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USING SOIL MORPHOLOGY FOR IDENTIFICATION, DELINEATION AND MITIGATION OF WETLANDS IN COASTAL ZONE LANDSCAPES

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Wetlands are lands where water is at or near the surface long enough during the year to produce hydric soils and support the growth of hydrophytic vegetation. Wetlands perform vital ecological functions, including floodwater storage and water supply, water quality improvement through filtering of sediment and contaminants and excess nutrient removal, and high biological diversity through unique wildlife and vegetative habitats (Mitsch and Gosselink 1993). More than 6 percent of the vegetated wetlands of the Coastal Zone were lost during the 2 decades from the mid-1970's to the mid-1990's (Dahl and C.E. Johnson 1991; Dahl 2000). Part of the continued acreage loss occurs from failure of wetland mitigation projects to be designed correctly, created according to design, or created at all. Wetland restoration refers to the reestablishment of a wetland from a disturbed or altered condition by human activity to a previously existing condition (Mitsch and Gosselink 1993). Restoration success depends on properly restoring the former hydrology. Wetland creation refers to the conversion of an upland or water area into a wetland by human activity (Hammer 1997). Wetland mitigation (both restoration and creation) projects frequently fail or fall short of expectations generally because the hydrology of the proposed site was not properly assessed (Mitsch and Gosselink 1993).

Experience gained from wetland creation projects has shown that proper interpretation of soil morphology will maximize the likelihood of successful restoring or creating wetland hydrology (Kentula et al. 1992). Repeated long term cycles of saturation, reduction, translocation, mineralization, and oxidation in the soil leave distinct redoximorphic features that can be interpreted as indications of wetness in hydric and nonhydric soils.

PROCESSES AND MORPHOLOGICAL FEATURES

Biogeochemical Processes

The principal morphological differences between wetland soils and upland soils can be attributed to the fact that, in wetlands, specific biogeochemical processes take place because soil water frequently fills the soil pores and void spaces, resulting in saturated conditions. Hydric soils are saturated near the surface and/or inundated (free water occurs above the surface) for more than a few days. Soil saturation or inundation activates anaerobic microbiological activity that results in a depletion of oxygen. This anaerobiosis promotes biogeochemical processes such as the accumulation of organic matter and the reduction, translocation, and/or accumulation of iron and other reducible elements (Hurt et al. 2002). Distinctive soil morphologies (redoximorphic features) form by oxidation-reduction (redox) reactions, provided water is not moving through the profile and microbes are active (warm temperature) and have an available food source (Vepraskas and Faulkner, 2001). These biogeochemical processes are responsible for the formation of characteristic soil morphological organic and redox features that persist during both wet and dry periods, making them particularly useful for identifying hydric and other wet soils (Mausbach and Richardson 1994). The features do not form in all anaerobic soil horizons. For those somewhat rare situations, dye indicators or electrodes may be used to confirm reducing conditions (USDA NRCS 2005 link to Hydric Soils, Technical Notes, and Technical Note 11). When present, however, organic and redox features are positive indicators of anaerobiosis and other biogeochemical processes.

Distinctive Morphology - Organic and Redox Features

Anaerobic decomposition rates of organic matter (on the order of 10-30% of aerobic decomposition rates) result in reduced mineralization and accumulation of organic matter and/or carbon compounds (Hammer 1997). Soils with long duration near surface saturation and/or inundation are most likely to build up organic soil materials at the surface, form mucky modified mineral textures in surface horizons or organic compounds may coat and bridge the majority of the soil particles. Aerobic soils lack appreciable organic accumulation thereby producing a "salt and pepper" appearance. Leaching and subsequent subsurface accumulation of the organic compounds associated with shallow fluctuating water results in the formation of organic aggregates, very dark colored zones, horizons, or layers at various depths in the soil profile. Zones and horizons may become stripped of oxidized forms of Fe or Mn because the reduced forms are soluble in anaerobic soil water. The leaching of reduced forms of these elements leaves a depleted background color (depletion) of neutral gray, the natural color of uncoated mineral soil particles after they have been stripped of oxidized coatings. Soluble, reduced forms of Fe or Mn may oxidize and accumulate to form concentrations of soft masses, pore linings, concretions and nodules (Vepraskas 1994), provided the soil solution contains available Fe or Mn. In sandy subsoils, both depletion and concentration of organic and Fe/Mn compounds may occur within the same horizon to produce a distinctive splotchy pattern.

Contemporary versus Relict Redoximorphic Features

Relict redoximorphic features are no longer actively functioning due to geologic changes. Only on close examination is it evident that hydric soil morphologies do not exist. Several morphological characteristics that can distinguish between contemporary and relict redoximorphic features (Vepraskas, 1994) are described below.

1. Contemporary hydric soils may have nodules or concretions with diffuse boundaries, irregular surfaces, and if smooth and round surfaces exist, red to yellow corona should be present. Relict hydric soils may have nodules or concretions with abrupt boundaries and smooth surfaces without accompanying corona.
2. Contemporary hydric soils may have Fe depletions along stable macropores in which roots repeatedly grow that are not overlain by iron rich coatings (redox concentrations). Relict hydric soils may have Fe depletions along stable macropores in which roots repeatedly grow that are overlain by iron rich coatings (redox concentrations).

