USDA Natural Resources Conservation Service
U.S. DEPARTMENT OF AGRICULTURE

In cooperation with the National Technical Committee for Hydric Soils

Hydric Soils of Problematic Conditions and Altered Materials

A Working Compendium of Contemporary Scenarios and Solutions
Version 1.0, 2025

Hydric Soils of Problematic Conditions and Altered Materials

A Working Compendium of Contemporary Scenarios and Solutions
Version 1.0, 2025

United States Department of Agriculture
Natural Resources Conservation Service
in cooperation with the
National Technical Committee for Hydric Soils

Edited by A. J. Miller, USDA Natural Resources Conservation Service, New Mexico; M. J. Vepraskas, North Carolina State University; and J. F. Berkowitz, U.S. Army Corps of Engineers, Vicksburg, Mississippi.

Citation: USDA Natural Resources Conservation Service. (2025). *Hydric soils of problematic conditions and altered materials* (Ver. 1.0).

Questions or Comments: For questions or comments, please contact the chair of the National Technical Committee for Hydric Soils.

Cover: Soil from the slate belt of North Carolina that changes chroma due to seasonal shifts in hydrology. The influx and leaching of reduced iron in this system allows the soil to seasonally meet requirements for hydric indicators, but during dry periods it will rise in chroma and not meet the requirements of an indicator. Note the redox concentrations visible in the profile. See section on seasonally dynamic hydric soil morphology for more information.

Forward

Content for this compendium was compiled from several primary publication sources, which are listed in the references section. This is a compilation of the current state-of-the-science for problematic hydric soils. This compendium will remain a living document that will capture the evolution of each problematic topic as the body of knowledge continues to develop. Often the content was adapted from (and sometimes directly taken from) these sources in an attempt to convey the exact information that was intended to be communicated in its original form. Some sources are not formally published, such as the technical notes and minutes from proceedings of the National Technical Committee for Hydric Soils (NTCHS). Other sources may come from communications with soil survey staff during routine investigations for the purposes of conducting technical soil services for wetland compliance activities or for soil survey production work. The intent is that individual investigators and researchers will use this document as a resource to evaluate problematic settings and accurately identify hydric soils.

Contents

Introduction

This compendium addresses the challenges that soil scientists encounter in conducting field determinations for hydric soils. It provides a resource for soil scientists across the U.S. to reference information on problematic hydric soils and access guidance to address problematic scenarios. It will also serve as a reference for future investigators, within the realm of hydric and problematic hydric soils, to both promote the prioritization of research and help to direct future funding opportunities. The hope is that access to an organized framework will encourage and stimulate innovations that will continue to generate further solutions for hydric soil problems.

Problematic hydric soils do not exhibit the characteristic hydric soil morphologies that commonly result from the redistribution of Iron (Fe), Sulfur (S), or soil organic matter compounds under anaerobic conditions. Wetland investigators typically rely on observable morphologic traits to indicate the presence of a hydric soil. In most cases, the inability of a hydric soil to meet the requirements of any of the hydric soil indicators as listed in the current publication for "Field Indicators of Hydric Soils in the United States" (USDA NRCS, 2024) is due to specific landscape settings and hydrologic and biogeochemical conditions that, despite prolonged soil saturation and anoxia, inhibit the formation of redoximorphic features. Therefore, problematic conditions may exist across a variety of soil systems and for a variety of reasons that challenge our ability to make hydric determinations using current published indicators.

Problematic soil morphologies can also occur in soils that appear to exhibit hydric soil characteristics that are derived from the properties of soil parent materials, either native or manipulated, and are not related to in-situ hydrology. The suite of soil properties inherited from any source may contribute compounds of Fe, S, organic carbon, and inorganic carbon in significant quantities that dominate the appearance of the matrix. Therefore, some upland soils could mistakenly meet requirements of one or more hydric indicators.

Through efforts of the NTCHS and other groups and individuals working to tackle problematic hydric soil topics, progress on the indicators and other methodologies has continued to advance the body of scientific knowledge for the hydric soils discipline. We now have indicators for many conditions of problematic situations that were previously unaddressed. However, for several hydric settings, solutions have resolved only discreet components of these topics, but problematic situations remain. For example, the F21, Red Parent Material, indicator is only applicable in locations that have been formally vetted for use. There are still many undocumented locations where such deposits occur, but, within these unvetted land resource areas, hydric soils in red parent material settings do not yet meet the geographic applicability requirements. More importantly, these underdocumented locations are exactly where indicators are meant to be tested so that future investigators can benefit from expanded coverage of that knowledge.

Where problematic conditions occur, the proper identification of hydric soils may require assistance by professional soil scientists that possess knowledge of local characteristic environments.

A. Settings with Problematic Hydric Soils

Problematic hydric soils are encountered in a variety of environmental settings or conditions that can be categorized into thematic topics. Within this section, the headings represent an effort to systematically group problem scenarios by unifying themes into a finite domain of settings. Not all of the settings are mutually exclusive. Problematic hydric conditions for any given soil could occur in one or more of these settings.

1. Alkaline Soils

Anaerobic conditions may be precluded by chemical or physical constraints on the microbial environment. The formation of redox concentrations and depletions requires that soluble Fe, S, manganese (Mn), and organic matter be present in the soil. In a neutral to acidic soil, Fe and Mn readily enter into solution as reduction occurs and then precipitate in the form of redox concentrations as the soil becomes oxidized. High pH environments require lower redox potentials for the reduction of Fe and Mn (Boettinger, 1997). If chemically reduced, free Fe^{2+} and Mn^{2+} may not be chemically stable phases in alkaline soils. As a result, identifiable Fe or Mn features may not readily form in saturated alkaline soils.

High pH (7.9 or higher) can be caused by many factors. In the arid west, salt content is a common cause of high soil pH. The concept of high pH includes the USDA terms moderately alkaline, strongly alkaline, and very strongly alkaline (Soil Science Division Staff, 2017) and may be part of the soil component phase name, which should also be part of a soil map unit name.

Alkalinity can be detrimental to microorganisms or can induce nutrient deficiencies (micronutrients). High salinity levels may dehydrate microorganisms. The salinity, alkalinity, and induced nutrient deficiencies can limit microbial and plant biomass production.

Barren or sparsely vegetated areas populated by halophytes can limit the supply of organic carbon and nitrogen to soil microorganisms. This limits the potential for microbial activity and chemical reduction during periods of saturation.

Many Aquisalids are saturated in winter, especially in the xeric moisture regimes of the conterminal western States. These low seasonal temperatures will suppress microbial metabolism. The poor expression of Fe and Mn redoximorphic features may result as carbonates buffer the soil system. The presence of redoximorphic features may be masked by carbonates, gypsum, and soluble salts (Environmental Laboratory, 1987). The presence of FeS may be the only reliable indicator during periods of soil saturation in these settings.

If the pH is high, indicators of hydrophytic vegetation and wetland hydrology are present, and landscape position is consistent with wetlands in the area, the soil may be hydric even in the absence of a recognized hydric soil indicator. In the absence of an approved indicator, thoroughly document soil conditions, including pH, in addition to the setting (e.g., landscape position, vegetation, evidence of hydrology, etc.) as rationale for identifying the soil as hydric (Environmental Laboratory, 1987). Boettinger (1997) indicated that the presence of a brittle salt crust in depressional areas would indicate the seasonal ponding of water.

2. Parent Materials Low in Iron, Manganese, and Sulfur

These soils include those with parent materials such as some sands, volcanic ash, and diatomaceous earth. Clean sand, ash of volcanic origin that has high levels of volcanogenic silica, and some parent materials derived from floor sediments of water bodies made up of diatoms can be inherently low in Fe, Mn, and S. Many hydric soil indicators are formed predominantly by the accumulation or loss of Fe, Mn, or S and, therefore, cannot form in these soils.

Gley colors, Fe depletions, redox concentrations, and reaction to α,α-dipyridyl dye all require the presence of weatherable Fe. In volcanic ash soils, reduction and solubilization of Fe appear to be significantly slower in andic soils, especially during the first few weeks after flooding and development of anaerobic conditions. Dissolution of ferrihydrite is retarded by surface adsorption of silicon and organics. Since both of these can be found in relatively large quantities in many Andisols of the northwest U.S. (Dahlgren et al., 1993; McDaniel et al., 1993), their adsorption to ferrihydrite surfaces may also inhibit Fe reduction. Although quantities of oxalate-extractable aluminum in Udivitrands and Andic Haplocryands are less than values that are reported to be required to completely inhibit Fe reduction (30 g kg^{-1}) (Nanzyo et al., 1993), they nevertheless appear sufficient to retard Fe reduction and subsequent release into solution. (McDaniel, et al., 1997)

If sufficient weatherable Fe-bearing material is lacking in a saturated soil, most hydric soil indicators will be very weak or absent. Focus then should be on indicators that rely on organic matter or S dynamics.

