Assessing Wetland Functions Using HGM

The hydrogeomorphic (HGM) approach was designed to have both scientific and practical utility. In this second of a two-part series, the author explains how the approach is applied

By Mark Brinson

Through policies promulgated by both the Bush and Clinton administrations, the United States has set a national goal of increasing the quality and quantity of our wetland resource. If we are ever to meet that goal, we must have the capacity to measure accurately the net change in functioning resulting from both degradation and restoration. At a minimum, we should have the capability to measure gains and losses on a local scale for single projects.

Functional assessment using the hydrogeomorphic (HGM) approach is designed to perform that measurement. The HGM approach takes the extensive amount of scientific information and professional judgement we already have about how wetlands function and utilizes that knowledge base to make useful rapid assessments. By using the HGM approach to improve the precision of our measurement of wetland function losses and gains, we will have the data needed to make better local management decisions and to measure our progress toward national wetland goals.

In the first article of this two-part series, I laid out the fundamental assumptions and structure of the HGM approach (see box on next page). In this second part, I first continue describing the HGM approach before emphasizing its application to the Section 404 program.

How is a function estimated?

To measure changes or differences in the functioning of wetlands, it is important to distinguish between two sources of variation. The first is natural variation in wetness, water sources, species composition, soils, and other properties. While much of this variation is a result of where the wetland is positioned in the landscape (its geomorphic setting), many wetlands undergo extensive swings on interannual scales and may appear completely different during wet and dry periods of climatic variation. Such cycles occur in the prairie glacial wetlands of Iowa (10*) and may range from open water after muskrats have removed emergent vegetation during a wet phase, to a dry phase when emergent plants dominate and persist. This type of variation is not measured as a change in functioning by the HGM approach, but rather the variation is subsumed within natural and allowable conditions characteristic of "reference standard sites." (See Table 1 for definitions.)

The second source of variation, changes due to impacts by human activities, includes but is not limited to alterations in water sources and hydrodynamics, or changes in shape of the wetland through filling. These are the changes for which the HGM approach is designed to detect and measure. Differences or changes in functioning are measured by comparing an impacted or degraded wetland with reference standards developed from the "best of the lot" wetlands of that subclass (Table 2). For this reason, it is critical that the assessor recognize to which subclass the impacted wetland originally belonged. In order to measure changes in functions for a proposed project, the assessor must predict the effects of a particular alteration, whether it be a reduction or elimination of functioning due to a project or the amplification of functioning due to restoration.

Building data sets and models

The HGM approach is designed for rapid determination of differences and changes in functional performance. In order to be rapid, information must be synthesized from the research literature to develop logical models on how the wetland subclass functions, and field work must be conducted on wetland sites to make measurements to calibrate the models used to estimate

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*** Numbers in parentheses in this article refer to the sources listed on page 16.**

Editor's Note

This article is the second of a two-part series on the HGM approach to functional assessment of wetlands. Mark Brinson's November-December 1995 article provided an overview of the fundamentals of the HGM approach and explained how the approach differs from other functional assessment methods.

Functional assessment methods have been used for more than two decades, but Dr. Brinson writes that several factors have limited the utility of those approaches. For example, a single method has been applied to all of the widely varying wetlands in the United States. Also, methods have failed to make a clear distinction between science and policy — between functions and values — which has led to confusion when the social significance of an assessed function changes.

The HGM approach deals with these problems in three ways: First, wetlands are classified based on differences in functioning. This "hydrogeomorphic" classification recognizes, for example, that depressional wetlands and river floodplains occupy different parts of the landscape and therefore differ in both the number of functions that they perform and the relative intensity at which they perform them.

Second, the HGM approach maintains a clear policy-science separation. Societal issues are dealt with only after changes in function are determined. Third, the HGM approach uses reference wetlands, which are sites that encompass the known variation in the functioning of the subclass of wetlands. Reference wetlands allow measurement by departure from standards rather than the more time-consuming measurement of absolutes.

In this second article, Dr. Brinson presents more information on the HGM approach and then offers an example of how to apply it to assess a particular function of a particular wetland type: the buffering capacity of riverine wetlands.

levels of function. For regions such as the northern prairie depressional wetlands, the information base is extensive (6). For other less studied wetland subclasses, the basis for building assessment models may necessarily rely more on best professional judgement by individuals who have spent considerable field time in the wetlands.

