United States
Environmental Protection
Agency

Office of Water
Office of Science and Technology
Washington, DC 20460

EPA-822-R-07-004
September 2007
www.epa.gov

Nutrient Criteria Technical Guidance Manual

Wetlands

Full Guidance Document available in full at:
http://www.epa.gov/waterscience/criteria/nutrient/guidance/

Chapter 3 Classification of Wetlands

3.1 INTRODUCTION

Developing individual, site-specific nutrient criteria is not practical for every wetland. Instead, criteria for groups of similar wetlands in a region are needed. To this end, a means of grouping or classifying wetlands is required. This chapter introduces the scientific rationale for classifying wetlands, reviews some common classification schemes, and discusses their implications for establishing nutrient criteria for wetlands. Use of a common scheme across State boundaries should facilitate collaborative efforts in describing reference condition for biota or water quality and in developing assessment methods, indices of biotic integrity (IBI) (USEPA 1993b, http://www.epa.gov/emap/remap/index.html), nutrient-response relationships, and nutrient criteria for wetlands. This chapter describes a series of national classification systems that could be used to provide a common framework for development of nutrient criteria for wetlands, and suggests ways in which these classification schemes could be combined in a hierarchical fashion. Many existing classification schemes may be relevant and should be considered for use or modification, even if they were not originally derived for wetland nutrient criteria because: 1) they incorporate key factors that control nutrient inputs and cycling; 2) they have already been mapped; and, 3) they have been incorporated into sampling, assessment, and management strategies for wetland biology or for other surface water types, thus facilitating integration of monitoring strategies. Adoption of any classification scheme should be an iterative process, whereby initial results of biological or water quality sampling are used to test for actual differences in reference condition for nutrients or nutrient-response relationships among proposed wetland classes. Wetland classes that behave similarly can be combined, and apparent outliers in distributions of nutrient concentrations from reference sites or in nutrient-response relationships can be examined for additional sources of variability that may need to be considered. In addition, new classification schemes can be derived empirically through many multivariate statistical methods designed to determine factors that can discriminate among wetlands based on nutrient levels or nutrient-response relationships.

The overall goal of classification is to reduce variability within classes due to differences in natural condition related to factors such as geology, hydrology, and climate. This will minimize the number of classes for which reference conditions must be defined. For example, we would expect different conditions for water quality or biological community composition for wetland classes in organic soils (histosols), compared to wetlands in mineral soils. In assessing impacts to wetlands, comparing a wetland from within the same class would increase the precision of assessments, enable more sensitive detection of change, and reduce errors in characterizing the status of wetland condition.

REFERENCE CONCEPT

Reference conditions "describe the characteristics of waterbody segments least impaired by human activities and are used to define attainable biological or habitat conditions" (USEPA 1990, Stoddard et.al., 2006). At least two general approaches have been defined to establish reference condition—the site-specific and the regional (U.S. EPA 1990b, http://www.epa.gov/bioindicators/). The current approach to developing water quality criteria for nutrients also emphasizes the identification of expected ranges of nutrients by waterbody type and ecoregion for the least-impaired reference conditions (U.S. EPA 1998, http://www.epa.gov/waterscience/standards/nutrient.html).

Although different concepts of reference condition have been used in other programs (e.g., for evaluation of wetland mitigation projects (Smith et.al., 1995; http://el.erdc.usace.army.mil/wetlands/pdfs/wrpde9.pdf)), for the purposes of this document, the term "reference condition" refers to wetlands that are minimally or least impacted by human activities. Most, if not all, wetlands in the U.S. are affected to some extent by human activities such as acid precipitation, global climate change, or other atmospheric deposition of nitrogen and mercury, and changes in historic fire regime. "Minimally impacted" is therefore operationally defined by choosing sites with fewer stressors or fewer overall impacts as described by indicators of stressors, such as land-use or human activities within the watershed or buffer area surrounding a wetland and source inputs. Identifying reference wetlands in areas of high local or regional atmospheric deposition of nitrogen should also be carefully considered because indicators such as local land use activities may not be sufficient to indicate nutrient enrichment from dry or wet air deposition.

3.2 EXISTING WETLAND CLASSIFICATION SCHEMES

There are two different approaches for classification of aquatic resources. One is geographically-based, and the other is independent of geography but relies on environmental characteristics that determine aquatic ecosystem status and vulnerability at the region-, watershed-, or ecosystem-scale (Detenbeck et.al., 2000). Ecoregions (including "*nutrient ecoregions*") and Ecological Units represent geographically-based classification schemes that have been developed and applied nation-wide (Omernik 1987, Keys et.al., 1995). The goal of geographically-based classification schemes is to reduce variability in reference condition based on spatial co-variance in climate and geology, along with topography, vegetation, hydrology, and soils. Geographically-independent or environmentally-based classification schemes include those derived using watershed characteristics such as land-use and/or land-cover (Detenbeck et.al., 2000), hydro geomorphology (Brinson 1993), vegetation type (Grossman et.al., 1998), or some combination of these (Cowardin et.al., 1979). Both geographically- and environmentally-based schemes have been developed for wetland classification. These approaches can be applied individually or combined within a hierarchical framework (Detenbeck et.al., 2000).

GEOGRAPHICALLY-BASED CLASSIFICATION SCHEMES

Regional classification systems were first developed specifically for the United States by land management agencies. The U.S. Department of Agriculture (USDA) has described a hierarchical system of Land Resource Regions and Major Land Resource Areas based mainly on soil characteristics for agricultural management (USDA SCS 1981). Ecoregions were then refined for USDA and the U.S. Forest Service based on a hierarchical system in which each of several environmental variables such as climate, landform, and potential natural vegetation were applied to define different levels of classification (Bailey 1976). Subsequently, Omernik and colleagues developed a hierarchical, nationwide ecoregion system to classify streams using environmental features they expected would influence aquatic resources, as opposed to terrestrial resources (Hughes and Omernik 1981, Omernik et.al., 1982). The latter was based on an overlay of “component maps” for land use, potential natural vegetation, land-surface form, and soils, along with a subjective evaluation of the spatial congruence of these factors as compared to the hierarchical approach used by Bailey, which relied only on natural features (not land-use). Omernik has produced a national map of 84 ecoregions defined at a scale of 1:7,500,000 (Figure 3.1; Omernik 1987, http://water.usgs.gov/GIS/metadata/usgswrd/XML/ecoregion.xml). More detailed, regional maps have been prepared at a scale of 1:2,500,000 in which the most “typical” areas within each ecoregion are defined. Cowardin et.al., (1979) have suggested an amendment to Bailey’s ecoregions to include coastal and estuarine waters (Figure 3.2a). In practice, Omernik’s scheme has been more widely used for geographic classification of aquatic resources such as streams, but few examples to verify the appropriateness of this grouping to wetland nutrients are available.