3. Fluvial Sediments and Flood Plains

These soils may occur on vegetated bars within the active channel and above the bank-full level of rivers and streams or can be part of broad flood-plain systems. In some cases, these soils lack hydric soil morphology due to seasonal or annual deposition of fresh sediments or removal of soil material, low Fe or Mn content, addition of Fe from flood water, and low organic matter content.

Well aerated stream flow can also interact with the water table of flood plains, and water will not stagnate where a strong stream gradient is present. As a result, anaerobic conditions will be slow to initiate, if they initiate at all. This is especially true if the alluvial materials are coarse and permit water to move through rapidly (Environmental Laboratory, 1987)

Where high organic matter content is present, perhaps at or above 30 g kg-1 for Gulf Coast areas (Lindbo, 1997), and reasonable temperatures are present for decomposition, redox features can develop quickly, especially if the sediments contain adequate Fe. In colder climates where soils warm up slowly, the depressed rates of decomposition can result in a delay of weeks to months before redoximorphic conditions develop, especially if stream gradients keep cold groundwater moving through the system (Lindbo, 1997).

Guidance from USACE Regional Supplement publications indicates that redox concentrations can sometimes be found on the undersides of coarse fragments and between soil stratifications in areas where organic matter gets buried, such as along the fringes of flood plains (Environmental Laboratory, 1987). Such areas, and their subtle features that may be present, should be examined closely to see if they satisfy the requirements of an indicator.

In areas that have historically been plowed as part of the cropping practices, bare ground and intense, high-altitude sun can heat the ground and induce capillary discharge from the water table. These scenarios have been correlated with salt accumulations near the surface and isolated areas of elevated soil pH (personal communications from NRCS technical soil services). As a result, the formation of redoximorphic features have been slow to develop, even in areas where hydrophytic plants are present. The collection of documentation at the right time of year, during warm months when water tables are at their peak, may be a crucial factor in any determination. Additional strategies presented in the section below for “Solutions to Problematic Hydric Soils” could also be useful in this setting.

In New Mexico, flood plains along the lower Rio Grande can have one or more intersecting challenges to hydric soil determinations. They contain recent sediment deposition (within 50 years) that has high chromas, low amounts of organic matter, and often sandy-textured strata, usually starting within a 50-cm depth. Groundwater tables are stream-stage controlled whereby the water continues to move, although slowly, downstream through the sediments. The fluids here may not achieve stagnancy long enough to become anaerobic to the point that redox processes alter the soil morphology. In many parts of the flood-plain complex, snowmelt from headwaters in the Rocky Mountains brings the stream stage to elevated levels and water tables are near the surface for greater than two weeks during the spring when the growing season is active. However, cold groundwater temperatures, resulting from snowpack meltwater during runoff seasons, could act to depress biological activity enough to delay the development of anaerobic conditions.

Hydric Indicator F19, Piedmont Flood Plain Soils, was developed to address conditions across the Mid-Atlantic where relatively young soils developed in alluvium that is believed to be of post-colonial settlement age. The deeper—and thus older—buried strata have strong redox indicators. These soils have matrix hues of 10YR or 2.5Y, values of 4 or 5, and chromas of 3 to less than 4 with redox concentrations and depletions. This is evidence that younger surface deposits of stratified materials are in the process of developing stronger redoximorphic character similar to the buried layers. These soils can have seasonal high water tables and are often in proximity to very wet soils in the lowest parts of the landscape.

4. Seasonally Ponded Soils

Seasonally ponded, depressional wetlands occur in basins and valleys throughout the U.S. as a variety of features such as playas on plains, plateaus, and intermountain basins; backwater marshes or sloughs in fluvial systems; prairie potholes and kettle lakes in glaciated terrain; and grady ponds or Carolina bays in the humid coastal plains. Most are perched systems with water ponding above a restrictive soil layer, such as a hardpan or clay layer, that is at or near the surface (e.g., in Vertisols) (Environmental Laboratory, 1987). It is these internally drained systems, experiencing seasonal drought or significant drying-out periods, that pose potential problematic scenarios.

Intermittently ponded soils are often problematic because they can be low in organic matter due to the periodic drowning of upland herbaceous vegetation. This results in a reduction of net primary production to the system that decreases soil organic matter inputs and the food source for microbial activity. As a result, decomposition and rates of oxygen consumption required for anoxic conditions are suppressed and redox features cannot form.

Hydric soils that occur in depressions with finer textures or have an impediment to vertical drainage of water through the system may not form depleted matrices. Where surface water enters these systems through precipitation and runoff, it ultimately leaves through evapotranspiration so that any reduced ferric Fe becomes soluble ferrous Fe in place. The lack of leaching means Fe cannot leave the system. Fe in the soil, when reduced, is likely to recycle within this enclosed system so that it will dissolve and reprecipitate within the various depths of the profile, often varying year to year based on the water table dynamics. As a result of minimized redistribution or loss of Fe, depleted matrices may not occur.

Depressional features are in a low part of the landscape where mobilized soil particles can transport and accumulate. This aggradation of upland sediment rejuvenates the floor of the depression, often with Fe-bearing materials, leading to further reinforcement of high chroma colors. Typical soil colors in depression landscape positions have a hue of 5YR with values of 2 or 3 and chromas of 2 or 3 or a hue of 7.5YR with a value of 3 and chroma of 2. On adjacent flats or very slightly convex landscape positions, typical colors are 5YR 3/4, 7.5YR 3/4, or brighter. Indicator F8, Redox Depressions, may also be useful in areas that are subject to ponding, such as in riparian depressions containing red soils (Environmental Laboratory, 1987).

In arid and semi-arid playa systems of the Southern Great Plains of the U.S., many of the depressional wetlands can be infrequently inundated. Any redoximorphic features that develop during wet periods are thought to be erased during prolonged drier periods from various processes described above. Examples of other processes that cause obliteration of redox features include vertic mixing of soil bodies, livestock or wildlife trampling, and manipulation through agricultural practices. Vertic mixing occurs when topsoil material falls into cracks and is incorporated into the matrix upon rewetting.

A common practice in Southern Great Plains playas is the manipulation through excavation of a center tank to hold deeper water longer, therefore prolonging the period of a livestock watering source. This acts to decrease the total acreage of seasonal ponding by concentrating water that was formerly spread across the playa into a smaller confined area. Because the availability of water in playas will attract more animal traffic, impacts in and around the playa can multiply.

Grazing pressure will also extend into the surrounding uplands, leading to higher rates of soil surface disturbance through particle detachment and erosion. Subsequent transport and deposition of these materials into the playa bottoms will increase accordingly. This scenario will be more likely to occur in areas subjected to continuous grazing, especially during periods of prolonged drought.

Playa hydrology increases in water supply, either through larger inputs (bigger watershed) or reduced outputs, ponding duration, and frequency increases, lead to more persistent redoximorphic features. Larger playas have thicker deposits of clay-rich soil materials that restrict deep leaching and may store moisture for a longer duration, even in more arid locations, than those in more humid climates with lower clay contents or thinner clay beds. The smaller playas, especially when over bedrock such as those within the Canadian Plateaus Land Resource Unit (LRU) of the Southern High Plains Major Land Resource Area (MLRA 70A), can dry through the entire profile and permit deep leaching into bedrock fractures. Therefore, smaller playas are less frequently ponded for long durations.

Playa soils within the Volcanic Plateaus, an adjacent LRU for MLRA 70A, have clay minerals derived from volcanic sediments that have higher shrink-swell activity. These playas often have vertic properties that, when dry, produce cracks that can extend to the depth of the entire profile. The cracks create bypass flow that helps to drain ponded water following heavy rains. During extended wet periods, clay minerals can hydrate and swell, sealing desiccation cracks and effectively ponding water. This may lead to prolonged periods of reduction that can develop hydric morphology. For these reasons, playas in the Volcanic Plateaus are more likely to have hydric morphology than those of the Canadian Plateaus, even though periods of ponding may occur less frequently.

5. Vertisols

Vertisols have high quantities of clay with shrink-swell properties that can mix or churn soil materials and obscure or destroy redoximorphic features over time. Such vertic mixing can incorporate organic matter into the soil that often leads to the formation of organo-mineral complexation, causing dark colors to form over time that can mask redoximorphic features. With vertic mixing, the redox concentrations are often not distinct or prominent and are difficult to see.

Dark colored Vertisols may seem to have plenty of organic matter to feed the microbial decomposition processes that facilitate the formation of redox features, but the organo-mineral complexation with clay physically prevents much of it from being easily decomposed. This is especially true when the soils are alkaline, which can lead to depressed rates of anaerobiosis.

