delineate the recognized swimming area, lifeguards, and lifeguard facilities. If available, the use of sand fill for a beach would make the borrow pit more attractive for swimming. A detailed discussion of designs for swimming beaches is provided in paragraphs 461-470. Such development would require investment by the local sponsor for lifeguards and supplementary facilities, since under Federal cost-sharing regulations operation and maintenance is not the responsibility of the CE.

384. If borrow pits are located in cold climates that permit ice of sufficient strength to form and remain for a reasonable portion of the year, ice-skating becomes attractive as a potential recreational use. For safety purposes, shallow borrow pits are more attractive for ice-skating than deep borrow pits since the danger of drowning from breaking through the ice is decreased. Posting and/or patrolling during thin ice conditions would serve to further increase safety considerations.

385. Boating could be a valid recreational use on larger borrow pits where sufficient area exists in the pit to make boating worthwhile and to minimize problems with excessive congestion of boats. Providing access, along with a boat-launching facility, would stimulate boating. A detailed discussion on boat-launching facilities is provided in paragraphs 454-460.

386. In addition to recreational values, borrow pits provide visual diversity and interest to the landscape (Wiedeman 1962)

(Figure 26). Interdisciplinary teams that include landscape architects who are sensitive to the local landscape and geologic patterns can develop individual designs that add interest while ensuring continuity. Such designs include considerations for form, line, color, and texture.

387. Form can be used to reinforce surrounding landscape features. Spacing of forms can be used to create rhythms that are sympathetic to existing landforms. Lines, including shorelines, access roads, and other features, should relate to lines of the surrounding landscape. They can be used to lead the eye toward a focal point or reinforce the direction of the landscape.

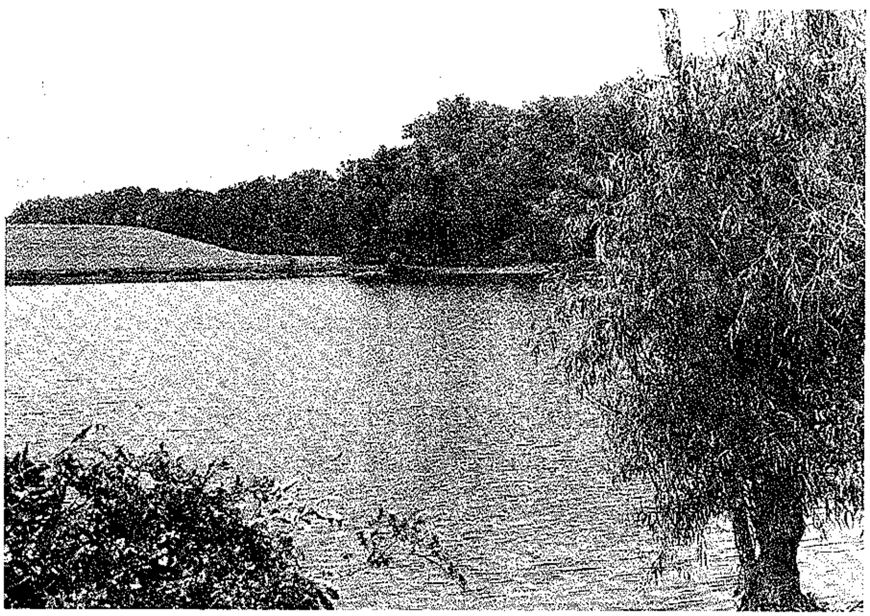

Figure 26. Borrow pits can enhance the levee landscape

388. Color is a function of surface material, vegetation, and water, but varies with climate and weather conditions; texture depends on the surface material and the distance at which is is perceived. Both can be made to blend or contrast with the surrounding landscape depending on the effect desired.

Performance

389. Although the amount of specific design varies, CE project plans of the Omaha District proposed that borrow pits be used for recreationally and aesthetically enhancing uses (US Army Engineer

District, Omaha 1976), while pits in the vicinity of Monticello, Iowa, are to be designed for ice-skating, picnicking, and other recreational uses (US Army Engineer District, Rock Island 1974a). Fishing is planned for a borrow pit adjacent to the Sun River in Montana (US Army Engineer District, Omaha 1979), while fishing, boating, and swimming were considered to be appropriate in Evansdale, Iowa (US Army Engineer District, Rock Island 1970).

390. In the LMVD, existing borrow pits receive significant use for hunting and fishing. Boating is a common use, either for fishing or for its intrinsic recreational value. A borrow pit existing on the Evansdale, Iowa, project is also extensively used for fishing and for nonconsumptive wildlife observation. Although it was initially designed for swimming, the inability of the local sponsor to provide lifeguard facilities has limited this use. However, an adjacent project in Waterloo, Iowa, has borrow pits used extensively but informally for swimming.

391. A number of authors have commented on the visual diversity provided by waters. Most notably, Wiedeman (1962) noted that borrow pits associated with highways add a great deal of visual interest for travelers. Litton et al. (1974) also concluded that water areas provide favorable aesthetic appeal in landscape environments.

Limitations

392. When a borrow pit is set aside for recreation, commercial, industrial, residential, and agricultural land uses for the pit and the adjacent vicinity will usually be preempted. Engineering limitations discussed previously for borrow pit designs for fish and wildlife enhancement (paragraphs 147-153 and 168-170) also apply to recreational or aesthetic development. Borrow deposits that are amenable in size, shape, and quantity are needed before recreational/aesthetic development of borrow pits is possible. Foreshore borrow pits may be subject to erosion or sedimentation damage during high floods, and this factor should be considered in design.

393. Certain recreational uses have specific limitations. Swimming, for example, will be limited to those borrow pits whose water

quality meets or exceeds water quality standards for contact recreation. Boating should be limited to pits large enough so that boats do not interfere with each other.

Costs

394. Cost considerations for borrow pit designs, as well as specific considerations for fish and wildlife, were discussed previously in paragraphs 154-155 and 171-174. Subsequent sections of this part deal specifically with costs for various types of development mentioned in this section.

Uses for Levee Access Roads and Crowns

Purposes

395. Levee access roads developed as recreational trails provide the public visual access to the river and connect points of interest along the river into an integrated recreational system.

Description

396. Recreational options for levee access roads include scenic drives, bicycle trails (Figure 27), hiking/jogging trails, and bridle paths. The first step in developing levee access roads as recreational sites involves determining which of the options best meets local recreational needs, and whether recreational activities conflict. Potentials for conflict become apparent when the atmosphere required for each activity and expected levels of use for various development alternatives are examined. For example, scenic drives are usually not compatible with bridle paths, since automobiles frighten many horses. Bicycling and hiking trails are compatible with bridle paths at low levels of use but not at high levels of use.

397. Basic design decisions for recreational trails include (a) determining the most appropriate width for the trail, (b) deciding upon the type of surfacing based on the planned use(s), (c) planning for signs and barriers that foster the intended use but discourage inappropriate uses of the trail, and (d) locating access points. CE guidance for design of recreational trails is given in ER 1120-2-400

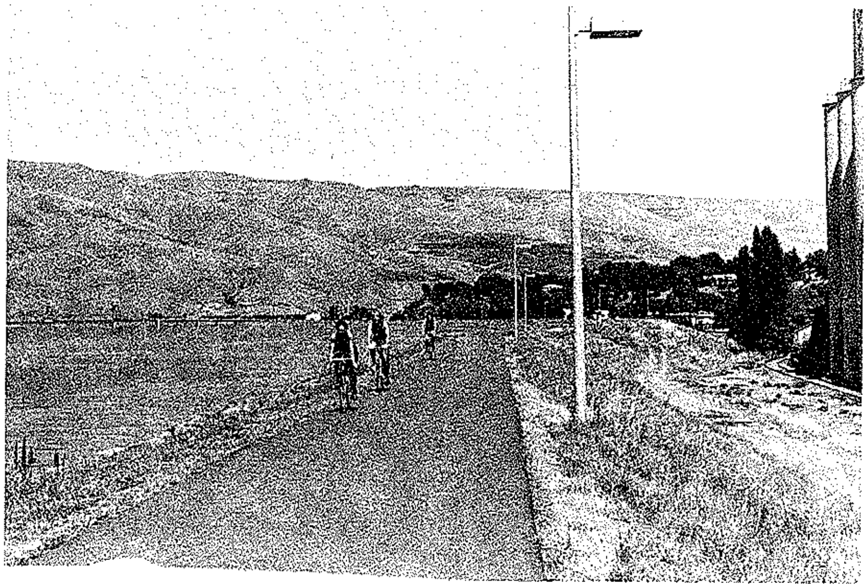

Figure 27. Levee access road in Lewiston, Idaho, designed for hiking and bicycling

(US Army, Office, Chief of Engineers 1976) and EM 1110-2-400 (US Army, Office, Chief of Engineers 1971b). Standard widths for access of operational maintenance activities usually are sufficient for most recreational uses, including hiking, jogging, bicycling, and horseback riding. Additional width may be needed if two-way scenic drives are incorporated, if a high use is expected, or if uses are combined, such as horseback riding with bicycling.

398. Trail surfacing options include dirt, gravel, or a pavement. Gravel or pavement is required for maintenance access roads. Dirt and/or gravel surfaces are appropriate for horseback riding or hiking. Paved surfaces are needed for scenic drives and bicycle trails and reduce the potential for jogging injuries. Paving is also appropriate if heavy pedestrian use is anticipated.

399. Signs and/or barriers can be used to ensure that only appropriate use of the levee access road or trails occurs. Signs can state what use(s) is appropriate and/or what use(s) is prohibited, but should meet CE standards and regulations (US Army, Office, Chief of Engineers 1972b). Barriers can be as simple as vertical posts or

horizontal bars with openings only large enough to allow passage for appropriate users.

400. Points of access should be located convenient to existing roads, parking facilities, and other community structures. Spacing between access points will vary depending upon available land, existing transportation patterns, and distances that users can reasonably be expected to travel. They may consist simply of ramps leading to the levee's crown and major recreational trail, or they may incorporate various other recreational facilities discussed subsequently in this chapter, including parking facilities, sanitary facilities, picnic areas, interpretive centers, and game fields.

401. A variety of supplementary areas and facilities can be added to increase trail utility. Rest stops (Figure 28) consisting of benches or picnic tables, trash receptacles, water fountains, bicycle racks, and/or shaded areas provide opportunities for resting and passive enjoyment of scenery. Lighting enables nighttime trail use. Interpretive centers, playing fields, picnic grounds, and other facilities along the trails provide users with rest areas and destinations.

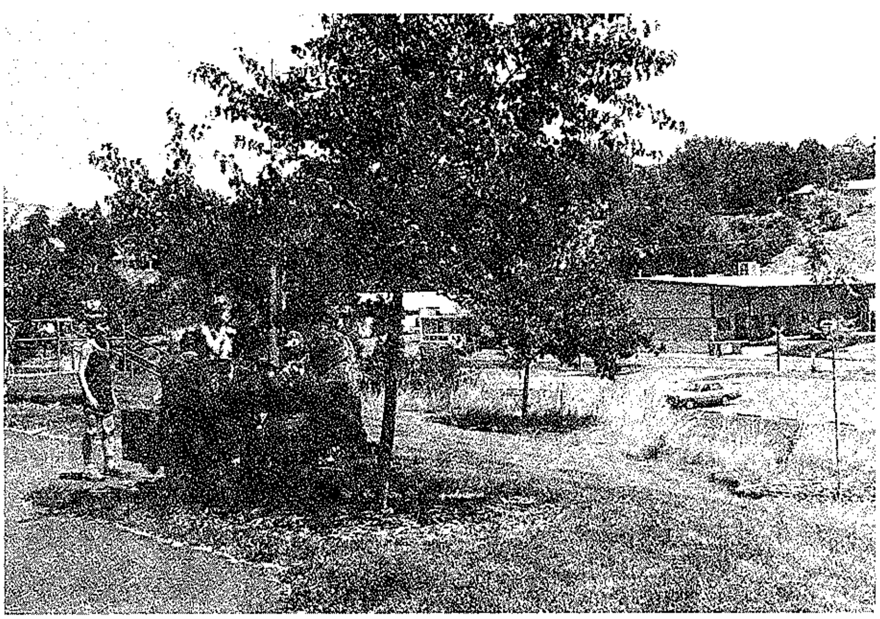

Figure 28. Rest areas along the Lewiston levee for picnicking, enjoyment of the river, and relaxation

Such facilities can be located on overbuilt levee crowns or in landside or foreshore areas where space is available. Design of supplemental facilities is best accomplished early in project design to ensure adequate space is available.

Performance

402. Several CE levee projects have included recreational trails. The Lewiston, Idaho, levee (Osmundson and Associates 1972, Osmundson 1973), for example, incorporated a complex trail design with a variety of supplemental features. Benches, picnic areas, and lighting are provided along the paved trail that is used for hiking, jogging, and bicycling. Interpretive centers, wet interior collection ponds, a local park, and several boat tie-up facilities are intimately linked to the trail. A site visit showed this system of a trail and supplemental recreational facilities to be extensively used by local residents.

403. Likewise, a CE levee project on California's Alameda Creek (US Army Engineer District, San Francisco 1969) incorporates a hiking/biking trail that appears to be heavily used by local residents (Osmundson 1980). Various other projects proposed or included recreational trails into project design (Table 4).

Limitations

404. Opening of the levee crown to recreational use could compromise maintenance and flood-fighting operations if users were on the trails during these periods. Moreover, recreationalists using trails during these periods could be subjected to increased risk. There would be some risks at any time, so that a need exists to determine and evaluate potential liability issues.

405. Use of levees by motorized vehicles will require conformance with State and local highway standards. Such standards may require the levee to be overbuilt to provide sufficient widths and strengths to support traffic.

406. Over the long term, periodic resurfacing may be required. Ongoing recreational area maintenance (paragraphs 611-621) needs would be created.

Table 4

Recreational Trails Incorporated or Proposed for CE Levee Projects

District	Project	Date	Designated Use	Surface	Width, ft	Unit Cost
Chicago	Little Calumet River	1982	Horseback Hike/bike	Mineral aggregate	12 3	* *
Huntington	Scioto River	1980	Hike/bike Walking	Asphalt Crushed stone	6 2-3	$11.00/lin ft 4.37/lin ft
Los Angeles	San Luis Rey River	1981	Bicycle	Asphalt	12	40.00/ton
Los Angeles	Santa Ana River	1980	Horse/bike/ hike	**	**	**
Los Angeles	Sweetwater River	1982	Bike/horse/ hike	Asphalt	10	45.00/ton
Omaha	Missouri River Unit R-616	1976	Drive Bike/hike	† *	32 10	 *
Rock Island	Clinton, Iowa	1974	Walking Bike	Crushed stone Paved	4 7-10	0.37/sq ft 17.49/sq yd
Rock Island	Davenport, Iowa	1976	Bike/hike	Paved	10	5.89/sq yd
Sacramento	Merced County	1980	Bike/hike	Blacktop	8	3.16/lin ft
San Francisco	Alameda Creek	1969	Hike/horse Bike	Mineral aggregate Paved	12 3	** 1.95/lin ft
Walla Walla	Lewiston, Idaho	1970	Bike/hike	Paved	6	6.80/lin ft††

* Project plans called for recreational trails to be located on service roads, and thus no cost would be incurred for recreational development.

** Final details and cost estimate not completed.

† Final plans and cost estimate not completed because local sponsor rejected feature as too expensive.

†† Six different surfacings were to be used on the trail. Value presented above is the mean of all surfacing costs. Costs ranged $3.09-$10.59/lin ft.

Costs

407. Basic costs include trail surfacing and signage. Surfacing estimates for various projects are provided in Table 4. Signage costs were estimated at $65 each for directional signs and $164 each for informational signs (US Army Engineer District, Huntington 1980).

408. Five projects provide estimates for staging and resting areas. In Merced County, Calif., two staging areas were estimated at $17,500 (US Army Engineer District, Sacramento 1980). Staging areas would consist of chemical toilets, small parking areas, provisions for water supply, and trash receptacles. Rest areas along the Alameda Creek levee (US Army Engineer District, San Francisco 1969) were established at $9,270 each and included chemical toilets ($835 each), picnic tables ($220 each), and trash receptacles ($75 each). On the Des Moines River, estimates for rest areas included tables ($280 each), shelters ($14.50 per square foot), fountains ($838 each), benches ($56 each), and lights ($560 each) (US Army Engineer District, Rock Island 1971). For the Davenport, Iowa, project (US Army Engineer District, Rock Island 1976) estimates included tables ($150 each), a shelter ($5,900 for 1,036 sq ft), and trash containers ($90 each).

409. Recreational trail maintenance includes vegetation management, repair of facilities, and solid waste disposal. For Merced County, Calif. (US Army Engineer District, Sacramento 1980), this was estimated to be $11,100 annually for a 6-mile bike path.

Aesthetic Considerations for Plantings

Purposes

410. Aesthetic plantings enrich the visual environment and soften adverse visual impacts of levee projects. Plantings encourage recreational use by providing pleasant surroundings.

Description

411. Successful use of aesthetic plantings depends upon both plant arrangement and selection of species that will survive and add to visual diversity. Major viewing and/or use points should be identified

so that plantings may be arranged and located to provide maximum visual effect. Perception of plantings will vary depending upon whether they will be viewed from up close or from afar. More subtle arrangements of form, texture, and color are perceived close up, while longer perspectives require more dramatic delineation. CE policy regarding landscape plantings at levee projects is given in EM 1110-2-301 (US Army, Office, Chief of Engineers 1972a).

412. Mann et al. (1975) discussed general principles for arranging plantings to enhance their appearance and to screen undesirable visual characteristics of projects. Arrangement of plants in masses is usually preferable to single specimens. Groups or drifts of plants (Figure 29) are more compatible with the scale of the levee, while individual specimens, unless they are unique trees, often create an undesirable, spotty appearance. Color, texture, form, and height can be varied in massed plantings to create a sculptured or artistic effect. Plant masses can also reinforce the visual nature of the undulations in overbuilt levees (paragraphs 92-104). Formal planting schemes are appropriate in urban settings, while informal, natural arrangements blend into rural settings. The use of plant masses is somewhat constrained, however, by the need to periodically visually inspect the levee.

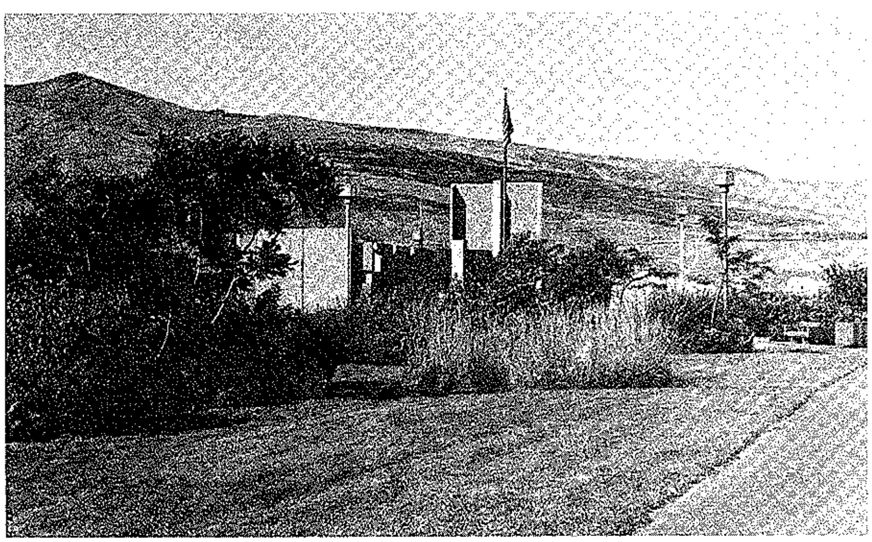

Figure 29. Plant massing around this interpretive center identifies it as a unique site

Therefore, plantings on or near levee embankments need to be designed by interdisciplinary teams of both landscape architects and engineers to ensure visual enhancement is maximized while threats to levee integrity are minimized.

413. Selection of appropriate species for aesthetic plantings involves consideration of sensory values and survivability. As discussed in the section on wildlife plantings (paragraphs 317-347), a variety of site-related factors including physical/chemical soil characteristics, moisture levels, exposure to sun and wind, and other factors will influence plant survival and necessitate different prescriptions for different sites. Species that are native to the site, are known invaders of disturbed sites in the region, or have proven successful in previous, similar plantings generally stand a better chance of survival than introduced or exotic species and have less potential of eventually becoming weeds. Hardiness, resistance to pests, soil requirements, tolerance to abrasion from waterborne debris, and drought/flood tolerance are all factors to consider when choosing species for aesthetic plantings. By carefully considering these factors, maintenance activities (i.e., fertilization, liming, irrigation, and replacement of dead plants) and associated costs (paragraphs 345-347) can be kept to a minimum. Cost and availability of alternate plant species also influence the practicality of using them in planting programs.

414. Plant sensory values include available size, ultimate height and/or spread, rate of growth, silhouette, texture, loose versus formal character, and bark characteristics, as well as presence, scent, and color of flowers and foliage. Mann et al. (1975) described these characteristics along with necessary site conditions and regional adaptability for over 300 species of trees and shrubs that are available for landscape plantings and listed a wide variety of herbaceous plant material that may be applicable. Plants that are attractive to wildlife accordingly have additional sensory value.

415. Aesthetic planting programs require consideration of the engineering concerns regarding structural stability of the levee, which

were discussed for wildlife plantings (paragraphs 337-344) and in EM 1110-2-301 (US Army, Office, Chief of Engineers 1972a). Two of these concerns, the potential for root-caused seepage and erosion around the bases of trees, can be addressed by either using an overbuilt cross section (discussed in paragraphs 95-102) or by planting materials in concrete tubs or planters (Figure 30) that limit root penetration. Although planters can be used either above or below the ground, buried planters will generally have a more natural appearance. If tubs are used, lone-term costs can be reduced by choosing plants that will not become root-bound. Additional information regarding landscaping CE project lands is available in EM 1110-2-400 (US Army, Office, Chief of Engineers 1971b), ER 1110-2-400 (US Army, Office, Chief of Engineers 1972a), and Technical Manuals (TM) 5-830-1 and 5-830-2 (Headquarters, Department of the Army (HQDA) 1965, 1961).

Performance

416. A number of CE levee projects include successful aesthetic plantings. The Lewiston, Idaho, levee (US Army Engineer District,

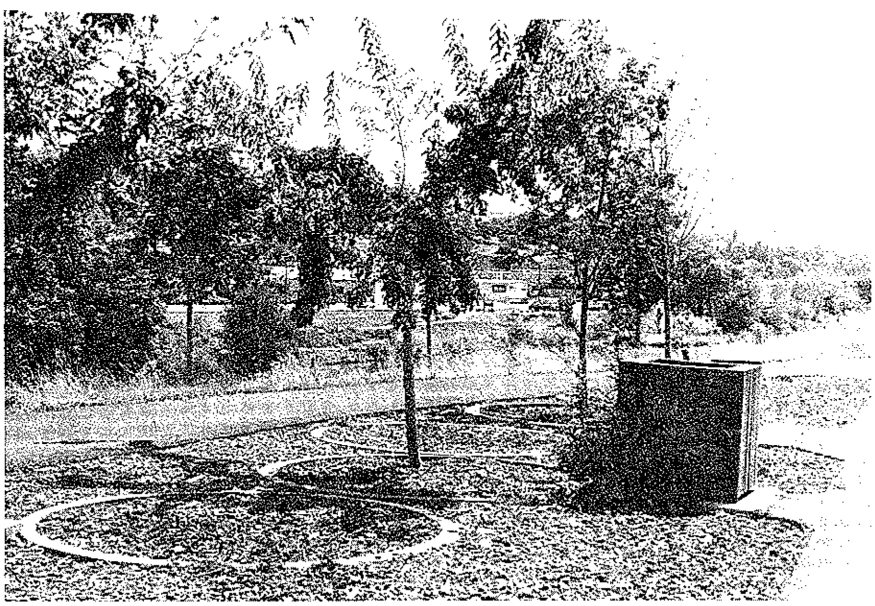

Figure 30. Concrete tubs set into the ground to provide planting that does not conflict with the structural integrity of the levee

Walla Walla 1970; Osmundson and Associates 1972; Osmundson 1973) illustrates the successful use of planters to promote a wide variety of trees, shrubs, and herbaceous vegetation on a levee that receives continuous hydraulic loading. Plantings on an overbuilt levee add visual diversity to the Waterloo, Iowa, project, as do plantings of trees, shrubs, and vines which are part of a floodwall project in Evansdale, Iowa. Success has been experienced with aesthetic plantings of selected species in the Sacramento District (Davis, Ito, and Zwanch 1967).

417. A number of other planting programs have been proposed for CE levee projects. These include, but are not limited to, the Des Moines River (US Army Engineer District, Rock Island 1971); Monticello, Iowa (US Army Engineer District, Rock Island 1974a); Davenport, Iowa (US Army Engineer District, Rock Island 1976); and various proposed projects in the Los Angeles District.

Limitations

418. Plant mortality is the most common problem experienced for levee aesthetic plantings. Plantings on the Alameda Creek levee, for example, failed to survive (Osmundson 1980), as did most plantings on Sacramento River levees (Davis, Ito, and Zwanch 1967). Harsh site conditions, high variability of sites, vandalism, and improper maintenance by local sponsors have been identified as causes for poor plant survival rates.

419. Policy constraints and engineering concerns previously described for wildlife plantings also limit the use of aesthetic plantings. Engineering concerns include: (a) plant interference with visual inspection of embankments for animal holes, boils, and erosion problems; (b) seepage problems created by decayed roots; (c) habitat fostering through plantings for some burrowing mammals; and (d) severe flood-caused scour erosion around trees and uprooting of trees. The validity of these concerns is somewhat controversial; however, sound engineering practice requires a conservative approach.

420. Although policy and engineering concerns are similar for both aesthetic and wildlife plantings, they may be somewhat less at

issue for aesthetic plantings, for several reasons. First, wildlife planting prescriptions commonly attempt to create extremely dense configurations for the purpose of providing cover, while aesthetic plantings can be somewhat more open. Second, aesthetic plantings can be expected to receive more maintenance than wildlife plantings, although because of cost considerations, use of low-maintenance vegetation wherever possible is required.

421. A poor landscape design may facilitate crime in certain settings. Areas screened by plantings can provide criminals a place to hide from their victims.

Costs

422. Construction and materials costs vary markedly depending upon the species chosen, available sources of planting stock, intensity of planting, the amount of area planted, and the need for supplementary preparation and cultivation measures. A number of estimates are available from several CE levee design memoranda and contract estimates (Table 5).

423. Supplementary measures that may have to be included in overall costs involve irrigation (paragraphs 578-588), seedbed preparation, and fertilization. Ongoing maintenance costs would involve removal and/or replacement of dead vegetation, mowing, weed control, insect/disease control, and pruning (paragraphs 611-622).

Uses for Periodically Flooded Areas

Purposes

424. Recreational or open space development of periodically flooded areas accomplishes two major objectives. Floodplain development is avoided, and the levee project is developed as a regional recreational corridor with interest and activity nodes.

Description

425. The basic concept for developing uses for periodically flooded areas involves providing facilities that are either floodproof or inexpensive enough to be expendable. Periodically flooded areas

Table 5

Selected Unit Costs for Aesthetic Plantings on Various CE Levee Projects

District*	Project*	Date*	Item	Unit Cost, dollars
Rock Island	Monticello Iowa	1974	Overall landscaping, 0.75 mile of levee	35,000
Rock Island	Des Moines River, Minnesota	1971	Grass seeding	894/acre
			Shade trees	112/each
			Deciduous shrubs	20/each
			Evergreen shrubs	20/each
Rock Island	Davenport, Iowa	1976	Total beautification, 21,000 lin ft of levee	284,000
			Seeding	1,177/acre
Rock Island	Evansdale, Iowa	1970	Seeding	765/acre
			Flowering trees	64/acre
			Evergreens	18/each
Walla Walla	Lewiston, Idaho	1976**	Planting tubs	883/each
		1970	Trees	190/each
			Shrubs	77/each
			Honeysuckle pots	4/each
			Lawn seeding (on irrigated areas)	6,375/acre
			Dryland grass seeding (nonirrigated areas)	3,825/acre

* Reference to planning document (in references section) from which cost data were obtained.
** Contract estimate.

associated with levee projects include the foreshore or batture and interior drainage areas. Options for development include playgrounds, picnic areas, campgrounds, game courts, and sports fields. General criteria for design of these types of facilities are given by EM 1110-2-400 (US Army, Office, Chief of Engineers 1971b).

426. Consideration of several general principles will increase the attractiveness of recreational areas. Grouping of diverse yet compatible facilities provides opportunities to combine a variety of recreational activities into a single experience. For example, picnic areas that are associated with playing fields enable spectators to enjoy a meal outside while watching their sport. A playground would occupy the interest of children while making quiet conversation possible for adults that are supervising in an adjacent location equipped with benches or tables. Moreover, locations that center on significant local or regional views or historic locations add other options to a diverse mix of activities available to users. However, grouping diverse facilities can cause severe management problems if conflicting uses or user groups are combined.

427. Easy access, both from the foreshore and from the landside, increases use of recreational areas. Areas adjacent to road intersections near the levee provide access from several directions.

428. Picnic area facilities include tables, grills, solid waste receptacles, and sanitation facilities. Equipment needed for playgrounds varies depending upon available funds, the size of the area, and the desires of children expected to utilize the site. Shelters serve to focus group areas for both picnic areas and playgrounds. If shelters are used, individual designs that reflect the nature of the site provide visual balance. If existing vegetation on the site can be retained during construction, it may provide shade and visual diversity and reduce needs for plantings. Picnic facilities should be located within easy walking distance from parking (about 300 ft).

429. Campground designs will include tent and/or trailer sites, depending on potential users. Generally, tables and fireplaces are provided at tent sites, and electrical, waste, and water hookups may be

provided at trailer sites. Other facilities provided are for sanitation and solid waste disposal and for water.

430. General-purpose sports fields may be developed in periodically flooded areas (Figure 31). The US Departments of the Army, Navy, and Air Force (1975) present design dimensions and methods for constructing many of the facilities that could be appropriate (Table 6). Since these areas will be periodically flooded, the use of flood-tolerant grasses for ground cover may increase stability, and underdrainage could lengthen periods of usefulness. In some cases levee side slopes may be terraced for spectator seating or used as boundaries for game fields. Use of fencing to mark boundaries or to prohibit access from spectators should be avoided on the riverside since it may trap debris or be damaged by floods.

Performance

431. Several CE levee projects illustrate use of periodically flooded areas for recreational purposes. Interior drainage areas on the Lewiston, Idaho, levee are used as baseball fields and as picnic areas, while an interior drainage structure for the Monticello, Iowa, project (US Army Engineer District, Rock Island 1974a) is planned as a

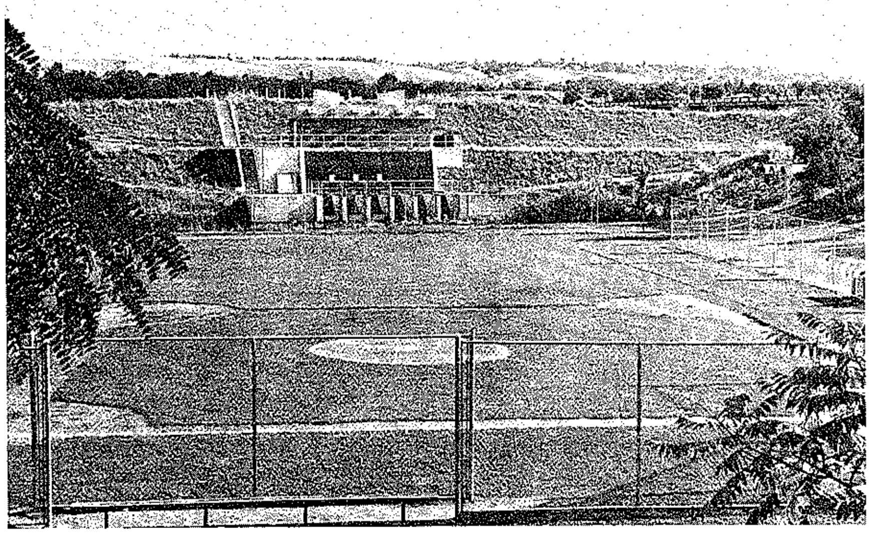

Figure 31. Interior drainage collection area doubles as a baseball field

Table 6

Land and Facility Requirements for Selected Game Fields and Sports Facilities*

Facility	Land Requirements**	Surfacing	Supplementary Equipment
Football field	1 acre	Grass	Goal posts, yard markers, player benches
Soccer field	1.7-2.1 acres	Grass	Goals, player benches
Softball/baseball field	1-3.85 acres	Dirt/grass	Backstop, mound, outfield fences, bases, player benches
Tennis courts	7200 sq ft	Grass, clay, or paved	Net, line markers, boundary fences
Volleyball courts	4000 sq ft	Grass/paved	Net, boundary markers
Basketball courts	4822-7280 sq ft	Paved	Baskets, boundary lines
Horseshoe areas	1400 sq ft	Grass	Stakes
Archery ranges	0.65 acre	Grass	Backstops, targets, fencing
Unorganized game area	Varies	Grass	None

* Information extracted from US Departments of the Army, Navy, and Air Force (1975).
** For one facility, excluding adjacent areas for gathering and access.

combination picnic area, pond, and playground. All facilities on the Lewiston project appear to be heavily utilized by local residents.

432. In the Vicksburg District, 108 acres of battured lands in the vicinity of Warfield Point, Miss., were developed for a combination picnic/camping area equipped with a supplementary playground and observation area. Both trailer and tent sites are provided, along with restrooms and public water supplies.

433. Several local and State parks are located on the riverside of the Sacramento River levees, while the foreshore in the Evansdale, Iowa, project is used for a playground and a picnic area. An informal picnic area and boat ramp on the riverside of the Fulton, Ill., project receive use by boaters, fishermen, and picnickers; and a simple park in the Point Lookout/Willow Point area of the Vicksburg District is used for camping, picnicking, and access to the river. An area on the riverside of the folding floodwall in Monroe, La., is developed as an observation and interpretive area (US Army Engineer District, Vicksburg 1971). Other examples of plans for recreational use of periodically flooded areas are evident in the US Army Engineer District, Los Angeles (1980, 1982), and the US Army Engineer District, Rock Island (1971, 1974b, 1976).

Limitations

434. Important limitations on development of periodically flooded areas include availability of land, accessibility, and availability of potable water. Distance from potential users may also limit implementation in selected cases.

Costs

435. Unit costs for various items used in developing periodically flooded areas in CE levee projects are presented in Table 7. Additional data for picnic/camping facilities were provided in paragraph 408.

Table 7

Selected Cost Estimates for Developments in Periodically Flooded Areas

District	Project	Date	Item	Description	Unit Cost
Rock Island	Monticello, Iowa	1974	Playground set	Monkey bars, swings, and slides	$ 1,550
Rock Island	Davenport, Iowa	1976	Baseball field	Backstop, fence, bleachers	20,400
Vicksburg	Warfield Pt., Mississippi	1975	Total development	Public use and access facilities	2,300,000
			Tent pad	17.5- by 12-ft area enclosed with concrete planks and filled with pea gravel	680
			Foundation/ faucet structure	Masonry, freeze-proof with steps for children	2,200
			Restroom	Picnic area, masonry with wood/asphalt roof, plumbing	35,000
			Restroom	Camping area, same as above with showers and hand laundry basins	64,000
			Water distribution system	Connection to city system, with 3-in. main, 1- and 2-in. feeders	208,000
			Waste disposal system	Small pump, piping, connection to city treatment plant	201,000
			Electrical supply system	Connection to power company, building lighting, area lighting, and outlets for trailer camping sites	115,000

Interpretive Centers, Observation Areas, and Culturally Important Areas

Purposes

436. Providing and/or interpreting points of interest along the levee gives users a sense of regional context and preserves the significance of historic events.