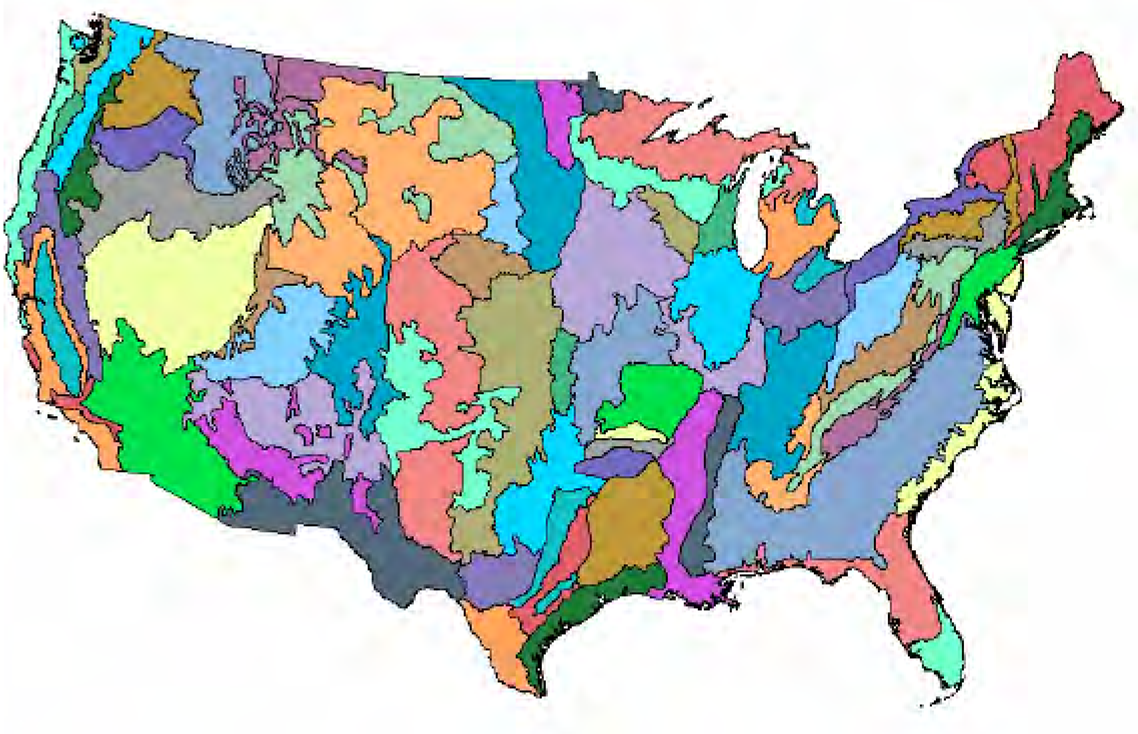

Figure 3.1 Map of Omernik aquatic ecoregions.

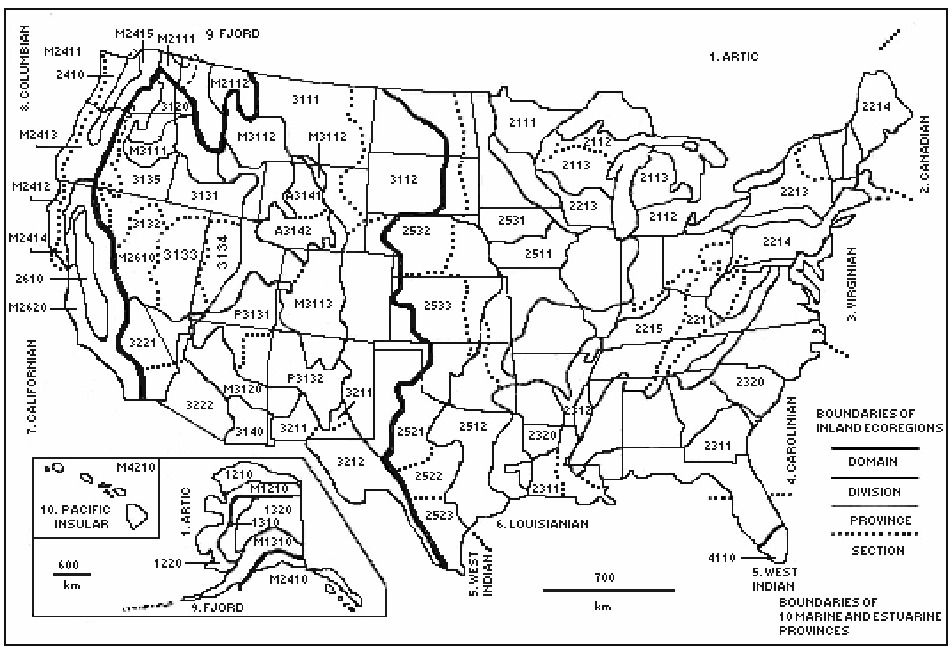

Figure 3.2a. Map of Bailey ecoregions with coastal and estuarine provinces (Cowardin et al., 1979).

Figure 3.2b. Legend

[a]Domains, Divisions, Provinces, and Sections used on Bailey's (1976) map and described in detail in Bailey (1978). Highland ecoregions are designated M mountain, P plateau, and A altiplano.

