WETLAND RESTORATION AND CREATION: DEVELOPMENT OF A HANDBOOK COVERING SIX COASTAL WETLAND TYPES

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January 1995
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Mention of company names is for informational purposes only, and should not be taken as an endorsement or censure by the North Carolina Division of Coastal Management. Also, in Section IV of the handbook, the Profile, Overview, and Reference sites sub-sections for each wetland type were modified from the N.C. Natural Heritage Program (NHP) and their document entitled "Classification of the Natural Communities of North Carolina: Third Approximation".

WRRI Project No. 50186
One hundred and fifty copies of this report were printed at a cost of $1,290.54 or $8.60 per copy.
ACKNOWLEDGEMENTS

The authors would like to thank Dr. Tom Hoban for providing guidance in refining our questionnaire. Appreciation is also expressed to Drs. Stephen Broome, Ernest Seneca, Donald Hammer, Edger Garbisch, Russ Lea, Douglas Fredrick, and Curtis Richardson for reviewing, providing material, and commenting on sections covering the different wetland types. Thanks are in order for Dr. Jim Wuenscher, Ron Ferrell and their staffs for input during the development of this document.

A portion of this document is being printed by the Division of Coastal Management as "Wetland Restoration and Creation: A Techniques Handbook of Six Coastal Wetland Types," while the entire document titled "Wetland Restoration and Creation: Development of a Handbook on Six Coastal Wetland Types" is being printed by the Water Resources Research Institute.
ABSTRACT

This document discusses techniques to be considered for successful restoration and creation of wetlands. The project was made possible with funding from the North Carolina Division of Coastal Management and carried out in three phases. Phase One consisted of identifying techniques used for wetland creation and restoration through a literature review and consultation with wetland experts currently involved in restoration and creation projects. Phase Two was to develop and distribute a questionnaire concerning specific restoration and creation techniques being utilized by wetland experts. Phase Three was to compile a handbook incorporating information from the literature, on-going projects, and expert opinion from the questionnaire for six broad wetland types found in the Southeastern United States. The six wetland types are saltwater/brackish marsh, freshwater marsh, bottomland hardwood, swamp forest, pocosin, and estuarine salt-shrub.
# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ................................................................. ii

ABSTRACT ................................................................................ iii

LIST OF FIGURES ........................................................................... x

LIST OF TABLES .............................................................................. xi

I. INTRODUCTION ............................................................................ 1
   A. BACKGROUND ........................................................................ 1
   B. PURPOSE ............................................................................. 2

II. LITERATURE REVIEW ................................................................. 4
   A. OVERVIEW ........................................................................... 4
   B. RESULTS ............................................................................. 4
   C. CONCLUSIONS .................................................................... 7

III. QUESTIONNAIRE SURVEY ......................................................... 8
   A. APPROACH .......................................................................... 8
   B. RESULTS ............................................................................. 8
   C. CONCLUSIONS .................................................................... 13
IV. WETLAND RESTORATION AND CREATION TECHNIQUES .......... 15

A. INTRODUCTION ................................................. 15

B. GENERAL TECHNIQUES FOR WETLAND RESTORATION/CREATION ........ 15
   1. Determine Success Criteria (i.e. goals) .................. 15
   2. Plan with Government and Consultant .................. 16
   3. Select a Reference Site ................................. 17
   4. Preparation of Soil and Site ............................ 17
      a. Vegetation ............................................. 18
      b. Fertilizers ............................................ 19
   5. Hydrology .................................................. 20
      a. Reliability versus Predictability ..................... 20
      b. Water Budget ......................................... 22
      c. Design Plans .......................................... 23
      d. Hydrologic System Types ............................. 23
   6. Planting ..................................................... 26
   7. Time ........................................................ 28
   8. Cost ........................................................ 28

C. BRACKISH/SALT MARSH .......................................... 29
   1a. Profile: Brackish Marsh ................................. 29
      a. Landscape position ................................... 29
      b. Typical hydrology .................................... 29
      c. Soils .................................................... 29
      d. Dominant plants ...................................... 29
   1b. Overview ................................................... 29
   2a. Profile: Saltwater Marsh ............................... 29
      a. Landscape position ................................... 29
      b. Typical hydrology .................................... 29
      c. Soils .................................................... 29
      d. Dominant plants ...................................... 30
   2b. Overview ................................................... 30
   3. Determine Success Criteria (i.e. goals) .................. 30
   4. Preparation of Soil and Site ............................ 31
D. FRESHWATER MARSH

1. Profile ........................................ 40
   a. Landscape position ................................ 40
   b. Typical hydrology ................................ 40
   c. Soils ........................................... 40
   d. Dominant plants .................................. 40

2. Overview ........................................ 40

3. Determine Success Criteria (i.e. goals) .......... 41

4. Preparation of Soil and Site .................... 43
   a. Design ........................................ 43
   b. Location ...................................... 43

5. Hydrology ....................................... 44

6. Planting ......................................... 46
   a. Methods of establishment ....................... 46
   b. Reintroduction of Fauna ......................... 50
   c. Management .................................... 50
   d. Water Level Regulation .......................... 50
   e. Monitoring ..................................... 52

7. Time ............................................. 53

8. Cost ............................................. 53
9. Reference Sites: Freshwater Marsh ................................. 55
   a. Bennett’s Creek .................................................. 55
   b. Durant Island ..................................................... 55
   c. Goose Creek ...................................................... 55
   d. Shackleford Banks ............................................... 55
   e. Mackay Island .................................................... 55
   f. Ocracoke Island .................................................. 55
10. Contacts ............................................................ 56

D. BOTTOMLAND HARDWOOD FOREST/SWAMP FOREST ........... 57
  1a. Profile: Bottomland Hardwoods ................................ 57
      a. Landscape position ........................................... 57
      b. Typical hydrology ........................................... 57
      c. Soils .......................................................... 57
      d. Dominant plants ............................................. 57
  1b. Overview ........................................................ 58
  2a. Profile: Swamp Forest ........................................... 58
      a. Landscape position ........................................... 58
      b. Typical hydrology ........................................... 58
      c. Soils .......................................................... 58
      d. Dominant plants ............................................. 58
  2b. Overview ........................................................ 59
  3a. Profile: Estuarine Fringe Forest ................................. 59
      a. Landscape position ........................................... 59
      b. Typical hydrology ........................................... 59
      c. Soils .......................................................... 59
      d. Dominant plants ............................................. 59
  3b. Overview ........................................................ 60
  4. Determine Success Criteria (i.e. goals) ......................... 60
  5. Preparation of Soil and Site ................................... 65
  6. Hydrology ........................................................ 65
  7. Planting .......................................................... 66
     a. Natural Regeneration ......................................... 71
     b. Direct Seeding ................................................ 71
     c. Artificial Reforestation ..................................... 71
  8. Cost ............................................................... 73
9. Reference Sites: Bottomland Hardwoods ........................................ 74
   a. Waccamaw River ......................................................... 74
   b. Roanoke River .......................................................... 74

10. Reference Sites: Cypress-Gum Swamp ........................................... 74
    a. Black River .......................................................... 74
    b. Waccamaw River ...................................................... 74
    c. Lumber River .......................................................... 74
    d. Roanoke River .......................................................... 74
    e. Neuse River ............................................................ 74

11. Reference Sites: Other Swamp Forests .......................................... 75
    a. Alligator River ......................................................... 75
    b. Dismal Swamp ........................................................... 75
    c. North River ............................................................ 75
    d. Durant Island .......................................................... 75
    e. Dollison’s Swamp ....................................................... 75

12. Contacts ............................................................................. 76

E. POCOSIN/SALT-SHRUB ............................................................... 77

1a. Profile: Pocosin
   a. Landscape position ....................................................... 77
   b. Typical hydrology ....................................................... 77
   c. Soil ............................................................................ 77
   d. Dominant plants ......................................................... 77

1b. Overview ............................................................................. 77

2a. Profile: Salt shrub
   a. Landscape position ....................................................... 78
   b. Typical hydrology ....................................................... 78
   c. Soils ........................................................................... 78
   d. Dominant plants ......................................................... 78

2b. Overview ............................................................................. 80

3. Preparation of Soil and Site ...................................................... 80

4. Hydrology ........................................................................... 80

5. Planting ............................................................................. 83

6. Time ................................................................................. 83

7. Cost .................................................................................. 84
LIST OF FIGURES

1. Number of Publications Each Year, 1940-1988 ................................. 5
2. Frequency of Monitoring the Various Parameters ................................ 6
3. Employer: Survey Question #25 ............................................................ 10
4. Wetland Specialization: Survey Question #2 ......................................... 10
5. Form of Record Keeping: Survey Question #11 ...................................... 12
6. Important Sources of Information: Survey Question #13 ...................... 12
7. Information for Handbook: Survey Question #15 ................................. 14
8. Use of Hydrologic Models: Survey Question #19 ................................ 14
9. Indicators of High Water Levels ............................................................ 25
10. Average Surface Salinity of Water in Sounds for April ....................... 33
11. Vegetative Stabilization Site Evaluation Form ....................................... 34
12. An Isolated Wetland Before and After Development ............................ 45
13. Pocosins in Coastal North Carolina as of 1979 .................................. 79
14. Salt-shrub Zone in a Typical Saltwater Marsh ..................................... 81
15. Relationship Between Vegetation and Organic Soil ............................ 82
# LIST OF TABLES

1. Number of Citations for Various Wetland Types ................................ 5
2. Sources of Information on Wetland Dredge and Fill Activities .......... 16
3. Seeding and Planting Transplants ............................................. 21
4. Recommended Application of Fertilizer ..................................... 21
5. Advantages and Disadvantages of Using Donor Soils ..................... 27
6. Brackish and Salt Marsh Species Zonation .................................. 31
7. Common Restoration Problems .................................................. 42
8. Advantage and Disadvantage of Distant Spacing .......................... 48
9. Items to be Considered in a Monitoring Plan ................................ 52
10. Estimate of Costs for Vegetative Establishment .......................... 54
11. Forested Wetland Restoration/Creation Checklist ....................... 61
12. Site Characteristics Related to Services Performed ..................... 64
13. Water Tolerances of Lowland Tree Species ................................. 67
I. INTRODUCTION

A. BACKGROUND

An estimated 274 million acres of wetlands remain in the United States. North Carolina ranks sixth among the states in the number of existing wetland acres (Dahl, 1990). The original amount of wetlands in North Carolina is thought to have been over 10 million acres, and current estimates are that 49 percent of the original acreage has been impacted. Impact in this case means whether the wetland partially supports, or does not support its original functions. Wet pine flatwoods and ponds, the only two wetland types that have increased over time, have increased by approximately 1.7 million acres (NCEHNR, 1992). Of all the wetlands located in North Carolina over 95 percent are found in the 41 counties that make up the Coastal Plain. This is based on U.S. Soil Conservation Service estimates of hydric soil acreage in each county. Steps have been taken by state and federal agencies to curb the number of wetland acres lost to development activities. Also, wetland restoration and creation are becoming a more common component of the Clean Water Act wetland regulatory program, and the U.S. Fish and Wildlife Service is restoring wetlands on its refuges. However, restoration experience is limited and there is only one known national guidance document on wetland creation and restoration techniques. This is Chapter 13 developed by the U.S. Soil Conservation Service (SCS) in 1992 as part of their Field Handbook. An outline of Chapter 13 of the SCS Field Handbook and the early outline of the upcoming Army Corps of Engineer’s Wetland Engineers Handbook can be found in Appendix B.

Currently, what is the number of restoration and creation projects that are being undertaken in North Carolina? To answer this question contact was made with the three main agencies involved with wetlands. These agencies are the U.S. Army Corps of Engineers (USACOE), U.S. Fish and Wildlife Service (USFWS) and the North Carolina Division of Environmental Management (NCDEM). Wetland projects fall under one of two components that include the regulatory and non-regulatory. The regulatory component involves both mitigation and enforcement actions tied to federal dredge and fill provisions permitting process (Section 404 of the Clean Water Act) that are regulated by the USACOE. There are approximately 45 wetland mitigation projects covering 460 acres (available data from 1991-93). The North Carolina Department of Transportation (NCDOT) has 16 projects involving
approximately 200 acres, and the remaining 29 projects and approximately 260 acres are non-NCDOT projects. There are approximately 125 cases per year in which some form of mitigation is required as part of an enforcement action required by the USACOE. In 90 percent of the cases, this usually means restoring a wetland by removing the material that has been placed on it and allowing the site to recover naturally. Current acreage figures for the wetland enforcement actions are not available (personal communication, Wayne Wright, U.S. Army Corps of Engineers, Wilmington, NC and Ron Ferrell, N.C. Division of Environmental Management, Raleigh, NC, July, 1993). The non-regulatory projects appear to be mainly associated with the USFWS efforts to restore wetlands to their original state on the National Wildlife Refuges, conservation easements, and private land. There are approximately 1200 acres that are actively being converted back to wetland habitat (personal communication, Mike Wicker, U.S. Fish and Wildlife Service, Raleigh, NC, July, 1993).

B. PURPOSE

The North Carolina Water Resources Research Institute (WRRI) has undertaken a project to develop a techniques handbook for the restoration and creation of wetlands. Funds for this project have been provided by the North Carolina Division of Coastal Management. The handbook includes a literature review, list of on-going projects, and expert opinion from the questionnaire for six broad wetland types found in the southeastern United States. The six wetland types are brackish/saltwater marsh, freshwater marsh, bottomland hardwood forest, swamp forest, pocosin and estuarine salt-shrub.

The purpose of this handbook is to describe to the user what is involved with wetland restoration and creation. Emphasis is placed on restoration, as creation is more of an engineering matter.

The authors are well aware that "cook-book" approaches for complex environmental activities can provide a false sense of assurance by giving specific procedures which do not always work within individual biological systems or individual sites. Problems may arise during wetland mitigation that are unique to a particular site; therefore, the most significant recommendation this publication can offer is to consult a knowledgeable and reputable practitioner before, during, and
after establishment. This handbook provides only general guidelines for restoration and creation of wetlands.
II. LITERATURE REVIEW

A. OVERVIEW

The first phase of the project was to search the literature for restoration and creation techniques for six wetland types. A literature review by the Fish and Wildlife Service (Schneller-McDonald et al., 1990) was found to be an excellent source of information. This review provided a description and summary of 1100 articles and reports from 1940-1988. Their summary of the literature indicated: (1) the most cited wetland type was freshwater marshes (Table 1.); (2) the number of restoration & creation citations dramatically increased in the mid-1970’s (Figure 1.); and (3) the most frequently monitored parameter was vegetation (Figure 2.).

B. RESULTS

Since the Fish and Wildlife Service (FWS) literature review was so extensive, the authors felt that including additional references would complement this existing source of information. There were 548 new wetland restoration & creation articles and reports added to the FWS review. All cited sources included proceedings (463), unknown sources (421), reports (358), journal articles (275), books (102), thesis (23), and newsletters (6). One limitation of the FWS document was the main source of their information was peer-reviewed articles. Since the field of wetland restoration and creation is relatively young compared to other fields of science, a great deal of information is from "gray" literature sources and is not found in the FWS document. This gray literature can be just as valuable as the peer-reviewed sources especially since much of the work is actually conducted by private consultants. Examples of the gray literature are reports, thesis, and newsletters. The majority of all sources of information were produced between 1985 and 1989 with the peak year being 1988. Currently, the authors are developing a bibliographic database (RestoreWet) that can be installed on a DOS based personal computer to quickly search the restoration and creation literature. RestoreWet should be available by November 1994.

After reviewing all of these sources of information on wetland restoration & creation, three type of documents stand out as key sources. The most complete book was Wetland Creation and Restoration: The Status of the Science edited by J.A. Kusler and M.E. Kentula (1990). This book was developed from a meeting
Table 1. Number of Citations for Various Wetland Types

<table>
<thead>
<tr>
<th>System</th>
<th>Number of records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine</td>
<td>88</td>
</tr>
<tr>
<td>Lacustrine</td>
<td>238</td>
</tr>
<tr>
<td>Riverine</td>
<td>311</td>
</tr>
<tr>
<td>Estuarine</td>
<td>499</td>
</tr>
<tr>
<td>Palustrine</td>
<td>598</td>
</tr>
</tbody>
</table>

Selected system-class

<table>
<thead>
<tr>
<th>System</th>
<th>Number of records</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riverine-riparian</td>
<td>89</td>
</tr>
<tr>
<td>Estuarine (intertidal)-emergent</td>
<td>320</td>
</tr>
<tr>
<td>— unconsolidated shore</td>
<td>125</td>
</tr>
<tr>
<td>— aquatic bed</td>
<td>107</td>
</tr>
<tr>
<td>Palustrine-emergent</td>
<td>380</td>
</tr>
<tr>
<td>— forested</td>
<td>170</td>
</tr>
<tr>
<td>— scrub-shrub</td>
<td>148</td>
</tr>
<tr>
<td>— aquatic bed</td>
<td>132</td>
</tr>
<tr>
<td>Lacustrine (littoral)-aquatic bed</td>
<td>27</td>
</tr>
<tr>
<td>— unconsolidated shore</td>
<td>22</td>
</tr>
<tr>
<td>— emergent (nonpersistent)</td>
<td>25</td>
</tr>
<tr>
<td>Marine (intertidal)-aquatic bed</td>
<td>29</td>
</tr>
<tr>
<td>— unconsolidated shore</td>
<td>16</td>
</tr>
</tbody>
</table>

Figure 1. Number of Publications Each Year, 1940-1988

Based on 1100 Records in the Wetland Creation/Restoration Data Base

Source: Scheller-McDonald, et al. (1990)
Based on 1,100 records in the Wetland Creation/Restoration Data Base.

Figure 2. Frequency of Monitoring the Various Parameters.
with potential authors in February 1987 and the final document covered both regional reviews and specific perspectives. There were 28 separate topics included in this 591 page book. The most complete literature review, as discussed earlier, was Wetland Creation and Restoration: Description and Summary of the Literature by Scheller-McDonald et al. (1990) of the FWS. The most complete journal on the subject appeared to be two sources. The non peer-reviewed journal is Restoration and Management Notes which provides the reader with reviews of current research being conducted in the field. The peer-reviewed journal is Restoration Ecology which gives an in-depth discussion of specific restoration research.

C. CONCLUSIONS

Based on the literature review conducted for this project, the restoration and creation techniques needed to restore and create six coastal wetland types were in most cases very scattered and rarely complete. Since most of the information from the literature was quite scattered, we found that input from wetland experts working in each wetland type was required to fill in the information gaps the literature review did not provide. However, there were some exceptions to this trend as in the case of the report titled Creation and Restoration of Tidal Wetlands of the Southeastern United States by S.W. Broome. This biological report was found to be excellent and utilized in the section covering brackish/saltwater marsh types.
III. QUESTIONNAIRE SURVEY

A. APPROACH

The second phase of this project was to gain more information directly from the "practitioners" about the techniques they utilize to restore and create wetlands. A questionnaire was developed with the help of Tom Hoban, North Carolina State University - Department of Sociology and Anthropology, and wetland experts. The questionnaire consisted of 29 questions covering such topics as sources of information, wetland types, and handbook information needed. A list of practitioners was developed from individuals attending a workshop conducted by the Army Corps of Engineers - Waterways Experiment Station on Engineering for Wetlands Restoration: A National Workshop. This workshop took place in St. Louis, Missouri on August 2-5, 1993. Participants at the workshop were asked to fill out the questionnaire and return it by the end of the workshop. Approximately 50% of the 224 attendees returned the questionnaire. A list of the individuals that did not attend the workshop was developed with the assistance of the Army Corps of Engineer's staff. Individuals on the list were mailed the questionnaire with a follow-up letter to individuals that did not return the questionnaire after one month. Other "practitioners" were contacted with the assistance of known wetland experts. In all, 400 questionnaires were sent out with 175 individuals returning a completed survey form. Appendix C is a copy of the survey form used to obtain the information presented in this section of the report.

B. RESULTS

Results of the survey will be presented in six areas: organization/classification, record keeping, sources of information, material needed in handbook, personal and plant/soil/hydrology information. The responses are presented as frequencies (converted to percentage) for 28 questions. The percentages given for each question do not always add up to 100% because of missing or incomplete information. Question #9 and its follow-up questions could not be expressed by frequency analysis and these questions were not included in this discussion.

There were five personal questions relating to type of organization, location of work, years of experience, area of training and main responsibility. There were 53.0% federal agency, 23.5% private consultants, 15.1% state or local agency,
4.8% college or university, and 0.6% conservation or environmental group participants in the survey (Figure 3). This is not surprising because of the heavy involvement of many federal agencies such as Army Corps of Engineers, Environmental Protection Agency and U.S. Fish and Wildlife Service. The main location of work was localized to one state (38.7%) or one region (28.6%). The remaining two larger areas of national and international consisted of less than 15%. Results of this question appeared to indicate that wetland practitioners were rather localized to one state or region. Experience in wetland management (70.9%) ranged from 2 to 15 years. Training was most represented by the fields of biology (33.3%) followed by ecology (22.6%) and then engineering (18.5%). The least represented fields were administration/business and law. Therefore, biology including botany and ecology with 62%, represented the main field of training with between 2 and 15 years of experience.

There were 10 questions dealing with the practices of the individual’s organization concerning wetlands and the classification scheme utilized. Most organizations (64.5%) only spent between 0 and 20% of their resources on restoration and creation projects. When the number of projects increased to between 21 and 40% the percentage of organizations that worked on restoration and creation projects increased only to 79.5%. Freshwater marsh (64.9%) was the main wetland type that was specialized in followed by bottomland hardwood and hardwood flats (Figure 4). The least specialized wetland types (less than 18% each) were pocosin and estuarine salt-shrub. The project stages of objectives, site selection, planning, construction and monitoring were felt to be very important. The most important functions organizations attempted to restore or create were aquatic and terrestrial habitats/corridors (60.4%), water quality (39.6%) and flood and/or erosion control (31.4%). Success, defined as establishment, occurred only 38.4% of the time. Far and away the most limiting factor in an organization’s efforts was the cost involved (32.3%) and a distant second was regulations. Most organizations had been involved with more than 20 restoration and creation projects (46.6%), and between 1 and 5 projects were attempted by 25.0% of the organizations represented in this survey. Restoration & creation project was considered to be moderately successful 65.2% of the time and very successful 20.7% of the time. Project success was usually determined between 2 to 5 years after the project (49.6%) was completed. This success time period of 2 to 5 years was the general guideline used by the Army Corps of Engineers. Poorly suited sites for restoring/creating were required sometimes (40.0%), success was affected
sometimes (41.5%) and the intended functions of a wetland were changed
sometimes (53.3%). Most participants (65%) used the Cowardin/Fish and Wildlife
Service classification system while the others used a variety of other systems, but
most (61.8%) were based on plant communities. A comparison of three
classification systems can be seen in Appendix D. The other main factors in a
classification system were hydrology and hydrogeomorphology (32.3%).

There was one question that dealt with record keeping. Most organizations
(86.2%) kept records on their projects and the most important information kept
were plant survival rate, colonization by other plant species and wetland functions.
Monitoring records were kept in 88% of the cases and between 86.1 and 91.5%
of the participants would allow government agencies and wetland researchers
access to their records. Records (84%) were kept mostly in the form of written
reports (Figure 5).

Two questions dealt with sources of information for restoration/creation efforts.
The four key sources of reference material were the Army Corps of Engineers,
scientific/ professional journals, personal communication with a consultant and the
U.S. Fish and Wildlife Service. The least referred to source for information was the
Environmental Protection Agency (5.8%) based on the list of nine different areas
presented (Figure 6). Only 64% of the organizations disseminated information
concerning their restoration/creation work. Most of the information was
disseminated through project reports (82%) and conference presentations (58.4%).

One question covered the possible topics to be included in the handbook. Planting
procedures, plant selection, ecological functions of different wetland types,
hydrology restoration and sources of regional expertise were felt to be the most
important topics presented. The most important topic was hydrology restoration
(Figure 7).

The remaining 9 questions included plant, soil and hydrology questions. The
question as to planting as opposed to natural colonization was split 50/50% but
the wetland types were different. Planting included freshwater marsh, bottomland
hardwoods, hardwood flats, swamp forest and brackish marsh. Natural
colonization included freshwater marsh and bottomland hardwood. When obtaining
plants for a site, 59.5% of the time both natural areas and nursery stocks were
used but more is purchased than is taken from natural areas. The important
Figure 5. Form of Record Keeping: Survey Question #11

- Written Reports: 84%
- Computer database: 38.2%
- Permits: 34%
- Other: 14.9%

Figure 6. Important Sources of Information: Survey Question #13

- Army Corps of Eng.: 31.7%
- Prof. Journals: 31.2%
- Consultants: 27.8%
- Fish & Wildlife: 23.2%
- Soil Conser. Service: 20.3%
- Univ. Researchers: 15%
- State Agencies: 14%
- Wetland Manual '87: 14%
- EPA: 5.8%
hydrologic conditions are hydroperiod lengths and season, volume of water inputs relative to outputs, duration of inundation, frequency of inundation and near surface saturation. Only 33.3% of the organizations polled use a hydrologic model (Figure 8). The three most important soil/substrate preparation is grading (70.2%), clearing (36.3%) and importing soil (33.3%). Only sometimes (34.1%) and rarely (28.3%) is soil imported to the restoration/creation site. In most cases soil parameters are not monitored (61%). Water control structures are utilized 79.6% of the time to regulate the site. Vegetation (73.2%) was listed the main erosion control technique.

