ERDC/EL TR-11-12

Environmental Laboratory

US Army Corps
of Engineers®
Engineer Research and
Development Center

Ecosystem Management and Restoration Research Program

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley, Version 2.0

Charles V. Klimas, Elizabeth O. Murray, Jody Pagan,
Henry Langston, and Thomas Foti

September 2011

Ecosystem Management and Restoration
Research Program

ERDC/EL TR-11-12
September 2011

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley, Version 2.0

Charles V. Klimas, Elizabeth O. Murray

U.S. Army Engineer Research and Development Center
Vicksburg, MS 39180

Jody Pagan

5-Oaks Wildlife Services Inc.
P.O. Box 586
Stuttgart, AR 72042

Henry Langston

Arkansas State Highway and Transportation Department
P.O. Box 2261, Little Rock, AR 72203

Thomas Foti

Arkansas Natural Heritage Commission
323 Center Street, Little Rock, AR 72201

Final report

Prepared for Arkansas Multi-Agency Planning Team
#2 Natural Resources Drive
Little Rock, AR 72205-1572

In cooperation with U.S. Environmental Protection Agency, Region IV
State and Tribal Program Section
1445 Ross Avenue, Suite 1200, Dallas, TX 75202-2733

Monitored by U.S. Army Engineer Research and Development Center
Environmental Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

Abstract: The Hydrogeomorphic (HGM) Approach is a method for developing and applying indices for the site-specific assessment of wetland functions. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review process to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the design of wetland restoration projects, and management of wetlands.

This is Version 2.0 of a Regional Guidebook that presents the HGM Approach for assessing the functions of most of the wetlands that occur in the Delta Region of Arkansas, which is part of the Lower Mississippi River Alluvial Valley. The report begins with an overview of the HGM Approach and then classifies and characterizes the principal wetlands that have been identified within the Delta Region of Arkansas. Detailed HGM assessment models and protocols are presented for six of those wetland types, or subclasses, representing all of the forested wetlands in the region other than those associated with lakes and impoundments. The following wetland subclasses are treated in detail: Flat, Mid-gradient Riverine, Low-gradient Riverine Backwater, Low-gradient Riverine Overbank, Headwater Depression, Isolated Depression, and Connected Depression. For each wetland subclass, the guidebook presents (a) the rationale used to select the wetland functions considered in the assessment process, (b) the rationale used to select assessment model variables, (c) the rationale used to develop assessment models, and (d) the functional index calibration curves developed from reference wetlands that are used in the assessment models. The guidebook outlines an assessment protocol for using the model variables and functional indices to assess each of the wetland subclasses. The appendices provide field data collection forms, spreadsheets for making calculations, and a variety of supporting spatial data intended for use in the context of a Geographic Information System.

Contents

Figures and Tables

Figures

Tables

Preface

This Regional Guidebook is a revision of one published in 2004. This report was prepared in accordance with guidelines established by the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS. The original Regional Guidebook was developed as a cooperative effort between the Arkansas Multi-Agency Wetland Planning Team (MAWPT) and Region 6 of the U.S. Environmental Protection Agency, which provided funding through the Wetland Grants 104(b)(3) program for States, Tribes, and Local Governments. Charles V. Klimas (Charles Klimas and Associates, Inc., currently with ERDC) directed the field studies and prepared the guidebook manuscript, under contract to the Arkansas Game and Fish Commission MAWPT Coordination Office. Elizabeth O. Murray (MAWPT Coordinator, Arkansas Game and Fish Commission, currently with ERDC) prepared most of the figures. All of the persons listed as authors of this guidebook were involved in every aspect of the project, including classification, field sampling, and model testing, and otherwise contributed materially to production of the document. The affiliations of the other authors are as follows: Thomas Foti (Arkansas Natural Heritage Commission), Jody Pagan (Natural Resources Conservation Service, currently with 5-Oaks Wildlife Services), and Henry Langston (Arkansas State Highway and Transportation Department). Other representatives of the MAWPT member agencies provided technical oversight for the project and, together with other organizations, participated in the field studies and workshops that produced the wetland classification system, community characterizations, and assessment models used in this document. D. J. Klimas archived and summarized the field data and generated the data summary graphs in this report.

The original Regional Guidebook for the Delta Region of Arkansas was the first of five guidebooks developed for the state of Arkansas (Klimas et al. 2004, 2005, 2006, 2008a, 2008b) largely with the personnel listed above. During the development of subsequent Regional Guidebooks, some approaches were altered and variables improved. This Regional Guidebook is being revised to make it consistent with later Guidebooks, and to improve it based upon later experiences. New Excel-based data sheets have been created to ease FCI and FCU calculations. The revisions were done primarily by Elizabeth O. Murray and Charles V. Klimas.

Participants in the original project included representatives of federal agencies (U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, Natural Resources Conservation Service); Arkansas state agencies (Arkansas Natural Heritage Commission, Arkansas Game and Fish Commission, Arkansas Soil and Water Conservation Commission, Arkansas State Highway and Transportation Department, Arkansas Forestry Commission, Arkansas Department of Environmental Quality, and University of Arkansas Cooperative Extension Service); state university personnel; and private sector representatives. All of the individuals involved are too numerous to list here, but some people contributed a particularly large amount of time and effort: Ken Brazil (Arkansas Soil and Water Conservation Commission); Rob Holbrook (Arkansas Game and Fish Commission); Joe Krystofik (formerly of Soil and Water Conservation Commission, currently with U.S. Fish and Wildlife Service); Gary Tucker (FTN Associates, Ltd.); Phillip Moore (Arkansas State Highway and Transportation Department); Jeff Raasch (formerly MAWPT Coordinator, Arkansas Game and Fish Commission, currently with Texas Parks and Wildlife); Bill Richardson (Arkansas State Highway and Transportation Department); and Theo Witsell (Arkansas Natural Heritage Commission). Ken Brazil, Tom Foti, Elizabeth Murray, and Jeff Raasch provided administrative continuity and coordination among participating and funding agencies, in addition to their direct technical participation.

This report is published by ERDC as part of the Hydrogeomorphic (HGM) Guidebook series under the Ecosystem Management and Restoration Program (EMRPP). EMRPP Program Manager was Glenn Rhett. Chris V. Noble, Wetlands and Coastal Ecology Branch, Ecosystem Evaluation and Engineering Division, Environmental Laboratory (EL), ERDC, reviewed the report for consistency with HGM guidelines. In addition, the methods and protocols used to prepare this report were closely coordinated with a study simultaneously undertaken in the Delta Region of Mississippi (the Yazoo Basin). Therefore, portions of the text and some figures are similar or identical to sections of the Yazoo Basin Guidebook ("A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Selected Regional Wetland Subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley," by R. D. Smith and C. V. Klimas, ERDC/EL TR-02-4, U.S. Army Engineer Research and Development Center, Vicksburg, MS). Note also that the Western Kentucky Regional Guidebook ("A Regional Guidebook for Assessing the Functions of Low Gradient, Riverine Wetlands of Western Kentucky," by W. B. Ainslie et al.

1999, Technical Report WRP-DE-17, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS) served as a template for the development of both this and the Yazoo Basin document. Parts of the discussion in the Western Kentucky document are included here without significant modification, particularly portions of the wildlife section (originally developed by Tom Roberts, Tennessee Technological University) and basic information on the HGM Approach and wetland functions (originally developed by R. Daniel Smith, EL). Many aspects of the classification system, field methods, and guidebook structure used here were based on reconnaissance studies in the Yazoo Basin and the Arkansas Delta conducted by Charles Klimas and R. Daniel Smith prior to initiation of this project.

1 Introduction

The Hydrogeomorphic (HGM) Approach is a method for developing functional indices and the protocols used to apply these indices to the assessment of wetland functions at a site-specific scale. The HGM Approach initially was designed to be used in the context of the Clean Water Act, Section 404 Regulatory Program, to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the determination of minimal effects under the Food Security Act, design of wetland restoration projects, and management of wetlands.

In the HGM Approach, the functional indices and assessment protocols used to assess a specific type of wetland in a specific geographic region are published in a document referred to as a Regional Guidebook. Guidelines for developing Regional Guidebooks were published in the National Action Plan (National Interagency Implementation Team 1996) developed cooperatively by the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), Federal Highway Administration (FHWA), and U.S. Fish and Wildlife Service (USFWS). The Action Plan, available online at http://www.epa.gov/OWOW/wetlands/science/hgm.html, outlines a strategy for developing Regional Guidebooks throughout the United States, provides guidelines and a specific set of tasks required to develop a Regional Guidebook under the HGM Approach, and solicits the cooperation and participation of Federal, State, and local agencies, academia, and the private sector.

This report is a Regional Guidebook developed for assessing the most common types of wetlands that occur in the Delta Region of Arkansas in the Lower Mississippi River Alluvial Valley in the United States. Normally, a Regional Guidebook focuses on a single regional wetland subclass (the term for wetland types in HGM terminology); however, a different approach has been employed in this Regional Guidebook: multiple regional wetland subclasses are considered. The rationale for this approach is that the Lower Mississippi River and its tributaries have created a complex landscape that supports a variety of interspersed wetland types in the Delta Region of

Arkansas specifically and the Lower Mississippi River Alluvial Valley generally. Subtle differences in terrain and water movement result in distinctly different functions being performed by wetlands that are in close proximity to or contiguous with one another. Further, massive flood control and drainage works instituted in the twentieth century have dramatically affected nearly all of the wetlands in the Lower Mississippi River Alluvial Valley. Because these wetland systems have closely related origins, and have been universally influenced by flood protection and drainage efforts, it is most sensible to deal with their classification and assessment in a single integrated Regional Guidebook. This does not mean that wetlands of different hydrogeomorphic classes and regional wetland subclasses are lumped for assessment purposes, but rather that the factors influencing their functions and the indicators employed in their evaluation are best developed and presented in a unified manner. Therefore, this Regional Guidebook was developed for multiple regional wetland subclasses that commonly occur together in a subbasin. It is expected that the classification of regional wetland subclasses, assessment variables, and the assessment models developed for the Delta Region of Arkansas will have general applicability in other subbasins of the Lower Mississippi River Alluvial Valley. However, development of Regional Guidebooks for other subbasins will require collection of additional reference data that reflect regional variation in wetland characteristics within a particular subbasin.

This Regional Guidebook addresses various objectives:

- To characterize selected regional wetland subclasses in the Delta Region of Arkansas within the Lower Mississippi River Alluvial Valley.
- To present the rationale used to select functions to be assessed in these regional subclasses.
- To present the rationale used to select assessment variables and metrics.
- To present the rationale used to develop assessment models.
- To describe the protocols for applying the functional indices to the assessment of wetland functions.

This report is organized in the following manner. Chapter 1 provides the background, objectives, and organization of the document. Chapter 2 provides a brief overview of the major components of the HGM Approach, including the procedures recommended for development and application of Regional Guidebooks. Chapter 3 characterizes the regional wetland

subclasses in the Delta Region of Arkansas included in this guidebook. Chapter 4 discusses the wetland functions, assessment variables, and functional indices used in the guidebook from a generic perspective. Chapter 5 applies the assessment models to specific regional wetland subclasses and defines the relationship of assessment variables to reference data. Chapter 6 outlines the assessment protocol for conducting a functional assessment of regional wetland subclasses in the Delta Region of Arkansas. Appendix A presents preliminary project documentation and field sampling guidance. Field data sheets are presented in Appendix B. Appendix C contains alternate field sheets, and Appendix D contains demonstration printouts of calculation spreadsheets. Appendix E presents spatial data. Common and scientific names of plant species referenced in the text and data sheets are listed in Appendix F.

While it is possible to assess the functions of selected regional wetland subclasses in the Delta Region of Arkansas using only the information contained in Chapter 6 and the appendices, it is strongly suggested that, prior to conducting an assessment, users also familiarize themselves with the information and documentation provided in Chapters 2-5.

2 Overview of the Hydrogeomorphic Approach

Development and application phases

The HGM Approach consists of four components: (a) the HGM classification, (b) reference wetlands, (c) assessment variables and assessment models from which functional indices are derived, and (d) assessment protocols. The HGM Approach is conducted in two phases. An interdisciplinary Assessment Team of experts carries out the Development Phase of the HGM Approach. The task of the Assessment Team is to develop and integrate the classification, reference wetland information, assessment variables, models, and protocols of the HGM Approach into a Regional Guidebook (Figure 1).

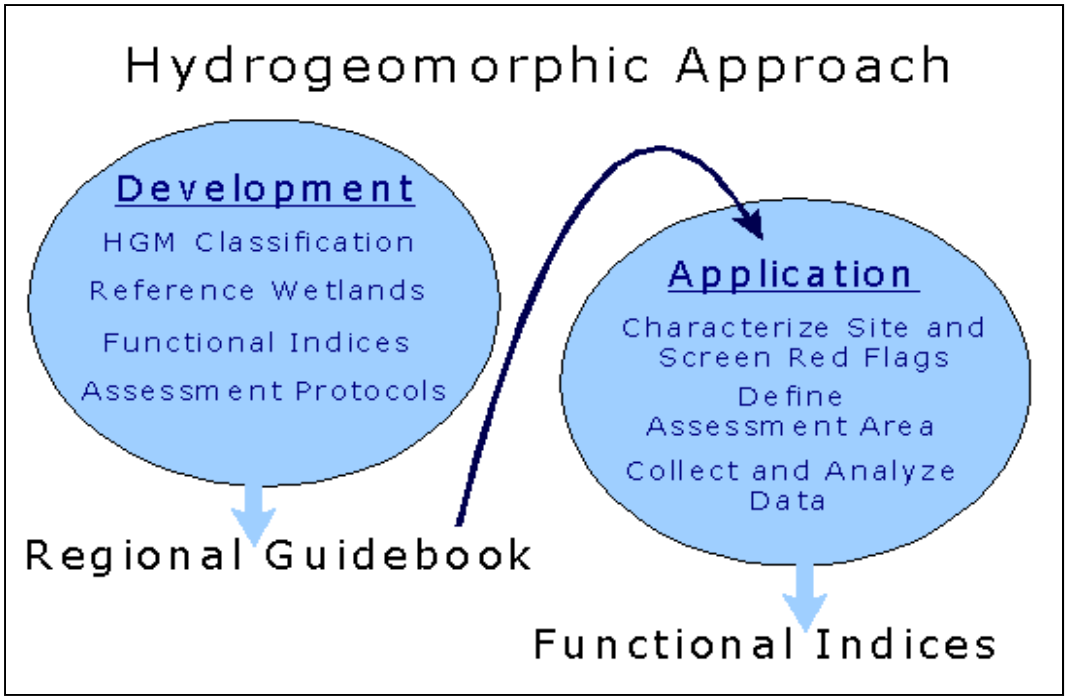


Figure 1. Development and Application Phases of the HGM Approach (from Ainslie et al. 1999)

In developing a Regional Guidebook, the team completes the tasks outlined in the National Action Plan (National Interagency Implementation Team 1996). After the team is organized and trained, its first task is to classify the wetlands of the region of interest into regional wetland subclasses using the

principles and criteria of Hydrogeomorphic Classification (Brinson 1993a; Smith et al. 1995). Next, focusing on a specific regional wetland subclass, the team develops an ecological characterization or functional profile of the subclass. The Assessment Team then identifies the important wetland functions, conceptualizes assessment models, identifies assessment variables to represent the characteristics and processes that influence each function, and defines metrics for quantifying assessment variables. Next, reference wetlands are identified to represent the range of variability exhibited by the regional subclass, and field data are collected and used to calibrate assessment variables and indices resulting from assessment models. Finally, the team develops the assessment protocols necessary for regulators, managers, consultants, and other end users to apply the indices to the assessment of wetland functions in the context of 404 Permit review.

During the Application Phase, the assessment variables, models, and protocols are used to assess wetland functions. This involves two steps. The first is to apply the assessment protocols outlined in the Regional Guidebook to complete the following tasks:

- Define assessment objectives.
- Characterize the project site.
- Screen for red flags.
- Define the Wetland Assessment Area.
- Collect field data.
- Analyze field data.

The second step involves applying the results of the assessment at various decision-making points in the planning or permit review sequence, such as alternatives analysis, impact minimization, assessment of unavoidable impacts, determination of compensatory mitigation, design and monitoring of mitigation, comparison of wetland management alternatives or results, determination of restoration potential, or identification of acquisition or mitigation sites.

Each of the components of the HGM Approach that are developed and integrated into the Regional Guidebook is discussed briefly in the following paragraphs. More extensive treatment of these components can be found in Brinson (1993a, b; 1995, 1996), Brinson et al. (1995, 1996, 1998), Hauer and Smith (1998), and Smith et al. (1995).

Hydrogeomorphic classification

Wetland ecosystems share a number of common attributes including hydrophytic vegetation, hydric soils, and relatively long periods of inundation or saturation by water. In spite of these common attributes, wetlands occur in a variety of climatic, geologic, and physiographic settings and exhibit a wide range of physical, chemical, and biological characteristics and processes (Cowardin et al. 1979; Mitch and Gosselink 1993; Semeniuk 1987). The variability of wetlands makes it challenging to develop assessment methods that are both accurate (i.e., sensitive to significant changes in function) and practical (i.e., can be completed in the relatively short time frame normally available for conducting assessments). "Generic" wetland assessment methods have been developed to assess multiple wetland types throughout the United States. In general these methods can be applied quickly, but lack the resolution necessary to detect significant changes in function. One way to achieve an appropriate level of resolution within a limited time frame is to employ a wetland classification system structured to support functional assessment objectives (Smith et al. 1995).

The HGM classification was developed specifically to accomplish this task (Brinson 1993a). It identifies groups of wetlands that function similarly using three criteria that fundamentally influence how wetlands function: geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the position of the wetland in the landscape. Water source refers to the primary origin of the water that sustains wetland characteristics, such as precipitation, floodwater, or groundwater. Hydrodynamics refers to the level of energy with which water moves through the wetland, and the direction of water movement.

Based on these three criteria, any number of functional wetland groups can be identified at different spatial or temporal scales. For example, at a continental scale, Brinson (1993a, b) identified five hydrogeomorphic wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995).

Generally, the level of variability encompassed by wetlands at the continental scale of hydrogeomorphic classification is too great to allow development of assessment indices that can be applied rapidly and still retain the level of sensitivity necessary to detect changes in function at a level of resolution appropriate to the 404 permit review. In order to reduce both inter- and intraregional variability, the three classification criteria

Table 1. Hydrogeomorphic Wetland Classes.

HGM Wetland Class	Definition
Depression	Depressional wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depressional wetlands may have any combination of inlets and outlets, or lack them completely. Potential water sources are precipitation, overland flow, streams, or groundwater flow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression. The predominant hydrodynamics are vertical fluctuations that may occur over a range of time, from a few days to many months. Depressional wetlands may lose water through evapotranspiration, intermittent or perennial outlets, or recharge to groundwater. Prairie potholes, playa lakes, and cypress domes are common examples of depressional wetlands.
Tidal Fringe	Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and riverflow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. Because tidal fringe wetlands are frequently flooded and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh or dunes. S*partina alterniflora* salt marshes are a common example of tidal fringe wetlands.
Lacustrine Fringe	Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bidirectional. Lacustrine wetlands lose water by evapotranspiration and by flow returning to the lake after flooding. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands.
Slope	Slope wetlands are found in association with the discharge of groundwater to the land surface or on sites with saturated overland flow with no channel formation. They normally occur on slightly to steeply sloping land. The predominant source of water is groundwater or interflow discharging at the land surface. Precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows, surface flows, and by evapotranspiration. They may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depression wetlands by the lack of a closed topographic depression and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands.
Mineral Soil Flats	Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large alluvial terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat non-wetland areas by their poor vertical drainage due to impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Pine flatwoods with hydric soils are an example of mineral soil flat wetlands.
Organic Soil Flats	Organic soil flats, or extensive peatlands, differ from mineral soil flats in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are examples of organic soil flat wetlands.
Riverine	Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank or backwater flow from the channel. Additional sources may be interflow, overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In headwaters, riverine wetlands often intergrade with slope, depressional, poorly drained flat wetlands, or uplands as the channel (bed) and bank disappear. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater, and evapotranspiration. Bottomland hardwood forests on floodplains are examples of riverine wetlands.

must be applied at a smaller, regional geographic scale, thus creating regional wetland subclasses. In many parts of the country, existing wetland classifications can serve as a starting point for identifying these regional subclasses (e.g., Golet and Larson 1974; Stewart and Kantrud 1971; Wharton et al. 1982). Regional subclasses, like the continental scale wetland classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. Examples of potential regional subclasses are shown in Table 2. In addition, certain ecosystem or landscape characteristics may be useful for distinguishing regional subclasses. For example, depression subclasses might be based on water source (i.e., groundwater versus surface water) or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients (Shafer and Yozzo 1998). Slope subclasses might be based on the degree of slope or landscape position. Riverine subclasses might be based on position in the watershed, stream order, watershed size, channel gradient, or floodplain width. Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

Table 2. Potential regional wetland subclasses in relation to classification criteria.

Classification Criteria			Potential Regional Wetland Subclasses	
Geomorphic Setting	Dominant Water Source	Dominant Hydrodynamics	Eastern USA	Western USA/Alaska
Depression	Groundwater or interflow	Vertical	Prairie pothole marshes, Carolina bays	California vernal pools
Fringe (tidal)	Ocean	Bidirectional, horizontal	Chesapeake Bay and Gulf of Mexico tidal marshes	San Francisco Bay marshes
Fringe (lacustrine)	Lake	Bidirectional, horizontal	Great Lakes marshes	Flathead Lake marshes
Slope	Groundwater	Unidirectional, horizontal	Fens	Avalanche chutes
Flat (mineral soil)	Precipitation	Vertical	Wet pine flatwoods	Large playas
Flat (organic soil)	Precipitation	Vertical	Peat bogs; portions of Everglades	Peatlands over permafrost
Riverine	Overbank flow from channels	Unidirectional, horizontal	Bottomland hardwood forests	Riparian wetlands

Note: Adapted from Smith et al. 1995, Rheinhardt et al. 1997.

Reference wetlands

Reference wetlands are the wetland sites selected to represent the range of variability that occurs in a regional wetland subclass as a result of natural processes and disturbance (e.g., succession, channel migration, fire, erosion, and sedimentation) as well as anthropogenic alteration (e.g., grazing, timber harvest, clearing). The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995, Smith 2001). Ideally, the geographic extent of the reference domain will mirror the geographic area encompassed by the regional wetland subclass; however, this is not always possible due to time and resource constraints.

Reference wetlands serve several purposes. First, they establish a basis for defining what constitutes a characteristic and sustainable level of function across the suite of functions selected for a regional wetland subclass. Second, reference wetlands establish the range and variability of conditions exhibited by assessment variables, and provide the data necessary for calibrating assessment variables and models. Finally, they provide a concrete physical representation of wetland ecosystems that can be observed and remeasured as needed.

Reference standard wetlands are the subset of reference wetlands that perform the suite of functions selected for the regional subclass at a level that is characteristic of the least altered wetland sites in the least altered landscapes. Table 3 outlines the terms used by the HGM Approach in the context of reference wetlands.

Table 3. Reference wetland terms and definitions.

Term	Definition
Reference Domain	The geographic area from which reference wetlands representing the regional wetland subclass are selected.
Reference Wetlands	A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and human alteration.
Reference Standard Wetlands	The subset of reference wetlands that perform a representative suite of functions at a level that is both sustainable and characteristic of the least human altered wetland sites in the least human altered landscapes. By definition, the functional capacity index for all functions in a reference standard wetland is 1.0.
Reference Standard Wetland Variable Condition	The range of conditions exhibited by assessment variables in reference standard wetlands. By definition, reference standard conditions receive a variable subindex score of 1.0.

Assessment models and functional indices

In the HGM Approach, an assessment model is a simple representation of a function performed by a wetland ecosystem. The assessment model defines the relationship between the characteristics and processes of the wetland ecosystem and the surrounding landscape that influence the functional capacity of a wetland ecosystem. Characteristics and processes are represented in the assessment model by assessment variables. Functional capacity is the ability of a wetland to perform a specific function relative to the ability of reference standard wetlands to perform the same function. Application of assessment models results in a Functional Capacity Index (FCI) ranging from 0.0 to 1.0. Wetlands with an FCI of 1.0 perform the assessed function at a level that is characteristic of reference standard wetlands. A lower FCI indicates that the wetland is performing a function at a level below the level that is characteristic of reference standard wetlands.

For example, the following equation shows an assessment model that could be used to assess the capacity of a wetland to detain floodwater.

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \quad (1)$$

The assessment model has five assessment variables: frequency of flooding (V_{FREQ}), which represents the frequency at which a wetland is inundated by overbank flooding, and the assessment variables of log density (V_{LOG}), ground vegetation cover (V_{GVC}), shrub and sapling density (V_{SSD}), and tree stem density (V_{TDEN}) that together represent resistance to flow of floodwater through the wetland.

Assessment variables occur in a variety of states or conditions. The state or condition of an assessment variable is indicated by the value of the metric used to assess a variable, and the metric used is normally one commonly used in ecological studies. For example, tree basal area (m^2/ha) is the metric used to assess tree biomass in a wetland, with larger numbers usually indicating greater stand maturity and increasing functionality for several different wetland functions where tree biomass is an important consideration.

Based on the metric value, an assessment variable is assigned a variable subindex. When the metric value of an assessment variable is within the

range of conditions exhibited by reference standard wetlands, a variable subindex of 1.0 is assigned. As the metric value deflects, in either direction, from the reference standard condition, the variable subindex decreases based on a defined relationship between metric values and functional capacity. Thus, as the metric value deviates from the conditions documented in reference standard wetlands, it receives a progressively lower subindex reflecting the decreased functional capacity of the wetland. Figure 2 illustrates the relationship between metric values of tree density (V_{TDEN}) and the variable subindex for an example wetland subclass. As shown in the graph, tree densities of 200 to 400 stems/ha represent reference standard conditions, based on field studies, and a variable subindex of 1.0 is assigned for assessment models where tree density is a component. Where tree densities are higher or lower than those found in reference standard conditions, a lesser variable subindex value is assigned.

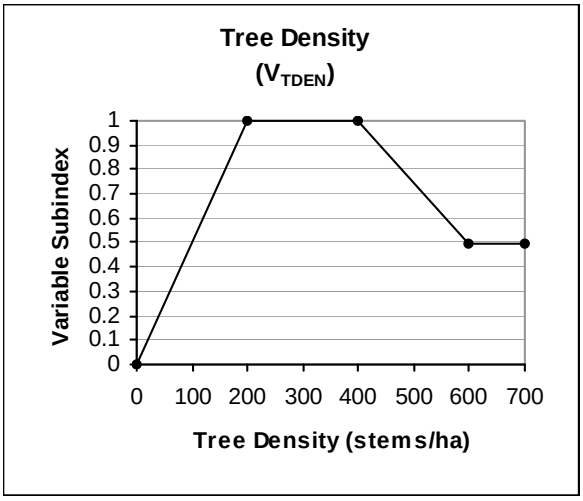


Figure 2. Example subindex graph for the Tree Density (V_{TDEN}) assessment variable for a particular wetland subclass.

Assessment protocol

All of the steps described in the preceding sections concern development of the assessment tools and the rationale used to produce this Regional Guidebook. Although users of the guidebook should be familiar with this process, their primary concern will be the protocol for application of the assessment procedures. The assessment protocol is a defined set of tasks, along with specific instructions, that allows resource professionals to assess the functions of a particular wetland area using the assessment models and functional indices in the Regional Guidebook. The first task includes characterizing the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. The second task is collecting the field data for assessment variables. The final task is an analysis that involves calculation of functional indices. These steps are described in detail in Chapter 6, and the required data sheets, spreadsheets, and supporting digital spatial data are provided in Appendices A through E.

3 Characterization of Wetland Subclasses in the Delta Region of Arkansas

Reference domain

The reference domain for this guidebook (i.e., the area from which reference data were collected and to which the guidebook can be applied) is the Delta Region of Arkansas, which is that portion of the alluvial valley of the Mississippi River that lies within Arkansas, bounded on the west by the Ozark and Ouachita Mountains, the Arkansas River Valley, and the West Gulf Coastal Plain, and on the east by the Mississippi River levee (Figure 3). The area between the Mississippi River and the main-line levee system that controls Mississippi River flooding (commonly called the batture) is not included in the reference domain. Crowley's Ridge, a narrow, elongate remnant coastal plain feature of Tertiary age rising as much as 75 m above the surrounding alluvial terrain in the northeastern part of the Arkansas Delta, also is not included in the reference domain. All references to the Delta Region of Arkansas in this report are intended to reflect the limits on the reference domain as described, and do not include the Mississippi River batture or Crowley's Ridge.

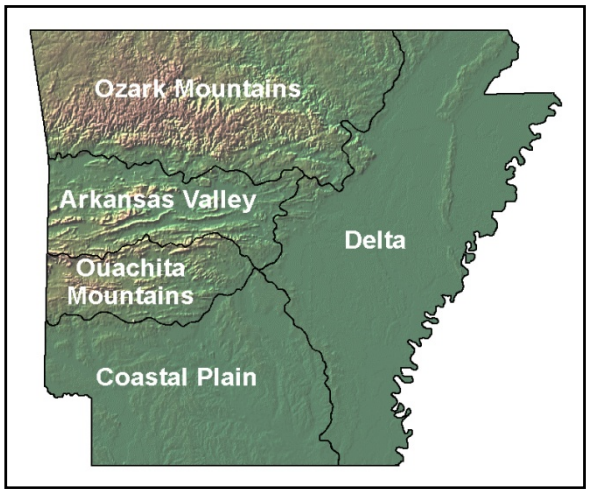


Figure 3. Wetland planning regions of Arkansas.

All of the wetlands within the reference domain are on landforms created by the action of the Mississippi River or its tributaries. In order to classify and assess wetlands in the region, it is important to understand the geology and geomorphology of both the Lower Mississippi Valley as a whole and the Delta Region of Arkansas, as well as the effects of human alterations to that landscape. The following sections review major concepts that have bearing on the classification and functions of wetlands in the modern landscape of the Delta Region of Arkansas. Descriptions of the wetland classes and subclasses that occur in the Delta and guidelines for recognizing them in the field are presented as the final section of this chapter.

Physiography and climate

The Delta Region of Arkansas is part of the Mississippi River Alluvial Valley, which is defined by Saucier (1994) as that portion of the Lower Mississippi Valley that is characterized by landforms and deposits that are primarily of Holocene and Wisconsin age. Certain pre-Wisconsin Pleistocene features of fluvial origin also are included. This definition excludes Crowley's Ridge, but includes the Grand Prairie area in Arkansas. Surface topography within the alluvial valley is defined by the characteristics of a deep alluvial fill that overlies Coastal Plain geologic formations and deeper Paleozoic and older rocks. Except for the mountains in Arkansas, the Lower Mississippi Alluvial Valley is bounded on the east and west by exposures of the Coastal Plain sediments.

Climate within the Delta Region of Arkansas is humid subtropical, with temperate winters and long hot summers. Prevailing southerly winds carry moisture from the Gulf Coast, creating high humidity levels and a high incidence of thunderstorms. Tornadoes and ice storms occur commonly in the area. Daily mean temperatures at Little Rock, on the west-central edge of the Delta Region, range from a low in January of 36.9 °F (2.7 °C) to a high of 81.5 °F (27.5 °C) in July, with an overall annual average of 61.8 °F (16.5 °C). Daily average maximum temperatures are 92.4 °F (33.5 °C) in July and 49.0 °F (9.4 °C) in January. Freezing temperatures reach the entire area for short periods in most years (Brown et al. 1971, Southern Regional Climate Center 2002).

Long-term average total precipitation does not vary greatly within the Delta Region of Arkansas. At Little Rock, the annual average is 50.86 in. (129.18 cm), with the most precipitation falling in April (5.49 in. or 13.94 cm), and the least in August (3.26 in. or 8.28 cm) (Southern Regional Climate Center 2002). Snow or sleet falls in the area in most years, but does not persist. The distribution of precipitation is such that excess moisture is present in the winter and spring months, and frequent soil moisture deficits occur in the months of June through September.

Drainage system and hydrology

The dominant drainage feature of the Mississippi Alluvial Valley is the Mississippi River. The drainage area of the Mississippi River basin is approximately 3,227,000 sq km, which is about 41 percent of the land area of the continental United States (USACE 1973). Major floods on the lower Mississippi River usually originate in the Ohio River basin, and can crest

in any month from January to May. High flows that originate in the upper Mississippi River system generally occur in late spring and early summer (Tuttle and Pinner 1982).

Average flow of the Mississippi River at Vicksburg, MS (which includes the flow from the Arkansas River and its tributaries), is 16,225 cu m/sec (573,000 cfs), and 225 million metric tons (250 million tons) of sediment are transported past that point annually (Bolton and Metzger 1998). Discharges during floods often have been 3 to 4 times the average flow. The 1927 flood peak discharge at Vicksburg was approximately 64,500 cu m/sec (2,278,000 cfs) (Tuttle and Pinner 1982). Seventeen major floods have occurred on the Lower Mississippi River since 1879. This is an average of one major flood every 7 years, but the actual interval between major events has ranged from 1 to 23 years (U.S. Army Engineer Division, Mississippi Valley 1998).

Prior to construction of modern levees, major Mississippi River floods would have inundated about half of the Delta Region of Arkansas (Moore 1972). Although modern mainstem levees generally prevent overbank Mississippi River flooding, they do not completely eliminate the influence of the river on hydrology of the region. High stages on the Mississippi River impede drainage of tributary streams, which results in backwater flooding. Under certain conditions, backwater flooding may be aggravated by levees that block return flows as mainstem water levels fall. Major backwater areas in the Arkansas Delta are in the St. Francis Basin and along the lower Arkansas and White Rivers.

The second-largest stream in the Delta Region is the Arkansas River, which traverses the Delta in a southeasterly direction from Little Rock to its junction with the Mississippi River about 30 km above Arkansas City. There are about 225 km of Arkansas River channel in the Delta, but the vast majority of its 416,000-sq-km drainage basin is outside of Arkansas in Oklahoma, Kansas, Texas, Colorado, and New Mexico (Moore 1972).

Neither the Mississippi River nor the Arkansas receive much direct overland runoff as they traverse the Delta Region because of the effects of both natural and man-made levees. Rather, most of the area drains to those rivers through tributaries that gather runoff within defined basins. The Arkansas Multi-Agency Wetland Planning Team has grouped the Delta drainage basins into Wetland Planning Areas (WPA), which are briefly described in the following paragraphs and illustrated in Figure 4.

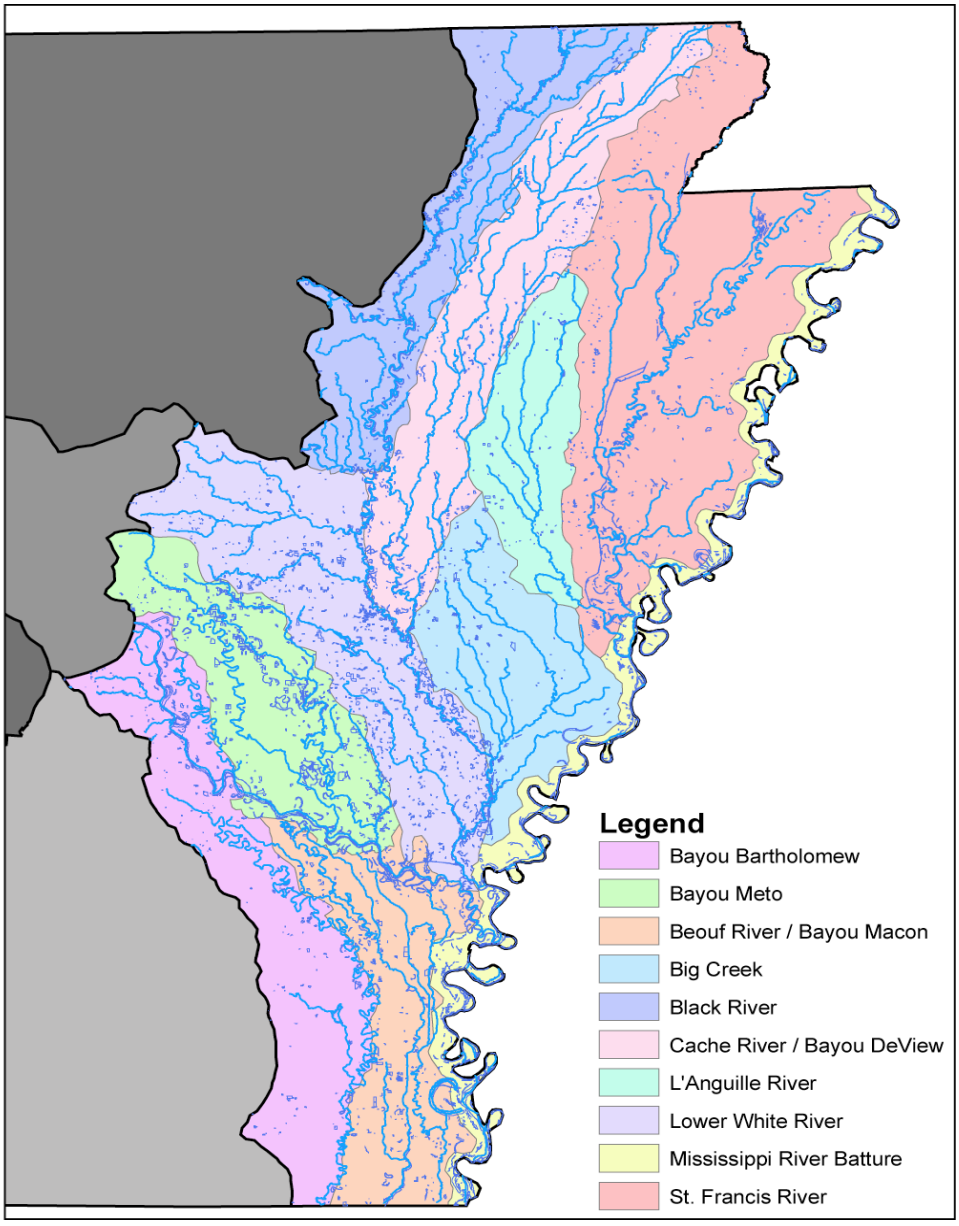


Figure 4. Wetland Planning Areas of the Delta Region of Arkansas.

Streams arising south and west of the Arkansas River occupy the Bayou Bartholomew and Boeuf River/Bayou Macon basins. These areas drain generally southward, eventually discharging to the Mississippi in Louisiana via the Ouachita and Red River systems.

The Bayou Meto basin drains most of the lowlands immediately north and east of the Arkansas River, as well as parts of the Grand Prairie. The principal internal streams are Bayou Meto and Bayou Two Prairie. It is the only major basin within the Delta that discharges directly to the Arkansas River.

Most of the Delta north of the Arkansas River drains to the Mississippi via the White River. The White River arises in the Ozarks and enters the Delta near Newport, then flows generally southward to join the Mississippi in the same vicinity as the confluence of the Arkansas River. The lower White River receives drainage from a variety of small streams on its western flank, including most of the drainage from the Grand Prairie. In addition, there are three other basins (or WPAs) within the Delta that discharge to the White River, and from there to the Mississippi: the Black River, which lies along the flank of the Ozarks and includes the White River above its confluence with the Little Red River; the Cache River/Bayou DeView basin, which lies between the Black River WPA and Crowley's Ridge; and Big Creek, which drains the area between the lower White River and the Mississippi.

The St. Francis River system in northeastern Arkansas arises in southeastern Missouri and empties into the Mississippi River north of Helena. Most of its internal tributaries have been straightened and deepened and incorporated into a massive drainage system. Near the point where the St. Francis discharges into the Mississippi River, it receives the flow of the L'Anguille River WPA, which is a much less altered basin draining the area on the eastern flank of Crowley's Ridge.

Groundwater also is a significant component of the hydrology of the Delta Region of Arkansas. The alluvial aquifer within the Mississippi Alluvial Valley occupies coarse-grained deposits that originated as glacial outwash and from more recent alluvial activity. Generally, the surface of the alluvial aquifer is within 10 m of the land surface, and it is approximately 38 m thick. It is essentially continuous throughout the Mississippi Alluvial Valley. Where the topstratum is made up of coarse sediments or thinly veneered with fine sediments, the alluvial aquifer is recharged by surface waters. Discharge is primarily to stream channels, which contributes to stream baseflow during low-flow periods (Saucier 1994, Terry et al. 1979).

All of the major elements of the drainage system and hydrology of the Delta Region of Arkansas have been modified to varying degrees in historic times. At the time of European settlement, much of the Delta Region of Arkansas was subject to prolonged, extensive ponding following the winter wet season in virtually all years, localized short-term ponding following rains at any time of year, and extensive inundation within tributary floodbasins due to rainfall in headwater areas in most years. During major flood events,

large-scale backwater flooding influenced tributary systems, and complete inundation of much of the basin occurred when Mississippi River stages were high enough to cause overbank flows. The engineering projects and agricultural activities, which have incrementally altered and continue to alter these various sources of wetland hydrology, are described in the Alterations to Environmental Conditions section.

Geology and geomorphology

Development of the Mississippi Alluvial Valley

The first comprehensive discussion of the geology and geomorphology of the Mississippi Alluvial Valley was presented by Fisk (1944). The only major reassessments since that work have been an overview by Autin et al. (1991), and a major synthesis by Saucier (1994). Unless otherwise attributed, the following discussion is derived primarily from the latter source.

The Mississippi Alluvial Valley had its origins in the continental rifting, warping, and uplifting that shaped the Mississippi Embayment, a massive syncline where Paleozoic rocks downwarp as much as 3,000 m. Areas of narrowing and changes in the orientation of the Lower Mississippi Valley reflect areas of uplift in west-central and southern Mississippi, northeastern Louisiana, and southeastern Arkansas. Faulting has occurred at various locations, but the effects are not particularly evident in most instances. However, faulting and uplift have occurred in recent times (Holocene) in the northern portion of the Lower Mississippi Valley in the area known as the New Madrid Earthquake Zone. Some of the more dramatic effects of this activity can be seen in the Reelfoot Lake area of western Tennessee, but some surface features in northeastern Arkansas also can be traced to tectonic activity, particularly the series of earthquakes that occurred in 1811–1812. Extensive “sand blows,” streambank caving, and stream channel realignments have been attributed to those events, as well as a probable deepening of the swamps in the Big Lake region of the St. Francis Basin (Saucier 1994).

The modern valley is, for the most part, bounded by Tertiary and Mesozoic sediments of the Gulf Coastal Plain (Autin et al. 1991), although the major part of the western valley wall in Arkansas is made up of older (Paleozoic) rocks, as is Crowley’s Ridge (Saucier 1994). Crowley’s Ridge, portions of the uplands forming the western valley wall, and many of the older (Pleistocene) fluvial surfaces within the Delta are blanketed with multiple

layers of wind-blown fine silts (loess) that originated in the glacial outwash carried down the Mississippi Valley during waning Pleistocene glacial cycles.

Although the Lower Mississippi Valley developed as a result of the downwarping of Paleozoic rocks and confinement by uplifted surfaces, the characteristics of the existing landscape were shaped largely by erosion and deposition processes. By the end of the Tertiary period, the downwarped surface had been largely filled by sediments transported from the north and upland flanks to the east and west. The ancestral Mississippi River was established in a valley smaller than the present, the source area (drainage area) was smaller than it is now, and the river had lower discharge. Pleistocene glaciation enlarged the drainage area of the river by diverting formerly north-flowing rivers into the Mississippi system. Over an estimated 2.8 million years, periods of waxing and waning glaciation and associated changes in flows, sediment loads, and base level gradually produced a wider valley filled with thick alluvium, with the Mississippi and Ohio Rivers flowing on opposite sides of Crowley's Ridge and converging somewhere south of present-day Helena, Arkansas. This general configuration was maintained until late in the Wisconsin stage, when the Mississippi shifted east of the Ridge and the Ohio became confluent farther north.

Two fundamentally different fluvial regimes have shaped the principal landscape features of the Arkansas Delta in approximately equal proportions. Most of the northern half of the delta is made up of landforms that resulted from multiple glacial outwash events during Wisconsin glacial cycles. These areas usually exhibit surface features characteristic of braided-stream depositional environments, such as relict braid bars and gathering channels, although those features may be obscured by later alluvial or wind-blown deposits. Land surfaces in the delta established at various other times during the Pleistocene and Holocene eras are composed primarily of meandering-river depositional features (Figure 5).

Remnants of pre-Wisconsin Arkansas and Mississippi River meander belts remain in the delta as high terraces, primarily along the southwestern valley wall and as the extensive terrace peninsula known as the Grand Prairie. There are also much later, lower elevation Wisconsin-age alluvial terraces along the southern margin of the Grand Prairie and adjacent to the Cache River. All of the alluvial terraces are characterized by features such as relict meandering channel segments, rather than the braided

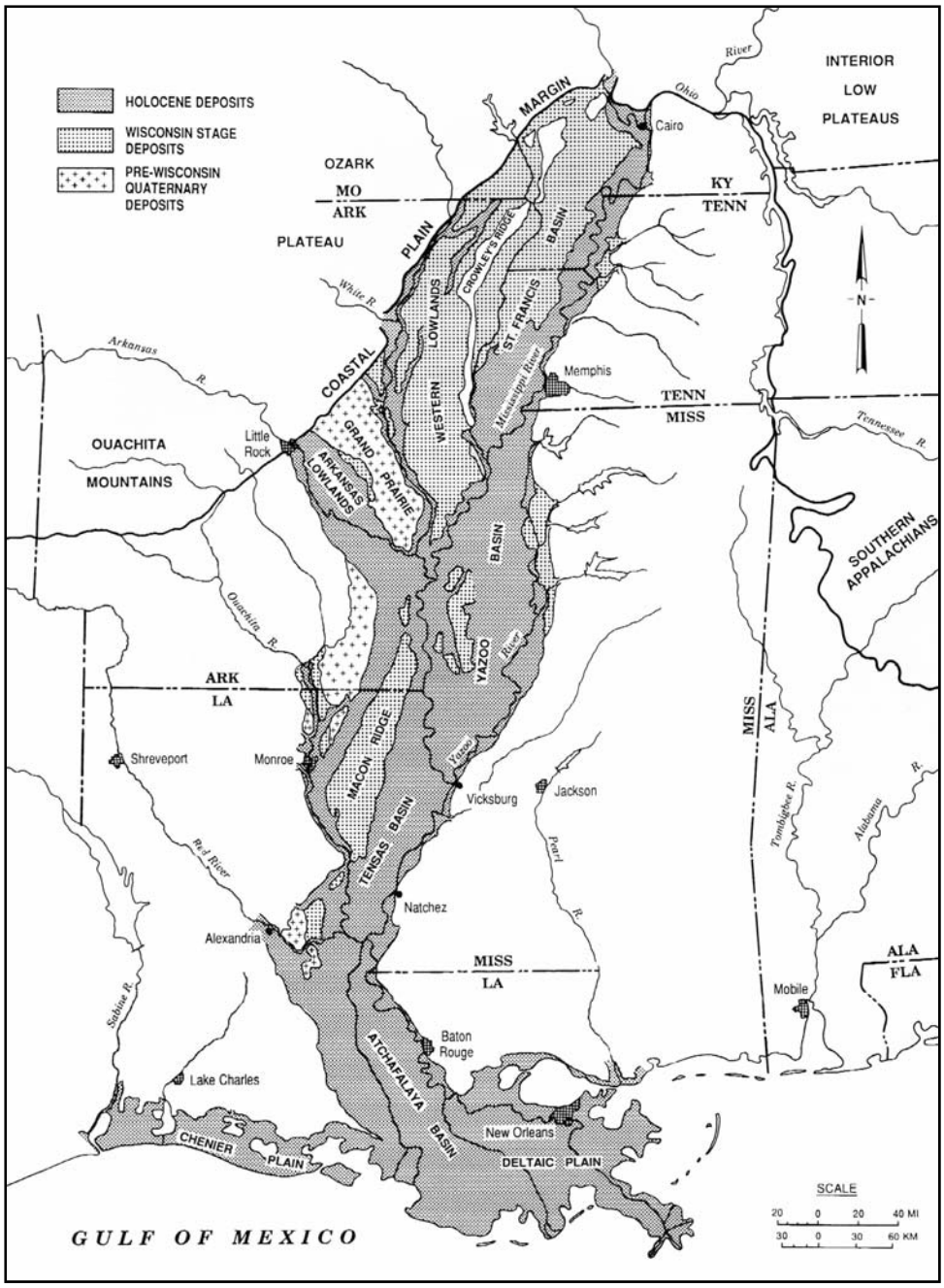


Figure 5. Distribution of the principal Quaternary deposits in the Lower Mississippi River Alluvial Valley (adapted from Saucier (1994)).

channels of the outwash or "valley train terraces," although the Wisconsin-age alluvial terraces tend to have larger meander features and thicker alluvial deposits because they formed during periods of much higher flows. A third major set of meandering-stream floodplain features was created after glacial outwash deposition ceased within the Lower Mississippi Alluvial Valley at the beginning of the Holocene epoch about 10,000 years ago. Sea level variation continued to influence depositional processes in

the southernmost parts of the valley, but in the central and northern portions of the valley all Holocene alluvial surfaces have been the result primarily of meandering stream processes. The Mississippi and Arkansas Rivers and various smaller streams have reworked portions of the glacially deposited material within broad meander belts, and the larger streams have relocated and established new meander belts at various times.

Within its meander belts, the Mississippi River has removed the pre-Holocene glacial outwash to an average depth of about 30 m (the average depth of the river channel), and replaced it with a complex of depositional features that includes abandoned stream channels, abandoned stream courses, point bar deposits, and natural levees. The current meander belt extends into the Arkansas Delta about 5 to 30 km from the river channel, and it has been occupied and carrying the full flow of the Mississippi River for about 2000 years. Smaller remnants of several older meander belts also remain in the Arkansas Delta, primarily east of Crowley's Ridge. Segments of various smaller streams, such as the L'Anguille River and Big Creek, now occupy portions of the former Mississippi River channels (abandoned courses) that remain within the older meander belts.

Multiple meander belts of the Arkansas River and intervening backswamps dominate the landscape of the Arkansas Delta south of the Grand Prairie. The backswamps and abandoned Arkansas River courses between Grand Prairie and the modern river now carry streams such as Plum Bayou and Bayou Meto. At various times in the past, the Arkansas flowed more directly southward into Louisiana, and remnants of those meander belts are currently occupied by Bayou Bartholomew and several smaller streams.

Geomorphic features of the Delta Region of Arkansas

The combination of meandering-stream processes and glacial outwash events has resulted in distinctive landforms that have been mapped in considerable detail throughout the valley (Figure 6 and Appendix E). Within the Delta Region of Arkansas, these landforms are categorized as valley trains (comprising all outwash features), and a suite of features created by meandering streams (backswamps, point bars, abandoned channels, abandoned courses, and natural levees) that are distinctive within the Holocene meander belts, but muted on the older Pleistocene alluvial terrace surfaces (Figure 7) (Kolb et al. 1968; Saucier 1994). Each of these landforms is discussed in the following paragraphs.

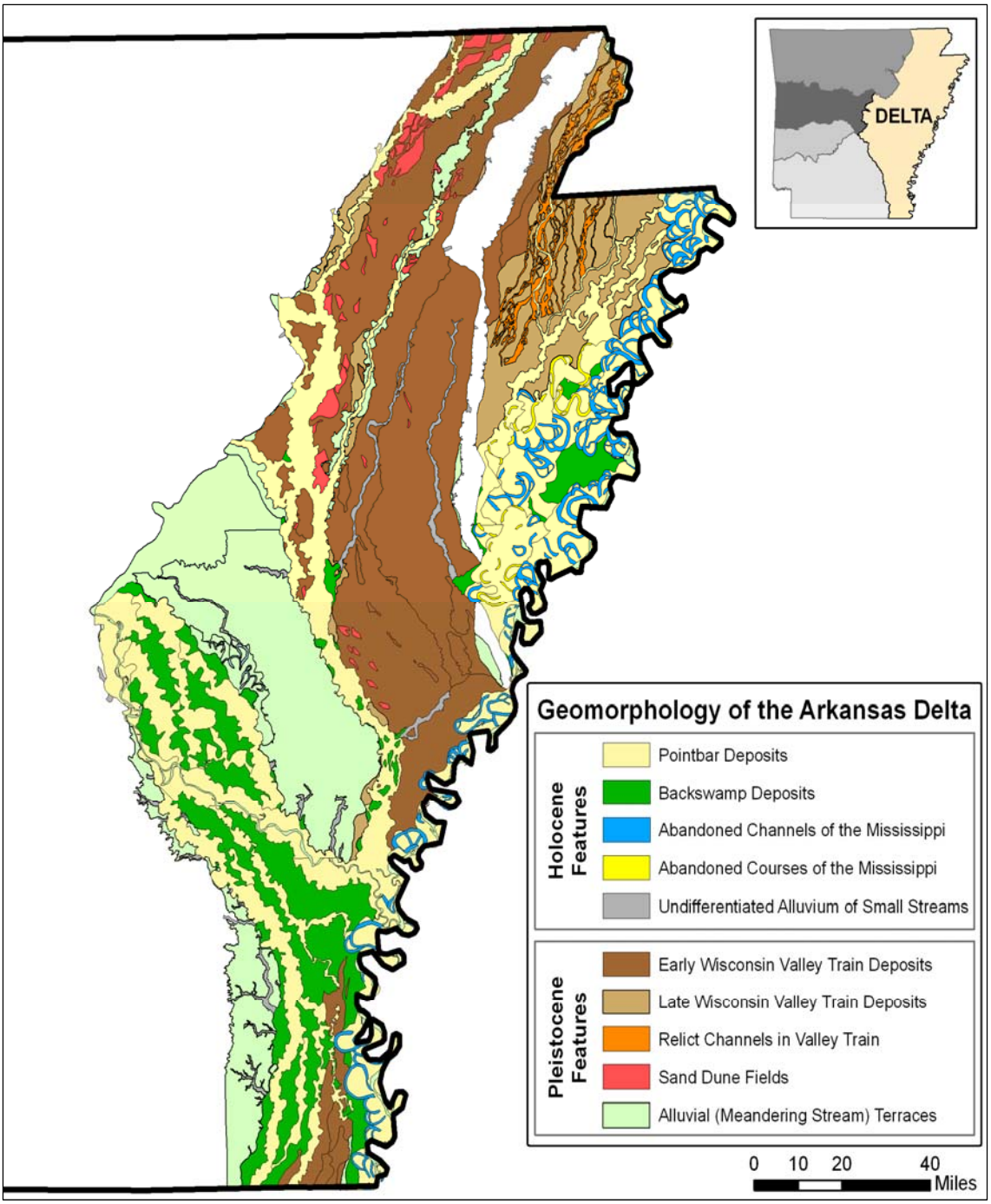


Figure 6. Distribution of the principal Quaternary deposits in the Delta Region of Arkansas (adapted from Saucier (1994)). The unlabeled inclusion is Tertiary upland (Crowley's Ridge).