3. Contemporary hydric soils may have iron enriched redox concentrations with Munsell colors of 5YR or yellowier with value and chroma 4 or more. Relict hydric soils may have iron enriched redox concentrations with colors redder than 5YR and value and chroma less than 4.
4. Contemporary pore linings may be continuous while relict pore linings may be broken.

Interpreting Seasonal High Saturation (SHS) from Soil Morphology
SHS is the highest expected annual elevation of saturation in a soil. Interpreting soil morphologies has facilitated prediction of SHS in nonhydric soils and provided the means for the establishment of hydric soil indicators used to identify hydric soils in the field. Soil morphology (organic and contemporary redox features) provides reliable evidence for delineating wetlands, especially in areas with unreliable or unavailable hydrologic data, where transitional vegetation exists, or where use of the list of plant species that occur in wetlands (Reed 1988) does not provide delineation assistance (Florida Soil Survey Staff 1992; Hurt and Brown 1995).

On-site wetlands investigations frequently require the determination of depth to SHS. This method of estimating SHS is applicable to those areas lacking hydrologic modifications and areas with modifications where the intent is to remove the modifications, because dikes, levees, ditches, and pavement can make the soil either wetter or drier (Bicki and Brown 1990). Only rarely are conditions (wet season of year and during a normal precipitation year) such that free water accurately reflects the SHS. The prediction of SHS depth is most accurately based on the contemporary organic and redoximorphic features above and the morphological features (but not the depths or thickness) required for the identification of a hydric soil (Hurt et al. 2002) because these features represent repeated saturation levels and biogeochemical processes. There is a strong correlation between the depth of SHS and the depth to approved NTCHS field indicators in hydric soils and the depth to other organic and contemporary redox features in nonhydric soils. Knowledge of the depth of SHS is essential for successful wetland restoration and planning, creation, and maintenance of created wetlands.

SUMARY AND CONCLUSIONS
Based on the previous discussion of hydric soil morphology, and the adopted guidelines for determining hydric soils, some general recommendations for wetland creation and restoration can be made.

1. Wetland restoration efforts must (by definition) be limited to hydric soils. These are the soils with Type “A” morphology (Table 1).
2. Wetlands can be created by excavating to or below depths indicated by morphological evidence on nonhydric soils and backfilling with a few inches of topsoil. These are the soils with Type “B” morphology (Table 1). Although wetlands can be created on nonhydric Type “B” soils without excavating, an external source of water must be readily available and maintained.
3. Created wetlands on Type “B” and “C” soils that require saturation above the

shallowest SHS features will require soil and hydrologic manipulation and a maintained water supply.

Understanding and applying of the basic concepts of hydric soil morphology and wetland soil biogeochemistry can provide an invaluable tool for siteing and design of restored or created wetlands. The SHS depths predicted from Table 1 indicate depths where soil saturation reliably occurs, or did occur on a regular basis before site modifications. The probability of success for the restoration and creation of wetlands will be greatly increased if the guidelines presented in this paper are used. Table 1 provides an index and key of morphological features that identify depth to SHS in soils. The morphologies used to predict SHS depth on-site have been explained previously on a regional basis (Florida Soil Survey Staff, 1992; Hurt and Brown, 1995; Hurt et al., 1995), and are updated here for the entire Coastal Zone of the United States.

Table 1. Organic and redox features that give evidence of SHS† in soils without hydrologic modifications for the Coastal Zone of the United States.

A. In soils with an approved hydric soil indicator (HSI), the SHS is the shallowest of the following:

1. Soils with the following HSIs have SHS at the surface or are inundated above the soil surface: A1 (Histosols), A2 (Histic Epipedon), A3 (Black Histic), A4 (Hydrogen Sulfide), A7 (2 in. Mucky Mineral), A8 (Muck Presence), A9 (1 cm Muck), A10 (2 cm Muck), S1 (Sandy Mucky Mineral), F1 (Loamy Mucky Mineral), and F10 (Marl).
2. Soils with the following HSIs have SHS within 15 cm of the soil surface: A5 (Stratified Layers), A6 (Organic Bodies), S4 (Sandy Gleyed Matrix), S5 (Sandy Redox), S6 (Stripped Matrix), S7 (Dark Surface), S8 (Polyvalue Below Surface), S9 (Thin Dark Surface), and F13 (Umbric Surface).
3. Soils with the following HSIs have SHS within 30 cm of the soil surface: F2 (Loamy Gleyed Matrix), F3 (Depleted Matrix).

B. In soils without a HSI, the SHS is the shallowest of the following:

1. Soils that meet all the requirements of a HSI except depth have SHS at the depth that meets all the requirements of a HSI.
2. In loamy and clayey soil material the depth to SHS is the depth to common or many, distinct or prominent redox depletions with value 5 or more and:
    a. chroma 2 or less, if the depletions occur between 30 and 100 cm, or
    b. chroma 3 or less, if the depletions occur below 100 cm.
3. In sandy soil material with a chroma 3 or more the depth to SHS is the depth to common or many, distinct or prominent redox concentrations with hue 10YR or redder, value 5 or more, and chroma 6 or more and occurs below 30 cm.

C. In soils without the above morphological expressions or the expressions are relict, SHS does not occur within the observed depth.

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† SHS exists where soil water pressure is zero or positive; the above depths are the deepest expected normal depth to SHS; duration is long enough to produce anaerobic conditions (Soil Survey Staff 1999).

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