Description

437. A wide range of designs have been used for interpretive centers, observation areas, and culturally important areas (Figures 32 and 33). Designs that blend with the surrounding area are most effective. These facilities provide interfaces between the river and the landside community and serve as effective entranceways to the greenbelt or recreational corridor associated with the levee. Architectural and landscape treatments around these areas suggest to the user that these are distinctive points along the levee--places to change pace, rest, and gain knowledge and appreciation of the river and the supporting systems.

438. Designs that are both unique and consistent with the local character are best accomplished by professionals who are sensitive to

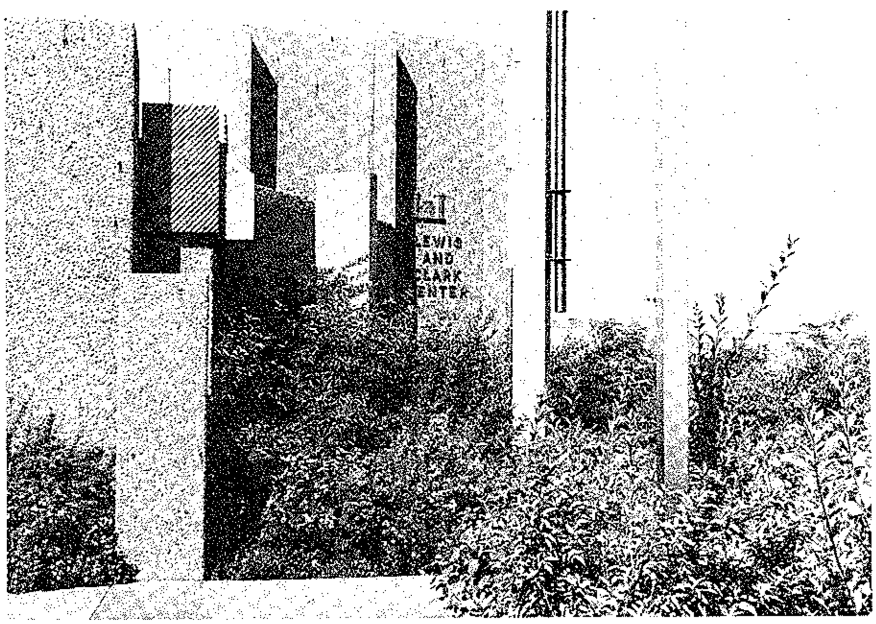

Figure 32. Interpretive center on the Lewiston levee

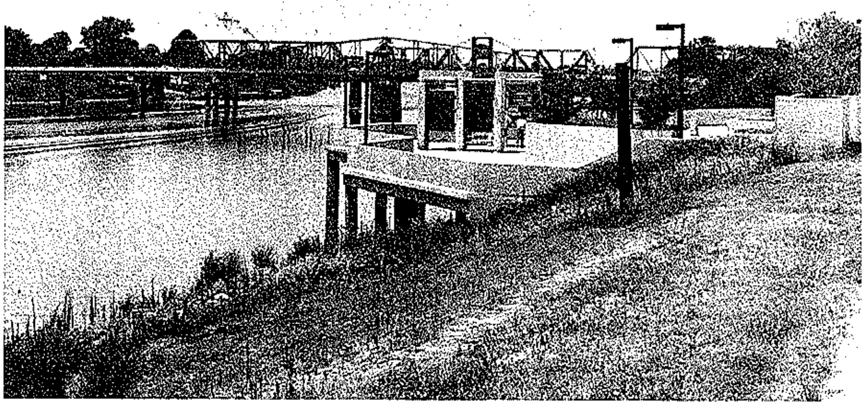

Figure 33. Observation area associated with the Monroe, La., folding floodwall

the needs of the region or area. Official CE guidance regarding interpretive services and signs is given in ER 1130-2-400 and ER 1120-2-400 (US Army, Office, Chief of Engineers 1971a, 1976). EM 1110-2-400 (US Army, Office, Chief of Engineers 1971b) provides general design criteria for information and guidance features. However, implementation of several principles may increase attractiveness to users and minimize maintenance requirements. First, understanding that such structures may be susceptible to floods influences design aspects in order to reduce maintenance. Signs and interpretive materials that are durable, as well as construction materials that will not collect sediments from high water, will make cleanup and repair manageable after flood events. Floods provide interesting subjects when interpreted by permanent markers of flood heights.

439. A range of subjects are appropriate for interpretation in designated centers. They include, but are not limited to, historical occurrences on the river, ecological character of the river, uses of the river, and/or a description of the levee. Users are generally attracted to graphics and interpretive discussions that are crisp, easily legible, concise, and simple to comprehend (Figure 34). Visual qualities of the site will also attract users, so that analysis of views from potential sites may be appropriate in order to choose the most scenic locations.

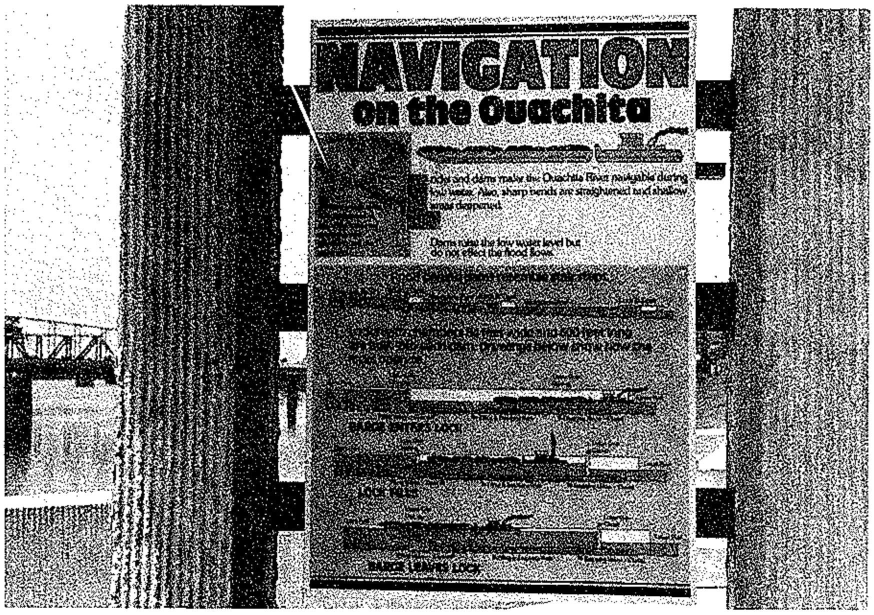

Figure 34. Example of attractive interpretive sign that is also resistant to flood damage

440. Facilities or markers that existed on the riverbank prior to levee construction make highly appropriate items for display and/or interpretation (Figures 35 and 36). In many situations, local

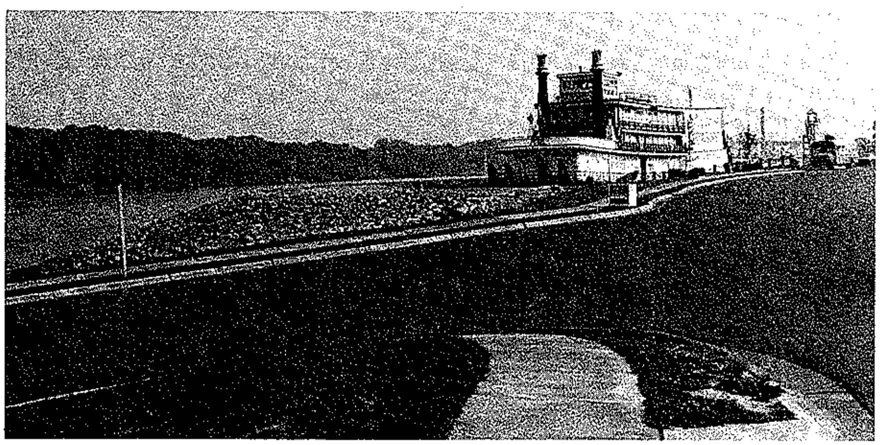

Figure 35. Mississippi stern-wheel showboat that was preserved by being built into the Clinton, Iowa, levee

residents have become so attached to such items that local levee development plans would be strongly resisted if these facilities were not preserved. Options for preservation include removal and storage of

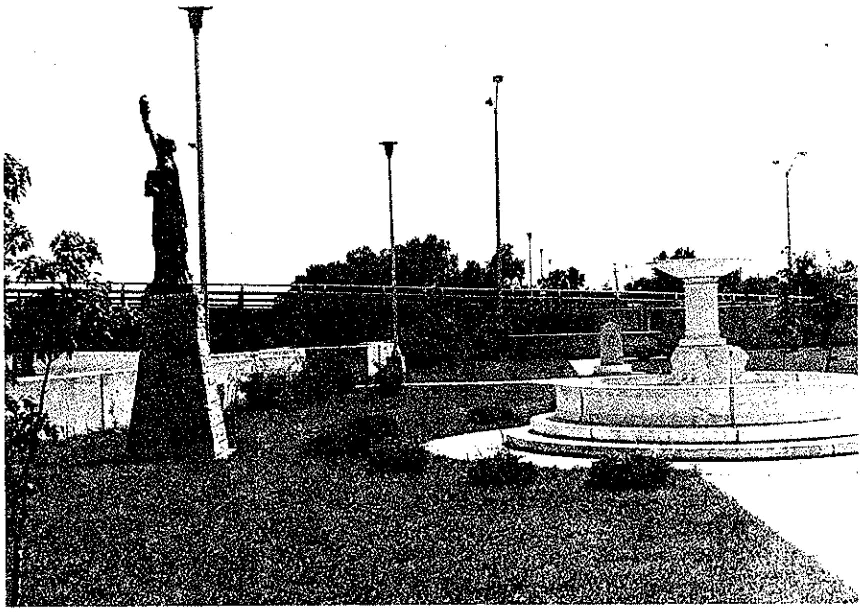

Figure 36. Historical artifacts preserved on floodwall project in Waterloo, Iowa

artifacts during levee construction and replacement into designated, planned areas after construction, or building artifacts into the levee structure. Early in the design process, settings that provide ample room for their display and appreciation should be designed. The character of the space should be designed with sensitivity to the importance of the artifacts.

Performance

441. Several CE levee projects include interpretive centers and observation areas. For example, two structures along the Lewiston, Idaho, levee have been constructed, and interpretive materials are currently being developed. One will take a historical theme, while the other will present information on the ecology of the Clearwater and Snake Rivers. Even without the interpretive materials, these centers serve as focal points for levee use. Simpler observation areas exist along the Moline, Ill., project and the Monroe, La., folding floodwalls. A river observation tower is part of a camping/picnic area in the vicinity of Greenville, Miss. (US Army Engineer District, Vicksburg 1975).

442. Projects in Waterloo and Clinton, Iowa, illustrate various means for preserving artifacts in special areas. In Waterloo, several statues, fountains, and other structures were removed prior to construction of a floodwall and replaced into a parklike area on the landside after construction. The Clinton project included building a Mississippi River stern-wheel boat into the levee. This structure is now being used successfully to house a local repertory theater company.

443. A variety of similar structures are proposed for other CE levee projects. Nature centers are planned for the Santa Ana River (US Army Engineer District, Los Angeles 1980) and the Little Calumet River (US Army Engineer District, Chicago 1982). Plans for scenic overlooks and multipurpose facilities exist for the Sweetwater River project (US Army Engineer District, Los Angeles 1982), the Little Calumet River (US Army Engineer District, Chicago 1982), the Des Moines River (US Army Engineer District, Rock Island 1971), and the Scioto River (US Army Engineer District, Huntington 1980).

Limitations

444. Interpretive facilities should be adjacent to the levee rather than on the levee, unless sections are overbuilt with sufficient space and stability to support the structure and the expected use. In order to receive use, such facilities should be readily accessible. Ongoing maintenance will be required, and staffing with full- or part-time personnel with interpretive capability may be warranted.

Costs

445. Costs range widely depending on the complexities of the structures involved. The two centers on the Lewiston levee were estimated to cost $85,000 and $115,000 by a contract estimate. The General Design Memorandum for Clinton, Iowa (US Army Engineer District, Rock Island 1974b), suggested a cost of $410,000 for building the showboat into the levee. Low bid for the Monroe floodwall listed an estimate of $301,000. An overlook tower at the Warfield Point site (US Army Engineer District, Vicksburg 1975) was estimated by the CE as costing $96,000.

Fishing Access

Purpose

446. Fishing access points enable the public to continue to use historically popular shoreline areas for fishing that would otherwise be destroyed by the existing levee. New areas can also be made available in this manner. This section discusses facilities providing fishing from shore; boat access is discussed as a subsequent feature.

Description

447. Special designs to enable fishermen to access foreshore borrow pits or the river itself may be appropriate if the existence of the levee would otherwise block or hinder such use. Levees and floodwalls can block fishing access in a number of ways. First, the simple existence of a large earthen mound between the community and the river creates an obstacle that must be climbed or otherwise crossed. Second, if the levee abuts the riverbank and is riprapped, those wanting to fish could experience significant difficulty in negotiating the riprapped slope. Third, floodwall projects that abut the river often provide no spaces to cross or to stand on while fishing.

448. The initial step in providing fishing access is locating the access facility. Areas that historically have been used extensively for fishing are sometimes good locations, and local game wardens can often provide this information.

449. A simple path or road may be built to provide access. Grades gentle enough for footpaths may be built using switchbacks or ramps. Rustic wooden stairsteps are sometimes appropriate. Handicapped and elderly users require more gradual path grades. In all cases, fishing access features should include provisions to ensure that structural stability of the levee will not be compromised by human use. Materials used for access paths should be appropriate to the intensity of use, availability of materials, and the character of the adjacent community. Where riprapped slopes are next to the water, concrete steps and platforms give fishermen sound footing and comfortable places from which to fish (Figure 37). If river stage varies considerably,

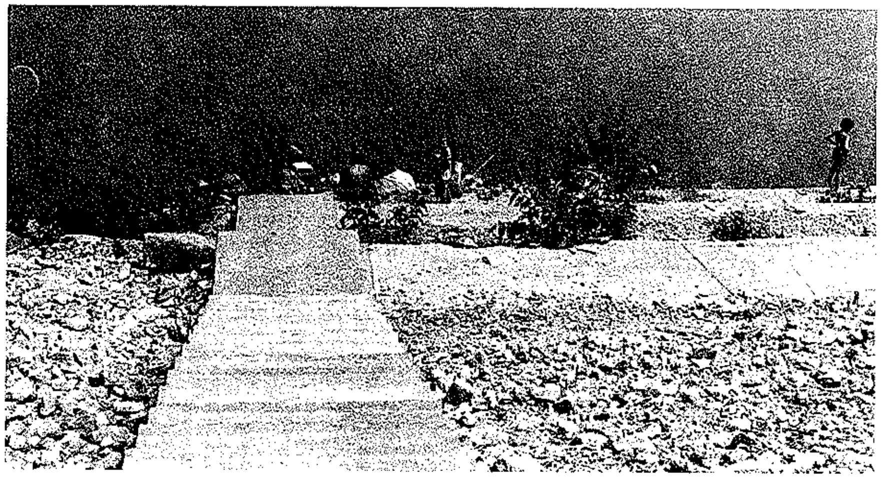

Figure 37. Steps and platforms provide fishing access on a riprapped levee

provisions for several platforms along the slope will increase the usefulness of the structure. Alternatively, piers can be constructed from the levee crown into the river.

450. Fishing access features for floodwall projects should include a means of crossing the floodwall and spaces for fishing. Removable floodwall panels, as discussed in paragraphs 471-478, provide a means of crossing the floodwall, while riverside base walkways (Figure 38) provide space for fishermen.

Performance

451. Existing fishing access features on several CE levee projects, including platforms and stairways along the Moline, Ill. (US Army Engineer District, Rock Island 1975), and Lewiston, Idaho, projects; walkways along floodwalls in Waterloo, Iowa; and a simple road and informal access area in Fulton, Ill., receive high levels of use.

Limitations

452. Three main limitations were identified for fishing access features. First, fishing access points must be located in areas that have harvestable sport fisheries that are accessible from shore. Public safety is a second limitation. Whatever agency (CE or local sponsor) takes control of fishing access facilities after construction may have some liability for certain serious accidents (falling on

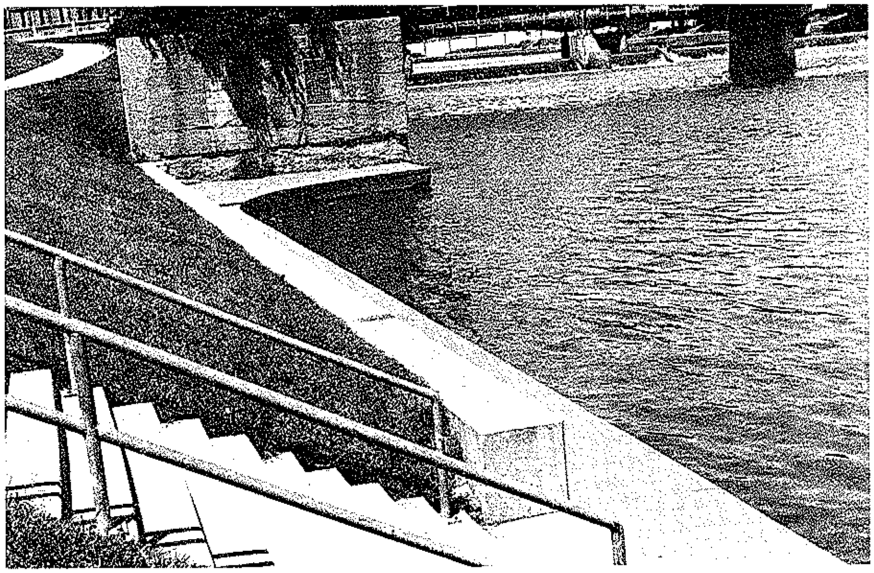

Figure 38. Openings and steps in the floodwall in Waterloo, Iowa, permit public access to the river. A portion of the floodwall can be seen in the background. The floodwall is recessed to allow for this area and bends around to the left of the picture.

steps, drownings, etc.) if they occur within the public access areas. Insurance may be needed, and clear limits of liability understood. Finally, paths over levees to fishing access points may facilitate erosion if they are overused, and erosion may occur if significant use develops off the designated paths. Paths should be adequately designed and effectively protected from erosion, and traffic confined to designated areas.

Costs

453. On the Scioto River, two access points for the handicapped have been proposed at a total cost of $11,000 (US Army Engineer District, Huntington 1980). These structures would consist of concrete platforms supported by retaining walls of 12-in.-diam treated timbers. The structures would essentially be piers that extend from the levee crown into the river.

Boat Ramps and Access

Purpose

454. Boat ramps can provide safe, well-defined, attractive areas for recreational boat launching.

Description

455. Boat ramps and launches can be located to enable recreational use of large riverside borrow pits, other waterbodies in the foreshore, or the river itself. As a part of larger recreational areas that include picnic grounds, playgrounds, sports fields, and other facilities, boat ramps can synergistically add to the recreational use of the levee site and shore facilities. Supplemental facilities, such as parking lots and restrooms, may be associated with all the activities in the development.

456. The locations and the numbers of launching sites will depend on several variables. Official CE criteria for inclusion and design of boat-launching facilities are given in EM 1110-2-400 (US Army, Office, Chief of Engineers 1971b). The size of the water body and the types of boats used on it will influence decisions on the size of the launching facility. Other factors to consider include numbers of other existing sites, availability of land for launching facility location, and the management capabilities of the sponsoring agency. Sites that would require periodic maintenance dredging, or that would interfere with other recreational uses such as swimming, are best avoided.

457. In its simplest form, a boat-launching facility merely requires a road leading to the water body and a gently sloped ramp into the water constructed of a stable material (Figure 39). If canoes are to be launched, all that may be required are steps leading down the riverside of the levee as described in paragraph 449 above. Roads and parking facilities should be designed to accommodate both vehicles and their trailers. Commonly, ramps are paved, but they can be constructed of bank material if such materials are stable, little or no current exists, and the ramps will not receive intensive use.

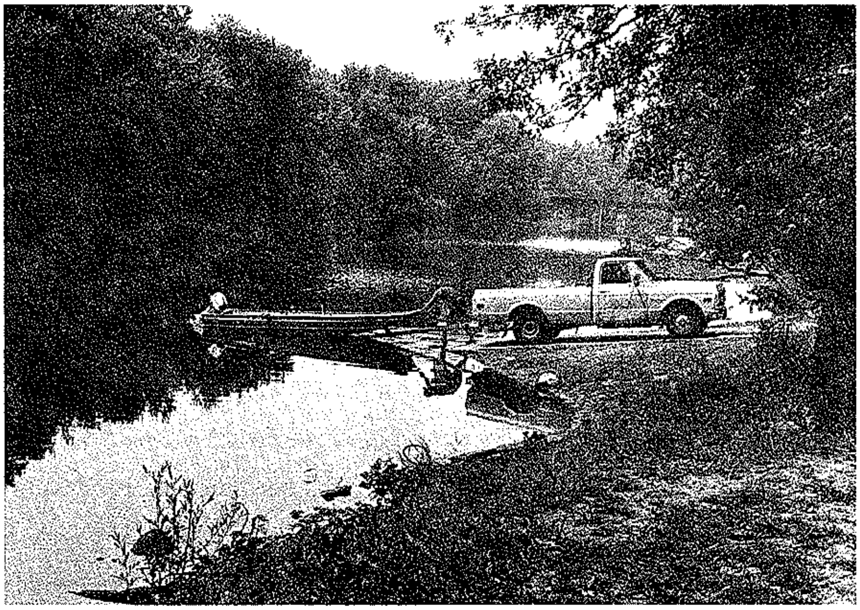

Figure 39. Simple boat ramp in foreshore of Fulton, Ill., levee

Performance

458. Heavily used boat ramps occur on a number of completed CE levee projects, including Lewiston, Idaho; Fulton, Ill.; Clinton, Iowa; and along the Sacramento River in California. Other boat ramps are planned for Davenport, Iowa (US Army Engineer District, Rock Island 1976), the Scioto River (US Army Engineer District, Huntington 1980), and Moline, Ill. (US Army Engineer District, Rock Island 1976).

Limitations

459. Ramps are appropriate only on waters that could be expected to receive recreational boating use. Smaller borrow pits and ponds and small streams are usually not appropriate sites for boat ramps.

Costs

460. Estimates range from $2,000 for a simple ramp on a borrow pit in the Vicksburg District (US Army Engineer District, Vicksburg 1980) to $224,000 for a major double-lane, divided, concrete ramp and marina in Davenport, Iowa (US Army Engineer District, Rock Island 1976). Basic ramps on the Sciota River were estimated at $9,000 each, but supplementary facilities including parking areas and restrooms raised total cost estimates for two facilities to $94,000 and $145,000

(US Army Engineer District, Huntington 1980). A one-lane launch ramp on the Lewiston, Idaho, levee was listed in 1976 contract estimates as costing $8,779, while a concrete plank ramp on a Michigan SCS levee was estimated at $18,000 (USDASCS State Office, Michigan 1969).

Swimming Beaches

Purposes

461. Properly designed and sited areas developed for swimming enable safe, enjoyable use of levee project sites.

Description

462. Swimming areas integrate well with picnic grounds, playgrounds, and other recreational facilities. Beaches may conflict with boat-launching facilities, so swimming areas should be located accordingly.

463. Suitable locations for swimming include both the leveed stream and riverside borrow pits that have smooth, gently sloping bottoms. Sand and gravel are usually required for beach material. Mud or cobbles are usually unsuitable. Water velocity at normal flow should be low enough to preclude safety hazards. Water quality should meet standards for contact recreation.

464. If swimming beaches are planned for borrow pits, gentle grading can be used to create different depths for beginning, intermediate, and advanced swimmers. In some locations, it may be necessary to deposit sand or other suitable material as a beach. If such filling is necessary, swimming areas should be located where periodic flooding would not cause significant loss of beach materials or damage to the surrounding area.

465. Swimming beaches are enhanced by various other nearby recreational facilities. Lifeguard facilities, restrooms, changing stations, and concession stands may increase attractiveness to potential users. As noted in paragraph 377, some types of supplementary facilities are ineligible for Federal cost sharing.

Performance

466. A borrow pit at the Evansdale, Iowa, project was developed specifically for swimming but unfortunately was never used because arrangements for lifeguards could not be made by the local sponsor. However, several other pits are being used at the Waterloo site (Figure 40) on an informal basis by local residents while the project is still under construction. On the Lewiston levee in Idaho, floating platforms originally designed as boat moorings are now being used more for swimming than for their original purpose (Figure 41).

Limitations

467. Safety considerations are the main limitations for swimming features. Water quality must be suitable for contact recreation, and currents should not be hazardous. Depths and shore and bottom material (sand) must be appropriate for swimming, or should be modified accordingly. Liability for accidents should be established before construction. Operation and maintenance requirements include lifeguarding, facility repairs, and solid waste disposal.

Costs

468. Swimming areas were constructed in conjunction with the Rock Island District's Waterloo and Evansdale, Iowa, levee projects.

Figure 40. Although not designated as a swimming area, this borrow pit attracts local residents for swimming because of sand beach and moderate depth

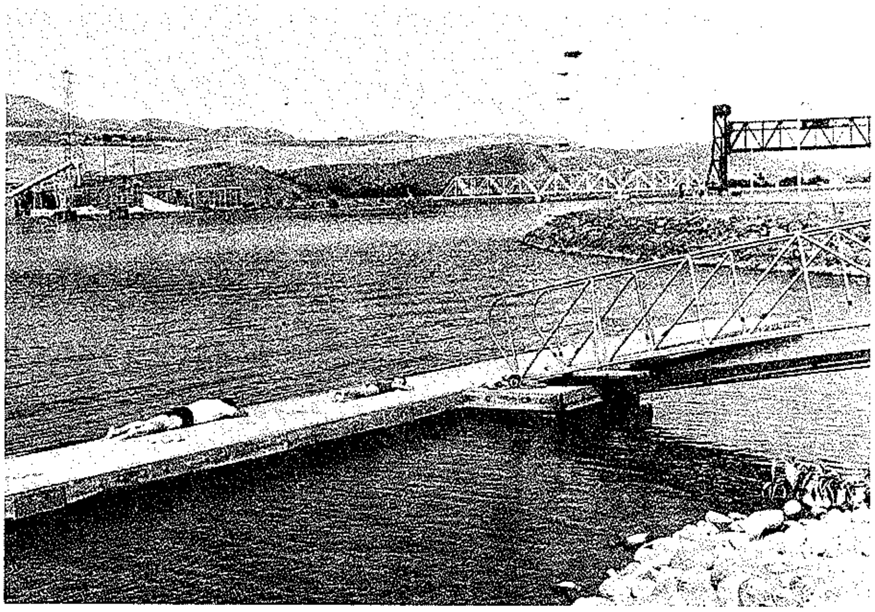

Figure 41. Originally designed as boat moorings, piers on the Lewiston levee are used by local residents for swimming and sunbathing

The swimming areas were located within borrow pits. Design slopes for the borrow pits required no alteration to facilitate swimming, and materials that existed on that site were sands suitable for beach material. Therefore, no additional construction cost was required.

469. In other projects, modification of borrow pit or riverbank slopes and placement of suitable fill for beach material might be required. Additional costs might also include construction of markings for the swimming area, diving platforms, and lifeguard stations. Supplementary facilities such as restrooms, changing stations, and parking lots might also be required.

470. Maintenance costs include lifeguarding, solid waste disposal, facility repairs, and cleaning.

Folding or Removable Floodwall Panels

Purpose

471. Folding or removable floodwalls enable visual and/or

physical contact with the river to be maintained. In contrast, standard floodwalls commonly serve as barriers between the community and the river.

Description

472. Floodwalls are only needed during high water. When water is at normal levels, folding or removable floodwalls can be taken down so as not to obstruct views of or access to the riverbank. Two folding or removable floodwall projects were reviewed. The first is a folding design used in Monroe, La. (US Army Engineer District, Vicksburg 1971), while the second is a removable design used in Waterloo, Iowa (US Army Engineer District, Rock Island 1976).

473. When folded, the Monroe floodwall looks like a sidewalk (Figure 42). Visitors to the downtown area can easily see the river from the street, or cross directly over the sidewalk/floodwall to a riverside observation area. However, the structure actually consists of a series of concrete panels on hinges. The panels can be raised quickly to a vertical position using a small crane. Once in the vertical position, metal braces that are stored under each panel are bolted to the concrete for additional support (Figure 43). Rubber

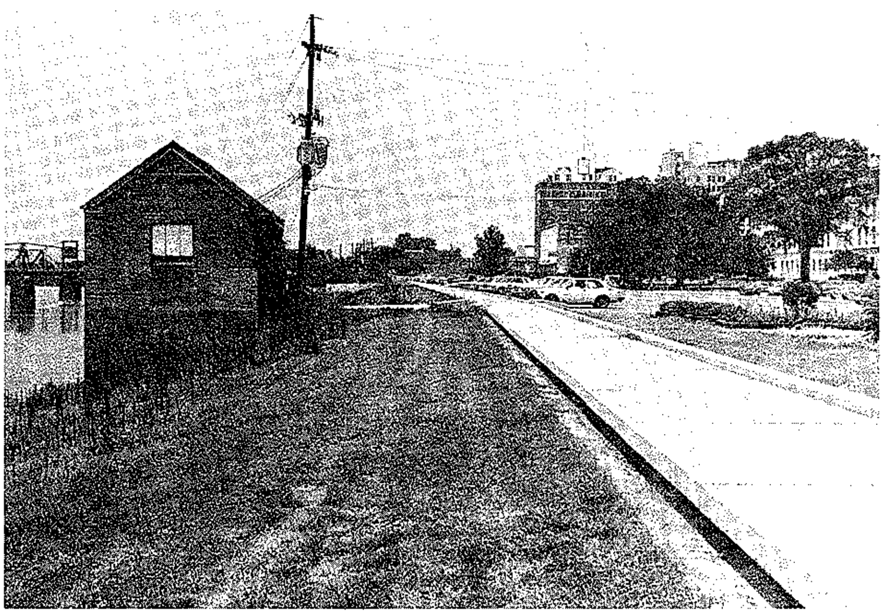

Figure 42. Monroe, La., folding floodwall in the collapsed position

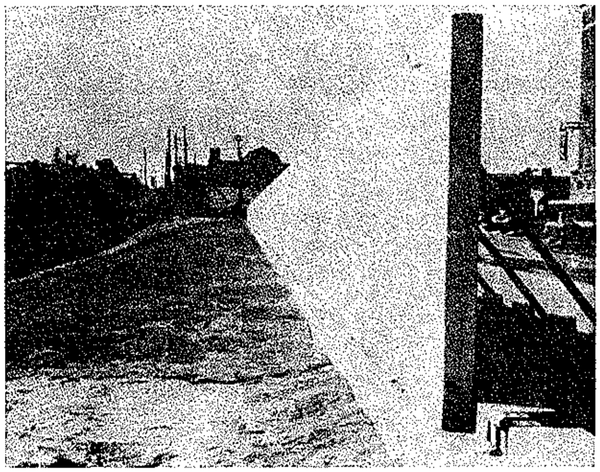

Figure 43. Monroe, La., folding floodwall in the raised position

sealant and gaskets are used to fill cracks between and under panels, and thus the structure becomes watertight.

474. In Waterloo, Iowa, a base structure remains in place at all times (Figure 44). However, the base structure is low enough not to interfere with views, and several openings are designed to enable users to pass through the floodwall and down to the river (Figure 45). However, panels that bolt onto the basic support structures are readily

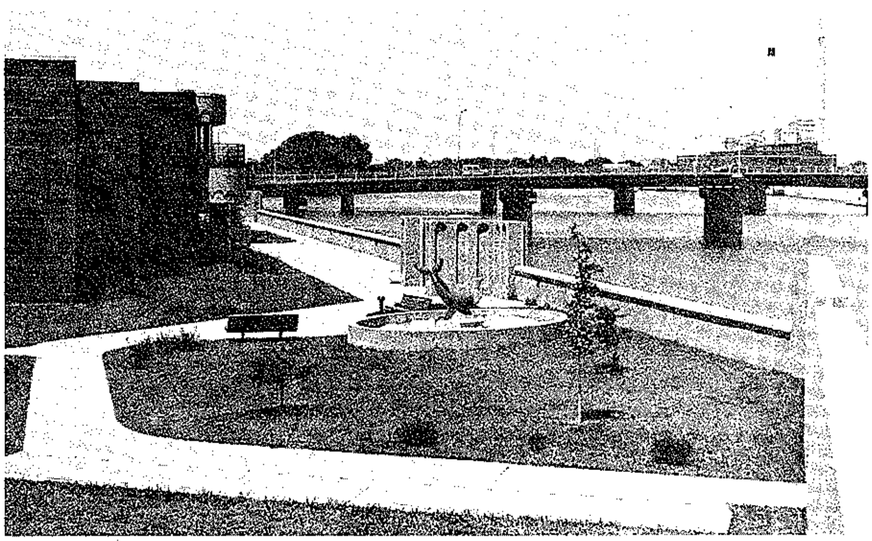

Figure 44. Supports for removable floodwall panels in Waterloo, Iowa

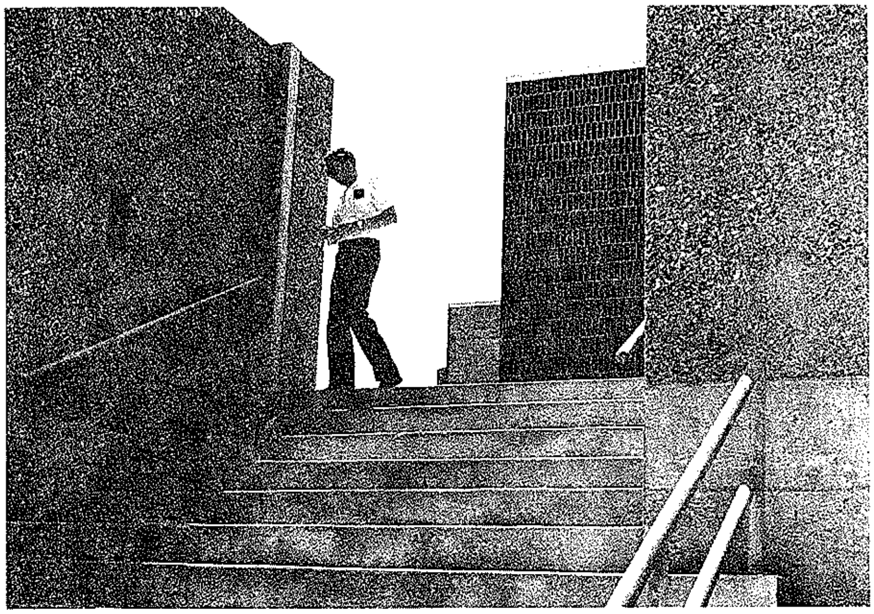

Figure 45. Removable panels on the Waterloo, Iowa, floodwall permit public access to the river during low-water periods

available and stored onsite. Once the panels are installed and plastic sealant is applied to joints, the structure provides full protection.

Performance

475. Both the folding floodwall of Monroe, La., and the removable floodwall of Waterloo, Iowa, won design awards for their unique features. Both structures are thought of highly by the local communities. Neither structure, however, has been tested by a flood. The Monroe floodwall was raised as a precautionary measure during flooding in late 1982, but high water never reached the base of the structure. Raising was accomplished within the allowable period under stated operation and maintenance guidelines with little difficulty. A few cracks developed in concrete panels during the erection process, but are not serious.*

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* Personal Communication, 1983, Mr. L. C. Corkern, Assistant Area Engineer, US Army Corps of Engineers, Monroe, La.

