

NWI Maps: What They Tell Us

National Wetlands Inventory maps continue to be the most frequently requested source of wetland data in the country. Yet the maps are frequently misinterpreted, prompting this review of what exactly NWI maps measure — and what they don't

By R.W. Tiner

Since the U.S. Fish and Wildlife Service began producing National Wetlands Inventory (NWI) maps in the mid-1970s, many advances in wetland science, technology, and protection have been made. The definition of wetland has been better articulated, largely out of the need to identify specific boundaries on the ground for regulatory purposes. Significant changes in the NWI mapping procedures and technology have improved the quality of the maps.

However, NWI maps have major advantages and disadvantages, and expectations about using a NWI map to identify wetlands must be realistic. Recent studies evaluating NWI maps have demonstrated that the maps are being improperly interpreted. These studies either were unaware of or did not consider NWI's target mapping unit (see below). Rather than evaluate the accuracy of what NWI was intending to map versus what it actually did map, studies have simply compared NWI maps to field delineations without regard to wetland size or wetland photointerpretability. In addition, some researchers believed that the smallest wetland designated on a NWI map is the minimum mapping unit, rather than being simply the tiniest wetland shown. While most of the assessments involved field work, one study compared NWI maps to soil survey data and made claims about the inaccuracy of NWI maps without any field data. These researchers also assumed that all hydric soil map units were regulated wetlands and even declared that somewhat poorly drained soils are often such wetlands.

In this article, I will describe the major strengths and weaknesses of NWI maps. I also will discuss the differences between NWI wetlands and regulated wetlands and between hydric soil map units and NWI wetlands. Finally, I offer some suggestions on what could be done with future wetland maps.

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The definition of wetland

Regulatory and nonregulatory wetland definitions have been developed for different purposes. The federal regulatory wetland definition for administering Section 404 of the Clean Water Act was published in the *Federal Register* on July 19, 1977. The Service's nonregulatory definition for conducting an inventory of the nation's wetlands was first published in 1977, then revised and finalized in 1979 in *Classification of Wetlands and Deepwater Habitats of the United States* (Cowardin et al. 1977, 1979). The regulatory definition deals strictly with vegetated wetlands while the latter includes both vegetated and nonvegetated areas. Yet both definitions are essentially the same for vegetated wetlands.

The Service's definition mentions a list of "hydrophytes and other plants occurring in wetlands" and a preliminary list of hydric soils being prepared to help recognize the nation's wetlands. Over the past 20 years, both lists have undergone critical review and refinement because of increased knowledge of plant-soil-hydrology relationships and widespread use of the lists for wetland delineation. When the NWI began, "hydric soil" was a new term coined by the authors of the Service's wetland classification system. The NWI Project brought the concept of hydric soils to the forefront of wetland identification. Today hydric soil is a criterion for identifying regulated wetlands, and an illustrated national list of hydric soil field indicators has been published. The concept of a hydrophyte is also better understood, and today there is much better information on what vegetation and soil characteristics are reliable wetland indicators.

We must also recognize that it wasn't until 1989 that the federal government standardized its practices for making wetland determinations. The *Federal Manual for Identifying and Delineating Jurisdictional Wetlands*, an interagency document, was adopted by four agencies (the U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, the Fish and Wildlife Service, and the Soil Conservation Service) as "the technical basis for identifying and delineating jurisdictional wetlands in the United States." The 1989 manual combined

existing methods used by these agencies into a consistent set of procedures for identifying and delineating vegetated wetlands. It was the first national technical standard for identifying vegetated wetlands in a consistent, repeatable, and scientifically defensible manner and remains the technical benchmark for identifying vegetated wetlands from a *scientific standpoint*.

These developments plus experience gained from mapping wetlands in numerous states have influenced NWI's application of the Service's definition of wetland. Many areas that might have been overlooked, principally because their plant communities were not dominated by typical wetland species, today are recognized as wetlands when undrained hydric soils are present. Consequently when using a NWI map, it is important to know when the map was produced.

NWI map strengths

In many areas of the country, NWI maps are the only wetland maps available. They are more comprehensive and current than the U.S. Geological Survey topographic map information (which uses swamp and marsh symbols).

NWI maps have been used for a variety of purposes. The most frequent usage is by wetland regulators, the regulated public, and environmental consultants for *preliminary* site assessments, as recommended by federal wetland delineation manuals. Other map uses include: refuge planning and acquisition, park and military base management, watershed planning, environmental impact assessment reports, preliminary site evaluation for development and transportation/utility corridors, oil spill contingency planning, potential wetland restoration site identification, natural resource inventories, wildlife surveys, preliminary assessment of damaged resources at Superfund sites, and land appraisals.

The state of Vermont uses NWI maps to identify "class two wetlands" (wetlands so significant that they merit protection under the state's wetland rules). They recognize NWI wetlands and any unmapped wetlands contiguous with them as this class. Indiana and Illinois use NWI maps to help assess property taxes (those owning wetland acreage receive reduced tax bills). Researchers have used NWI maps to identify training sites for satellite mapping studies. Sportsmen use the maps to locate areas for hunting and fishing. NWI maps and published reports have provided the public with better information on the distribution of nation's wetlands than previously available.