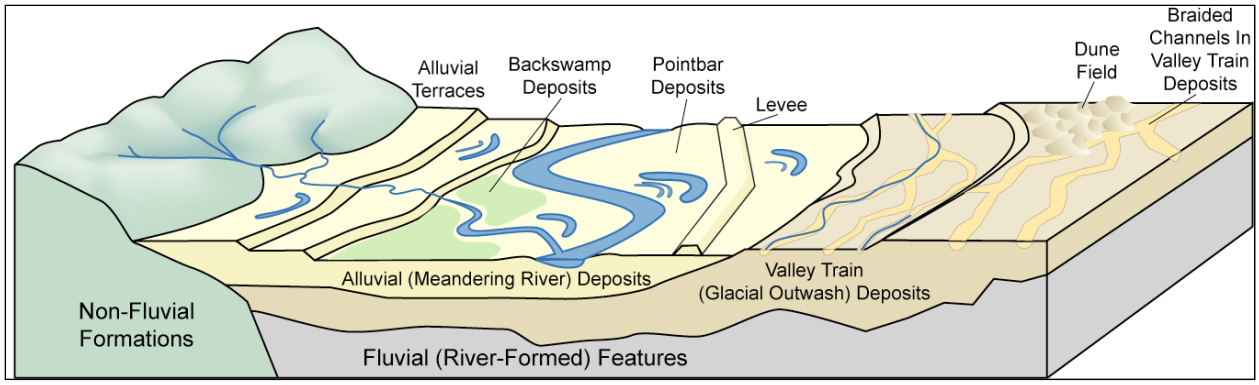


Figure 7. Principal geomorphic settings and features of the Delta Region of Arkansas.

Valley trains. Glacial outwash deposits have been episodically flushed into the Lower Mississippi Valley by the Mississippi and Ohio Rivers for more than a million years, and much of the valley fill underlying the Arkansas Delta is outwash. However, the outwash deposits that are present at the surface, generally termed *valley train* deposits, are the result of events during the various stages of Wisconsin glaciation, which spanned a period ranging from about 80,000 to 10,000 years ago. They dominate the Arkansas Delta north of the latitude of Memphis.

Valley trains consist of massive, coarse-grained deposits of relatively unsorted material deposited in a braided-stream environment. They are distinctive in that the ancient braided-stream channels are present and often recognizable at the surface. The topstratum of valley train deposits is a layer up to 3 m thick of predominantly fine-grained material that forms a continuous blanket across the relict braided channels and interfluves. The topstratum may include materials laid down during waning stages of glacial outwash deposition, loess, and slackwater overbank deposits from later Mississippi River meander belts. Other than this relatively fine-grained surface veneer, the braided channel systems on valley trains, both near-surface and at depth, tend to be filled with coarse sands deposited as flows waned in a particular channel segment. This distinguishes valley train channels from abandoned channel segments in the Holocene meander belts of the Mississippi and Arkansas Rivers, which are typically filled with clays.

There are several distinct valley train terraces in Arkansas, the oldest and highest Early Wisconsin deposits standing 10 m or more above the modern floodplain surface, while the youngest Late Wisconsin deposits are approximately contiguous with the adjacent Holocene meander belts. The remnant outwash channels are clearly visible on aerial photos on the youngest

surface, east of Crowley's Ridge, and have been mapped (Figure 8). On older valley train surfaces, outwash channels are obscured to varying degrees or have been captured by modern stream systems, but linear depressions and parallel drainage patterns remain as remnants of the Pleistocene surface channel systems.

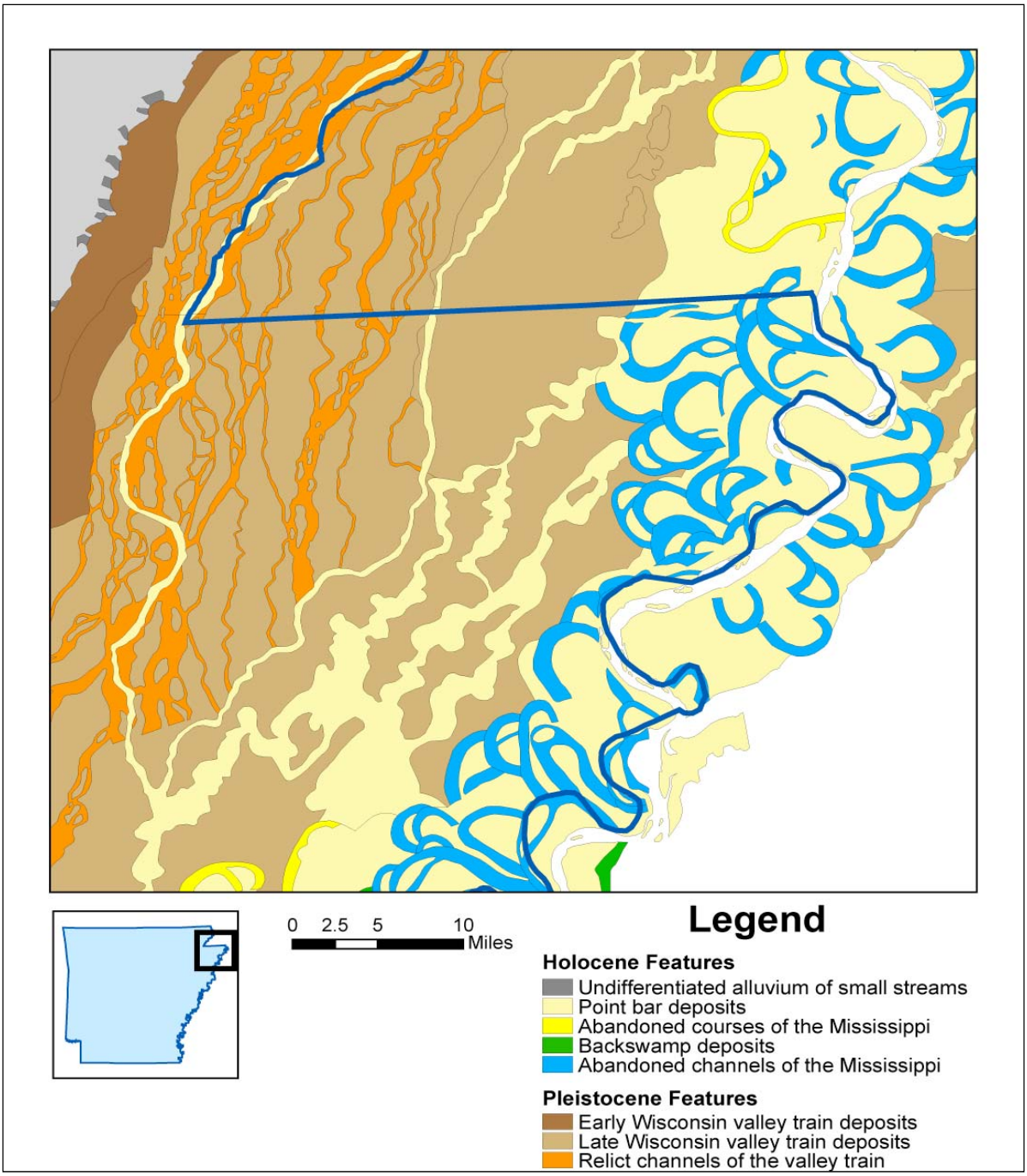


Figure 8. Geomorphic features of the Delta Region in Arkansas and parts of adjacent states, contrasting braided-stream Pleistocene outwash channels (left) and meandering-stream Holocene features (right) (adapted from Saucier (1994)).

Certain valley train surfaces are covered with extensive dunefields, made up of wind-blown sands deflated from Late Wisconsin outwash channels and deposited on the adjacent, older valley train terraces (Figures 6 and 7). These dunefields are unique to the Arkansas Delta Region of the Lower Mississippi Valley. Wind-blown silts (loess) from these and earlier outwash channels blanket much of the valley train surface in the Delta.

Backswamps. Backswamps are flat, poorly drained areas bounded by uplands and/or other features such as natural levees. In the Arkansas Delta, they are associated mostly with the multiple meander belts of the Mississippi River and especially the Arkansas River. Because sedimentation rates are highest along the active stream channel, meander belts tend to develop into an alluvial ridge, where elevations are higher than the adjacent floodplain. The result is that local drainage is directed away from the major stream channel, and the areas between meander belts become basins (backswamps) that collect runoff, pool floodwaters, and accumulate fine sediments. Backswamp environments in the Delta are underlain by coarse glacial outwash, but surface deposits are fine-grained sediments that were slowly deposited in slack-water conditions. Thus, under unmodified conditions, backswamps characteristically have substrates of massive clays, and are incompletely drained by small, sometimes anastomosing streams. They may include large areas that do not fully drain through channel systems but remain ponded well into the growing season. In much of the Mississippi Alluvial Valley, backswamp deposits are 12 m thick or more.

Note that sites mapped as valley train and backswamp have essentially the same sequence of deep, coarse glacial outwash overlain by fine-grained slackwater deposits. The basis for separating them as map units is the thickness of the fine-grained deposits – they are mapped as backswamp where the surface deposits are sufficiently thick to obscure the braided channel pattern on the valley train surface. On valley trains, surface deposits (other than those from historic erosion) are typically older and thinner and occupy better drained landscape positions than similar fine-grained deposits of backswamps.

Figures 7 and 9 illustrate typical locations of backswamps and other Holocene meander belt features relative to an active stream channel.

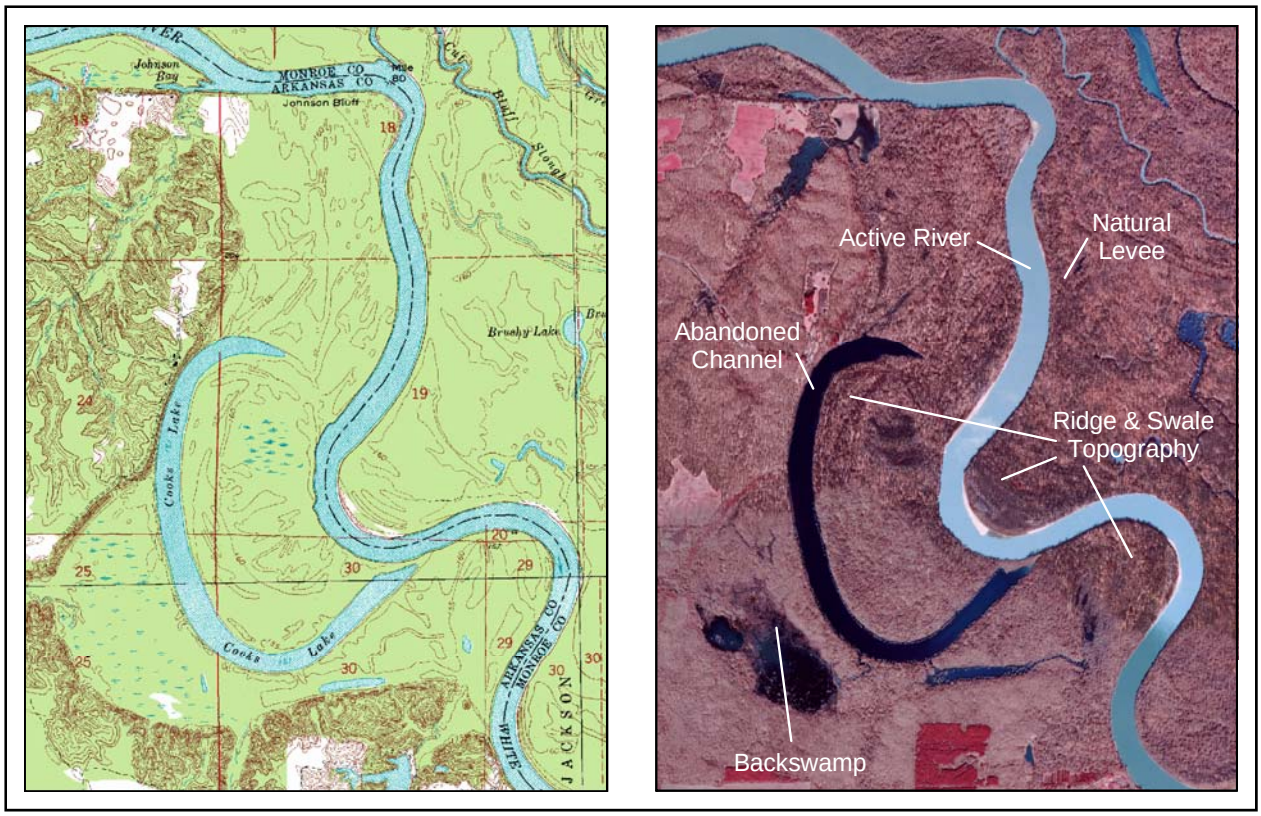


Figure 9. Topographic map and photomosaic showing typical geomorphic features of the Holocene meander belt of the lower White River. The higher terrain west of the river is part of the Grand Prairie Pleistocene alluvial terrace

Point bars. Point bar deposits predominate within the Holocene meander belts in the Arkansas Delta. They generally consist of relatively coarse-grained materials (silts and sands) laid down on the inside (convex) bend of a meandering stream channel. The rate at which point bar deposition occurs and the height and width of individual deposits vary with sediment supply, flood stage, and other factors. The result is a characteristic pattern of low arcuate ridges separated by swales ("ridge and swale" or "meander scroll" topography). Point bar swales range from narrow and shallow to broad and deep, and usually are closed at each end to form depressions. The scale and depth of point bar swales depend on the depositional environment that formed the adjacent ridges and the degree of sedimentation within the swale since it formed.

Abandoned channels. These features are the result of cutoffs, where a stream abandons a channel segment either because flood flows have scoured out a point bar swale and created a new main channel (chute cutoff), or because migrating bendways intersect and channel flow moves through the neck (neck cutoff). Chute cutoffs tend to be relatively small

and to fill rapidly with sediment. They do not usually form lakes, but may persist as large depressions. The typical sequence of events following a neck cutoff (which is much more common than a chute cutoff) is that the upper and lower ends of the abandoned channel segment quickly fill with coarse sediments, creating an open oxbow lake (Figures 7 and 9). Usually, small connecting channels (batture channels) maintain a connection between the river and the lake, at least at high river stages, so river-borne fine-grained sediments gradually fill the abandoned channel segment. If this process is not interrupted, the lake eventually fills completely, the result being an arcuate swath of cohesive, impermeable clays within a better drained point bar deposit. Often, however, the river migrates away from the channel segment and the hydraulic connection is lost, or the connection is interrupted by later deposition of point bar or natural levee deposits. In either case, the filling process is dramatically slowed, and abandoned channel segments may persist as open lakes or depressions of various depths and dimensions.

Abandoned courses. An abandoned course is a stream channel segment left behind when a stream diverts flow to a new meander belt (Figure 8). Abandoned course segments can be hundreds of miles long, or only short segments may remain where the original course has been largely obliterated by subsequent stream activity. There are a variety of possible fates for abandoned courses. In some cases, they are captured by smaller streams, which meander within the former channel and develop their own point bars and other features. For example, within the Arkansas Delta, parts of the L'Anguille River and several smaller streams now flow within abandoned courses of the Mississippi River, and much of Bayou Macon and Bartholomew Bayou occupy abandoned courses of the Arkansas River. Where the stream course is abandoned gradually, the remnant stream may fill the former channel with point bar deposits even as its flow declines. Thus, while abandoned channels often become depressions with heavy soils, abandoned courses are more likely to be fairly continuous with the point bar deposits of the original stream, or to become part of the meander belt of a smaller stream.

Natural levees. A natural levee forms where overbank flows result in deposition of relatively coarse sediments (sand and silt) adjacent to the stream channel. The material is deposited as a continuous sheet that thins with distance from the stream, resulting in a relatively high ridge along the bankline and a gradual backslope that becomes progressively more fine-

grained with distance from the channel (Figure 7). Along the modern Mississippi River, natural levees rise about 4.5 m above the elevation of the adjacent floodplain and may extend for several kilometers or more from the channel. Natural levees formed by smaller streams or over short periods of time tend to be proportionately smaller, but the dimensions and composition of natural levee deposits are the product of various factors, including sediment sources and the specific mode of deposition. Natural levees may be deposited in association with sheetflow or as a series of crevasse splays, which are deltaic deposits formed by small channels that breach the existing natural levee during high flows.

A different type of crevasse splay occurs where man-made levees have been breached during major floods. These splays may be very extensive; have an irregular, hummocky surface; and are composed of very coarse sediments. They are the result of very high velocity flows, because the initial levee break releases water that has a surface elevation much higher than the adjacent land surface. Often the point at which the levee failed is marked by a deep scour pool, commonly called a “blue hole.”

Soils

Parent materials of soils in the Delta Region of Arkansas are fluvial sediments. The alternating periods of meander belt development and glacial outwash deposition produced complex but characteristic landforms where sediments were sorted to varying degrees based on their mode and environment of deposition. The sorting process has produced textural and topographic gradients that are fairly consistent on a gross level and result in distinctive soils. Generally, within a Holocene meander belt, surface substrates grade from relatively coarse-textured, well-drained, higher elevation soils on natural levees directly adjacent to river channels through progressively finer textured, and less well-drained materials on levee backslopes and point bar deposits to very heavy clays in closed basins such as large swales and abandoned channels. Backswamp deposits between meander belts also are filled with heavy clays. Valley train deposits typically have a topstratum (upper 0.2–3 m) of fine-grained material (clays and silts) that blankets the underlying network of braided channels and interfluves. On older, higher valley train deposits, the topstratum contains considerable loess, and in some areas consists of sandy dunes. The lowest, most recent valley trains have surface soils that are derived primarily from Mississippi River flooding (Brown et al. 1971, Saucier 1994).

The gradient of increasingly fine soil textures from high-energy to low-energy environments of deposition (natural levees and point bars to abandoned channels and backswamps) implies increasing soil organic matter content, increasing cation exchange capacity, and decreasing permeability. However, all of these patterns are generalizations, and quite different conditions occur regularly. The nature of alluvial deposition varies between and within flood events, and laminated or localized deposits of varying textures are common within a single general landform. Thus, natural levees dominated by coarse-textured sediments may contain strata with high clay content, and valley train surfaces that are usually fine-grained may have some soil units with high sand content. Point bar deposits, which typically have less organic matter incorporated into the surface soils than backswamps or abandoned channels, may actually contain more total organic matter on a volume basis due to the presence of large numbers of buried logs and other stream-transported organic material (Saucier 1994).

Within the Holocene meander belts, soils of older meander belts are likely to show greater A soil horizon development than soils in equivalent positions within younger meander belts (Autin et al. 1991). Similarly, older soils are likely to be more acidic and deeper, show less depositional stratification and more horizonation, and otherwise exhibit characteristics of advanced soil development not seen in soils of younger meander belts. The classification of soils in the region reflects the importance of soil age and related development at the highest classification level (Soil Order). Alfisols are the oldest and most developed soils, Entisols the most recent deposits with the least development, and Inceptisols are of intermediate age and development. At the Suborder level, degree of wetness is a major classification factor, and at lower levels of classification the characteristics of specific soil horizons are among the principal discriminating factors. A brief overview of the principal soil associations within the Delta Region of Arkansas is presented in Table 4.

It should be noted that the classification of soils within the Lower Mississippi Valley has been undergoing considerable modification recently. However, the existing soil surveys do not reflect these changes; therefore, the classification and terminology used in this discussion remain consistent with the existing published resources. Detailed updated digital soils maps are provided in Appendix E. Individual soil series descriptions can be found on the Web at http://soils.usda.gov/technical/classification/scfile/index.html.

Table 4. Classification of the principal soil associations of the Delta Region of Arkansas.

Map Units	Principal Landscape Settings Within the Delta	Characteristics
Alfisols: Soils that are medium to high in bases and have gray to brown A horizons and B horizons of clay accumulation.		
DeWitt-Stuttgart	Pleistocene Alluvial Terraces (Prairie Complex).	Deep, somewhat poorly drained and moderately well drained, very slowly permeable, level to gently sloping, silty or clayey soils of the Grand Prairie.
Loring	Pleistocene Alluvial Terraces (Prairie Complex).	Deep, moderately well-drained, moderately slowly permeable, nearly level to moderately steep loamy soils of the Grand Prairie.
Foley-Jackport-Overcup	Valley Trains and Pleistocene Alluvial Terraces adjacent to the Cache River.	Deep, poorly drained and somewhat poorly drained, very slowly permeable, level to nearly level, loamy and clayey soils.
Calloway-Henry-Grenada-Calhoun	Pleistocene Valley Trains and Prairie Complex Terraces.	Deep, moderately well drained to poorly drained, slowly permeable, level to moderately sloping, loamy soils of older valley train deposits and prairie terraces
Dundee-Bosket-Dubbs	Pleistocene Valley Trains and dunefields.	Deep, somewhat poorly drained and well drained, moderately slowly permeable and moderately permeable, level to gently sloping, loamy soils.
Amagon-Dundee	Natural levees within Holocene meander belts of the White, Black, St. Francis, and other tributaries to the Mississippi River.	Deep, poorly drained and moderately poorly drained, slowly permeable and moderately slowly permeable, level to nearly level, loamy soils on bottom lands.
Rilla-Hebert	Natural levees within Holocene meander belts of the Arkansas River.	Deep, well-drained and somewhat poorly drained, moderately permeable and moderately slowly permeable, level to gently sloping soils on bottomlands.
Inceptisols: Soils that have weakly differentiated horizons; materials in the soil have been altered or removed but have not accumulated.		
Sharkey-Alligator-Tunica	Backswamp deposits within Holocene meander belts of the Mississippi River.	Deep, poorly drained, very slowly permeable, level to nearly level soils on bottomlands.
Sharkey-Steele	Point bar and backswamp deposits within Holocene mender belts of the St. Francis River.	Deep, poorly drained and moderately well drained, very slowly permeable, level to nearly level, clayey and sandy soils on broad flats and undulating areas of floodplains.
Kobel	Backswamp deposits within Holocene meander belts of the White, Black, St. Francis, and other tributaries to the Mississippi River.	Deep, poorly drained, very slowly permeable, level to nearly level, clayey soils on bottomlands.
Perry-Portland	Backswamp deposits within Holocene meander belts of the Arkansas River.	Deep, poorly drained and somewhat poorly drained, very slowly permeable, level to nearly level soils on bottomlands.
Roxanna-Dardanelle-Bruno-Roellen	Various environments of deposition within the modern meander belt of the Arkansas River.	Deep, excessively drained to poorly drained, rapidly permeable to slowly permeable, level to nearly level, loamy, sandy, and clayey soils.
Entisols: Soils that have little or no evidence of development of pedogenic horizons.		
Crevasse-Bruno-Oklared	Various environments of deposition within the modern meander belt of the Arkansas River.	Deep, excessively drained and well-drained, rapidly permeable and moderately rapidly permeable, sandy and loamy soils.
Commerce- Sharkey-Crevasse-Robinsonville	Various environments of deposition within the modern meander belt of the Mississippi River.	Deep, poorly drained to excessively drained, very slowly permeable to rapidly permeable, level to gently undulating, clayey, loamy, and sandy soils.
Note: Based on Saucier 1994; U.S. Department of Agriculture National Resources Conservation Service, Soil Survey Division (2002); U.S. Department of Agriculture Soil Conservation Service and Mississippi Agricultural and Forestry Experiment Station (1974); U.S. Department of Agriculture Soil Conservation Service and University of Arkansas Agricultural Experiment Station (1982).		

Vegetation

The Delta Region of Arkansas is in the west-central portion of the Mississippi Alluvial Plain Ecoregion (Omernik 1987; USEPA 1998). It is included in the Mississippi Alluvial Plain Section of the Southeastern Evergreen Forest Region by Braun (1950), and is classified as the Southern Floodplain Forest Type by Kuchler (1969). Forests of the basin are referred to as bottomland hardwoods, a term that incorporates a wide range of species and community types that can tolerate inundation or soil saturation for at least some portion of the growing season (Wharton et al. 1982).

Bottomland hardwood forests are among the most productive and diverse ecosystems in North America. Under presettlement conditions they were essentially continuous throughout the Lower Mississippi Valley, and they interacted with the entire watershed, via floodwaters, to import, store, cycle, and export nutrients (Brinson et al. 1980, Wharton et al. 1982). Although these conditions have changed dramatically in modern times (see following section, "Alterations to Environmental Conditions"), the remaining forests still exist as a complex mosaic of community types that reflect variations in alluvial and hydrologic environments. Within-stand diversity varies from dominance by one or a few species to forests with a dozen or more overstory species, and diverse assemblages of understory, ground cover, and vine species (Klimas 1988, Putnam 1951, Wharton et al. 1982). These forests support a detritus-based trophic network that includes numerous resident and migratory wildlife species that are adapted to the highly dynamic and diverse environment (Fredrickson 1978, Wharton et al. 1982).

Most major overviews of bottomland hardwood forest ecology emphasize the relationship between plant community distribution and inundation, usually assuming that floodplain surfaces that occupy different elevations in relation to a river channel reflect different flood frequency, depth, and duration (e.g., Brinson et al. 1981; Larson et al. 1981; Wharton et al. 1982). This leads to classification of forests in terms of hydrologic "zones," each zone having characteristic plant communities. In most cases, the authors employing zonal classification systems acknowledge that parallel bands of vegetation rarely exist, and that most floodplains are geomorphically complex and support mosaics of communities. Nevertheless, zonal characterization systems generally reference most sites to a presumed stream entrenchment process that leaves a sequence of terraces, and they often regard features such as natural levees as relatively minor components of the landscape (e.g., Larson et al. 1981). A certain degree of such

sequential zonation relative to flood frequency occurs in some major stream drainages within the Mississippi Alluvial Valley, such as the Cache River in Arkansas (Smith 1996). However, zonal concepts have limited utility in much of the Arkansas Delta where Pleistocene landforms and multiple abandoned Holocene meander belts dominate the landscape. In addition, features such as natural levees and abandoned channels, which may be rather minor components of some southeastern floodplains, are major deposits that occupy thousands of square kilometers in the Delta Region of Arkansas. In much the same way, the general zonal models imply that the principal hydrologic controls on community composition are flood frequency, depth, and duration, as indicated by elevation relative to a stream channel. However, stream flooding is just one of many important sources of water in the wetlands of the Arkansas Delta, and factors such as ponding of precipitation may be more important than flooding effects in many landscape settings.

Despite the complexity of the landscape and the misleading nature of zonal models of plant community distribution, plant communities do occur on recognizable combinations of site hydrology and geomorphology within the Delta Region of Arkansas. The synthesis documents of Putnam (1951) and Putnam et al. (1960) adopt a perspective that recognizes the unique terrain of the Mississippi Alluvial Valley, and summarize the principal combinations of landscape setting, drainage characteristics, and flood environment as they influence plant community composition. Table 5 is based on that approach. Table 6 equates Putnam's (1951) community types with corresponding community designations in the most commonly referenced forest classification system, the Society of American Forester (SAF) cover types (Eyre 1980).

Under natural conditions, forest stands within the Delta Region of Arkansas undergo change at various temporal and spatial scales. Primary succession occurs on recently deposited substrates, which include abandoned stream channels, point bars, crevasse splays, and abandoned beaver ponds. One familiar example is the colonization of new bars adjacent to river channels by pioneer species such as black willow (*Salix nigra*), which are replaced over time by other species such as sugarberry (*Celtis laevigata*) and green ash (*Fraxinus pennsylvanica*), and eventually by long-lived, heavy-seeded species such as oaks and hickories (Meadows and Nowacki 1996; Putnam et al. 1960). Although this sequential replacement does occur, it is actually a complex process that includes changes in the elevation and composition of

Table 5. Composition and site affinities of common forest communities in the Delta Region of Arkansas (after Putnam (1951)).

Forest Cover Type	Characteristic Species	Site Characteristics
Sweetgum - Water Oaks	*Liquidambar styraciflua* *Quercus nigra* *Quercus nuttallii* *Quercus phellos* *Ulmus americana* *Celtis laevigata* *Fraxinus pennsylvanica*	In first bottoms except for deep sloughs, swamps, fronts, and poorest flats. Also on terrace flats.
White Oaks - Red Oaks - Other Hardwoods	*Quercus michauxii* *Quercus similis* *Quercus pagoda* *Quercus shumardii* *Quercus falcata* var. *falcata* *Fraxinus americana* *Carya* spp. *Nyssa sylvatica* *Ulmus alata*	Fine, sandy loam and other well-drained soils on first bottom and terrace ridges.
Hackberry - Elm - Ash	*Celtis laevigata* *Ulmus americana* *Fraxinus pennsylvanica* *Carya aquatica* *Quercus phellos*	Low ridges, flats, and sloughs in first bottoms, terrace flats, and sloughs. Occasionally on new lands or fronts.
Overcup Oak - Water Hickory	*Quercus lyrata* *Carya aquatica*	Poorly drained flats, low ridges, sloughs, and backwater basins with tight soils.
Cottonwood	*Populus deltoides* *Carya illinoensis* *Platanus occidentalis* *Celtis laevigata*	Front land ridges and well-drained flats.
Willow	*Salix nigra*	Front land sloughs and low flats.
Riverfront Hardwoods	*Platanus occidentalis* *Carya illinoensis* *Fraxinus pennsylvanica* *Ulmus americana* *Celtis laevigata* *Acer saccharinum*	All front lands except deep sloughs and swamps.
Cypress - Tupelo	*Taxodium distichum* *Nyssa aquatica* *Nyssa sylvatica* var. *biflora*	Low, poorly drained flats, deep sloughs, and swamps in first bottoms and terraces.

Table 6. Correspondence between forest cover types in the Delta Region of Arkansas (Putnam 1951) and Standard Society of American Foresters Forest Cover Types.

SAF Forest Cover Types	Type No.	Putnam's Cover Type
Cottonwood	63	Cottonwood
Willow Oak - Water Oak - Diamondleaf (Laurel) Oak	88	Sweetgum - Water Oaks
Swamp Chestnut Oak- Cherrybark Oak	91	White Oaks - Red Oaks - Other Hardwoods
Sweetgum – Willow Oak	92	Sweetgum - Water Oaks
Sugarberry - American Elm - Green Ash	93	Hackberry - Elm – Ash
Sycamore - Sweetgum - American Elm	94	Riverfront Hardwoods
Black Willow	95	Willow
Overcup Oak - Water Hickory	96	Overcup Oak - Bitter Pecan
Baldcypress	101	Cypress – Tupelo
Baldcypress - Tupelo	102	Cypress – Tupelo
Water Tupelo - Swamp Tupelo	103	Cypress – Tupelo

the substrate as colonizing plants and flood flows interact to induce sedimentation, and on a longer term scale, as soils mature and river channels migrate away from the site and cease delivering new sediments. In the Arkansas Delta, creation and colonization of new point bars are limited because many streams have been channelized or their banks have been stabilized, both of which reduce channel migration and recruitment of sediments.

The typical natural regeneration process in established forest stands is initiated by single tree-falls, periodic catastrophic damage from fire or windstorm, and inundation mortality due to prolonged growing-season floods or beaver dams. Small forest openings occur due to windthrow, disease, lightning strikes, and similar influences that kill individual trees or small groups of trees (Dickson 1991). The resulting openings are rapidly colonized, but the composition of the colonizing trees may vary widely depending on factors such as existing advanced reproduction, seed rain from adjacent mature trees, and importation of seed by animals or floodwaters. Often, this pattern results in small, even-aged groves of trees, sometimes of a single species (Putnam et al. 1960).

In presettlement conditions, fire may have been a significant factor in stand structure, but the evidence regarding the extent of this influence is unclear. Putnam (1951) stated that southern bottomland forests experience a "serious fire season" every 5–8 years, and that fires typically destroy much

of the understory and cause damage to some larger trees, which eventually provides points of entry for insects and disease. Similarly, it is difficult to estimate the influence of beaver in the presettlement landscape, because they were largely removed very early in the settlement process. However, it is likely that the bottomland forest ecosystem included extensive areas that were affected by beaver and were dominated by dead timber, open water, marsh, moist soil herbaceous communities, or shrub swamp at any given time.

Alterations to environmental conditions

The physical and biological environment of the Delta Region of Arkansas has been extensively altered by human activity. Isolation and stabilization of the Mississippi and Arkansas Rivers have effectively halted the large-scale channel migration and overbank sediment deposition processes that created and continually modified the Holocene landscapes of the Arkansas Delta (Smith and Winkley 1996). At the same time, sediment input to depressions and sub-basins within the area has increased many-fold in historic times due to erosion of uplands and agricultural fields (Barnhardt 1988, Saucier 1994, Smith and Patrick 1991). The Mississippi River no longer overwhelms the landscape with floods that course through the basin, but it continues to influence large areas through backwater flooding. Patterns of land use and resource exploitation have had differential effects on the distribution and quality of remaining forest communities. Assessment of wetland functions in this highly modified landscape requires an understanding of the scope of the more influential changes that have taken place.

Land use and management

Natural levees, which commonly are the highest elevations in the landscape of the Delta Region and often are in direct proximity to water, have been the focus of human settlement during both prehistoric and historic times (Saucier 1994). At the time of the first European explorations of the Arkansas Delta in the 16th century, natural levees of the Mississippi and Arkansas Rivers were extensively used for maize agriculture by Native Americans (Hudson 1997). By the time detailed surveys of the Mississippi River were first made in the 1880s, European settlers were farming nearly all of the natural levees adjacent to the river through the Delta (Mississippi River Commission 1881–1897). Lower terrain had not been similarly developed (Barry 1997).

In the last two decades of the 19th century, local flood control and drainage efforts began to have widespread effects in the Delta, and railroads were constructed in formerly remote areas. These changes allowed logging and agricultural development to proceed on a massive scale throughout the Lower Mississippi Valley. In the period between 1880 and 1920, nearly all virgin forests in the Arkansas Delta were cut over (Smith et al. 1984). As the 20th century progressed, improvements to farming equipment and crops and the initiation of coordinated Federal flood control efforts allowed further conversion of forested land to agriculture. From an estimated original area of 9 to 10 million hectares, Mississippi Alluvial Valley forests had been reduced by about 50 percent by 1937, and currently less than 25 percent of the original area remains forested (Smith et al. 1993). In the Arkansas Delta, the losses are more dramatic – only about 15 percent of approximately 3.2 million original wetland hectares remains. Much of the remaining forest is highly fragmented, with the greatest degree of fragmentation occurring on drier sites (such as natural levees), and the largest remaining tracts being in the wettest areas, such as the White and Cache River lowlands (Creasman et al. 1992, Rudis 1995). Nearly all of the remaining forests within the basin have been harvested at least once, and many have been cut repeatedly and are in degraded condition due to past high-grading practices (Putnam 1951; Rudis and Birdsey 1986).

The near-total loss of certain wetland types, the extreme reductions and fragmentation of others, and the degradation of forest structure and composition in the remaining forests have had wide-reaching and little-understood effects on various ecosystem characteristics in the region. For example, the differential conversion of higher, drier riverfront sites to agriculture may be a major contributing factor in the near disappearance of the extensive stands of cane, which many early travelers remarked upon as common features of the natural levees (Remsen 1986, Dickson 1991). In turn, the loss of the canebrakes may have contributed to the extinction of Bachman's warbler (*Vermivora bachmanii*), which likely was dependent on cane thickets for some parts of its life cycle. Other wildlife species, such as the now-extinct ivory-billed woodpecker (*Campephilus principalis*), apparently required old-growth forest (Remsen 1986, Tanner and Hamel 2001), and mammals with large home ranges such as cougars (*Felis concolor*) and black bears (*Ursus americanus*) were no doubt adversely affected by forest fragmentation and isolation.

Of the remaining wetland acreage in the Delta, most of the largest tracts are in public hands or under easements that give public agencies some degree of control over management decisions. Federal lands include some wetlands in the National Forest System and wetlands owned or managed under easement by the Natural Resources Conservation Service. However, the largest units are in the National Wildlife Refuge system administered by the U.S. Fish and Wildlife Service. The largest of these refuges is the 64,000-ha White River National Wildlife Refuge. State-controlled lands include those in the state park system, and more than 70,000 ha in Wildlife Management Areas located throughout the Delta, which are operated by the Arkansas Game and Fish Commission (Demas and Demcheck 1996). Some of the most intact and unique wetlands in the region are under the protection of the Arkansas Natural Heritage Commission, a division of the Department of Arkansas Heritage, which owns or has easements on more than a dozen forested wetland sites in the Delta (Arkansas Natural Heritage Commission 1997). Various private landowners, including commercial timberland operations, and non-government organizations such as The Nature Conservancy, Ducks Unlimited, and the Audubon Society, also own, manage, or otherwise work to protect forested wetlands in the Delta.

Many of these public and private organizations have been particularly involved in wetland restoration in recent years. Schoenholtz et al. (2001) reported that between 1968 and 1998 nearly 16,000 ha of forested wetlands were planted in the Arkansas Delta in the State Wildlife Management Areas and by the U.S. Fish and Wildlife Service and the Natural Resources Conservation Service. A particularly effective effort, the Wetlands Reserve Program conducted by the Natural Resources Conservation Service, has been responsible for restoration of approximately 36,000 ha of Delta wetlands between 1994 and early 2002.[1]

In addition to restoring some of the lost wetland acreage in the Delta, various public and private entities concerned with Delta wetlands also are addressing the problems related to differential losses of certain wetland types, lack of old growth forest, and fragmentation of the remaining forests in the region. Initiatives that recognize the importance of landscape-scale management of remaining large tracts include the Cache-Lower White Rivers Joint Venture developed under the North American Waterfowl Management Plan, which is intended to protect the largest

[1] Personal Communication, January 2002, Jody Pagan, NRCS Arkansas WRP Coordinator.

contiguous block of forested wetland in the Lower Mississippi Valley outside the Atchafalaya Basin. This area also is recognized as a wetland of international significance under the Ramsar Convention of 1971 (Demas and Demcheck 1996). Similarly, the Arkansas Natural Heritage Commission and The Nature Conservancy have developed a White River-Lower Arkansas River Megasite Plan, which addresses the potential to coordinate restoration and management activities over an ecosystem encompassing nearly half a million hectares, about half of which is in public ownership (Lynch et al. 1992). On a broader scale, six Arkansas State agencies are members of the Arkansas Multi-Agency Wetland Planning Team (MAWPT), which has an overall goal "to preserve, conserve, enhance, and restore the acreage, quality, biological diversity and ecosystem sustainability of Arkansas' wetlands for citizens present and future." With the assistance of funding provided by the USEPA, this goal has been pursued through a variety of initiatives, including efforts to characterize the composition, function, and landscape patterns of wetlands in Arkansas (e.g., this guidebook), to provide public information and education, and to improve governmental participation in wetland-related decision-making. A major product of this effort is a set of Wetland Planning Area reports emphasizing wetland preservation and restoration potential on a watershed scale (Arkansas Multi-Agency Wetland Planning Team 1997).

Hydrology

The hydrology of the Delta Region of Arkansas has been modified extensively and purposefully. Unconnected wetlands associated with the higher alluvial terraces (such as Grand Prairie) and with the valley train terraces were not subject to major river flooding in historic times, and they could be readily drained with simple ditch systems, or used as sumps to collect drainage. The lowlands were far more difficult to convert to agricultural uses. By the mid-19th century, many individual plantations along the Mississippi River were protected with low levee systems, often built with slave labor, that were sufficient to exclude most floods, but not the periodic catastrophic event (Barham 1964; Barry 1997). Additional drainage and levee-building were accomplished under the provisions of the Federal Swamp Lands Act passed in 1849 and 1850 (Holder 1970), but the first truly extensive and effective efforts were undertaken in the late 19th century and into the first few decades of the 20th century, when numerous local levee and drainage districts were created and funded by land taxes and the sale of bonds, with the St. Francis Basin the focus of the most concerted activity

(Barham 1964; Moore 1972; Sartain, undated). In Mississippi County alone, the local interests constructed more than 1,600 km of ditches, and effectively drained and cleared nearly the entire county. However, even with this level of effort, the St. Francis Basin included some areas that defied drainage efforts, and today several large blocks of forested wetlands remain, mostly under the control of the Arkansas Game and Fish Commission.

The Arkansas River lowlands, which encompass most of the Delta south of the Grand Prairie, also were ditched and drained by local interests. Those drainage districts embarked on some ambitious projects, such as the construction of an extensive levee system and floodgate to protect the Bayou Meto Basin from floods originating on the Arkansas River (Holder 1970). That levee was later incorporated into the Federal levee system constructed along the lower Arkansas River.

Of the major lowland basins in the Arkansas Delta, only the Lower White River area escaped wholesale reclamation efforts by the early 20th century local drainage districts. Effective drainage was simply impossible in the face of the combined influence of regular flooding on streams within the basin, such as Bayou DeView and the Cache, Black, and White Rivers, and periodic backwater flooding due to high water on the Mississippi. Not until the 1970s did effective drainage and levee construction start to bring about large-scale changes in land use, but by then environmental concerns had begun to influence public policy in the region and wholesale agricultural conversion was averted (Foti 1993). As a result, the lower basin continues to support the extensive forested wetlands of the Cache and White River National Wildlife Refuges, described previously.

Despite the successes of the early drainage districts, their efforts could not overcome the effects of the Mississippi and Arkansas Rivers in flood stage; and periodic widespread destruction occurred with major flood events (Barry 1997). These have been addressed primarily through a massive Federal effort conducted by the U.S. Army Corps of Engineers: the Mississippi River and Tributaries Project (MR&T), which is the largest flood-control project in the world (U.S. Army Engineer Division, Mississippi Valley 1998). In order to understand the extent to which hydrology has been modified in the Delta Region of Arkansas and the way the remaining wetlands receive and move water, it is essential to understand the development and current status of the MR&T.

Corps of Engineers activities in the Lower Mississippi Valley through most of the 1800s focused principally on survey and engineering efforts relating to navigation improvement (Barry 1997). Surveys began on the Arkansas River in 1833, and by the end of the 1880s all major streams in the Arkansas Delta had been surveyed. During this same period, an extensive program of snagging was pursued on the Arkansas River, as well as clearing of forests or individual trees (potential future snags) along the banks and some dredging. Less extensive efforts were also pursued on some other Delta streams, notably the White River. But all of these efforts were piecemeal, and not all streams in the region or the Lower Mississippi Valley received the same level of attention (Clay 1986, Rathburn 1990).

In 1879, Congress authorized the creation of the Mississippi River Commission to oversee a coordinated Federal effort, to be carried out by the Corps of Engineers, to provide reliable navigation throughout the entire Mississippi River system (Moore 1972). Over the next five decades, the authority of the Commission was expanded, and its jurisdiction gradually enveloped various tributary stream systems. But in the early 20th century, flood control remained largely a local responsibility, and by 1927, the existing levees and related works were believed to be providing effective protection from Mississippi River floods, as well as effective drainage for communities and farmlands throughout the entire lower valley (Barry 1997).

A devastating flood in 1927 showed that the flood protection works were inadequate, and the Flood Control Act of 1928 authorized the Corps of Engineers to implement a new and comprehensive plan for preventing flooding in the Lower Mississippi Valley. The approach included construction of larger and stronger levees as well as various channel modifications, bank protection works, and other features. The multiple elements of this plan and its subsequent modifications are collectively referred to as the MR&T (Moore 1972).

Congress directed changes to the MR&T plan in the 1930s and 1940s that included the addition of cutoffs, tributary reservoirs, and an emphasis on maintenance of a stable, deep Mississippi River channel as a levee protection measure and to provide navigation benefits. In the 1950s, 1960s, and 1970s the project was expanded to include numerous tributary modifications, pump stations, harbor improvement projects, and lock and dam projects, as well as channel and levee projects throughout the system.

During this latter period, fish and wildlife considerations also became authorized project purposes. Meeting fish and wildlife objectives generally involved constructing water control structures within floodways and sump areas to allow habitat management for waterfowl (Moore 1972).

With the advent of the National Environmental Policy Act (NEPA) in 1969 and other environmental legislation, proposed modifications to the MR&T were subject to more complex planning and coordination requirements than previously existed. Actions likely to adversely affect fish, wildlife, wetland ecosystems, and other natural resources have been reevaluated to identify ways to avoid or minimize environmental impacts (Moore 1972; Bolton and Metzger 1998). Compensation for impacts deemed unavoidable has included acquisition and restoration of many thousands of acres of forest within the project area, as well as construction of additional water management facilities to benefit wildlife, particularly waterfowl (Young 1998). Maintenance of existing project features continues, and additional authorized features are under construction or in planning stages (Bolton and Metzger 1998).

The cornerstone of the Federal flood-control effort in the Lower Mississippi Valley is the mainstem levee system, which is essentially continuous on the western side of the Mississippi River from Cape Girardeau, MO, to Venice, LA, about 16 km above the mouth of the river, except where tributaries enter. On the eastern bank it is discontinuous, because bluffs near the river make the levee unnecessary in some reaches. The levee system on the south bank of the Arkansas River extends about 140 km from Pine Bluff to the mainstem Mississippi River levee, and on the north bank it extends from North Little Rock approximately 90 km to a point south of Gillett. Another large Federal ring levee protects the White River Backwater Area between Helena and the mouth of the White River, and about 80 km of levees protect towns along the lower White River itself. Federal efforts in the St. Francis Basin continued the work of the local drainage districts and included several hundred kilometers of levees, plus floodways, ditches, and channel modifications. Much of the St. Francis Basin as well as the White River Backwater Area are intended to be used as water storage basins during major Mississippi River floods, and both have been fitted with pumping stations to evacuate waters trapped within the levee systems. Additional flood-control projects remain authorized under the MR&T project, including a channel modification and pump construction project currently in the planning process for the Bayou Meto Basin. Some other

elements of the MR&T have been set aside due to disinterest on the part of local sponsors or public opposition. One major change was deauthorization of a series of extensive channel modifications planned for the lower Cache River, which instead became part of the National Wildlife Refuge System (Clay 1986, Mississippi River Commission 1970, Moore 1972, Williams 1986).

River engineering influences on the Arkansas Delta involve numerous other projects, including huge reservoir systems in the Ozarks and Ouachitas, channel modifications to streams of all sizes, and local levee systems. All of these clearly have significantly influenced wetland hydrology. Often, however, river engineering causes changes to wetlands that are less apparent. Navigation works may affect the hydrology of wetlands by changing the surface elevation of river reaches behind lock and dam structures and by altering the geometry of the river channel where dredging occurs, or where channel constriction structures are employed to scour a narrow, deep channel. More fundamental changes are effected by bank stabilization projects that prevent channel meandering, which is the mechanism by which new wetlands are created within active stream meander belts (Klimas 1991).

In addition to major engineering projects, the water that enters the modern Arkansas Delta is rerouted, stored, and exported from the system in complex patterns that can result in more or less water available to remaining wetlands. For example, the uneven annual distribution of rainfall makes both drainage and supplemental irrigation common agricultural practices (Brown et al. 1971). Drainage accomplished by ditching may dry up some wetlands, but cause others to receive excessive amounts of water when they are used as sumps to which adjacent fields drain. Drainage achieved by land leveling removes the subtle microtopography that sustains many wetlands by storing precipitation, and the accelerated runoff may adversely affect downslope or downstream systems. A variety of Delta wetlands may have some dependence on groundwater, but groundwater withdrawals for irrigation and other agricultural purposes have caused depletion of the aquifer in many areas. The alluvial aquifer of the Lower Mississippi Valley is one of the largest and most heavily used freshwater sources in the United States (Saucier 1994). Overuse can cause changes in water availability and water quality (Terry et al. 1979), and may adversely affect wetlands where they are maintained by discharge from unconfined aquifers. Currently, the groundwater supply in much of the Arkansas Delta

is being depleted faster than it is replenished. More than half of the Delta has been designated or proposed for designation as a "critical groundwater area," and the remainder of the region remains under study to determine if the "critical" designation is applicable (Arkansas Soil and Water Conservation Commission 2001).

Definition and identification of the HGM classes and subclasses

Brinson (1993a) identified five wetland classes based on hydrogeomorphic criteria, as described in Chapter 2. Pilot studies conducted in 1997 and 1998 indicated that wetlands representing four of these classes (Flat, Riverine, Depression, and Fringe wetlands) and a variety of subclasses occur within the Delta Region of Arkansas. However, categorical separation of these classes is sometimes difficult because of the complexity of the landscape and hydrology within the basin and because features of wetlands intergrade and overlap among types. Therefore, a set of specific criteria has been established to assist the user in assigning any particular wetland in the Arkansas Delta to the appropriate class, subclass, and community type. These criteria are presented in the form of dichotomous keys in Figures 10 and 11. In addition, each wetland type identified in the keys is described in the following section, which also includes a series of block diagrams illustrating the major wetland types and their relationships to various landforms and man-made structures. These relationships also are summarized in Table 7.

Some of the criteria that are used in the keys in Figures 10 and 11 require some elaboration. For example, a fundamental criterion is that a wetland must be in the 5-year floodplain of a stream system to be included within the Riverine Class. This return interval is regarded as sufficient to support major functions that involve periodic connection to stream systems. It was also selected as a practical consideration, because the hydrologic models used to develop flood return interval maps generally include the 5-year return interval.

The classification system recognizes that certain sites functioning primarily as fringe or depression wetlands also are regularly affected by stream flooding, and therefore have a riverine functional component. This is incorporated in the classification system by establishing "river-connected" subclasses within the Fringe and Depression Classes.

Key to Wetland Classes in the Delta Region of Arkansas

1. Wetland is not within the 5-year floodplain of a stream **2**

1. Wetland is within the 5-year floodplain of a stream..... **3**

2. Topography generally flat, principal water source is precipitation ..... **Flat**

2. Topography is depressional, or within the 5-year floodplain of a stream **3**

3. Wetland is not in a topographic depression or impounded..... **Riverine**
3. Wetland is in a topographic depression, or impounded **4**

4. Wetland is associated with a beaver impoundment, or with a shallow impoundment managed principally for wildlife (e.g., greentree reservoirs or moist soil units)..... **Riverine**

4. Wetland is in an impoundment or depression other than above **5**

5. Wetland is associated with a water body that has permanent water more than 2 m deep in most years ..... **Fringe**

5. Wetland is associated with a water body that is ephemeral, or less than 2 m deep in most years ..... **Depression**

Figure 10. Key to the wetland classes in the Delta Region of Arkansas.

The classification system addresses a major confounding aspect of overlap among wetland types that arises from the characteristic topographic variation within certain wetland types. Sites that function primarily as riverine wetlands and flats often incorporate small, shallow depressions, sometimes characterized as vernal pools and microdepressions. These features are regarded as normal components of the riverine and flat ecosystems, and are not separated into the Depression Class unless they meet specific criteria. Other significant criteria relating to classification are elaborated in the wetland descriptions in the following paragraphs.

Key to Wetland Subclasses and Community Types in the Delta Region of Arkansas		
CLASS: FLAT	**Subclass**	**Community Type**
1. Soil reaction acid ..... **Non-Alkali Flat (2)**		
1. Soil reaction circum-neutral to alkaline (lake bed deposits)		
2. Vegetation dominated by graminoids		*wet tallgrass prairie*
2. Vegetation dominated by woody species		
2a. Vegetation dominated by pine		*pine flat*
2b. Vegetation dominated by post oak		*post oak flat*
2c. Vegetation dominated by hardwoods other than post oak.....		*hardwood flat*
3. Vegetation dominated by graminoids		*alkali wet prairie*
3. Vegetation dominated by post oak.....		*alkali post oak flat*
CLASS: RIVERINE	**Subclass**	**Community Type**
1. Wetland associated with low-gradient stream (Stream Orders > 6, or other alluvial streams) 3		
1. Wetland associated with mid-gradient stream (Stream Orders 4–6) .....**Mid-gradient Riverine (2)**		
2. Water source primarily overbank flooding or lateral saturation.....		*mid-gradient floodplain*
2. Water source primarily backwater flooding, wetland typically located at confluence of two streams		*mid-gradient backwater*
3. Wetland not an impoundment.....**Low-gradient Riverine (5)**		
3. Wetland an impoundment ..... **Riverine Impounded (4)**		
4. Wetland impounded by beaver.....		*beaver complex*
4. Wetland impounded for wildlife management (greentree reservoirs and moist soil units).....		*managed wildlife impoundments*
5. Water source primarily overbank flooding (5-year zone) that falls with stream water levels, or lateral saturation from channel flow		*low-gradient overbank*
5. Water source primarily backwater flooding or overbank flows (5-year zone) that remain in the wetland due to impeded drainage after stream water levels fall		*low-gradient backwater*

Figure 11. Key to the wetland subclasses and community types in the Delta Region of Arkansas (Sheet 1 of 2).

CLASS: DEPRESSION	Subclass	Community Type
1. Depression not subject to direct stream flooding during a 5-year event; precipitation, runoff, and groundwater are the dominant inflows.....2		
1. Depression has significant direct stream inflows and outflows relative to stored volume and/or is influenced by overbank or backwater flooding during a 5-year event 4		
2. Depression discharges water to surface channels, but has no significant surface inflows relative to discharge .....Headwater Depression		*headwater swamp*
2. Depression has no significant direct surface outlet to a stream channel, or outflows are minor relative to stored volume ..... Unconnected Depression (3)		
3a. Precipitation-dominated depression in dunefields.....		*sandpond*
3b. Depressional feature in abandoned meander features (oxbows or swales) not subject to 5-year flood flows		*unconnected alluvial depression*
3c. Depressional feature in relict glacial outwash channel		*valley train pond*
4. Significant, perennial streamflow enters and leaves depression.....Not Depression Class: see Riverine Class		
4. Depression not subject to perennial flow, but receives overbank or backwater flooding during 5-year events ..... Connected Depression		*floodplain depression*
CLASS: FRINGE	**Subclass**	**Community Type**
1. Wetland on the margin of a man-made reservoir ..... Reservoir Fringe		*reservoir shore*
1. Wetland on the margin of water body other than a reservoir.....2		
2. Water body subject to stream flooding during 5-year flood events ..... .Connected Lacustrine Fringe		*connected lake margin*
2. Water body not subject to flooding during a 5-year event.....Unconnected Lacustrine Fringe		*unconnected lake margin*

Figure 11. (Sheet 2 of 2).

The following sections briefly describe the classification system developed for this guidebook for wetlands in the Delta Region of Arkansas. The system includes the four principal wetland classes that occur in the Delta, each of which comprises a number of subclasses and community types. All of the Delta wetland types are described, but assessment models and supporting reference data were developed for only a subset of these types, as described in Chapter 4. Additional details, including photos and distribution maps, for each of the wetlands described, as well as wetlands in the other regions of the state, can be found on the Arkansas Multi-Agency Wetland Planning Team Web site (http://www.mawpt.org/).

Table 7. Hydrogeomorphic Classification of Forested Wetlands in the Delta Region of Arkansas and Typical Geomorphic Settings of Community Types.

Wetland Classes, Subclasses, and Communities	Typical Geomorphic Setting
CLASS: FLAT	
SUBCLASS: ALKALI FLAT	
Alkali Post Oak Flat	Lacustrine sediments deposited in lake systems impounded by glacial outwash.
SUBCLASS: NON-ALKALI FLAT	
Hardwood Flat	Backswamp and point bar environments on Pleistocene and Holocene meander-belt topography, and on interfluves on valley trains.
Post Oak Flat	Pleistocene terraces.
CLASS: RIVERINE	
SUBCLASS: MID-GRADIENT RIVERINE	
Mid-Gradient Floodplain	Point bar and natural levee deposits within active meander belts of streams transitioning from uplands to alluvial plain, or dissecting terrace deposits.
Mid-Gradient Backwater	Backswamp and point bar deposits within active meander belts of mid-gradient streams near point of confluence with major alluvial river.
SUBCLASS: LOW-GRADIENT RIVERINE	
Low-Gradient Overbank	Point bar and natural levee deposits within active meander belts of alluvial streams.
Low-Gradient Backwater	Backswamp, point bar, and low-lying valley train deposits within and between both active and inactive meander belts of alluvial streams.
SUBCLASS: IMPOUNDED RIVERINE	
Beaver Complex	All flowing waters.
Wildlife Management Impoundment	Various settings.
CLASS: DEPRESSION	
SUBCLASS: HEADWATER DEPRESSION	
Headwater Swamp	In relict outwash channel, adjacent to scarp of a higher valley train terrace.
SUBCLASS: UNCONNECTED DEPRESSION	
Sand Pond	Eolian sand deposits (dunefields) on valley trains.
Valley Train Pond	Depressions atop buried braided outwash channels on valley trains.
Unconnected Alluvial Depression	Abandoned channels and large swales in former and current meander belts of larger rivers (including both Holocene and Pleistocene meander belt deposits).
SUBCLASS: CONNECTED DEPRESSION	
Floodplain Depression	Abandoned channels and large swales in former and current meander belts of larger rivers.
CLASS: FRINGE	
SUBCLASS: UNCONNECTED LACUSTRINE FRINGE	
Unconnected Lake Margin	Abandoned channels in meander belts and adjacent to man-made impoundments.
SUBCLASS: CONNECTED LACUSTRINE FRINGE	
Connected Lake Margin	Abandoned channels in meander belts and adjacent to man-made impoundments.