Limitations

476. Removable or folding floodwalls are only practical where flood warning periods allow adequate time for erection. Personnel must be continuously available to erect the structure. Erection personnel must be experienced; materials and equipment for erection must be in a constant state of readiness.

Costs

477. Low bid for the folding segment of the Monroe floodwall was $490,000 for materials and construction. Costs attributable to the Waterloo removable structure could not be separated from other project items.

478. Equipment and labor for erection may or may not result in increased costs, depending on whether equipment and personnel otherwise necessary for operation and maintenance of other facilities can be diverted for erection.

Treatment of Concrete Floodwalls

Purposes

479. Special materials for the floodwall construction soften the straight lines and reduce contrasts in line color, light value, and form when seen from a distance. By choosing materials carefully, floodwalls can be designed to harmonize with the visual environment and provide a special tactile quality.

Description

480. The standard material for floodwall construction is smooth concrete. However, several other facings, including "fractured fin" (Figure 46) and "exposed aggregate" (Figure 47) are commercially available and add color and texture to structures. Textures may be created by brushing the concrete while wet or by using special form liners. Distinctive and unique sculpturing of walls can be incorporated into the design, and colorants can be used to darken walls to blend into the natural landscape. Finally, paintings and murals by local artists can be used to brighten the floodwalls. Official CE

Figure 46. Fractured fin floodwall treatment

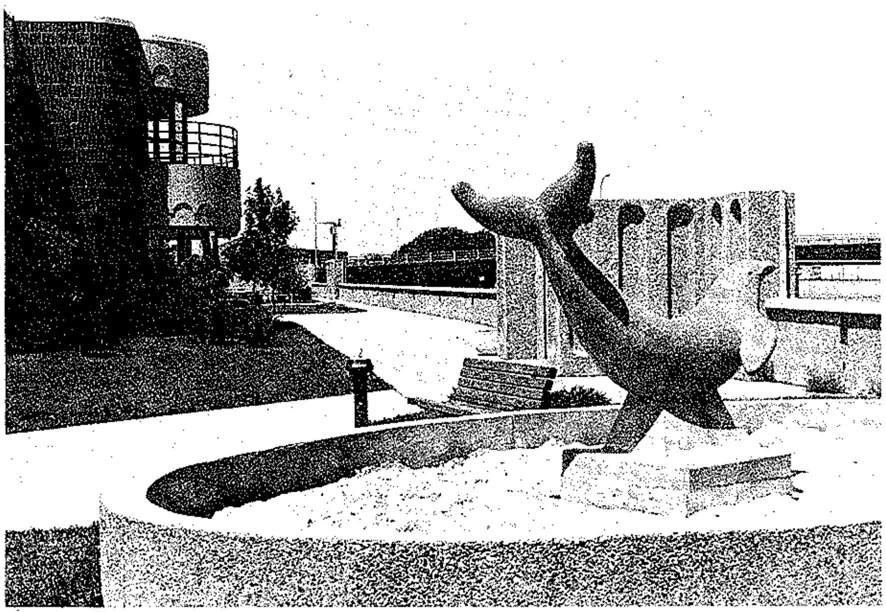

Figure 47. Exposed aggregate floodwall treatment chosen to complement adjacent building

guidance regarding aesthetic treatments for concrete is given in EM 1110-2-39 (US Army, Office, Chief of Engineers 1969).

481. When choosing alternative materials for floodwall construction or treating the walls to improve their appearance, sensitivity to

the overall surroundings enhances the potential for the project to complement the surrounding environment. For example, using materials in urban areas that are analogous to those used for highly visible buildings adjacent to the floodwall will create consistency between the wall and the building (Figure 47), and earth tones complement vegetation well. Areas that are somewhat gloomy may be enhanced by brightly colored floodwalls.

Performance

482. An award-winning sculptured floodwall constructed at Pembina, N. Dak., by the St. Paul District incorporated an inlay design and exposed aggregate facing. Likewise, various materials were used for floodwall sections in Waterloo and Evansdale, Iowa, all of which made the floodwall seem consistent with local architecture.

Limitations

483. Sedimentation or debris could be more difficult to remove after floods from treated floodwalls than from smooth concrete floodwalls. Moreover, graffiti and other vandalism could nullify positive visual aspects of treated floodwalls. However, sealants are available that will discourage graffiti or facilitate rapid cleaning.

Costs

484. Contract estimates for the Lewiston, Idaho, levee list materials costs for two commercially available floodwall treatments. The fractured fin treatment was estimated at $10.20 per square foot, while exposed aggregate was listed as $1.86 per square foot. Specially designed treatments or sculptures could be considerably more expensive.

PART V: ENVIRONMENTAL CONSIDERATIONS FOR MAINTENANCE ACTIVITIES

485. This part describes maintenance techniques that may be used to perform required levee maintenance functions with the most positive net environmental effect. Maintenance techniques discussed include walking inspection, selective vegetation management, irrigation, rodent control, and information/education programs. Descriptions of several vegetation management alternatives that are available are also presented, along with procedures for choosing the most appropriate options for individual sites. Vegetation management alternatives include mowing, grazing, prescribed fire, and chemical control.

Walking Inspection

Purposes

486. Routine and emergency inspections are performed to locate areas on the levees and in the adjacent area that require maintenance and repair. Inspection detects seepage, erosion, animal burrows, and undesirable vegetation. In some cases, conflicts between vegetation requirements for environmental quality (aesthetics and habitat) and levee inspection requirements can be minimized by using alternative inspection methods.

Description

487. Federal Regulations (33 CFR Part 208) require levees, closure structures, pumping stations, and floodwalls to be inspected immediately prior to the beginning of the flood season, after each major high-water period, and otherwise at intervals not to exceed 90 days. Inspection is usually accomplished from moving vehicles on the crown of the levee, with personnel watching on both sides. Although this method requires the least amount of effort, it is severely limited by vegetation on the levee that obscures animal burrows, depressions, boils, and loss of riprap. Thus, where practical, the use of inspections on foot could enable provision for more vegetation on the levee while ensuring the quality of the inspection process.

488. In contrast to vehicle inspections, walking inspections can be accomplished from the toe of the levee. The observer is able to look up at the embankment, and thus observe under vegetation that would obscure views from above. Moreover, the inspector is closer to the levee surface looking upslope rather than downslope. Research by the California Department of Water Resources indicates that inspectors can effectively detect areas needing maintenance on levees supporting tall grass for a distance 15 ft upslope from their position. Thus, one side of a levee embankment 30 ft along the slope would require two persons to inspect it, one at the toe of the levee and one at midslope.

489. The use of walking inspections instead of vehicle inspection will not be practical in all circumstances. Inspections for seepage problems away from the toe should be conducted as separate operations regardless of the method chosen for embankment inspection. Maintenance and periodic analysis of permanent records also provide benefits for both vehicle and walking inspections. These records, when summarized over long periods of time, may indicate regions or sites where erosion, animal burrows, seepage, and sloughing occur more frequently, and thus provide guidance to inspectors and maintenance personnel relative to what areas require more detailed inspection and maintenance activities. If areas of special concern are found, they can be more intensively treated for unwanted vegetation in order to facilitate rapid and thorough inspection.

Performance

490. Riley (1981) found that in spite of standard policies to inspect levees from moving vehicles, a variety of techniques including walking inspections and accomplishing other work onsite are used by landowners along the Sacramento River to identify potential levee problems with structures on their lands. These alternative inspection techniques did not, in themselves, seem to cause any additional threat to levee integrity from improper inspection. Many of the levees in the Portland District are routinely inspected by walking inspectors because there are no access roads on the crown or at the toe.

491. Provision for flexibility in inspection methods in order to

promote environmental values has been accepted for 1982 plans for levee maintenance along some sections of State-controlled levees on the Sacramento River (Schwartz, Fitzgerald, and Ringer 1982). Whether or not revised maintenance plans had any effect on levee integrity during 1982 floods is unknown.

Limitations

492. Levees with histories of slope instability and foundation problems and levees located in small watersheds that have frequent flash floods or in regions where flooding potential persists throughout the year demand more stringent requirements to ensure levee integrity. Maintenance and inspection activities that are especially intensive may be needed, and using alternative inspection techniques to enable relaxation of vegetation standards may not be possible.

493. Alternative inspection techniques would be more costly than the standard moving vehicle approach. As the sizes of the levees and the levee system increase, the cost differential between vehicle inspection and walking inspection will also increase. Thus, alternative inspection techniques may not be possible on larger and longer levees.

494. The use of alternative techniques for inspection would not only require additional labor, but a special type of labor, as well. Personnel would have to have the experience to detect potential levee integrity problems, but would also have to be willing to walk long distances in unfavorable terrain, sometimes under unpleasant weather conditions. The availability of qualified personnel is a problem for several land management agencies responsible for vegetation management (Center for Natural Areas 1980a, 1980b).

Costs

495. Although no specific data were found that would allow comparison of costs between standard and alternative inspection techniques, labor costs would probably be significantly higher for alternative techniques than for the standard moving vehicle approach. More inspector hours would be required per unit of levee inspected; inspectors might need special training in plant identification and other disciplines, and thus might require higher wages. As previously noted, the cost

differential between vehicle inspection and walking inspection would increase with the size of the system. However, through continual analysis of records of levee problems, guidelines for focusing inspection efforts could be devised. Such refinement might lead to a reduction in inspection frequency for some levees.

Selective Vegetation Management

Purposes

496. The ultimate aim of levee vegetation management activities is to ensure the structural integrity of the levee. Selective management methods may be used to promote diversity of vegetation on or around levee projects for aesthetics and wildlife habitat, reduce maintenance costs, and control burrowing animal populations.

Description

497. Several steps are involved in the development of a selective vegetation management program, and include (a) inventorying the natural successional patterns on levees, (b) evaluating plant characteristics, (c) developing and implementing an ongoing monitoring program, and (d) controlling undesirable vegetation.

498. An initial plant species inventory may be performed to generate a list of plant species that can be expected to colonize on the levee and in the surrounding area in between maintenance activities. The inventory should also generate information regarding successional patterns and the relative adaptabilities of plant species to the sites. Such data will be different for each site and will depend upon climate, moisture, and materials used in levee construction.

499. Two major categories of plant characteristics should be evaluated: (a) wildlife and aesthetic values, and (b) plant characteristics that threaten levee integrity or are otherwise undesirable. Wildlife values can be determined using considerations that were previously described for wildlife seedings and plantings (paragraphs 324-329), while aesthetic values are the same as those described for aesthetic plantings (paragraphs 410-421).

500. The determination whether specific plant types constitute threats to levee integrity or are undesirable for other reasons is difficult, and few data currently exist to enable such a determination. Criteria for such a determination are as follows:

a. Erosion protection. The degree to which vegetation protects riverside slopes from erosive currents during flood events is an important factor. Dense, shallow-rooting plants such as sods and young willows have proven to be valuable for erosion protection (Edminster 1950; Parsons 1963; Seibert 1968; Lines, Carlson, and Corthell 1979), while deep- or weak-rooted plants are undesirable, since they are prone to windthrow and uprooting by current may facilitate seepage. On the landside of pervious levees, however, even dense root systems can constitute threats, since they block water movement, create increased water pressures, and eventually may cause large sections of the levee to break free.

b. Inspectability. Vegetation that significantly compromises levee inspectability, either during routine maintenance or during flood-fighting operations, is undesirable. Periodic inspection is required for both the landside and the riverside, while flood-fight inspections are more likely to occur on the landside.

c. Seepage. Deep, tap-rooted plants and vegetation that has few, but large spreading roots may facilitate seepage through the embankment.

d. Burrowing animals. A variety of plant species may improve burrowing animal habitat. The attractiveness of vegetation to burrowing animals depends on the animal species of concern, the location of the levee relative to other habitat types and the river, and the levee materials.

e. Recreation. Thorny, dense, or poisonous plants discourage use of recreational areas.

f. Agricultural pests. Agricultural weeds, or plants that foster habitat for agricultural animal pests, might be undesirable for levee projects adjacent to farmland.

501. The third step of the selective vegetation management program is monitoring. A monitoring program would be most efficiently conducted as an integral element of efforts of periodic CE and sponsor inspections. Inspectors would have to be able to identify certain plant species in order to differentiate between desirable and undesirable

plants. Specific, detailed criteria for determining plant desirability would be required.

502. Monitoring data could be used to design a selective vegetation control program, eliminating only undesirable vegetation. The two most common methods for selective vegetation management are chemical control and manual cutting (Center for Natural Areas 1980a), although prescribed fire can also be employed if the fire ecology of the region in question is sufficiently understood. Grazing may be used for selective management in some cases if the complex array of grazing alternatives and effects is considered and a scientifically sound management plan developed.

Performance

503. General. The selective vegetation management concept was originally developed for transmission line rights-of-way (Engler 19752, 1958; Niering 1958, 1978, 1979; Niering and Goodwin 1974; Engler and Foote 1975) and later advocated for roadside vegetation management (Besadny, Kabat, and Rush 1968; Minnesota Department of Transportation, no date; The Wildlife Society, Minnesota Chapter 1978). The USDA Forest Service (1966) adopted selective vegetation management as standard policy in Region 9 (Northeast) for all rights-of-way in the National Forest System. Bramble, Byrnes, and Worley (1957); Bramble, Byrnes, and Hutnik (1958); Cavanagh, Olson, and Macrigeanis (1976); and Fowler et al. (1976) found that rights-of-way plant communities developed through selective vegetation management had higher wildlife use than vegetation on rights-of-way treated with broadcast methods. More recently, selective management practices are being advocated by selected local sponsors and State agencies for levee maintenance on the west coast (Davis, Ito, and Zwanch 1967; California Reclamation Board 1981; King County Department of Public Works 1982).

504. Based on an examination of Sacramento River levees, Davis, Ito, and Zwanch (1967) concluded that vegetation was less of a threat to levee integrity than was previously thought. However, they were not able to give specific guidance as to what vegetation constitutes what kind of threat. Riley (1981) noted a variety of vegetation management

techniques were practiced on the Sacramento River levees and thus concluded that opportunity existed for selective vegetation management.

505. The Seattle District has adopted minimum maintenance standards for levees in their jurisdiction eligible for emergency work under PL 84-99 which include variable standards for vegetation. More extensive vegetation is allowed on riverside levee slopes located on convex banks or in straight reaches or gentle bends. The standards limit tree and shrub size to a main stem diameter of 2 in. or less. No trees or shrubs are allowed on landside slopes or crowns. Undesirable growth such as blackberries and wild roses must be removed annually. These standards are reproduced in Appendix D. The Seattle District does not have a formal policy for vegetation on CE levees; they are handled on a case-by-case basis.

506. Pervious levees. In the Rock Island District, the most abundant material for levee construction is often sand; thus, levees are often constructed from sand (Figure 48). Sand levees are usually not planted because they are droughty and have low fertility; because the use of machinery to control vegetation could cause ruts, erosion and sloughing; and vegetation could hinder seepage and cause landside

Figure 48. Natural succession on a sand levee

failure during floods. Many sand levees do not receive any vegetation management at all. Over time, natural vegetative successional patterns occur. No instances of vegetation-caused failure of Rock Island District sand levees were discovered during this study.

507. In one instance, permitting natural vegetation on the riverside of an overbuilt CE levee has been unsuccessful. Dense growth of brush reduced channel capacity to the point that significant backwater effects occurred. The local sponsor had to engage in expensive handcutting operations within the channel to maintain flow capacity.

Limitations

508. Existing CE policy (US Army, Office, Chief of Engineers 1968) limits levee vegetation to dense, short, sod-forming grasses and selected specimens planted for aesthetic reasons (US Army, Office, Chief of Engineers 1972a). Nolan (1981) documents opinions of professional engineers regarding the undesirability of significant vegetation on levees. Since levee failure during a flood could cause loss of life in addition to significant property damage, the current maintenance standards may be the only feasible alternative when quantitative data on the effects of vegetation on levee integrity are not available. However, the potential for levees to provide significant wildlife habitat and aesthetically pleasing areas could be increased if data could be generated to evaluate the effects of various vegetation types on structure integrity.

509. Implementation of a selective vegetation management program would require personnel skilled in plant identification and with sufficient experience to differentiate allowable and undesirable conditions. Skilled personnel would be needed by both the CE and the local sponsor.

510. The various alternative methods of selective vegetation management have their own values and limitations. These are discussed subsequently in paragraphs 512-577.

Costs

511. Niering (1979) compiled a range of costs for selective vegetation management using herbicides and found overall prices to range $87-$851 per acre, depending on the chemicals used, the type of

treatment employed, and the density of the unwanted vegetation. When subjected to selective management, generally the vegetative community gradually stabilizes over time into an acceptable structure, and overall maintenance costs decline because fewer treatments are needed.

Mowing

Purposes

512. Mowing is one of several methods to maintain vegetation on levees that is consistent with regulations and does not compromise the integrity of the levee. Although mowing is not generally used to manipulate species composition for wildlife habitat enhancement, properly timed mowing efforts can avoid nest destruction to ground-nesting birds and reduce nest predation.

Description

513. Mowing is used to control the height of grass (Figure 49) on levees to conform to Federal standards that require levee vegetation to be under 12 in. in height (US Army, Office, Chief of Engineers 1968). Although machinery is available that can effectively mow woody vegetation, in most cases mowing is limited to areas that consist solely of grass and other herbaceous vegetation.

514. Mowing is less selective than other types of vegetation

Figure 49. Mowed levee with lack of vegetative diversity

management and tends to produce homogeneous stands of grass if conducted routinely over a long period of time. However, mowing can be used to retain areas of low vegetation beneficial for some species of wildlife and to foster the development of succulent green vegetation used by some species as food. For example, Atkeson and Givens (1953) found that mowing Southeastern fields of alfalfa and hay just before the first killing frost (a) exposes tender growth used by geese as food and also (b) produces areas that enable the geese to view their surroundings and thus be protected from predators. Moreover, periodic mowing can control woody vegetation in prairie vegetation that is more beneficial to wildlife as meadow. For example, Voorhees and Cassel (1980) found that mowing every 3 or 4 years was needed along South Dakota highway rights-of-way in order to discourage woody vegetation, which eventually made the sites unattractive as waterfowl nesting habitat.

515. Although wildlife require suitable habitat throughout the year, certain periods are especially critical. For example, ground-nesting birds are quite susceptible to major population declines if meadows or fields are mowed during nesting periods. Birds can be directly killed by the mowers, become more vulnerable to predation, and/or suffer a major loss of available food. Nests and eggs can be destroyed. Winter is also a critical period when wildlife require shelter from the elements and food supplies are low. Scheduling mowing activities to ensure that at least some cover is available during these periods improves wildlife habitat.

516. The exact dates preferred for mowing from a wildlife standpoint vary with latitude and particular species management objectives. However, common recommendations for the Eastern and Midwestern States guide operators not to mow until after the middle of July or the first of August. Moreover, if operations are completed by the middle of August, the vegetation may experience some fall growth that will provide winter and early spring cover. A compromise sometimes is necessary in order to provide both nesting and winter cover. For example, late mowing in Wisconsin benefitted pheasant nesting during that season, but because no residual cover existed the following spring, nest densities

sharply declined (Frank and Woehler 1969).

Performance

517. Mowing is perhaps the most extensively used technique for levee vegetation management. In most cases, mowing is not used as a wildlife management tool, but rather simply to control the height of grass on the levee in order to permit inspection. Thus, levees commonly support uniform plant communities; plants that are not beneficial to wildlife; and plants that are classed as exotic, unwanted invaders (Montz 1972). However, mowing has been used successfully in a number of instances to develop wildlife habitat. For example, mowing on a 2- or 3-year basis increased use of areas for waterfowl nesting in Wisconsin, while annual mowing decreased productivity (Livezy 1981). Burger and Linduska (1967) found that an annual or biennial mowing program that was instituted in Maryland kept fields in early successional stages and thus benefitted the development of quail habitat. Riley (1963) felt that strips mowed through grass/legume seedings in Ohio in September and October provided habitat diversity, new growth as winter food, and access for hunters. Duebbert et al. (1981) noted that mowing seeded prairie grasslands the first summer following establishment had a positive effect on stimulating vegetative vigor and favoring beneficial legumes.

518. Findings of several studies illustrate the value of properly timed mowing to wildlife. For example, George et al. (1979) observed a 73 percent nest mortality rate in Iowa pheasants that was caused by early June mowing. The authors recommended July mowing in order to reduce nest mortality and to provide residual cover the next spring. Likewise, Milonski (1958) found several instances of nest desertion and predation for waterfowl when mowing occurred while active nests were on the ground. Other authors have found that delaying mowing until after June improved survival of waterfowl nests (Burgess, Prince and Trauger 1965; Oetting and Cassel 1971), and mowing only once after August 1 produced higher pheasant nest densities (Joselyn, Warnock and Etter 1968).

519. Delayed mowing programs were proposed for one CE levee project on the Missouri River (US Army Engineer District, Omaha 1976). They

were also proposed for two USDASCS projects, one in Maryland (USDASCS State Office, Maryland 1973) and one in Michigan (USDASCS State Office, Michigan 1975).

Limitations

520. The use of mowing is limited to compacted levees with gentle or moderate slopes. The USDA-States-EPA 2,4,5-T Rebuttable Presumption Against Registration (RPAR) Assessment Team (1979) noted that the use of all forms of mechanical vegetation management were limited to slopes under 35 percent, while the US Army, Office, Chief of Engineers (1978) states that the maximum slope allowable for mowing is 2V:5H, which is equivalent to 40 percent. Uncompacted materials such as sands are subject to rutting and sloughing if traversed by heavy machinery.

521. From a biological perspective, many studies indicate that mowing that is too frequent or accomplished during critical periods has marked, adverse effects on wildlife. A number of authors (Jarvis and Harris 1971, Dwernychuk and Boag 1972, Jones and Hungerford 1972, Schrank 1972) found that heavier cover results in greater nest success for ground-nesting birds, and thus mowing that destroys nest cover has a detrimental effect. Annual haying reduced waterfowl nest density and success in agricultural lands in North Dakota (Duebbert and Kantrud 1974), and annual mowing on rights-of-way also reduced nest densities (Oetting and Cassel 1971, Higgins 1977, Voorhees and Cassel 1980). Marked effects of too frequent mowing have been demonstrated for a number of other wildlife species, including pheasants (Hanson and Progulske 1973, Dumke and Pils 1979) and passerine birds (George et al. 1979). Stauffer and Best (1980) found that actions to replace riparian woodlands with pasture and hayland in Iowa greatly reduced bird species diversity, while Geier and Best (1980) determined that conversion of a tall grass type to a short grass type greatly lowers the diversity of small mammal species. Hehnke and Stone (1978) and Hurst, Hehnke, and Goude (1980) found that mowed riparian areas consisting of grasses and forbs had bird species diversities that were much lower than natural riparian woodlands.

522. Leaving some areas on levees uncut, even for short periods,

may conflict with CE maintenance requirements (US Army, Office, Chief of Engineers 1968). Levee inspections cannot be hindered, and this is an especially strong limitation if nesting seasons occur concurrently with periods of high water. On the other hand, if mowing is accomplished just prior to a flood, the shorter vegetation will provide less erosion protection.

Costs

523. Although no cost estimates are available specifically for levee mowing, a variety of cost estimates have been compiled for mechanical vegetation management generally. On rangeland, mechanical control has been estimated as costing $7.00-$26.50 per acre, while an average cost of $215 per acre has been computed for rights-of-way (USDA-States-EPA 2,4,5-T RPAR Assessment Team 1979). Costs of mowing may sometimes be reduced by sale of the hay which is produced.

524. Conducting mowing by a specified schedule should not result in either additional labor or equipment. In fact, maintenance efforts may even be reduced. However, limiting the length of the time allowed to accomplish mowing may require a redistribution of the resources and thus require additional personnel, overtime, or equipment rental.

Grazing

Purposes

525. Scientifically designed grazing programs enable management of levee vegetation consistent with maintenance standards. Although grazing can have serious adverse effects, incorporation of prescriptions that are based on site-specific conditions minimizes damage to vegetation, levee slopes, and wildlife habitat. By using different species of livestock, some degree of selective vegetation management can be obtained.

Description

526. Grazing is possible on levees that have well-established vegetation and are not subject to erosion, sloughing, or other damage that could compromise the integrity of the levee. Even on these kinds

of sites, however, overgrazing results in loss of wildlife cover, erosion, and lessening of plant species diversity (Figure 50). Therefore, careful prescriptions for grazing intensity and timing are needed in order to ensure that excessive erosion and wildlife habitat damage do not occur.

527. Both Stoddart, Smith and Box (1975) and the USDASCS (1976) provide instructions for developing and implementing sound grazing management systems that enable harvesting of the plant resource while maintaining productivity of the soil, plant, and wildlife resources. The process begins with an inventory of the vegetation on the site to determine the existing plant species, the overall amount of vegetation available to livestock and wildlife, and the susceptibility of the site to erosion. Range managers that are experienced with the region can determine from such an inventory whether the range of pasture is being undergrazed, grazed properly, or overgrazed. From this information, a grazing prescription is developed that includes the intensity of grazing, the duration and timing of grazing, whether any special grazing systems are justified, and what species of livestock may be appropriate.

528. Grazing intensity refers to both the number of livestock allowed on the range and the length of time they are allowed to graze. In order to ensure a maximum sustainable yield, the amount of vegetation

Figure 50. Grazed levee exhibits a minimum amount of cover for wildlife

harvested by livestock should not exceed the amount of forage produced on the area (forage is generally defined as about 50 percent of the total herbage produced). Forage production will vary with soil, climate, and plant species composition.

529. A variety of complex grazing systems exist, all of which have advantages and disadvantages. Costs, fencing, manpower, livestock, and other limitations vary. Two examples of grazing systems are rest-rotation and deferred-rotation. Rest-rotation simply involves dividing the area into smaller segments; grazing each segment in rotation; and allowing the other segments to "rest" and set seed, allow for new seedling establishment, and regain plant vigor. Deferred-rotation is used in special circumstances where annual plants make up the bulk of the range to ensure plants have time to set seed before harvesting. On shortgrass prairie, rotation systems have not proven conclusively helpful; this is due to the physiology of the shortgrass prairie plants.

530. Use of various species of livestock, when done judiciously and for specific purposes, can provide for some degree of selective vegetation management and wildlife habitat improvement. Vallentine (1971) states that cattle feed predominantly on grass, but will use some selected forbs and shrubs. Therefore, where cattle are grazed, the amount of grass may decline, while the amount of forbs and shrubs will increase. Sheep grazing, on the other hand, will encourage grass production, since the sheep will select forbs and shrubs over grasses. Goats may be used to control shrubs and woody browse. Using various species of livestock for selective vegetation management is a complex process, and range management specialists are required to devise grazing plans that will meet vegetation and animal requirements.

531. Vallentine (1971) describes several specific instances that illustrate the use of livestock to control specific unwanted vegetation. In Nebraska, winter cattle grazing controlled small soapweed, a noxious weed. Sheep are commonly used on cattle ranges in order to remove plants that are unpalatable to the cattle; they have successfully controlled tall larkspur, a plant commonly poisonous to cattle. In Utah, cattle reduced grass competition with bitterbrush, a highly attractive

big game food, and stimulated growth of bitterbrush. Heavy fall grazing of sheep in sagebrush areas in the West has reduced the sagebrush and favored grass production, while concentrated sheep grazing in California was used to reduce Klamath weed. In eastern Texas, angora goats have been used to reduce shrubs and low brush, although such activities must be accomplished with care since goats commonly cause significant erosion on brush lands.

532. Continued monitoring of range and pasture conditions is needed to determine if grazing prescriptions are meeting vegetation management objectives. Monitoring provides data that enable the adjustment of grazing prescriptions for program management.

Performance

533. Levees in the LMVD and the Sacramento District and associated foreshore areas are grazed extensively. A variety of results have been obtained; however, overgrazing commonly results when grazing is not scientifically prescribed.

534. A number of research studies indicate that grazing does not necessarily decrease wildlife diversity or productivity. For example, Burgess, Prince, and Trauger (1965) found that a grazing rate of one cow per 8 acres improved nesting habitat for blue-winged teal in Iowa, and, if timing of grazing were limited to summer and early fall, heavier grazing intensities could be tolerated. Duebbert et al. (1981) stated that grazing in a carefully prescribed manner was one of the best and most natural ways of rejuvenating old seeded prairie grasslands. In Alberta, Keith (1961) determined that grazing levels of 1.2 acres per head per month from July through November did not seriously reduce duck nesting cover, but spring grazing was harmful.

535. In Montana, Gjersing (1975) and Mundinger (1976) noted a significant increase in waterfowl production when areas historically grazed intensively and continuously were shifted to a rest-rotation grazing management plan. Whyte and Silvy (1981) duplicated these results for wintering waterfowl in a Texas study. Iowa studies by George et al. (1979) indicated that grazing of two or three cow/calf units per acre during July and August would not interfere with the production of

pheasants, quail, doves, or passerine species on native grass pastures.

536. Saxton (1979) reported on a USDA Forest Service experiment in southern California using goats to control chaparral vegetation on fuelbreaks. He concluded that goats were able to control woody invaders in areas previously converted to grassland. Good control was obtained on birchleaf mountain mahogany, scrub oak, and chamise, while containment of the goats in small areas was needed to obtain reduction of ceanothus and manzanita.

537. In Louisiana, Chabrek (1968) found that cattle can be used to open up dense stands of perennial emergents in foreshore wetlands and thus benefit waterfowl. Further, he found that geese are benefitted by moderate grazing because new growth is exposed. Snipe are also greatly benefitted, while rails are not adversely affected.

538. Bue, Blakenship, and Marshall (1952) concluded in South Dakota that cattle played a beneficial role in controlling undesirable vegetation around stock ponds, but careful management was necessary in order for grazing to be complementary to waterfowl production. Grazing rates of 27 acres per cow appeared optimum, while complete exclusion was appropriate only on sites that had been badly degraded by overgrazing. Berg (1956) and Uhlig (1963) found that excluding cattle from artificial wetlands did not have any effect on waterfowl production.

539. Both Glover (1956) and Lokemoen (1973) found light/moderate grazing around ponds enhanced nesting and brooding cover for waterfowl. Holechek et al. (1982) reviewed available grazing techniques and found numerous instances where grazing had been used successfully to improve wildlife habitat for wild ungulates, upland game birds, and waterfowl; they discovered, however, that most of the literature reported grazing had a negative effect on nongame wildlife. The authors concluded that grazing can be a valuable tool for wildlife management, but generalized procedures for implementation are difficult to establish and depend upon site-specific conditions and management objectives.

540. In contrast, numerous studies have indicated that improperly prescribed grazing can have deleterious results. On Louisiana hurricane protection levees on the Marsh Island Wildlife Refuge, Chabrek (1968)

found that cattle use of peat levees for walkways or travel lanes prevented the establishment of vegetation and thus caused erosion. Moreover, he found serious soil compaction problems on these peat levees and thus felt that the overall life expectancy of the levees was reduced, as was the potential for future establishment of vegetation on them. Riley (1981) commented that some Sacramento River levees are overgrazed, and excessive erosion has been the result.

541. Vogl (1977) reports that, in California, grazing often resulted in site degradation due to cattle-related vegetative change, trailing, trampling, and soil compaction. Vegetative change included interrupting solid shrub stands and manipulating succession toward unpalatable species. In Missouri, grazing around farm ponds resulted in poorer habitat for both quail and rabbit (Greenwall 1948). Excluding cattle from a 20-acre pasture in Maryland resulted in the development of three new quail coveys (Burger and Linduska 1967). Both Stauffer and Best (1980) and Geier and Best (1980) determined that conversion of woody riparian areas in Iowa to pasture led to a decline in wildlife species diversity, while a number of other studies in riparian woodlands indicate that grazing reduces nongame and vegetative species diversity (Dahlem 1979; Martin 1979; Thomas, Maser, and Rodiek 1979).

542. Whyte and Cain (1981) found the effects of grazing on small south Texas ponds to degrade habitat conditions for waterfowl and marsh birds, and recommended periodic exclusions to allow for the vegetation to recover. Kirsch (1969) reported much lower waterfowl nesting densities and success on grazed compared to ungrazed areas in North Dakota and recommended that periodic cover removal be discontinued. In Louisiana marshes, overgrazing can lead to reductions in plants valuable for waterfowl food (Chabrek 1968; Chabrek, Yancy, and McNease 1975).

Limitations

543. In order for grazing not to result in environmental degradation, it must be carefully prescribed by personnel who have extensive professional regional experience in range and pasture management. Otherwise, overgrazing easily results.

544. From the previous discussion it is evident that livestock/

plant/soil/wildlife relationships are quite complex; thus, considerable knowledge and experience are needed to implement an ecologically sound grazing management scheme that is responsive to local conditions and management objectives. Many experts agree that advances are needed in the state of the art of grazing management before it can be successfully implemented to consistently improve wildlife habitat (Townsend and Smith 1977).

545. The development of grazing management programs for levee projects would normally be the responsibility of the landowner or local sponsor. Although CE personnel could suggest grazing management programs, economic considerations may outweigh environmental quality concerns, which would partially restrict grazing. In cases where erosion control and wildlife management concerns are in harmony, the CE can exert some control.

Costs

546. By using grazing to control vegetation on and around the levee, the local landowner would obtain some economic return from the levee instead of having to assume costs for vegetation management by other methods. However, whether or not this would be profitable would depend upon market conditions and the scale at which grazing is possible.

547. Costs of developing improved grazing or pasture utilization plans are commonly borne by the USDASCS through its technical assistance program to private landowners. Costs for developing improved grazing management plans have been estimated for various Watershed Work Plans compiled by the SCS. For the period 1979-1981, these estimates ranged from $1 to $65 per acre.

Prescribed Fire

Purposes

548. Like other methods of vegetation management, fire is commonly used to maintain levee vegetation to meet engineering objectives. However, prescribed fire may be used to foster plant types that are

dependent on fire and to institute selected species composition changes.

Description

549. Prescribed fire is often a nonselective technique for vegetation management. however, it can also be used to produce or maintain plant successional patterns that are beneficial to wildlife or aesthetics where specific plant communities are dependent on fire for their survival or reproduction. Examples include the prairie grassland ecosystem and a wide variety of wildflowers that are early invaders on burned sites. Fire has been extensively used for forestry, range, and wildlife habitat management, and a considerable information base exists which may be used to develop scientific burning prescriptions that are regionally and locally specific.

550. A number of variables influence the intensity of burn and thus the ecological results of prescribed fire. They include, but are not limited to, frequency of burns, direction of burn in relation to the wind, type of fuel, amount of available fuel, fuel moisture, wind speed, and season. The USDA Forest Service has developed several publications that describe the environmental effects of fire (Martin et al. 1979, Sandberg et al. 1979). Wright and Bailey (1982) is a valuable reference on fire ecology.

551. Duebbert et al. (1981) suggested a variety of dates, usually spring or fall, for rejuvenating prairie grass stands in the Dakotas. The authors felt that a fire frequency of once every 5-10 years was appropriate, depending on the stand. Green (1977) recommended burning grassy ground cover with scattered woody clumps to control woody vegetation in California; maximum control of woody vegetation occurs when the burn is conducted during the dry season after the grasses have matured. Burns must be conducted before the fall rains dampen old grass and stimulate new growth. Vogl (1977) reported that grasslands in California have been historically burned on an annual basis, and that such burning was often needed to maintain the grassland system. However, Vogl also reported that increased fire intensities have been responsible for converting valuable woody vegetation to grasses.