Regardless of the quantity of information available on a particular subclass, the HGM approach is completely open for examination by those who may wish to question the basis for classification, the assumptions upon which ecosystem structure is related to function, and the logic patterns used to connect variables with levels of functioning. I hope that this open architecture will reduce potential for abuse by exposing any hidden agendas that may be inconsistent application of the best information available. This same open architecture, however, could make the method vulnerable to misuse.

Model development can follow the pattern briefly outlined below, but other sources should be consulted to ensure uniformity and consistency of the method (e.g., 2, 9). In other words, details of which indicators to use, how to scale, categories of variables, and how to handle other region-specific information will vary from place to place. However, the HGM approach must be consistent enough across physiographic regions and wetland classes so that assessment results can be easily interpreted by practitioners working outside the region. Such conformity, and the work it requires, is necessary and substantial. The investment in method development reflects the price that must be paid to ensure that the assessment itself can be performed with accuracy (the same person will get the same answer when assessing two wetlands that have lost or gained similar amounts of function) and consistency (two assessors of the same wetland will reach similar conclusions on changes in function). Note that the benefits of this initial development work are realized each and every time a rapid assessment is conducted. For a single project in a specific wetland subclass, a minimum of four assessments may be necessary: pre-project and post-project on the project site, and pre-restoration and post-restoration on the mitigation site (Figure 1).

In order to estimate changes or differences in functional performance, the HGM approach takes advantage of both logic and an understanding of the fundamentals of ecosystem science. In fact, years of research effort can often be brought to bear on individual wetland functions. As an example, we recognize that the river floodplains function to store water that otherwise would be conveyed at faster rates downstream and in larger pulses if levees were constructed to exclude overbank flow. Other examples abound based not only on literature reports, but on best professional judgement. We need to move beyond the notion that each wetland is unique, and focus on shared properties of a particular wetland subclass that have more in common than they have in distinction.

Details of what data to collect for developing reference standards and how many reference wetlands are needed for a representative reference domain are beyond the scope of this article. However, there is a critical need to standardize the establishment of reference data sets and to maintain elements of quality control, such as peer review and uniformity of assessment models.

The HGM approach applied

In order to bring logic, professional judgement, and research findings into functional assessment, a series of indicators and variables are brought together in logical patterns to reflect the measurable properties of a function. Here I present an example of a function for riverine wetlands, "removal of imported elements and compounds," often referred to as the buffering capacity of floodplain or riparian wetlands.

The variables fall into two categories. First are hydrologic variables that transport elements and compounds to the wetland (overbank flow from the stream channel, and surface and subsurface flows from adjacent uplands to the floodplain wetland). Second are structural components within the wetland that facilitate removal (i.e., roughness features to detain water to allow time for exchanges of water-borne materials between sediments and the water column; surfaces of sediment particles, leaf litter, and plant surfaces to support microbes capable of biochemical transformations; and vascular plants to remove elements by uptake and assimilation into biomass).

The logic is that both groups of variables are required (e.g., interdependent) for imported elements to be removed. If water is not transported to the wetland, nothing in it can be removed by the wetland. Likewise, if the wetland is transformed into a smooth surface without living material or active sediment (i.e., it becomes a concrete parking lot), removal mechanisms will be totally lost. The convention used for the HGM approach is to combine the variables in such a way that the level of functioning can be estimated. (Those familiar with the Habitat Assessment Procedure will recognize the pattern.) For removal of imported elements and compounds, the function can be modeled as:

$$\text{INDEX OF FUNCTION} = [(V_{\text{OVERBANK SOURCE}} + V_{\text{UPLAND SOURCE}})/2 \times (V_{\text{SURFACE ROUGHNESS}} + V_{\text{SURFACES FOR MICROBES}} + V_{\text{VASCULAR PLANTS}})/3]^{\cdot}$$

(This index of function is used for illustration purposes only in this article, and may differ from those presented in guidebooks developed for regional application.)

Variables are all derived from measurements, visual indicators, and other sources that allow the variable to be scaled between zero and 1.0. By definition, 1.0 is equivalent to reference standards (Table 1). In the example above, if $V_{\text{VASCULAR PLANTS}}$ had only 50 percent canopy coverage in comparison with reference standards, the variable might be assigned a 0.5 relative to the "best of the lot" which receives a 1.0 by definition (e.g., 80 -100 percent canopy coverage).