Class: Flat

Flats have little or no gradient, and the principal water source is precipitation. There is minimal overland flow into or out of the wetland except as saturated flow. Wetlands on flat areas that are subject to stream flooding during a 5-year event are classified as Riverine. Small ponded areas within flats are considered to be normal components of the Flat Class if they do not meet the criteria for the Depression Class. Sites are considered to be Slope wetlands rather than Flats if they have sufficient gradient to cause runoff in a single direction (however, slope wetlands are rare in the Delta), and as Slope or Depression wetlands if groundwater discharge is the principal water source within the wetland. There are two subclasses and six community types in the Flat Class, all of which occur within the Delta Region.

Figure 12 illustrates common landscape positions where wetlands in the Flat Class are found. See Figure 7 to identify land surfaces.

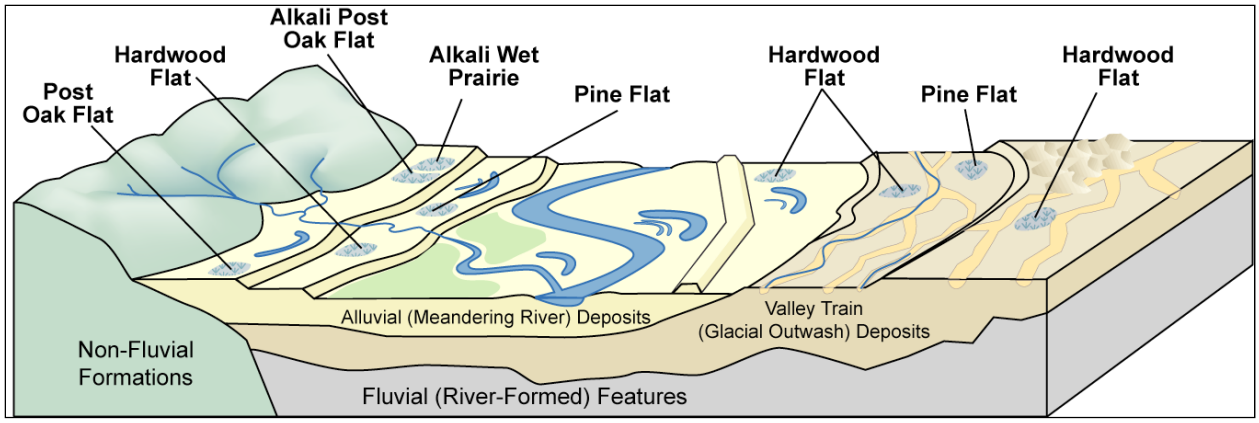


Figure 12. Common landscape positions of wetland community types in the Flat Class.

Subclass: alkali flat. Alkali flats (also called sodic or saline flats) have soils with high pH and high levels of sodium or magnesium salts in or near the surface layer. They typically have very poor drainage and a shallow hardpan. The combination of impeded drainage and unusual soil chemistry restricts the potential plant communities, and provides habitats for certain rare species. The two community types in this subclass are separated based on predominant vegetation, but in fact probably represent a continuum of change in soil conditions, where the forested community occurs on soils with deeper hardpans than the prairie community. Most sites with alkali soils are believed to be former Pleistocene lake beds.

Alkali flats are not common in the Delta, and assessment models applicable to these types are not presented in this guidebook. They are more common in the Coastal Plain Region, and will be addressed in the HGM Guidebook for that region.

Community types. The following communities occur within the alkali flats subclass:

a. *Alkali post oak flat.* Alkali post oak flats occur on sites where the soils have extremely poor drainage and concentrations of salts accumulate near or on the soil surface. These sites are believed to have been occupied by shallow lakes during the Pleistocene Epoch, when waning and waxing periods of continental glaciation to the north of Arkansas created temporary lakes within the modern Delta Region. Repeated filling and drying of the lakes caused salts to accumulate, and today the ancient lakebeds are flats that support unique wetlands with characteristic plants that are tolerant of the high salt concentrations and impeded drainage conditions. In most cases, alkali flats are a mosaic of prairie and unvegetated "slick spots" on soils with salts at or very near the surface, while soils with less surface salt or somewhat better drainage support stunted post oak trees. Alkali post oak flats have been reported from the Delta region (St. Francis County), and likely occur in other locations where soils are strongly saline.

b. *Alkali wet prairie.* The ancient Pleistocene lake beds that support alkali post oak flats also support small areas of alkali wet prairie (also called saline prairie) where soil salinity is highest or drainage is very poor. Where the salts accumulate on the surface, it is common to find a hard white or gray surface, termed a "slick spot." These areas may have salt crystals visible on the surface during dry periods, and they are largely devoid of vegetation. The perimeter of the slick spot often supports a crust of lichens, mosses, and liverworts. In Arkansas, the endangered plant species *Geocarpon minimum* is almost entirely restricted to this slick spot perimeter zone in alkali wet prairies, although it has not been reported from prairies in the Delta Region. Beyond the slick spot edge, prairie species are able to colonize as the depth to the zone of concentrated salts increases, and stunted trees and shrubs occur on still deeper soils. Species of three-awn (*Arstida* spp.) are particularly characteristic grasses of these communities.

Subclass: non-alkali flat. Flats with neutral and acid soils can support a variety of community types. They are differentiated based on predominant vegetation types, which generally reflect drainage conditions. Fire history may also be an important factor in certain instances. These wetlands are widely distributed within the Delta, and provide habitat for numerous plant and animal species. Because wet flats are maintained by precipitation rather than flooding, many were relatively easy to convert to agriculture with fairly minor changes to drainage conditions, and extensive flat areas have been cleared. In addition, many sites that were historically subject to regular flooding have been disconnected from streamflows by modern man-made levees, and these sites are now classified as flats.

This guidebook includes assessment models applicable to all of the forested non-alkali flats in the Delta Region. Assessment models were not developed for the wet tallgrass prairie type, for which few high-quality reference sites could be located in the Delta. Until such models are developed based on reference sites in other regions of Arkansas, tallgrass prairie wetlands are best assessed using a strictly floristic approach and site-specific evaluation of the drainage, soils, management programs, and proposed impacts.

Community types: The following communities are found in non-alkali flats:

a. *Wet tallgrass prairie.* The wet tallgrass prairie community type typically occurs within broad basins or headwater draws that have poor drainage, or in minor swales within larger expanses of dry prairie. All of these sites tend to stay wet, with areas of standing surface water, through spring. They usually become extremely dry in late summer. Wet tallgrass prairie is dominated by typical prairie species such as big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon scoparius*), Indian grass (*Sorghastrum nutans*), switch grass (*Panicum virgatum*), and numerous perennial forbs. However, it also includes wetland species such as beakrush (*Rhynchospora* spp.), marsh fleabane (*Pluchea foetida*), sundews (*Drosera* spp.) and sphagnum moss (*Sphagnum* spp.). Wet prairie is also likely to support species that are rare or unusual in Arkansas, such as prairie cordgrass (*Spartina pectinata*). Fire is essential to maintain prairies in Arkansas — without fire, trees will gradually establish. The original extent of prairie in Arkansas has been dramatically reduced by agriculture, development, fire control, and

forest management practices. In the Delta, remnant wet prairies are found primarily in the Grand Prairie area (Lonoke and Prairie Counties).

b. *Pine flat.* Pine flats, also called pine flatwoods, are common in the Coastal Plain, but in the Delta they are restricted to a relatively small area in the vicinity of Pine City in Monroe County. There, they occur on valley train deposits, on silt loam soils that are acid to strongly acid and with a high water table throughout the winter and spring. In the modern landscape, most of these sites have been dramatically altered by forest management, drainage, and by changes in fire frequency, timing, and intensity. The remaining examples in relatively good condition have large loblolly pines, but even these sites generally have a large hardwood component, characterized by sweetgum and a variety of oaks.

c. *Hardwood flat.* Hardwood flats occur on fairly level terrain that is not within the 5-year floodplain of stream systems, but nevertheless remains wet throughout winter and spring due to rainfall that collects in small shallow pools. These pools often refill and remain wet for days or weeks following summer rains. In the Delta region, hardwood flats often are dominated by Nuttall oak (*Quercus nuttallii*) in Holocene environments, and by water or willow oaks on older surfaces, where they are sometimes called oak flatwoods. Numerous other species occur on hardwood flats and may dominate.

d. *Post oak flat.* Post oak flats occur on clay soils with poor drainage, generally on the margins of the Grand Prairie, where they may intergrade with hardwood flats, but are distinctively dominated by post oak or Delta post oak. These sites are saturated to the surface in the wet season and following rains, but become extremely dry and hard in summer. Mima (or pimple) mounds often are present, and contribute to the extensive ponding on these sites by impounding rainwater and impeding runoff. The understory and groundcover are sparse, which results in a parklike appearance in many stands, and many post oak flats probably were savanna when frequently burned prairies were widely distributed on the Grand Prairie. Tree growth tends to be very slow, although trees are not stunted as they are on alkali post oak flats.

Class: Riverine

Riverine wetlands are those areas directly flooded by streamflow, including backwater and overbank flow, at least once in five years on average (i.e., they are within the 5-year floodplain). Depressions and fringe wetlands that are within the 5-year floodplain are not included in the Riverine Class, but beaver ponds and wildlife management impoundments are usually considered to be riverine. Riverine wetlands encompass many different types of wetland communities; there are three subclasses and six community types in the Riverine Class in the Delta (Table 7, Figure 13).

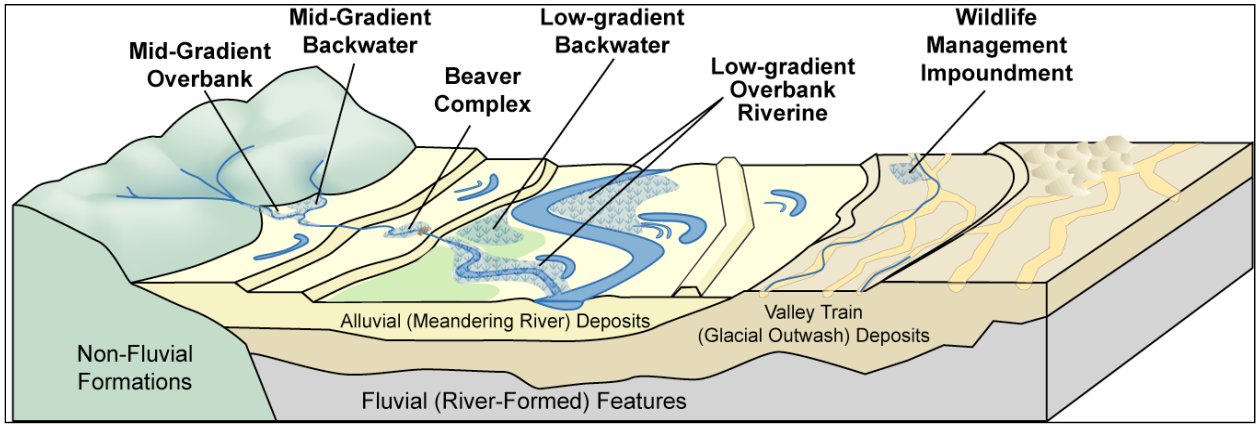


Figure 13. Common landscape positions of wetland community types in the Riverine Class.

Subclass: mid-gradient riverine. Mid-gradient riverine wetlands are associated with streams (typically 4th – 6th order) that have significant floodplain development, but are upstream of the meandering portion of a stream system. They are important sources for input of organic material to the stream system. Mid-gradient systems are of limited distribution in the Delta, being restricted to sites transitional to the Coastal Plain, Ozarks, and Ouachitas, and to some parts of the drainages flanking the Grand Prairie and Crowley's Ridge.

Due to the limited distribution of mid-gradient riverine systems in the Delta and consequent limited extent of potential reference wetlands for this subclass, no specific applicable assessment models have been developed for this guidebook. However, applicable models will be presented in the HGM Guidebooks for the Coastal Plain, Ouachitas, and the Ozarks, and can be used for adjacent mid-gradient sites in the Delta.

Community types. The following community types occur within the mid-gradient riverine subclass:

a. *Mid-gradient floodplain*. Mid-gradient floodplain wetlands occur along small streams with significant bar and floodplain formation. Riparian wetlands along mid-gradient streams are usually fairly small floodplain units that occur repeatedly, often alternating from one side of the channel to the other. They combine elements of upland and lowland forests, and can be highly diverse. Species such as river birch (*Betula nigra*), red maple (*Acer rubrum*), American elm (*Ulmus americana*), and green ash are characteristic.

b. *Mid-gradient backwater*. Mid-gradient backwater wetlands occur at the confluence of streams where high flows on the larger channel cause backwater flooding in the lower reaches of the mid-gradient tributary. They are sites where sediments accumulate rapidly, building natural levees and creating extensive backwater areas that drain slowly. Mid-gradient backwater systems tend to support plant communities that are more tolerant of flooding and sedimentation than the communities on most other mid-gradient floodplains. Species typical of adjacent hillslopes are not successful within the backwater zone, and some portions of the floodplain are occupied by species such as baldcypress (*Taxodium distichum*), that are more typical of lowland swamps.

Subclass: low-gradient riverine. Low-gradient riverine wetlands occur within the 5-year floodplain of meandering streams (usually 7th order or higher). They include a wide variety of community types, and have important functions related to habitat as well as sediment and water storage.

Community types. The following community types occur within the low-gradient riverine subclass:

a. *Low-gradient backwater*. Low-gradient backwater wetlands occupy sites that flood frequently (1- to 5-year flood frequency), but flooding is primarily by slack water, rather than by the high-velocity flows that predominate in overbank flood zones. Backwater flooding usually occurs when mainstem streams are in high stages, impeding the discharge of tributaries and causing them to back up onto their floodplains. This results in sediment accumulation and ponding that persists long after water levels have fallen in the stream channels. Sediments tend to be fine-grained, with considerable accumulation of organic material. Backwater sites that flood for long durations and

are very poorly drained are usually dominated by overcup oak (*Quercus lyrata*) and water hickory (*Carya aquatica*). Less flooded sites are often dominated by green ash, Nuttall oak or willow oak (*Quercus phellos*), and the driest backwater sites may have species such as water oak (*Quercus nigra*) and cherrybark oak (*Quercus pagoda*) as important components in the overstory. As with flats, vernal pools may be an important component of the low-gradient backwater community type. Many sites that were subject to backwater flooding in historic times are now protected by levees. Wetlands on these altered sites are classified as flats.

b. Low-gradient overbank. Low-gradient overbank wetlands occur on regularly flooded sites (1- to 5-year flood frequency zone) along or near streambanks and on bars and islands within channel systems. These sites are usually point bar deposits, often with a natural levee veneer. This type differs from the low-gradient backwater community type because floodwater usually moves through the overbank zone at moderate to high velocities, parallel to the channel. Sediments, nutrients, and other materials are exported downstream or imported from upstream sites differently than they are in backwater wetlands. Backwater sites may tend to accumulate fine sediments and organic material and to export dissolved materials in the water column. Overbank sites tend to be subject to scour or deep deposition of coarse sediments, and litter and other detritus may be completely swept from a site or accumulated in large debris piles. In-channel sandbars and riverfront areas usually are dominated by willows, sycamore (*Platanus occidentalis*), cottonwood, and similar pioneer species, while older and less exposed substrates support more diverse communities. In most cases, however, plant communities in the overbank flood zone tend to be dominated by species with broad tolerances for inundation, sedimentation, and high-velocity flows. Overbank sites sometimes include vernal pools, usually in the form of long, arched swales between the depositional ridges of meander-scroll topography, rather than the irregularly shaped pools typically found in backwater areas.

Subclass: impounded riverine. These wetlands occur in shallow impoundments that detain and slow stream flows, but generally remain flow-through systems. They include highly dynamic and unique beaver-dominated wetlands, as well as systems that are intensively managed to benefit particular groups of wildlife species.

There are no HGM models specific to beaver complexes, but the recommended approach is to regard them as a fully functional component of any riverine system being assessed.

Wildlife Management Impoundments are designed specifically to maximize a single wetland function (habitat) and often are targeted toward a specific wildlife group (usually waterfowl). They are intended to allow managers to flood large areas at times when water is not naturally present in those areas. Because the hydrological modifications usually imposed do not reflect the patterns observed in reference systems, this guidebook does not include models designed specifically for application to managed impoundments.

Community types. The following community types occur within the impounded riverine subclass:

a. *Beaver complex*. Beaver complexes were once nearly ubiquitous here and elsewhere in the continental United States, but became relatively uncommon during the past two centuries following the near-extirpation of beaver. In their most common form, they consist of a series of impounded pools on flowing streams. Beaver cut trees for dams and food, and they have preferences for certain species (e.g., sweetgum (*Liquidambar styraciflua*)), which alters the composition of forests within their foraging range. Tree cutting and tree mortality from flooding create patches of dead timber surrounded by open water, shrub swamps, or marshes. Beaver complexes may be abandoned when the animals exhaust local food resources or when they are trapped out. Following abandonment, the dams deteriorate, water levels fall, and different plants colonize the former ponds. When beaver reoccupy the area, the configuration changes again, the result being that systems with active beaver populations are in a constant state of flux.

b. *Wildlife management impoundment*. Wildlife management impoundments are areas managed specifically to provide habitat for waterfowl and other waterbirds. There are two versions of this management approach: greentree reservoirs and moist soil units. They are included in the Riverine Class because they usually draw water from and return it to stream systems, but the wetlands are contained within low levee systems that allow managers to create shallow flooding conditions suitable for use by foraging and resting birds. Greentree reservoirs are leveed sections of mature oak

bottomland forest, which provide access to acorns and forest invertebrates when artificially flooded to provide shallow water for waterfowl foraging. Moist soil units are leveed cleared fields where water management and farm machinery are employed to maintain marshlike conditions, which provide small seeds and different invertebrates than are found in forested wetlands.

Class: Depression

Depression wetlands occur in topographic low points where water accumulates and remains for extended periods. Sources of water include precipitation, runoff, groundwater, and stream flooding.

Depressions (both unconnected and connected) are distinguished from the ponded areas that occur within the Flat and Riverine Subclasses in several ways. Depressions tend to occur in abandoned channels, abandoned courses, and large point bar swales, while vernal pools within Flat and Riverine wetlands occur in minor swales or in areas bounded by natural levee deposits. Depressions hold water for extended periods due to their size, depth, and ability to collect surface and subsurface flows from an area much larger than the depression itself. They tend to fill during the winter and spring, and dry very slowly. Prolonged rains may fill them periodically during the growing season, after which they again dry very slowly. Vernal pools in Flats and Riverine settings, in contrast, fill primarily due to direct precipitation inputs and dry out within days or weeks. Depression Subclass wetlands usually exhibit two or more of the following characteristics:

- Depressional soils may have one or both of the hydric soil indicators F2 (Loamy Gleyed Matrix) or A4 (Hydrogen Sulfide) (USDA NRCS 2010).
- Depressions are distinct, closed units with relatively abrupt transitions to flats, riverine wetlands, or uplands (as opposed to extensive riverine backwater zones).
- Vegetation in depressions usually is dominated by one or more of the following species: baldcypress, water tupelo (*Nyssa aquatica*), swamp privet (*Forestiera acuminata*), water elm (*Planera aquatica*), and buttonbush (*Cephalanthus occidentalis*). Many depressions are fringed (and some are dominated) by species such as overcup oak and water hickory.

In the Delta Region of Arkansas, there are three subclasses and five community types in the Depression Class (Table 7, Figure 14).

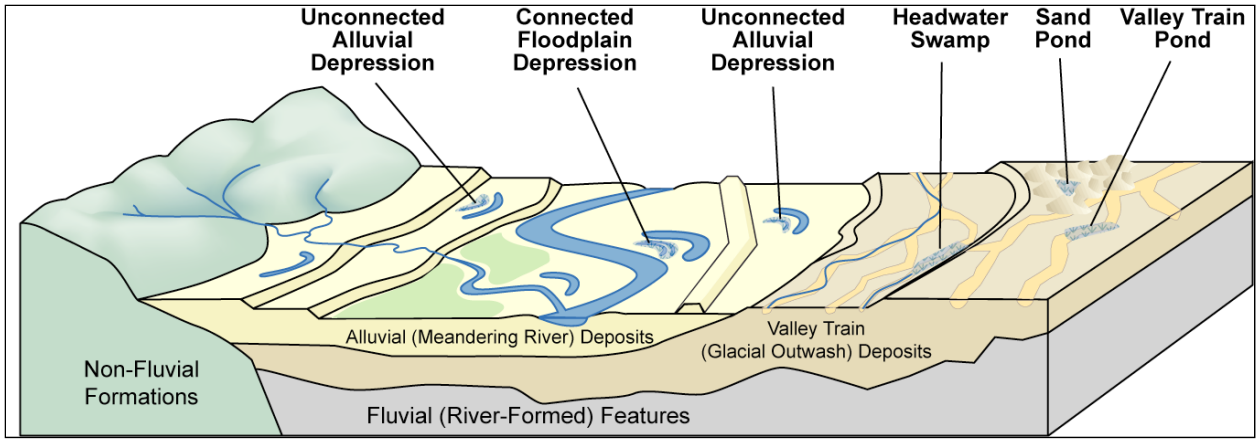


Figure 14. Common landscape positions of wetland community types in the Depression Class.

Subclass: headwater depression. Headwater depressions have one or more outlets that form the headwaters of perennial streams. They export materials such as nutrients and organic matter to downstream systems, and contribute to maintenance of stream baseflow. They differ from Connected Depressions in that they do not have a surface stream input, but rather are fed by groundwater, precipitation, and/or local runoff.

Community type. The following community type occurs within the headwater depression subclass:

a. *Headwater swamp*. Few examples of this wetland type are known, but those that have been examined appear to be restricted to basins formed in ancient glacial outwash channels that receive groundwater from adjacent higher terraces. The nearly constant water supply into the depression creates swamp conditions, where baldcypress and water tupelo are the most common tree species. Few species are present in the understory, and herbaceous species grow primarily on stumps or from a zone of mosses on tree trunks at the level where water tends to stabilize during the growing season. The perimeter forest is dominated by typical lowland species, such as green ash, overcup oak, and Nuttall oak. All known examples of this wetland type are in Monroe or Phillips Counties, including the largest example, which is located at the Louisiana Purchase State Park.

Subclass: unconnected depression. Unconnected depressions are found in a variety of landscape settings. They are maintained by precipitation, runoff, and sometimes by groundwater. Some may have small influent and outlet channels, but they are not overwhelmed by floodwaters during 5-year events; therefore, the import or export of materials is not a significant function of these wetlands except during extreme events. Their disconnection from river systems may result in very different wildlife functions than those associated with connected depressions. For example, unconnected depressions may lack predatory fish populations, and thereby provide vital habitat for certain invertebrate and amphibian species.

Community types. The following community types occur within the unconnected depressions subclass:

a. *Sand pond.* Sand ponds are depressions within dunefields. The dunes are wind-blown accumulations of sediments that were deposited in waning glacial outwash channels, and date from 12,000 and 30,000 years before present. Individual dunes typically are 3 to 5 m high, and support upland forests or have been converted to agriculture. Numerous small, enclosed depressions are confined by the dunes, resulting in a poorly drained environment that ponds rainwater and possibly intercepts local groundwater for extended durations. As a result, distinctive, unconnected wetlands form that usually include swamp species such as baldcypress or water tupelo in the deepest interior areas, and successively less water-tolerant species around the perimeter of the depression. Many sand ponds, particularly those in the northern part of their distribution, contain the shrub species pondberry (*Lindera melissifolia*) and corkwood (*Leitneria floridana*), which do not occur commonly in any other habitat in Arkansas. Sand pond wetlands occur in several distinct bands within the Delta region, and are associated with valley train deposits.

b. *Unconnected alluvial depression.* Unconnected alluvial depressions occur in major river floodplains that have been cut off from the channel by levees and on terraces (former floodplains that are higher than the modern floodplain). They are not affected by river flooding during common flood events (1- to 5-year flood frequency zone). This lack of connection to the river distinguishes this wetland type from floodplain depressions, but otherwise the two types are very similar. Unconnected alluvial depression wetlands typically

occur in abandoned river channels and large swales. Depressions that are deep enough to hold water year-round will have an open-water zone (less than 2 m deep) in the center, with baldcypress and buttonbush in areas that are rarely dry, and relatively narrow zones of progressively "drier" plants, such as overcup oak, around the depression perimeter. Many of these wetlands have been altered by agricultural activities including drainage works that either reduce or increase water storage within the depression.

c. *Valley train pond*. Valley train ponds are unconnected wetlands associated with glacial outwash ("valley train") deposits. They form in very shallow basins that are the remnants of ancient braided channel systems. Plant species in valley train ponds on the youngest outwash deposits (e.g., much of the St. Francis basin) are similar to those found in the alluvial depressions of active stream meander belts, such as baldcypress and water tupelo. Ancient sandbars within the valley train depressions may support species that are not commonly seen in swamps, but are more typical of sandy riverfront areas, such as sycamore and river birch. Older valley train deposits, where outwash channels are largely filled by stream backwater sediments, loess, or erosion from surrounding surfaces, have fewer, shallower ponds than younger surfaces, and tend to be dominated by species less tolerant of water such as willow and water oaks. Water sources for valley train ponds may include groundwater connections through the subsurface, sand-filled paleo-channel system, in addition to precipitation and local runoff. Valley train ponds have been described on outwash deposits between the White River and Crowley's Ridge, and in the St. Francis River lowlands.

Subclass: connected depression. Connected depressions occur within the 5-year floodplain of streams, and are integral components of the stream ecosystem with regard to materials exchange and storage. They often are used by fish and other aquatic organisms that move in and out of the wetland during floods.

Community type. The floodplain depression is the sole community type described within the connected depression subclass:

a. *Floodplain depression*. Floodplain depression wetlands are most commonly found in remnants of abandoned stream channels, or in broad swales left behind by migrating channels. They are usually

near the river, and are flooded by the river during the more common (1- to 5-year) flood events. They typically support swamp forests or shrub swamps in deeper water zones that remain flooded most of the time, and overcup oak-water hickory forests in areas that dry out in summer. Floodplain depression wetlands were once common in the Delta, but as effective flood-control works have been developed along major rivers, many depressions have become disconnected from stream systems and now function as unconnected alluvial depressions (discussed previously).

Class: Fringe

Fringe wetlands occur along the margins of lakes. By convention, a lake must be more than 2 m deep; otherwise associated wetlands are classified as Depressional.

In Arkansas, natural lakes occur mostly in the abandoned channels of large rivers (oxbows), but numerous man-made impoundments also support fringe wetlands. Typical examples within the Delta include the baldcypress fringe common on oxbow lakes, or the black willow fringe that is often associated with borrow pits. There are three subclasses and three community types in the Fringe Class (Table 7, Figure 15). No assessment models have been developed for any of the Fringe wetland subclasses in Arkansas, primarily because no single reference system can reflect the range of variability they exhibit. In particular, many water bodies that support fringe wetlands are subject to water-level controls, but the resulting fluctuation patterns are highly variable depending on the purpose of the control structure.

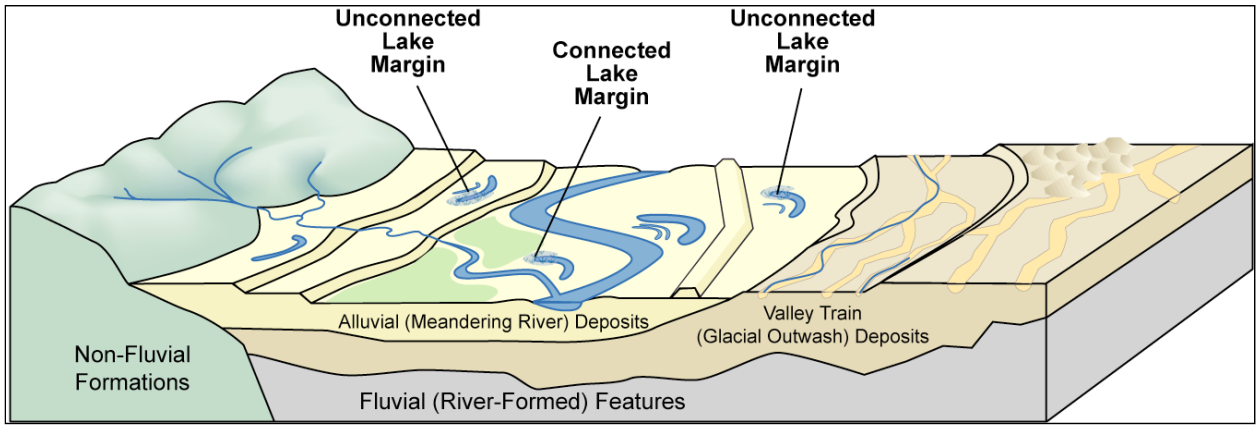


Figure 15. Common landscape positions of wetland community types in the Fringe Class.

Subclass: reservoir fringe. Wetlands that occur within the fluctuation zone of man-made reservoirs are classified as Reservoir Fringe. Reservoirs are distinguished from other man-made water bodies (such as borrow pits) in that they are specifically constructed and operated to store water for flood control, water supply, or similar purposes. As a result, they tend to have fluctuation regimes that are different from any natural pattern in the region.

Community type. The reservoir shore is the sole community type described within the reservoir fringe subclass:

a. *Reservoir shore.* Man-made reservoirs include a wide array of features, such as large farm ponds, municipal water storage reservoirs, and state recreational lakes. In almost all cases, these lakes are managed specifically to modify natural patterns of water flow; therefore their shoreline habitats are subjected to inundation at times and for durations not often found in nature. Steep reservoir shores usually support little perennial wetland vegetation other than a narrow fringe of cattails and rushes and willows. The most extensive wetlands within reservoirs usually occur where tributary streams enter the lake, and sediments accumulate to form deltas. These sites may be colonized by various marsh species, and sometimes black willow or buttonbush, but even these areas are vulnerable to extended drawdowns, ice accumulation, erosion due to boat wakes, and similar impacts.

Subclass: connected lacustrine fringe. Fringe wetlands are considered to be "connected" to other aquatic systems if they become contiguous with riverflows during a 5-year flood event. This means that aquatic organisms can move freely between the river and the lake on a regular basis; and nutrients, sediments, and organic materials are routinely exchanged between the riverine and lake systems.

Community type: The connected lake margin is the sole community type described in the connected lacustrine fringe subclass:

a. *Connected lake margin.* Connected lake margin wetlands occur primarily in oxbow lakes near large rivers, where they are frequently inundated during floods (that is, they are within the 1- to 5-year flood frequency zone). Many lakes that would have met this

criterion early in the 1900s have gradually been disconnected from riverflows due to the completion of large levees and other flood-protection works, and the wetlands in those lakes are now classified as unconnected lake margins. Connected lake margins differ from unconnected systems in that they routinely exchange nutrients, sediments, and aquatic organisms with the river system. Shoreline cypress-tupelo stands and fringe marshes are common, and the upper reaches of oxbow lakes often contain buttonbush swamps and expansive marsh systems. In addition to natural oxbows, there are man-made bodies of water, such as borrow pits, that support connected fringe wetlands. Connected lake margin fringe wetlands are common along large rivers within the Delta Region.

Subclass: unconnected lacustrine fringe. These fringe wetlands occur on lakes that are not within the 5-year floodplain of a river, although they may have small inflow and outflow streams. Many oxbow lakes that have been disconnected from big rivers by levees are in this category. Managed flood-control and water supply reservoirs are not included here, but deeply flooded borrow pits are included.

Community type. The unconnected lake margin is the sole community type described in the unconnected lacustrine fringe subclass:

a. *Unconnected lake margin*. Unconnected lakes are lakes that are not within the portion of a floodplain that is inundated by a river on a regular basis (that is, they are not within the 1- to 5-year floodplain). They are similar in appearance to connected lake margins but are classified separately because they do not regularly exchange nutrients, sediments, or fish with river systems. Most are associated with oxbow lakes, where baldcypress wetlands normally form in a narrow band along the shoreline. Shallow filled areas in the upper and lower ends of the lake sometimes develop more extensive wetland complexes of willows, buttonbush, and marsh species.

Most of these natural lake systems have been modified in various ways. Frequently, their outlets have been fitted with control structures to allow added storage and manipulation of water. Inflows have been altered by farm drainage and other diversions, and adjacent lands have been cleared or developed in many areas.

All of these actions have caused accelerated sedimentation within the lakes.

Naturally occurring unconnected lake margins are most common in the former floodplains of large rivers, especially the Mississippi and Arkansas Rivers, where levees now prevent flooding. Man-made lakes in this subclass can occur anywhere.

4 Wetland Functions and Assessment Models

This Regional Guidebook contains seven sets of assessment models applicable to wetlands in the Delta Region of Arkansas. Not all of the wetland subclasses and community types described in Chapter 3 and Table 7 can be assessed using the models presented here. Only forested wetlands (or sites that could support forested wetlands) are intended to be assessed using these models. No assessment models were developed for the Alkali Flat subclass or the Mid-Gradient Riverine subclass, because relatively few examples of these wetlands exist in the Delta. Models for assessment of these systems will be presented in guidebooks for other regions of the state and will be applicable to Delta systems. Finally, none of the Fringe Class or Riverine Impounded subclass wetlands are addressed in this document. Impacts to these wetlands are likely to involve subtle changes in water level management, which are beyond the scope of a rapid field assessment technique.

The Delta wetlands that can be assessed with the models presented here include all of the subclasses and community types not specifically excluded in the preceding paragraph, and represent most of the common forested wetland types in the region. For simplicity, the Non-Alkali Flat subclass will be referred to simply as the Flat subclass for the remainder of this guidebook. Also, the Low-Gradient Riverine subclass is sufficiently complex that separate models have been developed for its constituent community types, Low-Gradient Overbank and Low-Gradient Backwater wetlands. To maintain consistency, they also will be referred to as separate subclasses for the remainder of this guidebook.

Based on this guidebook discussion, the six wetland subclasses for which assessment models are presented in this chapter are the following:

a. Flat.

b. Low-Gradient Riverine Overbank.

c. Low-Gradient Riverine Backwater.

d. Headwater Depression.

e. Unconnected Depression.

f. Connected Depression.

The wetland functions that can be assessed using this guidebook were identified by participants in a workshop held in Arkansas in 1997. That group selected hydrologic, biogeochemical, and habitat functions that are important and measurable in Arkansas wetlands from a suite of potential functions identified in "A Guidebook for Application of Hydrogeomorphic Assessments to Riverine Wetlands" (Brinson et al. 1995). Based on the workshop recommendations, this regional guidebook provides models and reference data required to determine the extent to which forested wetlands of the Arkansas Delta perform the following functions:

a. Detain Floodwater.

b. Detain Precipitation.

c. Cycle Nutrients.

d. Export Organic Carbon.

e. Maintain Plant Communities.

f. Provide Habitat for Fish and Wildlife.

It should be noted that not all functions are performed by each regional wetland subclass. Thus, assessment models for each subclass may not include all seven functions. In addition, the form of the assessment model that is used to assess functions can vary from subclass to subclass.

In this chapter, each of these functions is discussed generally in terms of the following topics:

a. *Definition and applicability*. This section defines the function, identifies the subclasses where the function is assessed, and identifies an independent quantitative measure that can be used to validate the functional index.

b. *Rationale for selecting the function*. This section discusses the reasons a function was selected for assessment, and the onsite and offsite effects that may occur as a result of lost functional capacity.

c. *Characteristics and processes that influence the function*. This section describes the characteristics and processes of the wetland and the surrounding landscape that influence the function, and lays the groundwork for the description of assessment variables.

d. *General form of the assessment model*. This section presents the structure of the general assessment model and briefly describes the constituent variables.

The specific form of the assessment models used to assess functions for each regional wetland subclass and the functional capacity subindex curves are presented in Chapter 5. In the final chapter (Chapter 6), detailed descriptions are presented of assessment variables and the methods used to measure or estimate their values.

Function 1: Detain floodwater

Definition and applicability

This function reflects the ability of wetlands to store, convey, and reduce the velocity of floodwater as it moves through a wetland. The potential effects of this reduction are damping of the downstream flood hydrograph, maintenance of postflood base flow, and deposition of suspended sediments from the water column to the wetland. This function is assessed for the following regional wetland subclasses in the Delta Region of Arkansas: Low-Gradient Riverine Overbank, Low-Gradient Riverine Backwater, and Connected Depression.

The recommended procedure for assessing this function involves estimation of "roughness" within the wetland, in addition to a change in flood frequency. A potential independent, quantitative measure for validating the functional index is the volume of water stored per unit area per unit time (m^3/ha/time) at a discharge equivalent to the average annual peak event.

Rationale for selecting the function

The capacity of wetlands to temporarily store and convey floodwater has been extensively documented (Campbell and Johnson 1975; Demissie and Kahn 1993; Dewey and Kropper Engineers 1964; Dybvig and Hart 1977; Novitski 1978; Ogawa and Male 1983, 1986; Thomas and Hanson 1981). Many societal benefits related to the reduction of flood damage occur as a result of wetlands performing this function. Generally, floodwater interaction with wetlands dampens and broadens the flood wave, which reduces peak discharge downstream. Similarly, wetlands can reduce the velocity of water currents and, as a result, reduce erosion (Ritter et al. 1995). Some portion of the floodwater volume detained within floodplain wetlands is likely to be evaporated or transpired, reducing the overall volume of water moving downstream. The portion of the detained flow that infiltrates into the alluvial aquifer or that returns to the channel very slowly via low-gradient surface routes may be sufficiently delayed that it

contributes significantly to the maintenance of base flow in some streams long after flooding has ceased (Saucier 1994, Terry et al. 1979). Retention of particulates also is an important component of the flood detention function because sediment deposition directly alters the physical characteristics of the wetland (including hydrologic attributes) and influences downstream water quality.

This function deals specifically with these physical influences on flow and sediment dynamics. Floodwater interaction with floodplain wetlands influences a variety of other wetland functions in the Delta Region of Arkansas, including nutrient mobility and storage and the quality of habitat for plants and animals. The role of flooding in maintenance of these functions is considered separately in other sections of this chapter.

Characteristics and processes that influence the function

The capacity of a wetland to detain and moderate floodwaters is related to antecedent conditions, the characteristics of the particular flood event, the configuration and slope of the floodplain and channel, and the physical obstructions present within the wetland that interfere with flows. The intensity, duration, and spatial extent of precipitation events affect the magnitude of the stream discharge response. Typically, rainfall events of higher intensity, longer duration, and greater spatial extent result in greater flood peaks. Watershed characteristics such as size and shape, channel and watershed slopes, drainage density, and the presence of wetlands and lakes have pronounced effects on the stormflow response (Brooks et al. 1991, Dunne and Leopold 1978, Leopold 1994, Patton 1988, Ritter et al. 1995). The larger the watershed, the greater the volume and peak stream discharge that result from a rainfall event. Watershed shape affects how quickly surface and subsurface flows reach the outlet to the watershed. For example, a rounded watershed concentrates runoff more quickly than an elongated one and will tend to have higher peak flows. Steeper hillslopes and channel gradients also result in quicker response and higher peak flows. The higher the drainage density (i.e., the sum of all the channel lengths divided by the watershed area), the faster water is concentrated at the watershed outlet and the higher the peak flow. As the percentage of wetland area and/or reservoirs increases, the greater the flattening effect (i.e., attenuation) on the stormflow hydrograph. In general, these climatic and watershed characteristics are consistent within a given region and are considered constant for the purposes of rapid assessment.

The physical characteristics of the floodplain and the stream channel also are important determinants of flood flow interactions. The morphology of the stream channel and its floodplain reflect the discharges and sediment loads that have occurred in the past. Under stable flow and sediment conditions, the stream and its floodplain will eventually achieve equilibrium. Alteration to the stream channel or its watershed may cause instability that results in channel aggradation or degradation and a change in depth, frequency, and duration of overbank flow events (Dunne and Leopold 1978, Rosgen 1994). As the stream channel aggrades, available water storage in the channel decreases, resulting in greater depth, frequency, and duration of flooding on the floodplain, and an increase in the amount of surface water stored in the wetland over an annual cycle. Conversely, as the stream channel degrades, available water storage in the channel increases, resulting in less depth, frequency, and duration of flooding and a decrease in the amount of surface water stored in the wetland over an annual cycle. The duration of water storage is secondarily influenced by the slope and roughness of the floodplain. Slope refers to the gradient of the floodplain across which floodwaters flow. Roughness refers to the resistance to flow created by vegetation, debris, and topographic relief. In general, duration increases as roughness increases and slope decreases.

Of all of these characteristics, only change in flood frequency and the roughness component are incorporated into a rapid assessment of the Detain Floodwater function. The extensive channel modifications and levee construction that have taken place in the region make it difficult to ascribe detailed flood characteristics to any particular point on the ground, especially if it is not directly adjacent to a channel and near a stream gauge. At best, change in flood frequency can be estimated for some sites, at least to the extent needed to classify a wetland as riverine or connected (i.e., within the 5-year floodplain). In cases where flood frequency can be estimated more specifically, that information can be used in the assessment of this function.

General form of the assessment model

The model for assessing the Detain Floodwater function includes the following assessment variables, which are discussed in greater detail in Chapter 6:

V_{FREQ} = change in frequency of flooding

V_{LOG} = log density
V_{GVC} = ground vegetation cover
V_{SSD} = shrub-sapling density
V_{TDEN} = tree density

The model can be expressed in a general form:

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \quad (2)$$

The assessment model has two components: change in the frequency of flooding V_{FREQ} and a compound expression that represents flow resistance (roughness) within the wetland. The flood frequency variable is employed as a multiplier such that the significance of the roughness component is proportional to the change in how often the wetland is inundated.

The compound expression of flow resistance includes the major physical components of roughness that can be characterized readily at the level of a field assessment. They include elements that influence flow velocity differently depending on flood depth and time of year. For example, ground vegetation cover V_{GVC} and log density V_{LOG} can effectively disrupt shallow flows. Shrub and sapling density V_{SSD} have their greatest influence on flows that intercept understory canopies (usually 1–3 m deep), and tree stems V_{TDEN} interact with a full range of flood depths. Both tree stems and logs are equally effective in disrupting flows at all times of the year, while understory and ground cover interactions are less effective during winter floods than during the growing season. Other components of wetland structure contribute to roughness, but are not assessed here because they do not commonly influence flows to the same degree as these components (e.g., snag density).

Function 2: Detain precipitation

Definition and applicability

This function is defined as the capacity of a wetland to prevent or slow runoff of rainfall to streams. This is accomplished chiefly by micro-depression storage, infiltration, and absorption by organic material and soils. Both floodprone (riverine) wetlands and nonflooded wetlands (flats) are assessed for this function. Depressional wetlands also perform a precipitation storage function, but are not assessed for that function within

the Delta Region of Arkansas. Precipitation storage in depressions is related to local runoff to varying degrees, and it is difficult to consistently define source areas and available storage volumes in the context of a rapid field assessment. In contrast, precipitation storage in flats and riverine wetlands is more often a local effect related to microdepressional storage and infiltration capacity. Three wetland subclasses are assessed for the precipitation detention function in the Delta Region of Arkansas: Flat, Low-Gradient Riverine Overbank, and Low-Gradient Riverine Backwater.

The recommended procedure for assessing this function is estimation of available micro-depression storage and characterization of the extent of organic surface accumulations available to improve absorption and infiltration. A potential independent direct measure would be calculation of onsite storage relative to runoff predicted by a storm hydrograph for a given rainfall event.

Rationale for selecting the function

Like the floodwater detention function, capture and detention of precipitation prevent erosion, dampen runoff peaks following storms, and help maintain baseflow in streams. The stream hydrograph has a strong influence on the development and maintenance of habitat structure and biotic diversity of adjacent ecosystems (Bovee 1982, Estes and Orsborn 1986, Stanford et al. 1996). In addition, onsite storage of precipitation may be important in maintaining wetland conditions on the site, independent of the influence of flooding. The presence of ponded surface water and recharge of soil moisture also have implications for plant and animal communities within the wetland, but these effects are assessed separately.

Characteristics and processes that influence the function

Flats and riverine wetlands capture precipitation and local runoff in microdepressions and vernal pools. Microdepressions are usually formed by channel migration processes or tree wind-throw, which creates small, shallow depressions when root systems are pulled free of the soil. Vernal pools are usually found in ridge-and-swale topography, or they can be created by the gradual filling of formerly deeper depressions such as cutoffs or oxbows. In addition, the presence of surface organic accumulations reduces runoff and promotes infiltration. Therefore, sites with large amounts of microdepression and vernal pool storage and a thick, continuous litter or duff layer will most effectively reduce the

movement of precipitation as overland flow. Instead, the water is detained onsite, where it supports biological processes and contributes to subsurface water storage and eventually to maintenance of baseflow in nearby streams. Clearing of natural vegetation cover will remove the source of litter and the mechanism for developing new microdepressions. Land use practices that involve ditching or land leveling can eliminate onsite storage and promote rapid runoff of precipitation.

General form of the assessment model

The assessment model for the Detain Precipitation function includes the following assessment variables, which are discussed in greater detail in Chapter 6:

V_{POND} = percent of area subject to ponding
V_{OHOR} = O horizon thickness
V_{LITTER} = thickness of the litter layer

The model can be expressed in a general form:

$$FCI = \frac{\left[V_{POND} + \frac{\left(V_{OHOR} + V_{LITTER} \right)}{2} \right]}{2} \quad (3)$$

The assessment model has two components, which are weighted equally. The percentage of the assessment area subject to ponding V_{POND} is based on a field estimate. The second component expression is an average based on field measures of organic matter accumulation on the soil surface, which are represented by the thickness of the O horizon V_{OHOR} and the percentage of the ground surface covered by litter V_{LITTER}. Litter is sometimes a problematic variable to use, because it is seasonal in nature. However, litter is an important element in precipitation detention, and may be differentially exported from some riverine sites; therefore, it is included in the model despite the inherent difficulties. If users of this guidebook determine that litter cannot be estimated reliably in the wetland being assessed (for example, if fieldwork in two areas being compared will span several seasons), then litter can be removed from the model equation, and the model structure revised appropriately.

Function 3: Cycle nutrients

Definition and applicability

This function refers to the ability of the wetland to convert nutrients from inorganic forms to organic forms and back through a variety of biogeochemical processes such as photosynthesis and microbial decomposition. The nutrient cycling function encompasses a complex web of chemical and biological activities that sustain the overall wetland ecosystem, and it is assessed in all six wetland subclasses.

The assessment procedure described here utilizes indicators of the presence and relative magnitude of organic material production and storage, including living vegetation strata, dead wood, detritus, and soil organic matter. Potential independent, quantitative measures for validating the functional index include net annual primary productivity (gm/m^2), annual litter fall (gm/m^2), or standing stock of living and/or dead biomass (gm/m^2).

Rationale for selecting the function

In functional wetlands, nutrients are transferred among various components of the ecosystem, such that materials stored in each component are sufficient to maintain ecosystem processes (Ovington 1965, Pomeroy 1970, Ricklefs 1990). For example, an adequate supply of nutrients in the soil profile supports primary production, which makes plant community development and maintenance possible (Bormann and Likens 1970, Perry 1994, Whittaker 1975). The plant community, in turn, provides a pool of nutrients and source of energy for secondary production and also provides the habitat structure necessary to maintain the animal community (Fredrickson 1978, Wharton et al. 1981). Plant and animal communities serve as the source of detritus, which provides nutrients and energy necessary to maintain a characteristic community of decomposers. These decomposers, in turn, break down organic material into simpler elements and compounds that can then reenter the nutrient cycle (Dickinson and Pugh 1974, Harmon et al. 1986, Hayes 1979, Pugh and Dickinson 1974, Reiners 1972, Schlesinger 1977, Singh and Gupta 1977, Vogt et al. 1986).

Characteristics and processes that influence the function

In wetlands, nutrients are stored within, and cycled among, four major compartments: (a) the soil, (b) primary producers such as vascular and non-vascular plants, (c) consumers such as animals, fungi, and bacteria, and (d) dead organic matter, such as leaf litter or woody debris, referred to as detritus. The transformation of nutrients within each compartment and the flow of nutrients between compartments are mediated by a complex variety of biogeochemical processes. For example, plant roots take up nutrients from the soil and detritus and incorporate them into the organic matter in plant tissues. Nutrients incorporated into herbaceous or deciduous parts of plants will turn over more rapidly than those incorporated into the woody parts of plants. However, ultimately, all plant tissues are either consumed or die and fall to the ground where they are decomposed by fungi and microorganisms and mineralized to again become available for uptake by plants.

Many of the processes involved in nutrient cycling, such as primary production and decomposition, have been studied extensively in wetlands (Brinson et al. 1981). In the Southeast specifically, there is a rich literature on the standing stock, accumulation, and turnover of above- and below-ground biomass in forested wetlands (Brinson 1990, Brown and Peterson 1983, Conner and Day 1976, Day 1979, Elder and Cairns 1982, Harmon et al. 1986, Mulholland 1981, Raich and Nadelhoffer 1989, Nadelhoffer and Raich 1992, Symbula and Day 1988).

In controlled field studies, the approach for assessing nutrient cycling is usually to measure the rate at which nutrients are transformed and transferred between compartments over an annual cycle (Brinson et al. 1984, Harmon et al. 1986, Kuenzler et al. 1980), which is not feasible as part of a rapid assessment procedure. The alternative is to estimate the standing stocks of living and dead biomass in each of the four compartments and assume that nutrient cycling is taking place at a characteristic level if the biomass in each compartment is similar to that in reference standard wetlands. In this case, estimation of consumer biomass (animals, etc.) is too complex for a rapid assessment approach; thus, the presence of these organisms is assumed based on the detrital and living plant biomass components.

General form of the assessment model

The model for assessing the Cycle Nutrients function includes the following assessment variables, which are discussed in greater detail in Chapter 6:

V_{TBA} = tree basal area
V_{SSD} = shrub-sapling density
V_{GVC} = ground vegetation cover
V_{OHOR} = O horizon thickness
V_{AHOR} = A horizon biomass
V_{WD} = woody debris biomass
V_{SNAG} = snag density

The model can be expressed in a general form:

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \quad (4)$$

The two constituent expressions within the model reflect the two major production and storage compartments: living and dead organic material. The first expression is composed of indicators of living biomass, expressed as tree basal area V_{TBA}, shrub and sapling density V_{SSD}, and ground vegetation cover V_{GVC}. These various living components also reflect varying levels of nutrient availability and turnover rates, with the aboveground portion of ground cover biomass being largely recycled on an annual basis, while understory and tree components incorporate both short-term storage (leaves) as well as long-term storage (wood). Similarly, the second expression includes organic storage compartments that reflect various degrees of decay. Snag density V_{SNAG} and woody debris volume V_{WD} represent relatively long-term storage compartments that are gradually transferring nutrients into other components of the ecosystem through the mediating activities of fungi, bacteria, and higher plants. The thickness of the O horizon V_{OHOR} represents a shorter term storage compartment of largely decomposed, but nutrient-rich organics on the soil surface. The thickness of the A horizon (actually, the portion of the A where organic accumulation is apparent) V_{AHOR} represents a longer term storage compartment, where nutrients that have been released from other compartments are held within the soil and are available for plant uptake,

but are generally conserved within the system and not readily subject to export by runoff or floodwater.

All of these components are combined here in a simple arithmetic model, which weights each element equally. Note that one detrital component, litter accumulation, is not used in this model. That is because it is a relatively transient component of the onsite nutrient capital, and may in fact be readily exported. Therefore it is used as a nutrient-related assessment variable only in the carbon export function, discussed in the next section.

Function 4: Export organic carbon

Definition and applicability

This function is defined as the capacity of the wetland to export dissolved and particulate organic carbon, which may be vitally important to downstream aquatic systems. Mechanisms involved in mobilizing and exporting nutrients include leaching of litter, flushing, displacement, and erosion. This assessment procedure employs indicators of organic production, the presence of organic materials that may be mobilized during floods, and the occurrence of periodic flooding to assess the organic export function of a wetland. An independent quantitative measure of this function is the mass of carbon exported per unit area per unit time ($g/m^2/year$).

This function is assessed in wetlands that have outflow to streams, which includes four subclasses in the Delta Region of Arkansas: Low-Gradient Riverine Overbank, Low-Gradient Riverine Backwater, Headwater Depression, and Connected Depression.

Rationale for selecting the function

The high productivity of river-connected wetlands and their interaction with streams make them important sources of dissolved and particulate organic carbon for aquatic food webs and biogeochemical processes in downstream aquatic habitats (Elwood et al. 1983, Sedell et al. 1989, Vannote et al. 1980). Dissolved organic carbon is a significant source of energy for the microbes that form the base of the detrital food web in aquatic ecosystems (Dahm 1981, Edwards 1987, Edwards and Meyers 1986).

Characteristics and processes that influence the function

Watersheds with a large proportion of riverine and other wetland types have generally been found to export organic carbon at higher rates than watersheds with fewer wetlands (Brinson et al. 1981, Elder and Mattraw 1982, Johnston et al. 1990, Mulholland and Kuenzler 1979). This is attributable to several factors: (a) the large amount of organic matter in the litter and soil layers that comes into contact with surface water during flooding; (b) relatively long periods of inundation and, consequently, contact between surface water and organic matter, thus allowing for significant leaching; (c) the ability of the labile carbon fraction to be rapidly leached from organic matter when exposed to water (Brinson et al. 1981); and (d) the ability of floodwater to transport dissolved and particulate organic carbon from the floodplain to the stream channel.