- 1000 Polar
  - 1200 Tundra
    - 1210 Arctic Tundra
    - 1220 Bering Tundra
  - M1210 Brooks Range
- 1300 Subarctic
  - 1310 Yukon Parkland
  - 1320 Yukon Forest
  - M1310 Alaska Range
- 2000 Humid Temperate
  - 2100 Warm Continental
    - 2110 Laurentian Mixed Forest
      - 2111 Spruce-Fir Forest
      - 2112 Northern Hardwoods-Fir Forest
      - 2113 Northern Hardwoods Forest
      - 2114 Northern Hardwoods-Spruce Forest
    - M2110 Columbia Forest
      - M2111 Douglas-fir Forest
      - M2112 Cedar-Hemlock-Douglas-fir Forest
  - 2200 Hot Continental
    - 2210 Eastern Deciduous Forest
      - 2211 Mixed Mesophytic Forest
      - 2212 Beech-Maple Forest
      - 2213 Maple-Basswood Forest + Oak Savanna
      - 2214 Appalachian Oak Forest
      - 2215 Oak-Hickory Forest
  - 2300 Subtropical
    - 2310 Outer Coastal Plain Forest
      - 2311 Beech-Sweetgum-Magnolia-Pine-Oak
      - 2312 Southern Floodplain Forest
    - 2320 Southeastern Mixed Forest
  - 2400 Marine
    - 2410 Willamette-Puget Forest
    - M2410 Pacific Forest (in conterminous U.S.)
      - M2411 Sitka Spruce-Cedar-Hemlock Forest
      - M2412 Redwood Forest
      - M2413 Cedar-Hemlock-Douglas-fir Forest
      - M2414 California Mixed Evergreen Forest
      - M2415 Silver fir-Douglas-fir Forest
      - M2410 Pacific Forest (in Alaska)
  - 2500 Prairie
    - 2510 Prairie Parkland
      - 2511 Oak-Hickory-Bluestem Parkland
      - 2512 Oak + Bluestem Parkland
    - 2520 Prairie Brushland
      - 2521 Mesquite-Buffalo Grass
      - 2522 Juniper-Oak-Mesquite
      - 2523 Mesquite-Acacia
    - 2530 Tall-Grass Prairie
      - 2531 Bluestem Prairie
      - 2532 Whestgrass-Bluestem-Needlegrass
      - 2533 Bluestem-Gamma Prairie
    - 2600 Mediterranean (Dry-summer Subtropical)
      - 2610 California Grassland
      - M2610 Sierran Forest
      - M2620 California Chaparral
- 3000 Dry 3100 Steppe
  - 3110 Great Plains-Shortgrass Prairie
    - 3111 Gramma-Needlegrass-Wheatgrass
    - 3112 Wheatgrass-Needlegrass
    - 3113 Grama-Buffalo Grass
  - M3110 Rocky Mountain Forest
  - M3111 Grand-fir-Douglas-fir Forest
    - M3112 Douglas-fir Forest
    - M3113 Ponderosa Pine-Douglas-fir Forest
  - 3120 Palouse Grassland
    - M3120 Upper Gila Mountains Forest
    - 3130 Intermountain Sagebrush
      - 3131 Sagebrush-Wheatgrass
      - 3132 Lahontan Saltbush-Greasewood
      - 3133 Great Basin Sagebrush
      - 3134 Bonneville Saltbush-Greasewood
      - 3135 Ponderosa Shrub Forest
    - P3130 Colorado Plateau
      - P3131 Juniper-Pinyon Woodland + Sagebrush Saltbush Mosaic
      - P3132 Grama-Galleta Steppe + Juniper-Pinyon Woodland Mosaic
  - 3140 Mexican Highland Shrub Steppe
  - A3140 Wyoming Basin
  - A3141 Wheatgrass-Needlegrass-Sagebrush
  - A3142 Sagebrush-Wheatgrass
    - 3200 Desert 3210 Chihuahuan Desert
      - 3211 Grama-Tobosa
      - 3212 Tarbush-Creosote Bush
    - 3220 American Desert
      - 3221 Creosote Bush
      - 3222 Creosote Bush-Bur Sage
- 4000 Humid Tropical
  - 4100 Savanna
  - 4110 Everglades
  - 4200 Rainforest
    - M4210 Hawaiian Islands

Finally, an attempt has been made to integrate approaches across Federal agencies to produce regional boundaries termed Ecological Units (Keys et.al., 1995). Information has been combined on climate, landform, geomorphology, geology, soils, hydrology, and potential vegetation to produce a nested series of boundaries for the eastern U.S. Different combinations of environmental parameters are emphasized at each hierarchical level of classification. This scheme was developed to explain variation in both terrestrial and aquatic systems, and is consistent with a more comprehensive strategy to classify lotic systems down to the level of stream reaches (Maxwell et.al., 1995). The mapped system for the eastern U.S. includes classification at the following levels:

domain (n=2) > divisions (n=5) > provinces (n=14) > sections (n=78) > subsections (n=xxx),

where Sections are roughly half the size of Omernik ecoregions (Figure 3.3). For lotic systems, additional spatial detail can be added by defining watersheds (at the level of land type associations), subwatersheds (at the level of land types), valley segments, stream reaches, and, finally, channel units (Maxwell et.al., 1995). In reality, not all watersheds nest neatly within subsections, and may cross-subsection boundaries.

