1997

Development of monitoring protocol for created wetlands : project summary for 1997

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Submitted To:

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Environmental Section
Richmond, Virginia

Submitted By:

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RMAP Report No. 97.002.W

Project Title: Development of Monitoring Protocol for Created Wetlands

Principal Investigator: James E. Perry, Ph.D., PWS

Contact: Mr. Steve Russell, VDOT Environmental Section

VIMS Contract # 577802

Summary of activities to date:

Task 1: *Conduct a literature search and analysis to evaluate existing protocols and methods:*

Annotated bibliography was updated and completed in 1997. A copy is appended to this report. No comments were received on the drafts presented to VDOT in 1995 and 1996.

Task 2: *Develop and field test a protocol designed specifically for monitoring wetland compensation sites:*

All data collection and analysis is completed. Results are presented in the field manual. This includes comparison of methods for measuring dominant species in vegetation communities, recommended vegetation methods and caveats, use of hydrologic indicators and wells, soils genesis, control of invasive species, and measuring wildlife use of invasive species.

Data sheets have been developed and field tested. Although the emphasis was placed on four non-tidal sites along the route 58 southeastern Virginia corridor, the data sheets have been used verified for completeness, accuracy, and consistency on over 20 VDOT tidal and non-tidal created wetlands throughout eastern Virginia. Numerous modifications of the protocol during the 1996-1997 portion of this contract have resulted in repeat visits to many of the sites, resulting in over 100 sets of finished monitoring products. Copies of these data sheets are available upon request and will be provided as an appendix to the final report.

Task 3: *Coordinate development, field testing, and establishment of protocol with VDOT, and with state and federal agencies involved with the regulation and mitigation of wetlands impacts:*

Original protocol was presented to federal and state agencies in Nov. of 1995 and again in Nov. 1996. Only a few comments were received and only one from VDOT personnel. Draft manual was presented to VDOT in 1996 and again in spring 1997. An updated version has been presented the VDOT Central office and their wetland consultant for further review. I have been meeting with VDOT personnel on site to explain the protocol and familiarize them with filling out the data sheets. Efforts will continue to involve the federal and state regulatory agencies and VDOT in producing a final protocol.

Attachments: 1) Annotated bibliography, 2) field data sheet, and 3) draft protocol manual.

Appendix 1. Annotated Bibliography

Annotated Bibliography

Adamus, P.R. (1988). In Hook, D.D., W.H. McKee, Jr., H.K. Smith, J. Gregory, V.G. Burrell, Jr., M.R. DeVoc, R.E. Sojka, S. Gilbert, R. Banks, L.H. Stolzy, C. Brooks, T.D. Matthews, and T.H. Shear (eds.). The Ecology and Management of Wetlands. Volume 2: Management, Use, and Value of Wetlands. Timber Press, Portland, OR.

Presents criteria for assessment of replacement wetlands. Examines eight functions of wetlands and suggests that created should obtain ratings at least as high as a similar natural site. Suggests periodic site monitoring, making created sites the same size as the undisturbed site, and using WET or HEP since these are not based solely on biological resources.

Atkinson, R.B., J.E. Perry, E. Smith, and J. Cairns, Jr.. (1993). *Use of created wetland delineation and weighted averages as a component of assessment.* Wetlands 12(3): 185-193.

The vegetation of a created site is compared with that of a reference wetland site to determined whether it is practical to use vegetation alone as an indicator of created wetland success. Since vegetation may respond to soil chemistry and hydrology, it could possibly provide some early indications of conditions within the wetland. The authors conclude that using the vegetation alone to make comparisons to reference wetlands may work for some created wetlands.

Bernstein, G., and R.L. Zepp, Jr.. (1990). Evaluation of Selected Wetland Creation Projects Authorized Through the Corps of Engineers Section 404 Program. Annapolis, MD: U.S. Fish and Wildlife Service. 80 pp.

During the summer and fall of 1988, the USFWS, Annapolis Field Office, evaluated the status of 66 wetland compensation projects in the Baltimore, Norfolk, and Philadelphia Districts, all of which were authorized by the COE under Sec. 404 of the Clean Water Act. The objectives were two-fold: 1) to determine the success of compensation measures (attempted/completed), and 2) to evaluate the value of the created site with respect to the permit conditions. Data collected included dominant vegetation and indicator status, soil type and color, hydrology, and size of the created wetland. Function and value replacement as a test could not be used because pre-construction data was sparse or non-existent. Failure rates ranged from 65% to 72%, including sites where compensation had yet to be attempted. Based on the analysis, the study proposes several recommendations including standardizing permit conditions and implementing enforcement and monitoring procedures.

Brinson, M.M. and R. Rheinhardt. (1996). *The role of reference wetlands in functional assessment and mitigation.* Ecological Applications. Vol. 6, No. 1, p 69-76.

The authors offer an approach to standardize the analyses of compensatory mitigation projects and aim to strengthen the connection between ecological principles and policies for wetlands resources. The standards are extracted from reference wetlands with a high level of sustainable function and are then applied to created sites. They support the reference wetland approach because it 1. Identifies standards that typify sustainable conditions in a particular region, 2. Provide templates for design of creation, and 3. Establish a framework by which a decline or recovery in functions can be quantified.

Brinson, M.M., and L.C. Lee. (1989). *In-kind mitigation for wetland loss: Statement of ecological issues and evaluation of examples.* In Sharitz, R.R. and J.W. Gibbons (eds). Conference on Freshwater Wetlands and Wildlife. DOE Symposium Series No. 61. Oak Ridge, TN: USDOE, Office of Scientific and Technical Information, p 1069-1085.

Emphasis is on replacement of ecosystem processes and self-maintenance. Duplication of the energy signature via replacement of hydrologic, geomorphic and nutrient conditions, and biotic components, is regarded as the most critical design consideration. Three examples, representing Riverine, Fringe, and Basin wetland categories, illustrate the immaturity of wetland creation science. Hence the authors conclude that evaluation during development should focus on processes from which higher-level ecosystem indices (turn-over rates, ratios, production, etc.) can be derived for comparison with natural wetlands.

Brooks, R.. (1989). *Chapter 24: Monitoring Wetlands.* In S.K. Majumdar, R.P. Brooks, F.J. Brenner, and R.W. Tiner, Jr. (eds). Wetlands Ecology and Conservation: Emphasis in Pennsylvania. The Pennsylvania Academy of Science, p 289-299.

This chapter gives a good overview of the various techniques that may be used for monitoring wetlands, whether natural or created. Techniques are mentioned for monitoring hydrology, hydric soils, flora and fauna. Chapter ends with a guideline for sampling frequency.

Brown, M.T.. (1991). Evaluating Created Wetlands Through Comparisons with Natural Wetlands. Prepared for U.S. Environmental Protection Agency, Office of Research and Development, Corvallis, OR. EPA/600/3-91/058. 37 pp.

Critiques the methods for measuring and comparing natural and created wetlands as a measure of creation success. Problems with the field protocols were acknowledged and the relevance of certain variables in comparisons were questioned. The evaluation revealed that temporal changes in hydrology and plant succession were the primary determinants for wetland success.

Craft, C.B., E.D. Seneca, and S.W. Broome. (1991). *Porewater chemistry of natural and created marsh soils*. Journal of Experimental Marine Biology and Ecology. 152(2): 187-200.

Analysis of pore waters chemistry in the created and natural wetland soils showed a marked difference with respect to chemical and ion levels in sediments. After five years, during which emergent vegetation had begun to grow, the created wetland site had not made a complete transition from an upland to a wetland system. The created site had not obtained the level of nutrient cycling found in a natural site, possibly because upland soils may not have the capacity to provide the same nutrient cycling capabilities.

D'Avanzo, C.. (1989). *Long-term evaluation of wetland creation projects*. In Kusler, J.A. and M.E. Kentula (eds). Wetland Creation and Restoration: The Status of the Science. Volume 2: Perspectives. EPA/600/3-89/038. Corvallis, OR: U.S. Environmental Protection Agency Research Lab, p 75-84.

The chapter reviews and evaluates changes that occur over time in wetland creation projects. The results of 100+ wetland projects are discussed; the sites range from large-acreage federal projects to small private projects. The questions addressed are 1) how have artificial wetlands evolved over time, and 2) what can we learn from these effects concerning the feasibility of creating wetlands with long-term functions? The six criteria used to evaluate success and describe change over time are as follows: 1) vegetation growth characteristics, 2) habitat requirements, 3) success of planted species, 4) animal species composition, 5) soil analysis, and, 6) evidence of geologic or hydrologic changes with time. The results concluded that many projects fail due to improper hydrology, contaminated soils, and erosion. Hydrology seems to be the prominent factor in determining wetland community changes with time.

Dennison, M.S. and J.F. Berry. (1993). Wetlands: Guide to Science, Law, and Technology. New Jersey: Noyes Publication.

Presents background and ecological principles for different types of wetlands. Discusses the regulatory framework including Section 404, "dredge and fill" mitigation (sequencing and compensatory), and mitigation banking. Also includes information on restoration and creation through the process of functional assessments, identification of site objective, site selection, and development of concept plans. Discusses preparation of construction plans, implementation, maintenance, monitoring, and evaluation.

Eggers, S.D. (1992). *Compensatory Wetland Mitigation: Some Problems and Suggestions for Corrective Measures*. U.S. Army Corps of Engineers, St. Paul District, 63 pp.