C. CONCLUSIONS

The majority of the questionnaire participants had biological training and were employed by a federal agency. The main wetland type their organization specialized in were freshwater types and cost was said to be the most limited factor. When poorly suited sites were selected for restoration & creation effort approximately 40 to 50% of the problems arose. These responses indicate that federal agencies are heavily involved and the factors of economics and poorly suited sites limit current efforts.

Key informational sources included two federal agencies, private consultants and scientific/professional journals. A little over one-half the organizations disseminated information concerning their project through reports and conference presentations. These comments indicate the importance of federal agencies’ research efforts but the limited amount of current information available made all sources of information including the gray literature very important.

Hydrology restoration was the most important topic that should be considered in a handbook on restoration/creation techniques. However, only one-third of the organizations polled used hydrologic models. Restoration and creation efforts in wetlands have evolved from focusing on plants toward that of hydrology. Hydrology was one of the most difficult topics to deal with in wetland efforts but the most important in a project’s success.
IV. WETLAND RESTORATION AND CREATION TECHNIQUES

A. INTRODUCTION
The six coastal wetland types to be discussed include brackish marsh, freshwater marsh, bottomland hardwoods, swamp forest, pocosins and estuarine salt-shrub. From a restoration perspective, many of the techniques are the same for more than one of the above wetland types or little information exists and some types have been combined. The most common associations are brackish/saltwater marsh, bottomland hardwoods/swamp forest, and pocosins/estuarine salt-shrub.

Variations in site characteristics can make following a "cook-book" approach unreliable. Differences can include slope, soil physical and chemical properties, plant species composition, zonation, vigor and sometimes wave energy and salinity. The techniques described herein are general guidelines and may need to be modified to be successful with individual sites.

B. GENERAL TECHNIQUES FOR WETLAND RESTORATION/CREATION
There appear to be six key steps to follow in restoration efforts. The steps include determining the success criteria, planning with government agencies and a reputable consultant, selecting reference sites, preparing the site and soil, planting, and creating the hydrology. There are two important factors to also consider in the effort and they are estimating the time and associated cost.

1. Determine Success Criteria (i.e. goals)
The leading cause of failure in restoration projects is the lack of realistic or not properly identified goals (Erwin, 1990). Local government agencies and experienced consultants can assist in determining criteria for success. These criteria establish the goals of restoration and are essential to defining the success of the project. Success or failure of the project is determined by evaluating the outcome of the restoration/creation attempt alongside the original goals. Typical goals involve providing one or more of the following functional values (Hammer, 1992):
recreation
education
flood reduction
research
aesthetics
water purification
bank stabilization/protection
commercial products
baseflow augmentation
groundwater recharge

2. Plan with Government Agencies and a Reputable Consultant
Government agencies will help to guide you through the permitting process. In North Carolina, any or all of the following state agencies may be involved with wetland dredge and fill permitting: Division of Environmental Management, Division of Coastal Management, and the Division of Wildlife Resources. Federal agencies involved may be the Army Corps of Engineers, Environmental Protection Agency, and the Fish and Wildlife Service. Table 2 shows a list of agencies and other resources that can offer some assistance. Recommendations for reputable practitioners can be made by college/university faculty or staff, as well as any of the aforementioned agencies. Cross-referencing recommendations from different agencies will increase the probability of finding a dependable consultant.

Table 2. SOURCES OF INFORMATION ON WETLAND DREDGE AND FILL ACTIVITIES

- Agricultural Stabilization and Conservation Service (ASCS)
- Army Corps of Engineers (ACE)
- Environmental Protection Agency (EPA)
- Federal Emergency Management Agency (FEMA)
- Fish and Wildlife Service (FWS)
- Forest Service (FS)
- Geological Survey (GS)
- Office of Surface Mining (OSM)
- Soil Conservation Service (SCS)
- Tennessee Valley Authority (TVA)
- Geographical Information Systems (GIS)
- Landscape Ecology Journal
- Landuser

Source: U.S. Department of Agriculture (1992)
3. Select a Reference Site
If the same type of wetlands exist near the proposed wetland restoration site then use them as a reference site. However, if a reference site is not nearby try to locate the closest site. The reference site will be invaluable in visualizing what the wetland will be like once the site has been completed. A reference site is a functioning wetland near the project area which has characteristics that are to be replicated in the project area. Duplicating the characteristics of the reference site will probably be the easiest and most successful paradigm to follow for wetland restoration. The easier it is to emulate characteristics in the reference site the higher the probability of success. Therefore, choose a reference site that has characteristics that will make restoration efforts economical and obtainable. It is important to choose a reference site with a stable stand of vegetation composed of healthy plants to use as a guide in the planting site. Simulating the characteristics of a vigorous natural stand is especially crucial to wetland establishment.

An inventory of reference site characteristics must be made regarding the three areas that define a wetland: soils, vegetation, and hydrology. A vegetation survey should also be performed to determine species diversity and species density of the reference wetland. This will give the planner some idea of what to plant and in what proportions.

Vegetative factors to consider for wetland establishment are (1) selection of species (types and vigor); 2) propagation using the most effective means (cost vs. time), (3) propagation rate, (4) spacing of plants, (5) pH regime is critical, (6) flood tolerance of each species, (7) salinity tolerance of each species, and (8) proper elevation to plant species.

Since plant species vary with wetland type, specifics will be given on plant species characteristics within each section.

Wetland vegetation will grow on a wide range of slopes. Elevation limits for plantings can be determined by either trial plantings or by taking elevation measurements in a reference wetland. Doing so will give some idea of the flooding and salinity tolerances of each species of vegetation. The upper and lower elevational boundaries of a plant species can be determined by planting well above and well below the expected limits of survival. This technique may determine differences in site quality from the reference area. Such a technique may be used where the reference site has eroding peat soils. The natural site may suggest elevations in the upper limit of transplant survival, while in the planting site transplants may thrive well below the referenced elevations. This technique works well with large relatively flat areas (Woodhouse, 1979). Although recommended for tidal marshes, this technique may work well in non-tidal wetlands as well.

4. Preparation of Soil and Site
Soil factors affecting wetland establishment are: (1) the level of compaction (bulk density or mechanical impedance); (2) pH level; (3) nutrient availability; and (4) texture.
A sandy substrate is preferred because of its relatively high bearing capacity and trafficability and is generally easier to work with than a clayey or silty substrate. Planting ease is affected by soil texture. Whether the substrate is sandy, clayey, or organic, the ease of planting is the only difference in planting techniques. Sand is the most easy to plant on, then silt, and clay, with peat being most difficult (Woodhouse, 1979). Sandy soils allow for the use of mechanical transplanters, such as those used for tobacco or vegetable plants. Soil texture can be determined in the field via feel method or in a lab via particle size analysis. Planting in substrates with unsuitable physical properties (silt and clay) may require either the importing of soil or a novel approach to planting such as using walkways for access or rafts (Broome, 1990).

Mechanical impedance can be determined by using a soil penetrometer. A bulk density of 1.8 g/cm³ or greater is generally considered limiting for agricultural species. Clewell and Lea (1990) suggest bulk densities 1.6 g/cm³ or less for bottomland hardwood species. The nutrient and pH status of the soil can be determined via soil testing at the North Carolina Department of Agriculture's Soil Testing Lab located at the Blue Ridge Road Office in Raleigh. Their address is 4300 Reddy Creek Road, Raleigh, NC 27607-6465 and telephone number is (919) 733-2655.

In the Southeast, grading uplands to intertidal elevations can present problems such as low pH, low nutrient availability, and compact clay layers which can limit root growth and water movement. Topsoiling is an alternative to handling problematic subsoils. Topsoil has physical and chemical properties that are more conducive to plant growth than subsoils. The topsoil should be stripped, stockpiled, and the area graded, with topsoil being replaced until the proper elevation is achieved. However, topsoiling increases the cost of site preparation and may interfere with planting if stumps, roots and other debris are replaced with the topsoil (Broome et al., 1987).

The importance of soil tests before and after altering the soil can be demonstrated when grading in cat clays. Cat clays are soils high in reduced sulfur content. When grading exposes these soils to the atmosphere they oxidize and become highly acidified. Sulfide oxidation may make the soil too acidic for vegetation. Changes in soil pH can be determined if a soil test is performed before and after grading. If the soil pH drops after grading and subsequent air drying, then sulfate soils probably exist on the site. Solutions to this problem are (1) keep the soil saturated so the soil does not oxidize, (2) apply large amounts of lime, and (3) stockpile and replace topsoil. Acidic conditions may reduce the plant availability of some nutrients and increase heavy metal(s) availability which adversely affect plant growth (Brady, 1984).

**a. Vegetation** Plants for revegetation can be dug from nearby wetlands or purchased from a nursery. Seeds can be obtained from plants in the field or, for some species, a nursery. Plants collected from a wetland near the planned site will likely thrive at the restored site. In some states a permit
may be required for removal of vegetation in a wetland (Garbisch, 1993). In North Carolina it is illegal to collect wetland vegetation via mechanical means. Also, do not collect endangered or threatened species. If desired species are not available commercially then they must be collected from a wetland area.

It is best to establish a contract with the nursery well in advance (6 to 12 months) of the planting date as the nursery may need time to order and grow the species. To guard against problems that occur due to ecotypic variation, give the nursery a specific location where you would like seeds to be collected for growing your stock. A listing of wetland vegetation sources for the southeastern United States is given in Appendix E.

A variety of methods for establishing vegetation can be used, each with its own benefits and liabilities. Seeding is the least expensive method of vegetation establishment but has the lowest probability for success. Transplanting is a good technique to use for areas that may be difficult to establish via seed due to high wave energy or when faster establishment is needed. Table 3 lists the advantages and disadvantages of seeding and using transplants.

When plants/seed are stored one must ensure that they are stored properly. Specifics on storage requirements for wetland plants will be provided in each chapter dedicated to that particular wetland in which they exist.

Plants and seed should be obtained from a nearby wetland if not a nursery. Genetic variations can occur in species that grow over a wide geographic range. These genetic differences may mean the difference between a successful first planting and having to replant using vegetation from a different source. The most easily propagated plants are young and vigorous.

**b. Fertilizers** Problematic soil chemistry can be altered with soil amendments such as lime and fertilizer. However, fertilization is not always necessary for wetland establishment. Initial soil fertility will determine how responsive vegetation is to fertilizer. Other sources of nutrient inputs are sediment, precipitation, and runoff waters. Fertilization at planting may establish vegetation quickly which helps prevent washout and gives the desired vegetation an advantage over other species competing for the same space (Broome et al., 1992).

In North Carolina eroding shorelines may have exposed reddish, clayey banks. Nitrogen and phosphorous fertilization is critical for transplants on these areas (Broome et al., 1992). For fertilizer recommendations rely on the soil test to determine any changes needed for P and pH. Sediment deposited in the vegetated area may supply adequate amounts of N and P for growth.
Fine-textured substrates often have an adequate supply of nutrients and therefore need no fertilizers. A coarse grained substrate may need fertilizer if not receiving N and P from sediment or other sources. These two nutrients are likely to be the most limiting, especially if the B soil horizon has been exposed via grading or shoreline erosion.

On large, accessible sites use broadcast applications then disc into the soil. With small sites, for the first fertilizer application, use a spoon or cup to place a measured amount of fertilizer into a dibbled hole with about 2" of soil on top or 2" to the side of the seed/plant hole (Broome et al., 1992). Fertilizer is not placed in contact with the seed/plant because at such high concentrations, fertilizer can cause detrimental "burns".

To determine the total amount of fertilizer needed, a soil test gives the amount of fertilizer, in pounds or tons, per acre to be applied. Either multiply this amount by the number of acres to be planted or determine how many transplants per acre to plant using the equation below.

The approximate amount per plant for several types of fertilizer is given in Table 4 (Broome et al., 1992). The soil test will give nutrient requirements for the soil to enhance the growth of a certain species on a given soil type.

5. Hydrology
Unless otherwise stated the following information concerning wetland hydrology is from Planning Hydrology for Constructed Wetlands by Gary J. Pierce (1993).

The key to attaining suitable wetland hydrology is ensuring an adequate amount of water at an appropriate time. Timing and volume are primarily input determined.

a. Reliability versus Predictability Reliability of the supply should be determined. Factors to observe are groundwater development, irrigation, urbanization, agricultural and forestry practices. Inspecting historical records, the stability of erosion features, and any recent changes in the vegetation located in the downstream discharge area can be used to judge source reliability.

Precipitation is more reliable than predictable. Using rainfall data from a particular station, statistics can determine the range and standard deviation. Within certain limits, a quantity of precipitation will fall in a given month but it is not more accurately known when it will fall. Appendix A provides the addresses for the national and two regional climatic centers.

Groundwater is also more reliable than predictable. "The presence of a charged aquifer is reliable, but its behavior is usually not predictable" with current understanding. Also the regional flow can affect the understanding of the local water table.
Table 3. Advantages and Disadvantages of Seeding and Planting Transplants

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seeding</strong></td>
<td></td>
</tr>
<tr>
<td>1. lower cost</td>
<td>1. lower probability of success</td>
</tr>
<tr>
<td>2. easier to handle</td>
<td>2. longer establishment time</td>
</tr>
<tr>
<td></td>
<td>3. can not seed on site with a fetch of 2nm or higher</td>
</tr>
<tr>
<td></td>
<td>4. longer collection time</td>
</tr>
<tr>
<td><strong>Planting</strong></td>
<td></td>
</tr>
<tr>
<td>1. increases probability of success</td>
<td>1. higher cost</td>
</tr>
<tr>
<td>2. shorter establishment time</td>
<td>2. more difficult to handle than seeding</td>
</tr>
<tr>
<td>3. more tolerant of waves and currents</td>
<td></td>
</tr>
</tbody>
</table>

Source: Broome (1990)

Table 4. Recommended Application of Fertilizer

<table>
<thead>
<tr>
<th>Fertilizer Material</th>
<th>Analysis N-P_2O_5-K_2O</th>
<th>Approximate Amount/Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osmocote (8-9 month release)</td>
<td>18-6-12</td>
<td>0.5-1.0 oz. (2-4 tsp.)</td>
</tr>
<tr>
<td>Osmocote (3 month release)</td>
<td>14-14-14</td>
<td>0.5-1.0 oz. (2-4 tsp.)</td>
</tr>
<tr>
<td>Mag Amp</td>
<td>7-40-6</td>
<td>0.5 oz. (2 tsp.)</td>
</tr>
<tr>
<td>Osmocote</td>
<td>14-14-14</td>
<td>0.3-0.6 oz (1-2 tsp.)</td>
</tr>
<tr>
<td>Ammonium sulfate¹</td>
<td>21-0-0</td>
<td>0.4-0.8 oz (1-2 tsp.)</td>
</tr>
<tr>
<td>Concentrated superphosphate</td>
<td>0-46-0</td>
<td>0.2-0.4 oz (0.5-1 tsp.)</td>
</tr>
<tr>
<td>Mixed Fertilizers</td>
<td>10-10-10</td>
<td>0.8-1.6 oz (2-4 tsp.)</td>
</tr>
</tbody>
</table>

¹Ammonium nitrate may be substituted if ammonium sulfate is not available.

Source: Broome, et al. (1992)
Two planning methods can be used to make the water supply more predictable. The first is to use more than one water source. If the water table is low, stream discharge or precipitation may be used. The second method is to plan for supplementary water. The less predictable a water source the more important it is to have a supplementary volume from alternative sources. The authors suggest that where a water budget is unpredictable, five to ten times the normal volume used should be planned for the wetland.

**b. Water Budget** Water depths and potential drawdown need to be modeled for the project site. Modeling ensures there will be enough water at desired times to support planned vegetation. A model is based on the elements of a water budget without the detailed measurements of a water balance.

When calculating a water budget, a better understanding of the inaccuracies and errors can help identify a situation where a gross deficiency will occur. This situation can also indicate the need for a different approach.

The following is an often accepted water budget formula:

\[
P + \text{SWI} + \text{GWI} = \text{ET} + \text{SWO} + \text{GWO} + \Delta S
\]

where

- \(P\) = precipitation
- \(\text{SWI}\) = surface water inflow
- \(\text{GWI}\) = groundwater inflow
- \(\text{ET}\) = evapotranspiration
- \(\text{SWO}\) = surface water outflow
- \(\text{GWO}\) = groundwater outflow
- \(\Delta S\) = change in storage

A more simpler expression is,

**Inputs - Outputs = Change in Storage.**

The following five items need to be incorporated into the water budget estimates for wetland design:

- All inputs should be conservatively estimated and output generously estimated.

- All units should be of water depth over the design wetland or related to some reference elevation.

- All surface water inflow, groundwater inflow, groundwater outflow, surface water outflow, and storage should be estimated.
All precipitation data should be selected from historical records.

All monthly estimates of surface and ground water should be represented graphically.

c. Design Plans  Engineering design plans can be readily accessed in USDA (1982), Atlantic Waterfowl Council (1959), Stahre and Urbonas (1990), and Linde (1969). Low maintenance construction for deepwater areas can be achieved most readily by excavating into the landscape, which is preferred to damming swales. Recommended slopes for berms and dikes should be less than or equal to 1:10 (v:h). They should also be constructed as low and wide as is practicable. Such a design has a number of important features:

- Large amounts of earth can be deposited in the wide dike even though it is low.
- Muskrat and Nutria burrows which often cause failure in steeper banks (Linde 1969) will not breach a very wide bank.
- If available, burrowing furbearers will seek steeper banks for den sites.
- Upland dike top can be used to enhance upland habitat diversity.
- Piping along tree roots and subsequent berm failure is minimized.
- Need for a water tight dam core is reduced.
- Width of the transition from wetland to upland is maximized by allowing for an optimal zonation and habitat diversity on the berm.
- Berm top can be used for vehicular or pedestrian access with a minimum safety hazard and associated liability.
- Gently sloping upland berm will promote a parallel gentle slope below the ordinary high water pool thus maximizing the drawdown zone and associated vegetative vigor and diversity.

d. Hydrologic System Types  Eight commonly used hydrologic systems for wetland restoration and creation are discussed below:

Inline stream flow for wetland construction should be used only in the lowest energy segments of stream channels. Surface water slope wetlands can be constructed by placing a structure in a stream to flood the banks. Grading the banks and floodplain of the stream will allow water to spread and flood a greater area. The inline model is favored for areas with highly pervious substrates which would typically not support wetland hydrology. The major disadvantage of this model is that in a high energy waterway the erosion potential and site instability
are high. This model is appropriate for ephemeral and intermittent streams as well as perennial streams which do not "experience heavy seasonal flow and concomitant debris and water erosion".

**Offline stream flow** system is advantageous when the major water supply is from a stream that is banked too steeply or is too energetic or flashy to construct an inline system. Excess stream flow is diverted during normal high flow. The frequency of wetland recharge can be determined by using hydrologic calculations or stream gauge data. High water levels can also be estimated using biological benchmarks (Figure 9).

Advantages of the offline system are an excess amount of water, little excavation required on flat topography, construction on a low value floodplain. The offline systems disadvantages are high erosion potential and permits will likely be required for stream modification. Erosion control is important in the offline method because it involves a high energy system.

**Spring and seepage flow** can be found in the SCS Handbook *Ponds - Planning, Design, and Construction* (USDA, 1982). This handbook provide principles for constructing groundwater slope wetlands. In spring/seepage flow systems the "wetland is usually excavated into the side of a slope with its upslope edge just down hill from or intersecting" subsurface flow. The hydroperiod will depend upon the source of water. An annual drawdown usually results by excavating into a perched water table. An annual drawdown usually results if the source is interflow or a perched water table. Permanently flooded wetlands can be created by excavating into a continually charged aquifer.

Advantages of this technique include:
1. water source is reliable and predictable,
2. construction costs are low,
3. wetland habitat did not previously exist where develop is taking place.

Disadvantages include:
1. water control structures are needed, which could fail and
2. seep habitat may be destroyed.

**Surface flow wetlands** takes advantage of a concept known as "moist soil management". Moist soil management requires the growth of high food value vegetation for waterfowl. Management considerations involve water supply, soil permeability, water retention via berm construction, and vegetation management. Information on moist soil management can be obtained from Ducks Unlimited, State, and Federal wildlife resources agencies. An introduction to these management principles can be found in *Management of Seasonally Flooded Impoundments for Wildlife* (Fredrickson, 1982).
Figure 9. Indicators of High Water Levels

- Undisturbed
- Estimated high water level
- Debris evidence
- Water mark color change
- Debris
- Sediment deposits
- Water level during visit
- Signs of cutting
Ground water interception with surface water whenever possible. Reasons for failure of a ground water wetland are

- using a poorly understood water table which can create periods of excessive drought and
- side slopes with highly permeable soils become droughty during drawdown periods.

Sharing a water supply with an adjacent wetland is an effective practice. However, two serious drawbacks are possible. The first is that excavation of channels or swales commonly occurs at the delineated wetland boundary. This results in a dry expansion area. The second pitfall can occur when expanding the area of a wetland. Clay, silt and organic matter may be providing an impermeable substrate. If the wetland is expanded into permeable soils then the wetland may drain. Close attention should be paid to elevation, soil permeability, and the method by which water is conveyed in a shared water supply wetland.

Aquatic bed is defined as a zone of submerged or floating leaved vegetation in a permanently flooded site. Typically the zone is created within an existing water body. High water quality is important for the survival of an aquatic bed. Turbid water will reduce light penetration upon which submerged plants depend. Waves or strong currents may be problematic in an aquatic bed. Vegetation can incur leaf damage or be dislodged from the substrate.

Lake shore wetlands are the fringe communities around a deep and/or large body of water. To design a lake shore wetland the following steps are necessary:

- examine wave energy which impinges directly on the emergent fringe,
- provide an appropriate depth and drawdown regime, and
- protect plants from destruction by human use of the shore, by wildlife herbivory, and by debris damage.

Detailed information of shoreline planting can be found in Knutson and Woodhouse (1983), Allen and Klimas (1986), Gray and Leiser (1982), and Schiechtl (1980).

6. Planting
Determine the area to be planted. Next determine the number of available plants for each species that are to be planted. Plant availability is usually determined by the number of plants that are available at the time of planting. Plant spacing can be determined by using the equation:

\[ \text{Plant Spacing} = \frac{\text{Planting Area}}{\text{Number of Available Plants}} \]
An area of 1 ha (10,000 m²) planted with 5,000 plants will require a spacing of 2 m², since:

\[
\frac{10,000 \ m^2}{5,000} = 2 m^2
\]

In the planning stage, the area of the site to be planted should be determined as well as the plant species to be planted. The available number of plants or seeds should then be determined. This step can only be completed when a nursery has determined how many plants it can obtain or after the field work of gathering seed and/or plants is complete. Typically, the number of available plants/seed is the limiting factor (Woodhouse, 1979). If the number of available plants is not a limiting factor then consider the advantages and disadvantages of using donor soils (Table 5).

Table 5. Advantages and Disadvantages of Using Donor Soils

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth moving machinery is the only cost</td>
<td>Desirable species may not germinate</td>
</tr>
<tr>
<td>Entire community may be introduced</td>
<td>Relative species abundance may not be the same as the donor site</td>
</tr>
<tr>
<td>(isolated wetland may develop species groups not similar to natural communities)</td>
<td></td>
</tr>
<tr>
<td>Undesirable species may be deterred through rapid establishment of diverse vegetation</td>
<td>Management options may be needed for the control of undesirables until dominated by desirable. (Herbicides, water level manipulation, rotovating, burning, or a combination. Management may result in unwanted species.)</td>
</tr>
</tbody>
</table>

A great deal of information about specific plant species is given in Appendix F which includes herbaceous emergent plants, shrubs, and trees. For each species the genus/species, common name, wetland indicator status, water tolerance, salinity tolerance, light requirements, height range, rate of spread and other comments are given.
7. Time
The following is a check list of time considerations by Broome et al. (1988) to bear in mind:

- Plan and prepare at least one year prior to transplanting is necessary, if seed must be collected and germinated to grow plants.
- Allow time for obtaining permits.
- Delay of permitting and construction are common.
- Allow fill material to settle several weeks.
- Complete final grading and construction well in advance of the optimum planting times.
- Optimum planting time: April 1 to June 1. Planting before April 1 may incur storm damage and field-dug plants are difficult to obtain. Planting later than June 15 limits the growing season.
- Use potted seedlings may result in unhealthy or dead plants if there are long holding times.
- Use of manual digging and planting. Approximately 180 to 200 transplants can be dug and separated in about one hour and one hour to plant the same number of plants.
- Use of a mechanized operation can double the productivity of a manual operation (i.e. half the time of manual operation).