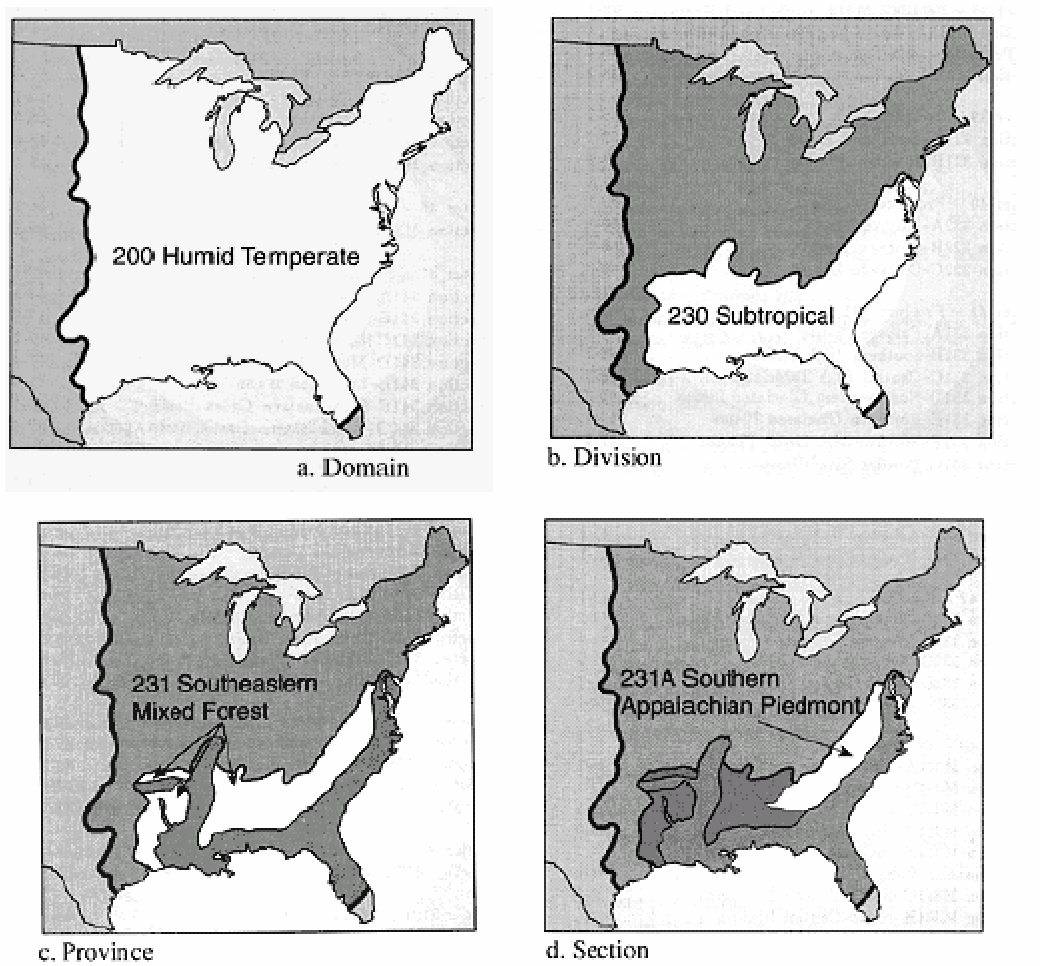

Figure 3.3 Examples of first four hierarchical levels of Ecological Units: domain, division, province, and section, from USEPA Environmental Atlas.

\

Some States have chosen to refine the spatial resolution of Omernik's ecoregional boundaries for management of aquatic resources (e.g., Region 3 and Florida). For example, the State of Florida has defined subecoregions for streams based on analysis of macroinvertebrate data from 100 minimally-impacted sites. Efforts are currently underway to define ecoregions for Florida wetlands based on variables influencing the water budget and plant community composition (Dougherty et.al., 2000, Lane 2000).

ENVIRONMENTALLY-BASED CLASSIFICATION SYSTEMS

Wetland habitat types are described very simply but coarsely by Shaw and Fredine (1956, Circular 39), ranging from temporarily-flooded systems to ponds. A more refined hierarchical classification system is available based on vegetation associations; for example, the system developed by the Nature Conservancy for terrestrial vegetation includes some wetland types (Grossman et.al., 1998). Vegetation associations have also been used to classify Great Lakes coastal wetlands within coastal geomorphic type (Michigan Natural Features Inventory 1997).

COWARDIN CLASSIFICATION SYSTEM

The Cowardin classification system (Cowardin et.al., 1979) was developed for the U.S. Fish and Wildlife Service (FWS) as a basis for identifying, classifying, and mapping wetlands, special aquatic sites, and deepwater aquatic habitats. The Cowardin system combines a number of approaches incorporating landscape position, hydrologic regime, and habitat (vegetative) type (http://www.nwi.fws.gov) (Figure 3.4). Wetlands are categorized first by landscape position (tidal, riverine, lacustrine, and palustrine), then by cover type (e.g., open water, submerged aquatic bed, persistent emergent vegetation, shrub wetlands, and forested wetlands), and then by hydrologic regime (ranging from saturated or temporarily-flooded to permanently flooded). Modifiers can be added for different salinity or acidity classes, soil type (organic vs. mineral), or disturbance activities (impoundment, beaver activity). Thus, the Cowardin system includes a mixture of geographically-based factors, proximal forcing functions (hydrologic regime, acidity), anthropogenic disturbance regimes, and vegetative outcomes. In practice, the Cowardin system can be aggregated by combination of hydrogeomorphic (HGM) type and predominant vegetation cover if digital coverages are available (Ernst et.al.,1995).