Care must be taken not to fall into the opportunity trap, whereby degraded uplands and pollution inputs cause wetlands to appear to function at higher but unsustainable levels. (See Part I for more about this.) For example, if the reference standard for $V_{\text{SURFACE ROUGHNESS}}$ were "50 stumps per acre," an assessed wetland with 75 stumps per acre would be scored either as a 1.0, the maximum, or receive less than 1.0. A score of less than 1.0 may be assigned if it is judged by logic or research that too many stumps may actually interfere with the function of "removal of imported elements and compounds," or, if the higher number of

Table 1
Categories and nomenclature

Reference domain: All wetlands within a defined geographic region that belong to a single hydrogeomorphic subclass.
Reference wetlands: Wetland sites within the reference domain that encompass the known variation of the subclass. They are used to establish the range of functioning within the subclass. Reference wetlands may include: (1) former wetland sites for which restoration to wetland is possible, and (2) characteristics of sites derived from historic records or published data.
Reference standard sites: The sites within a reference wetland data set from which reference standards are developed. Among all reference wetlands, reference standard sites are judged by an interdisciplinary team to have the highest level of functioning.
Reference standards: Conditions exhibited by a group of reference wetlands that correspond to the highest level of functioning (highest sustainable capacity) across the suite of functions of the subclass. By definition, reference standard functions receive an index score of 1.0.
Site potential: The highest level of functioning possible, given local constraints of disturbance history, land use, or other factors. Site potential may be equal to or less than levels of functioning established by reference standards.
Project target: The level of functioning identified or negotiated for a restoration or creation project. The project target must be based on reference standards and/or site potential and be consistent with restoration or creation goals. Project targets are used to evaluate whether a project is developing toward reference standards and/or site potential.
Project standards: Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target. Project standards should include and specify reasonable contingency measures if the project target is not being achieved.

Source: Smith et al., An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. *U.S. Army Corps of Engineers Waterways Experiment Station, Technical Report TR WRP-DE-10. Vicksburg, Miss. (In press).*

stumps is not a sustainable condition for the ecosystem.

This is but one function and five hypothetical variables to illustrate the approach. The Draft Riverine Wetland Guidebook (2) describes 15 functions with 44 variables, several of which are repeated in many of the functions. The draft guidebook for northern prairie depressional wetlands currently has 8 functions and 15 variables. Model structures for both are the same, however. Guidelines for identifying functions, establishing and combining variables, and utilizing field indicators are described in more detail in (9). By using 1.0 as the basis for reference standards and by not allowing any variables to exceed this level, functions will also be indexed to 1.0.

How is model output handled?

Let's say we have a project in which impacts are unavoidable. Yet the project has such high social significance that it is considered for approval. Consequently, compensatory mitigation must offset significant degradation to the wetland resource. It is usually at this point, well into the Section 404 process, that functional assessment becomes useful in more than a superficial way. In this hypothetical example, the permit is being prepared with the aid of functional assessment using the HGM approach.

For simplicity of explanation, let's say the wetland in our imaginary subclass has only five functions (A through E). All functions of the project wetland are indexed relative to 1.0, conditions expressed at the reference standard sites (Table 2). For illustrative purposes as well, we determine that all functions will be driven to zero for the project wetland, so the loss in functioning is represented by the difference between pre- and post-project indices of function (Table 2). This is straightforward. If it were not for the social significance of the project, the permit would be denied.

To offset project impacts, compensatory mitigation through restoration is chosen as the preferred option. A site for restoration is located, and it is assessed as it exists before the restoration treatment and is again assessed based on projected conditions after the restoration. The indices of the functions are given in the right-half of Table 2. These data depict a poorly functioning wetland before restoration that has some opportunity for improvement. During the five-year period when a functioning wetland will be established through compensatory mitigation, the five functions of the restoration site are projected to increase in levels between 0.0 and +0.5. For function A, the gain in functioning from 0.2 to 0.7 (+0.5) is the same amount as is lost by the project.

Thus, a 1:1 mitigation ratio would represent functional replacement, acre for acre. Correspondingly, function B requires a 3:1 mitigation ratio. Functional replacement is not possible for function C because there was no gain in function by the restoration wetland. For function D, the mitigation ratio is 1:3, meaning that only one-third of an acre of restoration would replace the function lost in an acre of project wetland. The last function, E, requires a 2.5:1 replacement.