A general overview of specific problems encountered in the construction of mitigation sites in Minnesota and Wisconsin. Considers design, engineering, construction, and long- and short-term monitoring. Contains no information specific to the creation of forested- or shrub-dominated wetlands, since no such project was undertaken. Maintains that limited information is available on the subject. Consists of a good survey of options and different techniques employed. Provides "generalized criteria" for monitoring success or failure of wetlands.

Erickson, P.A., and G. Camogis. (1980). Highways and Wetlands: Volume I, Interim Procedural Guidelines. Washington, DC: U.S. Department of Transportation, Office of Development.

Provides practical guidelines for making highway-related decisions consistent with the National and State goals of wetlands protection. Examines National Wetlands Inventory, guidelines for early phases of highway project development, guidelines for later highway project development, and recommends liaison and coordination activities during highway project development.

---. Highways and Wetlands: Volume II, Impact Assessment, Mitigation, and Enhancement Measures. (1980). Washington, DC: U.S. Department of Transportation, Office of Development.

Provides technical and scientific data, information, and analysis directly relevant to the guidelines. Emphasizes 1. the variety of wetland types and regional factors; 2. evaluation of the significance of individual and cumulative impacts with respect to probability of occurrence, duration, and magnitude; 3. areas of scientific consensus and disagreement; and 4. technical and economic feasibility of alternative mitigation/enhancement. Looks at location, structural, and procedural measures for early and late highway development in marine, estuarine, riverine, lacustrine, and palustrine wetlands.

Erwin, K.L.. (1994). *Section 6: Wetland Creation and Restoration.* In: Global Wetlands: Old World and New. Mitsch, W.J. (ed.). New York: Elsevier, p 429-516.

Presents information on the following projects: the use of *Spartina* for reducing coastal erosion in China, hydrological wetland restoration in Vietnam, cattail eradication as restoration, restoration strategies for India, an account of a successful construction of a freshwater herbaceous wetland in Florida, and ordination of insect populations as an potential evaluation or monitoring tool. Book also covers biogeochemistry, import and export of nutrients in a salt marsh, water quality and other ecological engineering implications, modeling of wetlands, functions and analysis, river and delta wetland management, wetlands and disease control, management of habitat and conservation of vanishing wildlife in Southeast Asia, and the regulatory framework for wetlands protection.

--- (1990). *Freshwater marsh creation and restoration in the Southeast.* In: J.A. Kusler and M.E. Kentula (eds.). Wetland Creation and Restoration: The Status of the Science. Washington, DC: Island Press, p 233-266.

Several uses of created wetland sites were presented, including groundwater recharge and/or discharge, flood storage, shoreline anchoring, sediment trapping, nutrient retention, food chain support, fishery habitat, active and passive recreation, and heritage function. Presents thirteen key elements to successful wetland construction including hydrological analysis; and water quality, vegetation, and soil and fauna protection.

--- (1989). *Wetland evaluation for restoration and creation.* In: J.A. Kusler, and M.E. Kentula (eds). Wetland Creation and Restoration: The Status of the Science. Volume 2: Perspectives. EPA/600/3-89/038. Corvallis, OR: U.S. Environmental Protection Agency Research Lab, p 429-449.

Devises a protocol for evaluating needs in restoration and creation of wetlands. The protocol outlines (1) assessing the original wetland, (2) setting goals for the restoration and creation of mitigation wetlands, (3) assessing projects during restoration, (4) determining post-project compliance, and (5) describing the long-term status. A general discussion of factors and considerations in wetland evaluation is given which provides an overview of choices available for performing data collection and analysis. The choices accommodate practical considerations such as time, budget, wetland type and size, degree of alteration, location, and personnel expertise. Both qualitative and quantitative evaluations are provided for hydrology, vegetation analysis, macro invertebrate monitoring, wildlife utilization, ecological watershed context, and social economic values.

Galatowitsch, S.M., and A.G. Van der Valk. (NEED CITE) Chapter 9: Natural Revegetation during Restoration of Wetlands in the Southern Prairie Pothole Region of North America.

This study found that although reforestation was assumed to take place rapidly, in the field those basins that were reflooded for three years regained only half of the wetland species of a comparable reference site. The method of drainage also affected vegetation restoration. Ditched sites retained a refugium of wetland species but were recolonized by emergent perennials as well. On the other hand, tile-drained sites (more thoroughly drained) lacked a refugium of wetland plants and were recolonized by mudflat annuals and submersed aquatics. These plants were more likely from dispersal than from the seed bank. Both drainage patterns indicated the lack of a perimeter zone of wet prairie and sedge meadow vegetation due to an absence of recolonization of these species. The authors recommend planting such species in order to attain complete restoration in prairie wetland vegetation.

Garbisch, E.W. (1989). *Chapter 22: Wetland Enhancement, Restoration, and Construction.* In:

S.K. Majumdar, R.P. Brooks, F.J. Brenner, and R.W. Tiner, Jr. (eds). Wetlands Ecology and Conservation: Emphasis in Pennsylvania. The Pennsylvania Academy of Science, p 261-275.

Discusses important elements for successful projects of tidal, nontidal, restored and enhanced wetlands. Stresses the importance of plans and specifications. A detailed list of such items as drawing scales for the plans, slopes, timetables, verification of the hydrology, planting tips, and landscape notes is given. The list contains crucial and easily assumed information that must be relayed to the construction supervisors. Qualitative design elements pertaining to intended function(s) are given. Avoidance techniques for common problems along with examples of salt stressed, ice damaged, waterlogged, and flooded soils are discussed.

Gray, R., R. Tuttle, R., and R.D. Wenberg. (1992). Engineering Field Handbook. *Chapter 13: Wetland Restoration, Enhancement, or Creation.* U.S. Dept. of Agriculture, Soil Conservation Service. 79 pp.

Designed to provide field personnel with a guide to the planning, design, construction, monitoring, and maintenance of wetland projects of all sizes, but not all wetland types. This project considers six major kinds of wetlands: Levee, Prairie Pothole, Floodplain, Freshwater, Riparian, and Depressional. Other types of wetlands are not addressed. Also, design of wetlands for specific uses such as pollution retention and water quality control are not described. Provides tables describing wetland functions and the design required to provide such functions. Design of soil, plant, and hydrology restoration is presented. Contains checklists for the planning and visiting of potential mitigation sites.

Haering, K., Genthner, M., Daniels, W.L., Stolt, M. and S. Nagle. (1993/94). *The Development of Effective Strategies for the Restoration and Creation of Non-Tidal Wetlands by VDOT.* Research Report. Dept. of Crop and Soil Environmental Sciences. Blacksburg, VA: Virginia Polytechnic Institute and State University.

Results and discussion of mitigation site inventory and mitigation practice survey for VDOT mitigation sites were summarized. Consists of general information on wetland types, success, hydrology, and vegetation composition on VDOT sites throughout Virginia. Discusses important regulatory and design issues such desired wetness, lack of transitional areas, on-site creation versus mitigation banking, and natural regeneration versus deliberate planting. Future considerations were presented to VDOT on wetland construction, monitoring, and road contracts; the necessity of sharing information on mitigation experiences; and upgrading and standardization of baseline data. They provided a list of other issues for research. One component of the VDOT wetlands research program is the development of an intensive monitoring program to compare soil, hydrology, and vegetation relationships in constructed wetlands as compared with natural reference sites. There are five mitigation sites, each with one natural reference wetland adjacent or within close proximity. All sites except one (Cub Creek created and reference wetland) are located within the Coastal Plain of Virginia. They provide methods for soil properties and water quality samples but not for vegetation samples. The results of the five paired wetlands will be given in the Fall 1994 report. No statistical analysis on the variables in question is provided.

Haering, K., J. Waller-Eling, W.L. Daniels, and M. Genthner. (1992). *Non-Tidal Wetland Soils and Wetland Mitigation: A Literature Review.* Dept. of Crop and Soil Environmental Sciences. Blacksburg, VA: Virginia Polytechnic Institute and State University. 49 pp.

The Virginia Department of Transportation (VDOT) and Center for Innovative Technology (CIT) are engaged in a multi-year project to develop scientifically-based approaches to the effective creation and restoration of non-tidal wetlands. The review focuses on wetland soils and hydrology and the various approaches and strategies used to create hydric soil and associated wetland properties. It reviews several wetland definitions: hydrology, hydric soil classifications, hydric soil chemistry, hydric soil morphology, landscape position and hydric soil formation, and vegetation/soil relationships. The mitigation process is thoroughly discussed from background information of wetland functions to procedures for implementing wetland mitigation projects. The literature review was intended to aid the university's funding partners in their wetland mitigation efforts.

Hammer, D.A.. (1987). Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural. Michigan: Lewis Publishers, Inc..

Four major sections: 1. General Principles – wastewater, wetland ecology, hydrologic factors in wetlands for water treatment, physical and chemical characteristics of wetlands vegetation, wetland microbial characteristics, and wildlife. 2. Case Histories – describes created wetlands used for wastewater treatment. 3. Design, Construction, and Operation – describes use of these factors and the States' attitudes towards them. Examines public perceptions of the use of wetlands in wastewater treatment, performance expectations and loading rates, configuration and design considerations for wastewater treatment, vegetation selection, pathogen removal, and monitoring. 4. Recent Results from the Field and Lab – describes the dynamics of inorganic and organic compounds; efficiency of substrates, vegetation, water level, and microbial population; management of domestic and municipal wastewater; treatment of non-point source pollutants (urban runoff and agricultural waste); applications to industrial and landfill wastewater; and control of acid mine drainage including coal pile and ash pond seepage.