Under dry conditions, the large cracks inherent to Vertisols can cause a delay in soil moisture accumulation at the onset of transition from dry seasons to wet seasons. Large vertical cracks of Vertisols will encourage bypass flow through the soils and not within the soil matrix. This transitional period of Vertisols, where they eventually moisten and seal the macropores, often has a long lag for hydrologic equilibration. Once moist, and with large cracks closed, matrix flow occurs. This flow causes the conductivity to become very slow so that water takes even longer to enter all the micropores that store reserves of oxygenated gases. This is when anaerobic conditions occur (Jacob, et al., 1997).

Presently, Vertisols do have an indicator for use and testing, F18, Reduced Vertic (USDA-NRCS, 2024), that is approved in the Gulf Coast Prairie region of MLRA 150, LRR T. This indicator requires a positive reaction to α,α- dipyridyl dye for at least 60 percent of a 10-cm thick layer that starts within the top 30 cm of the soil surface (or a 5-cm layer within the top 15 cm). This positive dye reaction must be continuous for 7 days over a cumulative 28 days during the growing season on a normal or drier year. This indicator is recommended for testing for all Vertisols or soils with vertic intergrades so that new regions and MLRAs can potentially apply it. This indicator requires data collection over a period of several days; it is not intended to be applied during a single field site visit. Therefore, it is considered one of the more cumbersome indicators and is less frequently deployed as a method for rapid determination.

6. Red Parent Material

Red parent material (RPM) in humid tropical soils formed under conditions of long-term weathering and oxidation and is primarily found on older islands (e.g., Kaua`i, O`ahu, Moloka`i, Lāna`i, and Maui) in the Hawaiian chain.

Soils derived from RPM are also common in the flood plains of the Arkansas, Brazos, Colorado, Ouachita, and Red Rivers and their tributaries in Arkansas, Louisiana, Oklahoma, and Texas and in the Northeast, including the Great Lakes region and the river valleys in Connecticut and Massachusetts (fig. 1). These soils contain very low amounts of organic matter, high amounts of Mn, and various crystalline forms of Fe that are difficult to break down. In addition, these soils are high in clay and may continue to receive new deposits from flooding.

Other soils derived from RPM occur in scattered locations throughout regions where residue from the erosion of Triassic rock formations has been deposited on adjacent lowlands or coastal plains.

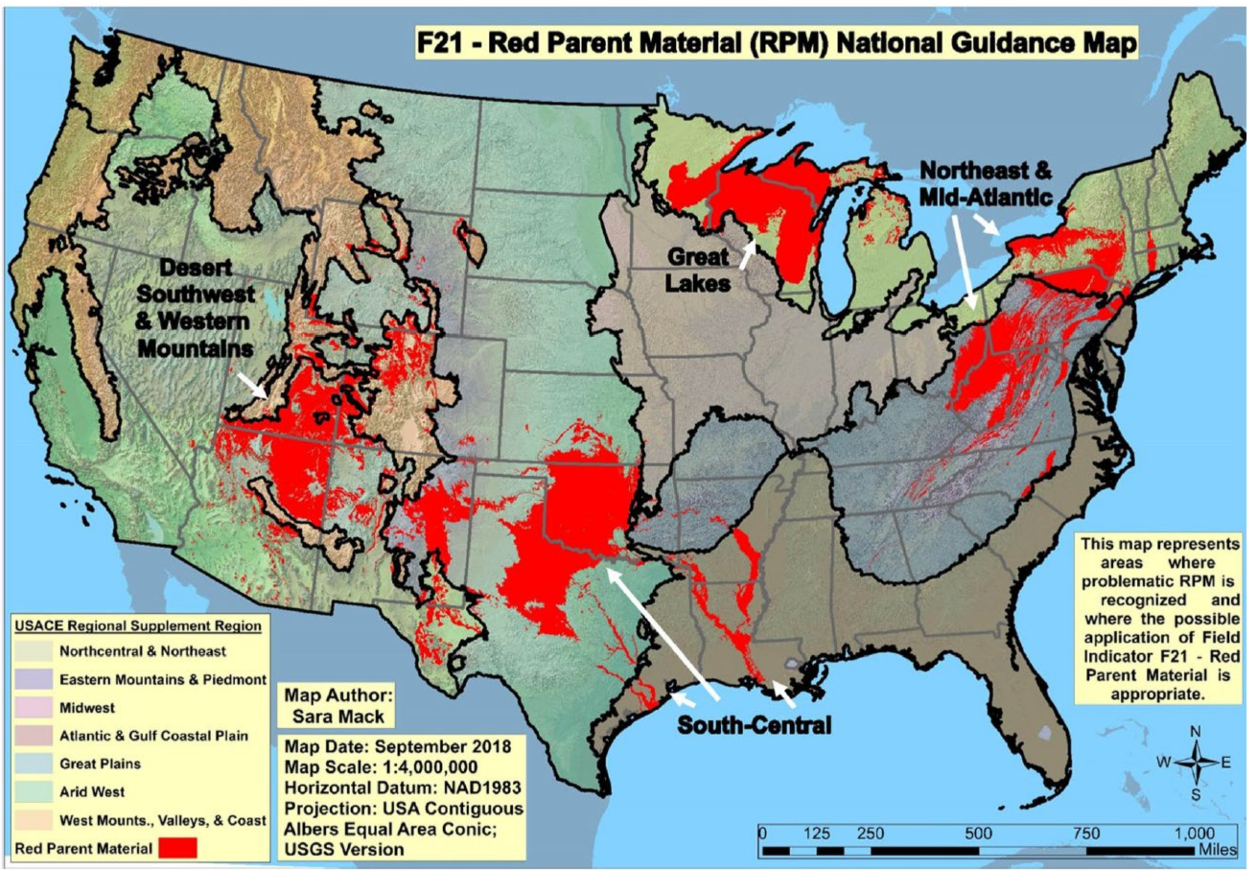

Figure 1.—National guidance map for recommended application of the F21, Red Parent Material, hydric soil field indicator in the U.S. Red areas, also identified with arrows, indicate locations with soils and geological formations where problematic RPM potentially occur. These areas include parts of the Colorado Plateaus of the Desert Southwest, the Great Lakes areas, south-central areas between Texas and Oklahoma, large river basins such as the Mississippi River Basin along the Gulf Coast, and the Valley and Ridge areas of the Northeast and Mid-Atlantic (from Mack et. al, 2019a).

The Mid-Atlantic Hydric Soil Committee (2011) discussed RPM-related problematic conditions being specific to transition areas, closer to the upland boundary or the margin of the wetland, where the minimum required duration of seasonal saturation occurs. In such scenarios, the Fe is never deeply reduced to be sufficiently transported out of the system (Mack et al., 2019b). Additionally, these margin locations can be susceptible to some amount of imported Fe from up-watershed that can replenish, or even increase, the amount of Fe-derived chroma in hydric soils.

To quantify whether soil parent materials have Fe oxide coatings or mineral assemblages that resist depletion under anaerobic conditions, Rabenhorst and Parikh (2000) developed the Color Change Propensity Index (CCPI). The CCPI, a laboratory procedure where soil samples are treated with a reducing agent and then measured for their color difference between pre- and post-treatment, determines whether the soils can form redoximorphic features. The resulting CCPI score groups soils into three RPM categories: 1) nonproblematic RPM soils displaying no color change resistance, 2) problematic RPM soils that resisted color change under reducing conditions, and 3) an intermediate range with potentially problematic RPM values in which soils displayed limited color change resistance.

F21, Red Parent Material, is the indicator designed to address RPM-related problematic situations (USDA NRCS, 2024). It recognizes soils where Fe contents are high and in resilient forms. The propensity for this Fe to reduce and mobilize is low, yet seasonal saturation does reduce and redistribute some smaller portion of its soil Fe. There will be some amount of visible morphological evidence as concentrations or depletions throughout the matrix. However, F21 has not been approved for use in many locations because RPM has not yet been documented. Additionally, in mixed sediments with some fraction of red materials, such as from alluvial or glacial deposits, the fraction of the matrix in non-RPMs depletes readily. When the fraction in RPMs is present in significant amounts, the matrix will not deplete and the indicator may not be applicable.

For areas that are not approved for F21, it is recommended that the test indicator be applied and that CCPI be derived for representative soils of the area. In areas with RPMs, where both hydrology and vegetative indicators are present but the requirements of F21 are not met, a transect sampling approach can be helpful in making a hydric soil determination (see “Transect” in section E of this document). In addition, attention to seasonal constraints on local hydrology with the timing of observations may be critical for proper hydric determinations.

