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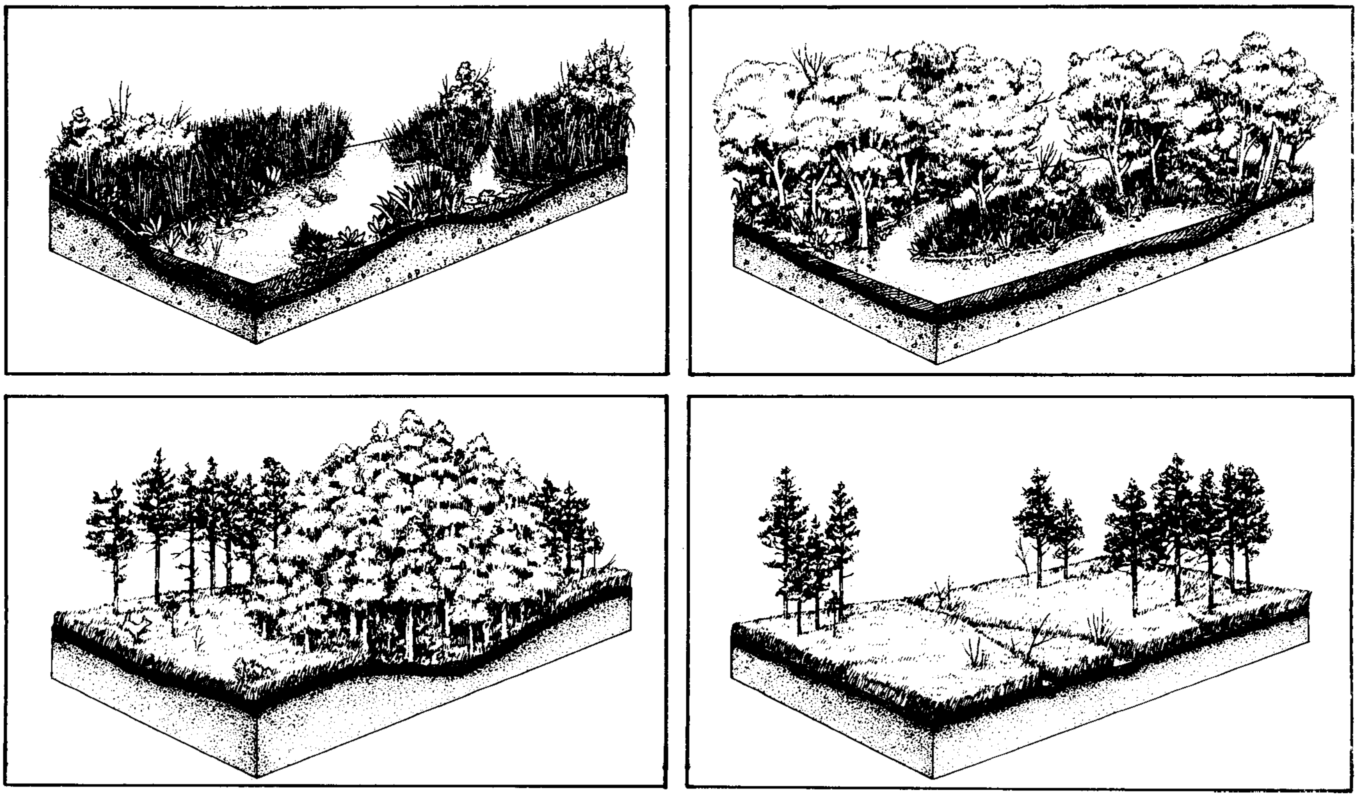
Environmental Impact Statement

Phase 1 Report

FRESHWATER WETLANDS FOR WASTEWATER MANAGEMENT



U. S. ENVIRONMENTAL PROTECTION AGENCY

REGION IV - ATLANTA

FRESHWATER WETLANDS FOR WASTEWATER MANAGEMENT

ENVIRONMENTAL IMPACT STATEMENT

PHASE I REPORT

February 1983

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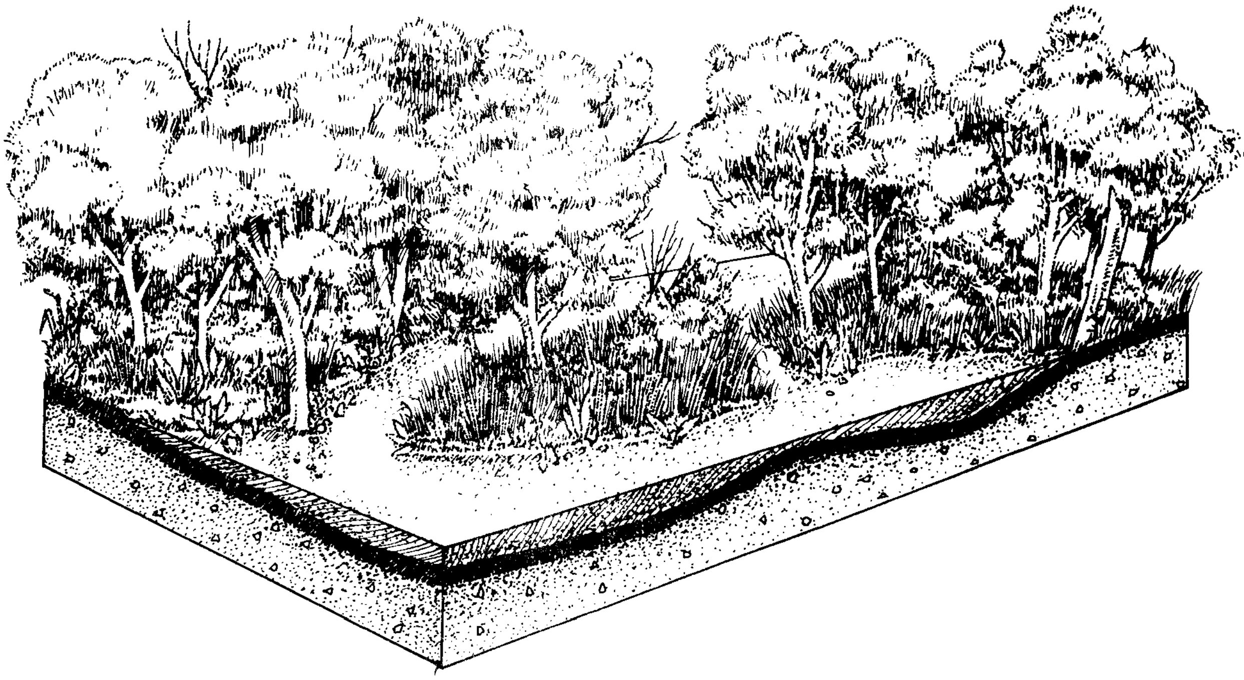


SECTION 1

INTRODUCTION

1.0 INTRODUCTION

EIS RESPONDS TO ISSUES ENCOUNTERED WITH EXISTING WETLANDS DISCHARGES

The understanding of wetlands values and functions has increased significantly during the past decade. During that period more attention has also been given to the use of wetlands for wastewater management. With increased pressure placed on wetland systems in recent years, regulatory and ecological issues have been raised. This EIS is designed to develop tools that can assist local, state and federal agencies in making wastewater management decisions affecting wetlands.

Since the late 1800's, natural wetland systems have been used for wastewater management in the Southeastern United States. In recent years, more communities have begun using wetlands for this purpose despite the increased attention given wetlands as their functions and values have become more fully understood. Research on wetlands has increased significantly during the past ten years, including research on wetlands used for wastewater management. Many systems used for wastewater management have been studied in Florida, and throughout the United States. But many questions regarding the use and management of natural wetland systems remain. This EIS has been initiated to address many of these questions, as more than 400 communities in the eight EPA Region IV states currently use wetlands for wastewater management.

EPA's involvement in wastewater management in freshwater wetlands is related to two specific program areas: Sections 201 and 402 of the Clean Water Act. Section 201 of the Act authorizes the Agency to participate in providing grant funds for the planning, design and construction of wastewater facilities. Section 402 of the Act authorizes the Agency to issue National Pollutant Discharge Elimination System (NPDES) permits to facilities that discharge treated wastewater to surface waters of the United States.

In the 201 program, the initial planning step involves the identification of a community's wastewater management needs and public health problems, and an investigation of available and reasonable wastewater management alternatives. The development and evaluation of wastewater management alternatives has become a critically important component of this planning step and EPA has provided considerable guidance to potential grant applicants in this area. Regional program offices have, however, identified a lack of guidance in the area of wastewater management in freshwater wetland areas. The pressures to continue and increase the use of wetlands for wastewater management are not likely to diminish in the near future. The cost of more conventional management alternatives is rising, treatment levels are becoming more stringent and surface water discharge opportunities are becoming more limited. This EIS is designed to be a supplement to the alternatives development and evaluation phases of the facilities planning process and will provide information and guidance concerning the means for considering wetlands as part of a wastewater management system.

1.0 Continued

Section 402 of the Clean Water Act established the National Pollutant Discharge Elimination System (NPDES) to provide a permitting system for all point source pollution discharges into waters of the United States. The issuance of NPDES Permits involves determining appropriate effluent limitations either to meet water quality standards or to meet minimal prescribed treatment levels (whichever is more stringent). For typical surface water discharges, this process is addressed in a fairly standard and straight forward fashion. In the case of wastewater discharges to freshwater wetlands, however, the permitting process and procedures are less clearly defined. This EIS should provide the institutional guidance and technical tools needed by applicants, consultants, states and federal regulatory agencies in the process of evaluating freshwater wetlands for wastewater management.

In addressing thses program needs, this EIS is designed to be a comprehensive study that fully recognizes and assesses the issues affecting the use of wetlands for wastewater management. Further, the EIS is intended to help coordinate the various issues that impact the 201 and NPDES Permit decision-making processes currently followed in Region IV states. The study will address all freshwater wetlands in Region IV with the exception of the Everglades and the South Florida wetlands that are unique to that area. Saltwater wetlands have also been excluded from this EIS but will be the subject of a separate study.

The EIS has been divided into two separate and distinct phases. Phase I is intended to collect the background information necessary to identify the major regulatory and ecological issues encountered in Region IV. Phase II tasks will lead to the development of procedures and tools for decision making that fully account for the key regulatory and ecological issues identified in Phase I. Stated another way, Phase I will involve inventory and data collection tasks: Phase II will involve the development and evaluation of decision-making tools. Both phases will address the variations that occur between states in data bases and policies.

The Phase I Report is preliminary to the major output of the EIS, which will be the delineation of tools and procedures for assessing the use of wetlands for wastewater management. These tools and procedures will be discussed fully in the Phase II Report and associated handbook.

The handbook will be designed for persons involved with decision making, such as local and state government officials, as well as engineering consultants and others who may be involved in the design or implementation of wetlandswastewater systems. Methods of analysis, safeguards and guidelines for evaluating, selecting, permitting and monitoring wetlands systems acceptable for wastewater management will be detailed.

This report is a comprehensive synopsis of institutional, scientific and engineering considerations associated with wetlands wastewater management systems in the Southeast. The literature on these topics is exhaustive. The literature also addresses a wide variety of auxilliary

1.0 Continued

topics, some of which have minimal importance in the discussion of southeastern wetlands. This report should not be considered a complete treatise on wetlands. Rather, the report summarizes the most important considerations that relate to the use of wetlands for wastewater management. A team of highly qualified wetlands researchers has assisted in reviewing the scientific and engineering aspects of the report.

Issues of Interest

- What are the scientific, institutional and engineering factors that are important for wastewater management in wetlands?
- Are scientific, engineering, and institutional issues equally important?
- What are the key factors in wetlands wastewater management for which further investigation, analytical tools or guidelines are needed?
- What mechanisms are available to avoid or mitigate detrimental impacts of wastewater discharges to wetlands?
- What is currently known about wastewater discharges to wetlands?

1.0 INTRODUCTION

1.1 Purpose of Study

EIS DESIGNED TO ASSESS FEASIBILITY OF USING WETLANDS FOR WASTEWATER MANAGEMENT

Wetlands have been used for wastewater management within Region IV for many years. In recent years the value of wetland ecosystems has been realized and several protection mechanisms have been established. Wetland discharges are now evaluated in light of these mechanisms.

Over the past several years, wetlands have received increased attention as valuable and sensitive ecosystems. Prior to that time, wetlands were commonly drained and/or filled, based on the perception that they had little importance. Even today many states, including some in Region IV, exert little influence over the development and destruction of valuable wetland resources. Intensive development within the southeastern United States has applied continuing pressure to these systems.

Unless purchased by the federal or state government, freshwater wetlands are virtually unprotected. The Corps of Engineers has authority under Section 404 of the Clean Water Act to permit requests to dredge or fill wetlands. Yet many small wetlands systems do not receive protection under this jurisdiction. In 1977 former President Carter issued an Executive Order instructing that federal funding not be provided for development activities in wetlands (or floodplains).

Wetlands disposal of treated wastewater is not a new concept. Wetlands have been used in this country and abroad for wastewater disposal for many years, in some cases dating back to the 1890's. It has only been recently, however, that wetlands have been studied for their capacity to accept and renovate wastewater. To a certain extent this corresponds to increased understanding of how wetlands function and the important role they have as ecosystems. A better understanding of how wetlands function now indicates that they provide a good natural mechanism for wastewater disposal and renovation under some circumstances.

The proposed use of freshwater wetlands for wastewater disposal must be viewed from two perspectives. In some respects, parallels exist between the issues of wetland development and wetland disposal. Yet the two are distinct in many ways, particularly regarding the types of impacts to wetlands. With development, the hydrologic regime of wetlands is typically altered or destroyed along with the vegetation of the system. With disposal of wastewater, the impacts are more subtle, and the wetland continues to function if the disposal is properly managed. But what changes are acceptable and how much change can occur before the result is alteration or degradation? These are some of the issues that will be addressed by this EIS.

This EIS is intended to explore the feasibility of utilizing freshwater wetlands for wastewater management throughout the eight states of EPA Region IV: Alabama, Florida, Georgia, Kentucky, Mississippi, North

1.1 Continued

Carolina, South Carolina and Tennessee. The various and unique wetlands systems present throughout Region IV must first be examined. Their location, extensiveness, function, and capability to renovate wastewater will be subsequently evaluated.

The analysis is approached from two entirely different perspectives: 1) institutional considerations as they relate to federal, state and local regulations and policies; and 2) technical considerations as they relate to scientific and engineering knowledge of wetlands and existing wetlands disposal systems.

The remaining objectives of the EIS deal primarily with conducting an inventory of existing wetlands discharges and identifying limitations in present understandings of wetlands systems and their response to perturbations.

This EIS is designed to respond to such questions as "Is wetlands disposal feasible for a community?", and "Can the important functions of a wetlands system be maintained if used in this manner?"

INSTITUTIONAL, SCIENTIFIC AND ENGINEERING ISSUES MUST BE CONSIDERED

Wetlands are complex ecosystems with many components. As managed systems, they must be evaluated for capabilities to renovate wastewater. Maintenance of natural functions must also be assured to achieve continued renovation and protect other values of wetlands ecosystems.

Wetlands embody several unique functions and are valuable ecosystems. They serve an important role in the provision of habitat, in nutrient cycling and in the flow regimes of both surface and groundwaters. As wetlands have been managed for wastewater management or aquaculture, many regulatory and legal issues have been raised. The dredging and filling of wetlands has also drawn increased attention to the ecological role of wetlands and their protection. As questions concerning the role of wetlands as managed natural systems have been posed, limitations in the existing information base and our subsequent understanding about wetlands have surfaced.

Two review committees have been formed to help identify issues of concern and to assist in the direction and review of this EIS. An institutional committee has been formed, composed of a representative from each of the eight Region IV states, the U.S. Fish and Wildlife Service and the U.S. Corps of Engineers. A technical committee has also been established, comprised of individuals who have direct research experience and practical experience with wetlands systems. Universities and federal agencies are also represented. Several other issues of special concern were identified by the Directive of Work for this EIS. These include:

Institutional

- Policies or regulations on wetlands disposal at federal, state, or local levels
- Differentiation of wetland types, indicating those most appropriate for wetlands discharges
- Methods for determining wasteload allocations
- Impacts of revised water quality standards regulations
- Treatment vs disposal issue

Scientific

- Assessment of wetland values and functions
- Presence of threatened or endangered species in wetlands
- Presence of wildlife with recreational and aesthetic values
- Impacts of various qualities and volumes of effluent on floral and faunal communities
- Hydrologic consequences of wetlands disposal
- Evaluation of existing data base and needs for data collection/monitoring

1.2 Continued

Engineering

- Specific effluent characteristics which would preclude wetlands disposal
- Potential beneficial results of wetlands disposal, particularly to artifically depleted wetlands
- Impacts to recreational or commercial resources
- Public health impacts
- Development of preferred planning, design, implementation and operation-maintenance techniques

Each of the areas of concern presented above will be addressed by this report, in an effort to acknowledge and respond to all issues that affect the feasibility of wastewater disposal to freshwater wetlands.

EIS IS BEING CONDUCTED IN A MULTI-PHASED APPROACH

The wetlands EIS will be conducted in multiple phases. This report reviews the findings of Phase I. Additional phases will establish guidelines for assessing wetlands management options and will evaluate the thoroughness and effectiveness of those guidelines.

Several major objectives of the EIS are identified in Sections 1.1 and 1.2. In defining the scope of work, EPA recognizes two distinct aspects of the study. The major goal of the study is to provide institutional and technical procedures by which existing and potential wetlands discharges could be evaluated. This is not necessarily an endorsement of wetlands discharges but rather an acknowledgement that they currently exist and should be properly evaluated and permitted.

It is necessary to compile pertinent information on existing discharges and the state-of-understanding of wastewater impacts on wetlands before a set of procedures can be established. Further, an inventory of all wetland types, wetland characteristics, and wetland functions is necessary.

Due to the importance of this information and the necessity of collecting it prior to establishing procedures, a multi-phased approach to the study has been adopted. Phase I deals with the collection and analysis of information concerning wetlands and wastewater discharges to wetlands. In addition, scientific, engineering, and institutional considerations are addressed by Phase I.

Based upon the results of Phase I, the Phase II Plan of Study will be prepared. Phase II will be designed to establish institutional and technical procedures for evaluating a potential wetlands discharge. Also included will be the delineation of monitoring requirements, back-up systems, treatment requirements, and acceptable wetlands systems (if any) for a potential discharge. Case studies will be conducted as part of Phase II; however, the degree and level of any field studies are not yet determined.

The remainder of this report details the findings of Phase I tasks that are indicated by the outline. STOP-format is used to help the reader quickly identify major components of the report and particular sections of interest. This format highlights the contents of each major section by using headlines and abstracts.

Several distinct topics, representing distinct tasks, were analyzed under Phase I. However, all the analyses were combined to form the Phase I report to indicate the comprehensive yet integrated nature of the study and present the information more cohesively than would a series of individual task reports.

Figure 1.3 displays the areas of analyses that comprise Phase I.

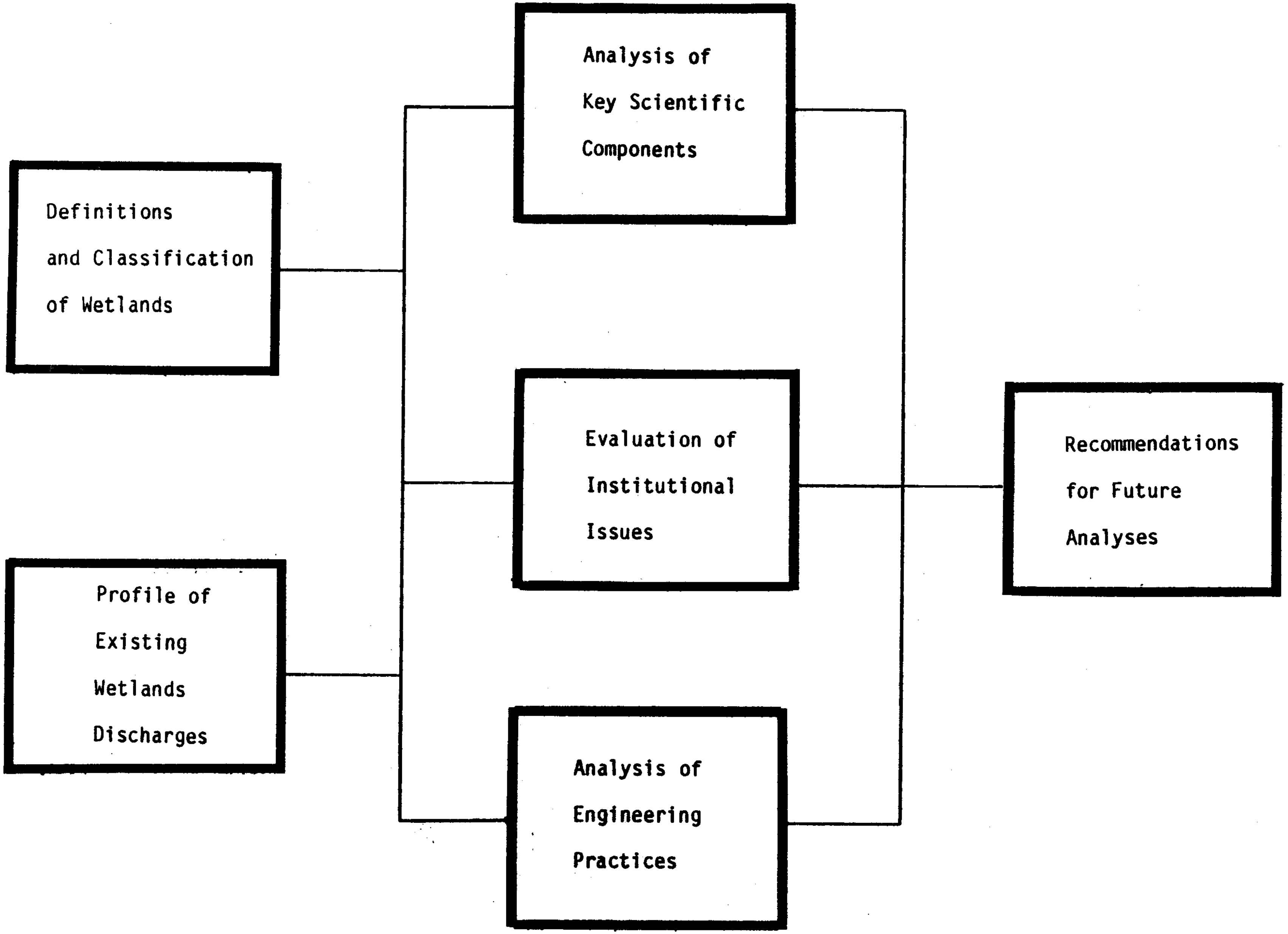


Figure 1.3. Levels of analysis incorporated into Phase I of EIS.

Source: Claude Terry & Associates, Inc. 1982.

RESEARCH PROJECTS ON MANAGED WETLANDS HAVE INCREASED IN RECENT YEARS

During the past 10 years, interest in wetlands research has expanded. Numerous research projects have been conducted. Several symposia have been held to review current research and assess the state-of-the-art.

Over the past decade, wetlands have received increased attention as indicated by the level of funding committed to research. Numerous symposia have been held on both natural and managed wetlands systems. The research conducted and conferences held on the state-of-understanding have assisted in defining critical functions, issues and data limitations that should be considered.

Major research efforts on wetlands systems have been conducted at numerous universities throughout the United States and abroad. Several universities have conducted long-term studies on managed wetland systems that have received wastewater effluent. These include:

- University of Florida, Center for Wetlands
- University of Michigan
- Louisiana State University, Center for Wetland Resources
- University of California (Davis), Dept. of Land, Air, and Water Resources.

Several federal agencies have also been involved with wetland studies, including:

- The U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS
- The U.S. Fish and Wildlife Service, National Wetlands Inventory, St. Petersburg, FL
- The U.S. Environmental Protection Agency, Region V, Chicago, IL
- The National Aeronautics and Space Administration, NSTL Station, MS
- The U.S. Environmental Protection Agency, Corvallis Environmental Research Agency, Corvallis, OR.

The U.S. Fish and Wildlife Service has also compiled an annotated bibliography of over 800 references concerning the various aspects of wetlands systems as they pertain to wetlands management.

In a series of studies conducted by universities, federal agencies, and a few engineering firms, several wetlands systems used for wastewater discharges in the Southeast have been examined. These systems are located primarily in Florida where much of the wetlands research in Region IV has occurred. Systems are located in or near the communities of:

- Clermont, Florida
- Gainesville, Florida
- Jacksonville, Florida
- Jasper, Florida
- Lake Buena Vista, Florida

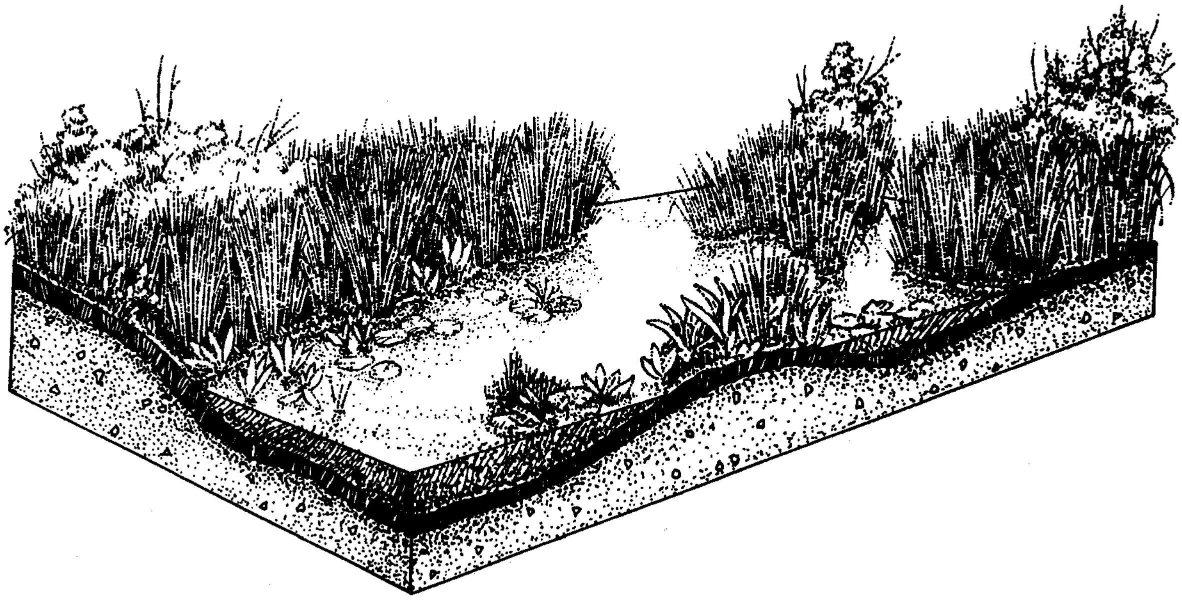
1.4 Continued

- Madison, Florida
- Waldo, Florida
- Wildwood, Florida.

Finally, a number of symposia or conferences on wetlands have been held since 1975. These have been useful for information transfer. The primary conferences pertinent to this project include:

- Wetlands Treatment of Municipal Wastewater, June 23-25, 1982, University of Massachusetts, Amherst, Massachusetts
- National Wetlands Technical Council: Bottomland Hardwood Wetlands, June 1-5, 1980, Lake Lanier, Georgia
- Aquaculture Systems for Wastewater Treatment, September 11-12, 1979 University of California, Davis, California
- Water Reuse Symposium, March 25-30, 1979 Washington, D.C.
- National Wetland Protection Symposium, 1979 U.S. Fish and Wildlife Service, Washington, D.C.
- National Symposium on Wetlands, November 7-10, 1978 Disney World Village, Lake Buena Vista, Florida
- Wetlands Utilization Conference, Kissimmee River Coordinating Council, Ongoing Annual Meetings since 1978
- Society of Wetland Scientists, Ongoing Annual Meetings since 1980, various locations
- Freshwater Marshes: Present Status, Future Needs, February, 1977, Rutgers University, New Brunswick, New Jersey.
- National Symposium on Freshwater Wetlands and Sewage Effluent Disposal, May 1976, University of Michigan, Ann Arbor, Michigan.

This does not represent an all-inclusive listing of wetlands symposia and research efforts. It does represent those activities that have provided major contributions to the understanding of wetlands systems and their role in wastewater management throughout the southeastern United States.



SECTION 2

WETLANDS DEFINITIONS AND INVENTORIES

2.0 WETLANDS DEFINITIONS AND INVENTORY

CLASSIFICATION SYSTEMS HAVE BEEN DEVELOPED TO DEFINE WETLANDS SYSTEMS

The identification and inventory of wetlands systems is dependent on an adequate system of classification. Several have been proposed but many have limitations for fully describing and delineating wetlands systems. Wetland inventories have been conducted in Region IV but are not exhaustive in coverage.

A critical component in studying wetlands is delineating their extent and location. In Region IV, there are numerous types of wetlands due to the temperature and topographic gradients across the area. Dependent upon these and other criteria, predominant vegetation assemblages form the basis for identifying and characterizing wetlands.

Wetlands are commonly differentiated and delineated based on major vegetation types. Several classification schemes have been developed by federal agencies and researchers. Among the federal agencies, the Corps of Engineers (COE) and Fish and Wildlife Service (FWS) have developed the most comprehensive systems. The system recently developed by the FWS is gradually being adopted by most agencies and is the most comprehensive of the systems developed to date.

Each of the eight Region IV states has conducted wetlands inventories. However, these have not been exhaustive studies and have used a variety of classification schemes and methods. A system will be adopted to help establish a consistent classification scheme for use in this EIS. The FWS system is proposed as the preferred system, with modifications or aids incorporated to assist in its use and interpretation. The FWS system was chosen because of its regional consistency and its recognition of significant ecological differences among wetland types. While wetlands definitions are important conceptually, they are inadequate for fully delineating wetlands variability without an associated classification scheme.

<u>Issues of Interest</u>

- How are wetlands defined by various governmental agencies?
- Why do these definitions vary?
- What wetland classifications systems are used for regulatory purposes?
- What wetland classification systems are used for inventory purposes in each Region IV state?
- Do wetland inventories exist for each state?
- Are existing classification systems suitable for wastewater management?

2.0 WETLANDS DEFINITIONS AND INVENTORY

2.1 Wetland Definitions

DEFINITIONS ARE IMPORTANT TO REGULATORY AND CLASSIFICATION EFFORTS

Wetland definitions vary depending on the required detail and perspective of the involved agency. Definitions provide a basis for wetland classification systems and a general agreement of what constitutes a wetland.

Whether or not an area is considered as wetlands usually depends on how wetlands are defined and classified. The difference between definitions and classification systems are often based on the definition of different wetlands characteristics. The classification systems used for wetlands delineation and identification are discussed in other sections. The purpose of this section is to review the various broad concepts describing a wetlands system.

Clark (1979) has defined a wetland as "a place that is sufficiently saturated with water, often enough, that typical wet soil plants grow there." This provides a clear concept of the basic characteristics of a wetlands system.

For regulatory, policy and classification purposes, several government agencies have proposed general definitions of wetlands. The U.S. Fish and Wildlife Service, in "Classification of Wetlands and Deepwater Habitats in the United States" Cowardin et al. (1979), have referred to wetlands in two different ways:

- Wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plants and animal communities living in the soil and on its surface.

- Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.

These two definitions written from slightly different perspectives highlight different elements of wetlands characteristics.

Much of the regulatory power over wetlands is held by the U.S. Army Corps of Engineers in the capacity of permitting dredge and fill activities in wetlands. While this jurisdiction does not directly impact the disposal of wastewater into wetlands, the Corps has established definitions (1977) and classifications which are widely held. The Corps of Engineers defines wetlands as:

- Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for existence in saturated soil conditions. Wetlands generally incude swamps, marshes, bogs, and similar areas.

2.1 Continued

Executive Order 11990 issued in 1977 by former President Carter regarding the protection of wetlands utilizes the Corps of Engineers' definition. However, it elaborates the Corps of Engineers' definition by expanding the last sentence to read: similar areas such as sloughs, potholes, wet meadows, river overflows, mud flats, and natural ponds.

Other definitions have been used for wetlands, but those discussed above indicate the general characteristics of wetlands as well as can be accomplished by a short statement. The definition of different wetland types and the differentiation between them require a detailed classification system. Any single definition cannot begin to encompass the variety and complexity of wetlands. Therefore, while a general definition is helpful to introduce basic concepts, the actual classification systems used are the mechanisms for defining wetland systems and their differences.

CLASSIFICATION SYSTEMS DESIGNED TO FIT NEEDS OF USER

Many wetlands classification systems have been devised within the scientific and regulatory communities. Most regulatory agencies rely on vegetation, soils and hydrologic indicators to typify and classify wetlands. The scientific community has also relied on these indicators for classifying wetlands but have also approached classification from a value/land use perspective.

The FWS employs an extensive and detailed wetland classification system developed by Cowardin et al. (1979) for the National Wetlands Inventory. This system provides several different levels of detail in the classification of a wetland, depending on the needs of the user. This classification system relies on vegetation, hydrology and soil indicators to characterize wetland types. The FWS previously used a simple classification system described in a document referred to as Circular #39. The document delineates wetlands into 20 different types, based on vegetation and hydrology. Because of its widespread use since 1956, a significant amount of state and federal legislation is tied to its definitions and classifications. At present a clear trend among regulatory agenices is to switch to the more detailed National Wetlands Inventory classification system to fulfill their needs and promote interagency consistency. Although the Corps of Engineers (COE) is primarily interested a jurisdictional definition of a specific wetland area, and not the type of wetland per se, it has also identified different wetland types in a series of wetland guides. These guides (COE 1978) are regionally specific and are designed to assist in the implementation of Section 404 in the regulation of dredge and fill activities.

Penfound (1952) developed a relatively simple, but straightforward and informative classification system of wetlands of the southeast. This benchmark work has provided the basis for many successive classification schemes for southern wetlands. Penfound's work also has value in highlighting several rare and unusual wetland types. Goodwin and Niering (1975) employed a modified Circular #39 definition to identify and inventory significant natural inland wetlands of the U.S.

Other wetland classification systems which have been developed by Golet and Larson (1974) and Steward and Kantrud (1971) are not especially applicable to wetlands of the southeast. Lonard et al. (1981) reviewed and analyzed over 20 methodologies which classified and assessed wetlands on the basis of various values such as habitat, hydrology, recreation and other values.

FISH AND WILDLIFE SERVICE HAS HISTORY OF INVOLVEMENT WITH DEVELOPMENT AND UTILIZATION OF WETLAND INVENTORY AND CLASSIFICATION SYSTEMS

Two major classification systems have been employed by FWS. Both systems utilize vegetative and hydrologic characteristics to delineate wetland types. The Circular #39 system is a simpler system, but the more recent National Wetlands Inventory (NWI) System allows greater differentiation of wetland types.

The U.S. Fish and Wildlife Service (FWS) has two operational wetland classification systems. The NWI system (Cowardin et al. 1979) has been officially adopted by the FWS to be used in all future wetland data base developments. The wetland classification system presented in Circular #39 (Shaw and Fredline 1956) has been used by FWS for over 20 years and has significant historical importance. Both of these classification systems employ aerial photography as the major tool in the location and classification of wetlands by physiographic province. Existing state information is utilized by both systems, and the need to maintain a standard national classification system is emphasized.

The NWI system employs a more extensive and detailed classification system than does Circular #39 and makes use of the advances in mapping technology developed in the 20 years since Circular #39 was first issued. The classification system used for the NWI also reflects the increased level of understanding of wetland structure and function. It recognizes the inherent ecological and hydrologic values associated with wetlands. Although the FWS has officially adopted the NWI system for its wetlands projects, FWS personnel may continue to use the old classification system where immediate conversion is not practicable or where applicable laws still reference that system. Because both systems are still in use and widely referenced, the next two subsections will discuss these systems in detail.

2.0 WETLANDS DEFINITIONS AND INVENTORY
2.2 Wetland Classification Systems
2.2.1 U.S. Fish and Wildlife Service Classification System
2.2.1.1 Circular #39

CIRCULAR #39 CLASSIFICATION RECEIVES WIDESPREAD USE AND ACCEPTANCE

Circular #39 recognizes 20 types of fresh and saline wetlands of the U.S. It has been a very influential document but has been criticized for ignoring important ecological distinctions among wetlands. Because the definitions of wetlands in Circular #39 are subject to wide interpretation and inconsistent application, it has been replaced as the official FWS classification system.

The primary goals of Circular #39 were to delineate the wildlife value of wetlands and to provide a perspective for balanced land use planning. The report was authored by S. P. Shaw and L. Fredine and was originally entitled "Wetlands of the United States--Their Extent and Their Value to Waterfowl and Other Wildlife." It was the fourth major document on wetlands inventory and classification commissioned by the U.S. government (others in 1906, 1922, 1940) and marked a significant departure in attitude and purpose from previous inventories. The emphasis of the earlier wetland documents was to determine the extent of swamp lands with potential for drainage, reclamation and conversion to agricultural uses. In contrast, Circular #39 was commissioned in 1956 in response to the rapid rate of conversion of wetlands to agriculture and other uses and the consequent adverse effects on waterfowl.

Circular #39 has received widespread use and acceptance in the past 20 years. Because of its long term use, a significant amount of state and federal legislation is directly and indirectly tied to its definitions and classifications, including the Water Bank Act of 1970 (PL 91-559).

The classification framework that Circular #39 employs places all wetlands in one of four major wetland categories: inland fresh, inland saline, coastal fresh and coastal saline. Within the four major wetland categories, 20 wetland types are identified based on characteristic flooding patterns and vegetation cover (see Table 2.2.1.1-a). Circular #39 provided total U.S. acreage estimates for each of the 20 wetland types, and also placed a qualitative value on wetlands on the basis of their importance as wildlife habitats. This document fulfilled its primary purpose, but its shortcomings as a comprehensive and definitive wetland classification and inventory system have been noted by several authors (Cowardin et al. 1979). The primary criticism of Circular #39 was that critical ecological differences among wetlands were ignored. Problems have also been reported in the consistency of application of Circular #39 definitions, which were subject to a variety of interpretations.

A description of each wetland type defined by Circular #39 that has bearing on this EIS is included in Table 2.2.1.1-b.

Table 2.2.1.1-a. Description of Wetland Types in the United States as Defined in Circular #39.

Category	Type	Water Depth*
Inland Fresh Areas		
	1. Seasonally flooded basins or flats	Few inches in upland, few feet along rivers
	2. Inland fresh meadows	Few inches after heavy rain
	3. Inland shallow fresh marshes	Up to 6 inches
	4. Inland deep fresh marshes	Up to 3 feet
	5. Inland open fresh water	Up to 10 feet; marshy border may be present
	6. Shrub swamps	Up to 6 inches
	7. Wooded swamps	Up to 1 foot
	8. Bogs	Shallow ponds may be present
Inland Saline Areas		
	9. Inland saline flats	Few inches after heavy rain
	10. Inland saline marshes	Up to 2 feet
	11. Inland open saline water	Up to 10 feet; marshy border
Coastal Fresh Areas		
	12. Coastal shallow fresh marsh	Up to 6 inches at high tide
	13. Coastal deep fresh marsh	Up to 3 feet at high tide
	14. Coastal open fresh water	Up to 10 feet, marshy border may be present
Coastal Saline Areas		
	15. Coastal salt flats	May have few inches at high tide
	16. Coastal salt meadows	May have few inches at high tide
	17. Irregularly flooded salt meadows	Few inches at wind tide
	18. Regularly flooded salt meadows	Up to 1 foot at hgh tide
	19. Sounds and bays	Up to 10 feet at high tide
	20. Mangrove swamps	Up to 2 feet

*Refers to average conditions during growing season except for Type 1. In Type 1 bottomlands, flooding ordinarily occurs in late fall, winter, or spring. In Type 1 upland areas, depressions may be filled with water during heavy rain or melting snow, predominantly in early spring.

Source: Shaw and Fredine. 1956.

Table 2.2.1.1-b. Circular #39 Wetland Types Addressed by this EIS.

Circular #39 Wetland Type	Vernacular Name	Description
1	Seasonally flooded basin or flat	Site is usually inundated or soils waterlogged on a seasonal basis. Includes bottomland hardwoods and some herbaceous growths.
2	Inland fresh meadows	Standing water rare during the growing season but soils generally waterlogged. Meadows may fill shallow lake basins or sloughs or border landward side of shallow marshes.
3	Inland shallow fresh marshes	Soil waterlogged much of the growing season, often covered with six or more inches of water. May fill shallow lake basins or sloughs or border landward side of deep marshes.
4	Inland deep freshwater	Soil covered with six inches to three feet or more of water during the growing season. May fill shallow lake basins, potholes, limestone sinks, sloughs, or border open waters.
5	Inland open freshwater	Includes shallow ponds and reservoirs. Water usually less than 10 feet deep fringed by a border of emergent vegetation.
6	Shrub swamps	Waterlogged during growing season, soil covered with six or more inches of vegetation. Occurs often along sluggish streams and flood plains.
7	Wooded swamps	Waterlogged at least to within a few inches of surface during growing season, often covered with one foot or more of water. Occurs mostly along sluggish streams on flood plains, flat uplands, very shallow lake basins. Often support herbaceous or aquatic understory and in association with shrub-swamps.

Table 2.2.1.1-b. Continued.

Circular #39 Wetland Type	Vernacular Name	Description
8	Bogs	Also known as pocosins, bogs, savannahs; soil waterlogged, supporting spongy layer of mosses. Occurs in shallow lake basins, sluggish streams and on flat uplands. Woody or herbaceous vegetation dominates.
12	Coastal shallow fresh marsh	Soils always waterlogged in growing season, up to up to one foot of water tidal influence, highly productive, waterfowl important, vegetation mostly consists of grasses, sedges, sawgrass, other freshwater marsh types.
13	Coastal deep fresh marsh	Average depth greater than above, tidal influence, vegetation dominates as floating aquatics or grasses tolerant to deeper water.
14	Coastal open freshwater	Average depth up to six feet, vegetation scarce, but sometimes mats of hyacinths along Gulf coast areas.

Source: Adapted from Shaw and Fredine. 1956.

NEW WETLAND CLASSIFICATION SYSTEM DEVISED FOR NATIONAL WETLAND INVENTORY

The FWS, in cooperation with other federal agencies, recently developed a classification system for use in the National Wetlands Inventory. The system encompasses both deep-water and wetland habitats and classifies them by their dominant vegetation, soil type and hydrologic conditions. Several levels of classification are available depending on user needs.

The classification system employed by the National Wetlands Inventory originated in 1974, when the FWS directed the Office of Biological Services to design and conduct a new national wetlands inventory to update the 1956 efforts. This directive resulted in the establishment of four long-term goals for the inventory and the classification system: (1) describe ecological units that have certain natural attributes in common; (2) arrange these units in a system that will aid in resource management decisions, (3) provide a system to inventory and map these units; and (4) provide conformity of concepts and terminology throughout the United States. The projected level of detail and scope of this inventory differed greatly from the previous national wetlands inventory (Circular #39, see previous section). Because of these differences, a new classification system had to be selected or devised.

A significant increase in wetland research in the past 15 years has produced several new classification systems. These have been, for the most part, only regional systems. They have been too difficult to apply at a national scale and were subsequently rejected by FWS. The FWS then elected to construct a new classification system as the first step towards implementing a new National Wetlands Inventory. The document that resulted from these efforts was authored by L. M. Cowardin et al. (1979) and entitled "Classification of Wetlands and Deepwater Habitats of the United States."

This wetlands classification system (Cowardin et al. 1979) uses a broad definition of wetlands. This document includes deepwater habitats and encompasses all aquatic systems of the U.S. within its classification system. This reflects its intended use by people or institutions with a variety of interests and objectives over an extremely wide geographic area.

The structure of this classification system is heirarchical, i.e., it has several tiers or layers of classification and detail. It begins with the most general categories or systems and progresses to more detailed categories and descriptors. There are 5 system names, 8 subsystem names, 11 class names, 28 subclass names, and an unspecified number of dominance types (see Figure 2.2.1.2-a for listings to class). Each system, subsystem, class, and subclass refers to some aspect of the vegetation, soil and hydrologic regime that forms the basis of this classification system and characterizes specific

2.2.1.2 Continued

ecotypes. The dominance types are the final biotic descriptors of this classification system. The dominance type name is taken from the plant or animal most characteristic of the area of interest (for example, Cypress, Oyster). The ecosystem is described further by a series of abiotic descriptors or modifiers referencing a particular characteristic of the water regime (hydroperiod), water chemistry (pH, salinity), or soil type (mineral, organic).

The result of the classification system is a unique taxon or name given to a particular ecotype. There is no direct reference to the region in which that taxon occurs. If a regional frame of reference is desired, the authors (Cowardin et al. 1979) suggest the use of Bailey's (1976) ecoregion system as a suitable way to regionalize the taxon derived from this classification system (Figure 2.2.1.2-b).

This system was designed to be used at varying levels of detail according to the amount of information available about a particular area and the needs of the user. All wetlands and deepwater habitats in Region IV can be classified by this system. Many wetlands remain to be classified dependent on necessary funds and interest for the completion of their classification and inventory (see Section 2.3.1.1 to 2.3.1.8).

The majority of wetlands considered in this EIS fall under the Forested Wetland, Scrub-shrub Wetland, Emergent Wetland and Moss-Lichen Wetland classes within the Palustrine systems (Figure 2.2.1.2-c). Emergent Wetland classes within the Lacustrine (lakes) and Riverine (rivers) systems are also considered as typical wetland types in Region IV and will be included in this EIS (Figure 2.2.1.2-d and 2.2.1.2-e).

Although the FWS was primarily responsible for the creation of this classification system, it did so with the cooperation of several federal agencies. In the future it is hoped that this classification system will be adopted by the other agencies (most notably Soil Conservation Service, Corps of Engineers) and will establish a uniform definition of wetland types among federal agencies. It is not, however, the intent of this classification and inventory system to define the limits of jurisdiction of any regulatory agency or the geographic scope of any regulatory program.

Table 2.2.1.2 provides a comparision between Circular #39 and the NWI equivalent. The heavy lines used in Figure 2.2.1.2 show those systems of importance for potential wastewater disposal in Region IV.

Table 2.2.1.2. Comparison of Wetland Types Described in U.S. Fish and Wildlife Service Circular #39 with Some of the Major Components of NWI System.

	Classification of Wetlands and Deepwater Habitats		
Circular #39 Type and References for Examples of Typical Vegetation	Classes	Water Regimes	Water Chemistry
Type 1--Seasonally flooded basins or flats Wet meadow (Dix and Smeins 1967; Stewart and Kantrud 1972) Bottomland hardwoods (Braun 1950) Shallow-freshwater swamps (Penfound 1952)	Emergent Wetland Forested Wetland	Temporarily flooded Intermittently flooded	Fresh Mixosaline
Type 2--Inland fresh meadows Fen (Heinselman 1963) Fen, northern sedge meadow (Curtis 1959)	Emergent Wetland	Saturated	Fresh Mixosaline
Type 3--Inland shallow fresh marshes Shallow marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland	Semipermanently flooded Seasonally flooded	Fresh Mixosaline
Type 4--Inland deep fresh marshes Deep marsh (Stewart and Kantrud 1972; Golet and Larson 1974)	Emergent Wetland Aquatic Bed	Permanently flooded Intermittently exposed Semipermanently flooded	Fresh Mixosaline
Type 5--Inland open freshwater Open water (Golet and Larson 1974) Submerged aquatic (Curtis 1959)	Aquatic Bed Unconsolidated Bottom	Permanently flooded Intermittently exposed	Fresh Mixosaline
Type 6--Shrub swamps Shrub swamp (Golet and Larson 1974) Shrub-carr, alder thicket (Curtis 1959)	Scrub-Shrub Wetland	All nontidal regimes except permanently flooded	Fresh

Table 2.2.1.2. Continued

Circular 39 Type, and References for Examples of Typical Vegetation	Classification of wetlands and deepwater habitats Classes	Water Regimes	Water Chemistry
Type 7--Wooded swamps Wooded swamp (Golet and Larson 1974) Swamps (Penfound 1952, Heinselman 1963)	Forested Wetland	All nontidal regimes except permanently flooded	Fresh
Type 8--Bogs Bog (Dansereau and Segadas-vianna 1952, Heinselman 1963) Pocosin (Penfound 1952, Kologiski 1977)	Scrub-Shrub Wetland Forested Wetland Moss-Lichen Wetland	Saturated	Fresh (acid only)
Type 12--Coastal shallow fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly flooded Irregularly flooded Semipermanently flooded-Tidal	Mixohaline Fresh
Type 13--Coastal deep fresh marshes Marsh (Anderson et al. 1968) Estuarine bay marshes, estuarine river marshes (Stewart 1962) Fresh and intermediate marshes (Chabreck 1972)	Emergent Wetland	Regularly flooded Semipermanently flooded-tidal	Mixohaline Fresh
Type 14--Coastal open fesh water Estuarine bays (Stewart 1962)	Aquatic Bed Unconsolidated Bottom	Subtidal Permanently flooded-tidal	Mixohaline Fresh

Source: Cowardin et al. 1979.

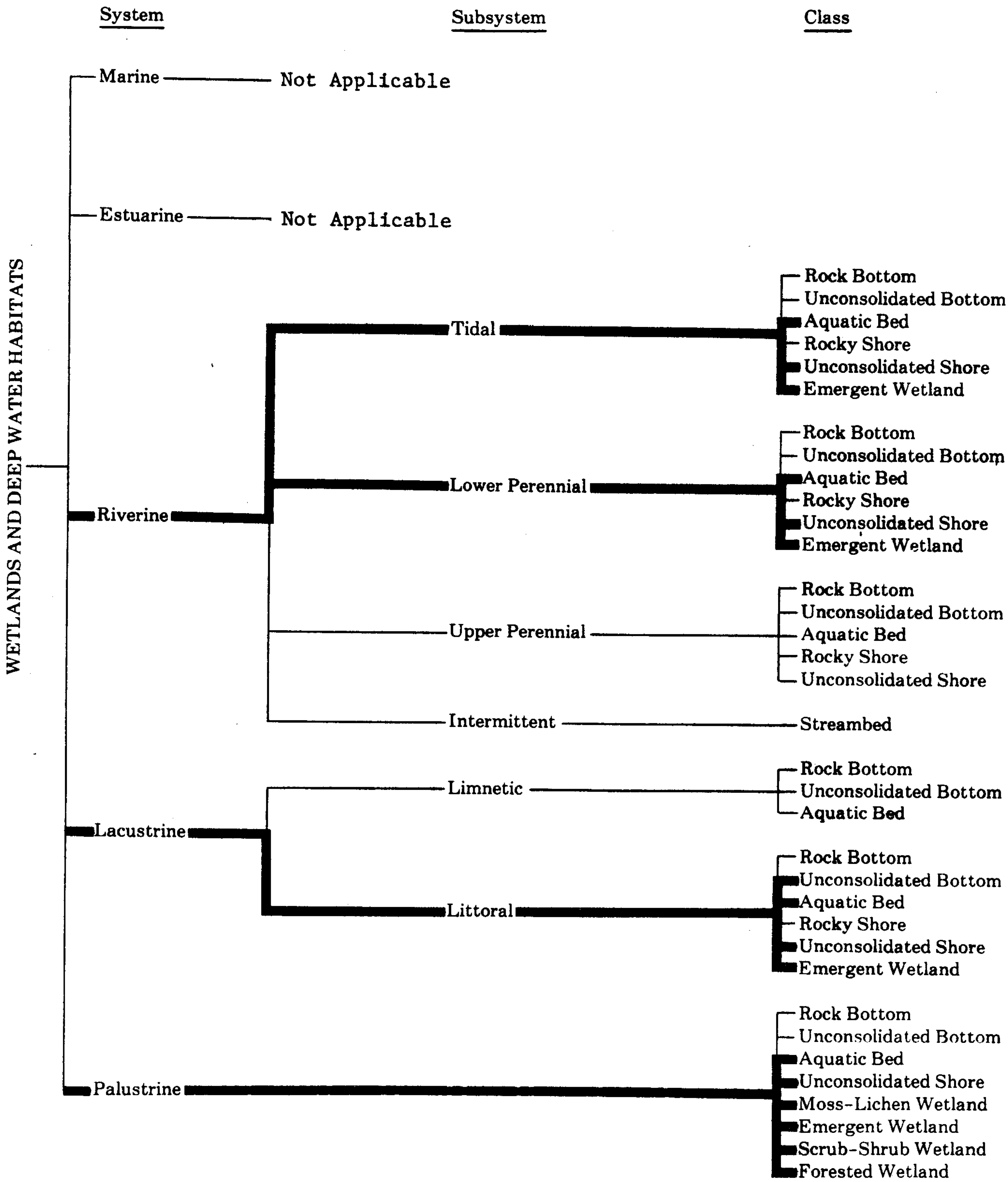


Figure 2.2.1.2-a. NWI wetlands classification system (wetlands applicable to this EIS are highlighted by dark line).

Source: Cowardin et al. 1979.

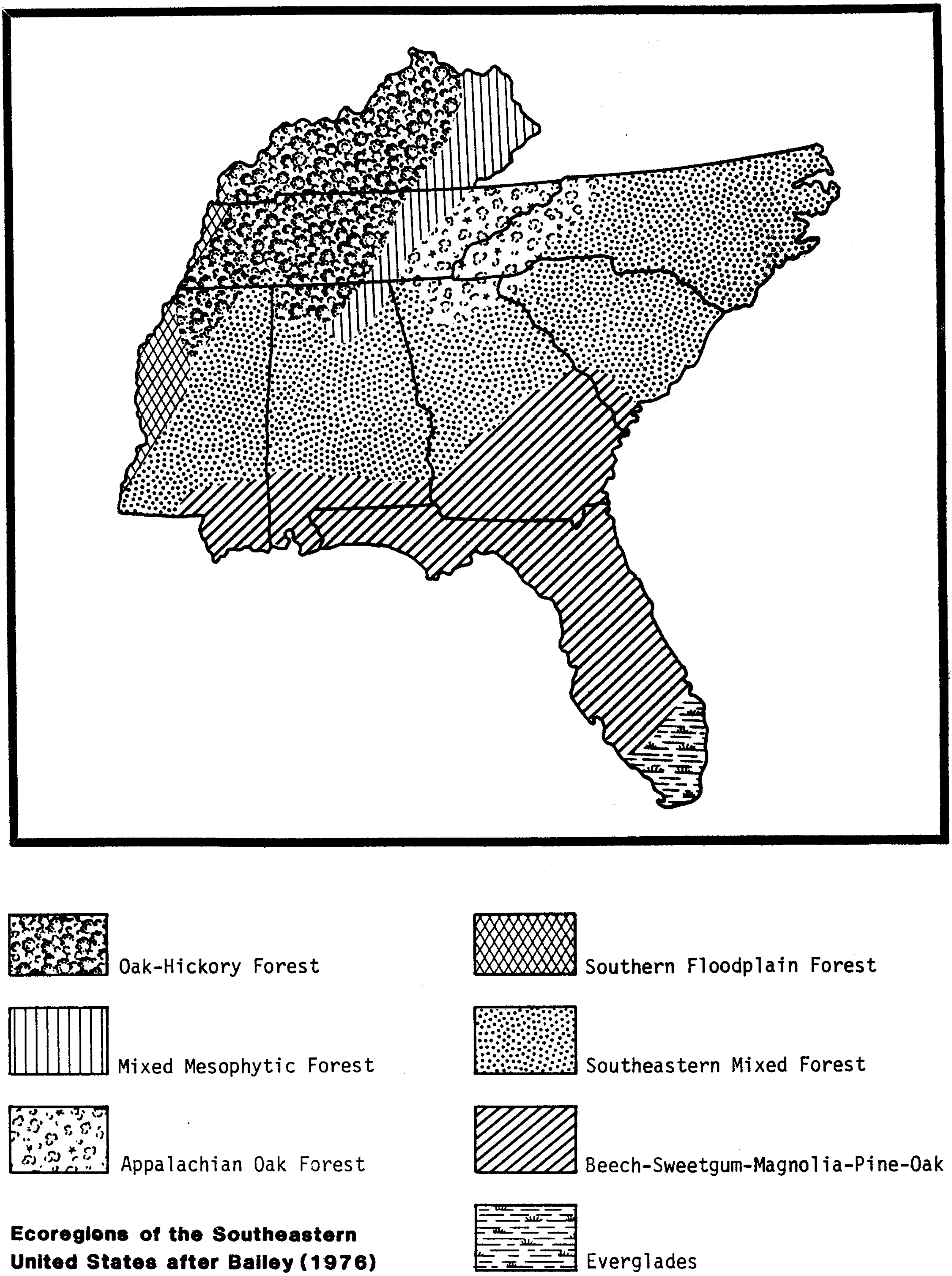


Figure 2.2.1.2-b. Ecoregions of the Southeastern United States.

Source: Adapted from Cowardin et al. 1979.

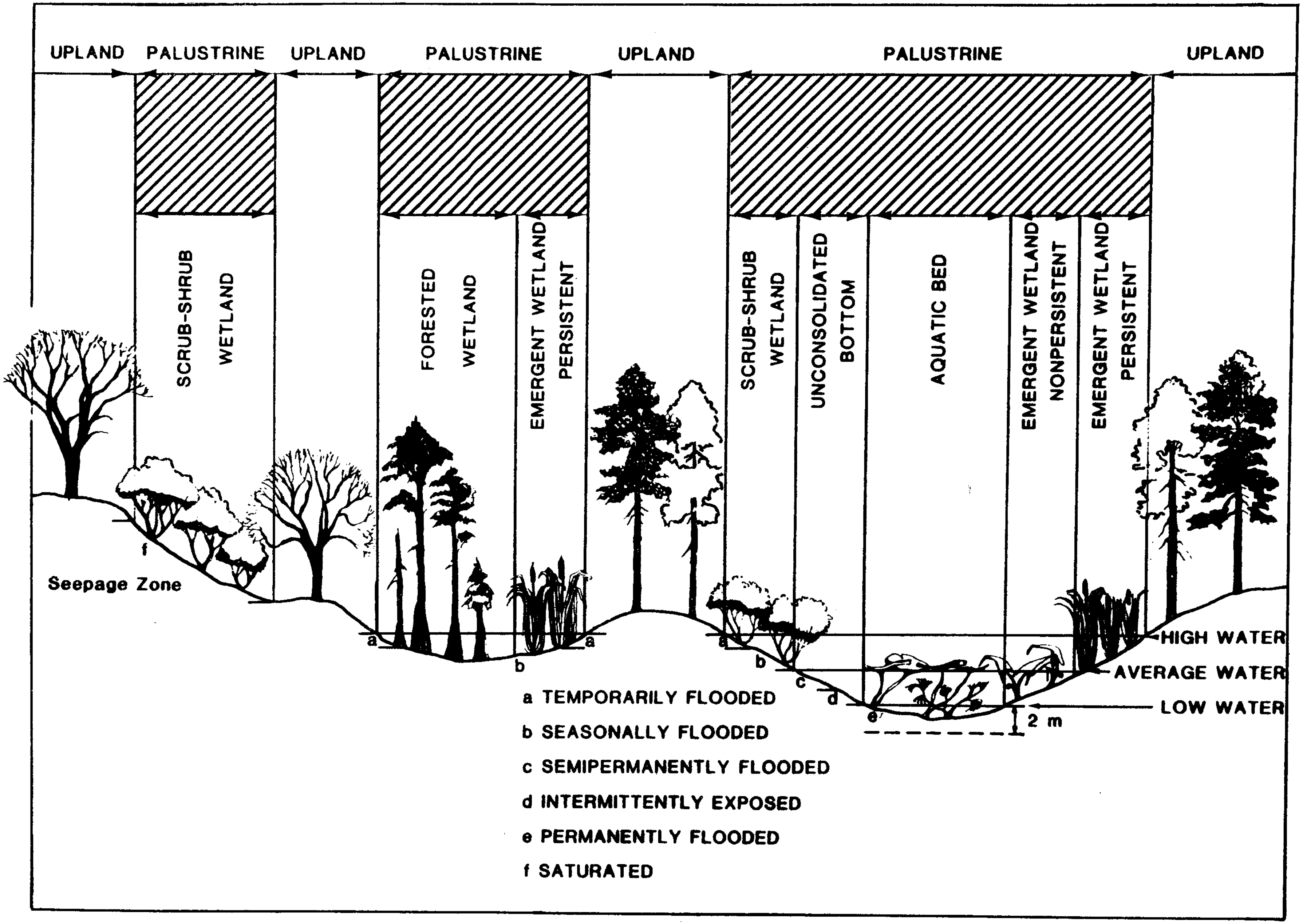


Figure 2.2.1.2-c. NWI palustrine wetland types.

Source: Adapted from Cowardin et al. 1979.

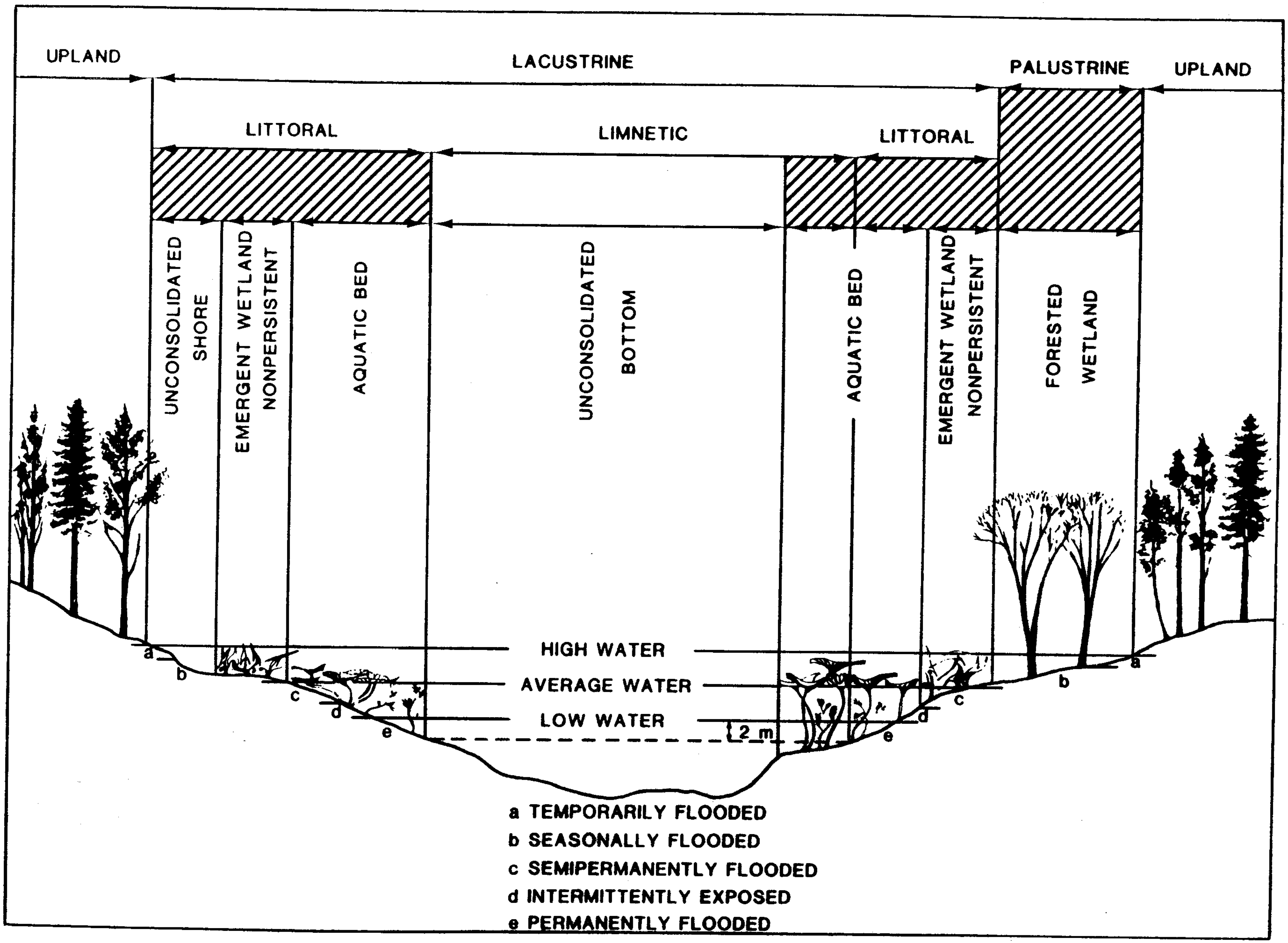


Figure 2.2.1.2-d. NWI lacustrine and palustrine wetland types.

Source: Adapted from Cowardin et al. 1979.

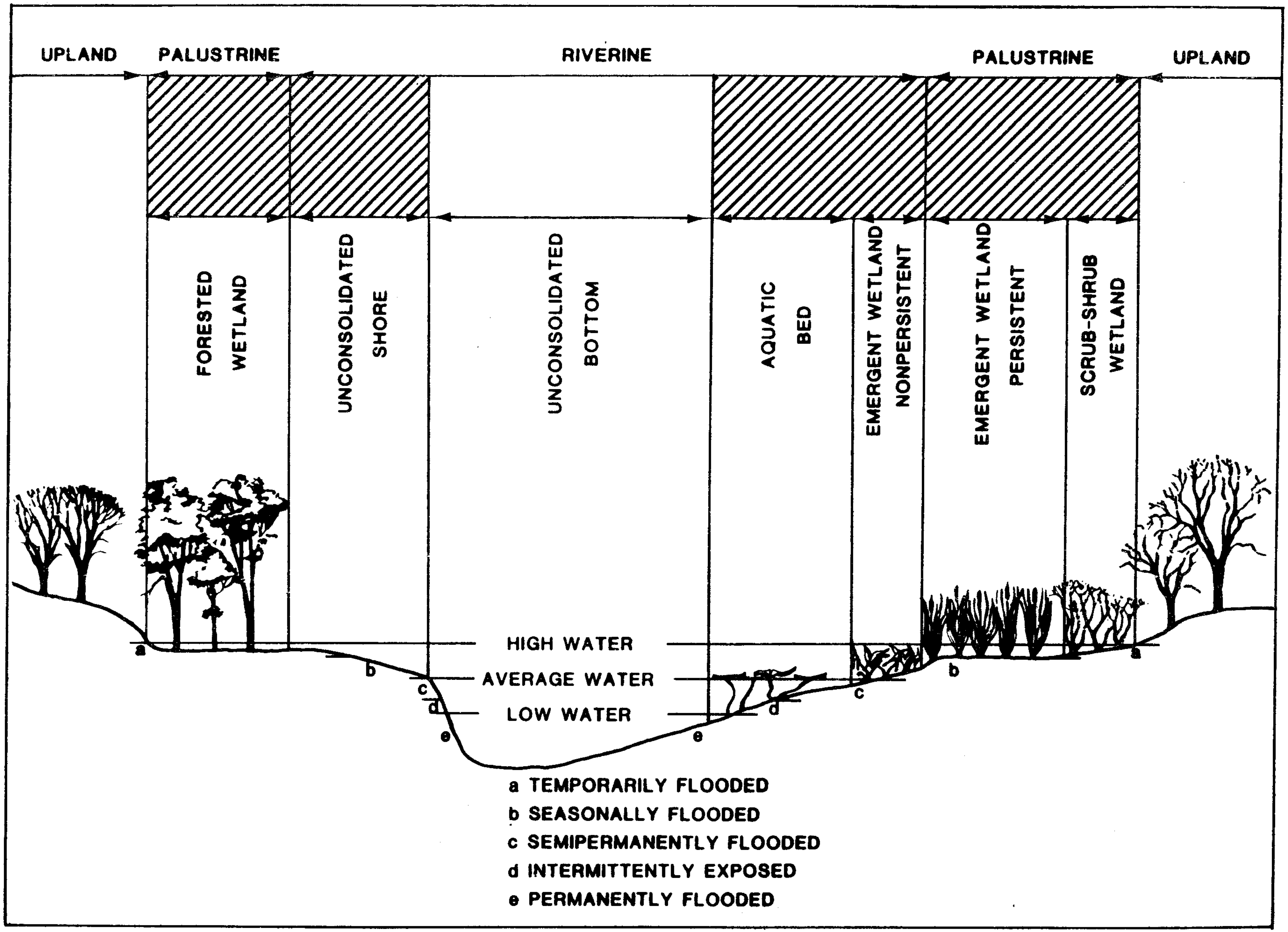


Figure 2.2.1.2-e. NWI Palustrine and riverine wetland types.

Source: Adapted from Cowardin et al. 1979.

DUE TO WETLANDS REGULATORY RESPONSIBILITY CORPS OF ENGINEERS MAINTAINS OWN WETLANDS DEFINITION AND CLASSIFICATION SYSTEM

The Corps of Engineers' (COE) primary interest in wetlands is in the implementation of Section 404 (WPCA 1972) permitting. In response, its official definition of wetlands is broad, but recent efforts at wetlands classification reflect a high amount of regional specificity of wetland types.

The wetlands definitions used by the COE have evolved and expanded in accordance with the broadening of their regulatory responsibilities by various institutional mechanisms (see Section 5.1 for more detailed discussion). The current wetland definition used by COE was developed jointly with EPA in 1977 (42 Federal Register July 19, 1977):

> Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.

The fundamental purpose of this definition is to determine whether a specified area falls under COE jurisdiction for regulation of dredging and filling activities in wetlands. It is implied from this definition that a potential wetland area will possess three unique and identifiable characteristics (vegetation, hydrology and soils) to indicate that it is a true wetland. While not an officially adopted policy, a number of COE districts interpret this to imply that an area must have all three wetlands indicators positive to fall within their definition of a wetland (Sanders 1982).

Eight regional guides have been planned to assist in the implementation of Section 404 (WPCA 1972) in regulating dredging and filling activities. These guides employ a simple classification scheme similar to Circular #39 classification system. The COE classification scheme places freshwater wetlands into one of four major types identified in Table 2.2.2. Guides are currently available for all areas within Region IV. The value of these guides lies in the description of community types, several in-depth plant lists for particular wetland habitats and the listing of regional differentiation of wetland types. See Figure 2.2.2 for the guide most appropriate to the area in Region IV of interest.

Table 2.2.2. The COE Wetland Classification System and Identifying Features Appropriate to Freshwater Wetlands

Wetland Type	Definition	Outstanding Features
1. Freshwater aquatic	Inland; flooded permanently or semipermanently by freshwater. Aquatic vegetation predominant (dominant plants free-floating or attached and having poorly developed tissues of structural support, supported and buoyed up by the water).	Occurs along streams ponds, canals, lakes and reservoirs as a narrow bank of vegetation in parallel with these shoreline areas. Vegetation dense especially in sloughs, backwater of rivers and streams or occasionally scattered. considered early successional communities eventually replaced by marshes, upland communities.
2. Freshwater flat	Wetlands that have 25 percent or less vegetative cover and are occasionally or regularly flooded by freshwater (e.g., mudflats).	Most common in areas of fluctuating water levels (reservoirs streams). Twelve dominant plant genera, varying widely in accordance with light and soil conditions. These systems readily change to marshes as vegetative cover increases but returns to former state after flooding.
3. Freshwater marsh	Wetlands that have more than 25 percent vegetative cover of herbaceous plants but 40 percent or less cover by woody plants that are occasionally or regularly flooded by fresh water (e.g., cattail marsh).	Major subtypes include Outer Coastal Plains Marshes, Interior Plain Marshes (driest), Wet Meadows (savannahs, sedge meadows). Forbs dominant in permanently wet areas, grasses (graminoids) in seasonally wet sites. Small changes in elevation (3"-4") responsible for rapid changes in species composition and boundary between this type and swamp type.
4. Freshwater swamp	Wetlands that have more than 40 percent cover by woody plants and are occasionally or regularly flooded by freshwater (e.g., cypress swamps).	Major subtypes include Deep and Prolonged Flooding, Prolonged and Shallow Flooding, Floodplains with Seasonal Flooding, Shrub-Bogs. Typical vegetative associations are cypress, tupelo, mixed hardwood, bayheads, willow heads. Transition to uplands sometimes gradual, distinct boundaries sometimes difficult to detect.

Source: ACOE. 1978.

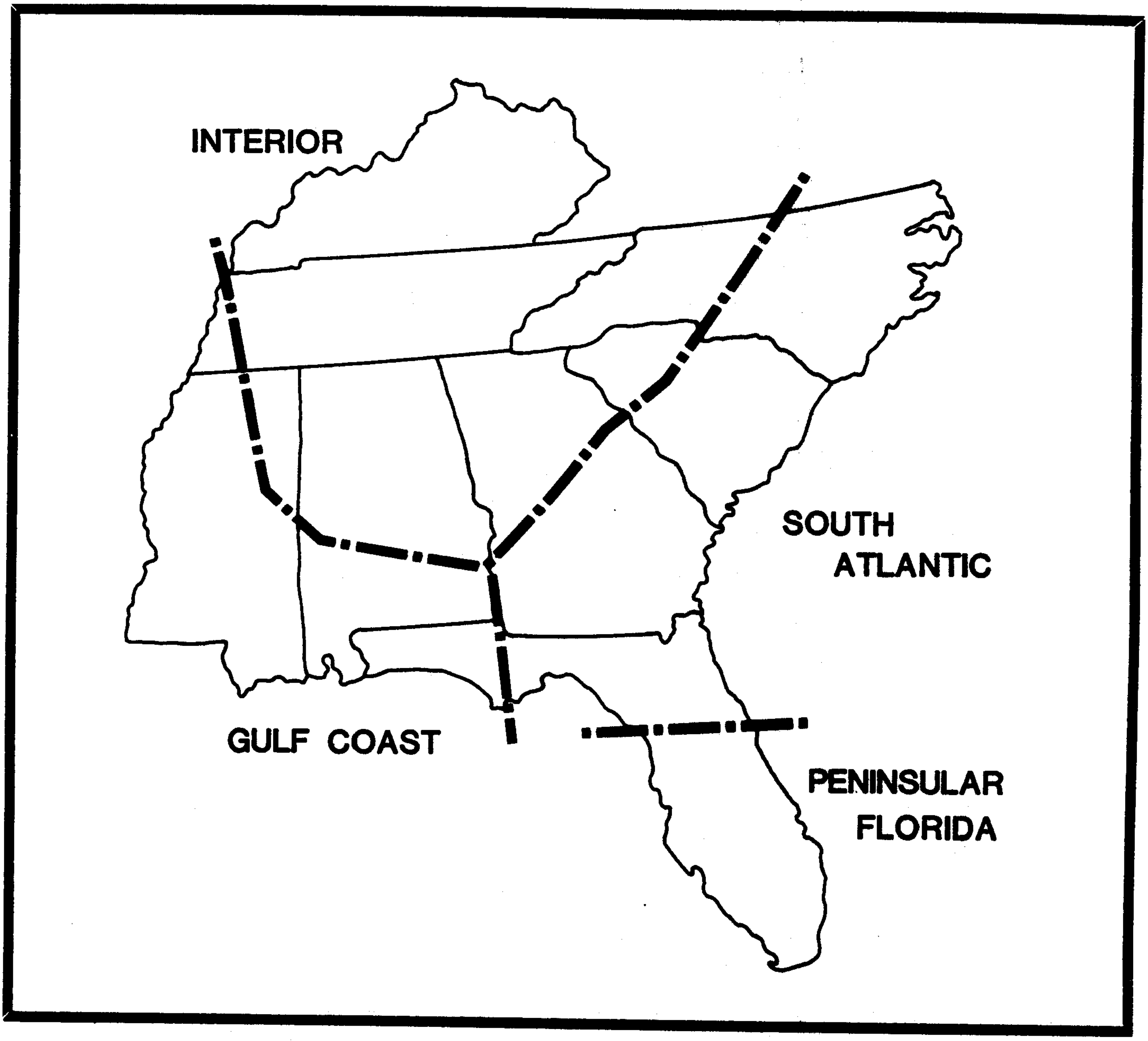


Figure 2.2.2. Boundaries for COE regional wetland guides found within Region IV.

Source: COE. 1978.

NO OTHER FEDERAL AGENCY HAS ESTABLISHED CLASSIFICATION SYSTEMS

Although EPA has jurisdiction over wetlands, it has not developed a separate classification system. EPA, along with most other federal agencies, will be adopting the FWS system.

The Fish and Wildlife Service and Corps of Engineers have been primarily involved with wetlands classifications due to their mandates to protect wetlands and permit activities in wetlands. EPA has regulatory responsibility through involvement with 404 Permit Review, NPDES permitting, water quality standards, and environmental protection. EPA has used the classification systems developed by the COE and FWS rather than developing its own system. This has provided consistency as EPA has interfaced with the responsibilities of the COE and FWS.

Several other federal agencies have indirect jurisdiction over wetlands. These are the Soil Conservation Service, Geological Survey, National Park Service, and Forest Service. In each case, jurisdiction is indirect and regulatory powers lie with either the COE and/or EPA. As a result, these agencies utilize the classification systems developed by the COE and FWS. While some agencies have been utilizing the Circular #39 system of the FWS for wetlands identification, they will gradually be adopting the new FWS classification system.

PENFOUND'S EARLY WORK WITH SOUTHERN SWAMPS AND MARSHES HAS PRESENT VALUE

Penfound defines five general swamp types and four general marsh types in the southeastern U.S. Important vegetational community types and some minor but rare associations are also identified.

The basis for the classification and identification of many freshwater wetlands in the southeastern United States can be traced to Penfound's review of Southern swamps and marshes as it appeared in 1952. The area he considered ranged from Virginia to Florida and west to eastern Texas. Physiographically, the review covers most of the Atlantic and Gulf coastal plains and nearly all of the Mississippi alluvial plain.

The classification system was relatively simple, dividing wetlands into salt or freshwater swamps or marshes. The major wetland types described by Penfound (1952) applicable to this EIS are summarized in Table 2.2.4.

Penfound emphasized that soil texture is a basic factor in the local distribution of hydric plants, but he did not include soils as part of the classification scheme. Fire is mentioned as a factor that controls the vegetational assemblages in certain wetlands. Eight minor swamp communities are mentioned by Penfound and are valuable for their uniqueness. In addition, five minor freshwater marsh communities are discussed for similar reasons.

Penfound recognized that many intergradations occur between "swamp" and "peaty swamps." The "transitional" marsh communities have been designated as Wet Prairies, Wet Meadows, Savannahs and Wet Pine Barrens by other investigators. The term "marsh" does not ordinarily include submerged, floating, or emergent stages of lakes or ponds in Penfound's opinion.

Penfound's classification system is straightforward and informative but lacks specificity for regulatory or inventory usage. However, many classification systems developed since 1952 have been based on his system.

Table 2.2.4. Major Freshwater Southeastern Wetland Types as Classified by Penfound (1952).

Wetland Type Definition	Characteristics	Major Communities*
Fresh Water Swamps		
Deep Swamps Deep swamps are fresh water, woody communities, with surface water throughout most or all of the growing season.	Relatively tall, deciduous trees, with swollen bases and "knees," and abundant epiphytes. Frutescent and herbaceous species few or none.	Southern cypress-tupelo gum (Taxodium distichum-Nyssa aquatica). Swamp gum-pond cypress (Nyssa biflora-Taxodium ascendens).
Shallow Swamps (transitional communities) Shallow swamps are freshwater, woody communities, the soil of which is inundated for only short periods during the growing season.	Deciduous trees or shrubs without evident hydrophytic characters except for production of water roots in buttonball and willows and swollen bases in green ash.	Black willow-sandbar willow (Salix nigra-Salix interior Buttonball-dogwood-willow (Cephalanthus-Svida-Salix). Overcup oak-water hickory (Quercus lyrata-Hicoria aquatica). Hackberry-elm-ash (Celtis-Ulmus-Fraxinus). Maple-red gum-oak (Rufacer-Liquidambar-Quercus). Alder-birch (Alnus-Betula).
Peaty Swamps Peaty swamps are oxylic, peat-forming, sclerophyllous woody communities, with surface water only during a part of the growing season.	Sclerophyllous, evergreen trees or shrubs, including many ericaceous species. Frutescent and herbaceous plants numerous.	Red bay-sweet bay (Tamala pubescens-Magnolia virginiana). Pond pine-slash pine (Pinus serotina-Pinus caribaea). Southern white cedar (Chamaecyparis thyoides). Evergreen shrub swamp (Ilex-Cyrilla-Zenobia).
Fresh Water Marshes		
Deep Marshes Deep marshes are freshwater grass-sedge-rush communities the soil of which is covered by water throughout most or all of the growing season.		Giant cut grass (Zizaniopsis milacca). Cattail-Bulrush-maiden cane (Typha-Scirpus-Panicum). Saw-grass (Mariscus jamaicensis).
Shallow Marshes (wet meadows) Shallow marshes are freshwater, grass-sedge-rush communities, in which surface water is usually present for only a small part of the growing season.		Panic grass-horned rush (Panicum-Rynchospora).

*Plant names according to Small (1933)
Source: Adapted from Penfound. 1952.

GOODWIN AND NIERING UTILIZE FWS CLASSIFICATION SYSTEM WITH ALTERATIONS

The classification systems developed by Goodwin and Niering follows closely the FWS system in Circular #39. The new system was applied to inventory the significant inland wetlands of the U.S. The FWS system was amplified to include habitats of relatively little importance to waterfowl.

The classification system developed by Goodwin and Niering (1975) considers only freshwater and inland wetlands. Wetlands are recognized as a site where the water table is near, at, or above the surface of the ground for at least some portion of the growing season. Floodplains are included in this classification as are lakes and ponds where they are ecologically related to specific wetland types.

Marshes, swamps and bogs are considered to constitute the major types of wetlands, as in Penfound (1952) and Martin et al. (1953). It is acknowledged that each wetland type may exhibit various phases or subtypes. Goodwin and Niering's classification system was employed in a survey of significant natural wetlands with recommendations regarding their potential as National Landmarks.

In the following paragraphs the classification types for freshwater wetlands are summarized. The letter after the type refers to fresh (F) as opposed to saline (S) wetlands. The number following this letter refers to the corresponding classification in Circular #39. If no number appears, no Circular #39 equivalent is suggested. The final letter indicates whether the wetland is a Marsh (M), a Shrub Swamp (Ss), a Wooded Swamp (Sw), or a Bog (B).

Seasonally flooded basins and flats (F-1). These sites are inundated periodically but not flooded during the growing season. They occur along water courses and on floodplains, especially in the lower Mississippi drainage and in the Southeast. Their vegetation is dependent upon the season and the duration of flooding. Bottomland forests along rivers (F-1-Sw) may be composed of gums (*Nyssa* spp.), oaks (*Quercus* spp.), sweet gum (*Liquidambar styraciflua*), and cypress (*Taxodium distichum*) in the South and Southeast.

Fresh Meadows (F-2-M). The water table is at or near the surface, but usually there is no standing water. Such sites often exhibit a rich floristic diversity including grasses, sedges and rushes.

Shallow Fresh Marshes (F-3-M). The soil is waterlogged throughout the vegetative season, and the sites are often covered with six inches or more of water. They occur throughout the United States as shallow basins and sloughs and along the margins of shallow lakes or the borders of deep marshes. The vegetation is dominated primarily by emergent aquatic plants.

Deep Fresh Marshes (F-4-M). This type includes natural shallow ponds, springs, and man-made impoundments usually less than 10 feet in depth. These areas include shallow lakes, sloughs, potholes, limestone sinks and margins of open water areas.

Open Fresh Water (F-5-M). This includes natural shallow ponds, springs and man-made impoundments usually less than 10 feet in depth. These are widespread but most abundant in Florida. The vegetation of the marginal zone is dominated by emergent vegetation (see F-3-M); the deeper areas by floating and submerged aquatics (see F-4-M).

Shrub Swamps (F-6-Ss) (sometimes referred to as carrs). The water table is at or near the surface throughout much of the year, and these areas may be flooded with as much as 6-12 inches of water at certain periods. Such swamps occur throughout the deciduous forest region in upland depress2.2.5 Continued

Wooded Swamps (F-7-Sw). The water table is at or near the surface throughout the year, and 6-12 inches of standing water during part of the year is common. These occur in poorly drained upland sites along streams, shallow river basins and deltas. The vegetation includes a vast acreage of bottomland hardwoods and cypress swamps of the Southeast. The Great Cypress Swamp of west Florida is one of the most extensive of such areas in North America. Although river floodplain swamp forests intergrade with seasonally flooded swamp forests (F-1 Sw), those more continuously flooded throughout the year are included here. Shrub and wooded swamp types may also intergrade. Forest composition varies geographically. In the Southeast primary trees are cypress (*Taxodium* spp.), water oak (*Quercus nigra*), tupelo gum (*Nyssa aquatica*), and pond pine (*Pinus rigida* var. *serotina*).

Bogs (F-8-B). These usually develop in deep lakes and poorly drained depressions of glacial origin and are underlain by extensive peat deposits. They occur throughout the glaciated regions of the United States on the Coastal Plain. They are represented in the Carolina Bay regions.

Riparian (R). These habitats consist of narrow bands of vegetation found along water courses. They may be transitional between seasonally flooded types (F-1) and more mesic vegetation. In some instances their flora is unique.

OTHER CLASSIFICATION SYSTEMS MEET SPECIFIC NEEDS OF USER

Appropriate wetland classification schemes should meet the needs of the user. Several diverse systems include the traditional vegetational-hydrologic approach and several value-type classifications.