Horner, R.R. and K.J. Raedeke. (1989). *Guide for Wetland Mitigation Project Monitoring*. Monitoring Guide, Operational Draft. Report WA-RD 195.1. Olympia, WA: Washington State Department of Transportation. 265 pp.

This draft was the result of a two-year cooperative research project between WSDOT, FHWA, and the University of Washington. The monitoring program was established to evaluate wetland mitigation sites by examining their progress toward achieving stated objectives. Objectives are two-fold: to develop wetland characteristics (hydrology, hydric soils and wetland vegetation), and to provide designated functions such as food chain support, ecosystem diversity, wildlife habitat and water quality benefits.

The guide is divided into two parts. Part 1 discusses two factors involved in monitoring: 1) assessing the achievement of mitigation objectives, and 2) diagnostic procedures. The former is intended to evaluate a project's success; the latter offers activities that may be carried out in planning a project or analyzing problems that occur in a completed project. Part 2 describes the various monitoring tasks that may be performed depending upon the specific mitigation objectives being evaluated or problems being diagnosed. These monitoring tasks are divided into five categories: 1) mapping and hydrology, 2) water quality, 3) soil and sediment, 4) primary producer monitoring, and 5) consumer monitoring. As an example, Water Quality Tasks include measurements for water temperature, Ph, dissolved oxygen, specific conductivity, and pollutant removal and retention. Each task description provides references and lists all materials and procedural steps needed to obtain and interpret data. Not all tasks are done on every site, and the monitoring protocol can be modified depending upon each plan's objectives and its applicability to the site.

John, J. (1993). *The use of diatoms in monitoring the development of created wetlands at a sand-mining site in Western Australia.* In: H. van Dam (ed.). Twelfth International Diatom Symposium. Vol. 269-270, p 427-436.

The changing chemical composition of created wetlands in former sand-mining pits were correlated with the change in diatom composition of the same area. The researchers also identified notable differences in the invertebrate and waterbird species diversity when the chemistry of the system changed. This correlation leads to a discussion of the value of diatoms in determining the development of the created sites.

Josselyn, M., K. Bobzien, S. Bach, and V. Brack, Jr.. (1989). *Mitigation of Wooded Palustrine Wetlands: Selecting Mitigation Sites.* In: Proceedings of an International Symposium: Wetlands and River Corridor Mangement. J.A. Kusler and S. Daly (ed.).

This paper presents the problem of finding a mitigation site for losses due to road construction. It presents examples/studies where mitigation is difficult due to the variety of site impacts. Gives figure of generalized procedure in developing wetlands mitigation for highway projects.

Kastning-Culp, N. and J. Lockwood. (1993). *Project end report, development of high mountain plant communities as wetland mitigation systems for copper mine effluent.*

Presents information on the best vegetation species to trap heavy metals and to prevent their reaching streams. Conducted lab and field studies (at mine sites in Wyoming, Utah, and Montana) to examine at plant uptake of metals and properties of heavy metals.

Kentula, M.E., R.P. Brooks, S.E. Gwin, C.C. Holland, A.D. Sherman, and J.C. Sifnos. (1992). In: *An Approach to Improving Decision Making in Wetland Restoration and Creation.* Ann J. Hairston (ed). Corvallis, OR: U.S. Environmental Protection Agency, Environmental Research Laboratory.

Project was initiated by EPA's Wetlands Research Program (WRP) to study sites less than five years old, particularly lake/pond fringe marshes (nontidal freshwater).

Chapter 1: performance curve as the major analytical approach, methods of comparing created mitigation sites to the various types of natural sites.

Chapter 2: how to use information from project files.

Chapter 3: sampling methods for projects and selection guidelines for study sites.

Chapter 4: presents post-construction monitoring strategy, three levels of sampling (as-built conditions, routine assessment, and comprehensive assessment).

Chapter 5: suggests performance curves, summary of descriptive graphs, time series graphs, and character curves as four presentation formats for data from site monitoring.

Chapter 6: recommends using data from local wetlands to improve design of projects, details design features (hydrology, vegetation, soils, slopes of banks, area and type of wetlands).

Kusler, J.A., M.L. Quammen, and G. Brooks. (1988). *Proceedings of the National Wetland Symposium: Mitigation of Impacts and Losses.* Berne, NY: Association of State Wetland Managers.

Chapter 1: perspectives on mitigation, defines coastal mitigation and its progress and problems from the perspective of the applicant and the developer.

Chapter 2: federal policies; Corps, Fish & Wildlife Service, and Federal Highway Program responsibilities and perspectives.

Chapter 3: Section 404 and the permit process.

Chapter 4: state policies and approaches; examples from Massachusetts, Louisiana, Michigan, Pennsylvania, Oregon, New Jersey, and California.

Chapter 5: approaches for reducing or compensating for the impacts of parties' activities; examples come from gravel, petroleum, dredge, and agriculture industries.

Chapter 6: addresses mitigation for cumulative impacts.

Chapter 7: special area management topics.

Chapter 8: effectiveness of wetland restoration and creation; measuring success of wetlands mitigation, USFWS mitigation evaluation project, and mitigation effectiveness.

Chapter 9: monitoring for restoration and creation sites.

Chapter 10: goal-setting for restoration and creation including in-kind and out-of-kind compensation; advocates a holistic approach for in-kind and notes special considerations for out-of-kind;

Chapter 11: methods and information for the evaluation of wetlands for restoration and creation.

Chapter 12: succession and stability in restoration/creation.

Chapter 13: physical requirements for restoration/creation.

Chapter 14: large scale projects and mitigation banking.

Chapter 15: case studies on restoration/creation.

Chapter 16: regionalization

Chapter 17; research needs and summary.

--- (1986). *Proceedings of the National Wetlands Symposium: Mitigation of Impacts and Losses*. Berne, NY: Association of State Wetland Managers.

This volume provides a comprehensive collection of information covering almost every aspect on wetland creation, restoration, and mitigation. It includes some federal and state policies, monitoring procedures for creation/restoration projects, goal-setting, and methods of evaluation. Also presents information on succession and stability in created sites, some physical requirements of created sites, research needs, and case studies on created wetlands.

Leibowitz, N., L. Squires, and J.P. Baker. (1991). *Research Plan for Monitoring Wetland Ecosystems*. Corvallis, OR: Environmental Research Laboratory, US EPA.

Introduction to the Environmental Monitoring and Assessment Program (EMAP) and its application to wetlands resources. Provides guidance in many areas of wetlands assessments and field-applicable techniques for sampling and interpretation of findings. Also includes chapters on data analysis, logistics approach, quality assurance, information management, and coordination.

Moy, L., and L. Levin. (1991). *Are Spartina Marshes a Replaceable Resource? A Functional Approach to Evaluation of Marsh Creation Efforts*. Estuaries. Vol. 14, No. 1, p1-16.

This article addresses the concept of functional ecological equivalence of man-made marshes and their natural counterparts. The study compared man-made to surrounding natural marshes on a site in North Carolina. The variation in sediment organic content resulted in dissimilar macro faunal composition. The natural marsh sediments were inhabited by subsurface, deposit-feeding oligochaetes whereas planted marsh sediments were dominated by tube-building, surface-deposit feeding polychaetes. This difference affected the *Fundulus* diet in the two systems, and overall *Fundulus* was more abundant in the natural marsh. The lower population of *Fundulus* in planted marshes may result from lower *Spartina* stem densities which provide inadequate protection for fundulids. The authors find that mitigation success at this site could have been improved with increased tidal flushing; however, overall they find that slat marshes should not be treated as a replaceable resource in the short term due to extreme spatial and temporal variability and the difficulty in exactly replacing functions.

Perry, E.W. and I. Garskof. (1989). *Regulatory and Technical Constraints for Wetland Creation and Mitigation.* In: S.K. Majumdar, R.P. Brooks, F.J. Brenner, and R.W. Tiner, Jr. (eds). Wetlands Ecology and Conservation: Emphasis in Pennsylvania. The Pennsylvania Academy of Science, p 276-288.

This chapter begins with a briefing on the regulatory and technical constraints in wetlands mitigation. In the past, replacing wildlife habitat value was considered sufficient mitigation, but the authors anticipate that there will be a growing emphasis on replacing all functional values. However, as the science develops, wetland creation may become less attractive as developmental and compliance monitoring costs become prohibitive. Nonetheless, the paper outlines some components to wetlands creation (hydrology, soils, site selection, site design, and vegetation) with some good suggestions.

Pritchett, D.A.. (1989). *Evaluation of Wetland Mitigation Projects* (EvaWetMit). Prepared for U.S. Environmental Protection Agency, Office of Wetlands Protection, Washington, D.C., EPA/101/F-90/018. 7 pp.

Mitigation projects required under Sec. 404 of the CWA (restricted to non-tidal palustrine wetlands) were examined to determine how different aspects of their construction contributed to success. Recommendations for proper construction of specific mitigation projects are made.

Planning, implementation and evaluation are posited as the important factors which control the success of a project.