What does one do with all of these numbers? First, please note that this is a hypothetical example rigged for purposes of demonstration. It is presented to make several points. The first is that HGM functional assessment ends with the calculation of replacement ratios. From this point forward, policy must handle the output of HGM. (Consult Figure 1 for the boundary — the dotted line — between functional assessment and policy.) There are a number of options on how to handle the output as mitigation ratios. They include but are not limited to: (1) choosing the highest ratio of 3:1 (aside from infinitely high ratios, i.e., not possible or "NP") so that three acres of restoration are required for every acre eliminated by the project; (2) choosing an average ratio and assuming that, if project targets (Table 1) are reached

Table 2

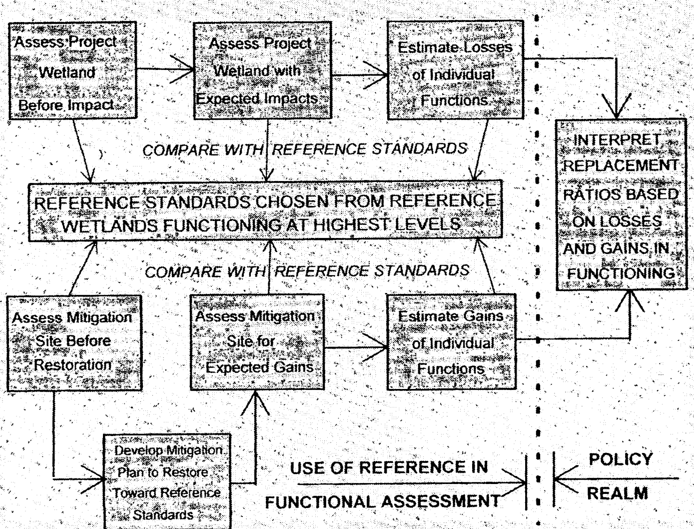
Hypothetical example of wetland functions lost in the project wetland due to unavoidable impacts, and responding functions gained in a five-year period by restoring a degraded wetland. Note that five years is insufficient time for functions to recover to a level of 1.0, the benchmark established from reference standard wetlands. Refer to Figure 1 for the sequence of steps in functional assessment.

	PROJECT WETLAND			RESTORATION WETLAND			Mitigation Ratio (acres of restoration needed to replace an acre of loss)
Function Assessed	Index before project	Index after project	Difference pre - post project (functions lost)	Index before restoration	Index after restoration	Difference pre - post restoration (functions gained)	
A	0.5	0.0	-0.5	0.2	0.7	+0.5	1:1
B	0.9	0.0	-0.9	0.3	0.6	+0.3	3:1
C	0.7	0.0	-0.7	0.1	0.1	0.0	NP*
D	0.1	0.0	-0.1	0.2	0.5	+0.3	1:3
E	0.2	0.0	-0.2	0.2	0.7	+0.5	2.5:1

* Not possible to restore this function under the conditions of the hypothetical restoration plan

Figure 1

The sequence of steps required to apply function assessment using reference wetlands to a Section 404 project and its mitigation. Reference standards must be used at each step of assessment to estimate gains and losses in functions for both project wetlands mitigation sites. Otherwise, estimations of functions either would be arbitrary or would require research and monitoring efforts far beyond a rapid assessment level. Interpretation of replacement ratios for individual functions requires policy guidelines beyond reference-based functional assessment.



within five years, additional gains in functioning as the wetland reaches "maturity" will offset functions lost that were below the average; and (3) stating that functional replacement is simply not possible because function C, essential to the sustainability of the wetland, cannot be restored.

As to the second point illustrated by the example, the assessment results make clear which functions are reduced and by how much. Consequently, negotiations on permit conditions within policy guidelines can focus on specifics of how wetlands work rather than fuzzy generalities. Instead of statements like "the project is damaging to the environment" and "the restoration doesn't seem adequate," both the regulator and project proponent are forced to discuss specific reasons for why functions are lost and which specific options are needed to compensate for the losses.