Several alternative approaches to wetland classifications are available. The ultimate classification system selected should reflect the needs of the individual user, so many wetland classification systems are modified to suit those needs. A wetland classification system may relate to one aspect of wetlands (vegetation, soils, etc.) or to any combination of parameters associated with wetlands.

Several legal or regulatory wetland classification systems have been discussed earlier. Other classification systems are used for decision making, ecological/scientific purposes or are popular because of their widespread use.

Küchler (1964), for example, classified wetlands of the U.S. by distinctive vegetative types (Table 2.6-a). Another approach to wetland classification is to assess values of wetlands. Over 20 methodologies have been developed to assess the various aspects of wetland values including habitat, hydrology, agriculture/silviculture, recreation and heritage functions, and geographic features. Leonard et al. (1981) reviewed and analyzed the methodologies for assessment of these wetland values.

Several classification schemes exist that apply only within a specific region. For example, 25 wetlands types were identified based on vegetation and hydrologic considerations for the Forested Wetlands of Florida Study (see Table 2.6-b). Steward and Kantrud (1971) and Golet and Larson (1974) are responsible for other classification systems that are widely used and applicable to specific wetland regions outside Region IV.

Table 2.2.6-a. Küchler's Wetland Vegetation Types.

Type No.	Name	Dominant plants	Location
49	Tule Marshes	Scirpus, Typha	Widespread; esp. Cal. and Utah
78	Southern Cord-grass Prairie	Spartina alterniflora	Southeast Tex.; Southern La.
79	Palmetto Prairie	Aristida stricta Serenoa repens	Central Fla.
80	Marl Everglades Grassland Hammocks	 Cladium jamaicense Persea borbonia Taxodium distichum	 South Fla. South Fla.
91	Cypress Savanna	Aristida, Taxodium, Cladium	South Fla.
92	Everglades Grassland Bayheads	 Cladium Magnolia virginiana Persea borbonia	 South Fla. South Fla.
94	Conifer bog	Larix laricina Picea mariana Thuja occidentalis	Glaciated eastern and central states
98	Northern Flood-plain Forest	Populus deltoides Salix nigra, Ulmus spp.	Midwestern river bottoms
113	Southern Flood-plain Forest	Nyssa aquatica, Quercus spp. Taxodium	South and Southeast
114	Pocosin	Pinus serotina Ilex glabra	Coastal Plain Va. to S.C.

Source: Goodwin and Niering 1975.

Table 2.2.6-b. Forested Wetlands of Florida.

Cypress Ponds (domes) - stillwater
Acid Water Ponds
Hardwater Ponds
Pasture Ponds
Enriched Ponds
Other Non-Stream Swamps
Gum Pond (swamp)
Lake Border Swamp
Dwarf Cypress
Bog Swamp (Okeefenokee Swamp)
Bay Swamp
Shrub Bog
Herb Bog
Seepage Swamp
Hydric Hammock (North Florida type)
South Florida Hammock
Melaleuca Swamp
Cypress Strand - slowly flowing water
River Swamps and Floodplains
Alluvial River Swamps
Blackwater River and Creek Swamps
Backswamp
Spring Run Swamp
Tidewater Swamp
Saltwater Swamps - Mangroves
Riverine Black Mangroves
Fringe Red Mangroves
Overwash Red Mangroves
Scrub Mangroves

Source: Wharton et al. 1976.

A COMPREHENSIVE WETLAND INVENTORY HAS NOT BEEN UNDERTAKEN BY ANY STATE

Each of the eight states in Region IV has had limited wetland maps prepared, primarily in association with specific coastal or river basin studies. Several federal agencies are involved in wetlands classification and mapping in conjunction with other responsibilities. The U.S. Fish and Wildlife Service (FWS) National Wetlands Inventory is currently the only comprehensive wetlands mapping project in Region IV.

The most extensive and detailed wetland mapping projects in Region IV have generally been conducted along the coastal regions. Freshwater wetlands are generally included in these projects but are usually a minor portion of the mapping effort. In several instances, coastal wetlands have been mapped by both state and federal agencies. The relative emphasis placed on coastal mapping is directly related to the recently accelerating coastal development pressures, the vital and often conflicting coastal interests (navigation, fish and wildlife habitat, tourism, energy development) and the availability of funding resources, primarily through the federal Coastal Zone Management Program.

Additional wetland classification and mapping projects have been done by a variety of state and federal agencies, primarily in association with specific river basin studies. The USDA Soil Conservation Service has mapped wetlands in the Northeast Gulf Rivers Basin and the Alabama River Basin. The Ohio River Basin Commission has mapped wetlands along the Ohio River Basin in Kentucky. The Obion, Forked Deer and Hatchie River Basins in west Tennessee have been mapped by several agencies. The St. Johns River Basin in Florida has been extensively mapped by the University of Florida Center for Wetlands, and the Santee and Cooper River Basins in South Carolina are being mapped in great detail by the South Carolina Wildlife and Marine Resources Department. Additional river basin wetlands mapping has been conducted in Mississippi by the Mississippi State University Remote Sensing Center.

In addition to the specific wetland mapping projects outlined above, several federal agencies are involved in generalized wetland mapping in conjunction with their other responsibilities. The USDA-Soil Conservation Service has prepared detailed soils maps covering most of Region IV. These maps delineate soils and can be used as a general indication of wetland areas. The standard U.S. Geological Survey 7.5-minute quadrangle maps also indicate wetland areas on a generalized basis. The U.S. Forest Service has been involved with various mapping efforts concerning forest resources in Region IV. In some instances, these maps indicate wetland areas in relation to forest resources.

The National Wetlands Inventory conducted by the FWS is the most comprehensive mapping effort in Region IV; however, this current inventory has been preceded by other national inventories. In 1906 and 1922 the U.S. Department of Agriculture prepared national inventories to determine wetland areas suitable for agriculture. In 1954, the FWS conducted a national inventory to assess the amount and type of valuable waterfowl habitat. Based on a classification system developed by Martin et al. (1953) specifically for the inventory, the results of the inventory and an illustrated description of the types were published by FWS as Circular #39 (Shaw and Fredine 1956) (see Section 2.2.1). In 1975 the National Park Service completed an inventory of inland wetlands as part of the Natural Landmarks Program. This project was undertaken to identify significant inland wetlands for possible designation as Registered Natural Landmarks. A total of 43 significant wetlands were identified and classified in the eight Region IV states (Goodwin and Niering 1975).

The FWS, as part of the current National Wetlands Inventory, has completed maps in portions of each Region IV state, except Kentucky. Again, most mapping has been done along the coast. However, extensive mapping has also been done in the Mississippi River Basin and along the Tennessee-Tombigbee Waterway in association with the Corps of Engineers. The figures accompanying each of the following sections (2.3.1 through 2.3.8) illustrate the status of the FWS National Wetlands Inventory as of March 1982.

WETLANDS MAPPING IN ALABAMA HAS BEEN DONE IN COASTAL COUNTIES AND ALONG THE TENNESSEE-TOMBIGBEE WATERWAY

Several wetlands mapping projects have been undertaken in recent years by the Alabama Marine Environmental Sciences Consortium in Mobile and Baldwin Counties. The USDA Soil Conservation Service has also mapped wetlands in the Northeast Gulf Rivers Basin and the Alabama River Basin. The U.S. Fish and Wildlife Service (National Wetlands Inventory) has mapped wetlands along the Tennessee-Tombigbee Waterway.

The federal government has been the major impetus behind most wetland mapping projects in Alabama. Using incentives provided by the federal Coastal Zone Management Act, the Alabama Marine Environmental Sciences Consortium has conducted a series of wetland mapping projects over the past seven years in Mobile and Baldwin Counties. Earlier mapping efforts focused on salt and brackish water habitats and ecologically critical areas along the Gulf Coast. However, the most recently completed project focused primarily on the freshwater wetland communities below the 10-foot contour. A current mapping project scheduled for completion in late 1982 will complete the mapping of freshwater habitats in the northern portion of the two coastal counties. Most coastal wetlands mapping has been conducted at a scale of 1:24,000 with a vegetational classification system developed by the state.

Mapping of wetlands in the Northeast Gulf Rivers Basin and the Alabama River Basin was completed in 1976 by the USDA-Soil Conservation Service. These maps, prepared in response to regional and local planning needs, were developed at a scale of 1:24,000 using USGS 7.5-minute topographic maps. County road maps and county photo index maps (Alabama River Basin) were used when USGS maps were unavailable. Additional wetlands mapping or updating of existing maps has not been done by the USDA-SCS.

Mapping along the Tennessee-Tombigbee Waterway has been done by the U.S. Fish and Wildlife Service in conjunction with the Corps of Engineers as part of the National Wetlands Inventory. Based on the FWS classification system (Cowardin et al. 1979), these maps are detailed along the waterway but are incomplete farther away.

Table 2.3.1 summarizes the mapping efforts to date in Alabama.

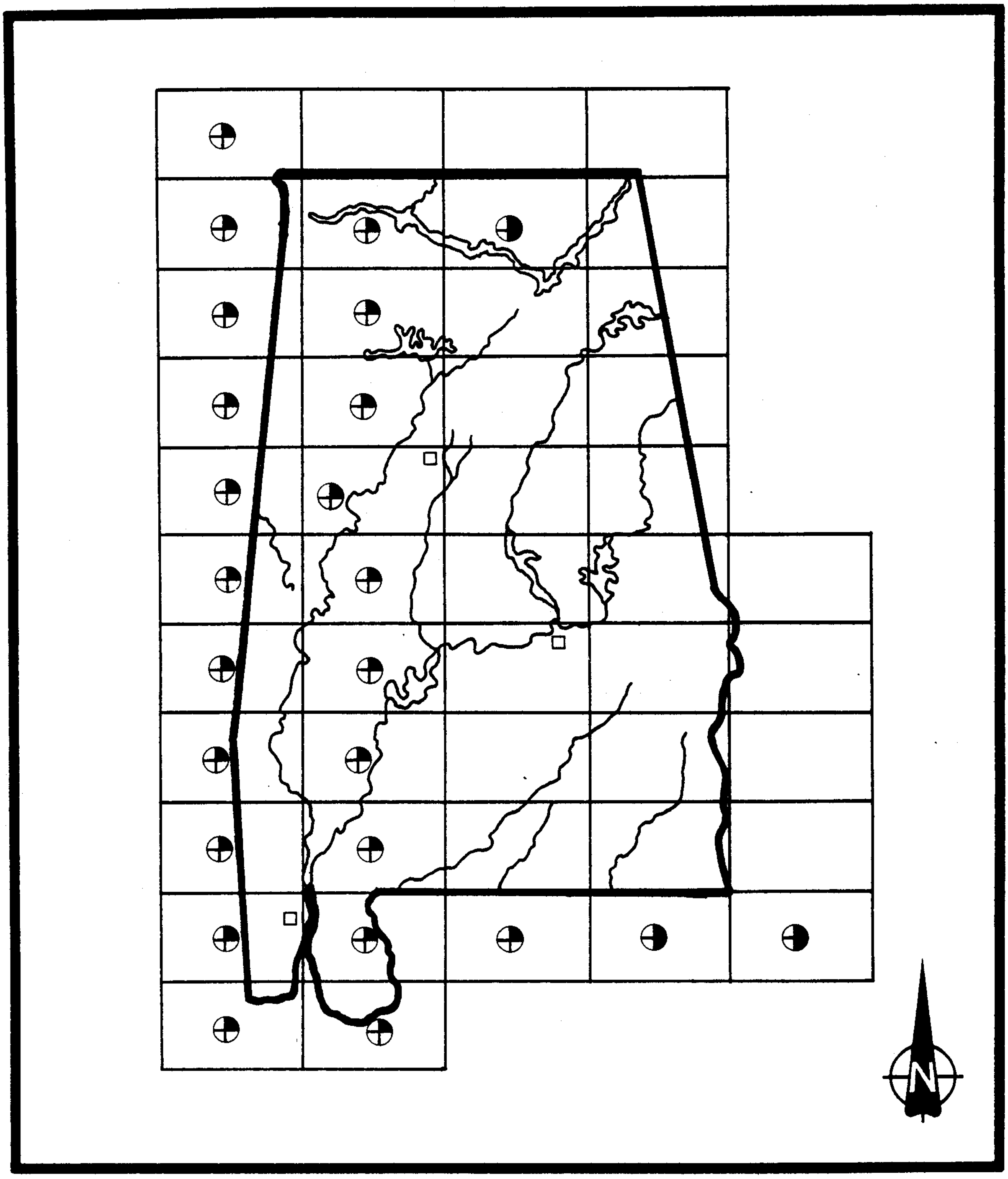
Table 2.3.1. Wetland Inventories in Alabama.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
AL1	All coastal wetlands in Mobile and Baldwin Counties up to the inland/upland boundary (primarily salt/brackish habitats)	Vegetational (species)	1:24,000	1976	1 acre	Alabama Development Office Ala. Coastal Area Board
AL2	All coastal wetlands up to the 50' contour (ecologically critical areas)	Vegetational (community)	1:24,000 1:62,500	1975	1-3 acres	Marine Environmental Science Consortium Dauphin Island Sea Lab
AL3	Northeast Gulf Rivers Basin	Vegetational (Martin et al.)	1:24,000	1976	20 acres	USDA Soil Conservation Service
AL4	Alabama River Basin	Vegetational (Martin et al.)	1:24,000	1976	20 acres	USDA Soil Conservation Service
AL5	Lower Mobile delta (primarily freshwater marshes)	Vegetational (species)	-	1963	-	Ala. Dept. of Conservation - Pittman-Robinson Project (F. X. Lueth)
AL6	All coastal wetlands in Mobile and Baldwin Counties below the 10' contour, south of the Hwy 90 causeway	Vegetational (community)	1:24,000	1981	1 acre	Marine Environmental Science Consortium Dauphin Island Sea Lab

Table 2.3.1 Continued

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
AL7	All coastal wetlands in Mobile and Baldwin Counties below the 10' contour, north of the Hwy 90 causeway	Vegetational (community)	1:24,000	1983	1 acre	Marine Environmental Sciences Consortium Dauphin Island Sea Lab (currently being conducted - available late 1982-1983)
AL8	Tennessee-Tombigbee Waterway (National Wetlands Inventory)	Hydrology/Soils Vegetation (Cowardin et al.) to the subclass and water regime level	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service in conjunction with the U.S. Army Corps of Engineers

Source: Claude Terry & Associates, Inc. 1982.



LEGEND
MAY 1981

- IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE MAP AVAILABLE
- SMALL SCALE MAPS ONLY

Figure 2.3.1. Status of the National Wetlands Inventory in Alabama.

Source: U.S. Fish and Wildlife Service. April 1982.

FLORIDA WETLANDS HAVE BEEN EXTENSIVELY MAPPED, GENERALLY AT LARGE SCALES

Coastal and inland wetlands throughout Florida have been mapped at generally larger scales than other states' mapping efforts. The most extensive mapping of freshwater wetlands has been done by the University of Florida Center for Wetlands in conjunction with state Water Management Districts.

Extensive wetlands mapping has been done throughout Florida, particularly in south Florida. Since south Florida is outside the scope of this EIS these mapping projects will not be discussed in detail; however, information concerning these projects is included in Table 2.3.2.

Mapping projects with the greatest relevancy to this EIS have been conducted by the University of Florida Center for Wetlands and the USDA Soil Conservation Service. In 1976, the Center for Wetlands mapped forested wetlands throughout the state at a scale of 1:500,000. Although several categories of wetlands were classified for that project, all categories were mapped as forested wetlands. The USDA-SCS also mapped wetlands in the Northeast Gulf Rivers Basin in 1976. Based on vegetative community and/or soil types, the USDA-SCS project provided maps in greater detail at a scale of 1:24,000. In 1979, the Center for Wetlands prepared wetland maps for the St. Johns River Water Management District (northeast Florida). Again, these maps were prepared at the relatively large scales of 1:63,360 (1 inch = 1 mile) and 1:253,440 (1 inch = 4 miles). However, this recent mapping effort by the Center for Wetlands provided greater detail through the use of several freshwater wetland categories based on vegetational communities.

The U.S. Fish and Wildlife Service has also been active in wetlands mapping in Florida as part of the National Wetlands Inventory. Most of south Florida has been completely mapped at both scales (1:24,000 and 1:100,000). Draft maps in both scales have recently been completed for northwest Florida.

Table 2.3.2 summarizes the mapping efforts to date in Florida.

Table 2.3.2 Wetland Inventories in Florida.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
F1	Wetlands in the Kissimmee-Everglades Basin of south Florida	Vegetational community (Univ. of Fla.)	1:500,000 1:250,000 1:154,000 1:77,116	-	-	University of Florida - Center for Wetlands
F2	Forested wetlands throughout the state	Vegetational community/hydrology (Univ. of Fla.)	1:500,000	1976	10 acres	University of Florida - Center for Wetlands
F3	Northeast Gulf River Basin	Vegetational community/ soils (FDNR)	1:24,000	1976	-	USDA Soil Conservation Service
F4	Central and Southern Florida Flood Control District	Vegetational community/ hydrology	1:500,000 1:24,000	1976	10 acres 2 acres	South Florida Water Management District
F5	Coastal wetlands	Vegetational community (Anderson et al.)	1:125,000	1975	40 acres	Fla. Dept. of Natural Resources - Bureau of Coastal Zone Planning
F6	Wetlands in the St. Johns River Water Management District (northeast Florida)	Vegetational community (Univ. of Fla.)	1:63,360 1:253,440	1979	15 acres	University of Florida - Center for Wetlands
F7	South and Northwest Florida (National Wetlands Inventory)	Hydrology/Soils/ Vegetation (Cowardin et al.) to the subclass and water regime level.	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service

Source: Claude Terry & Associates, Inc. 1982.

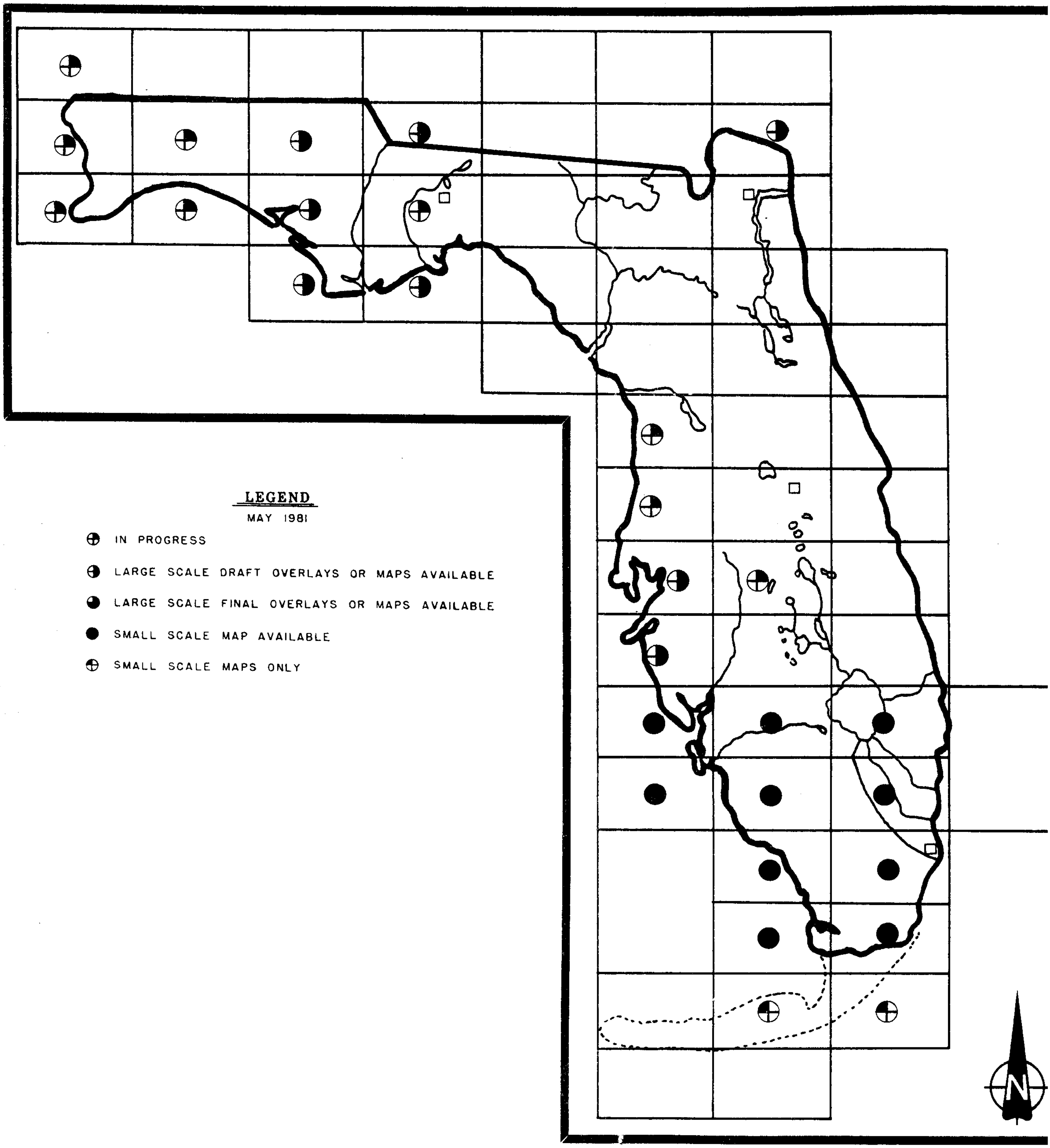


Figure 2.3.2. Status of the National Wetlands Inventory in Florida.

Source: U.S. Fish and Wildlife Service. April 1982.

COASTAL AREAS EXTENSIVELY MAPPED; INLAND AREAS MAPPED WITH LANDSAT DATA

The coastal areas of Georgia, including the barrier islands, have been extensively mapped by the Georgia Coastal Resources Division, the USDA Soil Conservation Service and the U.S. Fish and Wildlife Service. The entire state has been mapped using LANDSAT imagery; these maps provide generalized wetland locations without detailed classification.

The most detailed wetlands mapping in Georgia has been done for the eight coastal counties by a variety of state and federal agencies. The earliest mapping project was completed by the USDA Soil Conservation Service in 1977. This project used aerial photographs to classify and map coastal wetlands at the scales of 1:20,000 and 1:24,000, resulting in computer-reproduced maps as part of the Map Information Assembly and Display System (MIADS). Additional coastal wetlands mapping has been completed for the coastal barrier islands by a variety of agencies and organizations. Prepared as part of individual resource planning studies, these maps are generally available from the Georgia Coastal Resources Division of the Department of Natural Resources.

The U.S. Fish and Wildlife Service has also mapped coastal Georgia as part of the National Wetlands Inventory. These maps are based on the classification system developed by Cowardin et al. (1979) and are available at scales of 1:24,000 and 1:100,000. In Georgia, wetlands were classified only to the class level (see Section 2.2.1).

Wetlands mapping for the inland areas of Georgia has only been done on a generalized basis using LANDSAT imagery. In 1977, the Georgia Office of Planning and Research (GaDNR) prepared statewide maps indicating vegetative cover and land use. Based on LANDSAT imagery, these maps provide delineation of bottomland wetlands. Additional delineations according to vegetative communities are possible, depending on the time (season, tidal level) of photography. The USDA-SCS has recently completed generalized wetlands mapping as part of a Southwest River Basin Study covering portions of 32 Georgia counties. Prepared at a scale of 1:250,000, this river basin study is based on color-enhanced LANDSAT data.

The Georgia Department of Community Affairs is currently involved in another mapping project using LANDSAT imagery. Using data from March, 1981, this mapping project is being done on three levels: statewide (1:500,000); for three Area Planning and Development Commissions (APDC) (1:100,000); and three counties (1:50,000). These maps will provide generalized land cover and land use information similar to previous projects involving LANDSAT imagery.

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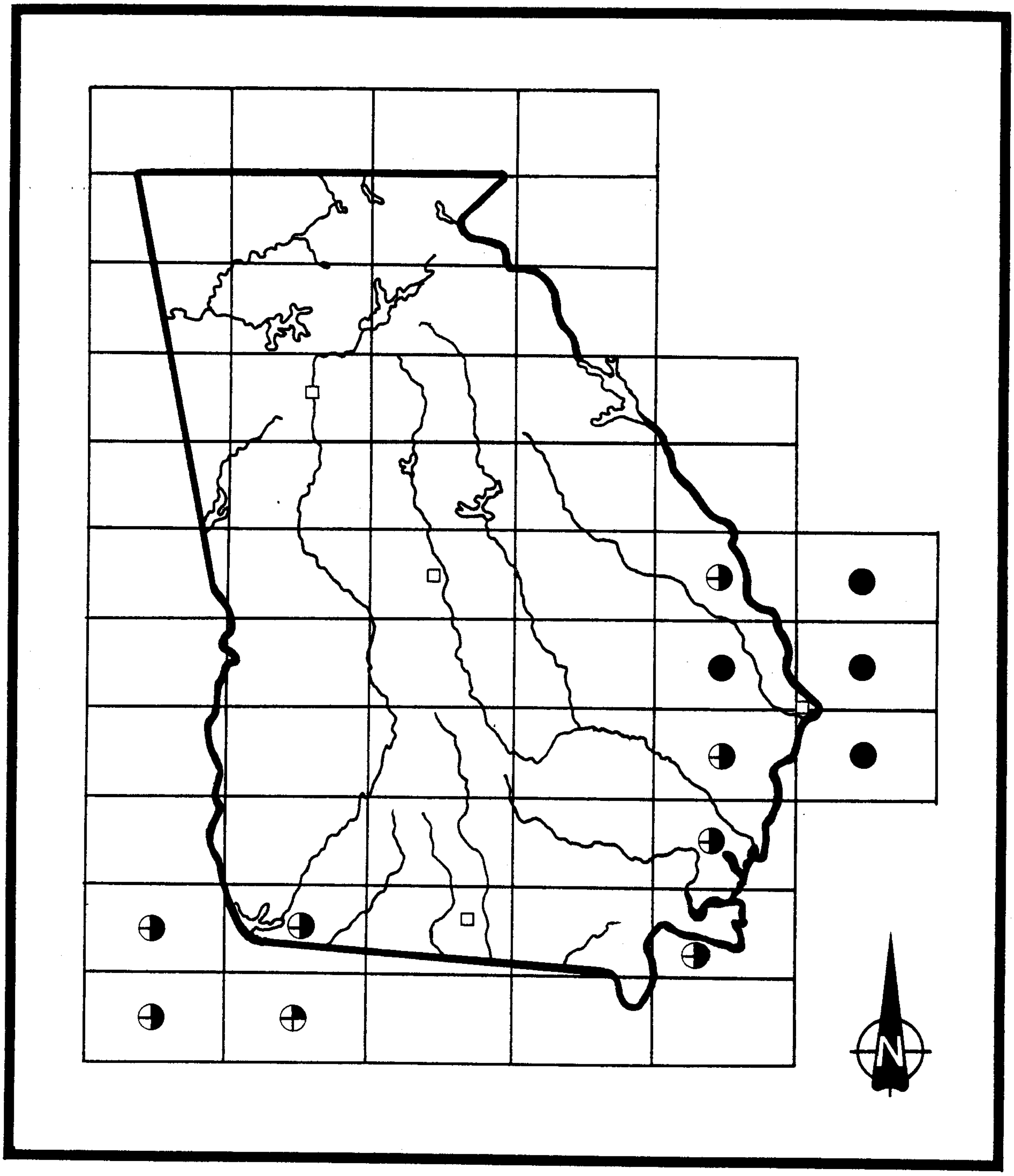
Table 2.3.3 Wetland Inventories in Georgia.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
G1	Coastal wetlands (eight coastal counties)	Vegetational community/ hydrology/soils (Martin et al.)	1:20,000 1:24,000	1977	3-10 acres	USDA Soil Conservation Service
G2	Coastal wetlands (National Wetlands Inventory)	Hydrology/Soils/ Vegetation (Cowardin et al.) classified only to the class level	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service
G3	Coastal wetlands on barrier islands	-	-	-	-	Ga. Dept. of Natural Resources, Coastal Resources Division
G4	Statewide land classification/vegetative cover	LANDSAT data	varied	1977	1 acre	Ga. Dept. of Natural Resources, Office of Planning & Research
G5	Selected areas of the state (Northeast, South and Southwest APDCs)	LANDSAT data	1:100,000 1:50,000	1982	1 acre	Ga. Dept. of Community Affairs

Source: Claude Terry & Associates, Inc. 1982.



LEGEND
MAY 1981

IN PROGRESS

LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE

LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE

SMALL SCALE MAP AVAILABLE

SMALL SCALE MAPS ONLY

Figure 2.3.3. Status of the National Wetlands Inventory in Georgia.

Source: U.S. Fish and Wildlife Service. April 1982.

LIMITED MAPPING FOCUSED ON THE OHIO RIVER AND THE KENTUCKY COALFIELDS

The Ohio River Basin Commission has mapped wetlands along the Ohio River. The EPA, in conjunction with the Kentucky Nature Preserves Commission, has mapped wetlands in the Eastern and Western Kentucky coalfields. However, a comprehensive wetlands mapping effort has not been undertaken in Kentucky.

While wetlands mapping efforts have been recent in Kentucky, they generally have not been extensive or comprehensive. In 1977 the Ohio River Basin Commission completed wetlands mapping along the Ohio River in Kentucky. Using the FWS Circular #39 classification system, wetlands were mapped at a scale of 1:24,000 (USGS quadrangle maps). While these maps are detailed along the Ohio River, inland areas are less detailed.

The EPA in conjunction with the Kentucky Nature Preserves Commission has prepared maps of the Western and Eastern Kentucky coalfields (Environmental Atlas Series). Using a generalized classification system, wetlands were mapped at a scale of 1:24,000, primarily from aerial photographs. The maps of the Eastern Kentucky coalfields (1979) detail very few wetlands; the maps for the Western Kentucky coalfields (1980) contain more extensive wetlands mapping.

Additional projects have been undertaken in Kentucky providing detailed wetlands mapping on a more localized level. The University of Louisville is currently involved in a research project also concerning the Western Kentucky coalfields. As part of this project a detailed analysis of wetlands at three specific sites in Hopkins, Muhlenberg and Henderson Counties has been completed by Mitsch et al. (1982). As a continuance of that project, an atlas of wetlands for a 1,500 mi^2 region of intense surface mining is now in draft stage. This mapping effort uses a modified FWS classification system and provides more detail than the EPA project.

The Kentucky Nature Preserves Commission has also prepared maps indicating wetlands in an oil shale region near the Eastern Kentucky coalfields (Knob Study 1981). This mapping effort was prepared at a scale of 1:24,000.

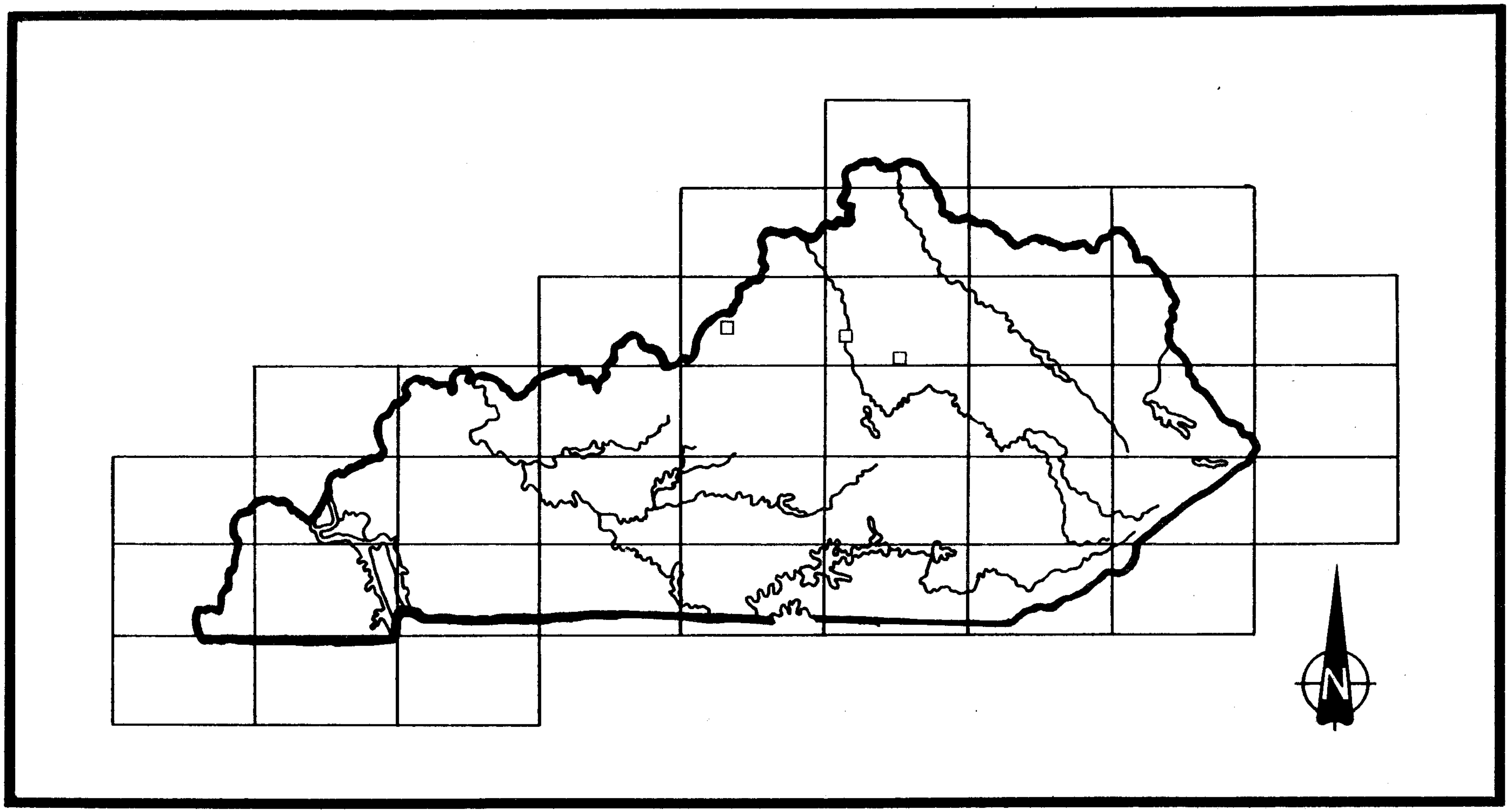
The FWS, as part of a Unique Ecosystem Study, has assembled detailed information, including maps, on bottomland hardwood areas in Hickman and Fulton Counties. This project was undertaken to identify and quantify the acreage of particular habitats. These maps include detailed information on land ownership. The FWS has not done any mapping in Kentucky as part of the National Wetlands Inventory.

Table 2.3.4 summarizes the mapping efforts to date in Kentucky.

Table 2.3.4 Wetland Inventories in Kentucky.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
K1	Ohio River Basin	FWS - Circular 39	1:24,000	1977	-	Ohio River Basin Commission
K2	Western Kentucky Coalfields	Vegetational/ hydrological	1:24,000	1980	-	EPA - Kentucky Nature Preserves Commission
K3	Eastern Kentucky Coalfields	Vegetational/ hydrological	1:24,000	1979	-	EPA - Kentucky Nature Preserves Commission
K4	Oil Shale Region/ Eastern Kentucky Coalfields (limited)	Vegetational/ hydrological	1:24,000	1981	-	Kentucky Nature Preserves Commission (Knobs Study)
K5	Western Kentucky Coalfields (1500 mi^2 region in heavy surface mining)	Vegetational/ hydrological (modified FWS)	1:24,000	1982	-	University of Louisville-funded by OSM and OWRT (Dept. of Interior)
K6	Hickman and Fulton Counties	FWS		1981	-	FWS

Source: Claude Terry & Associates, Inc. 1982.



LEGEND
MAY 1981

- IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE MAP AVAILABLE
- SMALL SCALE MAPS ONLY

Figure 2.3.4. Status of the National Wetlands Inventory in Kentucky.

Source: U.S. Fish and Wildlife Service. April 1982.

EXTENSIVE MAPPING COMPLETED IN MISSISSIPPI

The National Wetlands Inventory has completely mapped areas along the Mississippi River and partially mapped areas along the Tennessee-Tombigbee Waterway. Coastal wetlands and marshes have been mapped in the three coastal counties. The Mississippi State University Remote Sensing Center has completed wetland mapping projects along various inland waterways.

The most extensive wetlands mapping in Mississippi has been completed as part of the National Inventory by the U.S. Fish and Wildlife Service. Maps have been completed at two scales (1:24,000 and 1:100,000) within the Mississippi River Basin. Large-scale maps (1:24,000) have also been completed along the Tennessee-Tombigbee Waterway in conjunction with the Corps of Engineers. These maps are generally detailed along the waterway and less detailed away from the canal. Partial mapping has also been completed as part of the National Wetlands Inventory in southwest Mississippi.

Coastal wetlands and marshes have also been mapped in Mississippi. Wetlands in the three coastal counties, Jackson, Harrison and Hancock, were mapped in 1973 by the Mississippi Marine Resources Council. Prepared at a scale of 1:24,000, these maps indicate the generalized location of coastal wetlands for jurisdictional purposes. Coastal marshes associated with the St. Louis, Biloxi and Pascagoula estuarine systems were also mapped in 1973 by the Gulf Coast Research Laboratory. Saltwater wetlands were the primary focus of both of these mapping efforts although freshwater wetlands may have been included.

Additional mapping of inland freshwater wetlands has been done by the Remote Sensing Center at the Mississippi State University. The wetlands mapping project undertaken at MSU vary in scope and scale and are usually prepared in conjunction with various federal agencies, such as the U.S. Army Corps of Engineers and the Federal Energy Regulatory Commission (Miller 1982).

Table 2.3.5 summarizes the mapping efforts to date in Mississippi.

Table 2.3.5 Wetland Inventories in Mississippi.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
M1	Coastal Wetlands in Jackson, Harrison and Hancock Counties	no formal classification	1:24,000	1973	1 acre	Miss. Marine Resources Council (Bureau of Marine Resources)
M2	Coastal Marshes (St. Louis, Biloxi and Pascagoula estuarine systems)	Vegetational (Penfound & Hathaway)	1:62,500	1973	-	Gulf Coast Research Laboratory, Ocean Springs, MS
M3	Various inland waterways and river basins (localized)	Microtopography/ vegetative	Varied (1:12,000 1:24,000)	- -	1-5 acres	Mississippi State Univ. Remote Sensing Center
M4	Tennessee-Tombigbee Waterway/Mississippi River Basin (National Wetlands Inventory)	Hydrology/Soils Vegetation (Cowardin et al.) to the subclass and water regime level	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service

Source: Claude Terry & Associates, Inc. 1982.

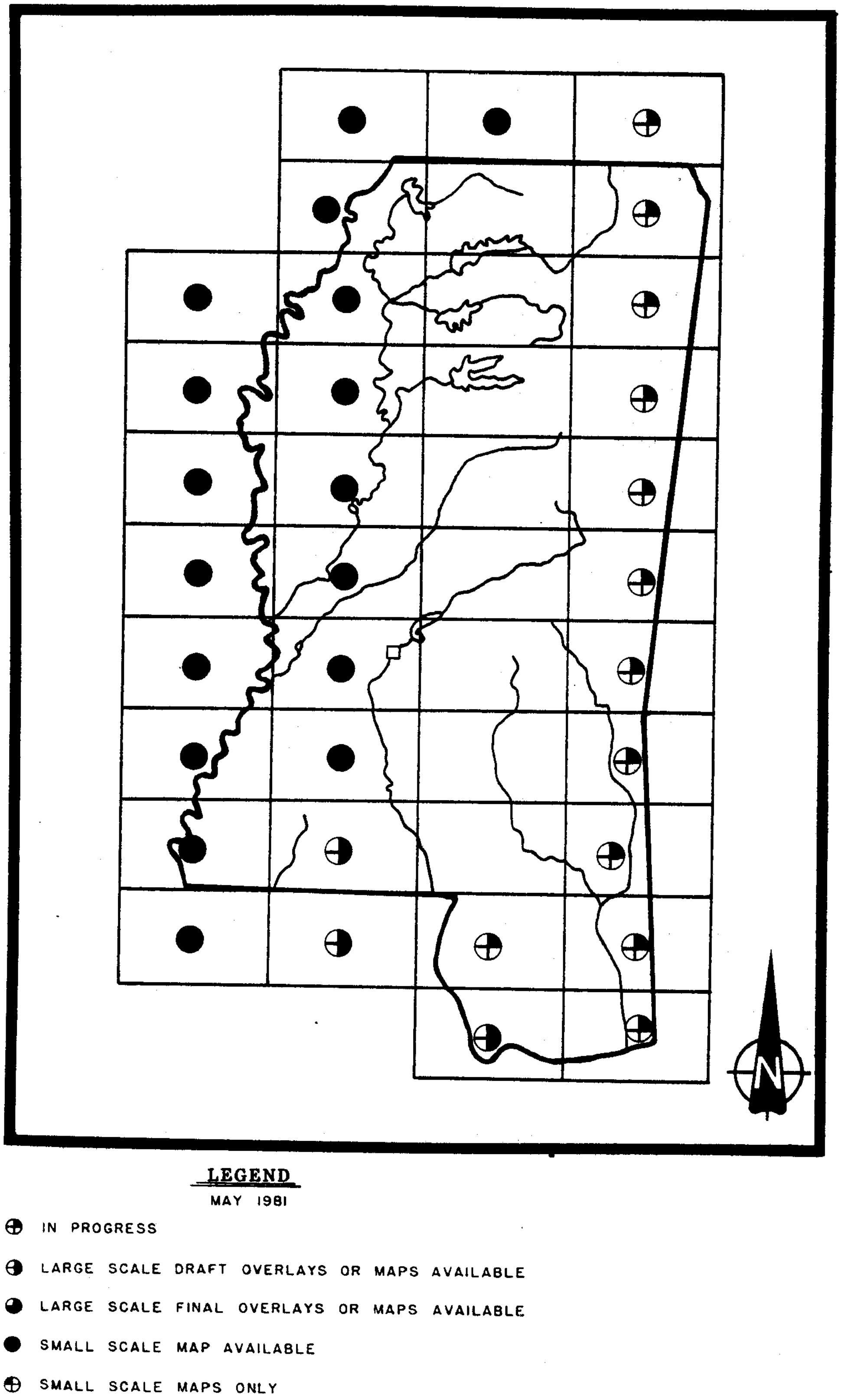


Figure 2.3.5. Status of the National Wetlands Inventory in Mississippi. Source: U.S. Fish and Wildlife Service. April 1982.

LIMITED MAPPING HAS BEEN DONE IN THE NORTH CAROLINA COASTAL PLAIN

Mapping efforts have been relatively limited in North Carolina, confined primarily to the coastal plain. Wilson (1962) and Richardson (1981) have mapped wetlands at a small scale (1:250,000) along the entire coastal plain of North Carolina. The U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency have prepared more detailed maps on a smaller area of the North Carolina coast.

One of the first extensive wetlands mapping efforts in North Carolina was conducted by Wilson in the late 1950's. This mapping project was one of the initial applications of the FWS Circular #39 classification system. With this project, wetlands in the 41 Coastal Plain Counties were mapped at a scale of 1:250,000. The N.C. Office of Coastal Management is currently reproducing these maps at a larger scale of 1:24,000. The original mapping effort is important in that it has formed a basis for subsequent studies concerning historical changes in North Carolina wetlands.

In 1979, Richardson used LANDSAT imagery to identify and map pocosins in the North Carolina coastal plain. A final map was produced at a scale of 1:250,000, although working maps were prepared on North Carolina Department of Transportation county maps (1:126,720).

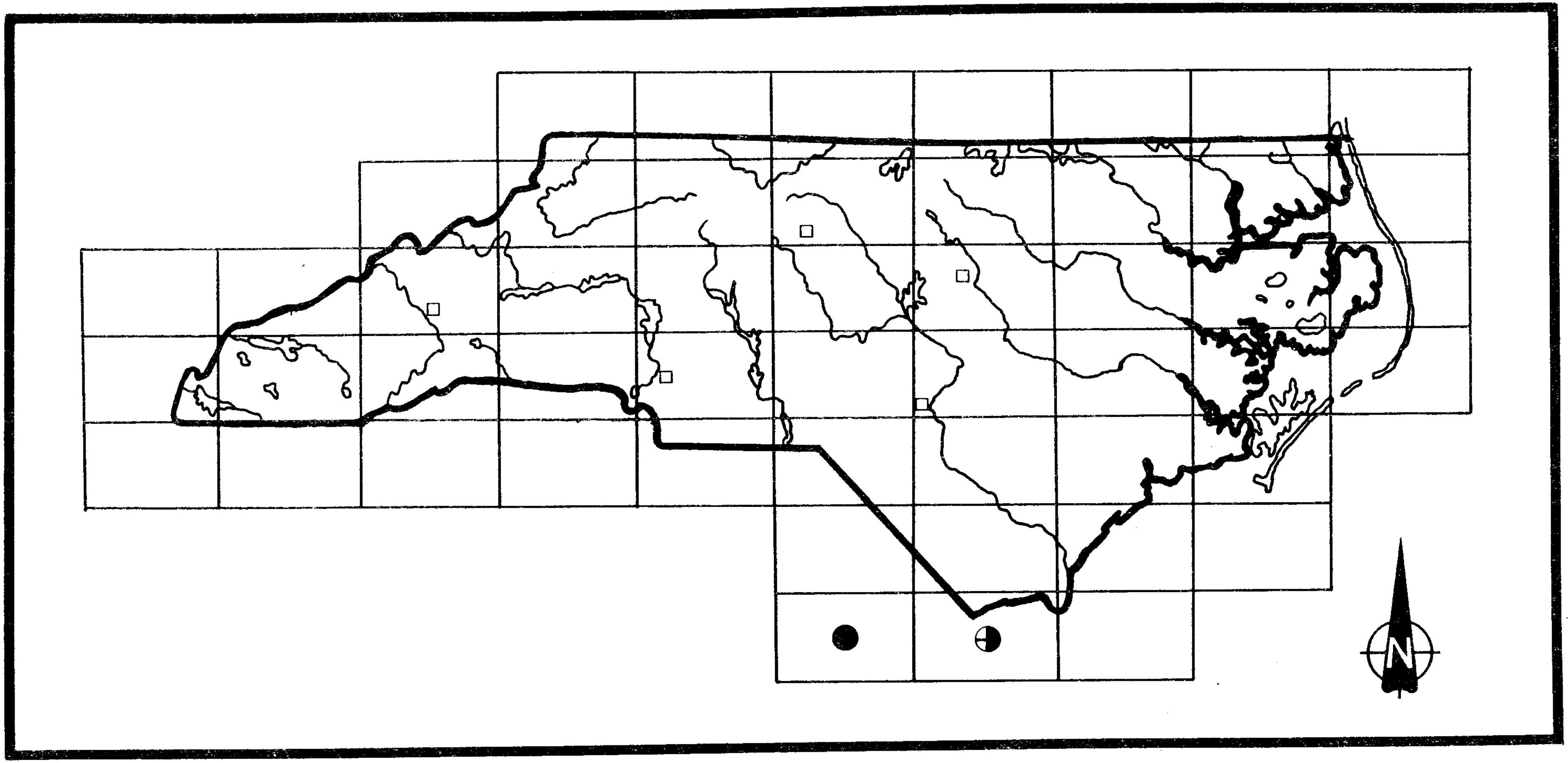
More recent mapping efforts have been undertaken in North Carolina but on a less extensive scale than previous efforts. The EPA is currently mapping wetlands in the several counties located between Albermarle and Pamlico Sounds. Prepared at a scale of 1:24,000 from 1981 color-infrared aerial photographs, these maps are being prepared in response to extensive land clearing activities in this area. The FWS has also prepared large-scale maps (1:24,000) for the Currituck Sound area as part of the National Wetlands Inventory. This represents the only mapping in North Carolina for the National Wetlands Inventory.

Table 2.3.6 summarizes the mapping efforts to date in North Carolina.

Table 2.3.6 Wetland Inventories in North Carolina.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
NC1	Coastal Plains of N.C. (41 counties)	Vegetational (FWS Circular #39)	1:250,000	1962	40 acres	N.C. Office of Coastal Management
NC2	Currituck Sound (National Wetlands Inventory)	Hydrology/Soils/Vegetation (Cowardin et al.) to the subclass and water regime level	1:24,000	1982	1 acre	U.S. Fish and Wildlife Service
NC3	Pocosins of the N.C. coastal plain (41 counties)	Vegetational (Wilson 1962) Land use	1:250,000	1980	-	Duke University, School of Forestry
NC4	Peninsula between Albemarle and Pamlico Sounds	Vegetational	1:24,000	1982	1 acre	U.S. Environmental Protection Agency

Source: Claude Terry & Associates, Inc. 1982.



LEGEND

MAY 1981

- IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE MAP AVAILABLE
- SMALL SCALE MAPS ONLY

Figure 2.3.6. Status of the National Wetlands Inventory in North Carolina.

Source: U.S. Fish and Wildlife Service. April 1982.

ONLY THE COASTAL PLAIN OF SOUTH CAROLINA HAS BEEN MAPPED

The U.S. Fish and Wildlife Service and the S.C. Wildlife and Marine Resources Department are the only agencies involved with wetlands mapping in South Carolina. Only the coastal plain and tidal areas of South Carolina have been mapped.

The South Carolina Wildlife and Marine Resources Department (SCWMRD) prepared maps of all non-forested tidal wetlands in 1976. Prepared at a scale of 1:24,000 with a minimum mapping area of one acre, these maps were never officially published. A current mapping effort is being undertaken by the SCWMRD in conjunction with the U.S. Fish and Wildlife Service concerning the Santee and Cooper River Basins. Initiated in anticipation of a proposed river diversion project, this mapping project is based on the FWS classification system (Cowardin et al. 1979), including the use of special modifiers to provide greater detail. These maps are being prepared at a scale of 1:24,000 and should be available by July 1982.

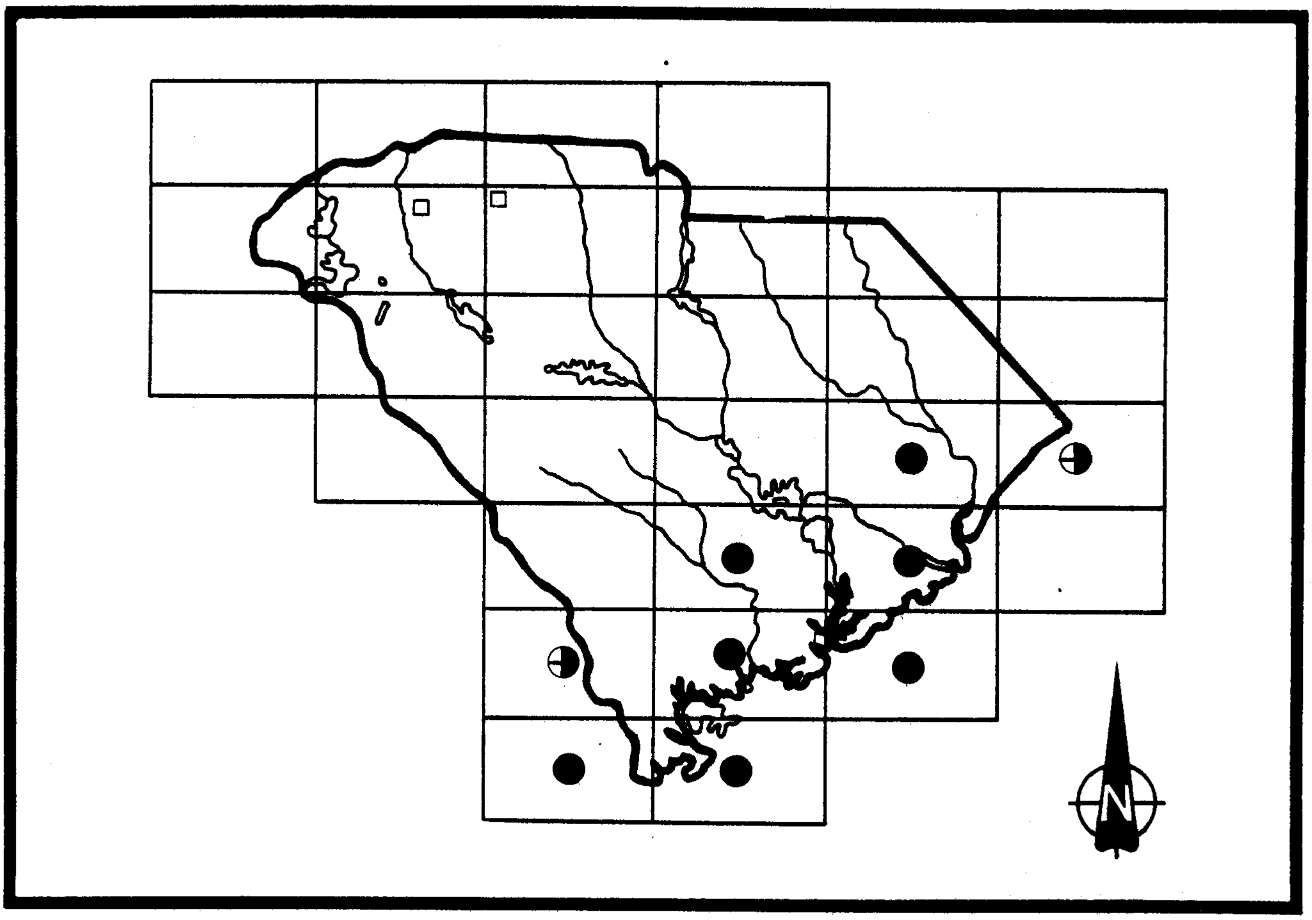
The FWS has also prepared extensive wetland maps of the South Carolina coastal plain as part of the National Wetlands Inventory. These maps are available at both large (1:24,000) and small scales (1:100,000).

Table 2.3.7 summarizes the mapping efforts to date in South Carolina.

Table 2.3.7 Wetland Inventories in South Carolina.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
SC1	Non-forested tidal wetlands (not published)	Vegetational	1:24,000	1976	1 acre	S.C. Wildlife and Marine Resources Department
SC2	Santee and Cooper River Basins	Hydrology/Soils Vegetation (Cowardin et al.) to the subclass level including special modifiers	1:24,000	1982	1-3 acre	S.C. Wildlife and Marine Resources Dept/ U.S. Fish and Wildlife Service
SC3	Coastal Plains (National Wetlands Inventory)	Hydrology/Soils Vegetation (Cowardin et al.) to the class level only	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service

Source: Claude Terry & Associates, Inc. 1982.



LEGEND
MAY 1981

- IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- SMALL SCALE MAP AVAILABLE
- SMALL SCALE MAPS ONLY

Figure 2.3.7. Status of the National Wetlands Inventory in South Carolina.
Source: U.S. Fish and Wildlife Service. April 1982.

2.0 WETLAND DEFINITIONS AND INVENTORY

2.3 Wetland Inventories in Region IV

2.3.8 Tennessee

ONLY WETLANDS IN WEST TENNESSEE HAVE BEEN MAPPED

Several wetland mapping projects have been undertaken in Tennessee, all located in west Tennessee (Mississippi River Basin). West Tennessee is the only portion of the state with extensive wetlands.

Several federal agencies have undertaken wetland mapping projects in west Tennessee. The U.S. Geological Survey and the Tennessee Valley Authority completed a joint wetlands mapping effort in four selected west Tennessee sites; Reelfoot Lake, Duck River, Hatchie River Bottoms and the White Oak Swamp. Using high-altitude, color infrared photographs, wetland areas as small as 1 acre (0.5 ha) were mapped at a scale of 1:24,000 (Carter et al. 1979).

The Corps of Engineers (Memphis District) have mapped wetlands in the Obion and Forked Deer River basins in west Tennessee. Using a classification system based on timber types, these maps have also been prepared at a scale of 1:24,000. The U.S. Fish and Wildlife Service, as part of the National Wetlands Inventory has also completed mapping in the Mississippi River basin in west Tennessee. Prepared at two scales (1:24,000 and 1:100,000), these maps use the classification system specifically developed for the National Wetlands Inventory (Cowardin et al. 1979).

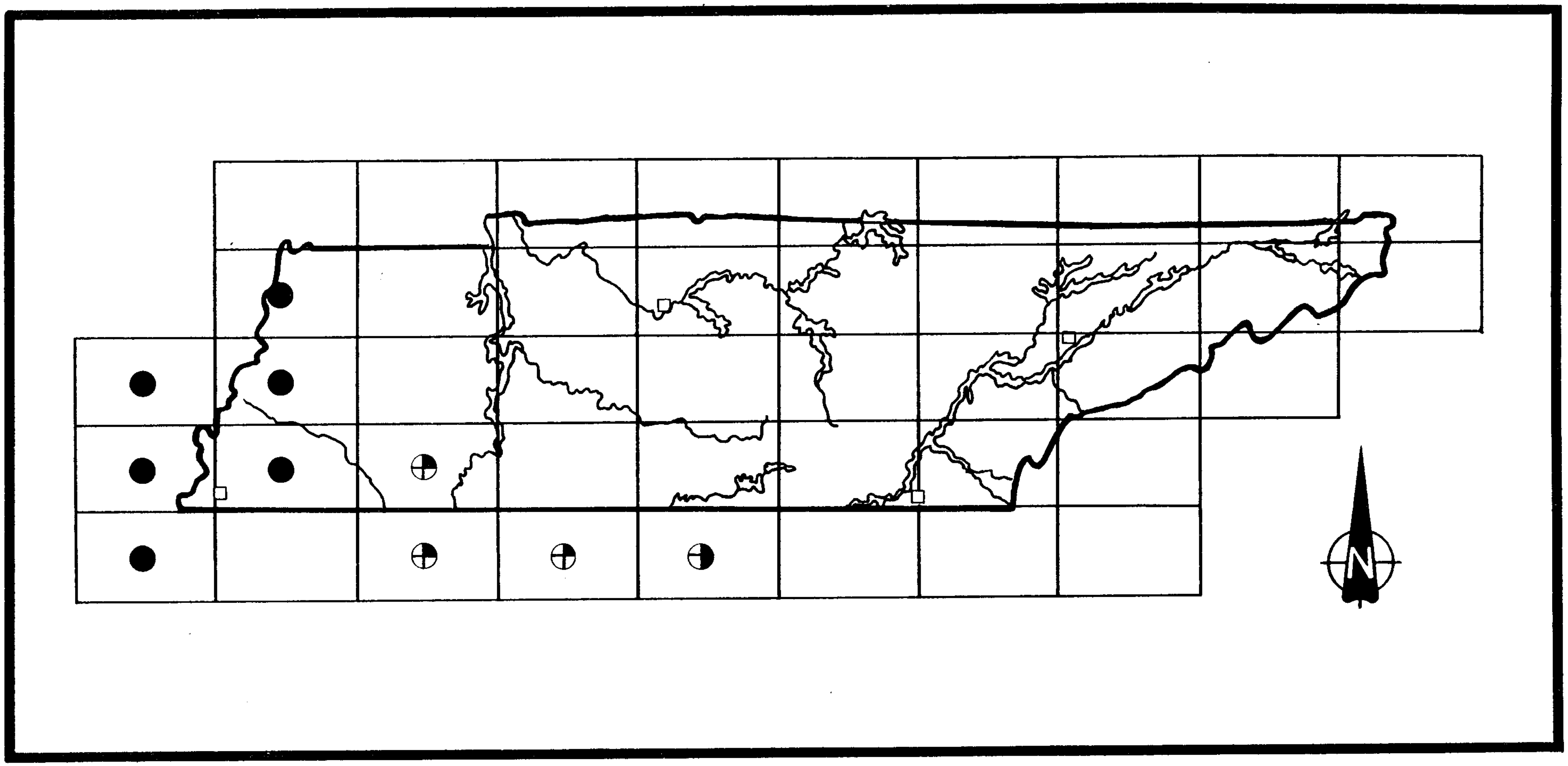
Additional mapping of wetlands may have been done as part of other comprehensive resource mapping in Tennessee. However, since these efforts vary greatly in their detail concerning wetlands, they are not included in this summary.

Table 2.3.8 summarizes the wetland mapping efforts to date in Tennessee.

Table 2.3.8 Wetland Inventories in Tennessee.

	Inventory Coverage	Classification	Scale	Date	Resolution	Agency
T1	Selected areas in West Tennessee (Reelfoot Lake, Duck River, Hatchie River Bottoms and White Oak Swamp)	Vegetation/ hydrology (developed for the Tennessee Valley Region)	1:24,000	1978	1 acre	U.S. Geological Survey/ Tenn. Valley Authority
T2	Obion/Forked Deer River Basins	Timber types	1:24,000	1981	-	U.S. Army Corps of Engineers (Memphis District)
T3	West Tennessee/ Mississippi River Basin (National Wetlands Inventory)	Hydrology/Soils Vegetation (Cowardin et al.) to the subclass and water regime level.	1:24,000 1:100,000	1982	1 acre	U.S. Fish and Wildlife Service

Source: Claude Terry & Associates, Inc. 1982.



LEGEND

MAY 1981

- ⊕ IN PROGRESS
- LARGE SCALE DRAFT OVERLAYS OR MAPS AVAILABLE
- LARGE SCALE FINAL OVERLAYS OR MAPS AVAILABLE
- ● SMALL SCALE MAP AVAILABLE
- ⊕ SMALL SCALE MAPS ONLY

Figure 2.3.8. Status of the National Wetlands Inventory in Tennessee.

Source: U.S. Fish and Wildlife Service. April 1982.

A MODIFIED VERSION OF THE FWS SYSTEM IS USED FOR THIS STUDY

Many classification systems have been proposed and used nationally and throughout Region IV. They vary from broad, general systems to extremely complex systems. The latter are necessary to distinguish adequately between types and characteristics of wetlands.

As indicated by previous sections, many classification systems have been used to delineate wetlands in the southeastern United States. The basis for these systems varies significantly with some based on soils, others on vegetation and still others on hydrologic regime. In attempting to select a classification for use on wastewater management issues, several considerations were assessed.

Emphasis was placed on systems used by federal agencies. Since this EIS will ultimately lead to procedures for assessing wetlands disposal of wastewater (if deemed appropriate), significant consideration was given to classification systems used or adopted by federal agencies, particularly EPA. EPA has joint responsibility with the Corps of Engineers for the 404 permitting process, so there is some rationale for using the COE system. However, while the COE wetland typing system (Table 2.2.2) is used by some state and federal agencies, it is based almost entirely on vegetative cover. This could be limiting in some respects when dealing with wastewater management since soils and hydrology are also extremely important.

Circular #39 describes the system that has been used by the FWS since 1956 and was based on the system proposed by Martin et al. (1953). This system has many advantages since it is easy to understand and classifies wetlands in common terms. But again the system has some limitations for wastewater management, particularly due to lack of differentiation between significantly different wetland ecosystems.

Another classification system that has been widely used was proposed by Penfound (1952). Though not adopted by federal agencies, it has been used by state agencies and as a basis for other classification work.

Based on information gathered during Phase I, it appears that EPA will be utilizing the classification system adopted by the Fish and Wildlife Service (Cowardin et al. 1979). This system is being used for the National Wetlands Inventory conducted by FWS. Other agencies are adopting this system as well. In assessing the applicability of this system to wastewater management decisions, it has been evaluated as the system most appropriate for use. The two major reasons for selection are: 1) it incorporates wetland characteristics that are important to wastewater management decisions (e.g., vegetation, hydrology, soils); and 2) EPA and other agencies are moving to adopt it.

Some modifications or clarifiers are being incorporated into the system for application to this EIS. The major limitations of the new FWS system relate to its complexity. Without direct training with the system, it is

2.4 Continued

difficult to understand and apply and is therefore limited in its usefulness to people who have not been trained. Scale problems have also been encountered since the scale used often precludes small wetlands. In an effort to enhance the understanding and applicability of the system, the matrix shown by Table 2.4 has incorporated common terminology and dominant assemblages. The characteristic flora listed in Table 2.4 were compiled by the U. S. Fish and Wildlife Service, Region IV based on common wetland types identified. Several important modifiers such as water regime, water chemistry and soils provide further differentiation of wetland types and should be ultimately incorporated as the system is used.

Because hydrology is an overriding factor which defines the character of many wetland elements, two basic conditions (hydrologically isolated and hydrologically open) are used to group wetland types. Some wetlands may fall into both categories, depending on locations. Those wetlands with only intermittent connections with other water bodies are grouped as hydrologically isolated systems.

The matrix provided, however, attempts to indicate how common wetlands terminology such as bogs, swamps, and marshes correlate to FWS terminology such as Palustrine evergreen needle-leaved wetland. This is an important key to understanding and using the FWS system. Secondly, the concept of predominant assemblages has been incorporated to relate common and FWS terms to typical vegetation types within Region IV. This should help identify the proper FWS term, since most systems are primarily recognized by their predominant vegetation type.

The proposed EIS classification system should provide sufficient detail to classify and evaluate a wetland system properly and yet allow use by a wide range of engineers and planners. For example, if a system is commonly known to be a cattail marsh, it can properly be keyed into the FWS classification as a palustrine emergent wetland. Then, through the identification of other key modifiers, the system can be properly defined and evaluated. The concept of hydrologically isolated and hydrologically open provide a starting point for evaluation of wetlands for wastewater management.

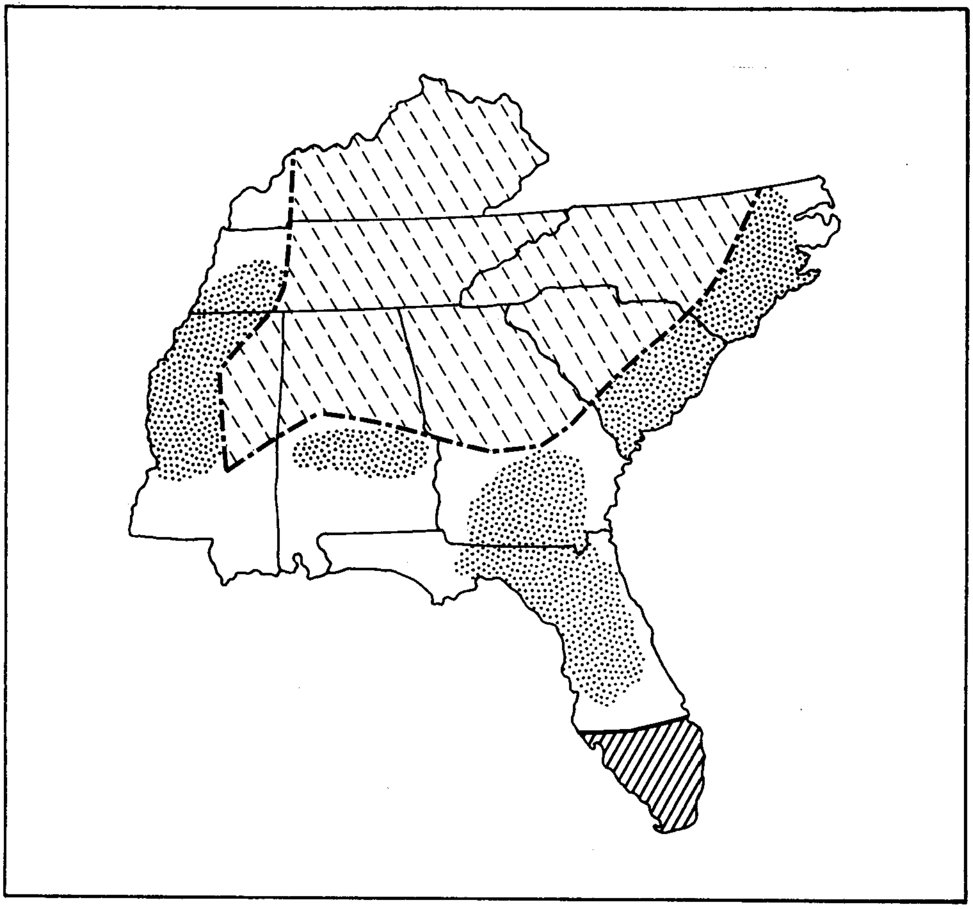
Table 2.4. Wetland EIS Classification Matrix.

Common Wetland Types	National Wetlands Inventory (Fish and Wildlife Service)			Characteristic Flora
	System Type	Class	Subclass	Common name (Botanical name)
Hydrologically Isolated System				
Wooded swamp*	Palustrine	Forested wetland	Broad-leaved deciduous	Water tupelo (Nyssa aquatica); swamp black gum (N. biflora); Ogeechee plum (N. ogeche); water elm (Planera aquatica); water, Carolina ash (Fraxinus caroliniana); bald cypress (Taxodium distichum); fetter bush (Lyonia lucida); leatherbush, titi (Cyrilla racemiflora); common alder (Alnus serrulata); wax myrtle (Myrica cerifera); black willow (Salix nigra); buttonbush (Cephalanthus occidentalis); Virginia willow (Itea virginica); overcup oak (Quercus lyrata); red maple (Acer rubrum var. drummondii)
Cypress dome	Palustrine	Forested wetland	Needle-leaved deciduous	Bald cypress (Taxodium distichum); pond cypress (T. ascendens)
Bog, pocosin, Carolina bay, evergreen shrub-bog, bay head	Palustrine	Scrub-shrub wetland	Broad-leaved deciduous	Leatherbush, titi (Cyrilla racemiflora); fetterbush (Lyonia lucida); inkberry, holly (Ilex glabra); Zenobia (Zenobia pulverulenta); pond pine (Pinus serotina); red maple (Acer rubrum); bay, bay magnolia, white bay (Magnolia virginiana); loblolly bay (Gordonia lasianthus); southern white cedar (Chamaecyparis thyoides); swamp bay (Persea borbonia); wax myrtle (Myrica cerifera); pepperbush (Clethra alnifolia)
Shrub swamp	Paulstrine	Scrub-shrub wetland	Broad-leaved deciduous	Common alder (Alnus serrulata); swamp privet (Forestiera acuminata); black willow (Salix nigra); buttonbush (Cephalanthus occidentalis); Carolina willow (S. caroliniana); Virginia willow (Itea virginica)
Pine flatwoods, pine swamp	Palustrine	Forested wetland	Needle-leaved evergreen	Pond pine (Pinus serotina); loblolly pine (P. taeda); slash pine (P. elliottii); longleaf pine (P. palustris); wax myrtle (Myrica cerifera); titi, leatherbush, (Cyrilla racemiflora)
Shallow freshwater marsh, deep freshwater marsh, inland marsh, bogue, prairie, savannah	Palustrine	Emergent wetland	Persistent; non-persistent	Cattail (Typha spp.); bulrush (Scirpus spp.); maidencane (Panicum hemitoman); lizards tail (Saururus cernuus); alligatorweed (Alternanthera philoxeroides); sedge (Carex spp., Cyperus spp., Rhynchospora spp.); rush (Juncus spp., Eleocharis spp.); reed (Arundo donax, Phragmites communis); aster (Aster); beggartick, stick-tight (Bidens spp.); water hemlock (Cicuta maculata); sawgrass (Cladium jamaicense); barnyard grass (Echinochloa crusagalli); spikerush (Eleocharis spp.); joe-pye weed, late boneset (Eupatorium spp.), mallow (Hibiscus spp.); iris (Iris virginica, Iris spp.); purslane (Ludwigia spp.); maidencane, switchgrass (Panicum spp.); joint grass (Paspalum distichum); pelandra (Peltandra virginica); smartweed (Polygonum spp.); pickeralweed (Pontederia cordata); arrowhead (Sagittaria spp.)

*May also be hydrologically open system

Table 2.4. Continued

Common Wetland Types	National Wetlands Inventory (Fish and Wildlife Service)			Characteristic Flora
	System Type	Class	Subclass	Common name (Botanical name)
Savannah, wet prairie	Palustrine	Emergent wetland	Persistent; non-persistent dependent on dominants	Grass pink (Calopogon spp.); coastal milkweed (Asclepias spp.); pitcher plant (Sarracenia spp.); St. Johns' wort (Hypericum spp.) toothache grass (Ctenium spp.); club-moss (Lycopodium prostratum); bog-button (Lachnocaula anceps); sea pinks (Sabatia spp.); yellow-eyed grass (Xyris spp.); meadow-beauty (Rhexia spp.); marsh fleabane (Pluchea spp.); muhly (Muhlenbergia spp.); Aristida spp.; lobelia (Lobelia spp.); nutrush (Scleria spp.); sun dew (Drosera spp.); Pagonia spp.; milkwort (Polygala lutea); pipewort (Eriocaulon spp.); bog-orchid (Habeneria spp.); sedge (Dichromena spp.)
Meadow, wet meadow fresh meadow	Palustrine	Emergent wetland	Persistent; Non-persistent (dependent on dominant)	Sedge (Carex spp.); flat sedge (Cyperus spp.); rush (Juncus spp.); beaked sedge (Rhynchospora spp.) tickweed, beggartick, stick-tight (Bidens spp.); aster (Aster spp.); goldenrod (Solidago spp.); joint-grass, para grass (Panicum spp.); broom straw (Andropogon spp.)
Hydrologically Open Wetl nds				
Marsh, bayou, brake, ox-bow, swamp creek, flat, prairie-marsh, slough	Palustrine Lacustrine Riverine	Aquatic bed	Various; dependent on dominants	Watershield (Brasenia schreberi); fanwort, cabomba (Cabomba caroliniana); hornwort (Ceratophylum spp.); water hyacinth (Eichornia crassipes); Elodea spp.; duckweed (Lemna spp.); pennywort (Hydrocotyle spp.); southern niad (Najas spp.); lotus (Nelumbo lutea); spatterdock (Nuphar advena); white water lily (Nymphaea oderata); pondweed (Potomogeton spp.); duckmeat (Spirodela polyrrhiza); bladderwort (Utricularia spp.); salvinia (Salvinia auriculata); mosquito fern (Azolla caroliniana)
Mixed bottomland hardwood, hardwood strand	Palustrine	Forested	Broad-leaved deciduous	Laurel oak (Quercus laurifolia); willow oak (Q. phellos); swamp chestnut (Q. michauxii); cherry bark oak, swamp Spanish oak (Q. pagoda); loblolly pine (P. taeda); American white elm (Ulmus americana); sweetgum (Liquidambar styraciflua); river birch (Betula nigra); ironwood, blue beech (Carpinus caroliniana); palmetto, dwarf palmetto (Sabel minor); cabbage palm (Sabel palmetto)
Marsh	Riverine Lacustrine	Emergent wetland	Persistent; non-persistent (dependent on dominants)	Lizards tail (Saururus cernuus); alligator weed (Alternanthera philoxeroides); sedge (Eleocharis spp.); iris (Iris virginica); pelandera (Peltandra virginica); smartweed (Polygonum spp.); pickeral weed (Pontederia cordata); wild rice (Zizania spp.); bulrush (Scirpus spp.); rush (Juncus spp.)
Cypress Strand	Palustrine	Forested wetland	Needle-leaved deciduous	Bald cypress (Taxodium distichum); pond cypress (T. ascendens)



SECTION 3

PROFILE OF EXISTING WETLANDS DISCHARGES

3.0 PROFILE OF EXISTING WETLAND DISCHARGES

A PROFILE OF EXISTING WETLAND DISCHARGES FOR REGION IV WAS ACCOMPLISHED THROUGH AN INFORMATION SURVEY PROGRAM

An inventory was conducted to obtain information from existing wetlands dischargers. Information obtained relates to land ownership, effluent characteristics, discharge frequency and duration, monitoring programs and identifiable problems.

The physical and biological characteristics of wetland ecosystems vary greatly between states in Region IV. To provide a better understanding of how wetland systems differ among states, an inventory and analysis of existing wetlands discharges was conducted for Alabama, Florida, Georgia, Mississippi, North Carolina, South Carolina and Tennessee. Kentucky has not, at this time, identified wastewater discharges to wetlands.

A list of existing wetland dischargers was obtained from the appropriate department in each state. A survey form (Table 3.0-a) was then sent to each discharger. The wetlands profile for each state was based on questionnaires received from dischargers who responded. Table 3.0-b gives the total number of wetlands discharges included in the survey by state and the number of respondents. An attempt was made to contact those dischargers in each state who did not respond so that a complete wetland discharge profile for each state could be presented. Information received from the surveyed wetland dischargers is discussed in the following subsections.

Field trips were also conducted through each of the seven states with identified wetlands discharges. These site visits were used to provide first-hand knowledge of selected wetland discharges and provide a greater understanding of the wetland systems in each state. In early April a trip was taken through south Georgia and Florida. In early June a field trip was taken through Alabama, Mississippi and west Tennessee while a second study team visited the coastal plain of South Carolina and North Carolina. Summaries of these site visits are included in the following subsections.

<u>Issues of Interest</u>

- What are the predominant wetland systems used for wastewater management in each of the EPA Region IV states?
- How many wetland discharges have been identified in EPA Region IV?
- What are the major characteristics of wetland discharges in EPA Region IV?

Table 3.0-a. Information Form Sent to Existing Wetland Dischargers in Region IV.

WETLANDS DISCHARGE SURVEY
CLAUDE TERRY & ASSOCIATES, INC., ATLANTA, GEORGIA

Name: ______________________________

NPDES Permit No.: ______________

Discharge Source: ______________________________

Would you like to be included on our mailing list to follow the progress of this study? ______ yes ______ no

1. Please describe the type and approximate area of the system you discharge to (e.g., river swamp, creek, swamp creek, cypress dome, etc.). Include a general description of the vegetation (e.g., cattails, hardwoods, etc.) and other uses.

2. Do you own this area? ____ yes ____ no
Do you have an easement to discharge to this area? ____ yes ____ no

3. How long have you been discharging into this water body? What is the frequency of discharge (daily, weekly, continuous, etc.)?

4. What changes in the receiving waters have you detected since you've been discharging (e.g., loss of vegetation, algae blooms, increased vegetation, rise in water level, etc.)?

5. What problems have you experienced relating to the discharge (e.g., citizen complaints, legal questions, regulatory difficulties, etc.)?

Table 3.0-a. Continued

6. What type of treatment system and backup system, if any, do you have? What type of disinfection?

7. Please describe your in-stream monitoring program, if any.

8. What type of effluent do you discharge (e.g., industrial, domestic, cooling water), and what is the average effluent flow?

9. What are your effluent characteristics?

BOD_5 ________	pH ________
NH_3 ________	Total Nitrogen ________
Dissolved Oxygen ________	Total Phosphorus ________
Temperature ________	Industrial Components ________
Total Suspended Solids ________	

Composite sample ________ frequency ________
Grab sample ________ frequency ________
Other (please describe)

10. In your opinion, are wetlands useful for wastewater treatment and/or disposal? What could be done to improve or enhance this use of wetlands?

Table 3.0-b. Total Number of Surveyed Wetlands Discharges by State and the Number of Respondents.

State	Wetlands Discharges	Number of Respondents
Alabama	13	8
Florida	58	30
Georgia	10	3
Kentucky	-	-
Mississippi	40	13
North Carolina*	61	21
South Carolina	34	22
Tennessee	12	8

*North Carolina listed 267 discharges to "swamp waters." The 61 in this table are discharges greater than 0.1 mgd that discharge directly to wetlands.

Source: Claude Terry & Associates, Inc. 1982.

3.0 PROFILE OF EXISTING WETLAND DISCHARGES

3.1 Alabama

SWAMP CREEKS WITH HARDWOODS REPRESENT THE PREDOMINANT WETLAND DISCHARGE IN ALABAMA

Alabama has 13 identified wetland discharges, most of which have been in operation for many years. Few dischargers have indicated any significant impacts or problems. Several survey respondents stressed that wetlands are useful only with adequate wastewater treatment. Four discharge sites in the central portion of the state were visited in early June.

A list of 13 wetland dischargers was obtained from the Alabama Water Improvement Commission (AWIC). These sites (10 municipalities; 3 industries) were identified based on the knowledge of the AWIC staff. The profile of existing dischargers in Alabama is based on eight survey responses and four site visits.

Based on the survey responses, most wetland dischargers dispose treated effluent into swamp creeks. Bottomland hardwoods and mixed hardwoods/pines are the predominant vegetation types surrounding these wetlands. Cattails and cypress were also identified at several Alabama discharge sites. All discharges were described as continuous with the period of discharge ranging from two years to 40 years (average: 18 years).

Few impacts or problems were identified by any of the wetland dischargers; two respondents noted increased vegetation while one respondant cited a pending lawsuit from an adjacent property owner (the legal issue was not elaborated). Most effluent was derived from domestic sources. Opinions were mixed concerning the use of wetlands for treatment or disposal with several respondents highlighting the need for adequate wastewater treatment and precautionary measures prior to discharging to wetlands.

Four municipal discharge sites located in the central portion of the state were selected for site visits in early June, 1982. These four discharge sites were highly channelized, forested streams, but local sources indicated that these discharges may enter typical wetlands at a distance farther from the discharge point. The following narratives describe the field conditions observed during the site investigations.

Auburn, AL. The Director of Public Works for the City of Auburn provided information concerning the two wastewater treatment plants serving the city. The northside plant discharges approximately 1.0 mgd to Sagahatchee Creek. No obvious odor problems were noticeable 1/4 mile from the discharge point. Although this plant was operating beyond design capacity, the trickling filter and clarifiers were producing an effluent of reasonable quality. The creek bed was composed of granite and clay. Sagahatchee Creek near the discharge point was highly channelized and forested with honeylocust and *Salix* spp. and did not appear to be a continuous wetland. It is possible that this creek drains into a wetland five to ten miles downstream but this was not verified.

3.1 Continued

The southside treatment plant discharges approximately 4.0 mgd to Parkers Mill Creek. Topographic maps indicate a wetland area exists one to two miles south of the discharge point. Local sources contend that this is a seasonal wetland and the stream generally remains channelized. Water quality studies by Dr. Joe Morgan (Auburn University Department of Civil Engineering) suggest that a significant amount of nitrification occurs along the length of Parkers Mill Creek. Measurements indicate that dissolved oxygen is at or near background levels (2-4 mg/l) at the Parkers Mill Creek confluence with Chewakla Creek. Chewakla Creek enters a large, permanently forested wetland in Macon County, Alabama, about five miles further south.

Tuskegee, AL. The moderately sized, extended aeration wastewater treatment plant at Tuskegee, Alabama discharges approximately 1.25 mgd to Calebee Creek, contributing approximately 5-10 percent to the total stream flow. Recent rains had raised this highly channelized creek four to six feet in the few days preceeding the site visit. The terrain at Calebee Creek was flatter than at Auburn and the soils were sandy in contrast to the clay and granite soils found near Auburn. The immediate discharge area was not a riverine wetland, but local sources acknowledge that the creek may enter a large swamp in the Tuskegee National Forest, five to ten miles downstream.

Union Springs, AL. The Water Superintendant for the City of Union Springs indicated there is no direct discharge to wetlands from either of the two wastewater treatment plants serving Union Springs. He was also unaware of any wetland areas downstream of the discharge plants.

Uniontown, AL. The Mayor of Uniontown provided information concerning the two sewage lagoons which provide treatment (no chlorination) for approximately 0.05 mgd of wastewater. The receiving creek was well-channelized at the time of the site visit but prone to flooding several times a year. The predominant vegetation along the creek was *Salix* spp., but this creek would not be classified as a wetland. The stream may enter a wetland area downstream but this was not verified. Industrial discharges reportedly cause periodic water quality problems (odors, algae blooms) along the stream course.

Table 3.1. The Profile of Wetlands Discharges Based on Questionnaire Response for Alabama.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
1	Swamp creek	Hardwoods, pines, thick underbrush	Easement	30 years	Continuous	None	Infrequent odor and color problems	Domestic	Wetlands are useful only wi proper treatment
2	Swamp creek	Pine, hard-woods, pasture	Ownership	40 years	Continuous	Improved water quality (effluent is 5 times creek flow)	Flooding, outfall backup	Domestic (60%) 3.0 mgd	Useful for wastewater treat
3	Swamp creek	Oaks, hickory pine, cattails	Easement	25 years	Continuous	Increased vegetation	Regulatory difficulties, citizen complaints	Domestic/ Industrial .589 mgd	Useful for wastewater disposal
4	Swamp creek	Hardwoods	Easement	6 years	Continuous	None	None	Domestic 1.25 mgd	Not useful for treatment; could be used for disposal
5	Creek	Hardwoods	Ownership	14 years	Continuous	Increased vegetation	None	Domestic/ Industrial .35 mgd	-
6	Creek	Mixed pine/ hardwoods	-	22 years	Continuous	Sedimentation of stream	Lawsuit by adjacent property owner	Domestic .375 mgd	Permit provisions need to adopted to allow wetlands for treatment
7	Swamp creek	-	-	2 years	Continuous	None	None	Industrial -	-
8	Creek	Hardwoods, cypress	Ownership	4 years	Continuous	None	None	Domestic/ Industrial .003 mgd	Could be useful for treatmer

Source: Survey of wetland dischargers conducted by Claude Terry & Associates, Inc., Spring 1982.

CYPRESS DOMES AND SWAMP CREEKS DESCRIBE THE MAJOR WETLAND DISCHARGE TYPES IN FLORIDA

Florida has 58 identified wetland discharges. Several have been in operation for many years. Most respondents believe wetlands are useful for wastewater treatment and disposal.