7. Dark-Colored Mineral Soils Due to Organic Matter Accumulation

The strong coloring properties of organic matter can mask redoximorphic features in hydric soils. Often, in hydric soils we observe organic matter accumulating due to the diminished decomposition rates, especially in colder climates. In depositional environments, organic matter pools can accumulate due to the accretion of materials that already contain organics. In this process, terrestrial carbon is transferred from a landscape position with high flux and turnover to a more stable position where it can be sequestered in large quantities. In this case, redox processes may or may not be responsible for organic matter accumulation, though they may play a role in its retention.

The indicator A5, Stratified Layers, was developed for use in alluvial systems where fresh sediments are deposited onto flood plains with varying amounts of organic matter incorporated into different strata (USDA NRCS, 2024). Any one of these strata starting within a depth of 15 cm must consist of a black layer due to accumulations of organic matter. Regions or MLRAs not yet approved for application of A5 should consider testing this indicator.

Other types of landscape systems can redistribute soil organic matter where they have slope complexity, with both convex and concave positions, due to slope processes such as overland flow (water) or soil creep (gravity). Generally, dark topsoil materials from convexities are redistributed into topographic hollows of concave positions causing cumulic soil material to aggrade into thick, dark, organic-rich epipedons. Not all cumulic positions are susceptible to seasonal or long-term interactions with the water table, and thus saturation and hydric soil indicators may or may not be readily visible as morphologic features. Soil types include fine-textured sediments derived from the Blackland Prairie region of Texas (MLRAs 86A and 86B), which are deposited on the coastal plain in the flood plains of the Trinity and Sulphur Rivers and their tributaries.

As little as 1.5 percent organic matter can color a soil black. Dark-colored organics are likely to obscure, coat, or complicate the visibility of chroma-based features from redox features such as concentrations, depleted matrices, and depletions. It is important to examine dark soils closely for small redox features and, if necessary, let saturated soils dry to a moist condition before describing the soil. Look for small and subtle evidence of Fe concentrations to meet requirements for F6, Redox Dark Surface, or examine below the dark surface layer, or layers, for a depleted or gleyed matrix using indicators A11, Depleted Below Dark Surface, and A12, Thick Dark Surface (USDA-NRCS, 2024). Some features may be observable under magnification (Stolt et al., 2001).

8. Black Parent Material

Soils derived from parent materials containing coal are a challenge for hydric soil identification because the dark matrix colors associated with these soils can mask hydric soil features. These soils are found throughout regions where coal-bearing deposits are located or where alluvium derived from these formations is found. These dark materials often form near surface or shallow subsurface layers and inhibit the use of indicators based on carbon accumulation (e.g., A5, Stratified Layers), redox depletions (e.g., A11, Depleted Below Dark Surface), and redox concentrations (e.g., F8, Redox Depressions) (USDA NRCS, 2024). Chemical reagents, such as α,α- dipyridyl, can also be useful in identifying reducing conditions in these soils. However, caution must be used because chemical reagents require the presence of saturated conditions and sufficient Fe content for a reaction to occur. (Berkowitz, et al., 2021)

Other soils formed in dark-colored (gray and black) parent materials derived from carboniferous and phyllitic bedrock occurring in the Narragansett Basin of Rhode Island, parts of southeastern and western Massachusetts, throughout Vermont, and in extreme western New Hampshire. These soils typically have both value and chroma of 2/1 and 3/1. They have high pH, high cation-exchange capacity, and high organic matter content and often receive new deposits, making them problematic for the development of observable redoximorphic features. Soils in some areas contain as much as 5 percent visible redoximorphic features, whereas other soils under similar hydrologic conditions have no visible redoximorphic features. (Environmental Laboratory, 1987)

9. Glauconitic Soils

These soils contain silt- to sand-sized aggregates containing the clay mineral glauconite, which has a characteristic green color. Glauconitic sediments are deposited on marine terraces and are exposed when sea levels drop. Glauconitic parent materials are commonly found in Maryland, Delaware, and New Jersey in MLRA 149A, but they are also known to occur in Arkansas and Louisiana. Where sufficient glauconite is present, the soil matrix often has a chroma of 2 or less, and the matrix color can match colors found on the gley pages of the "Munsell Soil Color Book" (X-Rite, 2009).

Glauconitic soils are excluded from the definition of gleyed matrix in "Field Indicators of Hydric Soils in the United States." The inherited low chroma and gleyed matrix colors can mask true low chroma depletions attributable to anaerobiosis and reduction. Therefore, the colors of glauconitic soils can be mistaken for a depleted matrix in areas where wetland hydrology is not present.

In areas where wetland hydrology is present and the soil is hydric, low-chroma colors can be overlooked as a parent material feature. Glauconitic parent materials also contain sulfides that, through weathering and oxidation, can produce concentrations of oxidized Fe mineral features that are not associated with a seasonal high-water table or wet conditions. These features may even be evident in well drained soils. (Environmental Laboratory, 1987)

In glauconitic hydric soils with sulfates, one could potentially use indicators A4 (H_2S) or A18 (FeS) to determine when the soils are hydric. Otherwise, it is the responsibility of the local, professional soil scientist to know about the potential presence of glauconite in an area and the specific landscapes where complicated scenarios for hydric soil determinations will exist.

10. Interdunal Swales with Mucky-Peat Surfaces

These hydric sandy soils are found in swales between coastal dunes in New Jersey, Delaware, Maryland, and Virginia in MLRAs 153B, 153C, and 153D, and they may occur elsewhere in LRR T. They generally have a thin layer—generally 5 cm or less—of mucky peat over sand. Many of these soils do not meet the requirements of indicator S5, Sandy

Redox, because they lack redox concentrations in the underlying sands. If a dark mineral surface layer is present, it often has a chroma greater than 1 or is too thin to meet the requirements of dark-surface indicators (e.g., S7, Dark Surface, or S9, Thin Dark Surface).

In some cases, the soil may meet the requirements of indicator S6, Stripped Matrix. These soils would meet the requirements of indicator S2, 2.5 cm Mucky Peat or Peat, or S3, 5 cm Mucky Peat or Peat, if one of these indicators was approved for use in the region. The organic surface is too thin to meet the requirements of A1, Histosol; A2, Histic Epipedon; or A3, Black Histic, and not decomposed enough to meet the requirements of A9, 1 cm Muck. (Environmental Laboratory, 1987)

Indicator S12, Barrier Islands 1cm Muck, was created for these soils, but it is only for barrier islands. The problem statement above does not include non-barrier island settings as it intends to target the fresh sediments from young landforms. It would be worth considering use of this indicator in coastal areas with dune-and-swale topography if it can be applied effectively. As for now, we would recommend testing this indicator in any currently unapproved locations where it could potentially become applicable.

11. Soils with Shallow Spodic Material

These soils form in sandy materials with very low Fe content and generally occur on broad, nearly level interstream divides in MLRAs 153A, 153B, 153C, and 153D. These soils have black surface layers that are underlain directly by soil materials (spodic materials) that have a chroma of 3 or more. Some of these soils are hydric and others are not. However, due to the presence of soil material with a chroma greater than 2, the absence of muck or mucky modified soil textures within 15 cm of the surface, and the absence of redox concentrations, these soils generally do not meet the requirements of any hydric soil indicators. (Environmental Laboratory, 1987)

Indicators S7, Dark Surface; S8, Polyvalue Below Surface; and S9, Thin Dark Surface, all require a dark surface layer with a chroma of 1 or less that starts within the upper 15 cm. The next layer directly beneath has a low chroma that occurs before any spodic layer with higher chroma. Either of these indicators could apply to a shallow spodic situation as long as there is an E horizon directly below the dark surface and overlying the spodic horizon.

The indicator A17, Mesic Spodic, which is only approved for use in MLRAs 144A, 145, and 149B and the mesic coastal parts of southern New England, the Connecticut Valley, Long Island, and Cape Cod also requires a similar dark or gray surface with a value of 4 or greater and chroma of 2 or less, but it allows for a spodic horizon to start at a depth as shallow as 5 cm if the black or gray layer is at least 5-cm thick. The indicators S7 and S8 should be tested for use in all other regions with Spodosols, whereas A17 could be tested in other mesic locations.

12. Anomalous Bright Sandy Soils

Bright sandy soils have morphology similar to the fine-textured hydric soils identified by indicator F20, Anomalous Bright Loamy Soils (ABSS). These soils occur adjacent to tidal areas where fresh groundwater movement is impeded once it hits the saturated tidal marsh and discharges to the surface. The reduced Fe carried with these freshwater fluids is thought to be precipitated into the sandy surface soils, thereby increasing the chroma. ABSS soils can occur along the coastline of New Jersey, Delaware, Maryland, and Virginia in MLRAs 149A, 153A, 153B, 153C, and 153D and can occur elsewhere in LRR T.