Schafer, J.A. and M.C. Ossinger. (1990). Washington State Department of Transportation Wetland Monitoring Program. Transportation Research Record 1366. Olympia, WA: Washington State Department of Transportation, Environmental Branch, p 31-34.

Introduces the *Guide for Wetland Mitigation Project Monitoring* designed by the Washington State Dept. of Transportation (WSDOT). The monitoring program was established to evaluate wetland mitigation sites by examining their progress toward achieving stated objectives. Objectives are two-fold: to develop wetland characteristics (hydrology, hydric soils, and wetland vegetation) and to provide designated functions such as food chain support, ecosystem diversity, wildlife habitat and water quality benefits. At present, ten wetlands are being monitored. Sites are monitored for five consecutive years. (See Horner and Raedeke (1989) for abstract on the *Guide.*)

Scodari, P.F., C.C. Bohlen, and A. Srivastava. (1995). *Prototype Information Tree for Environmental Restoration Plan Formulation and Cost Estimation.* Prepared for U.S. Army Corps of Engineers by King & Associates, Inc..

Describes roots of information trees (eutrophication, hydrologic alteration, sedimentation, and habitat alteration) as well as structure and contents of information trees. Outlines preliminary implementation areas (lakes and ponds, rivers and streams, and non-tidal areas) and future implementation needs (wetlands and tidal wetlands).

Streever, W.J. and T.L. Crisman. (1993). *A comparison of fish populations from natural and constructed freshwater marshes in Central Florida.* Journal of Freshwater Ecology 8(2): 149-153.

Several fish species were sampled in natural and created marsh systems. Some variations in the abundance and diversity of the species between the two types were detected. The authors concluded that these differences may be "attributed to differences in conditions found in constructed and natural marshes."

Turner, R.E., J.M. Lee, and C. Neill. (1994). *Backfilling Canals as a Wetland Restoration Technique in Coastal Louisiana.* OCS Study MMS 94-0026. New Orleans, LA: U.S. Department of Interior, Minerals Management Service. Gulf of Mexico OCS Region. 44 pp.

Describes the general approach, methodology, changes in site size, depth, canal and spoil bank restoration, vegetation restoration, success measures, and fish surveys from 1983/84 to 1990/93. Also presents data from models established on canal depth and vegetation.

U.S. Army Corps of Engineers, Baltimore District. (1993). *Sampling methodologies for wetland mitigation projects greater than 0.5 acre (total size).* Interagency Task Force Compensatory Mitigation Guidance.

The permittee is required to provide sampling methodologies to assess the success of the mitigation site. The first section of the article outlines density measurement techniques for emergent vegetation in both tidal and non-tidal wetlands. The second section details water level and water depth measurements for both tidal and non-tidal wetlands and describes the positioning of groundwater wells for non-tidal forested and scrub-shrub wetlands. The third and final section describes soil sampling techniques for non-tidal wetlands.

Wester, J.H. (1990). *Forested wetland reclamation success criteria development in North Florida.* In: Skousen, J. and J. Sencindiver (Chairs). Proceedings of the 1990 Mining and Reclamation Conference and Exhibition. April 23-26, 1990. Charleston, West Virginia, p 339-345.

Criteria for determining successful reclamation of forested wetlands in North Central Florida were determined. Four sites had been disturbed by phosphate mining procedures and were planted. The sites differed in vegetation, year of planting, and hydrology. The wetlands were monitored for tree density, tree diversity, growth rates, ground cover, hydrology, water quality, faunal criteria, soils criteria, seed production, and wildlife. All pre-established criteria were met in the four demonstration areas except tree diversity in one. Tree survival rates are less predictable for hardwood species, and animal damage affected the monitoring results for growth rate and height. The results verified that the criteria selected were measurable, reasonable, and good indicators of wetland success.

Wetland and Riparian Ecosystems of the American West: 8th Annual Meeting of the Society of Wetlands Scientists. (1987) Murz, K.M. and L.C. Lee (coordinators). p 112-180.

Presents techniques to restore, enhance, or create freshwater wetlands as well as providing success stories from the West Coast. Systems includes salt marshes, abandoned mines, stream channels, and dredge material wetlands. Also presents information on impacts of development near wetlands sites in California, Idaho, Oregon, and Utah.

White, T.A., R. Lea, R.J. Haynes, W.L. Nutter, J.R. Nawrot, M.M. Brinson, and A. F. Clewell. (1990). *Development and summary of MiST: A classification system for pre-project mitigation sites and criteria for determining successful replacement of forested wetlands.* In: Skousen, J. and J. Sencindiver (Chairmen). Proceedings of the 1990 Mining and Reclamation Conference and Exhibition. April 23-26, 1990. Charleston, West Virginia. p 323-335.

The Mitigation Site Type Classification System (MiST) allows managers to classify mitigated forested wetlands to determine the level of monitoring intensity required to achieve project success. A higher MiST classification level implies greater degradation and therefore warrants more intense monitoring. The system is composed of three parts. Part I classifies the proposed forested wetland mitigation site according to the condition of its plant community, soils, and hydrology versus a natural (reference) forested wetland. Part II defines mitigation performance standards to provide focus for the mitigation effort, and Part III lists the required monitoring and expected levels of performance for each attribute. The system aims to facilitate project evaluation and communication between mitigators and agencies.

Zedler, Joy, B.. (1996). *Coastal mitigation in Southern California: The need for a regional restoration strategy.* Ecological Applications. Vol. 6, No. 1, p 84-93.

The author summarizes what is known of the historic functioning of Southern California wetlands and describes four specific mitigation case studies. In documenting problems and concerns, the author advocates having a regional wetland restoration plan to guide wetlands modifications.

---. (1993). *Canopy architecture of natural and planted cordgrass marshes: selecting habitat evaluation criteria.* Ecological Applications. Vol. 3, No. 1, p123-138.

A specific case study is used to discuss standards for mitigation "success" of a habitat restoration site. This particular study evaluated the nesting requirements for the endangered Light-footed Clapper Rail

Appendix 2. Field Data Sheet

proto2.dft 10/7/97

DRAFT MONITORING DATA SHEET

PERSONNEL NAME____

DATE__________ SITE LOCATION ______________________________

DATE SITE COMPLETED___________HAS SITE BEEN MONITORED BEFORE?_____

IF YES, ARE REPORTS AVAILABLE?________VDOT PN____________________

DESIGN SIZE OF SITE__________HAS SITE BEEN DELINEATED_______________

1. Classification

   a. Class

_____Riverine   _____Mineral soil flats   _____Lacustrine fringe

_____Depressional   _____Organic soil flats   _____Estuarine fringe

_____Slope

   b. Subclass (if known)________________________________

   c. What were the goals of this site (if known)____________________

2. Site description (Zonation). Can site be divided into hydric (dry, saturated, inundated) and/or vegetative zones?________If yes, define the zones (estimate % of total site for each zone - if zonation not necessary, treat site as zone 1).

   Zone 1.________________________________

   Zone 2.________________________________

   Zone 3.________________________________

   Zone 4.________________________________

3. Hydrology: Are there field indicators of hydrology present?________. If yes, complete table 1. Check the appropriate indicators and quantify as best as you can (e.g. number or %):

Table 1. Hydrology	Zone 1	Zone 2	Zone 3	zone 4
Inundation				
Saturation				

Plant morphological adaptations				
Water marks on vegetation, posts, debris, etc.				
Sediment stains on leaves and/or ground				
Visible scouring of debris and detritus				
Drift lines				
Others				

4. Hydrology: Wells
    a. Are wells present?______
    b. If yes, how many?______
    c. If applicable, are wells placed in each zone?______
    d. Record well data in table on page 5 or attach data to sheet.

Notes on hydrology:____

5. Soils

a. Was there prepared soil profile on site?________If yes, please describe.

b. Please complete table 2.

Table 2. Soils	Zone 1	Zone 2	Zone 3	zone 4
Organic material in top 6"				
Soil color at surface				
Soil color at 12"				
Redoximorphic features present? Please list and explain in detail below				

Notes on soils:____

6. Vegetation (each strata to be done separately)

a. Herbaceous community: methods used (fill in plot size, number of plots):

Zone 1	Zone 2	Zone 3	Zone 4

cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________

Are herbs dominated by hydrophytes: 1_____ 2_____ 3_____ 4_____

b. Shrub community: methods used (fill in plot size, number of plots):

Zone 1	Zone 2	Zone 3	Zone 4
cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) Routine estimate__ Dominant Species __________ __________ __________ __________

Are shrubs dominated by hydrophytes: 1_____ 2_____ 3_____ 4_____

c. Sapling community: methods used (fill in plot size, number of plots):

Zone 1	Zone 2	Zone 3	Zone 4

cover (____.____)	cover (____.____)	cover (____.____)	cover (____.____)
density (____.____)	density (____.____)	density (____.____)	density (____.____)
basal area(___.___)	basal area(___.___)	basal area(___.___)	basal area(___.___)
Routine estimate__	Routine estimate__	Routine estimate__	Routine estimate__
Dominant Species	Dominant Species	Dominant Species	Dominant Species
__________	__________	__________	__________
__________	__________	__________	__________
__________	__________	__________	__________
__________	__________	__________	__________

Are saplings dominated by hydrophytes:1______2______3______4______

7. Invasive species: are problem invasive plants present?
YES______ (complete a and b), NO ______ (if NO, precede to b)

a. List species and estimated area (in square feet) for herbaceous ,and density for shrubs, saplings, or trees.