General form of the assessment model

The model for assessing the Export Organic Carbon function includes the following assessment variables, which are discussed in greater detail in Chapter 6:

V_{FREQ} = change in frequency of flooding
V_{OUT} = change in outflow
V_{LITTER} = thickness of the litter layer
V_{OHOR} = O horizon thickness
V_{WD} = woody debris biomass
V_{SNAG} = snag density
V_{TBA} = tree basal area
V_{SSD} = shrub-sapling density
V_{GVC} = ground vegetation cover

The general form of the assessment model follows:

$$FCI = \begin{bmatrix} V_{FREQ} \\ \text{or} \\ V_{OUT} \end{bmatrix} \times \left\{ \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG} \right)}{4} \right] + \left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} \right]}{2} \right\} \quad (5)$$

This model is similar to the model used to assess the nutrient cycling function in that it incorporates most of the same indicators of living and dead organic matter. The living tree, understory, and ground cover

components (V_{TBA}, V_{SSD}, and V_{GVC}) represent primarily organic production, indicating that materials will be available for export in the future. The dead organic fraction represents the principal sources of exported material, represented by litter, snags, woody debris, and accumulation of the O horizon (V_{LITTER}, V_{SNAG}, V_{WD}, and V_{OHOR}). This model differs from the nutrient cycling model in that materials stored in the soil are not included due to their relative immobility, and flooding (for riverine or connected depression subclasses) or outflow (for headwater depressions) is a required component of this model, because the export function is largely dependent on inundation and continuity with stream flows (V_{FREQ} or V_{OUT}). This model also includes litter as a component of the dead organic fraction, despite the fact that it is a highly seasonal functional indicator that is difficult to estimate reliably, and therefore is not included in other models where it may seem appropriate. However, it is included in this model because it represents the most mobile dead organic fraction in the wetland, and because it may be the only component of that fraction that is present in young or recently restored systems. If users of this guidebook determine that litter cannot be estimated reliably in the wetland being assessed (for example, if fieldwork in two areas being compared will span several seasons), then litter can be removed from the model equation.

Function 5: Maintain plant communities

Definition and applicability

This function is defined as the capacity of a wetland to provide the environment necessary for characteristic plant community development and maintenance. In assessing this function, one must consider both the extant plant community as an indication of current conditions and the physical factors that determine whether or not a characteristic plant community is likely to be maintained in the future. Various approaches have been developed to describe and assess plant community characteristics that might be appropriately applied in developing independent measures of this function. These include quantitative measures based on vegetation composition and abundance such as similarity indices (Ludwig and Reynolds 1988), and indirect multivariate techniques such as detrended correspondence analysis (Kent and Coker 1995). However, none of these approaches alone can supply a “direct independent measure” of plant community function, because they are tools that are employed in a more complex analysis that requires familiarity with the regional vegetation and collection of

appropriate sample data. This function is assessed in all six subclasses in the Delta Region of Arkansas.

Rationale for selecting the function

The ability to maintain a characteristic plant community is important because of the intrinsic value of the plant community and the many attributes and processes of wetlands that are influenced by the plant community. For example, primary productivity, nutrient cycling, and the ability to provide a variety of habitats necessary to maintain local and regional diversity of animals are directly influenced by the plant community (Harris and Gosselink 1990). In addition, the plant community of a river-connected wetland influences the quality of the physical habitat, nutrient status, and biological diversity of downstream systems (Bilby and Likens 1979, Elder 1985, Gosselink et al. 1990, Hawkins et al. 1982).

Characteristics and processes that influence the function

Numerous studies describe the environmental factors that influence the occurrence and characteristics of plant communities in lowland hardwood wetlands (Hodges 1997; Messina and Conner 1997; Robertson 1992; Robertson et al. 1978, 1984; Smith 1996; Wharton et al. 1982). Hydrologic regime is usually cited as the principal factor controlling plant community attributes. Consequently, this factor is a fundamental consideration in the basic hydrogeomorphic classification scheme employed in this guidebook. Soil characteristics are also significant determinants of plant community composition (see “Soils” section in Chapter 3). In addition to physical factors, system dynamics and disturbance history are also important in determining the condition of a wetland plant community at any particular time. These include past land use, timber harvest history, hydrologic changes, sediment deposition, and events such as storms, fire, beaver activity, insect outbreaks, and disease. Clearly, some characteristics of plant communities within a particular wetland subclass may be determined by factors too subtle or variable to be assessed using rapid field estimates. Therefore, this function is assessed primarily by considering the degree to which the existing plant community structure and composition are appropriate to site conditions and the expected stage of maturity for the site. Secondarily, in some subclasses, soil and hydrologic conditions are assessed to determine if fundamental requirements are met to maintain wetland conditions appropriate to the geomorphic setting.

General form of the assessment model

The model for assessing the Maintain Plant Communities function includes the following assessment variables, which are discussed in greater detail in Chapter 6:

V_{TBA} = tree basal area
V_{TDEN} = tree density
V_{COMP} = composition of tallest woody stratum
V_{SOIL} = soil integrity
V_{DUR} = change in growing season flood duration
V_{POND} = microdepressional ponding

The model can be expressed in a general form:

$$FCI = \left(\left\{ \left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right] \right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} + V_{POND} \right)}{3} \right] \right)^{1/2} \quad (6)$$

The first expression of the model has two components. One component describes the structure of the overstory stratum of the plant community in terms of tree basal area and density (V_{TBA} and V_{TDEN}). Together these indicate whether the stand has a structure typical of a mature forest with "gap" regeneration processes in place. The second term of the expression (V_{COMP}) considers the species composition of the dominant stratum, which will be the overstory in most instances, but which may be the shrub or ground cover layers in communities that are in earlier (or arrested) stages of development. This allows recognition of the faster recovery trajectory likely to take place in planted restoration sites (versus abandoned fields).

The second expression of the model considers three specific site factors that may be crucial to plant community maintenance under certain conditions. V_{SOIL} is a simple comparison of the soil on the site to the mapped or predicted soil type for the area and geomorphic setting. As described in the section "Vegetation" in Chapter 3, plant communities of the Delta Region of Arkansas are strongly affiliated with particular soil types, which in turn are the product of distinct alluvial processes. The V_{SOIL} variable allows recognition of sites where the native soils have been replaced or buried by sediments inappropriate to the site, or where the

native soils have been damaged significantly, as by compaction. The V_{POND} variable focuses on a specific aspect of site alteration—the removal of microtopography and related ponding of water on flats and riverine wetlands. As described previously, ponding of precipitation is a crucial mechanism for maintaining wetland character in many wetlands in the Delta Region of Arkansas. Flooding is also critical for the maintenance of many plant communities within the region, but this relationship is considered separately as a basic classification factor. Change in flood duration has a very significant impact on plant communities, and is included as well.

Function 6: Provide habitat for fish and wildlife

Definition and applicability

This function is defined as the ability of a wetland to support the fish and wildlife species that utilize wetlands during some part of their life cycles. Potential independent, quantitative measures of this function are animal inventory approaches, with data analysis usually employing comparisons between sites using a similarity index calculated from species composition and abundance (Odum 1950, Sorenson 1948).

This function is assessed in all six subclasses in the Delta Region of Arkansas.

Rationale for selecting the function

Terrestrial, semiaquatic, and aquatic animals use wetlands extensively. Maintenance of this function ensures habitat for a diversity of vertebrate organisms, contributes to secondary production, and maintains complex trophic interactions. Habitat functions span a range of temporal and spatial scales, and include the provision of refugia and habitat for wide-ranging or migratory animals as well as highly specialized habitats for endemic species. However, most wildlife and fish species found in wetlands of the Delta Region of Arkansas depend on certain aspects of wetland structure and dynamics, such as periodic flooding or ponding of water, specific vegetation composition, and proximity to other habitats.

Characteristics and processes that influence the function

The quality and availability of habitats for fish and wildlife species in wetlands of the Delta Region of Arkansas are dependent on a variety of

factors operating at different scales. Habitat components that can be considered in a rapid field assessment include vegetation structure and composition; detrital elements; availability of water, both from precipitation and flooding; and spatial attributes such as patch size and connectivity.

Forested wetlands typically are floristically and hydrologically complex (Wharton et al. 1982). Structural diversity in the vertical plane generally increases with vegetation maturity (Hunter 1990). Vegetation diversity on the horizontal plane derives from gap-phase regeneration dynamics and the complex patterns of alluvial deposition that produce interspersion of low ridges, swales, abandoned channel segments, and other features that differentially flood or pond rainwater, and support distinctively different plant communities (see Chapter 3). This structural diversity provides myriad habitat conditions for animals and allows numerous species to coexist in the same area (Schoener 1986). The compositional diversity typical of lowland forests also assures the availability of a wide variety of food resources (Allen 1987).

Detrital components of the ecosystem are of considerable significance to animal populations in lowland hardwood wetlands. Litter provides ideal habitat for small animals such as salamanders (Johnson 1987), and has a distinctive invertebrate fauna (Wharton et al. 1982) that is vital to some of the more visible members of the community. For example, prior to laying eggs, wood ducks forage extensively on macroinvertebrates found in the floodplain. Similarly, mallards heavily utilize the abundant litter invertebrate populations associated with flooded or ponded bottomland forests during winter (Batema et al. 1985). Logs and other woody debris provide cover and a moist environment for many species including invertebrates, small mammals, reptiles, and amphibians (Hunter 1990). Animals found in forested wetlands use logs as resting sites, cover, feeding platforms, and as sources of food (Harmon et al. 1986, Loeb 1993). Standing dead trees (snags) are used by numerous bird species, and several species are dependent on snags for their existence (Scott et al. 1977). Stauffer and Best (1980) found that most cavity-nesting birds, particularly the primary cavity nesters such as woodpeckers, preferred snags versus live trees. Mammals such as bats, squirrels, and raccoons also are dependent on snags to varying extents (Howard and Allen 1989), and most species of forest-dwelling mammals, reptiles, and amphibians, along

with numerous invertebrates, seek shelter in cavities, at least occasionally (Hunter 1990).

In wetlands of the Delta Region of Arkansas, hydrology is one of the major factors influencing wildlife habitat quality. A significant hydrologic component is precipitation, particularly where it is captured in vernal pools and small puddles. These sites are a source of surface water for various terrestrial animals, and provide reproductive habitat for invertebrates and amphibians, many of which are utilized as a food source by other animals (Johnson 1987, Wharton et al. 1982). Ponded breeding sites without predatory fish populations are very important for some species of salamanders and frogs (Johnson 1987).

While temporary ponding of precipitation is important to many species precisely because it provides an aquatic environment that is isolated from many aquatic predators, wetlands that are periodically river-connected also provide vital habitat for some species. Wharton et al. (1982), who provided an overview of fish use of bottomland hardwoods in the Piedmont and eastern Coastal Plain, stated that at least 20 families and up to 53 species of fish use various portions of the floodplain for foraging and spawning. Baker and Killgore (1994) reported similar results from the Cache River drainage in Arkansas, where they found that most fish species exploit floodplain habitats at some time during the year, many for spawning and rearing. In addition to flooding itself, the complex environments of floodplains are of significance to fish. Wharton et al. (1982) listed numerous examples of fish species being associated with certain portions of the floodplain. Baker et al. (1991) noted that the different microhabitats on the floodplain typically supported different fish assemblages from those of the channel. Baker and Killgore (1994) stated that “the structurally complex environment of irregularly flooded oak-hickory forests provide optimum habitat for many wetland fish.” A change in flood duration can also substantially shift plant dominance and animal use of sites.

Just as topographic variations provide essential wetland habitats such as temporary ponds and river-connected backwaters, they also provide sites that generally remain dry. Such sites are important to ground-dwelling species that cannot tolerate prolonged inundation. Wharton et al. (1982) stated that old, natural levee ridges are extremely important to many floodplain species, because they provide winter hibernacula and refuge areas during periods of high water. Similarly, Tinkle (1959) found that

natural levees were used extensively as egg-laying areas by many species of reptiles and amphibians.

Landscape-level features such as forest patch size, shape, connectivity, and surrounding land use are also important attributes that affect the lowland wildlife community (Hunter 1990, Morrison et al. 1992). It is generally assumed that reduction and fragmentation of forest habitat, coupled with changes in the remaining habitat, resulted in the loss of the ivory-billed woodpecker, Bachman's warbler, and the red wolf (*Canis rufus*), as well as severe declines in the black bear and Florida panther (*Puma concolor coryi*). The extent to which patch size affects animal populations has been most thoroughly investigated with respect to birds, but the results have been inconsistent (Askins et al.1987, Blake and Karr 1984, Howe 1984, Keller et al. 1993, Kilgo et al. 1997, Lynch and Whigham 1984, Sallabanks et al. 1998, Stauffer and Best 1980). However, the negative effects of forest fragmentation on some species of birds have been well documented (Finch 1991). These species, referred to as forest interior species, apparently respond negatively to unfavorable environmental conditions or biotic interactions that occur in fragmented forests (Ambuel and Temple 1983). The point at which forest fragmentation affects different bird species has yet to be defined, and study results have been inconsistent (e.g., Temple 1986; Wakeley and Roberts 1996). Thus, the area needed to accommodate all the species typically associated with large patches of forested wetlands in the region can only be approximated. One such approximation (Mueller et al. 1995) identified three groups of birds that breed in the Mississippi Alluvial Valley with (presumably) similar needs relative to patch size. That study suggested that, to sustain source breeding populations of individual species within the three groups, 44 patches of 4,000 – 8,000 ha, 18 patches of 8,000 – 40,000 ha, and 12 patches larger than 40,000 ha are needed. Species such as Swainson's warbler (*Limnothlypis swainsonii*) are in the first group; more sensitive species such as the cerulean warbler (*Dendroica cerulea*) are in the second group; and those with very large home ranges (e.g., raptors such as the red-shouldered hawk) (*Buteo lineatus*) are in the third group.

The land use surrounding a tract of forest also has a major effect on avian populations. Recent studies (Robinson et al. 1995, Sallabanks et al. 1998, Thompson et al. 1992, Welsh and Healy 1993) suggest that bird populations respond to fragmentation differently in forest-dominated landscapes than in those in which the bulk of the forests have been permanently lost to

agriculture or urbanization. Generally, these studies indicate that as the mix of feeding habitats (agricultural and suburban lands) and breeding habitats (forests and grasslands) increases, predators and nest parasites become increasingly successful, even if large blocks of habitat remain. Thus, in more open landscapes, block sizes need to be larger than in mostly forested ones. Conversely, Robinson (1996) estimated that as the percentage of the landscape that is forested increases above 70 percent (approximately), the size of the forest blocks within that landscape becomes less significant to bird populations.

In landscapes that are fragmented, corridors have been suggested as a means of ameliorating many of the anticipated negative effects of fragmentation (Harris 1985, Noss and Harris 1986), although there is disagreement over the benefits of corridors (Simberloff et al. 1992). In bottomland forest communities, probably the most significant habitat connection for many species is between floodprone areas and nonflooded habitats of similar structure, which allows terrestrial species to seek refuge during periods of high water (Wharton et al. 1982). In general, connections between different wetland types, and between uplands and wetlands, help maintain higher animal and plant diversity across the landscape than if habitats are more isolated from one another (Sedell et al. 1990).

General form of the assessment model

The model for assessing the Provide Habitat for Fish and Wildlife function includes the following assessment variables, which are discussed in greater detail in Chapter 6:

V_{FREQ} = change in frequency of flooding
V_{DUR} = change in growing season flood duration
V_{POND} = microdepressional ponding
V_{TCOMP} = tree composition
V_{SNAG} = snag density
V_{STRATA} = number of vegetation layers
V_{TBA} = tree basal area
V_{LOG} = log density
V_{OHOR} = O horizon thickness
V_{TRACT} = wetland tract size
$V_{CONNECT}$ = habitat connections
V_{CORE} = core area

The model can be expressed in a general form:

$$FCI = \left\{ \left[\frac{\left(V_{FREQ} + V_{DUR} + V_{POND} \right)}{3} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \right\}^{1/4} \quad (7)$$

The expressions within the model reflect the major habitat components described. The first expression concerns hydrology, and includes indicators of both seasonal inundation, which allows river access by aquatic organisms (V_{DUR} and V_{FREQ}) as well as the periodic occurrence of temporary, isolated aquatic conditions (V_{POND}). The second expression includes four indicators of forest structure and diversity, specifically overstory basal area (V_{TBA}), overstory tree species composition (V_{TCOMP}), snag density (V_{SNAG}) and a measure of structural complexity (V_{STRATA}). Together these variables reflect a variety of conditions of importance to wildlife, including forest maturity and complexity and the availability of food and cover. Habitat structure for animals associated with detrital components is indicated by two variables: the volume of logs per unit area (V_{LOG}) and the thickness of the O horizon (V_{OHOR}). Note that the litter layer, which is important to some species, is not included in the model due to its seasonality. Instead, the O horizon is used as an indicator of litter accumulation, since it is a direct result of litter decay. Three landscape-level variables are incorporated within the last term of the model to reflect the importance of habitat fragmentation and interhabitat continuity as considerations in determining habitat quality for a large percentage of wildlife species within the Delta Region of Arkansas: the size of the overall wetland complex independent of the boundaries of the assessment area (V_{TRACT}); the proportion of the assessment area that is buffered from surrounding land uses and edge effects (V_{CORE}); and the proportion of the assessment area boundary that is connected to other suitable habitat types via appropriate movement corridors ($V_{CONNECT}$).

5 Model Applicability and Reference Data

The assessment models described in Chapter 4 are applied to individual wetland subclasses in different ways. This is because not all of the assessment models and variables are applicable to all of the regional wetland subclasses. For example, the Export Organic Carbon function is applicable only to the Low-Gradient Riverine Overbank and Backwater, Headwater Depression, and Connected Depression subclasses, and is not assessed in subclasses having no export mechanism (flooding) (i.e., Unconnected Depressions and Flats). Similarly, some variables can be deleted from assessment models for subclasses where they cannot be consistently evaluated. For example, ground vegetation cover V_{GVC}, litter cover V_{LITTER}, woody debris and logs V_{WD} and V_{LOG}, and thickness of the O and A horizons V_{OHOR} and V_{AHOR} may be difficult to assess in depressions that are inundated, and modified versions of the models applicable to the depression subclasses are provided for use in those situations. The modified models are likely to be less sensitive than the full versions, but they are complete enough to be used when necessary.

Assessment models also differ among subclasses with regard to their associated reference data. Each subclass was the focus of detailed sampling during development of this guidebook, and the reference data collected for each subclass have been independently summarized for application. The following sections present information for each wetland subclass with regard to model applicability and reference data. For each subclass, each of the seven potential functions available for assessment is listed, and the applicability of the assessment model is described. The model is presented as described in Chapter 4 if it is applicable in its general and complete form; it is presented in a modified form if certain variables cannot be consistently assessed in certain subclasses; and the function is identified as “Not Assessed” in cases where the wetland subclass does not perform the function as described in Chapter 4, or where it cannot be assessed with the methods and model available for rapid field assessment. For each wetland subclass, functional capacity subindex curves are presented for every assessment variable used in the applicable assessment models, based on reference data.

Subclass: Flat

Four functions are assessed for this subclass. Most of the applicable assessment models have not been changed from the general model form presented in Chapter 4. Figure 16 provides the relationship between the variable metrics and the subindex for each of the assessment models based on the reference data. Note that, unlike other subclasses, the Flat subclass subindex curves for percent ponding reflect three different geomorphic settings, and it is necessary to identify the setting when assembling field data. Specific guidance is provided on the field data sheets for Non-Alkali Flat Wetlands (Flats) in Appendix B.

a. Function 1: Detain Floodwater. Not Assessed

b. Function 2: Detain Precipitation.

$$FCI = \frac{\left[V_{POND} + \frac{\left(V_{OHOR} + V_{LITTER}\right)}{2}\right]}{2} \tag{8}$$

c. Function 3: Cycle Nutrients.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \tag{9}$$

d. Function 4: Export Organic Carbon. Not assessed.

e. Function 5: Maintain Plant Communities.

$$FCI = \left(\left\{\frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP}\right]}{2}\right\} \times \left[\frac{\left(V_{SOIL} + V_{POND}\right)}{2}\right]\right)^{1/2} \tag{10}$$

f. Function 6: Provide Wildlife Habitat. Applicable in the following modified format:

$$FCI = \left\{V_{POND} \times \left[\frac{\left(V_{TCOMP} + V_{SNAG} + V_{STRATA} + V_{TBA}\right)}{4}\right] \times \left[\frac{\left(V_{LOG} + V_{OHOR}\right)}{2}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right]\right\}^{1/4} \tag{11}$$

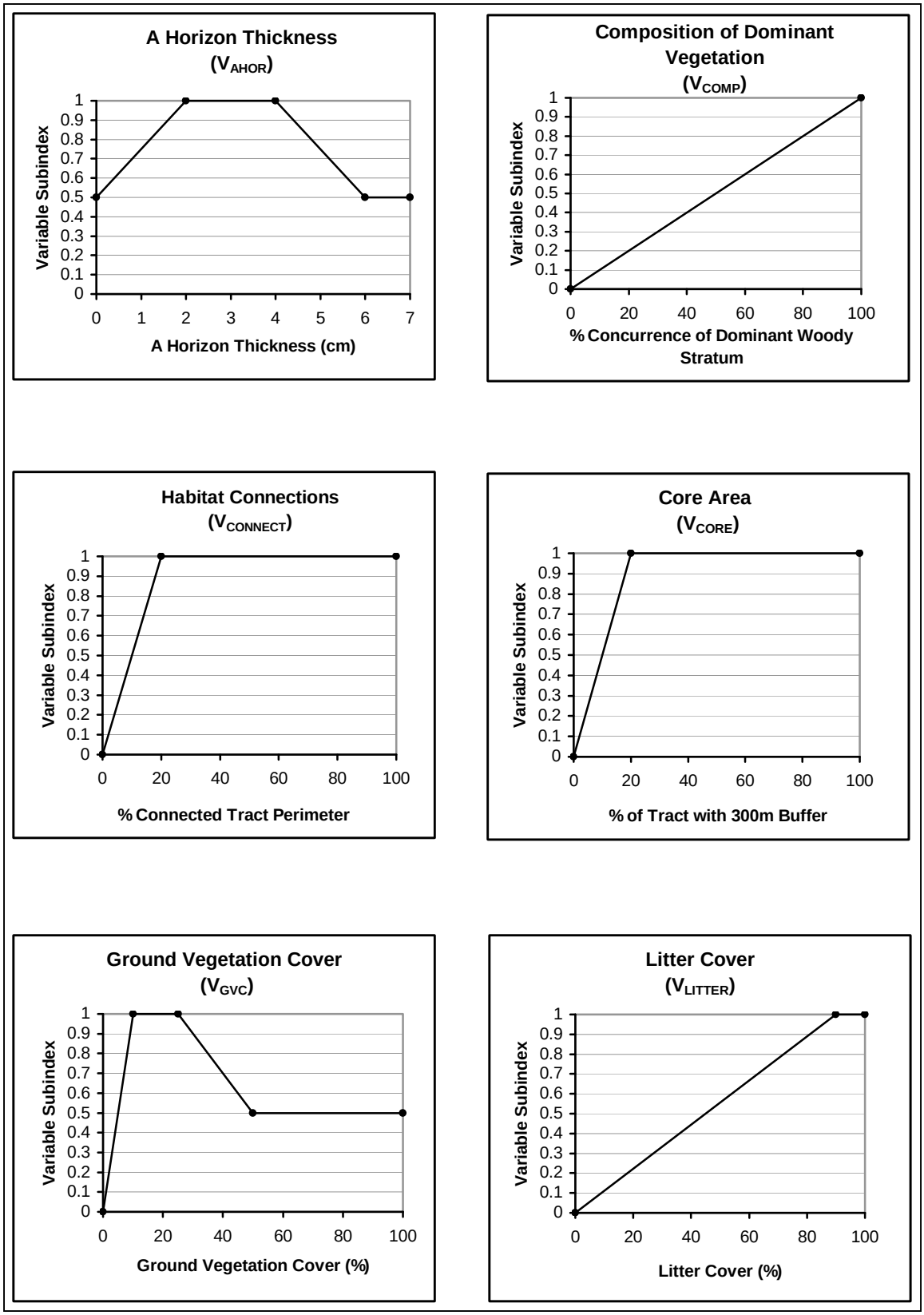


Figure 16. Subindex curves for Flat wetlands (Sheet 1 of 4).

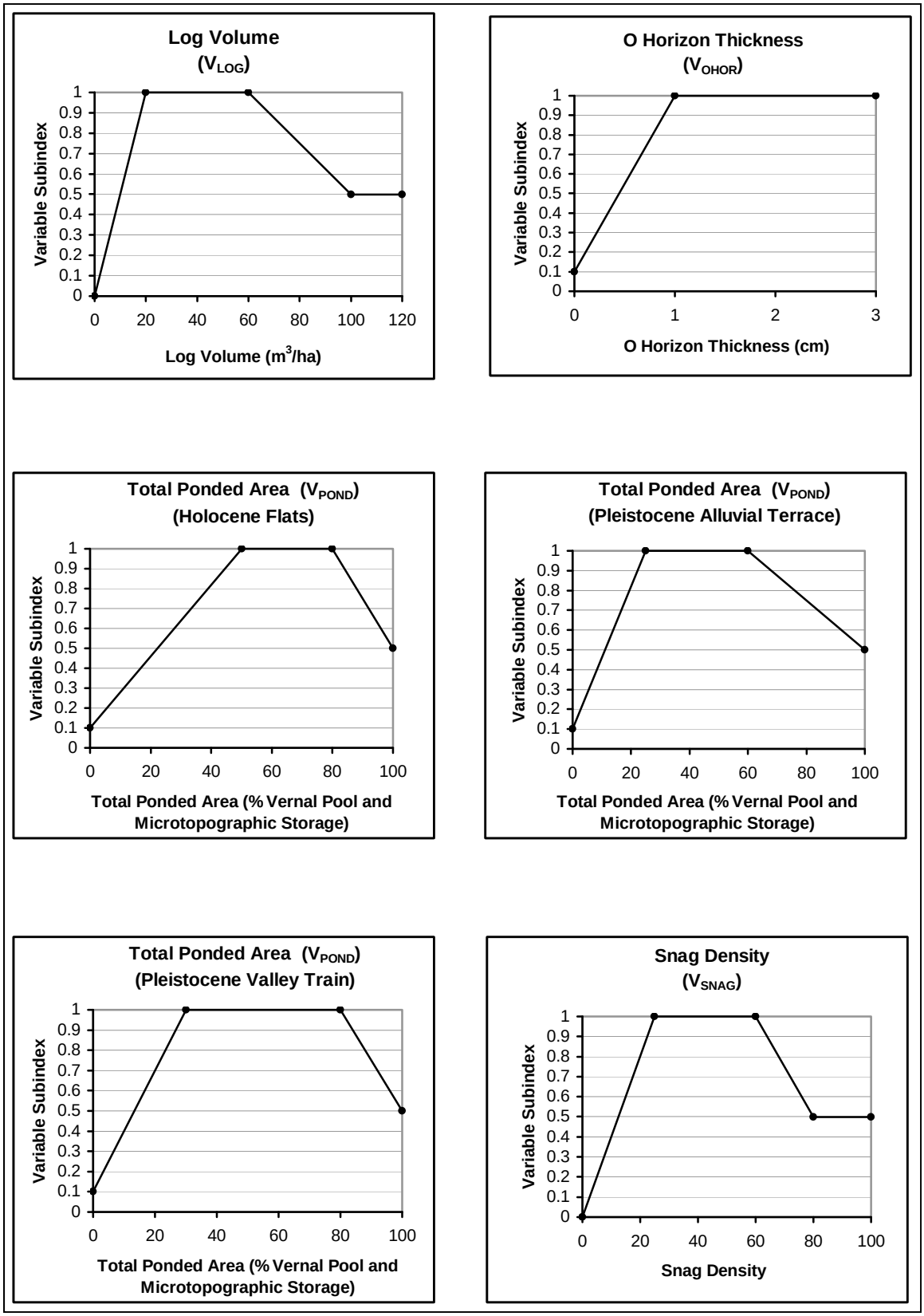


Figure 16. (Sheet 2 of 4).

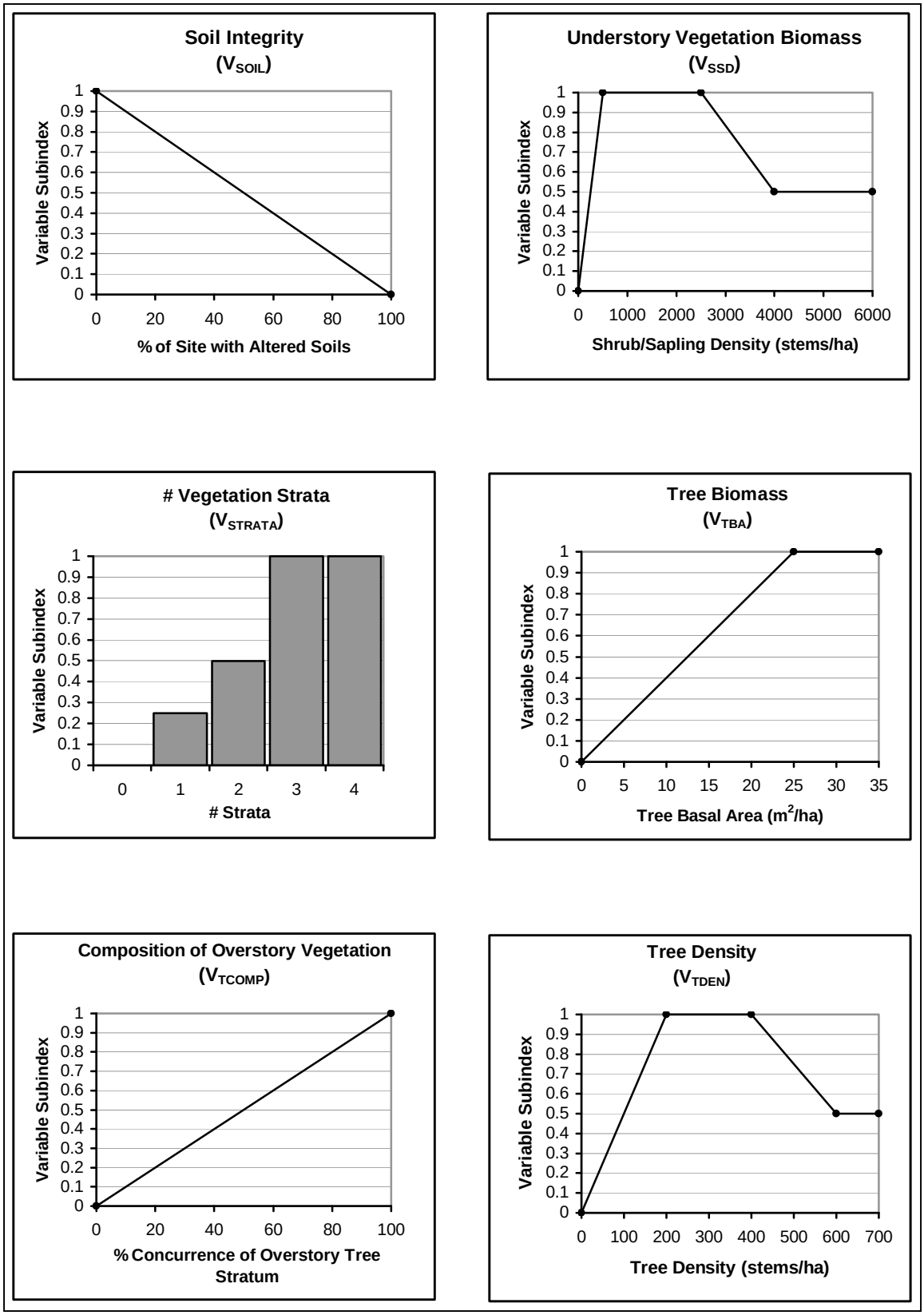


Figure 16. (Sheet 3 of 4).

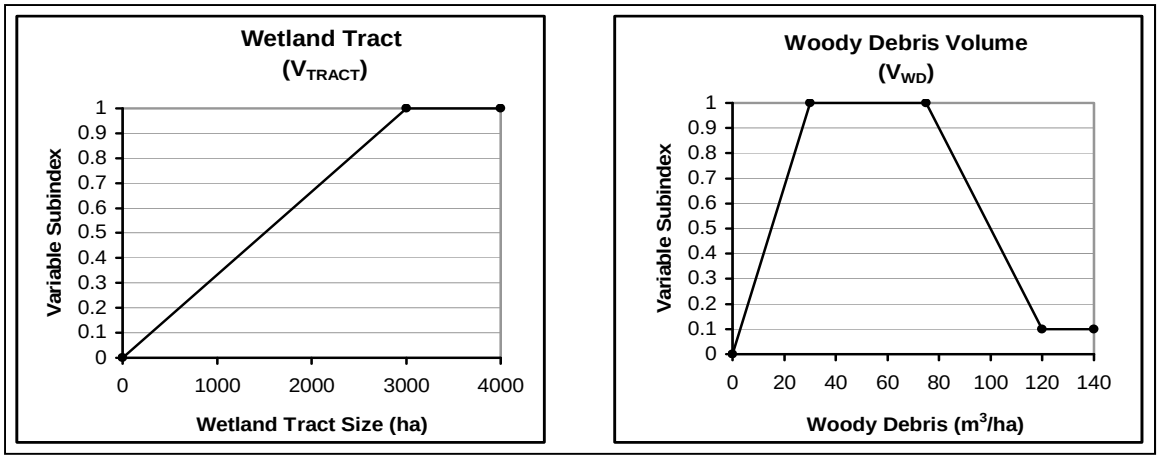


Figure 16. (Sheet 4 of 4).

Subclass: Low-Gradient Riverine Backwater

All functions are assessed for this subclass using the general form of each assessment model presented in Chapter 4 as follows. Figure 17 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the riverine backwater reference data.

a. Function 1: Detain Floodwater.

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \quad (12)$$

b. Function 2: Detain Precipitation.

$$FCI = \frac{\left[V_{POND} + \frac{\left(V_{OHOR} + V_{LITTER} \right)}{2} \right]}{2} \quad (13)$$

c. Function 3: Cycle Nutrients.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG} \right)}{4} \right]}{2} \quad (14)$$

d. Function 4: Export Organic Carbon.

$$FCI = V_{FREQ} \times \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG} \right)}{4} \right] + \left[\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3} \right]}{2} \quad (15)$$

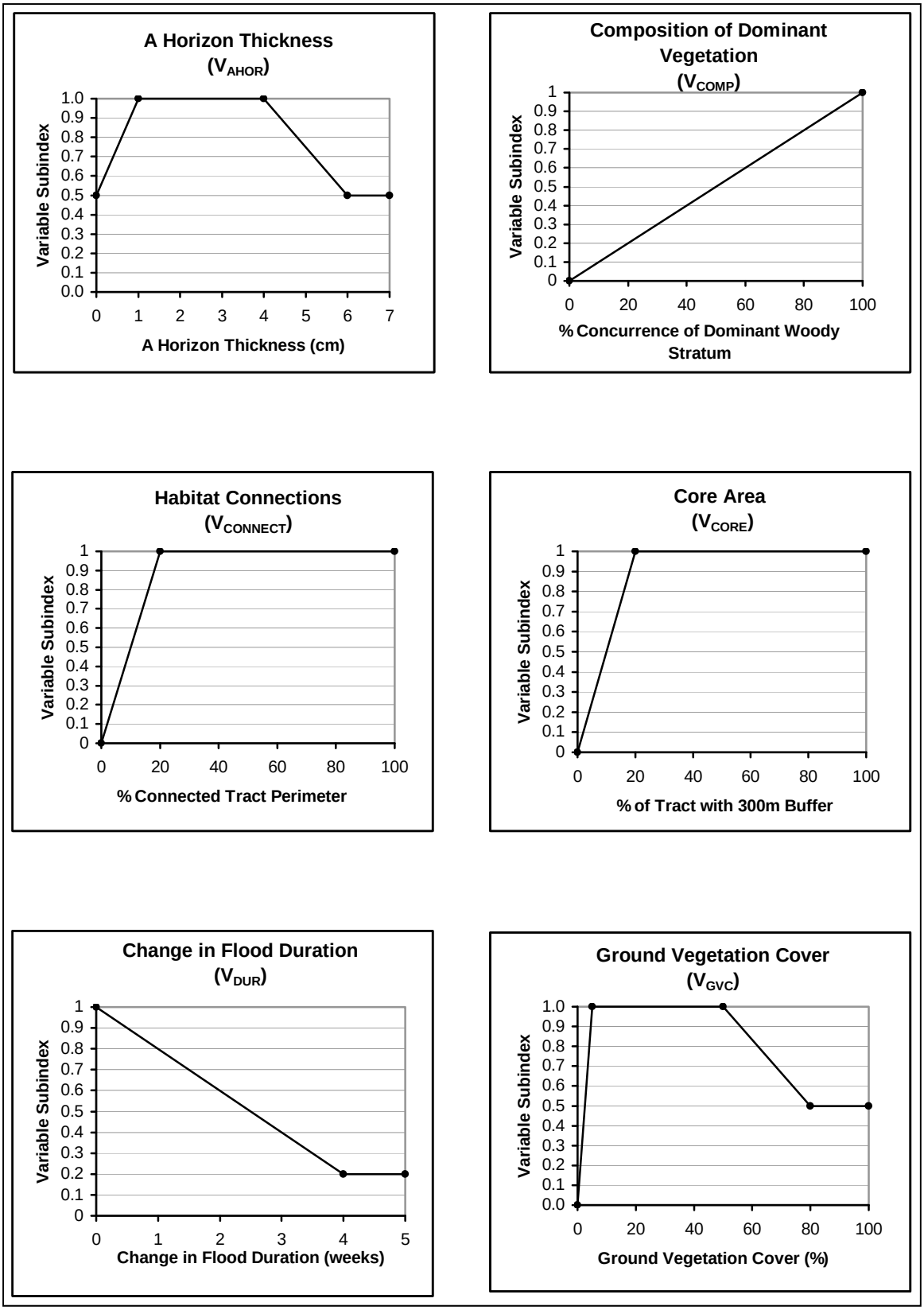


Figure 17. Subindex graphs for Low-Gradient Riverine Backwater wetlands (Sheet 1 of 4).

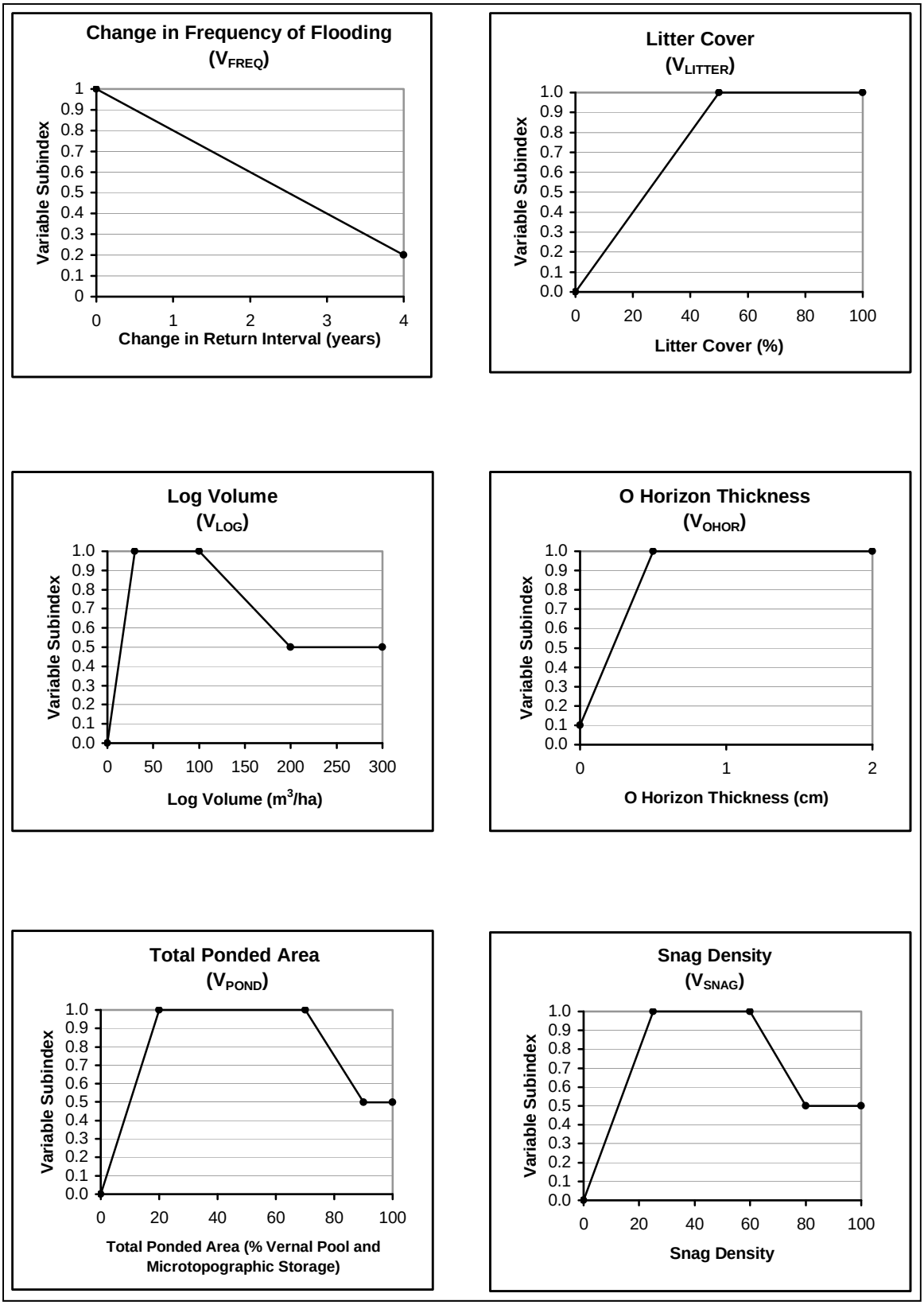


Figure 17. (Sheet 2 of 4).

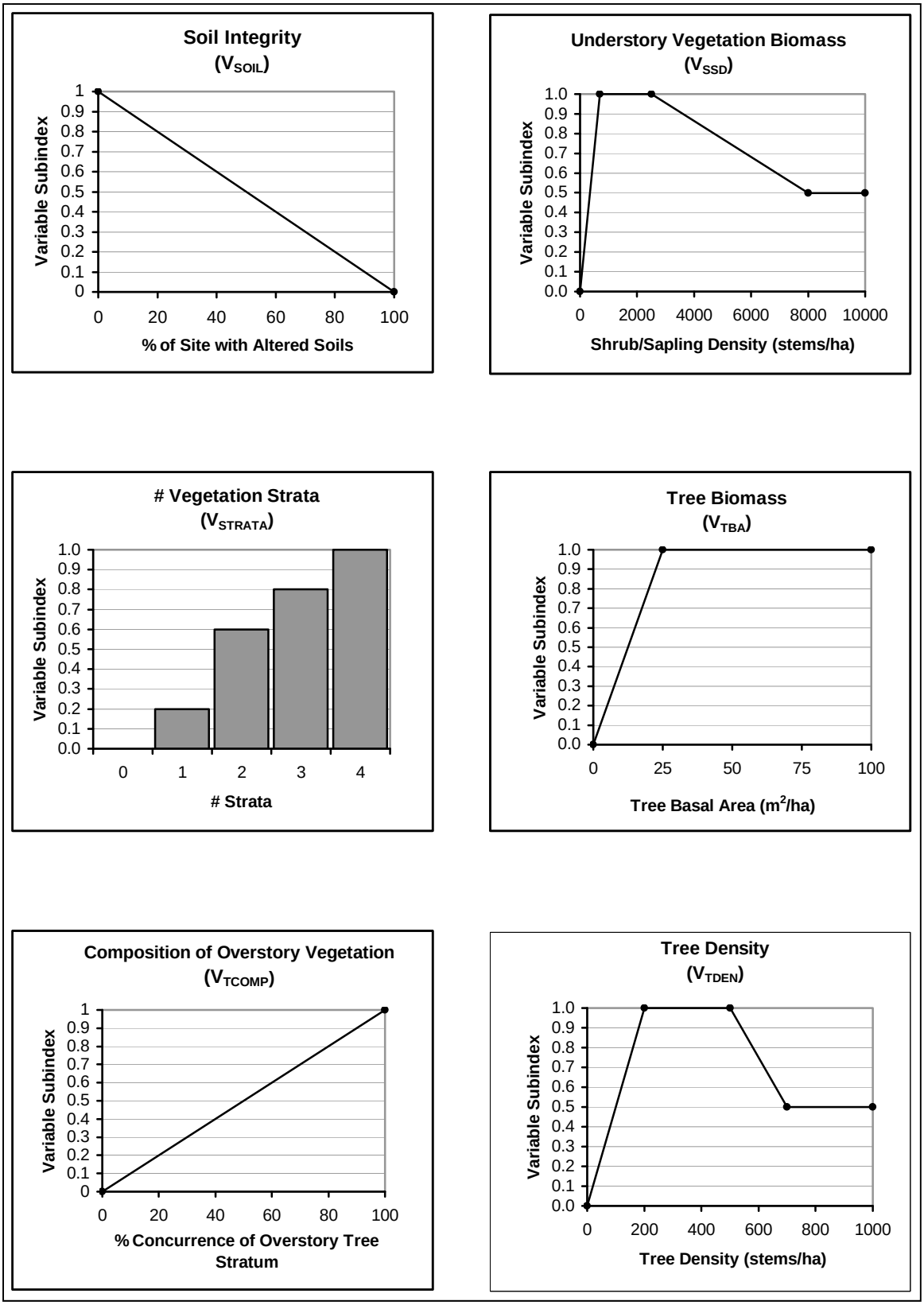


Figure 17. (Sheet 3 of 4).

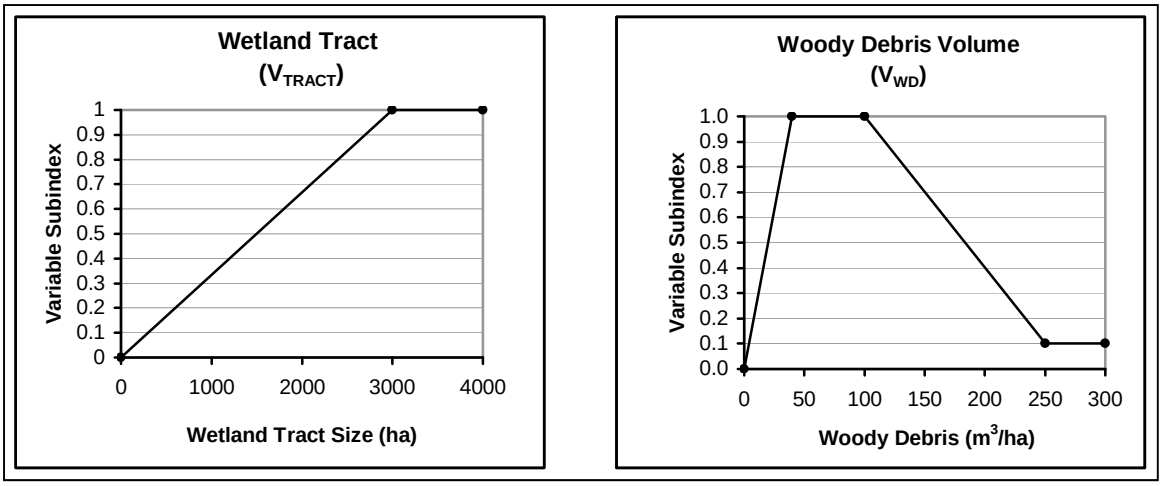


Figure 17. (Sheet 4 of 4).

e. Function 5: Maintain Plant Communities.

$$FCI = \left(\left\{ \left[\frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right] \right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} + V_{POND} \right)}{3} \right] \right)^{1/2} \quad (16)$$

f. Function 6: Provide Wildlife Habitat.

$$FCI = \left\{ \begin{array}{c} \left[\frac{\left(V_{FREQ} + V_{DUR} + V_{POND} \right)}{3} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/4} \quad (17)$$

Subclass: Low-Gradient Riverine Overbank

All functions are assessed for this subclass using the general form of each assessment model presented in Chapter 4 as follows. Figure 18 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the riverine overbank reference data.

a. Function 1: Detain Floodwater.

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN} \right)}{4} \right] \quad (18)$$

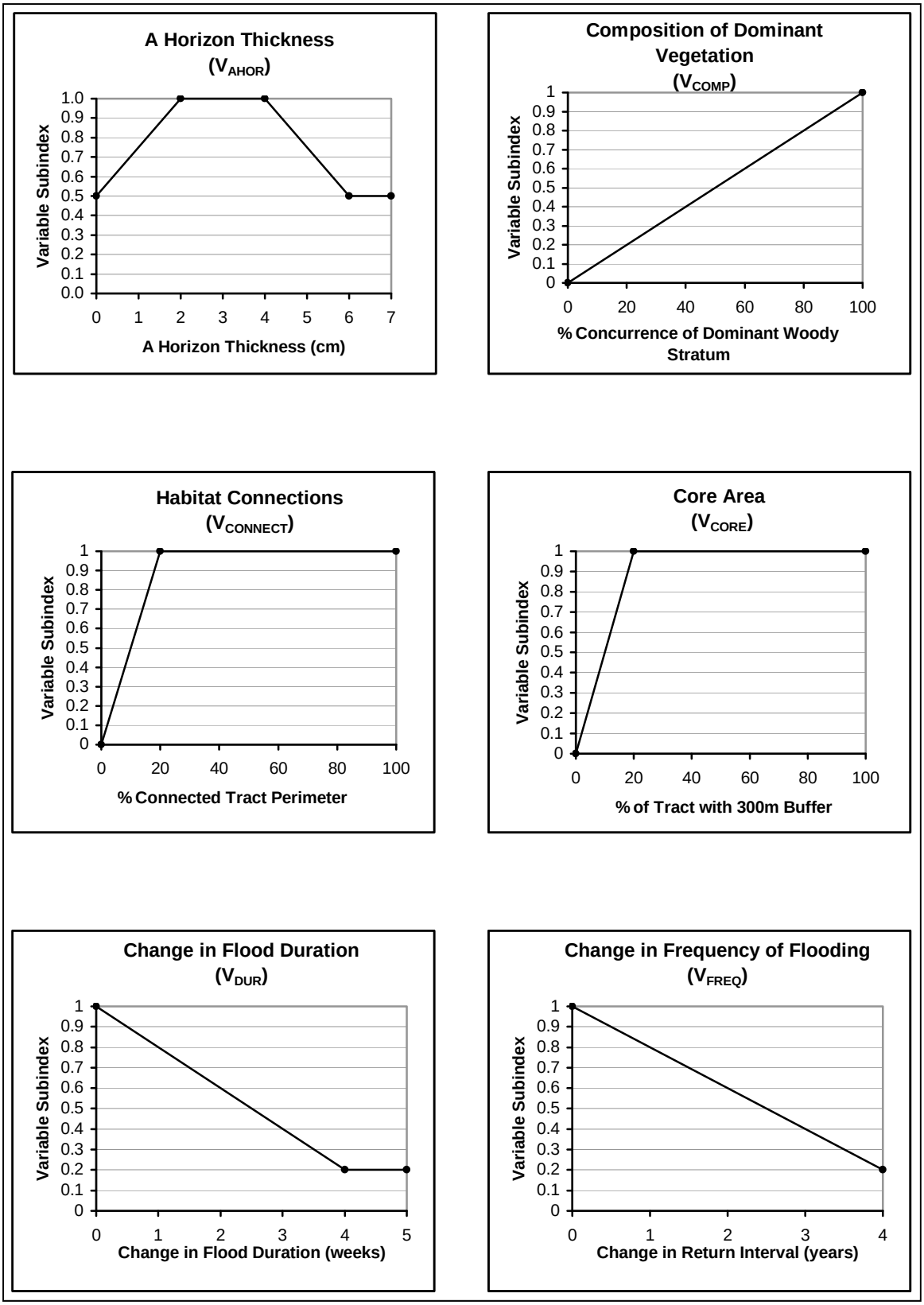


Figure 18. Subindex graphs for Low-Gradient Riverine Overbank wetlands (Sheet 1 of 4).

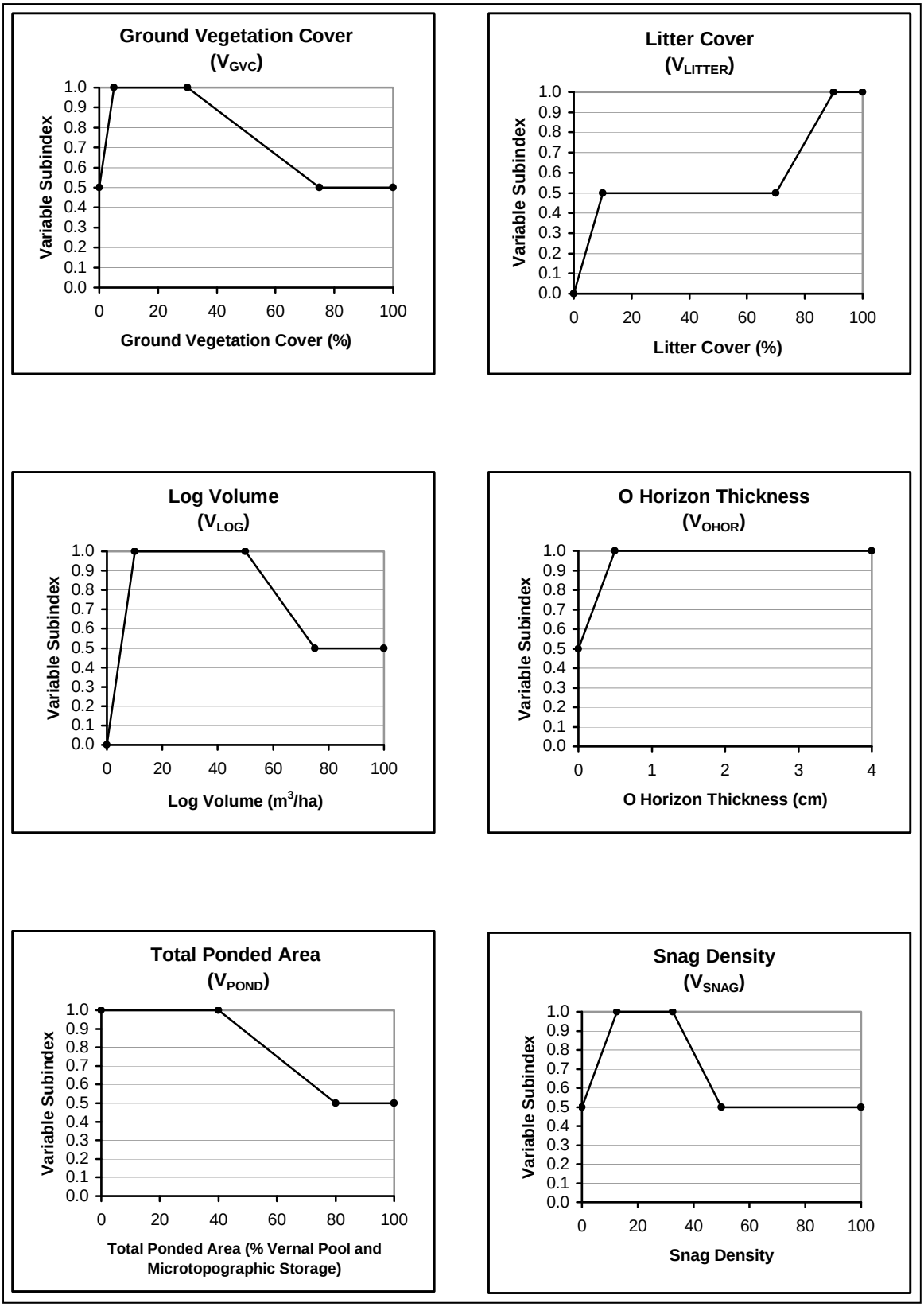


Figure 18. (Sheet 2 of 4).