8. Cost
King and Bohlen (1994) estimated restoration and creation costs based on data from 84 projects. Average project costs, not including land, ranged from $18,000 to $77,900 based on eight wetland groupings. A further breakdown into four input categories found the ranges were 31 to 74% labor, 8 to 54% materials, 9 to 34% equipment, and 0 to 14% other. Not surprising, the construction costs were higher than pre or post construction and ranged from 58 to 87% of the total project cost.
C. BRACKISH/SALT MARSH

1a. Profile: Brackish Marsh
   a. Landscape position Margins of sounds and estuaries, usually located away from inlets. Outer Coastal Plain.

   b. Typical hydrology Irregularly or regularly flooded by salt or brackish water and freshwater. Many are dissected by mosquito ditches.

   c. Soils Typically organic but occasionally mineral.

   d. Dominant plants Herb layer heavily dominated by salt meadow cordgrass and black needlerush with no tree or shrub layers. For information on these species’ wetland indicator status see Appendix F.

      Herbs: Black needlerush, Juncus roemerianus
             Salt meadow cordgrass, Spartina patens
             Big cordgrass, Spartina Cynosuroides

1b. Overview
Brackish marshes are distinguished by their lack of trees and shrubs and by the dominance of cordgrass and needlerush. Despite apparent uniformity, the plants actually form a mosaic reflecting subtle changes in salinity. These wetlands probably burned on a regular basis under natural conditions. Without fire, black needlerush grows into dense stands which clog drainage ways. Stagnant brackish marshes provide poorer habitat than those with good circulation of water.

Brackish marshes develop where freshwater from rivers dilutes saltwater from tides. Some brackish marshes are regularly flooded by tides while others experience only occasional flooding, depending on their location and elevation. They may be found interspersed between freshwater marshes and salt marshes or salt scrub wetlands as the mix of freshwater and saltwater changes.

Extensive brackish marshes occur on the mainland side of barrier islands and on the margins of estuaries. This wetland type is common in North Carolina.

2a. Profile: Saltwater Marsh
   a. Landscape position Margins of sounds and estuaries. This is usually located in close proximity to inlets. Outer Coastal Plain, particularly south of Cape Lookout.

   b. Typical hydrology Regularly flooded by (saltwater) lunar tides. Many salt marshes are dissected by mosquito ditches.

   c. Soils Mineral sands and silts.
**d. Dominant plants** Herb layer heavily dominated by smooth cordgrass with no tree or shrub layers. For information on these species' wetland indicator status see Appendix F.

Herbs: Smooth cordgrass, *Spartina alterniflora*
Glasswort, *Salicornia* sp.
Salt meadow cordgrass, *Spartina patens*
Black needlerush, *Juncus roemerianus*

**2b. Overview**
Salt marshes are found in shallow areas which are flooded by ocean tides on a regular daily schedule. They are easily identified by their lack of trees and shrubs and by their position on the margins of sounds and estuaries. Salt marshes are characterized by flat areas dissected by tidal creeks and mosquito ditches.

The plant and animal communities of salt marshes must adapt to daily inundation and drying as well as high salinity. Because of the environmental stress, this wetland type is heavily dominated by relatively few plant species such as smooth cordgrass. Those plants which have adapted can be highly productive because of regular inputs of nutrients. However, the extreme environment combined with wide distribution and lack of isolation cause salt marshes to contain very few rare plant species.

The upland borders and slight rises in salt marshes may develop into salt scrub wetlands. Salt marshes also gradually become brackish marshes as distance from the ocean and the influence of freshwater sources increases. On their lower borders, salt marshes grade into deepwater communities.

Salt marshes are common and extensive all along the North Carolina coast. They are best developed in the middle and southern portions of the coast where the tidal amplitude is greatest.

Some differences in site characteristics of brackish/salt marshes are wave energy, salinity strength, slope, fetch, soil physical and chemical properties, plant species composition, zonation, and vigor. Irregularly flooded brackish-water marshes are more complex with respect to growth of vegetation than are regularly flooded salt marshes (Broome et al., 1987).

**3. Determine Success Criteria (i.e. goals)**
Typical goals for tidal marsh restoration include: (a) dredged material stabilization or creation of marsh habitat using dredged material; (b) shoreline erosion control; (c) mitigation of destruction or adverse impact on natural stands; and (d) research.

The two most important factors for encouraging tidal marsh establishment are elevation and salinity. Species zonation is determined by inundation length and frequency which is controlled by elevation and tidal amplitude. Table 6 shows the plant species with their associated salinity and acidity ranges, typical location, and
the difficulty level of propagation. No matter which species are planted the site will eventually be colonized by plant communities that are adapted to the environment. There is less species diversity as salinity increases (Broome, 1990).

Table 6. Brackish and Salt Marsh Species Zonation

<table>
<thead>
<tr>
<th>Plant Species</th>
<th>Salinity Range (ppt)</th>
<th>Brackish or Salt Marsh</th>
<th>High or Low Marsh</th>
<th>Propagation Difficulty Level</th>
<th>— Soil pH</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Spartina alterniflora</em></td>
<td>0-35</td>
<td>Both</td>
<td>low</td>
<td>easy</td>
<td>7.3</td>
</tr>
<tr>
<td>smooth cordgrass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Spartina patens</em></td>
<td>0-35</td>
<td>Both</td>
<td>high</td>
<td>easy</td>
<td>7.0</td>
</tr>
<tr>
<td>saltmeadow cordgrass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Spartina cynosuroides</em></td>
<td>0-10</td>
<td>Brackish</td>
<td>high</td>
<td>easy</td>
<td>5.0-7.6</td>
</tr>
<tr>
<td>big cordgrass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Juncus roemerianus</em></td>
<td>0-35</td>
<td>Brackish</td>
<td>high</td>
<td>moderately difficult</td>
<td>6.6</td>
</tr>
<tr>
<td>black needlerush</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Distichlis spicata</em></td>
<td>0-50</td>
<td>Both</td>
<td>high</td>
<td>moderately difficult</td>
<td>6.6-7.6</td>
</tr>
<tr>
<td>saltgrass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Environmental Concern (1993)
2. Woodhouse (1979)
3. Beal (1977)

4. Preparation of Soil and Site
The following is a check list of characteristics to consider when restoring or creating tidal wetlands:

- Visually inspect a nearby natural marsh for plant species composition, dominance, zonation, and vigor.
- Determine elevations of upper and lower extent of the vegetation by using a surveyors level or by trial plantings.
- Establish slopes of 1-3% although successful establishment has occurred on slopes from less than 1% up to 10%. If these slopes exist, grading can be minimized if required at all. The main problems with slopes in the southeast is that they may be too flat, which inhibits drainage and eventually raises soil salinity (personal communication, Dr. Stephen Broome, Department of Soil Science - N.C. State University, October 1993). If the slopes are undesirable
then grading may be required. After importing soil or grading of the site, have the soil tested again. Soil chemistry conditions may have been altered.

- Test the following soil characteristics:

  a. Texture. A sandy substrate is preferred because of its relative high bearing capacity and trafficability and is generally easier to work with than a clayey or silty substrate.

  b. Salinity of Soil Water. A salinity less than 45 ppt must exist if any marsh vegetation is to survive. The forming of sand domes can assist in resolving high salinity problem areas. Sand domes are mounds of sand formed above and adjacent to the planting site. Dunes may also act in the same way as sand domes. The domes allow fresh rainwater to slowly move, as baseflow, through the lower slopes diluting the salinity level (Woodhouse, 1979). Average surface salinities of North Carolina coastal waters are given in Figure 10 (Giese et al., 1979).

  c. Soil Chemistry. The high levels of magnesium, calcium, potassium, and sulfur in seawater are adequate to supply these nutrients for brackish and saltwater marsh vegetation. Fertilization with nitrogen and in some cases phosphorus is necessary to produce good growth on some sites (Broome, 1990). Plant available nutrients can be tested at the North Carolina Department of Agriculture Soil Testing Lab. Brackish and salt marsh vegetation will not survive in soils with a pH below 3.0 and growth will be stunted with a pH between 3.0 and 4.0 (Broome, 1987).

  d. Soil Contaminants. Heavy metals and pesticides may affect growth of vegetation. There is also a risk of transferring the contaminants to the food chain. There are many commercial laboratories that can test for these contaminants in the soil. The North Carolina Department of Agriculture can provide a list of laboratories that conduct tests to determine the presence of these contaminants.

  e. Bulk Density. Compact soil or hard pans in the subsoil can impede root growth. Problems with pans can be determined using a penetrometer.

  f) Locate low wave energy sites. A high wave energy environment can prevent establishment of vegetation. Erosion and subsequent uprooting of transplants can occur in such an environment. If the site was seeded, the seeds may be uncovered by erosion and subsequently washed away. A site evaluation form (Figure 11) can assist in predicting the probability of success or failure in establishing tidal marshes (Knutson et al., 1981).
Figure 10. Average Surface Salinity of Water in Sounds for April

EXPLANATION

---/9--- SALINITY, IN GRAMS PER KILOGRAM. (Sea water contains about 34.5 grams of dissolved solids per kilogram.) Contour interval variable.

Giese et al. (1979)
Figure 11. Vegetative Stabilization Site Evaluation Form

<table>
<thead>
<tr>
<th>1. SHORE CHARACTERISTICS</th>
<th>2. DESCRIPTIVE CATEGORIES (SCORE WEIGHTED BY PERCENT SUCCESSFUL)</th>
<th>3. WEIGHTED SCORE</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. FETCH-AVERAGE</td>
<td>LESS THAN 1.1 (0.7) 3.1 (1.9) GREATER THAN 9.0 (5.6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.0 (0.6) 3.0 (1.9) 9.0 (5.6)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(87) (66) (44)</td>
<td></td>
</tr>
<tr>
<td>b. FETCH-LONGEST</td>
<td>LESS THAN 2.1 (1.3) 6.1 (3.8) GREATER THAN 18.0 (11.2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.0 (1.2) 6.0 (3.7) 18.0 (11.2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(89) (67) (41)</td>
<td></td>
</tr>
<tr>
<td>c. SHORELINE GEOMETRY</td>
<td>COVE (85) MEANDER OR STRAIGHT (62) HEADLAND (50)</td>
<td></td>
</tr>
<tr>
<td>d. SEDIMENT</td>
<td>0.0 – 0.4 0.4 – 0.8 0.8 – or greater</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(84) (41) (18)</td>
<td></td>
</tr>
</tbody>
</table>

4. CUMULATIVE SCORE

5. SCORE INTERPRETATION

a. CUMULATIVE SCORE

<table>
<thead>
<tr>
<th></th>
<th>0 – 200</th>
<th>201 – 300</th>
<th>300 – or greater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Success Rate</td>
<td>15 %</td>
<td>50 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>

Knutsen et al. (1981)
A low wave energy area is likely to have the following characteristics:

A short fetch (<5.5 nautical miles (nm)). Fetch is the length of open water in any one direction and can be readily measured on a map. The longer the fetch the more of a factor wind plays in wave energy. A large fetch will increase the wave energy and therefore the erosivity of waves. Generally, less than 2.5 miles can be tolerated without wave protection for transplants and less than about 0.6 miles for seed. Sites with a 5.5 mile or more of fetch have low probabilities of success, although the tidal range could modify fetch effects.

No maintenance planting should be expected for Spartina alterniflora and Spartina patens if planted on a site with an average fetch less than 1.0 km. Maintenance planting is the periodic replacement of dead plants that normally occurs when the restoration or creation of a wetland takes place. Establishment of marsh grass on a site where average fetch is 3.0-5.5 nm without a permanent offshore breakwater may be impractical (Broome, 1990).

Shallow offshore depth. Offshore depth should be considered when evaluating the wave climate. In shallow water the shore bottom dissipates waves more readily than deeper water. When waves hit the beach, friction dissipates their energy. In deep water friction is much lower, therefore, is not as effective at dissipating wave energy (personal communication, Dr. Stephen Broome, Department of Soil Science - N.C. State University, October 1993).

A sheltered shoreline configuration (i.e. cove or bay) Headland has higher wave energy.

Few boat wakes. Planting near channels can be problematic as this is where boat wakes are the most abundant.

Small sediment size. The level of wave energy determines the size of sand grains the tide can carry. Fine grained sand indicates a low energy wave climate, while a coarse grained sand indicates a high energy wave climate.

5. Hydrology
Since the key to proper wetland hydology is an adequate amount of water at an appropriate time (Pierce, 1993), there should not be a problem in the case of brackish/saltwater marshes. These wetlands are usually regularly or irregularly flooded.

6. Planting: Spartina alterniflora
S. alterniflora can be propagated via seed, nursery transplants, or dug from natural stands.
a. Seeding  The seeded area must be protected from waves. Seeding involves preparing a seedbed with a tillage implement (rake, rototiller, harrow, etc.). Once seeded incorporate seed, via tillage, to a depth of 2-3 cm. Successful establishment is generally limited to upper portion of intertidal zone. If only a limited number of seeds can be obtained, they may be best used to grow potted plants (Broome, 1990).

Source. The most abundant source of seed is found in recently colonized open stands or along such edges as creek banks.

Maturity. Late September (Maturity progresses from North to South with yearly instand variation)

Harvest. After maturity but before shattering; harvest seedheads via knife or clippers.

Storage. Store seedheads moist and refrigerated (20-5°C or 350-40°F) for 3 to 4 weeks before threshing. This will make separation from the stems easier. Store threshed seeds in plastic containers filled with seawater or artificial seawater so seeds are submerged. Seeds lose viability after about one year of storage.

Sowing Rate. 100 seeds / m²

b. Field Collected Plants  Remove plants with a shovel and separate stems.

Source. Marsh edges and new stands. Old marsh stands are less vigorous and have smaller stems and are more difficult to dig and separate due to the development of a dense root mat.

Description. Vigorous, large stems, small but growing shoots and rhizomes, well developed root system defines the plant. Ideal height is about 30 cm but a wide range of heights is acceptable. Plants on site are easier to dig and separate than plants from an old marsh.

Slow release vs soluble fertilizers. Used together, the slow release fertilizers Mag Amp and Osmocote have proven to be much more effective than soluble fertilizers. A slow release fertilizer is recommended for coarse substrates, since a coarse textured substrate cannot adsorb nutrients as readily as a fine textured substrate. Top dress in the summer of the second growing season with ammonium sulfate and concentrated superphosphate at low tide. Broome (1990) reported that this second application of fertilizer can double the above ground biomass and the number of stems within five months.

7. Time
The following is a check list of time considerations by Broome et al. (1988) to bear in mind:
Plan and prepare at least one year prior to transplanting is necessary, if seed must be collected and germinated to grow plants.

Allow time for obtaining permits.

Delay of permitting and construction are common.

Allow fill material to settle several weeks.

Complete final grading and construction well in advance of the optimum planting times.

Optimum planting time: April 1 to June 1. Planting before April 1 may incur storm damage and field-dug plants are difficult to obtain. Planting later than June 15 limits the growing season.

Use potted seedlings may result in unhealthy or dead plants if there are long holding times.

Use of manual digging and planting. Approximately 180 to 200 transplants can be dug and separated in about one hour and one hour to plant the same number of plants.

Use of a mechanized operation can double the productivity of a manual operation (i.e. half the time of manual operation).

8. Cost
Following are cost considerations listed by Broome et al. (1988) to bear in mind before starting a project:

- Planning and design
- Negotiating for the site
- Site preparation
- Structure construction (breakwaters)
- Planting and maintenance during establishment (vary with site conditions)
- Fertilizer (1 hectare’s worth of slow release fertilizer = $2,000. The cost for one broadcast application of soluble fertilizer for the same area = $400).
- Labor ~ 240 person hours x hourly wage. 150 person hours for transplanting sprigs or potted plants for 1 hectare (ha.) on a 2 ft spacing (using a mechanical auger). Only 10 person hours required to seed and cultivate 1 ha. 40 person hours to fertilize at planting. Five (5) person hours to broadcast fertilize after
planting. May-Oct. maintenance ~40 person hours for 1 ha (assume 20% of area will require replanting due to mortality)

- ~28,000 plants/ha (0.6 m spacing) x cost of each plant
- travel
- per diem
- overhead
- profit
- 20% of the total for a guarantee of the job

King and Bohlen (1994) estimated salt marsh wetland restoration and creation costs based on data from 9 projects. Average project cost, not including land, was $18,100. This figure was broken down into four input categories including 52% for labor, 27% for materials, 20% for equipment, and 2% for other. Most of the cost was in construction (73%) followed by preconstruction (16%) and postconstruction (11%).

9. Reference Sites: Brackish Marsh
- **a. Stumpy Point** Marshes found in the vicinity of Stumpy Point. Part of the Alligator River National Wildlife Refuge. Located adjacent to the Pamlico Sound and Stumpy Point Bay and east of U.S. 264 in Dare County.

- **b. Shackleford Banks** Found along the eastern sound side of the Shackleford Island. Part of the Cape Lookout National Seashore in Carteret County.

- **c. Motts Creek** Found along the mouth of Motts Creek on the Cape Fear River. Located southwest of Silver Lake and U.S. 421 in New Hanover County.

10. Reference Sites: Saltwater Marsh
- **a. Hammocks Beach** Marsh found along the northwest portion of Bear Island (Hammocks Beach State Park) and is bordered by the Atlantic Ocean, Intracoastal Waterway, Bogue Inlet, and Bear Inlet. Located in Onslow County

- **b. Shackleford Banks** Marsh found along the eastern sound side of the Shackleford Island. Part of the Cape Lookout National Seashore in Carteret County.

- **c. Smith Island** Marsh found along the northwestern complex of the Smith Island. The island is bordered by the Atlantic Ocean, Cape Fear River, and Bald Head Island. Located southeast of Southport in Brunswick County.
11. Contacts

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D. FRESHWATER MARSH

1. Profile
   a. Landscape position  Deep depressions and natural lakes in the Coastal Plain or in artificial impoundments or beaver ponds throughout. Freshwater marshes also develop in sounds at the mouths of large rivers.

   b. Typical hydrology  Semi-permanently to permanently inundated or flooded. The source may be stream flow, surface runoff or groundwater discharge or combination of these sources. In the Coastal Plain, many marshes are crossed by mosquito ditches.

   c. Soils  Generally not mapped, but often sands, silts and clays of alluvial origin. Soils in beaver ponds and farm ponds often develop mottling which can remain if the pond is drained.

   d. Dominant plants  Vary with zones of emergents, submergents and floating plants. Shrubs may occur around the edges or growing on old tree stumps in artificial impoundments. For information on these species’ wetland indicator status see Appendix F.

          Trees:  Black willow, *Salix nigra*
       Shrubs:  Buttonbush, *Cephalanthus occidentalis*
            Tag alder, *Alnus serrulata*
            Swamp Rose, *Rosa palustris*
            Wax myrtle, *Myrica cerifera* (Coastal Plain)
            Swamp rose mallow, *Hibiscus moscheutos*
          Emergents:  Cattail, *Typha sp.*
            Rush, *Juncus sp.*
            Bulrush, *Scirpus sp.*
            Pickerelweed, *Pontederia cordata*
            Arrowhead, *Sagittaria sp.*
            Blue flag, *Iris virginica*
       Floating plants:  Water lily, *Nymphaea odorata*
            Duckweed, *Lemna sp.*
            Bladderwort, *Utricularia sp.*

2. Overview
Freshwater marshes develop where standing water is generally present throughout the year such that trees cannot become established. Permanent freshwater marshes develop along the shorelines of natural lakes and in deep depressions. As there are very few natural lakes in North Carolina, most permanent freshwater marshes develop at the ends of small areas of Piedmont reservoirs. More temporary freshwater marshes develop behind beaver dams or along the shorelines and upper ends of farm ponds.
Many freshwater marshes exhibit complex zonation. A shoreline with gradual slope supports the development of a well-developed emergent zone. If the water is sufficiently clear, a diverse submergent community may form. Soft substrate and moderate depth allow the development of floating plants. If the water is temporarily or permanently removed, a tree overstory may develop and form a swamp. Some freshwater marshes in the Outer Coastal Plain are frequently burned under natural conditions.

Freshwater marshes grade into a variety of wetland and upland communities as well as deepwater habitats. In the Mountains, they are intermixed with mountain bogs and fens and bog forests. In the Piedmont, they commonly grade into bottomland hardwood forests at their upper borders. They are often associated with brackish marshes and swamp forests in the Outer Coastal Plain.

Freshwater marshes are fairly rare in the Mountains and more common in the Piedmont and Inner Coastal Plain. They are rare on the barrier islands of the Outer Coastal Plain.

3. Determine Success Criteria (i.e. goals)
In goal setting be creative and flexible, but define specific realistic goals. Lack of identifying realistic goals is a major shortcoming in wetland restoration and creation (Erwin, 1990). Refer to Table 7 for more detail concerning goals not attained. If there are multiple goals choose one functional value as a primary goal. Secondary goals will likely become functional without much effort if the primary goal is achieved. Typical goals for freshwater marsh restoration or creation involve providing one or more of the following functional values (modified from Hammer, 1992):

- Recreation
- Education
- Flood reduction
- Research
- Aesthetics
- Water purification
- Bank stabilization/protection
- Commercial products
- Sediment stabilization
- Fish/Wildlife habitat
- Ground water recharge
- Base flow augmentation
Table 7. Common Restoration Problems

1. Unrealistic or not properly identified goals
2. Unsatisfactory monitoring
3. Improper hydrogeology
4. Inadequate understanding and evaluation of wetland area to be mitigated
5. Watershed evaluation was inadequate
6. No practical methodology was applied to determine the level of goal attainment
7. Improper construction
8. Improper handling of mulch or plant materials
9. Established wetland was not kept free of problematic exotics
10. Area was not kept free of nuisance animals.
11. No entity was identified to be responsible for long term management plan with adequate funding
12. Unsuitable water source
13. Available budget was too small for the design
14. Long term watershed management plan was not adopted
15. Unsuitable soil

Source: Erwin (1990)
4. Preparation of Soil and Site

a. Design  A functional marsh can be established within 3 to 5 growing seasons. The marsh needs to be as free of maintenance requirements as possible. The main components of successful construction of a functional freshwater marsh include (Erwin, 1990):

- Measurable success criteria and realistic goals
- Pre-construction design evaluation including a hydrological analysis
- Contour design
- Construction technique
- Proper water quality
- Existing and future adjacent land use compatibility
- Suitable substrate properties
- Techniques for re-vegetation
- Re-introduction of fauna
- Protective structures and upland buffers
- Supervision by a qualified professional
- Long-term management plan after construction
- Monitoring and reporting criteria

b. Location  Evaluate the watershed at least generally with regard to plant communities, surface and groundwater conditions, geomorphology, wildlife, and land use. Determine existing and future land use plans of the watershed of the proposed wetland. The planned wetland would be better located in an area that has a land use plan which is conducive to marsh establishment. Alteration or elimination of the marsh may be called for where pressure for future development is high (Erwin, 1990).

Marsh establishment could be planned adjacent to an adequately designed lake. There it can serve as a buffer, which improves water quality, and as a littoral zone which is a valuable fish and wildlife habitat. Locating non-tidal freshwater marshes together with existing or proposed lakes is a preferable alternative to isolating them (Erwin, 1990).
Excavation can be accomplished via earth moving equipment such as excavators, dozers, or draglines, or by blasting. Boggy conditions inhibit the use of heavy equipment. Blasting with ammonium nitrate, triggered by dynamite can be much more cost effective. However blasting tends to produce "holes" instead of gradually sloping edges (Weller, 1987). These "holes" can be graded with earth moving equipment if necessary. An advantage of blasting is the absence of a spoil pile, which is scattered throughout the area by the blast (Jensen, 1993). The U.S. Army Corps of Engineers Wildlife Resource Management Manual (Technical Report EL-89-14, U.S. Army Engineer Waterways Experiment Station) outlines techniques for blasting in marshes.

5. Hydrology
The most critical aspect to design is hydrology. "Water depth is perhaps the dominant physical factor influencing the kind of adaptations required for the plant if it is to establish, live, and reproduce on a site" (Weller, 1987). In a geographic region where precipitation is higher than evapotranspiration, taking advantage of surplus water is most readily accomplished through the use and/or manipulation of topography. Therefore, perform a topographic and a bathymetric survey of the restoration and reference site. Correlate water levels (tidal or non-tidal) and vegetation with the elevational survey. Also correlate the vegetation from the reference marsh with its topography. Use all collected data to assist in implementing grading. A final grading plan should be developed using a 6 inch contour interval throughout vegetated areas (Garbisch, 1986).