Species #1 ____

Species #2 ____

Species #3 ____

b. Has invasive species control been practiced on the site?________ If yes, please explain in detail.

____

____

____

____

8. Are there deadfalls or snag trees present on the site (estimate number per acre, diameter, length)?____

____

9. Signs of wildlife use.
Common Name / Signs (e.g. sighting, tracks, scat)
(EXAMPLE: DEER / TRACKS OF TWO INDIVIDUALS) ____________________

____

____

____

____

WELL DATA (from 4. above)

Well # / Zone / Depths to Water Table

Well# / Zone / Depths to Water Table

10. Have the goals of this site been met? Please explain.

Zone 1

Zone 2

Zone 3

Zone 4

NOTES:

Appendix 3. Draft Manual for monitoring VDOT created wetlands.

Monitoring Protocol Manual for Created Wetlands: Draft Manual

Submitted To:

Virginia Department of Transportation
Environmental Section
Richmond, Virginia

Submitted By:

Department of Resource Management and Policy
Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

James E. Perry, Principal Investigator

November, 1997
RMAP Report No. 97.003.W

INTRODUCTION

Although creating wetlands has rapidly become an accepted form of mitigating wetland losses, many questions have arisen as to the "success" of these new systems. To that end, the process of how to monitor these created wetlands is currently receiving much attention (see appendix 1). Numerous protocols and methods for monitoring created wetlands have been suggested and/or recommended by local, state, and federal agencies. Unfortunately, most were developed for use very local or regional wetland systems. Furthermore, the validity of their use on created wetlands have not been thoroughly tested. The purpose of this manual is to present a monitoring protocol for VDOT tidal and non-tidal mitigation sites that will provide consistent data for the evaluation of soils, hydrology, and vegetation as indicators of wetland establishment in the state of Virginia. This protocol is to be developed with the input of VDOT, COE, EPA, FWS, NRCS, and DEQ/WPS staff. While it is not meant to be an original document, and, in fact, draws heavily from other works, especially the three parameter approach to wetland determination as presented in the COE 1987 wetland delineation manual, it does rely on several original research projects and field data collected to verify methods or to fill in holes in the knowledge base and/or the literature.

Efforts needed to monitor a site will vary from project to project and will depend on the complexity of the project. In all cases, it is important to clearly present the goals and/or objectives of the project. Most goals will be tied to measuring "compliance" to permit requirements (see Zedler 1997).

Site objectives are usually more descript and can be normally be described through data collection. These include such parameters as plant survival, vegetation cover, density, and diversity indecies, site hydrology, substrate maturation (e.g. organic accumulation in the soil), and habitat use. Vegetation succession processes in tidal wetlands are very distinct and easy to measure. If planting zones are chosen properly, there should be little movement in species. Movement of *Spartina alterniflora* slightly above and/or slightly below its designated zones can be expected and is not a cause for alarm. An increase in high marsh species into the low marsh zone over time, however, indicates elevation or zone designation problems. Monitoring of succession can be done by collecting ground data (cover and/or density of individual species) or by interpretation of aerial photographs, or a combination of both. In both cases, care should be taken to establish permanent markers for special reference. In most cases, a minimum of 5 years of monitoring data is needed. Longer time spans may be required for complicated and/or large sites. Parameters used to determine whether objectives have been reached are discuses briefly below and in detail throughout the manual.

Hydrology

Hydrology is, for the most part, the most important parameter of a wetland system. It can be measured directly using leisometers, peisometers, and/or stream or tide gauges. Often, however, direct hydrologic information is not available due to time or cost constraints. Minus the formation of mud waves or occurrence of severe erosion, little change in tide zone or range should occur. Establishing a permanent elevation reference point on a stable area near the project will allow quick reference to a known tidal datum.

Soil

Measuring soil maturity is a difficult process. Soil nutrient analysis is often well beyond the capabilities and/or budget of the monitoring agencies. Other soil parameters that may be used are percentage of particulate soil organic matter, bulk density, and soil particle size and composition. Soil particle size and composition should not change significantly over time since a well designed wetland would not have erosional problems. An increase in organic matter should be expected A small increase in clay and/or silt on the surface horizon may also be expected in fringing marshes. An increase in sand particle size, however, indicates the loss of fine particles and may be a sign of surface erosion.

For the Chesapeake Bay area, Garbisch (1990) has recommends dividing wetland creation into three phases: preliminary plans, draft mitigation plans, and final mitigation plans. In his outline for preliminary plans (presented below), he presents several points that indirectly provides the designers of a created wetland site with a list of goals and objectives.

First, he calls for text, plans, and photographs describing the existing conditions at the project site and particularly the wetlands on site and the proportions of these wetlands where the disturbance and/or loss is unavoidable. This step provides the base line classification for comparison.

Next, an evaluation of all wetlands that are proposed to be disturbed and/or lost including their apparent stabilities, their dominant vegetative composition, and their prevailing functions (e.g. use of a functional assessment model). This will allow designers to determine which parameters are important within the original system, and, therefore, should be monitored. For most purposes, hydrology, soil and water will be the critical factors.

Third, he suggests text and plans that describe conceptually the proposed wetland creation together with arguments, data, and calculations that demonstrate that the necessary hydrologic requirements will be realized. At this point, the designers are determining the goals and objectives of the project.

Finally, he suggests that an evaluation process of the proposed created wetlands, through monitoring, with an emphasis on functional replacement and enhancement relative to those provided by the existing wetland to be lost, should be conducted on site (Garbisch 1990).

With the latter in mind, we can conclude that any monitoring protocol needs to be established as early as possible and should outline methods for measuring plant survival, presence/absence of invasive species, and hydrology. A minimum of 5 years of monitoring data is needed, longer time spans may be required for complicated and/or large sites.

Finally, as the science of restoration ecology matures, we will learn more and more about how to improve our methods for creating wetlands. Therefore, all engineers, managers, regulators, and scientists involved in the design, construction, and monitoring of created wetlands must remain up to date concerning the most recent improvement to our methods for creating compensation sites and should not hesitate to incorporate them into their most recent projects. Therefore, the protocol presented below should be seen as an dynamic, forever evolving process that can change and grow with the addition of new knowledge.

ORGANIZATION OF PROTOCOL

General Information

Identify all personnel working to complete the data sheet (**Personnel Name**), record the date of the site visit (**Date**). Record site location (**Site Location**). Include distinguishing landmarks, e.g. "West of Nottoway River crossover of SR58, north side of road." Keep in mind that there may be more than one site in the general vicinity and you may need to add a qualifier such as "western most of the two sites located in the area". Where available, provide the VDOT project (contract) number (**VDOT PN**). Usually the final contract number is available through the Central Office in Richmond, or the local VDOT field agent. Provide the date the site was finished (**Date Site Completed**). If planted, this will be the date VDOT accepted the initial planting. If not planted, it will be the date VDOT accepted the final grading and/or, if necessary, the opening to hydrologic source (e.g. breaching or removal of berms). If the exact day, month and year is not available, give the month and approximate time during the month (e.g. late April or mid June). If neither are available, use seasons (e.g. early spring or late summer). The purpose of providing as correct a time frame as possible is to allow a more accurate calculation of the number of growing seasons that have passed since completion. By using just a year we do not know wether a site was completed in the spring or winter. The former would add one more growing season to the project and alter our judgement of where in the successional process the project should be. This is particularly important in the early years of growth.

The next question **(Has site been monitored before?)** refers to any data that may have been recorded from the completed site prior to this monitoring effort. If the answer is yes, it is important to try to obtain a copy of the report(s) and attach to the monitoring data sheet. Old monitoring reports and other data collecting efforts may add valuable information to on ongoing monitoring efforts. They will allow all agencies involved to see vegetation community succession, changes or stability in hydrologic processes, and/or signs or lack of hydric soil formation. Therefore, it is important to try to compile all previous biological, hydrological, and/or soil information from the site. Often, field personnel may not have access to all monitoring or other data, in which case the field personnel should do there best to designate who may have access to the information.

Design size of Site should be obtained from VDOT contract specification through the Central Office or local VDOT field personnel. This number may or may not represent the actual area that currently meets the wetland definition. The next question **(Has site been delineated)** directly addresses the total area that meets the federal jurisdictional definition of a wetland. Information should include total size of delineated wetlands and the agent/agency that performed the delineation. Note whether the COE has accepted the delineation. If possible, a copy of the delineation should be attached.

Classification:

The classification scheme developed by the Hydrogeomorphic Method of Wetland Assessment (HGM) (Brinson 1993) is used for classifying the sites (**Classification**). The HGM classification allows for easy comparison to reference sites. The most common classes in the Virginia will include mineral soil flats which make up a majority of our hardwood and cypress swamps; riverine, which include the flood plains along our major rivers; and the estuarine fringe, that includes tidal salt and fresh water marshes. Depressional would be used for karst and sinkholes, and slope wetlands, although found throughout the state, would occur most prominent in the mountainous regions.