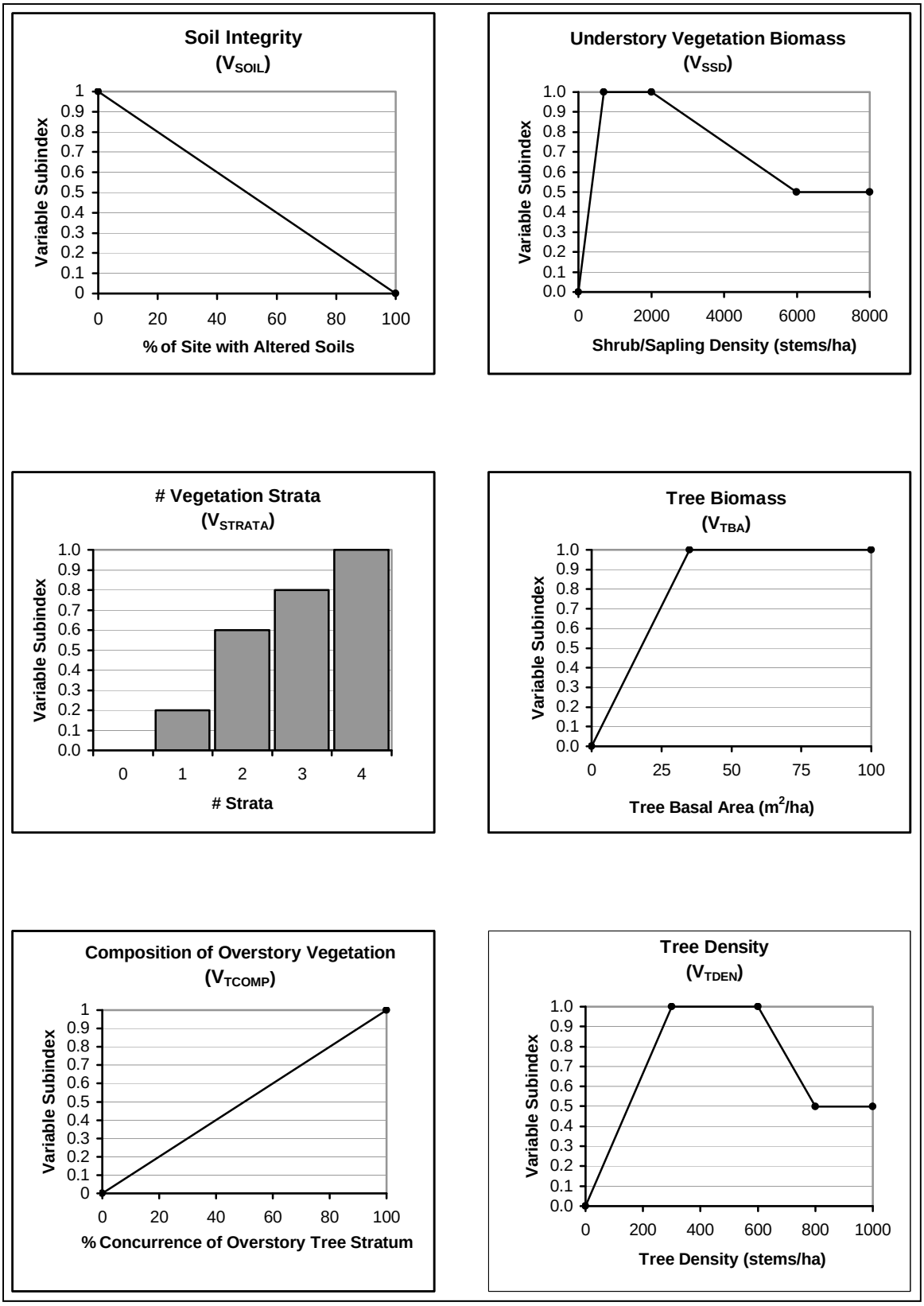


Figure 18. (Sheet 3 of 4).

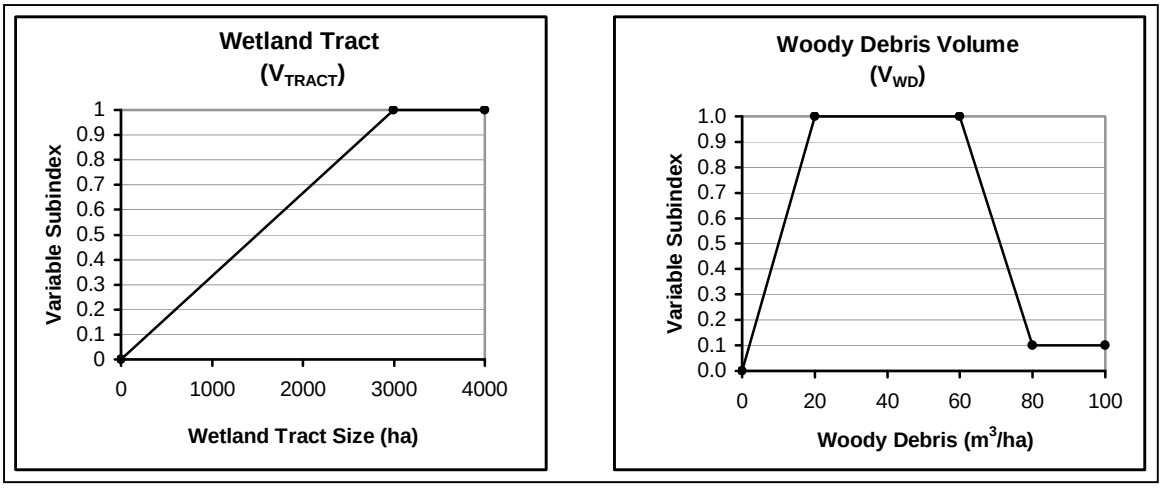


Figure 18. (Sheet 4 of 4).

b. Function 2: Detain Precipitation.

$$FCI = \frac{\left[V_{POND} + \frac{\left(V_{OHOR} + V_{LITTER}\right)}{2}\right]}{2} \tag{19}$$

c. Function 3: Cycle Nutrients.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \tag{20}$$

d. Function 4: Export Organic Carbon.

$$FCI = V_{FREQ} \times \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG}\right)}{4}\right] + \left[\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3}\right]}{2} \tag{21}$$

e. Function 5: Maintain Plant Communities.

$$FCI = \left(\left\{\left[\frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP}\right]}{2}\right]\right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} + V_{POND}\right)}{3}\right]\right)^{1/2} \tag{22}$$

f. Function 6: Provide Wildlife Habitat.

$$FCI = \left\{ \left[\frac{\left(V_{FREQ} + V_{DUR} + V_{POND} \right)}{3} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \right\}^{1/4} \quad (23)$$

Subclass: Headwater Depression

Four functions are assessed for this subclass as shown in the following subparagraphs. All of the applicable models are modified from the general form presented in Chapter 4. In addition, alternate models are provided, which can be used in the event that ground-level observations cannot be made due to inundation. Figure 19 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Headwater Depression reference data.

a. Function 1: Detain Floodwater. Not Assessed.
b. Function 2: Detain Precipitation. Not Assessed.
c. Function 3: Cycle Nutrients.

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG} \right)}{4} \right]}{2} \quad (24)$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG} \right)}{3} \quad (25)$$

d. Function 4: Export Organic Carbon.

$$FCI = V_{OUT} \times \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG} \right)}{4} \right] + \left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} \right]}{2} \quad (26)$$

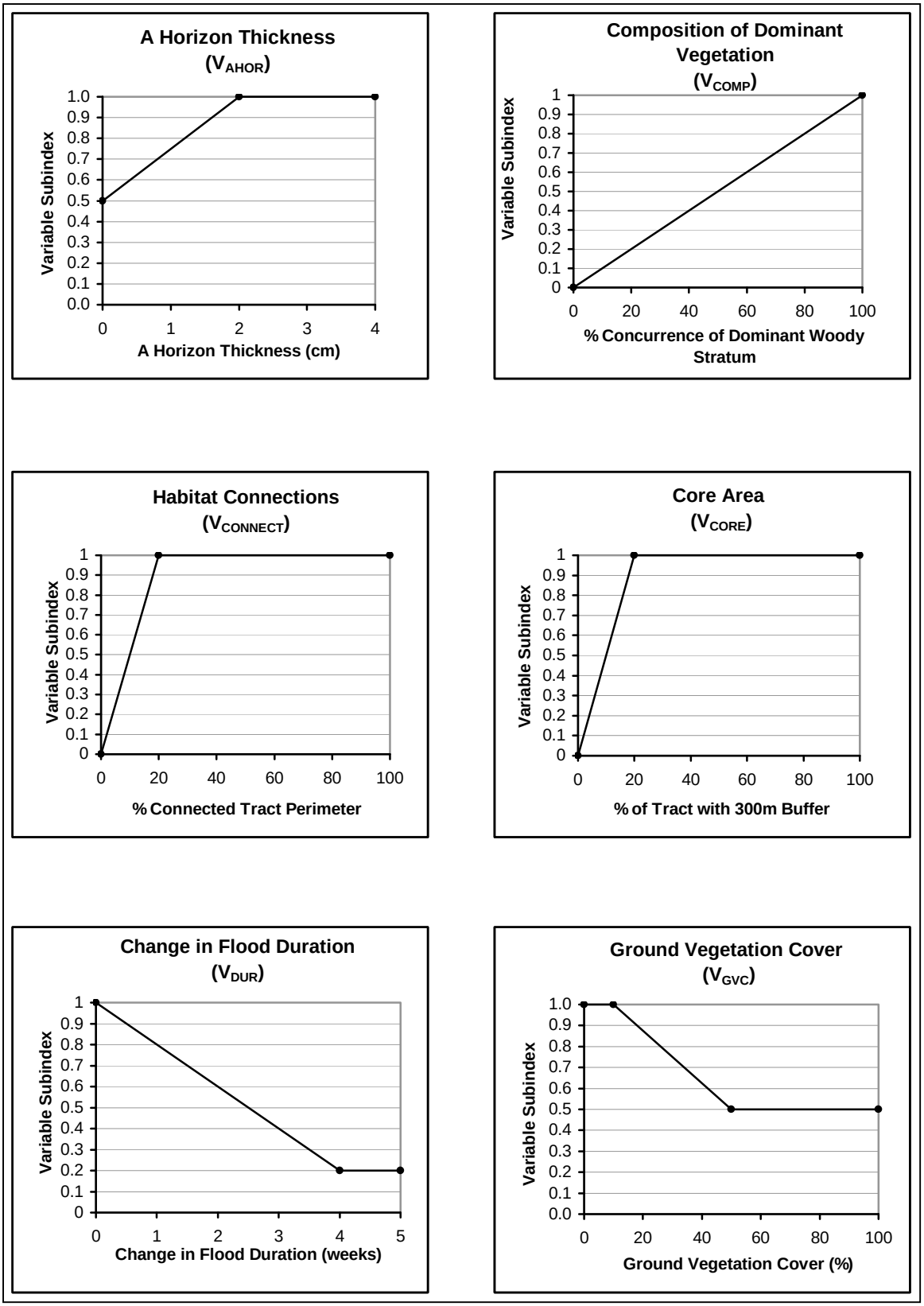
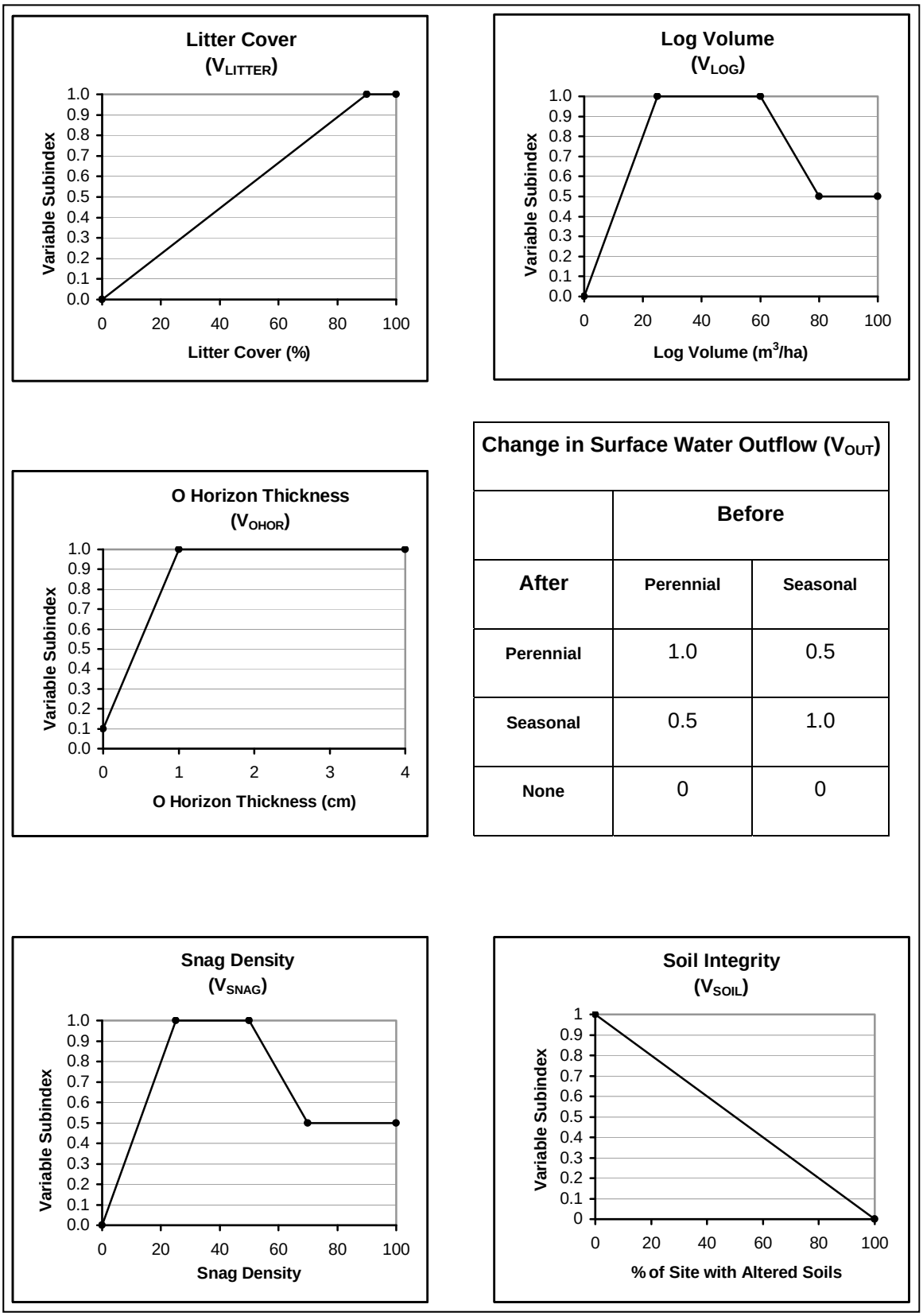


Figure 19. Subindex graphs for Headwater Depression wetlands (Sheet 1 of 4)



Change in Surface Water Outflow (V_{OUT})

	Before	
After	**Perennial**	**Seasonal**
Perennial	1.0	0.5
Seasonal	0.5	1.0
None	0	0

Figure 19. (Sheet 2 of 4).

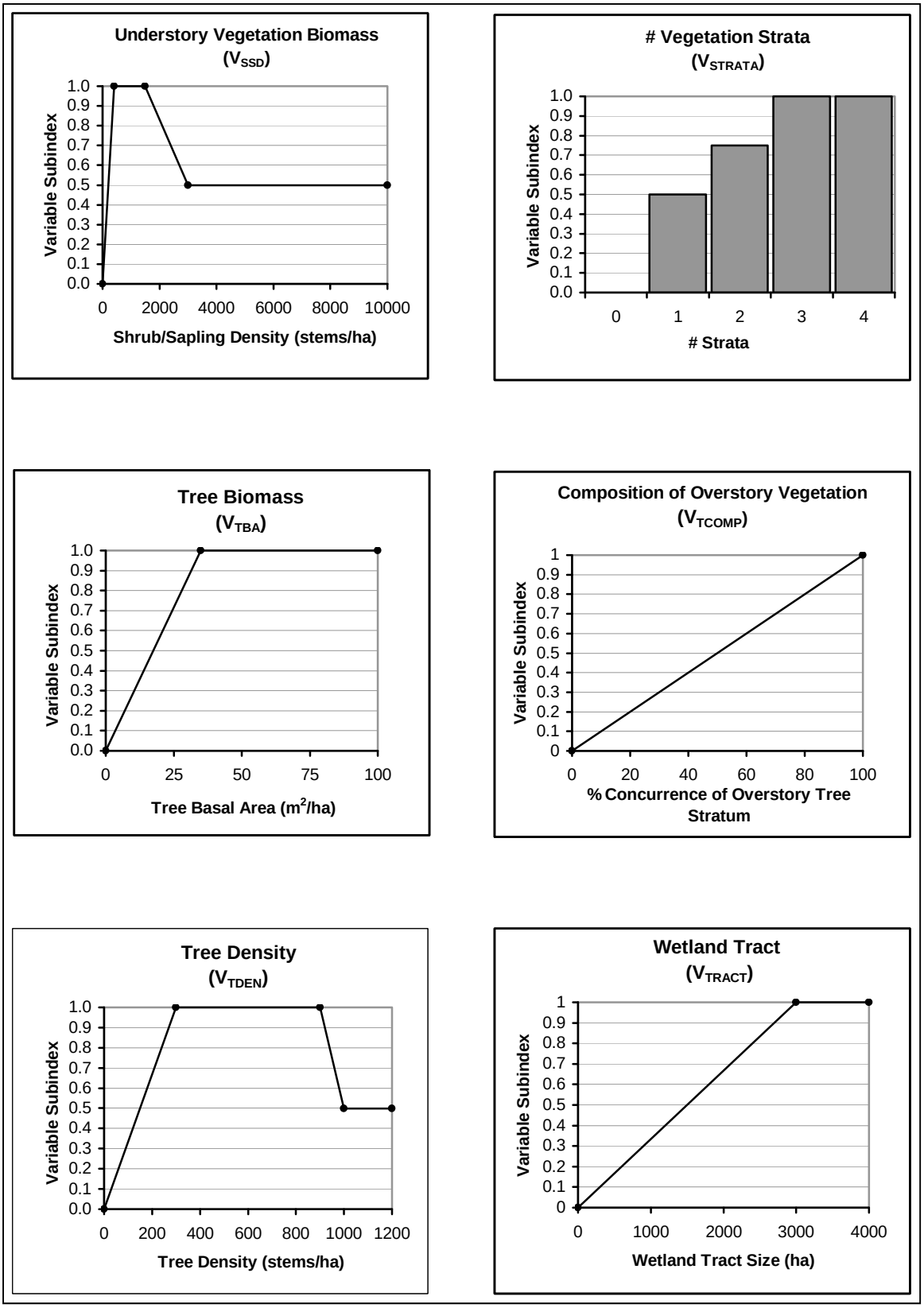


Figure 19. (Sheet 3 of 4).

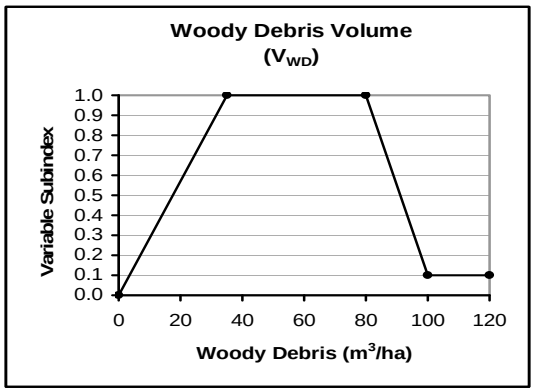


Figure 19. (Sheet 4 of 4).

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = V_{OUT} \times \left[\frac{\left(V_{TBA} + V_{SSD} + V_{SNAG} \right)}{3} \right] \tag{27}$$

e. Function 5: Maintain Plant Communities. Applicable in the following modified form:

$$FCI = \left(\left\{ \left[\frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right] \right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} \right)}{2} \right] \right)^{1/2} \tag{28}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left(\left\{ \left[\frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right] \right\} \times V_{DUR} \right)^{1/2} \tag{29}$$

f. Function 6: Provide Wildlife Habitat. Applicable in the following modified form:

$$FCI = \left\{ \begin{array}{l} V_{DUR} \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/4} \tag{30}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left\{ \begin{array}{c} V_{DUR} \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/3} \quad (31)$$

Note that Headwater Depressions differ from other wetland types in that they are connected to the river system, not by river flooding, but by being a headwater source of river flows. As such, V_{FREQ}, the change in frequency of riverine flooding, is not used in these models. V_{OUT}, the change in outflow, is used in the Export Organic Carbon model. However, the Detain Floodwater model is not assessed for this subclass, because that function as defined refers specifically to capture of out-of-bank stream floodwaters. Because the Headwater Depression type evidently is groundwater-maintained, water is unlikely to be delivered to the system with the sudden hydrograph peak observed on stream systems; thus the contribution to floodwater detention is more similar to non-flooded systems and is not assessed here.

V_{OUT} is used in the Export Organic Carbon model, because organic material produced within the wetland is likely to move downstream with the outflow. Headwater Depressions having unaltered connections to their streams, whether it be a seasonal or perennial outflow, are assessed as having a subindex of 1.0 for V_{OUT}. If the Headwater Swamp is altered such that the outflow has changed from perennial to seasonal (e.g., if a boarded outflow has been installed to increase ponding within the depression part of the year) or from seasonal to perennial (e.g., if irrigation runoff is directed through the depression), then the subindex is assessed as a 0.5. Any change to any Headwater Swamp that cuts it off from its stream (e.g., a berm across the outlet) results in a V_{OUT} of 0 (Figure 19).

V_{OUT} is not used as a hydrology variable in the wildlife habitat model, where V_{FREQ} normally is intended to indicate primarily waterfowl and fish habitat availability. This is because flood timing may differ significantly from other wetland types, and because it is unlikely that these systems have fisheries functions similar to those of the Connected Depression or Low-Gradient Riverine subclasses. Unlike those river-inundated systems, Headwater Depression wetlands are not periodically overwhelmed by

floodwaters, but are connected to downstream systems by small and often intermittent channels. Although fish may or may not access these sites on a regular basis, too little is known about such use to support inclusion of this variable in the assessment process for habitat functions.

As for all of the depressional subclasses, the "percent ponding" variable is excluded from the models. Ponding (microdepressional storage) is difficult to estimate within an overall depressional system, as these systems generally drain to a central low point, then fill and overwhelm individual pond sites. The functional contribution of the micro-sites to precipitation storage, wildlife habitat, and similar functions is not evident in a system where a single, large pool is the dominant hydrologic feature. However, unlike other depressions, flood duration (V_{DUR}) is used in the vegetation and habitat functional models. This is because the outflow point of a headwater swamp serves as a place where flows can easily be detained and the depth and duration of flooding can be maximized, altering vegetation composition and structure, as well as habitat potential. Reference sites often showed this sort of alteration, sometimes in the form of a blocked culvert.

Subclass: Unconnected Depression

Three functions are assessed for this subclass as follows. Some of the applicable models are modified from the general form presented in Chapter 4. Alternate versions also are provided that can be used in the event that ground-level observations cannot be made due to inundation. Figure 20 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Unconnected Depression reference data.

a. *Function 1: Detain Floodwater*. Not assessed.
b. *Function 2: Detain Precipitation*. Not assessed.
c. *Function 3: Cycle Nutrients.*

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC}\right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG}\right)}{4}\right]}{2} \qquad (32)$$

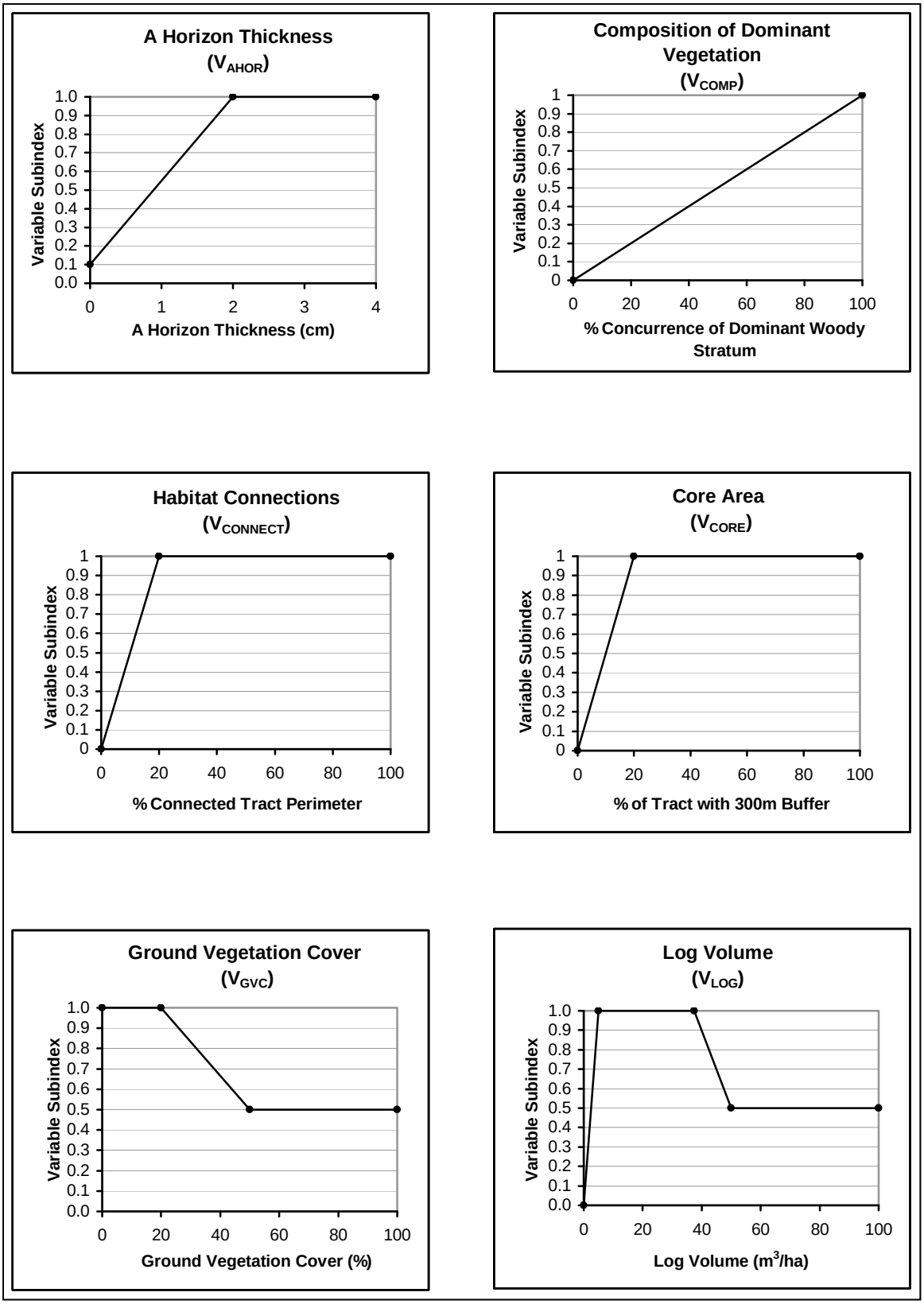


Figure 20. Subindex graphs for Unconnected Depression wetlands (Sheet 1 of 3).

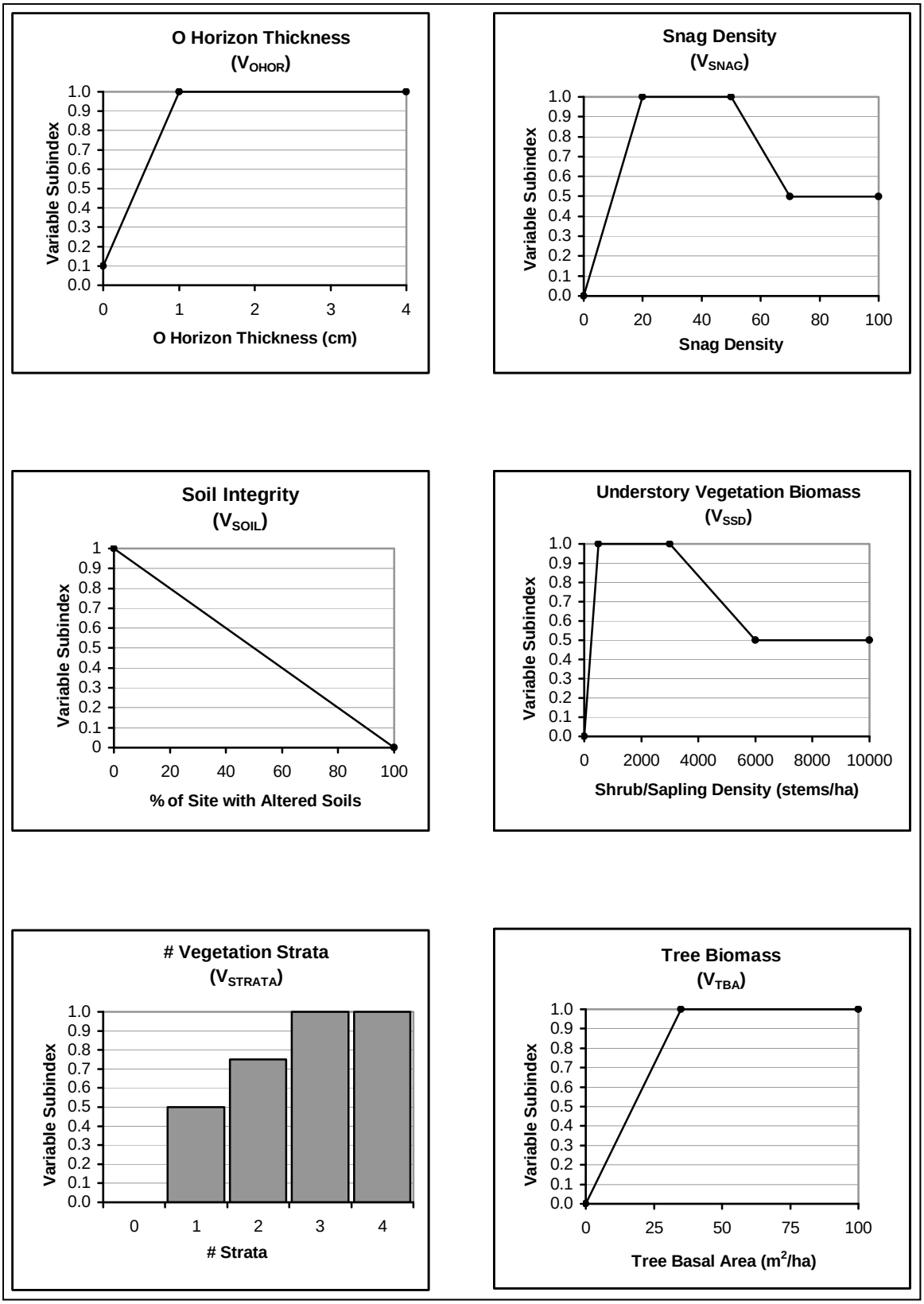


Figure 20. (Sheet 2 of 3).

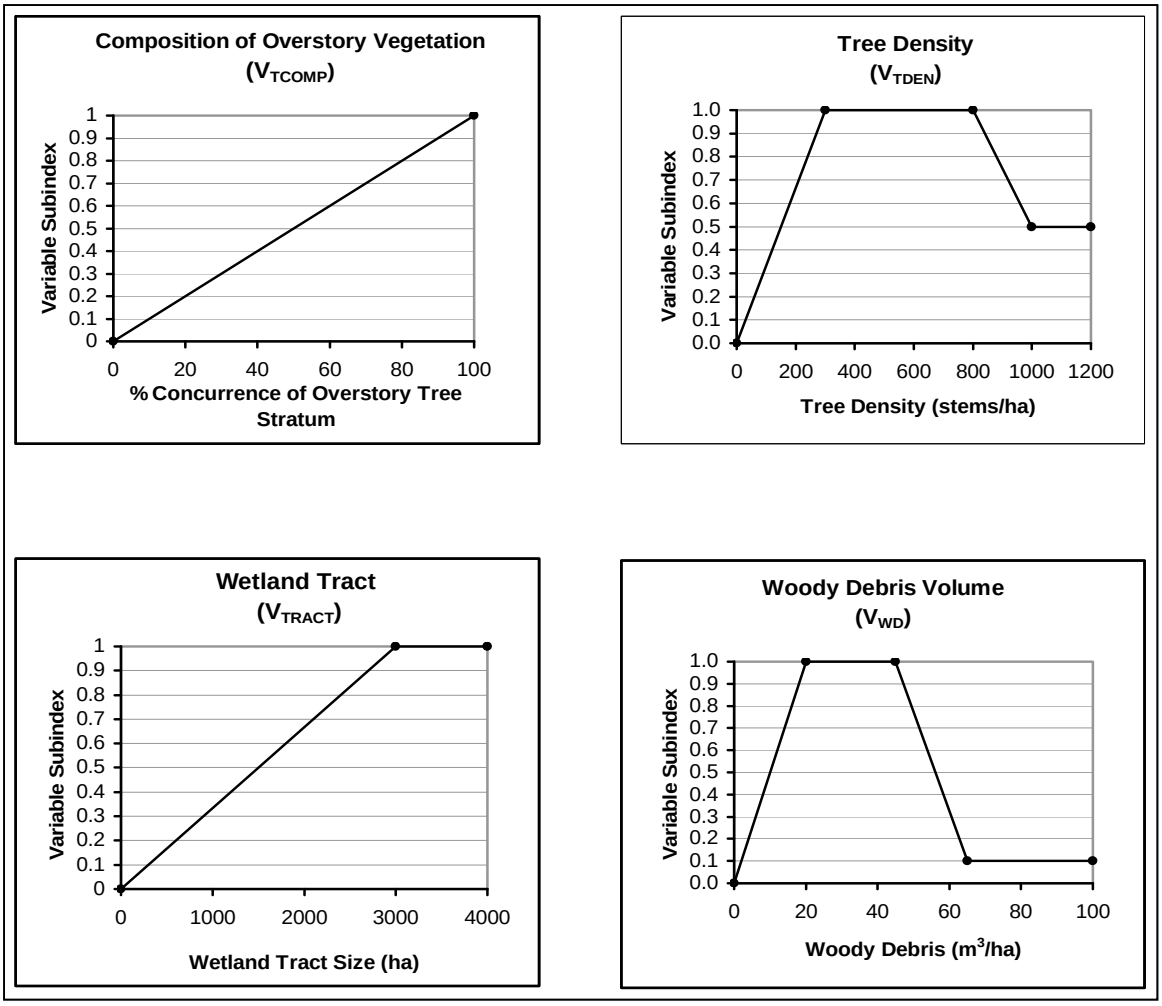


Figure 20. (Sheet 3 of 3).

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG}\right)}{3} \tag{33}$$

d. Function 4: Export Organic Carbon. Not assessed.

e. Function 5: Maintain Plant Communities. Applicable in the following modified form:

$$FCI = \left\{ \left[\frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP} \right]}{2} \right] \times V_{SOIL} \right\}^{1/2} \tag{34}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{TDEN}\right)}{2} + V_{COMP}\right]}{2} \quad (35)$$

f. Function 6: Provide *Wildlife Habitat*. Applicable in the following modified form:

$$FCI = \left\{\left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA}\right)}{4}\right] \times \left[\frac{\left(V_{LOG} + V_{OHOR}\right)}{2}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right]\right\}^{1/3} \quad (36)$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left\{\left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA}\right)}{4}\right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE}\right)}{3}\right]\right\}^{1/2} \quad (37)$$

Subclass: Connected Depression

Six functions are assessed for this subclass as follows. Some of the models have been modified from the general model form presented in Chapter 4. Figure 21 provides the relationship between the variable metrics and the subindex for each of the assessment variables based on the Connected Depression reference data.

a. Function 1: Detain Floodwater.

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{LOG} + V_{GVC} + V_{SSD} + V_{TDEN}\right)}{4}\right] \quad (38)$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

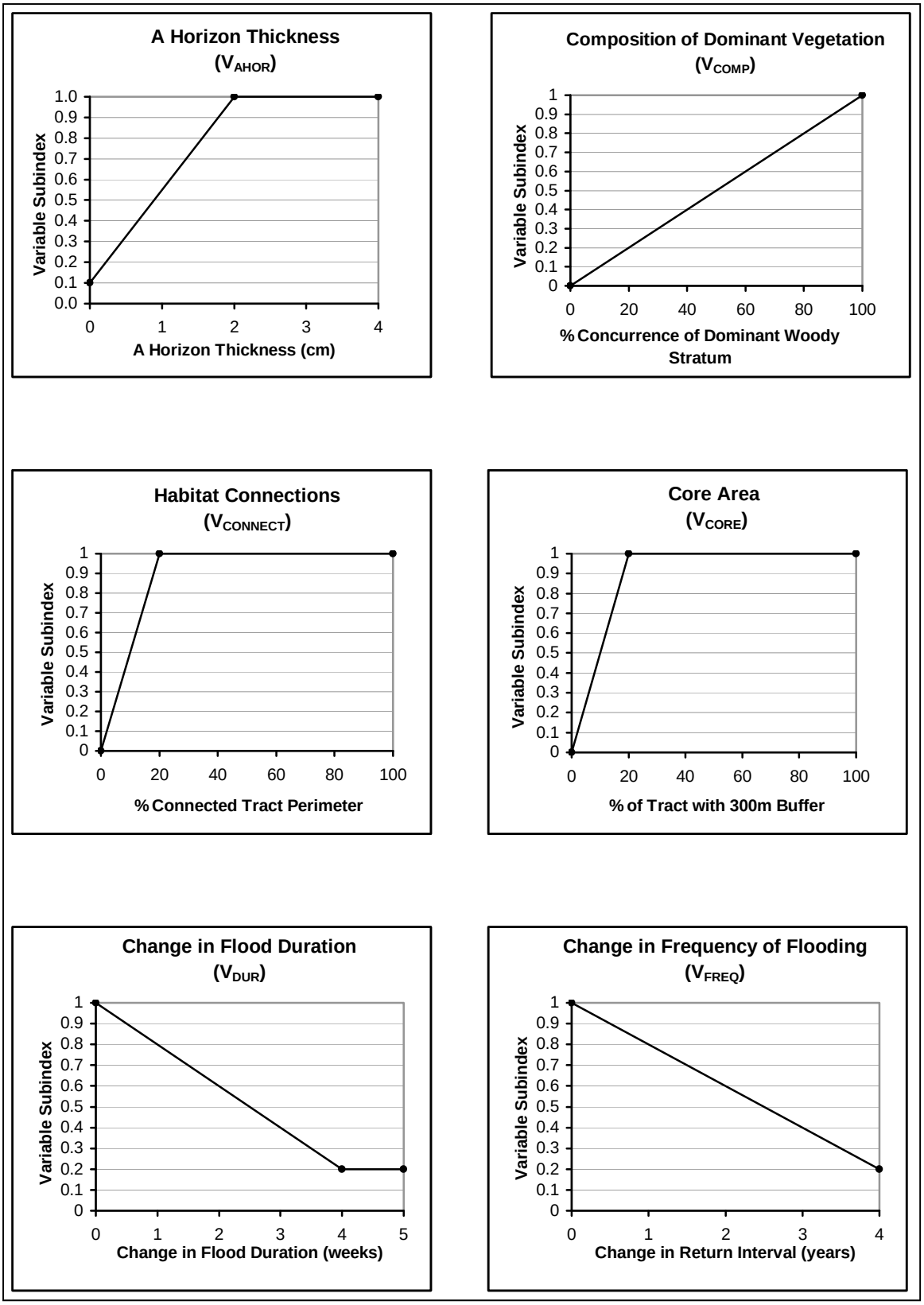


Figure 21. Subindex graphs for Connected Depression wetlands (Sheet 1 of 4).

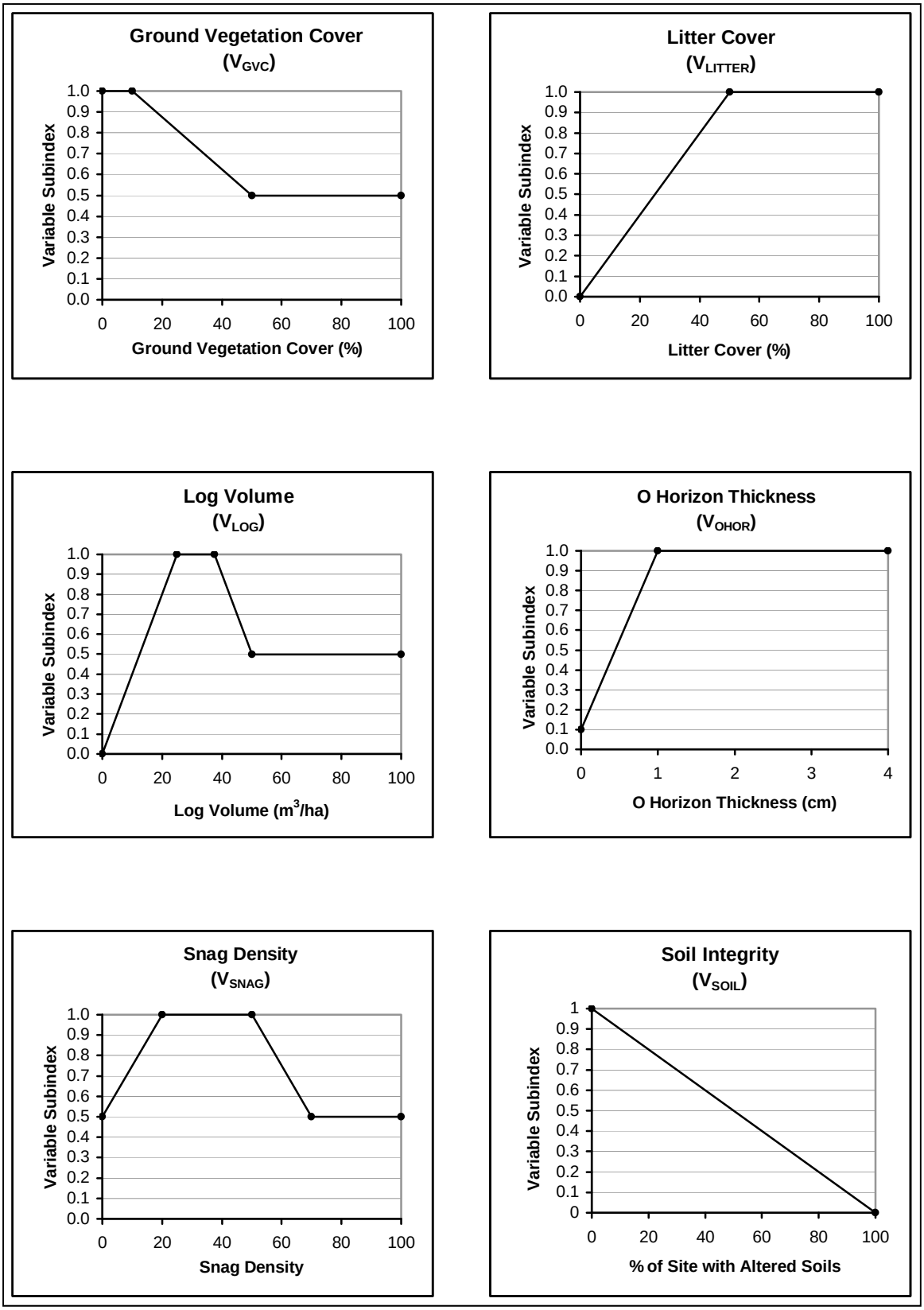


Figure 21. (Sheet 2 of 4).

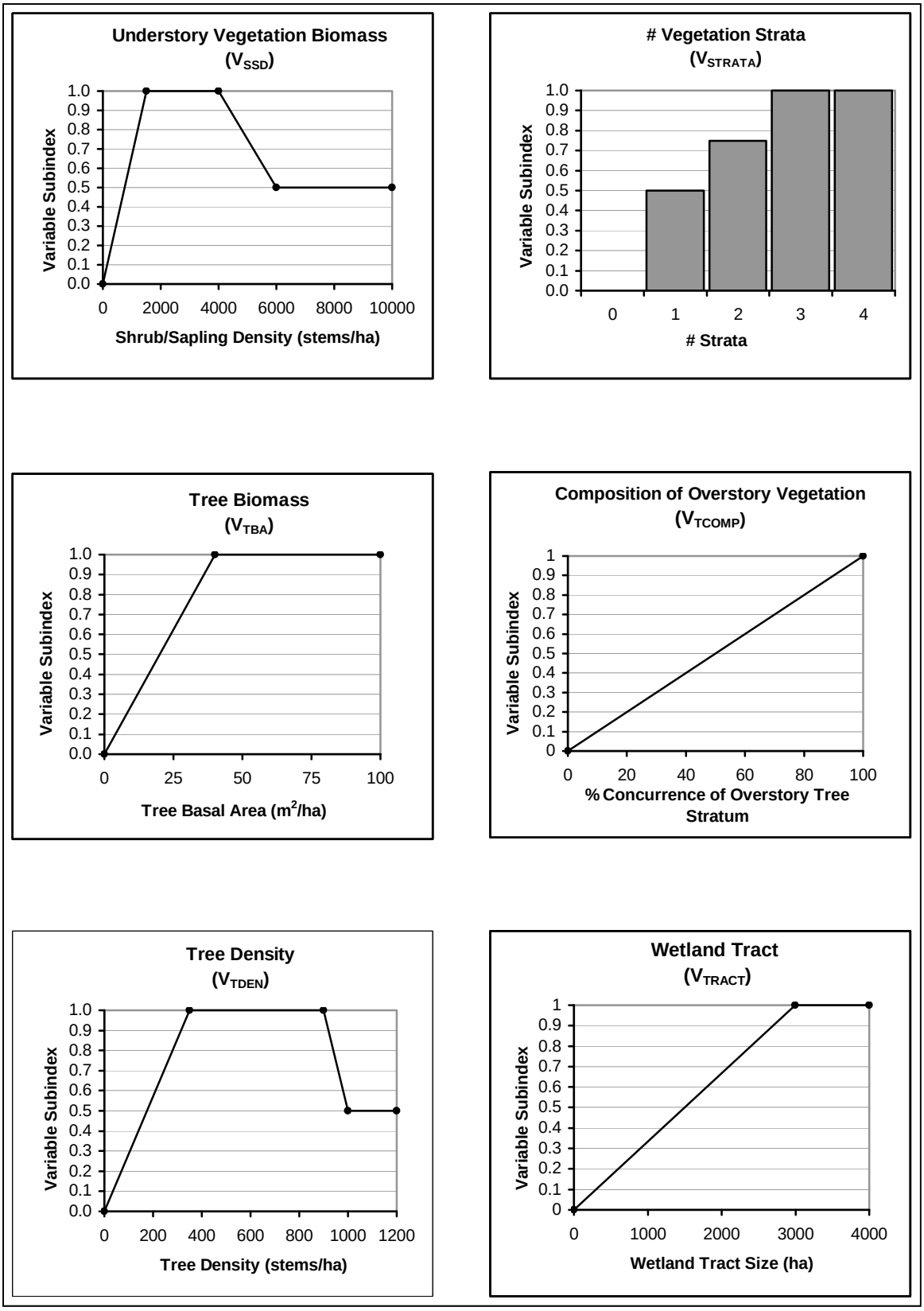


Figure 21. (Sheet 3 of 4).

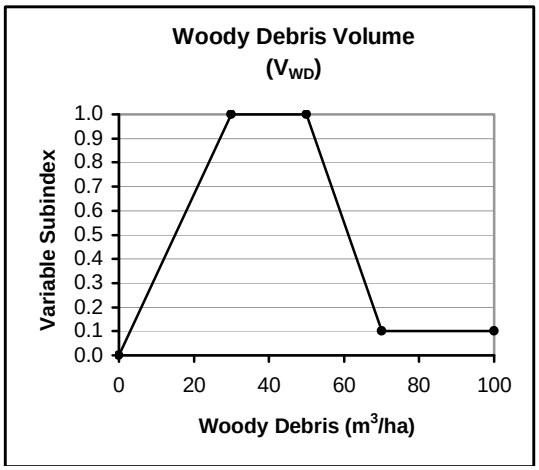


Figure 21. (Sheet 4 of 4).

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{SSD} + V_{TDEN} \right)}{2} \right] \tag{39}$$

b. Function 2: Detain Precipitation. Not assessed.

c. Function 3: Cycle Nutrients. Applicable in the following modified form:

$$FCI = \frac{\left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} + \frac{\left(V_{OHOR} + V_{AHOR} + V_{WD} + V_{SNAG} \right)}{4} \right]}{2} \tag{40}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \frac{\left(V_{TBA} + V_{SSD} + V_{SNAG} \right)}{3} \tag{41}$$

d. Function 4: Export Organic Carbon. Applicable in the following modified form:

$$FCI = V_{FREQ} \times \left\{ \frac{\left[\frac{\left(V_{LITTER} + V_{OHOR} + V_{WD} + V_{SNAG} \right)}{4} \right] + \left[\frac{\left(V_{TBA} + V_{SSD} + V_{GVC} \right)}{3} \right]}{2} \right\} \tag{42}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = V_{FREQ} \times \left[\frac{\left(V_{TBA} + V_{SSD} + V_{SNAG} \right)}{3} \right] \tag{43}$$

e. Function 5: Maintain Plant Communities. Applicable in the following modified form:

$$FCI = \left(\left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right\} \times \left[\frac{\left(V_{SOIL} + V_{DUR} \right)}{2} \right] \right)^{1/2} \tag{44}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left(\left\{ \frac{\left[\frac{\left(V_{TBA} + V_{TDEN} \right)}{2} + V_{COMP} \right]}{2} \right\} \times V_{DUR} \right)^{1/2} \tag{45}$$

f. Function 6: Provide *Wildlife Habitat*. Applicable in the following modified form:

$$FCI = \left\{ \begin{array}{c} \left[\frac{V_{FREQ} + V_{DUR}}{2} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{LOG} + V_{OHOR} \right)}{2} \right] \times \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/4} \tag{46}$$

Applicable in the following alternate form when inundation prevents observation of ground-level features:

$$FCI = \left\{ \begin{array}{c} \left[\frac{V_{FREQ} + V_{DUR}}{2} \right] \times \left[\frac{\left(V_{TCOMP} + V_{STRATA} + V_{SNAG} + V_{TBA} \right)}{4} \right] \times \\ \left[\frac{\left(V_{TRACT} + V_{CONNECT} + V_{CORE} \right)}{3} \right] \end{array} \right\}^{1/3} \tag{47}$$

6 Assessment Protocol

Introduction

Previous chapters of this Regional Guidebook have provided background information on the HGM Approach, characterized regional wetland subclasses, and have documented the variables, functional indices, and assessment models used to assess regional wetland subclasses in the Delta Region of Arkansas. This chapter outlines the procedures for collecting and analyzing the data required to conduct an assessment.

In most cases, permit review, restoration planning, and similar assessment applications require that pre- and post-project conditions of wetlands at the project site be compared to develop estimates of the loss or gain of function associated with the project. Both the pre- and post-project assessments should be completed at the project site before the proposed project has begun. Data for the pre-project assessment represent existing conditions at the project site, while data for the post-project assessment are normally based on a prediction of the conditions that can reasonably be expected to exist following proposed project impacts. A well-documented set of assumptions should be provided with the assessment to support the predicted post-project conditions used in making an assessment.

Where the proposed project involves wetland restoration or compensatory mitigation, this guidebook can also be used to assess the functional effectiveness of the proposed actions. The final section of this chapter provides recovery trajectory curves for selected variables that may be employed in that analysis.

A series of tasks are required to assess regional wetland subclasses in the Delta Region of Arkansas using the HGM Approach:

- Document the project purpose and characteristics.
- Screen for red flags.
- Define assessment objectives and identify regional wetland subclass(es) present, and assessment area boundaries.
- Collect field data.
- Analyze field data.
- Document assessment results.
- Apply assessment results.

The following sections discuss each of these tasks in greater detail.

Document the project purpose and characteristics

Data Sheet A1 (Site or Project Information and Assessment Documentation, Figure A1, Appendix A) provides a checklist of information needed to conduct a complete assessment, and serves as a cover sheet for all compiled assessment maps, drawings, data sheets, and other information. It requires the assignment of a project name, identification of personnel involved in the assessment, and attachment of supporting information and documentation. The first step in this process is to develop a narrative explanation of the project, with supporting maps and graphics. This should include a description of the project purpose and project area features, which can include information on location, climate, surficial geology, geomorphic setting, surface and groundwater hydrology, vegetation, soils, land use, existing cultural alteration, proposed impacts, and any other characteristics and processes that have the potential to influence how wetlands at the project area perform functions. The accompanying maps and drawings should indicate the locations of the project area boundaries, jurisdictional wetlands, wetland assessment areas (described later in this chapter), proposed impacts, roads, ditches, buildings, streams, soil types, plant communities, threatened or endangered species habitats, and other important features.

Many sources of information will be useful in characterizing a project area:

- Aerial photographs.
- Topographic maps.
- Geomorphic maps (Saucier 1994).
- County soil survey.
- National Wetland Inventory maps.
- Chapter 3 of this Regional Guidebook.

For large projects or complex landscapes, it is usually a good idea to use aerial photos and geomorphic information (from Appendix E) to develop a preliminary classification of wetlands for the project area and vicinity prior to going to the field. Figure 22 illustrates this process for a typical Delta lowland wetland complex. The rough wetland map can then be taken to the field to refine and revise the identification of wetland subclasses.

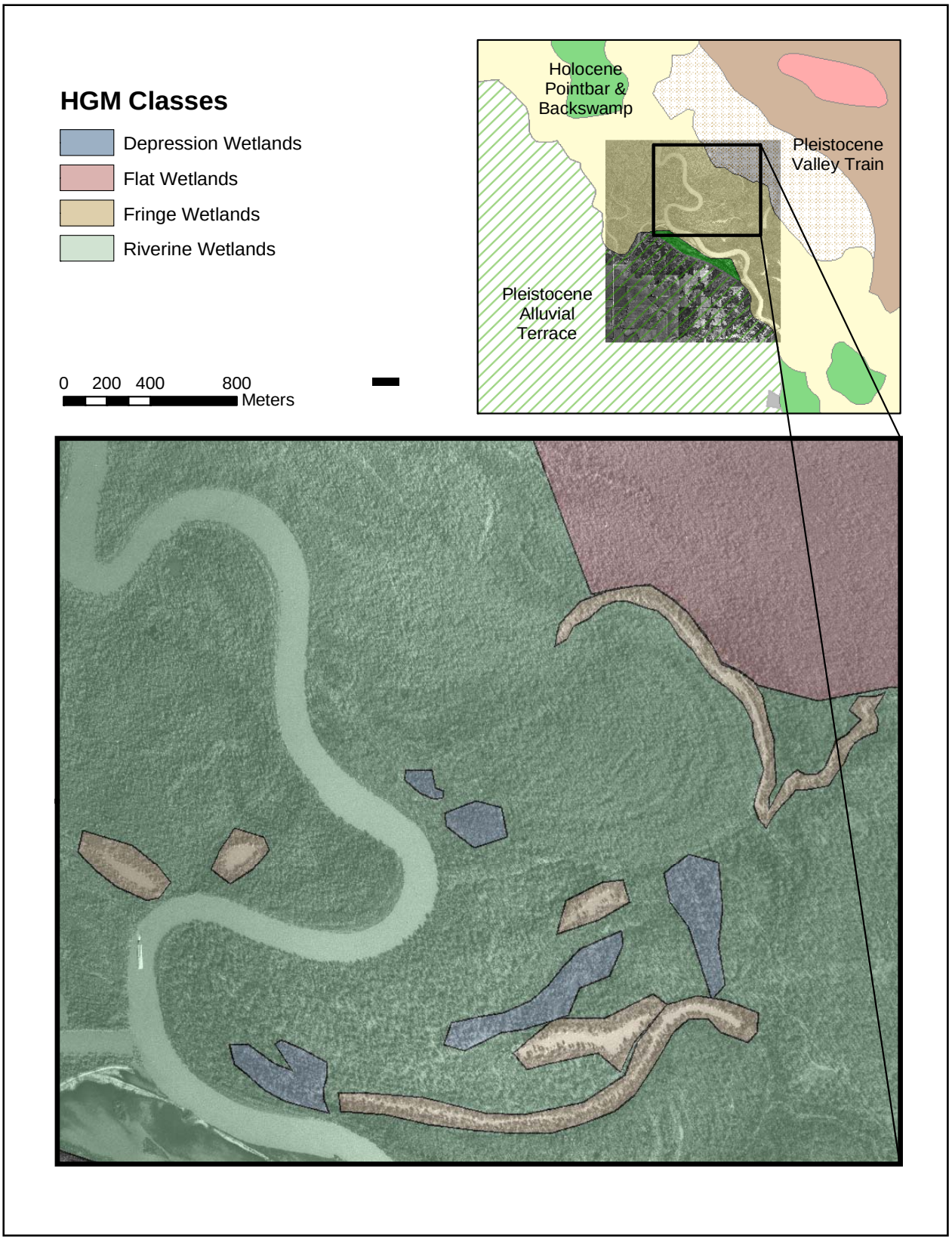


Figure 22. Example application of geomorphic mapping and aerial photography to develop a preliminary wetland classification for a proposed project area.