A list of 54 wetlands dischargers was obtained from the Florida Department of Environmental Regulation, Bureau of Water Analysis. The list was compiled from a newly created data base system, and some areas in the state had not stored pertinent information into the system at the time of data retrieval. Because of this, some existing wetland discharge areas may not be represented in the final list. Subsequently, four additional wetland discharges were identified by the Florida DER Southwest District bringing the total of identified wetland discharges to 58. The profile of existing wetlands in Florida is based on 30 responses. Fifteen responses were the result of the survey and 15 additional responses were provided by the district offices of Florida DER. Fifteen negative responses indicating non-wetland or discontinued discharges were also received, bringing the total response rate to nearly 78 percent. Many of the responses prepared by Florida DER, however, provided inadequate information.

A variety of wetland ecosystems in Florida are used as disposal sites for treated wastewater. Cypress domes, swamp creeks and marshes represent the most common wetlands used. These areas are vegetated with cypress, swamp maple, water oak, sawgrass, cattails, hyacinth and a diversity of weeds. The discharge areas are owned in 11 instances with the remaining respondents using easement rights to discharge. The frequency of discharge ranged from continuous in 19 areas to monthly in one area. Based on 25 responses, the average period of discharge is 22 years with a range from less than one year to 90 years.

Increased vegetation and water quality degradation were typical problems relating to changes in receiving water. Regulatory problems associated with discharging were indicated in seven areas. A variety of effluent is discharged into Florida wetlands. Most effluent is domestic, but there are several industrial and cooling water sites as well as one site that discharges stormwater. The minimum and the maximum daily effluent flows for 11 sites are 0.0005 mgd and 5.0 mgd, respectively. The respondents, as a majority, felt wetlands are useful for wastewater treatment and disposal. Table 3.2 profiles existing wetlands in Florida based on the survey responses and information from Florida DER.

A field trip to north and central Florida was conducted to examine the various types of wetlands discharges found in Florida. Nine discharges were visited and are summarized below.

Royal Lakes (Jacksonville), FL. The Royal Lakes treatment plant, originally serving the Royal Lakes subdivision but now serving as a regional plant, discharges to a forest swamp. The tour was conducted with the operator and the district engineers of the Jacksonville Suburban Utilities Corp. After secondary treatment the effluent is discharged to a canal which flows under a highway and into the swamp. Emergent and floating vegetation were observed in the canal. This discharge, as with several others in Florida, was the subject of another study; therefore, additional information is available for this site. One interesting aspect of this site was at a location where water from the swamp downstream of the effluent combined with water from a part of the swamp undergoing development. The latter was extremely sediment laden whereas the former showed no evidence of increased solids or vegetation associated with wastewater (duckweed).

Deerwood Subdivision (Jacksonville), FL. This wastewater treatment facility serves a large subdivision. After treatment in aerators, the effluent is discharged to a lagoon from which it is discharged to a canal that leads to a forest swamp. The swamp system was not investigated.

Lake Buena Vista, FL. The wastewater treatment system at Walt Disney World is one of the most innovative and sophisticated systems in operation. After undergoing a high degree of secondary treatment, effluent is disposed of by three different methods. An experimental artificial wetland system using water hyacinths is being studied for potential application. The major portion of the effluent from the plant (<5 mgd) is discharged into a cypress strand. Another portion is used for spray irrigation and the third portion combines percolation ponds with overland flow through a cattail marsh. This effluent, and that from the strand, ultimately discharge to the Reedy Creek system. A tour of the facilities was provided by a representative of the Reedy Creek Improvement District. This system appears to operate effectively but is land intensive.

Clermont, FL. The wastewater facility at Clermont, Florida, has also been researched by the University of Florida. At the time of research the discharge was to a marsh system. However, this has since been discontinued and discharge is now achieved via spray irrigation. The treatment system can still be considered to include wetlands since one of the three lagoons used for polishing after typical secondary treatment processes has become a volunteer wetland with extensive and varied emergent and subemergent vegetation. Wildlife is prolific in and around the polishing lagoons. Also, due to probable groundwater movements, water discharged by spray irrigation eventually leaches to the marsh system used for the research project.

Wildwood, FL. The discharge from Wildwood, Florida, is one of the most well established and oldest wetland discharges. After receiving secondary treatment the effluent is discharged to a canal which typically discharges to a swamp. No visible stress or damage to natural systems is evident. However, under severe flow conditions the effluent may migrate to a shallow lake that is characterized by extensive emergent, submergent and floating vegetation.

3.2 Continued

Gainesville, FL. The wastewater discharge at the Whitney Trailor Park in Gainesville, Florida, was the subject of a long-term study on the effects of wastewater disposed in cypress domes. A series of domes and strands were used. Two domes received wastewater effluent and one dome received groundwater only. The Austin Carey cypress swamp was used as control for these experiments. The effluent from the trailer park was treated in a package plant/oxidation pond system prior to discharge to the domes. This system was discontinued in early 1981 but generated much of the information gathered on the impacts of wastewater on cypress dome systems.

Waldo, FL. The city of Waldo, Florida, has been discharging primary effluent to a cypress/hardwood swamp for several years. After passing through an Imhoff tank, the wastewater travels through a canal to the swamp. This site has also been the subject of research by the University of Florida. Nutrient cycling, the fate of heavy metals and pathogenic microbes discharged to the swamp have been studied but final results are not yet available.

Lake City, FL. Of several wetlands discharges found in the area, the system visited was the Holiday Inn on I-75. This motel discharges to a cypress dome from a package plant operated by the motel. The operator provided a tour of the facilities. This site provided the best example of a stressed system since many of the cypress were dead. However, this was not related to the wastewater effluent but to a backwashing of salts which occurred in the mid-1970's from the motel's water softening operation (according to the current operator). The area currently receiving effluent showed only the signs of increased duckweed populations.

Jasper, FL. As with several of the other visited discharges, the Jasper, Florida, site has been the object of extensive research. The system is composed of secondary treatment processes with two polishing ponds. The effluent moves from the second pond into a marsh-swamp system with cattails and cypress. The cypress in this system were visibly stressed. The cause or causes are not fully understood but two explanations prevail: one, that the primary effluent discharged for many years overloaded the system; two, that a gasoline overflow from a nearby gasoline station (upgradient) impacted the strand. The prevailing explanations do not indicate that the secondary effluent has caused the observed problems.

Table 3.2. The Profile of Wetlands Discharges Based on Questionnaire Response for Florida.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment And/or Disposal
*1	Swamp creek	Cypress, hardwood	Easement	-	-	None	None	Domestic 0.4 mgd	Yes
2	Forested swamp	Swamp maple, bay, gum, water oak	Ownership	90 years	Continuous	None	None	Industrial 3.5 mgd	Wetland discharge is our only viable option.
3	Cypress swamp	Cypress	Ownership	3.5 years	-	Increase in phosphate	none -	- 3.3 mgd	Wetlands overflow discharge is effective.
*4	Marsh	-	Ownership	12 years	Daily	None	State of FL & local pollution control board do not accept marshland disposal methods	Domestic 0.0005 mgd	Wetlands disposal is only practical solution in much of central Florida.
5	Marsh	Sawgrass	Ownership	18 years	Continuous	Water level changes due to seasonal operations	None	Cooling water 0.09 mgd	-
6	Swamp	Pines, weeds	Ownership	23 years	Continuous	None	None	Domestic 75%, cooling water 25% 0.275 mgd	-
7	Swamp	-	Easement	24 years	Continuous	-	Regulatory difficulties	Domestic 0.275 mgd	Many large swamps in the area could be used for effluent disposal.
8	One mile through grassed ditch to private lake	Hyacinth and cattail	Ownership	9 years	Continuous	Increased vegetation	None	Industrial 0.005 mgd	Yes

Table 3.2. Continued

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
9	Wetland	Pumpkin ash, maple, black-gum, sweetgum, bald cypress, yellow poplar, swamp bay, wax myrtle, oak, magnolia, holly, peterbush, cabbage palm, Virginia willow	Easement	12 years	Continuous	None	Regulatory difficulties	Domestic -	Wetlands are useful; should be responsible monitoring.
*10	Wetland	Cypress, hardwood, cattail	Easement	66 years	-	Increased vegetation	Collection system has problems	Domestic 0.221 mgd	Wetlands are very useful if not overloaded.
11	Swamp	-	Easement	25 years	Continuous	None	Regulatory problems engendered by unrealistic attitude of EPA	Cooling water -	Yes. Our understanding is that wetlands operate naturally as cleaning areas and should be allowed to continue, bearing in mind natural characteristics.
12	Cypress dome swamp	Cypress, algae	Easement	37 years	Monthly	None	EPA said dissolved oxygen problems exist	Rainwater -	No opinion
13	Prairie basin	Cypress	Easement	62 years	-	Effluent may have caused an increase in algae, but other nonpoint sources of pollution exist.	Regulatory mandates to remove all effluent sites from lake basin. Nutrient loads in lake exceed permissible load which is 0 nitrogen and 0 phosphorus. Groundwater pollution also occurs	Domestic 2.0 mgd	Yes. A full environmental assessment should be made to evaluate wetlands' capabilities to accept discharge.

Table 3.2. Continued.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
14	Swamp	Cypress	-	72 years	Continuous	Water quality impacts	Some cypress trees have died, but exact cause is not known.	Industrial and domestic 0.45 mgd	-
15	Swamp creek	Cattails, hyacinth, other aquatic vegetation	Ownership	17 years	Continuous	Increased vegetation	None	Water from clay settling areas 5.0 mgd	In some cases wetlands are useful. The degree of usefulness would need to be evaluated in each case.
16	Swamp creek	Cypress, cattails	Ownership	1 year	Continuous	Increased vegetation	None	Non-contact cooling water	Yes
17	Creek	-	-		Continuous	-	-	Industrial	-
18	Canal	-	-	-	-	Loss of forests	Legal questions and regulatory problems	Industrial	-
19	Drainage	-	-	8 years	Intermittent	-	-	Industrial .0072 mgd	-
20	Swamp	-	-	-	-	-	-	Domestic	-
21	Cypress swamp	Cypress, bottomland hardwoods	-	-	Continuous	-	Unable to harvest timber	Domestic	-
22	Swamp	-	-	11 years	Continuous	-	-	Domestic	-
23	Swamp	-	None	10 years	Continuous	-	Fish kill molasses dump (1979)	Cooling water	-
24	Cypress dome	Cypress	-	1 year	Intermittent	-	Bad odors, potential problems	Laundry wastewater .0042 mgd	-
25	River swamp	-	Ownership	6 months	-	-	Depressed D.O.	Citrus wastes	-

Table 3.2. Continued

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment And/or Disposal
26	River swamp	-	-	5 years	Continuous	-	Permit noncompliance	Domestic	-
27	Swamp	-	Ownership	10 years	Continuous	-	Permit noncompliance	Domestic	-
28	Swamp	-	Easement	6 years	Continuous	-	None	Domestic (AWT) 1.3 mgd	-
29	Swamp	-	Easement	6 years	Continuous	None	None	Domestic (AWT) .844 mgd	
30	River swamp	-	Ownership	8 years	Continuous	None	Permit violations	Domestic .818 mgd	-

*Indicates site studied by the University of Florida, Gainesville.

Source: Survey of wetland dischargers conducted by Claude Terry & Associates, Inc., Spring 1982; supplemented by Florida DER district offices.

DISCHARGES TO INTERMITTENT AND SEASONAL WETLANDS ARE IDENTIFIED IN GEORGIA

Responses from a limited number of surveyed discharges provided information which indicates discharges are made to intermittent streams and seasonal wetlands. Responses from continuous, long term discharges identified few documented problems.

A list of 10 wetland discharges was provided by the Georgia Environmental Protection Division, Water Protection Branch. This list included eight municipal discharges and two industrial discharges. Additional wetland discharges may be permitted in Georgia but have not been identified as wetland discharges by the staff of Georgia EPD. Of the 10 dischargers surveyed, only three municipalities responded.

Information provided by the three dischargers indicated discharges to drainage canals or possibly intermittent streams which drain directly into wetland areas. Vegetation near the discharge sites include pines, mixed hardwoods, cypress and cattails. These three discharges have been relatively long-term and continuous. Two of the dischargers recognized a rise in water level with varying impacts on vegetation. Permit violations and high BOD loadings were cited as problems. These discharges consisted of domestic or combined domestic/industrial discharges. Specific information for these three dischargers is provided in Table 3.3.

A field trip through the south coastal plain of Georgia was conducted in early April 1982, in order to supplement the survey responses. The discharges of five communities were examined.

Cochran, GA. This discharge was typical of many observed in south Georgia. The wastewater was treated to secondary levels and then discharged into a swamp creek with a relatively low flow. The stream flowed through sandy soils with hardwoods and some cypress and was characterized by high organic color.

Alapaha, GA. After treatment via oxidation pond, the discharge entered a small channel that cut through low lying lands before entering the floodplain of the Alapaha River. The discharge stayed within the discharge channel for approximately one mile before spreading over the floodplain as sheetflow. The only evidence of this discharge was highly organic sediments within the channel and along its banks.

Pearson, GA. The Pearson, Georgia, wastewater treatment plant used a brush aerator system to provide secondary treatment. The wastewater moved through clarifiers and a contact chamber prior to discharge into a bottomland hardwood swamp. The effluent traveled through a pipeline approximately 50 meters long into the swamp, which had no discernable channel. The chief operator of the plant indicated that the direction of flow within the swamp was variable and the actual size, area of influence, and detention times were unknown. No visible stress on the system was evident, however large quantities of duckweed were observed in the swamp.

Hahira, GA. The discharge from the Hahira, Georgia, treatment facility was similar to that at Cochran. The receiving water was an organic-colored swamp creek with low flows. Such systems appear to stay in their channels under most conditions, with overflow occuring only during flood conditions. No visible signs of damage or stress to the vegetation was evident.

Camilla, GA. Of the several discharges examined, this was the only system which should probably not be considered a wetlands discharge. Although it ultimately discharged to a forest swamp, the wastewater travelled through a well-defined, non-vegetated channel for two to three miles. The impacts on the swamp from this discharge had not been examined to determine the degree of influence on the swamp or the extent of treatment achieved within the channel. The water quality was visibly poor within the channel. The situation in Camilla is important as it reflects the problems associated with determining what is or is not a wetlands discharge. What may be classified a wetlands discharge in one Region IV state may not be classified a wetlands discharge in another Region IV state.

Table 3.3. The Profile of Wetlands Discharges Based on Questionnaire Response for Georgia.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
1	Drainage canal	Pines, oaks cypress, myrtle buses	Easement	15 years	Continuous	Rise in water level, decreased fish population	Regulatory problems, permit violation	Domestic 1.6 mgd	No. Need a year round flow source. Wetland operations are more expensive
2	Creek	Hardwoods	Ownership/ Easement	25 years	Continuous	Loss of vegetation, increased algae growth	High BOD loading	Domestic/ Industrial	Yes, with adequate aeration
3	Drainage canal to creek	Cypress, cattails, tupelo	Ownership/ Easement	25 years	Continuous	Increased vegetation rise in water level	None	Domestic/ cooling water .65 mgd	Yes, should use more drainage ditches and canals

Source: Survey of wetland dischargers conducted by Claude Terry & Associates, Inc., Spring 1982.

KENTUCKY DOES NOT HAVE ANY PERMITTED WETLANDS DISCHARGES

Although Kentucky contains wetlands in various parts of the state, no permitted discharges to wetlands exist. However, some discharges to wetlands occur from coal mining operations.

The Kentucky Department for Natural Resources and Environmental Protection, Bureau of Environmental Protection, indicated that there is no provision in the Kentucky water quality standards for the specific classification of wetlands. Although wetlands exist in Kentucky, the state does not have a list of wetlands dischargers because no NPDES permit applications or permit issuances exist for wastewater discharges to wetlands. As a result, a profile of wetlands discharges in Kentucky was not feasible.

Kentucky has, however, identified wetland water quality problems in association with certain coal mining operations. In some areas, primarily western Kentucky, wetlands have been impacted by nonpoint runoff from surface mining operations, discharges from sedimentation and silt structures, and acid mine drain from abandoned mines. Discharges associated with coal mining operations may require NPDES permits; however, this type of wetland discharge is outside the scope of this EIS and has not been further evaluated.

3.0 PROFILE OF EXISTING WETLAND DISCHARGES
3.5 Mississippi

BAYOUS REPRESENT THE WETLAND TYPE IN MISSISSIPPI MOST FREQUENTLY USED FOR EFFLUENT DISPOSAL

Although only 13 positive responses were received from 40 identified wetlands discharges, useful information was obtained. Bayous and sloughs are the common wetland types used for discharges. Odor problems have been identified at some sites.

A list of 40 wetland discharges was obtained from the Mississippi Department of Natural Resources, Bureau of Pollution Control. The profile of existing wetlands dischargers in this state was based on 13 positive responses. Four additional responses indicated non-wetland discharges or discontinued discharges.

Bayous are the predominant wetland type used for wetland discharges in Mississippi. Pines, hardwoods and cattails characterize existing vegetation in these wetlands. Approximately half of the respondents own the discharge area; the other half use easements. The frequency of discharge is continuous for 12 wetlands profiled; one wetland site received effluent on a daily basis. Only one respondent indicated changes in the receiving waters since discharge was initiated. The apparent change was a rise in the water table, but other factors such as an atypical year of total rainfall may also have lead to this response.

The most common problem associated with the profiled discharges was odor. This invariably precipitated citizen complaint and regulatory difficulties. The predominant effluent discharged is domestic with a range of 0.05 mgd to 0.5 mgd. Most respondents had no opinion regarding the usefulness of wetlands for wastewater treatment and disposal. Table 3.5 profiles existing wetlands in Mississippi.

A field trip was conducted in June 1982 to examine wetland systems and discharges in Mississippi. Since the overwhelming majority of wetland discharges were identified in northwest Mississippi, four sites in this area of the state were selected for site visits. The wetlands which predominate in the western portion of the state are derived from old river scars and are typically oxbow shaped, forested wetland systems. Wetlands in this area of the state are subject to intensive pressures because the rising demand for agricultural products has placed a premium on tillable and marginally tillable land. Wetlands in this area are also subject to a high level of agricultural nonpoint runoff, which may contain potentially harmful pollutants (pesticides, herbicides and fungicides). The following narratives detail the observations made during the four selected site visits.

Tchula, MS. The town of Tchula is located approximately 70 miles north of Jackson in a flat delta region of the state. The total wastewater treatment system for the town of Tchula is represented by two separate lagoons, each with a flow of approximately 0.1 mgd. A small brake containing dead and

3.5 Continued

dying willows and sweetgum received effluent from one of the lagoons. This brake further drained toward Tchula Lake (an oxbow lake); however, the precise water course could not be traced. The effluent from the second lagoon was piped approximately 1/4 mile to the banks of Tchula Lake. The discharge area was viewed from the opposite side of the lake and contained an abundance of macrophytes with little apparent degradation.

Itta Bena, MS. Itta Bena is located approximately 35 miles northwest of Tchula. The wastewater treatment plant consists of a series of three lagoons with aeration and chlorination. The 0.3 mgd discharge flows approximately 1/4 mile in a ditch before entering Gayden Brake. This forested wetland begins at the end of the ditch and rapidly widens to over 3/4 mile. The total drainage area for Gayden Brake is not large but approximately 75 percent is agricultural. The brake extends approximately two to three miles southwest of the discharge and forms one end of Blue Lake, a large oxbow lake. Gayden Brake is heavily forested by tupelo gum and cypress and did not appear to be adversely affected by the sewage discharge. Blue Lake appeared to be eutrophic, but this condition may be more related to nutrients in agricultural runoff than from the influence of the sewage.

Webb, MS. Webb is located 35 miles north of Itta Bena. The recently installed package plant is situated adjacent to the highway and soybean fields and serves both Webb and Sumner. The discharge flows about 200 yards to the thin remnant of a brake. This now channelized brake eventually flows into Stanton Brake which we were unable to visit.

Tutwiler, MS. This lagoon system is located approximately ten miles from Webb on the outskirts of Tutwiler, and the 0.1 mgd discharge is into Hobson Bayou. Although a few cypress trees lined the banks of the bayou, it has been channelized and represents a sparsely forested creek. Channelization was initiated several years ago to reduce flooding in the town. The stream now represents a remnant wetland. The effluent from the lagoons did not constitute a large percentage of the flow at the time of this field investigation.

Table 3.5. The Profile of Wetlands Discharges Based on Questionnaire Response for Mississippi.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
1	Bog Creek	0	Easement	20 years	Continuous	None	None	Domestic 0.113 mgd	I believe effluent far exceed quality of creek area runoff.
2	Bayou	Pine, mixed hardwood	Easement	33 years	Continuous	None	None	Domestic -	Yes
3	Bog	Hardwoods, cattail, algae	Easement	10 years	Continuous	Rise in water table	Overflow of solids from plant	Domestic 0.5 mgd	No
4	Bayou	Hardwoods, oak, tupelo	Easement	10 years	Continuous	None	None	Domestic and 1 industrial, plastic industry	-
5	Lake	-	-	18 years	-	None	None	Cooling water -	-
6	Bayou	Burmuda grass, Johnson grass	Ownership	18 years	Continuous	None	None	- -	No
7	Bayou	-	Ownership	21 years	Continuous	None	None	Cooling water -	-
8	Large ditch	Soybeans	Ownership	24 years	-	None	Regulatory problems caused by overloaded flow and suspended solids.	Industrial and domestic 0.15 mgd	-
9	Bayou	-	Ownership	18 years	Continuous	None	None	Domestic 0.05 mgd	-
10	Bayou	Hardwoods	-	20 years	Continuous	None	Citizen complaints about odor problems in summer	Domestic -	Yes
11	Bayou	-	Easement	20 years	Continuous	None	Citizen complaints about odor problems in summer	Domestic 0.6 mgd	-

Table 3.5. Continued.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
12	Flowing creek	Pine, hardwood cattails	Ownership	10 years	Daily	None	Erosion around lagoons	Domestic plus an oil mill and wood factory	-
13	Bayou	Water grass, willows	Easement	17 years	Continuous	None	Fish industry over loaded lagoon causing odor problems	Domestic and one fish industry	-

Source: Survey of wetland dischargers conducted by Claude Terry & Associates, Inc., Spring 1982.

SWAMP ECOSYSTEMS ARE USED FOR WASTEWATER DISPOSAL IN NORTH CAROLINA

North Carolina has the most wetlands discharges of all Region IV states. Information was received from a small percentage of dischargers, so additional assistance was requested from NCDEM. Regulatory problems and citizen complaints have been experienced by some respondents.

The North Carolina Department of Natural Resources, Division of Environmental Management (NCDEM), lists 267 discharges into waters classified as "swamp waters". To obtain a shorter list, a selection process was developed based on two specific criteria. First, only those wetland areas receiving discharges greater than 0.1 mgd were selected. Second, only those areas discharging effluent directly into wetland waters were selected. The final list contained 61 discharges; of these, 36 responses were received resulting in a total response rate of approximately 59 percent. Of the 36 total responses, only 21 were positive; the other 15 negative responses indicated non-wetland or discontinued discharges. Several industrial discharges refused participation. Eight of the positive responses were provided by NCDEM.

River swamps and swamp creeks appear to be the predominant type of wetland used for wastewater disposal in North Carolina. Typical vegetation in these swamps include cypress, maple, sweetgum, oak, and various emergent plants. The average length of discharge is approximately 16 years with a range from four years to 26 years. Most discharges are continuous. Few dischargers indicated any apparent changes in the wetland; two discharges indicated dissolved oxygen problems. Regulatory problems were cited by several dischargers, including the surveys completed by NCDEM. Surveys completed by NCDEM also indicated several violations of effluent limitations. Most discharges consist of domestic wastewater; however, industrial components were included in several systems. Flow varied widely and conflicted with the original screening criteria in several instances. Reported flows averaged approximately 2.0 mgd with a range of 30.0 mgd to .02 mgd; most discharges are less than 1 mgd. Specific information concerning the 21 profiled discharges is included in Table 3.6.

To supplement the sketchy profile data, a field trip to North Carolina was taken in early June 1982. Due to time constraints and logistics, only two sites were visited in the south coastal plain of North Carolina.

Lake Waccamaw, N.C. The town of Lake Waccamaw, North Carolina, is served by a secondary treatment facility supplemented by a holding pond and aerated pond. This .15 mgd facility discharges to a well-defined channel which drains immediately into a bottomland hardwood swamp. Duckweed was abundant in the channel and swamp.

Whiteville, N.C.. The town of Whiteville, North Carolina, is served by a 2.5 mgd wastewater treatment facility which incorporates an oxidation ditch with post aeration. The facility has a current discharge of approximately

3.6 Continued

1.5 mgd into a canal which drains directly into a bottomland hardwood swamp within 200 yards (Whitemarsh Swamp). Eventual drainage is to Lake Waccamaw. No apparent impacts or problems were identified at this site; however, very little of the impacted wetland area was observed. No monitoring of the wetland area takes place.

Table 3.6. The Profile of Wetlands Discharges Based on Questionnaire Response for North Carolina.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
1	River Swamp	Hardwoods, cypress	Easement	14 years	Continuous	None	Chlorination system has failed, caus- causing water quality problems	Domestic 0.085 mgd	Wetlands should only be used for disposal of highl treated waste. Tertiary treatment should be requir
2	River	-	Easement	26 years	Daily	None	None	Domestic 0.350 mgd	-
3	Creek	Hardwoods, shrubs	Easement	20 years	Continuous	None	Regulatory problems	Domestic 0.165 mgd	-
4	Swamp	Pines	Easement	-	Daily	None	None	Domestic 0.067 mgd	In our case, wetland disposal has been satisfactor
5	Classic swamp	Cattails	Easement	7 years	Daily	Increased vegetation, decreased dissolved oxygen, algae blooms.	None	Domestic	Yes
6	Swamp creek	Hardwoods	Ownership	18 years	Continuous	None	Regulatory difficulties	Domestic 0.350 mgd	Yes
7	River swamp	Cypress, pine, oak, gum	Easement	13 years	Continuous	Increased color during low flows. Dissolved oxygen problems (9.5-1.0 mg/1)	Citizen complaints centered around color issue	Industrial 30.0 mgd	May provide reduction of nutrients where needed.
8	Hardwood swamp	Cypress	Easement	9 years	Continuous	None	None	Domestic 1.3 mgd	Wetlands are useful but it depends on topography and wetlands' ability to contain effluent.
9	Swamp creek	Maple, gum, cypress, cattails, reeds, Spanish moss	Easement	14 years	Continuous	Increase in vegetation	None	Domestic 0.846 mgd	Yes

Table 3.6. Continued.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
10	River swamp	-	Easement	5 years	Daily	None	None	Domestic 1.0 mgd	-
11	Swamp creek	Hardwoods	-	21 years	Continuous	Possible rise in water level	Regulatory problems	Domestic .321 mgd	No real advantage to using wetlands
12	Swamp creek (intermittent)	-	Easement	-	Continuous	None	None	Domestic .4 mgd	No opinion
13	Swamp creek	Hardwoods, cattails, grasses	Ownership	45 years	Continuous	Possible rise in water level, could be caused by beavers	Beavers	Domestic .35 mgd	Possibly
14	Swamp creek	-	-	15 years	Continuous	-	Regulatory problems/ effluent limits	Domestic .37 mgd	Yes
15	Swamp creek	-	-	7 years	Continuous		Regulatory problems/ effluent limits	Domestic .132 mgd	-
16	Swamp creek	-	-	20 years	Continuous	-	Effluent limits	Domestic .317 mgd	-
17	Swamp creek	-	-	4 years	Continuous	-	None	Domestic Industrial 2.4 mgd	-
18	Swamp creek	-	-	4 years	Continuous	-	None	Domestic .02 mgd	-
19	Swamp creek	-	-	18 years	Continuous	-	Effluent limits	Domestic .153 mgd	-
20	Swamp creek	-	-	24 years	Continuous	-	None	Domestic/ Industrial 1.042 mgd	-
21	Swamp creek	-	-	14 years	Continuous	-	Effluent limits	Domestic/ Industrial/ Cooling water .021 mgd	-

Source: Survey of wetland dischargers conducted by Claude Terry & Associates, Inc. [illegible]

SOUTH CAROLINA WETLAND DISCHARGE AREAS ARE PREDOMINANTLY SWAMP CREEK ECOSYSTEMS

South Carolina provided the highest percentage of returned information forms. As a result, it is the most complete profile. Several discharges have been occurring for many years, with an average period of 19 years.

A list of 31 individual wetlands dischargers representing 34 discharges was obtained from the South Carolina Department of Health and Environmental Control. The profile of existing wetlands in South Carolina was based on 21 responses representing 23 discharges; only one negative response was received indicating a system not yet in operation.

Swamp creeks are the dominant type of wetland in South Carolina used for wastewater disposal. Typical vegetation in these wetlands include cattail, oak, black gum, sweetgum, cypress, tupelo and duckweed. Approximately half the respondents own the discharge area. The frequency of discharge for 22 profiled areas is continuous, and the period of discharge ranges from one year to 100 years. The mean period of discharge is 19 years. According to 17 respondents, no changes in the receiving waters have occurred since discharging began. The most common problem relating to the discharge is regulatory difficulties, but this problem was infrequent, and the majority of respondents indicated no discharge-associated problems. The typical effluent discharged into wetlands is domestic. The range of effluent flow for 11 areas profiled is 0.015 mgd to 5.0 mgd. In general, respondents feel that wetlands are useful for wastewater disposal. However, one respondent stressed that swamps with little or no flow are poor choices for wastewater disposal. Table 3.7 profiles existing wetlands discharges in South Carolina.

A field trip was taken in early June 1982, to provide first-hand knowledge concerning wetland systems and discharges in South Carolina. This series of site visits is summarized in the narratives below.

Berkeley County, SC. Five treatment plants with disposal to wetlands were visited under the guidance of the Berkeley County sewer authority. Fairfax subdivision has a small 0.020 mgd package plant that discharges to a bottomland hardwood swamp. Crowfield subdivision has a similar type discharge from a 0.010 mgd package plant. The discharge flows through a channel several hundred yards before actually discharging to the swamp and was the subject of an inquiry by EPA due to potential problems resulting from the extensive development near the area. The Beverly Hills subdivision flows through a series of lagoons to another bottomland hardwood swamp, with a flow of 0.040 mgd. This treatment system employs diquat to control weeds around and in the lagoons, which raises a valid concern about potential impacts of herbicides on wetlands.

The final two systems visited were the Conifer Hall and Sangaree subdivisions. Conifer Hall is not considered a swamp discharge by the state but is similar to the previous discharges described. This again indicates

3.7 Continued

the potential problem with the definition of wetlands discharges between and within the states of Region IV. The Sangaree subdivision is a 0.40 mgd plant with brush aerators that discharges to a canal that empties into a forest swamp. The canal was extensively covered with floating, submergent and emergent vegetation both upstream and downstream from the point of discharge.

Andrews, SC. The city of Andrews, South Carolina, represents one of the few communities that has been involved in litigation over impacts to wetlands. For several years the municipal treatment plant, combined with two major industrial dischargers, has been discharging to a marsh-swamp system of cattails, hardwoods, and cypress. The wetland has been stressed as indicated by the death of numerous hardwoods. Potential causes include increased flows to the area with a change in the hydroperiod, toxic substances in the industrial effluent, and increased runoff and other impacts from road construction through the wetland. The 201 Plan Addendum still proposes use of the wetland areas for disposal of effluent by upgrading the lagoons which currently compose the system, purchasing the swamp, and continuing the discharge, which ranges between 2-2.5 mgd. About 1000 acres of wetland area would be purchased.

Loris, SC. The wastewater system at Loris, South Carolina, provides minimal treatment prior to discharge to the wetland, which is a forest swamp. The treatment system is composed of an oxidation pond containing large quantities of suspended and floating matter. Flow from the Loris system is about 0.325 mgd. Due to dense understory, the wetlands system was not examined in detail.

Lake City, SC. The treatment facility at Lake City was the most sophisticated of any facility visited in South Carolina. The plant incorporates a series of screens, an aerator, clarifier/sedimentation basin, rotating biological contactors, chlorine contact chamber, and oxygenation steps prior to wetlands discharge. Loris and Lake City represent the two extremes of pretreatment observed during the site visits. Lake City does have an industrial component in its wastewater that results in coloring the wastewater red. The treatment facility does not totally remove the dyes and, therefore, they are discharged to the wetland, which is a bottomland hardwood swamp. Impacts of the dye on this wetland system are unknown.

Florence, SC. The city of Florence, South Carolina, has a sophisticated secondary treatment facility with nitrification. It was the largest treatment plant visited, with a flow of 9 mgd. The discharge enters a channel that cuts through a bottomland hardwood swamp. At one time the effluent moved more as sheet flow across the wetland; however, the discharge cut a channel through which the effluent now flows, and the treatment plant operator indicated that impacts to the remainder of the wetland are now minimal. As a result, the discharge is not a pure wetlands discharge in that it rarely overflows the banks of the channel to impact the wetland. However, the channel transecting the wetland may have some influence on the hydrologic pattern of the wetland.

Table 3.7. The Profile of Wetlands Discharges Based on Questionnaire Response for South Carolina.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
1	River swamp	Cattails	-	45 years	Continuous	Some trees have died because logging roads were built	Complaint by present land owner over using his land without compensation	Domestic and industrial 1.2 mgd	Yes. Wetlands for tertiary treatment is a good alternative.
2	Pocataligo River	-	-	4.5 years	Daily	Rise in water table	None	Domestic and industrial 5.0 mgd	-
3	Swamp creek	Cattail, tupelo, cypress, hardwood	Easement	32 years	Continuous	None	None	Domestic -	No improvement occurs as a result of wetland itself.
4	Swamp	Hardwood	Ownership	8 years	Continuous	None	None	Domestic 0.015 mgd	Yes
5	Swamp	Cypress, duck weed, dead hardwoods	-	17 years	Continuous	-	NPDEDS permit to replace present permit has very strict limitations	Domestic 0.25 mgd	Wetlands especially swamps with low flow are poor choices, for waste disposal.
6	Swamp creek	Hardwoods, pines, reeds	Ownership	20 years	Continuous	Occasional algae blooms	None	Domestic plus one industry	Yes
7	Swamp creek	Dense aquatic vegetation and hardwoods; typical swamp	Ownership	10 years	Continuous	None	Occasional permit	Industrial 0.5 mgd	In cases where nutrient levels will be consistantly low and toxic substances are closely controlled.
8	Swamp creek	Pine, hardwoods	Ownership	12 years	Continuous	None	Citizen complaints regarding nearby septic tank malfunction	Domestic (90%) industrial (10%) 0.15-0.5 mgd	Yes
9	Swamp creek	Sweetgum, cypress	Easement	13 years	Continuous	None	None	Domestic and industrial 3.0 mgd	Yes

Table 3.7. Continued.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
10	Swamp creek	Black gum, cypress, hardwood	Ownership	15 years	Continuous	None	None	Domestic -	Yes, but obtain complete information regarding effluent quality and monitor wetland water quality.
11	Swamp	Hardwood	Ownership	27 years	Continuous	None	Discharge does not meet NPDES requirements	Domestic 0.3 mgd	-
12	Swamp creek	Hardwood, cattails	Easement	19 years	Continuous	None	Odor problems caused citizen complaints	Domestic -	Yes
13	Swamp creek	Surface algae, cattails, bottomland hardwoods	Easement	10 years	Continuous	Increased vegetation	Water quality parameters do not meet NPDES requirements	Domestic 0.037 mgd	Yes
14	Swamp creek	-	Yes	-	Continuous	-	None	Domestic	-
15	Swamp creek	-	Yes	2 years	Continuous (seasonal)	None	None	Domestic	Only if treatment facility discharges high quality effluent.
16	Swamp creek	Hardwoods	Ownership	30 years	Continuous	Vegetation loss	Regulatory problems w/ DHEC	Domestic 1.4 mgd	Yes
17	Swamp creek	Hardwoods	-	6 years	Continuous	None	None	Domestic 0.025 mgd	Treatment should be accomplished prior to discharge.
18	River swamp	Hardwoods	-	14 years	Continuous	None	Problems concerning the requirements of PL-92-500 as amended and priority for upgraded funding	Domestic 0.20 mgd	Yes

Table 3.7. Continued.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
19	Swamp creek	Hardwoods	Easement	9 years	Continuous	None	Infrequent permit violations, odor problems	Domestic .07 mgd	No opinion
20	Swamp creek	Hardwoods, pines	Easement	1 year	Continuous	None	None	Domestic -	-
21	Swamp creek	-	Easement	2 years	Continuous	None	None	Domestic	Yes, as long as high quality effluent is maintained
22	River swamp	Hardwoods	Easement	100 years	Continuous	None	None	Domestic (90%) Industrial (10%)	Yes

Source: Survey of wetland dischargers conducted by Claude Terry & Associates, Inc., Spring 1982.

FREQUENTLY USED WETLAND DISCHARGE AREAS IN TENNESSEE INCLUDE RIVER SWAMPS AND SWAMP CREEKS

The profile of existing wetlands discharges in Tennessee was based on six responses from a list of ten dischargers. The profile reflects discharges to large, typically wet areas such as backwaters, old channels and swamps. Most wetland discharges in Tennessee have been long-term and continuous.

A list of ten wetland dischargers representing 12 individual discharges was provided by the Southwest Regional Office of the Tennessee Division of Water Quality Control. State officials earlier indicated that all wetlands and wetlands discharges are located in west Tennessee. Of the ten dischargers, six responded, representing eight individual discharges.

River swamps and swamp creeks represent the wetland types most frequently used as discharge areas in Tennessee. Typical vegetation in these ecosystems includes hardwoods, cypress and cattail. Half of the respondents obtained an easement to discharge; the remaining respondents own the area. The average period of discharge for all profiled areas is approximately 18 years. The frequency of discharge is continuous for seven areas and daily for one area. Significant increases in algae in receiving waters were noted by four respondents, and a variety of problems relating to discharge operation was indicated. Several problems were engineering-oriented and resulted in temporary degradation of the discharge area. Domestic effluent is the type discharged at six areas. One area discharges industrial effluent, and the other area discharges cooling water. The average daily effluent flow is 0.70 mgd, the range being from 0.03 mgd to 2.74 mgd. The majority of respondents concluded that wetlands are useful for wastewater treatment and disposal. Table 3.8 profiles existing wetlands discharges in Tennessee.

A field trip was conducted through west Tennessee in early June 1982 to survey three wetland discharges. The wetlands in Tennessee are predominated by riverine swamps in the form of bottomland hardwood communities. The following narratives describe the visited sites.

Brunswick, TN. A small package plant serves the town of Brunswick, Tennessee, located approximately 15 miles northeast of Memphis. This package plant is operating above design capacity and discharges approximately 0.05 mgd to an old river channel draining into the Loosahatchie River. A sizeable number of dead trees (oaks, birch) were located in the immediate discharge area; however, it could not be determined if this problem was related to water quality or quantity. Further downstream from the discharge, the trees appeared to be healthy, and thick underbrush was apparent. The actual discharge point to the Loosahatchie River could not be located due to inaccessibility. Algae blooms and beaver dams are two operational/water quality problems noted by the discharger.

3.8 Continued

Moscow, TN. A simple lagoon system serves the town of Moscow, Tennessee, and currently discharges directly into a riverine swamp forest (Wolf River). At the time of the site visit the river channel was swollen by recent rains and measured approximately 75-100 feet across. Numerous cypress and gum trees of all sizes dominated the shallow floodplain, and cypress seedlings were noted along the edge of the river. The actual outfall could not be located since it was underwater at this flood stage. The zone of discharge was distinguishable by color and emergent macrophytes, which were especially thick at the discharge zone. A small stand of dead gum and cypress trees was located in the proximity of the outfall area; however, the cause of this tree kill is unknown.

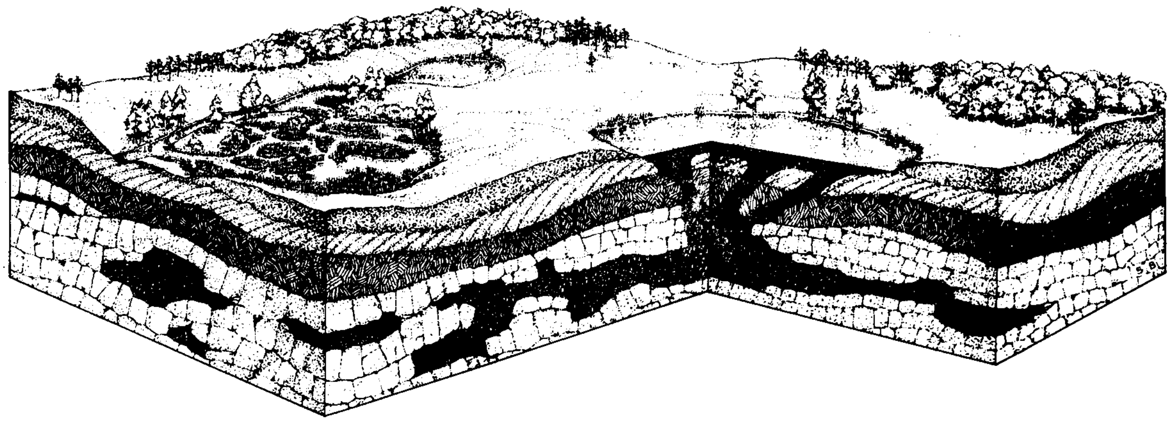
Bolivar, TN. The town of Bolivar, Tennessee, is served by a standard secondary treatment plant using a trickling filter and clarifier. This plant discharges approximately 0.35 mgd into nearby Spring Creek and has been operating continuously for 27 years. Spring Creek eventually flows into "Hatchie Bottom" (Hatchie River), which is a large flat area braided with numerous streams. The Hatchie River is a heavily forested river swamp designated as a Scenic River.

The discharge area was heavily forested with mixed bottomland hardwoods and cypress. The meandering stream channel readily changes with the flow because the land is extremely flat. The volume of the discharge was minimal compared to the total creek flow and wildlife was plentiful in the area. Beavers frequently dam portions of the stream, causing shifts in the stream channel and occasional tree kills.

Table 3.8. The Profile of Wetlands Discharges Based on Questionnaire Response for Tennessee.

Discharge Number	Wetland Type	Typical Vegetation	Easement or Ownership	Time Since Discharge Began	Discharge Frequency	Wetlands Impacts	Discharge Related Problems	Effluent Type and Average Daily Flow	Are Wetlands Useful for Wastewater Treatment and/or Disposal
1	River swamp	Small hardwoods	Easement	8 years	Continuous	Algae growth along swamp edge	Excess solids from food processing plant has caused odor problems	Industrial (food processing) 2.74 mgd	No
2	River swamp	Hardwoods, cattails	Easement	6 years	Continuous	Great increase in algae concentrations. Beavers dammed lower end of river.	No flow in swamp	Domestic 0.03 mgd	Where wetlands have free flowing water, it is a very efficient means of of disposal.
3	Swamp creek	-	Ownership	22 years	Continuous	Algae in discharge	Odor problems	Domestic 0.07 mgd	Yes
4	Swamp creek	-	Ownership	18 years	Continuous	Algae in discharge	None	Domestic 0.6 mgd	Yes
5	Swamp creek	Cattails	Ownership	12 years	Continuous	None	Problems with BOD and suspended solids	Cooling water 0.108 mgd	Yes
6	Swamp creek	Hardwoods, cypress	Easement	27 years	Daily	None	None	Domestic 0.35 mgd	Yes, for secondary treated waste.
7	Swamp creek	Cattails, hedge-hyssop, sedge grasses	Easement	29 years	Continuous	None	None	Domestic 1.0 mgd	Yes
8	River swamp	Cypress, bottomland hardwoods	Ownership	20 years	Continuous	None	None	Domestic -	Yes. Funding assistance is necessary for wetlands management

Source: Survey of wetland dischargers conducted by Claude Terry & Associates, Inc., Spring 1982.



SECTION 4

NATURAL WETLANDS CHARACTERISTICS

4.0 NATURAL WETLAND CHARACTERISTICS

SPECIFIC WETLAND CHARACTERISTICS BASED ON THE INTERACTION OF SOILS, HYDROLOGY, VEGETATION AND GEOMORPHOLOGY

The major components of wetland ecosystems interact to form and contribute to the basic fabric and integral function of wetlands. The hydrology, vegetation, water quality, wildlife and geomorphology of wetlands are the key elements identified and discussed in this section. These elements are discussed from the standpoint of preservation of their natural function and the potential impacts from wastewater addition.

The physical form of wetlands imparted by the geomorphology of the region provides a basis for defining and characterizing typical wetland types. The geomorphology of wetlands in Region IV states is characterized by a variety of geologic formations and physiographic provinces including floodplains, piedmonts and karstic areas. he majority of soils found in southeastern wetlands are highly organic although clays and loams are typical of alluvial plain wetlands.

The vegetation of wetlands form the basis for energy and material cycling and are among the most productive ecosystems in the world. However, not all wetlands within Region IV are highly productive. The vegetation is adapted for life with some level of flooding. The predominant vegetation types form the basis for the classification of wetlands. An understanding of the ecology and succession of wetland vegetation is necessary to maintain the natural structure and function of wetland ecosystems. This is especially true in preserving rare and valuable wetland ecosystems.

The hydrologic regime is the key regulator of wetland ecosystems. It influences the type of vegetation able to grow in wetlands and regulates the movement of nutrients into and out of wetlands. The hydrologic characteristics of wetlands define the filtration, buffering, storage and groundwater recharge capacity of wetlands types. Many factors contribute to the hydrologic characteristics of wetlands including physical characteristics, soils, and vegetation. Thus many wetland types have their own unique sets of hydrologic characteristics.

Water quality in wetlands is a complex set of often locally important chemical and biological parameters. The levels of pH and DO are typically low in wetlands. Heavy metals are commonly bound to sediments when introduced into wetlands, but many questions need to be resolved in this area. Nutrient levels and cycling characteristics vary among wetlands. Many wetlands act as a sink for nitrogen and phosphorus, while tidal freshwater and alluvial wetlands may act as a source or sink. Carbon and sulfur cycles are also important from the perspective of wastewater recycling. Most endemic microorganisms in wetlands serve to decompose organic matter and provide an important service of recycling nutrients. Endemic populations of encephalitis-causing microorganisms sometimes form significant reservoirs in mosquito and bird populations in wetlands.

4.0 Continued

The value of wetlands as wildlife habitat and food source is well documented. Wetlands have received much attention as a reservoir of threatened and endangered species. Perturbation or destruction of wetlands can result in loss of wildlife or rare and endangered species.

Issues of Interest

- What are the major natural characteristics of wetlands within Region IV?
- How do these characteristics interrelate?
- Why are natural characteristics important to wetlands structure and function?
- Which natural characteristics are likely to be affected by wastewater application?
- What are the major physical characteristics of wetlands within Region IV?
- How is vegetation important in wetland ecosystems?
- What role does hydrology have in maintaining and regulating wetland ecosystems?
- What water quality parameters are important in natural wetlands and are these parameters affected by wastewater addition?
- Why are wetlands valuable to wildlife? Which threatened and endangered species are dependent on wetlands?

4.0 NATURAL WETLAND CHARACTERISTICS
4.1 Geomorphology

PHYSICAL CHARACTERISTICS HELP DEFINE WETLANDS

The physical characteristics of wetlands systems are the result of geology, soils, vegetation, and hydroperiod. Common physical characteristics such as geology and topography help distinguish different types of wetlands.

Wetlands systems have distinct physical characteristics that relate directly to their occurrence and sustenance. The series of profiles illustrated in Figures 4.1-a through 4.1-f indicate the relationship of the systems to underlying substrate and/or topography. Dependent on the depth to the water table, proximity to surface waters and surface water depth, wetlands systems of different types exhibit rather common physical characteristics. The vegetation assemblage which develops depends on geology, soils, hydrologic cycle, water chemistry, and moisture conditions. Each of these elements will be discussed in detail in later sections. However, these combine to form the typical physical characteristics that are associated with different wetlands systems.

The geology and soils of wetlands play a significant role in the formation of wetlands and greatly influence their use for wastewater disposal. Throughout the Southeast, wetlands are usually associated with river floodplains and lakes, karstic (limestone) areas, or perched water tables. Geologic considerations are important when determining the potential for deep aquifer wastewater contamination through direct recharge from wetlands. This potential for groundwater contamination may be greatest with karstic formations; however, wetland systems associated with karstic dissolutions, such as some cypress domes, are not well understood. The cypress dome profile presented in Figure 4.1-a provides an orientation to the fundamental physical characteristics of a cypress dome receiving wastewater. The transition of submergent to emergent vegetation in a marsh wetland community is presented in profile in Figure 4.1-b. A similar profile of a transition between a riparian to a bottomland hardwood community is presented in Table 4.1-c. Wetland types can be highly interspersed due to changes in basin physiography as is illustrated in Figure 4.1-d. Fine differences in the vegetational assemblege within a wetland type may reflect subtle changes in the physiography. Various components of a bottomland hardwood ecosystem are profiled in Figure 4.1-e.

The predominantly organic soils associated with southeastern wetlands also have an important function in the formation and maintenance of wetlands. Fine-grained, highly decomposed peat soils are associated with many types of wetlands from North Carolina (pocosins, Carolina Bays) to Florida (cypress and gum domes). A profile of the soil layers beneath a North Carolina pocosin is presented in Figure 4.1-f. The presence and extent of various soil layers varies considerably among wetland types. Decomposition of these peat soils slows percolation. Kaolinate clay interfaces existing below peat soils in Florida cypress domes further impede subsurface water movement. This subsurface phenomena in conjunction with wetland hydrology and vegetation are important considerations when determining wastewater disposal potential. Soils such as marsh soils also affect nutrient cycling in wetlands and can further impact wastewater disposal alternatives.

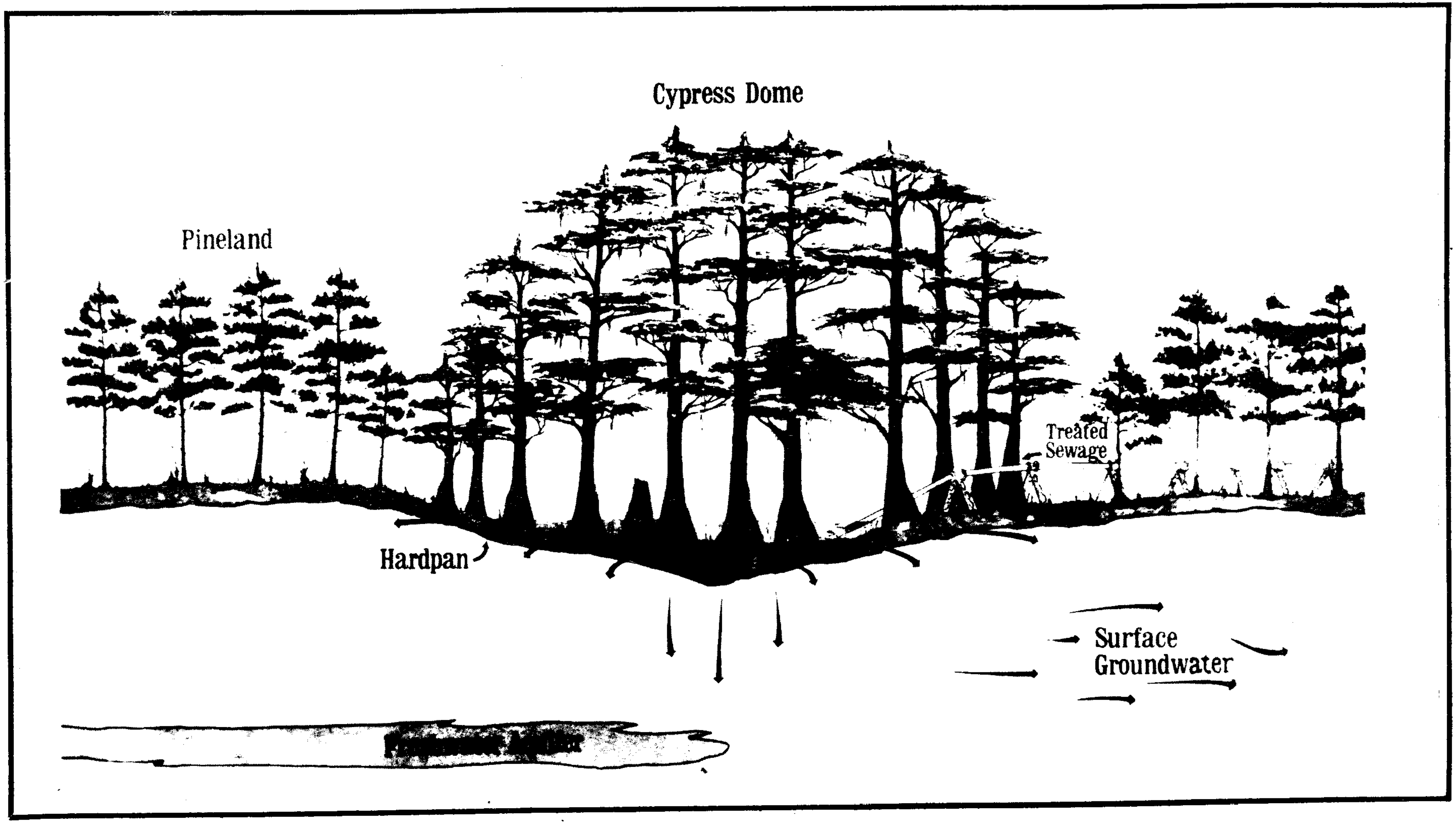


Figure 4.1-a. Physical profile of cypress dome receiving sewage effluent.

Source: Odum, et al.

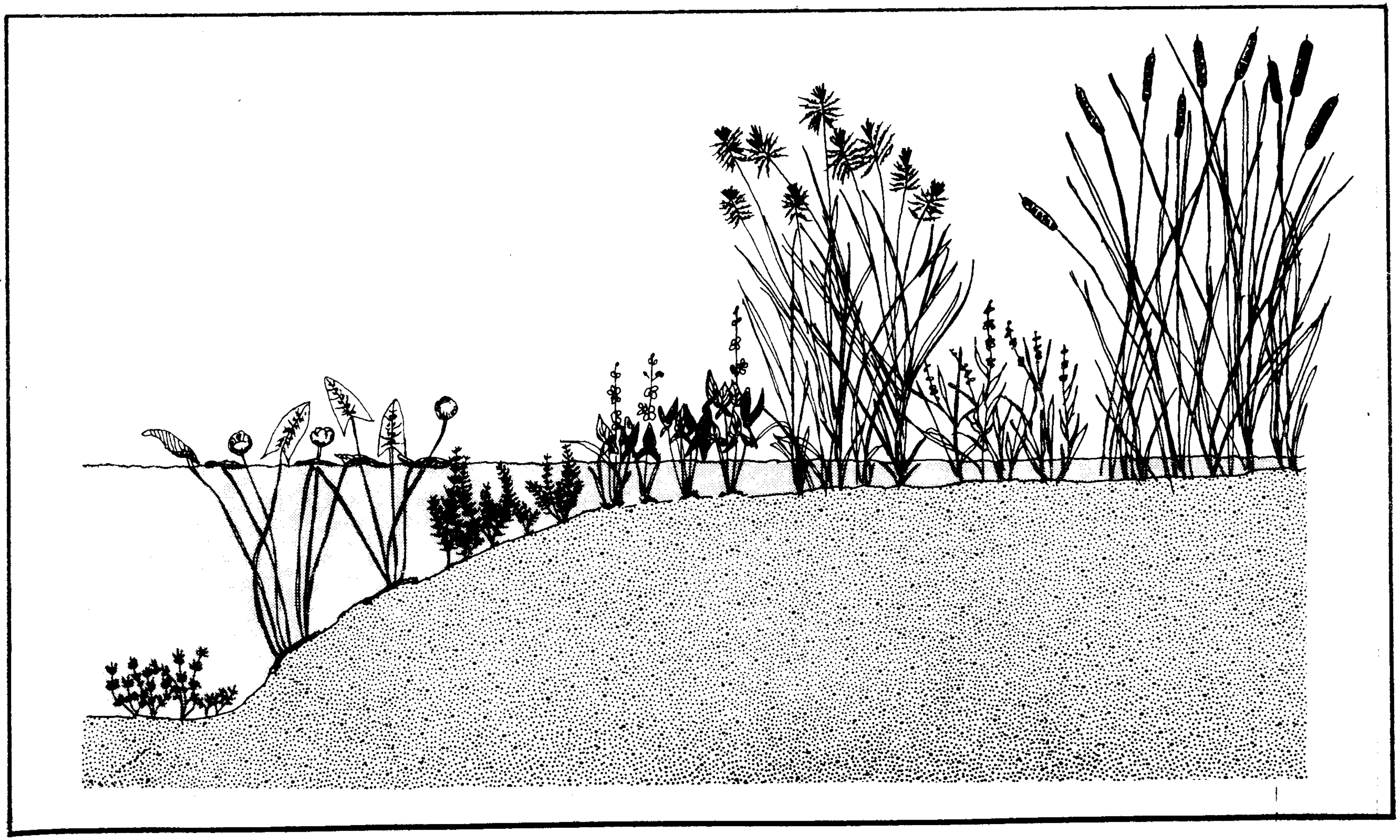


Figure 4.1-b. Profile of submergent and emergent wetland marsh community.

Source: Darnell et al. 1976.

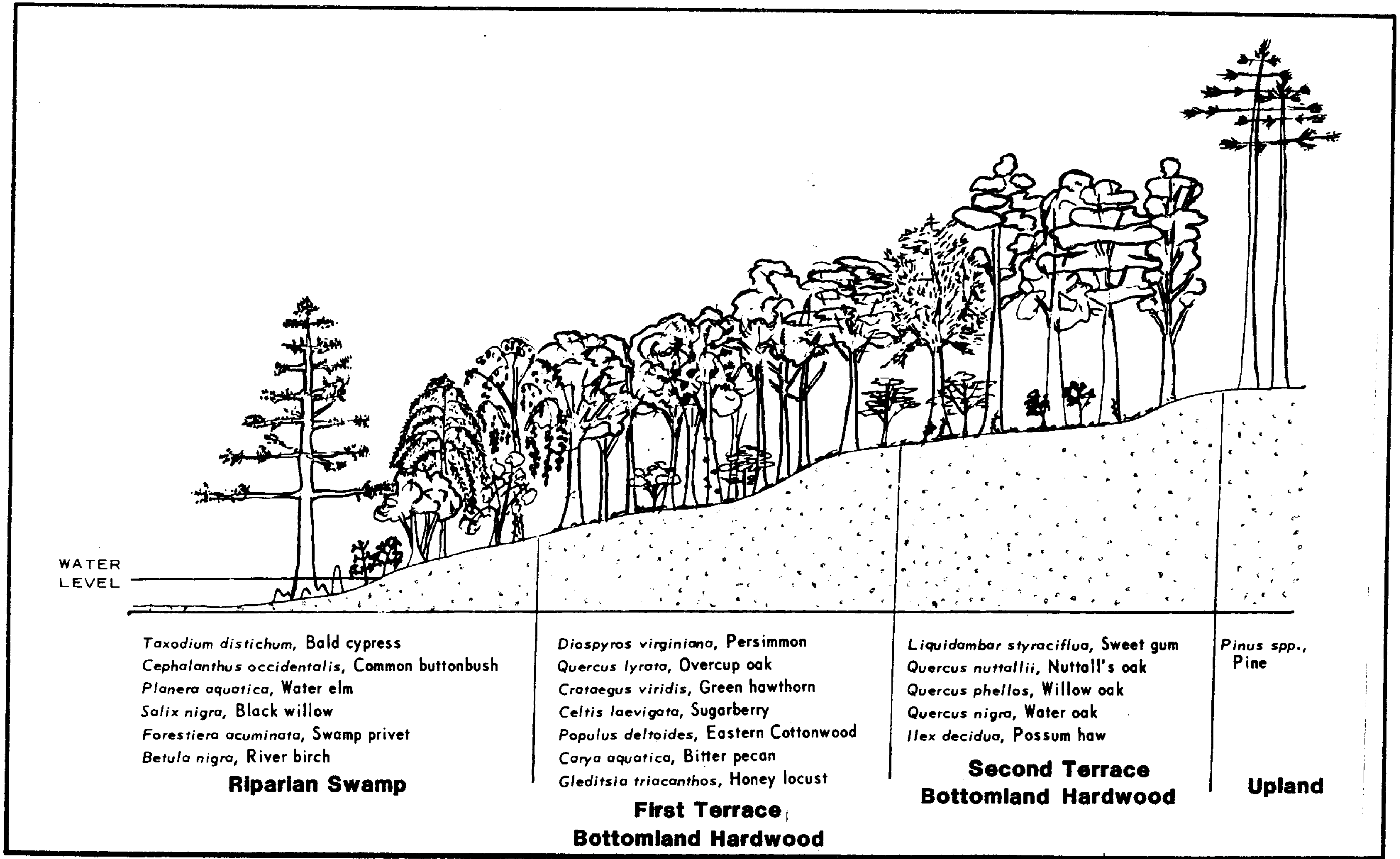


Figure 4.1-c. Transition from riparian wetlands to bottomland hardwoods.

Source: COE. 1978.

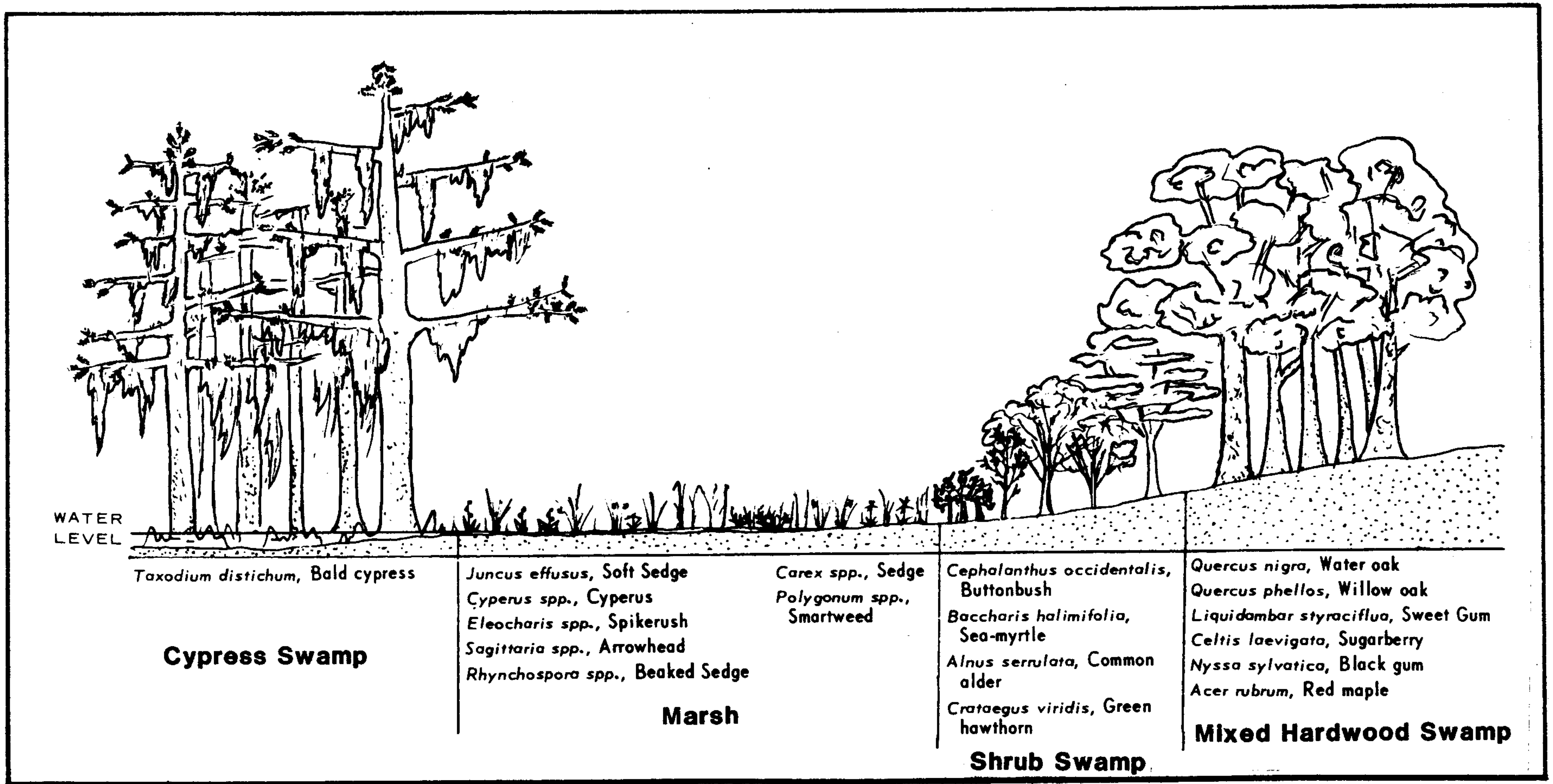


Figure 4.1-d. Profile of transition between several common wetland types.

Source: COE. 1978.

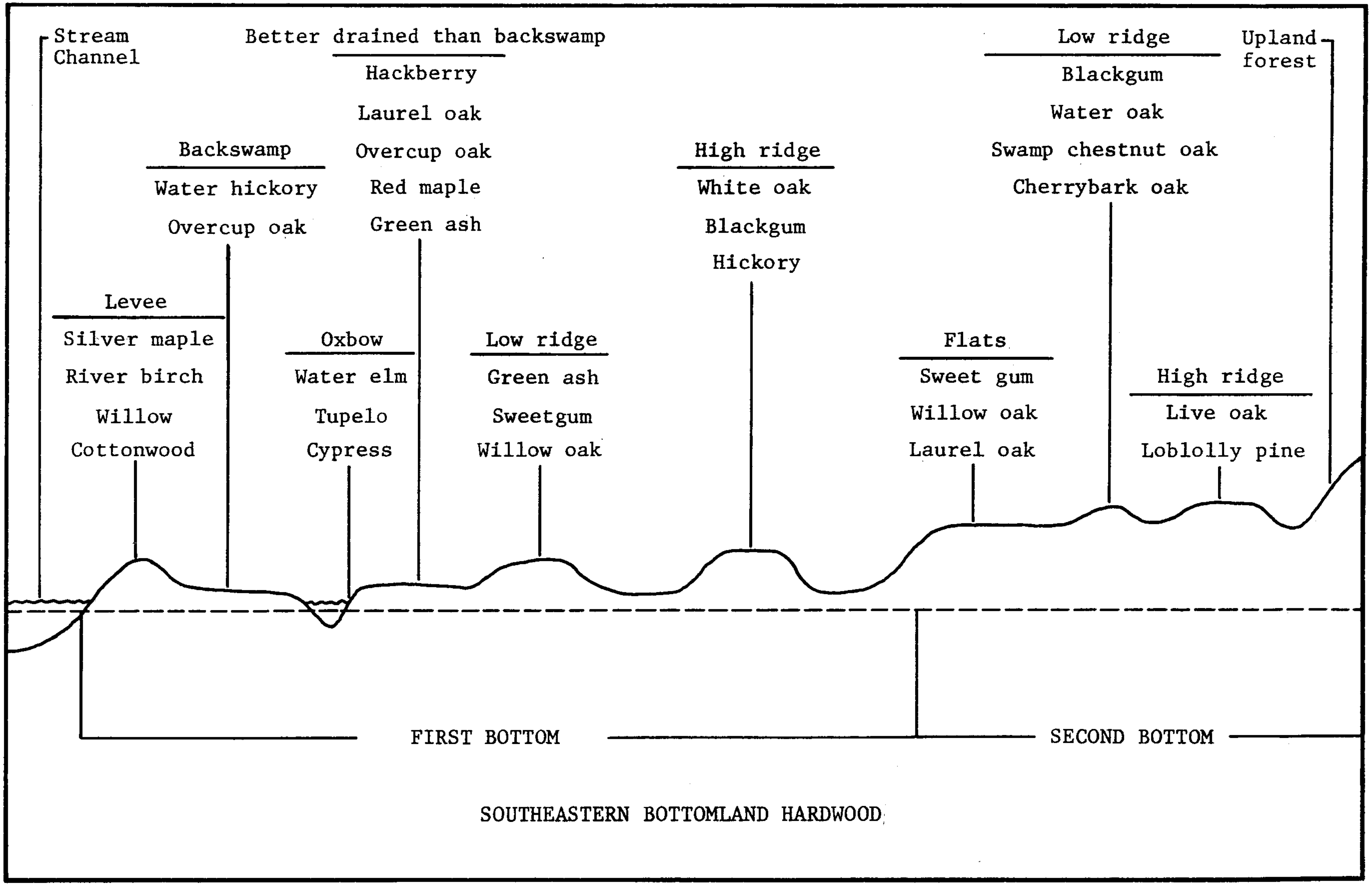


Figure 4.1-e. Profiled, various components of the bottomland hardwoods ecosystem.

Source: Brinson, et al. 1981.

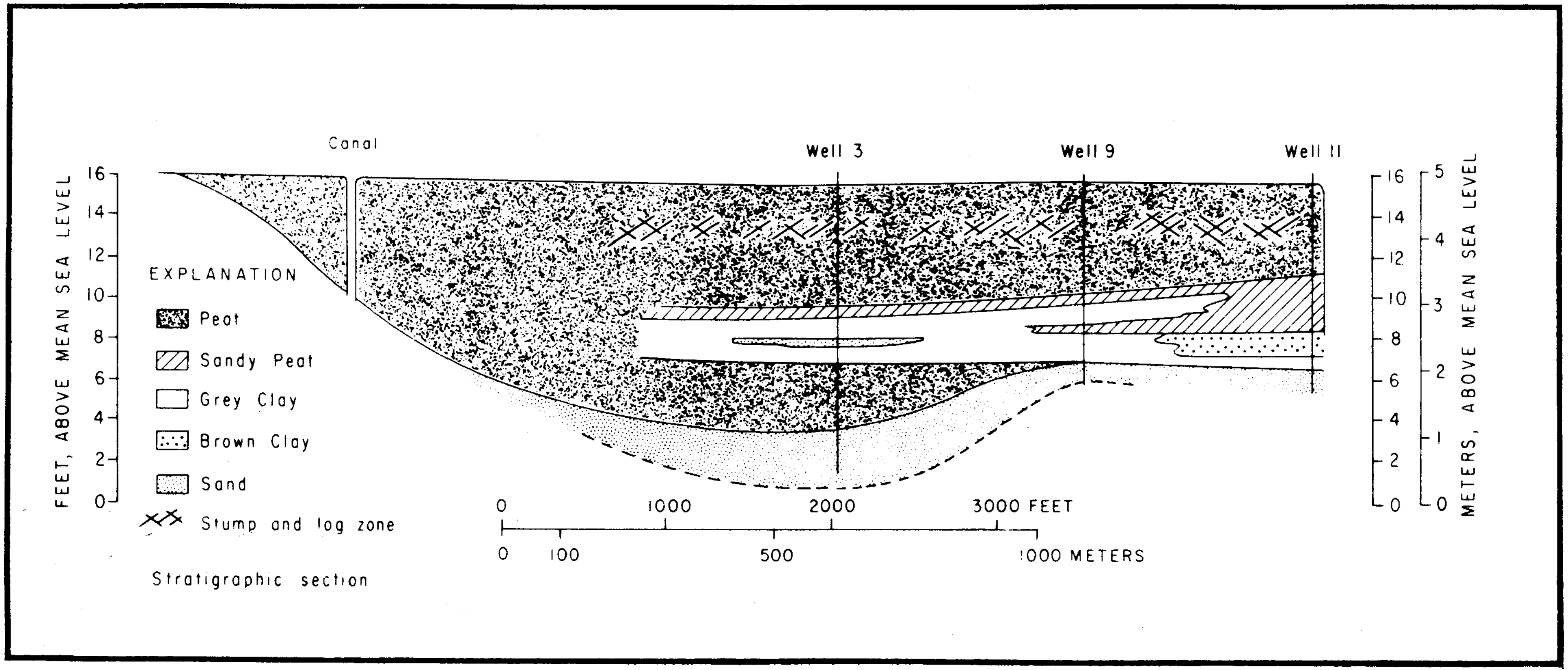


Figure 4.1-f. Stratigraphic profile of soil beneath a pocosin wetland.

Source: Daniel. 1981.

4.0 NATURAL WETLAND CHARACTERISTICS
4.1 Geomorphology
4.1.1 Geology

GEOLOGY HAS MAJOR INFLUENCE ON FORMATION OF WETLANDS

The geological characteristics of an area have a direct impact on the formation and maintenance of wetlands. Of particular interest to this study are formations which lead to direct recharge of aquifers.

The Region IV states are characterized by a variety of geologic formations and physiographic provinces. The Mississippi River system borders the region on the west and has a large influence on wetlands due to its extensive floodplain. The north central area is transected by the Blue Ridge mountains and is adjacent to the Ridge and Valley Province characterized by series of faults and folds which form the ridges and valleys. These mountainous areas transform into the Piedmont, which is rolling terrain dominated by clay soils. Moving to the south and southeast, a fault line separates the Piedmont from the Coastal Plain. This line occurs approximately across the middle of the states of Alabama, Georgia, South and North Carolina. The Coastal Plain is characterized by geologically recent sedimentary deposits formed by changes in sea level.

Numerous geological surveys of these areas have been undertaken to study the origin of substrate and outcrops, formation of land forms, and source of soils. As a result, these will not be discussed in this section. Rather, this section concentrates on correlating the formation and location of wetlands areas with geologic processes.

Most wetlands are found in low lying areas where the water table is at or near the surface. Many wetlands within Region IV are associated with riverine floodplains and areas contiguous to lakes. Many others are formed in interior regions, unassociated with major surface water bodies. These wetlands are found in association with karstic (limestone) areas and perched water tables (formed by near -surface impermeable substrate).

Karstic deposits are located primarily near the outer (seaward) portions of the Coastal Plain. However, they are also found in other areas in Region IV, as evidenced by the underground caverns located in portions of Tennessee and Kentucky.

The geologic origin of some wetland systems is poorly understood. Carolina bays, found in North and South Carolina, are unique systems whose origins are not totally understood. Cypress dome systems appear to be the result of karstic dissolution, but their origin is also less understood than wetlands associated with contiguous surface waters.

Beyond understanding the origin of wetlands and why they are located in certain areas, geology is important to this analysis of wetlands for its role in the formation of recharge mechanisms. Wetlands have a direct interface with shallow groundwater. For most wetlands systems, this interface is confined to the near surface or water table aquifer. Wetlands are extremely important components of the hydrologic cycle and hydrologic regime of many areas (See Section 4.3). But of major concern is an analysis of geologic formations that connect wetlands to deeper aquifers that are a more direct source of consumptive water supply.

The primary geologic formation associated with wetlands which leads to direct deep aquifer recharge are karstic deposits, although others may exist. Limestone deposits are particularly susceptible to dissolution, which opens cavities across aquicludes and allows direct recharge. Figure 4.1.1 shows a cross-section which typifies this situation. This type of formation is predominantly found in Florida and near coastal areas of other Region IV states. Other geologic process, while important to the formation and maintenance of wetlands, are not likely to result in major impacts from wastewater discharges. The specific importance of geologic factors in wastewater recycling hinges upon the water balance and the presence or absence of permeable or semi-permeable layers.

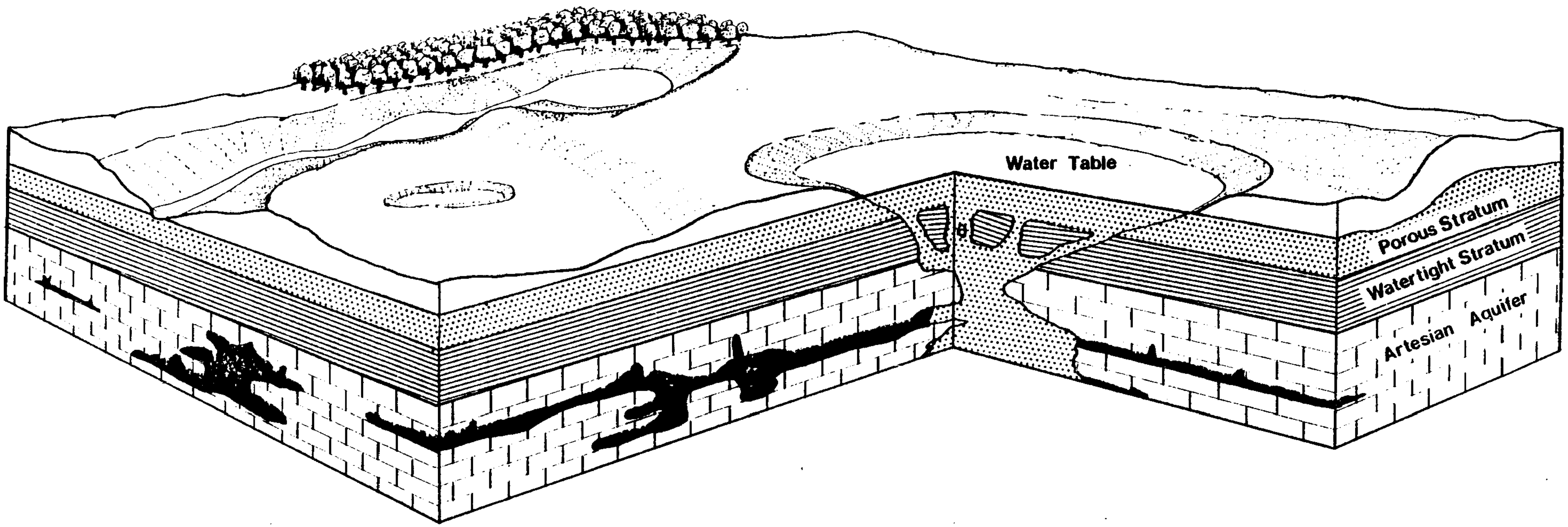


Figure 4.1.1. Representative cross-section of karstic geology.

Source: Claude Terry & Associates, Inc. 1980.

4.0 NATURAL WETLAND CHARACTERISTICS
4.1 Geomorphology
4.1.2 Soils

ORGANIC SOIL IS THE PREDOMINANT SOIL TYPE IN SOUTHEASTERN WETLANDS

Organic soils dominate the surface complex of most southeastern wetlands. In alluvial plain wetlands, clays and loams occur. In marsh soils, a thin aerobic surface layer serves as a release mechanism for nitrogen and increases the soils' ability to serve as a storage reservoir for phosphorus.

The majority of soils supporting southeastern wetlands are highly organic. These soils are commonly called bogs, moors, peats or mucks and are grouped in the histosol order. Soil orders consist of broad groupings of soils organized principally to show which soil-formation factor has had the greatest influence in determining the properties of a soil. Histosols develop in areas of impeded drainage where water stands on the soil surface for long periods of time. The degree of decomposition is closely related to fiber content and bulk density. Most histosols have bulk densities of less than 1 g/cc which tends to increase with decomposition. Physical difference between histosols relates to parent material, topography, time of development and hydrologic fluctuations.

Histosol soils vary in other ways including, but not limited to percent organic matter, water-holding capacity, pH and cation exchange capacity (CEC). The CEC is a soil property which can remove significant amounts of positively charged ions such as NH_4+, K^+ and others from waters in contact with the soil. Organic soils generally have higher CECs than mineral soils (Alexander 1977). The CEC is pH dependent. Further, the CEC increases as decomposition increases. Anions (negatively charged ions) may also be sorbed onto charged surfaces of peats (Kadlec and Tilton 1979). Nitrate is little influenced by this process, but some phosphate removal may be attributed to anion exchange. All these factors affect the nutrient absorptive capacity of wetland soils. The nutrient removal capacity is in turn affected.

In North Carolina, peat supports three distinct wetlands: 1) pocosins; 2)river floodplains; 3) Carolina Bays (Ingram and Otte 1981). Peat deposits are characterized as finegrained, highly decomposed hemic to sapric soils. In general, two peats exist. The first is characterized as a mixture of sedge and sphagnum peat associated with poor tree growth. The second type is predominately sphagnum peat that is dome shaped and isolated from groundwater sources (Very and Boelter 1978, Ingram and Otte 1981). As decomposition in peat becomes complete, pore space size decreases and water drains less easily. As a result, hydraulic conductivity is inversely related to the degree of decomposition.

Peat soils are also characteristic of Florida's cypress and gum domes and mixed hardwood domes. Spangler et al. (1975) analyzed soil profiles for several cypress domes typical of north central Florida. The upper horizon consists of a sapric peat followed by a zone of saturated coarse sand. A confining layer of kaolinate clay separates the dome from direct connection with underlying aquifers and allows virtually no vertical movement of water. Effluent disposal under these circumstances would be confined to the water table aquifer. Not all domes conform to this geologic arrangement and have different implications for wastewater management.

The diversity associated with alluvial floodplain soils is closely related to inundation, vegetation and the source of water input. Water is the primary factor that influences the type and properties of existing soils. Where saturated soil conditions exist throughout the year, clays (alfisols and inceptisol soil orders) usually dominate, and the soils exist in an anaerobic condition. Where soil saturation occurs for shorter periods (ultisols), clays and loams dominate, and an environment exists that is favorable for vegetative root respiration (Clark and Benforado 1980, Soil Survey Staff 1975).

The extent of soil saturation plays an important role in the development of wetland soil characteristics. In the Southeast these soils exist in an anaerobic condition, typify the alfisol soil order and maintain low redox potentials. The anaerobic condition results in slow rates of decomposition and mineralization. A thin aerobic oxidized surface layer (microzone) is intermittently present in wetland soil profiles; the layer serves as a regulatory mechanism for nitrogen release and increases the soil's ability to serve as a storage reservoir for phosphorus (Klopatek 1978).

VEGETATION IS MAJOR CHARACTERISTIC OF WETLANDS

A variety of vegetation types comprise wetlands. Different ecological processes, such as succession and productivity, determine wetland characteristics and functions. Various physical and biochemical components determine vegetative communities.

The vegetational characteristics of natural wetlands are among the best studied attributes of natural wetlands. The vegetative component of wetlands ecosystems have an important role in regulating hydraulic regimes, influencing nutrient cycling and providing wildlife habitats. Vegetation types are also important to soil processes and peat formation.

The types of vegetation which inhabit a particular wetland system are dependent on several factors. Among the most important are hydroperiod, soils and water chemistry. On a regional scale, climatic and temperature/precipitation conditions also have a significant influence on wetland communities, as certain species are limited to near coastal sub-tropical environments. The type of predominant vegetation helps differentiate wetlands.

Interactions between wetland components require that vegetation ecology be understood. Knowledge of the successional pattern or stage of a system assists in assessing the function of a wetland, its role with interacting ecosystems, and its stability.

Wetlands are extremely productive natural ecosystems. They provide habitat for a wide range of organisms during certain stages of their life cycle. Wetlands provide an export of detritus and nutrients at certain times of the year (in flowing wetland systems) which are critical to downstream ecosystems and the organisms which inhabit them. Productivity is largely dependent on interaction of the type of vegetation comprising a wetland, nutrient availability and hydrologic stress.

In evaluating wetlands throughout Region IV, it is apparent that some systems are particularly unique or limited in extent. These are identified in Section 4.2.5 and will be given special attention.

4.0 NATURAL WETLAND CHARACTERISTICS
4.2 Vegetation
4.2.1 Plant Ecology

PLANT ECOLOGY DESCRIBES INTERACTION OF WETLAND STRUCTURE AND FUNCTION

A thorough understanding of the ecology of wetlands vegetation is important to understanding how a wetland functions. The impacts of hydrology, sedimentation, and fire are important to the maintenance and succession of wetlands vegetation.

The interplay of physical, chemical, and biological factors shape the composition and ecology of vegetational communities. Because each part of an ecosystem is linked to another, the ecology of wetland vegetation is intricately linked by the flow of materials and energy to other wetland components such as wildlife, nutrient cycles, and hydrologic patterns.

Regional variations in precipitation, sunlight, and temperature are important physical factors which determine the ecology of wetlands vegetation in the Southeast. In general, the climate of Region IV is characterized by distinct seasonal rhythms in temperature, mild winters and the absence of a dry season. Annual rainfall varies from 40 to 65 inches and is generally distributed throughout the year.. In some cases, a large portion of the total accumulates during the summer months. Even the northern areas of Region IV (Kentucky, Tennessee) may experience over 250 frost-free days (Barry 1980). The seasonal variations in these climatic variables determine the timing, rates and extent of material flows in wetland plant environments. For example, the pattern of nutrient uptake throughout the year in North Carolina is quite different from that in Florida (Whigham and Bayley 1978). Similarly, important primary trophic level processes such as growth season, leaf fall, and productivity are seasonally related to local temperature and moisture regimes. In turn, other trophic levels (second, third, detrital, etc.) are affected. The life cycles of insects, soil organisms, reptiles and birds are all adapted to primary trophic level processes. Therefore, the ecology of wetland vegetation is important to the development and maintenance of wetland plant and animal life.

The ecology of wetland plants includes the adaptation of plants for survival and reproduction in wetlands. Adaptations to flood tolerance fall into two categories, physical and metabolic (Teskey and Hinkley 1977). Both types of adaptations have the similar purpose of decreasing the effects on the plant of an anaerobic (low-oxygen) environment in the root zone produced by high water levels. Physical mechanisms involve processes which increase the oxygen content in the roots. This is accomplished either by transport of oxygen from the upper part of the plant (stem lenticals, leaf stomatas) or from parts of the system where oxygen is more available in secondary and adventitious (above-ground) or possibly knee (cypress knee) roots (Brown 1981). Metabolic modification to anaerobic respiration enables plants to utilize less toxic end products or discharge toxic volatiles through leaf stomata.