Indicator A16, Coast Prairie Redox, is for use in MLRA 150A of LRR T, generally in depressional landforms within a specific geological unit (the Pleistocene age Lissie Formation) along the Texas and Louisiana coasts. Chert minerals in the alluvium are the source of occluded Fe that resists redox-driven color change. The indicator is not specified for use in MLRAs 153 A, B, C, or D, but it is recommended for testing throughout LRR S. It's not clear how A16 could be applicable for testing in other LRRs. This indicator should be tested for application in the MLRAs and LRRs stated above unless specific requirements restrict its use.

Bright sandy soils are also found in the oak openings of Ohio, Indiana, and Michigan along the boundary between LRRs L and M where about 10 to 15 percent of wetlands lack hydric soil indicators due to high-chroma subsoils (often a chroma of 4 or more). Underlying dense glacial till slows the infiltration of snowmelt and spring rainfall, causing water to perch for long periods within the sandy deposits above. Wind erosion in the oak openings can also transport soil material and bury natural soil horizons.

Soil textures are often fine sands, fine sandy loams, and loamy fine sands. Indicator S11, High Chroma Sands, was developed for LRRs K and L to address the high chroma sands along the shorelines of the Great Lakes at the landward edge of coastal marshes or in interdunal landscape positions of dune-and-swale complexes.

13. Carbonate Sands, Coral Rubble, and Cobble Soils

Carbonate sands are common in the Caribbean region and are derived from weathered shells, coral rubble, foraminifera, and coralline algae. Soils formed primarily of coral rubble and cobble can be found in coastal embayments, around salt ponds, and on cays, especially in the U.S. Virgin Islands. Some of these soils form when small inlets become closed off from the sea due to the development of coral reefs and rubble or cobble berms across their mouths, forming salt ponds (Thomas and Devine, 2005). Coral rubble and cobble soils may lack hydric soil indicators due to their recent origin, the dominance of coarse fragments, and frequent deposition of new sediment. Mangrove communities often develop on the strip of land separating a pond from the sea.

Care should be taken to examine the soil closely, as redox concentrations and depletions can be very small and have diffuse boundaries. Look for redox features along any visible roots or where sources of organic material occur. Organic-matter accumulations can be used to identify some hydric soils in carbonate sands; consider indicators S7, Dark Surface, and S1, Sandy Mucky Mineral. (Environmental Laboratory, 1987)

14. Discharge Areas for Iron-Enriched Groundwater

Discharge of Fe-enriched groundwater occurs in many locations throughout the U.S. The seasonal input of Fe from the groundwater produces soil chromas generally greater than 3 and as high as 6 below the surface layer. These soils are generally found in seepage areas, such as footslopes, toeslopes, and springs, and in areas with converging slopes, fractured bedrock, glacial till, and near-surface stratigraphic discontinuities.

Investigators should look for redox concentrations and depletions in the layer with high chroma and a depleted matrix below the layer of Fe concentration. Wetland hydrology indicator B5, Fe Deposits, can help to identify the presence of this problem soil. (Environmental Laboratory, 1987)

Within the central Piedmont region near Charlotte, NC, seasonal variations in hydrologic status have been documented as discharge or flow-through zones. During wet months and periods of excessive soil moisture when the plants are dormant, the hydrology exists for anaerobic conditions and hydrophytic vegetation is present. However, seasonal discharge of oxidized Fe (Fe^{3+}) appears to be masking any redox features or low chroma in the soil.

15. Soils with Low Organic-Carbon Content

Soil microbes require the presence of sufficient organic carbon in a soil to thrive. If little or no organic carbon is present in a saturated soil, microbial activity will often be insufficient to produce noticeable hydric soil indicators. This is especially true in young or recently formed soils. Examples include recently formed sandy and gravelly soils on flood plains, in coastal areas, and on outwash plains with recently deposited alluvial, marine, or glacial sediments.

16. Very Shallow Mineral Soils

In areas where bedrock is close to the surface, hydric mineral soils may meet the color requirements but not the thickness requirements of one or more hydric soil indicators. Indicator F22, Very Shallow Dark Surface, was established to handle this issue. Some shallow hydric soils in depressions in pāhoehoe lava flows may meet all requirements for indicator F22, Very Shallow Dark Surface, but are yet to be approved.

Shallow soils over limestone rubble, limestone, or other carbonate bedrock and in karst terrain, such as in sinkholes, streambeds running on bedrock, and buried reefs, often have a neutral to high pH. Higher pH soils (i.e., pH of 7.9 or greater) inhibit the biological processes that allow redoximorphic features to develop (refer to section on settings with alkaline soils). (Environmental Laboratory, 1987).

It is recommended that all other LRRs use this indicator for testing.

17. Seasonally Dynamic Hydric Soil Morphology

In humid locations with a wet winter season, soils within a throughflow water table can be reduced and leached of Fe in landscapes with low slope gradient and high silt content (possible link to argillite or slate belt along broad stream divides of the Piedmont region). Requirements for F3 or other depleted matrix indicators can be met in these cases.

During the spring following leaf-out when water demands increase due to onset of photosynthetic activity, these same locations become discharge zones. This leads to inputs of ferrous Fe from upslope groundwater sources causing the soil matrix to exceed the chroma standards required to meet the definition of a depleted matrix (fig. 2). The high content of silt is hypothesized to be important for these phenomena to occur. Silt-sized particles have enough surface area for capillary action to deliver the Fe-rich water into its oxidized matrix sufficiently enough to distribute high chroma minerals throughout. Yet, silty-textured soils are coarse enough to retain a sufficiently rapid saturated hydraulic conductivity to both leach Fe and receive Fe-rich fluids in short, seasonal timeframes (Vasilas, 2024).

Figure 2.—Sediments in a small drainageway tributary where reduced Fe is likely discharging from silty hydric soils of surrounding areas. When precipitated into its sediments, this imported Fe increases the chroma. The high seasonal water table, as seen in this photo, is keeping the imported Fe in solution (positive α,α-dipyridyl reaction shown). If reduction is simultaneously occurring locally, the annual flux of imported Fe exceeds the rate of export, leading to an increase in the system's Fe content.

B. Nonhydric Soils that Appear to Meet the Requirements of an Indicator

Less common, but also problematic, is when nonhydric soils have morphologic properties and features that enable them to meet the requirements of a hydric soil indicator. This occurs as a false positive when the hydric soil features are not derived from contemporary morpho-genetic processes tied to local landscape hydrology. This scenario does not include those soils that have undergone changes in hydrology to the point that they were formerly components of a functioning wetland and are now components of an upland.

Instead, these are soils in geomorphic landform positions that were never part of wetlands. In most cases, these problems occur in areas that have parent materials with colors that compete with those found in redox features, but the colors may be derived from other physical and chemical processes.

Relatively young and pedogenically unaltered or unweathered soil materials may appear similar to a soil matrix that had Fe oxides removed through redox reactions in anaerobic settings. As a result, lithochromic character is capable of being confused for redox features that would erroneously support the identification of a hydric soil. Soliciting expert local knowledge may assist investigators in avoiding misinterpretation of a field indicator.

1. Marl Soils

Most marl-derived soils occur in wetlands due to the source for their deposition requiring subaqueous settings. However, marl can occur in both relict landforms (e.g. uplifted shorelines or terraces) and secondary deposits that may or may not be part of a contemporary wetland. Marl soils have been identified on flood plains in the Great Limestone Valley (Hagerstown Valley) in the Ridge and Valley physiographic province of Maryland, West Virginia, Pennsylvania, Virginia, and New York. The soils have also been identified in minor limestone valleys in West Virginia. These soils developed in marl sediments deposited in water by algal precipitation of calcium carbonate and have been recently studied and characterized (Shaw and Rabenhorst, 1997), (MAHSC, 2011).