Attach the completed Project Description and supporting materials to Data Sheet A1.

Screen for red flags

Red flags are features in the vicinity of the project area to which special recognition or protection has been assigned on the basis of objective criteria (Table 8). Many red flag features, based on national criteria or programs, are similar from region to region. Other red flag features are based on regional or local criteria. Screening for red flag features determines if the wetlands or other natural resources around the project area require special consideration or attention that may preempt or postpone conducting a wetland assessment. For example, if a proposed project has the potential to adversely affect threatened or endangered species, an assessment may be unnecessary since the project may be denied or modified based on the impacts to the protected species alone.

Define assessment objectives, identify regional wetland subclass(es) present, and identify assessment area boundaries

Begin the assessment process by unambiguously stating the objective of conducting the assessment. Most commonly, this will be simply to determine how a proposed project will impact wetland functions. However, there are other potential objectives:

- Compare several wetlands as part of an alternatives analysis.
- Identify specific actions that can be taken to minimize project impacts.
- Document baseline conditions at a wetland site.
- Determine mitigation requirements.
- Determine mitigation success.
- Evaluate the likely effects of a wetland management technique.

Frequently, there will be multiple objectives, and defining these objectives in a clear and concise manner will facilitate communication and understanding among those involved in conducting the assessment, as well as other interested parties. In addition, it will help to define the specific approach and level of effort that will be required to conduct assessments. For example, the specific approach and level of effort will vary depending on whether the project is a 404 individual permit review, an Advanced Identification (ADID) project, a Special Area Management Plan (SAMP), or some other assessment scenario.

Table 8. Red Flag Features and Respective Program/Agency Authority.

Red Flag Features	Authority[1]
Native Lands and areas protected under American Indian Religious Freedom Act	A
Hazardous waste sites identified under Comprehensive Environmental Response, Compensation, and Liability Act (Super Fund) (CERCLA) or Resource Conservation and Recovery Act (RCRA)	I
Areas providing critical habitat for species of special concern	C
Areas covered under the Farmland Protection Act	K
Floodplains, floodways, or floodprone areas	J
Areas with structures/artifacts of historic or archeological significance	G
Areas protected under the Land and Water Conservation Fund Act	K
National Wildlife Refuges and special management areas	C
Areas identified in the North American Waterfowl Management Plan	C, F
Areas identified as significant under the Ramsar Treaty	H
Areas supporting rare or unique plant communities	C, H
Areas designated as Sole Source Groundwater Aquifers	I, L, M
Areas protected by the Safe Drinking Water Act	E, I, L
City, County, State, and National Parks	B, D, H, L
Areas supporting threatened or endangered species	C, F, H, I
Areas with unique geological features	H
Areas protected by the Wild and Scenic Rivers Act or Wilderness Act	D
State wetland mitigation banks	M

[1] Program Authority / Agency

A = Bureau of Indian Affairs

B = Arkansas State Parks

C = U.S. Fish and Wildlife Service

D = National Park Service (NPS)

E = Arkansas Department of Environmental Quality

F = Arkansas Game and Fish Commission

G = State Historic Preservation Officer (SHPO)

H = Arkansas Natural Heritage Commission

I = U.S. Environmental Protection Agency

J = Federal Emergency Management Administration

K = Natural Resource Conservation Service

L = Local Government Agencies

M = Arkansas Soil and Water Conservation Commission

Figures 23 through 26 present a simplified project scenario to illustrate the steps used to designate the boundaries of Wetland Assessment Areas (WAA), each of which will require a separate HGM assessment. Figure 23 illustrates a land cover map for a hypothetical project area. Figure 24

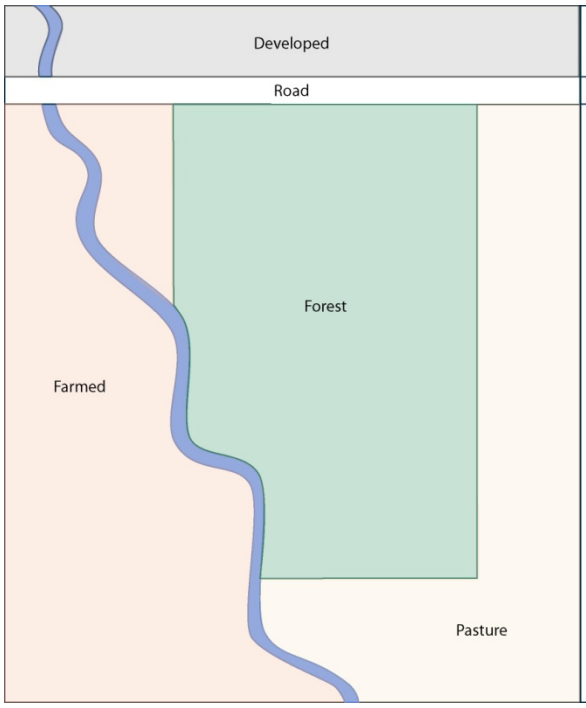


Figure 23. Land cover.

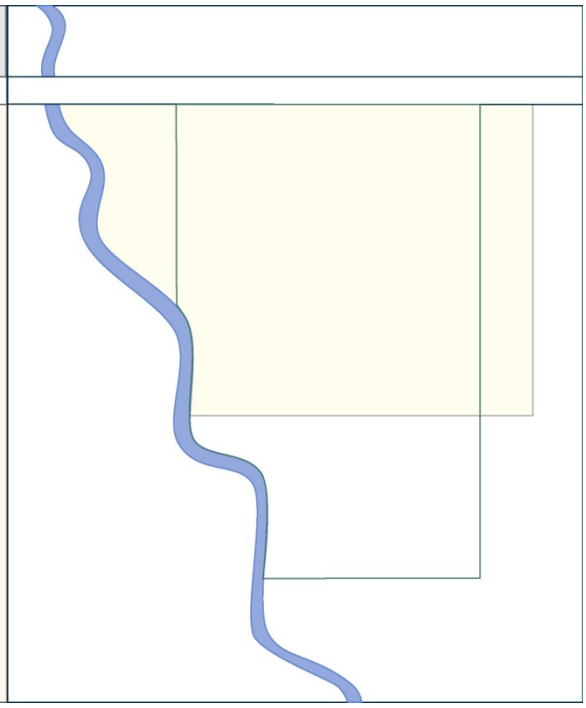


Figure 24. Project area (in yellow).

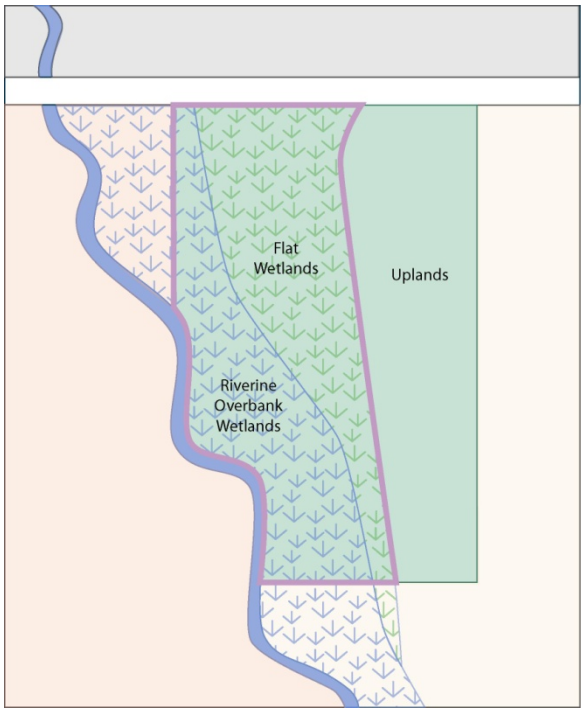


Figure 25. Wetland subclasses (purple line indicates extent of the "wetland tract").

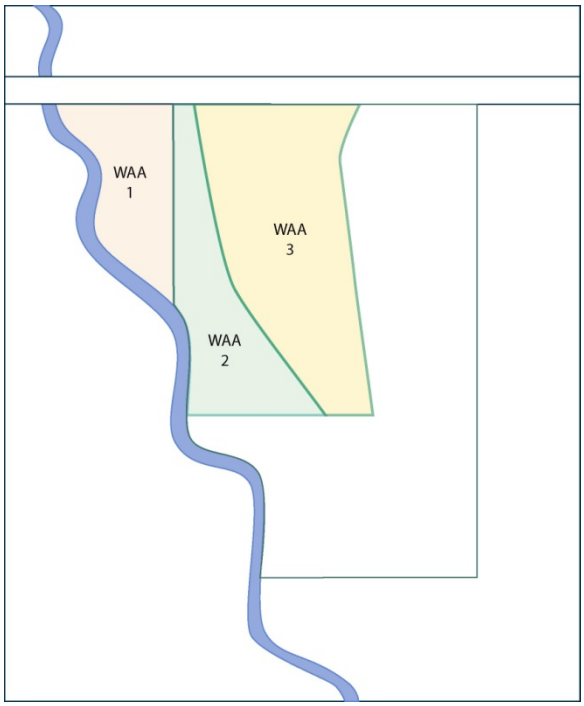


Figure 26. WAAs.

shows the project area (in yellow) superimposed on the land cover map. To determine the boundaries of the WAAs, first use the Keys to Wetland Classes and Subclasses (Figures 10 and 11) and identify the wetland subclasses within and contiguous to the project area (Figure 25). Overlay the project area boundary and the wetland subclass boundaries to identify the WAAs for which data will be collected (Figure 26). Attach these maps, photos, and drawings to Data Sheet A1 and complete the first three columns of the table on Data Sheet A1 by assigning an identifying number to each WAA, specifying the subclass it belongs to, and calculating the area in hectares.

Each WAA is a portion of the project area that belongs to a single regional wetland subclass and is relatively homogeneous with respect to the criteria used to assess wetland functions (i.e., hydrologic regime, vegetation structure, topography, soils, successional stage). However, as the size and heterogeneity of the project area increase, it is more likely that it will be necessary to define and assess multiple WAAs within a project area.

At least three situations can be identified that necessitate defining and assessing multiple WAAs within a project area. The first situation occurs when widely separated areas of wetlands belonging to the same regional subclass occur in the project area. Such noncontiguous wetlands must be designated as separate WAAs, because the assessment process includes consideration of the size and isolation of individual wetland units. The second situation occurs where more than one regional wetland subclass occurs within a project area, as illustrated in Figure 25, where both Flat and Low-gradient Riverine Overbank wetlands are present within the project area. These must be separated because they are assessed using different models and reference data systems. The third situation occurs where a contiguous wetland area of the same regional subclass exhibits spatial heterogeneity in terms of hydrology, vegetation, soils, or other assessment criteria. This is illustrated in Figure 26, where the area designated as Riverine Overbank Wetlands in Figure 25 is further subdivided into two WAAs based on land use and vegetation cover. The farmed area clearly will have different characteristics from those of the forested wetland, and they will be assessed separately (though using the same models and reference data).

In the Delta Region of Arkansas, the most common scenarios requiring designation of multiple WAAs involve tracts of land with interspersed

regional subclasses (such as depressions scattered within a matrix of flats or riverine wetlands) or tracts composed of a single regional subclass that includes areas with distinctly different land use influences that produce different land cover. For example, within a large riverine backwater unit, the following WAAs may be defined: cleared land, early successional sites, and mature forests. However, users should be cautious about splitting a project area into many WAAs based on relatively minor differences, such as local variation due to canopy gaps and edge effects. The reference curves used in this document (Chapter 5) incorporate such variation, and splitting areas into numerous WAAs based on subtle differences will not materially change the outcome of the assessment. It will, however, greatly increase the sampling and analysis requirements. Field experience in the region should provide a sense of the range of variability that typically occurs, and is sufficient to make reasonable decisions in defining multiple WAAs.

Collect field data

Information on the variables used to assess the functions of regional wetland subclasses in the Delta Region of Arkansas is collected at several different spatial scales, and requires several summarization steps. The checklists and data sheets in the appendices are designed to assist the assessment team in assembling the required materials and proceeding in an organized fashion. As noted, the Site or Project Information and Assessment Documentation Form (Appendix A1) is intended to be used as a cover sheet and for an overview of all documents and data sheets used in the assessment. Assembling the background information listed on this form should guide the assessment team in determining the number, types, and sizes of the separate WAAs likely to be designated within the project area. Based on that information, the field gear and data sheet checklists in Appendix A2 should be used to assemble the needed materials before heading to the field to conduct the assessment.

Note that different wetland subclasses require different field data sheets, because the assessment variables differ among subclasses (Table 9). Use the Data Sheet checklist in Appendix A2 to determine how many of each form are needed, then make copies of the required forms, which are provided in Appendix B.

Table 9. Applicability of variables by regional wetland subclass.

Variable Code	Flat	Riverine Backwater	Riverine Overbank	Headwater Depression	Unconnected Depression	Connected Depression
V_{AHOR}	+	+	+	*	*	*
V_{COMP}	+	+	+	+	+	+
$V_{CONNECT}$	+	+	+	+	+	+
V_{CORE}	+	+	+	+	+	+
V_{DUR}	not used	+	+	+	not used	+
V_{FREQ}	not used	+	+	not used	not used	+
V_{GVC}	+	+	+	*	*	*
V_{LITTER}	+	+	+	*	not used	*
V_{LOG}	+	+	+	*	*	*
V_{OHOR}	+	+	+	*	*	*
V_{OUT}	not used	not used	not used	+	not used	not used
V_{POND}	+	+	+	not used	not used	not used
V_{SNAG}	+	+	+	+	+	+
V_{SOIL}	+	+	+	*	*	*
V_{STRATA}	+	+	+	+	+	+
V_{SSD}	+	+	+	+	+	+
V_{TBA}	+	+	+	+	+	+
V_{TCOMP}	+	+	+	+	+	+
V_{TDEN}	+	+	+	+	+	+
V_{TRACT}	+	+	+	+	+	+
V_{WD}	+	+	+	*	*	*

Note: Variables not used in assessment of a particular subclass are identified. Variables always used in assessment of the subclass are indicated by +. Variables used unless site conditions preclude their observation are indicated by a shaded box marked with *.

The data sheets provided in Appendix B are organized to facilitate data collection at each of the several spatial scales of interest. For example, the first group of variables (Data Sheet 1) contains information about landscape scale or WAA-scale characteristics collected using aerial photographs, maps, and hydrologic information regarding each WAA and vicinity, or collected during a walking reconnaissance of the WAA. Data collected for these variables are entered directly on the Data Sheets, and do not require plot-based sampling. Information on the next group of variables is collected in sample plots placed in representative locations throughout the WAA. Data from a single plot are recorded on Data Sheet 2, which is made up of two

separate data sheets. Additional copies of Data Sheet 2 are completed for each plot sampled within the WAA.

All of the data sheets shown in Appendix B are printouts from the Arkansas Delta Data Sheets and FCI Calculator (Calculator), a single spreadsheet that allows raw data entry; the spreadsheet automatically calculates variable values, variable subindices and FCIs and FCUs. The Data Sheets from the spreadsheet should be printed out and taken in the field, and then the raw data may be entered in the same form in the Excel spreadsheet, so that automated calculations occur.

All data from each of the Data Sheets are compiled automatically by the Calculator in the Data Summary by Plot tab (Appendix D3). These summarized data are then used by the Calculator to automatically calculate the Functional Capacity of the wetland being assessed on the FCI/FCU Calculation Summary tab of the Arkansas Delta Data Sheets and FCI Calculator, once the Subclass is selected and raw data are entered.

The sampling procedures for conducting an assessment require few tools, but certain tapes, a shovel, specialized basal area estimation or measurement tools, reference materials, and an assortment of other items will be needed (Appendix A2). Generally, all measurements should be taken in metric units (although non-SI equivalents are indicated for most sampling criteria such as plot sizes). Collecting data in non-SI units will require conversion of sample data to metric before completing the necessary calculations of entering data into spreadsheets for summarization. There are two exceptions to this general rule: the recommended basal area prism is a non-SI 10-factor prism, which is an appropriate size for use in the forests of the Delta Region. A conversion factor is built into the data sheet to make the needed adjustments to the recorded field data. The second instance involves measurement of diameter-at-breast-height (dbh) using a special tape, and calculation of basal area, which is an alternative approach to the prism method. Because non-SI dbh tapes are more widely available than metric tapes, the summarization spreadsheets provided in Appendix D are able to accept either non-SI or metric units as input data.

A typical layout for the establishment of sample plots and transects in the hypothetical WAAs is shown in Figure 27. As in defining the WAA, there

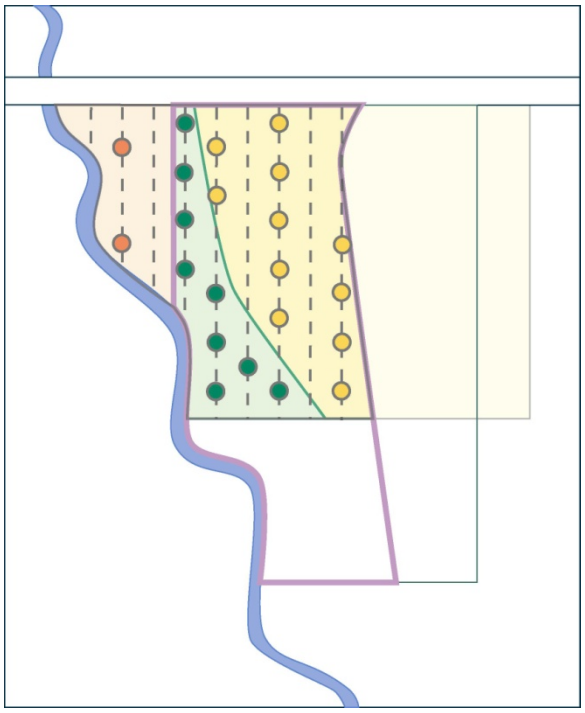


Figure 27. Example sample distribution (refer to Figure 26 for WAA designations).

are elements of subjectivity and practicality in determining the number of sample locations for collecting plot-based and transect-based site-specific data. The exact numbers and locations of the plots and transects are dictated by the size and heterogeneity of the WAA. If the WAA is relatively small (i.e., less than 2–3 acres, or about a hectare) and homogeneous with respect to the characteristics and processes that influence wetland function, then three or four 0.04-ha plots, with associated nested transects and subplots in representative locations, are probably adequate to characterize the WAA. Experience has shown that the time required to complete an assessment of an area of that size is 2–4 hours, depending primarily on the experience of the assessment team. However, as the size and heterogeneity of the WAA increase, more sample plots are required to represent the site accurately. Large forested wetland tracts usually include a mix of tree age classes, scattered small openings in the canopy that cause locally dense understory or ground cover conditions, and perhaps some very large individual trees or groups of old-growth trees. The sampling approach should not bias data collection to differentially emphasize or exclude any of these local conditions, but should represent the site as a whole. Therefore, on large sites the best approach often is a simple systematic plot layout, where evenly spaced parallel transects are established (using a compass and pacing) and sample plots are distributed at regular paced intervals along those transects. For example, a 12-ha tract, measuring about 345 m on each side, might be sampled using two transects spaced 100 m apart (and 50 m from the tract edge), with plots at 75-m intervals along each transect (starting 25 m from the tract edge). This would result in eight sampled plot locations, which should be adequate for a relatively diverse 12-ha forested wetland area. In Figure 27, WAA 2 illustrates this approach for establishing fairly high-density, uniformly distributed samples. Larger or more uniform sites can usually be sampled at a lower plot density. One approach is to establish a

series of transects, as described, and sample at intervals along alternate transects (see WAA 3 in Figure 27). Continue until the entire site has been sampled at a low plot density, then review the data and determine if the variability in overstory composition and basal area has been largely accounted for. That is, as the number of plots sampled has increased, are new dominant species no longer being encountered, and has the average basal area for the site changed markedly with the addition of recent samples? If not, there is probably no need to add further samples to the set. If overstory structure and composition variability remain high, then return to the alternate, unsampled transects and continue sampling until the data set is representative of the site as a whole, as indicated by a leveling off of the dominant species list and basal area values. Other variables may level off more quickly or slowly than tree composition and basal area, but these two factors are generally good indicators, and correspond well to the overall suite of characteristics of interest within a particular WAA. In some cases, such as sites where trees have been planted or composition and structure are highly uniform (e.g. sites dominated by a single tree species), it may be apparent that relatively few samples are adequate to reasonably characterize the wetland. In Figure 27, this is illustrated by the sample distribution in WAA 1, which is a farmed area where few variables are likely to be measurable, or at least will vary little from plot to plot. In this case, every other plot location is sampled along every other transect.

The information on Data Sheet 1 and on the multiple copies of Data Sheet 2 is compiled automatically by the Calculator in the Data Summary by Plot tab (Appendix D3). These summarized data are then used by the Calculator to automatically determine the Functional Capacity of the wetland being assessed on the FCI/FCU Calculation Summary tab of the Calculator for each WAA. All of the field and summary data sheets, as well as the printed output from the final spreadsheet calculations, should be attached to the Project Information and Assessment Documentation Form provided in Appendix A. Appendix C provides some alternate data sheets that may be needed in cases where alternative field methods are used, or where the user wishes to calculate summary data by hand, rather than using the spreadsheets. The use of these forms is explained on the forms themselves, and in the pertinent variable descriptions below. Appendix D contains the examples of the spreadsheets (in Excel format) that may be used to complete the data summary calculations, excluding those that make up the

Data Sheets in Appendix B. Appendix F is a listing of common and scientific names of tree and shrub species that are referenced on the field data sheets.

Detailed instructions on collecting the data for entry on Data Sheets 1 and 2 are provided in the following sections. Variables are listed in alphabetical order to facilitate locating them. Each set of directions results in an overall WAA value for the variable calculated on the Data Summary by Plot tab. Those numbers are then automatically used in FCI/FCU Calculation Summary tab (Appendix D4).

Not all variables are used to assess all subclasses, as described in Chapter 5 and Table 9, but the data sheets in Appendix B indicate which variables are pertinent to each subclass. The data sheets also provide brief summaries of the methods used to assess each variable, but the user should read through these more detailed descriptions and have them available in the field for reference as necessary.

V_{AHOR} - A Horizon Organic Accumulation

This variable represents total mass of organic matter in the A soil horizon. The A soil horizon is defined as a mineral soil horizon that occurs at the ground surface, below the O soil horizon, consisting of an accumulation of unrecognizable decomposed organic matter mixed with mineral soil (USDA SCS 1993). In practice, the HGM models using this variable are concerned with the storage of organic matter, so for these purposes the A horizon is identified in the field simply as a zone of darkened soil.

Thickness of the A horizon is the metric used to quantify this variable. Measure it using the following procedure:

1. Establish sample points by selecting two or more locations within the 0.04-ha circular plot that are representative of the range of micro-topographic conditions in the plot, or select two or more of the four 1-m^2 subplots established for litter and ground cover estimation (see descriptions of those variables). Dig a hole (25 cm or 10 in. deep is usually adequate in the Delta Region) and measure the thickness of the A horizon. Record measurements in the yellow spaces on Data Sheet 2. The average value for the plot will be calculated automatically.
2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically

averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{COMP} / V_{TCOMP} - Composition of Tallest Woody Vegetation Stratum / Composition of Tree Stratum

These variables represent the species composition of the tallest woody stratum present in the assessment area. If the tree stratum is the tallest covering at least 20% of the area, V_{COMP} and V_{TCOMP} will be the same. The tallest stratum could be the tree, shrub-sapling, or seedling stratum. Percent concurrence with reference wetlands of the dominant species in the dominant vegetation stratum is used to quantify this variable. Measure it using the following procedure:

1. Determine percent cover of the tree stratum by visually estimating what percentage of the sky is blocked by leaves and stems of the tree stratum (living woody stems ≥ 10 cm or 4 in. at breast height), or vertically projecting the leaves and stems to the forest floor. If the percent cover of the tree stratum is estimated to be at least 20 percent, check the box on Data Sheet 2 and go to Step 2. The tree stratum will be used to calculate concurrence for both V_{COMP} and V_{TCOMP}. If the percent cover of the tree stratum is estimated to be <20 percent, leave the box unchecked and go to Step 2. In this case, V_{TCOMP} will be zero, and the next tallest stratum covering at least 10% will be used to calculate concurrence for V_{COMP}.
2. Determine the stratum to be used for calculating concurrence. If the percent cover of the tree stratum was found to be at least 20% in Step 1 above, use that stratum and proceed to Step 3. If the tree stratum does not have at least 20 percent cover, determine the tallest woody stratum with at least 10 percent total cover. If there are no woody species present on the site, check the appropriate box at the bottom of the column for Group 3.
3. Determine concurrence. Within the selected stratum, identify the dominant species based on percent cover using the 50/20 rule: rank species in descending order of percent cover and identify dominants by summing relative dominance in descending order until 50 percent is exceeded; additional species with 20 percent relative dominance should also be included as dominants. Check the boxes for these species on Data Sheet 2. Accurate identification of woody species is critical for determining the dominant species in each plot. Sampling during the dormant season may require proficiency in recognizing plant form, bark, and dead or dormant plant parts. Users who do not feel confident in identifying trees and shrubs should get help.

4. Percent concurrence is automatically calculated and entered into V_{COMP} and V_{TCOMP} cells using the formula below, which weights dominant species based on their likelihood of being dominant in reference stands of varying condition. The result is intended to indicate the character of the developing forest.

$$\%Concurrence = \left[\frac{(\#Group1 \times 1.0) + (\#Group2 \times 0.66) + (\#Group3 \times 0.33)}{Total\_\#Species\_in\_All\_Groups}\right] \quad (48)$$

5. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

$V_{CONNECT}$ - Habitat Connectivity

This variable is defined as the proportion of the perimeter of a forested wetland tract that is connected to suitable wildlife habitat such as upland forests or other wetlands vegetated with native species (Figure 28). Agricultural fields, orchards, clear cuts, pastures dominated by non-native species, mined areas, and developed areas are examples of unsuitable habitats, regardless of whether they meet the criteria for federally jurisdictional wetlands or not. Note that because this is a landscape-level variable, the "tract" is not limited to the WAA under consideration, but includes all contiguous forested wetlands (Figure 25).

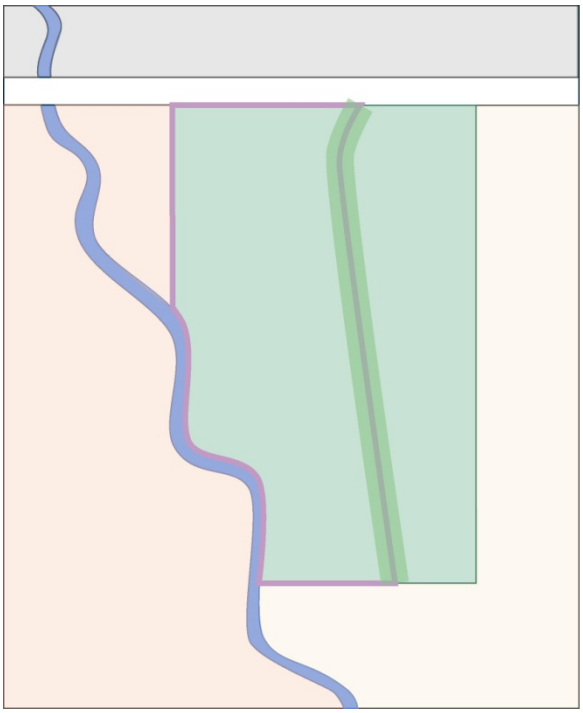


Figure 28. Identification of "connected perimeter" (green line). Refer to Figure 25 for subunit designations.

The percentage of the forested wetland tract boundary that is "connected" is used to quantify this variable. Note that the "tract" is not limited to the WAA under consideration, but includes all contiguous forested wetlands. An adja-

cent habitat is considered connected if it is within 0.5 km (0.31 mile) of the boundary of the forested wetland tract. Measure it as follows:

1. Calculate the length of the forested wetland tract boundary. Use field reconnaissance, topographic maps, aerial photography, Geographic Information System (GIS), or another suitable method or tool.
2. Calculate the length of the forested wetland tract boundary that is within 0.5 km (0.31 mile) of suitable habitats like those described previously.
3. Divide the length of connected forested wetland tract boundary by the length of the total forested wetland tract boundary, and then multiply by 100. The resulting number is the percent of the wetland tract boundary that is connected.
4. Record this percentage on Data Sheet 1 in the yellow box on the right-hand side of the $V_{CONNECT}$ row.
5. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{CORE} - Core Area

This variable is defined as the portion of a wetland tract that lies to the inside of a 100-m (330-ft) buffer interior of the boundary of the entire forested area (Figure 29). The percentage of a wetland tract that lies to the inside of this 100-m (330-ft) buffer zone is the metric used to quantify this variable. Note that the tract is not limited to the WAA under consideration, but includes all contiguous forested wetlands. Determine the value of this metric using the following procedure:

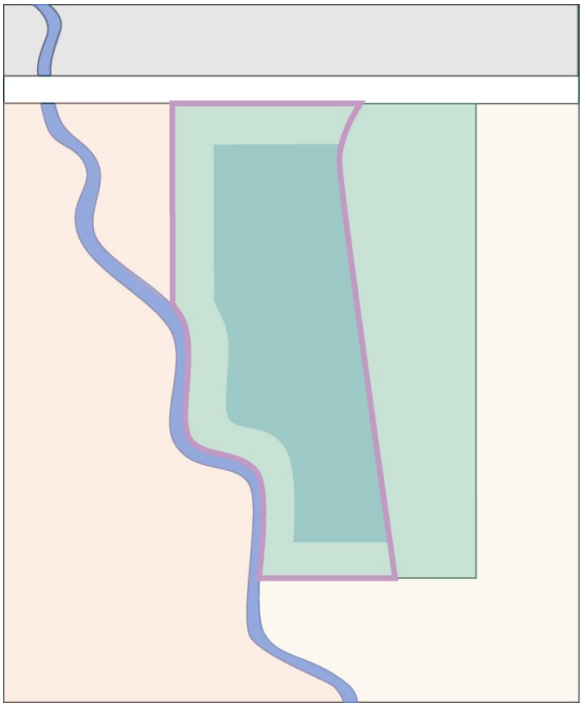


Figure 29. Identification of "core area." Refer to Figure 25 for subunit designations.

1. On a map or photo, draw a continuous line 100 m inside the boundary of the entire contiguous forested area.
2. Calculate the size of the wetland tract that lies inside this line. This is the core area.

3. Divide the size of the core area by the size of the wetland tract and then multiply by 100. The resulting number is the percent of the wetland tract that is the core area.
4. Record the percentage on Data Sheet 1 in the box on the right-hand side of the V_{CORE} row.
5. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{DUR} - Change in Growing Season Flood Duration

Growing season flood duration refers to the maximum number of continuous days in the growing season that overbank or backwater flooding from a stream inundates the WAA. Riverine and Connected Depression wetlands may flood as infrequently as one year in five (see the discussion of the V_{FREQ} variable in the following section). However, when flooding does occur, it usually extends for some days or weeks into the growing season, and strongly influences plant and animal communities. In some cases, where impoundments are constructed around existing wetlands (e.g., greentree reservoirs) or where stream engineering projects such as flood control projects are constructed, additional growing season flooding may occur in the spring or fall. The V_{DUR} variable is intended to reflect changes in function that result where changes in growing season hydrology have occurred or are expected to occur as a result of leveeing, drainage, impoundment, or other engineering projects. Either increases or decreases in growing season flood durations are assumed to cause reduced function relative to the pre-impact condition for both the Maintain Plant Communities and Provide Wildlife Habitat functions.

In order to account for this type of change, the V_{DUR} variable is incorporated in the relevant models. The V_{DUR} variable was developed for use primarily in the context of proposed Corps of Engineers water projects in the Delta Region, and is therefore structured specifically to accommodate the type of hydrologic information generated in the Corps project planning process. It was developed based on field studies on greentree reservoirs in the Bayou Meto basin (Heitmeyer and Ederington 2004), where changes in flood duration were expressed in terms of continuous days of flooding in the growing season. Changes in flood duration are presented as “zone changes,” where a single zone change corresponds to approximately one week of additional or reduced continuous flooding during the growing season. Because these data are usually generated to evaluate likely project-induced changes in the acreage of jurisdictional wetlands, the “period of continuous

flooding" may not correspond to the total days of flooding. At this time, no specific correlation has been established between this means of presenting flood duration data and the more common method of discussing flood durations that are based on total days of flooding in the entire annual cycle.

Estimates of growing-season flood durations are not typically readily available for any particular site, and in most cases the change in duration will be assumed to be zero unless specific information to the contrary is available from project planning or permit application documents. Whatever the case, the percent change should be calculated consistently for the before-project and after-project conditions as follows:

1. Determine the change in growing season flood duration by comparing the preproject and postproject flood durations.
2. Record the preproject and postproject growing season flood durations on Data Sheet 1 using drop-down menus in the V_{DUR} row.
3. The number of zone changes represented (where 1-week change in continuous growing-season flooding constitutes a zone change) will be automatically calculated.
4. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{FREQ} - Change in Frequency of Flooding

Frequency of flooding refers to the frequency (return interval in years) with which overbank or backwater flooding from a stream inundates the WAA. In the classification employed here, where the 5-year return interval distinguishes connected from unconnected wetlands, the frequencies of interest are the 1-, 2-, 3-, 4-, and 5-year return intervals. However, in the context of the assessment models where the V_{FREQ} variable is used, there is no implication that more frequent flooding translates to higher functionality. Rather, all connected wetlands are assumed to be fully functional with regard to the V_{FREQ} variable unless there has been a change in flood frequency, and any such change, whether more or less frequent, will have adverse effects on the wetland communities and processes currently in place. (Note: As with the classification system, flood frequencies established as a result of the major river engineering projects in the mid-twentieth century are considered to be the baseline condition in most assessment scenarios.) In practice, the change in flood frequency will be a consideration most often where the hydrology of a site has been recently modified, as through a levee, drainage, or pumping project, or where such a change is

proposed. In such situations the change in flood frequency can be used to indicate the magnitude of deviation from the preproject condition, calculated as follows:

1. Determine the change in recurrence interval by comparing the preproject and postproject flood frequencies. For the preproject condition, the recurrence interval can be determined or estimated using one of the following information sources:

   - Recurrence interval map.
   - Data from a nearby stream gage.
   - Regional flood frequency curves developed by local and State offices of USACE, U.S. Geological Survey (USGS) - Water Resources Division, State Geologic Surveys, or NRCS (Jennings et al. 1994).
   - Hydrologic models such as HEC-2 (U.S. Army Engineer Hydrologic Engineering Center (HEC) 1981, 1982), HEC-RAS (HEC 1997), or Hydrologic Simulation Program – Fortran (HSPF) (Bicknell et al. 1993).
   - Local knowledge.
   - A regional dimensionless rating curve.

   The same sources may be used to determine the postproject recurrence interval, or it may be specified in planning documents and applications.

2. Record the preproject and postproject recurrence intervals on Data Sheet 1 using the drop-down menus in the V_{FREQ} row.
3. The difference in return intervals will be automatically calculated.
4. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

   Example: A Riverine Overbank site that normally floods every year (5 years out of 5) will be affected by a nearby channel-deepening project that reduces flood frequency to 2 years out of 5. The change in return interval is 3 years.

Note that the number of possible changes in return interval varies depending on the starting flood frequency. This is due in part to the classification of the flood frequencies: any area flooded more frequently than once a year is grouped with the 1-year return interval group, and

everything flooded less frequently than every 5 years is no longer classified as riverine, and therefore the frequency variable no longer applies. As Figure 30 illustrates, the maximum of four zone changes is possible only for wetlands starting in the 1- or 5-year return interval categories (blue and red). This maximum change leads to a 0.2 variable subindex. In contrast, if the starting return interval is 3 years, a maximum of two zone changes is possible in either direction (green line), leading to a potential subindex of 0.6. A subindex of 0.0 occurs only if the change in frequency extends beyond the 5-year return interval required in the definition of riverine wetlands.

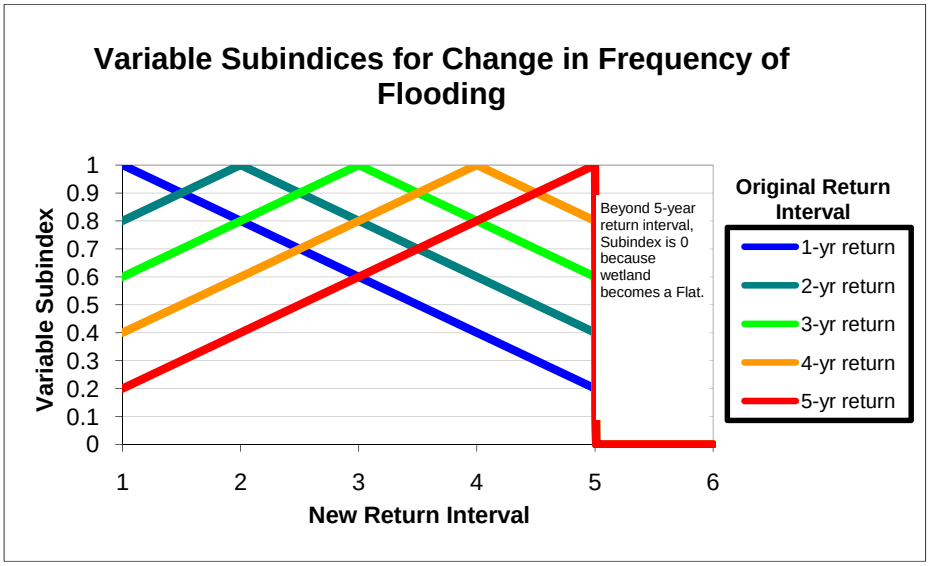


Figure 30. Potential variable subindices for different starting return interval frequencies.

V_{GVC} - Ground Vegetation Cover

Ground vegetation cover is defined as herbaceous and woody vegetation less than or equal to 1.4 m (4.5 ft) in height. The percent cover of ground vegetation is used to quantify this variable. Determine the value of this metric using the following procedure:

1. Visually estimate the proportion of the ground surface that is covered by ground vegetation by mentally projecting the leaves and stems of ground vegetation to the ground surface. Do this in each of four 1-m^2 subplots placed 5 m (15 ft) from the plot center, one in each cardinal direction as illustrated in Figure 31. Record measurements for each subplot in the yellow cells in the V_{GVC} row on Data Sheet 2. The subplot values will automatically be averaged.

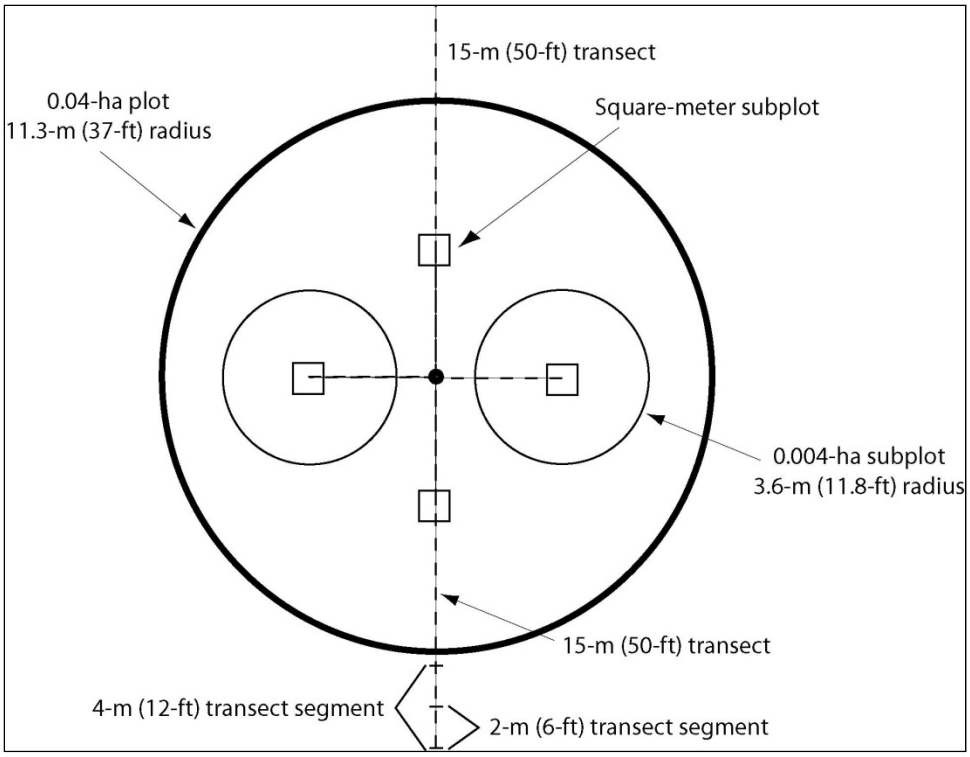


Figure 31. Layout of plots and transects for field sampling.

2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{LITTER} - Litter Cover

Litter cover is estimated as the average percent of the ground surface covered by recognizable dead plant materials (primarily decomposing leaves and twigs). This estimate excludes undecomposed woody material large enough to be tallied in the woody debris transects (i.e., twigs larger than 0.6 cm (0.25 in.) in diameter — see V_{WD} discussion). It also excludes organic material sufficiently decayed to be included in the estimate of O horizon thickness (see V_{OHOR} discussion). Generally, litter cover is easily recognized and estimated except during autumn, during active leaf fall, when freshly fallen materials should be disregarded in making the estimate, because the volume of freshly fallen material will inflate cover estimates.

The percent cover of litter is used to quantify this variable. Determine the value of this metric using the following procedure:

1. Visually estimate the proportion of the ground surface that is covered by litter. Do this in each of the four 1-m^2 subplots (the same subplots established for estimating ground vegetation cover, Figure 30). Record measurements for each subplot in the yellow cells in the V_{LITTER} row on Data Sheet 2. The subplot values will automatically be averaged.
2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{LOG} - Log Biomass

See discussions in the Woody Debris (V_{WD}) and Log Biomass (V_{LOG}) section later in this chapter.

V_{OHOR} - O Horizon Organic Accumulation

The O horizon is defined as the soil layer dominated by organic material that consists of partially decomposed organic matter such as leaves, needles, sticks or twigs < 0.6 cm in diameter, flowers, fruits, insect frass, dead moss, or detached lichens on or near the surface of the ground (USDA SCS 1993). The O horizon does not include recently fallen material or material that has been incorporated into the mineral soil.

Thickness of the O soil horizon is the metric used to quantify this variable. Measure it using the following procedure:

1. Measure the thickness of the O horizon in the same holes dug to determine the thickness of the A horizon discussed previously. That will result in two or more measurements per plot, which are recorded as subplot values in the V_{OHOR} section of Data Sheet 2. The average value for the plot will be calculated automatically.
2. The average plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{OUT} - Change in Surface Water Outflow

This variable represents the change in frequency at which water is discharged as surface flow from a headwater depression wetland to a

downslope stream. The variable is scored on the basis of field or map indicators that an alteration within the depression has affected surface water discharge.

The field procedure is as follows:

1. Inspect the lower perimeter of the headwater depression wetland and determine if there are indicators that surface water discharge has been altered. These may include a board structure to impede flow, a poorly designed or clogged culvert, a berm, or other impediment to flow across the lower end of the depression. Inspect the upper perimeter of the headwater depression for indications of additional water inputs such as irrigation pipe discharges or ditches flowing into the depression. Aerial photographs may also be useful for identifying these alterations.
2. If no alterations occur, or if the alterations do not appear to alter outflow (e.g., a well-functioning culvert), assume no change in the surface outflow of the wetland, and use the drop-down menus to indicate identical outflow regimes for pre- and post-project outflow. A subindex value of 1 will be automatically generated. If alterations have occurred (either additional inputs, or the impediment of outflow), but there is still some water making it through the lower end of the depression, make selections in the drop-down menus to reflect a change between perennial and seasonal outflow; a variable subindex of 0.5 will be generated. If a berm or other impediment has completely disconnected the depression from its stream, use the drop-down menu to indicate No Outflow, and a variable subindex of 0 will be generated.
3. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{POND} - Total Ponded Area

Total Ponded Area refers to the percent of the WAA ground surface likely to collect and hold precipitation for periods of days or weeks at a time. (Note: This is distinct from the area that is prone to flooding, where the surface of the WAA is inundated by overbank or backwater connections to stream channels). The smaller (microtopographic) depressions are usually a result of tree “tip ups” and the scouring effects of moving water, and typically they are between 1 and 10 m^2 in area. Larger vernal pools (usually at least 0.04 ha) occur in the broad swales typical of meander scroll topography, or in other areas where impeded drainage produces broad, shallow pools during rainy periods. The wetlands where these features are

important typically have a mix of both the small microdepressions and the larger vernal pools.

Estimate total ponded area using the following procedure:

1. During a reconnaissance walkover of the entire WAA, estimate the percentage of the assessment area surface having microtopographic depressions and vernal pool sites capable of ponding rainwater. Base the estimate on the actual presence of water immediately following an extended rainy period if possible, but during dry periods use indicators such as stained leaves or changes in ground vegetation cover. Generally, it is not difficult to visualize the approximate percentage of the area subject to ponding, but it is important to base the estimate on a walkover of the entire assessment area.
2. Report the percent of the assessment area subject to ponding on Data Sheet 1 in the yellow box on the right-hand side of the V_{POND} row, and transfer that value to the V_{POND} box on Data Sheet 3. Note that in the case of the Flats subclass, Data Sheet 2 also requires identification of the geomorphic surface on which the WAA is located, because percent ponding differs markedly among surfaces in the reference data set, which is reflected in the calibration curves and the summary spreadsheets. The geomorphic surface can be identified using the supplemental spatial data in Appendix E, or the map in Figure 6 may be adequate in many cases. Use the drop-down menu to assign the WAA to one of three possible surfaces:

    - Pleistocene Alluvial Terraces (formed by Pleistocene meander activity), identified as “alluvial (meandering stream) terraces” in the Pleistocene legend in Figure 6, and by map unit codes that begin with the following letters in Appendix E: Pt, Pd, Pi, Pp, and Qt.
    - Pleistocene Valley Train deposits (formed by glacial outwash events), identified as all Pleistocene surfaces other than terraces in Figure 6, and by map unit codes that begin with the letters Pv in Appendix E.
    - Holocene Alluvium (post-glacial meander belts), identified as all Holocene features in Figure 6, and by map unit codes that begin with the letter H in Appendix E.

3. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{SNAG} - Snag Density

Snags are standing dead woody stems at least 1.4 m (4.5 ft) tall with a dbh greater than or equal to 10 cm (4 in.). The density of snag stems per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Count the number of snag stems within each 0.04-ha circular plot. Record the number of snag stems in the yellow box on the V_{SNAG} row on Data Sheet 2. The stems/ha will be automatically calculated.
2. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{SOIL} - Soil Integrity

It is difficult in a rapid assessment context to assess soil integrity for two reasons. First, a variety of soil properties contribute to integrity that should be considered (i.e., structure, horizon development, texture, bulk density). Second, the spatial variability of soils within many wetlands makes it difficult to collect the number of samples necessary to characterize a site adequately. Therefore, the approach used here is to assume that soil integrity exists where evidence of alteration is lacking. Stated another way, if the soils in the assessment area do not exhibit any of the characteristics associated with alteration, it is assumed that the soils are similar to those occurring in the reference standard wetlands and have the potential to support a characteristic plant community.

This variable is measured as the proportion of the assessment area with altered soils. Measure it with the following procedure:

1. As part of the reconnaissance walkover of the entire WAA, determine if any of the soils in the area being assessed have been altered. In particular, look for evidence of excavation or fill, severe compaction, or other types of impact that significantly alter soil properties. For the purposes of this assessment approach, the presence of a plow layer should not be considered a soil alteration. (Note: the influence of past tilling is accounted for in the assessment of A horizon thickness).
2. If no altered soils exist, the percent of the assessment area with altered soils is zero. This indicates that all of the soils in the assessment area are

similar to soils in reference standard sites. If altered soils exist, estimate the percentage of the assessment area that has soils that have been altered.
3. Report the percent of the assessment area with altered soils in the yellow box Data Sheet 1 in the V_{SOIL} row.
4. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{SSD} - Shrub-Sapling Density

Shrubs and saplings are woody stems less than 10 cm (4 in.) dbh and greater than 1.4 m (4.5 ft) in height. Density of shrub-sapling stems per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Count woody stems less than 10 cm (4 in.) and greater than 1.4 m (4.5 ft) in height in two 0.004-ha circular subplots (radius 3.6 m or 11.8 ft) nested within the 0.04-ha plot (Figure 31). Record the number of stems in each 0.004-ha subplot in the yellow spaces provided in the V_{SSD} row on Data Sheet 2. The stems/ha will be automatically calculated.
2. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{STRATA} - Number of Vegetation Strata

The number of vegetation layers (strata) present in a forested wetland reflects the diversity of food, cover, and nest sites available to wildlife, particularly birds, but also to many reptiles, invertebrates, and arboreal mammals. Estimate the vertical complexity of the WAA using the following procedure:

1. During a reconnaissance walkover of the entire WAA, identify which of the following vegetation layers are present and account for at least 10 percent cover, on average, throughout the site.

    - Canopy (trees in the canopy layer greater than or equal to 10 cm dbh).
    - Subcanopy (trees below the canopy layer greater than or equal to 10 cm dbh. Recognize this layer if it is distinctly different from a higher, more mature canopy).

- Understory (shrubs and saplings less than 10 cm dbh but at least 4.5 ft tall).
- Ground cover (woody plants less than 4.5 ft tall and herbaceous vegetation).

1. Use the drop-down menu in the V_{STRATA} row on Data Sheet 1 to select the number of vegetation strata (0 – 4) present in the WAA.
2. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{TBA} - Tree Basal Area

Trees are defined as living woody stems greater than or equal to 10 cm (4 in.) dbh. Tree basal area is a common measure of abundance and dominance in forest ecology that has been shown to be proportional to tree biomass (Bonham 1989, Spurr and Barnes 1981, Tritton and Hornbeck 1982, Whittaker 1975, Whittaker et al. 1974). Tree basal area per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Use a basal area wedge prism (or other basal area estimation tool) as directed to tally eligible tree stems, and enter the tally in the yellow space on the V_{TBA} line on Data Sheet 2. Basal area prisms are available in various Basal Area Factors, and in both SI (metric) and non-SI (English) versions. Some are inappropriate for use in collecting the data needed here, because they are intended to be used for large-diameter trees in areas with little understory. The non-SI 10-factor prism works well in forests of the Delta region, and it is readily available.
2. Basal area in m^2/ha will be automatically calculated.
3. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

An alternative method also is available to directly measure tree diameters in the 0.04-ha plot, rather than use a plotless (e.g., wedge prism) estimation method. The difference between the two methods is likely to be insignificant at the level of resolution employed in the HGM assessment. However, if a wedge prism or similar tool is not available, or if undergrowth is too thick to allow a prism to be used accurately, direct diameter measurement (using a dbh tape or tree caliper) may be the only option available. The direct

measurement approach can be used to facilitate more rigorous data collection, particularly if the relative dominance of each tree species is an important consideration. Therefore, an alternative field form is provided in Appendix C1 that can be used to record the species and diameter of every tree within the 0.04-ha plot. Basal area can be calculated by hand on that data sheet, or on the spreadsheet provided in Appendix D. The spreadsheet will also indicate the basal area of each tree so the individual tree values for each species can be summed to determine the total basal area by species if desired. This can be used simply to provide more detailed documentation of the assessment process, or to improve the rigor of estimates for the V_{TCOMP} variable. Tree counts directly from the basal area sheets can also be used.

In general, the recommended field methods are likely to be much faster than the diameter measurement approach, but the outcome of the assessment should not differ significantly regardless of which method is used. The automated Calculator only accepts Factor-10 tallies.

The procedure for using the alternative (direct diameter measurement) method is as follows:

1. Using a metric (cm) diameter tape, measure the diameter of all trees (living woody stems greater than or equal to 10 cm (4 in.) at breast height) (dbh) in a circular 0.04-ha plot with a radius of 11.3 m (37 ft). Record each diameter measurement in Column 2 of Data Sheet C1. Recording the species of each tree (Column 1) is optional, but may be helpful, as described previously.
2. A spreadsheet is available (Appendix D1) to complete the calculations in Steps 2–5, or they can be done by hand as follows:

    a. Square the dbh measurement for each woody stem and enter that number in Column 3.
    b. Convert the squared diameters to square meters per hectare by multiplying by 0.00196. Enter this number in Column 4.
    c. Sum all Column 4 numbers to get total basal area (m^2 / ha) for the plot. Use this value in any hand calculations.

V_{TCOMP} - Tree Composition

See V_{COMP}/V_{TCOMP} discussion.

V_{TDEN} - Tree Density

Tree density is the number of trees (i.e., living woody stems greater than or equal to 10 cm or 4 in.) per unit area. The density of tree stems per hectare is the metric used to quantify this variable. Measure it using the following procedure:

1. Count the number of tree stems within the 0.04-ha plot (note: this is not the same as the stem count taken with the basal area wedge prism to determine V_{TBA}). Care should be taken not to err in determining whether or not a tree should be counted. Measure the plot radius to all marginal trees, and include only trees having at least half the stem within the plot. If tree diameters were recorded to calculate basal area, then the number of stems can be counted directly from the supplemental basal area field sheet (Data Sheet C1, Appendix C).
2. Record the stem count in the yellow space in the V_{TDEN} row on Data Sheet 2. The density in stems/ha will be automatically calculated.
3. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

V_{TRACT} - Wetland Tract

This variable is defined as the area of contiguous forested wetland that includes the WAA (Figure 25). Adjacent wetlands need not be in the same regional subclass as the assessment area to be part of the wetland tract.

Determine the size of the wetland tract using the following procedure:

1. Determine the size of the forested wetland area in hectares that is contiguous and directly accessible to wildlife utilizing the WAA (including the WAA itself). Use topographic maps, aerial photography, GIS, field reconnaissance or another appropriate method.
2. Record the forested wetland area in hectares in the yellow box in the V_{TRACT} row on Data Sheet.
3. The WAA value will be automatically transferred to the Data Summary by Plot tab and to the FCI/FCU Calculation Summary tab.