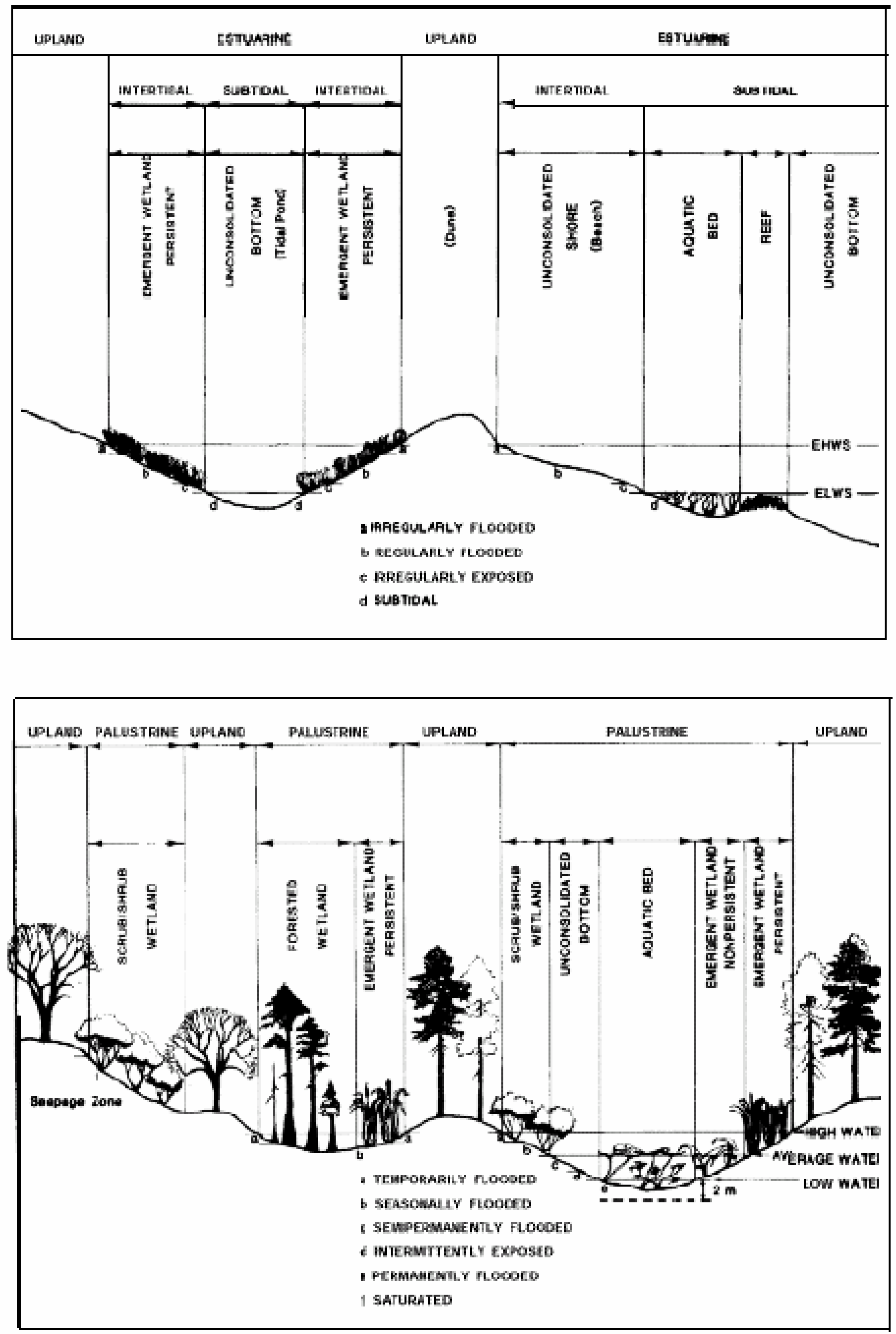

Figure 3.4. (Top) Cowardin hierarchy of habitat types for estuarine systems; (Bottom) Palustrine systems, from Cowardin et.al., 1979.

HYDROGEOMORPHIC CLASSIFICATION SYSTEM(S)

Brinson (1993) has defined a hydrogeomorphic classification system for wetlands based on geomorphic setting, dominant water source (Figure 3.5), and dominant hydrodynamics (Figure 3.6; http://www.wes.army.mil/el/wetlands). Seven classes have been described: depressional, lacustrine fringe, tidal fringe, slope, riverine, mineral soil flats, and organic soil flats (Smith et.al., 1995). Also see Hydrogeomorphic Classification in http://www.epa.gov/waterscience/criteria/wetlands/7Classification.pdf.

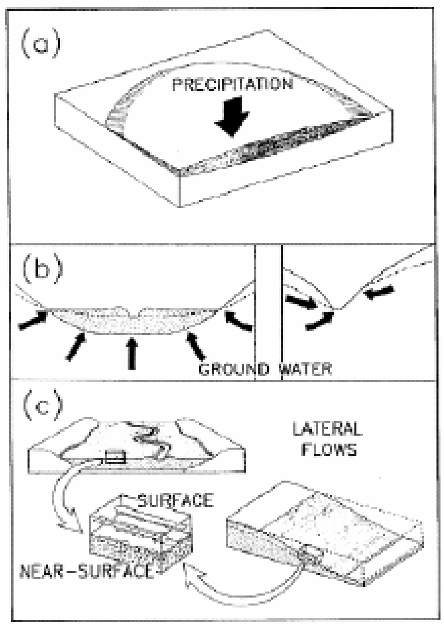

Figure 3.5. Dominant water sources to wetlands, from Brinson 1993.

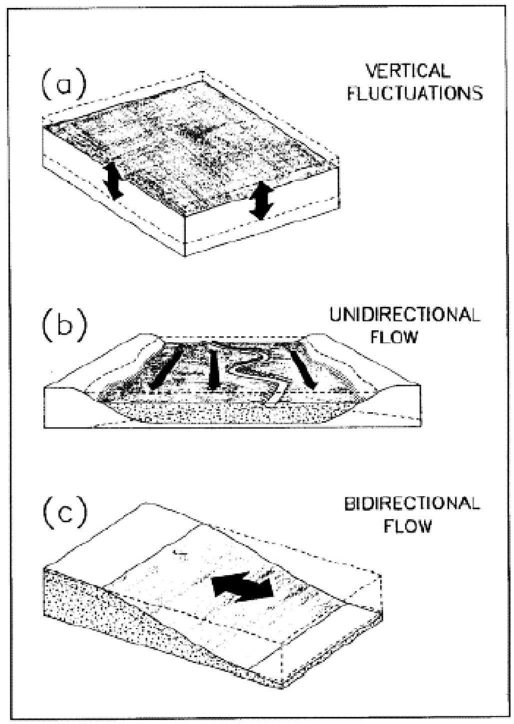

Figure 3.6. Dominant hydrodynamic regimes for wetlands based on flow pattern (Brinson 1993).

Depressional systems, as the name implies, are located in topographic depressions where surface water can accumulate. Depression wetlands can be further classified based on presence of inlets or outlets and primary water source as closed, open/groundwater, or open/surface water subclasses.