Marl soils are particularly problematic since the inherent color of precipitated calcium carbonate is gray to white with matrix chroma of 1 or 2. They commonly contain few to common distinct or prominent Fe oxide concentrations. Consequently, drier areas of these soils could easily be misinterpreted as meeting the requirements for F3, Depleted Matrix. True hydric soils generally occur in concave backwater sloughs and drainage areas immediately adjoining major limestone springs or in former lake basins with marl lakebed deposits. F10, Marl, applies to regions with known marl deposits where surface colors have values of 5 or more and chromas of 2 or less. (MAHSC, 2011)

About one-half to two-thirds of the marl soils mapped in the Great Limestone Valley, as described previously, are moderately well drained or even well drained but have soil morphology that qualifies as F3. Commonly, the subsoil matrix has chroma of 2, and few to common redox concentrations occur. The concentrations are primarily nodules or concretions, which are precluded from the definition of redox features in all but one indicator. Their location in smooth or convex areas apart from sloughs and drainageways emanating from major spring seeps helps to separate upland marl soils from hydric marl soils. (Environmental Laboratory, 1987)

2. Soils Derived from Dark or Gray Parent Materials

These soils formed in materials derived from gray or dark-colored shales of fine-grained sandstones. They have gray matrix colors that were inherited from the parent material. These soils are common in the Piedmont and occur in long, very narrow bands paralleling intrusions of igneous basalt dikes within and adjoining Triassic red shales. Soils in smooth or convex positions on the landscape are easily misinterpreted as hydric because the subsoil has a predominantly gray matrix and generally contains few to many very fine pieces of reddish shale that can be misinterpreted as redox concentrations. Potential hydric soils in concave landscape positions, such as drainageways, often have darker, thicker, organic-rich surface layers and redox concentrations as soft masses; they may meet one or more requirements of the dark-surface hydric soil indicators (e.g., F6, Redox Dark Surface). (Environmental Laboratory, 1987)

3. Black Parent Materials

These soils occur as near-surface, outwash, or erosional deposits from coal and are often found in association with coal mining operations. The soil surface layer is composed mainly of coal particles. The dark color of these soils reflects the color of the parent material and is not related to the organic accumulations typically associated with wetness. Use caution in applying the following hydric soil indicators in these areas: A5, Stratified Layers; A11, Depleted Below Dark Surface; A12, Thick Dark Surface; and S9, Thin Dark Surface. Some areas of these soils may be wet but do not develop hydric soil indicators because of the lack of organic matter or the continual deposition of new sediment. (Environmental Laboratory, 1987)

4. Spodic Materials

Spodosols are a common soil order in the north-central and northeast regions of the U.S. They form in relatively acidic soil materials and can be either hydric or nonhydric. In Spodosols, organic carbon, Fe, and aluminum are leached from a layer near the soil surface. This layer, known as the E horizon, has a bleached, light-gray appearance and consists of relatively clean particles of sand and silt. The materials leached from the E horizon are deposited lower in the soil in the spodic horizon (e.g., Bhs or Bs horizon). If sufficient Fe has been leached and redeposited, the spodic horizon will have a strong reddish color.

In some Spodosols, E-horizon and spodic-horizon colors can be confused with the redox depletions and concentrations produced under anaerobic soil conditions. Normally, E horizons and spodic horizons are present in the soil in relatively continuous horizontal bands. Chemical weathering in an aerated soil is accomplished by the downward movement of water; therefore, the layers or horizons are relatively parallel to the soil surface and consistent across the soil.

Transitions are relatively abrupt between the organic-enriched surface, the leached E horizon, and the Fe-enriched B horizon. Below the B horizon, the transition becomes more gradual as the red hue of the Fe-enriched B horizon gradually changes to the yellower hue of the underlying C horizon. However, if E horizons are thin or there are extensive plant roots, they may be discontinuous. The action from tree-throw events can also mix and break the horizons of aerated upland soils, as can activities such as plowing, so care should be taken to examine all site characteristics before concluding that a soil is hydric.

In contrast, hydric spodosols will often result in splotchy depletions or concentrations due to the heterogeneous nature of redox reactions spatially across the soil materials. Reduction often occurs in "hot spots" where some pockets of soil have more biological activity—and thus more rapid reduction reactions—than other pockets or zones of soil material. This may be due to the imperfect distribution of roots or other sources of decomposable sources for the micro-flora that are responsible for the redox reactions.

In sandy soils, use caution in areas where soil disturbances such as plowing may have brought red or black soil material from below to create what appears to be redoximorphic features near the surface.

C. Disturbed Hydric Soils

Disturbed hydric soils are those that have been altered in some way by human impact or activities. This can occur directly through manipulation of the soil materials or indirectly by modification of the local hydrology or the mobilization of soil materials in adjacent landscape positions that are subsequently deposited into the wetland.

1. Filled Hydric Soils (Historic Hydric Soils)

These altered soils have had additions of material placed on top of the original soil surface by human activities to the extent that they may no longer meet the definition of a hydric soil. The additions may be intentional (i.e., fill related to human alteration or activities on or around a wetland) or nonintentional (i.e., 1993 flooding deposition on the Missouri River flood plain). The thickness or depth of fill that can be placed on a hydric soil for that soil to remain hydric is directly related to the hydric soil indicator and hydric soil criteria present before filling.

Although the areas that meet hydric criteria generally have a hydric soil indicator, this is not a requirement. According to the deliberations of the NTCHS, areas that satisfy criteria

2, 3, or 4 are hydric if they either meet the requirements of an indicator or show evidence that the soil meets the definition of a hydric soil (Federal Register, 2012). It is important to understand that the requirements of the criteria must be met based on actual data or best professional judgment from observations and not the estimated soil properties.

Filled: Hydric Criterion 1

For Histosols and Histels that meet the requirements for Criterion 1 (Histels, except Folistels, and Histosols, except Folists), fill can be placed on the soil surface to the extent that the soil, after the placement of the fill, still meets the taxonomic requirements (Soil Survey Staff, 1999). Therefore, the maximum tolerance for thickness of fill material that can be added to hydric Histosols (or Histels) and the Histosols retain their hydric status is 40 cm (or 60 cm if three-fourths or more of the organic soil material is moss fibers). Hypothetically, this would be for hydric soils that have a 40-cm thick layer of organic soil material starting at the soil surface (the thickness can exceed 40 cm if three-fourths or more of the organic soil material is moss fibers). For Histosols and Histels with thinner organic layers or organic layers starting below the soil surface to maintain their hydric status, the tolerance for thickness of fill would be less.

Filled: Hydric Criterion 2

Criterion 2 includes other soils that are hydric due to saturation by a water table (a hydric soil indicator must be present or it must meet the hydric soil technical standard). The maximum tolerance for thickness of fill that can be placed on these soils and the soils retain their hydric status is variable. The range is from slightly less than 15 cm to none in soils with sandy soil materials, and the range is from slightly less than 30 cm to none in other soils. After fill materials are added, an indicator must be present in the original soil material within the prescribed depths for that soil to retain its hydric status. If the fill effectively deepens the layer exhibiting the hydric indicator below the required threshold, the soil is no longer hydric. If the depth requirements for the indicator are still met despite the fill, it remains a hydric soil.

Filled: Hydric Criteria 3 and 4

Criteria 3 and 4 hydric soils are those that are frequently flooded or ponded for a long or very long duration during the growing season. Following the application of fill materials, for soils to maintain their hydric status, the thickness of the fill must be slightly less than the height of ponding or flooding of long duration (more than 7 days). This height may be either measured or estimated but must meet the minimum duration threshold for these criteria. If estimated, professional judgement that the definition is met (anaerobiosis) must be carefully exercised. Although any of the indicators may occur on inundated landforms, indicators F8, Redox Depressions; F9, Vernal Pools; F11, Delta Ochric; F12, Fe/Mn Masses; and F16, High Plains Depressions, are restricted to inundated landforms.

2. Drained Hydric Soils

In the 1988 "National FSA Manual," NRCS defines prior converted cropland (PCC) as wetlands that "were both manipulated (drained or otherwise physically altered to remove excess water from the land) and cropped before 23 December 1985, to the extent that they no longer exhibit important wetland values." The "National FSA Manual" also indicates that any PCCs that were abandoned, per the NRCS provisions on abandonment, and reverted back to wetlands could be recaptured and subject to Clean Water Act regulation.

The concept of drained hydric soils maintaining their hydric status should be thoroughly understood. This is an important distinction to wetland scientists since soils that meet the requirements of a hydric indicator may or may not be functioning wetlands but are still hydric soils. By recognizing a soil with a hydric soil indicator as being hydric, regardless of hydrologic alteration, we keep soils capable of supporting wetlands (if hydrology was restored) in the same class as soils that are currently supporting wetlands. It has been demonstrated that restoring hydrology to former wetlands that have hydric soils is a much more cost-effective and predictably successful venture than the fabrication of artificial hydrology in uplands.

3. Recently Developed

Wetlands that have been recently developed include mitigation sites, wetland management areas (e.g., for waterfowl), other wetlands intentionally or unintentionally produced by human activities, and naturally occurring wetlands that have not been in place long enough to develop hydric soil indicators. The hydrology required for a wetland to function, and that must be maintained in order to sustain wetland functions, can be a management challenge in created wetlands.

Varying amounts of time will be required for redoximorphic features to develop, which will depend on a variety of conditions. These conditions include duration of saturation during the growing season, absolute temperatures during periods of saturation that promote biological activity and decomposition and lead to oxygen depletion, amounts and composition of organic matter, the ability of vegetation to rapidly occupy the site and provide the metabolic energy source for decomposition, and the availability of Fe and other compounds to create identifiable redox features.