V_{WD} - Woody Debris Biomass and V_{LOG} - Log Biomass

Woody debris is an important habitat and nutrient cycling component of forests. Volume of woody debris and log biomass per hectare are the metrics used to quantify these variables. Measure them with the following procedure (Brown 1974, Brown et al. 1982).

(Note: all stem diameter criteria and measurements for all size classes refer to diameter at the point of intersection with the transect line. Leaning dead stems that intersect the sampling plane are sampled. Dead trees and shrubs still supported by their roots are not sampled. Rooted stumps are not sampled, but uprooted stumps are sampled. Down stems that are decomposed to the point where they no longer maintain their shape but spread out on the ground are not sampled.)

1. Lay out two 15.24-m (50-ft) east-west transects, originating at the 0.04-ha plot center point (Figure 31).
2. Count the number of nonliving stems in Size Class 1 (small) (greater than or equal to 0.6 and less than 2.5 cm or greater than or equal to 0.25 and less than 1 in.) that intersect a vertical plane above a 2-m (6-ft) segment of each 15.24-m (50-ft) transect. This can be any 2-m (6-ft) segment, as long as it is consistently placed. Figure 31 illustrates it as placed at the end furthest from the plot center point. Record the number of Size Class 1 stems from each transect in the yellow spaces provided on the V_{WD} (Size Class 1) line on Data Sheet 2.
3. Count the number of nonliving stems in Size Class 2 (medium) (greater than or equal to 2.5 cm and less than 7.6 cm or greater than or equal to 1 in. and less than 3 in.) that intersect the plane above a 3.7-m (12-ft) segment of each 15.24-m (50-ft) transect. This can be any 3.7-m (12-ft) segment, as long as it is consistently placed. Figure 31 illustrates it as placed at the end furthest from the plot center point, overlapping with the 2-m (6-ft) transect segment. Record the number of Size Class 2 stems from each transect in the yellow spaces provided on the V_{WD} (Size Class 2) line on Data Sheet 2.
4. Measure and record the diameter of nonliving stems in Size Class 3 (large) (greater than or equal to 7.6 cm (≥3 in.)) that intersect the plane above the entire length of the 15.24-m (50-ft) transect. Record the diameter of individual stems (in centimeters) in Size Class 3 from each transect in the yellow spaces provided on the V_{LOG} and V_{WD} (Size Class 3) section on Data Sheet 2.

5. Volume of non-living fallen logs (V_{LOG}.) in m^3/hectare and volume of woody debris (V_{WD}.) in m^3/hectare will be automatically calculated.
6. The plot value will be automatically transferred to the Data Summary by Plot tab. An overall WAA value will be automatically averaged on that form in the right-hand column. This WAA average value will then transfer automatically to the FCI/FCU Calculation Summary tab.

   Alternative:

   Data Sheet C1 is an alternative field and calculation form that allows V_{LOG} and V_{WD} to be calculated by hand if the user does not wish to use the spreadsheet.

Analyze field data

The analysis of field data requires three steps. The first step is to transform the measure of each assessment variable into a variable subindex. This can be done manually by comparing the summary data (right-hand boxes) from the Data Summary By Plot tab to the graphs in Chapter 5. The second step is to insert the variable subindices into the appropriate assessment models in Chapter 5 and calculate the FCI for each assessed function. Finally, the FCI is multiplied by the area in hectares of the WAA to calculate FCUs for each assessed function.

However, all of these calculations are carried out automatically by entering the raw data into the Arkansas Delta Data Sheets and FCI Calculator. Note that the workbook creates appropriate data sheets and calculators for each subclass, and the subclass *must* be selected first, for proper variables, subindex curves, and formulae to be used. Starting at the FCI Calculator tab, enter the project name, general location, WAA number, WAA size (in hectares), and use the drop-down menu to select a subclass. If the analysis is going to include a simple mitigation sufficiency test using the Mitigation Sufficiency Calculator available at http://el.erdc.usace.army.mil/wetlands/datanal.html, use the drop-down menu for Project Site and Project Timing for instructions on where to enter the calculated FCIs.

Next go to the WAA & Tract Data Entry tab to enter data into Data Sheet 1. At the top of the page there is a place to enter Assessment Team and Sampling Date. Other relevant project data will be carried forward from the FCI Calculator tab. Note that there is a checkbox at the top of the page which, when assessing a Depression, asks if the site is inundated; ground-

level variables are not assessed in depressions with standing water. If desired, separate WAAs can be established for inundated and noninundated subsections of the depression.

When using the Arkansas Delta Data Sheets and FCI Calculator spreadsheet, note that in general yellow cells require data or information input. In many cases, drop-down menus are used. Green or white cells are generally values calculated by the spreadsheet based on data provided by the user. Only yellow cells and drop-down menus may be altered. Do not attempt to clear or enter data into any green or non-shaded boxes – the spreadsheet will not accept direct changes to those cells.

Enter all relevant data into Data Sheet 1. Then use the 11 Plot Data Entry tabs to enter Data Sheet 2 data for up to 11 plots. In the very unlikely case that more than 11 plots are necessary, divide the plots evenly into two WAAs and average the results. Additional plots cannot be added to the Arkansas Delta Data Sheets and FCI Calculator.

The Calculator checks the entered data against expected values, and identifies errors. For instance, if text is entered where a number is expected or a number greater than 100 is entered as a percent, an error message indicating “Invalid Entry” will appear. Likewise, if multiple plots are used, but not all of the variables are filled out for each plot, a “Check Data” message will appear. Address any error messages before continuing.

The last tab of the Calculator is the Data Summary By Plot tab. This may be printed out to show the values for all the variables across all plots within the WAA, as well as the average values. No data may be entered on this sheet.

After all data are entered, the FCI Calculator tab will have the summary of Average Variable Values, Variable Subindices, FCIs and FCUs in a single summary page with basic project and WAA information. This may be printed out or the values may be copied and pasted into Word or other programs.

The Calculator has been designed to be as automated as possible, while protecting the integrity of the numerous formulae necessary for the automated calculations. Hence, most cells cannot be altered, or even selected. This is to help in the speed and accuracy of data entry, but comes

at a cost. It is not possible to combine the use of the Calculator with the use of alternative methods (e.g., using dbh tape to calculate tree basal area rather than prisms). If these more manual sampling techniques are used, there is no easy way to incorporate the results into the Calculator.

Document assessment results

Once all of the data collection, summarization, and analysis steps have been completed, it is important to assemble all pertinent documentation. Appendix A2 is a cover sheet that, when completed, identifies the assembled maps, drawings, project descriptions, data sheets, and summary sheets (including spreadsheet printouts) that are attached to document the assessment. It is highly recommended that this documentation step be completed.

Apply assessment results

Once the assessment and analysis phases are complete, the results can be used to compare the same WAA at different points in time, compare different WAAs at the same point in time, or compare different alternatives to a project. The basic unit of comparison is the FCU, but it is often helpful to examine specific impacts and mitigation actions by examining their effects on the FCI independent of the area affected. The Calculator is a particularly useful tool for testing various scenarios and proposed actions — it allows experimentation with various alternative actions and areas affected to help isolate the project options with the least impact or the most effective restoration or mitigation approaches.

Note that the assessment procedure does not produce a single grand index of function — rather each function is separately assessed and scored, resulting in a set of functional index scores and functional units. How these are used in any particular analysis depends on the objectives of the analysis. In the case of an impact assessment, it may be reasonable to focus on the function that is most detrimentally affected. In cases where certain resources are particular regional priorities, the assessment may tend to focus on the functions most directly associated with those resources. For example, wildlife functions may be particularly important in an area that has been extensively converted to agriculture. Hydrologic functions may be of greatest interest if the project being assessed will alter water storage or flooding patterns. Conversely, this type of analysis can help to recognize when a particular function is being maximized to the

detriment of other functions, as might occur where a wetland is created as part of a stormwater facility; vegetation composition and structure, detritus accumulation, and other variables in such a setting would likely demonstrate that some functions are maintained at very low levels, while hydrologic functions are maximized.

Generally, comparisons can be made only between wetlands or alternatives that involve the same wetland subclass, although comparisons between subclasses can be made on the basis of functions performed rather than the magnitude of functional performance. For example, riverine subclasses have import and export functions that are not present in flats or unconnected depressions. Conversely, unconnected depressions are more likely to support endemic species than are river-connected systems. These types of comparisons may be particularly important where a proposed action will result in a change of subclass. When a levee, for example, will convert a riverine wetland to a flat, it is helpful to be able to recognize that certain import and export functions will no longer occur.

Users of this guidebook must recognize that not all situations can be anticipated or accounted for in developing a rapid assessment method. In particular, users must be able to adapt the material presented here to special or unique situations encountered in the field. For example, most of the reference standard conditions identified in the field were mature forests with high species diversity, and typically the riverine and flats subclasses were dominated by a variety of oak species while the depressional subclasses were dominated by baldcypress and overcup oak. Sites that deviate from these reference conditions may produce low scores for some functions. However, there are situations where deviation from the reference standard condition is appropriate, and should be recognized as such. In most of these cases, alternative reference standards have been identified in the discussions of assessment variables (e.g., cottonwood or willow dominating on new substrates is recognized as an appropriate V_{COMP} condition). In other instances, however, professional judgment in the field is essential to proper application of the models. For example, some depression sites with near-permanent flooding are dominated by buttonbush. Where this occurs because of water control structures or impeded drainage due to roads, it should be recognized as having arrested functional status, at least for some functions. However, where the same situation occurs because of beaver activity or changes in channel courses, the buttonbush swamp should be recognized as a functional component of

a larger wetland complex, and the V_{COMP} weighting system can be adjusted accordingly. Another potential way to deal with beaver in the modern landscape is to adopt the perspective that beaver complexes are fully functional but transient components of riverine wetland systems for all functions. At the same time, if beaver are not present (even in an area where they would normally be expected to occur), the resulting riverine wetland can be assessed using the models, but the overall WAA is not penalized either way. Other situations that require special consideration include areas affected by fire, sites damaged by ice storms, and similar occurrences. Note, however, that normal, noncatastrophic disturbances to wetlands (i.e., tree mortality causing small openings) are accounted for in the reference data used in this guidebook.

Because the HGM models are calibrated with reference to mature, complex plant communities, and the wildlife habitat models emphasize the requirements of species needing large, contiguous blocks of habitat, early successional wetlands in fragmented landscapes will receive very low assessment scores for the wildlife habitat function. In such situations, it may be useful to supplement the wildlife habitat assessment models with alternative methods such as the Habitat Evaluation Procedures (HEP) (U.S. Fish and Wildlife Service 1980). This approach can provide a more sensitive assessment of the early developmental period following wetland restoration or changes in management than the HGM models presented here.

Another potential consideration in the application of the assessment models presented here concerns the projection of future conditions. This may be particularly important in determining the rate at which functional status will improve as a result of restoration actions intended to offset impacts to jurisdictional wetlands. The graphs in Figure 32 represent general recovery trajectories for forested sites within the Delta Region of Arkansas based on a subset of the reference data collected to develop this guidebook. In selected stands, individual trees were aged using an increment corer to develop a general relationship between the age of sampled stands and the site-specific variables employed in the assessment models. Thus, a user can estimate the overstory basal area, shrub density, woody debris volume, and other functional indicators for various time intervals, and calculate functional capacity indices for all assessed functions. These curves are specifically constructed to reflect wetland recovery following restoration of agricultural land, which is the most

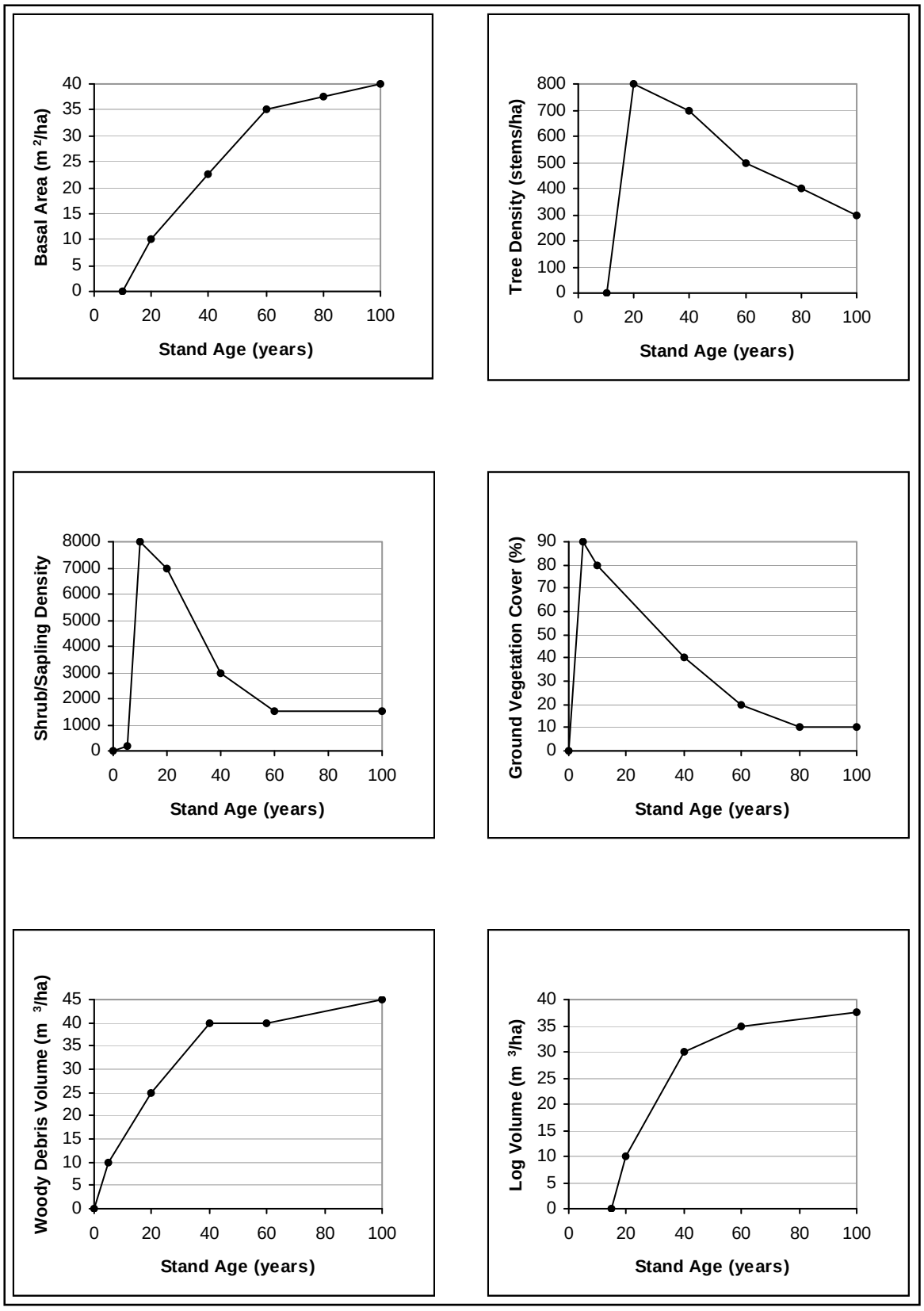


Figure 32. Projected recovery trajectories for selected assessment variables (Continued).

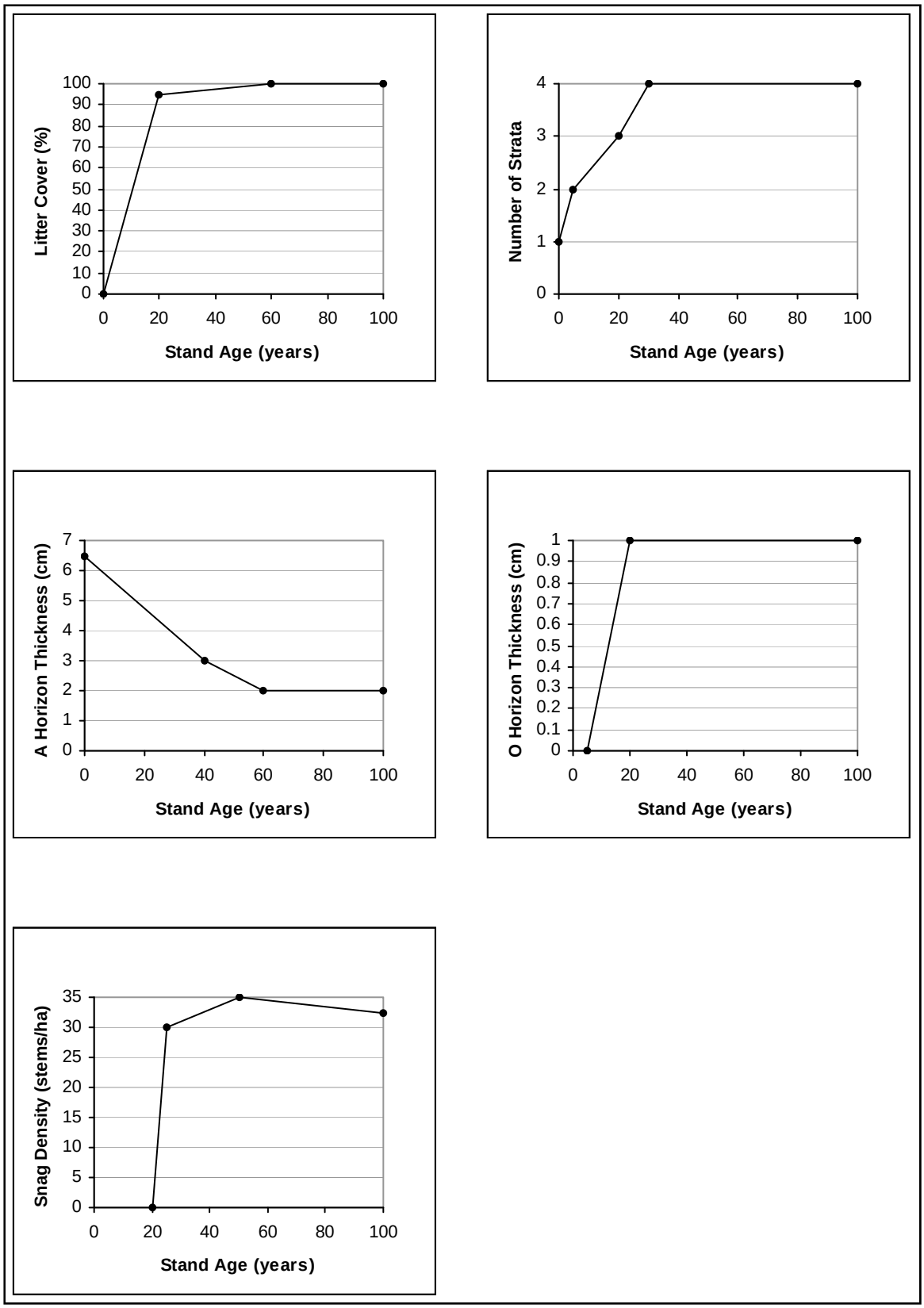


Figure 32. (Concluded).

common restoration scenario in the Delta Region of Arkansas. Therefore, they assume that the initial site condition includes bare ground that has been tilled (hence the deeper initial apparent A horizon). Note that landscape variables are not included here, because they require site-specific knowledge to project future conditions. However, it is also important to carefully consider the changing nature of the block size and connectivity variables used in the HGM models as the site matures. The spatial habitat variables (V_{TRACT}, V_{SCORE}, and $V_{CONNECT}$) are focused to a great extent on vegetation structure as it provides concealment and movement corridors. Thus, a wetland isolated from nearby forests at the initial assessment may be fully connected within a decade or two if the intervening fields have been allowed to grow into scrub and young forest habitats.

Ponding development rates also are not estimated, because ponding is the result of both geomorphic and biotic factors, and the initial site conditions (i.e., extent of land leveling). The degree of microtopographic relief will be dependent on the extent of site contouring work done prior to planting in most cases. Similarly, the rates of compositional change (V_{COMP} and V_{TCOMP}) are dependent on initial site conditions; generally, a site planted with appropriate species should have an FCI score of 1.0 soon after planting for the compositional variable V_{COMP}, and maintain that fully functional status indefinitely as V_{TCOMP} becomes the applicable compositional variable. Estimation of future composition for unplanted areas will require site-specific evaluation of seed sources and probable colonization patterns.

Note also that the graphs in Figure 32 are amalgams of data from all wetland subclasses. In situations where a site is expected to be unusual in one or more respects (such as a cottonwood stand, where basal areas are likely to increase more quickly than in hardwood forests), more specific data may exist, and should be substituted for these general curves as appropriate.

References

Ainslie, W. B., R. D. Smith, B. A. Pruitt, T. H. Roberts, E. J. Sparks, L. West, G. L. Godshalk, and M. V. Miller. 1999. *A regional guidebook for assessing the functions of low gradient, riverine wetlands of western Kentucky*. Technical Report WRP-DE-17. Vicksburg, MS: Wetlands Research Program, U.S. Army Engineer Waterways Experiment Station.

Allen, A. W. 1987. *Habitat suitability index models: Gray squirrel, revised*. Biological Report 82(10.135), U.S. Fish and Wildlife Service.

Ambuel, B., and S. A. Temple. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. *Ecology* 64, 1057-68.

Arkansas Multi-Agency Wetland Planning Team. 1997. *Arkansas wetland strategy*. Little Rock, AR: MAWPT Coordination Office, Arkansas Game and Fish Commission,.

Arkansas Natural Heritage Commission. 1997. *System of Arkansas natural areas*. Little Rock, AR: Department of Arkansas Heritage.

Arkansas Soil and Water Conservation Commission. 2001. *Critical groundwater designation fact sheet*. Little Rock, AR: Arkansas Soil and Water Conservation Commission.

Askins, R. A., M. J. Philbrick, and D. S. Sugeno. 1987. Relationship between the regional abundance of forest and the composition of forest bird communities. *Biological Conservation* 39: 129-52.

Autin, W. J., S. F. Burns, B. J. Miller, R. T. Saucier, and J. I. Snead. 1991. Quaternary geology of the Lower Mississippi Valley. In *Quaternary nonglacial geology: Conterminous U.S.* Vol. K-2, The Geology of North America, ed, R. B. Morrison. Boulder, CO: Geological Society of America, 547-82.

Baker, J. A., and K. J. Killgore. 1994. *Use of a flooded bottomland hardwood wetland by fishes in the Cache River System, Arkansas*. Technical Report WRP-CP-3, Wetlands Research Program. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Baker, J. A., K. J. Killgore, and R. L. Kasul. 1991. Aquatic habitats and fish communities in the lower Mississippi River. *Reviews in Aquatic Sciences* 3: 313-56.

Barham, A. F. 1964. As I saw it: *The story of the development of drainage and flood control in the St. Francis Basin of Arkansas*. Unpublished manuscript. Osceola, AR: St. Francis Levee District.

Barnhardt, M. L. 1988. Historical sedimentation in west Tennessee gullies. *Southeastern Geographer* 28: 1-18.

Barry, J. M. 1997. Rising tide – *The great Mississippi flood of 1927 and how it changed America*. New York, NY: Simon & Schuster.

Batema, D. L., G. S. Henderson, and L. H. Fredrickson. 1985. Wetland invertebrate distribution in bottomland hardwoods as influenced by forest type and flooding regime. In *Proceedings, Fifth Annual Hardwood Conference*, University of Illinois, Urbana.

Bicknell, B. R., J. C. Imhoff, J. L. Kittle, A. S. Donigan, and R. C. Johanson. 1993. *Hydrologic Simulation Program – Fortran (HSPF): User's manual for release 10.0*. EPA 600/3-84-066. Athens, GA: Environmental Research Laboratory.

Bilby, R. E., and G. E. Likens. 1979. Effect of hydrologic fluctuations on the transport of fine particulate organic carbon in a small stream. *Limnology and Oceanography* 24: 69-74.

Blake, J. G., and J. R. Karr. 1984. Species composition of bird communities and the conservation benefit of large versus small forests. *Biological Conservation* 30: 173-87.

Bolton, S. C., and J. E. Metzger. 1998. *The Vicksburg District 1977-1991*. Vicksburg, MS: U.S. Army Engineer District, Vicksburg.

Bonham, C. D. 1989. *Measurements for terrestrial vegetation*. New York: John Wiley.

Bormann, F. H., and G. E. Likens. 1970. The nutrient cycles of an ecosystem. *Scientific American* 223: 92-101.

Bovee, K. D. 1982. *A guide to stream habitat analysis using the in stream flow incremental methodology*. Instream Flow Information Paper No. 12, OBS-82/26. U.S. Fish and Wildlife Service.

Braun, E. L. 1950. *Deciduous forests of eastern North America*. New York: Hafner Press.

Brinson, M. M. 1977. Decomposition and nutrient exchange of litter in an alluvial swamp forest, *Ecology* 58, 601-9.

Brinson, M. M. 1985. Management potential for nutrient removal in forested wetlands. *Ecological considerations in wetlands treatment of municipal wastewaters*. P. J. Godfrey et al., ed., Van Nostrand Reinhold, New York, 405-16.

_____. 1990. Riverine forests. In *Forested wetlands*, ed. A. E. Lugo, M. M. Brinson, and S. Brown, 87-141. Amsterdam: Elsevier Scientific Publishers.

_____. 1993a. *A hydrogeomorphic classification for wetlands*. Technical Report WRP-DE-4. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

_____. 1993b. Changes in the functioning of wetlands along environmental gradients. *Wetlands* 13: 65-74.

_____. 1995. The hydrogeomorphic approach explained. *National Wetlands Newsletter*, November/December, Environmental Law Institute, Washington, DC.

_____. 1996. Assessing wetland functions using HGM. *National Wetlands Newsletter*, January/February, Environmental Law Institute, Washington, DC.

Brinson, M. M., H. D. Bradshaw, and E. S. Kane. 1984. Nutrient assimilative capacity of an alluvial floodplain swamp. *Journal of Applied Ecology* 21: 1041-57.

Brinson, M. M., A. E. Lugo, and S. Brown. 1981. Primary productivity, decomposition and consumer activity in freshwater wetlands. *Annual Review of Ecology and Systematics* 12: 123-61.

Brinson, M. M., H. D. Bradshaw, R. N. Holmes, and J. B. Elkins, Jr. 1980. Litterfall, stemflow, and throughfall nutrient fluxes in an alluvial swamp forest. *Ecology* 61: 827-35.

Brinson, M. M., F. R. Hauer, L. C. Lee, W. L. Nutter, R. D. Rheinhardt, R. D. Smith, and D. Whigham. 1995. *A guidebook for application of hydrogeomorphic assessments to riverine wetlands*. Technical Report WRP-DE-1. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Brinson, M. M., W. L. Nutter, R. Rheinhardt, and B. A. Pruitt. 1996. *Background and recommendations for establishing reference wetlands in the Piedmont of the Carolinas and Georgia*. EPA/600/R-96/057. U.S. Environmental Protection Agency National Health and Environmental Effects Laboratory, Western Division, Corvallis, OR.

Brinson, M. M., R. D. Smith, D. F. Whigham, L. C. Lee, R. D. Rheinhardt, and W. L. Nutter. 1998. Progress in development of the hydrogeomorphic approach for assessing the functioning of wetlands. In *Proceedings, INTECOL International Wetland Conference*, Perth, Australia.

Brooks, K. N., P. F. Ffolliott, H. M. Gregerson, J. L. Thames. 1991. *Hydrology and the management of watersheds*. Ames, IA: Iowa State University Press.

Brown, D. A., V. E. Nash, A. G. Caldwell, L. J. Bartelli, R. C. Carter, and O. R. Carter. 1971. *A monograph of the soils of the southern Mississippi Valley alluvium*. Southern Cooperative Series Bulletin 178, Arkansas, Mississippi, and Louisiana Agricultural Experiment Stations in Cooperation with the U.S. Department of Agriculture Soil Conservation Service.

Brown, J. K. 1974. *Handbook for inventorying downed woody material*. General Technical Report INT-16. U.S. Department of Agriculture Forest Service.

Brown, J. K., R. D. Oberheu, and C. M. Johnston. 1982. *Handbook for inventorying surface fuels and biomass in the interior west*. General Technical Report INT-129. Ogden, UT: U.S. Department of Agriculture Forest Service Inter-mountain Forest and Range Experiment Station.

Brown, S., and D. L. Peterson. 1983. Structural characteristics and biomass production of two Illinois bottomland forests. *American Midland Naturalist* 110: 107-17.

Campbell, K. L., and H. P. Johnson. 1975. Hydrologic simulation of watersheds with artificial drainage. *Water Resources Research* 11: 120-26.

Clay, F. M. 1986. A Century on the Mississippi: A history of the Memphis District, U.S. Army Corps of Engineers 1876-1981. Memphis, TN: U.S. Army Engineer District, Memphis.

Conner, W. H., and J. W. Day, Jr. 1976. Productivity and composition of a baldcypress-water tupelo site and bottomland hardwood site in a Louisiana swamp. *American Journal of Botany* 63: 1354-64.

Cooper, J. R., J. W. Gilliam, and T. C. Jacobs. 1986. Riparian areas as a control of nonpoint pollutants. *Watershed research perspectives*. D. L. Correll, ed., Smithsonian Institution Press, Washington, DC.

Cooper, J. R., J. W. Gilliam, R. B. Daniels, and W. P. Robarge. 1987. Riparian areas as filters for agricultural sediment. *Soil Science Society of America Journal* 51:(2), 416-20.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. *Classification of wetlands and deepwater habitats of the United States*. FWS/OBS-79/31. Washington, DC: Office of Biological Services Report, U.S. Fish and Wildlife Service.

Creasman, L., N. J. Craig, and M. Swan. 1992. *The forested wetlands of the Mississippi River, an ecosystem in crisis*. Baton Rouge, LA: The Nature Conservancy of Louisiana.

Dahm, C. M. 1981. Pathways and mechanisms for removal of dissolved organic carbon from leaf leachates in streams. *Canadian Journal of Fish and Aquatic Science* 38: 68-76.

Day, F. P. 1979. Litter accumulation in four plant communities in the Dismal Swamp, Virginia. *American Midland Naturalist* 102: 281-89.

Day, J. W., Jr., T. J. Butler, and W. H. Conner. 1977. Productivity and nutrient export studies in a cypress swamp and lake system in Louisiana. *Estuarine processes*, volume II. M. L. Wiley, ed., Academic Press, New York.

Demas, C. R., and D. K. Demcheck. 1996. Arkansas wetland resources. *National Water Summary on Wetland Resources*, 121-125. U.S. Geological Survey Water Supply Paper 2425.

Demissie, M., and A. Kahn. 1993. *Influence of wetlands on streamflow in Illinois*. Contract Report 561. Champaign, IL: Illinois State Water Survey.

Dewey and Kropper Engineers. 1964. *Effect of loss of valley storage due to encroachment— Connecticut River*. Report to the Water Resources Commission, Hartford, CT.

Dickinson, C. H., and G. Pugh. 1974. *Biology of plant litter decomposition*. London, England: Academic Press, Vol I.

Dickson, J. G. 1991. Birds and mammals of pre-colonial southern old-growth forests. *Natural Areas Journal* 11: 26-33.

Dunne, T., and L. B. Leopold. 1978. *Water in environmental planning*. San Francisco, CA: W. H. Freeman and Company.

Dybvig, W. L., and J. R. Hart. 1977. The effects of agricultural drainage on flood flows at Moose Jaw. In *Proceedings, 1977 Canadian Hydrology Symposium*. National Resources Council, 311-21.

Edwards, R. T. 1987. Sestonic bacteria as a food source for filtering invertebrates in two southeastern blackwater streams. *Limnology and Oceanography* 32: 221-34.

Edwards, R. T., and J. L. Meyers. 1986. Production and turnover of plantonic bacteria in two sub-tropical blackwater rivers. *Applied Environmental Microbiology* 52: 1317-23.

Elder, J. F. 1985. Nitrogen and phosphorus speciation and flux in a large Florida river-wetland system. *Water Resources Research* 21, 724-32.

Elder, J. F., and D. J. Cairns. 1982. *Production and decomposition of forest litter fall on the Appalachicola River flood plain, Florida*. Water Supply Paper 2196-B. Washington, DC: U.S. Geological Survey.

Elder, J. F., and H. Mattraw. 1982. Riverine transport of nutrients and detritus to the Apalachicola Bay Estuary, Florida. *Water Resources Bulletin* 18: 849-56.

Elwood, J. W., J. D. Newbold, R. V. O'Neill, and W. Van Winkle. 1983. Resource spiraling: An operational paradigm for analyzing lotic ecosystems. *Dynamics of lotic ecosystems*, ed. T. D. Fontaine and S. M. Bartell. Ann Arbor, MI: Ann Arbor Science.

Estes, C. C., and J. F. Orsborn. 1986. Review and analysis of methods for quantifying instream flow requirements. *Water Resources Bulletin* 22: 389-98.

Eyre, F. H. 1980. *Forest cover types of the United States and Canada*. Washington, DC: Society of American Foresters.

Faulkner, S. P., and C. J. Richardson. 1989. Physical and chemical characteristics of freshwater wetland soils. *Constructed wetlands for wastewater treatment*, ed. D. A. Hammer. Chelsea, MI: Lewis Publishers.

Finch, D. M. 1991. *Population ecology, habitat requirements, and conservation of neotropical migratory birds*. General Technical Report RM-205. U.S. Department of Agriculture Forest Service.

Fisk, H. N. 1944. Geological investigations of the alluvial valley of the lower Mississippi River. Vicksburg, MS: Mississippi River Commission.

Foti, T. 1993. The river's gifts and curses. *The Arkansas Delta: Land of paradox*, ed. J. Whayne and W. B. Gatewood, 30-57. Fayetteville, AR: Univ. of Arkansas Press,.

Fredrickson, L. H. 1978. Lowland hardwood wetlands: Current status and habitat values for wildlife. *Wetland functions and values: The state of our understanding*, ed. P. E. Greeson, J. R. Clark, and J. E. Clark, 207-306. Minneapolis, MN: American Water Resources Association.

Golet, F. C., and J. S. Larson. 1974. *Classification of freshwater wetlands in the glaciated Northeast*. Resource Publication 116. U.S. Fish and Wildlife Service.

Gosselink, J. G., L. C. Lee, and T. A. Muir. 1990. *Ecological processes and cumulative impacts illustrated by bottomland hardwood wetland ecosystems*. Chelsea, MI: Lewis Publishers.

Harmon, M. E., J. F. Franklin, and F. J. Swanson. 1986. Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15: 133-302.

Harris, L. D. 1985. *Conservation corridors: A highway system for wildlife*. ENFO Report 85-5. Winter Park, FL: Environmental Information Center of the Florida Conservation Foundation, Inc..

Harris, L. D., and J. G. Gosselink. 1990. Cumulative impacts of bottomland hardwood forest conversion on hydrology, water quality, and terrestrial wildlife. *Ecological processes and cumulative impacts illustrated by bottomland hardwood wetland ecosystems*, ed. J. G. Gosselink, L. C. Lee, and T. A. Muir, 259-322. Chelsea, MI: Lewis Publishers.

Hauer, F. R., and R. D. Smith. 1998. The hydrogeomorphic approach to functional assessment of riparian wetlands: Evaluating impacts and mitigation on river floodplains in the U.S.A. *Freshwater Biology* 40: 517-30.

Hawkins, C. P., M. L. Murphy, and N. H. Anderson. 1982. Effects of canopy, substrate composition, and gradient on the structure of macroinvertebrate communities in Cascade Range streams of Oregon. *Ecology* 63: 1840-56.

Hayes, A. J. 1979. The microbiology of plant litter decomposition. *Scientific Progress* 66: 25-42.

Heitmeyer, M. E., and B. Ederington. 2004. *An evaluation of bottomland hardwood forests in the Bayou Meto Basin Improvement Project area*. Report to Memphis District, U.S. Army Corps of Engineers.

Hodges, J. D. 1997. Development and ecology of bottomland hardwood sites. *Forest Ecology and Management* 90: 117-25.

Holder, T. H. 1970. *Disappearing wetlands in eastern Arkansas*. Little Rock, AR: Arkansas Planning Commission.

Howard, R. J., and J. A. Allen. 1989. Streamside habitats in southern forested wetlands: Their role and implications for management. In *Proceedings of the symposium: The forested wetlands of the southern United States*, ed. D. Hook and R. Lea. General Technical Report SE-50, D. U.S. Department of Agriculture Forest Service.

Howe, R. W. 1984. Local dynamics of bird assemblages in small forest habitat islands in Australia and North America. *Ecology* 65: 1585-1601.

Hudson, C. M. 1997. *Knights of Spain, warriors of the sun: Hernando DeSoto and the South's ancient chiefdoms*. Athens, GA: University of Georgia Press.

Hunter, M. L. 1990. *Wildlife, forests, and forestry: Principles of managing forests for biological diversity*. Englewood Cliffs, NJ: Prentice Hall.

Jennings, M. E., W. O. Thomas, Jr., and H. C. Riggs. 1994. *Nationwide summary of U.S. Geological Survey regional regression equations for estimating magnitude and frequency of floods for ungaged sites, 1993*. Water Resources Investigations Report 94-4002. U.S. Geological Survey.

Johnson, T. R. 1987. *The amphibians and reptiles of Missouri*. Jefferson City, MO: Missouri Department of Conservation.

Johnston, C. A. 1991. Sediment and nutrient retention by freshwater wetlands: Effects on surface water quality. *Critical Reviews in Environmental Control* 21: 491-565.

Johnston, C. A., N. E. Detenbeck, and G. J. Niemi. 1990. The cumulative effect of wetlands on stream water-quality and quantity: A landscape approach. *Biogeochemistry* 10: 105-41.

Kadlec, R. H. 1985. Aging phenomenon in wastewater wetlands. *Ecological considerations in wetland treatment of municipal wastewaters*, ed. P. J. Godfrey. New York: Van Nostrand Rheinhold.

Keller, C. M. E., C. S. Robbins, and J. S. Hatfield. 1993. Avian communities in riparian forests of different widths in Maryland and Delaware. *Wetlands* 13: 137-44.

Kent, M., and P. Coker. 1995. *Vegetation description and analysis, a practical approach*. New York: John Wiley and Sons.

Kilgo, J. C., R. A. Sargent, K. V. Miller, and B. R. Chapman. 1997. Landscape influences on breeding bird communities in hardwood fragments in South Carolina. *Wildl. Soc. Bull*. 25: 878-85.

Kitchens, W. M., Jr., J. M. Dean, L. H. Stevenson, and J. M. Cooper. 1975. The Santee Swamp as a nutrient sink. *Mineral cycling in southeastern ecosystems*, ed. F. G. Howell, J. B. Gentry, and M. H. Smith. ERDA Symposium Series 749513, Washington, DC.

Kleiss, B. A. 1996. Sediment retention in a bottomland hardwood wetland in Eastern Arkansas. *Wetlands* 16: 321-333.

Klimas, C. V., E. O. Murray, J. Pagan, H. Langston, and T. Foti. 2004. *A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley*. Technical Report ERDC/EL TR-04-16. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Klimas, C. V. 1988. *Forest vegetation of the leveed floodplain of the lower Mississippi River*. Lower Mississippi River Environmental Program Report 11. Vicksburg, MS: Mississippi River Commission.

_____. 1991. Limitations on ecosystem function in the forested corridor along the lower Mississippi River. In *Proceedings International Symposium on Wetlands and River Corridor Management*. Berne, NY: Assoc. State Wetland Managers.

Klimas, C.V., E. O. Murray, J. Pagan, H. Langston, and T. Foti. 2005. *A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in the West Gulf Coastal Plain Region of Arkansas*. ERDC/EL TR-05-12. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Klimas, C. V., E. O. Murray, H. Langston, T. Witsell, T. Foti, and R. Holbrook. 2006. *A Regional Guidebook for Conducting Functional Assessments of Wetland and Riparian Forests in the Ouachita Mountains and Crowley's Ridge Regions of Arkansas*. ERDC/EL TR-06-14. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Klimas, C. V., E. O. Murray, H. Langston, J. Pagan, T. Witsell, and T. Foti. 2008. *A Regional Guidebook for Conducting Functional Assessments of Forested Wetlands in the Arkansas Valley Region of Arkansas*. ERDC/EL TR-08-23. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Klimas, C. V., E. O. Murray, H. Langston, J. Pagan, T. Witsell, and T. Foti. 2008. *A Regional Guidebook for Conducting Functional Assessments of Forested Wetlands and Riparian Areas in the Ozark Mountains Region of Arkansas*. ERDC/EL TR-08-31. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Kolb, C. R., W. B. Steinriede, Jr., E. L. Krinitzsky, R. T. Saucier, P. R. Mabry, F. L. Smith, and A. R. Fleetwood. 1968. *Geological investigation of the Yazoo Basin, Lower Mississippi Valley*. Technical Report TR-3-480 (map folio). Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Kuchler, A. W. 1969. *Potential natural vegetation*. Map Sheet No. 90. Washington, DC: U.S. Geological Survey.

Kuenzler, E. J., P. J. Mulholland, L. A. Yarbro, and L. A. Smock. 1980. *Distributions and budgets of carbon, phosphorus, iron, and manganese in a floodplain swamp ecosystem*. Report No. 157. Raleigh, NC: Water Resources Institute of the University of North Carolina.

Larson, J. S., M. S. Bedinger, C. F. Bryan, S. Brown, R. T. Huffman, E. L. Miller, D. G. Rhodes, and B. A. Touchet. 1981. Transition from wetlands to uplands in southeastern bottomland hardwood forests. *Wetlands of bottomland hardwood forests*, Proceedings of a Workshop on Bottomland Hardwood Forest Wetlands of the Southeastern United States, Lake Lanier, GA, June 1-5, 1980. Developments in Agricultural and Managed Forest Ecology Vol. II. J. R. Clark and J. Benforado, ed., Elsevier Scientific Publishing Company, New York.

Leopold, L. B. 1994. *A view of the river*. Cambridge, MA: Harvard University Press.

Loeb, S. C. 1993. The role of coarse woody debris in the ecology of southeastern mammals. *Biodiversity and coarse woody debris in southern forests*, ed. J. W. McMinn, and D. A. Crossley, 108-18, GTR-SE-94. U.S. Department of Agriculture Forest Service Southern Research Station.

Lowrance, R., R. Todd, J. Fail, O. Hendrickson, R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. *Bioscience* 34: 374-77.

Ludwig, J. A., and J. F. Reynolds. 1988. *Statistical ecology: A primer on methods and computing*. New York: John Wiley.

Lynch, J. F., and D. F. Whigham. 1984. Effects of forest fragmentation on breeding bird communities in Maryland, USA. *Biological Conserv*. 28: 287-324.

Lynch, J. M., W. W. Baker, T. Foti, and L. Peacock. 1992. *The White River - Lower Arkansas River Megasite – A landscape conservation design project*. Little Rock, AR: Arkansas Natural Heritage Commission and The Nature Conservancy.

Meadows, J. S., and G. J. Nowacki. 1996. *An old-growth definition for eastern riverfront forests*. General Technical Report SRS-4. U.S. Department of Agriculture Forest Service Southern Research Station.

Messina, M. G., and W. H. Conner. 1997. *Southern forested wetlands: Ecology and management*. Boca Raton, FL: Lewis Publishers.

Mississippi River Commission. 1881-1897. Map of the lower Mississippi River from the mouth of the Ohio River to the Head of Passes. Vicksburg, MS.

Mississippi River Commission. 1970. *Flood control in the lower Mississippi River Valley*. Vicksburg, MS.

Mitch, P. P., and J. G. Gosselink. 1993. *Wetlands*. New York: Van Nostrand Reinhold.

Mitsch, W. J., C. L. Dorge, and J. R. Wiemhoff. 1979. Ecosystem dynamics and a phosphorus budget of an alluvial cypress swamp in southern Illinois. *Ecology* 60: 1116-24.

Moore, N. R. 1972. *Improvement of the lower Mississippi River and tributaries 1931-1972*. Vicksburg, MS: Mississippi River Commission.

Morrison, M. L., B. C. Marcot, and R. W. Mannan. 1992. *Wildlife-habitat relationships: Concepts and applications*. Madison, WI: University of Wisconsin Press.

Mueller, A. J., C. R. Loesch, and D. J. Twedt. 1995. Development of management objectives for breeding birds. In *Proceedings, Partners in Flight International Workshop*. Cape May, NJ.

Mulholland, P. J. 1981. Organic carbon flow in a swamp-stream ecosystem. *Ecological Monographs* 51: 307-32.

Mulholland, P. J., and E. J. Kuenzler. 1979. Organic-carbon export from upland and forested wetland watersheds. *Limnology and Oceanography* 24: 960-66.

Nadelhoffer, K. J., and J. W. Raich. 1992. Fine root production estimates and belowground carbon allocation in forest ecosystems. *Ecology* 73: 1139-47.

National Interagency Implementation Team. 1996. National action plan to implement the hydrogeomorphic approach (NAP). Federal Register Volume 61 Number 160, 42593-42603, Washington, DC.

Noss, R. F., and L. D. Harris. 1986. Nodes, networks, and MUMs: Preserving diversity at all scales. *Environmental Management* 3: 299-309.

Novitski, R. P. 1978. Hydrogeological characteristics of Wisconsin's wetlands and their influences on floods, stream flow, and sediment. *Wetland functions and values: The state of our understanding*, ed. P. E. Greeson, J. R. C. Clark, and J. E. Clark, 377-88. Minneapolis, MN: American Water Resources Association.

Odum, E. P. 1950. Bird populations of the Highlands (North Carolina) Plateau in relation to plant succession and avian invasion. *Ecology* 31: 587-605.

Office, Chief of Engineers. 1992. Memorandum on the "Clarification of Use of the 1987 delineation manual," Washington, DC.

Ogawa, H., and J. W. Male. 1983. *The flood mitigation potential of inland wetlands*. Publication Number 138. Amherst, MA: Water Resources Center.

_____. 1986. Simulating the flood mitigation role of wetlands. *Journal of Water Resources Planning and Management*. ASCE, 112, 114-28.

Omernik, J. M. 1987. Ecoregions of the conterminous United States. Map (scale 1:7,500,000), *Annals of the Association of American Geographers* 77: 118-125.

Ovington, J. D. 1965. Organic production, turnover and mineral cycling in woodlands. *Biological Review* 40: 772-85.

Patrick, W. H., Jr., and M. E. Tusneem. 1972. Nitrogen loss from flooded soil. *Ecology* 53: 735-37.

Patton, P. C. 1988. Drainage basin morphometry and floods. *Flood geomorphology,* ed. V. R. Baker, R. C. Kochel, and P. C. Patton, 51-64. New York: John Wiley.

Perry, D. A. 1994. *Forest ecosystems*. Baltimore, MD: Johns Hopkins University Press.

Peterjohn, W. T., and D. L. Correll. 1984. Nutrient dynamics in an agricultural watershed— Observations on the role of a riparian forest. *Ecology* 65: 1466-75.

Pomeroy, L. R. 1970. The strategy of mineral cycling. *Annual Review of Ecology and Systematics* 1: 171-90.

Pugh, G., and C. H. Dickinson. 1974. *Biology of plant litter decomposition*. Volume II. London: Academic Press.

Putnam, J. A. 1951. *Management of bottomland hardwoods*. Occasional Paper 116. U.S. Department of Agriculture Forest Service, Southern Forest Experiment Station.

Putnam, J. A., G. W. Furnival, and J. S. McKnight. 1960. *Management and inventory of southern hardwoods*. Agricultural Handbook No. 181. Washington, DC: U.S. Department of Agriculture Forest Service.

Raich, J. W., and K. J. Nadelhoffer. 1989. Belowground carbon allocation in forest ecosystems: Global trends. *Ecology* 70: 1346-54.

Rathburn, M. Y. 1990. Castle on the Rock: *The history of the Little Rock District, U.S. Army Corps of Engineers, 1881–1985*. Little Rock, AR: U.S. Army Engineer District.

Reiners, W. A. 1972. Terrestrial detritus and the carbon cycle. *Carbon and the biosphere*. Conference Proceedings 720510, ed. G. M. Woodwell and E. V. Pecan. U.S. Atomic Energy Commission.

Remsen, J. V., Jr. 1986. Was Bachman's Warbler a bamboo specialist? *Auk* 103: 216-219.

Rheinhardt, R. D., M. M. Brinson, and P. M. Farley. 1997. A preliminary reference data set for wet forested flats in North Carolina and its application to wetland functional assessment, mitigation, and restoration. *Wetlands* 17: 195-215.

Richardson, C. J. 1985. Mechanisms controlling phosphorus retention capacity in freshwater wetlands. *Science* 228: 1424-1427.

Ricklefs, R. E. 1990. *Ecology*. 3rd ed. New York: W. H. Freeman.

Ritter, D. F., R. C. Kochel, and J. R. Miller. 1995. *Process geomorphology*. 3rd ed., William C. Brown, Chicago, IL.

Robertson, P. A. 1992. Environmental factors affecting tree growth on three wetland sites in southern Illinois. *American Midland Naturalist* 128: 218-326.

Robertson, P. A., M. D. MacKenzie, and L. F. Elliot. 1984. Gradient analysis and classification of the woody vegetation for four sites in southern Illinois and adjacent Missouri. *Vegetatio* 58: 87-104.

Robertson, P. A., G. T. Weaver, and J. A. Cavanaugh. 1978. Vegetation and tree species patterns near the northern terminus of the southern floodplain forest. *Ecological Monographs* 48: 249-67.

Robinson, S. K. 1996. Setting objectives in forested habitats. *Presentation, partners in flight*, St. Louis, MO: Midwest and Southern Great Plains Workshop.

Robinson, S. K., F. R. Thompson, III, T. M. Donovan, D. R. Whitehead, and J. Faaborg. 1995. Regional forest fragmentation and the nesting success of migratory birds. *Science* 267: 1987-90.

Rosgen, D. L. 1994. A classification of natural rivers. *Catena* 22: 169-199.

Rudis, V. A. 1995. Regional forest fragmentation effects on bottomland hardwood community types and resource values. *Landscape Ecology* 10: 291-307.

Rudis, V. A., and R. A. Birdsey. 1986. *Forest resource trends and current conditions in the Lower Mississippi Valley*. Resource Bulletin SO-116. U.S. Department of Agriculture Forest Service Southern Forest Experiment Station.

Sallabanks, R., J. R. Walters, and J. A. Collazo. 1998. Breeding bird abundance in bottomland forests: Habitat, edge, and patch size effects. *Condor* 102: 748-58.

Sartain, E. B. undated *It didn't just happen*. Mississippi County, Arkansas Drainage Districts.

Saucier, R. L. 1994. *Geomorphology and quaternary geologic history of the Lower Mississippi Valley*. Vol I (report), Vol II (map folio). Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Schlesinger, W. H. 1977. Carbon balance in terrestrial detritus. *Annual Review of Ecology and Systematics* 8: 51-81.

Schoener, T. W. 1986. Resource partitioning. *Community ecology: Patterns and processes*, ed. J. Kikkawa and D. J. Anderson, 91-126. Melbourne: Blackwell.

Schoenholtz, S. H., J. P. James, R. M. Kaminski, B. D. Leopold, and A. W. Ezell. 2001. Afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley: Status and trends. *Wetlands* 21: 602-613.

Scott, V. E., K. E. Evans, D. R. Patton, and C. P. Stone. 1977. *Cavity nesting birds of North American forests*. Handbook 553. U.S. Department of Agriculture Forest Service.

Sedell, J. R., J. E. Richey, and F. J. Swanson. 1989. The river continuum concept: A basis for the expected ecosystem behavior of very large rivers. *Canadian Journal of Fisheries and Aquatic Science* 46: 49-55.

Sedell, J. R., G. H. Reeves, F. R. Hauer, J. A. Stanford, and C. P. Hawkins. 1990. Role of refugia in recovery from disturbances: Modern fragmented and disconnected river systems. *Environmental Management* 14: 711-24.

Semeniuk, C. A. 1987. Wetlands of the Darling System: A geomorphic approach to habitat classification. *Journal of the Royal Society of Western Australia* 69: 95-112.

Shafer, D. J., and D. J. Yozzo. 1998. *National guidebook for application of hydrogeomorphic assessment to tidal fringe wetlands*. Technical Report WRP-DE-16. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station.

Simberloff, D., J. A. Farr, J. Cox, and D. W. Mehlman. 1992. Movement corridors: Conservation bargains or poor investments? *Conservation Biology* 6: 493-504.

Singh, J. S., and S. R. Gupta. 1977. Plant decomposition and soil respiration in terrestrial ecosystems. *Botanical Review* 43: 449-528.

Smith, K. L., W. F. Pell, J. H. Rettig, R. H. Davis, and H. W. Robison. 1984. *Arkansas's natural heritage*. B. Shepherd, coordinating editor. Little Rock, AR: August House.

Smith, L. M., and B. R. Winkley. 1996. The response of the Lower Mississippi River to river engineering. *Engineering Geology* 45: 433-55.

Smith, L. M., and D. M. Patrick. 1991. Erosion, sedimentation, and fluvial systems. *The heritage of engineering geology: The first hundred years*, ed. G. A. Kiersch, Centennial Special Volume 3. Boulder, CO: Geological Society of America.

Smith, R. D. 1996. Composition, structure, and distribution of woody vegetation on the Cache River floodplain, Arkansas. *Wetlands* 16: 264-278.

_____. 2001. *Hydrogeomorphic approach to assessing wetland functions: Guidelines for developing regional guidebooks. Chapter 3: Developing the reference wetland system*. ERDC/EL TR-01-29. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Smith, R. D., and C. V. Klimas. 2002. A regional guidebook for applying the hydrogeomorphic approach to assessing wetland functions of selected regional wetland subclasses, Yazoo Basin, Lower Mississippi River Alluvial Valley. ERDC/EL TR-02-4. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Smith, R. D., A. A. Ammann, C. Bartoldus, and M. M. Brinson. 1995. *An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices*. Technical Report WRP-DE-9. Vicksburg, MS: US Army Engineer Waterways Experiment Station.

Smith, W. P., P. B. Hamel, and R. P. Ford. 1993. Mississippi Alluvial Valley forest conversion: Implications for eastern North American avifauna. In *Proceedings of the Annual Conference of Southeastern Fish and Wildlife Agencies* 47: 460-69.

Sorenson, T. A. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analyses of the vegetation on Danish commons." *Kongelige Danske Videnskabernes Selskab Biologiske Skrifter* 56: 1-34.

Southern Regional Climate Center. 2002. Electronic climate atlas. http://www.srcc.lsu.edu/gopherroot/Electronic_Climate_Atlas/electronic_atlas.html.

Spurr, S. H., and B. V. Barnes. 1981. *Forest ecology*. New York: John Wiley.

Stanford, J. A., J. V. Ward, W. J. Liss, C. A. Frissell, R. N. Williams, J. A. Lichatowich, and C. C. Coutant. 1996. A general protocol for restoration of regulated rivers. *Regulated Rivers Research and Management* 12: 391-413.

Stauffer, D. F., and L. B. Best. 1980. Habitat selection by birds of riparian communities evaluating effects of habitat alterations. *Journal of Wildlife Management* 44: 11-15.

Stewart, R. E., and H. A. Kantrud. 1971. *Classification of natural ponds and lakes in the glaciated prairie region*. Resource Publication 92. Washington, DC: U.S. Fish and Wildlife Service.

Symbula, M., and F. W. Day. 1988. Evaluation of two methods for estimating belowground production in a fresh-water swamp forest. *American Midland Naturalist* 120: 405-15.