Lacustrine fringe wetlands are located along lake shores where the water elevation of the lake determines the water table of the adjacent wetland. Great Lakes coastal wetlands represent one important region of lacustrine fringe wetlands. These coastal systems are strongly influenced by coastal forming processes, and, as such, have been further classified by geomorphic type through various schemes (Jaworski and Raphael 1979, and others summarized in Michigan Natural Features Inventory 1997). These geomorphic coastal positions will further influence the predominant source of water and the degree and type of energy regime (riverine vs. seiche and wave activity). Tidal fringe wetlands occupy a similar position relative to marine coasts and estuaries, where water level is influenced by sea level. Tidal fringe wetlands can be broken down further based on salinity into euhaline vs. mixohaline subclasses. Slope wetlands occur on slopes where groundwater discharges to the land surface, but typically do not have the capacity for surface water storage (Figure 3.7). Riverine wetlands are found in floodplains and riparian zones associated with stream channels. Riverine systems can be broken down based on watershed position (and, thus, hydrologic regime) into tidal, lower perennial, upper perennial, and nonperennial subclasses. Mineral soil flats are in areas of low topographic relief (e.g., interfluves, relic lake bottoms, and large floodplain terraces) with precipitation as the main source of water. The topography of organic soil flats (e.g., peatlands), in contrast, is controlled by the vertical accretion of organic matter.

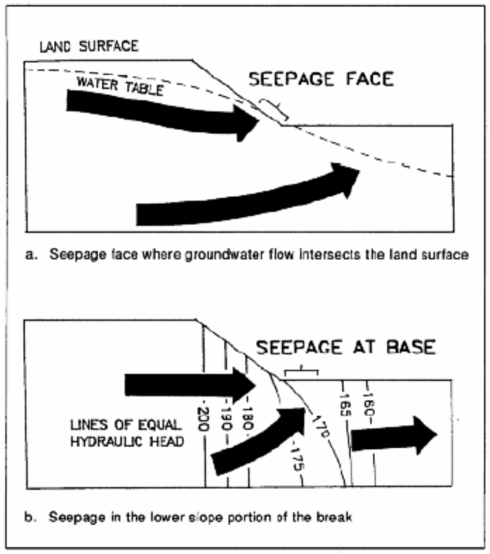

Figure 3.7. Interaction with break in slope with groundwater inputs to slope wetlands (Brinson 1993).

The HGM classification system is being further refined to the subclass level for different regions or States and classes (Cole et.al., 1997, http://www.wes.army.mil/el/wetlands). In addition to the classification factors described above, Clairain (2002) suggests using parameters such as the degree of connection between the wetland and other surface waters (depressional wetlands), salinity gradients (tidal), degree of slope or channel gradient (slope and riverine wetlands), position in the landscape (riverine, slope), and a scaling factor (stream order, watershed size or floodplain width for riverine subclasses). In some cases, existing regional schemes have been used as the basis for subclass definition (e.g., Stewart and Kantrud 1971, Golet and Larson 1974, Wharton et.al., 1982, Weakley and Schafale 1991, Keough et.al., 1999).

The HGM classification system has been applied primarily to assess wetland functions related to hydrology, biological productivity, biogeochemical cycling, and habitat (Smith et.al., 1995, http://www.wes.army.mil/el/wetlands/pdfs/wrpde9.pdf). The same environmental parameters that influence wetland functions also determine hydrologic characteristics and background water quality, which in turn drive wetland habitat structure and community composition and the timing of biotic events. Thus, the HGM classification system can serve as a basis for partitioning variability in reference trophic status and biological condition, as well as defining temporal strategies for sampling.

COMPARISON OF ENVIRONMENTALLY-BASED CLASSIFICATION SYSTEMS

If an integrated assessment of aquatic resources within a watershed or region is desired, it may be useful to consider intercomparability of classification schemes for wetlands, lakes, and riverine systems to promote cost-effective sampling and ease of interpretation. The HGM approach could integrate readily with a finer level of classification for lake type because lentic systems are separated out as lacustrine fringe or depressional wetlands based on lake or pond size and influence of water level on the adjacent wetland. Lacustrine classification systems for water quality have included geography (climate + bedrock characteristics, Gorham et.al., 1983) or hydrologic setting (Winter 1977, Eilers et.al., 1983) as factors for categorization. McKee et.al., (1992) suggest a modification of Cowardin's system for Great Lakes coastal wetlands incorporating landscape position (system), depth zone (littoral vs. limnetic subsystems), vegetative or substrate cover (class and subclass), and modifiers of ecoregions, water level regimes, fish community structure, geomorphic structure, and human modification. In contrast, the Michigan Natural Features Inventory (1997) categorizes Great Lakes coastal wetlands by Great Lake, then nine unique geomorphic types within lakes, then vegetative association.

For lotic systems, Brinson et.al., (1995) describes an approach to further classify riverine classes into subclasses based on watershed position and stream size/permanence. This strategy is consistent with current monitoring efforts to develop stream IBIs (Indices of Biotic Integrity), which typically use stream order as a surrogate for watershed size in explaining additional background variation in IBI scores (USEPA 1996). A more detailed classification of stream reach types, based on hydrogeomorphic character, is described by Rosgen (1996). This classification scheme has been predominantly applied to assessments of channel stability and restoration options, and not to development of criteria. Gephardt et.al., (1990) described a cross-walk between riparian and wetland classification and description procedures.

COMBINATIONS OF GEOGRAPHIC AND ENVIRONMENTALLY-BASED APPROACHES

It is possible to combine geographically-based classification with hydrogeomorphic and/or habitat-based approaches. For example, a scheme could be defined that nests Cowardin (Cowardin et.al., 1979) vegetative cover class within HGM class within ecoregion. Maxwell et.al., (1995) have defined a scheme for linking geographically-based units based on geoclimatic setting (domains => divisions => provinces => sections => subsections) to watersheds and subwatersheds, and thus to riverine systems composed of valley segments, stream reaches, and channel units, or to lacustrine systems composed of lakes, lake depth zones, and lake sites/habitat types.