552. Mobley et al. (1978) stated that in the Southern States the

most desirable season and sequence of burns vary regionally. Winter backfires result in less root kill than other types of burns. For forestry purposes, he reported, one approach involves an initial winter burn to reduce fuel loading and annual summer burns thereafter. Summer burns appeared to be more effective at killing hardwoods than winter burns.

553. When conducting prescribed burning, several steps are necessary in order to comply with local and State regulations, ensure safety, and make certain management objectives are achieved. First, State and local permits may be needed from fire departments and air quality agencies. Second, monitoring of weather conditions is needed to ensure that wind, moisture, and air quality conditions are such that successful burns are obtained, fires have minimal opportunity to escape to surrounding lands, and stress on local air quality is not a problem. Just prior to burning, firebreaks are constructed either by backfiring or cutting brush. Fire-fighting equipment should be present on standby in case the fire shows signs of escaping.

Performance

554. Site visits and discussions with CE personnel indicate that fire appears to be extensively used only in the Sacramento District for levee vegetation management (Figure 51). Opinions vary on its usefulness; some feel it promotes vegetative diversity on the levee, while others feel it creates an unsightly appearance, enhances erosion problems, and promotes drying and cracking of levees made from soils containing significant amounts of clay. As currently practiced, the use of fire is not prescribed in the sense that habitat considerations are not generally factors in fire design or scheduling.

555. A number of authors comment on the usefulness of fire for vegetation and wildlife management. Duebbert et al. (1981) felt that fire was one of the best means of rejuvenating prairie grasslands as duck nesting habitat and other wildlife cover. George et al. (1979) agreed that prescribed fire in prairie grasslands provides valuable new growth and discourages unwanted woody plants.

556. Biswell (1977) described the use of fire as working in

Figure 51. Levee vegetation management through prescribed fire

harmony with, rather than against, nature. Usually, multiple benefits are obtained through the use of fire. Mobley et al. (1978) described beneficial wildlife effects of prescribed burning in the South as increased yield and quality of herbage, legumes, and hardwood sprouts. Hardwood sprouts less than 3 in. in diameter at the ground line can be controlled through burning, and thus open, parklike appearances can be obtained.

557. Kirsch and Kruse (1973) presented both historical evidence and data from a study in North Dakota that illustrate the benefits of fire on the prairie ecosystem. Historical accounts noted that fire was a routine event in the prairies; prairies were soon invaded with woody vegetation without fire and that big game, ducks, and prairie grouse responded favorably to fire. In experimental work, the authors noted plant species diversity increased after a fire. While the numbers of avian nests were similar between burned and unburned plots, more species nested in burned plots 1 year after the burn than in unburned plots. More white-tailed deer fawns and upland game birds occurred on burned plots than unburned plots. Nest success was higher on burned plots for waterfowl, sharp-tailed grouse, and upland plovers.

558. Fire has been recommended as the most appropriate tool for the rejuvenation of sagebrush/grassland for sage grouse (Klebenow 1973). Westemeier (1973) found that redtop/timothy stands could provide favorable nesting habitat for prairie-chickens in southeastern Illinois if they were burned twice during a 6- to 9-year period after seeding. He recommended an initial August burn, followed by March burns as needed. Further, he recommended patch burning for the creation of habitat diversity.

Limitations

559. Smoke from prescribed burns can degrade visibility on nearby roads and thus constitute a hazard for motorists (Riley 1981). Further, smoke can adversely affect local air quality, and thus may be limited by local authorities to specific periods of time when it will dissipate quickly (Green 1977).

560. A number of factors beyond the manager's control can influence the effect and relative hazards of prescribed fire. For example, steep slopes provide less opportunity for uniform and controlled fires than level slopes (Center for Natural Areas 1980a). Thus, levee burning may be more hazardous than and not as effective as burns on adjacent grasslands. As stated earlier (paragraph 550), local weather conditions, fuel moisture, fuel loading, and other factors also influence the success of a burn. Thus, a number of authors (Biswell 1977, Mobley et al. 1978) have noted that implementation of an effective prescribed fire program is as much an art as it is a science.

561. Differing opinions exist as to whether prescribed burning causes degradation in soils and plant communities. Green (1977) felt grass fires in California do not damage the soil and regeneration is quick. However, Leisz and Wilson (1980) commented that too frequent burns can cause degradation of soils and flora in California brushlands.

562. A variety of undesirable wildlife effects have been noted from selected uses of prescribed fire. Fires in grassland areas can eliminate some forms of woody vegetation. In California, this woody vegetation sometimes provides critical nongame bird habitat (Hehnke and Stone 1978; Hurst, Hehnke, and Goude 1980). Moreover, fires in areas of

sprouting woody vegetation may only encourage their growth (Biswell 1977). Lillywhite (1977) noted a lowered wildlife diversity and net loss in wildlife resources and exploitation possibilities when prescribed fires are used for type conversion and maintenance of grasslands in California. Prescribed fires during periods critical to wildlife, including nesting seasons and winter, can result in lowered productivity and increased mortality (Mobley et al. 1978).

Costs

563. Green (1977) reported that costs for prescribed fire in California can be considerable, but are generally less than for alternative methods of vegetation management, except on small areas. The USDA-States-EPA 2,4,5-T RPAR Assessment Team (1979) reported costs of rangeland burning from $0.60 to $3.50 per acre, while costs on timberland range from $3.50 to $84.00 per acre. Mobley et al. (1978) reported prescribed burning costs for southern pine management to average $1.25 per acre. Because of steep slopes and the long, narrow shapes of levees, costs may be somewhat higher. Average cost for levee burning reported by the State of California to the Sacramento District is $72/acre.*

Chemical Vegetation Management

Purposes

564. Herbicides may be used for selective vegetation management and for general vegetation management on levees difficult to maintain with other methods because of their topography, soils, and other site constraints. In some cases vegetation control with herbicides reduces erosion over alternative methods of weed control. Supplementary precautionary measures are required to ensure that hazardous chemicals do not pollute the environment.

Description

565. Numerous options exist for the use of chemicals for vegetation management, including specific chemicals, formulations, and

* Personal Communication, 1983, Alisa Ralph, Environmental Resource Planner, US Army Engineer District, Sacramento, Sacramento, Calif.

methods of application. Available chemicals are described in Table 8. A variety of documents have been drafted to enable users to choose the most appropriate alternative for their purposes (Chemical Plant Control Subcommittee and Range Seeding Equipment Committee 1966; Gratkowski 1975, 1978; Brewer, Ham, and Marbut 1976; Asplundah Environmental Services 1978; Mann and Haynes 1978). Specific chemicals can be chosen based upon the species of plant needed to be controlled, options for application, and cost. Formulation alternatives include mixes of chemicals, carrying agents, and additives such as emulsifiers. Methods of application include aerial broadcast, ground broadcast, individual stem foliar (leaf application), basal spray, injection, and cut stump. Equipment costs, uses, efficiency, and other factors vary with the method of application.

566. Advantages of chemical treatment over other methods include relatively low cost, comparatively low site disturbance, selectivity, and the ability to use them in areas of steep topography and unstable soils. However, the hazardous nature of chemicals may limit their usefulness around water. Moreover, proper timing of chemical application relative to plant physiological condition is often needed to ensure effectiveness. Other disadvantages include limitations imposed by weather conditions, the development of fire hazards, and development of plant communities by natural succession that are resistant to chemicals.

567. Significant concerns exist regarding the potential danger to human health from exposure to herbicides. Therefore, chemical vegetation management should be carefully compared to other alternatives before implementation. Plans should be developed in coordination with all interested parties. Steps in a chemical vegetation management program include (a) description of the weed problem and of the desired vegetative type, (b) development of a prescription, and (c) application.

568. Description of the weed problem involves determination of which plants on the site constitute pests. A prescription is developed that will destroy pest plants while not harming desirable vegetation. This can be accomplished by determining the most appropriate herbicide in the correct formulation, the time of application that would be

Table 8

Properties of Selected Herbicides (from USDA-States-EPA 2,4,5-T RPAR Assessment Team 1979)

Herbicide	Formulation	Application Rate*	Selectivity	Route of Uptake	Cost
Fosamine	Krenite-water-soluble liquid, liquid	1-1/2 to 3 gal/acre, 300 gal/acre ground in water	Deciduous species	Foliage	$38/gal
Amitrole-T	Amino triazole + ammonium	1/2 to 1	Salmonberry and elderberry	Foliage	$15/gal
Asulam	Asulam-sodium salt liquid	1 gal/acre	Bracken fern	Foliage	$45/gal
Atrazine	80% wettable powder	3 to 4 lb ai/acre	Annual grasses and some forbs	Root	$3.30/lb
Cacodylic acid	Dimethylarsinic acid	Undiluted	Hardwoods and conifers by injection	Cut surface	$4.35/lb
Dalapon	74% sodium and magnesium salts-water-soluble	3 to 11 lb ai/acre	Annual and perennial grasses for use with atrazine or directed sprays	Foliage and root	$2.30/lb
Picloram	Triisopropanolamine salts to picloram and 2,4-D (Tordon 101R and Tordon 101)	Undiluted	Hardwoods and conifers by injection	Cut surface	$12/lb for Tordon 101R and $20.60/gal for Tordon 101
Pronamide	50% wettable powder	1 to 2 lb/acre	Grasses only	Root	$15/lb
Dicamba	Dimethylamine salt	Undiluted or 1:4 in water	Hardwoods and conifers by injection	Cut surface	$40/gal
	Dimethylamine salts of dicamba and 2,4-D	1 to 3 gal/acre	Shrubs and weed trees	Foliage	$15 to $21/gal
	Oil-soluble of dicamba and isooctyl esters of 2,4-D	1 gal/acre	Shrubs and weed trees	Stem	$20 to $24/gal
DNBP	Emulsifiable dinitrophenol	1 to 2 gal/acre	Nonselective, nontranslocated desiccant used to prepare herbaceous and woody vegetation for burning	Foliage	$9.40/gal
MSMA	Monosodium acid methanearsonate	Undiluted	Hardwoods and conifers by injection	Cut surface	$14.50/gal
Picloram	Potassium salt + invert emulsions of 2,4-D	1 to 4 qt picloram + 1 to 4 gal of phenoxy invert	Shrubs and weed trees	Foliage	$71/gal + invert
Triclopyr	Amine salt, water-soluble	2-4 lb/acre	Deciduous and evergreen brush	Foliage	$53/gal
Simazine	80% wettable powder	3 to 4	Annual grasses and some forbs	Root	$3.60/lb
2,4-D	Amine	Undiluted or 1:1 with water	Hardwoods cherry and big-maple, by injection	Cut surface	$7.65 at 4 lb ae/gal
2,4-D	Low volatile ester (Isooctyl, BEE, PGBE)	1/4 to 3/4	Shrubs, weed trees, and forbs.	Stem and foliage	$9.40/gal to 4 lb ae/gal
Velpar	Granular hexazinone	1 lb ae/acre	Hardwoods	Roots	$17.65/lb
Glyphosphate	Isopropylamine salt-water-soluble	1/4 to 3/8 gal/acre	Deciduous woody species and herbs	Foliage	$70.60/gal

* ae - acid equivalent; ai - active ingredient.

optimum for obtaining the best selective control, and the most cost-effective method of application.

569. Application is usually strictly regulated through the US Environmental Protection Agency and the various State pesticide control authorities. Label directions and general regulations promulgated by these agencies have the power of law and should be strictly followed. Certified applicators are required for some restricted herbicides.

Performance

570. Effectiveness of the various herbicides on different plant species is generally extremely well researched by the US Department of Agriculture and the chemical companies. Compilations of this information are available through those references cited above and Beste (1983).

571. Chemical control has received widespread use and has proven effective for forest, range, right-of-way, and agricultural needs for at least two decades. However, herbicide use is declining due to concerns over its health effects. Herbicide use is suggested and permitted for levees through official CE policy (US Army, Office, Chief of Engineers 1968).

Limitations

572. A significant concern surrounding the use of herbicides is their potential for chemical environmental contamination. Much contradictory data have been generated (Center for Natural Areas 1980a, 1980b), and no resolution is evident for the near future. Thus, in selected instances the use of herbicides by Federal agencies has been adamantly opposed by local residents.

573. Because of its potential for creating public health concerns, herbicide use is strictly regulated at both the Federal and State levels. Applicable Federal legislation includes the Federal Insecticide, Fungicide and Rodenticide Act and the Environmental Pest Control Act (7 USC 135-136). Court rulings against both the USDA Forest Service and the USDI Bureau of Land Management found that their use of chemicals constituted significant Federal actions under NEPA (42 USC 4321, 4332-4335, 4341-4347), and thus required formalized processes involving

preparation of Environmental Impact Statements and Environmental Assessments (Center for Natural Areas 1980a).

574. From a practical standpoint, weather conditions will influence both risk and efficacy of herbicide use. In order to minimize drift, wind should be at a minimum; for maximum effectiveness, no rain should occur during or immediately after application. Herbicide effectiveness will also vary with season, based upon the development of the target plant.

575. Herbicides can be toxic to fish and wildlife, but the potential for habitat changes caused by the use of herbicides often overshadows toxicity issues. Habitat changes can be beneficial or adverse, depending upon the objectives of the vegetation management program.

576. If herbicides are used in areas that receive intensive recreational use, health effects will be of greater concern. Moreover, extensive amounts of herbicide-created standing dead vegetation will create adverse aesthetic effects.

Costs

577. Although costs for herbicide application are not available specifically for levees, various costs for timber, range, and right-of-way use were compiled by the USDA-States-EPA 2,4,5-T RPAR Assessment Team (1979). These include site preparation on timberlands ($12-$180 per acre), release on timberlands ($12-$88 per acre), hand injection for thinning ($12-$88 per acre), range brush treatment ($4.75-$12.00 per acre), broadcast treatment on rights-of-way ($118-$146 per acre), basal spray treatments on rights-of-way ($87-$260 per acre), and cut stump treatments on rights-of-way ($164-$851 per acre).

Irrigation

Purpose

578. Irrigation increases survival of plantings for wildlife and aesthetics where moisture is a limiting factor for plant growth.

Description

579. Options for irrigation range from temporary arrangements to

give newly planted vegetation a start to complex, permanent designs for ongoing operations. Although requirements for water just after planting can be reduced somewhat by timing planting to occur during wet seasons, some temporary methods may be appropriate in arid climates and at dry sites to ensure initial survival. For temporary systems, water trucks or hookups to municipal water supplies often provide a low-cost alternative. Some commercial irrigation systems are movable and available on a rental basis and can be used for temporary irrigation.

580. Where climates are extremely dry and plants that require considerable moisture are desired, more permanent systems may be designed into the project. Such systems typically consist of one or more pumps, supply lines, distribution lines, and risers. Lines that are under constant pressure should not be used, as a rupture and leakage when the system is unattended could seriously erode the levee.

581. Irrigation systems are best incorporated early in the levee design process. Available systems vary among regions, and use of locally available systems can reduce construction and maintenance costs. If a permanent system is used, watering will be accomplished on a regular basis. On recreational areas, since watering may interfere with recreational use, it should be timed for periods of low use.

Performance

582. A permanent irrigation system was installed at a CE project in Lewiston, Idaho (Figure 52) (US Army Engineer District, Walla Walla 1970; Osmundson and Associates 1972; Osmundson 1973), while temporary facilities were used for the Alameda Creek project in California (US Army Engineer District, San Francisco 1969; Osmundson 1980). A variety of park facilities associated with Sacramento River levees have irrigation systems. Plans for irrigating levees have been also developed for the Tijuana River (US Army Engineer District, Los Angeles 1977).

583. In Lewiston, Idaho, a permanent irrigation system allowed the use of numerous aesthetic plantings. Plantings were conducted where water was in short supply but where selected areas were irrigated; plants that are generally beneficial to wildlife, but not desirable in

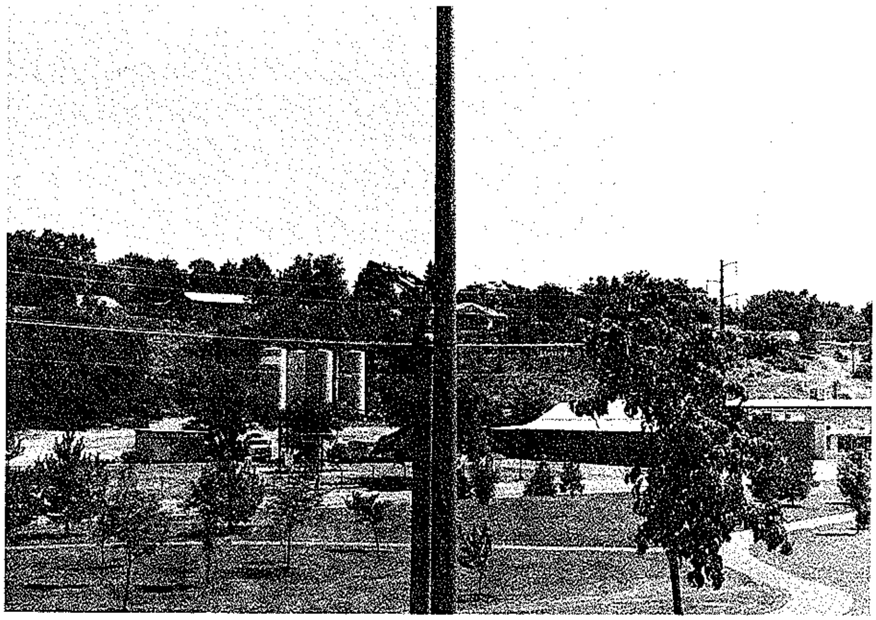

Figure 52. "Big-gun" irrigation sprinkler on the Lewiston levee

other areas because of their tendency to spread, could be used since they would not survive outside the irrigated zone. The Alameda Creek irrigation system was less successful because it was extensively vandalized and eventually had to be removed.

Limitations

584. The following limitations on levee irrigation should be considered:

a. Since irrigation systems are usually costly, they are appropriate only where needed to ensure plant survival. Arid climates and specific areas on the levee are more appropriate than others for irrigation system location. Specifically, areas high on the slope and levee crown are more likely to require irrigation than foreshore areas.

b. As noted previously, vandalism has been documented as a problem for levee irrigation systems. An ongoing commitment will be needed to operate and maintain the system.

c. From a structural standpoint, irrigation and water supply lines constructed into the levee may burst and thus threaten the structural integrity of the levee. Moreover, waterlines in the foreshore or riverside area could be threatened by floods.

_d_. A power supply must be available for pumping, and a cheap supply of water is also needed. Sites requiring irrigation are likely to be located where water supplies are limited. Water rights for irrigation may be difficult to obtain.

Costs

585. A temporary irrigation system to last 2 years and irrigate 6,000 ft of levee for a proposed project along the Tijuana River (US Army Engineer District, Los Angeles 1977) was estimated at $69,000. The estimate included stream spray-type sprinklers and automatic station controllers.

586. On the Lewiston, Idaho, levee, two irrigation systems were installed. Contract estimates for this project stated that one system for the West Lewiston levee would cost $199,000, while the North Lewiston irrigation system was to cost $59,000. Both systems included use of the commercial big-gun irrigation system.

587. On Alameda Creek, a 1969 supplement to the General Design Memorandum (US Army Engineer District, San Francisco 1969) estimated a system cost of $195,000 for installation and maintenance. In addition, connection to the main waterline was to cost $7,520 and rental of meters was to cost $3,620. Thus, a total cost of the system was listed as $206,000.

588. As stated previously, ongoing costs will occur for permanent irrigation systems. These will include costs for water, labor for operation and maintenance, and replacement parts.

Rodent Control

589. Certain species of rodents that den underground may damage levees by burrowing into them and creating pathways for water passage during floods. Rodent control is often practiced as part of levee project maintenance. Rodent control programs should be designed to have minimum adverse effects on nontarget wildlife and humans.

Description

590. CE levee maintenance policy (US Army, Office, Chief of

Engineers 1968) requires both backfilling of animal burrows in levees and efforts to exterminate the animals. Several types of rodents are the targets of such programs. Beaver, muskrat, and nutria often den in riverbanks, and thus cause problems where levees are immediately adjacent to the top bank. The California ground squirrel digs into upland sections of levees (Figure 53) and becomes a nuisance to adjacent farmers by eating crops. In the East, the woodchuck could potentially burrow into levees, but instances of this occurring have not been documented. Landin* noted that, in LMVD, no beavers were observed in upland levee sections adjacent to 25 borrow pits under investigation, although beavers existed in all of the pits. Rodent control steps include determining whether a pest problem exists, choosing an appropriate mix of control strategies, and implementing them.

591. Hawthorne (1980) described signs of various problem rodent species and noted that careful and thorough monitoring and evaluation of pest problems were prerequisites to effective control programs. Typical beaver signs include cone-shaped tree stumps that indicate feeding, as well as peeled sticks and tooth marks. Evidence of ground squirrels is

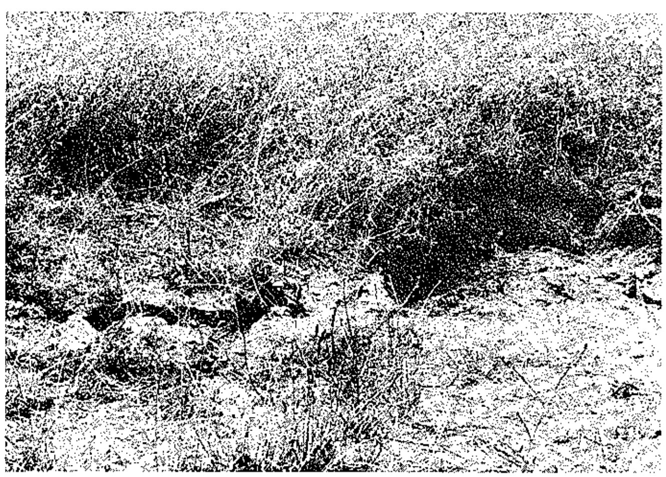

Figure 53. Damage to Sacramento River levees caused by California ground squirrels

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* Personal Communication, 1983, M. C. Landin, Wildlife Biologist, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

indicated by direct observation of burrows or individuals, as well as opened seed hulls and food caches. Although a definite sign for muskrat is burrows into the bank, they are commonly visible only during low water. Other muskrat signs include bank slides and cave-ins, tracks, and droppings. Presence of woodchucks is indicated by their burrows, droppings, and trails.

592. A number of control techniques exist for each species of burrowing animal. Although specific techniques vary, they can be grouped under general categories of habitat modification, trapping, chemical control, and biological control. As of 1979, all Federal agencies were encouraged to implement programs of integrated pest management that consist of mixes of the various alternatives that achieve the most effective degree of pest control and the minimum amount of adverse effect to the environment (Council on Environmental Quality 1979).

593. Habitat modification consists of developing a sound understanding of the requirements of the pest species and modifying vegetative types on and around the levee to produce conditions that do not meet the basic food and/or cover requirements of the species. Beaver (Hawthorne 1980) and nutria, for example, prefer sapling and pole-sized deciduous trees including sweetgum, cottonwood, willow, alder, and aspen, while emergent aquatic vegetation, especially cattails, attract muskrat. All three of these species will only burrow into earth that is immediately adjacent to water. A habitat of closely cropped grass and a slope no greater than 3:1 on the water side of water-retarding structures is thought to discourage muskrat burrowing (Hawthorne 1980), as are sand or gravel toppings on the structures.

594. Both Bond (1945) and Klitz (1982) noted that ground squirrels were attracted to sparsely vegetated areas where they can readily observe their surroundings for predators; however, Eadie (1954) listed food requirements for ground squirrels as succulent green vegetation, nuts, seeds, and fruits, which indicate a habitat requirement for more dense vegetation. Klitz (1982) and Daar (1982) concluded that the prevalence of ground squirrel food sources adjacent to the levee makes food

not a limiting factor for ground squirrels on levees and thus not an appropriate avenue for habitat modification. Like the ground squirrel, the woodchuck prefers fairly open areas that allow prior warning of predators, although woodchucks are also common in woody edge habitats adjacent to more open areas.

595. Trapping has been described as a viable alternative for both beaver and muskrat (Eadie 1954, Hawthorne 1980), but effective only on a local scale for ground squirrels. Although trapping can be conducted both by official maintenance personnel and by commercial trappers, Eadie (1954) concluded that where a commercial market existed for fur, commercial trapping for beaver and muskrat commonly served as the most cost-effective control method. Whether accomplished commercially or by maintenance personnel, trapping programs need to use the most appropriate style and size of trap for the species being controlled. Such guidelines for trap selection are provided by Hawthorne (1980).

596. Chemicals can be applied either through fumigation of burrows or through baiting programs. Available fumigants include calcium cyanide, carbon disulfide, chloropicyrin, methyl bromide, ethylene dibromide, ethyl dicloride, and sulfur dioxide. Baiting programs can be accomplished either through multidose programs using anticoagulents (Wafarin, Pival, Fumarin, Diphacinone, Prolin, PMP, and Chlorophacinone) or single-dose poisons including zinc phosphide or strychnine. An additional single-dose poison, compound 1080, is available on the market but prohibited from use by Federal agencies for its potential of poisoning nontarget wildlife. Hawthorne (1980) discussed the values of the alternative chemicals for various pest target species.

597. To date, biological control efforts have concentrated on fostering predation on target species. Most notably, enhancing habitat for raptors was determined to be a potentially valuable control strategy for rodents in California agricultural fields (Hall, Howard, and Marsh 1981) and recommended for further study relative to ground squirrel populations on levees (Daar 1982, Klitz 1982).

598. In all cases where direct control efforts (trapping or poisoning) are implemented, highest degrees of efficacy are obtained if

control actions are concentrated during periods of high susceptibility of target species. For example, several studies on ground squirrels indicate the period immediately following their emergence from winter hibernation is when the highest degrees of bait acceptance and mortality occur (Fitch 1954, Sullins and Verts 1978).

Performance

599. Although not widely tested, the concept of habitat modification has been widely implemented in field animal control programs. A study is currently in progress by the John Muir Institute on Sacramento River levees to determine whether or not habitat modification offers potential for ground squirrel control. In studies of pocket gophers, Keith, Hansen, and Ward (1959) found habitat modification through the use of herbicides resulted in an 87-percent population decline in the target species.

600. Fairly high rates of rodent mortality have been reported for direct control efforts (trapping and chemical control), especially for the use of chemicals. However, most studies indicate that direct control efforts commonly do not result in long-term population declines. For example, Matschke et al. (1982) found that a 95-percent kill of Richardson's ground squirrels using zinc phosphide was not sufficient to reduce population levels the following year. Kalinowski and deCalestra (1981) also determined that annual treatments were needed using compound 1080 as a control agent. Moreover, studies by Horn (1943) and Howard, Marsh, and Cole (1977) found that use of the same direct control agent over time eventually results in the species becoming acclimated and the program becoming less effective even at obtaining initial mortality. Thus, direct control efforts need to be considered as ongoing programs, with individual methods altered periodically to prevent acclimatization by the target species.

601. Biological control has only recently begun to receive attention from researchers, and thus only limited data exist on its effectiveness. Hall, Howard, and Marsh (1981) found that habitat improvement structures to foster raptors for the control of rodents on California agricultural areas did, in fact, greatly attract desired species.

However, effect of the raptors on controlling rodent populations was not evaluated.

Limitations

602. As noted earlier, animal control programs require careful monitoring and evaluation to determine whether or not a pest problem exists on individual sites. Unfortunately, the degree to which different burrowing mammals constitute threats to levee integrity is poorly understood. For example, of the species discussed above, only the muskrat is listed by standard animal control references (Eadie 1954, Hawthorne 1980) as being a significant threat to the structural integrity of water-retarding structures. However, beaver have also significantly affected the operation of some structures (Rundle and Fredrickson 1981). Many of the CE personnel interviewed for this study felt beavers and muskrats to be more significant problems, due to their larger holes, than ground squirrels. In the Pacific Northwest, nutria seem to be the biggest problem. Without detailed knowledge of the potential threat to structural stability of levees, it is difficult to determine threshold population levels at which control is warranted. Moreover, those species that burrow beneath the waterline are extremely difficult to detect until significant damage has already been done.

603. With the possible exceptions of trapping and biological control, methods of animal control have high potential for adversely affecting nontarget wildlife species. During a literature review, Klitz (1982) found a high incidence of mortality to nontarget wildlife from baiting programs using chemical methods. Habitat modification for selected species will also adversely affect other wildlife. For example, habitats preferred by beaver and nutria include deciduous woody riparian areas that are commonly high in species diversity for other wildlife. Habitat modification for muskrat would eliminate emergent wetland vegetation which also provides valuable habitat for waterfowl and a wide variety of other wildlife. CE policy stipulates that adverse effects to nontarget species from animal control programs are to be minimized (US Army, Office, Chief of Engineer 1983).

604. Traps and baits can constitute hazards to the public if

placed in heavily used recreational or residential areas. Serious physical injuries are possible with traps, while chemical agents could be contacted by children or domestic animals. Where market conditions are not favorable or where pelt quality is not adequate for pelts to be marketed, commercial trapping will not obtain effective control.

605. Bait acceptance will influence the degree to which chemical control is effective. Such acceptance can vary with season (Fitch 1954, Sullins and Verts 1978) and with the type of bait used (Marsh, Howard, and Palmateer 1970). To complicate matters, relative attractiveness of alternative baits can vary with season.

606. Like other pesticides, rodenticides are strictly controlled by Federal and State regulations, and all possess a danger for accidental poisoning of nontarget wildlife. Thus, precontrol evaluations are needed to determine not only the most appropriate chemical, but also to clearly document whether or not use of the rodenticides is the most practical, cost-effective, and least damaging of the alternatives. Moreover, precontrol baiting studies are needed to determine whether or not the poison will be accepted by the target species.

607. Both soil and burrow characteristics influence the efficacy of fumigants. Horn (1943) reported that fumigants are more effective in tight, nonporous soils than in porous soils, while smaller burrows are more easily treated with fumigants than extensive burrow systems.

608. Ground squirrel control through habitat management could interfere with the ability of maintenance personnel to inspect the levee. The desired habitat to discourage ground squirrels consists of tall, dense vegetation, while short, sparse vegetation is needed for inspection.

Costs

609. Most habitat modification methods consist mainly of vegetation management to discourage unwanted species. Costs for the various vegetation management options are discussed above (paragraphs 511, 523-524, 546-547, 563, 577, and 585-588). Set-back levees (paragraphs 69-80), could be considered habitat modification, since the distance

between the embankment and water affects attractiveness for burrowing mammals.

610. Costs for various direct control alternatives vary considerably, depending on the method chosen, the intensity of control efforts, and the number of treatments required. The least expensive form, commercial trapping, could be accomplished at no cost to the operation and maintenance authority, since it brings an economic return to those who practice it.

Maintenance of Recreation Areas

Purpose

611. Maintenance is accomplished on areas designed for recreational use in order to ensure that a clean, attractive, healthy, and safe environment continues to exist for users of the area.

Description

612. Moderately and intensively used recreational sites associated with levee projects (Figure 54) require regularly scheduled maintenance to ensure their attractiveness. Responsibility for such maintenance can lie either with the CE or with the local sponsor and is determined during the process of negotiation between the local sponsor and the CE. Official CE guidance for maintenance and operation of recreation areas is given in ER 1130-4-400 (US army, Office, Chief of Engineers 1971a). CE maintenance activities are normally limited to recreational features installed as "mitigation" rather than features for environmental enhancement that are cost shared. For example, facilities on the Lewiston, Idaho, levee are maintained directly by CE, while Evansdale, Iowa, recreational facilities are maintained by the local sponsor. Such responsibilities are determined by Federal cost-sharing policies, the relative ease at which alternative agencies can accomplish maintenance, and the division of responsibility determined through the negotiation process during project planning. Maintenance activities include, but are not limited to, solid waste disposal, mowing of grass, care of shrubs and trees, cleaning of recreational facilities, and re-

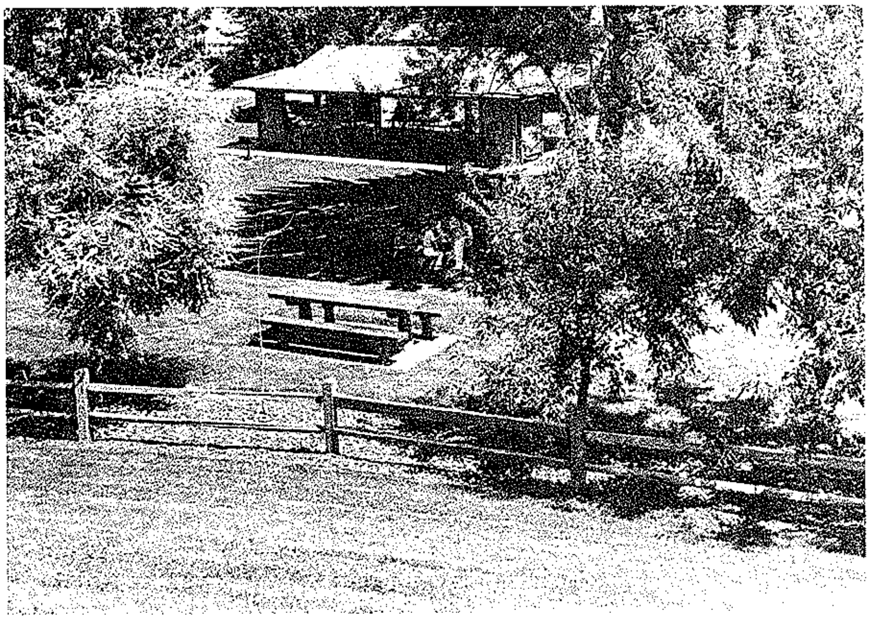

Figure 54. Levee recreation areas commonly require routine maintenance

pair or replacement of damaged or vandalized facilities.

613. Solid waste disposal consists of collection and management of refuse that is brought into the area by users and deposited in receptacles designed for that purpose. Collection should be accomplished frequently enough so that receptacles do not overflow and the trash does not attract pest insects and animals. Moreover, solid waste collection efforts are accomplished most efficiently and with the least inconvenience to facility users if they are timed to avoid high-use periods, such as weekends.

614. Mowing is performed to ensure that designated lawn areas remain attractive and usable to the public. Cotton (1981) recommended lawn mowing on a weekly basis, but schedules may vary depending upon the growth rate of the sod. Acceptable heights for various grass species are also provided by Cotton (1981). Supplementary activities to ensure healthy, attractive lawns could include watering, fertilization, weed control, insect and disease control, and renovating.

615. Shrub and tree care may include watering, pruning, installation and/or removal of stakes and guys, removal and/or replacement of

dead shrubs and trees, weed control, insect and disease control, and fertilization. However, extensive maintenance should not be used to compromise for poor planning during initial project stages in choosing shrubs and trees to foster. CE policy (US Army, Office, Chief of Engineers 1972a) states that only trees and shrubs that require low maintenance should be fostered on levee projects.

616. Law enforcement can be accomplished either by a special staff with legal enforcement power or through arrangement with the local police. Many alternatives exist including foot patrol, horse patrol, use of vehicles, or simply having a force that is available on call. On the Alameda Creek levee, helicopter patrol is used for law enforcement (Osmundson 1980).

617. The need for cleaning and repair of recreational facilities will vary with the extent of the facilities and the degree to which vandalism is a problem. Recreational facilities that will require regular cleaning and/or repair include, but are not limited to, recreational and interpretive centers, observation areas, shelters, restrooms, picnic sites, and irrigation systems.

Performance

618. Some degree of maintenance is practiced universally where facilities occur. However, based on site visits to several levee projects, the effectiveness of maintenance activities varies widely, depending on whether the facility requires high or low maintenance and whether the responsible agency (usually the local sponsor) is dedicated to ensuring that recreational sites remain attractive and safe. Maintenance activities were planned in detail for CE levee projects in Davenport, Iowa (US Army Engineer District, Rock Island 1976), and Lewiston, Idaho (US Army Engineer District, Walla Walla 1970).