This leads to a related point. The HGM approach provides guidance on restoration project design through information available on reference wetlands and reference standards. Although not apparent from the superficial treatment given here, data on the variables and indicators from reference standard sites (the best of the lot) can be used for design in setting project targets and project standards (Table 1). This is illustrated in part by the equation above for the function "removal of imported elements and compounds." Project standards for the variable $V_{VASCULAR\ PLANTS}$ can be established in such a way that project targets are achieved within the five years of monitoring.

In order for a restoration project on forested wetlands to achieve reference standards, more time (decades) would be required, well beyond the time that most projects are monitored. This is *precisely* why project standards are needed and must be scrutinized to ensure that they are not at odds with the ultimate goal of having the wetland reach reference standards. The goal is not to restore wetlands to a somewhat more elevated but degraded condition, or to create a wetland orchard that requires pruning, weeding, and watering in perpetuity, but to launch the mitigation site along a trajectory capable of achieving reference standards. If a restoration site happens to be incapable of supporting such levels of functioning because of limitations due to landscape degradation or other factors, then this should be recognized through the definition of site potential. Site potential is the highest level of functioning possible given local constraints of disturbance history, land use, or other factors.

Next steps

Reference wetland sites and reference standards should be developed by experienced wetland scientists who have a strong sense of both the natural variation and the variation due to human activities for wetlands in the reference domain. Ideally a team would represent the fields of hydrology, biogeochemistry, soils, plant ecology, and animal community or wildlife ecology. Input from regulatory agencies is also needed because agency personnel must become familiar with the approach in order to develop policy regarding assessment outputs.

Regional guidebooks of the assessment should be developed in a way that preserves the logic discussed above, but also is supported by documentation in the research literature. A considerable amount of iteration between field testing and model development will be necessary before regional guidebooks work smoothly. Testing of the variables and their combination into indices of function is a necessary component of the HGM assessment development process. Priority should be given to work on wetland subclasses that are causing the greatest regulatory difficulties locally. I would suggest working on only one subclass at a time in order to reach end products in a sequential manner that are ready for testing and use.

I firmly believe that we are at the threshold of an opportunity to incorporate a stronger science base in wetland management than we ever have before. The effort will require much work. No one agency or group of individuals can do it alone. Unlike efforts to produce one delineation manual to fit all situations in the United States, the reference-based approach of HGM must necessarily focus on regional subclasses rather than federal or state administrative boundaries.

In spite of the highly regional flavor of reference standards and regional subclasses of wetlands, there is plenty of opportunity for consistency and standardization of the method itself. In the brief hypothetical example that I presented above for the "removes imported elements and compounds" function, the logic can be carried from one wetland class to another without requiring a change in format. What will vary are the details, which include types of measurements, field indicators of variables, the subclasses of wetland ecosystems, and, in some cases, the functions themselves. This is as it should be, for it is wetland ecosystems that we are assessing within a physiographic region. We are not expecting regional wetland subclasses to fit into some idealized national standard for wetlands. And we are not trying to cast wetlands as disaggregated bundles of functions that can be manipulated independently of one another. Let's get back to recognizing wetlands for what they really are, as integral components of landscapes that have been singled out through regulatory practice to be the focal point of many water quality and other environmental issues.

In anticipating what can go wrong with the HGM approach, I worry that the legitimate complaints about the time and cost required to implement the approach will lead to either rejection of the approach or its misuse through taking shortcuts. As I have absolutely no influence as to whether the approach might be rejected or by whom, I have nothing useful to offer. In terms of misuse of the approach, I have some strong opinions. There is a

Agency commitment to HGM

Several publications either have been published (1, 3) or are in press (2, 4, 9) to provide guidance for initiating aspects of the HGM approach. These are conceptual treatments that outline the approach, but do not provide a method for conducting functional assessments in the field on a particular group of wetlands. The *Draft Guidebook for Northern Prairie Depressional Wetlands*, now under development, is likely to be ready for use by spring or summer of 1996. The Northern Prairie models were developed with support from federal agencies (the Natural Resource Conservation Service, the U.S. Army Corps of Engineers, and the U.S. Fish and Wildlife Service).