"Basin shape, water regimes, cover—water interspersion, and plant species diversity" produce the marsh structure (Weller, 1987). Basin topography is an important component of wetland design. More niches are provided when a variety of conditions exist on site. Variable slopes have a higher wildlife potential than similar slopes. A design enhancement to consider is creating islands within the marsh for nesting birds (Weller, 1987). However, abrupt edges are less attractive to swimming waterfowl than gently sloping edges. (Weller, 1987). Individual cells within the wetland (in series or parallel) can be effective at creating a variety of habitats and functions. Florida regulations dictate that slopes must be of a 6:1 ratio or flatter to a point of 60 to 77cm (2-2.5 feet) below the water surface (Mitsch, 1993).

Shisler (1990) states that the "construction of only the emergent wetland vegetation component will not result in a viable system and will not be comparable to the natural system in most cases". Usually, a "productive wetland system needs a combination of open water and ecotonal and upland habitats." Figure 12. depicts a before and after development of the surrounding upland. Will this marsh function the same as it did before development?

Comparing similar watersheds can assist in the predicting the hydrology for the project. Similar watershed characteristics (size and geomorphology) are necessary
Figure 12. Setting of an Isolated Wetland Before and After Development

The regulation of isolated wetlands results in the "preservation" of the wetland without regard to its adjacent landscape. A: Original setting of the wetland; B: Setting of the wetland after development of the adjacent area.

Shisler (1990)
for the replication of runoff volume and hydroperiod. Any differences that may affect the hydrologic budget in the two watersheds should be accounted for.

The water supply to this self-sustaining system needs to be natural such as groundwater, surface water, or from an adjacent system. Unnatural systems (i.e. pumps) should never be used as the main source of water for a project. Pumps are expensive, energy intensive, difficult to maintain and regulate (Erwin, 1990 and Weller, 1987).

6. Planting
   a. Method of Establishment

Vegetation type will depend upon the goals of the project. Marsh vegetation can be established via three methods discussed below.

   a. Volunteer colonization may be used where a marsh is being established adjoining an existing marsh. However, if the planned marsh is overly large volunteer colonization by desirable species may take too long to meet project goals. Avoid using volunteer colonization when problematic exotic vegetation such as *Melaleuca* or *Phragmites* are found on or adjacent to the project site (Erwin, 1990).

   b. Hand or mechanical planting. Local stock is more likely to have a greater percentage of survivability, greater growth, and establishment rates than commercial stock due to the more ecotypically adapted vegetation to the local site conditions.

Collect rhizomes and tubers once shoot growth has stopped late in the fall, or before extensive new growth begins in early spring. Process rhizomes by cutting into lengths which contain 2-3 nodes per rhizome, remove all vegetation growth, and store in a moist medium such as peat or sand until they are needed for planting. To prevent rhizome damage from fungus during winter storage treat with a dilute bleach solution (0.5% hypochlorite). This will inhibit fungal injury. Store at a temperature between 35-40°C. Spring collections are recommended over fall collections as viability is decreased during storage. Planting rhizomes in the spring has been successful. Although some species may do well when planted in the summer, typically, droughtiness and excessive heat lower success probability. Plant rhizomes to a depth of 5-13 cm (2-5 inches). In moist soils, rhizomes can be pushed in by hand. However in denser soils, use trowels or tree planting bars (dibbles).

When seeding on large sites use a broadcast seeder behind a low ground pressure tractor or broadcasting aerially from fixed-wing aircraft or helicopter. Small areas can be hand seeded.
Spacing intervals for planted material of 0.3m to 1.5m (1 to 5 ft) are recommended depending upon establishment and spreading rates of individual species. Allow space for the lateral spread of rhizomes. If a species can be successfully established in one growing season then 1.5m spacing is adequate. Spacings of 0.3 to 0.9m (1 to 3 ft) are recommended for less prolific species (Environmental Concern Inc., 1993).

Clustered planting of perennials provides species and spatial diversity. Fifty percent (50%) cover of inundated zones is desirable for waterfowl habitats, whereas 100% cover is too dense. Weller (1987) suggests that a good cover area to water area ratio is 50:50. Greater growth and vigor can be achieved by adding a 9g Agriform slow-release fertilizer tablet (22%N-8%P-2%K) to each planted propagule at the time of planting.

Wetland habitat management techniques should be followed when manipulating water levels that will promote germination and succession. A late spring drawdown can have a favorable impact on emergent perennials and germinating annuals. When timed properly, drawdowns can promote seed germination and stimulate growth, thus decreasing the need to revegetate the site. Do not try to create a wetland in one growing season. It is a long-term process (Warburton, 1985).

Vegetative patterns influence bird species composition and populations. Two relationships between vegetation and water birds to keep in mind are (Weller, 1987):

- The number of bird nests is proportional to the number of marsh plant communities; and

- Broken emergent vegetation is more likely to attract large duck nesting populations than solid emergent vegetation.

c. Seed Banks. Seed banks are locations where seeds of different wetland species are grown and harvested for use in restoring or creating wetland types. There is some debate as to the efficacy of seed banks in wetland restoration (Environmental Concern, 1993). However, there have been many studies suggesting their high degree of usefulness (Shuey and Swanson, 1979; Leck, 1993; McKnight, 1992; Erwin and Best, 1985; Erwin, 1990). Table 8 gives some advantages and disadvantages of distant spacing (Broome, 1990).
Table 8. Advantages and Disadvantages of Distant and Close Spacing

<table>
<thead>
<tr>
<th>Distant Spacing</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Costs less (i.e. fewer plants, seed, person-hours, and less fertilizer used)</td>
<td>1. Takes longer for establishment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Decreases likelihood of establishment</td>
</tr>
<tr>
<td>Closer Spacing</td>
<td>1. Takes less time to become established</td>
<td>1. Increases costs (i.e. more plants, seed, fertilizer, and person-hours)</td>
</tr>
<tr>
<td></td>
<td>2. Increases probability of success</td>
<td>2. Needs more seeds or plants so more effort is required to store</td>
</tr>
</tbody>
</table>

Source: Broome (1990)

Leck (1993) gives the following outline for considerations when using seed banks to vegetate a wetland.

- Does a seed bank exist? Preliminary study of the soil is necessary to determine if seeds of desirable species exist. There is no value in using a seed bank without seeds or with a high number of undesirables.
  - Study soils in flooded and nonflooded moisture regimes.
  - Sample collection may be required several times per year.
  - Knowledge of land use history may be helpful. Vehicles can destroy vegetation and seeds.
  - Use relict seed banks when possible. One may exist in an area that had been diked and drained. Drainage tiles and dikes can be removed to exploit the existant seed bank.

- Know the timing of seed production and dispersal.
  - Determine timing dispersal of desirable species particularly if the species persist for only one year (transient seed banks).
  - Collect soil following natural after-ripening of "seeds but before field germination" especially if the seed bank is depleted during the spring germination flush.
Transient seed bank species will most likely lose viability if stored for long periods of time. Greater timing flexibility is allowed if persistent seed bank species are used.

Depth of seed bank. The depth at which most viable seeds are generally found is in the upper 25 cm of soil. However depth distribution may vary from site to site.

Effects of Drying/Inundation

- Many wetland species produce seeds that are tolerant of prolonged saturated conditions (e.g. Typha, Nuphar, Pontederia)
- A few may lose viability if stored in prolonged saturated conditions (Impatiens capensis)
- Some seed species do not tolerate drying (Impatiens capensis and Zizaniopsis miliacea) so do not allow soil to completely dry.

Reproductive Biology of Desired Species. Some species may not be sexually reproductive. Therefore, transplanting would be required for such species.

Special Germination Requirements

- Seed germination can be affected by oxygen, light, temperature, and possibly salinity for some species.
  - **Light** Bideres laevis, Phalaris arundinacea
  - **High Temperature** Hibiscus palustris
  - **Low Temperature** (generally large seeded transient species germination occurs in early spring following after-ripening: Ambrosia trifida, Impatiens capensis, Polygonum arifoium
  - **Low Oxygen/Saturated**: Zizania aquatica, Pontederia cordata

Seedlings. Success of a seedbank depends upon recruitment (germination) and establishment of seedlings. The ability of seedlings to tolerate stresses such as saturation and competition varies. Annuals tend to germinate before perennials. Establishment may be affected because of competition with species already established.

Soil Storage. Use as soon as possible after stockpiling. This will prevent drying.
Site Preparation. Hydrologic, substrate, and any special requirements for germination on establishment need to be planned for when preparing a site. Maximum number of species can be established if a variety of microsites are provided. Until the seeded species have formed their own seed bank hydrology must be kept in mind. Undesirables can be eliminated by manipulating water levels.

Maintenance Regimes. Species can be maintained via maintenance regimes such as drawdown, flooding, and fire. Water tolerances for wetland vegetation is extremely important. Environmental Concern (1993) suggests water tolerances for freshwater vegetation listed in Appendix E. Some species may have ecotypical predispositions for greater or lesser tolerance to water.

b. Reintroduction of Fauna If site selection, hydroperiod, and vegetation are suitable then reintroduction of fauna will probably not be necessary. In an isolated marsh stocking of amphibians, herps and fish may be required. For a species list of fish see FWS report (Odum, 1984). Trapping and relocation of protected and/or uncommon species that currently inhabit the marsh to be impacted may be necessary for marshes that are to be isolated geographically.

c. Management Consider long term management while planning and designing the project so that a low maintenance design is implemented. An entity which will have the capital to implement management practices like exotic plant control should own the project. Protection of the project from undesirable uses of adjacent land should also be considered in a management plan. Identifiable project goals should be linked to management reports.

Heterogeneity can be maintained in a wetland complex by managing all marsh units in an area differently at the different times. This allows local wildlife population shifts to more optimal niches (Weller, 1987).

d. Water Level Regulation Water-level regulation is the ideal way to influence marsh vegetation. Where water control is possible follow the steps outlined below Weller (1978):

- When a marsh has become so open that it no longer provides cover and food for wildlife, revegetation comes most readily via drawdown of water levels to produce the germination phase. Overwinter drawdowns seem to stimulate greater growth than single-growing season drawdowns. Timing of the drawdown influences plant species composition, as does soil moisture.

- Following germination, water levels must be increased slowly in late summer or fall to avoid excessive loss of plants due to floatation or shading.
Similar water-level management during the following growing season will reduce bird use by some groups but will foster the greatest vegetative response. By the fall of the second growing season, water level management will be related more to wildlife use than to plant growth.

Vegetative propagation of emergents can be stimulated secondarily by lowering water levels. Whether the rate of growth can compensate losses to herbivores is dependent on their population status at the time. Few marshes seem to remain productive with continuous inundation.

Establishment of submergents vital to invertebrate production usually requires several years of stable levels of moderate depths. Flooding during the growth phase should be avoided because of clouding of the water with silt and other particulate matter that reduces light penetration.

To enhance the growth or regulation of populations of major marsh wildlife, the timing and degree of water-level manipulations are very important Weller (1978):

- Dramatic drawdowns should take place in early spring prior to bird territory establishment or in fall prior to muskrats lodging for winter. If properly timed, lowered water levels enhance harvest of muskrats and prevent wasteful mortality.

- Low water levels essential to survival of plants may induce use mainly by wet-meadow birds or, in larger units, restrict deep-marsh birds and muskrats to deeper, central areas of the marsh.

- Drastic manipulation of water levels following vegetation establishment may aid in regulation muskrat populations that threaten the vegetation. Habitat conditions influence reproductive rates and trapability.

- As central portions of the marsh are opened by muskrats and floatation, raising water levels makes peripheral areas more suitable for use by wildlife.

- Marshes associated with lakes often are major spawning beds and marshes are, therefore, of importance in planning marsh drawdowns. Nongame fish like carp are detrimental to survival of emergents and development of submergents and may be controlled by drawdown procedures.

Create openings in dense stands of emergents by cutting them during low water levels. The tops of the cut stems are then flooded during the next growing season. Herbicides can also be used, however the opening is not present until the following year and herbicides have uncertain side effects.

Regardless of wetland type, water level manipulation is crucial during the first growing season. After spring planting, first inundate the emergent vegetation area of the pool to a level of 2-3 cm above emergent substrate (5-150 cm for
submerged areas depending on topography) for 5-7 days. This retards highly competitive terrestrials while inhibiting germination of desired plants. Second, lower water levels to or just below the emergent zone’s substrate surface and maintain for 15-20 days. After this time, the transitional, shallow, mid, and deep zones throughout the system should have visible renewed growth. Emergent shoots can be expected to be 5-10 cm long. Seed within imported soil may have introduced additional species and may create a green carpet in the area where imported soil and emergent zone overlap. Third, gradually raise the water level to slightly deeper (3-5 cm) for 5-7 days then again lower and maintain for 15-20 days. Plant mortality may leave large unvegetated areas. If so, fourth, lower water levels to or just below the substrate elevation of the denuded area and replant as necessary. Replantings are less tolerant of stress and need to be watched during each inundation period.

By midsummer, terrestrial vegetation maybe outcompeting desirables in the transition zone. If a second drawdown period was implemented, many transitional or moist site species may have propagated in the emergent zone (Hammer, 1992).

e. Monitoring

The monitoring plan implemented needs to be of a suitable scope to determine level of success or failure in meeting the established project goals. Erwin (1990) suggests the items listed in Table 9 should be included in a monitoring plan for a restored/created freshwater marsh.

Included in a monitoring program should be "data requirements, evaluation criteria, and methods for reporting with goal evaluation in mind" (Erwin, 1990).

Table 9. Items to be Considered in a Monitoring Plan

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. Post-construction, pre-planting survey of project contours and elevations</td>
<td>4. Biological monitoring including, but not limited to, fish and macroinvertebrate data collection</td>
</tr>
<tr>
<td>2. Ground and surface water elevation data collection</td>
<td>5. Evaluation of vegetation species diversity, percent cover, and frequency</td>
</tr>
</tbody>
</table>

Source: Erwin (1990)

Ultimately, species richness may be the most simple index to habitat quality (Weller, 1987).
7. Time

No specific information for the time involved with freshwater restoration/creation was found. However, the cost, complexity and duration of a restoration/creation project will depend on the degree of alteration of hydrology, soil and biotic community. Typically restoration takes less time than creation projects (Hammer, 1992). The time considerations for saltwater marsh that were defined by Broome et al. (1988) are general enough to also be utilized for freshwater marshes. These considerations include the following:

- Plan and prepare at least one year prior to transplanting is necessary, if seed must be collected and germinated to grow plants.
- Allow time for obtaining permits.
- Delay in permitting and construction are common.
- Allow fill material to settle for several weeks.
- Complete final grading and construction well in advance of the optimum planting times.
- Optimum planting time is in the spring. Planting earlier may incur storm damage and field-dug plants will be difficult to obtain. Planting later in the summer limits the growing season.
- Use of potted seedlings may result in unhealthy or dead plants if there are long holding times.

8. Cost

Project costs include planning and design, obtaining a site, preparing a site, constructing any necessary structure, planting the site and maintaining the site during the period of establishment. Cost figures developed by Garbisch (1986) as part of his report to the Federal Highway Administration appear to still be valid (personal communication, Edgar Garbisch, President, Environmental Concern, Inc., December 1993). However, land and labor costs have the greatest amount of variability of all the factors considered. Table 10 shows the figures developed by Garbisch (1986).

King and Bohlen (1994) estimated freshwater emergent and freshwater tidal wetland restoration and creation costs based on data from 31 projects. Average project cost, not including land was $48,700 for emergent types and $42,000 for tidal types. The cost figure was further broken down into four input categories of labor, material, equipment, and other. Emergent wetland types had costs tied to
Table 10. Estimate of Costs for Vegetative Establishment

<table>
<thead>
<tr>
<th>Work Item</th>
<th>Unit Cost</th>
<th>Per Acre Cost</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant Materials (FOB origin)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Sprigs</td>
<td>0.15</td>
<td>1,634</td>
<td>2-ft grid; one unit/hill</td>
</tr>
<tr>
<td>b) Tubers, rhizomes, bulbs</td>
<td>0.25</td>
<td>2,723</td>
<td>2-ft grid; one unit/hill</td>
</tr>
<tr>
<td>c) Potted plants</td>
<td>0.55</td>
<td>5,990</td>
<td>2-ft grid; one unit/hill</td>
</tr>
<tr>
<td>d) Plugs</td>
<td>0.55</td>
<td>5,990</td>
<td>2-ft grid; one unit/hill</td>
</tr>
<tr>
<td>e) Seed</td>
<td>---</td>
<td>1,000</td>
<td>cost includes collecting, threshing cleaning, and cold storing ca. 500,000 seeds per acre</td>
</tr>
<tr>
<td><strong>Fertilizer</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Controlled release</td>
<td>0.85 lb</td>
<td>815</td>
<td>2-ft grid, side-dressed at time of planting with 40g/hill</td>
</tr>
<tr>
<td>b) 10.10.10</td>
<td>0.20 lb</td>
<td>240</td>
<td>2 applications at a rate of 600 lb/acre for each</td>
</tr>
<tr>
<td><strong>Labor</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Seeding</td>
<td>---</td>
<td>4 person-hours</td>
<td>broadcast seed plus cultivation</td>
</tr>
<tr>
<td>b) Transplanting</td>
<td>---</td>
<td>64 person-hours</td>
<td>2-ft grid using a mechanical auger to drill holes. A fully mechanical operation will require approximately one-half the time.</td>
</tr>
<tr>
<td>c) Fertilization (side-dress or surface applied)</td>
<td>---</td>
<td>16 person-hours</td>
<td>2-ft grid, each transplant at the time of planting</td>
</tr>
<tr>
<td>d) Fertilization (surface broadcasting)</td>
<td>---</td>
<td>2 person-hours</td>
<td>post-planting</td>
</tr>
<tr>
<td><strong>Period of Establishment</strong></td>
<td>---</td>
<td>96 person-hours/year</td>
<td>monthly maintenance work during May through October. For materials estimate, assume that 20% of the site will have to be revegetated due to transplant mortalities or unsuccessful seeding results.</td>
</tr>
</tbody>
</table>

Garbisch (1986)
63% labor, 26% material, 9% equipment, and 1% other. Tidal wetland types had costs tied to 31% labor, 54% material, 14% equipment, and 1% other. In both type of wetlands, the construction costs were the greatest ranging between 87 and 58%.

9. Reference Sites: Freshwater Marsh

a. Bennett’s Creek  Found along the border of Bennett’s Creek from the mouth upstream to Gatesville. Located south of NC 37 in Gates County.

b. Durant Island  Found along the eastern portion of Durant Island (The Frying Pan). Part of the Alligator National Wildlife Refuge. Located northeast of U.S. 64 bridge that crosses the Alligator River in Dare County.

c. Goose Creek  Found along the Pamlico River in Goose Creek State Park. Located east of Washington and south of U.S. 264 in Beaufort County.

d. Shackleford Banks  Many sites along the Back and Core Sound of Shackleford and Core Banks. Part of the Cape Lookout National Seashore. South and southeast of the mainland in Carteret County.

e. Mackay Island  Most of the interior portion of Mackay Island (Great Marsh). Part of the Mackay Island National Wildlife Refuge. Located on the North Carolina/Virginia state border in Currituck County.

f. Ocracoke Island  Many sites along the Pamlico Sound side of Ocracoke Island. Part of the Cape Hatteras National Seashore. Located southeast of the mainland in Hyde County.
10. Contacts

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WT-8
Knoxville, TN 37902
FAX No. 632-6128
Telephone (615) 632-6433

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President
Environmental Concern, Inc.
P.O. Box P, 210 West Chew Ave.
St. Michaels, MD 21663
FAX No. 745-3517
Telephone (410) 745-9620
D. BOTTOMLAND HARDWOOD FOREST/SWAMP FOREST

1a. Profile: Bottomland Hardwoods

a. Landscape position  Along medium to large streams and rivers in the Piedmont and Mountains and along almost all stream channels in the Coastal Plain. In the Piedmont, these forests are often found where tributary streams join or the stream gradient changes.

b. Typical hydrology  Irregularly to seasonally flooded. Overbank flooding from the stream is the primary source of water but surface flow and groundwater flow perpendicular to the stream channel may also contribute. Groundwater flow without obvious discharge is often a source in the Coastal Plain.

c. Soils  Predominantly mineral although mucky soils may occur in the Coastal Plain.

d. Dominant plants  A sparse to closed tree canopy with well-developed shrub and vine layers. Dominant plants vary with the type of sediments and subtle changes in elevation as well as the frequency and duration of flooding. For information on these species’ wetland indicator status see Appendix F.

Piedmont, Sandhills and Coastal Plain

Trees:    Red maple, *Acer rubrum*
          Green ash, *Fraxinus pennsylvanica*
          American elm, *Ulmus americana*
          River Birch, *Betula nigra*
          various oaks, *Quercus* sp.
          Sycamore, *Platanus occidentalis*

Shrubs/Vines:
          Poison ivy, *Toxicodendron radicans*
          Greenbriar, *Smilax* sp.
          Cane, *Arundinaria gigantea*
          Ironwood, *Carpinus caroliniana*
          Dog hobble, *Leucothoe axillaris* (Coastal Plain)
          Virginia willow, *Itea virginica* (Coastal Plain)
          Ti-Ti, *Cyrilla racemiflora* (Coastal Plain)

Herbs:    Lizard’s tail, *Saururus cernuus*
          Cinnamon fern, *Osmunda cinnamomea*
          Royal fern, *Osmunda regalis*
          Spotted touch-me-not, *Impatiens capensis*
          Virginia Chain fern, *Woodwardia virginica*
          Sensitive fern, *Onoclea sensibilis*
1b. Overview  Bottomland hardwood forests are highly diverse wetlands, but they share a common characteristic: they all develop along the floodplains of streams. In the Coastal Plain, bottomland hardwood forests and other wetlands cover the entire floodplain of most streams. Non-wetland community types only occur along major rivers. In floodplains of the Piedmont and Mountains, wetlands occur in a matrix of other community types. Bottomland hardwood forests often occur behind the levee rather than on the actual streambanks.

Dominant plants vary from west to east across the state. Mountain bottomland hardwood forests often contain more evergreen coniferous species. Piedmont sites tend to be dominated by hardwoods but may include dense thickets of cane. Coastal plain sites have the common Piedmont species as well as trees and shrubs more endemic to the Coastal Plain. For information on these species' wetland indicator status see Appendix F.

Bottomland hardwood forests in the Coastal Plain may be divided into the blackwater subtype and the brownwater subtype, according to the type of river. In general, the brownwater subtype has more diverse plant and animal communities due to its higher nutrient content. Brownwater rivers originate in the Piedmont and carry greater loads of nutrient-rich sediment.

At their edges, bottomland hardwood forests grade into swamp forests, freshwater marshes and various upland communities. They may include ephemeral wetlands or seeps.

2a. Profile: Swamp Forest

a. Landscape position  Along rivers in backswamps, sloughs and oxbows, along blackwater streams, and along shorelines of freshwater lakes. Most numerous and extensive in the Inner and Outer Coastal Plain.

b. Typical hydrology  Seasonally to semi-permanently flooded. Overbank flooding is usually the primary source of water.

c. Soils  Organic or fine-textured mineral soil. Sandy sediments are characteristic along blackwater streams.

d. Dominant plants  A well-developed tree layer with little or no shrub and herb layers. For information on these species' wetland indicator status see Appendix F.

Trees:  Bald cypress, *Taxodium distichum* (Coastal Plain)
Tupelo gum, *Nyssa aquatica*
Black gum, *Nyssa sylvatica* var. biflora
Willow oak, *Quercus phellos* (Piedmont)
Red maple, *Acer rubrum*
2b. Overview Swamp forests are one of the most familiar types of wetlands. Majestic cypress trees with knees, standing water for long periods of time and no shrub or herb layers are clear indicators of the swamp forest. Swamp forests are shaped by frequent and extended flooding which selects for plants and animals with high tolerance to water stress.

The plant species in swamp forests vary across the state. Bald cypress has a very high tolerance to flooding and dominates in swamp forests east of the fall line. In wetlands experiencing the greatest flooding, it may be the only tree. However, bald cypress depends on dry conditions for seed germination, so continuous inundation will eventually lead to loss of the tree layer as older trees die. In Piedmont and Mountain swamp forests, tupelo gum, black gum and red maple are dominant. In the Piedmont, willow oaks indicate greater flooding. Dominance by pines anywhere may indicate drainage or an extended dry period.

The plant associations in swamp forests vary in other ways. Bald cypress and tupelo gum dominate in richer sites while bald cypress, black gum and Atlantic white cedar was once widespread in the Coastal Plain, but has become rare due to fire suppression and logging.

Another subtype of swamp forests is the non-riverine swamp forest. This type is fed by groundwater discharge and surface runoff rather than overbank flooding and occurs in more upland positions. It is somewhat more shrubby than typical riverine swamp forests.