Limitations

619. The ease with which maintenance is accomplished is highly dependent on accessibility of the site to maintenance personnel. Thus, sites designed with access roads and trails and designated parking for maintenance personnel are much easier to maintain than facilities without these features. Maintenance requirements depend on facility design

and location. Maintenance requirements are usually projected for alternative developments during design, and maintenance costs are usually included in cost-benefit analyses.

620. Flood frequency is a key consideration in facility siting and design, particularly for riverside developments. Maintenance costs will be influenced by flood frequency, but costs may be reduced by designing flood-proof facilities or by locating sensitive facilities to reduce flood frequency. Examples of such techniques are evident through development of a State park near Grider, Ark., by the Memphis District (US Army Engineer District, Memphis 1974) and the Warfield Point site near Greenville, Miss. (US Army Engineer District, Vicksburg 1975). Plans for the Arkansas site include (a) a design for picnic tables to enable their removal during high water; (b) locating a comfort station on a mound to reduce flooding and building it of durable materials; (c) designing and constructing tent and trailer pads such that damage is minimized and repair is inexpensive; and (d) locating major structures (interpretive center, maintenance building, supervisor's residence, etc.) on the landside of the levee. At the Warfield Point site, plans call for restrooms, an overlook, and future structures to be placed above the 25-year flood elevation level. Other facilities are to be designed and constructed of durable materials so that damage due to inundation will be minimized.

621. Maintenance requirements also vary seasonally. Sites for outdoor activities in areas with severe winter climates will require maintenance only during spring, summer, and fall, while sites located in warmer climates or designed for all-season use will require intensive maintenance throughout the year. Maintenance needs will also vary depending upon whether or not the local populace is inclined toward vandalism of facilities. Vandalism has been a problem on a number of levee-related recreation facilities.

<u>Costs</u>

622. Maintenance costs can vary markedly between sites depending on several variables. These variables include, but are not limited to, size of the area, intensity of recreation use, types of development,

vandalism, and success of the initial planting program. Cotton (1981) provided cost estimates for the vegetation management aspects of recreation facility maintenance for California. The cost of lawn care, including mowing and all supplementary measures mentioned in the description section, ranges from $0.0120 to $0.0215 per square foot per month, depending on the size of the area and the type of irrigation system used. Cost of shrub care ranges $0.16-$0.79 per plant per month, depending on the size of the plant.

Information and Education Programs for Maintenance Personnel

Purpose

623. Information and education programs can be used to inform inspectors and maintenance personnel of the type of plants, wildlife, and fish that are indigenous to the area, and the type of habitat each requires. Moreover, the programs serve to educate inspectors and maintenance personnel on maintenance methods and practices that will ensure levee integrity at the lowest habitat cost. Personnel can be educated regarding the location and purpose of various project environmental features to avoid damages during maintenance activities.

Description

624. One option for information and education programs includes one or more films, video tapes, slide shows, or other aids that provide information on the project setting and recommended maintenance practices. Such aids might describe and show wildlife species which are known to exist on or around the levee within a specific maintenance district. Other presentations can include descriptions of inspection techniques required for vegetated levees, example of features to note during inspection, and techniques for maintenance that minimize environmental disturbance.

625. Since good management practices commonly change little with time, films and other visual aids that avoid showing vehicles, current clothing styles, and other dated items will remain useful for a longer

period of time. Use of political personages for comment or narration will prove to be a disadvantage, since viewers may feel the film reflects the views of a particular party or administration and may date the film. When experts appear to narrate or explain, they are most effective when they do not speak down or use terms unfamiliar to the audience. When dressed in work clothes rather than business clothes, these individuals will receive greater acceptance by the viewer.

626. Films and other aids may be shown as part of on-the-job training, and information in the films can be included on examinations used in merit systems. In some maintenance districts, agricultural functions (e.g., Grange meetings) may be suitable for presentations. Issues discussed are most effectively presented in order of their importance. Shorter presentations commonly receive better attention than longer ones, and presenting information when personnel have the immediate opportunity to apply it may increase retention.

627. For maximum effectiveness, education programs should be site specific. Urban areas may have floodwalls and other structures, while residential areas may have unique problems caused by children, homeowners, or developers. Agricultural areas may have problems with wildlife damaging crops.

Performance

628. Maintenance workers have ultimate control over the effectiveness of many environmental features. A good example of the damage that can be done by untrained maintenance workers occurred on a transmission line right-of-way project through lands of the National Forest System. Special plantings for wildlife were incorporated into the project and installed under the transmission line, but because contractor maintenance personnel could not identify the vegetation as a wildlife planting, it was destroyed during routine maintenance.

629. Untrained personnel can employ routine practices which destroy wildlife nesting areas, cause nesting mortality, eliminate winter cover, remove food sources, and produce unappealing structures. Through education, however, personnel can be trained to identify wildlife habitat and to plan maintenance items rather than apply routine practices.

Moreover, gaps between engineering concerns for levee integrity and biological concerns for habitat can be resolved through information and education programs that seek to maintain communication between both sides.

630. One instance of the use of information and education programs occurred for State and private levees on the Sacramento River. Under the auspices of the California Department of Water Resources, the State agency responsible for levee maintenance personnel have been prepared. According to State personnel, these programs have received widespread acceptance.

Limitations

631. The preparation of recorded information and education programs will require input from various disciplines, including engineers, biologists, landscape architects, and communications experts. Engineers need to define the areas of the levee to be discussed in each specific program and identify the significant concerns for structural integrity. Biologists and landscape architects should identify (a) the environmental issues and (b) what features produce what environmental effects. Communications experts will be needed to package the program into a form that permits rapid acceptance. Throughout the program development, the content should be checked for consistency with State and Federal maintenance standards.

632. Maintenance and inspection personnel may require incentives to treat information and education programs seriously. Measures depicted in the programs may be somewhat contrary to established practices, and confusion and/or anger of maintenance personnel could result.

633. Since non-Federal agencies are normally responsible for maintenance of CE levees, the CE has no authority to require information and education programs. However, CE personnel can encourage these and other attempts to enhance the competence of local agencies.

Costs

634. Factors to consider when determining the cost of information and education include the type of equipment used, the number and length of the program(s), and the number of times such programs are used. In

terms of equipment, video tapes are much less expensive than film, and video cassette machines and television sets for viewing the tapes have become common. If all aspects of film production are considered, an average cost of $1,000 per minute can be anticipated.*

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* Personal Communication, 1983, Ann Riley, Resources Planner, California Department of Water Resources, Sacramento, Calif.

PART VI: FLOOD FIGHTING AND ENVIRONMENTAL FEATURES

635. Flood fighting refers to operation and maintenance activities on levees that are accomplished during high-water events to prevent overtopping or levee failure. By coordinating design of environmental features with plans for flood fighting, conflicts can be reduced.

Description of Flood Fighting

636. Temporary repairs of an emergency nature must occasionally be made during flooding. Flood fighting provides the following services: temporary erosion protection or redirection of erosive flows; debris removal; seepage control; emergency filling of areas where sloughing or slippage has occurred; emergency pumping; sand-bagging or construction of temporary walls atop the levee to prevent overtopping; emergency construction of a set-back levee or floodwall when failure of the primary levee appears likely; and warning and evacuation of endangered citizens. In order to detect for potential damage, inspection occurs continually during high-water periods and must be accomplished in the fastest, most efficient manner possible.

Relationships Between Flood Fighting and Environmental Features

637. In order to ensure these operations are not impaired by environmental features or that flood fights do not result in unreasonable costs due to the loss of environmental features, designers should be aware of the necessity to move construction equipment and materials onto or near any part of the levee. This may result in the loss of plantings made for aesthetic or wildlife objectives. Other considerations include the following:

- a. It is necessary to stockpile materials for temporary repairs along the levee.
- b. Irrigation systems may have to be removed rapidly and without damage to the levee section.

c. Steps over the levee built to provide fishing access during dry periods may have to be removed.

d. Artificial habitat structures located on the riverside of the levee should be constructed so they will not break free and then become lodged in a manner which causes erosion at the levee.

e. Tree preservation should not preclude sufficient room in the vicinity of the levee to permit maneuvering equipment for repairs.

f. Wetland areas on the landside may complicate access and inspection of certain portions of the levee.

g. The use of operations-oriented flood prevention methods such as stop-log closures, complicated flap gates, folding floodwalls, sanitary and water supply shutoffs, and others, should be done judiciously, as human error could result in failure to perform.

h. Flood-related levee inspections required by Federal regulations often must be conducted during adverse weather conditions common to flood events and at night.

i. Public access to levee recreational sites and the levee generally must often be restricted or controlled during flood periods.

PART VII: CONCLUSIONS AND RECOMMENDATIONS

638. Numerous techniques can be used to improve fish and wildlife habitat, recreational potential, and aesthetic resources associated with CE levee projects. In order to obtain maximum benefits from environmental features, interdisciplinary approaches are needed throughout the planning and design processes in order to (a) develop management objectives that are appropriate to specific sites, (b) choose features which can be implemented successfully, (c) avoid compromising the basic flood protection objective of the levee system, and (d) ensure that resource conflicts are minimized. Maximum benefits are also reached when features are integrated with each other to improve environmental quality. Environmental features have been identified for all phases of levee projects: design, construction, operation, and maintenance.

Basic Design

639. Many potential conflicts can be avoided by careful layout of levee alignments. Sites of high ecological value may be identified and avoided, and sites may be provided for future habitat and recreational development. Rare, unique, and productive habitats are commonly associated with river systems, and potential is usually high for water-related recreational opportunities. Thus, careful collection and analysis of available information regarding locations of significant fish and wildlife habitats, land use patterns, and cultural sites can assist in determining optimal levee alignments and locations for associated structures and activities to avoid destruction of preproject environmental amenities. Set-back levees can be used to preserve a sizable portion of the riparian area.

640. Other benefits can be realized by carefully planning construction activities early in the design stage so that specific valuable trees are preserved and the overall area is minimally disturbed. Such activities, along with consideration of timing to avoid wet periods and

erosion protection for bare sites, will reduce adverse impacts due to construction.

641. Oversized embankment cross sections offer several advantages from an environmental standpoint. While use of minimum required sections may result in a reduction in overall area committed to the project, overdesigning and/or overbuilding the levee and related structures may permit a variety of other environmental features that would not otherwise be possible. These include, but are not limited to, allowing larger vegetation on the embankment and providing space for recreational development. Moreover, the added material for overbuilt sections can be used to shape the levee to conform to local topography or to add to visual diversity.

Borrow Pits

642. Besides incorporating environmental considerations into the basic design decisions, a number of optional features can be added to projects to improve environmental quality. Borrow pits, for example, have long been recognized for their potential as fish and wildlife habitats, recreational sites, and scenic qualities. Basic borrow pit design factors that influence environmental features include pit size and shape, depth, and side slope; in addition, factors which affect pit water quality are important for recreational and habitat development. Supplementary measures, including brush shelters, artificial islands, provisions to provide flushing, marsh vegetation establishment, water control structures, and fish stocking, can be used to further enhance biological, recreational, and aesthetic aspects of borrow pits.

Wildlife Habitat

643. Several methods can be used to develop upland wildlife habitat on or adjacent to levees. Propagation and fostering of vegetation valuable to wildlife through planting and vegetation management programs perhaps offer the most promise, but are limited by regulations that

prohibit larger types of vegetation in order to guard the structural integrity of the levee. However, the actual effects of large vegetation on levees have not been subjected to detailed, quantitative assessment. Research in this area might improve vegetation management practices, wildlife habitat, and aesthetics and reduce maintenance costs. Other upland features potentially useful include brush piles, artificial nesting and perching structures, and habitat development using excess dredged or excavated material.

Recreation

644. Since levees are structures that parallel streams long distances, they present opportunities for the development of recreational corridors. An access road on the levee's crown is normally designed into the structure, but with slight modification it can provide a road or trail for public recreation. Development of recreational/aesthetic nodes along this trail will increase its attractiveness to the public. Such nodes can consist of picnic areas, campsites, observation areas, game courts, sport fields, and/or interpretive facilities. If these areas are designed to be flood proof or inexpensive, they can easily be located in both landside and riverside areas of potential flooding that are otherwise unusable, as well as on the levee slope and crown. If standing water on the landside of the levee does not pose structural problems, areas periodically flooded on the landside, such as interior drainage collection structures, may be permanently impounded as ponds and wetlands for fish and wildlife.

645. Although levees usually bar the public from visual and recreational contact with the river, specially designed access facilities for fishing and boating can significantly ameliorate or reverse these effects. Moreover, floodwalls can be designed to be collapsible or removable and thus be visual barriers only during flood periods. Moreover, if construction materials are chosen carefully, floodwalls can be made to blend with the surroundings and/or to present an appealing view.

Operation and Maintenance

646. A variety of techniques are available for operating and maintaining levees, each of which is valuable if used correctly and chosen as the most appropriate option. Maintenance activities generally consist of vegetation management, control of animals that burrow into the levee, upkeep of recreational areas, and levee repair. Options for vegetation management include mowing, grazing, burning, and using chemicals. Each method fosters different vegetation and wildlife habitat types on levees and adjacent lands. Moreover, refinements to the basic methods including (a) timing operations to avoid critical periods, (b) selection of livestock and grazing periods, (c) determining timing and intensity of prescribed burns consistent with historical fire patterns, and others can be used to further maximize environmental values. Where it does not conflict with engineering concerns, the concept of selective vegetation management offers much promise for wildlife habitat improvement.

647. Alternatives for burrowing animal control include habitat manipulation, trapping/shooting, the use of rodenticides, and biological control. Methods for animal control are most effective when used in a system of integrated pest management. Finally, recreational area maintenance includes upkeep of planted areas, solid waste disposal, and repair of facilities.

Selection of Environmental Features

648. Significant variability exists among levee project sites, and mixes of appropriate environmental features will also vary. Land use patterns, available borrow and embankment material, onsite biological systems, amount of available land, physical/chemical soil and water characteristics, and other factors will all influence the degree to which the array of environmental features available will be applicable to individual projects. Moreover, many of the environmental features available constitute minor modifications of engineering features which

may or may not be required on individual projects. Thus, designers must become familiar with both the characteristics of the site and the limitations of environmental features in order to successfully implement CE environmental policies for individual levee projects.

Implementation

649. Levee project planners and designers can and should include many of the features described in this report in their projects as a matter of good engineering practice. In some cases, where significant costs or policy questions or other important factors are involved, it may be necessary to assign responsibility for mitigation or enhancement pursuant to agreements with the USDI Fish and Wildlife Service and State agencies. CE Division personnel should use this report as they review District proposals, and District personnel should use it as a resource during formulation of project designs.

REFERENCES

Adams, R. D., et al. 1978. "Shoreline Erosion in Coastal Louisiana: Inventory and Assessment," Louisiana Department of Transportation and Development, Baton Rouge, La.

Adamus, P. R. In press. "A Method for Wetland Functional Assessment," US Department of Transportation, Federal Highway Administration, Office of Research, Environment Division, Washington, DC.

Allen, H. H. 1979. "The Role of Wetland Plants in Erosion Control of Riparian Shorelines," National Symposium on Wetlands, National Wetlands Technical Council and American Water Resources Association, pp 403-414.

Allen, H. H., et al. 1978. "Habitat Development Field Investigations, Bolivar Peninsula, Marsh and Upland Habitat Development Site, Galveston Bay, Texas," Technical Report D-78-15, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Amimoto, P. Y. 1978. "Erosion and Sediment Control Handbook," Report No. EPA 440/3-78-003, California Department of Conservation and US Environmental Protection Agency, Washington, DC.

Anderson, B. W., and Ohmart, R. D. 1979. "Riparian Vegetation: An Approach to Mitigating for a Disappearing Habitat in the Southwest," The Mitigation Symposium; A National Workshop on Mitigating Losses of Fish and Wildlife Habitats, USDA Forest Service General Technical Report RM-65, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., pp 481-487.

Anderson, M. G., and Low, J. B. 1976. "Use of Sago Pondweed by Waterfowl on the Delta Marsh, Manitoba," Journal of Wildlife Management, Vol 40, pp 233-242.

Anonymous, 1979. "The Acquisition Alternative," National Wetlands Newsletter, Vol 1, No. 4, pp 1-2.

__________. 1982. "ENR Index History; Construction Costs Tracked for U. S.," Engineering News Record, Vol 208, No. 11, pp 116-123.

Asplundah Environmental Services. 1978. "Benefit Analysis; Use of 2,4,5-T for Vegetation Management on Rights-of-Way," Willow Grove, Pa.

Atkeson, T. Z., and Givens, L. S. 1953. "The Use of Hay Crops in Southeastern Waterfowl Management," Journal of Wildlife Management, Vol 17, No. 3, pp 382-383.

__________. 1954. "The Use of Livestock Pastures in Southeastern Waterfowl Management," Journal of Wildlife Management, Vol 18, No. 3, pp 407-408.

Atlantic Waterfowl Council. 1972. "Techniques Handbook of the Waterfowl Habitat Development and Management Committee--Atlantic Flyway Council," 2d ed., Bethany Beach, Del.

Ball, R. C. 1952. "Farm-Pond Management in Michigan," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 17, pp 221-225.

Barkalow, F. S., Jr., and Soots, R. F., Jr. 1965. "An Analysis of the Effect of Artificial Nest Boxes on a Gray Squirrel Population," Transactions of the North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Vol 30, pp 349-360.

Barko, J. W., et al. 1977. "Establishment and Growth of Selected Freshwater and Coastal Marsh Plants in Relation to Characteristics of Dredged Sediments," Technical Report D-77-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Barnickol, P. G., and Campbell, R. S. 1952. "Summary of Selected Pond Studies in Missouri," Journal of Wildlife Management, Vol 16, No. 3, pp 270-274.

Barstow, C. J. 1957. "A Comparative Study of Availability of Waterfowl Foods and Waterfowl Use on a Series of Clear and Turbid Farm Ponds in North-Central Oklahoma," Proceedings of the Southeastern Association of Game and Fish Commissioners, Vol 11, pp 364-372.

Becker, B. C., and Mills, T. R. 1972. "Guidelines for Erosion and Sediment Control Planning and Implementation," Report No. EPA-R2-72-015, Maryland Department of Water Resources and US Environmental Protection Agency, Washington, DC.

Bellrose, F. C., and Anderson, H. G. 1943. "Preferential Ratings of Duck Food Plants," Illinois Natural History Survey Bulletin, Vol 22, No. 5, pp 417-433.

Bellrose, F. C., and Brown, L. G. 1941. "The Effect of Fluctuating Water Levels on the Muskrat Population of the Illinois River Valley," Journal of Wildlife Management, Vol 5, No. 2, pp 206-212.

Bennett, G. W. 1945. "Overfishing in a Small Artificial Lake," Illinois Natural History Survey Bulletin, Vol 23, No. 3, pp 372-406.

__________. 1954. "The Effects of a Late Summer Drawdown on the Fish Population of Ridge Lake, Coles County, Illinois," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 19, pp 259-270.

__________. 1971. Management of Artificial Lakes and Ponds, Rheinhold, New York.

Bennett, G. W., and Childers, W. F. 1972. "Thirteen-Year Yield of Smallmouth Bass from a Gravel Pit Pond," Journal of Wildlife Management, Vol 36, No. 4, pp 1249-1253.

Benson, D., and Foley, D. 1956. "Waterfowl Use of Small, Man-Made Wildlife Marshes in New York State," New York Fish and Game Journal, Vol 3, No. 2, pp 217-224.

Berg, P. F. 1956. "A Study of Waterfowl Broods in Eastern Montana with Special Reference to Movements and the Relationship of Reservoir

Fencing to Production," Journal of Wildlife Management, Vol 20, No. 3, pp 253-262.

Besadny, C. D., Kabat, C., and Rush, A. J. 1968. "Practical Aspects of Selective Brush Management Program on Wisconsin Roadsides," Transactions of the North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Vol 33, pp 236-248.

Best, L. B., Stauffer, D. F., and Geier, A. R. 1979. "Evaluating the Effects of Habitat Alteration on Birds and Small Animals Occupying Riparian Communities," Proceedings of the Symposium on Strategies for Protection of Floodplain Wetlands and Other Riparian Ecosystems, USDA Forest Service General Technical Report WO-12, Washington, DC, pp 117-124.

Beste, C. E. 1983. "The Herbicide Handbook," Weed Science Society of America, Champaign, Ill.

Bishop, R. A., and Barratt, R. 1970. "Use of Artificial Nest Baskets by Mallards," Journal of Wildlife Management, Vol 34, pp 734-738.

Biswell, H. H. 1977. "Prescribed Fire as a Management Tool," Proceedings of the Symposium on the Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems, USDA Forest Service General Technical Report WO-3, Washington, DC, pp 151-162.

Bond, R. M. 1945. "Range Rodents and Plant Succession," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 10, pp 229-234.

Borst, H. L., and Woodburn, R. 1942. "Effect of Mulches and Surface Conditions on the Water Relations and Erosion of Muskingham Soils," Technical Bulletin No. 825, US Department of Agriculture, Washington, DC.

Bramble, W. C., Byrnes, W. R., and Hutnik, R. J. 1958. "Effects of Chemical Brush Control Upon Game Food and Cover," Agricultural Experiment Station Progress Report 188, Pennsylvania State University, University Park, Pa.

Bramble, W. C., Byrnes, W. R., and Worley, D. P. 1957. "Effects of Certain Common Brush Control Techniques and Materials on Game Food and Cover on a Power Line Right-of-Way," Agricultural Experiment Station Progress Report 175, Pennsylvania State University, University Park, Pa.

Brenner, F. J., and Mondok, J. J. 1979. "Waterfowl Nesting Rafts Designed for Fluctuating Water Levels," Journal of Wildlife Management, Vol 43, No. 4, pp 979-982.

Brewer, C. W., Ham, D. L., and Marbut, S. A. 1976. "Herbicides for Forestry," Clemson University, Clemson, S. C.

Broach, R. W. 1979. "Arkansas--the Mitigation Experience," The Mitigation Symposium; a National Workshop on Mitigating Losses of Fish and Wildlife Habitats, USDA Forest Service General Technical Report RM-65, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., pp 572-577.

Brown, C. J. D., and Thoreson, N. A. 1952. "Ranch Fish Ponds in Montana," Journal of Wildlife Management, Vol 16, No. 3, pp 275-278.

Brown, W. H.. 1950. "Results of Stocking Largemouth Black Bass and Channel Catfish in Experimental Texas Farm Ponds," Transactions of the American Wildlife Conference, Wildlife Management Institute, Vol 17, pp 259-268.

Brumsted, H. B., and Hewitt, O. H. 1952. "Early Investigations on Artificial Marsh Development in New York," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 17, pp 259-268.

Bue, I. G., Blankenship, L., and Marshall, W. H. 1952. "The Relationship of Grazing Practices to Waterfowl Breeding Populations and Production on Stock Ponds in Western South Dakota," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 17, pp 396-414.

Burch, C. W., et al. 1984. "Environmental Guidelines for Dike Fields," Technical Report E-84-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Burger, G. V. 1969. "Response of Gray Squirrels to Nest Boxes at Remington Farms, Maryland," Journal of Wildlife Management, Vol 33, No. 4, pp 796-801.

Burger, G. V., and Linduska, J. P. 1967. "Habitat Management Related to Bobwhite Populations at Remington Farms," Journal of Wildlife Management, Vol 31, No. 1, pp 1-12.

Burger, G. V., and Webster, C. G. 1964. "Instant Nesting Habitat," Waterfowl Tomorrow, US Government Printing Office, Washington, DC, pp 655-666.

Burger, J. 1981. "The Effect of Human Activity on Birds at a Coastal Bay," Biological Conservation, Vol 21, pp 231-241.

Burgess, H. H., Prince, H. H., and Trauger, D. L. 1965. "Blue-Winged Teal Nesting Success as Related to Land Use," Journal of Wildlife Management, Vol 29, No. 1, pp 89-95.

California Reclamation Board. 1981. "Guide for Vegetation on Project Levees," Sacramento, Calif.

Carlander, K. D. 1952. "Farm Fish Pond Research in Iowa," Journal of Wildlife Management, Vol 16, No. 3, pp 258-261.

Catchpole, C. K., and Tydeman, C. F. 1975. "Gravel Pits as New Wetland Habitats for the Conservation of Breeding Bird Communities," Biological Conservation, Vol 8, No. 1, pp 47-60.

Cavanagh, J. B., Olson, D. P., and Macrigeanis, S. 1976. "Wildlife Use and Management of Powerline Rights-of-Way in New Hampshire," Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management, Mississippi State University, Mississippi State, Miss., pp 275-285.

Center for Natural Areas. 1980a. "Background for Weed Management Program--Phase I Final Report; Evaluation of Forest Pest Management Programs," Contract FS-53-3187-9-30, USDA Forest Service, Washington, DC.

________. 1980b. "Analysis of Weed Management and Research--Phase II Final Report; Evaluation of Forest Service Pest Management Programs," Contract FS-53-3187-9-30, USDA Forest Service, Washington, DC.

Chabrek, R. N. 1968. "The Relation of Cattle and Cattle Grazing to Marsh Wildlife and Plants in Louisiana," Proceedings of the Southeastern Association of Game and Fish Commissioners, Vol 22, pp 52-58.

________. 1979. "Winter Habitat of Dabbling Ducks--Physical, Chemical, and Biological Aspects," Waterfowl and Wetlands--an Integrated Review; Proceedings of a Symposium, North Central Section of the Wildlife Society, pp 133-140.

Chabrek, R. H., Yancy, R. K., and McNease, L. 1975. "Duck Usage of Management Units in the Louisiana Coastal Marsh," Proceedings of the Southeastern Association of Game and Fish Commissioners, Vol 28, pp 507-516.

Chapman, R. J., et al. 1982. "Impact of Water Level Changes on Woody Riparian and Wetland Communities--Vol X; Index and Addendum to Vols I-VIII," FWS/OBS-82/23, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Chemical Plant Control Subcommittee and Range Seeding Equipment Committee. 1966. "Chemical Control of Range Weeds," US Department of Agriculture and US Department of the Interior, Washington, DC.

Childers, W. F., and Bennett, G. W. 1967. "Experimental Vegetation Control by Largemouth Bass--*Tilapia* Combinations," Journal of Wildlife Management, Vol 31, pp 401-407.

Clairain, E. J., et al. 1978. "Habitat Development Field Investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon; Summary Report," Technical Report D-77-38, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Clark, M. 1952. "Kentucky's Farm Fish Pond Program," Journal of Wildlife Management, Vol 16, No. 3, pp 262-266.

Cole, R. A. 1978. "Habitat Development Field Investigations, Buttermilk Sound Marsh Development Site, Atlantic Intracoastal Waterway, Georgia; Summary Report," Technical Report D-78-26, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Compton, L. V. 1952. "Farm and Ranch Ponds," Journal of Wildlife Management, Vol 16, No. 3, pp 238-242.

Cook, D. B. 1947. "A Useful Nest Box Design," Journal of Wildlife Management, Vol 11, pp 185-188.

Cotton, S. 1981. "Landscape Cost Estimating," Environmental Industries, Inc., Calabosas, Calif.

Council on Environmental Quality. 1979. "The President's Environmental Program," Washington, DC.

Cowardin, L. M., Cummings, G. E., and Reed, P. B., Jr. 1967. "Stump and Tree Nesting by Mallards and Black Ducks," Journal of Wildlife Management, Vol 31, No. 2, pp 229-235.

Craighead, J. J., and Stockstad, D. C. 1961. "Evaluating the Use of Aerial Nesting Platforms by Canada Geese," Journal of Wildlife Management, Vol 25, No. 4, pp 363-372.

Crawford, J. A., and Edwards, D. K. 1978. "Habitat Development Field Investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon; Appendix F: Postpropagation Assessment of Wildlife Resources on Dredged Material," Technical Report D-77-38, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Cronan, J. M. 1957. "Effects of Predator Guards on Wood Duck Box Usage," Journal of Wildlife Management, Vol 21, No. 4, p 468.

Daar, S. 1982. "Ground Squirrel Management Section, Levee Management Manual; First Draft," John Muir Institute for Environmental Studies, Inc., and Center for the Integration of Applied Sciences, Berkeley, Calif.

Dahlem, E. A. 1979. "Mahogany Creek Watershed--With and Without Grazing," Proceedings of the Forum--Grazing and Riparian/Stream Ecosystems, Trout Unlimited, pp 31-34.

Darnell, R. M. 1961. "Trophic Spectrum of an Estuarine Community Based on Studies of Lake Ponchartrain, Louisiana," Ecology, Vol 42, No. 3, pp 553-568.

Davis, L. C., Ito, S. I., and Zwanch, P. T. 1967. "Pilot Levee Maintenance Study," Bulletin No. 167, California Department of Water Resources, Sacramento, Calif.

Davison, V. E. 1943. "Construction Features Control Emergent Water Plants and Improve Fishing," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 8, pp 156-162.

Day, J. W., Smith, W. G., and Hopkinson, C. S. 1973. "Some Trophic Relationships of Marsh and Estuarine Areas," Proceedings of the Coastal Marsh and Estuary Management Symposium, Louisiana State University, Baton Rouge, La., pp 115-135.

Derrickson, S. R. 1979. "Social Interactions and Spacing Behavior in Breeding Dabbling Ducks," Waterfowl and Wetlands--an Integrated Review; Proceedings of a Symposium, North Central Section of The Wildlife Society, p 45.

Dickson, J. G. 1978a. "Seasonal Bird Populations in a South Central Louisiana Bottomland Hardwood Forest," Journal of Wildlife Management, Vol 42, No. 4, pp 875-883.

Dickson, J. G. 1978b. "Forest Bird Communities of Bottomland Hardwoods," Management of Southern Forests for Nongame Birds, USDA Forest Service General Technical Report SE-14, Southeastern Forest Experiment Station, Asheville, N. C., pp 66-75.

Dickson, J. G., Adams, C. D., and Hanley, S. H. 1978. "Response of Turkey Populations to Habitat Variables in Louisiana," Wildlife Society Bulletin, Vol 6, pp 163-166.

Doty, H. A. 1979. "Duck Nest Structure Evaluations in Prairie Wetlands," Journal of Wildlife Management, Vol 43, No. 4, pp 976-979.

Doty, H. A., and Kruse, A. D. 1972. "Techniques for Establishing Local Breeding Populations of Wood Ducks," Journal of Wildlife Management, Vol 36, No. 2, pp 428-435.

Doty, H. A., and Lee, F. B. 1974. "Homing to Nest Baskets by Wild Female Mallards," Journal of Wildlife Management, Vol 38, pp 714-719.

Doty, H. A., Lee, F. B., and Kruse, A. D. 1975. "Use of Elevated Nest Baskets by Ducks," Wildlife Society Bulletin, Vol 3, pp 68-73.

Dryness, C. T. 1975. "Grass-Legume Mixtures for Erosion Control Along Forest Roads in Western Oregon," Journal of Soil and Water Conservation, Vol 30, No. 4, pp 169-173.

Duebbert, H. F. 1982. "Nesting of Waterfowl on Islands in Lake Audubon, North Dakota," Wildlife Society Bulletin, Vol 10, pp 232-237.

Duebbert, H. F., and Kantrud, H. A. 1974. "Upland Duck Nesting Related to Land Use and Predator Reduction," Journal of Wildlife Management, Vol 38, pp 257-265.

Duebbert, H. F., and Lokemoen, J. T. 1976. "Duck Nesting in Fields of Undisturbed Grass-Legume Cover," Journal of Wildlife Management, Vol 40, No. 1, pp 39-49.

Duebbert, H. F., et al. 1981. "Establishment of Seeded Grasslands for Wildlife Habitat in the Prairie Pothole Region," Special Scientific Report; Wildlife 234, USDI Fish and Wildlife Service, Washington, DC.

Dumke, R. T., and Pils, C. M. 1979. "Renesting and Dynamics of Nest Site Selection by Wisconsin Pheasants," Journal of Wildlife Management, Vol 43, No. 3, pp 705-716.

Durham, L. 1949. "A Study of the Largemouth Bass--Bluegill Population of Martin's Pond, McLean Co., Illinois," M.S. Thesis, University of Illinois, Urbana, Ill.

Dwernychuk, L. W., and Boag, D. A. 1972. "How Vegetative Cover Protects Nests from Egg-Eating Birds," Journal of Wildlife Management, Vol 36, pp 955-958.

Eadie, W. R. 1954. Animal Control in Field, Farm, and Forest, MacMillan Co., New York.

Eaton, R. L. 1966. "Protecting Metal Wood Duck Houses from Raccoons," Journal of Wildlife Management, Vol 30, No. 2, pp 428-430.

Edminster, F. C. 1950. "Use of Shrubs in Developing Farm Wildlife Habitat," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 15, pp 519-550.

Egler, F. E. 1952. "Transmission Lines as Wildlife Habitat," The Land, Vol 11, No. 2, pp 149-152.

________. 1958. "Science, Industry, and the Abuse of Rights-of-Way," Science, Vol 127, No. 3298, pp 573-580.

Egler, F. E., and Foote, S. R. 1975. The Plight of the ROW Domain; Victim of Vandalism, Part I, Futura Media Services, Mount Kisco, N. Y.

Emerson, F. B. 1961. "Experimental Establishment of Food and Cover Plants in Marshes Created for Wildlife in New York State," New York Fish and Game Journal, Vol 8, No. 2, pp 130-144.

Emmerich, J. M., and Vohs, P. A. 1982. "Comparative Use of Four Woodland Habitats by Birds," Journal of Wildlife Management, Vol 46, No. 1, pp 43-49.

Environmental Laboratory. 1978. "Wetland Habitat Development with Dredged Material; Engineering and Plant Propagation," Technical Report DS-78-16, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Evrard, J. O. 1975. "Waterfowl Use of Dug Ponds in Northwestern Wisconsin," Wildlife Society Bulletin, Vol 3, No. 1, pp 13-18.

Fager, L. F., and York, J. C. 1975. "Floating Islands for Waterfowl in Arizona," Soil Conservation, Vol 41, No. 5, pp 4-5.

Fielder, P. C. 1979. "Two Techniques to Improve Nesting Sites for Canada Geese," Wildlife Society Bulletin, Vol 7, No. 1, pp 62-63.

Fitch, H. S. 1954. "Seasonal Acceptance of Bait by Small Mammals," Journal of Mammalogy, Vol 35, No. 1, pp 39-47.

Flake, L. D., Peterson, G. I., and Tucker, W. L. 1977. "Habitat Relationships of Breeding Waterfowl on Stock Ponds in Northwestern South Dakota," Proceedings of the South Dakota Academy of Science, Vol 56, pp 135-151.

Florida Department of Agriculture and Consumer Services, Division of Forestry. 1980. "Tree Protection Manual for Builders and Developers," Tallahassee, Fla.

Fowler, D. K., et al. 1976. "Cooperative Wildlife Habitat Development Along Transmission Line Corridors," Proceedings of the First National Symposium on Environmental Concerns in Rights-of-Way Management, Mississippi State University, Mississippi State, Miss., pp 296-301.

Frank, E. J., and Woehler, E. E. 1969. "Production of Nesting and Winter Cover for Pheasants in Wisconsin," Journal of Wildlife Management, Vol 33, No. 4, pp 802-810.

Frank, W. J. 1948. "Wood Duck Nesting Box Usage in Connecticut," Journal of Wildlife Management, Vol 12, pp 128-136.

Fredrickson, L. H. 1978. "Lowland Hardwood Wetlands: Current Status and Habitat Values for Wildlife," Wetland Functions and Values: The State of Our Understanding--Proceedings of the National Symposium on Wetlands, American Water Resources Association, pp 296-306.