4. Tilled Wetlands

Tilling of agricultural land mixes the surface layers of the soil and may cause compaction below the tilled zone (i.e., a plow pan) due to the weight and repeated passage of farm machinery. Plowing and tilling activities also churn the soil matrix, displacing and destroying many of the redoximorphic features that would be used to meet requirements for indicators. Any redox features observed in a recently tilled soil should at first be considered displaced redox features unless properly identified as forming in place (see section D).

D. Relict or Induced Hydric Soils

Some soils formed under past conditions that were wetter than they are currently; these soils can preserve some or all of their former hydric soil morphology or redoximorphic features. This could cause the soils to meet one or several of the requirements of hydric soil indicators. These features can persist in soil materials despite contemporary hydrologic conditions that no longer saturate and no longer reduce soil compounds. In many cases, relict and contemporary hydric soil morphology can appear to be indistinguishable. If the presence of hydrophytic vegetation and wetland hydrology can be identified, then hydric soil indicators can be assumed to be contemporary.

The following are morphological characteristics that can help distinguish between contemporary and relict redoximorphic features:

- Contemporary hydric soils may have nodules or concretions with diffuse boundaries or irregular surfaces. If surfaces are smooth and round, then red to yellow coronas should be present. Relict hydric soils may have nodules or concretions with abrupt boundaries and smooth surfaces without accompanying coronas.
- Contemporary hydric soils may have Fe depletions along stable macropores where roots repeatedly grow that are not overlain by Fe-rich coatings (redox concentrations). Relict hydric soils may have Fe depletions along stable macropores where roots repeatedly grow that are overlain by Fe-rich coatings.
- Contemporary hydric soils may have Fe-enriched redox concentrations with Munsell colors of 5YR or yellower and with a value and chroma of 4 or more. Relict hydric soils may have Fe-enriched redox concentrations with colors redder than 5YR and a value and chroma less than 4.
- Contemporary pore linings may be continuous while relict pore linings may be broken or discontinuous (Hurt and Galbraith, 2005).

1. Northeast Region

In this supplement, the word “marl” is restricted in meaning to the definition given in the “Field Indicators of Hydric Soils in the United States,” which defines marl as “an earthy, unconsolidated deposit consisting chiefly of calcium carbonate mixed with clay in approximately equal proportions, formed primarily under freshwater lacustrine conditions.” Marl soils occur on flood plains in the Great Limestone Valley (Hagerstown Valley) in the Valley and Ridge province of Pennsylvania, Maryland, West Virginia, and Virginia. These soils have also been identified in minor limestone valleys in West Virginia.

Marl soils developed in marl sediments of late Pleistocene to early Holocene age that were deposited in water through precipitation of calcium carbonate by algae (Shaw and Rabenhorst, 1997). Marl has a Munsell value of 5 or more and reacts with dilute hydrochloric acid (HCl) to evolve carbon dioxide (CO_2). Marl soils are problematic because the inherent color of precipitated calcium carbonate is gray to white with a matrix chroma of 1 or 2, and marl soils commonly contain distinct or prominent Fe-oxide concentrations. These soils can be misinterpreted as having a depleted matrix and can seemingly meet the requirements of hydric soil indicator F3, Depleted Matrix. Typical profiles also contain alternating buried surface layers with varying content of organic carbon. (Environmental Laboratory, 1987)

2. Western Mountains Region

Wetlands that were drained for agricultural purposes starting in the 1800s, such as large areas of California's Central Valley, may contain persistent hydric soil features. Wetland soils drained in recent history are still considered to be hydric, but they may no longer support wetlands.

Relict redoximorphic features can be found throughout the former lake basins of the Great Basin, which were inundated during the Pleistocene epoch. (Environmental Laboratory, 1987)

3. Atlantic and Gulf Coast Region

Some soils in coastal plains exhibit redoximorphic features and hydric soil indicators that formed prior to the conversion of vast wetland acres for agricultural purposes. Starting in the 1700s, large areas of the Carolinas, Georgia, Louisiana, and Mississippi were drained for agriculture and are likely to contain persistent hydric soil features (Environmental Laboratory, 1987).

E. Solutions to Problematic Hydric Soils

This section is intended to provide guidance for how to approach and handle encounters with problematic hydric soils. In the case where a hydric soil does not possess the redox features needed to meet the requirements of a hydric indicator but where supplemental information is available that provides the minimum prescribed documentation, determination of a hydric soil can be made.

In select wetland systems, where hydric soils have previously been studied and documented, the required supplementary information might include landscape position, presence or absence of restrictive soil layers, anthropogenic features, information about historic or contemporary hydrology, or the validation of a hydric component from a soil map unit polygon.

There is no perfect solution for every scenario. Each locational circumstance is potentially unique in how the system functions as well as the history of management or disturbance. More than one approach may be considered. Consult an experienced soil scientist or wetland scientist before committing to any one action. For novel approaches, consult the serving chair of the NTCHS or an active member.

1. Test Indicator

Apply a test indicator or propose an indicator from another region for testing in a new region. This strategy is usually offered as a first option for situations where the investigator is observing wetland indicators but no hydric soil indicators. This is especially relevant when addressing a site that meets the required hydrophytic vegetative metric for a wetland, as this is a reliable observation that saturation occurs for some length of time during the growing season for the soils to become anaerobic. Hydrology indicators may provide observable clues for flooding or ponding but don't usually provide enough evidence for prolonged saturation and reduced conditions.

2. Hydric Soil Technical Standard (HSTS)

Application of the HSTS (Berkowitz et. al, 2021) was designed to demonstrate that a site meets the definition of a hydric soil, especially where a hydric indicator is not present. This resource is also important for scenarios where an indicator is being tested for use in a new MLRA or LRR and is required to be used if a new indicator is proposed. The data and other documentation from the results of this application must demonstrate that the soil meets the minimum requirements of the HSTS to be considered a hydric soil.

3. Reduced Matrix

Soils that have been saturated for long enough to become anaerobic so that Fe becomes reduced—where insoluble mineral ferric iron (Fe^{3+}) transitions to soluble ferrous iron (Fe^{2+})—have, by definition, reduced matrices. The reduced matrix can only occur where soluble organic compounds are available for decomposition by microorganisms (Vepraskas, 1992). These matrices may change color when exposed to air due to the rapid oxidation of Fe^{2+} back to Fe^{3+}.

If the soil contains sufficient Fe, this can result in an observable color change, especially in hue or chroma. Using α,α-dipyridyl, a dye that reacts with reduced Fe to rapidly produce a visible red stain color, can provide evidence that a soil has a reduced matrix. This technique is often more useful in the field than the reliance on visible, measurable matrix color change upon exposure to air because its detection limits tend to be much lower and results are often produced more rapidly.

The use of Fe or Mn reduction indicator strips (IRIS or MRIS) allows an investigator to validate the presence of an anaerobic water table near the soil surface. This may be a component of the requirements needed to meet the HSTS or may be used as proof positive for a soil in a well understood wetland system (see directions below). Instructions for proper use of either IRIS or MRIS are found in the documentation of the HSTS (Berkowitz et. al., 2021).

A reduced matrix can be used to meet the requirements of the hydric soil indictor for F3, Depleted Matrix, in the absence of identifiable redox concentrations. According to the discussion in “Keys to Soil Taxonomy” (Soil Survey Staff, 2022) on redoximorphic features, in soils that have no visible redoximorphic features, a reaction to an α,α-dipyridyl dye satisfies the requirement for redoximorphic features. Therefore, in a soil with a value of 4 or more, a chroma of 2 or less, and a reduced matrix within a 5-cm thick layer starting at a depth of 10 cm or less from the soil surface or a 15-cm thick layer starting at a depth of 25 cm or less from the soil surface, the requirements for the F3, Depleted Matrix, indicator have been met. The identification of a depleted matrix occurs when application of the dye produces a positive result within 30 minutes as a red stain on indicator paper, when contact with the soil matrix produces colors that become redder by one or more pages in hue, or when the soil matrix increases in chroma by one or more when exposed to air (Vasilas, 2024).

The guidance from the regional supplements usually contains the following statement (Environmental Laboratory, 1987):

> If ferrous Fe is present as described below, then the soil is hydric.
>
> The soil is likely to be hydric if application of α,α, -dipyridyl dye to mineral soil material in at least 60 percent of a layer at least 10-cm thick within a depth of 30 cm of the soil surface results in a positive reaction within 30 seconds, evidenced by a pink or red coloration to the dye during the growing season.

It should be noted that this constitutes a liberal application of the HSTS whereby only one of the components is satisfied—evidence of reduction in the upper part. Additional requirements that need to be met to satisfy the HSTS include information on the antecedent precipitation period and landscape position. However, professional assumptions by the investigator can be entered into the records for documenting a hydric soil as prior knowledge of the local area may be sufficient to meet the needs of the study.