Swamp forests grade into bottomland hardwood forests, pocosins and freshwater marshes at their borders. This type is widespread in the lower Piedmont and the Coastal Plain of the state, rare in the upper Piedmont and in the Mountains.

3a. Profile: Estuarine Fringe Forest

a. Landscape position Along the margins of estuaries and freshwater sounds. Outer Coastal Plain, more common from Cape Lookout north.

b. Typical hydrology Semi-permanently to permanently saturated, rarely flooded by salt or brackish tides.

c. Soils Wet organic or sandy soils, usually with recent deposits of sand or silt.

d. Dominant plants A well-developed tree and shrub layer and sparse herb layer. For information on these species’ wetland indicator status see Appendix F.

Trees: Loblolly pine, *Pinus taeda*
Red maple, *Acer rubrum*
Sweetgum, *Liquidambar styraciflua*
Swamp gum, *Nyssa sylvatica* var. *biflora*
Shrubs: Wax myrtle, *Myrica cerifera*  
Gallberry, *Ilex glabra*  

Vines: Greenbrier, *Smilax laurifolia*  

Herbs: Virginia chainfern, *Woodwardia areolata*  
Cinnamon fern, *Osmunda cinnamomea*

3b. Overview  Estuarine fringe forests are most easily identified by their location along estuarine shorelines in the northern half of the Outer Coastal Plain. The hydrological inputs into this type are primarily from the adjacent estuary, from surface runoff and from precipitation.

Estuarine fringe forests are dominated by plants that invade areas after severe disturbances such as intense fires or prolonged flooding. These forests may be found between marshes and inland communities such as pocosins and wet flats that have a higher frequency of disturbance.

Estuarine fringe forests are fairly abundant in North Carolina.

4. Determine Success Criteria (i.e. goals)

Marked differences exist in the scope and approach between forested wetlands restoration and marsh restoration. Project goals for forest wetlands restoration/creation are more difficult to define than they are for marsh restoration. Establishment requires only a few years for marsh establishment and well known techniques are implemented. However, decades are required for the establishment of bottomland and swamp forests and unproven methodologies are used. Existing evidence indicates carefully planned and implemented forested wetlands restoration/creation can be successful in terms of vegetation establishment and physiognomonic characteristics. Physiognomy and composition are believed to be closely correlated with many functional attributes. However, functional equivalency with natural forest wetlands has yet to documented.

Most of the following information came from an article by Clewell and Lea (1990) unless so indicated in the text. Their paper also provided a check list (Table 11) of items that need to be taken into consideration when restoring or creating forested wetlands.

Forested wetlands provide many functions. Fifteen key functions are given below.

- Aesthetics
- Improved air quality
- Shellfish production
- Source of detritus (forms basis for shell and fin fish food chains)
- Flood abatement
- Honey production
- Maintenance of biotic diversity, food chain support, stream flow mediation, filtering, and water quality transformation.
Table 11. Forested Wetland Restoration/Creation Checklist

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have appropriate skilled professionals prepared the project plan?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Will they provide on-site supervision of site-preparation and planting? Of monitoring?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Forest Type To Be Created/Restored</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the forest type occur locally?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is there adequate baseline data to plan project goals (species composition, tree relative densities, data on water tables, stream flows, soil conditions, topography)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Is there a source of the necessary plant materials to install this project?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. What is the proposed land use after project release? Is it consistent with project goals? Will the released project be protected indefinitely?</td>
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<table>
<thead>
<tr>
<th>Project Siting</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Does the soil or substrate on the site have the properties to support the vegetation targeted for restoration or creation?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Does the proposed project conform to existing topographical and hydrological conditions?</td>
<td></td>
<td></td>
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<tr>
<td>3. Will the project be connected hydrologically with natural waters if it is advantageous to do so?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Are there any off-site constraints, such as watershed obstructions, recent or proposed drainage plans, asynchronous or thermal discharges up stream?</td>
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<tr>
<td>5. Is there any regional development plan which may affect siting?</td>
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<tr>
<td>6. Is an adequate buffer included to isolate and protect the project, if needed?</td>
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<td></td>
</tr>
<tr>
<td>7. Will the site be fenced or staked?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Will the water quality be adequate to support the project biota?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Has natural regeneration been considered? Are seed walls sufficiently close to the project, or will flood waters bearing seeds reach the project?</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Site Preparation</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is there a need for, and provisions to, manipulate hydrology early in the project (weirs, other control structures)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Will slopes be contoured to minimize erosion? If not, are there provisions to prevent erosion (berms, cover crops, etc.)?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Will stream channels be designed to minimize erosion and encourage meandering? (Deflectors, sprigging stoloniferous plants, engineering options, etc.)</td>
<td></td>
<td></td>
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</tbody>
</table>

Clewell and Lea (1990)
<table>
<thead>
<tr>
<th></th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.</td>
<td>Will irrigation be needed initially? If so, how will it be provided?</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Are there any noxious plants on site that should be removed, such as rhizomatous grasses, vines, or exotics?</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Are the soils adequate in terms of fertility, rooting volume, bulk density, crusting, or will conditioning be needed (subsoil ripping, pH adjustment, amendments of fertilizers or leguminous cover crops, incorporation of organic matter, etc.)?</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>If sludge is to be used as a soil amendment, have appropriate permits been obtained?</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Will topsoil be conserved? If so, can it be spread on the project site without prior stockpiling, to conserve its seed bank and other propagules?</td>
<td></td>
</tr>
</tbody>
</table>

**Project Installation**

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>Will a competent supervisor be on-site at all times during final grading and vegetation planting?</td>
</tr>
<tr>
<td>2.</td>
<td>Will there be provisions to harden nursery stock before delivery in terms of reduced fertilization and watering?</td>
</tr>
<tr>
<td>3.</td>
<td>Is there sufficient lead time to contract-grow trees?</td>
</tr>
<tr>
<td>4.</td>
<td>Will trees be delivered for planting at the appropriate time?</td>
</tr>
<tr>
<td>5.</td>
<td>Is the growing stock (seeds, bare root seedlings, tubelings, etc.) appropriate for the site conditions in terms of adequate moisture and competition from cover crops or weeds?</td>
</tr>
<tr>
<td>6.</td>
<td>Are there provisions for introducing preferred undergrowth species?</td>
</tr>
</tbody>
</table>

**Maintenance**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Does the site plan allow for unanticipated maintenance activities during the first 2 years, in terms of erosion control, sediment removal, and replanting of trees or other plant materials that did not survive?</td>
</tr>
<tr>
<td>2.</td>
<td>Are there strategies for minimizing competition from noxious species, such as specific site-preparation activities, nurse crops, or rapid tree-growing regimes? If not, are there provisions for weed removal?</td>
</tr>
</tbody>
</table>

**Monitoring**

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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Have adequate success criteria been drafted that pertain to project goals?</td>
</tr>
<tr>
<td>2.</td>
<td>Has a monitoring protocol been devised that answers questions posed by the success criteria?</td>
</tr>
<tr>
<td>3.</td>
<td>Will groundwater piezometers be installed and staff gauges be placed in water bodies, so that monthly water levels can be monitored?</td>
</tr>
<tr>
<td>4.</td>
<td>Will there be sufficient inspection tours to allow for necessary maintenance or remedial activities?</td>
</tr>
<tr>
<td>5.</td>
<td>Will reports be submitted and made publicly available?</td>
</tr>
</tbody>
</table>
Noise abatement
Recreation
Sediment retention
Pollution and nutrient sinks
Timber production
Floodplain water storage (contributes to dry season stream flow)
Contributes to groundwater in isolated systems
Wildlife habitat

Function and related characteristics are shown in Table 12 (Gosselink et al., 1990).

Ideal restoration is to duplicate the species composition, structure, and function of an original bottomland forest. However, since forests are constantly changing, this ideal can only be approached.

Typical project goals consist of:

- Creation of a forested wetland with similar species composition and physiognomy as a locally forested wetland community on areas that did previously support that community type.

- Restoration of the vegetation type which previously existed on the site and was removed without much disturbance to the soil and water balance.

- Enhancement of an existing forest to improve functioning (endangered species habitat) or accelerate seral processes. Most projects have unidentified goals or ones which were inappropriately conceived. "There has been an implicit attitude that success criteria will become self-evident, once the planted trees mature" (Lea and Frederick, 1992). They suggest that "the degree of success relative to the predetermined project goals, is proportional to the amount of on-site supervision by qualified professional during site preparation, planting and to the frequency of monitoring during the first few months". Success is also increased if the site has conducive hydrology and ecology.

In considering the appropriate goals for a project, there are six critical factors for forested wetland restoration that need to be reviewed. These factor are:

- Hydrology
- Substrate stabilization
- Rooting volume
- Soil fertility
- Control of noxious plants
- Control of herbivores.
Table 12. Site Characteristics Related to Services Performed by Bottomland Hardwood Ecosystems

<table>
<thead>
<tr>
<th>Service</th>
<th>Characteristic</th>
<th>Service Performed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flood Reduction</td>
<td>Floodplain surface area</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Site elevation</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Site slopes</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Soil saturation</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Detention storage</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Vegetation cover</td>
<td>+/-</td>
</tr>
<tr>
<td></td>
<td>Surface roughness</td>
<td>+</td>
</tr>
<tr>
<td>Velocity Reduction</td>
<td>Floodplain surface area</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Width/length ratio</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Stream sinuosity</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Slope</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Vegetation cover</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Surface roughness</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Debris</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Internal drainage</td>
<td>-</td>
</tr>
<tr>
<td>Base Flow Augmentation</td>
<td>Interflow/groundwater discharge</td>
<td>Area flooded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Hydraulic gradient</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infiltration rate (permeability)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contact time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evapotranspiration</td>
</tr>
<tr>
<td>Surface discharge delay</td>
<td>Storage capacity</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Velocity reduction</td>
</tr>
<tr>
<td>Groundwater Recharge</td>
<td></td>
<td>Hydraulic gradient</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Soil permeability (Infiltration rate)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Detention storage</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Evapotranspiration</td>
</tr>
</tbody>
</table>

Source: Gosselink (1990)

+ indicates the service is performed by the bottomland hardwood ecosystem for the specific characteristic indicated.

- indicates the service is not being performed by the bottomland hardwood ecosystem for the specific characteristic indicated.

+/- indicates the service may or may not be performed by the bottomland hardwood ecosystem for the specific characteristic indicated.
5. Preparation of Soil and Site (Soil Fertility, Soil Stabilization and etc.)

Soil conditioning and amendments may be needed. Improved soil fertility can be achieved via amendments of fertilizer, sludge and planting a leguminous cover crop. Fertilizer enhances growth which is particularly important in the first year. Some treatments are to alternately grow and disk fast-growing covercrops (green-manuring), and to spread organic matter such as sludge, wood fiber straw, and bark. Using composted sludge will introduce wood fiber. Soil microorganisms can be attracted or introduced through composted sludge amendments. Applications of sludge need to be confined to aerated soil. It should be kept in mind that regulations may restrict sludge applications near bodies of water.

Erosion can remove newly planted vegetation. Long gentle slopes can limit erosion as well as maximize the wetted perimeter. Since soil conditioning and application of soil amendments can be costly, the prevention of erosion can be considered an economical decision.

Rooting volume is affected by depth to wet season water table, compact soil horizons (pans), shallow soil horizons, and unsuitable soil chemistry. Roots of some species are unable to penetrate soils which have bulk densities over 1.4 g/cm$^3$ for clayey soil and 1.6 g/cm$^3$ for sandy soils (Lyle, 1987).

Grading and contouring compacts the soil and necessitates ripping, tilling, bedding, topsoiling, organic amendments. Proper tillage can be achieved by ripping all sites. Ripping can provide a friable 6-8 inches of topsoil.

The cheapest and most effective investment is fertilizer and lime. These soil amendments assist in quicker vegetation establishment and reaching full growth potential of seedlings the first year. Seedlings off to a slow start due to poor soil fertility are subject to stress and are targets for pests and will likely be overtopped by weeds (Lea and Frederick, 1992).

6. Hydrology

Successful restoration may be difficult without water control structures to prevent inundation of newly planted seedlings which are susceptible to water stress. The hydroperiod must be synchronous with life cycles and growth requirements. If possible water control structures need to be in place before revegetation begins.

More complex sites may require hydrologists and/or engineers to predict hydraulic characteristics (stage height, flooding duration, groundwater movement) of the site. Flashboard risers, flap gates, retention ponds, and spillways can assist in maintaining water levels
7. Planting

Species must not be planted indiscriminantly across a project. First of all the result will not resemble baseline forests. Secondly, mortality will be unnecessarily high and those that do survive will have low vigor. Knowledge of functional hydrology is imperative when selecting species, as varying degrees of flooding tolerance exist from species to species (Lea and Frederick, 1992). Planting species not tolerant of the site’s flooding regimes is apparently a common reason for high mortality rates and hence project failure (Dr. Russ Lea, Department of Forestry, N.C. State University, November 1993, personal communication). A listing of flood tolerant species with their associated tolerance rating is provided in Table 13. Hook’s (1984) definition of waterlogging tolerance is "a species’ ability, from seedling stage to maturity, to tolerate soil saturation or inundation during the growing season. It is used in the context of a species’ population in general and not for an individual tree”.

For full-scale projects the introduction of undergrowth should be planned for as well as overstory trees. Undergrowth species may be simultaneously established with trees or postponed until overstory species have a distinct height advantage indicating the ability to readily outcompete undergrowth vegetation. There is lower undergrowth species diversity as the soil moisture increases along the mesic to hydric hydrologic gradient.

On abandoned farmland, bottomland hardwoods could take 40-60 years to become self-regenerating.

If regional sources are not available vegetation from the north of the site will most likely be adaptive to the site. Stock south of the site will likely be less cold-hardy. Adaptations to precipitation regimes will vary in stock from the east or west of the area.

Nurse crops can hasten seral development which may be requisite for some species establishment. Nurse crops provide benefits to seedlings such as shade, adding humus, nitrogen, which is produced from symbionts, and area displacement which could be occupied by highly competitive species. Suitable nurse crop species have rapid growth, are short lived or are harvested for economic gain once their purpose has been served. Knowledge of successional patterns of the stand is required to take full advantage of nurse crops.

Black Locust and European Alder fulfill the purpose of nurse species. Overstory trees overtake these species in 17-20 years. Other suitable nurse crop species are cottonwoods, volunteer willow slash pines, which can be harvested and sold as fence posts, and wax myrtle, which has dense, evergreen foliage that provides shelter and nitrogen fixing symbionts.

Revegetation can be accomplished in two ways, natural regeneration (volunteer colonization) and artificial revegetation (planting).
Table 13. Waterlogging Tolerances of Lowland Tree Species

<table>
<thead>
<tr>
<th>Species</th>
<th>Waterlogging Tolerance Rating</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>common buttonbush</td>
<td>Most Tolerant</td>
<td>Both mature trees and seedlings tolerate deep &amp; prolonged flooding. Seed germinated better when submerged</td>
</tr>
<tr>
<td>swamp-privet</td>
<td>Most Tolerant</td>
<td>Less tolerant to deep flooding than buttonbush. 15% survived 2555 days of continuous flooding</td>
</tr>
<tr>
<td>Carolina ash</td>
<td>Most Tolerant</td>
<td>Frequent associate of swamp tupelo and water tupelo in SE swamps. Better seed germination under submerged than saturated soil.</td>
</tr>
<tr>
<td>pumpkin ash</td>
<td>Most Tolerant</td>
<td>Tolerates deep flooding. Better growth in saturated than field-capacity soil. Seed remained viable in submerged soil for months.</td>
</tr>
<tr>
<td>water tupelo</td>
<td>Most Tolerant</td>
<td>Tolerates deep flooding. Sensitive to soil fertility and relatively insensitive to flood level and nature of flood water in alluvial soil; more sensitive to flooding in nonalluvial soils. Does not tolerate complete submergence as well as green ash. Sensitive to silt laden waters. Develops adventitious and soil water roots. Roots oxidize rhizosphere.</td>
</tr>
<tr>
<td>water elm</td>
<td>Most Tolerant</td>
<td>Cannot tolerate flooding more than 50% of growing season.</td>
</tr>
</tbody>
</table>

Source: Hook (1984)
<table>
<thead>
<tr>
<th>Species</th>
<th>Tolerance Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>baldcypress</td>
<td>Most Tolerant</td>
<td>Tolerates deep flooding even in lakes but mortality may increase after 15-25 yrs. or with sudden and sustained deep flooding. Grows best in flooded soils. Also grows along estuarine but apparently will not tolerate salinities above 0.89% salt. Develops adventitious and soil water roots. Roots oxidize rhizosphere.</td>
</tr>
<tr>
<td>pondcypress</td>
<td>Most Tolerant</td>
<td>Restricted to piney woods swamps, perched ponds, sloughs and wet flats in the lower coastal plain east of the Mississippi River. Develops adventitious and soil water roots. Roots probably oxidize rhizosphere.</td>
</tr>
<tr>
<td>water hickory</td>
<td>Moderately Tolerant</td>
<td>Mature trees remain healthy where inundation occurs less than 50% of the time during the growing season. Flooding from Feb.-July increased radial growth of timber and pole-size trees.</td>
</tr>
<tr>
<td>waterlocust</td>
<td>Moderately Tolerant</td>
<td>Most frequently found where flooding occurs 29-40% of growing season.</td>
</tr>
<tr>
<td>overcup oak</td>
<td>Moderately Tolerant</td>
<td>Most frequent where flooding occurred 29-40% of growing season. Feb.-July flooding beneficial to timber-sized trees but not other categories. Submergence reduced seed germination.</td>
</tr>
<tr>
<td>boxelder</td>
<td>Moderately Tolerant</td>
<td>Rated tolerant in Illinois but less tolerant to flooding farther south. Seedlings tolerated shallow flooding (1 in.) but had higher mortality with 20-25 in. flooding.</td>
</tr>
</tbody>
</table>

Source: Hook (1984)
<table>
<thead>
<tr>
<th>Tree Species</th>
<th>Tolerance Level</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red maple</td>
<td>Moderately Tolerant</td>
<td>Varies considerably in tolerances over its range. The variety <em>drummondii</em> may be most common in swamps but authors except Wharton et al. (1982) did not identify to variety level. Remained healthy with flooding less than 37% of growing season. Develops adventitious water roots.</td>
</tr>
<tr>
<td>Silver maple</td>
<td>Moderately Tolerant</td>
<td>Much variation reported in response to flooding. More tolerant to flooding in the North than the South. Mature trees died after 2 yrs. of continuous flooding. Seedling height was better in saturated than field-capacity soils.</td>
</tr>
<tr>
<td>River birch</td>
<td>Moderately Tolerant</td>
<td>Mature trees had 77% survival for 240 days' flooding but zero after 730 days. Seedlings stunted by flooding. Healthy if flooding occurred less than 24% of growing season.</td>
</tr>
<tr>
<td>Atlantic white-cedar</td>
<td>Moderately Tolerant</td>
<td>Occurs principally on peat deposits (0-40 ft. thick) over sand and instream swamps. If underlying soil is silt or clay type usually converts to hardwoods. Favored by disturbances, such as fire, flooding, windthrow, and clearcutting.</td>
</tr>
<tr>
<td><em>Crataegus</em> spp</td>
<td>Moderately Tolerant</td>
<td>Species not listed by authors. Large variance in flood tolerance within genera (See Wharton et al. 1982)</td>
</tr>
<tr>
<td>Persimmon</td>
<td>Moderately Tolerant</td>
<td>Survival of mature trees was 67% after 240 days of flooding. Healthy if flooding occurred less than 31% of growing season. Seedlings relatively tolerant to flooding.</td>
</tr>
<tr>
<td>Green ash</td>
<td>Moderately Tolerant</td>
<td>Prefers very wet soils but not fully saturated or flooded. Growth of seedlings in flooded soil less than in well drained but better in saturated than field capacity. Mature trees died after 3-4 yrs. flooding. Occurs in low ridges, flats. and sloughs in first bottoms, terrace flats, and sloughs and occasionally new land. Develops adventitious water and soil roots. Roots have limited ability to oxidize rhizosphere.</td>
</tr>
</tbody>
</table>

Source: Hook (1984)
Table 13. (continued)

<table>
<thead>
<tr>
<th>Species</th>
<th>Tolerance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>honeylocust</td>
<td>Moderately Tolerant</td>
<td>Saplings killed or retarded by 105 days flooding during March-July. Mature trees remained healthy if flooding occurred less than 29% of growing season.</td>
</tr>
<tr>
<td>loblolly-bay</td>
<td>Moderately Tolerant</td>
<td>Tolerance based on associate species</td>
</tr>
<tr>
<td>possumhaw</td>
<td>Moderately Tolerant</td>
<td>Mature trees remain healthy if flooding occurred less than 35% of growing season. Saplings generally recovered from 105 days flooding (March-July).</td>
</tr>
<tr>
<td>sweetgum</td>
<td>Moderately Tolerant</td>
<td>Mature trees died if flooding occurred 44% of growing season. Seedlings died within 1-3 mos. of flooding or were severely stunted. May have large variation in tolerance to flooding. Occurs in edge of some swamps but more prevalent on mesic sites.</td>
</tr>
<tr>
<td>sweetbay</td>
<td>Moderately Tolerant</td>
<td>Tolerance based on associate species</td>
</tr>
<tr>
<td>redbay</td>
<td>Moderately Tolerant</td>
<td>Tolerance based on associate species</td>
</tr>
<tr>
<td>slash pine</td>
<td>Moderately Tolerant</td>
<td>Flooding decreased shoot and root growth. Some variety difference in flood tolerance. Species confined to bay swamps and boggy coastal plain flatwoods.</td>
</tr>
<tr>
<td>pond pine</td>
<td>Moderately Tolerant</td>
<td>Mature trees tolerated prolonged flooding but growth was slow. Endures poor soil aeration and high acidity. Confined mostly to ponds and bays of interstream areas.</td>
</tr>
<tr>
<td>loblolly pine</td>
<td>Moderately Tolerant</td>
<td>Mortality high if flooded but some trees survived and grew well if soil phosphorus was adequate. A strain more tolerant to wet sites probably exists but no data exist to support this assumptions. Flooding usually reduces growth but dormant-season flooding may be beneficial.</td>
</tr>
<tr>
<td>American sycamore</td>
<td>Moderately Tolerant</td>
<td>Occurs on sites too wet for eastern cottonwood. Grows in shallow swamps, sloughs and very wet river bottoms where soil is saturated 2-4 mos. during growing season. Occurs on the edge of muck swamps in SE.</td>
</tr>
<tr>
<td>eastern cottonwood</td>
<td>Moderately Tolerant</td>
<td></td>
</tr>
<tr>
<td>Nuttall oak</td>
<td>Moderately Tolerant</td>
<td></td>
</tr>
<tr>
<td>pin oak</td>
<td>Moderately Tolerant</td>
<td></td>
</tr>
<tr>
<td>willow oak</td>
<td>Moderately Tolerant</td>
<td></td>
</tr>
</tbody>
</table>

Source: Hook (1984)
a. Natural Regeneration  In many cases natural regeneration is more desirable than artificial planting or seeding because component plant species are "distributed according to the environmental gradients and microsites to which they are best adapted".

If only a few species are providing seeds, species richness may be inadequate and additional plantings of a variety of species may be necessary. A disadvantage of using natural regeneration is the attraction of noxious species, especially vines. Boxelder or river birch may capture the site if an adjacent "seed wall" has an inadequate supply of preferred species. If seed failure occurs in the seed wall or droughty conditions exist and overbank flow does not occur another attempt will have to be made the next year. A seed wall is wetland plants on adjacent land that are blown into the seed bank area.

Some site characteristics favorable to natural regeneration are:

■ Narrow sites (two tree heights or less from the surrounding seed wall),
■ Exposed to seed bearing flood waters,
■ Marginally altered, if it all, regarding hydrologic and soil condition.
■ Project areas that are contiguous with a seed source.

Site preparation for natural regeneration involves disking the site or removing most of the vegetation before the dormant season.

Full stocking may take several years if sites are remotely located from seed wall or from seed bearing floodwaters.

b. Direct Seeding  Manually or mechanically planting acorns has been prove to be an effective means of reforesting bottomland hardwoods. Broadcast seeding has met with mixed success and is not recommended. "Pelletized seeds are being developed for direct seeding, in which the coatings contain fertilizers, fungicides, and other substances designed to enhance successful germination" (Lea and Frederick, 1992).

c. Artificial Reforestation  Planting options that exist for artificial regeneration are discussed below.

Stem Cuttings. Poplars, willows, sycamore, sweetgum, green ash, are some of the hardwood species can be propagated in this manner. Whips are hardwood cuttings that are "30-55 cm long, harvested from one-year-old twigs during the dormant season and stored in plastic bags just above freezing until planting in the spring" (Lea and Frederick, 1992). Recommended are whip diameters are from 8 to 13 mm.
If preredooted in a nursery, other species will have more survival and growth. The most commonly used planting technique is to plant cuttings with apex of the stem flush with soil surface or with no more exposure than 3 cm, and with buds pointing up.