__________. 1979. "Floral and Faunal Changes in Lowland Hardwood Forests in Missouri Resulting from Channelization, Drainage, and Impoundment," FWS/OBS-78/91, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

__________. 1980. "Management of Lowland Hardwood Wetlands for Wildlife: Problems and Potential," Transactions of the North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Vol 45, pp 376-386.

Fremling, C. R., et al. No date. "The Feasibility and Environmental Effects of Opening Side Channels in Five Areas of the Mississippi River (West Newton Chute, Fountain City Bay, Sam Gordy's Slough, and Island 42)," USDI Fish and Wildlife Service, Twin Cities, Minn.

Gagliano, S. M. 1973. "Hydraulic and Geologic Studies of Coastal Louisiana, Report No. 14: Canals, Dredging, and Land Reclamation in the Louisiana Coastal Zone," Center for Wetland Resources, Baton Rouge, La.

Gagliano, S. M., Kwon, H. J., and van Beek, J. L. 1970a. "Hydrologic and Geologic Studies of Coastal Louisiana, Report No. 2: Salinity Regimes in Louisiana Estuaries," Center for Wetland Resources, Baton Rouge, La.

__________. 1970b. "Hydrologic and Geologic Studies of Coastal Louisiana, Report No. 3: Water Balance in Louisiana Estuaries," Center for Wetland Resources, Baton Rouge, La.

Garbisch, E. W., Jr. 1977. "Recent and Planned Marsh Establishment Work Throughout the Contiguous United States--A Survey and Basic Guidelines," Contract Report D-77-3, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

__________. 1980. "Highways and Wetlands, Compensating Wetland Losses," draft report submitted to US Department of Transportation, Federal Highway Administration, Washington, DC.

Gard, S. W. 1979. "Unmet Mitigation in the Lower Mississippi River and Tributaries," The Mitigation Symposium; a National Workshop on Mitigating Losses of Fish and Wildlife Habitats, USDA Forest Service General Technical Report RM-65, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., pp 419-523.

Garfinkel, A. P., and Lister, B. L. 1983. "Effects of High Embankment Construction on Archaeological Materials," State of California Department of Transportation, Division of Construction, Report No. FHWA/CA/TL-83/02, Sacramento, Calif.

Geier, A. R., and Best, L. B. 1980. "Habitat Selection by Small Mammals of Riparian Communities; Evaluating Effects of Habitat Alterations," Journal of Wildlife Management, Vol 44, No. 1, pp 15-24.

George, H. A., and Young, J. A. 1977. "Germination of Alkali Bulrush Seed," Journal of Wildlife Management, Vol 41, No. 4, pp 791-793.

George, R. R., et al. 1979. "Native Prairie Grasses as Nest Cover for Upland Birds," Wildlife Society Bulletin, Vol 7, No. 1, pp 4-9.

Gessel, S. P., and Cole, D. W. 1965. "Influence of Removal of Forest Cover on Movement of Water and Associated Elements Through Soils," Journal of the American Water Works Association, Vol 57, No. 10, pp 1301-1310.

Giroux, J. F. 1981a. "Use of Artificial Islands by Nesting Waterfowl in Southeastern Alberta," Journal of Wildlife Management, Vol 45, No. 3, pp 669-679.

__________. 1981b. "Ducks Nesting on Artificial Islands During Drought," Journal of Wildlife Management, Vol 45, No. 3, pp 783-786.

Givens, S., and Atkeson, T. Z. 1952. "Use of Italian Rye Grass as a Means of Attracting Waterfowl," Journal of Wildlife Management, Vol 16, No. 1, pp 107-108.

Givens, L. S., and Atkeson, T. Z. 1957. "The Use of Dewatered Lands in Southeastern Waterfowl Management," Journal of Wildlife Management, Vol 21, pp 465-467.

Gjersing, F. M. 1975. "Waterfowl Production in Relation to Rest-Rotation Grazing," Journal of Range Management, Vol 28, pp 37-42.

Glover, F. A. 1956. "Nesting and Production of the Blue-Winged Teal (Anas discors) in Northwest Iowa," Journal of Wildlife Management, Vol 20, No. 1, pp 28-36.

Goss, R. L., Blanchard, R. M., and Belton, E. R. "The Establishment of Vegetation on Non-Topsoiled Highway Slopes in Washington," Research Report Y-1009, Washington State Highway Commission and Washington State University Agricultural Research Center, Pullman, Wash.

Gosselink, J. G., et al. 1971. "Spoil Disposal Problems for Highway Construction Through Marshes," Georgia State Highway Department, Atlanta, Ga.

Grabill, B. A. 1977. "Reducing Starling Use of Wood Duck Boxes," Wildlife Society Bulletin, Vol 5, No. 2, pp 69-70.

Gratkowski, H. 1975. "Silvicultural Use of Herbicides in Pacific Northwest Forests," USDA Forest Service General Technical Report PNW-37, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

__________. 1978. "Herbicides for Shrub and Weed Tree Control in Western Oregon," USDA Forest Service General Technical Report PNW-77, Pacific Northwest Forest and Range Experiment Station, Portland, Oreg.

Green, J. R. 1977. "Fuelbreaks and Other Fuel Modification for Wildland Fire Control," Agricultural Handbook 499, US Department of Agriculture, Washington, DC.

Greenwall, G. A. 1948. "Wildlife Values of Missouri Farm Ponds," Transactions of the North American Wildlife Conference, Wildlife Management Institute, pp 271-281.

Griffith, M. A., and Fendley, T. T. 1981. "Five-Gallon Plastic Bucket: an Inexpensive Wood Duck Nesting Structure," Journal of Wildlife Management, Vol 45, No. 1, pp 281-284.

Griffith, R. 1948. "Improving Waterfowl Habitat," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 13, pp 609-618.

Grizzel, R. A., and Vogan, R. G. 1973. "Characteristics of Channels: Managing Rights-of-Way for Wildlife and Aesthetics," Wildlife and Water Management: Striking a Balance, Soil Conservation Society of America, Ankeny, Iowa.

Hafenrichter, A. L., et al. 1968. "Grasses and Legumes for Soil Conservation in the Pacific Northwest and Great Basin States," Agricultural Handbook 339, USDA Soil Conservation Service, Washington, DC.

Hall, H. D. 1974. "The Spatial and Temporal Distribution of Ichthyoplankton of the Upper Atchafalaya Basin," M.S. Thesis, Louisiana State University, Baton Rouge, La.

Hall, T. R., Howard, W. E., and Marsh, R. E. 1981. "Raptor Use of Artificial Perches," Wildlife Society Bulletin, Vol 9, No. 4, pp 296-298.

Hammerstrom, F., Herstrom, F. N., and Hart, J. 1973. "Nest Boxes: an Effective Management Tool for Kestrels," Journal of Wildlife Management, Vol 37, No. 3, pp 400-403.

Hammond, M. C., and Mann, G. E. 1956. "Waterfowl Nesting on Islands," Journal of Wildlife Management, Vol 20, No. 4, pp 345-352.

Hamor, W. H., Uhlig, H. G., and Compton, L. V. 1968. "Ponds and Marshes for Wild Ducks on Farms and Ranches in the Northern High Plains," Farmers Bulletin 2234, US Department of Agriculture, Washington, DC.

Hanson, L. E., and Progulske, D.R. 1973. "Movements and Cover Preferences of Pheasants in South Dakota," Journal of Wildlife Management, Vol 37, pp 454-461.

Harris, H. J., Jr., Ladowski, J. A., and Worden, D. J. 1981. "Water Quality Problems and Management of an Urban Waterfowl Sanctuary," Journal of Wildlife Management, Vol 45, No. 2, pp 501-508.

Harris, S. W., and Marshall, W. H. 1963. "Ecology of Water-Level Manipulations on a Northern Marsh," Ecology, Vol 44, No. 2, pp 331-343.

Harrison, J. 1970. "Creating a Wetland Habitat," Bird Study, Vol 17, No. 2, pp 111-122.

Hawkins, A. J., and F. C. Bellrose. 1941. "Wood Duck Habitat Management in Illinois," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 5, pp 392-395.

Hawthorne, D. W. 1980. "Wildlife Damage and Control Techniques," Wildlife Management Techniques Manual, 4th ed., rev., The Wildlife Society, Washington, DC, pp 411-440.

Headquarters, Department of the Army (HQDA). 1961. "Planting Turf," Technical Manual 5-830-2, Washington, DC.

__________. 1965. "Planting Design," Technical Manual 5-830-1, Washington, DC.

Heede, B. H. 1978. "Designing Gully Control Systems for Eroding Watersheds," Environmental Management, Vol 2, No. 6, pp 509-522.

Hehnke, M., and Stone, C. P. 1978. "Value of Riparian Vegetation to Avian Populations Along the Sacramento River System," Proceedings of the Symposium for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, USDA Forest Service General Technical Report WO-12, Washington, DC, pp 228-235.

Heilman, P. E., et al. 1978. "Habitat Development Field Investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon; Appendix E: Postpropagation Assessment of Botanical and Soil Resources on Dredged Material," Technical Report D-77-38, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Henderson, J. E., and Shields, F. D. 1984. "Environmental Features for Streambank Protection Projects," Technical Report E-84-11, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Heusmann, H. W. 1969. "An Analysis of the Potential Creation of Productive Wetlands by Interstate Highway Construction, with Emphasis on Waterfowl Management," M.S. Thesis, University of Massachusetts, Amherst, Mass.

Heusmann, H. W., Blandin, W. W., and Turner, R. E. 1977. "Starling-Deterrent Nesting Cylinders in Wood Duck Management," Wildlife Society Bulletin, Vol 5, No. 1, pp 14-18.

Hewitt, O. H. 1942. "Management of an Artificial Marsh in Southern Ontario for Ducks and Muskrats," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 7, pp 277-282.

Higgins, K. F. 1977. "Duck Nesting in Intensively Farmed Areas of North Dakota," Journal of Wildlife Management, Vol 41, No. 2, pp 232-242.

Ho, C. L., and Barrett, B. B. 1975. "Distribution of Nutrients in Louisiana's Coastal Waters Influenced by the Mississippi River," Technical Bulletin No. 17, Louisiana Wildlife and Fisheries Commission, Oysters, Water Bottoms, and Seafoods Division, Baton Rouge, La.

Hobaugh, W. C., and Teer, J. G. 1981. "Waterfowl Use Characteristics of Flood-Prevention Lakes in North-Central Texas," Journal of Wildlife Management, Vol 45, No. 1, pp 16-26.

Holechek, J. L., et al. 1982. "Manipulation of Grazing to Improve or Maintain Wildlife Habitat," Wildlife Society Bulletin, Vol 10, No. 3, pp 204-210.

Hopkins, H. T., et al. 1973. "Processes, Procedures, and Methods to Control Pollution Resulting from All Construction Activity," EPA 430/9-73-007, US Environmental Protection Agency, Washington, DC.

Horn, E. E. 1943. "Requirements and Techniques of Rodent Control," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 8, pp 417-423.

Howard, W. E., Marsh, R. E., and Cole, R. E. 1977. "Duration of Associative Memory to Toxic Bait in Deer Mice," Journal of Wildlife Management, Vol 41, No. 3, pp 484-486.

Hunt, L. J., et al. 1978. "Upland Habitat Development with Dredged Material: Engineering and Plant Propagation," Technical Report DS-78-17, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Hurst, E., Hehnke, M., and Goude, C. 1980. "The Destruction of Riparian Vegetation and Its Impact on the Avian Wildlife in the Sacramento River Valley, California," American Birds, Vol 34, No. 1, pp 8-12.

Hynson, J. R., et al. 1982. "Handbook for Protection of Fish and Wildlife from Construction of Farm and Forest Roads; Best Management Practices for Building Activities Associated with the Discharge of Dredged or Fill Materials," FWS/OBS-82/18, US Department of the Interior Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Jarvis, R. L., and Harris, S. W. 1971. "Land Use Patterns and Duck Production at Malheur National Wildlife Refuge," Journal of Wildlife Management, Vol 35, pp 767-773.

Jenkins, R. M., and Morais, D. I. 1971. "Reservoir Sport Fishery Effort and Harvest in Relation to Environmental Variables," Reservoir Fisheries and Limnology, Special Publication No. 8, American Fisheries Society, pp 371-384.

Johnson, R. F., Woodward, R. O., and Kirsch, L. M. 1978. "Waterfowl Nesting on Small Man-Made Islands in Prairie Wetlands," Wildlife Society Bulletin, Vol 6, No. 4, pp 240-243.

Jones, R. E., and Hungerford, K. E. 1972. "Evaluation of Nesting Cover as Protection from Magpie Predation," Journal of Wildlife Management, Vol 36, No. 3, pp 727-732.

Jones, R. E., and Leopold, A. S. 1967. "Nesting Interference in a Dense Population of Wood Ducks," Journal of Wildlife Management, Vol 31, No. 2, pp 221-228.

Joselyn, G. B., and Tate, G. I. 1972. "Practical Aspects of Managing Roadside Cover for Nesting Pheasants," Journal of Wildlife Management, Vol 36, No. 1, pp 1-11.

Joselyn, G. B., Warnock, J. E., and Etter, S. L. 1968. "Manipulation of Roadside Cover for Nesting Pheasants--a Preliminary Report," Journal of Wildlife Management, Vol 32, pp 217-233.

Kadlec, J. A. and Wentz, W. A. 1974. "State-of-the-Art Survey and Evaluation of Marsh Plant Establishment Techniques: Induced and Natural, Vol I: Report of Research," Contract Report D-74-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Kalinowski, S. A., and deCalesta, D. S. 1981. "Baiting Regimes for Reducing Ground Squirrel Damage to Alfalfa," Wildlife Society Bulletin, Vol 9, No. 4, pp 268-272.

Kaminski, R. M., and Prince, H. H. 1981. "Dabbling Duck and Aquatic Macro-Invertebrate Responses to Manipulated Wetland Habitat," Journal of Wildlife Management, Vol 45, No. 1, pp 1-15.

Kantrud, H. A., and Stewart, R. E. 1977. "Use of Natural Basin Wetlands by Breeding Waterfowl in North Dakota," Journal of Wildlife Management, Vol 41, No. 2, pp 243-253.

Keith, J. O., Hansen, R. M., and Ward, A. L. 1959. "Effects of 2,4-D on Abundance and Foods of Pocket Gophers," Journal of Wildlife Management, Vol 23, No. 2, pp 137-145.

Keith, L. B. 1961. "A Study of Waterfowl Ecology on Small Impoundments in Southeastern Alberta," Wildlife Monograph No. 6, The Wildlife Society, Washington, DC.

Keown, M. P., et al. 1977. "Literature Survey and Preliminary Evaluation of Streambank Protection Methods," Technical Report H-77-9, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Keran, D. C. 1978. "Site Selection for Wood Duck Nest Boxes," Loon, Vol 50, No. 4, pp 191-194.

King County Department of Public Works. 1982. "Draft Guidelines for Vegetation Management on Dikes, Levees, and Revetments," Letter Report submitted to US Army Engineer District, Seattle, Seattle, Wash.

Kirsch, L. M. 1969. "Waterfowl Production in Relation to Grazing," Journal of Wildlife Management, Vol 33, pp 821-828.

Kirsch, L. M., and Kruse, A. D. 1973. "Prairie Fires and Wildlife," Proceedings of the Tall Timbers Fire Ecology Conference, Vol 12, pp 289-303.

Klebonow, D. A. 1973. "The Habitat Requirements of Sage Grouse and the Role of Fire in Management," Proceedings of the Tall Timbers Fire Ecology Conference, Vol 12, pp 305-315.

Klein, H. G. 1955. "Wood Duck Production and Use of Nest Boxes on Some Small Marshes in New York," New York Fish and Game Journal, Vol 2, No. 1, pp 68-82.

Klimas, C. V., Martin, C. O., and Teaford, J. W. 1981. "Impacts of Flooding Regime Modification on Wildlife Habitats of Bottomland Hardwood

Forests in the Lower Mississippi Valley," Technical Report EL-81-13, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Klitz, W. 1982. "IPM to Control Ground Squirrel Populations Without Reducing Wildlife: Working Draft," Center for the Integration of Applied Sciences and the John Muir Institute, Berkeley, Calif.

Kruczynski, W. L., Huffman, R. T. and Vincent, M. K. 1978. "Habitat Development Field Investigations, Apalachicola Bay Marsh Development Site, Apalachicola Bay, Florida; Summary Report," Technical Report D-78-32, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Krull, J. N. 1969. "Seasonal Occurrence of Macroinvertebrates in a Greentree Reservoir," New York Fish and Game Journal, Vol 16, No. 1, pp 119-124.

Krumholz, L. A. 1950. "New Fish Stocking Policies for Indiana Ponds," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 15, pp 251-270.

__________. 1952. "Management of Indiana Ponds for Fishing," Journal of Wildlife Management, Vol 16, No. 3, pp 254-257.

Landers, J. L., et al. 1976. "Duck Foods in Managed Tidal Impoundments in South Carolina," Journal of Wildlife Management, Vol 40, No. 4, pp 721-728.

Landin, M. C. 1982. "Long-Term Monitoring of Habitat Development Field Sites Built of Dredged Material," Fifteenth Annual Dredging Seminar, New Orleans, La., Texas A&M University, College Station, Tex.

__________. 1984. "The Bird and Mammal Use of 26 Selected Lower Mississippi River Borrow Pits; Draft Final Report," US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Lee, L. C., and Hinckley, T. M. 1982. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol IX--The Alaska Region," FWS/OBS-82/22, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Leedy, D. L., Franklin, T. M., and Maestro, R. M. 1981. "Planning for Urban Fishing and Waterfront Recreation," FWS/OBS-80/35, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Leedy, D. L., Maestro, R. M., and Franklin, T. M. 1978. "Planning for Wildlife in Cities and Suburbs," FWS/OBS-77/66, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Leisz, D. R., and Wilson, C. C. 1980. "To Burn or Not to Burn: Fire and Chaparral Management in Southern California," Journal of Forestry, Vol 78, No. 2, pp 94-95.

Leopold, A. 1933. Game Management, Charles Scribner's Sons, New York.

Lillywhite, H. B. 1977. "Animal Responses to Fire and Fuel Management in Chaparral," Proceedings of the Symposium on the Environmental

Consequences of Fire and Fuel Management in Mediterranean Ecosystems, USDA Forest Service General Technical Report WO-3, Washington, DC.

Lines, I. L., Carlson, J. R., and Corthell, R. A. 1979. "Repairing Flood-Damaged Streams in the Pacific Northwest," Strategies for the Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, USDA Forest Service General Technical Report WO-12, Washington, DC, pp 195-200.

Lipsey, L. L. 1980. "Phytoplankton of Selected Borrow Pit Ponds in Northern Illinois," Ohio Journal of Science, Vol 80, No. 3, pp 108-113.

Lipsey, L. L., and Malcolm, S. 1981. "Summer Zooplankton Communities of Selected Borrow-Pit Ponds in Northern Illinois," Hydrobiologica, Vol 77, pp 81-85.

Litton, R. B., et al. 1974. "Water and Landscape; An Aesthetic Overview of the Role of Water in the Landscape," Water Information Center, Inc., Port Washington, N. Y.

Livezy, B. C. 1981. "Duck Nesting in Retired Croplands at Horicon National Wildlife Refuge, Wisconsin," Journal of Wildlife Management, Vol 45, No. 1, pp 27-37.

Lokemoen, J. T. 1973. "Waterfowl Production on Stock-Watering Ponds in the Northern Plains," Journal of Range Management, Vol 26, pp 179-184.

Lunz, J. D., Diaz, R. J., and Cole, R. A. 1978. "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations," Technical Report DS-78-15, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Lyon, L. J. 1976. "Elk Use as Related to Characteristics of Clear-Cuts in Western Montana," Elk--Logging Roads Symposium Proceedings, University of Idaho, Moscow, Idaho, pp 69-72.

Lyon, L. J., and Basile, J. V. 1979. "Influences of Timber Harvesting and Residue Management on Big Game," Environmental Consequences of Timber Harvesting in Rocky Mountain Coniferous Forests, USDA Forest Service General Technical Report INT-90, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Lyon, L. F., and Jenson, C. E. 1980. "Management Implications of Elk and Deer Use of Clearcuts in Montana," Journal of Wildlife Management, Vol 44, No. 2, pp 352-362.

MacClanahan, J., et al. 1975. "Sacramento River Levee Revegetation Study; Final Report," California Department of Water Resources, Central District, Sacramento, Calif.

MacDonald, P. O., Frayer, W. E., and Clauser, J. K. 1979. "Documentation, Chronology, and Future Projections and Bottomland Hardwood Habitat Loss in the Lower Mississippi Alluvial Plain: Vol 1, Basic Report," USDI Fish and Wildlife Service, Office of Ecological Services, Washington, DC.

MacGregor, W. G. 1950. "The Artificial Roost--A New Management Tool for California Quail," California Fish and Game, Vol 36, No. 3, pp 316-319.

Mack, G. D., and Flake, L. D. 1980. "Habitat Relationships of Waterfowl Broods on South Dakota Stock Ponds," Journal of Wildlife Management, Vol 44, No. 3, pp 695-699.

Mann, R., et al. 1975. "Landscape Concept Development for Confined Dredged Material Sites," Contract Report D-75-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Mann, W. F., and Haynes, M. J. 1978. "Status of Some New Herbicides," USDA Forest Service General Technical Report SO-21, Southern Forest Experiment Station, New Orleans, La.

Marsh, R. E., Howard, W. E., and Palmateer, S. D. 1970. "Effects of Odors of Rodenticides and Adherents on Attractiveness of Oats to Ground Squirrels," Journal of Wildlife Management, Vol 34, No. 4, pp 821-824.

Martin, A. D., Zim, H. S., and Nelson, A. L. 1951. American Wildlife and Plants, McGraw-Hill, New York.

Martin, R. E., et al. 1979. "Effects of Fire on Fuels; A State-of-Knowledge Review," USDA Forest Service General Technical Report WO-13, Washington, DC.

Martin, S. C. 1979. "Evaluating the Impacts of Cattle Grazing on Riparian Habitats in the National Forests of Arizona and New Mexico," Proceedings of the Forum--Grazing and Riparian/Stream Ecosystems, Trout Unlimited, pp 35-38.

Matschke, G. H., et al. 1982. "Population Reduction of Richardson's Ground Squirrels with Zinc Phosphide," Journal of Wildlife Management, Vol 46, No. 3, pp 671-677.

McComb, W. C., and Noble, R. E. 1981a. "Nest-Box and Natural Cavity Use in Three Mid-South Forest Habitats," Journal of Wildlife Management, Vol 45, No. 1, pp 281-284.

__________. 1981b. "Microclimates of Nest Boxes and Natural Cavities in Bottomland Hardwoods," Journal of Wildlife Management, Vol 45, No. 1, pp 284-289.

McGilvery, F. B., and Uhler, F. M. 1971. "A Starling-Deterrent Wood Duck Nest Box," Journal of Wildlife Management, Vol 35, No. 4, pp 793-797.

McIntyre, J. R., and Mathison, J. E. 1977. "Artificial Islands as Nest Sites for Common Loons," Journal of Wildlife Management, Vol 41, No. 2, pp 317-319.

McLaughlin, C. L., and Grice, D. 1952. "The Effectiveness of Large Scale Erection of Wood Duck Boxes as a Management Procedure," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 17, pp 242-259.

McQuilken, R. A., and Musbach, R. A. 1977. "Pin Oak Acorn Production on Greentree Reservoirs in Southeastern Missouri," Journal of Wildlife Management, Vol 41, No. 2, pp 218-225.

Meehan, O. L. 1952. "Problems of Farm Fish Pond Management," Journal of Wildlife Management, Vol 16, No. 3, pp 233-238.

Meeks, R. L. 1969. "The Effect of Drawdown Date on Wetland Plant Succession," Journal of Wildlife Management, Vol 33, No. 4, pp 817-821.

Meyer, L. D., Johnson, C. B., and Foster, G. R. 1972. "Stone and Wood Chip Mulches for Erosion Control on Construction Sites," Journal of Soil and Water Conservation, Vol 27, No. 6, pp 254-269.

Milonski, M. 1958. "The Significance of Farmland for Waterfowl Nesting and Techniques for Reducing Losses Due to Agricultural Practices," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 23, pp 215-228.

Minnesota Department of Transportation. No date. "Roadside Vegetation Management," St. Paul, Minn.

Mobley, H. E., et al. 1978. "A Guide for Prescribed Fire in Southern Forests," USDA Forest Service, Southeastern Area, Atlanta, Ga.

Montz, G. N. 1972. "A Seasonal Study of the Vegetation on Levees," Castanea, Vol 37, No. 2, pp 140-146.

Morgan, J. P. 1973. "Impact of Subsidence and Erosion on Louisiana Coastal Marshes and Estuaries," Proceedings of the Coastal Marsh and Estuary Management Symposium, Louisiana State University, Baton Rouge, La., pp 217-233.

Morris, J. H., et al. 1978. "Habitat Development Field Investigation, Salt Pond No. 3 Marsh Development Site, South San Francisco Bay, California; Summary Report," Technical Report D-78-57, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Moulton, J. C. 1970. "The Fishery Potential of Four Aquatic Environments Created by Interstate Route 91 Construction in Massachusetts," M.S. Thesis, University of Massachusetts, Amherst, Mass.

Mundinger, J. G. 1976. "Waterfowl Response to Rest-Rotation Grazing," Journal of Wildlife Management, Vol 40, No. 1, pp 60-68.

Murphy, P. K., and Noble, R. C. 1972. "The Monthly Availability and Use of Browse Plants by Deer on a Bottomland Hardwood Area in Tensas Parish, Louisiana," Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners, Vol 26, pp 39-57.

Musgrave, G. W. 1947. "The Quantitative Evaluation of Factors in Water Erosion--A First Approximation," Journal of Soil and Water Conservation, Vol 2, No. 3, pp 133-138.

Nawrocki, M., and Pietrzak, J. 1976. "Methods to Control Fine-Grained Sediments Resulting from Construction Activity," EPA 440/9-76-026, US Environmental Protection Agency, Washington, DC.

Nelson, R. W., Horak, G. C., and Olson, J. E. 1978. "Western Reservoir and Stream Habitat Improvements Handbook," FWS/OBS-77/51, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Niering, W. A. 1958. "Principles of Sound Right-of-Way Vegetation Management," Economic Botany, Vol 12, pp 140-144.

__________. 1978. "Right-of-Way Vegetation Management: An Evaluation of Techniques and Alternatives," Symposium on the Use of Herbicides in Forestry, US Department of Agriculture, Office of the Secretary, Washington, DC, pp 171-181.

Niering, W. A. 1979. "Right-of-Way Vegetation Management: Alternative Control Techniques," Proceedings for Integrated Pest Management Colloquim, USDA Forest Service General Technical Report WO-14, Washington, DC, pp 17-19.

Niering, W. A., and Goodwin, R. H. 1974. "Creation of Relatively Stable Shrublands with Herbicides: Arresting "Succession" on Rights-of-Way and Pastureland," Ecology, Vol 55, pp 784-795.

Nixon, C. M. 1979. "Squirrel Nest-Boxes--Are They Effective in Young Hardwood Stands," Wildlife Society Bulletin, Vol 7, No. 4, pp 283-284.

Noble, R. L., et al. 1979. "Wildlife Benefits Through Construction and Management of Floodwater Retarding Structures," The Mitigation Symposium; a National Workshop on Mitigating Losses of Fish and Wildlife Habitats, USDA Forest Service General Technical Report RM-65, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo., pp 181-185.

Nolan, M. F. 1981. "Vegetation on Corps of Engineers Project Levees in the Sacramento-San Joaquin Valley, California," California Riparian Systems Conference, University of California, Davis, Calif.

Nord, E. C., and Green, L. R. 1977. "Low-Volume and Slow-Burning Vegetation for Planting on Clearings in California Chaparral," USDA Forest Service General Research Paper PSW-124, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

Nunnally, N. R., and Shields, F. D. 1985. "Incorporation of Environmental Features in Flood Control Channel Projects," Technical Report in press, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Ocean Data Systems, Inc., Coastal Zone Resources Division. 1978. "Handbook for Terrestrial Wildlife Habitat Development on Dredged Material," Technical Report D-78-37, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Odum, E. P. 1978. "Ecological Importance of the Riparian Zone," Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems, USDA Forest Service General Technical Report WO-12, Washington, DC, pp 2-4.

Odum, W. E., and Zieman, J. C. 1973. "The Importance of Vascular Plant Detritus to Estuaries," Proceedings of the Coastal Marsh and Estuary

Management Symposium, Louisiana State University, Baton Rouge, La., pp 91-114.

Oetting, R. B., and Cassel, J. F. 1971. "Waterfowl Nesting on Interstate Highway Right-of-Way in North Dakota," Journal of Wildlife Management, Vol 35, pp 774-781.

O'Neill, E. J. 1972. "Alkali Bulrush Seed Germination and Culture," Journal of Wildlife Management, Vol 36, No. 2, pp 649-652.

Osmundson, T. F. 1973. "Breakthrough: U. S. Engineers Shift Policy with New Levee Designs," Landscape Architecture, Vol 63, No. 1, pp 118-123.

__________. 1980. "Engineers Relax Controls to Get a Living Levee," Landscape Architecture, Vol 70, No. 6, pp 622-628.

Osmundson, T., and Associates. 1972. "Recommendations for Environmental Enhancement, West Lewiston Levee--Snake and Clearwater Rivers; Lewiston, Idaho," prepared for US Army Engineer District, Walla Walla, Walla Walla, Wash.

Packer, P. E. 1967. "Criteria for Designing and Locating Roads to Control Sediment," Forest Science, Vol 13, pp 1-18.

Parsons, D. A. 1963. "Vegetative Control of Streambank Erosion," Proceedings of the Federal Inter-Agency Sedimentation Conference, USDA Agricultural Research Service, pp 130-143.

Pirnie, M. S. 1935. "Michigan Waterfowl Management," Michigan Department of Conservation, Lansing, Mich.

Plummer, A. P., Christensen, D. R., and Monsen, S. B. 1968. "Restoring Big-Game Range in Utah," Publication 68-3, Utah Division of Fish and Game, Ogden, Utah.

Poertner, H. L. 1981. "Urban Stormwater Management," Special Report 49, American Public Works Association, Chicago, Ill.

Pollard, J. F. 1973. "Experiments to Re-Establish Historical Oyster Seed Grounds and to Control the Southern Oyster Drill," Technical Bulletin 6, Louisiana Wildlife and Fisheries Commission, Baton Rouge, La.

Prince, E. D., and Maughan, O. E. 1978. "Freshwater Artificial Reefs: Biology and Economics," Fisheries, Vol 3, pp 5-9.

Probasco, G. E., and Bjugsted, A. J. 1978. "Nutrition and in vitro Digestibility of Tall Fescue for White-Tailed Deer, May Through November," USDA Forest Service Research Note NC-228, North Central Forest Experiment Station, St. Paul, Minn.

Rappoport, A. G., Mitchell, J. M., and Nagg, J. H. 1977. "Mitigating the Impacts of Water Resource Development on Wildlife," International Congress of Game Biologists, The Wildlife Society and The Wildlife Management Institute, Vol 13, pp 327-334.

Rawson, D. S., and Ruttan, R. A. 1952. "Pond Fish Studies in Saskatchewan," Journal of Wildlife Management, Vol 16, No. 3, pp 282-288.

Reed, R. 1976. "Engineers Build a Marsh on the Mississippi," Water Spectrum, Vol 8, No. 2, p 36.

Reed, W. C., and Heath, M. D. 1974. "Saltmarsh Relocation and Restoration in Maine," prepared for the Maine Department of Transportation, Augusta, Maine.

Reimold, R. J., Hardisky, M. C., and Adams, P. C. 1978. "Habitat Development Field Investigations, Buttermilk Sound Marsh Development Site, Atlantic Intracoastal Waterway, Georgia; Appendix A: Propagation of Marsh Plants and Postpropagation Monitoring," Technical Report D-78-26, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Reinhart, K. G., Eshner, A. R., and Trimble, G. R., Jr. 1963. "Effect on Streamflow of Four Forest Practices in the Mountains of West Virginia; An Interim Report," USDA Forest Service Research Paper NE-1, Northeastern Forest Experiment Station, Broomall, Pa.

Rekas, A. M. B., and Kirk, W. L. 1978. "Environmental Baseline Descriptions for Use in the Management of Fort Carson Natural Resources; Report 3: Inventory and Assessment of Current Methods for Rangeland Conservation and Restoration," Technical Report M-77-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Riley, A. L. 1981. "Observations and Analysis of Levee Maintenance Practices; Review Draft," California Department of Water Resources, Division of Planning, Sacramento, Calif.

Riley, C. V. 1963. "Revegetation and Management of Critical Sites for Wildlife," Transactions of the North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Vol 28, pp 269-283.

Ripken, J. F., Killen, J. M., and Gulliver, J. S. 1977. "Methods for Separation of Sediment from Stormwater at Construction Sites," EPA 600/2-77-033, US Environmental Protection Agency, Washington, DC.

Robel, R. J., and Browning, N. G. 1981. "Comparative Use of Woody Plantings by Nongame Birds in Kansas," Wildlife Society Bulletin, Vol 9, No. 2, pp 141-148.

Robinette, G. D. 1968. Off the Board/Into the Ground, W. C. Brown, Dubuque, Iowa.

Rossiter, J. A. 1980. "Waterfowl and Marsh Bird Use of Artificial Wetlands in North Dakota," M.S. Thesis, University of North Dakota, Grand Forks, N. D.

Rudolph, R. R., and C. G. Hunter. 1964. "Green Trees and Greenheads," Waterfowl Tomorrow, Bureau of Sport Fisheries and Wildlife, Washington, DC, pp 611-618.

Rundle, W. D., and Fredrickson, L. H. 1981. "Managing Seasonally Flooded Impoundments for Migrant Rails and Shorebirds," Wildlife Society Bulletin, Vol 9, No. 2, pp 80-87.

Russell, R. J. 1967. "River and Delta Morphology," Coastal Studies Series No. 20, Louisiana State University Press, Baton Rouge, La.

Ruwaldt, J. J., Jr., Flake, L. D., and Gates, J. M. 1979. "Waterfowl Pair Use of Natural and Man-Made Wetlands in South Dakota," Journal of Wildlife Management, Vol 43, No. 2, pp 375-383.

Sandberg, D. V., et al. 1979. "Effects of Fire on Air; A State-of-Knowledge Review," USDA Forest Service General Technical Report WO-9, Washington, DC.

Sanderson, H. R. 1975. "Den-Tree Management for Gray Squirrels," Wildlife Society Bulletin, Vol 3, No. 3, pp 125-131.

Saxton, E. H. 1979. "Smokey's Newest Ally--1000 Goats," American Forests, Vol 85, No. 7, pp 34-39.

Schimke, H. E., Green, L. R., and Heavilin, D. 1970, "Perennial Grasses Reduce Woody Plant Seedlings on Mixed Conifer Fuelbreak," USDA Forest Service Research Note PSW-203, Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

Schitoskey, F., Jr., and Linden, R. L. 1978. "Use of Wetlands by Upland Wildlife," Wetland Functions and Values: The State of Our Understanding--Proceedings of the National Symposium on Wetlands, American Water Resources Association, pp 307-311.

Schrank, B. W. 1972. "Waterfowl Nest Cover and Some Predation Relationships, Journal of Wildlife Management, Vol 36, pp 182-186.

Schroeder, L. D., et al. 1976. "Effects of Early Water Application on Waterfowl Production," Journal of Wildlife Management, Vol 40, No. 2, pp 227-236.