Wetland grasses, sedges and rushes which dominate marshes have the option of asexual reproduction which amplifies reproductive processes and species maintenance. Trees and most herbaceous species are dependent upon successful pollination, seed production, seed germination and seedling survival for reproduction and maintenance of the species. These processes are complicated, and the conditions for successful seed germination and seedling survival are not well understood for many wetland species. For example, cypress require dryer conditions for seed germination than other wetland species (cottonwood, ash) but are more flood tolerant as mature trees (FWS 1976).

Monk (1968) and others (Ewel and Mitsch 1978, Teskey and Hinckley 1977) stress the importance of fire in controlling the natural development of many plant communities of the Southeast. Lightening associated with thunderstorms in the Southeast (average 60-80/year in the Gulf coastal states) are a major source of fire in wetlands. Fire is a selective force which favors the establishment of fire resistant vegetation (cypress, pine, etc.) or vegetation adapted to rapid regeneration after fires (grasses) (see 4.2.3 on succession). Fire is also important in forming depressions in peat wetlands. During severe drought, peats will readily ignite burning depressions in the peat surface. These depressions form deep pools when water returns to normal. Fire also causes important releases and recycling of nutrients in wetland ecosystems.

The detrital component of wetlands is influenced by vegetation types. Cypress, pine, cedar and magnolia species have slowly decomposing leaf and stem parts. Decomposition is slow because of the high amount of refractory material such as waxes, oils and other organics formed as part of plant survival mechanism during flooding. The peat found in these wetlands is different in content and rate of formation than in wetlands dominated by maples, cottonwoods, ashes, certain grasses and herbs with relatively rapidly decomposing (labile) leaf and stem parts (litter). Perched bogs have only atmospheric inputs of nutrients and support vegetation adapted to a low nutrient (especially N and P) availability situation. The vegetation in these wetlands must adapt to limited internal nutrient cycling and water conservation. Riverine wetlands, strands, and minerotrophic wetlands have significantly more inputs of nutrients. The vegetation in these wetlands is adapted to high and seasonal assimilation. Efficient nutrient cycling is less critical since organic export and productivity is higher in these ecosystems (Brown 1981).

Many elements of wetland plant ecology are well described in the literature. Productivity measurements have been made, and successional patterns have been described (see Sections 4.2.3, 4.2.4). The importance of plants in nutrient cycles has also been investigated (Prentki et al. 1978, Klopotek 1978, and Simpson 1978). However, a full understanding of the intricate ecological associations of the vegetation with other components of the wetland ecosystem and among the plants themselves is still lacking. Little is known about the symbiotic relationships in wetlands or the interaction between canopy and sub-canopy trees in swamps. Although some authors (Brown 1981) have noted the impact of grazing insects on wetland productivity, it has not been quantified. Pollination ecology of wetland is unexplored and trophic

4.2.1 Continued

interactions are not well described. Competition, as it relates to productivity, ecosystem stability and successional patterns is not well understood.

How these limitations affect the understanding of wetlands processes in relation to wastewater management will be discussed further in Section 7.0

WETLANDS IN REGION IV ARE CHARACTERIZED BY A VARIETY OF DOMINANT VEGETATION TYPES

A large variety of vegetation types naturally occurs in wetlands, including trees, grasses, floating aquatics, and epiphytes. The presence or absence of an individual plant type is dependent on its ability to survive and reproduce in the wetland environment.

A number of factors are responsible for the persistance, development, and maintenance of vegetation types in the wetland environment. Local climate, topography, flooding frequency and duration (hydroperiod), water velocity and water quality are a few of the important properties determining types of vegetation present in wetlands. Biological factors such as vegetation history (succession), competition and inherent generic adaptibility to stress also influence the presence or absence of plant types found in wetlands.

Most plants occuring in wetlands are known as "hydrophytic" plants or literally "water loving" plants. "Water tolerant" would be a more accurate description of these plants because to most of these plants, flooding is a stress factor, decreasing photosynthesis and respiration (Teskey and Hinckley 1977). The varying ability of these plants to tolerate water stress forms a natural gradient of wetland plant types from mostly tolerant to moderately tolerant to mostly intolerant.

Plants which adapt to similar sets of environmental variables and hydrologic regimes form unique and recognizable plant associations or community types. These community types may form distinct associations or intergrade with other plant associations. Classification systems have relied upon these community types as the basis for differentiation.

Vegetational community types are intimately tied to many common-use terms describing wetland types. Marshes, for example, are commonly inundated with water for much of the year and contain grass-sedge-rush community types. Swamps imply a forest dominated by a variety of hydrophytic trees. The species of trees present exist along a hydrologic gradient of flooding; characteristically the more tolerant types (Cypress, gum) are found in the deeper portions while less tolerant types (Maple, Pine, Willow) are located in shallower, less frequently flooded areas. Bottomland hardwoods describes the areas along the less permanently flooded gradient where assorted hardwoods may predominate. Cypress domes are areas where cypress predominate under a special hydraulic region. Wet praires, meadows and savannahs are all common terms which refer to specific ecosystems in which characteristic vegetation types dominate. Table 2.4 shows the various vegetation types associated with different classifications of wetlands.

Sub-dominant vegetation types are also in wetlands. These types exploit unfilled niches within the ecosystem and adapt to life there. Epiphytes are air plants (bromelliads, orchids) which thrive in the humid swamp forests in

4.2.2 Continued

warmer climates of the southeast. The understory of these swamps may contain floating aquatic types where light does not permit emergent grasses to survive.

SUCCESSION OF COMMUNITIES IS RELATED TO HYDROPERIOD AND FIRE

Wetland succession describes the process of wetland community development, how it is maintained, and how it might change in the future. Certain attributes are characteristic of early wetland successional stages. Others are associated with later successional (climax) wetland communities.

Wetland succession is important in understanding the life stage of a wetland community. No natural ecosystems are permanent but are generally changing, developing and maturing in response to environmental variables. As ecosystems mature over perhaps hundreds of years, there is a tendency toward increased stability, a more complex system, greater total energy flows and more efficient utilization of resources. The high point of ecosystem development is called a climax community and is often characterized by the dominant vegetation at the site. Familiar examples of a climax forest are the oak-hickory climax on the Appalachians and the California redwoods (Oosting 1956). The southern mixed hardwoods of the Gulf South Atlantic Plain communities can be either early successional or late successional communities depending on species composition (Monk 1966). Late successional communities may exist for prolonged periods of time and are called subclimax communities. A climax community which is disturbed or degenerates forming a new stable ecosystem is called a disclimax community.

Monk (1968) concluded that cypress-dominated wetlands are subclimax communities, and bays and mixed hardwood swamps are climax wetlands. Marshes are most often considered early successional. Pocosins succession is controversial, and these wetlands are thought to be either subclimax, climax or even disclimax communities maintained by fire. Savannahs and some grass prairies are also subclimax communities which in periods of declining moisture tend to change into swamp forests. Scrub-bogs with more moisture may succeed into swamp forests (Barry 1980). Figure 4.2.3 indicates the relationship between hydroperiod, fire and succession among selected Florida ecosystems. While not general for the southeast, it is presented to emphasize the complex interaction of factors which influence succession.

Attributes characteristic of early and late (climax) successional stages are presented in Table 4.2.3. These attributes are the fabric of an ecological system which changes naturally over time. Ecosystem development may be arrested at certain stages for prolonged periods of time. Critical environmental factors such as fire and flooding often limit ecosystem development. White cedar bogs are thought to be "fire-climax" communities (Penfound 1952). When fires are prevalent, they are the climax communities; without fire, bay-magnolia swamps are climax. Wetland prairies and savannahs are also fire-dependent climax communities. With less fire or more water they may change into mixed hardwood swamps. Large tracts of swamps have had the natural order of succession and development altered by timber cutting and selective cutting of cypress.

Table 4.2.3. General Attributes of Successional Trends (after Odum 1963).

Ecosystem Characteristic	Successional Trend (early stage to climax)
Plant types and plant Diversity	Initially increases, stabilizes and may decline in older stages
Species Composition	Rapidly changes, then is more gradual
Plant size	Smaller, then larger
Total living biomass	Increases
Total nonliving Biomass (peat, etc.)	Increases
Stability	Increases
Net Productivity	Decreases
Total Energy Flows	Increases
Respiration	Increases
Ecological Relationships	More complex

Source: Odum 1963.

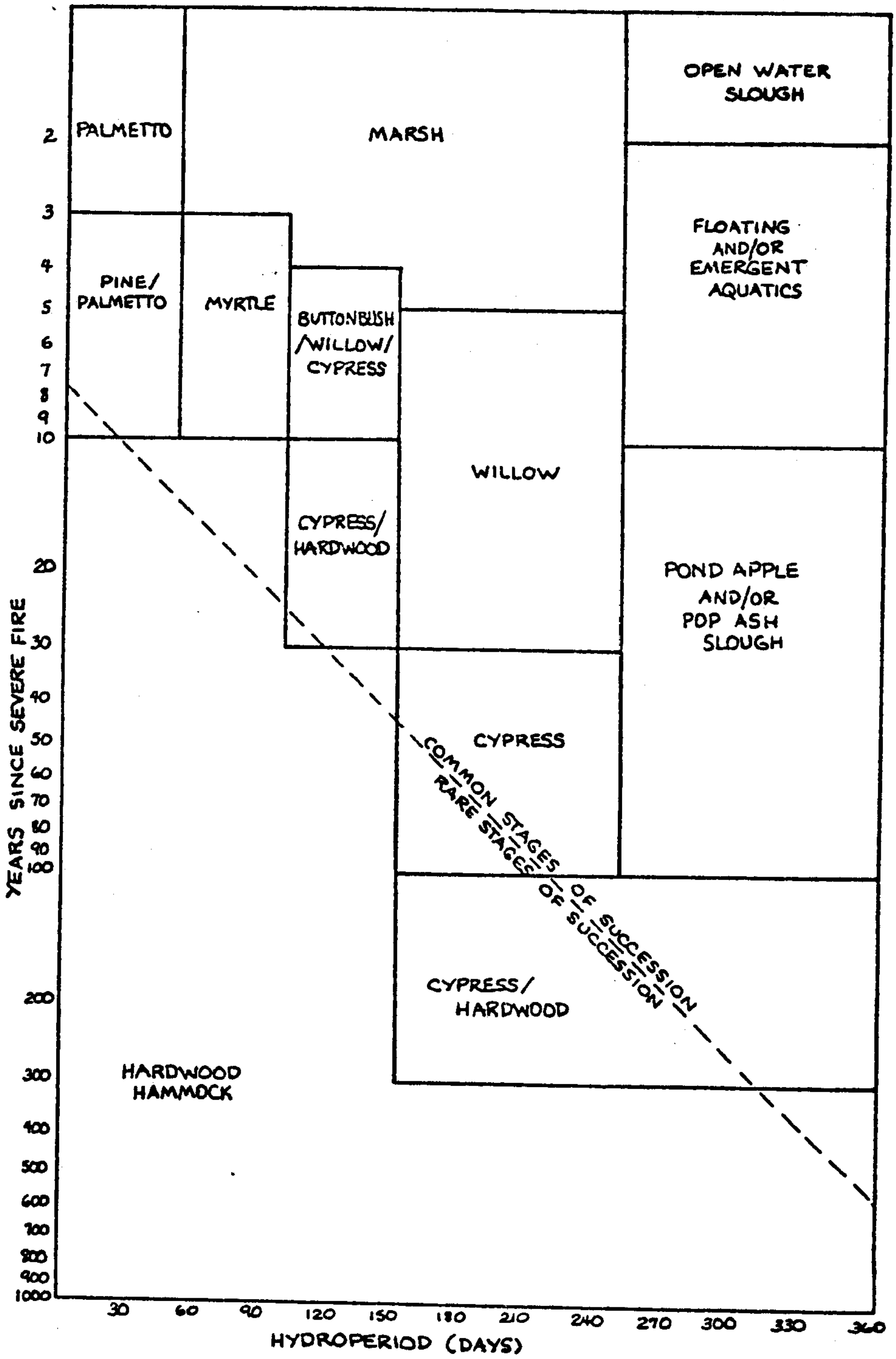


Figure 4.2.3. Relationship between hydroperiod, fire and succession for selected Florida ecosystems.
Source: Duever et al. 1976.

4.2.3 Continued

Agricultural crops such as wheat and corn are an example of a domesticated early successional ecosystem (Odum 1963). The high net yield of agriculture relies on the high net productivity characteristic of early successional ecosystems. Thus, succession can be managed to benefit man.

The integrity and ability of ecosystems to maintain equilibrium are altered when important successional forces such as fire frequency, water and nutrients are altered in an ecosystem (Figure 4.2.3), and natural successional trends are no longer maintained. Just as domesticated early successional ecosystems are valuable to man (agriculture), mature ecosystems (subclimax and climax) have important values in stabilizing water, nutrient and environmental factors. The importance of succession relative to wastewater recycling in wetlands is understanding the stability of wetlands, the characteristic rates of production and biomass accumulation in various wetland types, and the integrity of various wetland successional types and their importance to man.

SOUTHEASTERN WETLANDS EXHIBIT WIDE RANGE OF PRODUCTIVITY

Natural rates of production in wetlands vary from less than 200 to over 1600 $g/m^2/yr$. Tidal freshwater wetlands and riverine swamps exhibit the highest productivity and are among the most productive ecosystems in the world. Productivity is governed by many interacting factors and appears to be controlled by nutrients and hydroperiod stress in wetlands. Productivity is important in indexing the assimilative capacity of wetlands.

The primary productivity of wetlands is usually the measure of the rate of organic matter production by autotrophs (mostly plants). It is an important index to the activity of a system. Primary productivity reflects the ability and efficiency of wetlands in utilizing available nutrients and sunlight to produce organic matter. Some wetlands are potentially among the most productive ecosystems in the world (Odum 1963). Since many factors govern the productivity in wetlands, a wide range of productivity has been observed. Productivity is limited by genetic biotic potential, sunlight, and nutrient availability and other locally important stress factors.

Primary productivity is expressed as either gross primary productivity (GPP) or as net primary productivity (NPP). The GPP is the total amount of organic matter fixed including that used up by respiration. NPP is the organic matter stored in plant tissues in excess of respiration. Net production represents food potentially available to heterotrophs and for export. Under favorable conditions of light, moisture and nutrients, net production is high (90 percent of GPP). Under many conditions in nature, stress results in higher respiratory losses, and net production may be low.

A wide range of production has been reported for wetlands (Gosselink and Turner 1978). Mitsch and Ewel (1979) have hypothesized generalized productivity in forested wetlands. This emphasizes the importance of hydroperiod stress and productivity. Brown (1981) showed the importance of both hydroperiod and nutrients in determining productivity in swamp forests. She suggested that only those forested wetlands that receive nutrient subsidies either naturally from flooding rivers or artificially from sewage effluent are highly productive.

Brown's (1981) results indicate that increasing nutrient inputs (via hydrologic or man-induced additions) resulted in increased gross primary productivity, net productivity and plant respiration. The gross primary productivity measurements were more sensitive to changes in phosphorus input than other factors studied. These trends indicate that increased phosphorus inflow increases the rate at which sunlight fixes CO_2 into organic matter (gross primary productivity) but at a correspondingly higher cost (higher plant respiration). This counteractive effect results in a leveling of biomass production and net primary productivity instead of dramatic increases with greater phosphorus inputs. Another observation made by Brown (1981) was that with increasing phosphorus input, a proportionally less percentage of total phosphorus taken up by biomass is allocated to fruit and leaf production, indicating that excess phosphorus is stored in woody biomass.

Still and slow-flowing wetlands not receiving effluents have comparatively less production than flowing water (riverine) wetlands because of lower nutrient input (Brown 1981). The addition of sewage effluent will increase productivity by increasing available nutrient, but, as is evident in Figure 4.2.4, hydroperiod stress may constrain this increase.

Productivity and respiration may also be measured on the ecosystem level yielding total community production and total community respiration. The P/R rate of 1 reflects a steady state community (Odum 1963). If production and respiration are not equal (P/R greater or less than 1), with the result that organic matter is either accumulated or depleted, the community is expected to change by the process of ecological succession (see Section 4.2.3). Succession may proceed either from an extremely autotrophic state (R<P) or an extremely heterotrophic state (R>P) toward a new condition in with P=R (Odum 1963). Wetlands vary in their successional stages (see Section 4.2.3). Wetlands assimilating highly organic sewage effluent are an example of the heterotrophic state, where organic matter is used up faster than it is produced.

Peat-forming wetlands result from storage of large amounts of carbon production (i.e., high annual productivity). Riverine swamps and marshes export substantial amounts of organic matter to estuaries, which influence fish and shellfish harvests. Some wetlands (scrub cypress) are low in productivity, and peat layers may be minimal.

Seasonal differences as well as diurnal differences affect productivity. Winter typically causes lower productivity and subsequently lower nutrient uptake. The understory of swamp forests also has limited productivity because of shading effects. However, in the early spring, algae may temporarily dominate productivity in deciduous forests before leaves reappear (Brinson et al. 1980).

These temporal and wetland type variations in productivity are important in understanding and managing wetlands for nutrient assimilation. Especially important from an ecological viewpoint is limiting stress on a wetland that would significantly change the quantity and the quality of organic export, thus affecting downstream communities dependent on wetlands exports.

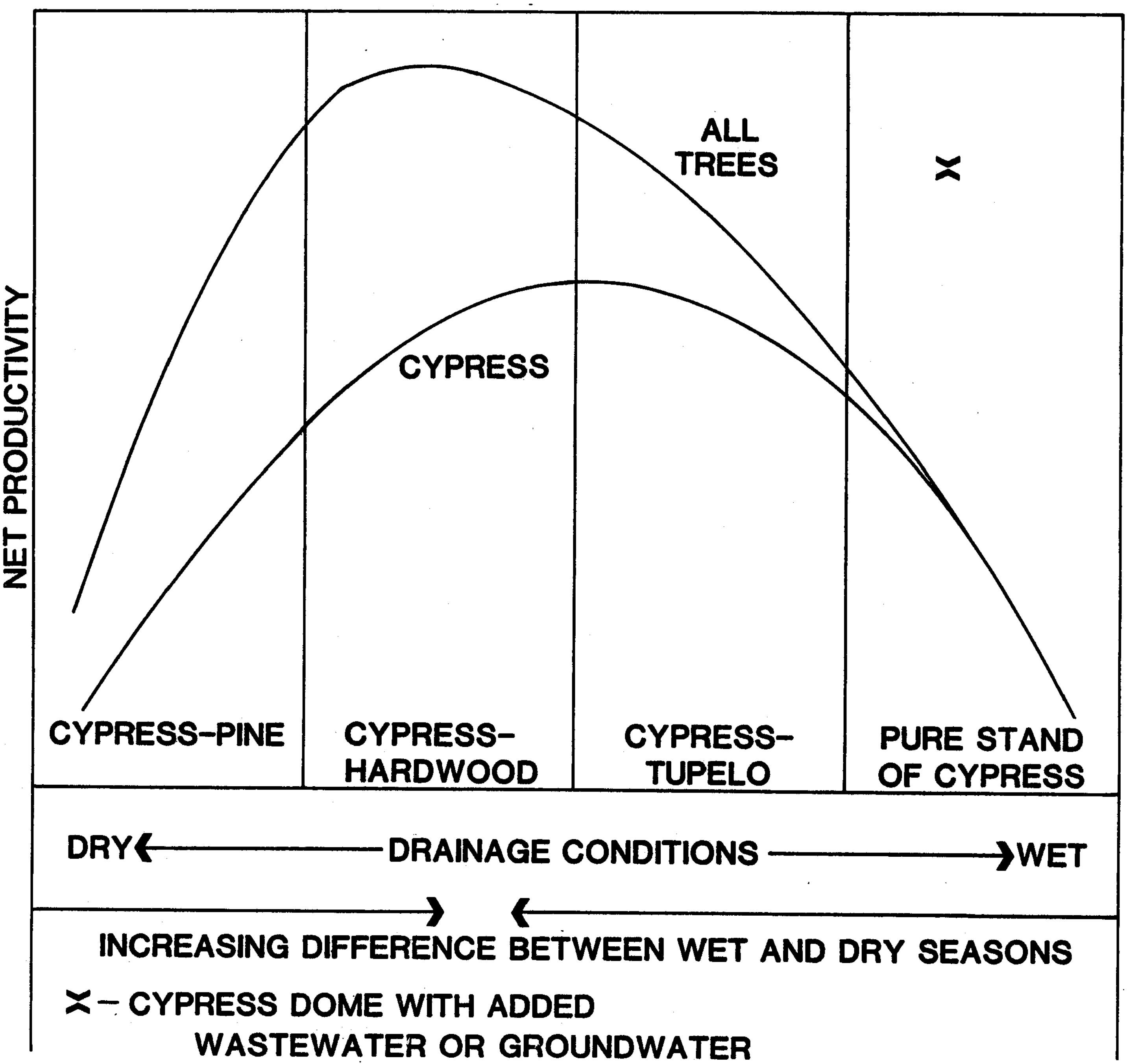


Figure 4.2.4. Hypothesized relationship between hydroperiod and net productivity for several wetland forests.

Source: Mitsh and Ewel. 1979.

WHITE CEDAR BOGS, OTHER WETLANDS MARKED FOR PRESERVATION

All wetlands have intrinsic natural value. Several wetland types must be given special protection due to their special ranges, uniqueness, scientific or cultural value.

The wetland resources of the U.S. have declined dramatically since the turn of the century. It has been estimated that over 40 million acres have been lost since then. The consequences of wetlands destruction include loss of flood storage, erosion control, wildlife production, and habitat and genetic diversity. The most significant source of encroachment on wetlands has been channelization activities and agricultural conversions. The use of wetlands for wastewater recycling does not fit into the above categories, but, for some wetlands, this practice may not be appropriate.

The wetlands described in this section are those which are outstanding in some regard. They deserve special consideration because of their rarity, uniqueness of habitat, location, special endemic species, and scientific or cultural values. As a result, they are less preferrable for use in a wastewater management system.

An extensive survey of unique wetlands of the United States was published in 1975 by the National Park Service (NPS) (see Section 2.3). The purpose of this report was to identify wetlands which may qualify as national landmarks. Wetlands were selected for their expanse, uniqueness, scientific and wildlife value. A descriptive listing of the landmark wetland types in each Region IV state is presented in Table 4.2.5-a. The NPS publication, "Inland Wetlands of the U.S." (Goodwin and Niering 1975), contains a complete listing and description of the wetland landmarks.

The group of wetlands listed by Goodwin and Niering (1975) is by no means a complete listing of rare and sensitive systems important in maintaining our wetland heritage. Wastewater recycling is a more sensitive issue regarding these wetlands since the possibility exists that some characteristic of the natural wetland may be altered (see Section 7.1.2). Identification of the uniqueness and value of a wetland is not a simple task (Golet 1978). Local authorities are best consulted to identify unique or unusual wetlands. South Carolina, for example, has a series of map overlays which identify wetlands in each county and key the distribution of rare and endangered plants to that wetland map (Phillips 1982).

Other wetland types which are noted for their rarity and scientific value on a region-wide basis are the white cedar bogs and the Carolina bays. The limestone sag ponds are wetlands with a limited regional distribution. Penfound (1952) mentions the eight minor freshwater swamps and five minor freshwater marshes (Table 4.2.5-b) which should be considered limited in distribution and possibly unique.

Table 4.2.5-a. Landmark Wetlands of Region IV

State	Areas Reported	Description
Alabama	3	Riverine swamps, floodplain forest, sloughs, beaver ponds, delta wetlands (fresh-saline, forest-marsh transitions).
Florida	11	Swamp forests, wet prairies, tree islands, scrub cypress, riverine headwaters.
Georgia	13	Coastal and Piedmont areas dominated by Southern River Swamps. Lack data on New Ridge Valley section of state. Sagpond areas unique.
Kentucky	2	Seasonally flooded river bottoms of Ohio and Mississippi Rivers. Sloughs. Include many scattered small sinks.
Mississippi	3	Extensive river bottom swamps. Southwesterly extension of white cedar at Juniper Swamp.
North Carolina	1	Long Hope Creek spruce bog of interest, numerous pocosins and bottomland swamps (riverine) exist, but not yet included as "Landmark" wetlands.
South Carolina	4	Extensive bottomland forest: The Congaree, Fourhole swamp, are outstanding examples. Channelization is a major threat.
Tennessee	5	All three major wetland types (marshes, bogs, swamps) represented. Bogs have specific scientific value in pollen records. Limestone marsh sinks have special habitat value. Some very diverse wetlands areas exist. The rare bluewinged teal is associated with these wetlands.

Source: Goodwin and Niering 1975.

Table 4.2.5-b. Minor Marsh and Swamp Types Discussed in Penfound (1952).

Swamps	Description
Water Elm Swamp Privet	*Planera aquatica*, *Forestiera acuminata* form distinctive swamp types within cypress-gum swamps. May occur in deeper waters than cypress.
Pop Ash	*Fraxinus caroliniana*: may occur in pure stands in Florida ponds.
Green Ash	*Fraxinus pennsylvania*: may occur in pure stands exhibiting buttressed bases in shallow ponds.
Mayhaw	*Crataegus aestivalis* ponds of coastal plain.
Canebrake	*Arundinaria gigantea*: covers large open areas in Dismal Swamp; results after cutting in both blackgum, white cedar swamps, spreads rapidly by underground stems.
Custard Apple	*Annona glabra* now almost extinct, best developed near Lake Okeechobee.
Palm Savannahs	

Marshes	Description
Flag Marshes	*Pontederia cordata*, *Sagittaria lancifolia*, *Thalia dealbata*, common in shallow ponds and sloughs, mostly in sandy areas of Florida.
Prairies	Similar to above with more diversified plant composition, "pseudo marshes" nearly devoid of sedges, grasses, rushes, common as medial stage of hyacinths mats into marshes.
Sphagnum spp. *Woodwardia virginica*	In open areas of Dismal Swamp, shallow areas of Okeefenokee Swamp, elsewhere.
Scirpus - *Erianthus*	This association of *Scirpus cyperinus* and *Erianthus saccharoides* major dominates in cutover areas of Dismal Swamp, elsewhere.
Bur-reed Marsh	*Sparganium americanum* dominated community in openings of swamp forests.

Source: Penfound 1952.

ALL ECOSYSTEM PROCESSES IN A WETLAND ARE DISTINCTLY AND SIGNIFICANTLY INFLUENCED BY HYDROLOGY

The natural integrator of most wetland ecosystem processes is hydrology. Understanding of hydrologic processes and their relation to effluent disposal can only be achieved through studying individual hydrologic processes amalgamated in the water budget. Each wetland is unique, and the receipt and deposition of water are directly influenced by wetland physical parameters.

An understanding of hydrologic processes in a wetland ecosystem is necessary if wastewater management considerations are to be evaluated properly. Hydrologic budgeting has considerable value as an index to the hydrologic process; it is a means of isolating and estimating individual flow and storage components that influence physical and biological wetland activities. Wetlands can receive water inputs from precipitation, overland flow and groundwater, but some wetlands receive only precipitation. Evapotranspiration, groundwater recharge and runoff constitute the primary water outputs.

Each wetland is unique in terms of location, morphology and other physical parameters that influence the receipt and deposition of water. Catchment size and morphometry, antecedent moisture, infiltration capacity and climatic fluctuations function as control mechanisms for inundation frequency and duration. The temporal characteristics of inundation determine vegetation distribution, diversity, and flows and regulate filtration processes. Wetlands typically reduce peak flows and regulate filtration processes. Wetlands typically reduce peak discharge and total stormflow volume because short-term detention storage is greater, and overland flow through a wetland frequently occurs as sheetflow.

Storage fluctuations in wetland ecosystems are closely linked to seasonal variations in rainfall, evapotranspiration, water table level and soil moisture. Groundwater is the major component of storage in a wetland basin and recharge and discharge processes depend on whether the wetland is isolated from underlying aquifers.

THE HYDROLOGIC BUDGET REPRESENTS THE NET EFFECT OF ALL PROCESSES THAT INFLUENCE THE HYDROLOGIC CYCLE OF A WETLAND ECOSYSTEM

Hydrologic budgeting has considerable practical value as an index to the wetland hydrologic process. The dominant components in a wetland budget include precipitation and surface and subsurface flows as inputs; evapotranspiration and surface and subsurface flows as outputs. The volume of precipitation input is primarily a function of canopy development, storm composition and prevailing climate (Lee 1980). Surface water inputs and outputs usually occur as sheetflow. Variations in precipitation timing affect total water yield, and more studies are needed before a clear correlation between precipitation timing and resulting streamflow is established. The importance of groundwater in the budget depends on the participation of the water table aquifer in recharge and discharge processes. Evapotranspiration is dependent on net radiation, wind speed, total availability of water and vapor pressure gradients.

Hydrologic budgeting is primarily used to isolate and estimate individual flow and storage components and to check on the accuracy of observational data. The long-term average water budget for a wetland catchment appears in various forms (Carter et al. 1978, Heimburg 1976, Boelter and Verry 1977). During periods of drying (storage decrease) the budget can be represented as

$$P + Qi + Gi + S = Et + Qo + Go$$

Where P is precipitation, Qi and Qo are surface water inflows and outflows respectively, Et is evapotranspiration, S is storage and Gi and Go are corresponding groundwater flows.

Figure 4.3.1 is a graphic representation of the dominant components of a hydrologic budget that can be identified for planning purposes. It differentiates clearly between those components that involve rates of movement (hexagonal boxes) and those that involve storage (rectangular boxes). The usual assumptions associated with budgeting are that 1) subsurface leakage into the catchment exists, 2) underflow and deep percolation from the catchment are negligible and 3) catchment storage is only subject to random or seasonal fluctuations. None of these assumptions is totally accurate, especially as applied to wetland catchments where hydrologic properties are not well understood and are difficult to analyze quantitatively. Nevertheless, budgeting has considerable practical value as an index to the wetland hydrologic process (Lonard et al. 1981). A brief description of the major water budget components is presented below.

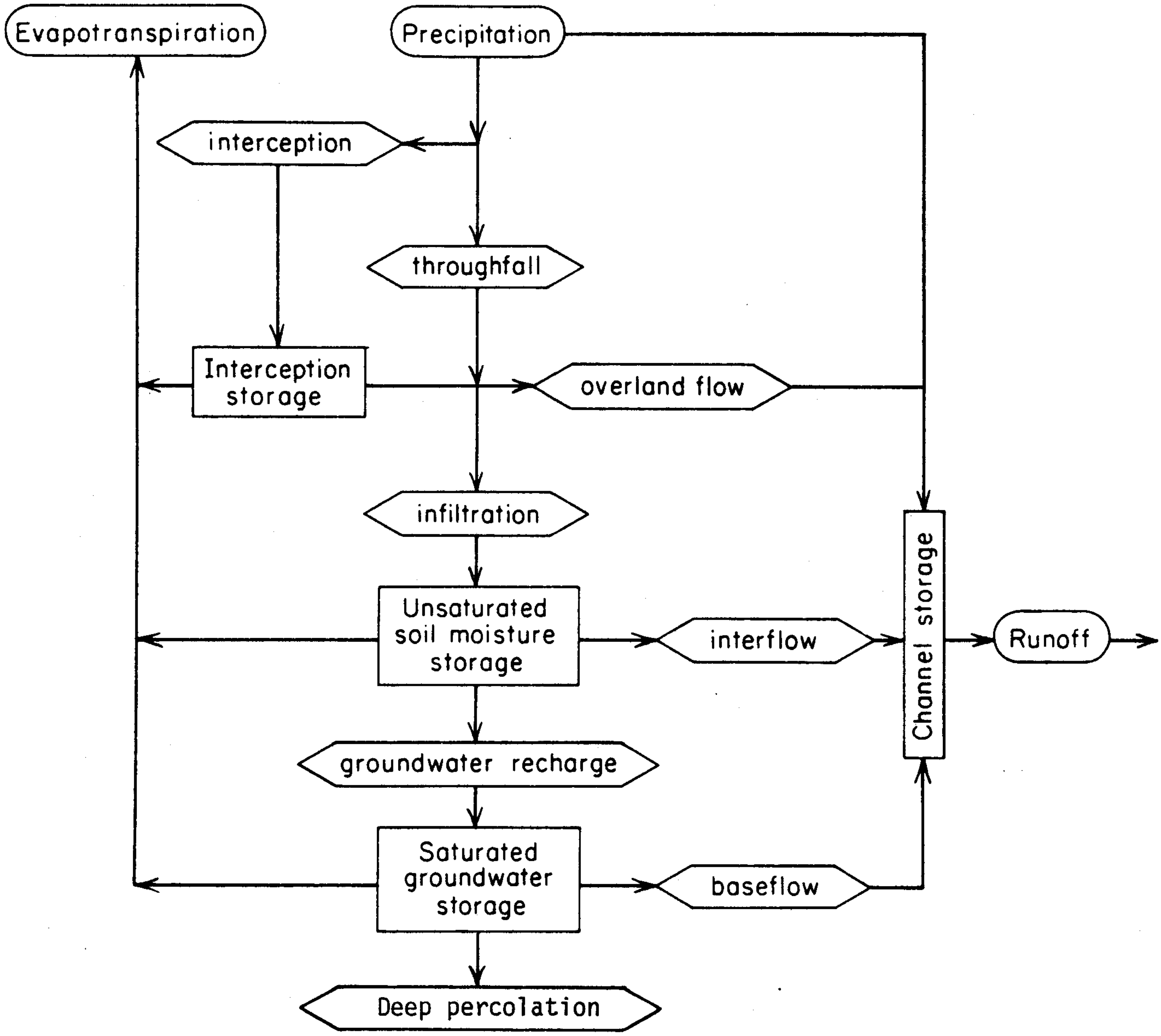


Figure 4.3.1. Systems diagram of the dominant components of a hydrologic budget.

Source: Freeze and Cherry. 1979.

4.3.1 Continued

Precipitation

The volume of precipitation input in most Southeastern wetlands is a function of canopy development, storm composition and prevailing climate (Lee 1980). Swamps are wooded ecosystems with well developed canopies; precipitation volume here is limited by canopy interception and subsequent canopy storage. Open marshes are generally covered with non-woody vegetation, and precipitation volume is limited mainly by climatic factors such as temperature and global radiation.

In several wetland types precipitation is the primary input, and measurement accuracy is critical. These wetlands represent restricted hydrologic regimes in the sense that they are isolated from groundwaters and receive no upland surface drainage. The central area of a perched bog represents the most restricted hydrologic wetland (Verry and Boelter 1978, Gosselink and Turner 1978). Pocosins in North Carolina are also typical of this situation. Included to a lesser degree is the Okeefenokee Swamp in Georgia and the Great Dismal Swamp in Virginia and North Carolina; these swamps are generally isolated from groundwater sources but do receive some upland surface runoff (Kuenzler et al. 1980, Gosselink and Turner 1978).

Precipitation timing has a bearing on wetlands being considered for effluent disposal. For most wetlands the timing of precipitation is dependent on seasonal variations. During periods of greatest seasonal rainfall the maximum effluent loading capacity could be exceeded in some localities. The timing and quantities of extreme rain events (hurricanes, etc.) need to be considered in engineering planning for wetlands used in wastewater management. Heimburg (1976) concluded that rainfall distribution in Florida cypress domes could limit wastewater loading rates during both the winter and summer wet season. High rainfall may mean lower nutrient concentrations and rapid export of effluents without natural treatment.

Surface Water

Total water yield for a catchment is primarily determined by atmospheric factors, catchment parameters and specific wetland influences. In small wetlands, considerable variation in water yield from year to year may occur, but the data base characterizing variations is largely incomplete (Carter et al. 1978, Daniel 1981). In general, a positive correlation exists between annual precipitation and water yield. Deviations from this norm may reflect carry-over effects of alternating wet and dry years, differences in catchment storage at the beginning of a year and variations in precipitation timing. More studies are needed before a clear correlation between annual precipitation fluctuations and resulting streamflow is established. Increases in solar and net radiation and air and surface temperatures result in decreases in water yield. Atmospheric humidity is positively correlated with water yield.

Water yield is more than an atmospheric phenomenon, and important differences in water yield from wetlands result from catchment location, relief, area, shape and substrata. At present no clear relationship exists between water yield and catchment area in cypress domes (Heimburg 1976). Daniel

(1981) concluded that flat topography contributed to low rates of surface runoff; in raised swamps and perched bogs, surface runoff was negligible.

Determination of specific wetland influences on water yield is important because of the existing variations in Southeastern wetland types. Gooselink and Turner (1978) developed a system that characterized wetlands, in part, by their source of surface water inputs and outputs. Perched bogs were classified as having no surface inflow or outflow. Sunken minerotrophic fens were classified as having a very slow surface water input and no downstream runoff. Lotic fens and swamps and riverines were classified as having significant surface water inputs and downstream ouputs. Surface water inflows to an individual wetland are related to many local physical and environmental factors. Factors affecting inflows include, orientation and size of wetland, surrounding soil characteristics and land use patterns, and storm characteristics. Riverine wetlands (bottomland hardwoods, etc.) may be extensively flooded as a response to upstream storms. Surface water inflows carry nutrient and sediment loads that influence the productivity and soil characteristics of wetlands. The environmental factors underlying these causal relationships should be quantified as wastewater management options are considered.

Groundwater

The importance of groundwater in the water budget depends on the participation of water table aquifers in recharge and discharge processes. Fens maintain contact with water table aquifers. The relative inputs and outputs of water are variable, but groundwater inputs are significant (Boelter 1978). Swamps and marshes may also have significant groundwater inputs. In well developed peatlands, groundwater can enter the ecosystem from the uphill edges or through amorphous groundwater channels (Boelter and Verry 1977; Kuenzler et al. 1980; Daniel 1981). Wang and Heimburg (1976) estimated infiltration, percolation and groundwater flows for two cypress domes in north Central Florida using standard techniques. One cypress dome served as both a discharge and recharge area. Another dome served only as a recharge area.

Evapotranspiration

Evapotranspiration for a given wetland depends on net radiation, wind speed, total availability of water and vapor pressure gradients. Wetlands with well developed canopies reduce direct evaporation by insulating the soil against radiant heating and wind, but they overcompensate for this during active growing seasons by drawing moisture from subsurface areas. Phreatophytes draw water directly from the saturated zone or its capillary fringe. Once the water table drops below the root system, evapotranspiration is reduced (Boelter and Verry 1977; Daniel 1981). In peatland ecosystems that are dominated by shrubs and hedges, evapotranspiration tends to be greater than in bottomland hardwood swamps because surface winds are higher and a greater biomass of transpiring plants exists (Daniel 1981). Maximum values of evapotranspiration in cypress domes generally occur during May, and minimum values occur during February (Heimburg 1976).

4.0 NATURAL WETLAND CHARACTERISTICS
4.3 Hydrology
4.3.2 Inundation: Frequency and Duration

DURATION AND FREQUENCY OF INUNDATION IS FIXED BY REGIONAL CLIMATE AND WETLAND PHYSICAL CHARACTERISTICS

Both duration and frequency of flooding in a wetland ecosystem are fixed to a large extent by regional climate. Other factors, however, play an important role in determining the hydrologic response of a particular wetland to runoff-producing storm events. The primary determinants include catchment size, antecedent moisture, infiltration capacity and climatic fluctuations.

Catchment Size

In wetlands associated with large catchments, the time of concentration is greater, and intense rainfall is less likely to occur over the entire area. As area increases, discharge per unit area decreases at high flows. However, both discharge and precipitation depths are usually greater at higher elevations. Smaller catchments that are restricted to more upland areas have greater discharges and associated peaks.

Antecedent Moisture

Increased flooding occurs when antecedent moisture conditions are greatest (Carter et al. 1978; Verry and Boelter 1978). When the water table is high, available soil storage is reduced and the same phenomenon occurs. Water table fluctuations are influenced by the hydraulic properties of the soil and underlying strata, the seasonal pattern of evapotranspiration and fluxes in the supply of water to underlying aquifers (Daniel 1981). Perched bogs exhibit greater water table fluctuations because of the seasonal influences of precipitation and evapotranspiration. Bogs fed by groundwater or riverine systems have a more uniform hydrologic regime, and water table fluctuations are less pronounced (Verry and Boelter 1978; Brinson et al. 1981).

Infiltration Capacity

Infiltration capacity is important because it determines the downward movement of water through the surface of mineral or organic soil. It is affected by soil physical properties and moisture content, permeability and soil microclimate. Little has been done in making comparisons of infiltration capacities for different wetland ecosystems. In peats infiltration is inversely proportional to the degree of decomposition (see Section 4.1.2 on Soils). Where precipitation is not strongly seasonal, maximum infiltration rates occur toward the end of the growing season. The dynamic aspects of infiltration in relation to inundation frequency and duration cannot be fully understood without further studies. Existing studies cover bogs (Boelter and Verry 1977; Verry and Boelter 1978) and cypress domes (Heimburg 1976).

4.3.2 Continued

Climatic Fluctuations

The frequency and duration of inundation is closely associated with seasonal climatic fluctuations. The greatest portion of annual flow from perched bogs occurs in early spring when rainfall exceeds evapotranspiration, and antecedent moisture is at a maximum. Most studies regarding cypress domes indicate that storm events must exceed 0.4 inches before surface flow occurs (Heimburg 1976). In riverine swamps inundation is greatest during late winter and early spring when water storage capacity and evapotranspiration rates are minimal (Brinson et al. 1981). This, however may not be true of all Region IV wetlands where, for example, a dry season may predominate during the winter (Florida).

4.0 NATURAL WETLAND CHARACTERISTICS

4.3 Hydrology

4.3.2 Inundation: Frequency and Duration

4.3.2.1 Relationship Between Flooding, Plants and Nutrients

THE EXISTENCE OF PLANTS AND THE AVAILABILITY OF NUTRIENTS DEPEND ON INUNDATION FREQUENCY AND DURATION

The duration and frequency of flooding are dominant factors responsible for plant species diversity, distribution and growth rate. The duration of inundation is the dominant factor influencing species distribution. The seasonal timing and the energy associated with flood waters affect the input, retention and export of nutrients.

The diversity, distribution, and growth rate of wetland vegetation depend to a great extent on the duration and frequency of inundation. Wetland vegetation in turn affects flooding by retarding surface water flows and controlling water inputs through canopy interception and evapotranspiration. The relationship between the distribution of wetland vegetation and flooding duration is so distinct that flooding characteristics for a given site can be evaluated by observation of species composition (Bedinger 1978; Bedinger 1980). Duever et al. (1977) related flood duration with six habitat types in Corkscrew Swamp, Florida. Carter et al. (1978) list numerous studies that assess the long-range effects of inundation frequency and duration on species growth rate, propagation and distribution for different wetland ecosystems.

The timing of inundation and the energy associated with flood waters affect the input, retention and export of nutrients. The physical configuration of a wetland area is related to the inputs of nutrients and water (Figure 4.3.2.1). Flood water provides a vehicle for the movement of dissolved and suspended solids. This movement provides a greater availability of micro-nutrients for plant growth; thus, plant growth is a function of discharge velocity, As velocity increases so does sediment input, and plant growth is accelerated. Nutrient availability is also a function of the source of water input. Ombrotrophic bogs, for example, are nutrient poor because the only input is rainwater. River and floodplain ecosystems, in contrast, are nutrient rich because water inputs include rainwater, streamflow and overhead flow (Figure 4.3.2.1). The abundance of nutrients usually associated with fens results from nutrient-rich groundwater supplies. Gosselink and Turner (1978) give an excellent review of inundation effects on nutrient availability.

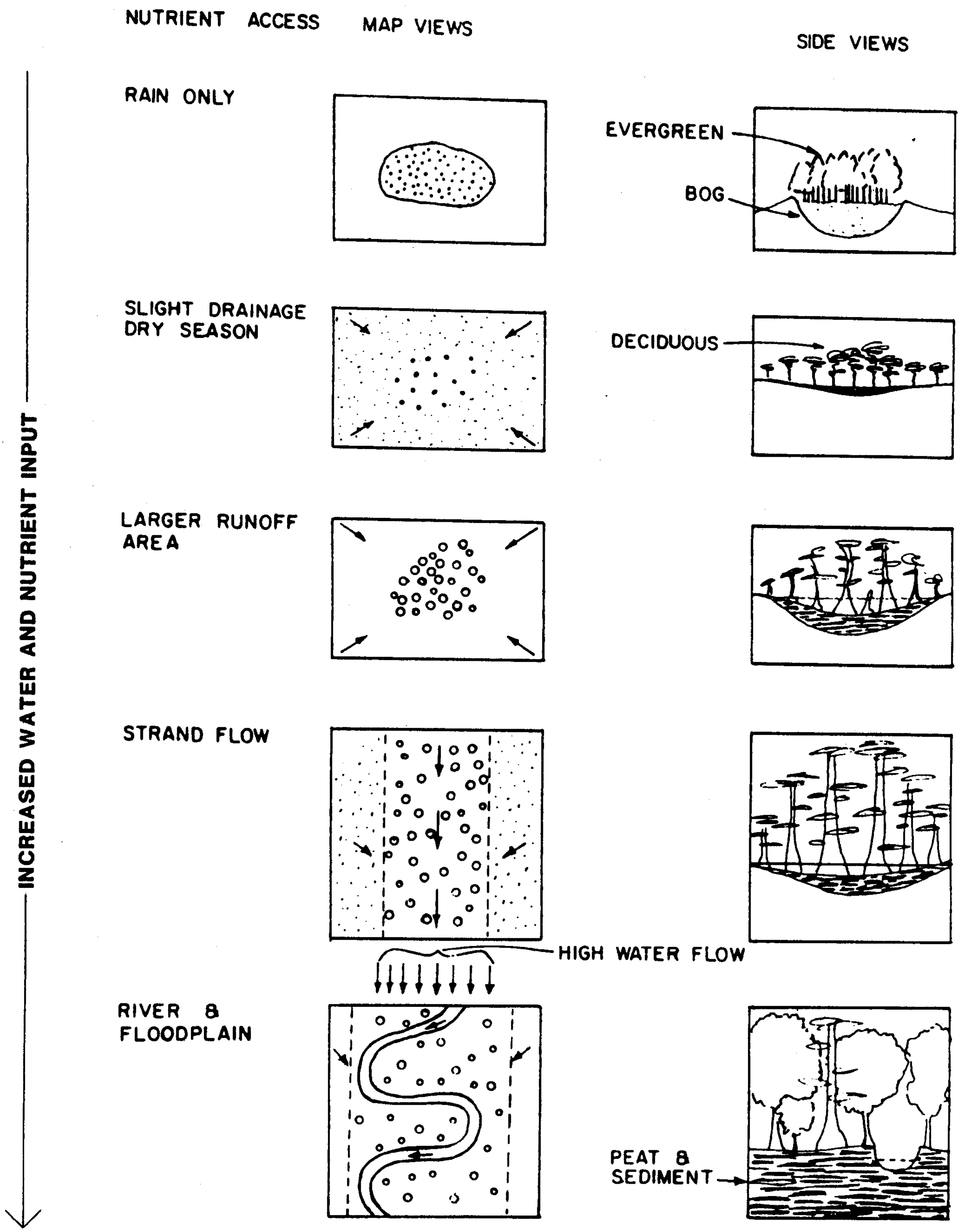


Figure 4.3.2.1. The relationship between wetland ecosystems, water input, and nutrient regime.

Source: Odum. 1980.

HYDROLOGY EITHER LIMITS OR ENHANCES FILTRATION

The duration and depth of inundation regulates filtration processes. This effect occurs primarily because water in wetlands travels mainly by sheetflow.

Vegetation type and density and soil type and physical properties play a major role in a wetland's ability to filter suspended matter. Direct hydrologic processes, however, significantly affect the degree of filtration through decreased flow rates. Decreased flows primarily occur because overland flow in many wetland types is sheetflow. Sheetflow is associated with decreased carrying power and fallout of suspended particles. Little quantitative data on this process exist (Boto and Patrick 1978); therefore, more studies are needed to determine the extent to which the duration and frequency of inundation, along with vegetation, regulate filtration. The amount of suspended sediment present in a wetland also impacts filtration and subsequent removal of nutrients and toxins associated with wastewater effluent. Filtration is an important mechanism for renovating water within a wetland.

THE DEGREE OF FLOOD REDUCTION DEPENDS ON TOPOGRAPHY AND PERCENT SURFACE WATER AREA

The ability of a wetland to attenuate flood peaks and storm flows are associated with wetlands having restricted outlets and flat topography. Wetlands with greater surface water area have greater detention storage and significantly lower flood peaks. Evapotranspiration of surface water reduces baseflow in wetlands during low flow periods.

An abundance of evidence exists supporting the observation that peak discharge is significantly less in wetlands than in other ecosystems (Carter et al. 1978, Boelter 1978, Verry and Boelter 1978). Flood reduction depends on the percentage of surface water in the catchment and topography. Wetlands primarily attenuate flood peaks (Figure 4.3.3) and storm flow volumes by temporarily storing surface water. This storage occurs because most wetlands have restricted outlets and are located in flat topographic regions. Basins with a greater percentage of water surface area have greater short term detention storage and thus reduced flood peaks. Storage of water in upper soil horizons is typically greater in areas of flat topography. This capacity also works to reduce flood peaks. The cypress domes of Florida, the Okeefenokee Swamp of Georgia and the Great Dismal Swamp of Virginia and North Carolina have long residence times for surface waters thus reducing potentially high peak discharges (Daniel 1981, Boelter and Verry 1977). The suppression of base flow also occurs in wetlands during low flow periods because evaporation of surface water is significant.

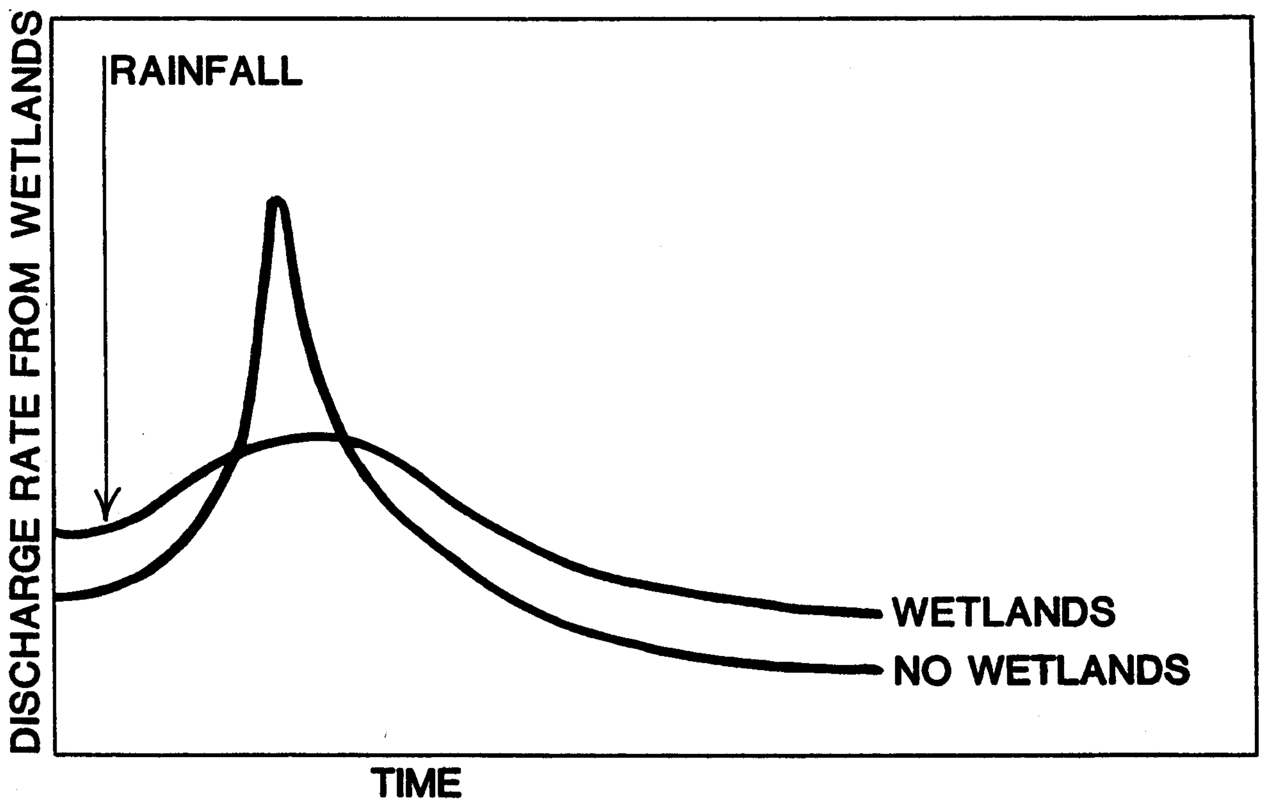


Figure 4.3.3. Graphic presentation of a floodplain's ability to attenuate discharge rate and peak flows with and without wetlands.

Source: Odum 1978.

STORAGE IN MOST WETLANDS OCCURS AS GROUNDWATER, SURFACE WATER AND SOIL MOISTURE

Groundwater is the major component of wetland storage, and fluctuations in groundwater storage relate to precipitation and evapotranspiration. Surface storage fluctuates in response to infiltration. Soil moisture storage depends on soil type, water table level, degree of decomposition and microclimate.

Groundwater

Groundwater is the largest component of storage in a wetland basin. It fluctuates slowly in response to precipitation and percolation inflow and to seepage outflow. Average seasonal variations in groundwater storage are highly correlated with the climatic balance between precipitation and evapotranspiration. Groundwater depletion lags behind increases in evapotranspiration. Topography can also influence the total volume of water stored as groundwater. Flat terrain contributes to low rates of surface runoff and greater opportunities for downward movement of water.

Surface Storage

Surface storage increases or decreases in response to infiltration. Water in a wetland ecosystem cannot continue to infiltrate unless percolation removes stored water in the water table aquifer. Surface storage is generally greatest in wetlands that function as a discharge area (Wang and Heimburg 1976, Heimburg 1976). The physical properties of the zone of aeration cause variations in this generalization by controlling subsurface storage and the direction of groundwater flow; so it is important to characterize soil moisture storage by estimating soil bulk density, porosity and moisture potential.

Soil Moisture

The storage capacity of wetland soils is clearly related to soil type, water table level, degree of decomposition and climatic factors. Specific retention, the fractional volume of water held against the force of gravity, is greatest in clay and smallest in solid limestone. Fibric peats have a high hydraulic conductivity because decomposition is less pronounced. Reduced water storage results as water easily passes into the water table aquifer. Soil moisture is a dynamic property of soils because water table fluctuations control the total volume of pore space available for storage. Storage of water in soil also responds to fluctuations in evapotranspiration because vegetation regulates insulation and transpiration processes.

4.0 NATURAL WETLAND CHARACTERISTICS
4.3 Hydrology
4.3.5 Groundwater Recharge

GROUNDWATER RECHARGE FOR A GIVEN WETLAND DEPENDS ON ITS INTER-CONNECTION WITH UNDERLYING AQUIFERS

Pathways associated with groundwater recharge include 1) infiltration from the surface through the zone of aeration, 2) vertical movement of water through streambeds and 3) seepage through confining beds. Recharge is substantially lower from wetlands where an impermeable clay interface separates the wetland from the underlying aquifer.

Groundwater recharge depends on wetland type. In perched bogs, groundwater recharge is negligible because usually no connection exists with underlying aquifers (Verry and Boelter 1978, Boelter and Verry 1977). Swamps and marshes adjacent to and drained by surface waters may or may not be recharge areas. Kuenzler et al. (1980) briefly discusses requirements needed for recharge to occur in these wetlands. Mineotrophic bogs mainly serve as discharge areas. Heimburg (1976) concluded that cypress domes can serve as recharge areas, but this depends on the existence of an impermeable clay interface.

INTERRELATED PARAMETERS CREATE COMPLEX WATER QUALITY IN WETLANDS

Dissolved oxygen, pH, nutrients, metals and bacteria are interrelated parameters in wetlands and result in a complex water quality system. Impacts to one parameter may have further repercussions on other parameters. In most cases, water quality parameters are site specific, which limits the establishment of uniform effluent limitations and loading rates for wetland discharges.

Dissolved oxygen (DO) values consistently below saturation have been reported for many wetlands in the Southeast. Low DO levels in humic swamp waters are attributed to heterotrophic respiration of organic matter, decomposition, and a chemical process of oxygen consumption in the presence of iron. DO levels also vary with water depth, season and time of day. Dissolved oxygen levels affect the release of nutrients, microbial respiration and organic matter decomposition. Increased organic loadings in wetlands, such as with the addition of wastewater, will alter the prevailing DO regime and require the flora and fauna of wetlands to adapt to a larger range of DO.

Wetlands are also typically acidic with pH levels less than 7.0. This low pH, associated with organic acids leached from wetland vegetation significantly impacts the species composition and water chemistry of closed wetland systems. Wetland systems that are well buffered tend to maintain a relatively constant pH; wetland systems that are not well buffered are generally those with high internal sources of acidity and few outside sources of alkalinity. The impact of wastewater disposal is dependent to some extent on the buffering capacity inherent in the wetlands and the composition of the wastewater.

Nutrient cycling may be the most important yet complex and least understood wetland characteristic. Nutrients (nitrogen, phosphorus, carbon and sulfur) and the dissolved constituents move through wetlands in association with the hydrologic regime and atmospheric diffusions. The path by which nutrients move through wetlands is altered by long-term uptake, internal cycling, dilution and diffusion. Nutrient retention or release in a wetland is site-specific and dependent upon litter fall patterns, rate of litter decay, internal chemistry, substrate composition, seasonality, hydrology and other locally important ecological parameters. The rate of nitrogen, carbon and sulfur transformations is further modified by bacterial action. An understanding of the specific nutrient cycling characteristics is essential in order to assess the impacts of increased nutrient loadings and altered patterns of nutrient cycling associated with wastewater disposal.

The fate and impact of heavy metals and other toxins in wetlands is particularly important because of their potentially adverse effects. Heavy metals entering wetland ecosystems may be transported through active plant or animal uptake, passive movement to surface or groundwaters, or immobilized into the soil matrix by physical or chemical forces (Kadlec and Kadlec 1978). Generally, studies of heavy metals in wetlands receiving wastewater effluent

4.4 Continued

heavy metals in wetlands receiving wastewater effluent have been inconclusive; however, it is undoubtedly understood that many aquatic plants and animals can assimilate heavy metals from the water. Potential loading limits for heavy metals are related to levels acceptable for potential plant and animal uptake, the rate of metal accretion and the degree of burial in the sediments, and the additional uses of the wetland area and potential for eventual human or animal exposure.

Specialized groups of bacteria also play a vital role in wetland water quality by regulating nutrient cycling, water chemistry and decomposing endemic and introduced organic materials. Certain endogenous and exogenous bacteria can directly or indirectly threaten human health, and wastewater introduced into wetlands may potentiate this problem.

Various water quality parameters are discussed further in the following subsections.

LOW DISSOLVED OXYGEN CHARACTERISTIC OF SHADED SWAMPS

Shaded swamp forests are characteristically low in dissolved oxygen, consistently below saturation but usually not anoxic. Marshes may have high daily fluctuations in oxygen. In the summer they may become supersaturated with oxygen and anaerobic in the same day.

Dissolved oxygen (DO) is an important chemical parameter of natural waters. It is a measure of the amount of oxygen dissolved in the water and is most often expressed in milligrams per liter (mg/l). The saturation value of dissolved oxygen is strongly dependent on temperature and salinity. The higher the temperature and salinity, the lower the saturation value for oxygen.

Low DO values consistently below saturation have been reported for several humic (tea-colored) swamps and bogs in the Southeast. Dierburg and Brezonik (1980) reported a seasonal range of DO in an undisturbed cypress dome of 0.25 mg/l to 6.75 mg/l with a bimonthly average value of 2.03 mg/l. Beck (1974) noted that the DO in the Satilla River was reduced when influenced by swamp waters. A reduction in DO content from 70-80 percent saturation to 12-35 percent saturation was observed when the White Nite River flowed through a swamp (Tallings 1957).

Low oxygen in humic swamp waters is attributed to several processes. Traditionally, heterotrophic respiration of organic matter has been noted for consuming available oxygen in water. Intense decomposition can cause severe oxygen deficits and create anoxic conditions (Wetzel 1975). There is also a chemical process of oxygen consumption proposed in the presence of iron (Fe) (Miles 1977). A catalytic cycle of Fe II and Fe III may reduce organics and consume oxygen, creating an active oxygen sink in wetlands.

The DO will often vary with depth of water or peat, generally declining with depth. The amount of DO is an important factor in determining the biotic community and type of decomposition by microorganisms. When oxygen becomes limiting in the roots (less than 1 mg/l), plants must develop an alternate means of acquiring oxygen. Benthic invertebrates and fish are also dependent on available oxygen. In well oxygenated marshes and swamps, aerobic (with oxygen) respiration will occur. When oxygen is limiting, anaerobic organisms dominate, and decomposition will take place at a much slower rate.

A large daily variation in DO is commonly observed in marsh waters or in those wetlands with a dense growth of aquatic or emergent plants (cattail, duckweed, etc.). The photosynthetic activity of the plants, especially during the summer, releases a large amount of oxygen into the water. The high temperatures lower the saturation value for oxygen and the water is often supersaturated, reported by Schwegler (1977) to exceed 200 percent

4.4.1 Continued

saturation. A high respiration may drive down the DO to extremely low values at night (less than 0.1 mg/l) as reported by Schwegler (1977). These highly productive wetlands have plants, animals and microflora adapted to great daily fluctuations in DO. These fluctuations are not as pronounced in the winter months since respiration and photosynthetic rates are lower, and the cooler temperatures allow greater DO retention in the winter.

Dissolved oxygen at the sediment-water interface controls the release of important nutrients such as phosphorus (Wetzel 1975). Though forested wetlands are usually low in DO (Dierburg and Brezonik 1980), they are not consistently anoxic. When anoxic conditions do occur (usually in the summer months), phosphorus may be released from the sediments in which it is usually bound. In the anoxic environment micronutrients tend to be more readily available, and toxic materials such as hydrogen sulfide accumulate in the substrate (Gosselink and Turner 1978)*. Low DO is also an essential condition for certain phases of the nitrogen, carbon and sulfur cycles (see Section 4.5).

The profound influence DO exerts on microbial respiration directly controls the rate and completeness of organic matter decomposition. Thus the rate of peat formation and the composition of the peat are controlled by DO levels since peat consists chiefly of decomposed and undecomposed organic matter (Alexander 1971).

Higher organic loadings in wetlands, such as with the addition of wastewater, will alter the prevailing DO regime. It will require the flora and fauna of wetlands to adapt to larger fluctuations in DO, if they are not already adapted. It will also result in greater decomposition rates and greater oxygen consumption.

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*Those species not adapted to lower DO or anoxic conditions will die or emigrate.

pH LEVELS INFLUENCE WETLANDS CHARACTERISTICS

The pH typically associated with wetlands is less than 7.0, indicating acidic conditions. This condition is derived from leaching organic acids from wetland vegetation. The pH significantly impacts the species composition and water chemistry of wetlands systems.

The surface waters of wetlands are generally acidic (pH less than 7.0). The low pH normally found in colored (humic) waters is derived from the acid nature of organic compounds dissolved in the water, typically leached from wetland vegetation. Dierburg and Brezonik (1980) proposed that rainfall supported the acidic conditions in cypress domes, since the outside sources of organic acids from runoff and stream flow are limited. Beck et al. (1974) reported that organic acids were primarily responsible for the acidity in riverine swamps of the southeastern United States.

The acidity of northern bog systems is greater in those communities dominated by Sphagnum (Clymo 1967). Clymo suggested that Sphagnum acts as a cation exchanger and is a major source of bog acidity. Sphagnum may also be responsible for acidity in wetlands of the Southeast. Dierburg and Brezonik (1980) suggested that other acidophilic plants such as Utricularia spp. (bladderwort) may also possess this capacity.

Daniel (1981) reported the pH in coastal pocosins of North Carolina ranged from 2.2. to 6.6, averaging 4.4. Kuenzler et al. (1980) in studies of riverine swamps of North Carolina noted average pH values ranging from 4.7 to 5.0 in a four-year study. Tributaries from a disturbed watershed tended to elevate this pH. A pH range of 3.5 to 5.4 was reported in an undisturbed cypress dome, with an average of 4.5 (Dierburg and Brezonik 1980). The mineral-rich groundwater beneath the dome registered pH of 6.0 and presumably did not significantly influence the character of dome surface water.

A wetland system that is well-buffered tends to maintain a constant pH throughout the year with little daily fluctuation. The buffering capacity of water is an indication of its effectiveness in minimizing a pH change resulting from an addition of either acids or bases. Buffering capacity results from the amount and type of dissolved material producing the acidity or alkalinity. The source of this dissolved material may originate within or outside the wetland. The surface water entering wetlands reflects the composition of the watershed. Dissolved substanaces may help to buffer the pH. At pH 7, the bicarbonate-carbonate equilibrium is the major buffering system. If groundwater is a major source of water for the wetland, its composition (especially hard groundwater, high in carbonates or other salts) will raise pH and buffering capacity. This is equally true of wetlands receiving drainage in watersheds with a high amount of calcium and magnesium salts, carbonate and bicarbonate ions, sulfate, chlorides or nitrates (hard waters).

4.4.2 Continued

Wetland systems that are not well buffered are generally those with high internal sources of acidity (plants, decomposition processes) and few outside sources of alkalinity (hardwater runoff) such as bogs, bays, domes, pocosins, and some marshes. Acidic rain throughfall helps maintain the acidic conditions. In periods of intense photosynthesis by floating, emergent or attached vegetation, the pH may be quite high (greater than 9.0); during periods of high respiration and decomposition, the pH may be quite low (less than 3.0). Respiration in sediments may depress pH locally due to the production of organic acids.

The pH of water in wetlands is a factor to which all wetlands organisms must adapt. Both nutrient release from sediments and the ionic form of nutrients are pH dependent. Most organisms have a range of pH outside of which they cannot effectively compete, grow or function. Some of these ranges are narrow, others broad. The pH of most domestic wastewater is approximately neutral and well buffered. The effects on the endemic pH of wetlands depend on the relative volume of wastewater and the buffering capacity inherent in the wetlands.

WETLANDS ACT AS NATURAL SINK FOR HEAVY METALS

Conclusive research about the fate of heavy metals in wetlands is sparse. Several pathways of metal transport and translocation have been identified. Metals tend to accumulate in the sediments, but may be mobilized under certain conditions. Because of the potential chronic, toxic and food-chain effects, impacts of metals on wetlands should be carefully considered.

Heavy metals are of concern because of their potential adverse effects. Opinions differ as to the definition of heavy metals from a toxicological standpoint. The most common heavy metals include titanium (Ti), vanadium (V), chromium (Cr), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn), arsenic (As), silver (Ag), cadmium (Cd), tin (Sn), mercury (Hg) and lead (Pb). The form of heavy metals is important to the solubility and toxicity in the aquatic environment (Figure 4.4.6). Heavy metals have been classified based on their solution chemistry into three classes: oxygen-seeking, nitrogen-sulfur seeking and intermediate (Nieboer and Richardson 1980).

The aquatic-related fate of these metals has been included in a review of this subject by Callahan et al. (1979). The health impacts, allowable limits related to acute, subacute and chronic toxicity, synergistic or antagonistic actions, teratogenicity, mutagenicity and carcinogenicity have been summarized by Sittig (1980).

Heavy metals entering wetland ecosystems may experience three immediate pathways of transport and translocation, (1) plant or animal uptake, (2) movement to surface or groundwaters, and (3) immobilization into the soil matrix (see Figure 4.4.5). Klien (1976) and Carriker (1977) studied the fate of heavy metals in freshwater cypress domes, but the concentrations of metals in the source (domestic effluent) was too low to determine the ultimate fate of metals. Boyt et al. (1977) reported low concentrations of zinc, copper, and lead in the effluent of the Wildwood, Florida sewage treatment plant and in the receiving swamp. The concentrations of metals in the surface water and sediment cores in a marsh receiving effluent since 1919 (Murdoch and Capobianco 1979) were low and variable and no trends were detected.

Aquatic plants undoubtedly assimilate heavy metals from the water (Kadlec and Kadlec 1979, Dinges 1978). The leaves of hyacinth culture receiving treated sewage were found to contain high levels of Cr, Cu, Fe, Hg, Mn, Ni and Zn. However, Ag, Cd and Pb concentrations were below detection limits (Dinges 1978). Roots are also known to assimilate metals (Lee et al. 1976). Heavy metals are easily adsorbed onto sediments trapped there by adsorption to ion-exchange sites, incorporation into the lattice structure, or precipitation as metal colloids. Carriker and Brezonik (1976) reported elevated levels of metal associated with surficial sediments of cypress domes receiving secondary effluent. Metals are also complexed by organic compounds such

4.4.3 Continued

as fulvic and humic acids found in wetlands (Boto and Patrick 1978) and may reduce bioavailability and uptake by insects, plants and animals.

These processes of transformation for soluble metals are important since secondary effluents tend to have a major proportion of metals in the dissolved state (Chen et al. 1974).

Changes in pH and Eh influence the solubility of metals and determine whether metals are retained or released by the sediments. For example, the release of Al, Mn, Fe, Zn from the sediments was observed for a pH range of 5-6, but Cs, Hg, Se showed reduced solubility (Schindler 1980). Metals loosely adsorbed to the surficial sediments have not been shown to migrate to groundwaters, but may be mobilized to surface waters (Tuschall et al. 1981). Boto and Patrick (1970) suggested that wetland systems can act as a high capacity sink for heavy metals deposited in the sediments. They warn that natural or man-made alteration of the system (lowering the water table, dredging, etc.) can result in the release of metals trapped in anaerobic sediments. Metals associated with sediments have a greater probability of accumulating in the benthic or detrital based food chain than assimilated by plants and entering another food chain.

The rate of metal accretion and the degree of burial in the sediments are critical factors in determining the loadings which can be endured by wetlands without damage. The wisdom in discharging high levels of bioavailable metals in an ecosystem where they can be circulated and accumulated is certainly questionable. While the natural attributes of wetlands may permit them to act as a sink for metals, it is not a fail-safe or even consistent attribute. Careful consideration should be given to disposal of these hazardous compounds whenever they are allowed to enter the ecosystem.

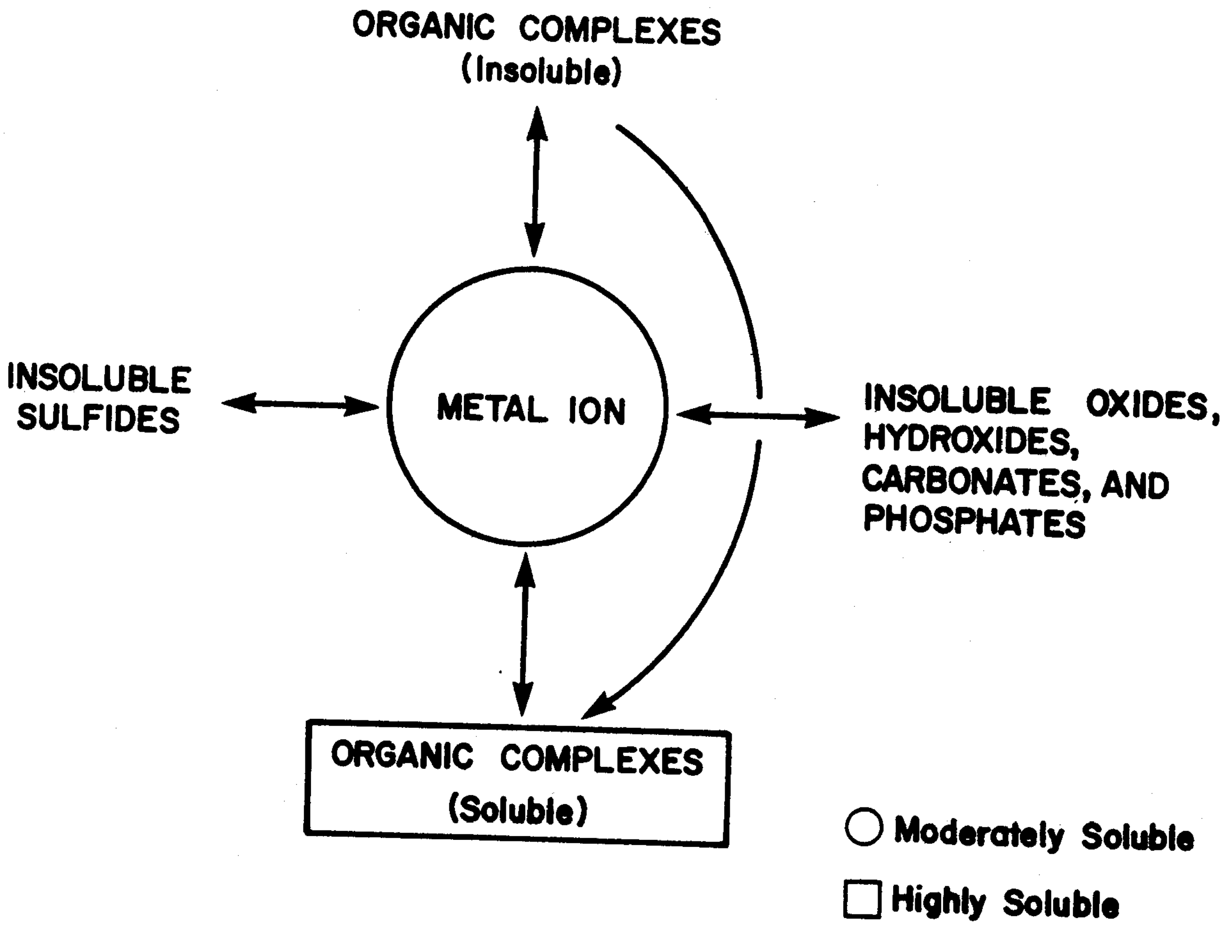


Figure 4.4.3. Relationship of heavy metal form and solubility in the aquatic environment.

Source: Tchobanoglous 1980.

4.0 NATURAL WETLAND CHARACTERISTICS
4.4 Water Quality
4.4.4 Nutrients

WETLANDS CYCLE AND TRANSFORM NUTRIENTS

Carbon, nitrogen, phosphorus and sulfur are the basic building blocks of living organisms. They are considered the major nutrients necessary for sustenance and growth. Understanding the flow of nutrients into and out of wetlands is essential to assessing wastewater recycling through wetlands.

Wetlands ecosystems couple biotic and abiotic components of the environment. Nutrients and other dissolved constituents, heavy metals, and suspended solids, move through wetlands in association with the hydrologic regime and atmospheric diffusion. These constituents can be altered by uptake, cycling, dilution and diffusion. Nitrogen, phosphorus, carbon and sulfur are major elements which cycle through the incoming waters and atmosphere into the water, plants and sediments. Net retention or release of these constituents is site dependent. The interpretation of the effect of wetlands on any material parameter requires an understanding of the hydrology of that site and mass balance calculations.

Nutrient flow into and out of wetlands is of prime importance to understanding the structure and function of wetlands. The dynamic character of wetland hydrology impacts the flow and rate of nutrient exchanges within wetlands and surrounding ecosystems. The ability of wetlands to act as nutrient traps depends on hydrologic regime, litter fall pattern, and the rate of litter decay (van der Valk et al. 1978). Wetlands with predominantly organic substrates accumulate less N and P in the above ground vegetation than those with predominantly organic substrates, yet organic substrates seem to be capable of long term storage of N and P (Whigham and Bayley 1978) by other means.

The dependence of downstream ecosystems (most notably estuaries) on the quantity and quality of water leaving riverine wetlands is being investigated in the Southeast (de la Cruz 1978). The buffering capacity of lacustrine marshes toward moderating nutrient inflow and eutrophication in lakes has been documented (Kadlec and Kadlec 1978). The impact of wetlands on nutrient dynamics in the environment is one of the important natural characteristics of wetlands.

Transformations of carbon, nitrogen, phosphorus and sulfur are influenced by the prevailing oxygen conditions (Figure 4.4.4). The rate of nitrogen, carbon and sulfur transformations are heavily modified by bacterial activity; however, phosphorus cycling is less dependent on bacterial activity. Bacteria actively respond to temperature, pH, DO and other environmental variables. For example, at pH less than 5.0, microbes involved in denitrification are severely inhibited.

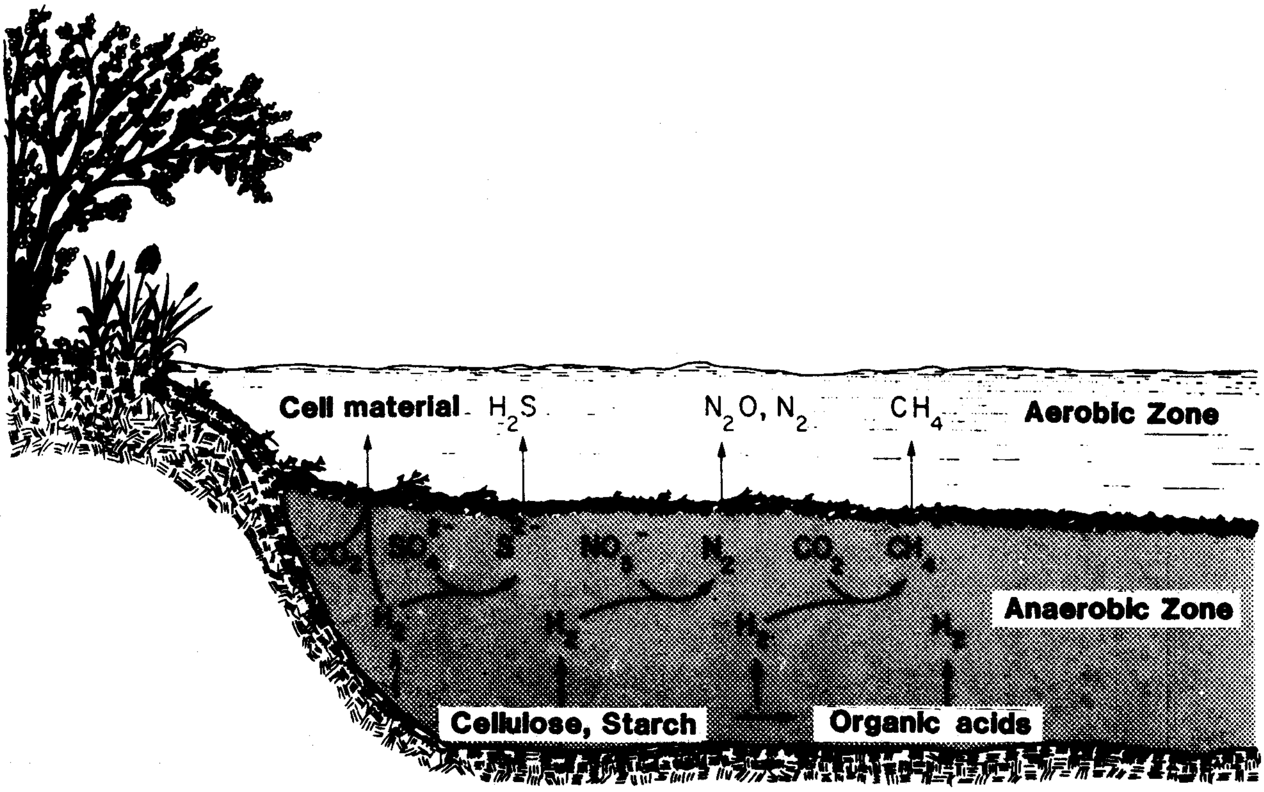


Figure 4.4.4. Carbon, nitrogen and sulfur transformations in oxygen-poor (anaerobic) environments.

Source: Cambell 1977.

4.0 NATURAL WETLAND CHARACTERISTICS
4.4 Water Quality
4.4.4 Nutrients
4.4.4.1 Nitrogen

NITROGEN CYCLING IN WETLANDS IS AN IMPORTANT AND COMPLEX FUNCTION

Nitrogen is an essential nutrient to vegetation and is abundant in wetlands. It can be either stored or exported depending on hydrology, chemical, and vegetational characteristics.

The nitrogen cycle in wetlands is complex and pathways are variable depending on site conditions (Figure 4.4.4.1-a). The major storages for nitrogen in wetlands are also variable. In wetlands with larger drainage patterns, generally more nitrogen will enter the wetlands (riverine marshes, swamps, others). Nitrogen fixation mediated by epiphytes or rhizosphere microflora (van der Valk 1979) may be a significant source of nitrogen for other wetlands. Nitrogen may then be cycled within the wetland or leave the wetland in two principal manners. Simple hydrologic export of both dissolved and particulate forms of nitrogen is important in riverine and lacustrine wetlands. This form of export is important to downstream ecosystems (Wharton et al. 1980). The escape of gaseous nitrogen formed in the wetland (denitrification) to the atmosphere is the other principle means of nitrogen loss to wetlands. Denitrification is an extremely important nitrogen sink in those wetlands which do not have a significant means of hydrologically exporting nitrogen (cypress domes, bay heads, bogs). Graetz et al. (1980) found that denitrification rates of 14 Florida wetland soils were variable. The Everglades soil removed an equivalent of 2,900 g ha^{-1} day^{-1} while only 600 g ha^{-1} day^{-1} was removed by Valkaria soil. These rates are indicative of the great potential for denitirfication in wetlands soils. Organic matter content and pH were the two variables used to explain variation of denitrification rate in a model constructed to predict denitrification rates of wetland soils.

Many wetlands are ideally suited for denitrification processes for several reasons. Denitrification first requires that nitrogen forms (NH_3+, organic-N) be converted to nitrates (NO_3) in an aerobic environment (ammonification and nitrification in Figure 4.4.4.1-b). The anaerobic sediments in wetlands with plentiful organic carbon is the prime site of actual denitrification, the reduction of NO_3 to N_2 (gaseous). The gaseous nitrogen then escapes through the water column and is lost to the atmosphere.

Nitrogen is also conserved and recycled within the wetland ecosystem. Dissolved nitrogen forms, especially ammonium (NH_4+) and nitrates (NO_3) are taken up (assimilation) by plants and bacteria and stored in biomass for varying lengths of time, then released to be either recycled again or exported or lost to sediment. Algae and bacterial use of nitrogen represents a short term storage unless trapped in sediments. Trees, shrubs and other higher order forms of biomass often represent long-term and nearly permanent nitrogen storage. This assimilation component of the nitrogen cycle is shown in Figure 4.4.4.1-b.

4.4.4.1 Continued

The sediments are also a storage for nitrogen in wetlands (Figure 4.4.4.1-a). For example, ammonia or nitrate nitrogen may be pumped out of the sediments by roots of plants for nutrition or may remain locked in organic matter (peat) until it is either released through peat degradation or flushed out by hydrologic surges. Leaching of fresh litter releases large amounts of nitrogen but older litter may act as a sink for nitrogen that is never released. Natural wetlands which become dry, or drained wetlands, may release large quantities of nitrogen. Ammonia can be lost to the atmosphere by volatilization (Figure 4.4.4.1-b). The decomposition in anoxic sediments is slow and nitrogen contained in organic matter may accumulate faster than it is released, acting somewhat like a nitrogen trap (van de Valk et al. 1978). Upon drawdown of water, the sediments become aerobic and decomposition is much more rapid, typically releasing large quantities of dissolved nitrogen (Alexander 1971).

Figure 4.4.4.1-a provides a graphic display of nitrogen and phosphorus cycling through the environment. Factors important in regulating the exchange of these compounds between the various compartments of their cycles are also illustrated in the figure.