**Containerized Seedlings.** These seedlings are more tolerant of harsh conditions than are bare root seedlings. They can be planted later in the growing season than bare root stock. Containerized seedlings should be limited to use only in harsh conditions due to their high cost. Below are several containers in which nurseries provide seedlings.

- Tubelings, plugs, or tray trees. These consist of a seedling, minimal amount of soil, in a plastic or styrofoam container.
- Sacks made of paper or other biodegradable material containers which are planted with seedling.
- Molded peat or wood fiber containers which are planted with seedling.
- Gallon sized plastic bag or pot. These are for 7 to 24 month old trees

Extreme care must be taken in the summer when transporting containerized seedlings. Temperature stress may occur in a covered truck and transpirational stress may occur in an open truck. Do not leave unplanted plants in the sun for a few hours. Transpiration may deplete all the soil moisture and if the containers are a dark color they may absorb enough heat to kill the roots.

**Bare Root Seedling.** The technology for producing bare root seedlings is well developed and there are standard stock for forest plantations. They survive and grow well in moist soil. Local sources of progeny tested seedlings are the best way to assure quality growth performance.

To see that seedlings are likely to survive and grow well do the following:

- Plant seedlings when they are fully dormant or hardened.
- Plant seedlings directly from the nursery. If not, they should be chilled to 1° - 4°C (34° - 39°F) and stored after lifting.
- Do not plant seedlings that have begun to flush with new growth.
- Plant seedlings with fibrous roots. Terminal buds should be well developed.
- Do not prune seedling roots or tops to increase planting efficiency. Since hardwood seedlings are usually larger than pine seedlings they are more difficult to plant and thus take longer to grow.
Do not plant seedlings with mineral deficiencies because they cannot withstand physiological drought.

Plant hardwood seedlings with root collar no less than 6 mm in size. Root collars of between 10 to 13 mm are highly recommended. Discard inferior seedlings and do not count them as planted.

Prevent desiccation and molding of plant seedlings by limiting the transportation time. Transport bags of seedlings in the shade with wind protection and kept at 1°C to 4°C (34°F to 39°F). It is important to avoid freezing temperatures.

**Saplings.** Transplanting large saplings is likely to produce mixed results. Transplants have high mortality rates even with proper handling. Growth may be stunted for a few years due to the reduction in root biomass upon removal from optimal nursery conditions.

In the Southeast, the preferred time to plant is between January and March. Seedlings should not be planted in frozen soil. The roots of seedlings should never be exposed while carrying the plant. A good day to plant has little or no wind, and is cool but not freezing. Fine roots can desiccate by the time the seedling is removed from the bag and placed into the soil on windy or cold days. On questionable days, roots need to be protected in buckets of water or protected in a canvas planting bag.

8. **Time**

No specific information for the time involved with bottomland hardwoods or swamp forests restoration/creation was found. However, the cost, complexity and duration of a restoration/creation project will depend on the degree of alteration of hydrology, soil and biotic community. Typically restoration takes less time than creation projects (Hammer, 1992). The time considerations for saltwater marsh that were defined by Broome et al. (1988) are general enough to also be utilized for freshwater marshes. These considerations include the following:

- Plan and prepare at least one year prior to transplanting is necessary, if seed must be collected and germinated to grow plants.
- Allow time for obtaining permits.
- Delay in permitting and construction are common.
- Allow fill material to settle for several week.
- Complete final grading and construction well in advance of the optimum planting times.
Optimum planting time is in the winter. Planting earlier may incur storm
damage and field-dug plants will be difficult to obtain.

Use of potted seedlings may result in unhealthy or dead plants if there are
long holding times.

9. Cost

King and Bohlen (1994) estimated freshwater forested wetland restoration and
creation costs based on data from 19 projects. Average project cost, not including
land, was $77,900. The high end of the range involved researching and restoring
hydrology and planting while the low end of the range involved restoring hydrology
only. This cost figure was broken down into four input categories including 51% labor, 30% material, 18% equipment, and 2% other.

10. Reference Sites: Bottomland Hardwoods

a. Waccamaw River Occurs along the Waccamaw River from Waccamaw Lake to
the North Carolina/South Carolina state line. Part of the Green Swamp. Located
south of U.S. 74/76 in Columbus and Brunswick Counties.

b. Roanoke River Found all along the Roanoke River particularly in the Roanoke
River National Wildlife Refuge sites. One site is located northeast of Williamston
along both sides of U.S. 17/13 for approximately 6 miles after crossing the
Roanoke River bridge in Bertie County. Other locations are in the Roanoke River
Wetland sites that are upstream of Williamston in Halifax, Martin, Bertie and
Northampton Counties.

11. Reference Sites: Cypress-Gum Swamp

a. Black River Found along the Black River and from Point Caswell upstream to
just above Rowan. Located northeast of N.C. 210 in Pender and Bladen Counties.

b. Waccamaw River Found along the Waccamaw River upstream of New Britain to
Pireway where N.C. 904 crosses river. Located in Columbus and Brunswick
Counties.

c. Lumber River Found along the Lumber River upstream of Maxton to Camp
Mackall Military Reservation. Includes the Counties of Hoke, Scotland and Robeson.

d. Roanoke River Different sites found along the Roanoke River from the mouth
(Great and Goodman Islands) to just below the Roanoke Rapids Dam (Occoneechee

e. Neuse River Found along the Neuse River floodplains. Located just downstream
of Griffton to just upstream of Bridgeton in Craven County.
12. Reference Sites: Other Swamp Forests

a. Alligator River  Many locations found within the interior portions of the Alligator River National Wildlife Refuge. Located in Dare and Hyde Counties.

b. Dismal Swamp  Many locations found in the Great Dismal Swamp National Wildlife Refuge. Located on the North Carolina/Virginia state line in Gates and Camden Counties.

c. North River  Found along Deep Creek within the North River complex. Located northwest of Bertha and west of U.S. 158 in Currituck County.

d. Durant Island  Found along the western portion of Durant Island. Part of the Alligator Wildlife Refuge and located in Dare County.

e. Dollison’s Swamp  Found within Dollison’s Swamp. Located west of Lake Sutton and southwest of U.S. 421 in Brunswick County.
13. Contacts

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E. POCOSIN/SALT-SHRUB

1a. Profile: Pocosin

**a. Landscape position** Poorly drained interstream divides and depressions such as Carolina bays, swales and lime sinks. Stream channels are generally absent, although ditches may be present. Inner and Outer Coastal Plain.

**b. Typical hydrology** Seasonally saturated or inundated by a high or perched water table.

**c. Soils** Organic soils or mineral soils with organic surface layers. Low pocosins have layers or peat several feet deep.

**d. Dominant plants** Primarily broad-leaved evergreen shrubs with scattered pond pine, although a more substantial canopy may occur. Herbs are nearly absent. For information on these species' wetland indicator status see Appendix F.

Trees: Pond pine, *Pinus serotina*
        Sweet bay, *Magnolia virginiana*
        Loblolly bay, *Gordonia lasianthus*

Shrubs: Fetterbush, *Lyonia lucida*
       Ti-ti, *Cyrilla racemiflora*
       Hollies and gallberries, *Ilex* sp.
       Blueberry, *Vaccinium* sp.

1b. Overview The name pocosin comes from an Algonquin Indian term meaning "swamp on a hill." While some pocosins occur on slight elevation, many more pocosins are found in nutrient-poor interstream divides or shallow depressions fed by rainwater.

Under natural conditions, pocosins are subject to periodic severe wildfires during droughts. The broad-leaved evergreen shrubs of the Family *Ericaceae* which dominate pocosins are adapted to periodic fire. Many of these plants sprout readily from their roots after the top is burned away. The plants which dominate a specific pocosin are determined by its hydroperiod and the thickness of its peat as well as fire frequency and severity.

Pocosins may be divided into low pocosins and high pocosins. Low pocosins occur in wetter areas with thick peat and low nutrient input and availability. Generally, they develop where the peat has accumulated to more than three feet deep, often creating a domed wetland, or over nutrient-poor sands. The accumulation of peat reflects a balance of plant production, biological breakdown and removal by burning. Lack of nutrients limits the height of vegetation in low pocosins; most trees and shrubs are less than five feet tall. High pocosins are relatively richer in
nutrients and have vegetation of normal height. They develop where peat is generally one foot or less deep.

Pocosins grade into wet flats, pine savannahs or upland communities at their edges. Pocosins occupy thousands of acres of the North Carolina coastal plain. However, their geographic range is limited to the Coastal Plain from Virginia to North Florida.

The streamhead pocosin is a subtype which occurs in the headwaters of small streams in the Sandhills. This subtype receives runoff and seepage from pocosin and sandhill areas and has vegetation similar to other pocosins.

Almost 70% of the United State’s pocosin areas are found within North Carolina. Fifty percent of North Carolina’s freshwater wetlands are comprised of pocosins (Richardson et al., 1981 and Richardson, 1991).

Richardson (1991), states that approximately 33% of North Carolina pocosins have been destroyed and over 51% of forested palustrine wetlands have been disturbed. The development status for North Carolina pocosins is graphically depicted in Figure 13 from an article by Sharitz and Gibbons (1982).

Due to their limited geographic distribution little research has been performed concerning the restoration of these wetlands. In fact, the authors have found no publications relating to their restoration. However, there are two current studies exploring restoration of Carolina Bays in South Carolina and reintroduction of wetland species to the Pocosin Lakes National Wildlife Refuge in North Carolina (personal communication, Gary Wein, University of Georgia, Savannah River Ecology Laboratory, Aiken, SC, and Mike Wicker, U.S. Fish and Wildlife Service, Raleigh, NC, April, 1994).

2a. Profile: Salt shrub

a. Landscape position  Landward margins and higher areas of salt and brackish marshes. Outer Coastal Plain.

b. Typical hydrology  Irregularly saturated or inundated (saltwater) wind tides.

c. Soils  Organic or mineral. These areas are generally mapped the same as adjacent marshes or uplands.

d. Dominant plants  Primarily shrub and herb layers. For information on these species’ wetland indicator status see Appendix F.

   Shrubs:  Marsh elder, *Iva frutescens*
           Silverling, *Baccharis halimifolia*
           Wax myrtle, *Myrica cerifera*
   Herbs:  Sea ox-eye, *Borrichia frutescens*
Figure 13. The Status of Pocosins in Coastal North Carolina as of 1979

Source: Sharitz and Gibbons (1982)
2b. Overview  Salt shrub wetlands can be identified by their lack of trees and their position along the margins of salt or brackish marshes. Their higher elevation protects them from frequent flooding so woody plants can thrive, but trees and less-tolerant shrubs cannot invade due to the salinity. In some cases, saltwater becomes trapped in salt shrub wetlands and through evaporation, becomes more saline than seawater. Because of these environmental stresses, salt shrub wetlands do not evolve into estuarine fringe forests.

Salt shrub wetlands grade into estuarine fringe forests, pocosins or wet flats on their upper boundaries. They typically adjoin salt marshes along their lower boundaries.

Salt shrub wetlands are common throughout the North Carolina coast.

Salt-shrub
This wetland type occurs as upland zone or small high area in saltwater and brackish water marshes and their extent is usually very limited as seen in Figure 14 (Marcellus, 1972). No publication related to salt-shrub restoration/creation was found by the authors. Therefore, since shrub species dominant both pocosin and salt-shrub wetland types and these two types were combined, any information about restoration or creation concerning pocosins should also apply to the salt-shrub wetland type.

3. Preparation of Soil and Site

Pocosin soils are mostly organic (histosols) of varying depths. The thickest layers of organic soil are found in the center while thinner organic or mineral soils are found at pocosin edges as depicted in Figure 15 (McDonald et al. 1983).

These organic soils are acidic and have low nutrient value. It is apparent that phosphorus is the most limiting nutrient (Richardson, 1991). Phosphorus availability increases along a natural gradient from a short to tall pocosin, and to a bay forest each with a decreasing soil N:P ratio. Fertilization would indeed enhance plant establishment on pocosin soils.

4. Hydrology

Natural pocosin hydrologic characteristics include gradual absorption of precipitation into the organic soil with slow lateral movement and equable distribution of sheet flow (Sharitz and Gibbons, 1982). During winter, spring, and early summer the water table ranges from above to just below the soil surface with deep peats rarely having a draw-down of more than 4 to 5 feet below the soil surface. The longest hydroperiod exists in the center of the pocosin due to the great depth of peat and degree of decomposition of peat which has an inherently low hydraulic conductivity.
Figure 14. The Narrow Zone of Salt-shrub in a Typical Saltwater Marsh

Spartina alterniflora

Juncus roemerianus

Spartina patens
and
Distichlis spicata

Salt-Shrub Zone

Iva frutescens
and
Baccharis halimifolia

Upland

Marcellus (1972)
Figure 15. The Relationship Between Vegetative and Organic Soil

McDonald et al. (1983)
Many natural watershed drainage patterns have been altered by major drainage ditches which traverse the pocosin ecosystem. These ditches result in higher runoff rates and lower water tables. Most of the topography has been graded to 0.5% (Sharitz and Gibbons, 1982).

5. Planting

It is recommended that planting be performed on mesic sites, then raise the water table (personal communication, Dr. Russ Lea, Department of Forestry, N.C. State University, December 1993). Since rooting volume depth is inhibited by saturated soil conditions, planting first will allow vegetation to become firmly anchored before the water table rises (Clewell and Lea, 1990).

In planning pocosin restoration it must be kept in mind that deer can destroy newly planted seedlings within one week of planting, which was the case of one restoration attempt. Electric fences about 5 feet tall have been the most successful deterrent to deer grazing (personal communication, Dr. Russ Lea, Department of Forestry, N.C. State University, December 1993).

6. Time

No specific information for the time involved with pocosin/scrub-shrub restoration/creation was found. However, the cost, complexity and duration of a restoration/creation project will depend on the degree of alteration of hydrology, soil and biotic community. Typically restoration takes less time than creation projects (Hammer, 1992). The time considerations for saltwater marsh that were defined by Broome et al. (1988) are general enough to also be utilized for pocosin/salt-shrub. These considerations include the following:

- Plan and prepare at least one year prior to transplanting is necessary, if seed must be collected and germinated to grow plants.
- Allow time for obtaining permits.
- Delay in permitting and construction are common.
- Allow fill material to settle for several weeks.
- Complete final grading and construction well in advance of the optimum planting times.
- Optimum planting time is in the winter. Planting earlier may incur storm damage and field-dug plants will be difficult to obtain.
- Use of potted seedlings may result in unhealthy or dead plants if there are long holding times.
7. Cost

No specific project costs were found for pocosin or salt-shrub wetland types but the cost figures developed by Garbisch (1986), as part of his report to the Federal Highway Administration, could be used as a general guide. However, land and labor costs have the greatest amount of variability of all the factors considered. Refer to Table 10 in the Freshwater Marsh section for costs of vegetative establishment that was developed by Garbisch (1986). King and Bohlen (1994) also developed cost figures for eight major wetland types. Pocosin and salt-shrub wetlands were not determined by King and Bohlen but the range of costs they developed should also include these two wetland types.

8. Reference Sites: Low Pocosin

a. Croatan National Forest  Found in the Croatan National Forest. South of the four lake system and west of U.S. 70 between Havelock and Newport. Mostly located in Carteret County.

b. U.S 264  Part of Alligator River National Wildlife Refuge. Located west of U.S. 264 in Dare County.


9. Reference Sites: High Pocosin


c. Angola Swamp  Found in Angola Bay Swamp Gameland. Located east of Wallace and I-40 in Duplin and Pender Counties.

10. Reference Site: Salt Shrub

a. Pea Island  Most shrub occurs on the Pamlico Sound side of Pea Island. Part of the Pea Island National Wildlife Refuge. Located southwest of N.C. 12 in Dare County.

b. Ocracoke Island  Most shrub occurs on the Pamlico Sound side of the Ocracoke Island. Part of the Cape Hatteras National Seashore. Located northwest of N.C. 12 in Hyde County.
c. Masonboro Island  Covers most of the interior of Masonboro Island and is bordered by the Atlantic Ocean, Intracoastal Waterway, Masonboro Inlet and Carolina Beach Inlet. Located southeast of Wilmington in New Hanover County.
11. Contacts

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Raleigh, NC 27695-8001
Fax No. 515-7231
Telephone (919) 515-2890
V. REFERENCES


APPENDIX A: NATIONAL AND REGIONAL CLIMATE CENTERS

National Climatic Data Center
Federal Building
Asheville, NC 28801-2696
(704) 259-0682
Serves 50 states and territories

Southeastern Regional Climate Center
Main ST. Suite 1100
Columbia, SC 29201
(803) 737-0800
Serves Alabama, Virginia, North Carolina, South Carolina, Georgia, Florida

Southern Regional Climate Center
260 Howe-Russell Bldg.
Louisiana State University
Baton Rouge, LA 70803
(504) 388-5021
Serves Mississippi, Arkansas, Louisiana, Oklahoma, Texas
APPENDIX B: OUTLINE OF SCS AND ACOE RESTORATION AND CREATION GUIDELINES

Army Corps of Engineers
Wetlands Engineering Handbook *

I. Introduction
   A. Background
   B. Purpose and scope

II. Defining Functions, Site Characteristics, and Design Criteria
   A. Initial evaluation of wetlands needs
   B. Selection of desired wetland type and function
   C. Baseline site surveys
      1. topographic
      2. hydrologic
      3. soils
      4. vegetative
   D. Selection of sites for restoration
   E. Design criteria

III. Engineering for Wetlands Substrate
   A. Suitability of existing substrate soils
   B. Fill or excavation requirements
   C. Elevation and grading requirements
   D. Borrow material sources for fill requirements
   E. Placement sites for excavated material
   F. Fill or excavation techniques and equipment
   F. Hydraulic fill requirements
      1. retention requirements for hydraulic fill
      2. retention dike or structure
      3. selection of hydraulic fill equipment
   G. Conventional soils handling
      1. soils handling requirements
      2. select equipment for soils handing techniques
   H. Consolidation of fill

IV. Engineering for Wetland Hydrology
   A. Models
      1. drainage analysis GeoSHED
      2. hydrodynamics FasTABS
      3. groundwater
   B. Requirements for water control
   C. Design of water control structure(s)
D. Requirements for erosion control
E. Design of erosion control measures

V. Engineering for Wetlands Vegetation
A. Vegetation requirements
B. Species selection
C. Methods of Vegetating
D. Source(s) of plant materials
E. Equipment for planting
F. Planting schedules

VI. Automated Systems and Software

VII. Monitoring and Management
A. Construction monitoring
B. Physical/Engineering
C. Chemical
D. Biological
E. Success Criteria
F. Management and monitoring plans
G. Remedial actions

* The Waterways Experiment Station (WES) is preparing this document and it will be available to the public in January 1995. For further information regarding the document contact Mike Palermo, Environmental Engineering Division, Department of the Army, Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.
APPENDIX B: OUTLINE OF SCS AND ACOE RESTORATION AND CREATION GUIDELINES

Soil Conservation Service (SCS) Engineering Field Handbook *
Chapter 13: Wetland Restoration, Enhancement, or Creation

I. Introduction
   A. Purpose and scope
   B. Background
   C. Information and agency sources

II. Wetland Processes and Characteristics
    A. Physical
    B. Chemical
    C. Biological

III. Planning and Site Selection
     A. Define objective and purpose
     B. Site evaluation

IV. Design
    A. Data collection
    B. The hydrologic system
    C. Structural components
    D. Substrate sealing
    E. Vegetation design
    F. Structural design examples

V. Implementation
   A. Quality control
   B. Site construction
   C. Wetland soils as sources of plant materials
   D. Vegetation

VI. Monitoring
    A. Criteria and baseline information
    B. Periodic monitoring

VII. Management
    A. Prairie pothole management
    B. Seasonally flooded impoundments for wildlife
    C. Bottomland hardwood management
    D. Greentree reservoir/moist soil unit management
References

Appendix A. Wetland planning checklist

Appendix B. Site visit checklist

Glossary

* To obtain a copy of this document, contact your state SCS Office
APPENDIX C: RESTORATION/CREATION SURVEY

Water Resources Research Institute (WRRI), in coordination with the North Carolina Division of Coastal Management has undertaken a project to develop a wetland restoration and creation handbook for wetland managers. This survey is the second phase of the project.

Your answers to the following questions will provide us with insight and advice that will be extremely helpful in assembling our handbook. Also, your answers could determine, coordinate, and focus resources for future research.

All the information you give us will be treated confidentially. If a particular question does not apply to your organization write below the question the letters "NA" for "not applicable". Question number 2 is important to us because many of your responses will depend on your answer to that question. Note that some of the questions have more than one part, so be sure to answer all parts. Thank you (in advance) for your participation.

1. Considering your organization's total work, about what percentage of time does your organization spend on creation and restoration projects?
   
   ______% Restoration & Creation (IF NONE, PLEASE GO TO QUESTION 25 ON PAGE 5)\(^4\)\(^-\)\(^6\)

2. Which wetland type(s) does your organization specialize in? (CIRCLE THE APPROPRIATE LETTER(S) BELOW).

   A. Estuarine, Intertidal, Emergent, Persistent (regularly flooded)-(irregular flooded)---(e.g. brackish marsh)\(^7\)
   B. Palustrine, Emergent, aquatic bed, rooted vascular (permanently flooded) ---(e.g. freshwater marsh)\(^8\)
   C. Estuarine, Intertidal, Scrub-shrub---(e.g. estuarine scrub-shrub)\(^9\)
   D. Palustrine, Scrub-Shrub, broad-leaved evergreen, needle-leaved evergreen (saturated), evergreen---(e.g. low pocosin)\(^10\)
   E. Palustrine, Forested, evergreen, broad-leaved evergreen (saturated) ---(e.g. high pocosin)\(^11\)
   F. Palustrine, Forested, Broad-Leaved Deciduous (seasonal flooded) ---(e.g. bottomland hardwood)\(^12\)
   G. Palustrine, Forested, deciduous (saturated) - (seasonally flooded) - (semipermanently flooded) - (intermittently exposed), needle-leaved deciduous (semipermanently flooded), broad-leaved deciduous (saturated) ---(e.g. swamp forest)\(^13\)
   H. Palustrine, Forested, Broad-Leaved Deciduous (temporarily flooded) ---(e.g. hardwood flats)\(^14\)
   I. Palustrine, Forested, Needle-Leaved Evergreen (temporarily flooded)-(seasonally flooded)---(e.g. wet pine flats)\(^16\)

3. In your organization, how critical are each of the following project stages for success in restoring/creating a wetland? (RATE EACH OF THE FOLLOWING FROM 1 (NOT IMPORTANT) TO 5 (VERY IMPORTANT) BY CIRCLING APPROPRIATE NUMBER)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Not Important</th>
<th>Very Important</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. defining your objectives(^16)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>B. site selection and evaluation(^17)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>C. project planning(^18)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>D. construction(^19)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>E. monitoring(^20)</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

   Are other topics important in determining success? (IF SO, LIST BELOW)\(^21\)-\(^24\)
4. Which functions does your organization primarily attempt to restore/create? RATE EACH OF THE FOLLOWING FROM 1 (NOT IMPORTANT) TO 5 (VERY IMPORTANT) BY CIRCLING APPROPRIATE NUMBER

<table>
<thead>
<tr>
<th>Function</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. aquatic and terrestrial habitats/corridors</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>B. flood and/or erosion control</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>C. production</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>D. water quality</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>E. aesthetics</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>F. research</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

5. How often does your organization establish success criteria before beginning a restoration/creation project(s)? (CIRCLE ONE LETTER)

- A. Never
- B. Rarely
- C. Sometimes
- D. Often
- E. Always

6. What is the most serious limiting factor in your organization's restoration/creation efforts? (CIRCLE ONLY ONE LETTER)

- A. cost
- B. regulations
- C. equipment
- D. lack of information
- E. time constraints on project
- F. lack of experience
- G. lack of monitoring
- H. lack of personnel

7. How many wetland areas has your organization attempted to restore/create? (CIRCLE ONE LETTER)

- A. 0
- B. 1-5
- C. 6-10
- D. 11-15
- E. 16-20
- F. 20 +

How successful would you say your organization has been in restoring/creating wetlands? (CIRCLE ONE LETTER)

- A. very successful
- B. moderately successful
- C. moderately unsuccessful
- D. very unsuccessful

What factors would you attribute to your organization's level of success?

8. At times organizations are required to restore/create wetlands on poorly suited sites. How often does the originally intended functions of the wetland change due to the site selection? (CIRCLE ONE LETTER)

- A. Never
- B. Rarely
- C. Sometimes
- D. Often

How often is your organization required to restore/create wetlands on poorly suited sites? (CIRCLE ONE LETTER)

- A. Never
- B. Rarely
- C. Sometimes
- D. Often

How often does this situation affect the success of your organization's restoration/creation projects? (CIRCLE ONE LETTER)

- A. Never
- B. Rarely
- C. Sometimes
- D. Often
9. Based upon the wetland type(s) you work with, what factor(s) needs more research to better assist in the restoration/creation practice? 