Schwartz, M. M., Fitzgerald, W. S., and Ringer, G. 1982. "1982 Levee Management Plans, Maintenance Areas 1, 3, 4, 9, 10, and 11," California Department of Water Resources, Sacramento, Calif.

Seibert, P. 1968. "Importance of Natural Vegetation for the Protection of the Banks of Streams, Rivers, and Canals," Freshwater, Nature, and Environment; Series 2, Council of Europe, pp 35-67.

Sherwood, G. A. 1968. "Factors Limiting Production and Expansion of Local Populations of Canada Geese," Canada Goose Management, Dembar Educational Research Service, Madison, Wis., pp 73-85.

Shields, F. D. 1982. "Environmental Features for Flood-Control Channels," Technical Report E-82-7, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Shields, F. D., Jr., and Palermo, M. R. 1982. "Assessment of Environmental Considerations in the Design and Construction of Waterway

Projects," Technical Report E-82-8, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Shuldiner, P. W., Cope, D. F., and Newton, R. B. 1979. "Ecological Effects of Highway Fills on Wetlands; Research Report," Report No. 218A, National Research Council, Transportation Research Board, Washington, DC.

Smith, H. K. 1978. "An Introduction to Habitat Development on Dredged Material," Technical Report DS-78-19, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Smith, R. H. 1953. "A Study of Waterfowl Production on Artificial Reservoirs in Eastern Montana," Journal of Wildlife Management, Vol 17, pp 276-291.

Snyder, W. D. 1974. "Pheasant Use of Roadsides for Nesting in Northeast Colorado," Special Report No. 36, Colorado Division of Wildlife, Denver, Colo.

Soots, R. F., Jr., and Landin, M. C. 1978. "Development and Management of Avian Habitat on Dredged Material Islands," Technical Report DS-78-18, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Spencer, J. E., Jr. 1968. "Man-Made Marshes for Maine Waterfowl," Game Division Bulletin No. 9, Maine Department of Inland Fisheries and Game, Augusta, Maine.

Sperry, C. C. 1947. "Botulism Control by Water Manipulation," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 12, pp 228-233.

State of California, Department of Transportation. 1970. "Bank and Shore Protection in California Highway Practice," Sacramento, Calif.

Stauffer, D. F., and Best, L. B. 1980. "Habitat Selection by Birds of Riparian Communities: Evaluating Effects of Habitat Alterations," Journal of Wildlife Management, Vol 44, No. 1, pp 1-15.

Steenhof, K. 1978. "Management of Wintering Bald Eagles," FWS/OBS-78/79, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Steinberg, I. H. 1960. "Russian River Channel Works," Journal of the Waterways and Harbors Division, Proceedings of the American Society of Civil Engineers, Vol 86, No. WW4, pp 17-32.

Stewart, R. E., and Kantrud, H. A. 1973. "Ecological Distribution of Breeding Waterfowl Populations in North Dakota," Journal of Wildlife Management, Vol 37, pp 39-50.

Stoddart, L. A., Smith, A. D., and Box, T. 1975. Range Management, McGraw-Hill, New York.

Strange, T. H., Cunningham, E. R., and Goertz, J. W. 1971. "Use of Nest Boxes by Wood Ducks in Mississippi," Journal of Wildlife Management, Vol 35, No. 4, pp 786-793.

Striffler, W. D. 1964. "Sediment, Streamflow, and Land Use Relationships in Northern Lower Michigan," USDA Forest Service Research Paper LS-16, Lake States Forest Experiment Station, St. Paul, Minn.

Sullins, G. L., and Verts, B. J. 1978. "Baits and Baiting Techniques for Control of Belding's Ground Squirrels," Journal of Wildlife Management, Vol 42, No. 4, pp 890-896.

Swales, S., and O'Hara, K. 1980. "Instream Habitat Improvement Devices and Their Use in Freshwater Fisheries Management," Journal of Environmental Management, Vol 10, pp 167-179.

Swingle, H. S. 1952. "Farm Pond Investigations in Alabama," Journal of Wildlife Management, Vol 16, No. 3, pp 243-249.

Swingle, H. S. 1956. "Determination of Balance in Farm Fish Ponds," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 21, pp 298-322.

Swingle, H. S., and Smith, E. V. 1943. "Effect of Management Practices on the Catch in a 12-Acre Pond During a 10-Year Period," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 8, pp 141-155.

Tardell, J. H., and Doerr, P. D. 1982. "Black Bear Damage to Bluebird Nest Boxes in Southeastern North Carolina," Journal of Wildlife Management, Vol 46, No. 1, pp 244-245.

Tarzwell, C. M. 1940. "The Fish Population of a Small Pond in Northern Alabama," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 5, pp 245-251.

Task Committee for Preparation of Manual on Sedimentation. 1969. "Chapter V: Sediment Control Methods, Introduction, and Watershed Area," Journal of Hydraulics Division, Proceedings of the American Society of Civil Engineers, Vol 95, No. HY2, pp 649-675.

Taylor, T. S. 1978. "Spring Foods of Migrating Blue-Winged Teals on Seasonally Flooded Impoundments," Journal of Wildlife Management, Vol 42, No. 4, pp 900-903.

Teskey, R. O., and Hinckley, T. M. 1977a. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol 1--Plant and Soil Responses," FWS/OBS-77/58, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

__________. 1977b. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol II--The Southern Forest Region," FWS/OBS-77/59, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

__________. 1977c. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol III--The Central Forest Region," FWS/OBS-77/60, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Teskey, R. O., and Hinckley, T. M. 1978a. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol IV--Eastern Deciduous Forest Region," FWS/OBS-78/87, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

_________. 1978b. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol V--Northern Forest Region," FWS/OBS-78/88, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Teskey, R. O., and Hinckley, T. M. 1978c. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol VI--The Plains Grassland Region," FWS/OBS-78/89, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Thackston, E. L., and Sneed, R. B. 1982. "Review of Environmental Consequences of Existing Waterway Design and Construction Practices," Technical Report E-82-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The Wildlife Society, Minnesota Chapter. 1978. "Roadsides as a Natural Resource, A Symposium Report," Minnesota Department of Transportation, St. Paul, Minn.

Thomas, J. W., Maser, C., and Rodiek, J. E. 1979. "Riparian Zones in Managed Rangelands--Their Importance to Wildlife," Proceedings of the Forum--Grazing and Riparian/Stream Ecosystems, Trout Unlimited, pp 21-31.

Thomas, P. M., Legault, R. O., and Carpenter, G. F. 1968. "Durability and Efficiency of Brush Shelters Installed in 1937 in Douglas Lake, Michigan," Journal of Wildlife Management, Vol 32, No. 3. pp 515-520.

Thorne, Robert M. 1984. "Preservation Is a Use--Experimental Archaeological Site Stabilization in the Tennessee Valley," Archaeological Papers of the Center for Archaeological Research, No. 5, University of Mississippi, University, Miss.

Thronson, R. E. 1973. "Comparative Costs of Erosion and Sediment Control, Construction Activities," EPA-430/9-73-016, US Environmental Protection Agengy, Washington, DC.

_________. 1979. "Best Management Practices Guidance, Discharge of Dredged or Fill Materials," EPA 440/3-79-028, US Environmental Protection Agency, Washington, DC.

Townsend, J. E., and Smith, R. J. 1977. "Proceedings of a Seminar; Improving Fish and Wildlife Benefits in Range Management," FWS/OBS-77/01, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Traver, R. P. 1980. "Urban Stormwater/Combined Sewage Management and Pollution Abatement Alternatives," Restoration of Lakes and Inland Waters; International Symposium on Inland Waters and Lakes Restoration, EPA-440/5-81-010, US Environmental Protection Agency, Washington, DC, pp 279-289.

Trimble, G. R., Jr., and Sartz, R. S. 1957. "How Far from a Stream Should a Logging Road Be Located," Journal of Forestry, Vol 55, pp 339-341.

Uhler, F. M. 1956. "New Habitat for Waterfowl," Transactions of the North American Wildlife Conference, Wildlife Management Institute, Vol 21, pp 453-469.

__________. 1964. "Bonus from Waste Places," Waterfowl Tomorrow, Bureau of Sport Fisheries and Wildlife, Washington, DC, pp 643-653.

Uhlig, H. G. 1963. "Use of Minnesota Ponds and Pits by Waterfowl," Wilson Bulletin, Vol 75, No. 1, pp 78-82.

US Army Engineer District, Baltimore. 1981. "Wyoming Valley, Luzerne County, Pennsylvania; Phase I General Design Memorandum, Main Report," Baltimore, Md.

US Army Engineer District, Chicago. 1982. "Phase I General Design Memorandum, Little Calumet River, Indiana," Technical Volume D, Chicago, Ill.

US Army Engineer District, Huntington. 1980. "Central Ohio Survey for Water Resources Development; Scioto River at North Chillicothe," Second Interim Report, Vol 1; Main Report and Environmental Impact Statement, Huntington, W. Va.

US Army Engineer District, Los Angeles. 1977. "Basis for Design Memorandum, Tijuana River Project, San Diego, Calif.," Los Angeles, Calif.

__________. 1980. "Phase I General Design Memorandum, Main Report and Supplemental Environmental Impact Statement, Santa Ana River Main Stem, Including Santiago Creek," Los Angeles, Calif.

__________. 1981. "San Luis Rey River, San Diego County, California; Phase I General Design Memorandum Main Report and Supplemental Environmental Impact Statement," Los Angeles, Calif.

__________. 1982. "Sweetwater River Final Environmental Impact Statement," Los Angeles, Calif.

US Army Engineer District, Memphis. 1974. "Mississippi River Flood Control; Mississippi River and Tributaries, Design Memorandum No. 1-A, Preliminary Master Plan, Recreational Development," Memphis, Tenn.

US Army Engineer Districts, Mobile and Nashville. 1982. "Final Supplement to the Environmental Impact Statement; Tennessee-Tombigbee Waterway, Alabama and Mississippi; Vol 1: Environmental Impact Statement," Mobile Ala., and Nashville, Tenn.

US Army Engineer District, New Orleans. 1982. "Louisiana Coastal Area; Freshwater Diversion to Barataria and Breton Sound Basins Feasibility Study; Draft Main Report and Draft Environmental Impact Statement," New Orleans, La.

US Army Engineer District, Omaha. 1975. "Final Environmental Statement; Missouri River Levee System, Units L 611-614," Omaha, Nebr.

US Army Engineer District, Omaha. 1976. "Final Environmental Statement, Missouri River Levee System, Unit R-616," Omaha, Nebr.

__________. 1979. "Final Supplemental Environmental Statement; Sun River Protection Project, Great Falls, Montana," Omaha, Nebr.

__________. 1980. "Supplemental Information Report for Missouri River Levee System Unit R-616," Omaha, Nebr.

US Army Engineer District, Rock Island, 1970. "Detailed Project Report for Flood Control at Evansdale, Iowa," Rock Island, Ill.

__________. 1971. "Jackson, Minnesota, West Fork Des Moines River; Detailed Project for Flood Control," Rock Island, Ill.

US Army Engineer District, Rock Island. 1974a. "Monticello, Iowa; Detailed Project Report for Flood Control," Rock Island, Ill.

__________. 1974b. "Mississippi River, Clinton, Iowa; Local Flood Protection Supplement No. 3 to Design Memorandum No. 1," Rock Island, Ill.

__________. 1975. "Final General Design Memorandum, Phase I: Mississippi River Local Flood Protection, Moline, Illinois," Rock Island, Ill.

__________. 1976. "Phase I General Design Memorandum; Plan Formulation for Flood Control, Davenport, Iowa," Rock Island, Ill.

US Army Engineer District, Sacramento. 1980. "Environmental Impact Statement; Merced County Streams, California," Sacramento, Calif.

__________. 1982. "Sacramento River and Tributaries Bank Protection and Erosion Control Investigation, California," Sacramento, Calif.

US Army Engineer District, San Francisco. 1969. "Design Memorandum No. 5; Alameda Creek Flood Control Project, Alameda County, California--Environmental Planning," San Francisco, Calif.

US Army Engineer District, Vicksburg. 1971. "Monroe Floodwall General Design Memorandum, Red River Basin, Ouachita and Black Rivers, Arkansas and Louisiana," Vicksburg, Miss.

__________. 1975. "Design Memorandum No. 9; Public Use and Access Facilities--Warfield Point, Mississippi," Vicksburg, Miss.

__________. 1980. "Point Lookout to Willow Point Environmentally Enhanced Levee Enlargement and Berms--Item 468 R; Draft Letter Report," Vicksburg, Miss.

US Army Engineer District, Walla Walla. 1970. "Design Memorandum 29.3; North Lewiston Levee, Lower Granite Project, Snake River, Washington and Idaho," Walla Walla, Wash.

US Army Engineer Waterways Experiment Station. 1980. "Publication Index and Retrieval System," Technical Report DS-78-23, Vicksburg, Miss.

__________. In preparation. "Wildlife Resources Management Manual," Chester O. Martin, ed., Vicksburg, Miss.

US Army, Office, Chief of Engineers. 1967. "Maintenance Guide," Engineer Manual 1130-2-303, Washington, DC.

__________. 1968. "Levee Maintenance Standards and Procedures," Engineer Regulation 1130-2-335, Washington, DC.

__________. 1969. "Architectural Concrete," Engineer Manual 1110-2-39, Washington, DC.

__________. 1971a. "Recreation-Resource Management of Civil Works Water Resources Projects, Engineer Regulation 1130-2-400, Washington, DC.

__________. 1971b. "Recreation Planning and Design Criteria," Engineer Manual 1110-2-400, Washington, DC.

__________. 1972a. "Landscape Planting at Floodwalls, Levees, and Embankment Dams," Engineer Manual 1110-2-301, Washington, DC.

__________. 1972b. "Design of Recreation Sites, Areas and Facilities," Engineer Regulation 1110-2-400, Washington, DC.

__________. 1976. "Recreation Resources Planning," Engineer Regulation 1120-2-400, Washington, DC.

__________. 1978. "Design and Construction of Levees," Engineer Manual 1110-2-1913, Washington, DC.

__________. 1980a. "Corps of Engineers Participation in Improvements for Environmental Quality," Engineer Regulation 1165-2-28, Washington, DC.

__________. 1980b. "Flood-Tolerant Plant Species," Engineer Pamphlet 1110-1-3, Washington, DC.

__________. 1982a. "Project Purpose Planning Guidance," Engineer Regulation 1105-2-20, Washington, DC.

__________. 1982b. "Planning Environmental Resources," Engineer Regulation 1105-2-50, Washington, DC.

__________. 1982c. "Planning Environmental Resources," Engineer Pamphlet 1105-2-55, Washington, DC.

__________. 1983. "Digest of Water Resource Policies and Authorities," Engineer Pamphlet 1165-2-1, Washington, DC.

USDA Forest Service. 1966. "Vegetation Management for Rights-of-Way: Selective Maintenance for Improved Wildlife Habitat and Scenic Values," Region 9, Milwaukee, Wis.

__________. 1969. "Wildlife Habitat Improvement Handbook," Forest Service Handbook 2609.11, Washington, DC.

USDA Soil Conservation Service. 1976. "Range Conservation Handbook," Washington, DC.

__________. 1977. "Land Clearing," National Handbook of Conservation Practices, Code 460-1, Washington, DC.

USDA Soil Conservation Service State Office, Maryland. 1973. "Work Plan for the Dividing Creek Watershed; Wicomico, Worcester, and Somerset Counties, Maryland," College Park, Md.

USDA Soil Conservation Service State Office, Michigan. 1969. "Watershed Work Plan; East Upper Maple River Watershed; Clinton, Gratiot, and Shiawassee Counties, Michigan," East Lansing, Mich.

__________. 1975. "Final Revised Environmental Impact Statement: East Upper Maple River Watershed; Shiawassee, Clinton, and Gratiot Counties, Michigan," East Lansing, Mich.

USDA Soil Conservation Service State Office, New York. 1980. "Watershed Work Plan and Environmental Impact Statement: Blind Brook Watershed, Westchester County, New York, and Fairfield County, Connecticut," Syracuse, N. Y.

USDA-States-EPA, 2,4,5-T Rebuttable Presumption Against Registration Assessment Team. 1979. "The Biologic and Economic Assessment of 2,4,5-T," Washington, DC.

US Departments of the Army, Navy, and Air Force. 1975. "Planning and Design of Outdoor Sports Facilities," Technical Manual 5-803-10; NAVFAC P-457; AFT 88-33, US Government Printing Office, Washington, DC.

USDI Bureau of Reclamation. No date (a). "Environmental Guidebook for Construction," US Department of the Interior, Washington, DC.

__________. No Date (b). "Protecting Nature's Estate--Techniques for Saving Land," Stock No. 024-016-00082-0, US Government Printing Office, Washington, DC.

US Environmental Protection Agency. 1975. "Methods of Quickly Vegetating Soils of Low Productivity, Construction Activities," EPA 440/9-75-006, Office of Water Planning and Standards, Washington, DC.

__________. 1980. "Clean Lakes Program Guidance Manual," EPA-440/5-81-003, Cincinnati, Ohio.

Vallentine, J. F. 1971. *Range Developments and Improvements,* Brigham Young University Press, Provo, Utah.

van Sickle, V. R., et al. 1976. "Barataria Basin: Salinity Changes and Oyster Distribution," Center for Wetland Resources, Baton Rouge, La.

Vogl, R. J. 1977. "Fire Frequency and Site Degradation," *Proceedings of the Symposium on the Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems,* USDA Forest Service General Technical Report WO-3, Washington, DC, pp 193-201.

von Geldern, C. E., Jr. 1966. "Warmwater Lake Management," *Inland Fisheries Management,* California Department of Fish and Game, Sacramento, Calif., pp 304-311.

Voorhees, L. D., and Cassel, J. F. 1980. "Highway Right-of-Way: Mowing Versus Succession as Related to Duck Nesting," *Journal of Wildlife Management,* Vol 44, No. 1, pp 155-163.

Walsh, M. R., and Malkasian, M. D. 1978. "Productive Land Use of Dredged Material Containment Areas: Planning and Implementation Considerations," Technical Report DS-78-20, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Walters, M. A., Teskey, R. O., and Hinkley, T. M. 1980a. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol VII--Mediterranean Region, Western Arid and Semi-Arid Region," FWS/OBS-78/93, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

__________. 1980b. "Impact of Water Level Changes on Woody Riparian and Wetland Communities; Vol VIII--Pacific Northwest and Rocky Mountain Regions," FWS/OBS-78/94, USDI Fish and Wildlife Service, Office of Biological Services, Washington, DC.

Webb, J. W., et al. 1978. "Habitat Development Field Investigations, Bolivar Peninsula, Marsh and Upland Development Site, Galveston Bay, Texas; Appendix D: Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources," Technical Report D-78-14, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Welch, E. B. 1981. "The Dilution/Flushing Technique in Lake Restoration," EPA-6003/81-016, US Environmental Protection Agency, Corvallis, Oreg.

Wenner, K. C., and Marion, W. R. 1981. "Wood Duck Production on a Northern Florida Phosphate Mine," Journal of Wildlife Management, Vol 45, No. 4, pp 1037-1042.

Wentz, W. A. 1981. "Wetlands Values and Management," USDI Fish and Wildlife Service and US Environmental Protection Agency, Washington, DC.

Westemeier, R. L. 1973. "Prescribed Burning in Grassland Management for Prairie Chickens in Illinois," Proceedings of the Tall Timbers Fire Ecology Conference, Vol 12, pp 317-338.

White, C. A., and Franks, A. L. 1978. "Demonstration of Erosion and Sediment Control Technology, Lake Tahoe Region of California," EPA 600/2-78/208, US Environmental Protection Agency, Washington, DC.

Whitlow, T. H., and Harris, R. W. 1979. "Flood Tolerance in Plants: A State-of-the-Art Review," Technical Report E-79-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Whyte, R. J., and Cain, B. W. 1981. "Wildlife Habitat on Grazed or Ungrazed Small Pond Shorelines in South Texas," Journal of Range Management, Vol 34, No. 1, pp 64-68.

Whyte, R. J., and Silvy, N. J. 1981. "Effects of Cattle on Duck Food Plants in Southern Texas," Journal of Wildlife Management, Vol 45, No. 2, pp 512-515.

Wiedeman, G. K. 1962. "Borrow Pits Can Be Assets," Landscape Architecture, Vol 52, No. 2, pp 92-93.

Wigley, T. B., et al. 1980. "Use of a Cottonwood Monoculture by White-Tailed Deer," Journal of Wildlife Management, Vol 44, No. 1, pp 264-265.

Will, G. C., and Crawford, G. I. 1970. "Elevated and Floating Nest Structures for Canada Geese," Journal of Wildlife Management, Vol 34, No. 3, pp 582-586.

Woodhouse, W. W., Jr., Seneca, E. D., and Broome, S. W. 1976. "Propagation and Use of *Spartina alterniflora* for Shoreline Erosion Abatement," CERC Technical Report 76-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Wright, H. A., and Bailey, A. W. 1982. Fire Ecology: United States and Southern Canada, John Wiley and Sons, New York.

Yahner, R. H. 1982. "Avian Use of Vertical Strata and Plantings in Farmstead Shelterbelts," Journal of Wildlife Management, Vol 46, No. 1, pp 50-60.

Yoakum, J., et al. 1980. "Habitat Improvement Techniques," Wildlife Management Techniques Manual, 4th ed., rev., The Wildlife Society, Washington, DC, pp 329-404.

Zeleny, L. 1977. "Song of Hope for the Bluebird," National Geographic Magazine, Vol 151, No. 6, pp 854-865.

Zion, R. L. 1968. Trees for Architecture and the Landscape, Rheinhold, New York.

Zwank, P. J., et al. 1979. "Utilization of Threatened Bottomland Habitats by White-Tailed Deer," Wildlife Society Bulletin, Vol 7, No. 4, pp 226-232.

APPENDIX A: RESEARCH METHODS USED IN ANALYSIS

1. The findings of an interdisciplinary team were used to develop this report. The team was directed to (a) survey the available information; (b) identify potential features that enhance environmental values and could be appropriate to levee projects; and (c) evaluate each potential feature relative to its effectiveness, engineering practicality, site-specific constraints, institutional considerations, conflicts with other natural resources, and cost. The interdisciplinary team was composed of two civil engineers, a wildlife biologist, an aquatic biologist, and a landscape architect.

2. A variety of materials were used as sources of available information. Scientific literature from civil engineering, biology, and landscape architecture was identified from computer searches, publication indexes, and "literature cited" sections of other publications. Official CE policy in the form of Engineer Regulations and Engineer Manuals was used to further identify features, as well as to note limitations and constraints. Moreover, planning documents (General Design Memoranda and Environmental Impact Statements) of levee projects that incorporated environmental features were reviewed for ideas potentially useful in the report. Based on reviews of available project planning documents, several CE Districts and/or projects were selected for individual case study-site visits. These Districts included Vicksburg, Sacramento, Rock Island, and Walla Walla. Each District was visited by one member of the interdisciplinary team for a 3- to 5-day period, during which time he was permitted to visit levee projects with environmental features; review in-house planning information; question project personnel regarding rationale behind specific features; and determine design elements, costs, and observed results of the various environmental features.

3. Many other CE Districts, as well as other State and Federal Government agencies and consultants, were contacted for information regarding specific environmental features actually implemented on CE and USDASCS levee projects. For completed projects and projects under

construction, cost data in the form of bid abstracts (DD 1501-1) were requested.

4. Once information was surveyed and obtained, potential environmental features were identified and evaluated using standardized forms that were circulated to all members of the interdisciplinary team. Specific formats and examples for both the identification process and the evaluation process are described below.

Feature Identification

5. Standardized documentation for the identification process consisted of a form (Figure A1) to summarize available information on each feature. Available design information and directions for implementation were summarized on each identification form, and sources for this information were cited completely. Finally, purposes or management objectives were noted.

6. The example shown depicts design considerations for borrow pits to make them attractive to wildlife. Based on the information summarized, specific recommendations were found for size, shape, depth, and slope.

7. The identification process was delegated among the interdisciplinary team, depending on the degree to which each feature corresponded to a specific discipline. Thus, project civil engineers developed the features for general levee design (Part II) and played a significant role in identifying features for maintenance (Part V). Project biologists identified specific measures for fish and wildlife (Part III) and also made significant contributions to discussions on maintenance. The landscape architect identified measures for recreational and aesthetic development.

Feature Evaluation

8. All members of the interdisciplinary team provided input to the evaluation process for each feature considered for possible

CE LEVEE ENVIRONMENTAL GUIDELINES
IDENTIFICATION FORM

TITLE: *Design Considerations for borrow pit wetland waterfowl areas* ID # A

SIMILAR GUIDELINES #S_____

PURPOSE(S): *(a) Restore disturbed sites*
(b) Create habitat for waterfowl and other wildlife

DESCRIPTION: *Yoakum et al. (1980) state that an ideal wetland would have 1/3 open water, 2/3 marsh. Further, authors state that planting should be done only after thorough evaluation to determine what plants should be there, and what plants aren't, and what plants are valuable to waterfowl in the area. Possible plants are pondweed, smartweed, duck potato, spike sedges, duckweeds, coontail, and grasses.*
Hamor et al (1968) stated that permanently flooded areas are better than temporarily flooded ones. Brood ponds should have over an acre of open water, with lots of scattered emergent plants. Slope bottom no more than 5 horizontal to 1 vertical. Irregular shorelines produce more than straight ones. Shuldiner et al (1979) noted that a variety of depths was essential. Lokemoen (1973) recommended ponds 1.5 acres or larger. Flake et al. (1977) found 2 most important variables as area (the bigger the better) and vegetation/open water ratio. 50/50 ratio the best. Smith (1953) found the oarger the surface area, the better.
Dikes can be installed and enable control of water level for waterfowl management purposes (USDI Fish and Wildlife Service 1964).
Mack and Flake (1980) noted that shoreline length also important (i.e., irregular shorelines). Hobaugh and Teer (1981) found the previously noted size/vegetation factors important in Texas waterfowl wintering areas.

REFERENCE(S):
COMPLETE CITES

Allan, P.F. 1939. Development of ponds for wildlife in the southern High Plains. Trans. North Amer. Wildl. Conf. 4:339-342.
Bauer, H.J. 1976. Artificial wetlands: damage to the landscape or valuable natural assets? Council of Europe Information Centre for Natural Conservation Rep. 46.221, No. 3.
Bouldin, D.R., D.J. Lathwell, E.A. Goyette and D.A. Lauer. 1973. Changes in water chemistry in marshes over a twelve-year period following establishment. N.Y. Fish and Game Jour. 20(2):129-146.
Bradley, B.O. and A.J. Cook. 1951. Small marsh development in New York. Trans. North Amer. Wildl. Conf. 16:251-264.
Brumsted, H.B. and O.H. Hewitt. 1952. Early investigations on artificial marsh development in New York. Trans. North Amer. Wildl. Conf. 17:259-268.
Carlozzi, C.A. 1971. Enhancement of ecological and aesthetic value of wetlands associated with interstate highways. USDI Office of Water Resources and Research Rept. 114 p.
Catchpole, C.K. and C.F. Tydeman. 1975. Gravel pits as new wetland habitats for conservation of breeding bird communities. Biol. Conserv. 8(1):47-60.
Cavanaugh, R.W.S. and A.G. Hall. 1962. Making ponds for wild ducks. New Zealand Dept. Intern. Affairs Wildl. Publ. 72.

Figure A1. Sample levee environmental feature identification form (Sheet 1 of 4)

REFERENCES, CONT.

Doepker, R.V. 1977. Ecology of highway borrow ponds with special reference to waterfowl. M.S. Thesis. Central Michigan Univ., Mt. Pleasant. 60 p.

Drahos, N. 1951. Building a wildlife marsh. N.Y. State Conserv. 6(3):27.

Edminster, F.C. 1951. Technical standards for the development of wildlife ponds. U.S. Soil Conserv. Serv. Region 1 Tech. Sci. 12, Bulll. 10.

Flake, L.D. 1979. Perspectives on man-made ponds and waterfowl in the northern prairies. pp. 33-36. In: Proc. 31st annual meeting, forestry committee, Great Plains Agriculture Council, Colorado State University, Fort Collins.

Hammond, M.C. 1958. Evaluation of artificial potholes and level ditches as refuge habitat development. Minutes of Regional Conf., Region III. U.S. Fish and Wildl. Serv., Minneapolis, Minn. Unpul. Rep. 355-368.

Hammond, M.C. 1964. Artificial potholes of Lower Souris. The Delta Seminar on the breeding biology of waterfowl. 3 pp. (mimeo).

Hammond, M.C. and C.H. Lacy. 1960. Ducks from artificial water areas. Conservation Volunteer 23(135):21-26.

Harrison, J. 1970. Creating a wetland habitat. Bird Study 17(2):111-122.

Harrison, J.G. 1976. Wetlands for waterfowl - an example of the management of a man-made wetland. Council of Europe Information Centre for Nature Conservation Rep. No. 23.

Heusmann, H.W. 1969. An analysis of the potential creation of productive wetlands by interstate highway construction, with emphasis on waterfowl management. M.S. Thesis, Univ. Mass. Amherst. 97 pp.

Hewitt, O.H. 1942. Management of an artificial marsh in southern Ontario for ducks and muskrats. Trans. N. Amer. Wildl. Conf. 7:277-282.

Hoffman, R.H. 1970. Waterfowl utilization of ponds blasted at Delta, Manitoba. J. Wildl. Manage. 34(3):586-593.

Klett, A.T. and L.M. Kirsch. 1976. Diurnal use of small wetlands by ducks. J. Wildl. Manage. 40(2):351-353.

Lathwell, D.J., D.R. Bouldin and E.A. Gayette. 1973. Chemical properties, physical properties and plant growth in twenty artificial wildlife marshes. N.Y. Fish and Game Jour. 20(2):108-128.

Lathwell, D.J., H.F. Mulligan and F.R. Bouldin. 1969. Chemical properties, physical properties and plant growth in twenty artificial wildlife marshes. N.Y. Fish and Game Jour. 16(2):158-183.

Lopinot, A.L., G. Arthur, L. Casey, F. Garrott and E. Keating. 1973. The planning, development and management of borrow areas for recreational use. Illinois Dept. Cons., Springfield, Ill. 8 pp.

Nelson, R.W., G.C. Horak, and J.E. Olson. 1978. Western reservoir and stream habitat improvements handbook. FWS/OBS-78/56. Western Energy and Land Use Team, Ft. Collins, CO. 260 p.

Peyton, T.O. and A. W. McIntosh. 1974. Distribution of heavy metals in a borrow pit. pp. 589-598. In: Proc. First Annual NSF Trace Contaminants Conf. Aug. 8-10, 1973. Oak Ridge, Tenn. Publ. USACE Off. Inf. Serv., Tech. Inf. Center, Oak Ridge.

Reed, R. 1976. Engineers build a marsh on Mississippi. Water Spectrum 8(2):36.

Reickhoff, J. 1965. Build a duck marsh. Wis. Conserv. Bull. 30(1):14-16.

Rossiter, J.A. 1980. Waterfowl and marsh bird use of artificial wetlands in North Dakota. Unpubl. M.S. Thesis. Univ. of North Dakota. Grand Forks. 95 p.

Ruwaldt, J.J., Jr. 1975. Distribution and importance of stockdams, dugouts and natural wetlands or breeding waterfowl in South Dakota. M.S. Thesis. S.D. State Univ., Brookings. 45 pp.

Figure A1. (Sheet 2 of 4)

REFERENCES, CONT.

Ruwaldt, J.J., Jr., L.D. Flake and J.M. Gates. 1979. Waterfowl pair use of natural and man-made wetlands in South Dakota. J. Wildl. Manage. 43(2):375-383.

Saugstad, S. 1939. Effect of artificial ponds on our duck population. North Dakota Agric. Exper. Sta. Bimonthly Bull. 2:6-8.

Seamans, R. (Chmn). 1959. An illustrated small marsh construction manual based on standard designs. Atlantic Waterfowl Council Comm. on Habitat Management and Development. Vermont Fish and Game Serv., Montpelier, Vt.

Uhler, F.M. 1956. New habitat for waterfowl. Trans. 21st. N. Amer. Wildl. Nat. Res. Conf. pp. 453-469.

Uhler, F.M. 1964. Bonus from waste places. pp. 643-653. In: J.P. Linduska (ed.) Waterfowl tomorrow. Bur. Sport. Fish. and Wildlife. U.S. Govt. Printing Office. Washington, D. C. xii + 770 p.

Uhlig, H.G. 1960. Pits, pond and puddlers. Conservation Volunteer 24(138): 11-12.

Uhlig, H.G. 1963. Use of Minnesota ponds and pits by waterfowl. Wilson Bull. 75(1):78/82.

USDA Soil Conservation Service. 1975. Engineering field manual for conservation practices. Washington, D.C.

Wiedeman, G.K. 1962. Borrow pits can be assets. Landscape Arch. 52(2):92-93.

White, W.M. and G. W. Malaher. 1964. Reserviors. pp. 381-390 In: J.P. Linduska (Ed.) Waterfowl tomorrow. Bur. Sport Fisheries and Wildlife. U.S. Govt. Printing Office. Washington, D. C.

Bue, I.G., H.G. Uhlig, and J.D. Smith. 1964. Stock ponds and dugouts. pp. 391-398 In: J.P. Linduska (Ed.) Waterfowl tomorrow. Bur. Sport Fisheries and Wildlife. U.S. Govt. Printing Office. Washington, D. C.

Edminster, F.C. 1964. Farm ponds and waterfowl pp. 399-408 In: J.P. Linduska (Ed.) Waterfowl tomorrow. Bur. Sport Fisheries and Wildlife. U.S. Govt. Printing Office. Washington, D.C.

Lokemoen, J.T. 1973. Waterfowl production on stock-watering ponds in the northern plains. J. Range. Manage. 26(3):179-184.

Benson, D. and D. Foley. 1956. Waterfowl use of small, man-made wildlife marshes in New York State. New York Fish and Game J. 3:217-224.

Keith L.B. 1961. A Study of waterfowl ecology on small impoundments in southeastern Alberta. Wildl. Manage. 6. 88 p.

Smith, R.H. 1953. A study of waterfowl production on artificial reservoirs in eastern Montana. J. Wildl. Manage. 17:276-291.

Shuldiner, P.W., D.F. Cope, and R.B. Newton. 1979. Ecological effects of highway fills on wetlands; research report. Nat'l. Coop. Highway Research Program Rept. 218A. Transportation Res. Bd., Nat'l. Res. Council. Washington, D.C. 34 p.

USDI Fish and Wildlife Service. 1964. Fish and wildlife in man-made and man-modified aquatic environments. pp. 369-383. In: Proc. of the MAR Conf. IUCN Publications New Series No. 3

Strohmeyer, D.L. and L.H. Fredrickson. 1967. An evaluation of dynamited potholes in northwest Iowa. J. Wildl. Manage. 31(3):525-532.

Flake, L.D., G.L. Peterson, and W.L. Tucker. 1977. Habitat relationships of breeding waterfowl onstock ponds in northwestern South Dakota. Proc. S.D. Acad. Sci. 56:135-151.

Miller, H.W. (Ed.). 1972. Wildlife on man-made water areas. USDI Bur. of Sport Fisheries and Wildl., Northern Prairie Wildl. Res. Center, Jamestown, N.D. 89 p.

Figure A1. (Sheet 3 of 4)

REFERENCES, CONT.

Mack, G.D. and L.D. Flake. 1980. Habitat relationships of waterfowl broods on South Dakota stock ponds. J. Wildl. Manage. 44(3):695-700.