HGM subclasses (**Subclass (if known)**) have not yet been defined in the state of Virginia, however, a reference to dominant vegetation and stage of succession, such as "mature pine hardwood mineral soil flats", "immature hardwood dry forest", or "immature broad leaf herbaceous estuarine fringe" will be adequate at this point in time. Needless to say, the term mature vs. immature will have to be subjective and will rely on the capability and background of the professional completing the monitoring form. However, we can adopt the definition of a sapling from the delineation manuals (COE 1987, IA 1989) to give us some guidance: any woody system whose canopy is dominated by saplings, defined as trees that are less than 4 inches in diameter at breast height (DBH) and less than 20 feet tall, can be considered immature. Thus, all hardwood plantings would be expected to fall within the immature range within the first ten to fifteen years of their life. Herbaceous vegetation can be divided into graminoid (grass like species including grasses, sedges, and/or rushes dominate) or herbaceous (broad leafed species dominate) and described by comparing the vegetation community to that of a natural (reference domain) systems. For example, the areal coverage of *Spartina alterniflora* of a mature salt marsh averages 60 to 80%. Any created saltmarsh that has a *S. alterniflora* cover of less than 60% should be considered immature. For a comparison of tidal fresh water and salt marsh diversity and vegetation parameters see Odum et al.(1984), Odum (1989), and Perry and Atkinson (1997). Finally, the species of any vegetation strata that comprise less than 2% of an area should not be considered as a dominant feature of the area (ICP 1989) (see also the discussion of vegetation parameters presented below).

The goals of the site (**What was the goal of the project?**)should identify (list) the HGM subclass and class that the project was designed to achieve, such as "hardwood mineral soil flats", "cypress depressional", "intertidal herbaceous estuarine fringe". Objectives, if available, should be listed. As mentioned above, these include quantitative data such as planting survival, cover estimates, hydrologic regime, soil ontogeny, etc. and should have been set out in the original design process.

Site description (Zonation):

When defining the area the investigator must decide whether the site can be defined by "zones" or can be done as a homogeneous unit. The site needs to broken into zones if: 1) area has visually different zones of hydrology (i.e. saturated vs. Inundated); 2) area has visually different zones of vegetation (can be separated by either presence or absence of specific strata or presence of different dominant species); 3) a combination of 1 and 2 the above. If broken into zones, a base map showing the different zones should to be provided. This could be a simple hand drawing on the back of the data sheets that delineates the zones. It is important to give a north direction arrow, main location features, and to denote the dominant vegetation and hydrologic regime (dry vs. saturated vs. inundated) of each zone. Depth of water and/or dominant vegetation for each zone needs to be quantified (estimated) on the data sheet. For water depth, use ranges such as 0 - 0.5 ft., 0.5 - 1.0 ft., 1.0 - 3.0 ft., >3.0 ft. For vegetation strata can be broken into tree, sapling, shrub, herbaceous, and, where appropriate, ground cover. For example:

A seven acre, five year old closed (i.e. no direct hydrologic connection by stream, creek, or ditch to an outside water source), immature hardwood created wetland, classified as a immature hardwood mineral flat, has two hydric zones: zone 1 inundated by 1 to 2 feet of water and is dominated by graminoids; zone 2 is inundated less than 1 foot of water and dominated by broad leaf species. The sheet would read:

Zone 1.<u>Inundated 1 to 2ft./Typha latifolia dominated (25%)</u>

Zone 2.<u>Inundated <1ft./Peltandra virginica-Polygonum spp. dominated (75%)</u>

Note that an estimate of the area cover by each species is given in parenthesis. This estimate, while it will usually be done in the field, could be improved upon by, prior to the site visit, reviewing recent aerial photographs of the site.

Environmental Parameters: The second set of questions address the sites environment. Parameters to be measured or estimated are presented on the Field Data Sheet according to their accuracy of predicting wetlands presence (i.e. hydrology, soil, and vegetation). Emphasis needs to be placed on visual signs of each parameters (primary and/or secondary indicators). It is also important to note, and possibly explain, any negative pertinants (e.g. when you do not find an indicator that you would expect to find, such as no buttresses on cypress trees growing under flooded conditions).

Hydrology: The hydrology questions have been arranged in order of availability and reliability. At the top of table 1, record wether the site is tidally influenced or non-tidal. There are sites in the coastal plain of Virginia that have both, therefore, it is necessary to be complete and record whether each zone is tidal or non-tidal. Visible hydrology is a primary wetland hydrology indicator (COE 1987, ICP 1989). The investigator should record the range of water depth for each zone (e.g. 1 feet to less than 1 inch, 6 inches to less than 1 inch, saturated within the first 10 inches, etc.). If tidal, record time of day, tide level at the time of the visit, and estimated tide range for the area. Other visible signs of hydrology include both the primary and secondary indicators listed in the COE (1987) and ICP (1989) manuals are given in table 1. Using our two zone example above, the first three lines of the table would appear as follow:

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	Yes/1 to 2ft	Yes/<1ft>1in		

Saturation	N/A	N/A		

Had one zone been saturated but not inundated, we would record the level of saturation from the surface. Lets say that zone 1 was saturated at the surface to 6 inches below the surface. The table would now read:

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	No	<1ft>1in		
Saturation	6in to surface	N/A		

Plant morphological indicators are often noted as hydrologic indicators. But, while each morphological indicator may have their strong points, they also have weak points that field professional must be aware of. Shallow roots are characteristic of shallow bedrock as well as high water table. Several genera of trees, including *Fagus* (beech), *Salix* (willow), and *Populus* (aspen) have shallow root regardless of the water table (). Other species such as Fraxinus and Liquidambar may, if initially grown under saturated or flooded conditions may have hypertrophied lenticels and slightly buttressed trunks that will persist even if presently growing under dry conditions (Perry per. obser.). Blackened leaves should not be used on plants with waxy cuticles (such as *Ilex opaca*). The wax often turns black under moist as well as wet conditions. However, for other species such as *Quercus* (oak), *Acer* (maple), or *Fraxinus* (ash), blackened leaves are an excellent indicator of long term anaerobic conditions. As well, in each case, it is important to note whether the indicators are rare, few, common, or abundant. One or two trees with shallow

roots out of several dozen present in the area does not seem to be inclusive of conditions on the rest of the site. If this occurs, the field personnel need to reevaluate and create a new zone for the defined as a vegetation defined by of shallow roots (possibly saturated) vs. one dominated by non-shallow roots (possibly dry). The recorder must also consider whether the shallow roots are on any of the species that characteristically have shallow roots or if they represent an artifact situation (e.g. old drainage swale, pre-ditched system). Thus, in all cases where plant morphological adaptations are presented as indicators of hydrology, as much quantification (number and species of trees with shallow roots and/or hypertrophied lenticels, etc.) as well as the preparers best professional judgement must be used. A list of plant morphological adaptations are given in table 2. Using our original example, if we found that a all of *Betula nigra* and most (greater than 75%) of *Salix nigra* saplings, dominant saplings on the site, had water induced adventitious roots at 18 inches above the ground level in zone 1 and 6 inches above ground level in zone 2. We also found evidence of pneumatophore formation on all of the *Taxodium districhum* (bald cypress) saplings found only in zone 1. Although note a dominant species, it is still important to record the presence of the pneumatophores. Our table would then appear as follows:

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	Yes/1 to 2ft	<1ft>1in		
Saturation	N/A	N/A		

Plant morphological adaptations	Advent. roots on all birch, willow (18in), pneu. on cypress	Advent. roots on all birch, willow (6in)		

It may also be helpful to note that no *T. districhum* occurred in zone 2.

Water marks represent a hydrologic indicator of both long and short term events and the preparer needs to be able to determine the difference. Ice marks, on trees are caused by a lowering of the water level in a flooded, frozen site in a mineral flat or from ice flows in a riverine bottom on a late winter/early spring flood. In both cases the ice scrapes the bark, removing pieces of the bark as well as bryophyte, lichen, and/or algae communities from the side of the trees. This will leave white rings around the bole of the trees at the elevation of the water head. The rings may occur at different levels on a tree bole representing several different events or raising or lowering of the water levels during one event, or a combination of both. In newly created wetlands, where bryophyte, lichen and algae communities may not have yet have had the time to form, ice marks may be difficult to see. However, other forms of marks, such as darkening of sapling and shrub bark, may be more useful. The dark color is usually the result of exclusion of the primary colonizers of *Ulothrix* (and other cyanobacters) and certain lichens (e.g. *Parmelia*) which give a tree bole a blue-green color. Anaerobic conditions will inhibit these species from spreading to the flooded section of the bole. In this case the water marks would represent the

highest level of inundation that creates the inhibiting anaerobic environment. It is usually well defined at a consistent elevation across the wetland area and, thus, should be found on nearly all taxa of saplings within the same zone that the marks occur. If we had found blackened water marks on nearly all saplings and shrubs up to 18 inches above the ground level in zone 1 and 6 inches in zone 2, our table 1 of the data sheet may now appear as:

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	1ft to 2ft	<1ft>1in		
Saturation	N/A	N/A		
Plant morphological adaptations	Advent. roots on all birch, willow (18in), pneu. on cypress	Advent. roots on all birch, willow (6in)		
Water marks on vegetation, posts, debris, etc.	black water marks from ground to 18in high on nearly all saplings and shrubs	black water marks from ground to 6in high on nearly all saplings and shrubs		

Note that the type of watermarks and quantity have been clearly stated.