Maxwell et.al., (1995) also define a series of fundamental hydrogeomorphic criteria for classifying wetlands based on Brinson (1993) and Winter (1992), including physiography (landscape position), water source, hydrodynamics, and climate. The first three of these are similar to the HGM classification system (see summary tables in Keys et.al., 1995). Finer scale variation in landforms is also discussed and may be of use in determining the dominance of different hydrogeomorphic classes of wetlands and associated surface waters (lakes and rivers). Characteristics and relative advantages and disadvantages of different classification systems are summarized in Table 3.2.

3.3 SOURCES OF INFORMATION FOR MAPPING WETLAND CLASSES

In order to select wetlands for sampling in a random- or random-stratified design (described in Chapter 4), it is important to have a record of wetland locations to choose from, preferably categorized by the classification system of interest. For some, but not all portions of the country, wetlands have been mapped from aerial photography through the National Wetlands Inventory (NWI) maintained by the U.S. Fish and Wildlife Service (http://www.fws.gov/nwi/; Dahl 2005). In other cases, individual States have developed inventories, or researchers have developed lists for specific types of wetlands within a given region, e.g., Great Lakes coastal wetlands (Herdendorf et.al., 1981). In order to sample these mapped wetland areas in a random fashion, it is important to have a list of each wetland that occurs within each class and its associated area. A geographic information system (GIS) allows one to automatically produce a list of all wetland polygons by type within a specified geographic region. Sources of digital information for mapping and/or classifying wetlands in a GIS are presented in the Land-Use Characterization for Nutrient and Sediment Risk Assessment Module (http://www.epa.gov/waterscience/criteria/wetlands/17LandUse.pdf).

Table 2. Comparison of landscape and wetland classification schemes.

Classification scheme	Scale	Hierarchical?	Levels of strata	Advantages	Disadvantages	Potential links with other schemes
Bailey's ecoregions	Nationwide	Yes	Domains Divisions Provinces Sections	Only natural attributes included Digital maps	Terrestrial basis Untested for wetlands No hydrology	Could form first strata for any of the schemes below ecological units
Omernik ecoregions	Nationwide	No	Ecoregions Subecoregions	Digital maps	Combines land-use with natural attributes Untested for most wetlands No hydrology	Could form first strata for any of the schemes below ecological units
Ecological units (Maxwell et.al.,1995)	Nationwide	Yes	Domain Divisions Provinces Sections Subsections	Digital maps	Greater number of strata and units than for ecoregions Untested for wetlands	Could form first strata for any of the schemes below ecological units Ties to classification schemes already defined within hydrogeomorphic types
US ACE Hydrogeomorphic Classes	Nationwide at class level; regionalized at subclass level	Yes - limited	Class Subclass	Specific for wetlands	Subclasses not comparable across different regions	Intermediate strata between geographic and habitat-scale
Rosgen channel types	Nationwide	Yes	Level I Level II	Captures differences in hydrologic regime for riverine wetlands	More focused on instream channel form than riparian characteristics Riverine only Not mapped	Intermediate strata between hydro-geomorphic type and habitat-scale

Table 2. Comparison of landscape and wetland classification schemes.

Classification scheme	Scale	Hierarchical?	Levels of strata	Advantages	Disadvantages	Potential links with other schemes
Anderson land-cover classes	Nationwide	Yes	Level I Level II Level III	Common basis for land-use/land-cover mapping	Not functionally based	Cross-walk w NWI system possible
Circular 39 classes	Nationwide	No	Class	Popular recognition	Mixture of criteria used to distinguish classes Not mapped	Strata below geographic but contains mixture of hydrogeomorphic type and habitat type
National Wetland Inventory	Nationwide	Yes	System Subsystem Class Subclass Hydrologic modifier Other modifiers	Digital maps available for much of nation (but smallest wetlands omitted)	Inconsistencies in mapping water quality modifiers Limited consideration of hydrogeomorphic type	Strata below geographic Hydrogeomorphic class could be improved by link w HGM system
Vegetation associations	International	Yes	System Formation class Formation subclass Formation group Formation subgroup Formation alliance Association	Consistency across terrestrial and aquatic systems	Not functionally based No digital maps Taxa specific	Could be used as lowest level within other schemes

In areas for which digital NWI maps do not yet exist, potential wetland areas can be mapped using GIS tools to predict relative wetness (e.g., Phillips 1990) or soil survey maps with hydric soil series can be used. It should be noted that in areas in which hydrology has been significantly altered (e.g., through ditching, tiling, or construction of urban stormwater systems), areas of potential wetlands could have been removed already. Similarly, although there are no current maps of wetlands by hydrogeomorphic class, these could be derived through GIS techniques using a combination of wetland coverages, hydrography (adjacency to large lakes and rivers), and digital elevation models to derive landforms (mineral and organic soil flats) and/or landscape position (slope and depressional wetlands).

3.4 DIFFERENCES IN NUTRIENT REFERENCE CONDITION OR SENSITIVITY TO NUTRIENTS AMONG WETLAND CLASSES

Very few studies to verify classification systems for wetland nutrient monitoring have been completed, although a number of monitoring strategies have been implemented based on pre-selected strata. Monitoring efforts to develop or assess biological criteria generally have used a combination of geographic region and hydrogeomorphic class or subclass (e.g., Cole et.al., 1997, Bennett 1999, Apfelbeck 1999, Michigan Natural Features Inventory 1997). Analysis of plant associations has been used to derive empirical classifications based on factors such as landscape position, water source, climate, bedrock, and sediment hydraulic conductivity (Weakley and Schafale 1991, Nicholson 1995, Halsey et.al., 1997, Michigan Natural Features Inventory 1997). Only one case of classification based on wetland macroinvertebrate composition was found. For Australian wetlands, wetland classes grouped by macroinvertebrate communities were distinguished by water chemistry extremes (low pH, high salinity), degree of nutrient enrichment, and water color (Growns et.al., 1992).