Hamor, W.H., H.G. Unlig, and L.V. Compton. 1968. Ponds and marshes for wild ducks on farms and ranches in the northern plains. U.S. Dept. Agric, Farmers Bull. No. 2234. Washington, D.C. 16 p.

Hobaugh, W.C. and J. G. Teer, 1981. Waterfowl use characteristics of flood-prevention lakes in north-central Texas J. Wildl. Manage. 45(1):16-26.

Kaminski, R.M. and H.H. Prince. 1981. Dabbling duck and aquatic macroinvertebrate responses to manipulated wetland habitat. J. Wildl. Manage. 45(1):1-15.

Yoakum, J., W.P. Dasmann, H.R. Sanderson, C.M. Nixon, and H.S. Crawford. 1980. Habitat improvement techniques. pp. 329-403, In: S.D. Schemnitz (Ed.) Wildlife management techniques manual - fourth edition:revised. The Wildlife Society. Washington, D.C.

Harris, H.J., Jr., J.A. Ladowski, and D.O. Worden. 1981. Water quality problems and management of an urban waterfowl sanctuary. J. Wildl. Manage. 45(2):501-507.

Atlantic Waterfowl Council. 1972. Techniques handbook of the waterfowl habitat development and management committee, Atlantic Flyway Council. Second Ed. Atlantic Waterfowl Council, Bethany Beach, Del. 218 p.

PROJECT PLANS, EA'S, EIS'S, AND SITES VISITED:

PERSONS INTERVIEWED:

ATTACH AND CITE APPROPRIATE ILLUSTRATIONS/GRAPHICS

Figure A1. (Sheet 4 of 4)

inclusion in the report. Concurrently with the identification process, the project member responsible for identifying and describing specific environmental features also summarized documented evidence regarding whether or not the feature was effective in obtaining purposes described on the identification form. This information was summarized on a separate evaluation form (Figure A2) as item 3. The member of the project staff responsible for feature identification also summarized information on site-specific and environmental limitations (item 2 of Figure A2) and on engineering and other technical, economic, and institutional design constraints (item 4 of Figure A2) that became evident during his review of the available information.

9. Following initial work by the member of the project team who identified the feature, both the completed identification form and the partially completed evaluation form were circulated to all members of the interdisciplinary review team for their input. The forms first were reviewed by the team's civil engineers, who identified applicable physical impacts on the impact matrix and rated the magnitude and nature of each physical impact. The team's civil engineers also elaborated on the site-specific limitations (item 2) of soils/geology, topography, and hydrology and completed the discussion on engineering and other technical, economic, and institutional constraints (item 4).

10. Using the information provided by the individual responsible for identifying the measure and the initial civil engineering evaluation, biological and landscape architecture members of the interdisciplinary team completed assessing secondary effects on the matrix and the site-specific and environmental limitations discussions within item 2. The landscape architecture staff was responsible for "Aesthetic Appearance" and "Developable Land" categories on the matrix and the site-specific/environmental limitations section.

11. The matrix itself is adapted from an analysis methodology developed by Shuldiner, Cope, and Newton (1979) to represent physical and biological impacts associated with levee projects and associated environmental features and to include rankings both with and without the environmental feature. Using the matrix, engineers on the project

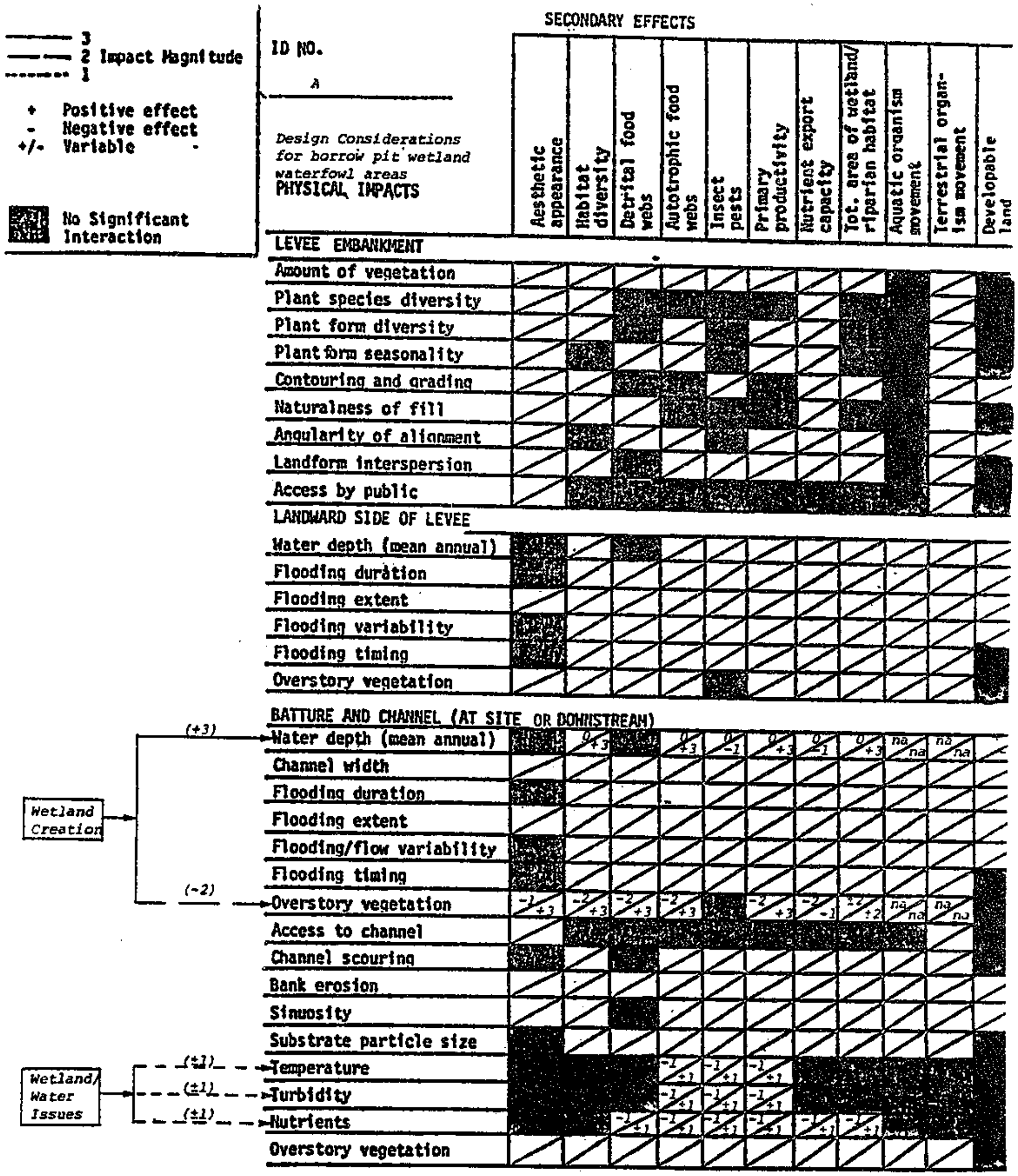


Figure A2. Sample levee environmental feature evaluation form (Sheet 1 of 3)

2.0 Site Specific and Environmental Limitations:
(Summarize and Cite)
Shuldiner et al. (1980) follows discussion of Heusman (1969).

Soils/Geology: *Productivity of wetland largely dependant on soil characteristics of surrounding watershed (Shyldiner et al. 1979). Due to nature of borrow pits, the substrate (sand and gravel) is likely to be unproductive, i.e., in Mass., a gravel pit in agricultural area had higher pH than one in softwoods. If done in upland areas with low water tables and very well-drained soils, a liner of clay might be required to hold water (Lokemoen 1973, Yoakum et al. 1980).*

Topography: *Terrain suitable for artificial waterfowl ponds is flat to gently rolling (Lokeman 1973).*

Hydrology: *A sufficient watershed must exist to drain enough water into the borrow area for it to fill, or other sources (steam, groundwater) must be available (Yoakum et al. 1980, Wiedeman 1962)*
Climate: *None.*

Water quality: *See wildlife, below.*

Wildlife: *If extensively used by waterfowl, artificial marshes can be subjected to nutrient pollution from waterfowl excrement, which could cause aesthetic and health problems (harris et al. 1981). Further, there is a tradeoff between the terrestrial and riparian habitat lost and the wetland habitat created. Finally, over the long term, value may decrease with eutrophication and/or sedimentation.*

Aquatic: *Optimal depth characteristics for fisheries would be somewhat deeper than that for waterfowl. Thus, some decision is needed either to emphasize waterfowl or fisheries.*

Surrounding land use: *Measure most appropriate where land values are not so high as to prohibit commitment if land for this purpose. Aesthetics and recreation*

Aesthetics and recreation: *Areas that would suffer from the nutrient pollution described under "wildlife" above would also have a negative effect on recreation and aesthetics.*

3.0 Summary of available information on effectiveness:
(Relate to stated purposes and city information sources)
Rossiter (1980) found breeding densities of waterfowl higher on artifical gravel pit wetlands in North Dakota than on a nearby natural lake in one year, but situation reversed itself the next. Author suggested the artificial areas in North Dakota roughly equivalent to that of natural areas. Flake et al. (1977) noted that man-made areas contribute much to waterfowl production in the Great Plains. In South Dakota, Ruwaldt et al. (1979)

Figure A2. (Sheet 2 of 3)

found artificial wetlands to be more productive than natural wetlands for waterfowl production, primarily because they were a more stable source of water. Smith (1953) found artificial wetlands to be significant to waterfowl production in Montana. Hobaugh and Teer (1981) found that artificial wetlands greatly improved waterfowl use in east Texas.

4.0 Engineering and Other Technical, Economic, and Institutional Factors Design Constraints

Design Constraints: *Dependent upon the amount of borrow needed, the size and shape of the deposits involved, and availability of alternate borrow materials*

Feasibility of Construction: *Other than design constraints listed above, none.*

Maintenance Requirements: *Hamor et al. (1968) noted the need to open up some densely vegetated marshes by blasting, mowing, or herbicides. Harris et al. (1981) there could be a requirement for dredging to remove excess nutrients and sediments as they built up over time. However, these needs would not always occur, and would be sporadic.*

Cost (Design, Construction, Maintenance): *Base costs are low to non-existent, because borrow is being excavated anyway. Cost of material that has to be left because of design considerations may be a factor, but would be highly variable. Supplemental measures, including water level controls, and plantings would vary widely.*

5.0 Determination (circle one)

accecptable   acceptable with modifications   not acceptable

6.0 Discussion (present reasoning for a "not acceptable" rating, or description and rationale supporting proposed modification for an "acceptable with modifications" rating.

Value to waterfowl is very well documented, and positive aspects outweigh the negative.

7.0 References if not listed on Identification Form (give complete citation and description of how reference was uses)

All references listed on idenfification form.

8.0 Unpublished sources not listed on Identification Form (include agency in-house planning documents, interviews, and site visits)

Figure A2. (Sheet 3 of 3)

team identified and assessed what physical impacts were caused by each feature, while other members of the team categorized the secondary effects of levee projects both without the environmental feature (upper left-hand corner of each intersection box) and with the environmental feature (lower right-hand corner of each intersection box). In order for a feature to be accepted, this analysis had to show that adverse environmental impacts of levees could be reduced through its implementation, or other environmental benefits could be created without causing potentially more serious environmental, engineering, or institutional concerns.

12. The feature "Design Considerations for Borrow Pit Wetland Waterfowl Areas" is presented as an example to describe this part of the evaluation process (Figure A2). The matrix shows that through the creation of wetlands, water depth increases and overstory vegetation changes could occur and would dramatically increase habitat diversity, wetland habitat, food web relationships, and aesthetics. However, some mosquito breeding areas would be created, and minor decreases would be seen in nutrient export and developable land (for agriculture). In sum, effects of the borrow pit wetland would be positive. Water quality changes would cause variable but small changes to downstream physicochemical characteristics either by adding organic material produced in the wetland or by filtering material going into the water.

13. Through the process of identifying limitations (item 2), on-site soils were found to influence the use of a borrow pit wetland by their chemistry (which would determine wetland productivity) and by their porosity (i.e., whether or not the soils would hold or pass the water). It was also found that the terrain upon which the borrow area is located should be flat to gently rolling. A sufficient source of water should exist to fill the pit, although this is not a problem at riverside locations. From the wildlife perspective, (a) the area could attract wildlife to the point of being detrimental to water quality, or (b) occasionally a borrow pit would fail to replace valuable riparian areas. Finally, a tradeoff would be necessary between fish and wildlife needs in designing optimal pit depth.

14. The process of summarizing data on effectiveness for this sample measure showed that numerous studies indicated that properly designed artificial wetlands have provided significant wildlife habitat. This research occurred in several regions. On some occasions, it was found that artificial wetlands were at least as productive as natural wetlands and sometimes more productive.

15. Analysis of engineering, economic, and institutional constraints in this example showed that the ability to implement the design is dependent on demand and supply for available borrow. Some maintenance could be involved, but construction costs would generally be quite low.

16. Following all input by each member of the interdisciplinary team, completed forms were reviewed by the principal investigator, who made and justified a decision whether to incorporate the feature into the report based upon environmental values, engineering and the economic feasibility, and institutional considerations. If a feature was determined to be acceptable, information on the form was used to develop the appropriate section in the report.

APPENDIX B: REJECTED MEASURES

1. This appendix contains brief discussions of three environmental features for levee projects that were rejected from detailed consideration. As discussed below, environmental, site-specific, cost, and institutional factors contributed to their rejection. These features were a sewage diversion facility, location of borrow pits to avoid water quality problems in the pits, and providing technical assistance to landowners for private ponds.

Sewage Diversion Facility

2. An interceptor sewer was proposed for a levee project for the Tijuana River (US Army Engineer District, Los Angeles 1977). Early planning documents described the purpose of the facility as diverting accidental discharges of sewage from the flood control channel during dry weather periods. Thus, small volumes of poor-quality water flows within the channel would be intercepted and treated by the city's sewage treatment plant. The facility was estimated to cost $230,000.

3. Although the interdisciplinary team concluded that in this case very significant water quality benefits could be realized, the feature was made necessary by a number of unique site factors that will generally not exist for the vast majority of CE levee projects. There would have to exist (a) a strong potential for accidental discharge of untreated sewage into the river system and (b) flood control works that have intermittent and/or highly variable flows. The facility's high cost further justified the conclusion that it was not widely applicable.

Locating Borrow Pits to Avoid Water Quality Concerns

4. A Missouri River levee project design document (US Army Engineer District, Omaha 1976) noted that because certain borrow pits would be fed by ground water rather than surface water, water quality in the pits would be more beneficial to wildlife, fisheries, and recreational

uses. The project team agreed that such water quality considerations would produce higher environmental values within the borrow pit proper, but disagreed that this necessarily would improve environmental values of the project site as a whole.

5. The team felt that if polluted surface runoff were a problem, it would contaminate other waters if it were excluded from the borrow pits. Excavated basins are used routinely at construction sites and in urban areas as settling basins to allow polluted surface waters to cleanse themselves; thus, borrow pits that permitted polluted surface water entry could also provide significant water quality benefits.

Private Ponds

6. Two USDASCS Watershed Work Plans (USDASCS State Office, Maryland 1973; USDASCS State Office, Michigan 1969) for levee projects proposed that as a part of the projects, agency personnel would encourage and provide technical assistance for nearby landowners to develop private farm ponds and wildlife marshes. The project team found several favorable factors in this approach. First, valuable fish and wildlife habitats would be created. Second, the created wetlands could to some extent moderate stormwater peak flows and thus reduce hydraulic loading on the levee system.

7. However, the team questioned whether technical assistance to private landowners was within the purview of the CE since both projects that proposed this feature were SCS works. SCS has mandated authority to provide such technical assistance; unlike SCS, however, the CE is a construction agency and has no such authority.

APPENDIX C: SUMMARY MATRICES

1. This appendix provides two tables to be used for quick reference by users in order to determine applicable environmental features. Both tables list each environmental feature discussed in the main body of the report. The first table relates each feature to generalized project settings, while the second relates each feature to the potential limitations that were determined through research on the project.

Setting/Feature Matrix

2. Each environmental feature is appropriate only to certain generalized settings. These settings include various land use types, alternative locations on the levee, different types of levee material, and various sizes of levees. Table C1 lists (a) environmental features discussed in the text and (b) the range of setting variables. In the intersections of the two dimensions, applicability of the measure to the setting is ranked as high (H), moderate (M), or low (L), with exceptions presented elsewhere in the table and in the report's text (E). If the intersection is left blank, the setting is excluded from consideration by definition of that particular feature.

Limitation/Feature Matrix

3. Table C2 summarizes limitations for the various environmental features discussed in the main body of the report. One axis lists the environmental features, while the other provides index numbers for 28 generalized limitations found during the course of the study. An "X" at the intersection between a feature and a limitation indicates that the limitation is appropriate to that feature.

Table C1

Setting/Feature Matrix

ENVIRONMENTAL FEATURE	Setting													
	Land Use Type			Location on Levee					Type of Levee Material				Levee Size	
	Urban/Urbanizing	Rural (forested)	Rural (agricultural)	Foreshore	Riverside slope	Crown	Landside slope	Landside	Pervious earthen	Impervious earthen	Impervious core	Floodwall	Standard	Overbuilt
Environmental considerations for general design														
Avoidance of ecologically sensitive areas	M	H	M	H	L	L	L	M	H	H	H	H	H	M
Tree preservation	H	H	M	H	L	L	L	M	M	H	H	H	H	M
Future land use considerations	H	L	L	M	L	L	L	H	H	H	H	H	H	H
Alignment to increase riverside land area	L	H	M	H					H	H	H	H	H	H
Minimization of cleared areas	H	H	M	H	L	L	L	H	M	H	M	M	H	M
Overbuilt levees	M	H	L	L	H	H	M	L	L	H	M	L		
Overdesigning drainage ditches	M	M	M	L	L	L	L	H	L	H	H	L	M	H
Planning and design for erosion and water quality control during construction	H	H	H	H	H	H	H	H	H	H	H	H	H	H
Environmental features for fish and wildlife														
Wildlife considerations for borrow pit design	M	H	M	H	L	L	L	M	H	H	L	L	H	H
Fishery considerations for borrow pit design	H	M	H	H	L	L	L	M	H	H	L	L	H	H
Interior drainage collection ponds	H	L	L	L	L	L	L	H	L	M	H	M	M	H

(Continued)

(Sheet 1 of 4)

Table C1 (Continued)

ENVIRONMENTAL FEATURE	Setting: Land Use Type: Urban/Urbanizing	Rural (forested)	Rural (agricultural)	Location on Levee: Foreshore	Riverside slope	Crown	Landside slope	Landside	Type of Levee Material: Pervious earthen	Impervious earthen	Impervious core	Floodwall	Levee Size: Standard	Overbuilt
Environmental features for fish and wildlife (Cont.)														
Flushing artificial ponds and wetlands	H	H	H	H	L	L	L	M	H	H	H	L	H	H
Freshwater diversions	L	H	H	H	H	H	H	H	L	H	L	L	H	H
Water control structures	M	H	M	H	L	L	L	M	H	H	H	H	H	H
Artificial islands	H	H	H	H	L	L	L	M	H	M	M	M	H	H
Fishery shelters in borrow pits	H	M	L	H	L	L	L	M	H	H	H	H	H	H
Fish stocking	H	L	L	L	L	L	L	H	H	H	H	H	H	H
Marsh vegetation establishment	H	H	H	H	L	L	L	M	H	H	L	L	H	H
Beneficial uses for dredged or excavated material	M	H	M	H	L	L	L	L	H	M	L	L	H	H
Land acquisition	L	H	L	H	L	L	L	M	H	H	H	H	H	H
Artificial nesting and perching structures	M	H	M	H	M	M	M	M	H	H	H	H	H	H
Seeding and planting for wildlife	M	H	M	H	E	E	E	L	L	M	M	L	M	H
Wildlife brush piles	L	H	M	H	L	L	L	M	H	H	L	L	H	H
Controlled access to wildlife areas	M	H	M	H	L	L	L	L	H	H	L	L	H	H

(Continued)

(Sheet 2 of 4)

Table C1 (Continued)

ENVIRONMENTAL FEATURE	Setting													
	Land Use Type			Location on Levee					Type of Levee Material				Levee Size	
	Urban/Urbanizing	Rural (forested)	Rural (agricultural)	Foreshore	Riverside slope	Crown	Landside slope	Landside	Pervious earthen	Impervious earthen	Impervious core	Floodwall	Standard	Overbuilt
Environmental features for fish and wildlife (Cont.)														
Fencing designs to enable or discourage wildlife passage	L	H	H	H	L	L	L	H	H	H	H	L	H	H
Environmental features for recreation and aesthetics														
Recreational and aesthetic aspects of borrow pit design	H	M	L	H	L	L	L	M	H	H	L	L	H	H
Uses for levee access roads and crowns	H	M	L	M	L	H	L	M	L	H	H	L	M	H
Aesthetic considerations for plantings	H	L	L	H	E	E	E	M	L	H	H	H	M	H
Uses for periodically flooded areas	H	L	L	H	L	L	L	H	L	H	H	H	H	H
Interpretive centers, observation areas, and culturally important areas	H	L	L	M	L	H	L	M	L	H	H	H	H	H
Fishing access	H	M	L	H	H	L	L	L	H	H	H	H	H	H
Boat ramps and access	H	L	L	H	M	L	L	L	M	H	H	L	H	H
Swimming beaches	H	L	L	H	L	L	L	L	H	M	M	M	H	H
Folding or removable foodwall panels	H	L	L									H	H	H

(Continued)

(Sheet 3 of 4)

Table C1 (Concluded)

ENVIRONMENTAL FEATURE	Setting													
	Land Use Type			Location on Levee					Type of Levee Material				Levee Size	
	Urban/Urbanizing	Rural (forested)	Rural (agricultural)	Foreshore	Riverside slope	Crown	Landside slope	Landside	Pervious earthen	Impervious earthen	Impervious core	Floodwall	Standard	Overbuilt
Environmental features for recreation and aesthetics (Cont.)														
Treatment of concrete floodwalls	H	L	L									H	H	H
Environmental considerations for maintenance activities														
Walking inspection	H	H	H	L	H	H	H	L	L	H	H	L	L	H
Selective vegetation management	L	H	M	H	E	E	E	M	M	H	M	L	M	H
Mowing	H	H	H	L	H	H	H	M	L	H	H	L	H	H
Grazing	L	M	H	H	M	M	M	H	L	H	L	L	M	H
Precribed fire	L	M	H	L	H	H	M	L	H	H	L	L	H	H
Chemical vegetation management	M	H	H	L	L	H	H	H	H	L	L	L	H	H
Irrigation	H	L	L	L	H	H	H	L	H	H	H	L	H	H
Rodent control	L	H	H	L	H	H	H	L	L	H	L	L	H	M
Maintenance of recreation areas	H	L	L	H	H	H	H	H	L	H	H	H	H	H
Information and education programs for maintenance personnel	H	H	H	H	H	H	H	H	H	H	H	H	H	H

(Sheet 4 of 4)

Table C2

Limitation/Feature Matrix

ENVIRONMENTAL FEATURES	Limitation Index Number*																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Environmental considerations for general design																												
Avoidance of ecologically sensitive areas	X	X		X	X	X		X												X								
Tree preservation			X	X			X																					
Future land use considerations						X	X	X																				
Alignment to increase riverside land area	X	X				X			X																			
Minimization of cleared areas							X																					
Overbuilt levees			X		X		X		X																			
Overdesigning drainage ditches												X																
Planning and design for erosion and water quality control during construction																										X		
Wildlife considerations for borrow pit design			X		X			X		X	X	X		X														

(Continued)

(Sheet 1 of 6)

Table C2. (Continued)

ENVIRONMENTAL FEATURES	Limitation Index Number*																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Environmental considerations for general design (Cont.)																												
Fishery considerations for borrow pit design			X		X			X		X	X	X		X										X				
Interior drainage collection ponds			X					X		X	X	X																
Flushing artificial ponds and wetlands	X									X	X																	
Freshwater diversions					X			X		X			X	X														
Water control structures	X							X		X	X		X	X									X					
Artificial islands	X		X		X					X				X	X	X	X											
Fishery shelters in borrow pits											X	X			X		X	X										
Fish stocking										X	X										X							
Marsh vegetation establishment	X									X									X				X				X	

(Continued)

(Sheet 2 of 6)

Table C2. (Continued)

ENVIRONMENTAL FEATURES	Limitation Index Number*																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Environmental considerations for general design (Cont.)																												
Beneficial uses for dredged or excavated material	X				X					X					X			X										
Land acquisition						X		X					X	X						X								X
Artificial nesting and perching structures	X										X		X				X											
Seeding and planting for wildlife			X	X							X								X									
Wildlife brush piles			X														X					X						
Controlled access to wildlife areas						X		X															X					
Fencing designs to enable or discourage wildlife passage						X	X										X					X						

(Continued)

Table C2. (Continued)

ENVIRONMENTAL FEATURES	Limitation Index Number*																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Environmental features for recreation and aesthetics																												
Recreational and aesthetic aspects of borrow pit design	X				X					X														X				
Uses for levee access roads and crowns							X						X										X	X				
Aesthetic considerations for plantings			X	X																			X				X	
Uses for periodically flooded areas	X							X					X										X	X				
Interpretive centers, observation areas, and culturally important areas								X	X				X										X	X				
Fishing access			X																				X	X				
Boat ramps and access								X															X	X	X			
Swimming beaches	X							X		X			X										X	X	X			
Folding or removable floodwalls	X																										X	

(Continued)

(Sheet 4 of 6)

Table C2. (Continued)

ENVIRONMENTAL FEATURES	Limitation Index Number* 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Treatment of concrete flood-walls							X																					
<u>Environmental considerations for maintenance activities</u>																												
Walking inspection							X						X														X	
Selective vegetation management			X				X				X																X	
Mowing	X																		X									
Grazing			X																									
Prescribed fire			X																X							X	X	
Chemical vegetation management																X		X	X									X
Irrigation			X										X										X				X	X
Rodent control							X												X									X
Maintenance of recreation areas																							X				X	
Information and education programs for maintenance personnel																											X	

(Continued)

Table C2. (Concluded)

* Limitation index numbers refer to the following limitations:

1. Optimum site may not be available.
2. May cause more expensive engineering modifications to ensure levee integrity.
3. May increase potential for seepage and/or erosion.
4. Natural vegetative plant succession and response to changed conditions may make feature hard to implement.
5. Adequate borrow is needed.
6. Resistance from public is possible.
7. Maintenance and access may be hampered or costs increased.
8. Existing land use may not be compatible.
9. Additional land would be required.
10. Amount, quality, and seasonal variations in water resources may limit applicability.
11. Wildlife or fish pest problems may develop.
12. Improvement may be short-lived.
13. Operation and maintenance activities for measure may be excessive.
14. Subjective development of management objectives is required.
15. Other, more valuable areas and habitats could be destroyed.
16. Separate permit may be required.
17. Unwanted vegetation types may develop.
18. Water and/or air quality problems could develop with implementation.
19. Unwanted vegetation types may develop.
20. Costs may be excessive.
21. Interspecific relations between species may limit usefulness.
22. Barriers to wildlife movement may be created.
23. Vandalism/illegal entry may occur.
24. Public access is needed, along with protection of the landowner from liability claims.
25. Usable resource should already exist at site.
26. Implementation would be the responsibility of the landowner.
27. Feature requires unique knowledge by personnel charged with implementing.
28. Public health and safety may be adversely affected.

APPENDIX D: SEATTLE DISTRICT MINIMUM STANDARDS FOR MAINTENANCE OF PL 84-99 LEVEES

MINIMUM STANDARDS
(District No. 6)

All levees within the sponsor's jurisdiction will be brought to minimum standards. The purpose of these "Minimum Standards" is to clearly delineate the responsibilities and requirements for Public Law 84-99 levee repair work and flood fighting activities undertaken by the Seattle District in the future. Levee maintenance, as prescribed by "Minimum Standards," is designed to insure levee integrity and access for inspection and repair while including measures which consider the impact of levees on the fish and wildlife which utilize these areas. Minimum standards for accomplishing the foregoing are as follows:

a. Material for restoration or improvements will be nonorganic (without limbs, twigs, etc.) with suitable structural soil properties (compactability, permeability, etc.)

b. A stand of hardy grasses will be promoted and maintained on both ~~sides of the levee embankment.~~

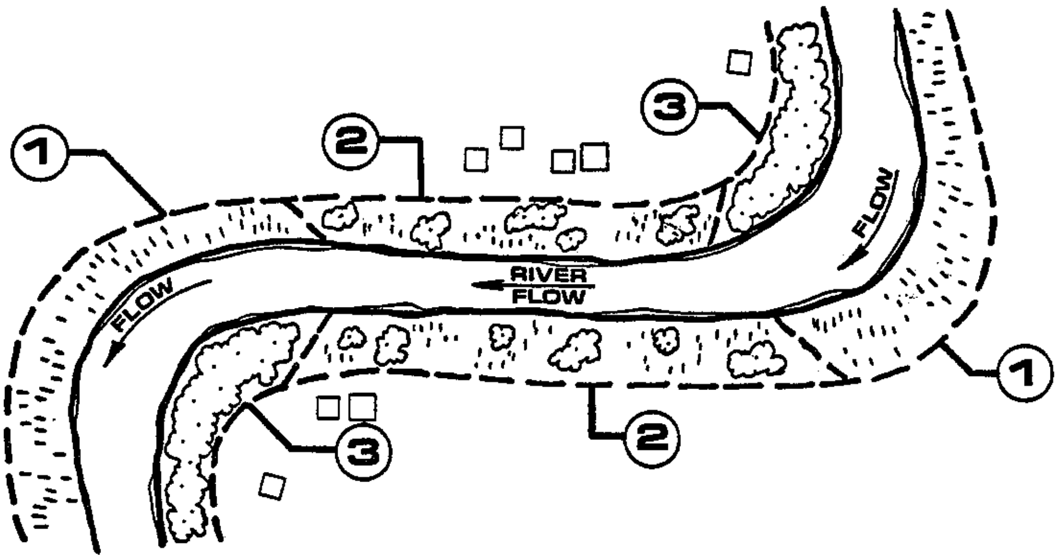
c. Undesirable growth (examples: blackberries, wild roses) on levee top and both sides will be removed from the levee embankment on an annual basis to provide easy inspection and access. Trees and shrubs with main stem diameter less than 2 inches may be allowed to remain on riverward slope to provide wildlife habitat. All trees and shrubs on levee top and landward side shall be removed. Inclosure 1 depicts a typical river section protected by existing levees. In this example, areas of high, intermediate, and low erosion damage potential are shown with their corresponding vegetation and wildlife habitat. Tree and shrub size is still controlled by stem diameter.

d. The embankment will be maintained to design grade and section by necessary restoration of erosion, sloughs, settlement, and ruts.

e. Rock spalls or gravel bank protection shall be maintained at no less than original construction lines.

The local sponsor is also required to comply with Title 33, Code of Federal Regulations, Part 208, Section 10(b). They are further required to submit to Seattle District a program outlining the sponsor's proposed plans and schedule for accomplishing items a through e above within 60 days of receipt of this document.

MANAGEMENT OF LEVEE VEGETATION



(1) Areas of HIGH potential damage, such as the outside of river bends, historically flooded areas, or levees adjacent to residences and critical use facilities should be cleared of trees and brush which could obstruct access for inspection and repair. In these levee sections, only grass and small forbs would be permitted.

(2) Areas of INTERMEDIATE damage potential such as relatively level, straight reaches and gentle bends could be selectively cleared, leaving clumps or strips of vegetation while allowing unimpeded access for inspection and repair. The type, amount and distribution of this vegetation would be carefully coordinated with the Corps of Engineers to insure levee integrity.

(3) Areas of LOW potential damage, i.e., the inside portion of river bends, levees which are seldom damaged or which protect large areas of undeveloped or relatively low value land could be maintained in a manner which would leave most levee vegetation intact, removing only that vegetation which could constitute a threat to the levee or impede levee accessibility.

APPENDIX E: REFERENCE INDEX

1. Part and section headings are provided below. Under each heading, references that are applicable are listed by their author/date citation. A complete citation of the references is provided in the References section.

Part I: Introduction

2. Anonymous (1982); Burch et al. (1984); Henderson and Shields (1984); Nunnally and Shields (1985); Shields (1982); Shields and Palermo (1982); Thackston and Sneed (1982); US Army, Office, Chief of Engineers (1967, 1968, 1972a, 1978, 1980a, 1983)

Part II: Environmental Considerations for General Design

Avoidance of Ecologically Sensitive Areas

3. Best et al. (1979); Chapman et al. (1982); Dickson (1978a, 1978b); Dickson et al. (1978); Fredrickson (1978); Geier and Best (1980); Hehnke and Stone (1978); Hurst et al. (1980); Hynson et al. (1982); Klimas et al. (1981); Lee and Hinckley (1982); MacDonald et al. (1979); Murphy and Noble (1972); Odum (1978); Schitoskey and Linden (1978); Shields and Palermo (1982); Stauffer and Best (1980); Teskey and Hinckley (1977a, 1977b, 1977c, 1978a, 1978b, 1978c); US Army Engineer District, Baltimore (1981); US Army Engineer District, Los Angeles (1981, 1982); US Army Engineer District, Rock Island (1974a); US Army Engineer District, Sacramento (1980); USDA Soil Conservation Service State Office, Maryland (1973); USDA Soil Conservation Service State Office, Michigan (1975); Walters et al. (1980a, 1980b); Wentz (1981); Whitlow and Harris (1979); Wigley et al. (1980).

Tree Preservation

4. Florida Department of Agriculture and Consumer Services, Division of Forestry (1980); Keown et al. (1977); Robinette (1968); State

of California, Department of Transportation (1970); Steinberg (1960); US Army Engineer District, Rock Island (1970, 1971); US Army Engineer District, Sacramento (1982); Zion (1968).

Future Land Use Considerations

5. US Army, Office, Chief of Engineers (1968).

Alignment to Increase Riverside Land Area

6. Dickson (1978a, 1978b); Dickson et al. (1978); Fredrickson (1978, 1979); Klimas et al. (1981); Murphy and Noble (1972); Russell (1967); Shields and Palermo (1982); US Army Engineer District, Sacramento (1982); US Army, Office, Chief of Engineers (1978); Whitlow and Harris (1979); Wigley et al. (1980).

Minimization of Cleared Areas

7. Hopkins et al. (1973); Hynson et al. (1982); US Army Engineer District, Los Angeles (1981); US Army Engineer District, Omaha (1976, 1979); US Army Engineer District, Sacramento (1980); US Army, Office, Chief of Engineers (1972a, 1978); USDA Soil Conservation Service State Office, Maryland (1973); USDA Soil Conservation Service State Office, New York (1980); USDA Soil Conservation Service (1977).

Overbuilt Levees

8. Nolan (1981); Osmundson (1980); US Army Engineer District, Chicago (1982); US Army Engineer District, Los Angeles (1977); US Army Engineer Districts, Mobile and Nashville (1982); US Army Engineer District, San Francisco (1969); US Army, Office, Chief of Engineers (1972a, 1978).

Planning and Design for Erosion and Water Quality Control During Construction

9. Amimoto (1978); Becker and Mills (1972); Borst and Woodburn (1942); Gessel and Cole (1965); Goss et al. (1970); Heede (1978); Hopkins et al. (1973); Meyer et al. (1972); Musgrave (1947); Nawrocki and Pietrzak (1976); Packer (1967); Poertner (1981); Reinhart et al. (1963); Task Committee for Preparation of Manual on Sedimentation (1969); Thronson (1973, 1979); Traver (1980); Trimble and Sartz (1957); USDA Soil Conservation Service (1977); USDI Bureau of Reclamation (no date b); White and Franks (1978).