Sediment stains on vegetation and/or other verticle objects are an indication of the minimum inundation level. The "stains may consist of mineral and/or organic sediments that coat leaves and objects as they settle out of the water column. Mineral sediment are light in color and tend to wash away after rain events. Mineral sediments are generally formed by erosive processes of stream banks or uplands. Organic sediments are usually dark in color and may be more persistent. They are normally composed of small pieces of partially decomposed plant material and may originate from autonthomus (internal, i.e. within the wetland) or allonthomous (external) sources. Mineral sediment stains are common to abundant in riverine, depression and flats where frequent flooding occurs while organic stains tend to be more common in tidal systems. In created systems sediment stains are often found near dendritic patterns, creeks, or ditches that may overflow during heavy rain events. Sediment stains, when present, should occur on nearly all species. It is important for the field professional to take note of type, elevation, and distribution pattern of stains on a site. In our example we would not expect to see sediment stains unless the water is drawn down. Thus our table would reflect that there were no sediment stains present:

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	1ft to 2ft	<1ft>1in		
Saturation	N/A	N/A		

Plant morphological adaptations	Advent. roots on all birch, willow (18in), pneu. on cypress	Advent. roots on all birch, willow (6in)		
Water marks on vegetation, posts, debris, etc.	black water marks from ground to 18in high on nearly all saplings and shrubs	black water marks from ground to 6in high on nearly all saplings and shrubs		
Sediment stains on leaves and/or ground	none	none		

It is important not to leave a cell blank (except for those in the unused zone columns) even if an indicator is not present. To do so may be mistaken as neglected to look for the parameter.

Drainage patterns are usually limited to riverine systems and may consist of visible signs of channels (braided or meandering patterns eroded in the soil), scouring of organic (leaf) material from soil, and/or debris piled up against standing vegetation (COE 87). Needless to say, moving water is a key element in forming this indicator. We would not expect to see it in small depressional or small flat areas that have no direct hydrologic drainage such as a channel, creek, or ditch. In our example we defined a fairly small (seven acres) closed system. Therefore, we would not expect to find strong evidence of scouring or drainage pattern formation. Table 1 now reads:

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	1ft to 2ft	<1ft>1in		
Saturation	N/A	N/A		
Plant morphological adaptations	Advent. roots on all birch, willow (18in), pneu. on cypress	Advent. roots on all birch, willow (6in)		
Water marks on vegetation, posts, debris, etc.	black water marks from ground to 18in high on nearly all saplings and shrubs	black water marks from ground to 6in high on nearly all saplings and shrubs		
Sediment stains on leaves and/or ground	none	none		

Drainage patterns or visible scouring	none	none		

Drift lines are also associated with moving water such as streams and rivers (COE 1987) and represent the areas of deposition of floating debris on the highest water levels (deposited when water recedes) or trapped on protruding objects. The elevation of drift lines will normally be associated with high tides or high water and may be found in most wetland systems. In flats or small depressions, and estuarine wetlands the debris is usually comprised of branches, leaves, stems, and twigs of vegetation from the wetland. In riverine systems the debris may be from an upstream source. Therefore, if present, it is useful to note the composition of the drift lines. If we had drift lines in the upper margin of zone 2 that was comprised of maple seeds, leaves and assorted tree/sapling twigs, our example would read:

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	1ft to 2ft	<1ft>1in		
Saturation	N/A	N/A		
Plant morphological adaptations	Advent. roots on all birch, willow (18in), pneu. on cypress	Advent. roots on all birch, willow (6in)		

Water marks on vegetation, posts, debris, etc.	black water marks from ground to 18in high on nearly all saplings and shrubs	black water marks from ground to 6in high on nearly all saplings and shrubs		
Sediment stains on leaves and/or ground	none	none		
Drainage patterns or visible scouring	none	none		
Drift lines	none	small rack line at upper elevation comprised of maple leaves and assorted stems.		

The last row of the table is for recording other information that may be of hydrologic significance.

Table 1. Hydrology	Zone 1 Non-tidal	Zone 2 Non-tidal	Zone 3	zone 4
Inundation	1ft to 2ft	<1ft>1in		
Saturation	N/A	N/A		
Plant morphological adaptations	Advent. roots on all birch, willow (18in), pneu. on cypress	Advent. roots on all birch, willow (6in)		
Water marks on vegetation, posts, debris, etc.	black water marks from ground to 18in high on nearly all saplings and shrubs	black water marks from ground to 6in high on nearly all saplings and shrubs		
Sediment stains on leaves and/or ground	none	none		
Drainage patterns or visible scouring	none	none		

Drift lines	none	small rack line at upper elevation comprised of maple leaves and assorted stems.		
Other	none			

Soil: Measuring soil maturity is a difficult process. Soil nutrient analysis is often well beyond the capabilities and/or budget of the monitoring agencies. Other soil parameters that may be used are percentage of particulate soil organic matter, bulk density, and soil particle size and composition. Since natural marsh formation usually begins on a sand substrate and maintains its relative elevation in respect to sea level through an organic substrate accumulation over the sand, one would expect an increase in soil organics and decrease in bulk density over time. Soil particle size and composition should not change significantly over time since a well designed tidal saltmarsh would have a stable substrate environment (with the exception of organic matter accumulation). A small increase in clay and/or silt on the surface horizon can be expected and considered normal. An increase in sand particle size, however, indicates the loss of fine particles and may be a sign of surface erosion.

5. Soils

a. Was there prepared soil profile on site?________If yes, please describe.

b. Please complete table 2.

Table 2. Soils	Zone 1	Zone 2	Zone 3	zone 4
Organic material in top 6"				
Soil color at surface				
Soil color at 12"				
Redoximorphic features present? Please list and explain in detail below				

Notes on soils:

Vegetation: There are numerous methods available for measuring and calculating the dominant vegetation of a plant community. Some are simple to comprehend (e.g. species survival), others more complicated (cover estimates). There is often a trade off between the amount of information that can be obtained and the time it takes to complete the different methods. A discussion of all of the available methods is beyond the scope of this manual.

Therefore, we will concentrate on those commonly used in the state of Virginia. For a more comprehensive discussion on these and other methods see Mueller-Dombois and Ellenberg (1974).

Plant survival is used to measure "survival" of plantings. Survival counts can be measured by counting living plants in randomly located plots in large wetlands or for smaller areas (less than a few acres) the entire wetland. If random plots are used, we recommend using 37 foot diameter plots (3 per acre) for trees (Meuller-Dombois and Ellenberg 1974), a 10 meter X 10 meter square plot (5 per acre) for saplings or shrubs, and 1m x 1m plots (10 per acre) for herbaceous. The suggested plot sizes will allow for easy comparison with existing studies, however, other shapes and sizes may be used. Although easy to preform, plant survival is not in itself a measure of abundance or dominance. Therefore, it provides little to no information concerning the functions of the plant community or the hydric conditions on a site and serves little value to a monitoring plan. For monitoring purposes, we, therefore, recommend that survival counts be preformed only when procured as a byproduct of the methods discussed below.

The most common plant communities parameters found in the literature include vegetation cover, frequency, density counts, biomass, importance values, and diversity indices. Although more time consuming than a simple species count, the information gained from using these techniques is relatively easy to obtain with a moderate amount of training in plant identification of individual species an can identify them throughout the plants growth stages (i.e. can recognize a plant in a young as well as mature form), in establishing random or stratified plots, and in

tabulating data.

Cover

Cover estimates supply the information necessary to describe the spatial array of wetland vegetation communities. Vegetation cover can be estimated for all strata but is most accurate for herbaceous and short shrub and sapling communities (Mueller-Domdois and Ellenberg 1974). Recommended plot sizes are 10 meter X 10 meter square quadrats for trees, saplings and shrubs and 1 meter X 1 meter quadrats for herbaceous strata. Mueller-Dombois and Ellenberg (1974) recommend seven plots per homogeneous community for trees, saplings and shrubs. Recommended minimum number of cover plots is three, however, more are recommended for areas over one acre in size and areas with a heterogeneous distribution of herbaceous species. For areas in doubt, we recommend constructing a species area curve (appendix one) to determine minimum number of plots needed.

Although there are several cover class estimating techniques available, there are few differences among them (Mueller-Dombois and Ellenberg 1974). We recommend the modified Daubenmire technique (Daubenmire 1959, 1966, 1968)(table COVER) since it has been used extensively to describe Atlantic coastal terrestrial and wetland systems (Levy 1976, Levy et al. 1984, Perry and Atkinson 1997, and others) and produces data that are appropriate for hypothesis testing and long-term monitoring. It also allows for easy estimation of species-cover-to-area relationships, application at different sites, duplication from year to year, and consistency of measurement by different personnel (Meuller-Dombois and Ellenberg 1974). The cover classes

have been arranged in such a way that human error and variation becomes minor and does not affect the outcome of the data (Mueller-Dombois and Ellenberg 1974). Locally, the Daubenmire technique has been used in marshes, swamps, and maritime forest to estimate individuals species coverage and to determine vegetational changes over time (Levy 1976, Levy et al. 1984, Wilcox 1989, Perry 1994, Reinhardt 1992, Perry and Atkinson 1997). Cover estimates also have been used as a basis for detecting and monitoring spatial and temporal changes in Louisiana wetlands (Sklar et al. 1986, Shaffer et al. 1992).