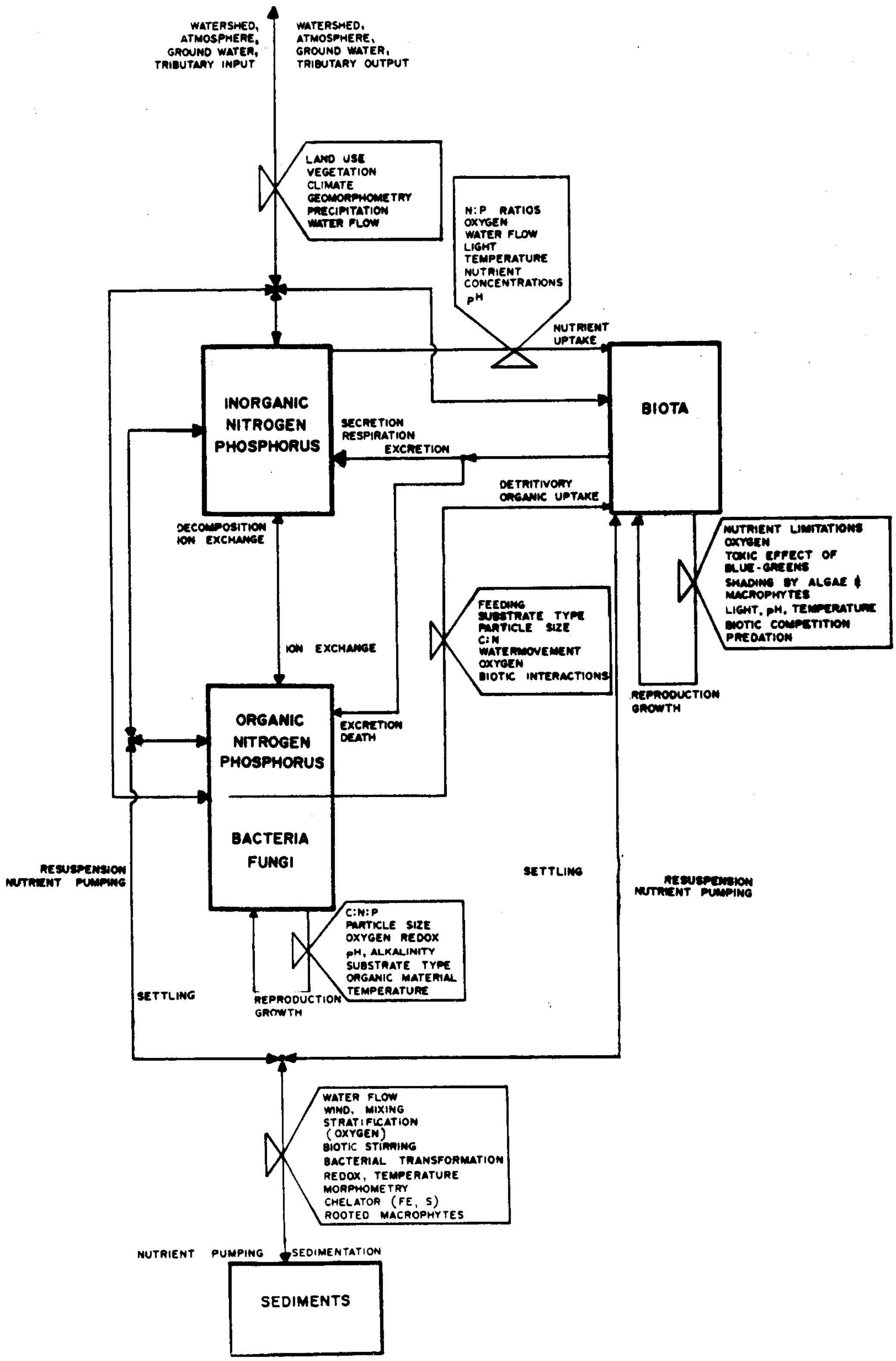


Figure 4.4.4.1-a. Generalized nitrogen and phosphorus cycling in aquatic environments.

Source: Farnworth et al. 1979.

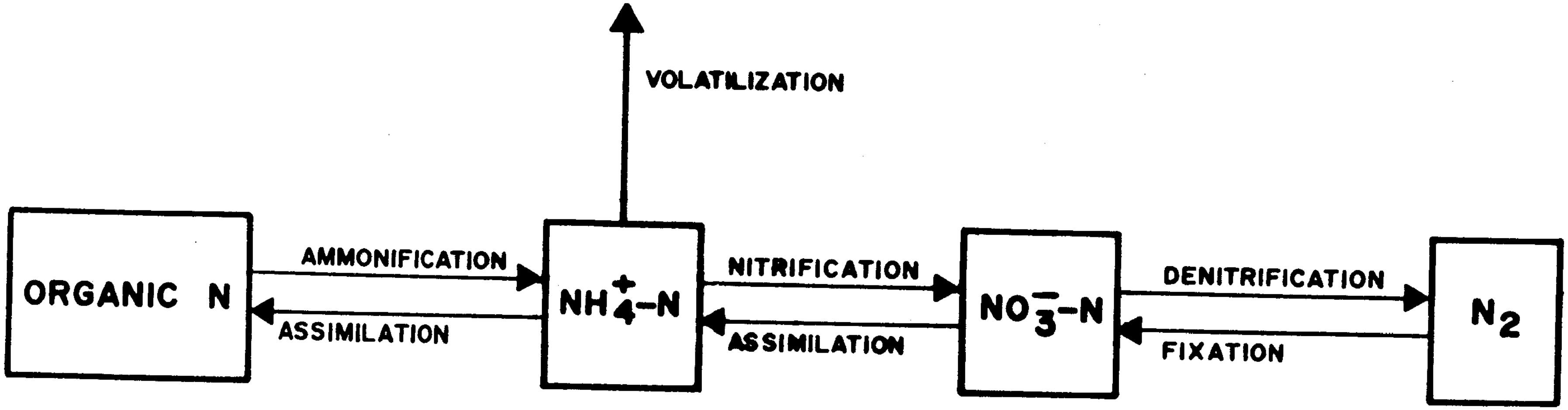


Figure 4.4.4.1-b. Major components of the nitrogen cycle in aquatic environments.

Source: Farnworth et al. 1979.

PHOSPHORUS CONCENTRATIONS DEPENDENT ON VEGETATION AND SOILS

Like nitrogen, phosphorus is an essential nutrient to wetlands vegetation. Unlike nitrogen, the phosphorus cycle is not complicated by significant export to the atmosphere. Certain vegetation are able to utilize phosphorus more effectively than others.

The movement of phosphorus in wetlands closely parallels nitrogen movements. A significant exception is that phosphorus cannot leave or enter wetlands in a gaseous form as does nitrogen (see Section 4.4.4.1). Consequently fewer pathways exist within the phosphorus cycle, which is further simplified by having fewer ionic valance states. Phosphorus, like nitrogen, is an essential element for plant growth and may limit productivity in some instances (Brown 1981), and like nitrogen, the patterns of phosphorus input, output and availability is dependent on local hydrologic regimes.

Phosphorus may enter wetlands as one of many forms of organic-P or inorganic-P from either surface waters or rain and throughfall at varying rates (see Table 4.4.4.2), depending on local conditions. In many wetlands, groundwaters may contribute to total phosphorus inputs. Phosphorus in the ionic form is easily leached from trees and leaves. Mitsch et al. (1979) found more phosphorus contributed by throughfall than actual rainfall in a floodplain forest. Phosphorus is converted from organic-P to inorganic-P in the sediments or the surface waters of wetlands by hydrolysis. Inorganic-P may be present as ortho- or poly-phosphate. Sorption of organic-P to sediments is an important pathway in some wetlands, although sorption by sediments inhibits the rate of hydrolysis (Rodel et al. 1977).

Phosphorus is transported from wetlands via hydrologic export through surface and groundwaters, or biological export. Ionic forms of phosphorus have a high affinity to clays (Brown 1981). Exchange reactions with clays underlying some wetlands will immobilize phosphorus and prevent it from reaching groundwater (Odum et al. 1978).

Within wetlands, phosphorus in the ortho-phosphate form is a mobile ion and is readily assimilated by plants and returned to the soil in litter fall. Phosphorus may also be precipitated or sorbed onto organic matter in an exchange reaction. New leaf litter leaches phosphorus rapidly, while older litter may actually accumulate phosphorus (van der Valk et al. 1978).

In oxygen-rich surface waters, ortho-phosphate forms insoluble complexes with certain ions, most notably iron, aluminum and calcium. Aluminum and iron phosphate fractions predominate in an acidic environment (Nur and Bates 1979). The resulting precipitate removes phosphorus from the water column. Phosphorus is released from the sediments back to the oxygenated water column when anaerobic conditions prevail (Stumm and Morgan 1970). Phosphorus may also be released as a result of the activity of sulfate reduction (Mitchell 1974).

The dynamics of phosphorus in wetlands is similar to nitrogen in its dependence on hydrologic regimes for essential inputs. The patterns of availability, assimilation and export of phosphorus vary among wetlands. In wetlands with naturally high phosphorus inputs (floodplain forests) phosphorus is found to accumulate in the leaves (Brown 1981).

The pattern of phosphorus uptake and release is also dependent on the vegetation. Typical marsh vegetation and epiphytes are capable of rapid phosphorus uptake and generally do so more rapidly than trees and shrubs (swamp vegetation). The assimilation rate varies highly among plant species, location and season (Kadlec and Kadlec 1978). Many plants take up nitrogen and phosphorus in excess of current needs, a well documented phenomenon in emergent marsh plants (Wetzel 1975). These same plants release nutrients back into the wetland, and depending on the labileness of the returned substance may be permanently stored in peats like nitrogen, or exported in hydrologic surges.

Table 4.4.4.2 Inputs of Total Phosphorus to Four Types of Cypress Ecosystems.

Study site	Rainfall	Inputs ($gP\ m^2\ yr^{-1}$) Surface Runoff	Overbank Flooding	Total
Scrub cypress	0.11	*	**	0.11
Large Dome	0.09	0.12	**	0.21
Sewage Dome	0.09	13.90[1]	**	13.99
Floodplain forest	*	*	1620.0	1620.0

*Not estimated.
**Does not occur in these ecosystems.
[1]Includes sewage effluent

Source: Brown 1981.

4.0 NATURAL WETLAND CHARACTERISTICS
4.4 Water Quality
4.4.4 Nutrients
4.4.4.3 Carbon

CARBON HAS A CENTRAL ROLE IN THE BIOLOGICAL AND CHEMICAL FUNCTIONING OF WETLANDS

Carbon flow in wetlands is biologically regulated by photosynthesis and respiration. Hydrologic imports and exports of carbon are significant only in riverine and lacustrine wetlands. Carbon is stored in biomass and in organic sediments. The pH regulates the inorganic carbon forms in natural waters and is a selective pressure on plants. Organic carbon exports have important linkages with downstream ecosystems. Humic and fulvic acids are primary components of dissolved organic carbon which imparts the typical tea-coloring to many wetland waters.

Carbon has a central role in the chemistry of life in wetlands. Like other macronutrients (N,P,K, etc), carbon is present in organic and inorganic forms. The majority of carbon in freshwater systems is often present as simple inorganic carbon, principally as products of carbonic acid equilibrium (CO_2, H_2CO_3, HCO_3-, CO_3=). A lesser amount occurs in organic carbon compounds as either dissolved particulate, or detrital organic carbon.

A small fraction of the total carbon in freshwater occurs as living biomass (Wetzel 1975). Dissolved inorganic carbon in freshwater is important in both biological and chemical processes. From a chemical standpoint, inorganic carbon forms the basis of the carbonate-bicarbonate buffering system in most freshwaters. Aquatic plants and algae utilize dissolved inorganic carbon during photosynthesis. Some aquatic plants utilize bicarbonate (HCO_3-) which predominates at neutral pH, others (mosses) can only utilize free CO_2 which predominates at pH less than 5.0. Other plants and algae are able to utilize both HCO_3- or CO_2 (Wetzel 1975). The forms of carbon in the water acts as a selective pressure for some plants (Etherington 1975).

In research on a floodplain forest, the primary inputs of carbon were from the net primary productivity process of trees (Kuenzler et al. 1980). The second most important source of carbon was hydrologic inputs (inorganic and organic). Minor sources of carbon inputs were from the shrub-understory, and algae. In the spring, before trees and shrubs begin active photosynthesis, algae temporarily dominate carbon inputs (Kuenzler et al. 1980). Rainfall and groundwater sources of carbon were minor.

The export of carbon from swamp forest wetlands is primarily from respiration (biological) and hydrologic pathways. In the swamp floor, litter decomposition was the major respiratory pathway with carbon returned to the atmosphere (Kuenzler et al. 1980). Respiration in the water column and benthic respiration were other significant biological pathways of carbon export. Hydrologic export in dissolved and particulate carbon was the most significant physical export of carbon. Release of carbon by benthic respiration may occur under aerobic or anaerobic conditions. Methane production during benthic respiration is strongly associated with anaerobic conditions (see Figure 4.4.4), but is usually only a minor carbon export.

The accumulation of carbon reserves in wetlands is commonly stored in biomass and the peats. This soil organic matter is typically 50 percent carbon by dry weight (Wetzel 1975). Although many marshes, bogs and swamps accumulate peats, it is not as typical in riverine swamps and marshes because the organic matter is either flushed out or lost during drydown when respiration is more rapid. A significant carbon export from some wetlands occurs by fire. This is typically not on an annual basis but represents an important export of carbon in those wetlands which are maintained by fire (see Section 4.2.2). Fire is capable of releasing many years of accumulated organic matter, much like periodic floods carying away accumulated sediments (Ewel and Mitsch 1978, Monk 1968).

The aforementioned carbon inputs and outputs are not all applicable to each wetland type within Region IV, but vary among wetland types and with local conditions. The importance of any one pathway may be amplified or diminished in accordance with local conditions and seasonal pulses.

In those wetlands with significant hydrologic export (riverine, lacustrine, wetlands), particulate and dissolved aquatic carbon export has significant ecological importance. Both dissolved and particulate carbon forms exported from wetlands have important ecological downstream linkages to riverine and estuarine productivity. The seasonal timing of this export is a delicate ecological balance in estuaries (Whigham and Bayley 1978, Simpson et al. 1978), and wetland integrity is critical to maintaining this balance.

Humic and fulvic acids are dissolved organic (carbon-based) acids which give many wetland waters their characteristic tea color. Dierburg and Brezonik (1980) found a significant correlation between total organic carbon (TOC) and color. These carbon compounds are important to the water chemistry of wetlands. They also impede light penetration and thus algal productivity by reducing the photic zone in wetlands. Humic or fulvic acids, often associated with metals such as Fe or Zn, may bind with orthophosphate ions. Humic materials are known for their complexing properties, most notably heavy metals. Humics are also resistant to microbial decomposition (Alexander 1977).

SULFUR AFFECTS CYCLING OF OTHER NUTRIENTS, PRODUCTIVITY, AND METALS DISTRIBUTION

The abundance of $SO_4^=$ in oxygenated surface water rarely makes sulfur a limiting nutrient for plant growth. Reduced forms of sulfur produced by decomposition may mobilize phosphorus and increase plant growth. Sulfur-metallic interactions provide a sink for metals in wetlands.

Sulfur is used in both chemical and biotic forms by all living things. The amount of organic sulfur in the biota and detritis is small in comparison to the inorganic sulfur compounds in natural waters. The distribution and cycling of sulfur in wetlands revolves around the various chemical states and biotic activities endemic to wetlands. Typical transformations and storages in the sulfur cycle are illustrated in Figure 4.4.4.4.

The source of sulfur inputs to wetlands is through rainfall and dry deposition. In many wetlands hydrologic sulfur inputs are important, similar to that of other nutrients. Sulfate ($SO_4^=$) is the predominant form of sulfur in oxygenated surface waters, naturally ranging from 5 to 30 mg/l (Wetzel 1975), depending on local geochemistry. Groundwater may be a source or sink of sulfur according to hydrologic flows. Sulfur from groundwater sources are likely to be contributed in a chemically reduced state (H_2S), but usually a minor percentage of the total sulfur inputs.

Sulfur is generally present in excess of the needs of plants. It is rarely a direct limiting factor in plant productivity for aquatic plants (Wetzel 1975). The most commonly assimilated form of sulfur is the sulfate ion ($SO_4^=$) which is used to build proteins. Some bacteria assimilate H_2S and oxidize this form of sulfur as an energy source in anaerobic environments. During decomposition, sulfur is released as H_2S. The H_2S is rapidly converted to $SO_4^=$ by any oxygen which is present, effectively acting as a scavenger of available oxygen.

No significant amounts of H_2S were reported in natural cypress dome sediments due to the oxygenated state of these sediments (Dierburg and Brezonik 1980). The odor of H_2S has been detected in the domes when sediments are disturbed (Dierburg and Brezonik 1980) indicating that H_2S may be present at localized sites. Elemental sulfur (S^o) may also be found deposited by bacteria under low O_2 and Eh conditions. The presence of HS is rare in wetlands unless they are alkaline.

Several bacterial groups are important in sulfur cycle transformations. The genus *Proteus* contains a group of common bacteria which degrade the proteins contained in organic matter. High numbers of *Proteus* release significant amounts of H_2S which results in a reduction of Eh and dissolved oxygen. This alteration of the chemical environment mobilizes phosphorus

4.4.4.4 Continued

from the sediments which contributes to phosphorus limited plant productivity. Two other bacteria groups are found in connection with the production of H_2S in wetlands. The groups Beggiatoa and Thiothrix oxidize H_2S as an energy source. They are also known to store elemental sulfur (S^o) intercellularly. They may be essential in protecting plant roots from the phytotoxic effects of H_2S in anaerobic sediments.

Another aspect of the sulfur cycle is the formation of metal sulfides by this general reaction:

$$H_2S + \text{metal } (Me^{++}) \longrightarrow MS.$$

There is a strong affinity between sulfide (H_2S) and iron (Fe) and once formed (FeS), they are extremely insoluble. The precipitation of FeS is a common sulfur-cycle pathway in wetlands. The removal of sulfide also increases the migration of other metals (zinc, copper, lead) to the sediments, forming precipitates more insoluble than FeS.

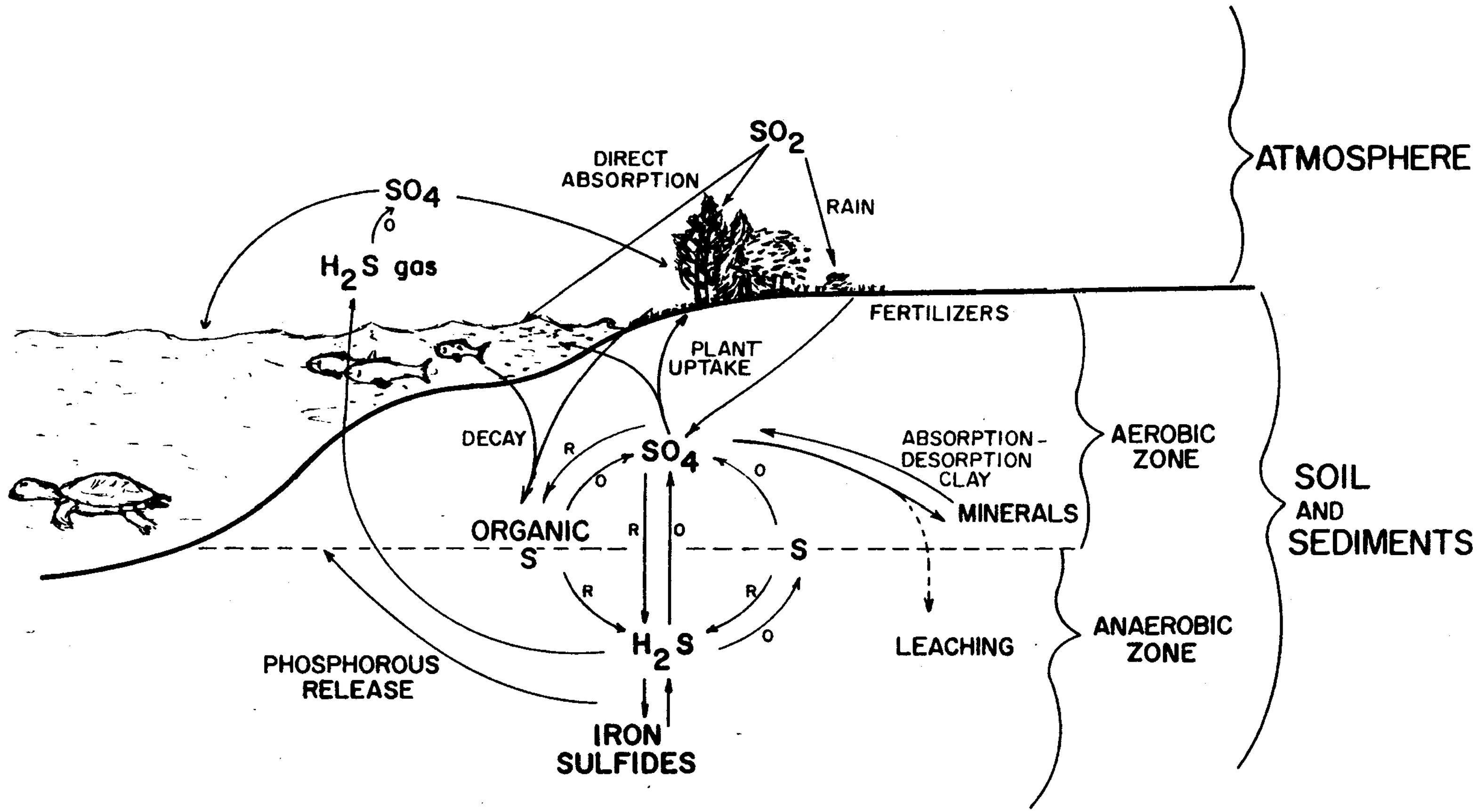


Figure 4.4.4.4. Generalized sulfur cycling in the environment.

Source: Odum 1971.

BACTERIA ARE IMPORTANT IN NUTRIENT CYCLING, DETRITUS FORMATION

Specialized groups of bacteria are important in the cycling of N, P, C, and S in wetlands. More generalized groups are responsible for an equally important task of decomposition and detritus formation. The public health aspects of natural wetlands require close attention.

The microbial flora of wetlands is quite diverse. Certain microorganisms are restricted in function to key roles in regulating nutrient cycling. Others are generalized organisms adapted to decompose endemic and introduced organic materials in wetlands. Still other microorganisms endemic to wetlands (arbovirus) are significant threats to humans as reservoirs of debilitating disease (Davis 1978).

The regeneration of nutrients is one of the most essential functions of microorganisms in wetlands (Mitchell 1974). In order for these organisms to function properly and release nutrients bound up in organic matter, they require specific environments with regard to pH, oxygen conditions, carbon substrate and temperature (Mitchell 1974). The regeneration of nutrients begins with proteolytic bacteria, fungi, or actinomycetes which decompose organic matter into simpler molecules. Decomposition proceeds more rapidly for most organic substances in aerobic conditions than in anaerobic conditions. Anaerobic degradation of organic matter is not only slow by comparision but often results in the production of organic acids and incomplete degradation. The refractory portion of organic matter forms the basis for peat formation. If exposed again to air, the organic matter will continue to be degraded.

Once simpler molecules are produced by general decomposing bacteria, specialized groups of bacteria are responsible for further breakdown of organic matter. For example, organic acids are utilized by a specialized group of bacteria to produce methane (see Figure 4.4.4). Certain Bacillus and Pesudomonas groups are responsible for converting nitric acid to nitrogen gas for atmospheric release. Important transitions of sulfur compounds are mediated by bacteria (see Section 4.4.4.4.). Each species has highly specific range of environmental variables (pH, O_2, temp.) outside which it will not function. When these ranges are exceeded, important cycles may be interrupted. For example, Nitrobacter is inhibited at low temperatures and high pH. It is responsible for converting nitrite to nitrate. If this bacteria does not function, a buildup of nitrite may occur which is toxic to fish and humans. Nutrient cycle imbalances occur when conditions for key microorganisms are not present.

The fate of other bacteria including fecal coliforms and pathogens will be discussed in Section 7.1.5, Public Health.

COMMON, THREATENED AND ENDANGERED WILDLIFE SPECIES USE WETLANDS AT LEAST DURING SOME PART OF THEIR LIFE CYCLE

Wetlands provide abundant food, water and shelter needed for the continued existence of many wildlife species. Thus, in many instances, a positive correlation exists between wildlife survival and the availability of wetlands. This provides a basis for establishing wildlife and recreational values of wetlands. This is particularly important with regard to species that are listed as endangered or threatened by federal and state agencies. A large group of these species depend on wetlands for survival, but many of these species do not appear on appropriate lists and may not be protected by state or federal laws or statutes.

Wetlands provide abundant food, water and shelter needed by a large number of wildlife species. Thus, adequate tracts of wetland areas are needed if many species are to remain extant. Other factors unrelated to the wetland itself affect the level of importance a given wetland plays in the continued existence of wildlife. Climatic variability and atypical reproductive periods are examples of other factors affecting the density and diversity of species inhabiting wetland areas.

Many southeastern wetlands provide the requisites of survival for a wide variety of wildlife species. Included are cypress domes, marshes, pocosins and bottomland hardwood wetlands. The density and diversity of species present in these wetlands at any one time depends on the current needs of the species, the present ecological status of the wetland and the population status of the species where the wetland is located. This abundance of wildlife includes but is not limited to game animals and fish, song birds, raptors, owls, racoons, minks, turtles, salamanders and snakes. The wildlife values of wetlands lie not only in the survival of these wildlife groups, but as well to conservation and education groups and those who pursue hunting and fishing activities.

Several species of wildlife listed as endangered or threatened under the Endangered Species Act of 1973 are dependent on wetlands for nutritional and/or reproductive requirements. Each state in Region IV also maintains a list of endangered or threatened species endemic to the state. Included in these lists are species that are wetland-dependent. State listed species of the endangered or threatened status may or may not be protected by state laws or statutes.

4.0 NATURAL WETLAND CHARACTERISTICS

4.5 Wildlife

4.5.1 Value of Wetlands as Habitat for Wildlife

WETLANDS PROVIDE FOOD, WATER, ESCAPE COVER AND REPRODUCTIVE REQUIREMENTS FOR MANY WILDLIFE SPECIES

The use of wetlands by wildlife is common. Wetlands are generally associated with greater habitat diversity which, in turn, leads to a greater number of species and individuals of each species. Climatic variability and wetland size are examples of factors unrelated to habitat that may affect species density and diversity in wetland ecosystems. Pocosins, cypress domes, marshes and bottomland hardwood wetlands provide food, shelter and reproductive requirements for a wide variety of wildlife species, and many species depend heavily on wetlands for survival during some portion of their life cycles.

The ability of wetlands to serve wildlife needs for food, shelter and water depends on a variety of interrelated factors. Wildlife needs differ with season and reproductive cycles. Weather conditions, predation and atypical reproduction cycles may cause changes in species abundance from year to year that are not associated with the condition of the wetland. Conversely, wetlands generally contain a large number of species (species richness) and a large number of species individuals (species density) because wetlands form the meeting point between two or more types of plant communities.

This interface of ecological communities is called the edge effect; both the number of species and the total biomass will be larger in the edge area than in any comparable area contained wholly within one or the other community type. The degree of edge determines in part the carrying capacity of an area (the limitation of the number of any one species that can be maintained). Most wetlands compare favorably with the best managed moist terrestrial systems, in terms of primary productivity (Odum 1971). Thus, the heterogeneity of ecosystem types in a wetland complex creates habitat diversity including high species richness.

Other factors may play an important role in determining whether wildlife species are abundant in wetlands. For instance, the size of a wetland and vegetation type and structure are vital to the maintenance of wetland fauna. Wetlands wildlife also change in response to climatic (and seasonal) influences. In many instances, the form of vegetation seems to be more important to wildlife than taxonomic composition (Schitoskey and Linder 1978).

In marshes, several distinct plant zones are produced by changes in depth of inundation. A naturally devegetated marsh that is dewatered produces a subsequent germination phase. Shallow-marsh plants dominate during this period and are succeeded, after inundation depth increases, by more water tolerant species such as cattail. This phase of vegetation change is associated with a dense habitat dominated by vigorous aquatic emergents.

4.5.1 Continued

Thus, dewatering followed by reflooding produces excellent interspersion of emergent cover and water, and species richness and species diversity is enhanced (Weller 1981).

Pocosins provide food, water, escape cover and reproductive needs for several species which once ranged widely in North Carolina but are now confined only to pocosins. The black bear (Ursus americana), white tailed deer (Odocoileus virginianus) and the pine barrens treefrog (Hytia andersoni) are examples of species which depend on pocosins for suitable habitat because other areas have been developed. Pocosins also serve as food support systems for species endemic to other community types. The eastern diamondback rattlesnake (Crotalus adamentius) is endemic to flatwood ecosystems but feeds on rabbits that depend on pocosins for food and shelter (Wilbur 1981). Several small game species, including the marsh rabbit (Sylvilagus palustris), exist where pocosins and surrounding agricultural areas meet, but habitat loss has been an overriding factor causing a decline in total numbers (Monschein 1981). Birds use pocosins as nesting sites and/or as a source of food. Bobwhite quail (Colinus virginianus) use pocosins as a source of food. Pocosins provide nesting and roosting sites for the mourning dove (Zenaidura macroura), and the woodcock (Philohela minor) uses pocosins for shelter during the day. The information available on pocosins as habitat for fish is scarce. Monschein (1981) lists several endemic species occurring in canals, lakes and streams.

Natural cypress domes serve a very important role as refuges for wildlife. These wetlands also aid in stabilizing animal communities and providing abundant edge through which many species find food, water and shelter. The edges of cypress ponds are highly dynamic areas of animal activity. Jetter and Harris (1976) studied the effect of sewage effluent on wildlife species in Florida cypress domes and tabulated important species endemic to dome areas. They noted higher frog densities, lower mosquito, fish and crayfish densities, greater numbers of dipteran detritivores, fewer herons and greater passerine birds in the dome receiving sewage than in the control (groundwater) dome.

Bottomland hardwood wetlands are transitional zones between the aquatic stream ecosystems and the upland ecosystem. These wetlands are used extensively by a large variety of wildlife. Many riverine fish species use these types of wetlands for feeding, spawning and nursery grounds. Regardless of how briefly bottomland hardwood wetlands are flooded, they contribute significantly to the viability of riverine fishes and invertebrates. Prolonged inundation of vegetated zones increase the probability of survival of fishes during early life stages (Clark and Benforado 1980). The use of bottomland hardwood wetlands by bird and mammals will differ by species, season and flooding regime. Wharton et al. (1980) describes the major wildlife species found in bottomland hardwood ecosystems.

ALL STATES IN REGION IV HAVE ENDEMIC SPECIES OF WILDLIFE CLASSIFIED AS ENDANGERED OR THREATENED WHICH DEPEND ON WETLANDS FOR NUTRITIONAL AND REPRODUCTIVE NEEDS

The Federal Endangered Species Act of 1973 lists 15 species endemic to Region IV that depend on wetlands for food, shelter, and reproductive needs during at least some part of the species' life cycle. The act emphasizes the need to preserve critical habitats on which endangered and threatened species depend for their continued existence. Every state in Region IV has a list of unique state species of the endangered, threatened or special concern status that includes wetland dependent species. These species may or may not be protected by state laws or statutes.

The U. S. Department of Interior lists under the Endangered Species Act of 1973 67 threatened and endangered wildlife species endemic to Region IV. These two classes of protected species are defined as follows:

Threatened species: any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

Endangered species: any species which is in danger of extinction throughout all or a significant portion of its range other than a species of the class Insecta determined by the Secretary to constitute a pest whose protection under the provisions of this Act would present an overwhelming and overriding risk to man.

In addition to protecting threatened and endangered species of wildlife, the Act emphasizes the need to preserve critical habitats on which endangered species depend for their continued existence. Individual states are also encouraged to establish guidelines which will complement the goals of the Act.

Fifteen species included in the federal list of endangered and threatened species endemic to Region IV are known to be wetland dependent. For the purposes of this report, wetland-dependent species classified as threatened or endangered are species which depend on wetland habitat for food, water, shelter and/or reproductive needs at least during some portion of the specie's life cycle. Many species use wetlands exclusively for nutritional and reproductive requirements and shelter needs. Some species, however, require wetlands during only short periods of their life cycle. Table 4.5.2 lists these species and their distribution within Region IV.

4.5.2 Continued.

The appropriate environmental resource agency for each state in Region IV maintains and updates a state list of endangered or threatened species. Most state lists are amalgamations of endangered and threatened species included in the federal list and endemic wildlife deemed endangered, threatened, or of special concern by state officials. Several states in Region IV have not enacted specific laws to accomplish protection of state listed endangered species, but instead, have general protective provisions for wild birds and animals. These provisions are deficient in terms of ultimate authority and enforceability to accomplish adquate protection of these species.

Table 4.5.2. United Stated Department of Interior Fish and Wildlife Service List of Wetland-dependent Endangered (E) and Threatened (T) Species Endemic to Region IV.

	Status	Distribution
Mammals		
Florida panther (*Felis concolor coryi*)	E	AL, FL, GA, MS, SC, TN
Birds		
Mississippi sandhill crane (*Grus canadensis pulla*)	E	MS
Bald eagle (*Haliaeetus leucocephalus*)	E	AL, FL, GA, KY, MS, NC, SC
American peregrine falcon (*Falco peregrinus*)	E	AL, FL, GA, KY, NC, SC, TN
Bachman's warbler (*Vermivora bachmanii*)	E	AL, FL, GA, KY, MS, NC, SC
Everglade kite (*Rostrhamus sociabilis plumbeus*)	E	FL
Cap Sable seaside sparrow (*Ammospiza maritima mirabilis*)	E	FL
Dusky seaside sparrow (*Ammospiza maritima nigrescens*)	E	FL
Ivory billed woodpecker (*Campephilus principalis*)	E	FL
Brown pelican (*Pelecanus occidentalis carolinensis*)	E	AL, FL, GA, MS, NC, SC
Amphibians and Reptiles		
American alligator (*Alligator mississippiensis*)	E	AL, GA, MS, NC, SC
American alligator ((*Alligator mississippiensis*)	T[1]	FL, GA, SC
Pine barrens treefrog (*Hyla andersoni*)	E	FL
Fish		
Bayou darter (*Etheostoma rubrum*)	T	MS
Okaloosa darter (*Etheostoma okaloosae*)	E	FL

[1]Alligator populations are threatened in Florida and coastal areas of Georgia and South Carolina.

Source: Adapted from the United States Fish and Wildlife Service List of Threatened and Endangered Species of Fish and Wildlife (50 CFR 17.11)

4.0 NATURAL WETLAND CHARACTERISTICS
4.5 Wildlife
4.5.2 Threatened and Endangered Wildlife Species
4.5.2.1 Alabama

ALABAMA HAS 25 SPECIES LISTED AS THREATENED, ENDANGERED OR OF SPECIAL CONCERN

The Alabama Department of Conservation and Natural Resources maintains and updates an unofficial list of species considered to be in need of protection, but Alabama has no official law or regulation that protects these species. The unofficial list includes a variety of wetland dependent mammals, birds, fish and reptiles and amphibians. These species are classified as being threatened, endangered or of special concern.

Alabama has no law or regulation that protects rare and endangered species in the state. An unofficial list of endangered species does exist. The list includes all species protected by federal laws and regulations and species which the Alabama Department of Conservation and Natural Resources (DCNR) has considered to be in need of protection. By using a uniform classification scheme, DCNR lists endangered species as those in danger of extinction throughout all or a significant portion of their range in Alabama. Threatened species are likely to become endangered. Species of special concern must be continually monitored because imminent degrading factors, their limited distribution or other physical or biological characteristics may cause them to become threatened or endangered in the foreseeable future.

Table 4.5.2.1 lists all wetland dependent species classified as endangered, threatened, or of special concern in Albama. Boschung (1976) discusses the methodologies used in the classification of species into one of the three categories.

Table 4.5.2.1. List of Wetland-Dependent Species in Alabama of Endangered Status (E) Threatened Status (T) and Special Concern Status (S).

	Status
Mammals	
Florida black bear (Ursus americanus floridanus)	E
Florida panther (Felis concolor coryi)	E
Southeastern shrew (Sorex longirostis)	S
Marsh rabbit (Sylvilagus palustris palustris)	S
Bayou grey squirrel (Sciurus carolinensis fuliginosus)	S
Meadow Jumping Mouse (Zapus hudsonius americanus)	S
Fish	
Slackwater darter (Etheostoma boschungi)	T
Broadstripe shiner (Notropis euryzonus)	S
Brindled madtom (Noturus miurus)	S
Birds	
Bald eagle (Haliaeetus leucocephalus)	E
Osprey (Pandion haliaetus)	E
Peregrine falcon (Falco peregrinus)	E
Bachman's warbler (Vermivora bachmanii)	E
Ivory-billed woodpecker (Campephilus principalis)	E
Little blue heron (Florida caerulea)	S
Wood stork (Mycteria americana)	S
Swallow-tailed kite (Elanoides forficatus)	S
Sandhill crane (Grus canadensis)	S
Amphibians and Reptiles	
Flatwoods salamander (Ambystoma cingulatum)	E
American alligator (Alligator mississippiensis)	T
Alabama red-bellied turtle (Pseudemys alabamensis)	T
River frog (Rana heckscheri)	S
Greater siren (Siren lacertina)	S
Florida green water snake (Natrix cyclopion floridana)	S
North Florida black swamp snake (Seminatrix pygaea pygaea)	S

Source: Adapted from Boschung. 1976.

FLORIDA HAS 31 SPECIES OF WETLAND-DEPENDENT WILDLIFE CLASSIFIED AS EITHER ENDANGERED, THREATENED OR OF SPECIAL CONCERN

The Florida Endangered and Threatened Species Act of 1977 recognizes species of endangered or threatened wildlife including mammals, birds, fish, amphibians and reptiles. The act applies to any member of the animal kingdom and defines the terms endangered, threatened and special concern. The Florida Game and Fresh Water Fish Commission has published a list of animals classified under these three categories. Included in the list are 31 wetland-dependent species.

In 1977 the State of Florida enacted the Florida Endangered and Threatened Species Act of 1977. The act applies to a list of species classified as either endangered, threatened or of special concern. The Florida Game and Fresh Water Fish Commission defines an endangered species as a resident of the state during a substantial portion of its life cycle and which is in immediate danger of extinction or extirpation from the state or which may attain such a status within the immediate future unless it or its habitat are fully protected in such a way as to enhance its survival potential. The commission defines a threatened species as one which is acutely vulnerable to environmental alteration and whose habitat is declining in area at a rapid rate and as a consequence is destined to become an endangered species within the foreseeable and predictable future. A species of special concern, as defined by the commission, is one which warrants special protection because it occurs disjunctly or continuously in Florida and has a unique and significant vulnerability to habitat modification or environmental alteration which may result in its becoming a threatened species.

Table 4.5.2.2 lists and designates the endangered, threatened and special concern species in Florida. Pritchard (1978) discusses ranges and habitat requirements and describes most of the species listed in the table.

Table 4.5.2.2. List of Wetland-Dependent Species in Florida of Endangered Status (E) Threatened Status (T) and Special Concern Status (S)

	Status
Mammals	
Pallid beach mouse (*Peromyscus polionotus decoloratus*)	E
Florida panther (*Felis concolor coryi*)	E
Choctawhatchee beach mouse (*Peromyscus polionotus allopyhrys*)	T
Perdido Bay beach mouse (*Peromyscus polionotus trisyllepsis*)	T
Florida black bear (*Ursus americanus floridanus*)	T
Everglades mink (*Mustela vison evergladensis*)	T
Fish	
Okaloosa darter (*Etheostoma okaloosae*)	E
Crystal darter (*Ammocrypta asprella*)	T
Saltmarsh topminnow (*Fundulus jenkinsi*)	S
Birds	
Wood stork (*Mycteria americana*)	E
Everglade kite (*Rostrhamus sociabilis*)	E
Peregrine falcon (*Falco peregrinus*)	E
Ivory-billed woodpecker (*Campephilus principalis*)	E
Bachman's warbler (*Vermivora bachmanii*)	E
Dusky seaside sparrow (*Ammospiza maritima nigrescens*)	E
Cape Sable seaside sparrow (*Ammospiza maritima mirabilis*)	E
Eastern brown pelican (*Pelecanus occidentalis carolinensis*)	T
Bald eagle (*Haliaeetus leucocephalus*)	T
Audubon's caracara (*Caracara cheriway auduboni*)	T
Florida sandhill crane (*Grus canadensis*)	T
Roseate tern (*Sterna dougallii*)	T
Little blue heron (*Florida caerulea*)	S
Snowy egret (*Egretta thula*)	S
Louisiana heron (*Hydranassa tricolor*)	S
Amphibians and Reptiles	
Pine barrens treefrog (*Hyla andersoni*)	E
Florida brown snake (*Storeria dekayi victa*)	T
American alligator (*Alligator mississippiensis*)	S

[1]Classified as endangered on the federal list.

Source: Adapted from Pritchard. 1978.

GEORGIA LISTS SIX ENDANGERED SPECIES AND ONE THREATENED SPECIES THAT ARE WETLAND DEPENDENT

The Georgia Department of Natural Resources lists 23 unusual, rare, threatened or endangered species. Of these, seven species use wetlands during some part of their life cycles. Under the Georgia Endangered Wildlife Act of 1973, only habitats on public lands are protected to enhance the survival of these species. The Act does not affect private property rights nor can it impede construction of any nature. Georgia law has, however, established a regulatory program and review process to provide for the protection of certain identified species and their habitat.

In 1973, Georgia passed the Endangered Wildlife Act to protect various species existing in the state. Under this Act, the Georgia Department of Natural Resources (DNR) was required to identify species considered endangered, threatened, rare, or unusual. These classes are defined as follows:

Endangered Species: Any resident species which is in danger of extinction throughout all or a significant portion of its range or one which is designated as endangered under the provisions of the federal Endangered Species Act of 1973.

Threatened Species: Any resident species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range or one that is designated as threatened under the provisions of the federal Endangered Species Act of 1973.

Rare Species: Any resident species which, although not presently endangered or threatened as previously defined, should be protected because of its scarcity.

Unusual Species: Any resident species which exhibits special or unique features and because of these features deserves consideration in its continued survival in the state.

Georgia's act provides that only habitats on public lands shall be protected (Smith 1978). The DNR has made a list of 23 species which are rare, unusual, threatened or in danger of extinction. The list includes seven species which depend on wetlands. All of these species are endangered with the exception of the American alligator (*Alligator mississippiensis*). This reptile is classified as endangered along the Georgia coastal plain and threatened in other coastal regions. Odum et al. (1977) gives a complete description of each species range and habitat requirements.

Table 4.5.2.3 lists these species and indicates their status.

Table 4.5.2.3. List of Wetland-Dependent Species in Georgia of Endangered Status (E) Threatened Status (T), Rare Status (R) or Unusual Status (U)

	Status
Mammals	
Florida panther (*Felis concolor caryi*)	E
Fish	
none	
Birds	
Ivory-billed woodpecker (*Campephilus principalis*)	E
Peregrine falcon (*Falco peregrinus*)	E
Southern bald eagle (*Haliaeetus leucocephalus leucocephalus*)	E
Brown pelican (*Pelecanus occidentalis carolinensis*)	T
Bachman's warbler (*Vermivora bachmanii*)	E
Amphibians and Reptiles	
American alligator (*Alligator mississippiensis*)	E/T[1]

[1]American alligator is an endangered species along the Georgia coastal plain and a threatened species in coastal areas.

Source: Adapted from Odom et al. (eds). 1977.

4.0 NATURAL WETLAND CHARACTERISTICS
4.5 Wildlife
4.5.2 Threatened and Endangered Wildlife Species
4.5.2.4 Kentucky

KENTUCKY LISTS 14 RARE OR ENDANGERED SPECIES THAT ARE WETLAND DEPENDENT

Species designated as endangered by the Secretary of Interior are considered an endangered species in Kentucky. The state also has a list of rare, threatened, or endangered species, many of which are affected by these regulations. From the total list, 14 species are wetland dependent; three are endangered, the rest are considered rare.

Kentucky administrative regulations allow the state to comply with the federal Endangered Species Act of 1973 and gives the jurisdiction for enforcing these regulations to the Kentucky Department of Fish and Wildlife Resources. The regulations pertain to the federal list of endangered and threatened species listed in Table 4.6.1. Kentucky also maintains and updates a state list of rare species which the Endangered Species Regulation does not protect. These species are protected (except rats, mice and shrews) by Kentucky statutes unless there is a regulation permitting them to be taken. Fourteen endangered and rare wetland-dependent species are protected by federal regulations or Kentucky statutes.

Table 4.5.2.4 lists endangered and rare species in Kentucky, and Parker and Dixon (1980) describes their distribution, habitat and characteristics.

Table 4.5.2.4. List of Wetland-Dependent Species in Kentucky of the Endangered Status (E) Threatened Status (T), or Rare Status (R)[1].

	Status
Mammals	
Cougar (Felis concolor)	E
River otter (Lutra canadensis)	R
Black bear (Ursus americanus)	R
Swamp rabbit (Sylvilagus aquaticus)	R
Fish	
Mud darter (Etheostoma asprigene)	R
Birds	
Bald eagle (Haliaeetus leucocephalus)	E
American peregrine falcon (Falco peregrinus)	E
Osprey (Pandion haliaetus)	R
Mississippi kite (Ictinia misisippiensis)	R
Sandhill crane (Grus canadensis)	R
Amphibians and Reptiles	
Western lesser siren (Siren intermedia)	R
Western bird voiced treefrog (Hyla avivoca avivoca)	R
Green treefrog (Hyla cinera cinerea)	R
Western mud snake (Farancia abacura reinwardti)	R
Green water snake (Natrix cyclopion cyclopion)	R
Broad-banded water snake (Natrix fasciata confluens)	R
Alligator snapping turtle (Macroclemys temmincki)	R
Slider (Chrysemys concinna hieroglyphica)	R

[1]Rare species are protected (except rats, mice and shrews) by Kentucky statutes unless there is a regulation permitting them to be taken.

Source: Adapted from Parker and Dixon. 1980.

4.0 NATURAL WETLAND CHARACTERISTICS
4.5 Wildlife
4.5.2 Threatened and Endangered Wildlife Species
4.5.2.5 Mississippi

IN MISSISSIPPI, 14 ENDANGERED AND THREATENED WILDLIFE SPECIES ARE WETLAND-DEPENDENT

The Mississippi Game and Fish Commission adopted a list of endangered and threatened vertebrates in 1977. Fourteen wetland-dependent species are included in this list.

The State of Mississippi passed the Nongame and Endangered Species Conservation Act to manage and protect wildlife and fish included in the United States List of Endangered Fish and Wildlife. The state act requires the Mississippi Game and Fish Commission to maintain an official list of endangered and threatened species. All species on the list are protected by state laws regulated by the Commission. The Commission defines an endangered species as one which is in danger of extinction throughout all or a significant portion of its range. A threatened species is one which may become an endangered species within the foreseeable future in all or a significant portion of its range. The list includes 14 species which are wetland dependent.

Table 4.5.2.5 lists these species and indicates whether they are endangered or threatened.

Table 4.5.2.5. List of Wetland-Dependent Species in Mississippi of the Endangered Status (E) and Threatened Status (T).

	Status
Mammals	
Florida panther (Felis concolor coryi)	E
Black bear (Ursus americanus)	T
Fish	
Bayou darter (Etheostoma rubrum)	E
Crystal darter (Ammocrypta asprella)	E
Birds	
Mississippi sandhill crane (Grus canadensis pulla)	E
Bald eagle (Haliaeetus leucocephalus)	E
Peregrine falcon (Falco peregrinus)	E
Bachman's warbler (Vermivora bachmanii)	E
Ivory-billed woodpecker (Campephilus principalis)	E
Amphibians and Reptiles	
Rainbow snake (Farancia erytrogramma)	E
American alligator (Alligator mississippiensis)	E
Black-nobbed sawback turtle (Graptemys nigrinoda)	E
Ringed sawback turtle (Graptemys oculifera)	T
Yellow-blotched sawback turtle (Graptemys flavimaculata)	T

Source: Adapted from the Mississippi Department of Wildlife Conservation Bureau of Fisheries and Wildlife, Public Notice No. 2156.

NORTH CAROLINA HAS EIGHT WETLAND-DEPENDENT SPECIES CLASSIFIED AS ENDANGERED OR THREATENED

The North Carolina Wildlife Commission is responsible for monitoring the effects of proposed projects on any wildlife species that is listed as either endangered or threatened by federal or state authorities. Seventeen resident species of wildlife are designated as endangered, and eight of these species are wetland dependent. These eight wetland-dependent species are also listed as endangered under the federal Endangered Species Act of 1973.

North Carolina has general statutes authorizing the protection of endangered and threatened wildlife species. Public funds may not be spent in a way that would jeopardize the continued existence of certain species. The North Carolina Wildlife Resources Commission is responsible for monitoring the effects of proposed projects on these species. A listing of 17 endangered and four threatened species has been compiled for North Carolina. The terms threatened and endangered, as defined by the Endangered Species Act of 1973, are used to determine the status of species existing in North Carolina. Eight wetland-dependent species are found on the North Carolina list. These species are also included on the federal list and protected by federal laws.

Table 4.5.2.6 lists these species and indicates whether the species is endangered or threatened. Parker and Dixon (1980) discuss the description, distribution, habitat and characteristics of these species.

Table 4.5.2.6. List of Wetland Dependent Species in North Carolina of the Endangered Status (E) and Threatened Status (T)

	Status
Mammals	
Eastern cougar (*Felis concolor cougar*)	E
Fish None	
Birds	
American peregrine falcon (*Falco peregrinus*)	E
Artic peregrine falcon (*Falco peregrinus tundris*)	E
Bachman's warbler (*Vermivora bachmanii*)	E
Bald eagle (*Haliaeetus leucocephalus*)	E
Ivory-billed woodpecker (*Campephilus principalis*)	E
Brown pelican (*Pelecanus occidentalis*)	E
Amphibians and Reptiles	
American alligator (*Alligator mississippiensis*)	E

Source: Adapted from Parker and Dixon. 1980.

THIRTEEN WETLAND-DEPENDENT WILDLIFE SPECIES ARE CLASSIFIED AS ENDANGERED OR THREATENED IN SOUTH CAROLINA

The South Carolina Nongame and Endangered Species Conservation Act of 1976 lists 25 endangered or threatened wildlife species. Thirteen species on this list inhabit wetlands at least during some portion of their life cycle. A variety of other state laws, including the Heritage Trust Program Act, provide wetland habitat protection for threatened or endangered wildlife species.

The South Carolina Wildlife and Marine Resources Department manages and protects certain threatened and endangered wildlife species residing in the state. Under the South Carolina Nongame and Endangered Species Conservation Act of 1976, 25 endangered and threatened species are afforded protection; of these species, 13 are wetland dependent. The act states that it is unlawful to take, posess, or sell any of these species, but taking and possession of these animals may be permitted in limited circumstances (Smith 1978). Wetland habitat for threatened or endangered species can be protected from development or other disturbances either directly or indirectly by a variety of state laws including the Coastal Zone Management Act and the Heritage Trust Program Act.

Table 4.5.2.7 lists the 13 wetland dependent wildlife species. Parker and Dixon (1980) characterize the habitat and distribution of these species.

Table 4.5.2.7. List of Wetland Dependent Species in South Carolina of the Endangered Status (E) and Threatened Status (T).

	Status
Mammals	
Eastern cougar (Felis concolor cougar)	E
Fish	
None	
Birds	
American peregrine falcon (Falco peregrinus)	E
Bachman's warbler (Vermivora bachmanii)	E
Eastern brown pelican (Pelecanus occidentalis carolinensis)	E
Golden eagle (Aquila chrysaetos)	E
Swallow-tailed kite (Elanoides forficatus)	E
Wood stork (Mycteria americana)	T
Cooper's hawk (Accipiter cooperii)	T
American osprey (Pandion haliaetus)	T
Amphibians and Reptiles	
Pine barrens treefrog (Hyla andersoni)	E
American alligator (Alligator mississippiensis)	E

Source: Adapted from Parker and Dixon. 1980.

THIRTEEN WETLAND-DEPENDENT WILDLIFE SPECIES ARE CLASSIFIED AS ENDANGERED OR THREATENED IN TENNESSEE

A number of wildlife species in Tennessee have been officially listed by the Tennessee Wildlife Resources Agency as endangered or threatened. Thirteen species that depend on wetland ecosystems for survival are included in this list. The Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 requires the protection of these species. The Tennessee Department of Conservation maintains a computer bank concerning key habitats used by these species.

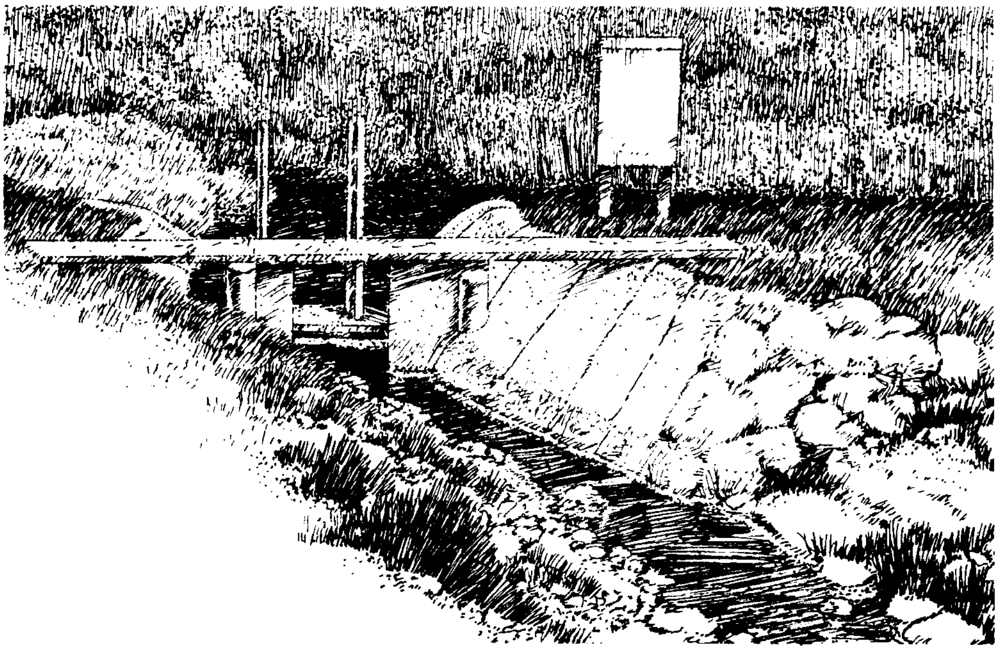
The Tennessee Wildlife Resources Agency (TWRA) and the Heritage Program (THP) of the Tennessee Department of Conservation are most directly concerned with the protection of rare species endemic to Tennessee. Through the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974, these agencies protect and classify wildlife species whose existence is deemed to be endangered, threatened, or in need of management. In general, the state uses the federal definitions of endangered and threatened to classify rare species. In need of management and special concern are terms assigned to those species which may not currently exist at or near their optimum carrying capacity (Eagar and Hatcher 1980). Fifty-seven species of wildlife are listed as either endangered or threatened in Tennessee. The Tennessee Department of Conservation maintains a computer bank concerning the location of key habitat areas for these species. Thirteen wildlife species of the endangered or threatened status depend on wetland ecosystems for survival. Eagar and Hatcher (1980) have surveyed the status of these species to learn their distribution, population density, ecological requirements, limiting factors and management potential.

Table 4.5.2.8 lists all wetland-dependent wildlife species classified as endangered and threatened in Tennessee.

Table 4.5.2.8. List of Wetland Dependent Wildlife Species in Tennessee of the Endangered Status (E) and Threatened Status (T)

	Status
Mammals	
Eastern cougar (Felis concolor cougar)	E
Florida panther (Felis concolor coryi)	E
River otter (Lutra canadensis)	T
Fish	
Slackwater darter (Etheostoma boschungi)	T
Trispot darter (Etheostoma trisella)	T
Birds	
Bachman's warbler (Vermivora bachmanii)	E
Peregrine falcon (Falco peregrinus)	E
Bald eagle (Haliaeetus leucocephalus)	E
Ivory-billed woodpecker (Campephilus principalis)	E
Brown pelican (Pelecanus occidentalis)	E
Mississippi kite (Ictinia misisippiensis)	E
Osprey (Pandion haliaetus)	E
Marsh hawk (Circus cyaneus hudsonius)	T
Black-crowned night heron (Nycticorax nycticorax)	T
Amphibians and Reptiles	
Western pigmy rattlesnake (Sistrurus miliarius sticckeri)	T

Source: Adapted from Eagan and Hatcher. 1980.



SECTION 5

INSTITUTIONAL CONSIDERATIONS

5.0 INSTITUTIONAL CONSIDERATIONS

INSTITUTIONAL CONSIDERATIONS HAVE AN IMPORTANT BEARING ON IMPLEMENTATION OF WETLAND DISCHARGES

Federal and state regulations determine the feasibility and final form of wetland discharges; however, regulations must be promulgated on a firm base of technical understanding. The question of considering wetlands for treatment or disposal of wastewater effluent is one example of an institutional issue which must be resolved through technical and regulatory considerations in order to facilitate implementation. Additional implementation problems and institutional issues which must be addressed concern wetlands ownership and proprietary rights, wasteload allocations and effluent limitations, wetlands definitions, and the need for evaluative criteria.

Wetlands, as part of the waters of the United States, are under the jurisdiction of several federal agencies charged with natural resource management and pollution control. In addition, wetlands are almost always considered waters of the state under individual state laws and are further regulated under Section 404 (dredge or fill permits) or Section 402 (NPDES permits) of the Federal Water Pollution Control Act (PL 92-500, as amended). Wetlands have also been the subject of official policy statements and executive orders concerning resource protection and federal funding.

With the emphasis that has been placed on resource protection, it is understandable that wetlands use, particularly for treated wastewater discharges, has not been pursued in a systematic manner. Potential policy conflicts exist between federal agencies, between state and federal agencies, and among various states. Existing state policies concerning wetland discharges vary between all eight EPA Region IV states and may result in regulatory inequities at the state and regional levels.

While certain policy differences between individual states are necessary considering the variability of wetland types, certain questions must be addressed at the regional or even national levels. The issue concerning wetlands for treatment or disposal has a direct bearing on many other institutional considerations such as wastewater treatment levels, effluent limitations, ownership and proprietary rights, and potential federal funding. Although existing regulations preclude consideration of wetlands for treatment, the technical literature illustrates the treatment capacity of certain wetlands. Clearly, the issue of treatment or disposal remains open to further debate and clarification. Other institutional issues such as wetland definitions and the need for evaluative criteria also highlight the need for state initiatives under the direction of regional policies.

Institutional considerations are discussed further in the following subsections as well as in Section 9.2, Summary of Critical Institutional Considerations.

5.0 Continued

Issues of Interest

- Which federal agencies are involved in wetlands protection and regulation?
- How do federal policies and regulations affect the use of wetlands for wastewater effluent disposal?
- What are the state policies and regulations concerning wetland discharges and how do they differ among the eight EPA Region IV states?
- How are wasteload allocations currently set for wetland discharges?
- What are the arguments concerning the use of wetlands for wastewater treatment vs. wastewater disposal?
- What are the current implementation problems facing potential wetland dischargers?

5.0 INSTITUTIONAL CONSIDERATIONS

5.1 Federal Policies and Regulations

EPA, COE AND FWS ARE THE PRIMARY FEDERAL AGENCIES WITH WETLANDS REGULATORY JURISDICTION

The U.S. Environmental Protection Agency (EPA) has promulgated regulations pertaining to wetlands pursuant to Section 402 and 404 of the Federal Water Pollution Control Act. The U.S. Army Corps of Engineers (COE) has jurisdiction over dredge and fill activities in wetlands (Section 404 Permit Program). The U.S. Fish and Wildlife Service (FWS) has only advisory functions relating to the Fish and Wildlife Coordination Act.

Federal involvement in the protection and regulation of wetlands stems from the definition of "waters of the United States" (40 CFR 122.3) and the Federal Water Pollution Control Act (PL 92-500, as amended). Section 402 of the Act established the National Pollutant Discharge Elimination System (NPDES) to provide a permitting system for all point source pollution discharges into waters of the U.S. Section 404 of the Act established a permit program, administered jointly by EPA, COE and approved states, to regulate the discharge of dredge or fill material into waters of the U.S. The FWS has review authority over all Section 402 and Section 404 Permits in accordance with the Fish and Wildlife Coordination Act.

In addition to the above mentioned federal laws and regulations, several policy statements have been issued pertaining specifically to wetlands. In 1973, EPA issued a Statement of Policy on Protection of the Nation's Wetlands, which elaborated the agency's position concerning wastewater disposal to wetlands. However, implementation of this policy through rules and regulations has not taken place. In 1977, President Jimmy Carter issued Executive Orders 11988, Floodplain Management, and 11990, Protection of Wetlands. Both executive orders limited federal activities in floodplains and wetlands and further emphasized the need for interagency cooperation concerning the protection of these sensitive areas.

The following sections detail the involvement of the EPA, COE and the FWS in the protection of wetlands, with special emphasis on the disposal of treated wastewater to wetlands.

5.0 INSTITUTIONAL CONSIDERATIONS

5.1 Federal Policies and Regulations

5.1.1 U.S. Environmental Protection Agency

EPA REGION IV HAS NOT INSTITUTED AN OFFICIAL POLICY CONCERNING THE DISPOSAL OF TREATED WASTEWATER TO WETLANDS

Discharges of treated domestic wastewater to wetlands are regulated under Section 402 of the Federal Water Pollution Control Act. In order to comply with the Act, municipal dischargers must achieve at least secondary treatment; however, certain aquaculture systems may be specially permitted. The EPA issued an official Statement of Policy on Protection of Nation's Wetlands on March 20, 1973 (38 FR 10834).

Based on the definition of "waters of the United States" (40 CFR 122.3), discharges of treated wastewater to wetlands are regulated under Section 402 of the Federal Water Pollution Control Act (PL 92-500, as amended). Section 402 of the Act established the National Pollutant Discharge Elimination System (NPDES) for permitting all point source pollutant discharges. All potential dischargers must apply for and obtain an NPDES Permit before discharging to wetlands. Further, in accordance with the Act, all municipal dischargers were to achieve secondary treatment by July 1, 1977, unless the water quality showed that stricter controls were needed. Proposed amendments to the water quality standards regulations may have a distinct bearing on water quality standards and criteria for wetlands. These proposed amendments are further discussed in Section 5.1.4.

Based on Section 318 of the Act, aquaculture systems may be specially approved and permitted under the NPDES Permit Program. The EPA Administrator is authorized to promulgate regulations establishing procedures and guidelines appropriate to the "discharge of a specific pollutant or pollutants under controlled conditions associated with an approved aquaculture project" (Section 318(a), FWPCA). Each state is also authorized to administer its own aquaculture permit program upon approval of the program by the EPA Administrator. "Aquaculture project" is defined as a "managed water area which uses discharges of pollutants into that designated area for the maintenance or production of harvestable freshwater, estuarine, or marine plants or animals" (40 CFR 122.56). Additional regulations or requirements pertaining to aquaculture projects have not been promulgated.

On March 20, 1973, EPA Issued an official Statement of Policy on Protection of Nation's Wetlands (38 FR 10834). The explicit purpose of the policy statement was to "establish EPA policy to preserve the wetland ecosystems and to protect them from destruction through wastewater or nonpoint source discharges and their treatment or control..." Minimizing alterations in the quantity or quality of the natural wetlands flow was also a stated policy of EPA. It was further stated that "it should be the policy of this Agency not to grant federal funds for the construction of municipal wastewater treatment facilities or other waste-treatment-associated opportunities which may interface with the existing wetland ecosystem..." Specific requirements or review procedures were not implemented in conjunction with this policy statement.

COE RESPONSIBILITIES RELATE PRIMARILY TO DREDGE AND FILL ACTIVITIES

COE responsibilities concerning the use of wetlands are derived primarily from Section 404 of the Federal Water Pollution Control Act. Permits must be issued by the COE before any dredge or fill activities can take place in waters of the United States, including wetlands. A nationwide general permit has been authorized for all utility line crossings, including sewers and sewage outfalls.

The U.S. Army Corps of Engineers (COE) is not directly involved in the permitting of wetlands for wastewater disposal. Jurisdiction in wetlands is derived from Section 404 of the Federal Water Pollution Control Act (PL 92-500, as amended) and the definition of waters of the United States (40 CFR 122.3). Section 404 of the Act establishes a permit program, administered by the Secretary of the Army, to regulate the discharge of dredge or fill material into waters of the United States.

In the past, the COE restricted its regulatory authority concerning the discharge of dredge or fill material to mean high water levels and below. However, in 1975 the COE was ordered by a U.S. Court to expand its jurisdiction to all waters of the United States, including the primary tributaries of navigable waters, adjacent wetlands, and lakes. Section 404 Permits are not generally required for discharges beyond the "headwaters" of a river or stream unless the interests of water quality require assertion of COE jurisdiction. "Headwaters" is defined as "the point on the stream above which the flow is normally less than five cubic feet per second" (Federal Register, 7/19/77, Part II, p. 37124).

COE review and a Section 404 Permit may be required in conjunction with the construction of sewage treatment facilities in wetlands, if dredge or fill activities are part of the general construction. However, a specific permit for pipeline or outfall construction may not be required. A nationwide permit has been authorized for all "dredge and fill material placed as backfill or bedding for utility line crossings provided there is no change in preconstruction bottom contours... A "utility line" is defined as any pipe or pipeline for the transportation of any gaseous, liquid, liquifiable or slurry substance for any purpose ..." (33 CFR 323.4). Additional information concerning the COE Section 404 Permit program is contained in 33 CFR 323-Permits for Discharges of Dredged or Fill Material into Waters of the United States. Additional regulations pertaining to the discharge of dredge or fill material have been promulgated by the EPA (40 CFR 230).

The COE does not have an official policy concerning the use of wetlands for wastewater disposal.

5.0 INSTITUTIONAL CONSIDERATIONS
5.1 Federal Policies and Regulations
5.1.3 U.S. Fish and Wildlife Service

FWS RESPONSIBILITIES ARE PURELY ADVISORY

FWS responsibilities concerning the use of wetlands are primarily derived from the Fish and Wildlife Coordination Act. Although the FWS is authorized to review all NPDES Permits and wastewater facilities funding by EPA, most review activities in relation to wetlands are focused on the Section 404 Dredge or Fill Permits issued by the COE.

The Fish and Wildlife Coordination Act (PL 85-624 as amended by PL 89-72) is the major impetus behind the involvement of the U.S. Fish and Wildlife Service (FWS) in wastewater management planning. According to this law, any federal agency involved with a project to impound, divert, control or modify the waters of any stream or other body of water must consult with the FWS. This provision applies to the issuance of NPDES Permits and Section 404 Dredge or Fill Permits. Recommendations of the FWS should be made an integral part of any report prepared or submitted by any federal agency responsible for engineering surveys and construction of water resources projects. In this review capacity, the comments and findings of the FWS are only advisory and have no legal bearing on the approval or denial of any federal permit or authorization.

In addition to the above review responsibilities, the FWS is authorized under the Act to make appropriate investigations as deemed necessary to determine the effects of domestic sewage on wildlife and to make reports to Congress concerning the results of these investigations. These investigations should include a determination of appropriate water quality standards, the study of pollution abatement and prevention, and the collection and distribution of appropriate data.

Although the FWS is authorized to review all NPDES Permits issued by EPA, most review responsibilities of the FWS are focused on the Section 404 Dredge or Fill Permits issued by the COE (Brown 1982). Dredge or fill activities are generally considered by the FWS to be more damaging to wetlands; however, the agency has expressed concern about wetland discharges. These concerns are centered on alterations to wildlife habitat such as degradation of water quality, accelerated eutrophication and vegetational changes. The FWS does not have an official policy on the use of wetlands for wastewater disposal but does have an official policy concerning the mitigation of the loss of fish, wildlife and their habitat from land and water developments. Based on this Mitigation Policy, the FWS response to a proposed wetland discharge would depend upon the fish and wildlife resource values involved, potential impacts to those resources, mitigation opportunities, and the availability of feasible, less damaging alternatives (Huber 1982).

PROPOSED AMENDMENTS MAY AFFECT WATER QUALITY CRITERIA FOR WETLANDS

Fundamental changes have been proposed to the water quality standards regulations established under the Clean Water Act. These changes will increase the states' flexibility to review and revise water quality standards on priority water bodies or segments rather than reviewing all standards statewide every three years. States will also be allowed to establish site-specific criteria and remove or modify designated use classifications based on analyses of the attainability of the uses and on benefit-cost assessments.

Water quality standards are the foundation of the nation's water quality management program and are used to define the water quality goals of a particular water body. Specific uses are designated for a water body and criteria are established to protect or achieve those uses. Criteria are numerical or narrative descriptions of water quality parameters or pollutants that must be maintained if the designated uses are to be met. It has been argued that some existing water quality standards are unrealistic stemming from the designation of overly-ambitious uses and the inflexibility of recommended water quality criteria. Amendments to the regulations have been proposed based on the premise of use attainability and the experience gained from administering the program over the past several years. Proposed changes to the water quality standards regulations concern the following:

- Focusing on priority water bodies rather than reviewing all standards every three years.
- Determining the attainability of uses by characterizing present uses, analyzing environmental and physical factors impacting the attainment of a use, and assessing the benefits and costs of attaining a use.
- Promoting changes to (adding, removing or modifying) designated uses, where reasonable.
- Developing site-specific criteria.
- Clarifying the antidegradation policy.

Provisions concerning use attainability, site-specific criteria, and varying levels of aquatic protection may have the greatest bearing on water quality standards for wetlands.

Use Attainability

In the past, water quality standards were often set to provide for the protection and propagation of fish, shellfish and wildlife, and recreation, often without adequate analysis as to whether these uses were attainable. Agricultural and industrial uses and navigation, which may have been more appropriate uses, were usually rejected as not meeting the requirements of the Clean Water Act. As a result, standards reflecting unreasonable stream uses were sometimes adopted which either forced overly stringent and costly treatment controls or were simply ignored in the implementation of water pollution control programs (EPA Proposed Rule, 40 CFR Part 131).

The proposed amendments to the water quality standards regulations will allow states to change use designations when legitimate factors effectively prevent a use from being met. Use attainability analyses and benefit-cost assessments will be used to determine the reasonableness of existing use designations and justify proposed changes in the designations.

In the case of wetlands, discussions with state officials have indicated that most wetlands are classified for fish and wildlife use. However, in some instances, wetlands associated with other water bodies may carry the use designation of the other water body, along with the corresponding water quality criteria. This situation may have resulted in the application of inappropriate or unreasonable water quality criteria to the wetland. The proposed amendments provide a mechanism for modifying use designations and corresponding criteria where the current designations are found to be unreasonable.

Site-Specific Criteria

Under Section 304(a)(1) of the Clean Water Act, EPA has developed guidelines for surface water criteria. In the past, EPA operated under the policy of presumptive applicability, requiring states to adopt a criterion for a particular water quality parameter at least as stringent as the 304(a)(1) criteria recommendation unless the state was able to justify a less stringent criterion. No guidance was provided to assist states in modifying criteria based on site-specific local conditions and few modifications were in fact accepted. Since the Section 304(a)(1) criteria are not rules and have no direct regulatory impact, EPA rescinded the policy of presumptive applicability on November 28, 1980 (45 FR 79320). (EPA Proposed Rule, 40 CFR Part 131).

The proposed amendments to the water quality standards regulations will encourage states to develop site-specific criteria reflecting local conditions such as high natural background levels of certain pollutants and differences in temperature, hardness, and other parameters. In certain instances designated uses may be met even though specific criteria are exceeded, and the proposed regulations will allow these criteria to be modified following EPA review and approval.

Site-specific criteria are most applicable to wetlands, where background conditions usually differ significantly from other water bodies. Again, the application of site-specific criteria will provide for greater flexibility in regulating wetland water quality and may provide for greater use of wetlands for wastewater management.

5.1.4 Continued

Levels of Aquatic Protection

Level of protection refers to the impact on propagation, growth, survival and diversity of species relative to various water quality criteria levels in a water body. Levels of aquatic protection are also dependant on the type of fisheries present and the existing habitat values. While the existing regulations do not provide explicit references to define levels of protection within the aquatic protection use category, the proposed amendments will provide states the opportunity to define sub-categories of aquatic protection uses (for example, warm water and wild water fisheries, fish survival, fish passage, put-and-take fisheries, etc.)

The flexibility to assign varying criteria based on subcategories of aquatic protection will increase the states flexibility in regulating wetlands. Levels of aquatic protection for wetlands designated for fish and wildlife use may vary according to the specific type of wetland and the naturally occurring fish and wildlife community. This increased regulatory flexibility may provide greater opportunities for wetlands use.

WETLAND DISCHARGE POLICIES AND REGULATIONS VARY BY STATE THROUGHOUT REGION IV

Only Florida and South Carolina have explicit wetland discharge policies; however, all states recognize the inherent variability of natural water quality and provide for exceptions to certain water quality criteria. Most states use technological guidelines and qualitative analyses when determining effluent limitations for discharges into aquatic systems that cannot be modelled.

Definition

The definition of wetlands has an important bearing on how wetlands are delineated and regulated at the state level. All eight states in EPA Region IV recognize wetlands as waters of the state for the purpose of controlling water quality and permitting wastewater discharges. However, variations in the extent to which "waters of the state" is defined could have an important impact on jurisdictional limits.

Florida is the only state which precisely defines the landward extent of the waters of the state through the use of detailed species lists. All other states maintain a broad definition subject to further clarification and debate. Most states also deliberately limit the state's jurisdiction over certain waters. With the exceptions of Kentucky, North Carolina and South Carolina, Region IV states exempt from state regulations those waters wholly confined and retained on the property of an individual owner or corporation. No state limits the definition of "waters of the state" based on size or use.

Additional definition and delineation of wetlands is often done by the individual states for the purpose of issuing Sections 404 Dredge or Fill Permits or administering state fish and wildlife programs. Only North Carolina and South Carolina define "swamp waters" for the purpose of establishing water quality criteria and permitting wastewater discharges.

Wetland Policies

State policies concerning wastewater disposal to wetlands vary and can be either explicit or implicit. Only Florida and South Carolina have explicit state policies concerning the conditions under which wetland discharges can be permitted. All other states in EPA Region IV vary in the degree to which they recognize wetlands as distinct systems and accommodate alternative water quality criteria.

All state water quality regulations and criteria recognize the inherent variations in natural water quality; however, Alabama and Georgia are the only states which do not explicitly provide for exceptions to the water quality criteria when the natural conditions are below the adopted standards. Exceptions to water quality criteria have, however, been granted in both Alabama and Georgia. North Carolina and South Carolina are the only states which have defined "swamp waters" in terms of water quality. Most often, dissolved oxygen and pH are the parameters which are recognized as needing variable criteria. No state explicitly permits discharges as a component of the treatment process; wetlands discharge is only viewed as a disposal method for treated effluent. Only Florida explicitly recognizes the potential treatment capabilities of wetland systems.

Wasteload Allocations/Effluent Limitations

Each state has its own method of determining wasteload allocations and effluent limitations for wetland discharges. Kentucky, North Carolina and Tennessee are the only states that modify their standard stream models in order to set permit limitations for discharges to wetlands; additional states use water quality modeling for a wetland system as long as a distinct channel can be defined. Most states simply use secondary treatment as a basis and perform site-specific baseline studies to determine additional treatment requirements and water quality criteria. EPA technical guidelines are often used as the basis for treatment requirements when the aquatic system cannot be modeled.

Monitoring Requirements

All state water quality regulations allow the establishment of monitoring requirements on a site-specific basis. Most typical effluent monitoring requirements include flow, BOD, dissolved oxygen, pH and total suspended solids. Again, only Florida has explicit monitoring requirements outlined for wetland discharges. In Florida, control system monitoring is required for experimental wetlands.

5.2.1 Alabama

ALABAMA REQUIREMENTS FOR WETLAND DISCHARGES DO NOT DIFFER FROM OTHER WASTEWATER DISCHARGES

The Alabama Water Improvement Commission (AWIC) does not distinguish wetlands from other waters of the state for the purpose of permitting wastewater discharges. Permit limits are based on technology guidelines and water use and flow characteristics for the receiving waters. Alabama was authorized to administer its NPDES permit program in 1979.

Definition

Wetlands in Alabama are considered waters of the state, which are broadly defined as "all waters of any river, stream, watercourse, pond, lake, coastal, ground or surface water, wholly or partially within the state" (CA 22-22-1). Exceptions are made for waters totally confined or retained completely upon the property of a single individual. The AWIC further defines and delineates wetlands using the Corps of Engineers definition (see Section 2.2.2). Other state agencies, specifically the Department of Conservation and Natural Resources and the Coastal Area Board, may have different definitions of wetlands which are better suited to their regulatory responsibilities.

Wetlands Policy

The State of Alabama does not distinguish wetlands from other waters of the state for the purpose of permitting wastewater disposal. Alabama regulations recognize that natural waters may have characteristics outside of the limits established by state water quality criteria; however, provisions are not available to provide exceptions to specific water quality criteria. At a minimum, secondary treatment is required for all wastewater discharges.

Wasteload Allocations/Effluent Limitations

Specific procedures and guidelines have not been developed for establishing wasteload allocations and effluent limitations for wetland discharges. Generally, permit limits for industrial discharges are developed from EPA Best Available Technology/Best Conventional Pollutant Control Technology (BAT/BCT)guidelines. In the absence of EPA guidelines, best engineering judgement is used. Secondary treatment provides the initial basis for municipal discharge permit limits. In all cases, an analysis of water use and flow characteristics for the receiving water shall be used for determining the degree of treatment required.

Monitoring Requirements

Specific monitoring requirements have not been established for wetland discharges. The AWIC is responsible for determining the monitoring requirements for each discharge, and the monitoring requirements may vary according to the specific conditions and needs associated with each discharge. Most discharges, at a minimum, monitor flow, BOD, total suspended solids, ammonia-nitrogen and dissolved oxygen. Additional requirements may be imposed on industrial discharges depending on the constituents of the effluent.

WETLANDS DISCHARGES ARE PERMITTED WITH MODIFIED CRITERIA

Specific sections of the Florida Water Quality Standards and the Permit Requirements provide for site-specific water quality criteria and exemptions for experimental use of wetlands. Additional requirements concerning hydraulic loading and nitrogen and phosphorus removal may also be applied to wetland discharges. Criteria are established based on baseline studies without water quality modelling. Florida has not been granted full authority to administer the NPDES permit program.

The State of Florida has recognized the specific nature and potential importance of wastewater disposal to wetlands. As a result, specific exemptions and modifications can be made to the state water quality criteria in order to permit wetland discharges, taking into consideration the site-specific water quality and the nature of wetland systems.

Definition

Under state law, most wetlands are considered waters of the state and, therefore, are under the jurisdiction of the Florida Department of Environmental Regulation (FDER). Chapter 17-4 FAC Section 17-4.02 (17) defines "landward extent of waters of the state" as that portion of a surface water body indicated by the presence of one or a combination of the following as the dominant species: (species list divided between submerged marine species and submerged freshwater species) or that portion of a surface water body up to the waterward first fifty (50) feet or the waterward quarter (1/4) of the entire area, whichever is greater, where one or a combination of the following are the dominant species: (species list divided between traditional freshwater species). Wetlands isolated from other bodies of waters may not be considered waters of the state. This area of jurisdiction is not explicit, and jurisdiction of certain wetlands must be determined on a case-by-case basis.

Waters of the state, as defined under the Florida Air and Water Pollution Control Acts (Florida Statutes, Chapter 403) includes, but is not limited to "rivers, lakes, streams, springs, impoundments, and all other bodies of water including fresh, brackish, saline, tidal, surface or underground. Waters owned entirely by one person other than the state are included only in regard to possible discharge on other property or water." (FS 403:031).

Wetlands Policy

Wetlands contiguous to another body of water would be considered a part of that water body and would possess the same water quality standards. However, it is recognized that certain portions of waters of the state (particularly wetlands) do not meet specific water quality criteria due to man-induced or natural causes. Most frequent wetlands "violations" occur for pH and dissolved oxygen. Under Section 17-3.031 FAC (Site-Specific Alternative Criteria) alternative water quality criteria may be applied based on designated water use, extent of biota adaptions to the background conditions, evidence of ecological stress and adverse impacts to adjoining waters. Site-specific alternative criteria offer permanent relief under a given set of background conditions.

Exemptions to specific water quality criteria are also granted for the experimental use of wetlands for low-energy wastewater recycling. Under Section 17-4.243(4) FAC (Exemptions from Water Quality Criteria), exemptions from certain criteria may be granted upon petition indicating that the appropriate criteria will not adversely affect public health or adversely impact the biological community in the receiving waters or the contiguous water body. With this exemption, appropriate criteria are not necessarily the background levels. In addition, an exemption has to be renewed every five years based on long-term monitoring data, whereas alternative criteria (Section 7-3.031 FAC) provide permanent permit conditions. These exemptions are provided to encourage experiments designed to lead to the development of new information concerning wastewater disposal to wetlands.

Additional requirements concerning loading rates and treatment levels are usually applied to wetland discharges (Thabaraj 1982). Hydraulic loading rates are usually resticted to 0.5 to 1.0 inch per week. Minimum treatment required would be secondary treatment (Chapter 17-6 FAC) followed by disinfection and storage in a holding pond (with a detention time of three days at design flow) to achieve dechlorination. Nitrification before discharge would be necessary to optimize nitrogen removal in wetlands where the ambient pH level is not conducive for nitrification. Pretreatment to remove phosphorus would also be necessary for flow-through wetlands unless site-specific information is available to indicate long-term storage by the wetland sediments. These above requirements can be modified based on consideration of the type and ambient water quality of the downstream water body. In addition, some form of legal control of the wetland would be necessary in order to restrict public access to the site.

Wasteload Allocations/Effluent Limitations

The assimilative capacity of wetlands for nutrients, organics and metals are site-specific and primarily dependent on hydological regimes. Standard water quality models are not generally applicable to wetlands, and as a result, FDER has not used predictive modeling to assess the potential impacts of wastewater discharges on wetlands. In instances where ambient conditions warrant site-specific criteria or exemptions, baseline water quality studies are used to determine the appropriate criteria. It is the responsibility of the discharger to design, construct and operate the permitted treatment and disposal system to maintain the revised criteria in the wetlands (Thabaraj 1982). At this time, Florida has not been granted authority to administer the NPDES permit program.

Monitoring Requirements

When exemptions to water quality criteria are granted to provide for wetland discharges, state regulations require the implementation of various experimental controls to monitor the long-term ecological effects and waste recycling efficiency. Monitoring of the significant chemical and biological parameters, including control systems, is required to insure that the applicable water quality criteria are met. Monitoring requirements vary from site to site and may include the usual parameters (pH, dissolved oxygen, suspended solids, etc.) in addition to more specific parameters such as chlorides/sulfates, fecal streptococcus, benthic macroinvertebrates, and possibly annual aerial infrared photography and vegetation species distribution surveys.

GEORGIA REQUIREMENTS FOR WETLANDS DISCHARGES DO NOT DIFFER FROM OTHER WASTEWATER DISCHARGES

The Georgia Environmental Protection Division (EPD) does not distinguish wetlands from other waters of the state for the purpose of permitting wastewater disposal. However, permit limitations for wetland discharges are set based on qualitative analyses rather than predictive modeling. Georgia was authorized to administer its NPDES permit program in 1974.

Definition

Section 17-503 of the Georgia Code defines waters of the state as "all rivers, streams, creeks, branches, lakes, reservoirs, ponds, drainage systems, springs, wells, and all other bodies of surface or subsurface water, natural or artificial, lying within or forming a part of the boundaries of the state which are not entirely confined and retained completely upon the property of a single individual, partnership, or corporation." Georgia EPD does not distinguish wetlands from other waters of the state for the purpose of permitting wastewater discharges.

Wetlands Policy

The Georgia EPD does not have an official policy concerning the discharge of treated wastewater to wetlands. Georgia water quality regulations recognize that certain natural waters of the state may have a quality that will not be within the criteria of the regulations. In addition, a provision in the regulations allows for the incorporation of "alternative effluent limitations or standards where warranted by 'fundamentally different factors.'" (Section 391-3-6.06 Waste Treatment and Permit Requirements). It should be noted, however, that alternative effluent standards do not constitute exceptions to the water quality criteria.

Wasteload Allocations/Effluent Limitations

Water quality criteria and permit limitations for wetland discharges are usually established on a case-by-case basis depending on the treatment facility, the size and nature of the wetland and the water quality conditions. Permit requirements are based on federal effluent guidelines, secondary treatment, or some degree of treatment more stringent where it is necessary to achieve and/or maintain the water quality standards. The Georgia EPD does not use predictive modeling to establish effluent limitations for wetland discharges but instead relies on site analyses and qualitative judgements (Welsh 1982). Certain wetland systems such as swamp creeks might be modeled if a defineable channel exists. In this situation, however, the discharge would not be considered a wetlands discharge under current policies.

5.2.3 Continued

Monitoring Requirements

Monitoring requirements for wetland discharges do not generally differ from other wastewater discharges. However, monitoring requirements are not specifically outlined in the Georgia regulations; provisions are established to allow the Georgia EPD to require additional monitoring, recording and reporting as may be determined appropriate. Generally, Georgia dischargers are required to monitor BOD, total suspended solids and flow.

NO WETLAND DISCHARGES ARE CURRENTLY PERMITTED IN KENTUCKY

The Kentucky Division of Water (DOW) administers the water quality programs in Kentucky. Wetlands are not distinguished from other waters of the Commonwealth, and wetland discharges have not yet been permitted. However, provisions are available for case-by-case analysis of wetland discharges. Kentucky has not yet been granted the authority to administer the NPDES permit program.

Definition

The Kentucky DOW does not differentiate wetlands from other waters of the Commonwealth. "Waters of the Commonwealth" are broadly defined in the Kentucky Environmental Protection Law (KRS, Chapter 224) as "any and all rivers, streams, creeks, lakes, ponds, impounding reservoirs, springs, wells, marshes and other bodies of surface or underground water..." Wetlands are further identified and classified by the Kentucky Department of Fish and Wildlife using the FWS classification system (Cowardin et al. 1979).

Wetlands Policy

Since wetlands are not distinguished from other waters of the Commonwealth, a specific policy concerning wastewater discharges to wetlands has not been developed by the Kentucky DOW. However, wastewater discharges, either industrial or domestic, are not expressly prohibited to any waters of the Commonwealth, with the possible exception of certain outstanding resource waters. Application for discharge to a wetland would be reviewed on a case-by-case basis with input from the Kentucky Department of Fish and Wildlife and the Kentucky Nature Preserves Commission.

Kentucky regulations provide for variances to certain classification criteria when demonstrated that the applicable criteria are not attainable due to naturally occuring poor water quality. Determinations of appropriate criteria are made on a case-by-case basis and are subject to review at least every three years (401 KAR 5:029, Section 9).