4. Transect

In the absence of an approved indicator, a landscape transect can be a methodical approach to determine the hydric soil boundary. Soil and landscape conditions should be documented thoroughly and should include the rationale for considering the soil to be hydric (e.g., landscape position, vegetation, evidence of hydrology, and references to similarly studied hydric soil systems in the area).

To help identify the hydric soil boundary, examine soils in obvious wetland and nonwetland locations within the landscape to determine what features to look for in soil profiles near the boundary. Use caution in areas where soil disturbances, such as plowing, may have brought red or black soil material from below to create what appears to be redoximorphic features near the surface. (Environmental Laboratory, 1987)

An investigator begins by describing soil pedons in obvious upland and wetland locations of the study site and records the differentiating soil morphologic features of both end members in a table or matrix. Examples of documented features may include colors and textures of surface and subsurface layers, presence of mottles or multiple matrix colors, colors of pores or coatings on roots or root channels, thickness of organic or topsoil layers, presence of O horizons and their textures and composition, presence of organic bodies, organic coatings on grains and fragments, and any reactions to α,α - Dipyridyl dye, peroxide treatments, or HCl.

The investigator then proceeds across the transition zone in a methodical manner, from one end to the other. As the transect proceeds, the investigator documents the correlation of any changes to the surface topography, plant responses, or other soil properties and changes within the soil profile (matrix color and redoximorphic features) that are related to the hydrologic gradient. The investigator should examine the soil carefully along the gradient since changes may be subtle or faint.

The resulting comparison table should help flush out soil properties that are most useful to this area. The investigator should use plant indicators, where present, to document where the hydrophytic divide coincides with the documented features of hydric soil morphology to help propose the criteria for the hydric soil boundary.

As a product of the Food Security Act and its requirements for wetland compliance, the hydric soil indicators were designed to be a conservative approach to estimating functioning hydric soil boundaries. When used in a transect scenario, this results in a wetland determination of smaller acreage than what is truly functioning as a wetland.

The hydric soil indicators that are most helpful for identifying the locations closer to a functioning wetland boundary focus on the presence of redox concentrations and usually incorporate the depleted matrix into the indicator’s diagnostics. These indicators include A11, A12, S5, S7, F3, F6, F7, and F11 as well as indicators designed for specific materials and landforms or landform positions such as S11, S12, F8, F12, F13, F16, F19, F20, and F21.

It may be prudent to consult with a local, professional wetland scientist to help understand the unique plant and hydrologic indicators for each system to demonstrate seasonal saturation periods and events.

5. Soil Survey Data

Where the investigation involves a soil map unit with known hydric components, direct or indirect validation or identification of the hydric or nonhydric components can be effectively accomplished using soil survey data. A deep knowledge of the landscape features, landform positions, and microfeatures with respect to their relative hydrologic functions is required. Responsibility falls on the investigator to decide when this technique is appropriate for the intended use or application of the hydric determination. Refer to local NRCS field office technical guides for guidance.

References

Berkowitz, J. F., Vepraskas, M. J., Vaughan, K. L., and Vasilas, L. M. (2021). Development and application of the hydric soil technical standard. *Soil Science Society of America Journal*, *85*(3), 469–487. https://doi.org/10.1002/saj2.20202

Boettinger, J. L. (1997). Aquisalids (Salorthids) and other wet saline and alkaline soils: Problems identifying aquic conditions and hydric soils. In M. J. Vepraskas and S. W. Sprecher (Eds.), *Aquic conditions and hydric soils: The problem soils* (pp. 79–97). Soil Science Society of America. https://doi.org/10.2136/sssaspecpub50.c5

Dahlgren, R., Shoji, S., and Nanzyo, M. (1993). Mineralogical characteristics of volcanic ash soils. In S. Shoji et al. (Ed.), *Volcanic ash soils: Genesis, properties, and utilization* (pp. 101-143). Elsevier.

Environmental Laboratory. (1987). *Corps of Engineers wetlands delineation manual* (Technical Report Y-87-1). United States Army Corps of Engineers, Waterways Experiment Station.

Hurt, G. W., and Galbraith, J. M. (2005). Using soil morphology and soil survey data for restoring and creating wetlands. *Soil Survey Horizons*, *46*(3), 109–119. https://doi.org/10.2136/sh2005.3.0109

Jacob, J. S., Griffin, R. W., Miller, W. L., and Wilding, L. R. (1997). Aquerts and Aquertic soils: A querulous proposition. In M. J. Vepraskas and S. W. Sprecher (Eds.), *Aquic conditions and hydric soils: The problem soils* (pp. 61–77). Soil Science Society of America. https://doi.org/10.2136/sssaspecpub50.c4

King, M. Vaughan, K. L., Clause, K., and Mattke, D. (2019). Limitations to redoximorphic feature development in highly calcareous hydric soils. *Soil Science Society of America Journal*, *83*(5), 1585–1594. https://doi.org/10.2136/sssaj2019.04.0108

Lindbo, D. L. (1997). Entisols-Fluvents and Fluvaquents: Problems recognizing aquic and hydric conditions in young, flood plain soils. In M. J. Vepraskas and S. W. Sprecher (Eds.), *Aquic conditions and hydric soils: The problem soils* (pp. 133–151). Soil Science Society of America. https://doi.org/10.2136/sssaspecpub50.c8

Mack, S. C., Berkowitz, J. F. and Rabenhorst, M. C. (2019a). Improving hydric soil identification in areas containing problematic red parent materials: A nationwide collaborative mapping approach. *Wetlands*, 39, 685–703. https://doi.org/10.1007/s13157-018-1114-6

Mack, S. C., Rabenhorst, M., and Berkowitz, J. (2019b). Understanding the inhibition of color change in problematic red parent material hydric soils. *Soil Science Society of America Journal*, *83*(3), 838–847. https://doi.org/10.2136/sssaj2018.10.0390

Mid-Atlantic Hydric Soils Committee. (2011). *A guide to hydric soils in the Mid-Atlantic Region* (Ver. 2.0). L. M. Vasilas and B. L. Vasilas (Eds.). USDA Natural Resources Conservation Service.

McDaniel, P. A., Fosberg, M. A. and Falen, A. L. (1993). Expression of andic and spodic properties in tephra-influenced soils of northern Idaho, USA. *Geoderma*, *58*, 79-94. https://doi.org/10.1016/0016-7061(93)90086-Z

McDaniel, P. A., Huddleston, J. H, Ping, C. L., and McGeehan, S. L. (1997). Aquic conditions in Andisols of the northwest USA. In M. J. Vepraskas and S. W. Sprecher (Eds.), *Aquic conditions and hydric soils: the problem soils* (pp. 99–111). Soil Science Society of America. https://doi.org/10.2136/sssaspecpub50.c6

Nanzyo, M., Dahlgren, R., and Shoji, S. (1993). Chemical characteristics of volcanic ash soils. In S. Shoji et al. (Eds.), *Volcanic ash soils: Genesis, properties, and utilization* (145-187). Elsevier.

Rabenhorst, M. C., and Parikh, S. (2000). Propensity of soils to develop redoximorphic color changes. *Soil Science Society of America Journal*, *64*(5),1904–1910. https://doi.org/10.2136/sssaj2000.6451904x

Shaw, J. N., and Rabenhorst, M. C. (1997). The geomorphology, characteristics, and origin of the freshwater marl sediments in the Great Limestone Valley, Maryland, USA. *Catena*, *30*(1), 41-59. https://doi.org/10.1016/S0341-8162(97)00005-2

Soil Science Division Staff. (2017). *Soil survey manual* (Agriculture Handbook 18). U.S. Government Printing Office.

Soil Survey Staff. 2022. *Keys to Soil Taxonomy* (13th ed.). USDA Natural Resources Conservation Service.

Stolt, M. H., Lesinski, B. C., and Wright, W. (2001). Micromorphology of seasonally saturated soils in carboniferous glacial till. *Soil Science*, *166*(6),406–414. https://doi.org/10.1097/00010694-200106000-00006

Thomas, T., and Devine, B. (2005). *Island peak to coral reef: A field guide to the plant and marine communities of the Virgin Islands*. University of the Virgin Islands.

USDA Natural Resources Conservation Service. (2024). *Field indicators of hydric soils in the United States* (Ver. 9.0).

Vasilas, L. M. (2024). *NTCHS annual business meeting notes* (unpublished notes). National Technical Committee for Hydric Soils Annual Meeting, Charlotte, NC.

Vepraskas, M. J. (1992). *Redoximorphic features for identifying aquic conditions*. (North Carolina Agricultural Research Service, Technical Bulletin 301). North Carolina State University. https://content.ces.ncsu.edu/redoximorphic-features-for-identifying-aquic-conditions

X-Rite. (2009). *Munsell soil color charts* (rev. ed.). X-Rite.