Guidebooks for other wetland classes, such as slope, lacustrine and tidal fringe, and organic soil flats, are not available either in generic national format or as guidebooks for regional subclasses. A working paper (8) has been produced to begin to draft models and suggest reference standards for mineral soil forested flats of the North Carolina coastal plain (pine flatwoods). More data on reference wetlands for wet pine flats are needed to serve as a basis for an operational method. The details of the fate of these publications and priorities for other products are now at the discretion of the National Interagency Implementation Team consisting of federal agency representatives (the Corps' Waterways Experiment Station, the Fish and Wildlife Service, the U.S. Environmental Protection Agency, the Natural Resources Conservation Service, and the Federal Highway Administration).

While I am encouraged by progress toward developing a useful rapid assessment approach for wetlands, I am concerned about the low level of support for implementing the procedure relative to the perceived need for a functional accounting system for wetlands. I am not suggesting that any one agency can or should provide funding to develop regional guidebooks for all subclasses of wetlands. Progress toward implementation of the HGM approach will require efforts in many locations and on many wetlands subclasses for which consistent assessment approaches are critically needed.

One of the more encouraging activities is the use of HGM logic and functions by the Natural Resources Conservation Service in order to provide more consistency in their determinations of whether an exemption should be allowed under the Food Security Act because an activity would have only "minimal effects" on the hydrology and biology of a wetland. Principles of HGM and policy guidelines are now published in the *National Food Security Act Manual*. As L.C. Lee has suggested, a similar approach could be developed for the Section 404 program so that thresholds for "significant degradation" could be interpreted from HGM output. (Under Section 404(b)(1), permits are prohibited for discharges of dredged or fill material that will "cause or contribute to significant degradation of the waters of the United States.")

— *Mark Brinson*

strong temptation to skip over the process of identifying reference wetlands and developing reference standards from them. Without reference standards derived from reference standard sites, the HGM approach cannot be applied. This does not mean that project proponents cannot develop reference sets for specific projects, as well as adapting models of functions from other regions that utilize locally calibrated indicators and variables. However, such initiatives will probably fail unless regulators who review permits are familiar with the HGM approach, know through observation the condition of sites used for reference standards, and feel comfortable that the best science is being applied. Regulators must have a level of understanding sufficient to formulate the necessary policy guidelines for handing the assessment output (Figure 1).

Policies must be developed so that output can be fairly and consistently applied. Without allowing time and effort to be brought to bear on implementing the HGM approach, there is a great risk of misuse and misapplication. This is probably a natural consequence of trying to deal with the great amount of variability that is encompassed by the simple word "wetland." I am convinced that this is a risk that we must face and deal with at a level that allows the best information to be applied to the management of wetland resources.

Finally, while the HGM approach deals with specific wetland sites and individual wetlands, the currency used for assessment of functions lost and functions gained may be useful beyond the individual project scope. We should begin to explore if gains and losses of wetland function multiplied by wetland area can be effectively tallied for given wetland subclasses within administrative units. Such an approach might take us one step beyond net gains and losses based on area alone, and may provide a useful perspective based on area *and* function. Until such time that the Section 404 process for wetlands deals more explicitly with landscape-level issues at watershed scales, the synergistic aspects of cumulative effects of impacts (5) may be beyond the reach of the HGM approach. However, the nibbling dimensions identified by Preston and Bedford (7), whereby incremental losses of area and function follow linear trends, may well be quantified by the HGM approach. Our principal task, however, is to make sure that the best available science is applied to wetland resource management, and that the tools used for its application are flexible enough to accommodate new insight into the functioning of wetland ecosystems. ■

Table 3

Literature cited

The core group of individuals who were responsible for major development of the HGM method includes Lyndon Lee, Wade Nutter, R. Daniel Smith, Dennis Whigham, and, more recently, Garret Hollands and Richard Rheinhardt. Others involved in the development of the approach are recognized in authorship of several publications listed here. The HGM approach has been a group effort, and the concepts discussed here are the outcome of contributions by numerous individuals. Major funding was received initially from the Wetlands Research Program of the U.S. Army Corps of Engineers Waterways Experiment Station.

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10. van der Valk, A.G. and C.B. Davis. 1978. The role of seed banks in the vegetation dynamics of prairie glacial marshes. *Ecology* 59:322-335.

**The status of these reports has been relegated to the curious category of "Operational Draft." Lest that be of concern, readers are reminded that the 1987 delineation manual still carries the same designation. Copies of WES reports may be obtained from U.S. Army Engineer Waterways Experiment Station, ATTN: CEWES-ER-W, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.*