To date, Kentucky has not permitted any discharges of treated wastewater to wetlands.

Wasteload Allocations/Effluent Limitations

Since no wetlands discharges have been permitted in Kentucky, a procedure for assigning effluent limitations has not been tested. However, the Kentucky DOW has indicated that stream segments that are characterized as marshes are assumed to respond as natural channels under critical flow conditions. Under this assumption, wetlands would be modeled similarly to any other free flowing stream segments using DOW's broad based general dissolved oxygen model (domestic discharges). Industrial discharge limitations would be developed on a case-by-case basis.

5.2.4. Continued

Monitoring Requirements

General provisions are included in the Kentucky Waste Discharge Regulations (40 1 KAR 51005, Section 9) to provide for effluent monitoring and reporting. The type and frequency of analysis may be specified on the permit, allowing for special considerations for wetlands should the need arise.

BAYOU AND OXBOW LAKE DISCHARGES ARE EVALUATED QUALITATIVELY

Most apparent wetland discharges in Mississippi are to bayou and oxbow lake systems. Discharges to these systems are evaluated qualitatively on a case-by-case basis. Provisions are available for establishing specific water quality criteria and monitoring requirements. The State of Mississippi was granted authority to administer its NPDES permit program in 1974.

Definition

Wetlands in Mississippi are considered waters of the state, which are defined as "all waters within the jurisdiction of this State, including all streams, lakes, ponds, impounding reservoirs, marshes... and all other bodies or accumulation of water surface and underground... except lakes, ponds, or other surface waters which are wholly landlocked and privately owned." (MPC 3-74). The Mississippi Bureau of Pollution Control (MBPC) further defines and delineates wetlands using the Corps of Engineers definition (see Section 2.1).

Wetlands Policy

The State of Mississippi does not distinguish wetlands from other waters of the state for the purpose of permitting wastewater discharges. When determining appropriate water quality criteria, the MBPC considers whether the wetland is isolated or contiguous to other state waters. At a minimum, the state applies Fish and Wildlife Service criteria, establishing minimum levels for various water quality parameters. However, it is recognized that certain waters of the state may not fall within desired or prescribed limitations due to natural background conditions or irretrievable man-induced conditions. Under these circumstances, exceptions can be made to the standard water quality criteria.

Wasteload Allocations/Effluent Limitations

Wasteload allocations and effluent limitations for wetland discharges in Mississippi are established in the same manner as for other discharges. When a discernable channel and flow exist, a standard stream model is applied. However, many apparent wetland discharges in Mississippi are to bayou and oxbow lake systems, for which standard steady-state river models are inappropriate.

For those systems determined unmodelable, qualitative evaluations are made to estimate the effect of the proposed discharge. Water quality studies are used to determine any existing water quality problems. Eutrophication studies may be used to determine whether a proposed discharge will cause significant increase in nutrient loadings. The relative size of the water body to the discharge may also be considered.

5.2.5 Continued

Mississippi was granted authority to administer its NPDES Permit program in 1974.

Monitoring Requirements

Monitoring requirements for all permitted discharges are variable and can be set by the State NPDES Permit Board. Requirements may include the installation, use, and maintenance of monitoring equipment or methods, including biological monitoring methods. Recording and reporting requirements are also outlined in the state NPDES regulations. Generally, wetland dischargers in Mississippi are not required to perform any additional or specific monitoring.

NORTH CAROLINA REGULATIONS RECOGNIZE DISTINCT WETLAND CHARACTERISTICS

The North Carolina Division of Environmental Management (NCDEM) has jurisdiction over wastewater discharges in North Carolina and has defined swamp waters for the purpose of applying appropriate water quality standards, primarily lower pH and dissolved oxygen levels. However, the state does not have a specific policy concerning wetland discharges; generally, stringent treatment levels are applied in order to protect all standards in the receiving water. North Carolina was granted authority to administer its NPDES permit program in 1975.

Definition

Wetlands are recognized by NCDEM as specific water bodies and are classified as swamp waters. Swamp waters are defined as "...those waters which are so designated by the Environmental Management Commission and which are topographically located so as to generally have very low velocities and certain other characteristics which are different from adjacent streams draining steeper topography" (NCAC 15-2B.0202). Swamp waters are categorized as distinct water bodies for the purpose of applying appropriate water quality standards; however, all true wetlands may not be categorized as swamp waters. In some cases they may be classified as part of a contiguous water body.

Wetlands Policy

The NCDEM does not have a specific policy to encourage or prohibit wastewater discharges to wetlands. However, wetlands disposal is viewed as a viable alternative and has been widely used throughout the coastal plain river basins. State regulations recognize that natural waters may "have characteristics outside of the limits established by the standards. Where wastes are discharged to such waters, the discharger shall not be considered a contributor to substandard conditions provided maximum treatment in compliance with permit requirements is maintained..." (NCAC 15-2B.0205). Since it may be impossible or impractical to bring the quality of the receiving waters into complaince with the applicable water quality standards, variances from the standards may be authorized.

Water quality standards are applied according to designated best-use categories. Swamp waters are recognized in every surface water classification except Class A-1 Waters (potable water supply). In every other surface water classification, exceptions are made for swamp waters in terms of pH and dissolved oxygen; swamp waters may have a low pH of 4.3 and may have dissolved oxygen levels below 4.0 mg/l. All other appropriate water quality standards are applied according to the designated classification. Discharges to wetlands are not permitted as a buffering or treatment devices.

5.2.6 Continued

Additional provisions in the state regulations pertain specifically to the dissolved oxygen standards and nutrient sensitive waters. Specific revisions to the dissolved oxygen standards may be granted for certain stream segments for Class C waters where natural background conditions preclude the attainment of a daily average dissolved oxygen concentration of 5.0 mg/l. Treatment levels for discharge to these waters must be at least as stringent as present waste treatment technology (NCAC 15-2B.0213). In addition, certain waters may be classified as nutrient sensitive waters for the purpose of controlling the growth of microscopic or macroscopic vegetation. For waters classified as nutrient sensitive, no increase in phosphorus and/or nitrogen over background levels will be allowed unless it is shown that the increase is the result of natural variations, or will not endanger human health or cause an economic hardship (NCAC 15-2B.0214). These provisions could have a precise impact on the feasibility of using wetlands for wastewater disposal; the dissolved oxygen revision could be used to permit wetland discharges, whereas the nutrient sensitive designation could be used as a protective device.

Wasteload Allocation/Effluent Limitations

No specific provisions are made for determining wasteload allocations and effluent limitations for wetland discharges. As with all other receiving waters in North Carolina, predictive modeling is used to establish permit limits. The standard Streeter-Phelps model is modified for wetland-type systems. Variances may be granted for certain water quality parameters when the natural background conditions warrant it. North Carolina was granted authority to administer its NPDES permit program in 1975.

Monitoring Requirements

No specific monitoring requirements have been instituted for wetland discharges. Monitoring requirements are established by regulation according to the size of the treatment facility and the receiving water classification. Additional tests and measurements may be required for certain industries, based on the Standard Industrial Classifications.

WETLANDS DISPOSAL POLICY PERMITS DISCHARGES AS LAST OPTION

The South Carolina Department of Health and Environmental Control (SCDHEC) has jurtisdiction over all waters of the state, including wetlands, for the purpose of permitting wastewater discharges. A specific policy has been adopted for the purpose of determining wasteload allocations for wetland discharges. State regulations also recognize the distinct differences of swamp waters. South Carolina was authorized to administer its NPDES program in 1975.

Definition

Wetlands are considered waters of the state as defined under the South Carolina Pollution Control Act (SCC Section 48-1-10 (2)) and, therefore, are under the jurisdiction of the South Carolina Department of Health and Environmental Control (SCDHEC) for the purpose of permitting wastewater discharges. Swamp waters have been specifically defined for the purpose of assigning wasteload allocations and permitting wetland discharges. As outlined in the Summary of Methodology and Policies for Determining Stream Assimilative Capacity and Developing Wasteload Allocations for Point Source Discharges (SCDHEC, March 1981), swamp waters are defined as:

> ...those waters which have been exposed for a substantial period of time to conditions which cause these waters to have all of the following characteristics:
>
> - Chemical and biological characteristics found in waters which have been exposed for a substantial time to decaying organic matter. For example, low velocity, low dissolved oxygen, low pH, and a dark color.
>
> - Inundated land areas covered by trees and other vegetation. This inundation occurs much of the year.

Wetlands Policy

Wetlands discharges are distinguished from other wastewater discharges in South Carolina, and the SCDHEC has developed a policy specifically concerning the determination of wasteload allocations for wetland discharges. Wetland discharges are currently authorized only as a last resort when there are no other reasonable alternatives. In addition, SCDHEC advises that the wetlands should be owned by the discharger or that an easement should be acquired.

The State Water Classification Standards System recognizes that some natural waters may have characteristics outside the established limits. Specific exceptions may be made in Class A and Class B waters where natural conditions have lowered dissolved oxygen and pH levels. Separate numeric standards may be established for other waters which have natural conditions outside existing standards; however, specific standards for wetlands have not yet been established (Sansbury 1982).

SCDHEC recognizes that waters vary in their ability to assimilate nutrient loadings. Therefore, nutrient loadings and specific nutrient standards for waters are addressed on a case-by-case basis.

Wasteload Allocations/Effluent Limitations

The policy adopted by the SCDHEC for developing wasteload allocations recognizes the difficulties in defining average water quality conditions in wetlands and in predicting the assimilative capacity of these waters. When specific water quality data are not available to identify the impact of a wastewater discharge to swamp waters, publicly-owned treatment facilities will provide secondary treatment or comply with current EPA policy on treatment greater than secondary. Privately-owned treatment facilities will provide best available treatment (BAT) as defined by SCDHEC.

In some instances, a site investigation of a proposed wetland discharge will indicate a drainage system that can be described with an appropriate mathematical model. If so, modeling techniques will be used in setting a wasteload allocation. In addition, higher winter effluent limits for ammonia may be permitted on a case-by-case basis.

South Carolina was authorized to administer its NPDES program in 1975.

Monitoring Requirements

Under the South Carolina Pollution Control Act (SCC 48-1), the SCDHEC has the power to require wastewater dischargers to install, use, and maintain monitoring equipment or methods and to sample and analyze the effluent. Generally, specific monitoring requirements are not estabished for wetland discharges. Usually, only BOD, dissolved oxygen, temperature, total suspended solids, pH, ammonia and flow are required to be monitored.

TENNESSEE DOES NOT HAVE A SPECIFIC POLICY CONCERNING WASTEWATER DISCHARGES TO WETLANDS

The Tennessee Department of Public Health, Division of Water Quality Control permits wastewater discharges to wetlands associated with other water bodies. Predictive modeling is used to determine wasteload allocations under low flow and no flow conditions. Tennessee was granted authority to administer its NPDES permit program in 1977.

Definition

Wetlands in Tennessee are considered waters of the state and as such are under the jurisdiction of the Department of Public Health for the purposes of protecting water quality and permitting wastewater discharges. Exceptions are made for wetlands which are confined within the limits of private property in single ownership and which do not form a junction with natural waters (Tennessee Water Quality Control Act; TC 70-324).

Wetlands are further classified and delineated in Tennessee using the FWS classification system (Cowardin et al. 1979). The COE definition is used for regulatory purposes (404 permits).

Wetlands Policy

The State of Tennessee does not have a specific policy concerning wastewater discharges to wetlands; however discharges are permitted to wetlands. The Tennessee Water Quality Criteria state "the rigid application of uniform water quality criteria is not desirable or reasonable because of the varying uses of such waters." In addition, the assimilative capacity varies depending upon the volume of flow, depth of channel, rate of flow, temperature and natural characteristics (Chapter 1200-4-3.01(2)). Therefore, the established water quality criteria are considered as guides, and additional criteria may be set to meet the needs of particular situations. Although considered as guides, these water quality criteria have been determined to be legally applicable and enforceable under state law.

Water quality criteria are established for specific use categories. Most wetlands in Tennessee are designated for Fish and Aquatic Life (Bowers 1982). Under this use category, the dissolved oxygen criteria is set at 5.0 mg/l except where the natural background conditions are less than the desired minimum. These exceptions to the dissolved oxygen limit are determined on a case-by-case basis, but in no instance will the dissolved oxygen concentration be allowed to fall below 3.0 mg/l (Chapter 1200-4-3.01(3)). The pH criteria for Fish and Aquatic Life is set at 6.5 to 8.5, which may be higher than that naturally associated with wetlands.

5.2.8 Continued

Wasteload Allocations/Effluent Limitations

The Tennessee Division of Water Quality Control has not instituted specific procedures concerning wasteload allocations and effluent limitations for wetland discharges. Generally, predictive modeling using a modified Streeter Phelps model is used when a discernable channel is present; low flow conditions are modeled and overbank flooding to associated wetlands is ignored. When the flow is slow or nonexistent, or when a distinct channel is not distinguishable, a lake model is used.

The Tennessee Water Quality Control Board has adopted general and specific requirements for effluent limitations (Chapter 1200-4-5). Effluent limitations for effluent limited and water quality limited stream segments have been adopted in conformance with the Federal Water Pollution Control Act.

Monitoring Requirements

No specific monitoring requirements have been established for wetland discharges in Tennessee. Monitoring and reporting requirements can be set on a case-by-case basis, allowing for modifications on an individual basis.

THE TREATMENT/DISPOSAL ISSUE IS IMPORTANT TO IMPLEMENTATION OF WETLAND DISCHARGES

The consideration of wetlands discharges as either treatment or disposal has specific implications on regulating discharges. Currently, wetlands are considered part of the waters of the United States and as such cannot be used in lieu of secondary treatment.

As currently defined, wetlands are considered waters of the United States (40 CFR 122.3). Therefore, whether a wastewater discharge is considered as disposal or as part of the treatment process has several specific implications. As waters of the United States two criteria must be met: 1) A minimum of secondary treatment is required for discharges, and 2) established uses of these waters must be maintained through the water quality standards and NPDES permitting programs.

Some have suggested that wetlands, due to their inherent ability to renovate wastewater, serve as part of the treatment process and should be considered as such. This would allow permitting difficulties associated with wetlands dischargers (effluent limitations) to be bypassed. However, as waters of the United States, wetlands cannot be incorporated as part of the treatment process. Therefore, under their current status, wetlands must be assessed for their capacity to dispose of wastewater effluent as any other receiving water.

Wetlands research projects conducted to assess the use of wetlands for wastewater discharges have evaluated wetlands to determine the degree of treatment received and have considered wetlands to be a part of the treatment process. In the case of the University of Florida project that discharged to cypress domes, the wastewater had received secondary treatment prior to discharge. The cypress domes were being studied for their capability to provide additional wastewater renovation. In certain other cases in Region IV where municipalities were discharging raw or primary effluent, wetlands discharges were considered to be both a means for treatment and disposal. In this context, it is clear that wetlands systems provided a degree of treatment and, therefore, were part of the treatment process. For small communities, wetlands discharges may provide benefits in conjunction with conventional treatment processes.

Conversely, some existing municipal discharges to wetlands were likely begun as the least expensive method of disposal by discharging only nominally treated wastewater to a wetland. This is true for discharges begun several years ago when wetlands were not considered to be valuable ecosystems. Problems associated with considering a wetlands discharge as only a disposal mechanism relate to determining meaningful effluent limitations and disregarding potential benefits resulting from natural assimilative processes in wetlands. Effluent limitations are typically based on modelling, but with characteristics such as intermittent flows, undefineable channels and seasonal hydroperiods, the capability to assign meaningful effluent limitations is constrained.

5.3 Continued

With the recently proposed revisions to the water quality standards regulations, greater flexibility in addressing the treatment/disposal question is likely. Concepts of use attainability, site-specific criteria and benefit-cost analysis provide the institutional framework to better address the subtleties of discharges to wetlands. A minimum of secondary treatment, as currently required for waters of the United States has not been shown to be an unreasonable predisposal condition. This requirement may be a reasonable level of pretreatment unless a wetland is to be removed from the public domain and fully dedicated to treatment alone. Recent amendments to the Clean Water Act that defines oxidation ponds, lagoons, ditches, and trickling filters as the equivalent of secondary treatment (when water quality will not be adversely affected) add flexibility in meeting a secondary treatment predisposal requirement.

The revision or modification of uses and the establishment of site-specific criteria to meet water quality standards will be the key institutional mechanisms involved in discharges to wetlands. Use of a wetland for wastewater management must be consistent with the other established uses of a wetland. The maintenance of these other established uses will be achieved through NPDES permitting and water quality monitoring processes.

Phase II of the EIS will further explore the treatment/disposal question and will consider institutional options that are available in addressing this issue. Regardless of whether a discharge is considered treatment or disposal, wetland functions and values should be maintained and assimilative capacities should not be exceeded.

TECHNICAL AND LEGAL QUESTIONS MAY IMPEDE IMPLEMENTATION

Increased implementation of the use of wetlands for wastewater disposal requires further clarification of several legal and institutional issues. These issues concern wetlands ownership and proprietary rights, effluent limitations, wetlands definitions, and the need for evaluative criteria.

Of the eight states in EPA Region IV, only two, Florida and South Carolina, have officially recognized wetland discharges as being distinct from other surface water discharges. North Carolina has defined swamp waters for the purpose of applying appropriate water quality criteria but has not instituted a formal policy for permitting wetland discharges. The initial step towards instituting the use of wetlands for wastewater disposal (aside from a basic understanding of the natural systems) involves a recognition of wetlands as distinct systems. This recognition requires a specific definition of wetlands, leading to the development of official policies and analytical tools for establishing effluent limitations. Finally, the question of ownership and proprietary rights must be addressed to avoid legal problems.

Wetlands Policies

Wetlands definitions need to be developed before a comprehensive wetlands disposal policy is formulated. An official definition of wetlands is necessary to establish jurisdictional limits and provide a basis for applying an official wetlands discharge policy.

Only Florida has defined the "landward extent of waters of the state" using a detailed species list. North Carolina and South Carolina have defined swamp waters in a general manner in terms of water quality but do not provide for an accurate delineation of wetland areas. Other states in EPA Region IV consider wetlands as waters of the state but do not provide a specific definition nor allow for precise delineation. Several states define wetlands for the purpose of permitting Section 404 Dredge or Fill Permits (COE definition, see Section 2.2.2) or for fish and wildlife management purposes. These definitions may be adapted for the purpose of permitting wastewater discharges, provided consideration is given to appropriate water quality parameters.

Wetlands are most appropriately defined at the state level because of the variability of wetland types throughout the region. Each state needs a definition which will best address the natural systems in that state and the regulatory requirements of state agencies. However, attention must also be paid to the need for regional consistency. Definitions should be consistently applied from one state to another within the framework of the Federal Water Pollution Control Act and EPA regulations and guidelines.

5.4 Continued

Wasteload Allocations/Effluent Limitations

Currently in EPA Region IV eight different methods exist for determining wasteload allocations and effluent limitations for wetland discharges. From the state perspective, difficulties may be encountered when applying models which may not be precisely appropriate or using qualitative analyses which limit consistency. When technological guidelines are followed, consistency in application may be achieved at the expense of individual dischargers by possibly requiring treatment levels that, in some cases, are unnecessarily stringent. The use of models and qualitative analyses may allow recognition of the variability of wetland systems but may not provide adequate protection of the natural system. On the other hand, when low-flow conditions are used as a basis for effluent limitations, valuable assimilative capacity may be ignored, again resulting in unnecessarily stringent treatment levels.

From a regional perspective, different methods of permitting wetlands discharges may limit consistency of wetlands use and protection. Treatment levels permitted in one state may not be allowed in another, creating economic inequities and inefficient resource use. At the same time, the regional variability of wetland systems must be recognized and accounted for while maintaining consistent application of a regional wetlands discharge policy. In fact, the feasibility of a regional wetlands discharge policy must be examined in view of the differences in wetland systems and the different permitting methodologies.

Evaluation Criteria

Before wetland discharges can be widely implemented, evaluation criteria are necessary to determine the effectiveness of permitted treatment levels. In terms of water quality, it is difficult to determine when a wetland system has been degraded by effluent discharges. A change in species composition (vegetation) or reduced growth or loss of vegetation may indicate stressed conditions; however, irreparable damage may occur before such overt changes are noted. Certainly, evaluation criteria will vary between wetland types. Still, these criteria are needed to balance wetlands use and protection.

Ownership/Proprietary Rights

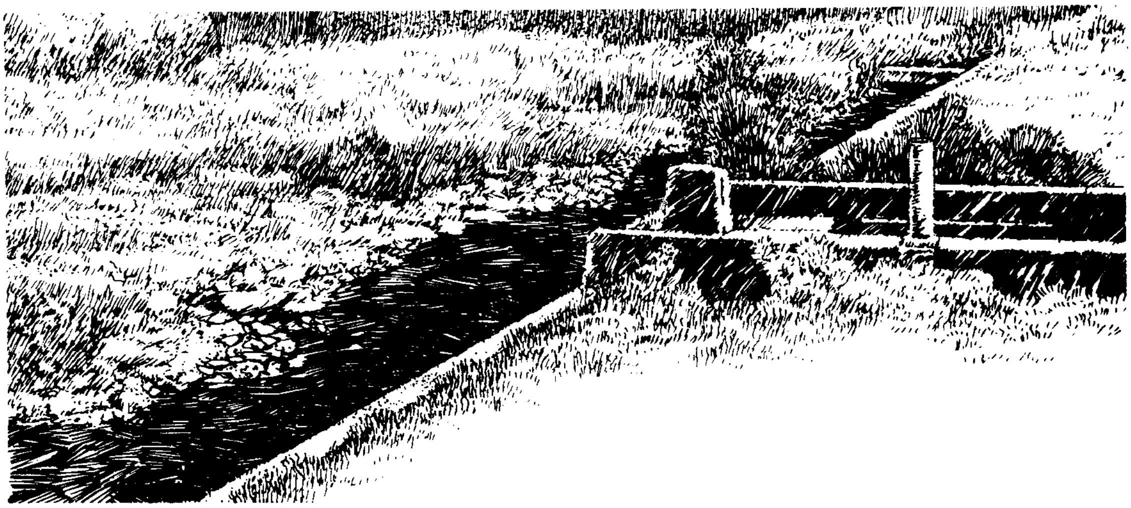
In contrast to distinct water courses, wetlands can be, and in many instances are, privately owned. The question of private ownership and proprietary rights has distinct implications on the use of wetlands for wastewater disposal, as illustrated by an example in South Carolina. Litigation is currently underway in South Carolina pertaining to damages to a privately owned wetland allegedly resulting from a permitted wetland discharge from the town of Andrews. A private landowner is suing the State of South Carolina for the loss of harvestable timber on his land. The plaintiff contends that the cause of his timber loss relates to the permitted discharge and that the State is responsible because it issued a permit for the discharge. As a result of this case, the State has adopted a policy to require, as a precondition to a wetlands discharge permit, ownership of the wetland to be used or an easement from the owner.

5.4 Continued

While the question of ownership and proprietary rights has not been faced in any other state, Florida is the only state that has specifically addressed this issue. Legal control of the wetland to be used (ownership, lease, easement, etc.) is required before a permit to discharge is issued in Florida.

Additional questions related to ownership include the extent of ownership to be required and additional uses of the wetland. Due to the unpredictable flow associated with wetlands, it is difficult to delineate the area that may be potentially affected by an effluent discharge. This determination must be made to establish ownership requirements and avoid legal problems similar to the town of Andrews, South Carolina. Additional uses of wetlands used for wastewater disposal may need to be limited. Florida requires posting of wetlands used for effluent disposal to restrict public access. Potential public health effects need to be determined before wetlands used for effluent disposal can also be used for recreation, including the consumption of fish and wildlife from these areas. In addition, the harvesting of timber from these wetlands may need to be restricted to insure continuation of the wetlands' assimilative functions. Limitations on the use of privately owned wetlands due to wastewater discharges may have to be compensated by the state or discharger.

The question of EPA funding the purchase of wetlands needs to be addressed in conjunction with the ownership issue. If wetlands are included as an integral component of the wastewater treatment and disposal alternative, can EPA funding be used for the purchase of the wetlands? Land costs associated with land application systems may be eligible for EPA funding; does the same principle apply to the use of wetlands? These questions have an important bearing on the future implementation of wetland discharges and need to be addressed on the regional and national levels.



SECTION 6

ENGINEERING CONSIDERATIONS

6.0 ENGINEERING CONSIDERATIONS

ENGINEERING CRITERIA STILL IN DEVELOPMENTAL STAGES

The primary goal in the design of a wetlands-wastewater system is to enhance the treatment capabilities of the wetland while protecting its environmental values and functions. Several wetlands wastewater disposal systems have been studied in recent years. Design criteria are being developed more rapidly for artificial systems than for natural systems.

The objective of this section is to assess engineering considerations associated with facilities for discharging wastewater to natural and artificial freshwater wetlands within Region IV. Engineering considerations include facilities planning, design, installation, and operation and maintenance (O&M).

Engineering considerations are important to the implementation and proper functioning of wetland disposal systems. Three major areas of importance are addressed:

- Potential engineering problems
- Planning, design, installation, and O&M criteria noted from existing wastewater disposal systems to wetlands
- Incomplete or missing criteria.

Generally, more is known about the design and performance of artificial wetlands and aquaculture systems than natural wetland systems. Artificial wetlands are those areas that become wetlands only with supplemental, engineered inputs of water. Within these areas, additional wetland habitat is created. Operation and maintenance procedures such as plant harvesting and altering water levels can be included as part of the design of a wastewater-wetland system. Volunteer wetlands is a term sometimes utilized to denote irrigated fields or lagoons that become wetlands as a result of applying wastewater to an area or some other form of hydrologic modification.

Aquaculture systems refer to artificial wetland areas operated for multiple purposes often including biomass production and perhaps energy production as well as wastewater treatment. Five types of aquaculture-wastewater systems have been tested: hyacinth, duckweed, common reed and cattail, invertebrate, and fish pond systems. Hyacinth ponds are the most extensively studied because of their high biomass production. However, the geographic ranges of duckweed, reed and cattail ponds are more expansive as they can tolerate wider temperature fluctuations (Wolverton and McDonald 1981). Aquaculture-wastewater systems utilizing invertebrates or fish are considered to be in the exploratory/developmental stage and not ready for widespread use. In addition, aquaculture systems involving animals are generally less efficient in treating wastewater, require more land area, and are more difficult to control than plant systems (Schwartz and Sin 1980).

6.0 Continued

Issues of Interest

- Can a single set of preliminary design considerations for costs, system configurations, treatment potential, and system operation be usefully defined for wetlands-wastewater systems?
- Are costs favorable compared to other wastewater treatment methods?
- How are wetland-wastewater systems installed without damaging the wetland?
- What type of monitoring activities should be conducted to assure the proper operation of the system and the condition of the wetland?
- Can too much wastewater adversely affect wetland conditions?
- How long can a wetland-wastewater system be expected to function properly?

6.0 ENGINEERING CONSIDERATIONS

6.1 Facilities Planning/Preliminary Design

VEGETATION AND HYDROLOGY IMPACT DESIGN CRITERIA

Physical and biological characteristics of wetlands influence design since hydrologic processes and vegetation type largely control renovation of wastewater. Artificial wetlands can be designed to optimize such characteristics.

Physical characteristics of natural and artificial wetlands differ, although planning considerations are quite similar. The many planning considerations for both natural and artificial wetlands have been segregated into eight categories; one category is addressed in each of the eight portions of Section 6.1.

Distinguishing physical, biological and chemical characteristics of wetland systems have been presented in earlier sections. Those characteristics relevant to engineering considerations are:

- The variety and assemblage of vegetation types
- Water patterns as existing within channels or as sheet flow over the entire wetland surface area
- Natural wetlands can be hydrologically open (connected to lake or stream) or closed (isolated such as a bog)
- Water from a wetland area may discharge to a nearby water body; percolate downward during drier periods; evaporate; or be transpired by plants.

Artificial wetlands including aquaculture systems can be purposely designed with fewer types of vegetation than natural wetlands and more predictable flow patterns. The only physical restriction is that an artificial wetland area must be relatively level and able to pond water; otherwise, the area will function as a more conventional land appliction system. Significant components of an artificial wetland are: 1) plant species utilized, 2) spacing and diversity of vegetation, 3) the extent to which wastewater is disposed by downstream discharge, percolation to water table, transpiration by plants, and evaporation, and 4) detention time. Possible types of artificial methods are presented in Table 6.1.

To design properly a wetlands-wastewater system, the proposed use of the wetland must be clarified. This should be done in conjunction with site selection since the type and size of available wetlands impact design considerations. While information regarding pre-treatment requirements and allowable loadings is increasing for some wetlands systems, information for design criteria is still limiting. Finally, cost analyses are important in determining the feasibility of a wetlands discharge. The major component of cost analyses relates to the distance to and size of available wetlands.

Table 6.1. Artificial Wetlands Used for the Treatment of Wastewater.

Type	Description
Freshwater	
Marshes	Areas with semi-pervious bottoms planted with various wetlands plants such as reeds or rushes.
Marsh-pond	Marsh wetlands followed by pond.
Ponds	Ponds with semi-pervious bottoms with embankments to contain or channel the applied water. Often, emergent wetland plants will be planted in clumps or mounds to form small sub-ecosystems.
Trench	Trenches or ditches planted with reeds or rushes. In some cases, the trenches have been filled with peat.
Trench (lined)	Trenches lined with an impervious barrier usually filled with gravel or sand and planted with reeds.
Aquaculture	One or more basins or ponds with one or more species of aquatic plants (e.g., water hyacinths, duckweed, or reeds and cattails) and/or stocked with invertebrates or fish. As wastewater is treated, biomass can also be harvested and utilized for food or energy production.

Source: Tchobanaglous and Culp. 1980, except for aquaculture description.

6.0 ENGINEERING CONSIDERATIONS

6.1 Facilities Planning/Preliminary Design

6.1.1 Proposed Use of Wetlands

WETLANDS CAN BE MANAGED FOR THE ASSIMILATION OF POINT AND NONPOINT POLLUTION SOURCES

Wetlands serve many functions for the direct benefit of society. They can be further managed to enhance these benefits although proper protection and maintenance become crucial under such conditions, particularly when considering wastewater discharges.

The most basic planning analysis is to determine how a wetland area is to be utilized. In other words, what types of flows (wastewater, runoff, flood water) are to enter the wetland area. Such a decision must be made on a site-by-site basis; subsequent engineering activities are based on this assertion.

Potential engineered uses of a wetland area include: wastewater treatment, wastewater disposal, both wastewater treatment and disposal, runoff treatment and/or disposal, creation of habitat for plants and animals, flood control, drought inhibition, biomass production for animal feed or energy, and resource recovery. A number of technical factors enter into this first planning-level decision:

- the nature of the effluent (e.g., the presence of industrial by-products)
- the level of pre-treatment prior to discharging wastewater to a wetland
- the frequency and duration of discharges (e.g., to be disposed seasonally or year-round)
- the sensitivity of downstream rivers, lakes or streams to pollutant loadings
- adjoining land uses
- the amount of runoff from areas farther upstream
- the amount of contaminants input from upstream sources
- environmental impacts resulting from diverting runoff from areas farther upstream
- the susceptibility of local wildlife to habitat alteration
- the need for additional wetland habitat or regeneration of degraded wetlands
- the susceptibility of downstream areas to flooding
- the potential significance of the wetland for drought inhibition (relative to the overall potential for a drought to occur and drought ramifications)
- the potential for biomass production which could also be utilized economically for energy production or feed.

Those wetland treatment systems specified to have multiple aquaculture components in a single unit or that combine with other aquaculture or conventional units to form a process are called combined systems. If combined systems are to be employed, another factor to consider is the relative lack of rational design criteria. It is difficult to optimize the aquaculture

6.1.1 Continued

units of combined systems for both wastewater treatment and biomass/protein production in the same unit (Reed, Bastian and Jewell 1982).

Structurally, several options are available for implementing wetlands management:

- Little or no modification to a wetland area would allow runoff and floodflows to continue to enter and exit the area.
- A wetland area can be controlled hydrologically by constructing earth dikes around the perimeter. Flow paths can be modified adjacent to the wetland area to allow extra water which previously entered the wetland area to be controlled without drainage or scouring problems.
- Wastewater flows entering a wetland area as surplus flows can: 1) percolate downward if underlying soils allow, 2) be released from the downstream portion of the wetland area, or 3) increase water depths within the wetland area. This decision regarding the ultimate method of wastewater disposal will depend primarily upon downstream water uses and wetland area characteristics.

6.0 ENGINEERING CONSIDERATIONS
6.1 Facilities Planning/Preliminary Design
6.1.2 Site Selection

SIZE, TYPE AND ACCESSABILITY OF NATURAL WETLANDS IMPACT SITE SELECTION

The site selection process proceeds from very general considerations to detailed site selection surveys. Different wetland areas can have significantly different wastewater management capabilities and different sensitivities to wastewater flows. The size, type, and accessability of available wetlands are important.

This section addresses the selection of a preferred wetland area for WWTP owners that have such flexibility and for state agencies that are considering the use of a wetlands area for wastewater management. This section also addresses wastewater management site selection for areas with limited wetlands.

Natural wetlands and potential artificial wetlands can be mapped using newly-developed film and aerial photography techniques. The State of South Carolina has developed a technique that distinguishes different types of plant communities. This technique is based on wetlands being composed of specific types of vegetation.

LANDSAT (satellite) imagery can be utilized to identify larger wetland areas. This technique is being utilized for the Savannah River area, Savannah and Augusta, Georgia. The LANDSAT technology can also be utilized to assess the capability of a wetland area to assimilate wastewater (EPA 1982).

Once a WWTP owner has decided that the use of a nearby wetland area is worth consideration, the area needs to be evaluated by the following criteria (selected criteria from EPA 1981):

- physical accessibility to the wetland area itself and to locations upstream and downstream of the area
- the time period during which a discharge to the wetland area would take place
- timing of the discharge (either continuous, periodic or seasonal), feasibility of winter operation
- source of wastewater
- wastewater loading rates in gallons (or pounds) per acre per day (Section 6.1.5).

Site selection is also dependent on a judgment of how much wastewater a wetland area can assimilate. Within Florida, for example, cypress domes are said to be limited in their ability to assimilate wastewater because 1) allowable loading rates are low and 2) each dome has a small physical size (Fritz and Helle 1978). In certain cases significant lengths of pipeline are needed to transport wastewater to cypress domes. Conversely, cypress strands are larger and therefore capable of assimilating larger quantities of wastewater (Fritz and Helle 1978). These considerations would impact costs and ultimately, the feasibility of a discharge.

6.1.2 Continued

Climate may be the most important consideration when evaluating sites for the use of an aquaculture system. Water hyacinths grow most rapidly in waters with temperatures between 28° and 30°C (82-86°F). Hyacinth growth ceases if water temperatures are below 10°C (50°F) or above 40°C (104°F). Hyacinth leaves are destroyed if air temperatures of -3°C (27°F) are experienced for 12 hours; the plants are killed entirely if air temperatures of -5°C (23°F) are experienced for 48 hours. Hyacinths are able to grow year-round only in southern Florida. Within the other areas of the Southeast where hyacinths exist, growth occurs for seven to ten months each year. Transparent covers placed over the plants can extend the growing season (O'Brien 1981). Duckweed, reeds and cattails have a wider range of temperature tolerance than water hyacinths. Duckweed is able to grow at water temperatures greater than 1° to 3°C (33 to 37°F).

Artificial wetlands (much like land treatment systems) can potentially be built nearly anywhere, given appropriate (or in some instances substantial) engineering input and capital (Bastian 1982). Site selection processes should include the ultimate level of construction necessary to achieve treatment goals.

THE ENGINEERING CONFIGURATION FOR THE USE OF WETLANDS IS IMPORTANT TO OVERALL WASTEWATER MANAGEMENT EFFECTIVENESS AND TO NEARBY LAND USE

Engineering activities can influence the mechanisms by which discharges enter and leave a wetland area, wastewater treatment and storage configurations, and flow patterns within a wetland area.

Wastewater discharges to and from a wetland area can be designed as 1) one point source, 2) a number of point sources, or 3) overflow/runoff from a storm or intentional discharge. The selection of a preferred discharge configuration will depend primarily upon costs, other uses of the wetland area, and upon activities further downstream.

Costs, installation impacts, operation impacts, energy requirements, and operation and maintenance requirements, may limit the choice of discharge configurations. In general, these limitations are less substantial for artificial systems because artificial systems are designed and constructed specifically for wastewater treatment purposes and existing wetland habitats are not impacted. Conceivable discharge system configurations include the following:

- Point discharge(s) at edge of wetland, gravity flow
- Channel discharge at edge of wetland, gravity flow
- Distribution within wetland, gravity flow
- Distribution within wetland, spray flow

Treatment plant and storage configurations must also be considered. In many cases, wetlands discharges are associated with existing treatment facilities. However, in other instances treatment and/or storage facilities may be required. In such cases, a treatment plant or storage basin could be located adjacent to the wetland area, or adjacent to any other disposal point (e.g., a stream or a conventional land application site). Factors involved in this decision, in addition to costs, are:

- locations of densely populated areas
- extent to which discharges would be released to wetlands for locations where other disposal options are available
- age and suitability of the existing wastewater treatment plant
- land availability
- impacts of developing a new site for a wastewater treatment plant.

6.1.3 Continued

Where possible, artificial wetlands and aquaculture systems should be designed with a minimum of two units (ponds, basins, etc.) in parallel, each having the capacity to treat average daily flow. This allows one unit to be periodically taken out of service for routine maintenance and repairs.

Additionally, flow patterns within a wetland area can be altered to improve wastewater management effectiveness or enhance some other objective established for the wetland. Channels can be dredged, dikes added, growths of vegetation can be controlled, and some form of dredging can be done to achieve these objectives.

THE DEGREE OF TREATMENT AND TYPE OF DISINFECTION ARE MAJOR CONSIDERATIONS

Primary wastewater treatment conducted within a conventional wastewater treatment plant, instead of within a wetland area, generally is cost-effective. Conventional secondary treatment, however, may not be cost-effective in a treatment plant compared to utilizing land application or wetland areas. Whether the effluent needs to be chlorinated (possibly followed by dechlorination) prior to its release to a wetland area merits consideration.

One aspect of using wetlands for wastewater management is the level of pretreatment required prior to discharge. As indicated earlier, a minimum of secondary treatment is currently required for wetlands discharges. However, assessing the abilities of wetlands to receive primary effluent or to be incorporated as part of the treatment process provides valuable information. Persche (1980) has indicated that primary treatment is best accomplished by conventional wastewater treatment processes. Grit, grease and floatable materials could seriously impede wetland processes. The following considerations should be evaluated for different levels of pretreatment:

- the environmental sensitivity of the wetland and downstream areas to higher pollutant loadings from primary effluent than from secondary effluent
- the potential stimulating effect of higher loadings from primary effluent (Tuschall et al. 1981)
- the uncertainty of wetland treatment efficiencies (see Section 6.1.8)
- preferable form of nutrients for wetland assimilation
- removal of potentially toxic constituents prior to discharge.

Most of the pilot-scale and full-scale research projects regarding wastewater applications to natural wetland areas within the southeastern United States have involved application of secondary effluent. Most full-scale projects with both natural and artificial wetland areas have also been designed to receive secondary treated effluent (EPA 1982). Hyacinth systems, on the other hand, have been designed to provide secondary treatment of untreated (raw) wastewater or advanced secondary treatment of secondary effluent.

Another important pretreatment consideration is whether effluent should be chlorinated prior to applying it to wetland areas. However, several studies indicate a high percentage of microorganism removal or neutralization is available within wetlands systems. Further, some laboratory studies indicate potential toxicity or adverse effects from chloramines (resulting from chlorinated sewage effluent) as well as chlorine residuals. As a result, the cost and operability of chlorine addition (and possibly dechlorination via aeration and/or sunlight exposure) may have to be weighed against health impacts of not providing disinfection or the use of a different type of disinfectant (e.g., ozonation).

SITE-SPECIFIC CHARACTERISTICS AND COMPLEX PHYSICAL-CHEMICAL-BIOLOGICAL MECHANISMS WITHIN WETLAND AREAS ARE IMPORTANT IN ESTIMATING THE EXTENT OF NECESSARY WASTEWATER PRE-TREATMENT

Each wastewater constituent is affected, converted or removed from the waste stream to various extents within a wetland area. The variables and conversion mechanisms are not entirely definable. A significant level of uncertainty exists for estimating the capacity of a wetland area to provide wastewater treatment for certain constituents.

Most of the existing projects involving wastewater application to wetland areas have physical dimensions and capacities based on the objective of providing nutrient removal, particularly nigrogen and phosphorus removal. The following key points with regard to nutrient removal in wetland areas are taken primarily from Nichols (1981):

- Nutrient removal capability depends upon specific soil characteristics, hydrologic conditions (based on hydraulic detention time of the wastewater within the wetland area), types of vegetation, and wastewater loading rates.

- Growth of wetland vegetation in general represents only a minor sink for nutrients. In a Florida wetland, however, 43 percent of the applied phosphorus from wastewater was taken up by cypress root tissue (Ewel and Odum 1978).

- Natural wetlands receiving wastewater have had widely varying nitrogen removal efficiencies.

- The length of time during which a particular type of wetland can remove any wastewater constituent, particularly phosphorus, is not known.

- Nutrients can be flushed from a wetland area due to die-off of vegetation and high runoff flows.

- Wetlands in warmer climates remove nutrients more efficiently. Also, nutrients may be flushed in pulses as a result of storms, depending upon a wetland's physical configuration.

- Certain types of vegetation are able to store and utilize nutrients better than others. Stored nutrients that are not utilized are often returned to the water upon death and decay of the vegetation.

- Some marsh systems apear to have a limited capacity for assimilating nutrients (Steward and Ornes 1975).

- Nutrient uptake by plants varies seasonally.

6.1.5 Continued

- Effective nitrogen removal can occur while phosphorus concentrations remain at significant levels (Tuschall et al. 1981).

- Long-term removal of nutrients over a period of years is questionable without harvesting vegetation or burning peat layers periodically.

Each of these must be considered when designing a wetlands system that will maintain its function and assimilative capacity. Natural and artificial wetland-wastewater systems can be operated to enhance nutrient removal, as discussed in Section 6.4, by promoting percolation through soil and subsequent denitrification within soil under anaerobic conditions. Maximum nutrient removal for aquaculture systems is obtained in shallow ponds that are harvested frequently.

A major difficulty in establishing allowable loadings to a wetlands area relates to the varied mechanisms or pathways for the assimilation of pollutants. Section 4.4 and its subsections describe nutrient cycles and assimilative mechamisms of other pollutants. These are summarized in Table 6.1.5-a.

Detention time, the time period over which removal mechanisms can act on the wastewater, should also be considered when estimating allowable loadings. Time-dependent mechanisms include suspended solids removal, BOD removal, denitrification and nutrient removal. If the detention time is too low, removal mechanisms will not be able to act long enough to achieve the desired treatment level. Beyond a certain time period, however, removal efficiencies will drop. Detention time is dependent on the volume and water budget of the wetland area. The components of the water budget are illustrated in Figure 4.3.1. If the water budget is well defined, the desired detention time can be maintained through changing conditions by control of wastewater inflow or water depth. For example, in summer months when evapotranspiration is high and detention times increase, reducing the liquid depth can bring detention times down to the desired level. In natural wetlands, where the water budget is hard to quantify, such control may prove more difficult.

The size of wetland areas needed to achieve treatment requirements will depend on the allowable loading rate. For example, at a loading rate of 3 cm/wk (1.2 in/wk) a 946 cubic meters/day (0.25 mgd) community would require 22 hectares (54 acres) of wetland area. This result is based on 3 centimeters of wastewater being spread evenly over 22 hectares for a one-week time period. Unfortunately, other factors are involved which complicate considerations.

Acreage requirements vary with: 1) portion of land to receive wastewater, 2) detention time specified for the effluent and 3) desired water-wastewater depth as well as loading rate and percentage of time when effluent is applied to a wetland. This can be represented by the following equation:

$$A_r = \frac{(Q_i + Q_e)t_1}{D} \text{ X (unit conversion factors)}$$

and

6.1.5 Continued

$$A_r = PA_t$$

where

Q_i = net water inputs to a wetland other than wastewater
Q_e = wastewater flow (e.g., mgd)
t_1 = desired detention time (e.g., days)
D = desired water depth of both effluent and other inputs (precipitation, evaporation, runoff...)
A_r = wetland area receiving wastewater
A_t = total wetland area
P = portion of total wetland area receiving wastewater

Q_i, D and P could vary with time. Q_e could also vary. The above equations neglect infiltration to the underlying soil by Q_i or Q_e, although it can be considered part of Q_i (Metcalf and Eddy 1979).

For water hyacinth systems, organic loading rates and detention times are similar to those for more conventional, wastewater stabilization ponds that utilize untreated wastewater. Harvesting of hyacinth growth may be needed for high performance levels as it is for high levels of nutrient removal (Reed, Bastian and Jewell 1980). Wolverton has suggested that harvesting should be conducted every five weeks during the warm growing season (EPA 1977).

Preliminary results from two hyacinth-wastewater systems in Florida indicate that a final effluent can be produced that meets all advanced wastewater treatment (AWT) requirements except the level of phosphorus. The difficulty with removing phosphorus may result because the nitrogen-to-phosphorus ratio of secondary effluent is slightly less than the same ratio in harvested plants. Addition of nitrogen to a hyacinth pond may be a viable method for correcting this problem. Other methods, not yet mentioned, for achieving AWT treatment levels may include 1) additions of iron salts to prevent chlorosis and 2) provision of facilities for phosphate precipitation if removal of phosphorus is critical and not achieved by other means (O'Brien 1981).

Achieving high treatment efficiencies for a long period of time is somewhat uncertain because no hyacinth systems have been operated for an extended period of time. Proper O&M is essential for long-term operation.

Primarily, long term allowable loadings depend on the assimilative capacity of a wetland as well as on maintaining natural wetlands functions. This depends in part on whether a system is hydrologically open or closed and whether resulting changes in the wetland system are acceptable or unacceptable. From an engineering standpoint it will be difficult to establish broad, quantitative guidelines. Site-specific characteristics of the wastewater and wetland system will ultimately determine allowable loadings. Such guidelines will be established in Phase II of this EIS.

Design criteria and associated removal (conversion) of wastewater constituents obtained from existing natural, artificial and aquaculture wastewater-wetland systems within the southeastern United States are summarized in Tables 6.1.5-b, 6.1.5-c and 6.1.5-d.

Table 6.1.5-a Removal (Conversion) Mechanisms in Wetlands for the Contaminants in Wastewater

Mechanism	Contaminant Affected[1]								Description
	Settleable Solids	Colloidal Solids	BOD	Nitrogen	Phosphorus	Heavy Metals	Refractory Organics	Bacteria and Virus	
Physical									
Sedimentation	P	S	I	I	I	I	I	I	Gravitational settling of solids (and constituent contaminants) in pond/marsh settings.
Filtration	S	S							Particulates filtered mechanically as water passes through substrate, root masses, or fish
Adsorption		S							Interparticle attractive force (van der Waals force).
Chemical									
Precipitation					P	P			Formation of or co-precipitation with insoluble compounds.
Adsorption					P	P	S		Adsorption on substrate and plant surfaces.
Decomposition							P	P	Decomposition or alteration of less stable compounds by phenomena such as UV irratiation, oxidation, and reduction
Biological									
Bacterial Metabolism[2]		P	P	P			P		Removal of colloidal solids and soluble organics by suspended, benthic, and plant-supported bacteria. Bacterial nitrification/denitrification.
Plant Metabolism[2]							S	S	Uptake and metabolism or organics by plants. Root excretions may be toxic to organisms of enteric origin.
Natural Die-Off								P	Natural decay of organisms in an unfavorable environment.

[1]P=primary effect, S=secondary effect, I=incidental effect (effect occurring incidental to removal of another contaminant).
[2]The term metabolism includes both biosynthesis and catabolic reactions.

Source: Tchobanaglous and Culp. 1980.

Table 6.1.5-b Engineering Characteristics and Treatment Efficiencies for Various Aquaculture-Wastewater Systems in the Southeastern United States.[1]

Location	Project Status	Engineering Characteristics: Surface Area, ha.	Water Depth, m.	Vegetation	Soil Substrate	Pre-Treatment	Flow, cubic meters per day	Surface Area Loading cm/wk	Hydraulic Detention Time, days
Coral Springs, FL	Field testing (5 basins in series)	0.5	0.4	Hyacinths	-	Secondary (activated sludge)	380	0.82	6 (2,1,1,1,1)
Walt Disney World, FL	Experimental (3 channels)	0.1	0.4	Hyacinths	-	Primary	190	-	5 to 14
Lakeland, FL	Demonstration (3 basins in series)	0.4	-	Hyacinths	-	Secondary	450 to 980	-	-
NSTL, MS	Field testing (Single Cell Lagoon)	2.0	1.22	Hyacinths	-	None	475	-	54
Lucedale, MS	Field testing (Single cell facultative lagoon)	3.6	1.73	Hyacinths	-	None	935	-	67 (approx.)
Gulfport, MS	Field testing (2 aerated lagoons in parallel 3 unaerated lagoons)	0.28	1.83	Hyacinths	-	<Secondary (aerated lagoons)	1000	-	6.8
Biloxi, MS	Field testing	0.07	1.5	Duckweed	-	<Secondary (aerated lagoons)	49	-	22

NOTE: The reference for information presented in this table in US EPA, 1982 unless otherwise noted.

[1]Within the states comprising Region IV of the US Environmental Protection Agency.
[2]This column represents pre-treatment of the wastewater prior to it reading the hyacinth or duckweed aquaculture units.

Table 6.1.5-h Continued

Location	Wetland Treatment Efficiencies, in percent: Five-day BOD	Suspended Solids	Total Nitrogen	Total Phosphorus	Comments
Coral Springs, FL	77	48	96	67	15 to 20% of plants are harvested every 4 weeks
Walt Disney World, FL	91	89	-	-	Best harvesting pattern not yet determined
Lakeland, FL	50 to 90	80 to 100	75 to 85	38 to 40	Influent quality was better than typical secondary effluent
NSTL, MS	93	90	-	-	Influent quality was 11 mg/l BOD_5, 97 mg/l TSS into aquatic system
Lucedale, MS	86	95	-	-	Influent quality was 161 mg/l BOD_5 and 125 mg/l TSS into aquatic system
Gulfport, MS	72	69	-	-	Influent quality was 50 mg/l BOD_5 and 49 mg/l TSS into aquatic system
Biloxi, MS	57	91	-	-	Influent quality was 35 mg/l BOD_5 and 155 mg/l TSS into aquatic system

NOTE: The reference for information presented in this table in US EPA, 1982 unless otherwise noted.

Table 6.1.5-c Engineering Characteristics and Treatment Efficiencies for Various Natural or Artificial Wetland-Wastewater Systems in Region IV.

Location	Surface Area, ha.	Water Depth, m.	Vegetation	Soil Substrate	Pre-Treatment	Flow, cubic m/day	Surface Area[1] Loading cm/wk	Hydraulic Detention Time, days
Natural Wetlands								
Whitney Park, FL	6	variable[2]	Cypres	Organic muck Duckweed	Secondary	230	2.7	-
Wildwood, FL	202	-	Swamp	Native clay	Secondary	946	0.33	
Reedy Creek, FL	41	up to 1	Swamp	Native soils, muck	Secondary	7,570	13	-
Clermont, FL[3]	0.8	variable	Marsh	Peat soil, sands	Secondary	-	-	-
Gainesville, FL	1.6	1.5	Cypress dome	Sandy clays	Package plant	95	1	-
Jasper, FL	-	-	Cypress swamp	-	Secondary	-	6 to 7	variable[5]
Waldo, FL[4]	-	-	Cypress strand	-	Primary	-	-	-
Jacksonville, FL	189.4	-	Swamp		Secondary	285-368	- gal/min	-

[1]Based on a 7-day per week operation

[2]Water depths are kept below the tops of cypress knees

[3]The Clermont, FL system is said to be more closely controlled than the Wildwood, FL system (US EPA 1981)

[4]This system has been in operation for over 40 years (EPA 1981)

[5]Storm runoff entering the wetland area reduces wastewater detention time to as low as 4 days; during dry periods wastewater detention time can be as high as 64 days.

Table 6.1.5.-c Continued

Location	Wetland Treatment Efficiencies, in percent[8] Five-day BOD	Suspended Solids	Total Nitrogen	Total Phosphorus	Comments
Natural Wetlands					
Whitney Park, FL	-	-	89	91[4]	Reference is EPA, 1982 unless otherwise noted
Wildwood, FL	-	-	90	98[4]	
Reedy Creek, FL	-	-	-	-	
Clermont, FL	-	-	-	94	Reference: Solan et al. in Drew 1978
Gainesville, FL	-	-	-	90+	Fritz and Halle, 1978
Dulac, LA	-	-	51	53	Meo, Day and Ford 1975
Jasper, FL	-	-	to 1.9 mg/l as N	-	Boyle Engineering Corp., March 1981
Waldo, FL	-	-	-	-	Fritz and Helle, US EPA 1979
Jacksonville, FL	-	-	87.0	61.8	CH_2M-Hill Engineering.
					No artificial wetland projects have been reported in the literature for the Southeastern U.S.

[8]Treatment efficiencies can be based on constituent concentrations or constituent loadings. The EPA 1982 reference does not specify the basis.

Table 6.1.5-d Performance of Polyculture Systems Utilizing Fish.

Source	Coleman et al. 1974	Henderson. 1979.
Location	Oklahoma	Arkansas
Period	June-Oct., 1973	Dec. 1978-July 1979
Major Culture	channel catfish	Silver and bighead ca
Minor Culture	Tilapia	Channel catfish
	Minnows	Buffalofish
		Grass carp
Flow (mgd)	1.0	0.45
Unit Area (acres/mgd)	26	36
Average Depth (ft)	3.9-4.3	4.0
Detention time (days)	35	47
Loading (lb BOD5/acre/day)	7.8	6.5
(lb TSS/acre/day)	23	8.7
Initial fish stocked (lb/acre)	27	378
Net fish produced (lb/acre/mo)	34	340
(lb/lb BOD5 removed)	0.2	2.9
(lb/lb TSS removed)	0.06	2.4
Performance: Influent - Effluent (% Removal)		
BOD5 (mg/l)	24-6 (75)	28.1-9.4 (67)
TSS (mg/l)	71-12 (83)	38.0-17.1 (55)
Total N (mg/l)	7.04-2.74 (61)	--
NH_3-N (mg/l)	0.4-0.12 (70)	5.1-2.0 (60)
NO_2-N (mg/l)	0.96-0.16	0.02-0.11
NO_3-N (mg/l)	2.31-0.29	0.01-0.5
Total P (mg/l)	7.97-2.11 (74)	3.0-2.5 (17)
Fecal coliform (no/100 ml)	1380-20	--
pH	8.2-8.3	7.88-8.19
DO (mg/l)	--	3.0-7.4

Source: Schaurtz and Shin. 1980.

LAND USE AND BACK-UP METHODS ARE OTHER CONSIDERATIONS ASSOCIATED WITH SYSTEM DESIGN

Industrial wastes, septage, land values, storage facilities, back-up methods, federal grant conditions, and considerations unique to artificial wetlands are presented. Factors important to the operation of wetland-wastewater systems are also listed.

Preliminary design considerations that significantly affect costs, environmental impacts and operability but that have not been previously discussed are presented in this section. Some of these considerations are directly associated with system design, while others are associated with operation and maintenance.

The considerations directly associated with system design are as follows:

- The presence of industrial wastes within the wastewater can result in significant adverse effects on a wetland area. These effects could result in adverse environmental impacts and/or less efficient removal (conversion) of wastewater constituents

- Work at a water hyacinth treatment facility at Bay St. Louis, Mississippi, showed one particular industrial wastewater to be treatable with water hyacinths (O'Brien 1980). The uniqueness of each industrial waste would necessitate laboratory and pilot-scale testing before a full-scale waste treatment facility could be implemented.

- Septage from on-lot wastewater systems could be applied to an artificial wetland area once it undergoes primary treatment. Septage quality and flow are preliminary design considerations

- The enhancement (or detraction) resulting from wastewater entering a wetland area can alter the economic value of surrounding locations

- Storage facilities such as holding ponds can be utilized both to store effluent during wet periods and to prevent unusually large, intense, short-term flows from reaching wetland areas. With adequately large storage facilities, wastewater can be applied to wetland areas in consistent quantities as a function of time

- For long periods of time when no wastewater should be applied to wetland areas, a back-up method of wastewater treatment or disposal would be needed.

- EPA does have the option of imposing grant conditions in connection with federal funding provided for a natural or artificial wetland-wastewater system. A grant condition could conceivably address any aspect of design or O&M: pre-treatment requirements of water or nutrient balance calculations, soil characteristics, land area requirements, surrounding land use, vegetative cover, treatment efficiency, method of ultimate disposal, monitoring requirements, or a directive to hire a biologist for operating and maintaining the system.

Implementation of an artificial wetland system or aquaculture system allows greater design flexibility than in a natural wetlands system. A number of additional design considerations need to be evaluated for an artificial wetland system:

- Two systems in parallel can be installed

- Various ecological communities can be utilized in series. For example, two possible configurations are marsh-pond and meadow-marsh-pond. When a variety of ecological communities are utilized, nutrient retention is enhanced (Blume 1978). Ponds can also be provided in alternating sequence. Different plant types could be purposely instituted to improve wastewater treatment efficiency (also possible with "natural" wetlands).

- Flows can be spread uniformly over an area or channelized

- Vegetation can be harvested regularly.

- The Grass and Plants Interstate Shipment Act (Public Law 874) prohibits interstate transport or sale of water hyacinths, alligator grass, water chestnuts and seeds of these plants (O'Brien 1981). Therefore, within Region IV of the EPA, water hyacinth-wastewater systems cannot be installed north of Georgia, Alabama and Mississippi. In more natural settings, these plants are considered to be great nuisances.

Operational factors that can also be relevant to preliminary design considerations are:

- energy required to pump wastewater into a wetland area and/or to harvest vegetation

- chemical requirements for chlorination and/or enhanced nutrient removal

- equipment as needed--pumps, chemical feeders, plant harvesting equipment

- management of accumulated solids materials within any wetland-wastewater system, particularly if primary or untreated effluent is being applied.

- Mosquito control may be necessary. Fish that prey on mosquitoes and good water circulation are methods to inhibit mosquito populations. A mat of duckweed will prevent mosquito production in an aquaculture system as long as the entire surface area of each pond is covered.

- Water losses as a result of hyacinth growth can be significant. Evapotranspiration rates have been reported to be approximately three to six times higher for waters covered with hyacinths than for open waters (O'Brien 1981). Within Florida, water losses could be a particular concern. Total dissolved solids build-ups can also result. Greenhouse structures can reduce water losses and, at the same time, allow hyacinths to grow year-round if water temperatures can be kept at favorable levels. Costs for such greenhouse structures have not been reported in the literature.

For natural wetlands, an important operational consideration is to allow the area to maintain its natural condition (Odum 1980):

- A wetland area should be allowed to maintain its self-organizing patterns

- Artificial changes in water table levels and flow patterns should be limited

- Artificial swamps and marshes can be created if the water seal, inflow-outflow patterns and nutrient regime can be adjusted. Diversity of seeding is the safest principle for insuring that a wetlands ecosystem is established quickly.

These concepts represent a different approach to those described for the artificial system above. It should be noted that both approaches potentially have merit depending on the natural system available for use, the size of area available for development as a wastewater management system, and the amount of wastewater to be discharged per unit area.

6.0 ENGINEERING CONSIDERATIONS

6.1 Facilities Planning/Preliminary Design

6.1.7 Costs and Economic Values

COSTS CAN BE FAVORABLE COMPARED TO MORE CONVENTIONAL WASTEWATER TREATMENT PROCESSES

Several site-specific conditions can affect system costs. In general, wetland wastewater systems are less costly than more conventional processes (systems) because the natural environment and naturally available energy are utilized. The importance of considering all aspects of costs including uncertain treatment reliability, is also discussed.

Various pilot-scale and full-scale wetland systems have been shown to be more cost-effective and energy efficient than comparable, conventional wastewater treatment processes (Weber et al. 1981). Both capital costs for facilities and operation-maintenance costs associated with labor and energy needs have been lower.

Costs for natural wetland systems primarily result due to costs for planning, design, implementation, operation and maintenance of:

- Pre-application treatment
- Piping and perhaps pumping wastewater from a treatment plant to a wetland area
- Distributing wastewater to a wetland area
- Potential land costs
- Minor earthwork.

These costs should include costs for field work and monitoring as well as for other aspects of wastewater management. More extensive containment structures and channels may be needed for artificial wetland systems which increase total system costs. Costs can be kept low by: 1) not installing many facilities within a wetland area, 2) not removing vegetation from a wetland area on a continuing basis unless energy production or resource recovery from removing vegetation is cost-effective or if removal of vegetation is a necessary part of treatment activities, 3) optimizing or minimizing storage requirements, 4) optimizing chlorination and dechlorination requirements, and 5) avoiding large land costs.

Very little costing information is available in the literature for hyacinth-wastewater systems. A series of basins with associated weirs and pumps is neither particularly sophisticated nor costly. Capital costs for these facilities depend primarily upon hydraulic detention time and pond depth. If untreated wastewater is input to the system, additional equipment such as a bar screen, grit chamber and perhaps an additional basin is required. Aerators and greenhouse covers are optional equipment that could enhance system performance.

Within any aquaculture system, biomass needs to be harvested periodically if biomass production is to be kept as high as possible. Unfortunately, biomass harvesting cannot, at the present time, pay for itself by utilizing harvested biomass for animal feed, fertilizer, or energy production. Harvesting and various other equipment is needed, including a front-end loader, a truck and/or a wagon, and perhaps a mechanical chopper (for hyacinths, depending upon how the harvested biomass is to be utilized). Hyacinths can be composted and digested anaerobically to produce methane or processed into animal feed. All of these processes have been shown feasible but not competitive economically. Additional studies of converting hyacinths to energy are needed to investigate more economically efficient conversion methods and also to market the potential for the product.

Tchobanoglous and Culp (1980) have prepared cost estimates for these comparable wastewater treatment-disposal systems: 1) activated sludge (AS) plus chlorination (C), 2) primary treatment (P) plus artificial wetlands (AW) plus chlorination, and 3) facultative pond (FP) plus artificial wetlands. Plant harvesting and energy production from plant biomass were not included in the cost estimates. The third option included no sludge management or dechlorination costs. No mention is made of provisions for back-up facilities. The results of this cost estimate are shown in Table 6.1-7. Facilities were sized to represent typical systems under average climate, topography and wastewater conditions.

As shown, the second system-primary treatment plus artificial wetlands plus chlorination-is the least costly. The authors go on to state that even with land costs of $10,000 per acre the second system is still less costly than conventional, activated sludge treatment plus chlorination.

This analysis by Tchobanoglous and Culp (1980) does imply, however, that treatment efficiencies are similar for the three systems. Such similar treatment efficiencies are not necessarily obtainable. Moreover, the costing assumptions which were utilized could differ significantly on a site-specific basis.

No cost analyses have been found in the literature for the general use of natural or artificial wetlands to provide more advanced forms of treatment, such as nutrient removal. Such a cost analysis would need to include an even larger number of assumptions than Tchobanoglous and Culp had to utilize, many of which could differ significantly at different locations. Therefore, costs for wetland-wastewater systems should be compared to costs for more conventional forms of treatment only on a site-specific basis.

Fritz and Helle (1978) have developed a site-specific cost analysis for an anticipated advanced treatment system in Waldo, Florida. Their analysis does indicate that, for Waldo, Florida, advanced treatment utilizing cypress wetlands is less costly than spray irrigation or physical-chemical treatment of secondary effluent.

Table 6.1.7. Annual and Unit Costs,[1] Excluding Land, for Treatment Systems.

Item	AS+c Plant size, mgd 0.1	0.5	1.0	P+AW+c Plant size, mgd 0.1	0.5	1.0	FP+AW Plant size, mgd 0.1	0.5	1.0
Capital cost, \$ x 10^6	0.71	1.23	1.60	0.37	0.55	0.90	0.49	1.12	1.80
O&M cost, \$/y									
Labor, \$10/p.h	16,000	36,000	55,000	12,500	30,000	45,000	12,500	30,000	45,000
Power, \$0.06/KWH	10,400	27,940	41,556	5,572	11,378	19,456	5,883	11,494	18,600
Chlorine, \$300/ton	457	2,283	4,566	228	1,142	2,283	--	--	--
Parts and supplies	8,000	12,000	16,000	3,000	5,000	7,000	3,500	4,500	6,500
Subtotal	34,857	78,223	117,122	21,300	47,520	73,739	21,883	45,990	70,100
Amortized capital									
(8% at 20 y)	72,313	125,275	126,960	37,684	52,962	91,655	49,905	114,072	183,330
Total annual cost, \$	107,170	203,498	280,082	58,984	100,482	165,404	71,788	160,062	253,430
Unit cost, \$1000 gal	2.94	1.12	0.76	1.62	0.55	0.45	1.97	0.88	0.69

[1]Land costs are excluded. Costs represent June 1979 prices.

AS+C: activated sludge plus chlorination
P+AW+C: primary treatment plus artificial wetland plus chlorination
FP+AW: facultative pond plus artificial wetland

Source: Tchobanoglous and Culp. 1980.

6.1.7 Continued

Demgen and Note (1980) have presented site-specific costs of an artificial wetland wastewater system for Mt. View Sanitary District in California.

Crites (EPA 1979) has developed comparable cost estimates for conventional, advanced secondary treatment processes, land application, and hyacinth-wastewater systems managing 3,800 cubic meters per day (1 mgd). The conclusion from this effort is that hyacinth-wastewater systems offer low-cost, low-energy wastewater treatment options. For the given conditions, land application was found to be more costly than a hyacinth-wastewater system.

Cost-effectiveness must consider environmental impacts, system operability and system implementability as well as costs. Mitigative measures, such as actions to control mosquitoes, flies or odors, must also be included. In addition to mitigative measures, the use of wetland areas for wastewater management could alter local economic conditions. Wetlands can attract investments to a local area according to Odum (1980), at least for locations which he has considered. In contrast, management of wetlands could also detract from investments under certain conditions. These effects should be included in any cost effectiveness analysis for wetland-wastewater systems.

6.0 ENGINEERING CONSIDERATIONS

6.1 Facilities Planning/Preliminary Design

6.1.8 Areas of Uncertainty

SOME UNCERTAINTIES EXIST THAT COULD IMPACT DECISION MAKING

Variability of the natural environment (particularly climate) from location to location, inability to quantitatively predict biological reactions, a lack of large amounts of experience with wetland-wastewater systems, and the difficulty with monitoring ecological stress are the primary uncertainties of applying wastewater to wetland areas.

Wetlands discharges, from an engineering design viewpoint, pose a variety of problems that differ from traditional treatment and discharge considerations. Wetland types vary significantly in their ability to assimilate wastewater, in dominant vegetation, size, and hydrologic characteristics, all of which affect design criteria. A series of concerns unique to wetlands need to be incorporated into engineering design, yet sufficient information to establish criteria is limited. Some of these issues include:

- the inability to predict biological and ecological changes as functions of temperature, water availability, wastewater characteristics, and other variables (e.g., changes in species composition, odor production, mosquito/fly breeding)

- a lack of long-term experience with wetland-wastewater systems that limit estimates of long-term effects of wastewater applications (e.g., accumulation of substances within wetland areas, potential toxic effects, or long-term changes in species composition and productivity)

- limited information exists to evaluate changes in a regional water budget if significant quantities of wastewater are diverted to wetland areas

- meteorological parameters are relatively unpredictable; water levels and circulation patterns within a wetland area will be unpredictable as a result

- limits concerning how much a wetland area can be disturbed by wastewater management activities before intolerable consequences occur have not been quantified.

Many of these uncertainties can, unfortunately, affect the entire performance of a wetland-wastewater system in significant and adverse ways. Rational design criteria for wastewater-wetland systems may only be able to be developed as more systems are implemented. These systems are too complex to be designed reliably based on mathematical equations and laboratory simulations.

Tchobanaglous and Culp (1979) contend that reliable, standard design criteria cannot be developed even if hundreds of reliable natural wetland wastewater systems are implemented. Variations in environmental characteristics at different locations would force pilot-scale testing to be conducted

6.1.8 Continued

at a site before a full-scale wetland-wastewater system could be implemented and effectively operated. So many unknowns or uncertainties are related to soils, vegetation, and other site characteristics that design, installation and operation procedures must be tailored to individual wetland areas. This does not necessarily detract from the use of wetlands for wastewater disposal. It acknowledges that standard design criteria as developed for conventional systems probably cannot be developed for wetlands systems. However, guidelines and ranges of acceptability can be established for the design of wetlands systems.

Fewer uncertainties and research needs are evident for hyacinth-wastewater systems than for any other type of wetland-wastewater or aquaculture-wastewater system. Yet even for hyacinth-wastewater systems, more data are needed to establish: 1) preferred hyacinth harvesting and utilization techniques (Middlebrooks 1980), 2) optimum harvesting strategies that would vary for different locations, 3) alternataive methods to provide improved phosphorus removal wherever such removal is needed (O'Brien 1980), and 4) the best wastewater management methods to institute during periods when hyacinths are unable to grow. For more northern locations within Region IV of the EPA, efforts are needed to establish treatment efficiencies, costs and operability of other aquatic plant-wastewater systems, such as duckweed systems. In addition, the economics of converting harvested plant mass to compost, energy or animal feed need to be periodically re-evaluated in light of uncertain economic conditions at the present time. If new, less expensive technology for converting plant mass to energy could be developed, aquatic plant-wastewater systems could conceivably pay for themselves in the future.

TRADITIONAL DESIGN CRITERIA FOR WASTEWATER MANAGEMENT SYSTEMS NOT AS APPLICABLE TO WETLANDS

Although numerous wetlands disposal sites currently exist insufficient evaluations have been conducted to establish design criteria for the variety of wetlands found in Region IV. It is clear, however, what type of design criteria should be developed.

As for any wastewater management system, a variety of tasks must be undertaken to properly design the system. As indicated in the previous section generic design criteria applicable to all wetlands is probably not feasible. However, a range of criteria can be proposed based on evaluations of existing wastewater systems: even then uncertainties remain. This represents a major difference between traditional wastewater systems and wetlands wastewater systems. Despite this limitation the range of values observed for existing wetlands discharges will be related to design criteria.

Not unique to wetlands discharges but an area that requires unique considerations is that of mixing and flow patterns. This relates directly to the type of wastewater distribution system that might be most effective for a particular wetland.

Site access and easements, safety factors, and specifications for structures are elements of design of any wastewater management system yet involve a different series of considerations for wetlands systems.

GENERIC DESIGN CRITERIA FOR ALL WETLAND TYPES NOT FEASIBLE

Pilot studies may be required at natural wetlands to determine proper loading rates and design criteria for each wetland system. Some general criteria have been suggested for artificial wetlands which may be applicable to natural systems as well. Design criteria for water hyacinth systems have been recommended.

The lack of established design criteria for natural and artificial wetlands is due, in part, to the relatively small number of operating systems and the extent of long-term research conducted. However, this void is also a function of the many site-specific components, such as climate, vegetation, soils and natural flow patterns.

In the design of artificial wetland systems, some degree of control over the site-specific components is possible. Tchobanoglous and Culp (1980) developed the preliminary design parameters shown in Table 6.2.1-a and Crites (1979) reports the following values used for artificial wetlands:

Parameter	Reported Range
Detention Time, days	2 to 25
Depth, ft (m)	0.52 to 3 (0.2 to 0.9)
Area, Acres/mgd ($ha\text{-}day/m^3$)	10 to 130 (0.0011 to 0.0139)

For natural wetland areas, detention times may be considerably longer than for artificial wetlands. However, because such characteristics as flow paths, extent of percolation, and nonpoint source imputs are so difficult to quantify for a natural wetland, detention time as historically defined (volume/flow rate) becomes less meaningful as an engineering term. Land area requirements typically range from 30 to 60 acres per million gallons of wastewater, although larger areas may be required for significant removal of nitrogen and phosphorous (Tchobanoglous 1980). Loading rates to artificial (Table 6.1.5-c) and natural wetland systems which have been studied in Region IV vary greatly:

Location	Pre-Treatment	Loading $ha\text{-}day/m^3$ (acres/mgd)
Whitney Park, FL	Secondary	0.026 (243)
Wildwood, FL	Primary	0.214 (1,997)
Reedy Creek, FL	Secondary	0.0054 (50)
Gainesville, FL	Package Plant	0.0168 (157)
Jacksonville, FL	Secondary	0.094 (880)

Table 6.2.1-a. Preliminary Design Parameters for Planning Artificial Wetland Wastewater Treatment Systems[a]

		Characteristic/design parameter					
	Flow	Detention Time, d		Depth of Flow, ft (m)		Loading rate $g/ft^2 \cdot d$ (cm/d)	
Type of System	Regime[b]	Range	Typ.	Range	Typ.	Range	Typ.
Trench (with reeds or rushes)	PF	6-15	10	1.0-1.5 (0.3-0.5)	1.3 (0.4)	0.8-2.0 (3.25-8.0)	1.0 (4.0)
Marsh (reeds rushes others)	AF	8-20	10	0.5-2.0 (0.15-0.6)	0.75 0.25	0.2-2.0 (0.8-8.0)	0.6 (2.5)
Marsh-pond							
1. Marsh	AF	4-12	6	0.5-2.0 (0.15-0.6)	0.75 (0.25)	0.3-3.8 (0.8-15.5)	1.0 (4.0)
2. Pond	AF	6-12	8	1.5-3.0 (0.5-1.0)	2.0 (0.6)	0.9-2.0 (4.2-18.0)	1.8 (7.5)
Lined trench	PF	4-20 (hrs)	6 (hr.)	--	--	5-15 (20-60)	12 (50)

[a]Based on the application of primary or secondary effluent.
[b]PF = plug flow, AF = arbitrary flow (partial mixing).

Source: Tchobanoglous and Culp. 1980.

6.2.1 Continued

Loading rates for natural wetlands will be greatly influenced by the hydrology of the system (see Sections 4.3 through 4.3.5). If nutrient (nitrogen and phosphorus) removal is an objective of a natural wetland-wastewater system, nutrient cycling and transformations within the wetland area must be also investigated (see Sections 4.4.4 through 4.4.4.2).

Aquaculture systems generally consist of one or more basins or ponds inhabited by one or several species of aquatic plants or animals. Selection of plant/animal species is based on several factors (Bowker 1982):

- degree of pre-treatment
- required treatment level
- by-product recovery
- requirements of plant/animal species.

Preferred plant species for aquatic systems have the following characteristics (Bowker 1982):

- rapid growth rate in waste-enriched waters
- high nutrient and mineral absorption capability
- harvesting ease (floating plants)
- good nutritive value or value for energy production
- not susceptible to minor environmental changes
- disease resistant.

Water hyacinths have been the most commonly used plant for aquatic systems in the past. This species thrives in waters with municipal effluent; it also appears to do well in mixtures of municipal and industrial wastewater. The use of water hyacinths is limited, however, by the fact that growth ceases at temperatures below 10°C (50°F). Duckweed, another species which has been used in aquatic systems, has a much wider geographic range because it vegetates above 1-3°C (33.8-37.4°F), and it winters well (O'Brien 1981).

Several sets of design criteria have been noted in the literature. These criteria are essentially similar; discrepancies result from differences in influent quality and treatment objectives. Middlebrooks (1980) suggests that hydraulic loadings to a water hyacinth system of 1) 2,000 m^3/ha-day (214,000 gal/acre-day) of secondary effluent and 2) 200 m^3/ha-day (21,400 gal/acre-day) of untreated wastewater "appear reasonable" if nutrient control is not an objective. These values are consistent with those given by O'Brien (1981) for raw wastewater systems (Table 6.2.1-b) and by the Texas Department of Health (Table 6.2.1-c) for secondary effluent systems without nutrient control.

Broad, rectangular basins with a length to width ratio of 3 to 1 are recommended for aquatic plant systems to provide suitable hydraulic characteristics (EPA 1982). Water hyacinth basins should have an area less than or equal to 0.4 ha (1 acre) based on ease of harvesting and cleaning. A long rectangular basin may have an area greater than 0.4 ha (1 acre) (Middlebrooks 1980).

6.2.1 Continued

To produce an effluent with 2 mg/l of TN, Middlebrooks (1980) suggests less than 0.4 meter (1.3 ft) pond depth and an approximate loading rate of 500 m^3/ha-day (53,500 gal/acre-day) of stabilization pond effluent. These criteria are intended to provide maximum contact of wastewater with the root system. In addition, regular harvesting should be conducted to remove nutrients from the system. As shown in Table 7.2.4, O'Brien gives a depth of 0.91 meter (3 ft) and a loading rate of 800 m^3/ha-day (85,500 gal/acre-day) to provide an effluent with less than or equal to 5 mg/l TN.

As the harvesting of hyacinths disrupts treatment, Dinges (EPA 1979) recommends draining each basin annually and removing accumulated sludge and plant debris. Harvested hyacinths should be dried prior to ultimate disposal. This can be accomplished on sloped, impervious areas; the water released as the plants decompose can be drained to a soil absorption system. Dried plants can be plowed or disked into adjacent farmland, composted, made into animal feed or converted to biogas through anaerobic digestion (O'Brien 1981).

There appears to be sufficient data for the design of water hyacinth aquatic systems. Although much of the design of other types of plant aquatic systems may be similar, several critical parameters, particularly the loading rate and detention time, will vary with different plant characteristics. Scant data are available on which to base design criteria for animal or integrated systems. More research is needed before standards can be developed for this technology.

Table 6.2.1-b Design Criteria for Water Hyacinth-Wastewater Treatment Systems to be Operated in Warm Climates (based upon best available data).

Parameter	Design Value Metric	Design Value English	Expected Effluent Quality
A. RAW WASTEWATER SYSTEM (Algae Control)			
Hydraulic Residence Time	> 50 days	> 50 days	BOD5 ≤ 30 mg/l
Hydraulic Loading Rate	200 m^3/ha·day	0.0214 mgd	SS ≤ 30 mg/l
Depth, Maximum	≤ 1.5 meters	≤ 5 feet	
Area of Individual Basins	0.4 hectare	1 acre	
Organic Loading Rate	≤ 30 kg BOD5/ ha.day	≤ 26.7 lbs BOD5/ac.day	
Length to Width Ratio Hyacinth Basin	>3:1	>3:1	
Water Temperature	>10°C	>50°F	
Mosquito Control	Essential	Essential	
Diffuser at Inlet	Essential	Essential	
Dual Systems, Each Designed to Treat Total Flow	Essential	Essential	
B. SECONDARY EFFLUENT SYSTEM			
(Nitrogen Removal and Algae Control)			
Hydraulic Residence Time	> 6 days	> 6 days	BOD5 ≤ 10 mg/l
Hydraulic Loading Rate	800 m^3/ha·day	0.0855 mgd	SS ≤ 10 mg/l
Depth, Maximum	0.91 meter	3 feet	TP ≤ 5 mg/l
Area of Individual Basins	0.4 hectare	1 acre	TN ≤ 5 mg/l
Organic Loading Rate	≤ 50 kg BOD5/ ha·day	≤ 44.5 lbs BOD5/ac·day	
Length to Width Ratio of Hyacinth Basin	> 20°C	> 68°F	
Mosquito Control	Essential	Essential	
Diffuser at Inlet	Essential	Essential	
Dual Systems, Each Designed to Treat Total Flow	Essential	Essential	
Nitrogen Loading Rate	≤ 15 kg TKN/ ha·day	≤ 13.4 lbs TKN/ac·day	

Source: O'Brien 1981, and Middlebrooks 1979.

Table 6.2.1-c Recommendations for the Construction of Hyacinth Basins for Upgrading Stabilization Pond Effluent.

Parameter	Design Value Metric	English
Loading rate	2000 m^3/ha-day	0.2 mgd/acre
Basin length to width ratio	3:1	3:1
Basin construction		
-Side slopes	1:3	1:3
-Freeboard	0.61 m	2 ft
-Width	3.0 m	10 ft
Minimum		
Basin piping (diameter)	0.25 m	10 inches

Additional specifications:

- Dual systems, each capable of treating average daily flow
- Barrier provided by 1 percent of total area in clear area around the outlet
- Mosquito control provided by 8 to 10 ft. diameter fish enclosures spread throughout the basins.
- Man-proof fencing surrounding system
- Water level gage to provide depth control

Source: Dinges. 1976.

WETLAND MIXING AND FLOW PATTERNS INFLUENCE APPLICATION METHOD

Selection of application method is site-specific. Mixing and flow patterns can be controlled.

The source, velocity and application rate of wastewater into a wetland directly control the spatial heterogeneity of flows in wetlands and the nutrient, oxygen, and toxin load of sediments. These secondary factors in turn control or modify such ecosystem characteristics as species composition, primary productivity, organic deposition and flux, and nutrient cycles (Gooselink 1978).

Numerous methods of effluent application can be employed. A single discharge from the point at which a stream enters a wetland, at the edge of a wetland, or at a location within the interior of a wetland is possible. A discharge can also be distributed uniformly across a lateral section, perpendicular to the general direction of flow. Such a multi-point discharge provides greater initial mixing with the receiving water and smaller area loadings. As compared to a single-point discharge, however, the multipoint discharge would have greater construction impacts, be more difficult to operate and maintain, and would be more expensive (particularly if a number of unrelated disposal locations are utilized). Based on site visits conducted during this EIS the following observations were made:

- wastewater treatment plant owners will utilize the least costly effluent disposal system (point discharge to edge of wetland) unless required to do otherwise

- installing pipe in any manner other than laying it on the ground surface will require temporary drainage, excavation, and backfill

- continuous flows of wastewater from a pipe or channel will create channelized flow for at least a few hundred feet into the wetland area.

The location and type of effluent application for a given wetland area should be selected based on the following factors:

- path and direction of flow

- type, arrangement, and density of vegetation

- potential for mixing with receiving waters.

The choice of discharge configurations is important if a specific level of treatment is desired and is imperative to maintaining the environmental values and functions of a natural wetland. At higher application rates configurations which provide distribution within the wetland are more attractive because 1) adequate distribution is needed to achieve desired treatment, and 2) erosion and channelization impacts from point discharges

Table 6.2.2. Effluent Application Configurations.[1]

Effluent Application Configurations	Advantages	Disadvantages	Comments
Point discharge at edge of wetland, gravity flow	- Low cost - Low O&M requirements - Low energy use - Can be installed with minimal impacts to a natural wetland	- Often poor or unknown distribution of wastewater - Erosion and channelization may occur if wastewater velocity is high - Solids may accumulate near discharge if wastewater velocity is low	- Distribution may be improved by selection of discharge point to take advantage of natural flow paths, increasing the number of discharge points, or enhancing mixing within the wetland by mechanical or physical devices - Erosion control techniques are available.
Channel discharge at edge of wetland, gravity flow	- Low O&M requirements - Installation impacts limited to edge of wetland - May provide some dechlorination within channel (cascade affect)	- Often poor or unknown distribution of wastewater - Erosion or channelization may occur if wastewater velocity is high - Solids may accumulate near discharge if wastewater velocity is low	- Concrete or grass-lined channel may be used - Erosion control techniques are available
Distribution within wetland, gravity flow	- More uniform distribution - Relatively low O&M requirements (no moving parts)	- Installation impacts to natural wetands - Installation costs	- Distribution may be accomplished by pipe outfalls at a variety of points within wetland, or by perforated or gated pipes - Pipes can be installed on the surface, buried or elevated - Surface pipes will have lesser installation impacts and costs but will have greater O&M requirements
Distribution within wetland, spray flow	- Distribution of wastewater - May provide some dechlorination - Low erosion potential via spraying	- Aerosols may cause public health impacts - Energy required - Nozzles may clog unless pretreatment includes fine screening - O&M requirements higher than for other alternatives - Installation impacts to natural wetlands - Installation costs	- Piping may be laid on the surface, buried or elevated - Surface piping will have lesser installation impacts and costs but will have greater O&M requirements

1. U.S. EPA. Assessment of current information on overland flow treatment of municipal wastewater. May 1980, p. 63.

Source: Gannett Fleming Corddry and Carpenter, Inc.

6.2.2 Continued

can become significant if not properly controlled.

To further enhance mixing in a wetland area, wind-driven circulators or aerators can be used. Flow paths in artificial systems can be controlled by structures (wiers, dikes, baffles, etc.), vegetation, or levees.

Many methods are available; few have been utilized, particularly for natural systems. Least-cost discharges to the edge of wetlands nearest wastewater treatment plants have most often been utilized within Region IV.

6.2.3 Site Access and Easements

THE GOAL IS OFTEN TO PROVIDE ACCESS TO OPERATORS AND TO PREVENT ACCESS BY THE PUBLIC

Inlet/outlet location and multiple plots can provide greater operator access for natural and artificial systems respectively. Fencing and buffer zones can discourage public access.

A wetland-wastewater system should be designed to provide easy access for operation and maintenance while at the same time controlling public contact with the system.

For a natural wetland area, inlet and outlet structures should be located to provide easy access with the least possible removal of natural vegetation. Site access can be made easier in an artificial wetland by providing multiple plots divided by levees large enough for vehicular traffic. Multiple plots also provide greater control of erosion and vectors.