10. Does your organization use the Cowardin/Fish and Wildlife Service classification system to classify wetland communities and habitats?  
   Yes  No  (CIRCLE ONE) (IF YES SKIP TO QUESTION 11) 

   IF NO: What specific classification system do you use?  
   1. plant communities  3. geomorphology  
   2. hydrology  4. hydrogeomorphology  

11. Does your organization keep restoration/creation records on projects in which you have been involved?  
   Yes  No  (CIRCLE ONE) 

   IF YES: What types of information are included? (CIRCLE ALL THAT APPLY)  
   1. wetland functions  7. plant health and vigor  
   2. water chemistry data  8. wetland classification  
   3. water budget changes  9. surrounding land use changes  
   4. plant survival rate  10. area  
   5. off-site or on site  11. objectives stated  
   6. colonization by other plant species (desireable and nuisance)  

   Are monitoring records kept?  Yes  No  (CIRCLE ONE) 

   Would you allow government agencies or wetland researchers access to these records?  
   -government agencies  Yes  No  (CIRCLE ONE)  
   -wetland researchers  Yes  No  (CIRCLE ONE) 

   In what form are records kept? (CIRCLE ALL THAT APPLY)  
   A. written reports  C. computer database  
   B. permits  D. other (SPECIFY) 

12. At what length of time after project completion of wetland restoration/creation do you determine whether a project has been successful? (CIRCLE ONE LETTER)  
   A. 0-3 months  D. 10-12 months  G. 5-10 years  
   B. 4-6 months  E. 1-2 years  H. 10+ years  
   C. 7-9 months  F. 2-5 years  

13. How important are the following sources of reference material for restoration/creation projects? (RATE EACH OF THE FOLLOWING FROM 1 (NOT IMPORTANT) TO 5 (VERY IMPORTANT) BY CIRCLING APPROPRIATE NUMBER)  

   A. scientific and professional journals  
   B. U. S. Fish and Wildlife Service  
   C. Army Corps of Engineers  
   D. Soil Conservation Service  
   E. state agency  
   F. Wetland Manual 1987  
   G. Environmental Protection Agency  
   H. personal communication (talk to consultant)  
   I. university researchers  

Not Important: 1  2  3  4  5  
Very Important: 1  2  3  4  5
14. THIS QUESTION WILL ALLOW US TO DETERMINE WHICH MEDIA PROVIDE RELEVANT LITERATURE ON PROJECTS. Does your organization disseminate information concerning your restoration/creation work?

Yes  No  (CIRCLE ONE)  

IF YES: Through which media do you disseminate information about wetland restoration/creation? (CIRCLE ONLY THE LETTER(S) THAT APPLY. PLEASE SPECIFY DETAILS IN BLANKS PROVIDED).

A. project report (to whom)  
B. conference presentation (where)  
C. journal article (title)  
D. newsletter (title)  
E. public hearing (by whom)  
F. workshop (title)  

15. How important would each of the following types of information be in a field handbook? (RATE EACH OF THE FOLLOWING FROM 1 (NOT IMPORTANT) TO 5 (VERY IMPORTANT) BY CIRCLING APPROPRIATE NUMBER)  

A. planting procedures  
B. plant selection  
C. plant sources  
D. ecological functions of different wetland types  
E. hydrology restoration  
F. locations of successful sites  
G. sources of regional expertise  
H. glossary of terms  

Would other topics be important? IF SO, LIST BELOW  

16. To vegetate a wetland do you typically plant or do you depend upon natural colonization to occur? (CIRCLE LETTER AND PLEASE INDICATE THE LETTER OF THE WETLAND TYPE(S) CHOSEN FROM QUESTION 2 IN THE BLANK PROVIDED)  

A. Plant (LIST WETLAND TYPE)  
B. Natural Colonization (LIST WETLAND TYPE)  

17. If you plant, do you obtain vegetation from nearby natural areas or purchase nursery stock? (CIRCLE ONE LETTER)  

A. Natural areas  
B. Purchase nursery stock  
C. Both  

18. How important is it to restore/create each of the following hydrologic conditions for the wetlands in which you work? RATE EACH OF THE FOLLOWING FROM 1 (NOT IMPORTANT) TO 5 (VERY IMPORTANT) BY CIRCLING APPROPRIATE NUMBER.  

A. hydroperiod lengths and season  
B. volume of water inputs relative to outputs  
C. duration of inundation  
D. depth of inundation  
E. frequency of inundation  
F. near surface saturation  

19. Does your organization use a hydrologic model for wetland restoration/creation?

Yes  No  (CIRCLE ONE)  

IF YES: Which model?
20. Does your organization use water control structures to regulate the restored/created wetland?  
   Yes  No  (CIRCLE ONE)  
   IF YES: Which structures?

21. What soil/substrate preparation or management techniques are usually required for the type of wetland in which you work? (CIRCLE ALL THAT APPLY)  
   A. fertilization  B. tilling/ripping  C. organic amendments  
   D. grading  E. import soil  F. clearing

22. For the wetland types you work with, what types of erosion control techniques has your organization used? (CIRCLE ALL THAT APPLY)  
   A. silt fence  B. sediment basin  
   C. vegetative cover  D. grading

23. How often does your organization import soil to the restoration/creation site? (CIRCLE ONE)  
   A. Never  B. Rarely  C. Sometimes  D. Often  E. Always

24. Do you monitor soil parameters after restoration/creation?  
   Yes  No  (CIRCLE ONE)

THE REMAINING QUESTIONS PROVIDE US WITH IMPORTANT BACKGROUND INFORMATION ABOUT YOU AND YOUR ORGANIZATION. REMEMBER THAT ALL INFORMATION WILL BE TREATED CONFIDENTIALLY.

25. What type of organization do you work for? (CIRCLE ONE LETTER)  
   A. private consulting  B. federal agency  C. state or local agency  
   D. college or university  E. conservation or environmental group  F. other (SPECIFY)

26. Is your wetlands work mainly in (CIRCLE ONE)  
   A. one state (SPECIFY)  B. one region (SPECIFY)  
   C. national  D. international

27. How many years have you been involved in wetlands management including restoration/creation? (CIRCLE ONE LETTER)  
   A. 0-2 years  B. 2-5 years  C. 5-10 years  D. 10-15 years  E. 20+ years

28. Circle the one field in which you have the most training? (CIRCLE ONE LETTER)  
   A. engineering  B. biology  C. geology  
   D. botany  E. ecology  F. hydrology  
   G. forestry  H. law  I. soil science  J. administration/business  K. other

29. What are your main responsibilities in dealing with restoration/creation? (CIRCLE ALL THAT APPLY)  
   A. Project Planning  B. Site Selection  C. Construction  
   D. Planting  E. Monitoring  F. Management  
   G. Regulatory  H. Research  I. other
## APPENDIX D: WETLAND CLASSIFICATION COMPARISON

<table>
<thead>
<tr>
<th>DEM/DCM WETLAND TYPE¹</th>
<th>NHP WETLAND TYPE²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wetlands created by rainfall-</td>
<td></td>
</tr>
<tr>
<td>pine savannas</td>
<td>pine savanna</td>
</tr>
<tr>
<td>wet flats</td>
<td>wet pine flatwoods</td>
</tr>
<tr>
<td>pocosins</td>
<td>low pocosin</td>
</tr>
<tr>
<td>high pocosin</td>
<td></td>
</tr>
<tr>
<td>pond pine woodland</td>
<td></td>
</tr>
<tr>
<td>bay forest</td>
<td></td>
</tr>
<tr>
<td>streamhead pocosin</td>
<td></td>
</tr>
<tr>
<td>small depression pocosin</td>
<td></td>
</tr>
<tr>
<td>Wetlands created by groundwater discharge-</td>
<td></td>
</tr>
<tr>
<td>mountain bogs and fens</td>
<td>southern Appalachian bog</td>
</tr>
<tr>
<td></td>
<td>Southern Appalachian fen</td>
</tr>
<tr>
<td>seeps</td>
<td>high elevation seep</td>
</tr>
<tr>
<td>low elevation seep</td>
<td></td>
</tr>
<tr>
<td>sandhill seep</td>
<td></td>
</tr>
<tr>
<td>Wetlands created by groundwater and surface water-</td>
<td></td>
</tr>
<tr>
<td>bog forests</td>
<td>swamp forest/bog complex</td>
</tr>
<tr>
<td>headwater forests</td>
<td>Coastal Plain small stream swamp</td>
</tr>
<tr>
<td>freshwater marshes</td>
<td>piedmont/mountain semipermanent impoundment</td>
</tr>
<tr>
<td></td>
<td>small depression pond</td>
</tr>
<tr>
<td></td>
<td>natural lake shoreline</td>
</tr>
<tr>
<td></td>
<td>maritime wet grassland</td>
</tr>
<tr>
<td></td>
<td>tidal freshwater marsh</td>
</tr>
</tbody>
</table>

¹ North Carolina Division of Environmental Management and Division of Coastal Management
² North Carolina Natural Heritage Program
## APPENDIX D: WETLAND CLASSIFICATION COMPARISON

<table>
<thead>
<tr>
<th>DEM/DCM WETLAND TYPE¹</th>
<th>NHP WETLAND TYPE²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wetlands created by surface water flow:</strong></td>
<td></td>
</tr>
<tr>
<td>bottomland hardwood forests</td>
<td>Coastal Plain bottomland hardwoods</td>
</tr>
<tr>
<td></td>
<td>Piedmont/mountain bottomland forest</td>
</tr>
<tr>
<td></td>
<td>Piedmont/mountain alluvial forest</td>
</tr>
<tr>
<td></td>
<td>montane alluvial forest</td>
</tr>
<tr>
<td>ephemeral wetlands</td>
<td>floodplain pool</td>
</tr>
<tr>
<td></td>
<td>vernal pool</td>
</tr>
<tr>
<td></td>
<td>cypress savannah</td>
</tr>
<tr>
<td>swamp forests</td>
<td>cypress-gum swamp</td>
</tr>
<tr>
<td></td>
<td>oxbow lake</td>
</tr>
<tr>
<td></td>
<td>Coastal Plain semipermanent impoundment</td>
</tr>
<tr>
<td></td>
<td>Piedmont/mountain swamp forest</td>
</tr>
<tr>
<td></td>
<td>nonriverine swamp forest</td>
</tr>
<tr>
<td></td>
<td>peatland Atlantic White Cedar forest</td>
</tr>
<tr>
<td></td>
<td>streamhead Atlantic White Cedar forest</td>
</tr>
<tr>
<td></td>
<td>tidal cypress-gum swamp</td>
</tr>
<tr>
<td><strong>Wetlands influenced by the ocean:</strong></td>
<td></td>
</tr>
<tr>
<td>estuarine fringe forests</td>
<td>estuarine fringe loblolly pine forest</td>
</tr>
<tr>
<td>brackish marshes</td>
<td>brackish marsh</td>
</tr>
<tr>
<td>salt shrub wetlands</td>
<td>salt shrub</td>
</tr>
<tr>
<td>salt marshes</td>
<td>salt marsh</td>
</tr>
<tr>
<td></td>
<td>salt flat</td>
</tr>
</tbody>
</table>

¹ North Carolina Division of Environmental Management and Division of Coastal Management
² North Carolina Natural Heritage Program
# APPENDIX D: WETLAND CLASSIFICATION COMPARISON

<table>
<thead>
<tr>
<th>DEM/DCM WETLAND TYPE¹</th>
<th>NWI WETLAND TYPE²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wetland created by rainfall</strong>-</td>
<td></td>
</tr>
<tr>
<td>Carolina Bay</td>
<td>Palustrine, Scrub-Shrub, Broad-leaved evergreen (saturated), needle-leaved evergreen (saturated), evergreen, freshwater evergreen (saturated), freshwater needle-leaved evergreen (saturated)</td>
</tr>
<tr>
<td>hardwood flat</td>
<td>Palustrine, Forested, Broad-leaved Deciduous (temporarily flooded)</td>
</tr>
<tr>
<td>pine flat</td>
<td>Palustrine, Forested, Needle-leaved Evergreen (temporarily flooded)-(seasonally flooded)</td>
</tr>
<tr>
<td>low pocosins</td>
<td>Palustrine, Scrub-Shrub, broad-leaved evergreen, needle-leaved evergreen (saturated), evergreen</td>
</tr>
<tr>
<td>high pocosins</td>
<td>Palustrine, Forested, evergreen, broad-leaved evergreen (saturated)</td>
</tr>
<tr>
<td><strong>Wetlands created by groundwater and surface water</strong>-</td>
<td></td>
</tr>
<tr>
<td>freshwater marsh</td>
<td>Palustrine, Emergent, aquatic bed, rooted vascular (permanently flooded)</td>
</tr>
<tr>
<td><strong>Wetland created by surface water flow</strong>-</td>
<td></td>
</tr>
<tr>
<td>bottomland hardwood forests</td>
<td>Palustrine, Forested, broad-leaved deciduous (seasonally flooded)</td>
</tr>
<tr>
<td>swamp forests</td>
<td>Palustrine, Forested, deciduous (saturated)-(seasonally flooded)-(semipermanently flooded)-(intermittently exposed), needle-leaved deciduous (semipermanently flooded), broad-leaved deciduous (saturated)</td>
</tr>
<tr>
<td><strong>Wetlands influenced by the ocean</strong>-</td>
<td></td>
</tr>
<tr>
<td>brackish marshes</td>
<td>Estuarine, Intertidal, Emergent, Persistent (regularly flooded)-(irregularly flooded)</td>
</tr>
<tr>
<td>estuarine salt-shrub</td>
<td>Estuarine, Intertidal, Salt-shrub</td>
</tr>
</tbody>
</table>

¹North Carolina Division of Environmental Management and Division of Coastal Management
²U.S. Fish and Wildlife Service - National Wetland Inventory
APPENDIX E: WETLAND VEGETATION SOURCES FOR THE SOUTHEAST

Beersheba Wildflower Gardens
Beersheba Springs, TN
Phone: (615)692-3575

Boyd Nursery Company *
P.O. Box 71
McMinnville, TN 37110
Phone: (615)668-9898, 4747

Carolina Seacoast Beach Plants
Professional Park Suite 8
P.O. Box 1194
Morehead City, NC 28557-1194
Phone: (919)240-2415

Champion International Corporation
Carolina Nursery *
2341 Redmond Mill Road
Swansea, SC 29160-9737
Phone: (803)568-2436

Environmental Concern Inc.
P.O. Box P, 210 West Chew Ave.
St. Michaels, MD 21663
Phone: (410)745-9620
FAX: (410)745-3517

Environmental Consultants, Inc.
P.O. Box 3198
Suffolk, VA 23434
Phone: (804)539-4833

Federal Paper Board Company, Inc.
J.B. Lattay Forest Tree Nursery and Genetics Center *
P.O. Box 1007
Lumberton, NC 28359
Phone: (919)739-7596

Gardens of the Blue Ridge
P.O. Box 10
Pineola, NC 28662
Phone: (704)733-2417

Green Biz Nursery & Landscaping, Inc.
P.O. Box 64995
Fayetteville, NC 28306
Phone: 1-800-848-6634

Green Images
P.O. Box 1330
Christmas, FL 32709
Phone: (407)568-1333

Hastings
434 Marietta Street, N.W.
P.O. Box 4274
Atlanta, GA 30302
Phone: (404)524-8861

Hawkersmith and Sons Nursery, Inc.
Route 4-Box 4155
Tullahoma, Tennessee 37388
Phone: (615)455-5436

Hillis Nursery Company, Inc.
Rt. 2, Box 142 *
McMinnville, TN 37110
Phone: (615)668-4364

Hoffman Nursery
5520 Bahama Road
Rougemont, NC 27572

Horticultural Concepts
P.O. Box 113
Southern Pines, NC 28338-0113
International Paper Company
South Carolina Supertree Nursery #3 *
Rt. 1, Box 112
Blenheim, SC 29516
Phone: (803)528-3203

Lilypons Water Gardens
6800 Lilypons Road
P.O. Box 10
Buckeystown, MD 21717-0010
Phone: (301)874-5133
FAX: (301)874-2959

Little River Farms
Rt. 1, Box 220
Middlesex, N.C. 27557
Phone: (919)965-9507

Mangrove Systems, Inc.
504 S. Brevard Avenue
Tampa, FL 33606

Maryland Aquatic Nursery
3427 N. Furnace Rd.
Jarretsville, MD 21084
Phone: (301)557-7615
FAX (301)557-7615

Niche Gardens
1111 Dawson Rd.
Chapel Hill, NC 27515
Phone: (919)967-0078

North Carolina Division of Forest Resources *
Claridge State Forest Nursery
762 Claridge Nursery Road
Goldsboro, NC 27530
Phone: (919)731-7988

North Carolina Division of Forest Resources *
Edwards State Forest Nursery
701 Sanford Drive
Morganton, NC 28655
Phone: (704)438-6270

Perry’s Water Gardens
191 Leatherman Gap Rd.
Franklin, NC 28734
Phone: (704)524-3264

Plants for Tomorrow, Inc.
Phone: 800-448-2525

The Salt and the Earth
P.O. Box 51
Deltaville, VA 23043
Phone: (804)776-6324

Savage Farms - Nurseries
P.O. Box 125
McMinvillle, TN 37110

Slocum Water Gardens
1101 Cypress Gardens Road
Winter Haven, FL 33880
Phone: (813)293-7157

South Carolina Forestry Commission
Taylor Forest Tree Nursery *
P.O. Box 116
Trenton, SC 29847
Phone: (803)275-3578

Tall Pines Nursery *
Rt. 1, Box 1110
Cross, SC 29436
Phone: (803)753-3341

Tennessee Division of Forestry
East Tennessee Nursery *
P.O. Box 306
Delano, TN 37325
Phone: (615)263-1626

Tennessee Division of Forestry
West Tennessee Nursery *
P.O. Box 120
Pinson, TN 38366
Phone: (901)988-5221
Triangle Nursery, Inc.
Route 2, Box 229
McMinnville, TN 37110
Phone: (615)668-8022

Tropical Pond & Garden
5190 Lake Worth Rd.
Green Acres, FL 33463

Union Camp Corporation
Union Camp Nursery *
18229 Eppes Drive
Capron, VA 23829-0129
Phone: (804)658-4184

United States Forest Service
W.W. Ashe Nursery *
368 Ashe Nursery Road
Brooklyn, MS 39425
Phone: (601)584-8488

Van Hoose’s Nursery
Rt. 1 Box 1760
West Point, VA 23181
Phone: (804)539-4833
(804)843-3216
FAX (804)843-9733

Virginia Department of Forestry
Garland Gray Forestry Center
Route 2, Box 111 *
Courtland, VA 23027
Phone: (804)834-2855

Virginia Department of Forestry
New Kent Forestry Center *
Box 305
Providence Forge, VA 23140
Phone: (804)966-2201

Warren County Nursery *
Rt. 2, Box 204
McMinnville, TN 37110
Phone: (615)668-8941

Water & Garden Creations
7621 Rock Service Station Road
Raleigh, NC 27603
Phone: (919)662-7677

Water Lily Gardens, Inc.
Pineville, N.C.
Phone: (704)889-8560

The Waterworks
120 S. Edisto Ave.
Columbia, SC 29205
Phone: (803)765-1572

Westvaco Corporation *
Westvaco Nursery
P.O. Box 1950
Summerville, SC 29484
Phone: (803)556-8391

Weyerhaeuser Company *
G.H.W. Weyerhaeuser Nursery
Rt. 2, Box 339
Washington, NC 27889
Phone: (919)946-7718

Weyerhaeuser Company *
J.P. Weyerhaeuser Seed Orchard
Regeneration Center
250 Weyerhaeuser Lane
Trenton, NC 28585
Phone: (919)324-1116

Weyerhaeuser Company *
Quail Ridge Nursery
169 Weyerhaeuser Road
Aiken, SC 29801
Phone: (803)649-0489

Wicklein’s Water
1820 Comwell Bridge Rd.
Baltimore, MD 21234
Phone: (301)823-1335

* only woody species available
## HERBACEOUS EMERGENT PLANTS

<table>
<thead>
<tr>
<th>SPECIES (COMMON NAME)</th>
<th>WETLAND INDICATOR STATUS</th>
<th>WATER TOLERANCE</th>
<th>SALINITY TOLERANCE (ppt)</th>
<th>LIGHT REQUIREMENTS</th>
<th>HEIGHT RANGE</th>
<th>RATE OF SPREAD</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acorus calamus (Sweet flag) perennial</td>
<td>OBL</td>
<td>above MHW or 0-6 in.</td>
<td>0-10</td>
<td>partial</td>
<td>2-3 ft</td>
<td>medium</td>
<td>inconspicuous, green spathe in Apr. - May; forms clumps; tolerates dry periods; leaves similar to iris; tolerates acidic conditions</td>
</tr>
<tr>
<td>Andropogon glomeratus (Bushy beardgrass) perennial</td>
<td>FACW+</td>
<td>seasonal saturation</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>2-5 ft</td>
<td>slow</td>
<td>flowers Aug. - Oct.</td>
</tr>
<tr>
<td>Andropogon virginicus (Broomsedge) perennial</td>
<td>FACU</td>
<td>irregular saturation</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>1-3 ft</td>
<td>slow</td>
<td>clump grass, persistent in winter; provides seed for upland game and songbirds; excellent cover</td>
</tr>
<tr>
<td>Asclepias incarnata (Swamp milkweed) perennial</td>
<td>OBL</td>
<td>seasonal saturation</td>
<td>0-5</td>
<td>full sun</td>
<td>up to 6 ft</td>
<td>slow</td>
<td>pale pink flowers in umbels June - Aug.</td>
</tr>
<tr>
<td>Aster novi-belgii (New York aster) perennial</td>
<td>FACW+</td>
<td>irregular saturation</td>
<td>0-5</td>
<td>full sun</td>
<td>1-3 ft</td>
<td>slow</td>
<td>blue violet flowers July - Oct.</td>
</tr>
<tr>
<td>Carex stricta (Tussock sedge) perennial</td>
<td>OBL</td>
<td>0-6 in.</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>2-4 ft</td>
<td>medium</td>
<td>very high wildlife value (food)</td>
</tr>
<tr>
<td>Distichlis spicata (Spike grass) perennial</td>
<td>FACW+</td>
<td>above MHW</td>
<td>0-50</td>
<td>full sun</td>
<td>8-16 in</td>
<td>rapid</td>
<td>flowers Aug. - Oct.; often intermixed with S. patens; often found in high salinity depressions</td>
</tr>
<tr>
<td>Eryngium aquaticum (Marsh eryngo) perennial</td>
<td>OBL</td>
<td>seasonal saturation or near MHW</td>
<td>0-5</td>
<td>full sun</td>
<td>up to 5 ft</td>
<td>slow</td>
<td>purplish flowers in compact heads July - Sept.</td>
</tr>
<tr>
<td>Eupatorium dubium (Joe-Pye weed) perennial</td>
<td>FACW</td>
<td>seasonal saturation</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>2-5 ft</td>
<td>slow</td>
<td>small, purple flowers in clusters July - Sept.</td>
</tr>
<tr>
<td>Hibiscus moscheutos (Marsh hibiscus) perennial</td>
<td>OBL</td>
<td>0-3 in. or near MHW</td>
<td>0-15</td>
<td>full sun</td>
<td>4-7 ft</td>
<td>slow</td>
<td>showy, red, white, or pink flowers in late summer; seed capsules persist through winter; tolerates dry periods; nectar used by ruby-throated hummingbirds</td>
</tr>
</tbody>
</table>

Source: Modified from Environmental Concern Inc. 1993
## Appendix F: Characteristics of Wetland Species