In some cases (e.g., northern peatlands) classification criteria derived on the basis of plant associations are less powerful in discriminating among nutrient regimes (e.g., Nicholson 1995); this may be particularly true where variation in vegetation type is related to differences in major ion chemistry and pH, rather than nutrients. The same is true in southern pocosins, where short and tall pocosins differ in seasonal hydrology but not soil chemistry. However, when contrasting pocosins and swamp forests, soil nutrients differed strongly (Bridgham and Richardson 1993). For some potential indicators of nutrient status such as vegetation nitrogen to phosphorus ratios, indicator thresholds will be consistent across species (Koerselman and Meuleman 1996), while response thresholds for other indicators of plant nutrient status vary across functional plant groupings with different life history strategies. These differences may indicate potential differences in sensitivity to excess nutrient loading (McJannet et.al., 1995). Thus, vegetation community types are not always a good predictor of background nutrient concentrations (reference condition) or sensitivity to nutrient loading.

Sensitivity to nutrient loading (as evidenced by differences in nutrient cycling and availability) may also be related to differences in hydroperiod among wetlands. Wetland mesocosms exposed to pulse discharges had higher nutrient loss from the water column than those exposed to continuous flow regimes (Busnardo et.al., 1992). Depending on the predominant mechanism for nutrient loss (e.g., plant uptake versus denitrification), nutrient-controlled primary production could be either stimulated or reduced. Mineralization rates of carbon, nitrogen, and phosphorus differ significantly among soils from northern Minnesota wetlands, related to an ombrotrophic to minerotrophic gradient (i.e., degree of groundwater influence), and aeration status (Bridgham et.al., 1998).

In general, very few definitive tests of alternative classification schemes for wetlands are available with respect to describing reference condition for either nutrient criteria or biocriteria. However, evidence from the literature suggests that in many cases both geographic factors (e.g., climate, geologic setting) and landscape setting (hydrogeomorphic type) are expected to affect water quality and biotic communities.

3.5 RECOMMENDATIONS

Classification strategies for nutrient criteria development should incorporate factors affecting background nutrient levels and wetland sensitivity to nutrient loading at several spatial scales.

- Classification of physiographic regions eliminates background variation in lithology and soil texture (affecting background nutrient levels and sorption capacity), in climate (affecting seasonality, productivity, decomposition, and peat formation), and in landforms, which determines the predominance of different hydrogeomorphic classes.

- Classification by hydrogeomorphic class reduces background variation in predominant water and nutrient sources, water depth and dynamics, hydraulic retention time, assimilative capacity, and interactions with other surface water types (Table 3).

- Classification by water depth and duration (which may or may not be incorporated into hydrogeomorphic classes) helps to explain variation in internal nutrient cycling, dissolved oxygen level and variation, and the ability of wetlands to support some higher trophic levels such as fish and amphibians.

- Classification by vegetation type or zone, whether to inform site selection or to determine sampling strata within a site, helps to explain background variation in predominant primary producer form (which will affect endpoint selection), as well as turnover and growth rates (which will affect rapidity of response to nutrient loadings).

In general, the choice of specific alternatives among the classification schemes listed above depends on their intrinsic value as well as practical considerations, e.g., whether a classification scheme is available in mapped digital form or can be readily derived from existing map layers, whether a hydrogeomorphic or other classification scheme has been refined for a particular region and wetland type, and whether classification schemes are already in use for monitoring and assessment of other waterbody types in a State or region. Revisiting classification decisions once data from a sufficient number of sites have been sampled may be useful to ensure the original classification was correct.

Table 3. Features of the major hydrogeomorphic classes of wetlands that may influence background nutrient concentrations, sensitivity to nutrient loading, nutrient storage forms and assimilative capacity, designated use and choice of endpoints.

HGM Class	Organic Flats	Mineral Flats	Depressional	Riverine	Fringe	Slope
Predominant Nutrient Source(S)	Atmospheric Deposition	Atmospheric Deposition, Groundwater	Runoff (Particulate and Dissolved), Surface and Groundwater	Runoff (Particulate), Overbank Flooding (Particulate, Dissolved)	Adjacent Lake, Possible Stream or Riverine Source, Groundwater	Groundwater
Landscape Position				Adjacent to Rivers	Adjacent to Lakes	Slope, Toe of Slope
Hydrologic Regime	Saturated, Little Standing Water	Saturated, Little Standing Water	Depth and Duration Varyfrom Saturated to Temporary to Seasonal to Semi-Permanent to Permanent Inundation	Depth, Duration Vary With River Flooding Regime	Standing Water In Emergent and Submerged Aquatic Zones, Short-Term Fluctuation Related to Seiche Activity, Long-Term to Wet-Dry Cycles	Saturated
Hydraulic Retention Time	Decades	Decades	Varies With Inflows/Outflows, Landscape Position	<Day to Few Days	< Day	< Day
Nutrient Assimilation Capacity	Low	High Sorption Capacity	High Sorption, Plant Uptake, (Limited) Sediment Storage	High Sorption, Sediment Trapping, Plant Uptake In Floodplain	Some Sediment Trapping Nutrient Transformer	High Sorption Capacity

Table 3 cont'd.

HGM Class	Organic Flats	Mineral Flats	Depressional	Riverine	Fringe	Slope
Predominant Vegetation Growth Form	Mosses Sedges	Sedges	Varies With Zone And Duration of Flooding: Wooded Grass/Sedge Emergents Submerged Aquatics*	Wooded, Emergent Vegetation Submerged Aquatics*	Varies With Zone: Grass/Sedge Emergents Submerged Aquatics*	Wooded Grasses Sedges
Top Trophic Level	Mammals Birds Amphibians Invertebrates	Mammals Birds Amphibians Invertebrates	Mammals Birds Mudminnows Amphibians Invertebrates	Fish Birds Mammals	Fish Birds Mammals	Mammals Birds Amphibians Invertebrates
Commercially-Important Fish/Wildlife			Waterfowl	Fish*	Waterfowl Fish*	
Recreational Use Likely			Yes	Yes	Yes	
Drinking Water Source Downstream			Possible	Likely	Possible	