Most wetland-wastewater system should have a fence or posting around its periphery if public access is to be prevented. Additionally, a buffer zone surrounding the system should be provided. No information was found in the literature regarding the size of such a buffer zone. A 200-foot buffer is generally provided for spray irrigation land application systems. A similar figure may also be appropriate for use with wetland systems.

SAFETY FACTORS ARE IMPORTANT FOR WETLAND DISPOSAL SYSTEMS
DUE TO THEIR FUNCTION AND COMPLEXITY AS ECOSYSTEMS

Given the uncertainties associated with the design of wetland systems safety factors must be incorporated. These include buffer zones, storage facilities, and monitoring of wetlands.

Given the small number of operating wetland-wastewater systems and the limited knowledge regarding removal/conversion mechanisms and rates, it will be desirable to incorporate certain safety factors into the design of the system. Such factors could include the following:

- storage facilities to provide for excessively wet periods, cold periods (if nutrient and metal uptake are significant and desired in the system), and, possibly, dechlorination

- nutrient removal in pre-treatment

- buffer zone

- system isolation

- chlorination perhaps followed by dechlorination

- monitoring of system discharge and receiving waters (surface and groundwater)

- monitoring of vegetation for:

  1. metal or toxin accumulation
  2. changes in natural vegetation

- harvesting of vegetation.

These measures can help assure that a wetland system is not overloaded, that wastewater is properly assimilated, and that wetland functions are maintained.

GUIDELINES FOR DRAFTING AND SPECIFICATIONS OF STRUCTURES AND EQUIPMENT ARE NOT ESTABLISHED

A representative list of items that require specification includes pipe sizes, influent structures, and flow path controls.

Because of the small number of wetland-wastewater systems in operation, no guidelines on drafting and specifications have been established. Generally speaking, however, the following list is representative (but not all inclusive) of the type of items that will require specification to the contractor:

- pipe depths, sizes, and types for transmission of wastewater to a wetland and the distribution system
- influent structures such as 1) stand pipes, wiers, or gate valves for artificial wetlands or cypress domes or 2) irrigation pipes (aluminum) with multiple flap gates
- plastic or clay liner to prevent percolation to water table for artificial wetlands, if desired
- artificial substrates used to enhance or replace vegetation in artificial wetlands
- structures or mechanical devices to control flow paths or mixing patterns, such as
    1. vegetation
    2. levees
    3. wind driven circulators or aerators
- filter around effluent structure of aquaculture system to prevent the escape of plants
- circular galvanized wire mesh enclosures in ponds to improve production of fish used for controlling mosquitos
- installation equipment and methods to minimize construction impacts.

Any operation and maintenance procedures that could directly affect the performance of structural facilities can be incorporated into design specifications or within an operation and maintenance bulletin or manual.

INSTALLATION AND CONSTRUCTION TECHNIQUES ARE IMPORTANT TO MAINTENANCE OF WETLAND

Overly expedient or careless installation procedures can cause operating problems as well as damage to natural wetland areas. Techniques to both minimize disturbances and enhance distribution of effluent throughout a wetland area are presented.

Excellent planning, design, operation and maintenance will not ensure satisfactory wastewater treatment results from a wetlands area if installation causes irreparable damage to the wetland system.

Little information exists in the literature pertaining to installing a wetland-wastewater system. Many of the concepts presented in this section are based on experience with installing other types of wastewater systems. Other types of construction experience in wetlands (highways, etc.) may be helpful in avoiding the difficulties presented in the construction of wastewater facilities. The lack of experience with installing wetland-wastewater systems should, at a minimum, force engineering contractors to be more careful and conservative in their activites.

Installation as it pertains to artificial wetland systems and aquaculture systems involves creating a wetland area where previously such an area did not exist. Installation in a natural area involves constructing the means of applying wastewater to the existing area. Installation within natural wetlands either attempts to simply transport wastewater to the wetland or to circulate wastewater to the desired locations. Associated pumping stations and treatment facilities may also be required.

INSTALLATION TECHNIQUES THAT MINIMIZE ADVERSE IMPACTS ARE DESIRED

Natural wetland areas and artificial wetland areas require different installation techniques. Possible techniques to minimize adverse impacts include berms and boardwalks.

The major factor affecting the selection of installation techniques is the type of wetland in question. To inhibit adverse environmental impacts natural wetlands should be as undisturbed as possible when being incorporated into a wastewater treatment scheme. This lack of disturbance limits installation flexibility. Artificial wetlands, by definition, require significantly more construction activity, which allows for greater flexibility in installation alternatives. Some of the methods utilized to minimize disturbance from installing wastewater application systems in natural wetlands are listed below (EPA 1981):

- planks laid on peatland to permit laying of pipe and movement of people (Drummond, WI)
- walkway suspended above a peatland surface (Houghton Lake, MI)
- berm and pathway lined with gravel into a forested wetland (Bellaire, MI)
- a point discharge ditch at the periphery of a wetland (Kincheloe, MI).

No study has been done to determine the relative merits of these or other methods (EPA 1981).

Installation techniques for natural wetlands are necessarily dictated by the physical characteristics of the wetland area such as:

- type of wetland (e.g., peat bog versus reed meadow)
- soil depth to stable material
- erodability of wetland material
- water velocities and circulation patterns
- ecological sensitivity of the wetland system.

Although the desire to minimize wetland disturbances is a primary objective in the installation of artificial systems, the greatest concern is stabilizing areas disturbed by required construction activity. In some cases, actual construction activity may be significant, while for other cases, minimal activity may be required. Installation techniques will generally be dictated by such factors as: costs, system size, equipment availability, site configuration and contractor experience.

6.3.1 Continued

Supplemental installation activities such as the following can be instituted, particularly for natural wetlands:

- minimize all slopes to reduce erosion potential

- avoid soil compaction where not required

- revegetation will require water-tolerant species

- all levees should be at least ten feet wide and one foot above the highest water level for access ease (ASCE 1978)

- maintain strict control of water entering and leaving the site during installation to avoid unnecessary soil erosion and inhibition of installation activities

- avoid installing pipelines or facilities directly adjacent to a wetland during ecologically-sensitive periods (e.g., during reproductive periods for sensitive wetland species).

Improper installation can result in failure of the wetland system to perform as envisioned. Artificial and aquaculture systems may not have sufficient detention time if water flow to the system is not controlled. Flow patterns within natural wetlands may be altered by installation of distribution pipes. Modified water depths resulting from improper installation activities can also have detrimental impacts on naturally occurring plant species. Natural wetland materials can be eroded if wastewater is applied too heavily. Therefore, proper inspection of installation techniques and materials is an important component of installation. Additional information that could be useful in the installation of various types of equipment in wetland environments may be available through pipe line contractors who have worked under such conditions.

INSPECTION OF INSTALLATION TECHNIQUES AND MATERIALS IS NEEDED DURING CONSTRUCTION

Improper installation techniques and materials can cause adverse environmental impacts. Inspection activities should assure minimal disturbance to wetlands areas.

The objective of construction inspection is to ensure that all components of the wetland system will function as intended after installation is completed. Because wetland areas may be significantly damaged by system installation, proper inspection becomes very important.

The primary item of concern with inspection of wetland-wastewater system construction is protection of the wetland area. Of particular concern for both natural and artificial wetland areas are:

- maintenance of wetland vegetation and animal populations
- minimal disturbance of wetland soils and runoff patterns
- contamination of a wetland by construction material
- minimizing fuel and lubricant spillage
- controlling access to actual locations of construction.

Construction inspection for artificial wetland systems including aquaculture systems has many of the same concerns as for natural wetlands. However, there are some factors that are unique to natural wetlands so that additional effort should be used to ensure proper compliance. The factors of major concern are as follows:

- control of water depths and the size of the area to be receiving wastewater
- limited access to the wetland area
- effective erosion control

Inspection activities need to focus on three areas: 1) site development, 2) materials, and 3) construction. Site development and construction have been previously discussed. The materials used in wetland installation should be compatible with site conditions; they must be able to withstand prolonged wetness. Materials need to be able to function year-round for extended periods of time to avoid excessive maintenance costs.

The primary benefits of inspection activity for wetland systems is the added insurance that the system will function as intended. Additional costs

6.3.2 Continued

incurred with detailed inspection should be considered as an inherent installation expense. The complexities and uncertainties of wetland areas make detailed inspection an integral part of installation procedures.

IMPROPER INITIATION PROCEDURES CAN DAMAGE WETLAND AREAS

Initiation procedures may differ between natural and artificial systems. Season of the year and site are among the factors influencing selection of initiation procedures.

Initiation for wastewater applications to natural wetlands differs considerably from that for artificial wetlands. Natural systems have existing vegetation present to assimilate wastewater consitutents. Artificial systems need to establish stands of plants sufficient to treat wastewater effectively. The process of establishing wetland vegetation could take 6 to 12 months (Tchobanoglous and Culp 1980). Within more southern areas of the country, growths could develop more quickly.

Water hyacinths are well known for their ability to cover a wetland area quickly and completely. Large aquaculture systems may require a mechanical approach to harvesting such as that used at Walt Disney World, Florida (Kruzic 1979). Because hyacinths normally begin to grow and multiply during the spring, system start-up at that time would be appropriate and perhaps more successful than during seasons when plant growth is inhibited. Duckweed, other aquatic plants or animal-based aquaculture systems would require more care and time to begin operations effectively (Stowell et al. 1980). A specialist knowledgeable in such aquatic systems may be needed.

Natural wetland system initiation is critical; an artificial system can be re-seeded if the original vegetation does not survive. A natural system, however, may be damaged by initiation procedures that overload the immediate capacity of the wetland. The degree of damage is site-specific. Damage itself can be either organic or hydraulic in nature. Initiation of aquatic systems needs to take the following concerns into consideration:

- season of the year
- water levels
- ambient temperatures
- wastewater temperatures
- condition of wetland due to other environmental disturbances.

Specific initiation procedures need to be determined based on the wetland site characteristics and the wetland's ability to assimilate projected wastewater loads. Procedures used for conventional land treatment systems may be a useful source of ideas. The following list suggests some ideas that should be considered to begin effective operation of wetland systems:

6.3.3 Continued

- apply wastewater gradually
- begin when the wetland is at its most productive stage
- apply water when the greatest dilution exists but when hydraulic overloads will not occur
- maintain suitable water levels
- ensure the wetland is not stressed for DO when wastewater is applied.

Within three northern artificial wetlands, aquatic plant communities were established with relative ease, and efficient wastewater renovation was accomplished (EPA 1981). For these three artificial wetlands, the installation process was monitored sufficiently to assess its success. Such monitoring of wetland water levels, flow patterns, and vegetation growth can help to determine if and when installation procedures can be modified or halted on a temporary basis.

PROPER O&M IS ESSENTIAL TO SATISFACTORY PERFORMANCE

Present knowledge of effects of O&M techniques is limited. O&M will be dependent on the primary objective of the system.

Even if a wetland-wastewater system has been well-planned, well-designed and well-installed, the system can still fail without proper and well-executed operation and maintenance. Although natural wetlands are more environmentally significant, the artificial wetland and, particularly, aquaculture systems require more intensive O&M because wastewater loadings per hectare (acre) are generally higher for artificial systems.

O&M decisions are dependent upon the primary objective of the system. Some examples of primary objectives are the following:

- Maximize the level of treatment obtained within the wetland
- Minimize odor production, excessive erosion, and/or sludge accumulation
- Minimize adverse environmental impacts to the wetland
- Maximize the wildlife values of the wetland
- Maximize the amount of effluent released to the wetland
- Maximize biomass production.

Some wetland-wastewater systems may also be operated and maintained with research as an objective. Once the primary objective is established (and approved by the appropriate environmental agency if necessary), O&M procedures can be more clearly defined. O&M activities at operating wetland systems visited by members of the project team were generally minimal. Costs and a lack of established O&M procedures were noted as contributing factors. The desire is to keep costs at a minimum.

FLOW PATHS AND DISTRIBUTION PATTERNS CAN BE CONTROLLED AS PART OF SYSTEM OPERATION

Methods and purposes of controlling flow paths and distribution patterns are important to functions of wetland systems. Periodic inspection of facilities and management structures are important to operation.

Techniques for controlling flow paths and distribution patterns include the following:

- Provide and maintain channels
- Provide mechanical or wind-driven aerators/circulation devices, or simple baffles
- Manage the types and densities of vegetation within the wetland
- Control inflows and/or outflows by utilizing weirs, levees, and storage ponds.

The use of storage ponds is discussed in Section 6.4.3.

Structures would require inspection and periodic maintenance. Mechanical aerators would require electrical energy and connection to a source of such energy. Managing vegetation types and densities may require plant harvesting equipment and plant seeding materials, as well as a person knowledgeable of the impacts of such activities on the wetland. Inflows and/or outflows can be controlled by designing and maintaining: 1) adjustable weirs whenever water is released from a wetland to downstream areas, 2) levees or berms to control the extent of wetland inundation, and/or, 3) storage ponds with adjustable outlet weirs, outlet pipes with valves or pumping capability.

Alternate flow patterns could be established through a wetland by placing channels, levees and weirs in specific configurations. Use of more than one configuration within one wetland system provides operational flexibility in case treatment efficiences are not as high, environmental impacts are unacceptably adverse, or some other primary objective is not being met. However, operational flexibility carries with it additional O&M efforts.

Additional efforts which would affect effluent distribution patterns within a wetland are:

- The possibility of periodically flushing a wetland system (Tchobanoglous and Culp 1980) to remove soluble compounds or to remove solid particles with adsorbed nutrients
- Purposely encouraging or inhibiting vertical percolation beneath the soil surface

6.4.1 Continued

- Periodic harvesting of vegetation

- Purposely flooding a wetland system, perhaps during a particular portion of the year, to promote anoxic conditions in the underlying soil. Denitrification, which results in the release of nitrogen gas, can occur only under anoxic conditions if an organic (carbon and combined hydrogen) source is available. Water levels would need to be varied as well (Sloey et al. 1978).

Vertical percolation can be encouraged by artifically draining adjacent lands, providing underdrains, or by removing clay soils from a wetland. Percolation can be inhibited by adding clay soils or an artificial layers, or by allowing sludge from a wastewater treatment plant to be distributed throughout all or part of a wetland.

For the objective of removing nutrients, as well as affecting flow patterns, vegetation should be harvested several times during the growing season. However, such harvesting can destroy aquatic habitat and, at the same time, remove only 5 to 20 percent of the nutrients detained within a wetland system (Sloey et al. 1978). Further, multiple harvests have been observed to reduce production and in some cases lead to plant succession (Sanville 1983).

Water hyacinths must be harvested to obtain effective removal of nutrients and BOD from wastewater. Such harvesting may need to be done every four to six weeks during growing seasons (EPA 1977 and O'Brien 1980). Approximately 15 to 20 percent of the hyacinth plants can be harvested at one time to produce optimum results (Coral Springs, Florida, system in EPA 1982). Harvesting must be planned to avoid significantly decreasing the detention time of wastewater within the hyacinth system.

Harvesting procedures have been estimated to require six to seven hours of time for every 0.1 hectare (0.25 acre) to be harvested. Hyacinth biomass can be composted after two to three weeks of drying. The biomass could also be anaerobically digested to produce energy, or, as in Lakeland, Florida, the biomass can be chopped, pressed and dried as part of a system to produce pelletized animal feed (USEPA 1982). Duckweed harvesting is somewhat easier than hyacinth harvesting.

Duckweed can be harvested by utilizing one of a variety of skimmer devices developed originally for conventional wastewater treatment plants and oil recovery systems. Duckweed could also be transported by pipe. Stored quantities of duckweed can remain unspoiled for periods of weeks without being treated (Hillman and Culley 1978). Costs for precise harvesting or processing methods for duckweed or for any other aquatic plants, except water hyacinths, have not been developed.

According to Ryther et al. (Clark and Clark 1979) a hyacinth harvest yield of 88 dry metric tons per hectare per year is considered to be close to the maximum yield obtainable within the continental United States. These authors assumed the hyacinths have an energy content of 20 million BTU per dry ton, half of which would be recoverable via anaerobic digestion. Such

6.4.1 Continued

estimates provide a preliminary basis for anticipating the amount of energy which can be produced from harvested hyacinths.

Harvested yields of duckweed and hydrilla are 14 and 15 dry metric tons per hectare per year compared to 88 dry metric tons of hyacinths per hectare per year (Ryther et al. 1979).

Frequent harvesting of rooted aquatic plants is not recommended, because plant stems are harvested while roots remain in the substrate. These roots will extend more significantly if the stems are harvested frequently, thereby contributing to system clogging (Pope 1981).

The optimal method for controlling flow patterns is largely dependent upon both the system's primary objective and upon site-specific characteristics and uncertainites. Possible operational policies towards flow paths and effluent distribution include:

- Total "hands-off"
- Avoid inundation of vegetation or excessive erosion only
- Modify or avoid discharges when effluent or wetland displays certain characteristics, such as poor effluent quality, large runoff flows from upstream or noticeable adverse impacts of the wetland community
- Divert runoff flows from upstream areas away from the wetland system
- Manipulate flows into, around and out of the wetland system to accomplish whatever objectives are primarily desired. Daily, weekly, and/or seasonal procedures can be developed.
- Manipulate flows to promote revegetation or other natural reproduction, wildlife.

Based on the extent of current understanding, pilot-scale testing of possible techniques might be beneficial before affecting a large portion of a wetland system with various artificially operated patterns of effluent distribution. Distribution system alternatives will be dependent largely on the type of wetland used for a discharge.

6.0 ENGINEERING CONSIDERATIONS

6.4 Operation and Maintenance

6.4.2 Resting Periods and Use of Storage Facilities

RESTING PERIODS MAY BE BENEFICIAL FOR SOME WETLAND SYSTEMS

Resting periods may be used to recover wastewater treatment capacity or to enhance environmental quality. Storage facilities can provide the means to regulate water depths, detention time, and wastewater inflows to wetland areas.

Flows and water depths within a wetland system need to be maintained if wastewater renovation is a primary objective. Denitrification is often encouraged with greater water depths; the release of nutrients and toxic compounds can be regulated by adjusting water depths (Tchobanoglous and Culp 1980), and detention time can be regulated by water depth and flow. Storage facilities and control of discharges from wetlands to downstream areas can allow wastewater flow and water depths within a wetland system to be regulated.

A wetland system may require a resting period in order to: 1) recover its capacity to renovate wastewater effluent, or 2) to enhance or maintain important wetland functions. During a resting period, the treatment capacity can be enhanced by 1) doing nothing, 2) passing water with silt through the system to restore absorption capacity, or 3) passing nutrient-rich water through the system to enhance growth. Bypasses of wastewater to other areas should only be utilized when the impacts of that discharge on the downstream areas receiving the discharge are judged to be acceptable.

Inoperability of aquaculture systems during winter months is a significant concern. Hyacinths and other aquatic plants do not grow significantly, even in central and southern Florida, between November and February. Since a high level of wastewater flows may continue during these months, the wastewater will need to be stored or treated in some other manner, or a tropical climate will need to be artificially established through the use of greenhouse covers.

Storage facilities and/or bypasses can also be utilized to maintain relatively constant inflows to wetland systems. The natural environment is often susceptible to adverse consequences if large flows of water or toxic compounds are allowed to reach it. Difficulties and uncertainties about how large to design storage facilities and bypasses and about when to utilize and not utilize the facilities will be evident. The aspect of O&M associated with resting periods and use of storage facilities/bypasses is, therefore, best accomplished by experienced, innovative operators.

ENERGY AND CHEMICAL REQUIREMENTS MINIMAL

For most wetland systems, energy and chemical requirements are low. O&M equipment needs can be important, but are not extensive. O&M equipment can be major uses of energy.

Energy requirements vary for different systems because of site-specific topographic characteristics. Wetland wastewater systems generally utilize less energy than conventional advanced treatment processes and some land application systems, because wastewater only needs to be distributed in the wetland. Energy is often required for pumping wastewater or, if needed, for providing disinfection, mechanical aeration, or harvesting of vegetation.

Chemicals to be utilized, if any, could include alum, ferric chloride, or a polymer to enhance phosphorus removal and chlorine dioxide, other halogenated compounds, or ozone for disinfection. Lower amounts of disinfectant may be needed for discharges to a wetland than for discharges to a stream, river or lake.

Supplemental quantities of nitrogen could also be added to a wetland system in order to increase vegetation production and thereby improve phosphorus removal from wastewater. Iron salts can be added to prevent buildups of chloride compounds (O'Brien 1980).

Equipment needs for O&M include pumps, replacement pipe and pipe support structures, access vehicles (if needed) and vegetation removal equipment. None of these forms of equipment are particularly difficult to obtain. Harvesting equipment for aquaculture systems can include (EPA 1982):

- a "weed-bucket equipped, truck-mounted guideline" (Coral Springs, Florida)

- a front-end loader, double-belt conveyor and chopper, and a forage wagon (Lake Buena Vista, Disney World, Florida).

For natural and artificial wetlands, vegetation removal techniques can include manual removal of vegetation from small areas or the use of a backhoe or loader to scoop vegetation from the sides of channels. Control of algal blooms, which limit BOD and suspended solids removal, can be provided by zooplankton that utilize algae and organic detritus material as food sources (ASCE 1978).

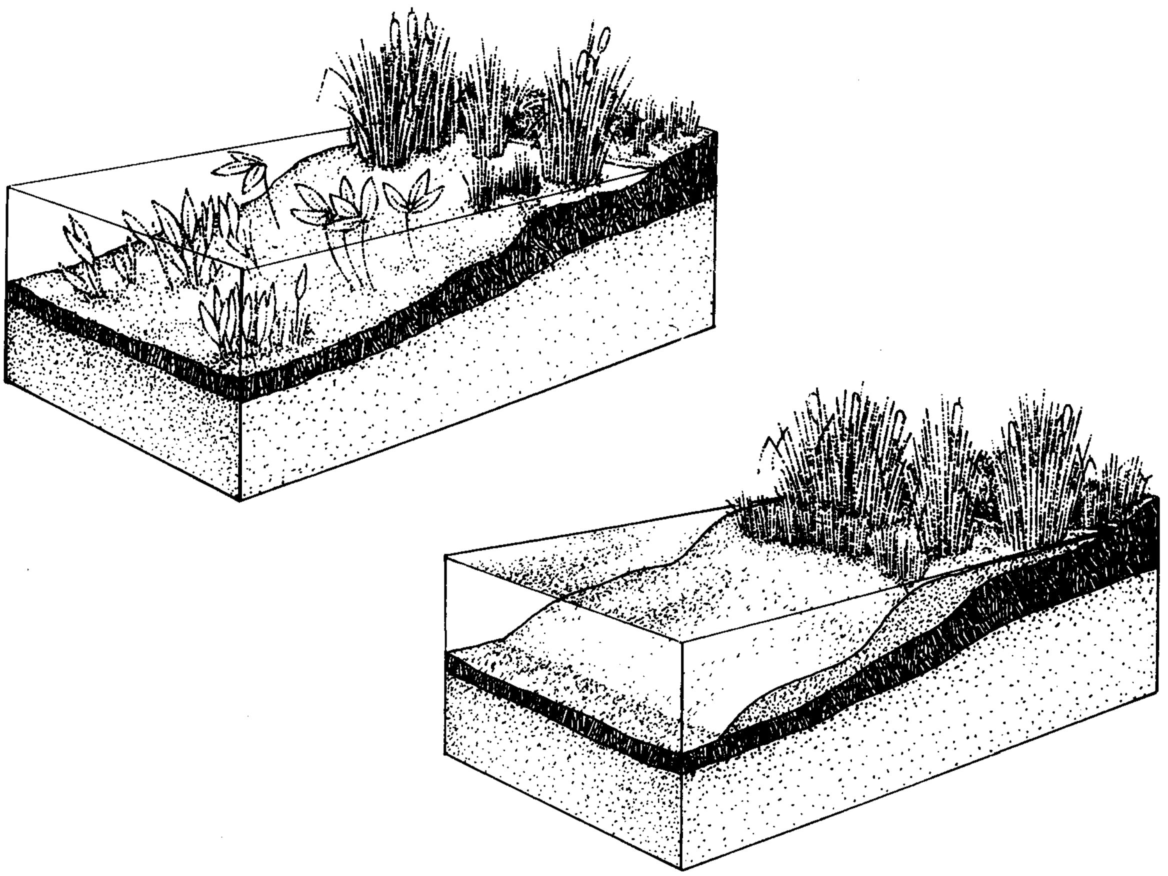
IMPROPER O&M CAN CAUSE POTENTIAL ENVIRONMENTAL AND HEALTH PROBLEMS

In addition to causing the system to fail in accomplishing its objective, improper O&M can cause adverse environmental impacts and public health effects, odors, and may impair wetland functions.

Without proper O&M, a wetland can become ineffective in its ability to assimilate wastewater constituents. At worst, wastewater added to a wetland could also cause adverse environmental impacts such as:

- Breeding of flies, mosquitoes and other disease vectors (mosquito fish can often discourage the growth of mosquitoes)
- Deteriorated water qualty and undesired release of nutrients to downstream areas
- Development of odors
- Increased populations of plants and animals considered to be pests
- Sludge accumulation inhibiting growth of organisms which require original wetland substrate
- Accumulation of toxic heavy metals or other toxic compounds within the wetland food chain, and
- Adverse impacts on protected species.

To avoid these impacts, O & M activities must be controlled keeping the primary objectives of the wetland-wastewater system in mind. As new information becomes available, individual wetland dischargers should be kept abreast of advances. Carefully-conceived O&M activities, can prevent adverse impacts to a wetland system.



SECTION 7

MANAGED WETLANDS CONSIDERATIONS

7.0 MANAGED WETLAND CONSIDERATIONS

PROPER MANAGEMENT OF WETLANDS INVOLVES UNDERSTANDING PROCESSES AND MONITORING

Management of wetlands leads to certain changes in wetlands which should be understood and monitored. Artificial wetland systems may provide a reasonable alternative for some communities and contribute to establishing design criteria.

The use of wetlands as part of a wastewater management strategy is a relatively new concept despite the use of wetlands by some communities for many years. To consider wetlands for widespread use, certain analyses must be conducted. First, an understanding of the types and range of changes that could occur in a wetland is important. Also important is the degree to which wetlands assimilate or renovate wastewater. The acceptability of using wetlands for wastewater discharges is contingent upon the understanding of these issues. The data base on natural systems has increased, but certain data limitations remain.

Another approach to the use of wetlands for wastewater management is the development of artificial/aquaculture systems. This is also a new area of endeavor, as only a few communities throughout the country have utilized this approach. It is a viable approach, however, for many small communities and information gained from the design of such systems may be applicable to natural systems as well.

If a system is to be managed properly, management tools are helpful. A major issue with wetlands systems has been the assessment of wasteload allocations. However, with no models designed for that purpose for wetlands, wasteload allocations remain a problem. Models, or analytical tools, are discussed in Section 7.4 as they relate to the wasteload allocation process.

Finally, a managed system must be monitored adequately. In the case of wetlands, monitoring should be conducted to assess not only the quality of effluent entering and leaving a wetland but also the functions and characteristics of the wetland. If a major goal of using a wetland area is to maintain its function and role as an ecosystem, such monitoring will be extremely important.

<u>Issues of Interest</u>

- What types of changes occur in wetlands as a result of discharging wastewater?
- Can wetlands' functions and values be maintained?
- Are artificial wetland systems preferable to natural systems for wastewater discharges?
- What types of artificial systems exist?

7.0 Continued

- Can the effects of wastewater discharges on wetlands be predicted by models?

- What can be done to monitor the impacts of wastewater on wetlands and the effectiveness of wetlands in renovating wastewater?

7.0 MANAGED WETLAND CONSIDERATIONS

7.1 Impacts to Natural Characteristics

KNOWLEDGE ABOUT MANAGED WETLANDS SYSTEMS HAS INCREASED IN RECENT YEARS

Despite limitations in the data base, much is known about the impacts of wastewater on some types of wetlands. Some types remain unstudied, which could affect their acceptability for use.

This section is designed to parallel Section 4, Natural Wetland Characteristics, which summarizes the characteristics, functions and processes inherent to wetlands systems. With the addition of wastewater, or other management measures, certain changes occur in a wetland. Some changes are predictable. However, some are unpredictable based on the limitations of knowledge regarding the impacts of management strategies on natural systems.

As existing wetlands discharges have received increased attention in recent years, research on such systems has increased. For some types of wetlands systems, data have been collected not only on the impacts of wastewater to wetlands but also on their ability to assimilate or treat wastewater. Unfortunately, many wetlands systems have not been studied for their capacity to receive wastewater.

The impacts of wastewater on wetland systems is interactive in nature. The effects of changes in water chemistry and water quantity are not always separable. Chan et al. (1980) have summarized the responses of ecosystems to shifts in hydrologic regime related to velocity, renewal rate and timing (Table 7.1). Ecosystem parameters of species composition, primary productivity, material cycling and nutrient cycling are evaluated in light of potential alterations due to changes in hydrologic regime. This analysis highlights the interactive changes which take place during ecosystem alterations and illustrate the "interconnectedness" of ecosystem compartments.

Given the state of knowledge concerning wetland-wastewater systems, the following sections summarize and evaluate the types of changes that occur in wetlands used for wastewater disposal. Some changes can be objectively evaluated (e.g., public health impacts), whereas others are more subjective based on current knowledge (e.g., acceptability of species shifts).

Table 7.1. Wetland Ecosystem Responses to Various Hydrologic Factors.

Ecosystem Characteristics	Source	Hydrologic factors		
		Velocity	Renewal rate	Timing
Species composition and richness	o Nutrient overload may alter species diversity	o Affects distribution & deposition of sediments, influencing elevation and plant zonation o Species richness found to increase directly with velocity	o Provides vehicle for water movement and circulation o Uniform mixing leads to monospecific stands to vegetation o Diversity tends to increase with elevation, which is influenced by flooding duration & depth	
Primary productivity	o Affects availability of dissolved nutrients for plant growth o Sediment inflow increases substrate density, leading to more vigorous plant growth o Salts, pesticides and other toxins detrimental to productivity	o Increased velocity related to greater sediment input and increased plant growth o "Edge-effect"--stimulation of production along channels due to increased velocity o Affects flow and availability of toxins o Stagnant waters linked to anaerobic conditions and plant stress o Dissolved oxygen related to velocity	o Availability of water seems to control lateral spread of ombrotrophic bogs o Availability of nutrients for plant growth related to availability of water o Regular renewal of water in tidal areas minimizes salt accumulation and plant stress o Regular renewal supplies O_2, minimizing stressful anaerobic conditions; depth & duration of flooding most important	o Timing or seasonality of rain input may affect lateral and vertical spread of ombrotrophic bogs o Frequency of flooding influences availability of toxins to wetland flora and fauna
Organic deposition and flux		o Rate of total particulate and total organic export directly proportional to flow rate (and velocity)	o Increased flow rate related to greater silt input and organic matter outflow	o Flooding frequency directly related to silt input and organic matter outflow o Soil organic concentration increases on gradient from actively flooded stream banks to less actively flooded inland high marshes
Nutrient cycling	o Influences nutrient loading and acidity Ombrotrophic bogs--nutrient poor Minerotrophic bogs--nutrient rich		o Influences mass loading, transport and flux of nutrients	o Nutrient flux related to timing of flooding with respect to plant growth cycle.

Source: Chan et al., 1980

7.0 MANAGED WETLAND CONSIDERATIONS

7.1 Impacts to Natural Characteristics

7.1.1 Hydrology

THE EFFECTS OF WASTEWATER DISCHARGE TO A WETLAND ECOSYSTEM ON HYDROLOGY RELATE DIRECTLY AND INDIRECTLY TO BUFFERING

The addition of wastewater to wetlands increases surface storage and soil moisture content and decreases the wetland's ability to store excess rainfall. The addition of wastewater reduces infiltration capacity, and increases the probability of downstream flooding. If effluent is rich in nutrients, plant growth is likely to accelerate resulting in a reduction in total water input through increased canopy interception and evapotranspiration. Most effluent is likely to be stored as surface water; this can change plant species composition and distribution.

Naturally functioning wetlands provide water, maintain water quality and aid in flood prevention. When a wetland is altered through the addition of wastewater, a change in water input occurs which causes direct changes in the hydrologic regime of the wetland. This is clearly seen through an understanding of the hydrologic budget; when water inputs increase, a corresponding increase in outflow must occur. When wastewater is applied to a wetland ecosystem, surface storage increases, and the ability of the wetland to store excess rainfall decreases. Thus, downstream inundation resulting from an extreme rainfall event is more likely to occur.

Wastewater additions to wetland ecosystems also increases moisture content to those wetlands not permanently inundated. This reduces the downward movement of water through the soil surface resulting in a decrease in the infiltration capacity. Higher water table levels and greater moisture content prior to storm events increases downstream flooding probability.

Moderate applications of wastewater rich in nutrients usually accelerates plant growth. Increased wetland vegetation would retard surface water flows and reduce water inputs through canopy interception and evapotranspiration. Also, if the loading of wastewater is significant enough to increase discharge velocity, micronutrient availability to plants would increase.

Groundwater, surface area and soil pore space are the significant storage areas for water inputs to wetlands. Continuous wastewater addition would decrease the degree of seasonal fluctuations occurring in these storage reservoirs through uniform effluent application. Infiltration and percolation of effluent to groundwater areas depends on the physical components of the soil. Most effluent is likely to be stored as surface water. Significant increases in surface water force changes in plant species composition and distribution which, in turn, may affect wildlife species abundance and diversity.

7.0 MANAGED WETLAND CONSIDERATIONS
7.1 Impacts to Natural Characteristics
7.1.2 Vegetation

VEGETATION IMPACTS SHOULD BE MINIMAL, OCCURRING MOSTLY AS INCREASED PRODUCTIVITY

The impacts on vegetation in wetlands managed for wastewater disposal generally result in increased growth and biomass comparable to naturally productive systems. Species replacement may occur, and successional trends may be altered. Adverse effects have been found in wetlands receiving wastewater, but these are not always the result of domestic effluent inputs. Careful management is stressed to avoid adverse impacts.

The plant community in wetlands employed for wastewater disposal is affected by the management pattern in operation. A carefully administered wastewater plan can be expected to increase productivity and cause few perturbations in the vegetational community. The magnitude and severity of the effects of wastewater on wetland plant communities are dependent on the quality of the effluent, the amount of wastewater applied, the manner in which wastewater is applied, and the ability of the existing wetland ecosystem to assimilate wastewater.

The best documentation of impacts of wastewater on wetland vegetation is derived from the Florida wetland studies. Impacts were noted in the structure, productivity and biomass components of wetland vegetation. Differences in structural characteristics between cypress domes receiving sewage effluent and control domes were most easily detected in those compartments with short turnover times. For example, leaf biomass in the sewage dome was 1.4 times higher than in control domes. The total leaf area index was more than twice that in control area due to dense canopy (Lemna).

Comparisons of biomass, structure and productivity of domes receiving effluent and other natural systems were made by Brown (1981). She found the chlorophyll _a_ values for the sewage dome were similar to the values reported for floodplain forests, tropical rain forests (2.3 g/m2, Odom 1920) and a cove forest in the Smokey Mountains (2.2g/m2, Whittaker and Woodell 1969). The high overall chlorophyll _a_ in natural systems resulted from a combination of high leaf area index (LAI) and average leaf chlorophyll _a_ content. Conversely, the sewage dome achieved its high overall chlorophyll _a_ value as a result of an average LAI and high leaf chlorophyll _a_ content.

A marsh near Clermont, Florida, showed increased peak biomass in plants receiving wastewater over those that did not. The presence of standing water resulted in significant physical and chemical changes that affected plant growth. Extensive growth of algae and floating plants was noted. Some species, especially shorter grasses (Pancium sp.), declined in density from increased competition, thus altering community structure. The low availability of oxygen may have limited some plants. Emergent plants such as _Sagittaria_ spp. are not limited by this factor since they are capable of supplying oxygen to their roots through their vascular system. Micronutrients, phosphorus availability, and the generation of hydrogen sulfide (toxic to root metabolism) were other factors considered as important deterrents or stimulants to plant growth in this study. These factors are applicable in evaluating impacts to vegetation in other wetlands.

Wastewater was reported to increase the Typha and Lemna biomass approximately 30 percent at the effluent outfall in a Michigan marsh but changed succession patterns (Kadlec et al. 1980). Algae was abundant, but effects declined away from the outfall. Some species shifts were noted as Polygonium, Utricularia and Myriophyllum densities declined, possible outcompeted by Typha and Lemna. No effects on woody vegetation were detected in the short-term study.

Significant detrimental impacts on wetland vegetation receiving sewage effluents have been demonstrated in several instances. In a pilot project with sawgrass marshes having limited nutrient uptake ability (Stewart and Ornes 1975), the addition of wastewater severely upset the natural equilibrium of this marsh vegetation. Tree ring analysis showed depressed growth rates of cypress trees during the addition of raw and primary sewage to a hardwood swamp near Jasper, Florida, over a period of 20 years. Small trees and shrubs (red maple, Baccahris) replaced many dying cypress near the effluent outfall to this swamp, but the causes were not obvious. A petroleum spill, logging, toxic effects of raw sewage and hydroperiod alteration have been suggested as possible causes, but actual causes have not been determined. The cypress forest near Waldo, Florida, received primary effluent without apparent adverse effects for over 40 years, so causes other than normal effluent characteristics at Jasper are thought to contribute to the observed changes there.

An Andrews, South Carolina, gum-tupelo swamp receiving wastewater effluent has been reported to be severely damaged (J. Jones 1982). It has not been determined whether the sewage effluent directly affected the swamp. Indirect hydroperiod stress and catastrophic chemical discharge have also been suggested as causes.

A cypress swamp adjacent to Lake City, Florida, was receiving domestic effluent, but a large number of trees were reported as dead or dying. On a recent staff field trip to this site, local sources indicated that salts from a water softening agent were discharged into the swamp along with the effluent and was the suspected cause for the severe impacts on vegetation there. A hardwood swamp receiving effluent contiguous with Pottsburg Creek near Jacksonville, Florida, was reported to have a high number of tree crown kills. Winchester (1981) found that the distribution of tree kills in the swamp was unrelated to effluent discharge points in the swamps. It was suggested that hydroperiod alteration rather than effluent characteristics was the cause of vegetation impacts.

On a long-term basis, subtle effects have been difficult to detect in the sites studied, but several have been suggested on a generic level. Long-term maintenance of a vegetation community requires replacement of mature organisms. Concern has been expressed that a prolonged hydroperiod may prevent seed germination for cypress and perhaps other woody species. Changes in

7.1.2 Continued

water chemistry may influence successional trends. Monk (1966) suggested changes from low calcium, pH and water levels to high calcium, pH and water levels (similar to wastewater addition effects) will encourage shifts from evergreen to decidious vegetation dominants in Florida wetlands. The presence of wastewater also affects the rate of litter fall decomposition in wetlands (Deghi 1976), and the long-term effects on peat composition and accumulation are speculative. Other potential long-term impacts on vegetation include the effects of wastewater on the frequency and severity of fire in wetlands. Some wetlands are dependent on fire for maintaining their vegetation composition (Monk 1969, Richardson 1980, Ewel and Mitch 1980). Released from fire, vegetation species composition will undergo change in these wetlands, which may or may not experience adverse effects.

On a generic level, the diversity of vegetation in wetlands of Region IV makes the assurance of low impact from wastewater addition impossible. Quantitative data are also lacking on the impact of wastewater on many vegetation types within Region IV. Since vegetation is such an essential component of wetlands, impacts from wastewater additions should be minimized and carefully managed by controlling the quality and quantity of effluent introduced to wetlands. Figure 7.1.2 shows the type of changes that could be observed as a result of wastewater additions to wetlands.

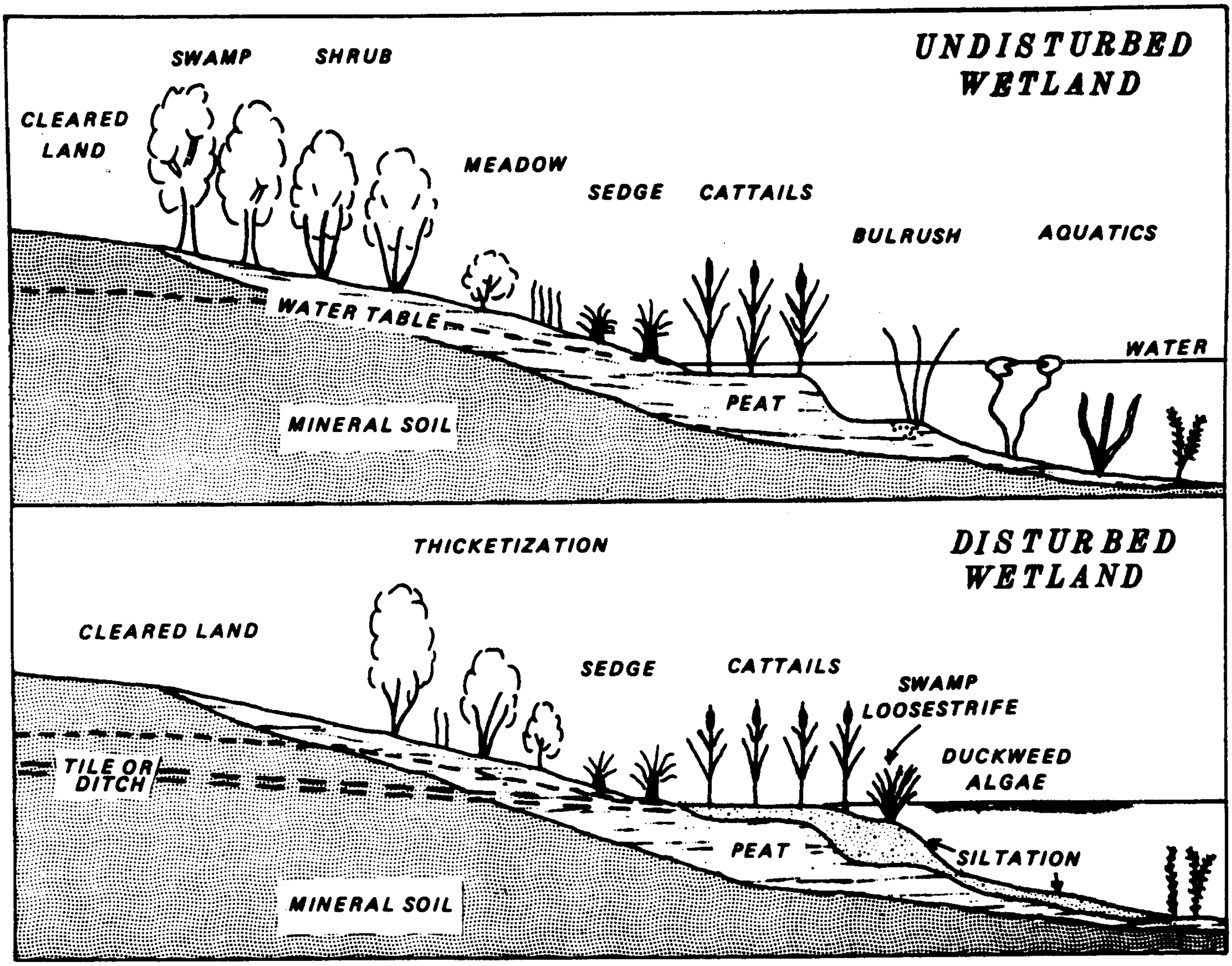


Figure 7.1.2. Potential modifications resulting from wetland management.

Source: Jaworiski and Raphael. 1978.

7.0 MANAGED WETLAND CONSIDERATIONS
7.1 Impacts to Natural Characteristics
7.1.3 Nutrients

NATURAL CHARACTERISTICS IMPORTANT IN DETERMINING NUTRIENT RETENTION

Removals of nitrogen and phosphorus reported for wetlands receiving wastewater has varied from site to site. The capacity to remove nitrogen is much greater than phosphorus due to the atmospheric escape of nitrogen and the excess of phosphorus in biological assimilation. Nitrate is more easily removed than ammonium. Accurate removal rates are difficult to assess due to lack of hydrologic information. Long term capacity seems promising at several sites, but should be evaluated on a case by case basis. Impacts to vegetation are not generally adverse. The abundance of some plant species may be altered.

The natural nutrient transformation processes (Section 4.4.4) enable many wetlands to satisfactorily assimilate and store increased levels of nutrients from wastewater sources. In wetlands managed for wastewater assimilation, conditions which maximize nitrogen and phosphorus removal are of primary concern. Minor elements may be of concern on a local basis.

Nitrogen and phosphorus in domestic wastewater is present in several organic and inorganic forms. The natural nitrogen to phosphorus ratio of approximately 10:1 is frequently much lower (1:1 to 2:1) in domestic wastewaters, causing an excess in phosphorus for biological assimilation. This ratio varies with source of sewage and level and efficiency of pretreatment. The impacts of nutrients are minimized by maintaining a high quality (low nutrient) effluent. In numerous circumstances (Sloey et al. 1975) wetlands have been shown to act as natural nutrient traps, some permanent, (domes, peat, etc.) and others on a seasonal or intermittent basis (tidal marshes, riverine swamps). The reported nutrient removal rates for those wetlands receiving sewage effluent reflects the expansion of the wetlands capacity to assimilate nutrients above the natural levels.

At Wildwood, Florida, (Boyt et al. 1977) reported an 89.5 and 98.1 percent reduction for total nitrogen and phosphorus respectively in domestic secondary sewage water, passing through a mixed hardwood swamp. At Waldo, Florida, primary effluent total posphorus concentrations were reduced 51 percent in surface waters leaving a cypress strand and 77 percent after passing through the soil profile into shallow groundwaters (Nessel 1978). A 69 percent reduction was reported for total nitrogen after secondary effluent passed through mixed hardwood strand near Jasper, Florida (Tushall 1980). Kohl and Mekin (1981) studied nutrient removal rates of a hardwater cypress swamp south of Orlando. Total nitrogen concentration was reduced 88.1 percent but no corresponding total phosphorus reduction was observed. The combination of the sandy soils and phosphorus-laden stormwater runoff were factors cited as preventing observable phosphorus-removal. At Clermont, Florida, experimental natural marsh plots receiving secondary sewage effluent reported 80 and 97 percent retention of total nitrogen and phosphorus as the water passed through the soil profile (Zoltec et al. 1979). Experimental chambers were located in the floodplain of a bottomland hardwood (cypress tupelo) swamp in North Carolina to determine the assimilative capacity of these systems for nitrogen and phosphorus (Brinson et al. 1981). These authors suggested that the capacity for nitrate (NO_3) form was much greater than the ammonia (NH_4+) form of nitrogen. The nitrate was rapidly lost through denitrification (see Section 4.4). Ammonia was accumulated until conditions for nitrification and subsequent denitrification were present (usually during summer drawdown). The rate of phosphorus accumulation was reported to be proportional to phosphorus loading. These authors suggested that the lack of an atmospheric pathway for phosphorus may limit the capacity of swamps for long term phosphorus assimilation and long term sewage application. However, increased particulate matter may provide long-term binding of phosphorus. In analyzing nutrient levels and nutrient reduction, dilution should not be confused with actual removal via nutrient removal pathways. Some of the literature may be misleading in this regard and should be properly interpreted.

The principal pathways by which nitrogen can be permanently removed from a wetland is by denitrification or by hydrologic export. Export through surface waters is a major loss for those wetlands with this capacity. Export through groundwater has the advantage of additional filtering and treatment. Because of the importance and sensitivity of conditions correct for denitrification, (see Section 4.4.4), the manipulation of water depths and oxygen conditions is essential to achieve good nitrogen removal via this pathway (Sloey et al. 1980). Other chemical processes which are important in nitrogen and phosphorus removal are co-precipitation and sorption reactions. These reactions are important in nitrogen and phosphorus retention in the soil profile. While the retention appears permanent for wetlands studied, exceptions have been noted (Stewart and Ornes 1975).

As noted in Section 4.4.4, phosphorus has no significant means of atmospheric loss and is highly dependent on physical-chemical reactions for removal. Biomass uptake is also a route for storage of nutrients. In swamps, the storage of nutrients in this compartment is larger than in marsh vegetation where biomass turns over on an annual basis (labile). Biomass storage may be extended for long periods of times, for example, when nutrients became stored in woody biomass. Excess phosphorus is stored in leaves of cypress and gum (Brain 1981) in swamps receiving sewage. Other wetlands may use roots as nutrient storage devices (Klopatek 1979). The leaf fall results in some phosphorus leached from the leaves and returned to the surface waters. The refractory constituents of litterfall continue to hold nitrogen and phosphorus and may eventually form a permanent storage as peat.

The fate of nutrients in wetlands is important in understanding the nutrient removal capacity. Sloey et al. (1978) have presented a diagrammatic representation of sources, rates of transfer and storage compartments of nutrients in wetlands receiving wastewater (see Figure 7.1.3). It is valuable in understanding the complexity of nutrient trapping and storage in wetlands.

7.1.3 Continued

In general, the addition of wastewater has resulted in increased levels and storages of nutrients in wetlands. The impact has been favorable for many wetland plants, however some species are replaced by those better adapted to higher nutrient and hydrologic loadings (Sloey et al. 1981). This loss of diversity may not be desirable in all circumstances, especially when valuable wildlife and rare and endangered species are involved (Section 4.6).

Concern has been expressed over the ultimate retention capacity for nutrient storage. Several long term studies have given conflicting results. The persistence of nitrite and unionized ammonia forms of nitrogen are also of concern due to their toxicity to fish (Kadlec 1978; Ruffier et al. 1981). Florida sites have demonstrated long term assimilation capacity for nitrogen and phosphorus (Nessel 1978, Tuschal 1981) but a California site displayed a reduction in phosphorus removal efficiency (Whigham and Bayley 1979). Because of the variability in wetlands, the nutrient retention capacity and associated impacts must be evaluated on a case by case basis. Salient factors important to this evaluation include hydrologic input and outputs, soil profile composition, and the vegetational characteristics of the wetland. The most limiting factors in evaluating the removal and retention capacities of wetlands are the availability of accurate hydrologic information for mass balance calculations and the long term prospects of nutrient retention. Nutrient retention is especially important upstream from lakes or reservoirs which might be sensitive to nutrient additions. However, in riverine systems this may not be as critical if impacts on downstream water bodies can be identified and assessed.

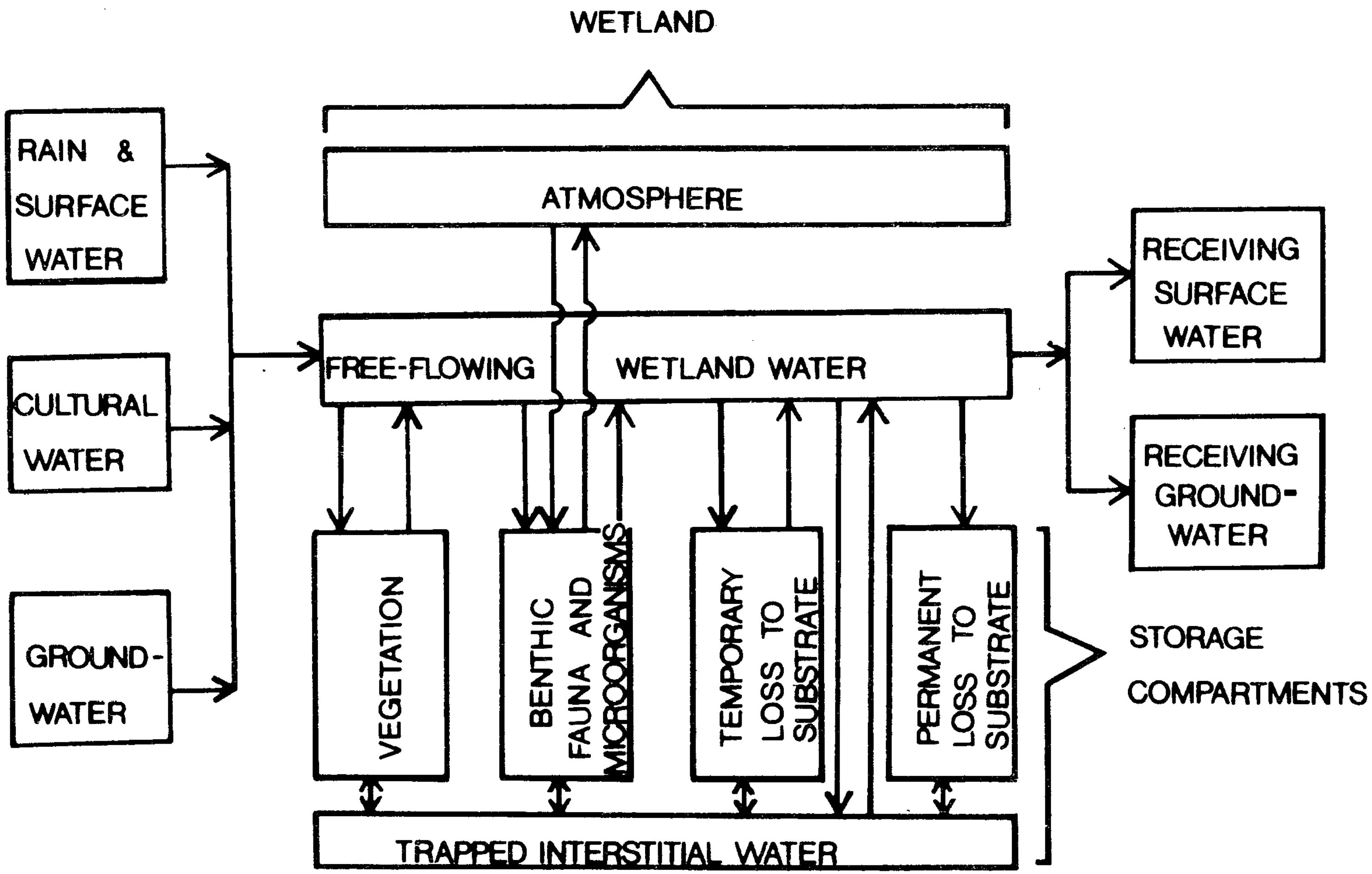


Figure 7.1.3. Representation of nutrient storages and flows in wetland ecosystems receiving wastewater ("cultural water").

Source: Sloey et al. 1978.

WASTEWATER DISPOSAL TO WETLANDS MAY HAVE ADVERSE AND BENEFICIAL EFFECTS ON WILDLIFE SPECIES

A complicated array of interrelated biological and chemical changes in natural wetlands subsequent to effluent disposal may force changes on the existing wildlife community. These changes are difficult to quantify but usually result from changes in the flow rate and water level and the structure and composition of vegetation. Alteration of the water and vegetation regime will determine the presence of other impacts. Water quality impacts to wildlife are usually determined by the degree of treatment prior to disposal. Inadequate treatment would reduce dissolved oxygen levels and increase the presence of toxic substances. These impacts may lead to a decrease in species richness through increases in the occurrence of wildlife diseases.

Potential changes in the wildlife community of a wetland ecosystem resulting from managed wastewater additions may occur from a complicated array of interrelated biological and chemical changes in the wetland. Most of these changes would be secondary, but several direct impacts may also occur. Potential wildlife impacts are difficult to quantify and evaluate completely because they usually involve dilatory shifts in natural wetland parameters. Specific studies are lacking in the southeast on the potential changes and impacts to wildlife from the addition of wastewater. In general, major wildlife impacts would result from changes in the following:

- flow rates and water level
- structure and composition of vegetation
- amount of edge
- availability of food

These changes are interrelated, and in many instances, the degree of one impact will determine the presence and degree of another. Changes in flow rates may change the types and densities of escape cover. Water level changes may force changes in the distribution and composition of plant species, and this could alter the horizontal and structural diversity of the wetland plant regime. Thus, changes in flow rates and water levels determine, in part, changes in structure and composition of vegetation and availability of food. Food availability alters the carrying capacity of a wetland; if this occurs, distinct changes in wildlife species composition are possible.

Changes in water quality after subsequent discharge of treated effluent may cause indirect changes in the wildlife community. Increases in nutrient levels can alter macroinvertebrate, algal and insect populations. Changes in pH and alkalinity may impact fish populations and plant species composition, distribution and biomass. Increased sedimentation may eliminate submerged

7.1.4 Continued

plants, and reduction in levels of dissolved oxygen may depress normal levels of algal and invertebrate populations. The above impacts could eventually lead to changes in species richness and species diversity through alterations in the quality and quantity of available food.

Wildlife impacts would also be controlled by the degree of wastewater treatment prior to disposal. Poorly treated effluent may be associated with heavy metals and viral or bacterial pathogens. Absorption of these constituents by plants and invertebrates may lead to bioaccumulation and increases in the occurrence of wildlife diseases.

In Region IV, few long-term studies have been conducted on wildlife impacts resulting from wetland disposal of treated effluent. Harris (1975) studied the effect of sewage effluent on wildlife species endemic to Florida cypress domes. Most benthic invertebrates, fish and juvenile amphibians were eliminated from a dome receiving effluent rich in organic material. Insects concentrated in the center of the dome, which increased the number of frogs present, but anaerobic conditions limited tadpole development. Several migrating passerine bird species increased drastically in numbers during the winter and spring because fly populations increased.

General estimates of the effects of wastewater discharge on wildlife may be inferred from studies outside Region IV. Kadlec (1979) reported no major shifts in species richness or species diversity at a Michigan lake treatment site after two years of wastewater discharge. Possible long term effects, however, could not be quantified. Studies on the beneficial and adverse effects of effluent discharge on wildlife populations and habitats of wetland ecosystems would prove helpful in assessing the long-term impacts of a wetlands discharge.

7.0 MANAGED WETLAND CONSIDERATIONS

7.1 Impacts to Natural Characteristics

7.1.5 Public Health Impacts

MECHANISMS TO REDUCE POTENTIAL PUBLIC HEALTH PROBLEMS EXIST BUT ARE NOT FAIL-SAFE

Although many types of wetlands remain unstudied in Region IV, studies from Florida suggest that wetland soils are excellent natural barriers against groundwater contamination. Surface waters adjoining wetlands receiving wastewater may acquire some contamination if detention time of treatment is not sufficient. Exotic diseases were not found to be amplified by wastewater addition to wetlands.

The public health implictions of wastewater recycling in wetlands have not been fully evaluated for all natural wetland types in Region IV. Potential adverse impacts include increasing the threat of waterborne disease (via surface or groundwater contamination) and increasing the incidence of insect-, bird-, or mammal-vectored diseases. Several Florida wetland types have been studied in this regard, and much current knowledge is derived from these studies. No study to date has been designed to provide direct epidemiological evidence on this subject.

A substantial reduction (90-99 percent) in bacteria (Fox and Alison 1978, Zoltec et al. 1979) and viruses (Scheuerman 1978) has been observed in wastewater passed through typical marsh (peat) and cypress dome soil profiles of peat, sand and clay mix. However, Sheuerman (1978) demonstrated that binding was not permanent, and viruses could be released from the soil profile under certain conditions. Wellings (1978) isolated viruses from a well at the same cypress dome experimental site, demonstrating that although the soil profile retained viruses and bacteria, it was not a fail-safe system.

Those wetlands receiving wastewater that interconnect with other bodies of water (lakes, streams, etc.) could potentially transmit bacteria and viruses. At the Jasper experimental site, fecal and total coliforms were exported at variable rates, depending on the detention time of the strand (Brezonik et al. 1981). Generally, the longer the detention time, the greater the sedimentation and die-off of coliform populations. Wells monitored at this site indicated a limited sphere of contamination extending vertically in the limestone surrounding the swamp, but groundwater supplies were basically protected (Brezonik et al. 1981).

Concern has been expressed over the possible amplification of the enzootic eastern equine encephalitis (EEE) vectors in swamps receiving sewage (Davis 1975). Possible increase in bird and mosquito populations associated with EEE was the basis for concern. Subsequent study (Davis 1978) of EEE vectors of mosquitos and sentinel birds demonstrated that EEE activity was not substantially greater in cypress domes receiving sewage than in natural domes. Although known EEE mosquito vectors (Culiseta melanura, Culex nigropalpus) increased, human nuisance mosquitos (Aedes infirmata, Aedes atlantica) declined due to elimination of habitat in this case. Mosquito populations elsewhere may react differently and concern has been expressed over the amplification of nuisance mosquito populations, but this has not been field verified.

Other public health aspects of wastewater discharges to wetlands remain uncharacterized. For exmple, the persistance of nitrite resulting in contamination of drinking water supplies presents potential toxicity problems, especially for infants (methemoglobomenia). Un-ionized ammonia compounds are directly toxic to fish and other creatures (Ruffier et al. 1981). The effects of adverse weather conditions (storm events, freezing, etc.) on treatment efficiency are unknown, and the long-term capability of soil layers to protect groundwater resources is not fully understood. While sufficient data exist to indicate the potential for public health problems arising from wetlands discharges, no incidences of disease resulting directly from such discharges have been identified.

LOWER COSTS ASSOCIATED WITH NATURAL WETLANDS

Artificial and natural wetlands are capable of providing cost-effective upgrading of domestic effluents. Artificial wetlands may have higher O&M costs but are more amenable to multiple-use management plans and handling industrial effluents. Natural wetlands have been reported to be more efficient at removing BOD but less efficient at removing nitrogen and phosphorus.

The utility of natural and artificial wetlands has been demonstrated in many instances as effective tools in upgrading the quality of domestic effluents. The overall advantage of one system over the other is dependent on many site specific variables and general treatment objectives. Traditionally, artificial wetlands are engineered systems designed to provide treatment of a variety of effluent types. In this regard, artificial systems generally provide for greater reliability and predictability of the treatment process and its products than are observed in natural systems.

Artificial and natural treatment alternatives are land-intensive compared to conventional treatment systems. Given a natural wetland of adequate size and reasonable proximity to a wastewater treatment plant, the artificial wetlands treatment system is generally more capital and energy intensive than a natural wetland of equivalent capacity. This, however, would depend greatly on the design of the artificial/aquaculture system and largely on its degree of mechanization. The O&M costs of artificial systems also tend to be higher; however, extensive environmental surveillance of natural wetlands used for wastewater may equalize these differences. This fact again highlights the site-specific nature on which these factors must be analyzed.

Artificial systems, in addition to possessing greater predictability, are reported (Table 7.1.2) to be more efficient in removing phosphorus, COD and nitrogen from wastewater than are natural wetlands. These ranges were derived from field data and illustrate the variability among and between artificial and natural systems. Slightly greater BOD removals were reported for natural than for artificial wetlands. The low phosphorus removal reported for both systems suggests that some type of pre-treatment for phosphorus may yield quantifiable benefits.

Artificial wetlands offer potential benefits of harvestable biomass for food or energy production. Forested natural wetlands receiving wastewater have also been cited for additional use in harvestable timber management plans. Natural wetlands have additional benefits of water conservation and greater embodied habitat and wildlife potential.

In the final analysis, site-specific factors and treatment objectives dictate the system most desirable for a specific area.

Table 7.1.6. Reported Removal Efficiency Ranges for the Constituents in Wastewater in Natural and Artificial Wetlands.

Constituent	Removal efficiency, %			
	Natural wetlands		Artificial wetlands	
	Primary	Secondary	Primary	Secondary
Total solids		40-75		
Dissolved solids		5-20		
Suspended solids		60-90		
BOD_5		70-96	50-90	
TOC		50-90		
COD		50-80	50-90	
Nitrogen (total as N)		40-90	30-98	
Phosphorus (total as P)		10-50	20-90	
Refractory organics				
Heavy metals[a]		20-100		
Pathogens				

[a]Removal efficiency varies with each metal.

Source: Tchobanoglous and Culp. 1980.

QUANTITATIVE ANALYSIS OF THE MAJOR WETLAND HYDROLOGIC PROCESSES IS DIFFICULT

Measurement of the major hydrologic inputs and outputs of a wetland ecosystem is difficult but necessary if proper effluent loading and assimilation rates are to be established. Precipitation measurement is difficult because of the extreme local and microscale variability of precipitation at ground level. The difficulty involved in measuring surface water relates to channel boundary determination and estimates of sheetflow. Measurement of groundwater resources is limited by financial concerns. Evapotranspiration is usually estimated as the difference between precipitation and discharge, thus introducing difficulties involved in estimating these parameters.

Quantitative measurement of water inputs and outputs in a wetland ecosystem is difficult because of the complexity of interrelated hydrologic processes and the difficulty involved in measurement itself. Climatic variations compound the situation, but monitoring of precipitation, surface water, groundwater and evapotranspiration would allow the assessment of effluent loading and assimilation rates for a wetland. A brief discussion of measurement techniques for these hydrologic and climatic processes is presented below.

Precipitation

The standard rain gauge is a cylindrical open topped vessel that modifies the windfield in its immediate vicinity, causing a deficiency in catch that increases with wind speed. The local and microscale variability of rain in wetland areas introduces a large degree of uncertainty with regard to aerial interpretations. Because of this, aerial weighting techniques such as the Thiessan and Isohyetal methods have been developed to take into account ground level variabilities associated with atmospheric and topographic influences.

Surface Water

Surface water inputs and outputs are usually computed in terms of volumes, depths or average flow rates for months, seasons and years. The flow rate in natural wetland channels may be described in terms of its stage and velocity. Stage and velocity data are used to determine discharge rate. Since the cross-sectional area of flow and the change in velocity across the stream segment in question are needed to develop flow rates, boundary determinations for the stream channel and catchment divide must be determined. Unfortunately, surface water runoff usually does not exit a wetland area through a single outlet, and sheetflow often results from intense storm events (Daniel 1981). Sheetflow inputs and outputs are difficult to measure; the Chezy-Manning equation has been modified for estimating sheetflow, but few published estimates of Manning's roughness coefficient exist for wetland ecosystems (Carter et al. 1978).

Groundwater

In most cases the measurement of groundwater inputs and outputs are limited by time and money. Observation wells are needed to establish potentiometric surfaces so directions of flows can be determined. A piezometer is the basic device used for the measurement of hydraulic head, and several piezometers are needed to determine hydraulic gradients. Once the hydraulic gradient has been estimated, Darcy's law is used to obtain specific discharge. The hydraulic conductivity (K) factor in Darcy's law is a function of the density and viscosity of water and the physical properties of the aquifer itself. Carter et al. (1978) lists several studies that have developed techniques for measuring hydraulic conductivities. By applying Darcy's law, standard techniques can be used to determine not only specific discharge but also porosity, specific yield and head.

A practical but precarious method of estimating groundwater inputs and outputs is to determine groundwater as the residual in the water budget equation. Unfortunately, all errors associated with measurement of other budget components accumulate and appear in final estimates of groundwater inputs or outputs.

Evapotranspiration

Evapotranspiration losses from wetlands cannot be measured directly but must be estimated as the residual in either water or energy budget equations by use of standard field techniques or by empirical methods such as those proposed by Thorwaithe and Mather and Penman. The determination of evapotranspiration as the residual in the energy or water budget equation is considered the most accurate estimate of total evaporation losses. Standard field techniques include National Weather Service Class A evaporation pans for determining evaporation from a free water surface. Lysimeters are used to measure normal evaporation from bare soil or evapotranspiration from vegetated areas. Wang and Heimburg (1976) estimated evapotranspiration from a cypress dome aquifer by analyzing groundwater level fluctuations. Brown (1981) measured total vaporization losses in three cypress domes in Alachua County, Florida by monitoring water vapor changes in plastic chambers enclosing plants in the dome system.

POSSIBLE MONITORING NEEDS AND METHODS ARE DESCRIBED

A monitoring effort can be limited to the discharge from the system, or it can include the wetland system itself. For each parameter to be monitored, sample timing, frequency, and location must be established.

In general, an owner of a wastewater treatment plant will monitor what the state environmental protection agency or the EPA require. Because wetlands are highly dynamic systems that are more complex and less understood than typical receiving waters, monitoring may need to be more intensive and extensive than for more conventional types of wastewater management systems. Considerations for a monitoring effort include parameters to be measured, timing and frequency of monitoring, and sampling locations. Quality control and the need for scientist and technician training are also important.

A key decision which needs to be made for each wetland wastewater system is whether the wetland system itself is to be monitored as part of the environment receiving wastewater or only the water released from a wetland. Monitoring activities can be based on viewing a wetland as a "black box", monitoring along transects or at specific locations, or monitoring at assorted locations as a function of time.

Items related to monitoring activities are the following:

- Parameters which could be measured: five-day BOD, total organic carbon, total suspended solids, various forms of nitrogen and phosphorus, chlorine residual, selected metals, selected organic compounds, and various biological indicators of health hazards (pathogens, coliforms, and other organisms).

- Effects of toxic substances would need to be measured in isolated conditions where all but one parameter can be controlled (EPA 1981).

- For invertebrate analyses, use of an indicator species is considered an effective method (EPA 1981).

- Concentration of metals within vegetation under natural conditions can not be utilized as indicators of metal uptake or treatment efficiency, because many variables affect metal uptake, such as climate and soil conditions, types of plants and availability of metals (EPA 1981).

- Monitoring of metals, particularly calcium, potassium, magnesium, zinc, iron, and manganese would allow the extent to which metals accumulate within the food chain to be measured. Both water column, sediment and plant material would need to be monitored. Such an effort would be best conducted by a university or a research institute.

7.2.2 Continued

- Chloride concentrations can be measured to indicate the dilution which wastewater has undergone.

- Sampling of water in monitoring wells along the perimeter of a wetland would help assess lateral percolation of wastewater constituents through the soil.

- 24-hour composite sampling is needed to establish mass balances through a system for any wastewater constituent of interest (O'Brien 1980).

- Non-wastewater hydrologic input and outputs should be evaluated in wetlands receiving wastewater. It can be done with simple rain gauges, and gauging stations. This is important to understanding the impact wastewater has on endemic hydrologic flows and may assist in indexing the assimilative capacity of the wetland.

- Monitor for adverse changes in the structure and function of vegetational community. The methods employed must be tailored to the dominant vegetation type (emergent, submergent, tree, shrub). Methods previously employed include aerial photography (especially infrared), harvest methods, litter fall estimates, gas exchange productivity chambers, and simple point-quarter counts.

- Detailed cycling should be monitored by litter bag studies, or sediment composition and accrual analyses.

- Use of sentinal birds to monitor for enzootic disease (encephalitis).

- Monitor nuisance insect populations for possible amplification of disease vectors,

- Establish and monitor control areas for appropriate parameters (vegetation, wildlife, sediments, chemical parameters).

Supplemental funding would be needed by a treatment plant owner to implement the more sophisticated monitoring activities if they prove to be necessary to properly assess and monitor a wetlands discharge. Selection of monitoring activities may vary for each wetland wastewater system. These issues will be addressed by Phase II.

FEW MODELS EXIST WHICH CAN BE USED EFFECTIVELY FOR ESTABLISHING EFFLUENT LIMITS

Existing wetland models have been developed for specific ecosystems and only simulate particular environmental processes applicable to certain geographic regions. Models have been developed to simulate ecosystem processes and impacts for cypress domes and bottomland hardwood swamps. Other wetland ecosystem models that integrate a wide range of wetland environmental parameters are needed.

The inherent difficulties involved in quantifying hydrologic processes associated with wetland ecosystems have resulted in few wetland models being developed. Existing models are simplified and can only be applied to specific wetland types. Carter et al. (1978) examined three approaches to hydrologic modeling and referenced pertinent studies. Whitlow and Harris (1974) reviewed modeling attempts to predict the impact of flooding on vegetation. The authors stated that few models are available for direct use in assessing the impacts of floods on woody vegetation because extensive empirical data on species tolerance and occurrence in the immediate locale is needed. Ecosystem processes and impacts have been modeled in detail for cypress domes in Florida.

Wang and Heimburg (1975) developed a water budget model for Florida cypress domes, calibrated for two different years and for three different domes. Layland (1975) simulated the major ecosystem interactions between cypress swamps and watersheds based on a conceptual energy model developed by H. T. Odum (1971). Auclair (1975) has developed a model that simulates the fate and effects of total phosphorus levels in natural and effluent-treated cypress domes.

Similar models have been developed for bottomland hardwood ecosystems. MacCullum (1980) developed a dynamic mathematical model of the zone of aeration for bottomland hardwood swamps describing the vertical distribution of water available for vegetation use. A forest simulation model (swamp) developed by Phipps (1979) simulates the effect of flood frequency and depth to water table on floodplain forest vegetation dynamics. Franz and Bazzaz (1977) constructed a similar model that describes the distribution of bottomland vegetation as a function of flood-stage probability to predict changes in species distribution resulting from stream impoundment. Hopkinson and Day (1980) have modeled hydrology and eutrophication processes in a Louisiana swamp forest.

Few models developed for specific wetland types can be modified and adapted for use in other ecosystems. Gupta (1977) developed a broad model applicable to many wetland ecosystems that explores the response of ecosystem physical parameters to a planned wastewater addition. The model keeps track of inputs and outputs over time for a particular ecosystem, thus developing general trends that can be expected for certain changes in inputs such as

7.3.1 Continued

wastewater loading rates. Mitsch et al. (1982) provides the most recent review of models of freshwater wetlands in North America. These models generally cannot be utilized to assess loadings to wetlands or impacts from discharges. Therefore, basing NPDES Permits on modeling is probably not appropriate for wetlands based on current knowledge and models.

NO STATE USES A SPECIFIC WETLAND MODEL FOR DETERMINING EFFLUENT LIMITATIONS

North Carolina and Tennessee have modeled wetlands for wasteload allocations using a modified form of the Streeter Phelps model. South Carolina has modeled swamps using a standard water quality model developed by the Texas Water Quality Board. The remaining states have not modeled wetlands as part of any permit application program.

Most states in Region IV use various water quality models to aid in issuing NPDES permits and establishing effluent limitations. The models are generally used to estimate the assimilative capacity of a water body and the maximum wasteload allocation. Water quality models are designed to apply to streams or rivers where flow is one dimensional; only advective transport is simulated and steady state conditions are assumed. Wetlands in general do not have these characteristics, but the lack of specific models applicable to wetland ecosystems and the absence of a sound wetlands data base have forced most states to either use stream models or make qualitative evaluations.

Inherent problems with modeling wetland systems are related to topography and life cycle changes. In order to properly model an aquatic system, flow paths need to be defineable; flat topography and lack of defined channels allow flow paths to vary easily from day to day and from season to season. In addition, biochemical roles of life forms vary with life cycles. Steady-state conditions are rarely observed.

Florida

No wetland modeling has been conducted by Florida as part of an effort to establish effluent limitations.

Georgia

Georgia uses a modified version of the DOSAG model developed by the Texas Water Quality Board. The model is applicable to unbranched river segments and has not been used for wetland analyses.

Kentucky

The State of Kentucky has developed a general broad-based dissolved oxygen model to be used for setting permit limitations for wetland ecosystems as well as other water bodies. The model has not been used to date because no permit applications or issuances for wastewater discharges to wetlands exist.

7.3.2 Continued

Mississippi

Mississippi State University has developed a Standard Water Quality Model called AWFRESH for determining effluent limitations for streams where little or no field data are available. Bayous with and without flow are not modeled, but a qualitative judgment is made concerning the effect of an anticipated discharge on water quality.

North Carolina

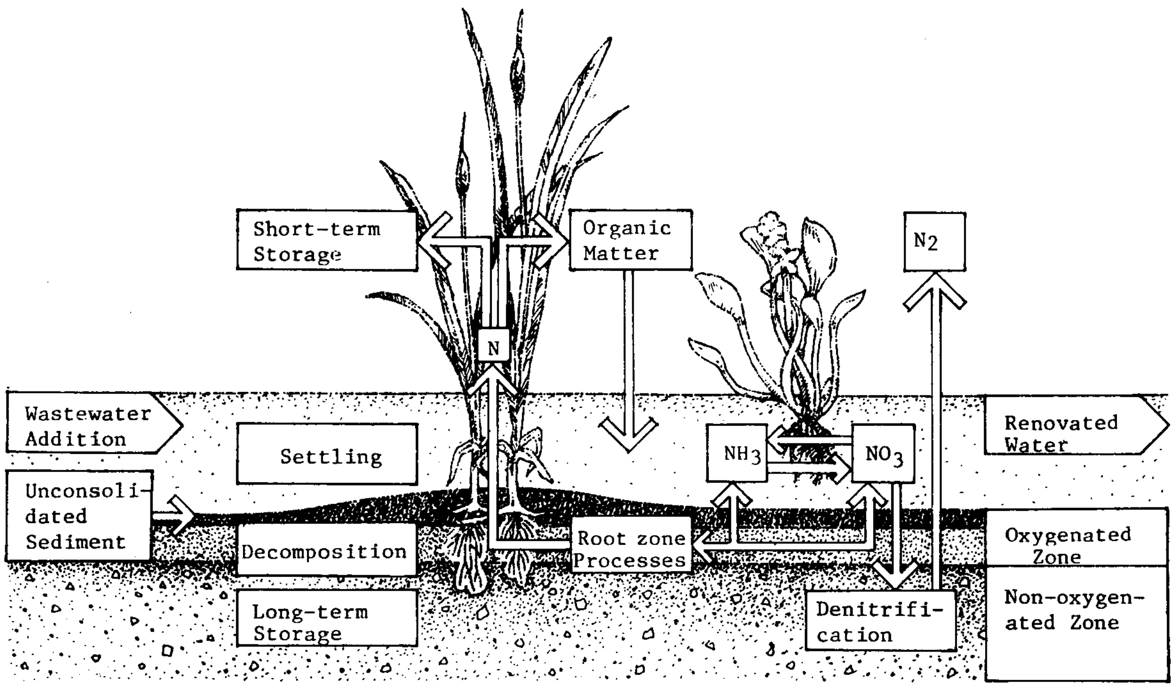
A modified form of the Streeter Phelps model is used to determine effluent limits for wetland ecosystems in North Carolina.

South Carolina

South Carolina models swamps that have definable channel geometry and obvious flow using DOSAG II, a standard water quality model developed by the Texas Water Quality Board.

Tennessee

Tennessee does not differentiate between wetlands and stream discharges. Because of this, a modified form of the Streeter Phelps model is used to establish limits for these water bodies. For wetlands where little or no flow exists, a lake model similar to that developed by Chen and Orlob is used.



SECTION 8

RANGE OF KEY FACTORS

8.0 RANGE OF KEY TECHNICAL FACTORS

ENVIRONMENTAL FACTORS ARE EQUALLY IMPORTANT AS ENGINEERING FACTORS IN EVALUATING WETLANDS WASTEWATER DISCHARGE

The key technical factors which must be evaluated include traditional engineering considerations and nontraditional environmental and management evaluations.

The key factors identified in this section reflect technical areas of importance which must be evaluated by decision makers involved in the design, operation, monitoring or permitting of wastewater discharges to wetland areas. The unusual nature and great potential of the wetlands-wastewater interface demands unique sets of design, operation, and permitting criteria. In addition to the traditional engineering criteria (unit processes, nutrient loading, hydrologic loading, BOD, SS, etc.) wetlands receiving wastewater require a different approach to operational and environmental management considerations.

The key criteria traditionally involved with an engineering assessment of wastewater disposal are summarized in Section 8.1. Included in that discussion are ranges of observed values which have been noticed in wetlands receiving wastewater.

The key environmental/managerial factors that determine the feasibility of a wetlands-wastewater discharge are presented in Section 8.2. These environmental criteria, because of the uniqueness of wetland systems, must be evaluated equally with the traditional engineering considerations. The environmental/managerial criteria take into consideration the assimilative capacity of the wetland and the potential environmental costs of wastewater application to wetlands.

From an implementability standpoint, the use of a wetland site for the disposal of wastewater can be declared unfeasible if these key engineering environmental criteria are not satisfied. A wetland site may also be undesirable for use as a wastewater management option if one of the many factors discussed in this report are not satisfied. These key technical factors are put forth as the most likely limiting factors in the implementability of a particular wetlands-wastewater disposal system.

Issues of Interest

- Can reliable design criteria for wetland-wastewater systems be based on existing information?
- Can engineering design overcome the limitations of particular wetlands?
- What are the most important factors that should be considered during design?
- What conditions preclude the use of a wetland from any wastewater discharges?

8.0 RANGE OF KEY TECHNICAL FACTORS

8.1 Key Engineering Considerations

HYDRAULIC LOADING AND DETENTION TIME REQUIREMENTS
ARE KEY ENGINEERING CRITERIA

The key engineering considerations involved with discharges to wetlands focus on hydrologic elements, nutrients and other water quality parameters. The feasibility of wetlands utilization for alternative wastewater management schemes is dependent on these key engineering factors.

A multitude of engineering considerations are involved in the planning, design and operation of any wastewater management system. Factors such as facilities planning and preliminary design, detailed design, installation and operation and maintenance, have been discussed in Sections 6 and 7. Completion of each of these engineering tasks is necessary to implement a wastewater management plan. Wetlands systems incorporated into wastewater management plans are subject to these and other constraints.

Hydrologic factors are key considerations in determining pollutant removal efficiencies. The relationship of important hydrologic parameters to several pollutant removal mechanisms known to occur in wetlands is presented in Table 8.1. This summary demonstrates the importance of hydrology to pollutant removal and the complexity of the processes involved. The importance of interdependence of hydrology, water quality and ongoing ecosystem processes are also highlighted by the information provided in Table 8.1.

The hydrologic loading rate of wastewater to wetlands is one of the key engineering factors for a particular wetlands discharge. The hydrologic loading rates for several wetlands are presented in Section 8.1.1 and are intended to serve as guidelines for what has been observed or proposed for each wetland system discussed. The observed values are based on a limited number of field investigations and are not intended to be applicable to all wetland systems. Water quality considerations such as nutrient loadings, BOD, pH and dissolved oxygen are of primary importance and influence engineering considerations. Their specific limits and influences on wetlands receiving wastewater are presented in Section 8.1.2.

Table 8.1. Relationship of Hydrologic Factors to Pollutant Removal in Wetlands.

Hydrologic factors	Major pollutant removal mechanisms			
	Sedimentation	Aeration	Biochemical transformations	Sediment/Soil adsorption
Circulation and flow distribution (cont'd)	Beaver dams beneficial in dispersing flow over meadowlands to enhance sedimentation and filtration. Circuitous flow paths and sheet flow lead to large settling areas and good sedimentation.	Internal circulation important in distributing O_2 from surplus to deficit areas	Broad flow distribution leads to large effective areas for biological contact and high removal rates.	Soil-water interface essential as major site of sorption, deactivation and denitrification.
Turbulence and wave action		Reaeration a function of channel roughness. Wind can be important in keeping localized parts of wetland water aerated and mixed.		
Seasonal and climatic factors	Most dramatic sediment reductions associated with storm episodes in meadowlands--more even flow distribution over wetland.	Pond and pond-like areas nearly depleted of DO in summer and supersaturated in winter and spring. Nitrifying and denitrifying bacteria limited in activity during drought or low water temperatures.	Freezing promotes release of N and P from plants and soils for subsequent washout. Spring snow melt appears to have flushing effect on nutrients. Best plant uptake of nutrients in spring-summer growth period. First flush of wet season may wash out decaying organic matter from prior winter. Temperate systems experience winter release of nutrients. Seasonal rainfall and runoff important as diluting agent and to encourage water circulation.	
Soil saturation		Lowering of water table leads to aeration, mineralization and greater mobilization of N. G.W. table within 5-10 cm of wetland surface promotes anaerobic (reducing) conditions.	Level of soil saturation controls microbial activity. Higher respiratory activity and biological decomposition with well drained soil conditions.	

Table 8.1. Continued

Hydrologic factors	Major pollutant removal mechanisms			
	Sedimentation	Aeration	Biochemical transformations	Sediment/Soil adsorption
Soil saturation (cont'd)		Lowering of water table allows aeration and decomposition of organic matter and slug release of nutrients in next flush of runoff.		
Permeability and groundwater movement			Source and amount of g.w. inflow influences pH and resultant solubility and precipitation reactions.	Seepage wetlands may act similarly to flood-irrigation forage grass systems in virtual completeness of P removal. Nitrogen removal through nitrification/denitrification may be excellent in surface soils and shallow seepage zone.

Source: Chan et al. 1981.

8.0 RANGE OF KEY TECHNICAL FACTORS
8.1 Key Engineering Considerations
8.1.1 Hydrologic Parameters

HYDRAULIC LOADING AND GROUNDWATER RECHARGE ARE KEY HYDROLOGIC PARAMETERS

Hydraulic loading rates and the extent of groundwater recharge are identified as key hydrologic parameters which affect wetland utilization. The importance of adequate detention time and maintenance of acceptable water depths are also stressed for optimum treatment and for minimizing adverse environmental impacts.

The hydrologic loading rate is a key engineering consideration in the design of artificial or natural wetlands-wastewater management systems. This study has shown that although many wetlands within Region IV are unintentionally or intentionally part of a wastewater management strategy (see Section 2.2.3), few have been studied in this most important regard. Appropriate hydrologic loadings are dependent on endemic hydrologic patterns, soils and the extent to which changes in wetlands ecosystems are acceptable. Ranges of observed loading rates for several natural and artificial wetlands are presented in Table 8.1.1. Hydrologic loading rates for hydrologically isolated natural wetland systems ranged from less then 1 to 13 cm/wk. Hydrologically open, natural wetland systems had a similar range of observed loading rates. The data base for this table is from Florida studies and may not apply to similar systems in other states on a year-round basis. The diversity of wetland types also requires that great care be used in applying these observed values to any wetland system. These hydrologic loadings have been expressed on a cm/wk basis. The loading rates for hydrologically isolated systems give a slight indication that they have a lesser loading capacity on an areal unit basis than the generally larger, hydrologically open systems. This raises the question of the relationship between per unit capacity and catchment basin size which has not yet been resolved.