### HERBACEOUS EMERGENT PLANTS

<table>
<thead>
<tr>
<th>SPECIES (COMMON NAME)</th>
<th>WETLAND INDICATOR STATUS</th>
<th>WATER TOLERANCE (in.)</th>
<th>SALINITY TOLERANCE (ppt)</th>
<th>LIGHT REQUIREMENTS</th>
<th>HEIGHT RANGE</th>
<th>RATE OF SPREAD</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Iris pseudacorus</em> (Yellow flag) perennial</td>
<td>OBL</td>
<td>0-6 in.</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>1-3 ft</td>
<td>slow</td>
<td>showy flowers late spring; clumps; limited wildlife value; requires full sun for flowering</td>
</tr>
<tr>
<td><em>Juncus effusus</em> (Soft rush) perennial</td>
<td>FACW+</td>
<td>0-1 ft. or near MHW and above</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>3-4 ft</td>
<td>slow</td>
<td>often grows in tussocks or hummocks, avifauna eat seed</td>
</tr>
<tr>
<td><em>Juncus roemerianus</em> (Black needlerush) perennial</td>
<td>OBL</td>
<td>above MHW</td>
<td>0-35</td>
<td>full sun</td>
<td>1-4 ft</td>
<td>medium</td>
<td>flower May - Oct: low wildlife value</td>
</tr>
<tr>
<td><em>Kosteletzkya virginica</em> (Seashore mallow) perennial</td>
<td>OBL</td>
<td>above MHW</td>
<td>0-10 ±</td>
<td>full sun</td>
<td>2-4 ft</td>
<td>slow</td>
<td>attractive, pink flowers July -Sept.</td>
</tr>
<tr>
<td><em>Leersia oryzoides</em> (Rice cutgrass) perennial</td>
<td>OBL</td>
<td>0-3 in. or near MHW</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>1-3 ft</td>
<td>medium</td>
<td>tolerates periods of dryness; excellent erosion control; very high wildlife value</td>
</tr>
<tr>
<td><em>Limonium carolinianum</em> (Sea lavender) perennial</td>
<td>OBL</td>
<td>above MHW</td>
<td>0-30 ±</td>
<td>full sun</td>
<td>1-2 ft</td>
<td>slow</td>
<td>small, lavender flowers in sprays July - Oct.</td>
</tr>
<tr>
<td><em>Lobelia cardinalis</em> (Cardinal flower) perennial</td>
<td>FACW+</td>
<td>regular saturation or near MHW</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>up to 5 ft</td>
<td>slow</td>
<td>attractive, scarlet flowers in spikes; blooms July - Oct.; nectar supply for hummingbirds</td>
</tr>
<tr>
<td><em>Nuphar luteum</em> (Spatterdock) perennial</td>
<td>OBL</td>
<td>1-3 ft or below MLW</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>up to 16 in</td>
<td>slow</td>
<td>semi-emerged, floating aquatic; single yellow flower May - Oct.</td>
</tr>
<tr>
<td><em>Panicum virgatum</em> (Switch grass) perennial</td>
<td>FAC</td>
<td>MHW to upland</td>
<td>0-10 ±</td>
<td>full sun</td>
<td>2-4 ft</td>
<td>slow</td>
<td>clumping grass; delicate texture; ornamental particularly in winter; very high wildlife value; flowers July - Sept.</td>
</tr>
<tr>
<td><em>Peltandra virginica</em> (Arrow arum) perennial</td>
<td>OBL</td>
<td>0-1 ft or midtide to MHW</td>
<td>0-1 ±</td>
<td>partial</td>
<td>2-3 ft</td>
<td>slow</td>
<td>attractive, statuesque accent; inconspicuous, green flower in late spring; not subject to wildlife depredation; berry-like seed preferred by wood duck</td>
</tr>
</tbody>
</table>

Source: Modified from Environmental Concern Inc. 1993
### HERBACEOUS EMERGENT PLANTS

<table>
<thead>
<tr>
<th>SPECIES (COMMON NAME)</th>
<th>WETLAND INDICATOR STATUS</th>
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<th>SALINITY TOLERANCE (ppt)</th>
<th>LIGHT REQUIREMENTS</th>
<th>HEIGHT RANGE</th>
<th>RATE OF SPREAD</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polygonum punctatum (Marsh smartweed) perennial</td>
<td>OBL</td>
<td>0-0.5 ft or midtide to MHW</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>to 3.5 ft.</td>
<td>medium</td>
<td>whitish flowers Aug. - Oct.; high food value for avifauna</td>
</tr>
<tr>
<td>Polygonum pensylvanicum (Annual smartweed) annual</td>
<td>FACW</td>
<td>0-6 in. or above MHW</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>up to 6.5 ft</td>
<td>??? see plant guide</td>
<td>small, pink flowers May - Oct.; high food value for wildfowl</td>
</tr>
<tr>
<td>Pontederia cordata (Pickerelweed) perennial</td>
<td>OBL</td>
<td>0-1 ft or midtide to MHW</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>1-3.5 ft</td>
<td>medium</td>
<td>heart-shaped leaves; showy, blue flowers in spikes June - Nov.; of some interest to black and wood ducks</td>
</tr>
<tr>
<td>Sagittaria latifolia (Duck potato) perennial</td>
<td>OBL</td>
<td>0-2 ft or near midtide</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>up to 4 ft</td>
<td>rapid</td>
<td>broadleaved; white flowers on stalk July - Sept.; underground tuber preferred by at least 15 species of duck including canvasback</td>
</tr>
<tr>
<td>Saururus cernuus (Lizard's tail) perennial</td>
<td>OBL</td>
<td>0-1 ft or near midtide</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>up to 4 ft</td>
<td>rapid</td>
<td>attractive, nodding, white flowers in spikes June - Sept.; valued by wood duck; colonizes large areas</td>
</tr>
<tr>
<td>Scirpus cyperinus (Woolgrass) perennial</td>
<td>FACW+</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>4-5 ft</td>
<td>medium</td>
<td>dense clumps; nodding, persistent seed clusters; flowers Aug. - Sept.</td>
</tr>
<tr>
<td>Scirpus pungens (Common three-square) perennial</td>
<td>OBL</td>
<td>0-0.5 ft or midtide to MHW</td>
<td>0-15</td>
<td>full sun</td>
<td>to 4 ft</td>
<td>rapid</td>
<td>erect, triangular stems; heavy predation by muskrat, nutria, and geese; birds eat seeds; flowers June - Sept.</td>
</tr>
<tr>
<td>Scirpus robustus (Saltmarsh bulrush) perennial</td>
<td>OBL</td>
<td>near MHW</td>
<td>0-30</td>
<td>full sun</td>
<td>to 4 ft</td>
<td>medium</td>
<td>tube-like stems; drooping seed clusters at top; good vertical accent; moderate wildlife value; flowers June - Sept.</td>
</tr>
<tr>
<td>Scirpus validus (Soft stem bulrush) perennial</td>
<td>OBL</td>
<td>0-1 ft or near midtide</td>
<td>0-5±</td>
<td>full sun</td>
<td>6-10 ft</td>
<td>rapid</td>
<td>tube-like stems; drooping seed clusters at top; good vertical accent; moderate wildlife value; flowers June - Sept.</td>
</tr>
<tr>
<td>Solidago sempervirens (Seaside goldenrod) perennial</td>
<td>FACW</td>
<td>above MHW</td>
<td>0-10±</td>
<td>partial</td>
<td>3-4 ft</td>
<td>slow</td>
<td>yellow flowers in dense, one-sided spikes July - Nov.</td>
</tr>
</tbody>
</table>

Source: Modified from Environmental Concern Inc. 1993
**HERBACEOUS EMERGENT PLANTS**

<table>
<thead>
<tr>
<th>SPECIES (COMMON NAME)</th>
<th>WETLAND INDICATOR STATUS</th>
<th>WATER TOLERANCE (ft)</th>
<th>SALINITY TOLERANCE (ppt)</th>
<th>LIGHT REQUIREMENTS</th>
<th>HEIGHT RANGE</th>
<th>RATE OF SPREAD</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Sparganium americanum</em> (Eastern bur-reed) perennial</td>
<td>OBL</td>
<td>0-0.5 ft</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>to 5 ft</td>
<td>rapid</td>
<td>good for sediment stabilization; high waterfowl, muskrat, canada goose food value</td>
</tr>
<tr>
<td><em>Sparganium eurycarpum</em> (Giant bur-reed) perennial</td>
<td>OBL</td>
<td>0-1 ft</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>to 7 ft</td>
<td>rapid</td>
<td>good for sediment stabilization; high waterfowl, muskrat, canada goose food value</td>
</tr>
<tr>
<td><em>Spartina alterniflora</em> (Smooth cordgrass) perennial</td>
<td>OBL</td>
<td>midtide to MHW</td>
<td>0-35 ±</td>
<td>full sun</td>
<td>4-7 ft</td>
<td>rapid</td>
<td>shore erosion control; rhizome eaten by muskrat and geese; birds eat seeds; recommended seeding rate: 10 pls./ft²</td>
</tr>
<tr>
<td><em>Spartina cynosuroides</em> (Big cordgrass) perennial</td>
<td>OBL</td>
<td>above MHW</td>
<td>0-10 ±</td>
<td>full sun</td>
<td>to 9 ft</td>
<td>medium</td>
<td>shore erosion control; may be invasive; tolerates drought once established</td>
</tr>
<tr>
<td><em>Spartina patens</em> (Salt meadow hay) perennial</td>
<td>FACW +</td>
<td>above MHW</td>
<td>0-35 ±</td>
<td>full sun</td>
<td>1-3 ft</td>
<td>medium</td>
<td>shore erosion control; tolerates drought once established; good cover and nesting</td>
</tr>
<tr>
<td><em>Typha angustifolia</em> (Narrow-leaved cattail) perennial</td>
<td>OBL</td>
<td>0-1 ft or near MHW and above</td>
<td>0-15 ±</td>
<td>full sun</td>
<td>to 6 ft</td>
<td>rapid</td>
<td>forms dense, persistent stands; good cover/nesting; waterfowl eat rootstock/seed; muskrat eat stems/rootstocks; flowers June - July</td>
</tr>
<tr>
<td><em>Typha latifolia</em> (Broad-leaved cattail) perennial</td>
<td>OBL</td>
<td>0-1 ft or near MHW and above</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>to 6 ft</td>
<td>rapid</td>
<td>refer to <em>T. angustifolia</em> flowers in May - June</td>
</tr>
<tr>
<td><em>Verbena hastata</em> (Blue vervain) perennial</td>
<td>FACW +</td>
<td>seasonal saturation</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>to 5 ft</td>
<td>slow</td>
<td>bluish-violet flowers in multiple, small, dense spikes June - Oct.</td>
</tr>
<tr>
<td><em>Veronica noveboracensis</em> (New York ironweed) perennial</td>
<td>FACW +</td>
<td>seasonal saturation</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>3-7 ft</td>
<td>slow</td>
<td>vivid purple flowers in heads Aug. - Sept.; can be invasive</td>
</tr>
</tbody>
</table>

Source: Modified from Environmental Concern Inc. 1993
## SHRUBS

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<thead>
<tr>
<th>SPECIES COMMON NAME</th>
<th>WETLAND INDICATOR STATUS</th>
<th>WATER TOLERANCE</th>
<th>SALINITY TOLERANCE (ppt)</th>
<th>LIGHT REQUIREMENTS</th>
<th>MATURE HEIGHT (ft)</th>
<th>AERIAL SPREAD (ft)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alnus serrulata</em> (Smooth alder)</td>
<td>OBL</td>
<td>above MHW or regular inundation 0-1 ft.</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>12-20</td>
<td>12-20</td>
<td>nitrogen fixer; food and cover for waterfowl and game birds; fruit in Aug. persists to Feb; tolerates acid soil (pH 5.5 - 7.5)</td>
</tr>
<tr>
<td><em>Aronia arbutifolia</em> (Red chokeberry)</td>
<td>FACW</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>partial</td>
<td>6-12</td>
<td>3-6</td>
<td>white flowers in May; red fruit in Sept. - Dec.; emergency winter food for many species; tolerates acid soil (pH 5.1-6.5)</td>
</tr>
<tr>
<td><em>Aronia melanocarpa</em> (Black chokeberry)</td>
<td>FAC</td>
<td>regular inundation</td>
<td>resistant</td>
<td>partial</td>
<td>3-6</td>
<td>3-6</td>
<td>white flowers in May; black fruit Sept. - Nov. eaten by songbirds (fruit is also edible to humans); tolerates acid soil (pH 5.1-6.5)</td>
</tr>
<tr>
<td><em>Aronia prunifolia</em> (Purple chokeberry)</td>
<td>FACW</td>
<td>regular inundation</td>
<td>resistant</td>
<td>partial</td>
<td>6-12</td>
<td>3-6</td>
<td>tolerates acid soil (pH 5.1-6.5); white flowers April -May; purple berries Sept. - Dec.; used by songbirds, mammals, browsers</td>
</tr>
<tr>
<td><em>Baccharis halimifolia</em> (Groundsel tree)</td>
<td>FACW</td>
<td>above MHW or seasonal inundation 0-6 in.</td>
<td>0-15 ±</td>
<td>full sun</td>
<td>6-12</td>
<td>6-12</td>
<td>tolerates alkaline soil (pH 7.0-8.5); poor soil stabilizer; flowers Aug. - Sept.</td>
</tr>
<tr>
<td><em>Cephalanthus occidentalis</em> (Buttonbush)</td>
<td>OBL</td>
<td>near MHW and above or 0-3 ft</td>
<td>resistant</td>
<td>shade</td>
<td>6-12</td>
<td>12-20</td>
<td>numerous, tubular flowers in ball-shaped heads May - Aug.; tolerates pH 6.1-8.5; poor flowers in full shade; will adapt to dry sites</td>
</tr>
<tr>
<td><em>Clethra alnifolia</em> (Sweet pepperbush)</td>
<td>FAC+</td>
<td>regular inundation</td>
<td>resistant</td>
<td>shade</td>
<td>6-12</td>
<td>3-6</td>
<td>white flowers in spikes, flowers July to Aug.; tolerates acid soil (pH 4.5-6.5)</td>
</tr>
<tr>
<td><em>Cornus amomum</em> (Silky dogwood)</td>
<td>FACW</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>6-12</td>
<td>6-12</td>
<td>white flowers May - June; blue berries in Aug.; very high food value to many songbirds and mammals</td>
</tr>
</tbody>
</table>

Source: Modified from Environmental Concern Inc. 1993

*continued*
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<thead>
<tr>
<th>SPECIES COMMON NAME</th>
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<th>MATURE HEIGHT (ft)</th>
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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Cornus foemina/racemosa</em> (Gray dogwood)</td>
<td>FAC</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>6-12</td>
<td>6-12</td>
<td>white flowers May - June; white berries Aug. - Sept.; very high food value to songbirds, waterfowl, and mammals</td>
</tr>
<tr>
<td><em>Ilex glabra compacta</em> (Inkberry)</td>
<td>FACW-</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>partial</td>
<td>6-12</td>
<td>6-12</td>
<td>flowers May - June; black fruit in Sept., persists to Mar.; tolerates acid soil (pH 4.5-6.0)</td>
</tr>
<tr>
<td><em>Ilex verticillata</em> (Winterberry)</td>
<td>FACW+</td>
<td>above MHW or seasonal inundation</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>6-12</td>
<td>6-12</td>
<td>flowers in June; red/orange berries in Aug. persist to Feb.; food for many songbirds and small mammals; tolerates acid to alkaline soil (pH 4.5-8.0)</td>
</tr>
<tr>
<td><em>Lindera benzoin</em> (Spice bush)</td>
<td>FACW-</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>shade</td>
<td>6-12</td>
<td>6-12</td>
<td>fragrant foliage; scarlet berries in September; very high food value for birds; twigs and foliage browsed by deer; tolerated acid soil (pH 4.5-6.5)</td>
</tr>
<tr>
<td><em>Magnolia virginiana</em> (Sweet bay magnolia)</td>
<td>FACW+</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>shade</td>
<td>12-20</td>
<td>12-20</td>
<td>white, 2-3 in. flowers May - June; scarlet seeds in slits of erect follicles</td>
</tr>
<tr>
<td><em>Myrica cerifera</em> (Wax myrtle)</td>
<td>FAC</td>
<td>above MHW or regular inundation</td>
<td>0-10</td>
<td>shade</td>
<td>30</td>
<td>?</td>
<td>nitrogen fixer; small, bluish berries with waxy coating; considered by some to be a tree</td>
</tr>
</tbody>
</table>

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### SHRUBS

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</tr>
</thead>
<tbody>
<tr>
<td><em>Myrica pensylvanica</em> (Bayberry)</td>
<td>FAC</td>
<td>above MHW or seasonal inundation</td>
<td>0-20</td>
<td>shade</td>
<td>6-12</td>
<td>6-12</td>
<td>nitrogen fixer; flowers Mar. - Apr.; gray berries in Sept., persist to May; tolerates slightly acid soil (pH 5.0-6.5)</td>
</tr>
<tr>
<td><em>Rhododendron viscosum</em> (Swamp azalea)</td>
<td>OBL</td>
<td>regular inundation</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>6-12</td>
<td>6-12</td>
<td>pink to white, tubular flowers in July; tolerates acid soil (pH 4.0-6.0)</td>
</tr>
<tr>
<td><em>Rhus aromatica</em> (Fragrant sumac)</td>
<td>UPL</td>
<td>irregular inundation</td>
<td>resistant</td>
<td>full sun</td>
<td>6-12</td>
<td>12-20</td>
<td>sends out suckers which root-good for bank stabilization; dark red berries in July persisting to March are winter food</td>
</tr>
<tr>
<td><em>Rosa palustris</em> (Swamp rose)</td>
<td>OBL</td>
<td>regular inundation</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>7</td>
<td>?</td>
<td>pink flowers June - Oct.</td>
</tr>
<tr>
<td><em>Salix purpurea</em> (Streamco purple-osier willow) (Basket willow)</td>
<td>?</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>10-18</td>
<td>?</td>
<td>use for erosion control along streambanks; twigs and buds eaten by grouse, rabbits, beaver, and muskrat; poor drought tolerance; tolerates low pH &amp; variety of soils</td>
</tr>
<tr>
<td><em>Sambucus canadensis</em> (Elderberry)</td>
<td>FACW+</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>6-12</td>
<td>6-12</td>
<td>sends out suckers; small, white flowers in large, flat-topped clusters; purple berries Aug. - Sept.; relished by birds; hoofed browsers eat twigs</td>
</tr>
<tr>
<td><em>Vaccinium corymbosum</em> (Highbush blueberry)</td>
<td>FACW-</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>shade</td>
<td>13</td>
<td>?</td>
<td>require acid soil (pH 3.5-6.0); whitish, urn-shaped flowers Apr. - July; blue berries very valuable for wildlife</td>
</tr>
</tbody>
</table>

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### SHRUBS

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<th>AERIAL SPREAD (ft)</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Viburnum dentatum</em> (Arrowwood)</td>
<td>FAC</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>partial</td>
<td>6-12</td>
<td>6-12</td>
<td>white flowers May - June; blue fruit Sept. - Nov. valuable to birds and small mammals</td>
</tr>
</tbody>
</table>

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### TREES

<table>
<thead>
<tr>
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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acer negundo</strong> (Box elder)</td>
<td>FAC+</td>
<td>above spring tide, or regular inundation</td>
<td>resistant</td>
<td>full sun</td>
<td>35-75</td>
<td>35-50</td>
<td>seed July - Sept. may persist to Feb. eaten by birds and small mammals; tolerates drought; can grow 15 to 20 ft. in 5 yrs.</td>
</tr>
<tr>
<td><strong>Acer rubrum</strong> (Red maple)</td>
<td>FAC</td>
<td>above spring tide, or seasonal inundation</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>75-100</td>
<td>50-75</td>
<td>seeds April - June eaten by birds and small mammals; tolerates drought; tolerates acid soil (pH 4.5-6.5)</td>
</tr>
<tr>
<td><strong>Acer saccharinum</strong> (Silver maple)</td>
<td>FACW</td>
<td>above spring tide, or seasonal inundation</td>
<td>resistant</td>
<td>partial</td>
<td>75-100</td>
<td>75-100</td>
<td>seeds April - May eaten by birds; tolerates drought; can grow 25 to 35 ft. in 10 yrs.; prefers acid soil (pH 5.5-6.5)</td>
</tr>
<tr>
<td><strong>Amelanchier canadensis</strong> (Shadbud) (Serviceberry)</td>
<td>FAC</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>shade</td>
<td>35-50</td>
<td>35-50</td>
<td>dark purple berries; high food value for songbirds; flowers May - July</td>
</tr>
<tr>
<td><strong>Aralia spinosa</strong> (Devil’s walking stick)</td>
<td>FAC</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>35-50</td>
<td>20-35</td>
<td>branches and foliage armed with sharp prickles; high value to birds and small mammals</td>
</tr>
<tr>
<td><strong>Betula nigra</strong> (River birch)</td>
<td>FACW</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>full sun</td>
<td>50-75</td>
<td>35-50</td>
<td>can grow 30 to 40 ft. in 10 yrs. seeds June - Aug. eaten by birds</td>
</tr>
<tr>
<td><strong>Chamaecyparis thyoides</strong> (Atlantic white cedar)</td>
<td>OBL</td>
<td>irregular to permanent inundation</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>40-50</td>
<td>10-20</td>
<td>prefers fluctuating water table and little competition; deer and pine siskin use for winter food (deer browse)</td>
</tr>
<tr>
<td><strong>Chionanthus virginicus</strong> (Fringe-tree)</td>
<td>FAC+</td>
<td>irregular inundation</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>20-35</td>
<td>10-35</td>
<td>flowers white, drooping in feathery bunches in May - June; blue berries Sept. - Oct. eaten by songbirds; tolerates acid soil (pH 4.6-6.5)</td>
</tr>
<tr>
<td><strong>Diospyros virginiana</strong> (Persimmon)</td>
<td>FAC-</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>partial</td>
<td>50-75</td>
<td>35-50</td>
<td>produces sweet, orange fruit Sept. - Nov.; high wildlife value (edible to humans after killing frost)</td>
</tr>
<tr>
<td><strong>Fraxinus pennsylvanica</strong> (Green ash)</td>
<td>FACW</td>
<td>regular inundation</td>
<td>resistant</td>
<td>partial</td>
<td>50-75</td>
<td>35-50</td>
<td>can grow 2.5 to 3 ft. per yr.; winged seed eaten by waterfowl and other birds; browsed by deer</td>
</tr>
</tbody>
</table>

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### TREES

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<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Hamamelis virginiana</em> (Witch-hazel)</td>
<td>FAC-</td>
<td>irregular inundation</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>20-35</td>
<td>20-35</td>
<td>unusual, yellow flowers with threadlike, kinky petals; flowers in Sept. remain until Dec.</td>
</tr>
<tr>
<td><em>Ilex opaca</em> (American holly)</td>
<td>FACU+</td>
<td>irregular inundation</td>
<td>&lt;0.5</td>
<td>shade</td>
<td>40-50</td>
<td>18-40</td>
<td>evergreen; foliage more dense in full sun; red berries in Oct. persist through winter; male and female hollies required for fruit</td>
</tr>
<tr>
<td><em>Juniperus virginiana</em> (Eastern red cedar)</td>
<td>FACU</td>
<td>irregular inundation</td>
<td>resistant</td>
<td>partial</td>
<td>50-75</td>
<td>35-50</td>
<td>evergreen; blue, berry-like cones in July persist to March eaten by many birds; browsers eat twigs and foliage</td>
</tr>
<tr>
<td><em>Liquidambar styraciflua</em> (Sweet gum)</td>
<td>FAC</td>
<td>regular inundation</td>
<td>resistant</td>
<td>partial</td>
<td>75-100</td>
<td>50-75</td>
<td>orny, woody ball produced in July persists to Jan., eaten by songbirds and others</td>
</tr>
<tr>
<td><em>Nyssa aquatica</em> (Black tupelo)</td>
<td>OBL</td>
<td>regular inundation</td>
<td>resistant</td>
<td>partial</td>
<td>30-75</td>
<td>20-50</td>
<td>reddish purple fruit</td>
</tr>
<tr>
<td><em>Nyssa sylvatica</em> (Black gum)</td>
<td>FAC</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>partial</td>
<td>50-75</td>
<td>35-50</td>
<td>bluish black fruit Sept. - Oct. eaten by waterfowl and other birds including Pileated woodpecker</td>
</tr>
<tr>
<td><em>Pinus taeda</em> (Loblolly pine)</td>
<td>FAC-</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>partial</td>
<td>40-50 (up to 90)</td>
<td>?</td>
<td>good pioneer species - aggressive; adaptable to extremes of soil</td>
</tr>
<tr>
<td><em>Quercus bicolor</em> (Swamp white oak)</td>
<td>FACW+</td>
<td>seasonal inundation</td>
<td>resistant</td>
<td>partial</td>
<td>75-100</td>
<td>50-75</td>
<td>acorns Sept. - Oct. eaten by waterfowl (especially wood duck), songbirds, shorebirds, gamebirds, and small mammals</td>
</tr>
<tr>
<td><em>Quercus nigra</em> (Water oak)</td>
<td>FAC</td>
<td>seasonal inundation</td>
<td>&lt;0.5</td>
<td>?</td>
<td>100</td>
<td>?</td>
<td>acorns high in wildlife value; tolerates drought</td>
</tr>
</tbody>
</table>

**Wetland Indicator Status:**
- **FAC** = Facultative (34-66% likelihood in wetland)
- **FACU** = Facultative Upland (67-99% likelihood in upland)
- **FACW** = Facultative Wetland (67-99% likelihood in wetland)
- **OBL** = Obligate Wetland (>99% likelihood in wetland)
- **UPL** = Upland species and indicator status not determined
- **-** = Less often found in wetland
- **+** = More often found in wetland