Tanner, J. T., and P. B. Hamel. 2001. A long-term view of old-growth deciduous forests. Bottomland forests of the Mississippi Alluvial Valley: Characteristics and management of natural function, structure, and composition, ed. P. Hamel, and T. Foti, 160-109. Gen. Tech. Report SRS-42. Asheville, NC: U.S. Dept. of Agriculture, Forest Service, Southern Research Station.

Temple, S. A. 1986. Predicting impacts of habitat fragmentation on forest birds: A comparison of two models. *Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates,* ed. J. Verner, M. L. Morrison and C. J. Ralph, 301-04. Madison, WI: University of Wisconsin Press.

Terry, J. E., R. L. Hosman, and C. T. Bryant. 1979. *Summary appraisals of the nation's ground-water resources – Lower Mississippi Region*. U.S. Geological Survey Professional Paper 813-N, 41 pp.

Thomas, D. M., and M. A. Hanson. 1981. *Generalization of streamflow characteristics from drainage-basin characteristics*. Water Supply Paper 1-55. Washington, DC: U.S. Geological Survey.

Thompson, F. R., III, W. D. Dijak, T. G. Kulowiec, and D. A. Hamilton. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. *Journal of Wildlife Management* 56: 23- 30.

Tinkle, D. W. 1959. Observations of reptiles and amphibians in a Louisiana swamp. *American Midland Naturalist* 62: 189-205.

Tritton, L. M., and J. W. Hornbeck. 1982. *Biomass equations for major tree species of the northeast*. General Technical Report NE-69. Broomall, PA: Forest Service, Northeast Forest Experiment Station.

Tuttle, J. R., and W. Pinner. 1982. *Analysis of major parameters affecting the behavior of the Mississippi River*. Potamology Program Report 4. Vicksburg, MS: U.S. Army Engineer Lower Mississippi Valley Division.

U.S. Army Corps of Engineers. 1973. *Mississippi River & tributaries post-flood report-1973*. Vicksburg, MS: Lower Mississippi Valley Division and Mississippi River Commission

U.S. Army Engineer Division, Mississippi Valley. 1998. *The Mississippi River and tributaries flood control project*. Text of a briefing for the Disaster Response Focus Meeting, 18 June 1988.

U.S. Army Engineer Hydrologic Engineering Center. 1981. *HEC-1 flood hydrograph package. Users manual*. Davis, CA.

U.S. Army Engineer Hydrologic Engineering Center. 1982. *HEC-2 water surface profiles. Users manual*. Davis, CA.

_____. 1997. HEC- RAS river analysis system. User manual. Davis, CA.

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). 2010. *Field indicators of hydric soils in the United States, Version 7.0*. ed. L. M. Vasilas, G. W. Hurt, and C. V. Noble. Washington, DC: USDA NRCS in cooperation with the National Technical Committee for Hydric Soils. (http://soils.usda.gov/use/hydric/)

U.S. Department of Agriculture, National Resources Conservation Service, Soil Survey Division. 2002. Official soil series descriptions. http://soils.usda.gov/technical/classification

U.S. Department of Agriculture, Soil Conservation Service (USDA SCS). 1993. *Soil survey manual*. U.S. Department of Agriculture Handbook 18. Washington, DC: U.S. Government Printing Office.

U.S. Department of Agriculture, Soil Conservation Service and Mississippi Agricultural and Forestry Experiment Station (MAFES). 1974. General soil map – State of Mississippi. Jackson, MS: Mississippi State Department of Agriculture and Commerce.

U.S. Department of Agriculture, Soil Conservation Service, and University of Arkansas Agricultural Experiment Station. 1982. General soil map – State of Arkansas. Cooperative Extension Service, University of Arkansas.

U.S. Environmental Protection Agency. 1998. Level III ecoregions of the continental United States (map). Corvallis, OR: National Health and Environmental Effects Laboratory.

U.S. Fish and Wildlife Service. 1980. Habitat Evaluation Procedures (HEP). Ecological Services Manual 102. Washington, DC: U.S. Department of Interior Fish and Wildlife Service.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences* 37: 130-37.

Vogt, K. A., C. C. Grier, and D. J. Vogt. 1986. Production, turnover, and nutrient dynamics of above and belowground detritus of world forests. *Advances in Ecological Research* 15: 303-77.

Wakeley, J. S., and T. H. Roberts. 1996. Bird distribution and forest zonation in a bottomland hardwood wetland. *Wetlands* 16: 296-308.

Welsh, C. J. E., and W. M. Healy. 1993. Effect of even-aged timber management on bird species diversity and composition in northern hardwoods of New Hampshire. *Wildlife Society Bulletin* 21: 143-54.

Wharton, C. H., V. W. Lambou, J. Newson, F. V. Winger, L. L. Gaddy, and R. Mancke. 1981. The fauna of bottomland hardwoods in the southeastern United States. In *Proceedings, Workshop on Bottomland Hardwood Forest Wetlands of the Southeastern United States,* ed. J. R. Clark and J. Benforado, 87-160. Elsevier, New York.

Wharton, C. H., W. M. Kitchens, E. C. Pendleton, and T. W. Sipe. 1982. *The ecology of bottomland hardwood swamps of the Southeast: A community profile.* Report FWS/OBS-81/37. Washington, DC: Office of Biological Services, U.S. Fish and Wildlife Service.

Whittaker, R. H. 1975. *Communities and ecosystems*. New York: MacMillan.

Whittaker, R. H., F. H. Bormann, G. E. Likens, and T. G. Siccama. 1974. The Hubbard Brook Ecosystem Study: Forest biomass and production. *Ecological Monographs* 44: 233-54.

Williams, B. J. 1986. *Into the second century: Memphis Engineer District 1976-1981.* Memphis, TN: U.S. Army Engineer District.

Yarbro, L. A. 1983. The influence of hydrologic variations on phosphorus cycling and retention in a swamp stream ecosystem. *Dynamics of lotic ecosystems,* ed. T. D. Fontaine and S. M. Bartell, 223-46. Ann Arbor, MI: Ann Arbor Science.

Yarbro, L. A., E. J. Kuenzler, P. J. Mulholland, and R. P. Sniffen. 1984. Effects of stream channelization on exports of nitrogen and phosphorus from North Carolina coastal plain watersheds. *Environmental Management* 8: 151-60.

Young, G. L. 1998. *Environmental design and mitigation for water resource projects, Yazoo Basin, Mississippi (abstract)*. Presentation summaries. American Society of Civil Engineers Wetlands Engineering and Restoration Conference, 1988. Reston, VA: American Society of Civil Engineers.

Appendix A: Preliminary Project Documentation and Field Sampling Guidance

Contents

Please reproduce these forms locally as needed.

SITE or PROJECT INFORMATION and ASSESSMENT DOCUMENTATION

(Complete one form for entire site or project area)

Date: _____

Project/Site Name: _____

Person(s) involved in assessment:

Field _____

_____

Computations/summarization/quality control _____

_____

The following checked items are attached:

_____ A description of the project, including land ownership, baseline conditions, proposed actions, purpose, project proponent, regulatory or other context, and reviewing agencies.

_____ Maps, aerial photos, and /or drawings of the project area, showing boundaries and identifying labels of Wetland Assessment Areas and project features.

_____ Other pertinent documentation (describe): _____

_____

_____ Field Data Sheets and assessment summaries (listed in table below):

Wetland Assessment Area (WAA) ID Number	HGM Subclass	WAA Size (ha)	Number of plots sampled	Attached Data Sheets and Summary Forms		
				Data Sheets (number attached)		FCI/FCU Summaries (spreadsheet D3 printouts or hand calculations)
				Form 1	Form 2	

Alternative Field and Summarization Forms Attached:

_____ Basal Area (DATA SHEET C1)

_____ Log and Woody Debris (DATA SHEET C2)

FIELD ASSESSMENT PREPARATION CHECKLIST

Prior to conducting field studies, review the checklist below to determine what field gear will be required, and how many copies of each data sheet will be needed. It may be helpful to complete as much of the Project or Site Description Form (Appendix A1) as possible prior to going to the field, and for large or complex assessment areas, that form should be completed as part of a reconnaissance study to classify and map all of the Wetland Assessment Areas within the project area or site boundary.

FIELD GEAR REQUIRED	COMMENTS
DISTANCE TAPE (preferably metric, at least 50 ft or 20 m) AND ANCHOR PIN	Minimum of 1, but 2 will speed work if enough people are available to independently record different information. A survey pin is handy to mark the plot center and anchor the tape for woody debris transects and for determining plot boundaries.
FOLDING RULE	A folding rule, small tape, or dbh caliper suitable for measuring the diameter of logs is needed.
PLANT IDENTIFICATION MANUALS	At least one person on the assessment team must be able to readily and reliably identify woody species, but field guides are recommended as part of the assessment tool kit. If species of concern, threatened, or endangered species are potentially present, the assessment team should include a botanist who can recognize them.
PLOT LAYOUT DIAGRAM	A copy is attached to this checklist.
DATA SHEETS	See data sheet requirements table, below.
BASAL AREA PRISM OR DBH TAPE OR SUITABLE SUBSTITUTE	A 10-factor non-SI unit wedge prism (available from forestry equipment supply companies) is the recommended tool for quickly determining tree basal area. Other tools may be substituted if they provide comparable data. Guidelines for the use of the wedge prism are attached to this checklist. If using a dbh tape or caliper, note that you will need the supplemental field data sheet for recording diameter measurements (Data Sheet C1).
SOIL SURVEY	Optional, but may be helpful in evaluating soil-related variables.
HGM GUIDEBOOK (this document)	At minimum, Chapter 6 should be available in the field to consult regarding field methods. All assessment team members should be familiar with the entire document prior to fieldwork.
SHOVEL OR HEAVY-DUTY TROWEL	If heavy or hard soils are anticipated, a shovel will be necessary. You need to be able to dig at least 10 in. deep. A water bottle is recommended if conditions are dry, to help distinguish soil colors (organic-stained soils must be distinguished from mineral soil).
MISCELLANEOUS SUGGESTED GEAR	You'll need clipboards and pencils, and extra data sheets are highly recommended. Flagging may be helpful for establishing plot centers and boundaries, at least until the assessment team is comfortable with the field procedures. A camera and GPS unit will improve documentation of the assessment and are highly recommended. Record position and take a representative photo at each plot location. Field copies of aerial photos and topo maps may be important if multiple Wetland Assessment Areas must be established and recognized in the field.

DATA SHEETS

Print the following data sheets (Data Sheets 1 and 2, found in Appendix B) in the numbers indicated. (Extras are always a good idea.) Be sure to use the forms developed specifically for the wetland subclass(es) you are assessing.

DATA SHEET	Number of Copies Required
Project or Site Description and Assessment Documentation (1 page)	1
Data Sheet 1 - Tract and WAA-Level Variables (1 page) (Complete using maps, photos, hydrologic data, field reconnaissance, etc.)	1 per Wetland Assessment Area
Data Sheet 2 - Plot-Level Variables (2 pages per set) (Complete by sampling within nested circular plots and along transects)	Multiple sets, depending on size, variability, and number of Wetland Assessment Areas (see Chapter 6)
OPTIONAL: **Alternate Basal Area Field Form** (2 pages) Use if sampling with a dbh tape or caliper (rather than prism); you will also need Form C1 to calculate basal area. Both forms are located in Appendix C. Use of this alternate form does not allow automated calculation of FCIs and FCUs, since only raw prism data may be entered into the calculator.	Multiple copies (same number as Data Sheet 2 sets)

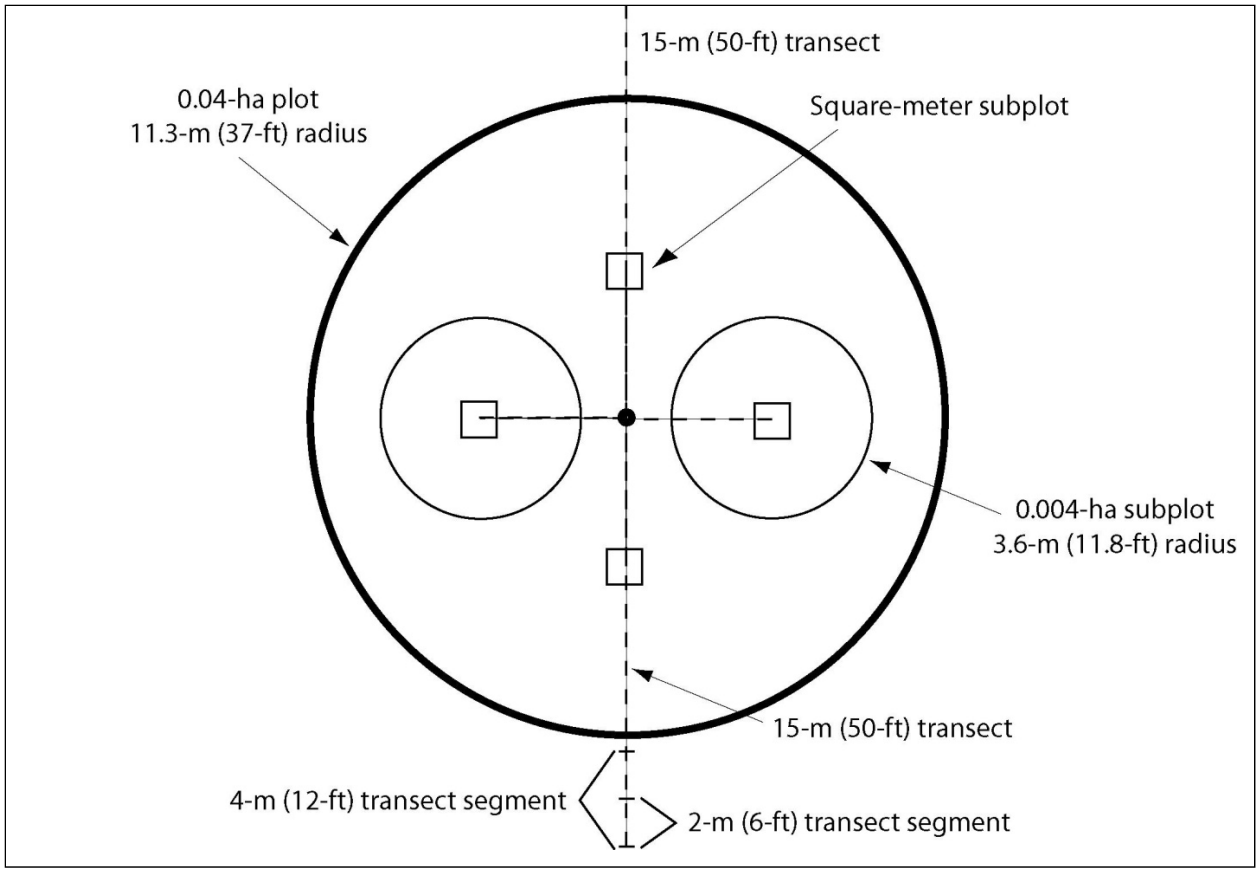


Figure A1. Layout of plots and transects for field sampling.

Appendix B: Field Data Sheets

All of the data sheets shown throughout this appendix are printouts from the Arkansas Delta Data Sheets and FCI Calculator, a single spreadsheet that allows raw data entry, calculates variable values, variable subindices and FCIs and FCUs. In this appendix, only those pages for which raw data are entered are presented. They may be printed out and taken in the field, and then the raw data may be entered in the same form in the Excel spreadsheet, so that automated calculations occur. Pages of the spreadsheet that are completed automatically are not included here, but examples of them are shown in Appendix D.

Contents

Note: This appendix contains printouts of the Arkansas Delta Data Sheets and FCI Calculator spreadsheet. A working copy is available for download at http://el.erdc.usace.army.mil/wetlands/datanal.html

Appendix B1: Field Data Sheets for Nonalkali Flat Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B1-1	Flat	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Flat Project Type: _____ Timing: _____

☐ N/A, For Depressions Only

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1 V_{TRACT} Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."

2 V_{CORE} Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area.

Percent of the Wetland Tract within the Core :

3 $V_{CONNECT}$ Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions.

Lineal percentage of perimeter with suitable habitat within 0.5 km:

4 V_{FREQ} Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Not Used

Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

5 V_{DUR} Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10. enter 10. Not Used

Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

6 V_{OUT} Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Not Used

Pre-project Outflow:

Post-project Outflow:

Sample Variables 7-9 during onsite field reconnaissance.

7 V_{POND} Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below.

ONLY If Flat, Choose Geomorphic Surface: Percent ponding:

8 V_{STRATA} Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover.

Choose:

Canopy (trees ≥ 10 cm dbh that are in the canopy layer)
Subcanopy (trees ≥ 10 cm dbh that are below the canopy layer)
Understory (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall)
Ground cover (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation)

9 V_{SOIL} Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.

Appendix B1-2 **Flat** **Data Sheet 2 - Plot Data** **Sheet 1 of 2**

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____

Project Name: _____ UTM Northing: _____

Location: _____ Sampling Date: _____

WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____

Subclass: Flat Project Type: _____ Timing: _____

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10 V_{TBA} Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.

Number of trees tallied _____

Observations within a 0.04-ha plot

11 V_{TDEN} Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of trees tallied _____

12 V_{SNAG} Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of snags tallied _____

13 V_{OHOR} Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present).

Subplot 1: _____ Subplot 2: _____ Subplot 3: _____ Subplot 4: _____

14 V_{AHOR} Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons).

Subplot 1: _____ Subplot 2: _____ Subplot 3: _____ Subplot 4: _____

15 V_{COMP} Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.

16 V_{TCOMP} Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Carya ovata*	☐ *Acer negundo*	☐ *Carpinus caroliniana*
☐ *Pinus taeda*	☐ *Carya aquatica*	☐ *Cornus foemina*
☐ *Quercus lyrata*	☐ *Carya illinoensis*	☐ *Crataegus spp.*
☐ *Quercus michauxii*	☐ *Celtis laevigata*	☐ *Forestiera acuminata*
☐ *Quercus nigra*	☐ *Diospyros virginiana*	☐ *Gleditsia triacanthos*
☐ *Quercus nuttallii*	☐ *Fraxinus pennsylvanica*	☐ *Maclura pomifera*
☐ *Quercus pagoda*	☐ *Liquidambar styraciflua*	☐ *Morus rubra*
☐ *Quercus phellos*	☐ *Platanus occidentalis*	☐ *Ulmus crassifolia*
☐ *Quercus stellata*	☐ *Populus deltoides*	☐ *Ulmus alata*
☐ —	☐ *Quercus falcata*	☐ —
☐ —	☐ *Ulmus americana*	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B1-2	Flat	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B2: Field Data Sheets for Low-Gradient Riverine Backwater Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B2-1	Low-Gradient Riverine Backwater	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Low-Gradient Riverine Backwater Project Type: _____ Timing: _____

☐ N/A, For Depressions Only

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area.	
		Percent of the Wetland Tract within the Core :	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions.	
		Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration.	
		Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	
		Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10. enter 10.	
		Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
		Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project.	Not Used
		Pre-project Outflow:	
		Post-project Outflow:	

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below.	
		ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover.	
		Canopy (trees ≥ 10 cm dbh that are in the canopy layer) Choose:	
		Subcanopy (trees ≥ 10 cm dbh that are below the canopy layer)	
		Understory (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall)	
		Ground cover (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation)	
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.	

Appendix B2-2 Low-Gradient Riverine Backwater Data Sheet 2 - Plot Data Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Low-Gradient Riverine Backwater Project Type: _____ Timing: _____

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10 V_{TBA} Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.

Number of trees tallied

Observations within a 0.04-ha plot

11 V_{TDEN} Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of trees tallied

12 V_{SNAG} Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of snags tallied

13 V_{OHOR} Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present).

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

14 V_{AHOR} Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons).

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

15 V_{COMP} Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.

16 V_{TCOMP} Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Carya aquatica*	☐ *Acer drummondii*	☐ *Carpinus caroliniana*
☐ *Quercus lyrata*	☐ *Acer negundo*	☐ *Cornus drummondii*
☐ *Quercus nuttallii*	☐ *Acer rubrum*	☐ *Cornus foemina*
☐ *Quercus phellos*	☐ *Carya illinoensis*	☐ *Crataegus spp.*
☐ —	☐ *Celtis laevigata*	☐ *Forestiera acuminata*
☐ —	☐ *Diospyros virginiana*	☐ *Ilex decidua*
☐ —	☐ *Fraxinus pennsylvanica*	☐ *Planera aquatica*
☐ —	☐ *Gleditsia aquatica*	☐ —
☐ —	☐ *Liquidambar styraciflua*	☐ —
☐ —	☐ *Salix nigra*	☐ —
☐ —	☐ *Ulmus americana*	☐
☐	☐ *Ulmus crassifolia*	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B2-2 Low-Gradient Riverine Backwater Data Sheet 2 - Plot Data Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B3: Field Data Sheets for Low-Gradient Riverine Overbank Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B3-1	Low-Gradient Riverine Overbank	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Low-Gradient Riverine Overbank Project Type: _____ Timing: _____

☐ N/A, For Depressions Only

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1 V_{TRACT} Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."

2 V_{CORE} Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area.

Percent of the Wetland Tract within the Core :

3 $V_{CONNECT}$ Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions.

Lineal percentage of perimeter with suitable habitat within 0.5 km:

4 V_{FREQ} Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration.

Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

5 V_{DUR} Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10. enter 10.

Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

6 V_{OUT} Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Not Used

Pre-project Outflow:

Post-project Outflow:

Sample Variables 7-9 during onsite field reconnaissance.

7 V_{POND} Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below.

ONLY If Flat, Choose Geomorphic Surface: Percent ponding:

8 V_{STRATA} Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover.

Canopy (trees ≥ 10 cm dbh that are in the canopy layer) Choose:
Subcanopy (trees ≥ 10 cm dbh that are below the canopy layer)
Understory (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall)
Ground cover (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation)

9 V_{SOIL} Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.

Appendix B3-2 Low-Gradient Riverine Overbank Data Sheet 2 - Plot Data Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Low-Gradient Riverine Overbank Project Type: _____ Timing: _____

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10 V_{TBA} Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.

Number of trees tallied

Observations within a 0.04-ha plot

11 V_{TDEN} Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of trees tallied

12 V_{SNAG} Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of snags tallied

13 V_{OHOR} Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present).

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

14 V_{AHOR} Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons).

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

15 V_{COMP} Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.

16 V_{TCOMP} Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Carya aquatica*	☐ *Acer rubrum*	☐ *Acer negundo*
☐ *Carya illinoensis*	☐ *Acer saccharinum*	☐ *Carpinus caroliniana*
☐ *Gleditsia aquatica*	☐ *Celtis laevigata*	☐ *Crataegus spp.*
☐ *Platanus occidentalis*	☐ *Diospyros virginiana*	☐ *Forestiera acuminata*
☐ *Populus detoides*	☐ *Fraxinus pennsylvanica*	☐ *Morus rubra*
☐ *Quercus lyrata*	☐ *Liquidambar styraciflua*	☐ *Planera aquatica*
☐ *Quercus nuttallii*	☐ *Quercus nigra*	☐ *Ulmus crassifolia*
☐ *Quercus pagoda*	☐ *Ulmus americana*	☐ —
☐ *Quercus phellos*	☐ —	☐ —
☐ *Salix spp.*	☐ —	☐ —
☐ *Taxodium distichum*	☐ —	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B3-2	Low-Gradient Riverine Overbank	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B4: Field Data Sheets for Headwater Depression Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B4-1	Headwater Depression	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Headwater Depression Project Type: _____ Timing: _____

☐ Check if Depression is Inundated

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1 V_{TRACT} Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."

2 V_{CORE} Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area.

Percent of the Wetland Tract within the Core :

3 $V_{CONNECT}$ Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions.

Lineal percentage of perimeter with suitable habitat within 0.5 km:

4 V_{FREQ} Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Not Used

Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

5 V_{DUR} Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10. enter 10.

Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

6 V_{OUT} Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project.

Pre-project Outflow:

Post-project Outflow:

Sample Variables 7-9 during onsite field reconnaissance.

7 V_{POND} Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. Not Used

ONLY If Flat, Choose Geomorphic Surface: Percent ponding:

8 V_{STRATA} Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover.

Canopy (trees ≥ 10 cm dbh that are in the canopy layer) Choose:
Subcanopy (trees ≥ 10 cm dbh that are below the canopy layer)
Understory (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall)
Ground cover (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation)

9 V_{SOIL} Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.

This variable not used if the depression is inundated.

Appendix B4-2 Headwater Depression Data Sheet 2 - Plot Data Sheet 1 of 2

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Headwater Depression Project Type: _____ Timing: _____
Uninundated Depression

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10 V_{TBA} Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.
Number of trees tallied

Observations within a 0.04-ha plot

11 V_{TDEN} Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.
Number of trees tallied

12 V_{SNAG} Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.
Number of snags tallied

13 V_{OHOR} Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present).
This variable is not used if depression is inundated.
Subplot 1: Subplot 2: Subplot 3: Subplot 4:

14 V_{AHOR} Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons).
This variable is not used if depression is inundated.
Subplot 1: Subplot 2: Subplot 3: Subplot 4:

15 V_{COMP} Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.

16 V_{TCOMP} Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Acer drummondii*	☐ *Cephalanthus occidentails*	☐ —
☐ *Acer rubrum*	☐ *Diospyros virginiana*	☐ —
☐ *Fraxinus pennsylvanica*	☐ *Forestiera acuminata*	☐ —
☐ *Nyssa aquatica*	☐ *Gleditsia aquatica*	☐ —
☐ *Populus heterophyla*	☐ *Planera aquatica*	☐ —
☐ *Quercus lyrata*	☐ *Ulmus americana*	☐ —
☐ *Taxodium distichum*	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B4-2	Headwater Depression	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

These variables are not used if depression is inundated.

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B5: Field Data Sheets for Unconnected Depression Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B5-1	Unconnected Depression	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number:

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Unconnected Depression Project Type: _____ Timing: _____

☐ Check if Depression is Inundated

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1 V_{TRACT} Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."

2 V_{CORE} Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area.

Percent of the Wetland Tract within the Core :

3 $V_{CONNECT}$ Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions.

Lineal percentage of perimeter with suitable habitat within 0.5 km:

4 V_{FREQ} Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Not Used

Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)

5 V_{DUR} Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10. enter 10. Not Used

Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)

6 V_{OUT} Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Not Used

Pre-project Outflow:

Post-project Outflow:

Sample Variables 7-9 during onsite field reconnaissance.

7 V_{POND} Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. Not Used

ONLY If Flat, Choose Geomorphic Surface: Percent ponding:

8 V_{STRATA} Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover.

Canopy (trees ≥ 10 cm dbh that are in the canopy layer) Choose:

Subcanopy (trees ≥ 10 cm dbh that are below the canopy layer)

Understory (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall)

Ground cover (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation)

9 V_{SOIL} Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted.

This variable not used if the depression is inundated.

Appendix B5-2 **Unconnected Depression** **Data Sheet 2 - Plot Data** **Sheet 1 of 2**

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Unconnected Depression Project Type: _____ Timing: _____
Uninundated Depression

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10 V_{TBA} Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.

Number of trees tallied

Observations within a 0.04-ha plot

11 V_{TDEN} Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of trees tallied

12 V_{SNAG} Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of snags tallied

13 V_{OHOR} Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present).

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

14 V_{AHOR} Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons).

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

15 V_{COMP} Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.

16 V_{TCOMP} Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Acer rubrum*	☐ *Acer negundo*	☐ —
☐ *Carya aquatica*	☐ *Celtis laevigata*	☐ —
☐ *Fraxinus tomentosa*	☐ *Cephalanthus occidentails*	☐ —
☐ *Nyssa aquatica*	☐ *Diospyros virginiana*	☐ —
☐ *Populus heterophyla*	☐ *Forestiera acuminata*	☐ —
☐ *Quercus lyrata*	☐ *Liquidambar styraciflua*	☐ —
☐ *Quercus palustris*	☐ *Planera aquatica*	☐ —
☐ *Taxodium distichum*	☐ *Ulmus americana*	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B5-2	Unconnected Depression	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

These variables are not used if depression is inundated.

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix B6: Field Data Sheets for Connected Depression Wetlands

Data Sheet	Number of Pages	Title
1	1	Tract and Wetland Assessment Area Level Data Collection
2	2	Plot-Level Data Collection
Please reproduce forms for local use as needed.		

Appendix B6-1	Connected Depression	Data Sheet 1 WAA/Tract Data	Sheet 1 of 1

These data sheets represent printouts of an electronic Excel data form that uses raw data to calculate variable indicator values, variable subindices, and ultimately functional capacity indices and units. Enter raw data in the yellow cells. When entering at the computer, use the drop down menus where provided. Green boxes are used by the calculator to run any necessary computations of the raw data before they are compared to subindex curves and translated to a variable subindex in the bottom of Data Sheet 2. Information that is relevant to the entire WAA will only be entered in the WAA/Tract data entry form, and will be carried to the plot data entry summaries and project summary tables.

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ WAA Number: _____

Project Name: _____

Location: _____ Sampling Date: _____

Subclass: Connected Depression Project Type: _____ Timing: _____

☐ Check if Depression is Inundated

Sample Variables 1-5 using aerial photography, topographic maps, soil survey maps, etc.

1	V_{TRACT}	Forest tract size (ha). From aerial photos or field reconnaissance, estimate the size of the forested area that is contiguous to the WAA and accessible to wildlife (including the WAA itself, if it is forested). Include both upland and wetland forests. Record the area at right. If it exceeds 2,500 ha, (6,178 acres) enter "2500."	
2	V_{CORE}	Percent of wetland tract with at least a 100-m buffer from surrounding land uses. To do this, measure in 100 m from the perimeter of the entire forested area and draw a line. The portion of the wetland tract that lies inside this line is the core area. Percent of the Wetland Tract within the Core :	
3	$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats: upland forests, forested riparian areas, non-forested wetlands, and other natural communities. Excludes farm fields, pastures, heavily grazed or farmed wetlands, isolated clusters of trees, fencerows, clearcuts, wooded subdivisions. Lineal percentage of perimeter with suitable habitat within 0.5 km:	
4	V_{FREQ}	Change in flood frequency. Determine (or estimate) the frequency of flooding from streams for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter 0 if this is not an assessment involving hydrologic alteration. Pre-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5) Post-project flood return interval (years): Choose one (0, 1, 2, 3, 4, 5)	
5	V_{DUR}	Change in flood duration. Determine (or estimate) the duration of continuous flooding from streams (longest single event) during the growing season for sites within the 5-year floodplain for both pre-project and post-project conditions. Enter average weeks of continuous growing season flooding. If greater than 10. enter 10. Pre-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10) Post-project flood duration (weeks): Choose one (0, 1 ,2 ,3, 4, 5, 6, 7, 8, 9, 10)	
6	V_{OUT}	Change in frequency of outflow in Headwater Depressions Only. Determine (or estimate) whether surface output is perennial, seasonal or zero both pre-project and post-project. Pre-project Outflow: Post-project Outflow:	Not Used

Sample Variables 7-9 during onsite field reconnaissance.

7	V_{POND}	Percentage of the site capable of ponding water. Estimate the area likely to pond following extended rainfall. This includes both large vernal pool sites (swales) and microdepressions such as those left by trees that have blown over and uprooted. For Flats, select geomorphic surface below. ONLY If Flat, Choose Geomorphic Surface: Percent ponding:	Not Used
8	V_{STRATA}	Number of vegetation strata present. Vegetation layers are considered present if they account for at least 10% cover. **Canopy** (trees ≥ 10 cm dbh that are in the canopy layer) **Subcanopy** (trees ≥ 10 cm dbh that are below the canopy layer) **Understory** (shrubs and saplings < 10 cm dbh but at least 1.4 m (4.5 ft) tall) **Ground cover** (woody plants < 1.4 m (4.5 ft) tall, and herbaceous vegetation)	Choose:
9	V_{SOIL}	Soil integrity. Estimate the percentage of the site that has significantly altered soils. Normal farm tillage is not considered a significant alteration in this case, but fill, land leveling that removes surface horizons, and compacted areas such as roads are counted. This variable not used if the depression is inundated.	

Appendix B6-2 **Connected Depression** **Data Sheet 2 - Plot Data** **Sheet 1 of 2**

Arkansas Delta HGM Field Data Sheet and Calculator

Assessment Team: _____ UTM Easting: _____
Project Name: _____ UTM Northing: _____
Location: _____ Sampling Date: _____
WAA Number: _____ Plot Number: _____ of _____ Plot Area (0.04 ha is standard): _____
Subclass: Connected Depression Project Type: _____ Timing: _____
Uninundated Depression

Sample Variables 10-21 within one or more representative 0.04-ha (0.1-acre) plot(s) within the WAA (separate data sheet each plot)

Observations from the Center Point

10 V_{TBA} Basal area. Use a basal area wedge prism (English 10-factor) as directed, and tally eligible tree stems. The calculator automatically multiplies this tally by the conversion factor 2.3 to determine m^3/ha.

Number of trees tallied

Observations within a 0.04-ha plot

11 V_{TDEN} Tree density. Count the number of trees (dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of trees tallied

12 V_{SNAG} Snag density. Count the number of snags (standing dead trees at least 1.4 m (4.5 ft) tall and dbh ≥ 10 cm). The calculator automatically multiplies this tally by 25 to determine stems/ha.

Number of snags tallied

13 V_{OHOR} Thickness of the O horizon. Select two or more points within the plot that are representative of the range of microtopography within the plot as a whole. Dig a hole and measure the thickness of the O horizon (organic accumulation on the soil surface, excluding fresh litter, but including surface root mats if present).

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

14 V_{AHOR} Thickness of the A horizon. In the same holes as above, measure the thickness of the A horizon (mineral soil with incorporated organic matter, indicated by distinct darkening relative to lower horizons).

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

15 V_{COMP} Composition of tallest woody vegetation stratum, percent concurrence. If tree cover is ≥ 20%, use the 50/20 rule (see Chapter 6 for details) and check the dominant trees in Columns A, B, and C. If a dominant does not appear on the list, use local knowledge or literature to assign it to the appropriate column. If tree cover is < 20%, identify the next tallest woody stratum with at least 10% cover.

16 V_{TCOMP} Tree composition. ☐ Check box if tree cover is greater than or equal to 20%, and the composition concurrence below is for the tree stratum.

Group 1 = 1.0	Group 2 = 0.66	Group 3 = 0.33
☐ *Acer rubrum*	☐ *Celtis laevigata*	☐ —
☐ *Carya aquatica*	☐ *Forestiera acuminata*	☐ —
☐ *Fraxinus pennsylvanica*	☐ *Gleditsia aquatica*	☐ —
☐ *Nyssa aquatica*	☐ *Planera aquatica*	☐ —
☐ *Quercus lyrata*	☐ *Salix nigra*	☐ —
☐ *Taxodium distichum*	☐ *Ulmus americana*	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐ —
☐ —	☐ —	☐
☐	☐ —	☐
☐	☐	☐ **Check here if there are no woody species.**
☐	☐	
0 Species in Group 1	0 Species in Group 2	0 Species in Group 3

50/20 Rule: Rank species in descending order of percent cover, summing relative dominance in descending order until 50 percent is exceeded. This list of species, along with any additional species comprising at least 20 percent relative dominance, represent the dominant species in the plot.

Appendix B6-2	Connected Depression	Data Sheet 2 - Plot Data	Sheet 2 of 2

Observations within two 0.004-ha plots. From the center point, measure north and south 5 m and establish two circular subplots with a radius of 3.6 m (11.8 ft). Within each subplot, measure the following:

17 V_{SSD} Shrub/Sapling density. Count the number of woody stems that are at least 1.4 m (4.5 ft) tall, but less than 10 cm dbh in each subplot. The calculator multiplies the sum of both plots by 125 to determine understory stems/ha.

Subplot 1: Subplot 2:

Observations within 4 1-m × 1-m square subplots. From the center point, measure 5 m in each cardinal direction and establish a 1-m × 1-m square subplot. Within each subplot record the following:

18 V_{GVC} Ground vegetation cover. Estimate the percent cover of all herbaceous plants and woody plants < 1.4 m (4.5 ft) tall. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

19 V_{LITTER} Litter cover. Estimate the percent of the plot area covered by undecomposed litter. The calculator automatically averages the results of the four subplots.

This variable is not used if depression is inundated.

Subplot 1: Subplot 2: Subplot 3: Subplot 4:

Observations along transects.

20 V_{LOG} Log biomass. Volume per hectare of non-living fallen logs (m^3/ha).

21 V_{WD} Woody debris biomass. Volume per hectare of non-living fallen woody stems (m^3/ha).

These variables are not used if depression is inundated.

	Transect 1	Transect 2
Number of stems with diameters greater than or equal to 0.6 cm (0.25 in) and less than 2.5 cm (1 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Number of stems with diameters greater than or equal to 2.5 cm (1 in) and less than 7.6 cm (3 in) in diameter intersecting a 6-ft length of the 50-foot transect:		
Enter diameters (cm) of each fallen woody stem 7.6 cm (3 inches) or greater in diameter in each 50-foot transect. If there are no logs of this size, enter 0.		

Plot Summary

Variable	Value	VSI
V_{TRACT}		
V_{CORE}		
$V_{CONNECT}$		
V_{FREQ}		
V_{DUR}		
V_{OUT}		
V_{POND}		
V_{STRATA}		
V_{SOIL}		
V_{TBA}		
V_{TDEN}		
V_{SNAG}		
V_{OHOR}		
V_{AHOR}		
V_{COMP}		
V_{TCOMP}		
V_{SSD}		
V_{GVC}		
V_{LITTER}		
V_{LOG}		
V_{WD}		

Notes:

Appendix C: Alternate Field Forms

Contents

Please reproduce these forms locally as needed.

ALTERNATIVE DATA SHEET C1 (1 page) – BASAL AREA DETERMINTATION USING DIAMETER MEASUREMENTS

SUBCLASS: _____

WAA # _____

PLOT # _____

If you are not using a basal area prism or similar tool to estimate tree basal area for the V_{TBA} variable, but instead are measuring individual tree diameters, use the form below to record tree diameters within each 0.04-ha plot. Follow the directions to summarize these data in terms of m^2/ha at the plot level, or use the spreadsheet provided in Appendix D. Note that species need not be associated with each diameter measure, but that option is included in case you wish to sum individual basal areas of each species to develop a more accurate estimate of V_{TCOMP} than the reconnaissance-level sample provides. You can also count the trees in the table below to get tree density (V_{TDEN}) rather than using the plot count specified on Data Sheet 2.

Record the species (optional) and dbh (cm) of all trees (i.e., woody stems ≥ 10 cm or 4 in dbh) in the 0.04-ha plot in Columns 1 and 2 in the table below. Complete the calculations (or use spreadsheet) to derive basal area per tree, and sum to get total plot basal area (m^2/ha).

1	2	3	4	1	2	3	4
Species Code (optional)	dbh (cm)	Square the value in column 2 (dbh x dbh)	Multiply the value in column 3 by 0.00196 to get m^2/ha per tree	Species Code (optional)	dbh (cm)	Square the value in column 2 (dbh x dbh)	Multiply the value in column 3 by 0.00196 to get m^2/ha per tree

SUM ALL COLUMN 4 VALUES TO GET TOTAL PLOT BASAL AREA = _____ (m^2 / ha)

Record Total Basal Area on Data Sheet 2 in the V_{TBA} row as a plot value

ALTERNATIVE DATA SHEET C2 (2 pages) – PROCEDURES FOR MANUALLY CALCULATING WOODY DEBRIS AND LOG VOLUME

SUBCLASS: _____

WAA # _____

PLOT # _____

If you do not wish to use the spreadsheet provided in Appendix D to calculate woody debris and log volume for use in generating the V_{WD} and V_{LOG} variables, you can calculate the same summary data manually. Transfer the transect data recorded on Data Sheet 2 (Plot-Level Data Collection, Observations along Transects) to the data sheet below, and make the indicated calculations.

From Data Sheet 2, transfer the small woody debris stem counts (Size Class 1 - stems between 0.6 and 2.54 cm in diameter) for Transects 1 and 2, sum them, and multiply by 0.722 to convert to volume per hectare:

Stem Count, Transect 1 ____

Stem Count, Transect 2 ____

total number of stems = _____ × 0.722 = _____ m³/ha, Size Class 1

From Data Sheet 2, transfer the medium woody debris stem counts (Size Class 2 - stems between 2.54 and 7.6 cm in diameter) for Transects 1 and 2, sum them, and multiply by 3.449 to convert to volume per hectare:

Stem Count, Transect 1 ____

Stem Count, Transect 2 ____

total number of stems = _____ × 3.449 = _____ m³/ha, Size Class 2

From Data Sheet 2, transfer the diameter (cm) of each stem of Size Class 3 (large stems, > 7.6 cm, or >3 in.) measured along Transect 1 and Transect 2 into the table below. Multiply each diameter measurement by 0.3937, and then square the result. Sum all results, then multiply that sum by 0.2657 to get large woody debris volume (m³/ha).

Transect 1			Transect 2		
1	2	3	1	2	3
Stem Diameter (cm)	Multiply stem diameter by 0.3937	Square the result in column 2	Stem Diameter (cm)	Multiply stem diameter by 0.3937	Square the result in column 2
	SUM=			**SUM=**	

ALTERNATIVE DATA SHEET C2 (2 pages) – PROCEDURES FOR MANUALLY CALCULATING WOODY DEBRIS AND LOG VOLUME

SUBCLASS: _____

WAA # _____

PLOT # _____

V_{LOG} Sum of Size Class 3 Transect 1 + Sum of Size Class 3 Transect 2 = _____ × 0.2657 = _____ m^3/ha, Size Class 3
V_{WD} Sum of Size Class 1 _____m^3/ha + Size Class 2 _____m^3/ha + Size Class 3 _____m^2/ha = _____ m^3/ha (total woody debris volume/ha)

Appendix D: Spreadsheets

Contents

Note: This appendix contains demonstration printouts of these spreadsheets. Working copies are available for download at: http://el.erdc.usace.army.mil/wetlands/datanal.html

Basal Area (V_{TBA}) Calculator (Version of 12/2001)			
Use one of the forms below (depending on whether tree diameters were measured in centimeters or inches) to calculate total basal area (m^2/ha) for a plot. Transfer the Total Plot Basal Area value (located in red cell) to the V_{TBA} line on Data Form 3 (Wetland Assessment Area Data Summary). Delete values from all green input cells and repeat data entry as needed for additional plots. (Note: Recording of species codes is optional. Users may want to include species associated with individual tree diameters to assist in determining dominance for V_{TCOMP} calcuations, but the spreadsheets below will work without entering species codes.)			
Enter individual tree species code in cells A6-A35 (optional)	Enter individual tree diameters (cm) in cells B6-B35	Converts to cm^2/0.04 ha 3.14*(tree diameter/2)^2=cm^2	Converts to m^2/ha - Column C*0.0001*25=m^2/ha
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		0.00	0.00
		Total Plot Basal Area in m^2/ha :	0.00

Figure D1. Example of the input form used in the basal area calculator spreadsheet.

Fill in Size Class 1 (stem count), Size Class 2 (stem count), and Size Class 3 (stem diameters in centimeters) in appropriate light green shaded areas below. Find resulting plot values for V_{LOG} and V_{WD} subindices in yellow shaded areas at the bottom of the sheet.

	Size Class 1 No. of Stems/ 1.83 m Transect		**Size Class 1** Total Stem Count	**Size Class 1** tons/acre	**Size Class 2** No. of Stems/ 3.65 m Transect		**Size Class 2** Total Stem Count	**Size Class 2** tons/acre
	Transect 1	Transect 2			Transect 1	Transect 2		
Plot 1			0	0.0			0	0.0
Plot 2			0	0.0			0	0.0
Plot 3			0	0.0			0	0.0
Plot 4			0	0.0			0	0.0
Plot 5			0	0.0			0	0.0

Size Class 3 Stem Diameters (cm) 15.25 m Transect		**Size Class 3** Stem Diameter² (in)		**Size Class 3** Stem Diameters (cm) 15.25 m Transect		**Size Class 3** Stem Diameter² (in)		**Size Class 3** Stem Diameters (cm) 15.25 m Transect		**Size Class 3** Stem Diameter² (in)	
Plot 1		**Plot 1**		**Plot 2**		**Plot 2**		**Plot 3**		**Plot 3**	
Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0			0.0	0.0

Size Class 3 Stem Diameters (cm) 15.25 m Transect		**Size Class 3** Stem Diameter² (in)		**Size Class 3** Stem Diameters (cm) 15.25 m Transect		**Size Class 3** Stem Diameter² (in)	
Plot 4		**Plot 4**		**Plot 5**		**Plot 5**	
Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2	Transect 1	Transect 2
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0
		0.0	0.0			0.0	0.0

Figure D2. Example of the input form used in the woody debris calculation spreadsheet (Continued).

	Size Class 3 Sum of Stem Diameter^2 (in)		Size Class 3 Total Diameter^2 (in)	Size Class 3 tons/acre	Size Class 3 ft^3/acre	Size Classes 1, 2, 3 tons/acre	Size Classes 1, 2, 3 ft^3/acre
	Transect 1	Transect 2					
Plot 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Plot 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0

V_{LOG} and V_{WD} plot values can be found below:

Plot Number	(V_{LOG}) Size Class 3 m^3/ha
Plot 1	0.0
Plot 2	0.0
Plot 3	0.0
Plot 4	0.0
Plot 5	0.0

Plot Number	(V_{WD}) Size Classes 1, 2, 3 m^3/ha
Plot 1	0.0
Plot 2	0.0
Plot 3	0.0
Plot 4	0.0
Plot 5	0.0

Figure D2. (Concluded).

WAA Data Summary	WAA Number :	Low-Gradient Riverine Backwater

	Variable	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Plot 11	Number of Plots Used	Average Measure
1	V_{TRACT}													
2	V_{CORE}													
3	$V_{CONNECT}$													
4	V_{FREQ}													
5	V_{DUR}													
6	V_{OUT}													
7	V_{POND}													
8	V_{STRATA}													
9	V_{SOIL}													
10	V_{TBA}													
11	V_{TDEN}													
12	V_{SNAG}													
13	V_{OHOR}													
14	V_{AHOR}													
15	V_{COMP}													
16	V_{TCOMP}													
17	V_{SSD}													
18	V_{GVC}													
19	V_{LITTER}													
20	V_{LOG}													
21	V_{WD}													

Ver. 6-27-11

FCI/FCU Calculator for the Arkansas Delta HGM Guidebook

To create appropriate plot data entry forms and ensure accurate calculations, select the HGM Subclass present on the site in the drop list below. Enter in the yellow cells the number and size of the Wetland Assessment Area (WAA) being sampled, the project name, and location. Use the drop down menus to indicate whether this WAA represents the Project Site or Mitigation Site, before project or after project. Then go to the Data Entry tabs to enter individual field measurements for each plot. Information that is relevant to the entire WAA will only be entered in Plot 1, and will be carried to the other plots and summary sheet. For information on determining how to split a project into WAAs, see A Revised Regional Guidebook for Applying the Hydrogeomorphic Approach to the Functional Assessment of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi Valley (Klimas *et al.* 2011). The Mitigation Sufficiency Carlucaltor is available for download at the ERDC website.

Enter information in yellow cells, and select HGM Subclass and Site information from dropdown menus. A Subclass must be selected prior to printing out data sheets.

Project Name:
Location:
Sampling Date(s): Enter dates on Plot Sheets

Select HGM Subclass present at this WAA: Low-Gradient Riverine Backwater

WAA number:
WAA size (ha): 1

Project Site:

Project Timing:

All summaries of results are automatically calculated based on data entered into the individual plot entry data sheets.

Functional Results Summary:

Please Fill Out Site and Project Information Above

Function	Functional Capacity Index	Functional Capacity Units
Detain Floodwater		
Detain Precipitation		
Cycle Nutrients		
Export Organic Carbon		
Maintain Plant Communities		
Provide Habitat for Fish and Wildlife		

Variable Measure and Subindex Summary:

Variable	Name	Average Measure	Subindex
V_{TRACT}	Forested Tract Size (ha)		
V_{CORE}	Percent of wetland tract with at least a 100-m buffer		
$V_{CONNECT}$	Percent of wetland tract perimeter within 0.5 km of suitable habitats		
V_{FREQ}	Change in flood frequency (years change)		
V_{DUR}	Change in growing season flood duration (weeks change)		
V_{OUT}	Change in frequency of surface outflow in Headwater Depressions only		Not Used
V_{POND}	Total Ponded Area (%)		
V_{STRATA}	Number of Vegetation Strata		
V_{SOIL}	Soil Integrity (%)		
V_{TBA}	Tree Basal Area (m^3/ha)		
V_{TDEN}	Tree Density (stems/ha)		
V_{SNAG}	Snag Density (stems/ha)		
V_{OHOR}	O Horizon Organic Accumulation (cm)		
V_{AHOR}	A Horizon Organic Accumulation (cm)		
V_{COMP}	Composition of Tallest Woody Vegetation Stratum (%)		
V_{TCOMP}	Tree Composition (%)		
V_{SSD}	Shrub-Sapling Density (stems/ha)		
V_{GVC}	Ground Vegetation Cover (%)		
V_{LITTER}	Litter Cover (%)		
V_{LOG}	Log Biomass (m^3/ha)		
V_{WD}	Woody debris biomass (m^3/ha).		

Appendix E: Spatial Data

The following digital spatial data pertinent to the Delta Region of Arkansas are available for downloading to assist in orienting field work, assembling project area descriptions, and identifying geomorphic surfaces and soils. Unless otherwise indicated, the files are in ArcView format, and a copy of ArcExplorer is included in the download folder to allow access to the files. Some familiarity with ArcView is required to load and manipulate the digital information.

- ArcExplorer (program file: ae2setup – includes user manual)
- Roads
- Cities and Towns
- Counties
- Geomorphology (Saucier 1994)
- Hydrology
- STATSGO soils
- Wetland Planning Regions and Wetland Planning Areas

All of this information can be downloaded from the ERDC website at http://el.erdc.usace.army.mil/publications.cfm?Topic=techreport&Code=emrrp

Appendix F: Common and Scientific Names of Plant Species Referenced in Text and Data Sheets

Scientific Name	Common Name
Acer drummondii	Swamp red maple
Acer negundo	Box elder
Acer saccharinum	Silver maple
Amorpha fruticosa	Leadplant
Asimina triloba	Paw-paw
Betula nigra	River birch
Callicarpa americana	Beautyberry
Carpinus caroliniana	Ironwood
Carya aquatica	Water hickory
Carya cordiformis	Bitternut hickory
Carya illinoensis	Pecan
Carya laciniosa	Shellbark hickory
Carya ovata	Shagbark hickory
Carya tomentosa	Mockernut hickory
Catalpa speciosa	Catalpa
Celtis laevigata	Sugarberry
Cephalanthus occidentalis	Buttonbush
Cornus drummondii	Smooth dogwood
Cornus florida	Flowering dogwood
Cornus foemina	Swamp dogwood
Crataegus spp.	Hawthorn
Diospyros virginiana	Persimmon
Forestiera acuminata	Swamp privet
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green ash
Gleditsia aquatica	Water locust
Gleditsia triacanthos	Honey locust
Hibiscus spp.	Hibiscus
Ilex decidua	Deciduous holly
Itea virginica	Virginia willow
Leitneria floridana	Corkwood
Ligustrum spp.	Common privet
Lindera melissifolia	Pondberry

Scientific Name	Common Name
Liquidambar styraciflua	Sweetgum
Morus rubra	Red mulberry
Nyssa aquatica	Water tupelo
Nyssa sylvatica	Blackgum
Pinus taeda	Loblolly pine
Planera aquatica	Water elm
Platanus occidentalis	Sycamore
Populus deltoides	Eastern cottonwood
Populus heterophylla	Swamp cottonwood
Prunus angustifolia	Chickasaw plum
Prunus serotina	Black cherry
Quercus falcata	Southern red oak
Quercus lyrata	Overcup oak
Quercus michauxii	Cow oak
Quercus nigra	Water oak
Quercus nuttallii	Nuttall oak
Quercus pagoda	Cherrybark oak
Quercus palustris	Pin oak
Quercus phellos	Willow oak
Quercus shumardii	Shumard oak
Quercus similis	Delta post oak
Quercus stellata	Post oak
Quercus velutina	Black oak
Rubus spp.	Blackberry
Salix nigra	Black willow
Sambucus canadensis	Elderberry
Styrax americana	Storax
Taxodium distichum	Baldcypress
Ulmus alata	Winged elm
Ulmus americana	American elm
Ulmus crassifolia	Cedar elm
Vaccinium spp.	blueberry
	(concluded)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
September 2011	Final report	

4. TITLE AND SUBTITLE

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Functions of Forested Wetlands in the Delta Region of Arkansas, Lower Mississippi River Alluvial Valley, Version 2.0

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)

Charles V. Klimas, Elizabeth O. Murray, Jody Pagan, Henry Langston, Thomas Foti

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road, Vicksburg, MS 39180;
U.S. Department of Agriculture, Natural Resources Conservation Service
700 W. Capitol Avenue, Little Rock, AR 72201

(see reverse)

8. PERFORMING ORGANIZATION REPORT NUMBER

ERDC/EL TR-11-12

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Environmental Protection Agency, Region VI, State and Tribal Program Section
1445 Ross Avenue, Suite 1200, Dallas, TX 75202-2733;
U.S. Army Engineer Research and Development Center, Environmental Laboratory
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Hydrogeomorphic (HGM) Approach is a method for developing and applying indices for the site-specific assessment of wetland functions. The HGM Approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review process to analyze project alternatives, minimize impacts, assess unavoidable impacts, determine mitigation requirements, and monitor the success of compensatory mitigation. However, a variety of other potential uses have been identified, including the design of wetland restoration projects, and management of wetlands.

This is Version 2.0 of a Regional Guidebook that presents the HGM Approach for assessing the functions of most of the wetlands that occur in the Delta Region of Arkansas, which is part of the Lower Mississippi River Alluvial Valley. The report begins with an overview of the HGM Approach and then classifies and characterizes the principal wetlands that have been identified within the Delta Region of Arkansas. Detailed HGM assessment models and protocols are presented for six of those wetland types, or subclasses, representing all of the forested wetlands in the region other than those associated with lakes and impoundments. The following wetland subclasses are treated in detail: Flat, Mid-gradient Riverine, Low-gradient Riverine Backwater, Low-gradient Riverine Overbank, Headwater Depression, Isolated Depression, and Connected Depression. For each wetland subclass, the guidebook presents (a) the rationale used to select the wetland

(see reverse)

15. SUBJECT TERMS

404 Regulatory Program
Arkansas Delta
Clean Water Act
Functional assessment
Geomorphology
Hydrogeomorphic (HGM) Approach
Hydrology
Impact Assessment
(see reverse)

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED		222	

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Arkansas State Highway and Transportation Department
P.O. Box 2261, Little Rock, AR 72203;

Arkansas Natural Heritage Commission
323 Center Street, Little Rock, AR 72201

14. ABSTRACT

functions considered in the assessment process, (b) the rationale used to select assessment model variables, (c) the rationale used to develop assessment models, and (d) the functional index calibration curves developed from reference wetlands that are used in the assessment models. The guidebook outlines an assessment protocol for using the model variables and functional indices to assess each of the wetland subclasses. The appendices provide field data collection forms, spreadsheets for making calculations, and a variety of supporting spatial data intended for use in the context of a Geographic Information System.

15. SUBJECT TERMS

Lower Mississippi River
Mississippi Alluvial Valley
Mississippi Valley
Mitigation
National Action Plan
Reference wetlands
Wetland
Wetland assessment
Wetland classification
Wetland function
Wetland restoration