Water depths may become a limiting factor if existing vegetation in natural systems is not adapted to extensive and deep flooding. Cypress and gum are naturally adapted for the deepest areas but rarely tolerate depths of >2m for prolonged periods. Consistent depths of >1m may limit some wetland types for long-term application since seeds from some endemic species (cypress) will not germinate and survive in deep water. Marsh applications may be limited by depth of flooding that exceeds the range of flooding to which they are adapted. Greater than usual depths may also limit diffusion of metabolites and gases which tend to exacerbate the physiological problems created by flooding (see Section 7.1). Many wetland communities are adapted to cyclic flooding (bottomland hardwoods, other riverine wetlands especially). Cyclic applications of wastewater may be a more successful application methodology to avoid the stress created by maintaining consistent water depths. Fritz and Helle (1979) suggested that sheetflow (versus channelized flow) should be maintained in wetland strand systems to improve efficiency of treatment.

8.1.1 Continued

Detention time is difficult to quantify in many wetland systems. Removal efficiencies decline in hardwood and cypress strands when high hydraulic loadings wash out nutrients before they can be assimilated or otherwise removed. Considering detention time as a flood duration factor, some wetlands may be excluded because they are strictly adapted to infrequent flooding and tolerate standing water for only short durations (bottomland hardwoods for example). Sloey et al. (1978) indicate that palustrine wetlands (nontidal wetlands not confined by channels and not marginal to lakes) are more amenable to management for wastewater treatment than are other major wetlands (tidal, riverine, lacustrine) because palustrine wetlands are hydraulically isolated from open surface water, and hydraulic residence times are high. Fritz and Helle (1979) determined that a cypress strand receiving secondary effluent near Jasper, Florida, has detention times ranging from 4 to 64 days with an average of 32 days. Treatment efficiencies were quite variable as a result. Their ultimate recommendation was that detention time in a wetland should average 30 days with a path length of discharge of 1500 feet, or any combination which results in a detention time sufficient to convert most of the nitrogen to nitrate form.

Soils are another key engineering consideration. Sutherland and Bevis (1979) suggested that hydraulic conductivities of 10^{-4} to 10^{-5} cm/sec would be desirable for wetlands receiving wastewater. They felt that this rate of percolation would provide adequate detention time for the trapping and degradation of wastewater constituents.

On a physical-chemical basis, underlying clay mineral soil layers have a greater capacity to adsorb and retain nutrients and pathogenic microorganisms than do organic soils. This characteristic is important in protecting groundwater supplies from contamination and relates to the geologic history of the area. Conversely, highly organic soils in wetlands indicate that organic matter is accumulating due to certain biological and hydrological conditions. These systems seem to be more amenable to increased nutrient uptake and long-term storage in biomass than those wetlands with strictly coarse mineral alluvial soils.

Addition of wastewater to wetlands includes suspended solids (SS) load. The SS load varies according to efficiency of pre-treatment. Where the long-term addition of wastewater has taken place, unconsolidated sediments unlike those found in natural areas have been reported (Winchester 1981). These sediments have been formed because the accumulation of SS exceeded the rate of degradation and export. The SS load may influence benthic plant communities and filtration capacities (Boto and Patrick 1978). Limits to accumulation have not been determined. This build-up is more likely to be a long-term than a short-term consideration, unless accumulation is excessive in the short-term.

Aquaculture (hyacinth) systems

The hydraulic loading rates in aquaculture systems are limited by the uptake rate of the plants involved and the containment basin characteristics. The most efficient plant tested has been the water hyacinth (*Eichhornia* sp.)

Table 8.1.1. Hydrologic Loading in Artificial and Natural Wetland Systems.

System	Range of Observed Values cm/wk	Observations[1]
Hydrologically Open Wetlands		
Strand-Mixed Hardwoods	0.11 - 9.81	Wide range of observed loading; system performance limits not exceeded by these rates, site specific factors important
Strand-Cypress	2.3 - 13.0	Wide range of rates also observed, site specific factors important
Marsh	1.5 - 9.6	Studies indicated "slight" changes occurred at observed rates
Hydrologically Isolated Wetlands		
Cypress Dome	1 - 13.7	This range has shown minimal impact at this level; greater rates could be possible with larger domes
Pocosins	2.3 - 2.4	Rational design criteria projected for pocosin-wastewater system developed by CH_2M Hill
Artificial Wetlands		
Aquaculture	0.037-13.0	This loading minimizes odor problems associated with higher loadings

[1]Observations derived from recent wetlands research concerning wastewater management.

Source: Claude Terry & Associates, Inc. 1982.

8.1.1 Continued

and the majority of the data presented has been generated from hyacinth systems. Loading rates of 240 to 3,570 m^3/ha-day are reported for these systems in the literature. For artificial systems receiving untreated effluent, loadings have ranged from 240 to 680 m^3/ha-day. Loading rates considered as "reasonable" from field tests are presented in Table 8.1.1. Few studies exist with nutrient removal as the principal objective. Middlebrooks (1980) estimates that 500 m^3/ha-day or less of secondary effluent should provide effluent with ≤ 2 mg/l of total nitrogen and 50 percent phosphorus reduction.

Most investigators recommend water depths of 0.9 meter or less. The objective is to provide shallow depth so the suspended hyacinth roots can penetrate through most of the water. Depths of 0.4 meter assure complete wastewater contact with the root system.

Only one study has actually measured detention time utilizing dye releases. Ratios of actual to theoretical detention times were reported to be approximately 0.75 for long, narrow channels and 0.5 or less for more circular basins and systems adapted to water hyacinths. The values for detention times shown on Table 8.1.2-e.

INFORMATION ON OBSERVED RANGES OF SHORT TERM NUTRIENT LOADINGS AVAILABLE FOR SOME WETLANDS; INFORMATION ON OTHER WATER QUALITY PARAMETERS SPARSE

A wide range of nutrient loadings has been reported for natural wetlands along with one case of unacceptable loading rate. Phosphorus presents a greater limitation than does nitrogen (especially in the nitrate form). Guidelines for DO, BOD and metals inputs are not well developed. Temperature is an important consideration in biological treatment processes. Hyacinth aquaculture is capable of assimilating large quantities of TN and TP but allowable metal and toxicant uptake is restricted in those systems coupled with feed or energy production.

Natural Systems

Ranges for total nitrogen loading in cypress and mixed hardwood strands have been reported from 0.004-0.36 kg/ha•day. Ranges of total phosphorus have varied from 0.01-0.04 kg/ha•day. Cypress domes receiving 0.07 total nitrogen (TN) and 0.05 total phosphorus (TP) kg/ha•day have been documented without apparent adverse effects. A marsh receiving up to 0.31 TN and 0.17 TP kg/ha•day for two years was also not significantly disturbed. However, Steward and Ornes (1975) reported that a marsh receiving 0.06 TP kg/ha•day was significantly disturbed. These authors suggested that this marsh was adapted to low nutrient conditions and was incapable of assimilating highly elevated levels of phosphorus. In Table 8.1.2-a a range of observed TP and TN loadings for natural and artificial systems are presented. The effect of P-loading on P-removal is presented in Figure 8.1.2-a.

Metals may be removed by precipitation, absorption, and plant uptake in natural systems. These limits, however, are not well described. The dangers of bioaccumulation and biomagnification should be recognized when metal or toxicants are introduced into wetlands. The great number of toxic compounds in the environment permit few generalizations with regard to their limiting effects in wetlands application of wastewater. The effects, distribution and degradation of toxic compounds in wetlands is best dealt with on a case-by-case basis. The information provided in Table 8.1.2-c indicates the heavy metal uptake potential of several common wetland plants. Artificial wetlands may be used to remove metals from solution (Table 8.1.2-d).

The pH of most domestic wastewater is well buffered near neutral pH (7.0). Most wetlands have a lower, more acidic pH (3.5-5.5). Concern has been expressed regarding the alteration of this endemic pH, especially with acidophilus plants. Christianson et al. (1978) expressed concern over *Sphagnum* sp. and their potential elimination resulting from pH alteration.

Table 8 1.2-a. Nutrient Loading in Artificial and Natural Wetland Systems.

System	Range of Observed Values kg/ha·day		Observations
	TP	TN	
Hydrologically Open Wetlands			
Strand-Mixed Hardwoods	0.01-0.04	.004-0.07	No gross changes noted in systems receiving these levels
Strand-Cypress	0.02-0.03	0.36	No gross changes noted in systems receiving these levels
Marsh-Organic	0.06-0.17	0.31	"Slight" changes at observed levels
Marsh-Mineral	0.06	-	Observed value caused apparent harm; recommend order of magnitude safety factor or improve management of application
Hydrologically Isolated Wetlands			
Cypress Dome	0.05	0.07	Small changes at observed levels
Pocosins	-	0.05	Proposed in CH_2M Hill study
Artificial Wetlands			
Hyacinths	0.5-3.03	0.15-0.79	High rate potential; proposed range depends on management objective; facilities plan

Source: Claude Terry & Associates, Inc. 1982.

Table 8.1.2.b. Summary of Nutrient Loading Rates Applied to Water Hyacinths Wastewater Treatment Systems.

Location	Organic Loading Rate	Nutrient Loading Rates to First Unit		Percent Nutrient Removal		Comments
	kg BOD_5/ha.day	kg TN/ha.day	kg TP/ha.day	TN	TP	
Williamson Creek,TX						
Phase I (109 m^3/d)	43	15.3	-	70	-	Single Basin, surface area = 0.0585 ha
Phase II (109 m^3/d)	89	18.5	-	64	-	Single Basin, surface area = 0.0585 ha
Coral Springs, FL	31	19.5	4.8	96	67	Five Basins in Series Total surface area = 0.52 ha
National Space Technology Labs	26	2.9	0.9	72	57	Single Basin Receiving Raw Wastewater, surface area = 2 ha

Source: Middlebrooks 1980.

Table 8.1.2-c. Typical Concentrations of Metals in Aquatic Plants Grown in Metals Contaminated Environments.

Plant	Metals Concentrations (ppm of dry wt.)					
	Cd	Pb	Cr	Cu	Ni	Zn
Water hyacinth	10	45	12	48	15	50
Duckweed	17	120	65	79	26	110
Cattail	-	9	8	37	8	30
Bulrush	--	--	12	7	5	50

Source: Stowell et al. 1980

Table 8.1.2-d. Influent and Effluent Concentrations of Metals from a Cattail Marsh Receiving Comminuted Wastewater with 15 Days Residence Time.

Metal	Influent (mg/l)	Effluent (mg/l)
Zn	1.3	0.2
Cr	0.05	0.01
Cu	0.07	0.03

Source: Stowell et al. 1980.

Table 8.1.2-e. Documented Values or Ranges for Various Key Factors for Aquaculture Systems.

Key Factor	Aquaculture (Hyacinth) Systems: Receiving Untreated[1] Primary, or Lagoon Effluent	Receiving Secondary Effluent
Hydraulic loading, cm per week or or m^3/ha/day	- 200 or less (Middlebrooks)	0.8 (Bouter: Coral Springs, FL) 2,000 or less (Middlebrooks)
Water depth, meters	1.2 to 1.8 (3 Mississippi systems)	0.4 (2 Florida systems)
Wastewater detention time, days (calculated)	50 or more (2 MS systems)	6 or more (Coral Springs, FL)
Maximum basin size, ha	0.4 (Dinges 1979)	0.4 (Dinges 1979)
# basins	-	3 in series
Costs	-	$165,000 construction cost for 0.1 mgd system (Bowker 1982)
Temperature, °C	28 to 30 C for maximum productivity (O'Brien 1980)	
BOD_5 loadings, kg/ha/day	30 or less (Middlebrooks)	-
Evapotranspiration losses	3.2 to 5.7 times greater than for open water (O'Brien 1980)	
Hydraulic loading, cm per week	0.33-1.0	0.037-13
or m^3/ha/day	-	100 or less[2]
Wastewater detention time via surface streams, days	-	30 or more[3]

Middlebrooks. 1980.

[1]Two MS systems receive untreated effluent with five-day BOD concentrations of 90 to 160 mg/l.
[2]Hydraulic loadings of 500 m^3/ha-day or less of sec. effl. are estimated to be needed to obtain TN <2 mg/l (Middlebrooks 1980).
[3]For flow-through cypress domes in Florida (Boyle Engr. Corp. 1981). The range for detention time in the Jasper, FL system is reported to be from 4 to over 60 days depending upon storm events.

8.1.2 Continued

The effects of pH alteration on wetlands are not well documented. Extreme pH elevations (>9.0) outside the natural range (3.5-8.0) are expected to have impacts on nutrient availability and result in potentially harmful effects on invertebrates and fish. These impacts would be highly species-specific. High salt contents in effluents have been suspected of causing severe disturbances in at least two freshwater wetlands, but critical concentrations and other documentation are not yet available.

The dissolved oxygen regime may interfere with degradation and respiration processes in sediments; however, no adverse effects have been reported for wetlands. The DO levels vary diurnally and seasonally ranging from <1.0 to supersaturation. Many wetland components are adapted to low and periodically anoxic (no D.O.) regimes. The magnitude of DO fluctuation is expected to increase with wastewater addition, but its effects are unknown.

A Florida cypress dome receiving secondary sewage tolerated short-term values of 25 mg/l of BOD without appreciable harm. Control domes averaged 5 mg/l BOD. The limits and effects of BOD loadings in wetlands within Region IV is not well documented. Stowell et al. (1980) studied the relationship between BOD loading and BOD removal in natural and artificial wetlands. From their studies (Figures 8.1.2-b,c,d), it appears that greater than 50 percent removal can be anticipated from the use of some wetland systems.

Wetlands modify local climatic factors (Gannon et al. 1979), and the effects of wastewater addition to this wetland function are unknown. Seasonal fluctuations may limit the temperature-dependent wastewater renovation processes in wetlands. For those wetlands in the northern sections of Region IV, essential biological processes are slowed down in the winter, resulting in build-up of nitrites and lowering denitrification rates. Microbial respiration, important in the breakdown of organic matter, is impeded. Nutrient uptake by plants as a removal mechanism in winter is slowed down or eliminated. In southern sections of Region IV, duckweed is important in nutrient cycling during the winter when trees, shrubs and grasses are respiring at low rates. Temperature also affects chemical processes of nutrient removal (precipitation, absorption)/ The limits to the seasonality of wastewater renovation by wetlands in Region IV have not been documented but may be limited in some areas to warmer months. Higher water levels can affect temperature moderation in marshes that may protect vegetation from marginal freezes or droughts.

<u>Aquaculture</u>

Hyacinths can thrive in municipal wastewater and in mixtures of certain industrial and municipal effluents. See Table 8.1.2-b and c for nutrient loading rates and removal efficiencies reported in the literature. Removal of nutrients/metals/toxic organics is obtainable, but such removal can be a disadvantage if the hyacinths are to be utilized for feed or energy production. Some data are available concerning metals associated with aquaculture systems (Table 8.1.2-c,d) but conclusive statements are not yet available regarding removal efficiencies.

8.1.2 Continued

Two Mississippi systems accepting untreated wastewater (influent five-day BOD of 90 to 160 mg/l) have been utilizing loading rates of 26 and 44 kg/ha-day, respectively. The system operating at 26 kg/ha-day reportedly operated without significant odors whereas the system operating at 44 kg/ha-day developed odors at night. Loading rates for systems receiving secondary effluent range from 31 to 197 kg/ha-day. Only two such systems have provided significant amounts of data.

Hyacinth aquaculture operates at maximum efficiency between 28-30°C (see Table 8.1.1-e). The use of plants with lower temperature optima should be investigated in northern areas of Region IV.

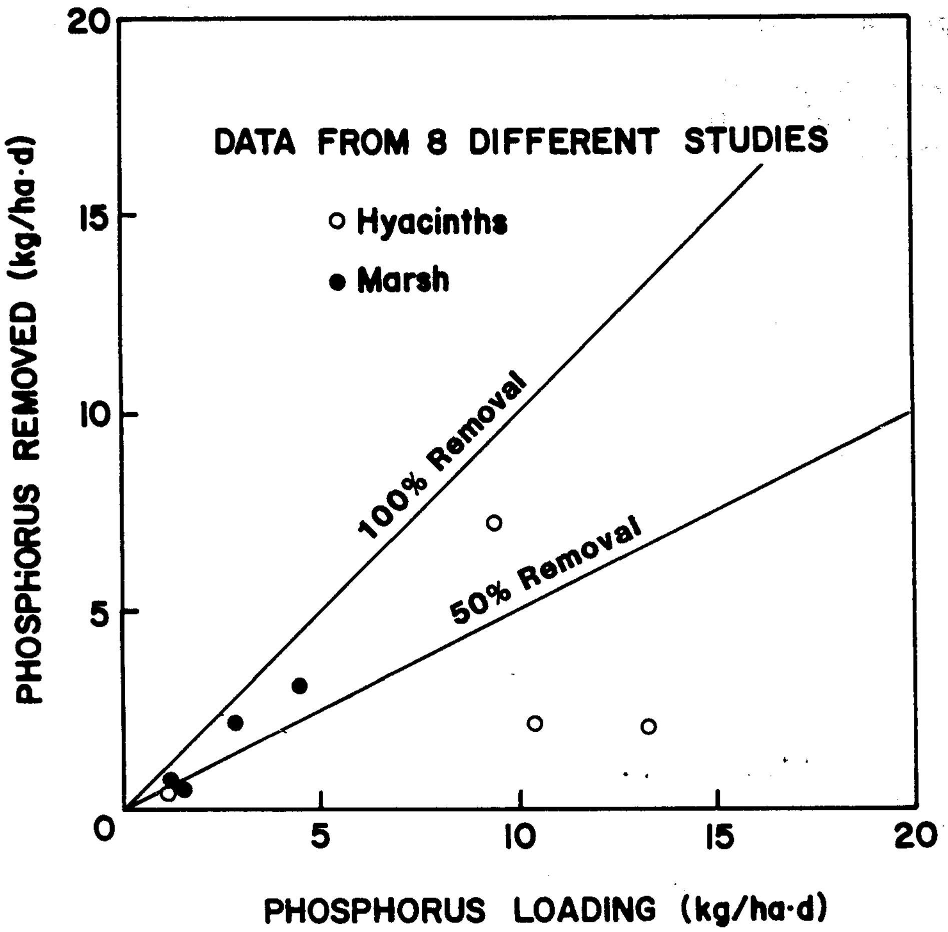


Figure 8.1.2-a. Effect of phosphorus loading on phosphorus removal.
Source: Stowell et al. 1980.

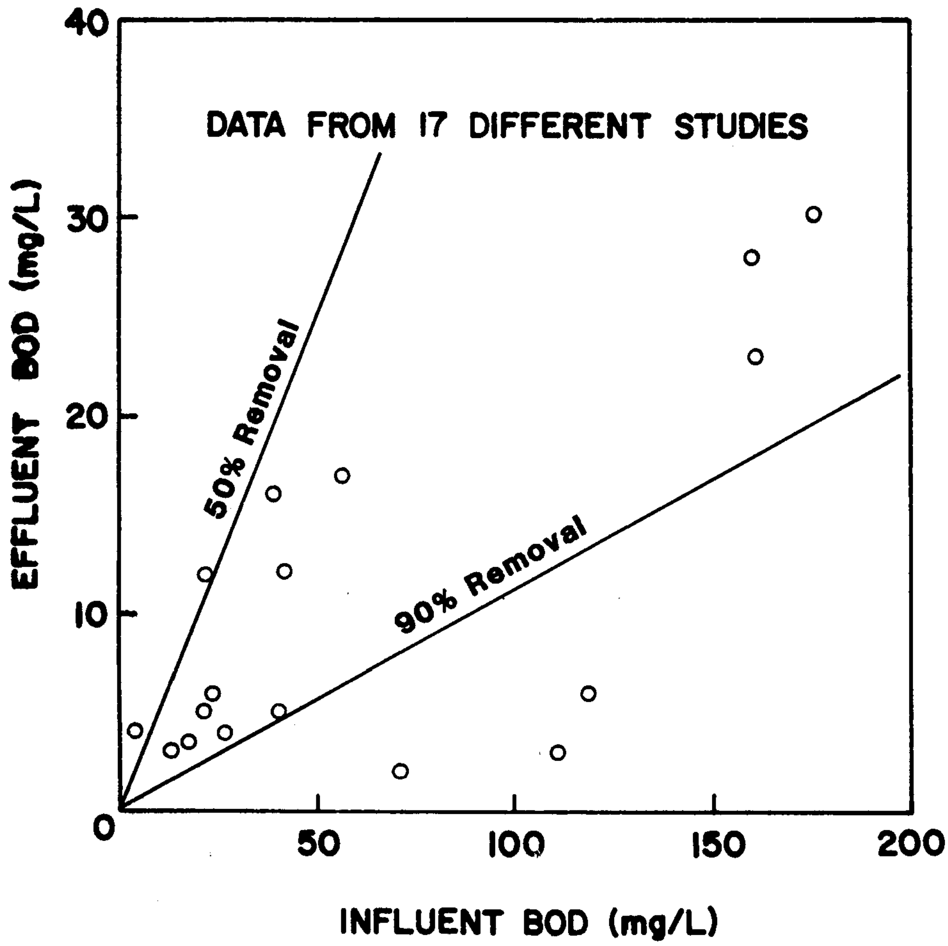


Figure 8.1.2-b. Effluent BOD concentrations (aquaculture systems).
Source: Stowell et al. 1980.

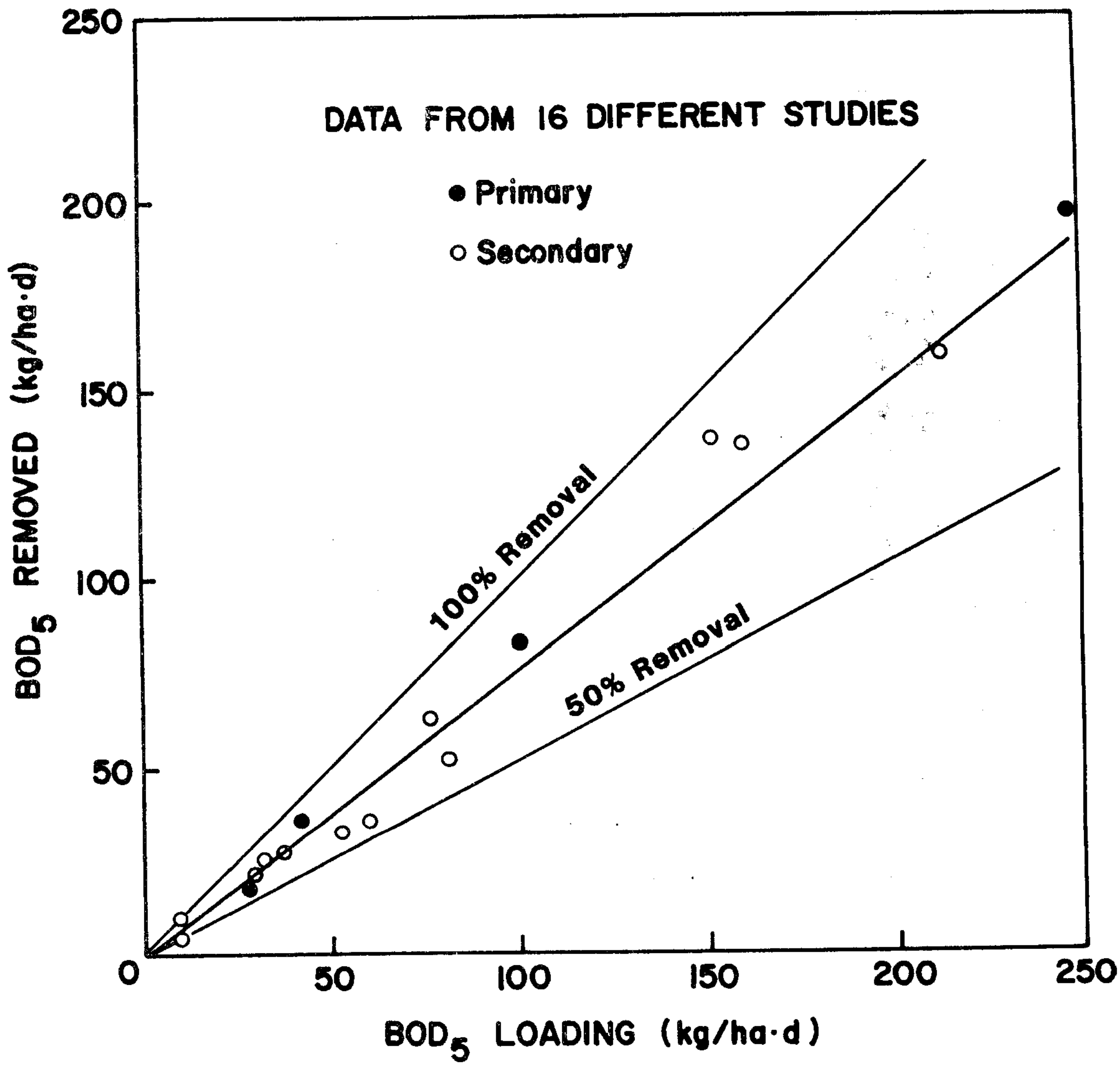


Figure 8.1.2-c. Effect of BOD loading on BOD removal.

Source: Stowell et al. 1980.

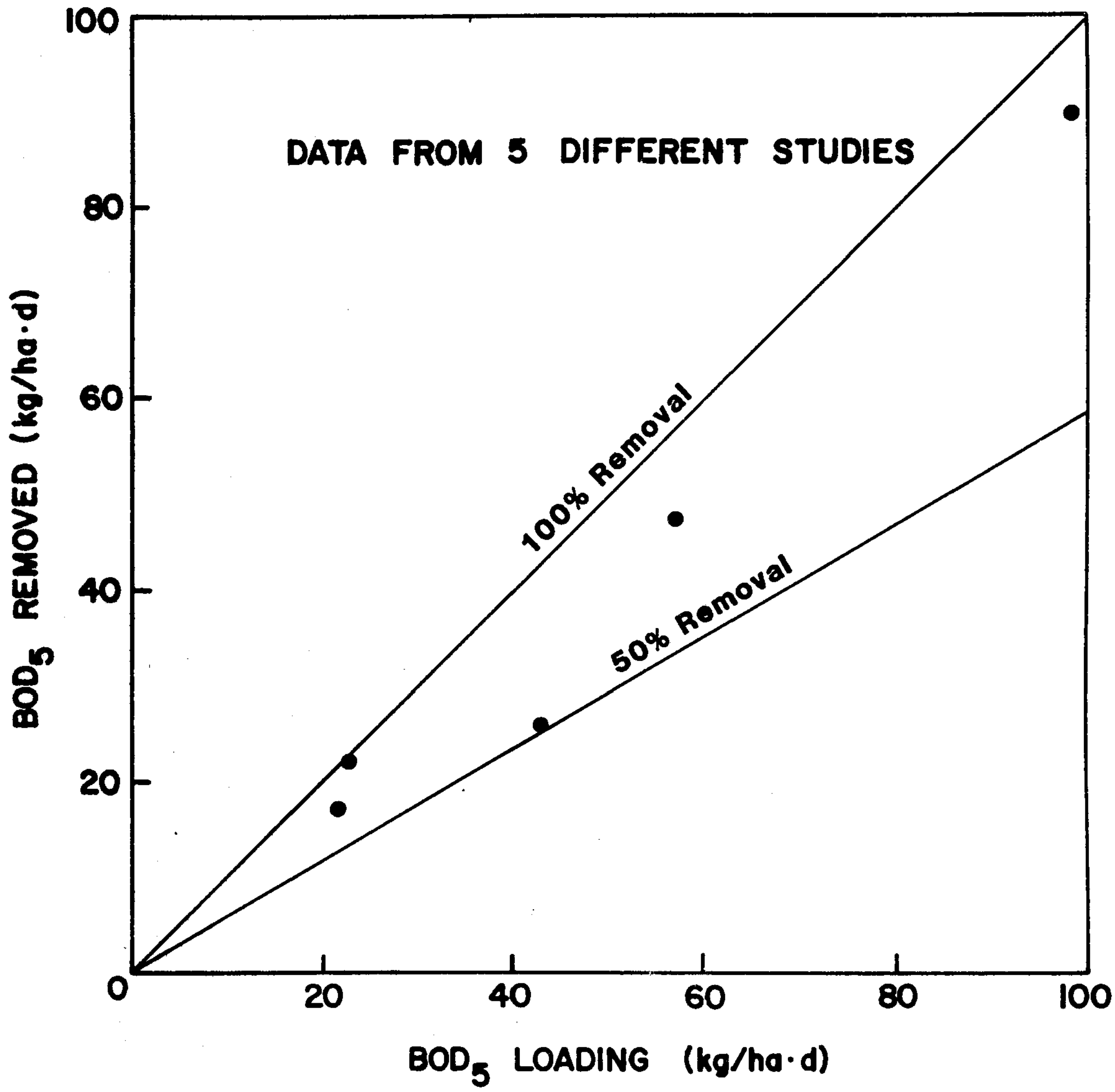


Figure 8.1.2-d. Effect of BOD loading on BOD removal (marsh and peatland systems)

Source: Stowell et al. 1980.

HABITAT ALTERATION AND CHANGES IN SPECIES COMPOSITION ARE CRITICAL ISSUES IN WETLAND CONSERVATION EFFORTS

Wetlands serve as reservoirs for rare and endangered species. The significant alteration of known or suspected habitats of protected species should be avoided. Habitat alteration and changes in species composition may occur as a result of wastewater addition, but the extent and significance of these changes are open to interpretation.

Natural Systems

Habitat alteration and species shifts are critical issues in wetland conservation efforts. The most basic changes in wetlands as a result of wastewater addition are the increase in nutrient and hydrologic regimes. The more these factors depart from the natural regimes, the greater the potential impact to habitat and species composition both within wetlands and in downstream ecosystems which are closely linked to wetland processes and functions (estuaries, etc.). For example, bottomland hardwoods are adapted to extremely high nutrient loading, and excess nutrients would likely have minimal impact in this system. The plants and animals in bottomland hardwoods, however, are sensitive to alterations in the natural pattern of hydrologic fluctuations and might suffer significant adverse impacts. On the other hand, marshes and some cypress ecosystems are adapted to nearly continuous inundation and low nutrient regimes and impacts to wildlife might be less severe. Concern has been expressed (Kuenzler 1982) that the increasing eutrophication problems in the upper estuaries of North Carolina result from the remaining wetlands (30 percent of original acreage left) no longer being able to filter-out increasing nutrient loadings from disturbed watershed runoff. Logically, increased nutrient loadings from wastewater additions may further exacerbate the eutrophication problem in the estuaries.

Shifts in nutrient regimes and habitats affect community dynamics. In cypress domes with sewage additions, a shift from tadpoles to surface feeding herbivores and detritus feeders was observed (Davis 1976), and a replacement of herons by more passerine birds was hypothesized. Similar effects on trophic levels may occur in other wetlands receiving sewage, but this has not been documented. The limitations these effects may place on wastewater addition to wetlands are basically open-ended questions. Thus, the known or suspected presence of a protected species may preclude the use of certain wetlands for wastewater recycling.

Aquaculture Systems

Habitat and wildlife considerations are not specifically applicable to aquaculture systems, except in the case of multiple-use artificial systems that have been developed to create habitat for water fowl and other wildlife. This is a potentially positive aspect of creating artificial wetlands. Existing observations from the Mountain View system in California indicate a high degree of success in creating a habitat for water fowl.

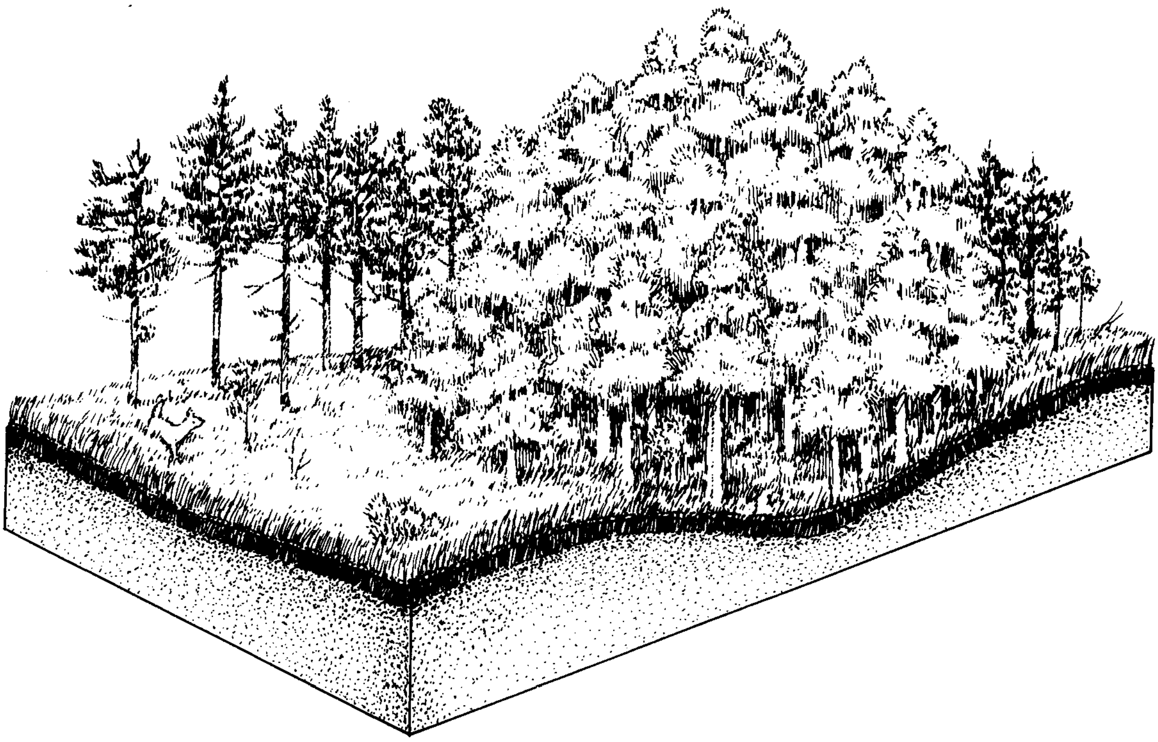
EFFECTS OF BACTERIA AND VIRUS ON WETLAND VALUES AND GROUNDWATER SHOULD BE CONSIDERED

The public health concerns of wastewater recycling in wetlands include the effect on groundwater and export of waterborne disease in surface waters. Enzootic diseases do not appear to be amplified. Other key public health factors are noted, but their relevance to the limitations of this practice are unknown.

Several key factors exist with regard to the public health aspects of wastewater recycling in wetland areas. The protection of groundwater resources from contamination is of primary concern. For example, the soil profiles beneath several Florida wetlands act as effective although not total barriers against groundwater contamination from surface-applied wastewaters. The key soil constituents were clays, sand and organic matter. The ability of other wetland soils beneath Region IV wetlands to provide similar barriers against groundwater contamination is unknown.

Another key factor is the fate of potentially hazardous microorganisms in surface waters of wetlands and in adjacent water bodies. Longer detention times within wetlands allows for more sedimentation and great inactivation of enteric microorganisms. This detention time subsequently lowers the probability of export of vectors of waterborne disease. The amount of reduction required to meet water quality standards depends on the pre-treatment efficiency. The potential vectorborne disease and nuisance problems of wastewater disposal in wetlands have not been fully examined. Results from studies on impacts of wastewater on enzootic encephalitis vectors in Florida indicated no problem existed. The modern relationship of other such vectored diseases (malaria, tularemia) has not been studied.

Other key public health factors in wetlands disposal systems include: 1) the unknowns regarding long-term effectiveness and limitation of each Region IV wetland type in removing, treating or confining pathogens (or other hazardous material), 2) food-chain effects of bioaccumulation or biomagnification, 3) effects of variable seasonal factors (rainfall, temperature, etc.) on treatment efficiency, 4) implications of restricted future use of affected wetlands 5) whether chlorination of wastewater previous to discharge to wetlands is wise in view of hazards presented by low-molecular weight chlorinated hydrocarbons resulting from contact of chlorine with organics found in water (characteristic of wetlands) and 6) the presence of potentially toxic unionized ammonia and nitrite. Many of these concerns are relevant to surface water discharges as well. Research is being performed to address some of these concerns.



SECTION 9

SUMMARY

9.0 SUMMARY

KEY TECHNICAL AND INSTITUTIONAL ISSUES MUST BE RESOLVED TO ASSESS WETLANDS DISPOSAL FEASIBILITY

The implementation of wetlands disposal systems is dependent on the resolution of key technical and institutional considerations. This section identifies and discusses these considerations and provides a basis for evaluating the feasibility of using wetlands for wastewater management in Region IV.

This section is intended to focus on the technical and institutional considerations that may act independently or jointly to influence the feasibility of using wetlands as a wastewater management alternative. The importance of many of these key elements has regional significance while others are of only state or local consequence.

The technical considerations include general elements that may limit the feasibility of wetland discharge in a number of ways. Adequate knowledge may not exist on a key technical element and the resulting uncertainties may produce unacceptable risks. From an engineering or environmental standpoint, existing knowledge may be adequate to disqualify a wetland from rational utilization.

The institutional issues examined in this section address problems in permitting, legal issues and environmental regulations that may impede the implementation of wetlands disposal systems. Agency conflicts are discussed as potential problems. Inappropriate regulatory policy results in inadequate or inconsistent resolution of the wetlands disposal issue.

Issues of Interest

- What are the key engineering elements which affect the use of wetlands disposal systems?
- What are the areas of scientific knowledge required for predicting and mitigating the impacts of wastewater on wetlands?
- Do institutional mechanisms adequately address the wetlands disposal issue?
- What types of conflicts exist in permitting wastewater discharge to wetlands?
- What institutional considerations are most likely to impede the utilization of wetlands in a wastewater management scheme?

9.0 SUMMARY

9.1. Critical Technical Considerations

WETLANDS HAVE DEMONSTRATED TECHNICAL POTENTIAL AS A WASTEWATER MANAGEMENT TOOL BUT IMPAIRMENT OF NATURAL FUNCTIONS IS MAJOR CONCERN

Accelerated research efforts in applied wetland sciences have greatly increased our knowledge of wetlands and their potential use as wastewater management systems. Critical technical considerations are presented in this section from both a general and site specific perspective. Many technical elements must be examined to ensure against loss of wetland value from wastewater additions.

The immense ecological importance, variety and complexity associated with natural wetlands are highlighted by the results of studies within Region IV and elsewhere. Despite certain limitations, large quantities of scientific information are available on wetland systems in the southeast. This information has also provided an increased understanding of the processes and problems associated with natural and artificial wetlands and their use in wastewater management. From this information it is possible to identify key elements critical to the proper maintenance and functioning of wetlands receiving wastewater. The assessment of these elements on both a general and wetland specific perspective provides a basis for discussing the technical feasibility of using wetlands for wastewater recycling.

The difficulty in summarizing the technical elements that must be considered in evaluating wetlands disposal systems lies in the diversity of wetland types and limits in existing knowledge. The approach taken in section 9.1.1 relies on a comprehensive list of general technical factors that control the feasibility or desirability of a wetlands discharge. They are intended as guidelines to assist in the formulation of elements relevant to evaluating a potential or existing wetlands discharge. These elements include but are not limited to geomorphology, vegetation, hydrology, water quality, wildlife values and engineering considerations. Included in this section are more detailed issues associated with each of these topics and a brief explanation of why they are important and what functional role these issues take in maintaining the value of wetland areas. This analysis is not meant to imply that all these factors are equally applicable to all wetlands. In fact, the site specific nature of wetland characteristics causes the opposite to be true.

The translation of these general factors to key issues relevant to specific wetland types is exemplified in section 9.1.2. These key issues were identified based on the relative degree of importance in maintaining wetland values and the status of knowledge of these issues in reference to specific wetland types. Those elements with a high degree of importance and a low status of knowledge are highlighted in the discussion of selected wetland types. A matrix was developed to assess these general elements on a wetland specific basis and is presented in the Appendix to this report.

9.0 SUMMARY

9.1. Critical Technical Considerations

9.1.1 General Elements Critical to Evaluating Wetland Discharges

DELINEATION OF WETLAND VALUES AND DEVELOPMENT OF ACCEPTABLE POLLUTANT AND HYDROLOGIC LOADINGS ARE IMPORTANT DETERMINANTS

A generalized perspective helps identify the range of considerations that may limit the use of wetlands for wastewater management. The discussion of hydrology, vegetation, wildlife values, engineering considerations and other parameters provides a technical orientation and guidance for the evaluation of wetlands receiving wastewater.

An evaluation of the potential use of wetlands for wastewater management must encompass a number of factors. The complex values, functions and diversity of wetlands results in the degree of importance varying among wetlands and between wetland types. These factors include vegetation, hydrology, geomorphology, water quality, wildlife values, engineering considerations, and linkages to other systems. The interaction of these considerations should also be assessed when identifying the key parameters impacting the feasibility of a wetlands discharge. The examination of these parameters should provide the technical orientation and guidance for assessing wetlands discharges.

The general topics contained in Table 9.1.1 are the fundamental areas that maintain the structure and function of wetland areas. Within each of these topics specific issues are identified salient to the management of wastewater application to wetlands. The geomorphology of wetlands areas encompass several variables including physical shape, soils, and geology of wetlands watersheds. These basic properties, in turn, influence other wetland properties and processes. Soils, for example, influence nutrient and hydrologic retention capacity. Hydrology is the key regulator for many wetland processes. Components of the water budget need to be evaluated both in terms of storages and flow rates in order to estimate the magnitude of hydrologic impacts of wastewater applied to wetlands. Hydrologic flows also indicate the pathways that wastewater constituents may follow as they pass through wetlands. Critical factors such as depth, detention time and flooding properties will also determine, in part, the assimilative capacity of wetlands.

Vegetation is one of the fundamental components of wetlands. The major issue in preserving the integrity and value of wetlands is maintaining the compositon and structure of the biotic community. Several specific areas such as succession, productivity, and community composition provide insight into the impacts of wastewater on wetlands and act as indicators for the potential use or non-use of wetlands for wastewater management. The vegetational structure of wetlands is important in maintaining the wetland habitat for wildlife species and Threatened and Endangered species. These and other areas of importance relating to the functional role of vegetation and wildlife is presented in Table 9.1.1.

Table 9.1.1. Areas of Concern of Key Wetland Characteristics.

Topic	Areas of Importance	Functional Role and Importance
Geomorphology		
-Geology	Karstic Areas	Groundwater interactions in limestone areas uncertain; pose potential benefits and hazards
	Drainage Basin Characteristics - form	Areas of high topographic relief create potential for strong flood pulses resulting in undesirable flushing of effluent out of wetland without treatment
	Drainage Basin Characteristics - types	Carolina Bay and other formations have intrinsic scientific, cultural and hydrologic values which may be threatened by wastewater application
-Soils	Organic Soils	Nutrient retention potential low, permeability may be too low
	Mineral Soils	High nutrient retention potential, permeability may be low Clay pan impermeability protects groundwater resources but may impede surface water loading capacity
-Physical Characteristics	None	Manifested in other parameters (geology, hydrology, etc.)
Vegetation		
-Plant Ecology	Material Cycling	General ecosystem functioning; wastewater addition may possibly augment or imbalance
	Adaptations	Plants specialize to grow and successfully compete in wetlands; modifications in nutrient and hydrologic regimes may alter species assemblages
	Fire Frequency	Fire is important in maintaining the character of some wetlands; continuous wastewater application may prevent necessary dry-down for fire to occur
-Vegetative types	Dominant vegetation	Essential in determining community structure and productivity, also habitat value, and influences water quality, surface water flows
	Subdominant vegetation	Important in filling and creating specialized ecological niches
-Succession	Community equilibrium	Necessary to maintain a stable and productive ecosystem
-Productivity	Rate of production and respiration	Controls nutrient uptake and storage capacity; determines quality and quantity of detritus, and influence evapotranspiration values. Diurnal pattern may be of sufficient intensity to alter water quality parameters of DO and pH
-Rare and endangered	Delicate, unique and irreplaceable ecosystems	The location, range and inherent scientific and cultural values of these ecotypes require that these genetic pools are maintained intact and inplace
	Delicate, unique and irreplaceable species	The location, range and inherent scientific and cultural values of these species require that these genetic pools are maintained intact and inplace

Table 9.1.1. Continued.

Topic	Areas of Importance	Functional Role and Importance
Hydrology		
-Budget	Precipitation Component	Limit loading rates of wastewater
	Groundwater Component	Groundwater discharge area places limits on loading rates of wastewater. Groundwater recharge area may prohibit wastewater application if effluent quality is poor
	Surface water/Runoff Component	Sources, rates and timing of inflow critical to maintaining wetland vegetation, detrital sediment and nutrient loading Outflow characteristics define seasonal pattern of surface water storages, location of outflow may limit acceptability of wastewater application
-Inundation	Frequency and Duration	Dominant force in shaping distribution and character of wetland vegetation. Changes in catchment size and shape, antecedant moisture, and watershed topography will alter flooding characteristics
-Infiltration	Capacity of Vertical Water Movement	Infiltration capacity important in limiting loading rates, treatment capacity and efficiency
-Flooding Effects	Nutrient Import/Export	Major source of nutrients for some wetlands and downstream ecosystems may be dependent on wetlands exports for nutrients and food supply
	Buffer Capacity	Wetlands have value as regional flood buffering devices, and aid in low-flow augmentation. Wastewater addition may lower this hydrologic buffering capacity
-Evapotranspiration	None	Not important unless drastic ecosystem alteration takes place. Wastewater may increase evapotranspiration
Water Quality		
-Chemical	Dissolved Oxygen	Plant and fish life tolerate low DO; but zero DO is detrimental Controls type of microbial respiration and organic matter degradation
	pH	Some plants present (Sphagnum) depend on low pH. Nutrient release from sediments is pH dependent. Wastewater addition increases pH, and carbonate buffering capacity
	Nutrients	Nutrient cycles need to be balanced for proper ecosystem production. Productivity may be limited by nutrient availability. Nutrient exports by open wetland ecosystems create important links to downstream ecosystems
	Metal/Toxins/Refractory Organics	Direct - acute and chronic effects from exposure to detrimental concentrations Indirect - bioaccumulation
-Physical	Turbidity/Suspended Solids	Important source of particulate organic matter. Sedimentation of these particles provide basis for sediments, detrital food chain
	Temperature	Effluent extends growing season in cooler climates, and may promote frost damage

Table 9.1.1. Continued.

Topic	Areas of Importance	Functional Role and Importance
-Biological	Microbial Respiration	Breakdown of organic matter, nutrient cycles
	Public Health Vectors	Maintain or increase reservoir of imported or endemic water or arthropod borne disease
	Algae blooms	Odor, aesthetic, toxic producing nuisance
	Increase in macrophytes	Short term, seasonal storage of nutrients, influences subcanopy ecology in swamp forests
Wildlife Values		
-Habitat	Edge Effect/Niche Separation	Maintains trophic levels productivity for ecological balance
-Threatened or Endangered Species	Habitat loss - Species Maintenance interfered with	Scientific and cultural values; maintains genetic diversity
Engineering Considerations		
-Evaluation/ Site Selection Procedures	Screening potential sites--consistency of selection processs	Need to identify wetlands with disposal potential; eliminate those with low potential, in a justifiable and rational manner
-Pre-treatment Requirements	Design of wastewater treatment facility	Reduce concentration of waste load to within a range of values acceptable to wetlands assimilative capacity
-Hydrologic Loading	System Capacity	Determines ultimate volumetric capacity of wetlands; Impacts vegetation type and occurrence
-Catchment Basin size/ Detention Time	System capacity--contact time	Determines wetland capacity; places limits on "contact opportunity" for degradation and assimilation of wastewater constituents
-Depth	System capacity--method of application	Adverse depths may cause harm to vegetation; reduce treatment efficiency and limit ultimate capacity of system
-Frequency of Effluent Application	Seasonal application Continuous application	Steady periodic and seasonal application of wastes to wetlands have differing advantages which should be evaluated at each potential wetland discharge site
-Effluent Application Methodology	Distribution Systems	The use of single or multiple outfalls should be evaluated to minimize adverse effects; sheet flow may optimize treatment efficiency; flow pattern and path to outflow also important function

9.1.1 Continued

The quality of water within wetlands and discharging from wetlands is of concern in wetlands utilized for wastewater management. The chemical, physical and biological processes that impact water quality may produce undesirable changes within wetlands or have adverse impacts on adjacent water bodies. Uncertainties about the fate and potential effects of toxins and pathogens contained in wastewater are of concern. The removal of these and other wastewater constituents, the maintenance of wetland habitat and valuable linkages to other ecosystems are the principal objectives of the engineering considerations listed in Table 9.1.1. Linkage of wetlands to other ecosystems is important. In many watersheds, the removal of nutrients and sediments from floodwaters by wetlands is crucial to maintaining water quality of lakes streams and estuaries. The engineering considerations involved with the design of distribution systems and evaluating pollutant and hydrologic loading capacity are among the most difficult issues to address, but the technology is developing in this area.

The evaluation of these fundamental components of wetlands outlined in this section should be approached from an integrative perspective. It is evident that not all these factors have an equal role in determining the feasibility of a wetlands discharge. The evaluation of these factors in reference to a particular wetland or wetland type is needed to bring meaning to these parameters. This type of evaluation will highlight the diversity of wetland types and their relative compatability with wastewater applications.

EXCLUSIVITY OF WETLAND TYPES REQUIRES SITE SPECIFIC ANALYSES

Major wetland types within Region IV are assessed with regard to their potential use for wastewater management. Hydrologically open systems are endowed with attributes useful in wastewater treatment; hydrologically isolated systems provide greater control over treatment parameters. Maintenance of habitat for wildlife and retention of wastewater constituents are highlighted as areas of concern in all wetland types.

The purpose of this section is to extend the concepts developed in 9.1.1 and apply them to specific wetland types found within Region IV. The goal of these assessments is to identify those key elements that are most critical in the maintenance of the value and function of wetlands receiving wastewater.

The elements outlined in Section 9.1.1 highlight the sensitive technical issues important to specific wetland types and their use as wastewater management alternatives. Specific elements are assessed on the basis of their degree of importance and status of knowledge. These two parameters were rated high, medium, or low for each key factor identified in Section 9.1.1. The ratings for each factor as they pertain to the selected wetland types are presented in the Appendix. Those key factors rated as having a high degree of importance and a low status of knowledge were selected as those most likely to become primary determinants in controlling the feasibility or desirability of initiating a wetlands discharge. Conversely, those technical elements rated with a low degree of importance and high degree of knowledge are of less generic concern, but may take on high local values and importance. Table 9.1.2 summarizes the most important considerations germane to each wetland group.

Wetland types highlighted in this report are broadly grouped as either hydrologically open or hydrologically isolated systems (Table 9.1.2), as discussed in section 2.3. and are further typified by characteristic vegetation. The corresponding National Wetlands Inventory classification for the wetlands types listed in Table 9.1.2 may be found by consulting the classification matrix developed for this EIS (Table 2.3).

Among the hydrologically isolated systems, cypress domes have received the most attention in researching the use of wetlands as wastewater management tools. However, several areas of concern persist (for example, groundwater contamination and proximity to developed areas) that may limit the use of cypress domes for wastewater management. Other hydrologically isolated wetlands possess significant ecological uncertainties that may preclude their use without cautious appraisal of these potentially limiting parameters. For example, the presence of Threatened and Endangered Species, the effects of pH elevation in acid bogs, material cycling and retention of wastewater constituents are elements that are of critical concern in several of the hydrologically isolated systems highlighted in Table 9.1.2. These wetlands in general, being less "connected" to flows of nutrients and water than are hydrologically open systems, are more likely to be altered by the addition of wastewater (Day 1980).

Hydrologically open wetlands (riverine swamps, bottomland hardwoods, strands, etc.) are more dynamic and transitory systems, responding rapidly to changes in water levels. These systems are also amenable to naturally high nutrient loadings. The addition of wastewater to these systems have potentially adverse implications to downstream ecosystems inextricably linked to the maintenance of wetlands buffering and cleansing processes. The high recreation values and hydrologic uncertainties of these systems are elements that must be adequately considered in assessing the use of these systems for wastewater discharges.

Nonetheless, the structure of riverine wetlands endows them with certain characteristics valuable in wastewater disposal including but not limited to: (1) sheet flow which maximizes exposure of effluent to nutrient exchange and renovation mechanisms, (2) adaptations to high levels of nutrient loadings, (3) potential for nitrification and denitrification processes, (4) storage of nutrients in biomass, (5) high rates of nutrient cycling and (6) proximity to existing point sources of nutrient addition. However, considerations such as potential food webb accumulation of toxic substances and irregular hydrologic regimes that may minimize pollutant dissipation or retention and lead to overloaded downstream ecosystems must be recognized.

This brief assessment of wetland types and their potential use in wastewater management has highlighted key technical elements which should be considered when evaluating a wetlands discharge. The inherent diversity and variety of wetland types suggests that a site specific evaluation of wetlands will produce a set of unique and separate factors of concern for each wetland evaluated. The exclusivity of wetlands is the overriding factor that prevents greater resolution of site specific varibles that will ultimately determine the acceptability or feasibility of a wetlands discharge.

Table 9.1.2. Areas of High Importance in Selected Region IV Wetlands.

Systems	Areas of High Importance
Hydrologically Isolated	
Cypress Dome	Long term maintenance of dominant vegetation. Preservation of ecotype in regions where ecotype is uncommon. Applicability of established wastewater management techniques to domes other than those studied. Soil structure relative to retention capacity of wastewater constituents. Proximity to developed areas. The following areas of high importance are of special concern because of the low status of knowledge: o Groundwater contamination o Wildlife values
Carolina Bays, Pocosins	As habitats subject to developmental pressures, great concern over preserving the integrity of these ecosystems including habitat, recreational and wildlife values, threatened and endangered species, and alteration of successional trends. Hydrologic characteristics and soil types vary throughout, resulting in uncertainties in nutrient retention capabilities. Effects and/or limits of other pollutant loadings (bacterial, metals, toxin) are not well quantified and effects of increased hydrologic loadings are not well studied. The following areas of high importance are of special concern because of the low status of knowledge: o Rare and endangered ecotypes o Threatened and Endangered Species o Underlying geology o Material cycling o Sub-dominant vegetation o Effects of pH
Marshes, wet meadows, savannahs, wet prairies	Wide variety of marsh types indicate need for high degree of site specificity in planning wastewater disposal. Hydrologic characteristics, soil types and vegetative cover influence capacity to assimilate and adapt to hydrologic and pollutant loadings. Species shifts of macrophytes may be of concern. High wildlife and recreational values must be preserved. Information from artificial wetlands created for wastewater management may increase our understanding and help alleviate these uncertainties. The following areas of high importance are of special concern because of the low status of knowledge:

Table 9.1.2. Continued

Systems	Areas of High Importance
	o Material cycling o Vegetation composition and succession o Rare and endangered ecotypes o Hydrological characteristics o Effects of pH alteration o Nutrient retention o Immobilization of metals, pathogens, toxins o Threatened and Endangered Species
White Cedar Bogs	Many unknowns; primary concern over protection of unique and rare ecosystems may preclude likelihood of utilization in a wastewater management plan. Effects of increasing ambient pH of concern. Inadequate knowledge of ecosystem structure and function. Preservation of wildlife and threatened and endangered species necessary. The following areas of high importance are of special concern because of the low status of knowledge: o Rare and endangered ecotypes o Material cycling o Soils o Habitat alteration o Succession, productivity o Threatened and Endangered Species o Hydrologic characteristics o Nutrient retention o Effect of pH alteration
Hydrologically Open	
Bottomland Hardwood Forests	Effects of alteration of hydrologic regime on vegetation density and species composition, habitat maintenance. Ability of ecosystem to adapt to increased pollutant and hydrologic loading. Damages to hardwoods may be more difficult to reverse than damages to vegetation with short life cycles. Concern over nutrient retention or washout during hydrologic surges. Preservation of recreational values. Linkage with other ecosystems is very important. Groundwater interaction uncertain. The following areas of high importance are of special concern because of the low status of knowledge: o Material cycling o Interactions with groundwater o Nutrient and sediment removal from floodwaters
Cypress and Mixed Hardwood Strands	Retention of wastewater constituents difficult to predict. Hydrologically complex and variable. Management of wastewater flows critical to success of

Table 9.1.2. Continued

Systems	Areas of High Importance
	habitat maintenance and functional elements of ecosystem. Effects of wastewater addition studied in Florida, but unknown if similar effects will be found elsewhere. Difficulty in determining effects on ecosystems linked to strand ecosystems. Relative importance of these variables is also site specific. The following areas of high importance are of special concern because of the low status of knowledge: o Material cycling o Interactions with groundwater o Linkages with other systems o Recreational and wildlife values o Threatened and Endangered Species
Riverine, Lacustrine (Lake) Wetlands	Potential impacts on adjacent ecosystems relate to retention of wastewater constituents. Hydrologic interaction between wetland and adjacent systems needs clarification. Short circuiting of wastewater flow through marsh potential area of concern. Wildlife and recreational values must be maintained or improved. The following areas of high importance are of special concern because of the low status of knowledge: o Hydrologic characteristics o Interactions/linkages with other systems o Retention of wastewater constituents.
Freshwater Tidal Wetlands	The influences of drainage basin characteristics and orientation of the wetland on nutrient and sediment retention during peak flows are critical. Retention of wastewater constituents, immobilization of toxins, pathogens, metals within wetland site is important. Linkages with adjacent systems are critical, especially for maintaining estuarine water quality and quantity. High wildlife and recreational values must be maintained. The following areas of high importance are of special concern because of the low status of knowledge: o Linkages with estuaries o Wildlife, Threatened and Endangered Species o Hydrologic uncertainties o Turbidity

Table 9.1.2. Continued

Systems	Areas of High Importance
Bogue, slough, Oxbow wetlands	Changing drainage basin characteristics have degraded many of these habitats. Wastewater additions may exacerbate this problem. Wildlife, eutrophication problems must be mitigated. Hydrologic characteristics are uncertain. Retention or fate of major wastewater constituents is unstudied. The following areas of high importance are of special concern because of the low status of knowledge: o Preservation of threatened ecosystem o Groundwater interactions o Nutrients, retention of other wastewater constitutents o Linkages with other ecosystems

INSTITUTIONAL CONSTRAINTS COULD LIMIT IMPLEMENTATION OF WETLAND DISCHARGES

Coordination between local, state and federal agencies is essential in order to avoid conflicts concerning wetlands protection and use and to establish adequate wastewater discharge permitting procedures. The issue of ownership also needs to be settled to avoid legal problems associated with the potential infringement on private property rights.

Institutional constraints and problems can severely limit the ability to implement concepts and technologies. Critical institutional considerations concerning the use of wetlands for wastewater disposal include regulatory policies concerning wetlands protection and use, ownership and proprietary rights of private wetlands, and the various regulations and policies associated with the NPDES Permit Program.

An understanding of wetland functions and values must form the basis for any resolution of potential institutional conflicts or problems. Priorities based on water quality and resource management goals will be needed to settle potential conflicts between wetlands protection and use. Ownership requirements will need to be based on technical considerations as they relate to assimilative capacity and potential type and extent of impact. Finally, agreements must be reached among state agencies and among local, state and federal agencies concerning the circumstances under which wetland discharges will be permitted and the methodologies used for establishing permit conditions. In this way inequities concerning wetlands use can be avoided while maintaining important wetland functions and values.

The following three sections elaborate these critical institutional considerations.

POTENTIAL CONFLICTS EXIST ON SEVERAL INSTITUTIONAL LEVELS

Potential conflicts concerning the protection and use of wetlands exist among state agencies, among federal agencies, and among local, state and federal agencies. Additional clarification of wetland values and the suitability of multiple-use concepts is needed before wetlands disposal can be widely implemented. The restoration of wetlands using wastewater effluent may serve the dual purpose of wetlands protection and use.

Potential conflicts on several institutional levels relate to the question of whether wetlands used for wastewater disposal can also be used for other purposes. Although the concept of multiple-use management has long been accepted and practiced in many forested areas, the applicability of this concept to wetland ecosystems is untested, especially in relation to wastewater disposal. Florida, for example, requires wetlands used for wastewater disposal to be posted to restrict public access. This requirement could cause conflicts between agencies concerned with fish and wildlife management for public recreation and those agencies concerned with permitting wastewater discharges. These potential conflicts exist on both the state and federal levels when wetlands protection and use must be balanced.

Most wetland protection efforts relate to Section 404 Dredge or Fill Permits administered by the Corps of Engineers (COE). State agency review, either as part of the water quality certification process (Section 401 Certification) or in conjunction with state permitting programs, is usually afforded to Section 404 Permits. Additional federal review is accorded the U.S. Fish and Wildlife Service (FWS) and the U.S. Environmental Protection Agency (EPA). Although Section 404 Permits may not be associated with all wetland discharges, the overall policy towards wetlands protection has been established by most review agencies and will likely carry over to the review of NPDES permits. Requirements restricting public access in wetland disposal areas may conflict with the legislative and policy mandates of review agencies and inhibit widespread implementation of wetlands disposal.

Specific state legislation relating to wetlands protection has only been enacted in response to coastal zone management in EPA Region IV. Georgia and Mississippi have enacted specific coastal wetlands protection laws. The other coastal states in the region, North Carolina, South Carolina, Florida and Alabama, have enacted general coastal zone management laws which indirectly protect coastal wetlands. No state in EPA Region IV has enacted legislation specifically concerned with inland wetlands. The emphasis on coastal wetlands is most likely the result of the federal impetus and funding associated with the federal Coastal Zone Management Act of 1972 (PL 92-583, as amended).

9.2.1 Continued

All states in EPA Region IV have state level agencies responsible for the management of fish and wildlife resources. The general mandate of most of these agencies is the protection and management of fish and wildlife resources relating to hunting and fishing interests, the primary source of most state revenues available for fish and wildlife management. State management programs often involve the acquisition and/or management of wetland areas for fish and wildlife habitats. If the use of wetlands for wastewater disposal impedes their use for hunting and fishing, interagency conflicts may arise. Similar conflicts have been recognized between the FWS and EPA and have been addressed at both regional and national levels.

The resolution of these potential policy conflicts will require an understanding of wetland functions and values. The use of certain wetlands for wastewater disposal may not necessarily infringe upon the value of that wetland for wildlife habitat. However, consumption of fish or wildlife from wetland disposal areas may be prohibited and may limit the value of that wetland for certain recreational purposes. Additional consideration must be accorded to migratory species, especially waterfowl, which may spread potential public health impacts far from the area of discharge. Timber production is another wetland value which may be reduced with wastewater disposal and will need to be assessed before wetland discharges are permitted.

Not all wetland disposal projects involve a trade-off between protection and use. The restoration of damaged wetland areas through the application of wastewater effluent may serve the dual purpose of preserving valuable wetland habitat and functions while also providing a means of wastewater disposal. To date, most wetland restoration efforts have focused on tidal marshes and have primarily involved revegetative efforts (Garbisch 1977). Commonly recognized purposes of wetland restoration have included erosion protection, creation of wildlife habitat, and the rehabilitation of dredge spoil areas. Little research has been conducted on the rehabilitation of inland freshwater wetlands except as a management tool for wildlife (Garbisch 1977). However, two projects are under construction on Hilton Head Island, South Carolina, and will involve the discharge of treated wastewater to wetland areas which have been hydrologically altered by road construction and changed drainage patterns. These and similar restoration projects will provide much needed information concerning this potentially valuable method of wetlands restoration and use.

In summary, existing state and federal laws provide for the protection of wetlands primarily through the issuance of dredge or fill permits. In addition, channels of review have been established between state agencies, COE, EPA and the FWS. Potential conflicts may arise when the use of wetlands for wastewater disposal impede other uses for which review agencies have responsibility. Potential inter-agency policy conflicts need to be resolved through memoranda of understanding and the establishment of wetland use priorities. The basis for conflict resolution will be an understanding of wetland functions and values and the improvement of wetland multiple-use management. Increased knowledge gained from current wetland restoration projects involving wastewater discharges may resolve potential conflicts concerning wetlands protection and use.

INFRINGEMENT ON PRIVATE PROPERTY RIGHTS IS A POTENTIAL PROBLEM

State and municipal governments may be potentially liable for damages to private wetlands resulting from wastewater discharges. This potential liability points out the need for ownership or legal control of wetlands used for wastewater disposal. Additional questions concerning necessary extent of ownership and possible EPA funding are raised by the issue of ownership.

Recent litigation in South Carolina involving a wetland discharge from the town of Andrews has illustrated the need for legal control over wetlands used for wastewater disposal. In this current court case, the State of South Carolina is being sued for damages relating to the loss of timber in a private wetland area. The plaintiff's contention is that the wastewater discharge is the cause of his timber loss and the state is responsible since it permitted the discharge. Subsequently, the state has amended its policy and now requires ownership or some other form of legal control before a wetland discharge will be permitted. Florida is the only other state which has such explicit requirements. Similar policies may need to be adopted in other states before increased implementation of wetland discharges results in legal problems.

In conjunction with the ownership issue, the required extent of ownership and the eligibility for EPA funding need to be clarified. Investigations will probably be needed on a case-by-case basis to determine the extent of the area which may be potentially affected by wastewater discharges. No known legal precedent has been established to define the extent of accountability of wetland dischargers. Once the need for ownership or legal control has been established, the question of EPA funding will need to be addressed. The resolution of this issue will require a discussion of treatment vs. disposal (Section 5.3) as well as a review of current EPA regulations and policies.

State definitions of "waters of the state" and the extent of state jurisdiction is another issue related to the ownership of wetlands. Only Kentucky, North Carolina and South Carolina do not provide for exemptions to waters of the state. All other states in EPA Region IV exempt waters totally confined and retained on private property under single ownership. In many cases, the extent of state jurisdiction will need to be determined on a site-specific basis. The potential for discharging to private wetlands outside of the state jurisdiction needs to be further addressed.

MODIFICATIONS MAY BE NECESSARY TO IMPROVE IMPLEMENTATION OF WETLAND DISCHARGES

Under existing laws and regulations, the discharge of wastewater effluent to most wetlands requires an NPDES Permit. However, most state permit programs do not recognize the specific nature of wetland systems. Modifications to the permit process, including modeling and monitoring requirements, may be necessary to improve the implementation procedures and insure adequate protection and use of the wetland resources.

The National Pollutant Discharge Elimination System (NPDES) was established by the Federal Water Pollution Control Act of 1972 in order to regulate the discharge of pollutants into the nation's waters. Under the terms of the Act, the states were encouraged to establish their own water quality standards and criteria leading to the administration of their own permit program under the guidance of EPA. To date, only Florida and Kentucky have not received authority from EPA Region IV to administer the NPDES Permit Program.

A review of state legislation and regulations indicates a wide range of variation in terms of special consideration for wetland discharges. Only Florida and South Carolina have official wetland disposal policies. Only South Carolina and North Carolina define swamp waters in terms of water quality, although all states recognize that characteristics of natural waters may be below specific standards and criteria. Definitions of "waters of the state" are generally similar, but only Florida defines the landward extent of waters of the state through the use of detailed species lists. Methodologies for determining wasteload allocations and effluent limitations also vary widely with some states applying standard stream models while other states use baseline studies and qualitative analyses. Monitoring requirements also vary from state to state with only Florida requiring special monitoring for experimental wetland discharges.

Although most states do not distinguish wetlands from other waters of the state for purposes of permitting wastewater discharges, provisions in the laws and regulations allow for flexibility in applying water quality standards and monitoring requirements. Therefore, the distinct nature of wetland systems can often be accommodated; however, there is no assurance that standards and requirements will be applied consistently within a state or between different states.

Understandably, regulations and requirements will vary between states in order to meet specific needs. In view of the variability of wetland types, flexibility in applying water quality criteria is necesary, within a state as well as between states. However, consistency in permitting procedures may be essential at both the state and regional levels in order to provide protection for wetland resources and avoid economic inequities.

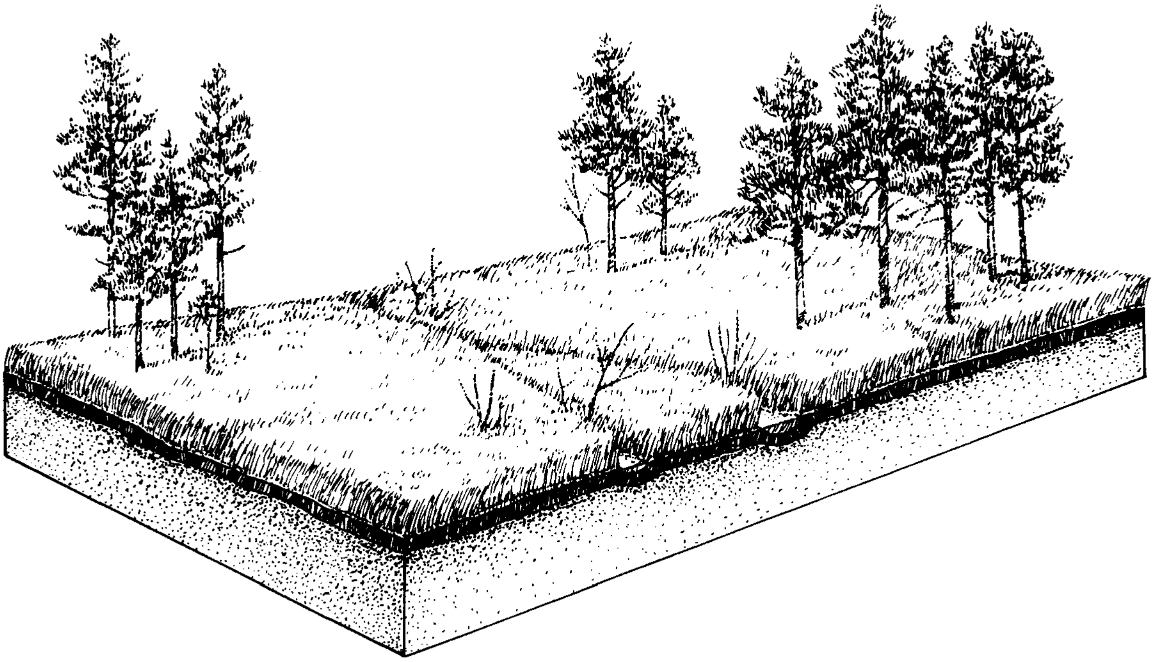
9.2.3 Continued

The initial step to assuring consistency in the application of criteria and requirements is the precise definition of wetlands for the purpose of wastewater management. In some cases, accepted regulatory (COE) or biological (FWS) definitions may be adapted. However, in other instances, water bodies which have water qualities characteristic of wetland systems may not be defined as such. Systems commonly referred to as swamp creeks, sloughs, oxbow lakes and various other dystrophic systems may or may not be considered wetlands for the purpose of permitting discharges. In several EPA Region IV states, as long as a discernable channel or flow is present, the system is modeled in the same manner as any other riverine or stream system.

Official policies based on an established wetland definition would be helpful in consistently applying wasteload allocation and effluent limitation procedures. The variability of wetland systems will likely require some degree of qualitative analysis; however, as long as the methodologies and procedures are established, consistency in application could be achieved. Policies concerning monitoring requirements for wetland discharges would also be useful in increasing the knowledge of wetland systems while insuring protection of the resource. Evaluation criteria will be needed in conjunction with the monitoring requirements in order to judge the extent of wetland degradation or enhancement.

Proposed changes to EPA water quality standards regulations may help overcome some of the permitting difficulties associated with wetland discharges. Revisions to use classifications based on use attainability and benefit-cost assessments and the establishment of site-specific criteria may provide states with a mechanism for addressing the specific characteristics of wetlands systems. In addition, the use of varying levels of aquatic protection will allow for modifications even within the fish and wildlife use classification. The actual impact of these proposed regulations on the use of wetlands for wastewater disposal remains hypothetical at this time.

A streamlined and straightforward permit process is also a major institutional consideration. Although precise problems or deficiences have not been identified with any of the state permit processes, several wetland dischargers have expressed dissatisfaction with the regulatory requirements (see Section 3.0). Consideration should be given to the fact that most wetland discharges are from small municipalities or package plants. Therefore, added regulatory burdens or delays could severely reduce the implementability of wetland disposal for those entities that could potentially benefit the most.



SECTION 10

RECOMMENDATIONS FOR PHASE II

10.0 RECOMMENDATIONS FOR PHASE II

PHASE II PRODUCTS NECESSARY FOR DECISION MAKING

Phase II is designed to provide tools for assessing the feasibility of potential wetlands discharges. Its products are necessary for decision making and meeting the objectives of the EIS. Information gained from Phase I must be incorporated into a format and process amenable to consistent decision making.

The Phase I Report has summarized key scientific, engineering, and institutional considerations associated with wastewater disposal to wetlands. Further, Phase I has profiled existing wetlands discharges and associated policies in each of the eight Region IV states.

As a result of Phase I efforts, the broad extent of wastewater discharges to freshwater wetlands in Region IV has been documented. However, most of the existing discharges have been developed without design criteria, have little basis for effluent limits, are delineated and defined inconsistently, and incorporate few safeguards for or monitoring of critical wetland functions.

As envisioned, Phase II is primarily intended to provide tools for decision makers for evaluating wastewater discharges to wetlands. The goals of Phase II are to identify, evaluate and recommend available and appropriate procedures or analytical tools to address each of the key institutional, scientific and engineering factors identified in Phase I. The approach to Phase II is centered on the need to develop procedures for assessing potential wetlands discharges and filling data voids that are important to that process. A decision-tree approach is one that clearly defines the areas of importance which should be addressed to have a sound basis for decision making.

Figure 10.0 provides a brief overview of the major components of a decision-tree for wastewater disposal to wetlands.

The remaining EIS products include, as a minimum:

1. Institutional procedures to satisfy local, state and federal regulatory or program requirements.

2. Scientific procedures or tools to identify and evaluate important ecological impacts.

3. Engineering guidelines to assure maintenance of wetland functions and values.

4. Procedures for collecting information needed by decision makers

5. Case studies to test tools and procedures

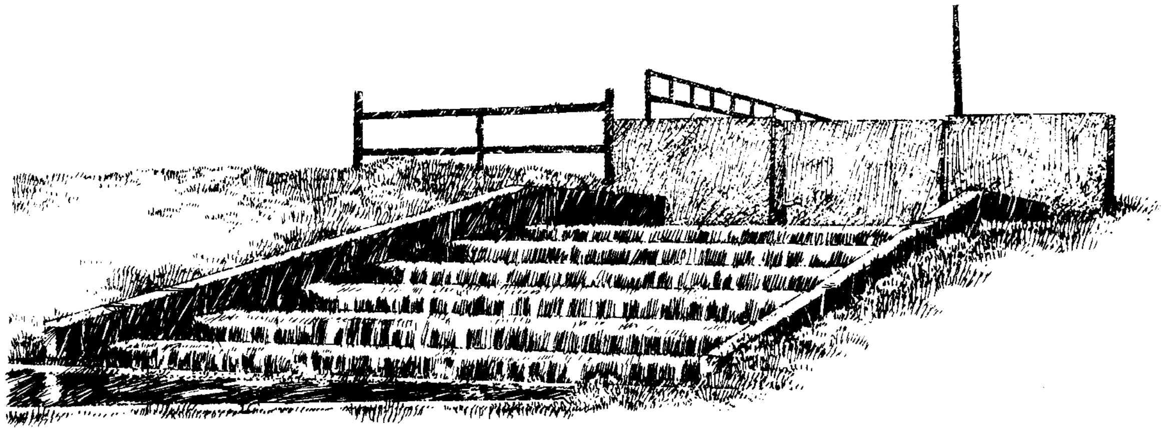
6. Phase II Report

10.0 Continued

7. Handbook of procedures and analytical tools for evaluating wastewater discharges to freshwater wetlands

8. Draft and Final EIS.

The tasks leading to each of these products will be conducted in close association with a representative of each Region IV state.



SECTION 11

APPENDIX

Appendix A. Degree of Importance (I) and Status of Knowledge (K) of Key Areas of Importance in Hydrologically Isolated Systems (H = High, M = Medium, L = Low).

Area of Importance	Cypress Dome		Pocosin		Carolina Bay		Savannah, Wet Prairies		Marshes, Wet Meadows		White Cedar Bogs	
	I	K	I	K	I	K	I	K	I	K	I	K
Geomorphology												
Underlying Geology	M	M	M	M	H	L	M	M	M	M	M	L
Soils	H	H	H	H	H	M	H	M	H	M	H	L
Drainage Basin Characteristics	M	H	M	H	M	H	M	M	M	M	M	L
Vegetation												
Material Cycling	H	H	H	M	H	L	H	L	H	L	H	L
Adaptations	M	H	H	M	M	H	M	M	M	H	M	L
Fire Frequency	M	M	M	M	M	M	M	M	M	M	M	M
Dominant Vegetation	H	H	H	H	H	H	H	H	H	M	H	L
Subdominant Vegetation	L	L	H	L	H	L	H	L	H	L	H	L
Succession	H	M	H	M	H	M	H	L	H	L	H	L
Productivity	M	M	H	M	M	M	M	M	M	M	H	M
Rare Endangered Ecotypes	H	M	H	M	H	M	H	L	H	L	H	L
Hydrology												
Groundwater	M	H	M	M	M	L	M	L	M	L	M	L
Surface Water Runoff	M	H	M	M	M	M	M	M	M	M	M	M
Infiltration	M	M	M	M	M	M	M	L	M	L	M	L
Budget Predictability	H	H	H	M	H	M	H	L	H	M	H	L
Fluctuation of Water Depth	H	H	H	M	M	M	M	M	M	M	M	L
Water Quality												
Chemical												
DO	M	H	M	H	M	H	M	L	M	M	M	L

Appendix A. Continued

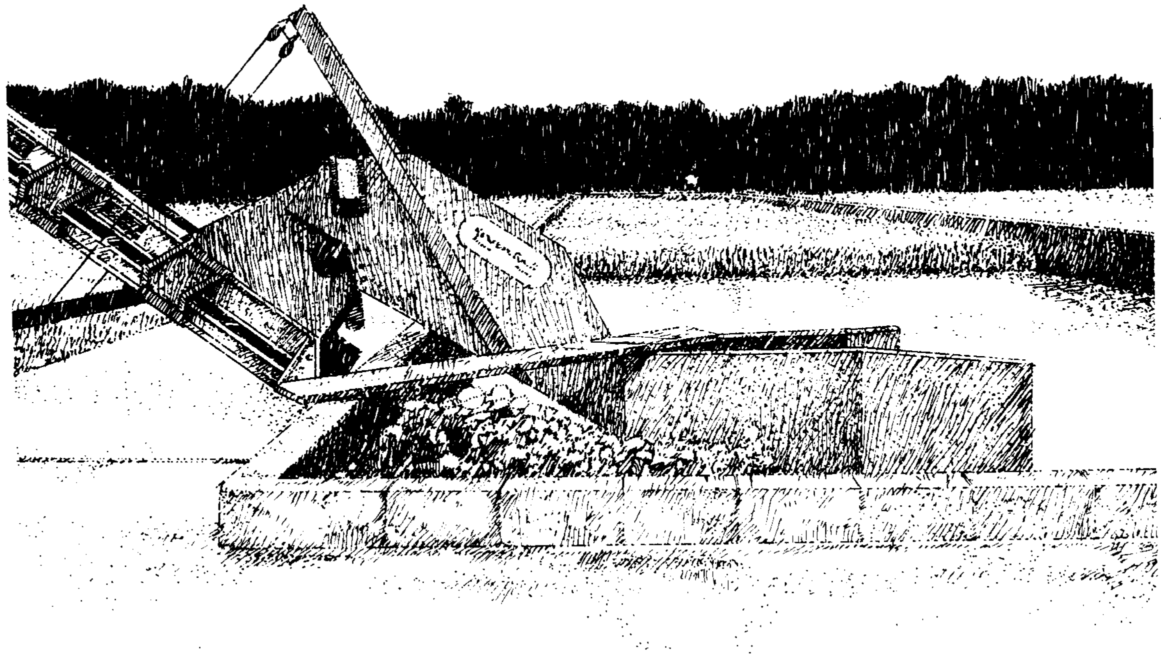
Area of Importance	Cypress Dome		Pocosin		Carolina Bay		Savannah, Wet Prairies		Marshes, Wet Meadows		White Cedar Bogs	
	I	K	I	K	I	K	I	K	I	K	I	K
pH	M	M	H	M	H	L	H	L	H	L	H	L
Nutrient Levels	M	H	H	L	H	L	M	M	M	M	M	L
Metals, Toxins, Indus. Effluent	H	M	H	L	H	L	H	L	H	L	H	L
Physical												
Temperature	L	H	M	M	M	M	L	L	M	L	L	L
Turbidity	L	H	L	H	L	H	L	H	L	H	L	L
Biological												
Macrophyte Increases	L	H	M	L	M	L	L	H	L	H	M	L
Habitat Alteration	M	M	H	L	M	L	M	L	M	L	H	L
Threatened & Endangered Species	H	H	H	M	H	M	H	M	H	L	H	L
Algal Bloom	L	H	M	M	M	M	M	M	M	M	M	L
Public Health Vectors	H	M	H	M	H	M	H	M	H	M	H	M
Microbial Respiration	M	M	M	M	M	M	M	M	M	M	M	M
Wildlife and Recreation Value	H	L	H	M	H	M	H	M	H	M	H	M
Linkage to Other Systems												
Nutrient and Sediment Removal from Flood Waters	L	L	L	L	L	L	L	L	L	L	L	L
Production of Wading/ Migratory Birds	M	M	M	M	M	M	M	M	M	M	M	L
Spawning Grounds for Fish	M	M	M	M	M	M	M	M	M	M	M	M
Timber Production	M	M	L	L	L	L	L	L	L	L	L	L

Appendix B. Degree of Importance (I) and Status of Knowledge (K) of Key Areas of Importance in Hydrologically Open Systems (H = High, M = Medium, L = Low).

Area of Importance	Bottomland Hardwood Forest		Cypress, Mixed Hardwood Strand		Riverine, Lake Marshes		Freshwater Tidal Wetlands		Bogue, Bayou, Brake Oxbow, Slough	
	I	K	I	K	I	K	I	K	I	K
Geomorphology										
Soils	H	M	H	M	H	M	H	M	H	M
Underlying Geology	M	M	M	M	M	M	M	M	M	M
Drainage Basin Characteristics	H	M	H	M	H	M	H	M	M	M
Vegetation										
Material Cycling	H	L	H	L	H	M	H	M	H	M
Adaptations	H	M	H	M	H	M	H	M	H	M
Fire Frequency	L	M	M	M	L	L	L	L	L	L
Dominant Vegetation	M	M	M	M	M	M	M	M	M	M
Subdominant Vegetatio	M	L	M	L	M	L	M	L	M	L
Succession	M	M	M	M	M	H	M	L	M	L
Productivity	M	H	M	H	M	M	M	H	M	L
Rare and Endangered Ecotypes	H	M	H	M	H	M	H	M	H	L
Hydrology										
Groundwater	H	L	H	L	H	L	M	L	H	L
Surface Water Runoff	M	M	M	L	H	M	M	L	H	M
Infiltration	M	L	M	L	M	L	M	L	M	L
Budget Predictability	H	M	H	M	H	M	H	M	H	M
Fluctuation of Water Depth	H	M	H	M	M	M	M	M	M	M
Water Quality										
Chemical										
DO	M	M	M	M	M	M	M	M	M	M

Appendix B. Continued

Area of Importance	Bottomland Hardwood Forest		Cypress, Mixed Hardwood Strand		Riverine, Lake Marshes		Freshwater Tidal Wetlands		Bogue, Bayou, Brake Oxbow, Slough	
	I	K	I	K	I	K	I	K	I	K
Chemical										
pH	M	M	M	L	M	L	L	M	L	M
Nutrient Levels	M	H								
Nutrient Retention	H	M	H	M	H	M	H	M	H	L
Metals, Toxins Indust. Effluent	H	M	H	M	H	M	H	M	H	M
Physical										
Temperature	M	M	M	M	M	M	M	M	L	M
Turbidity	M	M	M	M	M	M	H	L	L	M
Biological										
Macrophyte Increase	M	M	M	L	M	H	M	H	M	L
Habitat Alteration	M	M	M	M	M	M	H	M	H	M
Threatened and Endangered Species	M	M	M	M	M	M	M	M	M	M
Algae Blooms	M	M	M	M	M	M	M	M	M	M
Public Health Vectors	M	H	M	H	M	H	M	H	M	M
Microbial Respiration	M	M	M	M	M	L	M	L	M	L
Wildlife and Recreation Value	H	M	M	M	M	M	M	M	M	M
Linkage to Other Systems										
Nutrient and Sediment Removal from Flood Waters	H	M	H	M	H	M	H	M	H	M
Production of Wading Birds	H	H	H	H	H	H	H	H	H	H
Spawning for Fishes	H	M	H	L	H	M	H	H	H	L
Timber Production	M	M	M	M	M	M	L	L	L	L
Salinity Peak Modification	M	M	H	M	H	M	H	H	H	M



SECTION 12

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