Density

The total number of stems of an individual species that occurs in all plots along a transect represents the density of that species. All stems of all species need to be counted. Only stems that are rooted in the plots are to be counted. Vegetation that is not rooted within a plot but hangs over (therefore shadding part of a plot) would not count in the density measurement but will receive a cover value. Recommended plot sizes are 37.5 foot radius for trees, 5 meter X 5 meter square quadrats for saplings and shrubs and 1 meter X 1 meter quadrats for herbaceous strata. Mueller-Domdois and Ellenberg (1974) recommend seven plots minimum for large areas to adequately measure trees and saplings. However, recent studies found that three plots were adequate in the bottomland hardwood flats of southeastern Virginia (Spencer et al. 1997). We recommend a minimum a three plots for trees, saplings and shrubs in homgeneous areas less than 5 acres in size and seven or more in larger wetlands. For herbaceous vehgetation the recommended minimum number of cover plots is three, however, more are recommended for areas over one acre in size and areas with a heterogeneous distribution of herbaceous species. For

areas in doubt, we recommend, as with cover estimate plots, constructing a species area curve (appendix one) to determine minimum number of plots needed.

Frequency

Frequency is a measure of the presence/absence of a species in relation to the other species present. It is indirectly measured when either cover or density data is taken. For each plot on a transect, the list of species that have cover values in the plot represented a count of one (1) for each species. To find the frequency of individual species, the total number of times that species occurred along a transect is divided by the sum of all species occurrences in all plots for that date. Frequency does not need to be measured directly. You can use the data from either cover or density plot to produce frequency values instead by converting the values to a present (1) or absence (0) number from each plot.

Biomass

Biomass, the dry weight of species, can also be used as an abundance measure. It is usually very time consuming (requires the cutting, drying, and weighing of the clipped vegetation), is highly variable in nature (quantitatively, Wohglemuth 1991), and destroys the vegetation in the plot that you are working in (thus it can not be used if permanent plots are desired). Therefore, we do not recommend its use in monitoring.

Importance Values and Species Diversity Indices

Relative frequency, relative density, and relative cover (using the midpoints of the cover

categories)(relative biomass can be substituted for cover) are used to measure the weigh the dominance of individual species against each other. Each are calculated as follows:

$$\text{Relative frequency} = \frac{\text{Species frequency}}{\text{Sum of the frequency values for all species}} \times 100$$

$$\text{Relative density} = \frac{\text{Number of individuals of the species}}{\text{Number of individuals of all species}} \times 100$$

$$\text{Relative cover (or biomass)} = \frac{\text{Species cover (or biomass)}}{\text{Sum of cover (or biomass) values for all species}} \times 100$$

Although each could be used individually as a measure of dominance, there is one problem that usually needs to be resolved: cover estimates tend to over-emphasize the dominance of broad leaved species (such as *Peltandra virginica* and *Sagittaria latifolia*) while density counts usually over-emphasize ceaspatose species (caespatose is defined as many clustered stems or culms as found in the grasses and sedges such as *Eleocharis parvula* and *Carex strigosus,* both common successional species in created wetlands) (although biomass also avoids the problem, see discussionn above concerning its use). To overcome this shortcoming Meuller-Dombois and Ellenberg (1974) recommend using Importance Values (IV). Species importance values (IV's) are the sum of the above three parameters, Curtis and McIntosh 1950, Phillips 1959, Mueller-Dombois and Ellenberg 1974). Once IV's have been calculated individual species can be ranked by ascending order. The dominant species will chosen from the species with the highest

IV's.

Calculation of a species diversity for a study site proivides a descriptive number that is useful for site comparisons. The Shannon index (Shannon and Weaver 1949) is recommended for plant diversity as it concentrates on dominant species (Margurran 1989). The index is calculated using the IV's for the species of a site:

$$DI = -P \log P$$

where DI = diversity index, P = importance probability, i.e. the individual species IV divided by total IV of each species.

The Shannon DI ranges from 0 to 5, with sites of very low vascular plant diversity, such as a salt marsh, in the 0.3 to 0.4 range and tidal and non-tidal marshes in the 1.25 to1.5 range (Perry 1994, Perry and Atkinson 1997). DI can be calculated for each transect or an individual site. Although time consuming, if IV's have been calculated for a site, a computer program can easily be written to produce the DI. We therefore recommend that if IV's are calculated you procede to the next step and produce the DI.

Comparative studies: To better understand the use of the methods in the field setting several studies were undertaken. Permanent plots were established on four sites and the dominant vegetation calculated using cover estimates, density counts, importance values, and the routine method defined by the COE delineation manual (COE 1987). Two different teams, one comprised of professional botanists and the other of new graduate students (team in training) with

basic botanical training, were established to collect the data. We also recorded the time required to complete each method. The results (table TIME) showed that the routine method took the less time by far, with cover a distinct second. Density counts proved to be extremely time expensive and importance values, which require density counts, more so. There was strong agreement in the dominant species calculated by the professional team and team in train when cover, density, or importance values were used to calculate dominance. However, there was little agreement between the team in trainings routine method dominants and professional teams routine method dominants (table DOMINANT). Also, while the professional teams routine methods did not vary from the calculated methods, those of the team in training did. We draw the following recommendations from these studies: The routine method is by far the most time effective method and can be very accurate WHEN preformed by professionals. If new or poorly trained teams are used, cover estimates should be the method of choice. Although more time consuming, using cover will avoid the errors associated with miss identifications and skewed estimates.

Vegetation data sheet:

Each strata is to be done separately on the data sheet. If a strata comprises less than 2% cover, the dominant species of that strata should not be counted as a a dominant species on the site. The information collected will be similar, but the methods will vary (see discussion above). If *Nuphar lutea* and *Callitriche heterophylla* domniated zone 1 and *Typha latifolia*, *Leersia oryzoides*, *Ludwigia palustris*, and *Eleocharis obtusa* dominated zone 2 from our previous sample, we would have:

Zone 1	Zone 2	Zone 3	Zone 4

cover (1m^2 10)	cover (1m^2, 50)	cover (___, ___)	cover (___, ___)
density (___, ___)	density (___, ___)	density (___, ___)	density (___, ___)
Routine estimate__	Routine estimate__	Routine estimate__	Routine estimate__
Dominant Species	Dominant Species	Dominant Species	Dominant Species
NupLut	TypLat		
CalHet	LeeOry		
	LudPal		
	EleObt		

Note that we have added the plot size (and shape) and number taken. We have chosen to represent the doiminant species using a code commonly used in botanical field work (first three letters of the genus and first three of the speces). However, the field personnel are free to use whatever method they choose, but if common names are used it is important to remember that they may vary from locality to locality. As well, some species, such as *Ludwigia palustris*, have no common name. Thus, often we may find ourselves using whatever is most appropriate at the time. It is also good practice to write the genus and spesies for each code you use in the note section at the end of the data sheet to avoid memory errors. For example, if you have writen down CypFil as a dominant, does it stand for *Cyperus filicinus* or *C. filiculmis* (the latter is a very rare species)? Finally, calculate whether the herbaceous flora is dominated by hydrophytes. In our example, both zones had 100% hydrophytes, thus?:

Are herbs dominated by hydrophytes:1 yes 2 yes 3 4

The shrub and sapling community tables follow the exact format with the exception of the addition of a box for basal area method.

Zone 1	Zone 2	Zone 3	Zone 4

cover (____,____) density (____,____) basal area(___,___) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) basal area(___,___) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) basal area(___,___) Routine estimate__ Dominant Species __________ __________ __________ __________	cover (____,____) density (____,____) basal area(___,___) Routine estimate__ Dominant Species __________ __________ __________ __________

Habitat Function and Value: Three specific questions address habitat function and value: one concerns invasive species and the two wildlife use.

8. Are there deadfalls or snag trees present on the site (estimate number per acre, diameter, length)?____
____

9. Signs of wildlife use.
Common Name / Signs (e.g. sighting, tracks, scat)
*(EXAMPLE: DEER / TRACKS OF TWO INDIVIDUALS)*________________________________

Invasive Species: The problem of invasive plants in wetlands has been well documented (e.g.: Shisler 1990, Buttery and Lambert 1965, Friesen 1966, Rawlinski and Malecki 1984, Smith 1964, Stuckey 1980, Vogle 1973, Jones and Lehman 1986). Therefore, early detection and corrective action is an essential part of any monitoring protocol. A list of potential invasive vascular plants (both native and introduced) is given in Table INV. Methods for control of invasive species include mechanical removal, chemical treatment, and biological control. Implementation of the latter two methods is still controversial (Malecki et al. 1993) and requires permits from the USDA. The first can be very time consuming and has had limited success (Malecki et al 1993). Therefore, although implementation of control methods are beyond the scope of this manual, it is important to note that, in practice, a combination of methods are usually employed for most wetland species.

7. Invasive species: are problem invasive plants present?
YES______ (complete a and b), NO ______ (if NO, precede to b)

a. List species and estimated area (in square feet) for herbaceous ,and density for shrubs,

saplings, or trees.

Species #1 ____

Species #2 ____

Species #3 ____

b. Has invasive species control been practiced on the site?________ If yes, please explain in detail.

Table 1. Vegetation cover estimate midpoint ranges (modified from Daubenmire 1959, 1968). When recording field data, the observer decides which range of cove a species falls into and records the mid-point range as the data for that species.

RANGE OF COVER %	CLASS MIDPOINTS %
96-100	97.5
76-95	85.0
51-75	62.5
26-50	37.5
6-25	15.0
1-5	2.5
>1<0	0.1