The NWI maps were "generally found to be very accurate" in a multi-agency Maryland field evaluation of NWI maps and satellite mapping produced by the National Oceanic and Atmospheric Administration. Studies have reported high accuracies of NWI maps in Massachusetts, Vermont, New Jersey, and Maine. The National Research Council's 1995 report *Wetlands Characteristics and Boundaries* noted that "wetland delineation on NWI

maps is generally accurate [in] areas where there is an abrupt change in hydrology, soil, or vegetation at the wetland boundary." In evaluating various remote sensors for wetland mapping, the Wetland Subcommittee of the Federal Geographic Data Committee concluded that "the best technique for *initial* wetland habitat mapping and inventory is the technique currently used by the FWS's NWI project. . . ." (emphasis added).

By current design, NWI maps tend to err more by omission (Type I error) than by commission (Type II error). This means that if a NWI map indicates the presence of wetland in a given area, it is highly likely that a wetland is there. This is supported by several studies. Conversely, if a NWI map does not indicate a wetland, one is usually not there, but users should not be surprised to find unmapped wetlands, especially drier-end wetlands and wetlands that are difficult to photointerpret (such as certain evergreen forested wetlands, farmed wetlands, mowed and grazed wetlands, and significantly drained wetlands).

The fact that NWI maps do not show all wetlands should not negate their use or value to the public. Users should realize that remote sensing technology (photointerpretation or satellite image analysis) cannot detect all wetlands. In most cases, the larger and wetter wetlands plus most open waterbodies are depicted on the NWI maps. NWI maps can form the base for more detailed local inventories, such as was done in Puget Sound, Washington.

Another strength of NWI maps is that they attempt to show all types of wetland, regardless of whether they are regulated or not. In some areas, such as the Gulf-Atlantic Coastal Plain, many mapped wetlands are not regulated by the Corps because they fail the Corps manual's three-parameter test. While these requirements may change due to politics, the NWI maps attempt to show scientifically accepted wetlands. Moreover, the Service's wetland trends studies show how the nation's wetland resource (at least that which is photointerpretable) is faring and, therefore, provide a consistent means of assessing to what level these wetlands are being protected.

NWI maps continue to be the most frequently requested source of wetland data in the country. Resource managers, regulators, industry representatives, scientists, and others request more than 250,000 NWI map products (hard-copy and digital) annually. Many of these users are repeat customers who have used the information for many years. The usefulness of the NWI maps also is reflected in the fact that more than 100 state and federal agencies and local governments have provided nearly \$26 million to the NWI to produce wetland maps and digital data for their area of interest.

Map limitations

The earliest NWI maps (pre-1980) used the operational draft

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Table 1
Examples of major NWI map limitations

1. **Target Mapping Unit (tmu).** A tmu is an *estimate* of the minimum sized wetland that the NWI is attempting to consistently map. It is *not* the smallest wetland shown on the maps. The tmu for wetlands generally varies with the scale of the aerial photography used, wetland type, project design, and funding. See Table 2.
2. **Spring photography.** Where spring photography is used, aquatic beds and nonpersistent emergent wetlands are usually undermapped. These areas are classified as open water, unless vegetation was observed during field investigations. In a few cases, scrub-shrub wetlands are submerged, avoiding photo-detection; they too are included within mapped open waterbodies.
3. **Summer (leaf-on) photography.** This photography makes it difficult to identify many forested wetlands as well as seasonal wetlands. For example, the presence of a leafy canopy makes it extremely difficult to separate all but the wettest forested wetlands from upland forests. The wetness of the forest floor is obscured, except where canopy openings exist. In some areas, such as the Pacific Northwest, spring photography is difficult to acquire due to cloud cover so leaf-on photography was used for wetland mapping. In Alaska, most of the aerial photography is acquired in mid-summer. In both these examples, the NWI Project is conservative in mapping forested wetlands. Also, summer photography makes it more difficult to recognize seasonal wetlands that are flooded in winter and spring, but dry out before the aerial photos are acquired.
4. **Forested wetlands.** These are among the more difficult types to photointerpret. Consequently, these types are conservatively mapped. Forested wetlands on glacial till are often difficult to photointerpret, so many of these wetlands do not appear on NWI maps. The location of temporarily flooded or seasonally saturated forested wetlands are among the most difficult to identify on the ground as well as through photointerpretation, so many of these wetlands do not appear on the NWI maps. This limitation is common along the Coastal Plain and perhaps in glaciolacustrine plains such as the Ontario Plain (New York). In areas where 1:80,000 black and white photography was used, many forested wetlands were not photointerpretable.
5. **Upland inclusions.** Small upland areas may occur within delineated wetlands due to target mapping size. Field inspections and/or use of larger-scale photography may be used to refine wetland boundaries when necessary.
6. **Estuarine and tidal waters.** Delineation of estuarine and riverine (tidal) systems and the oligohaline (slightly brackish) segment of estuaries should be considered approximate based on available reports or limited field checking.
7. **Intertidal flats.** Since the aerial photos are not always captured at low tide, all intertidal flats are not visible; boundaries of these nonvegetated wetlands are approximated from coastal and geodetic survey maps and topographic maps.
8. **Coastal wetlands.** Identification of high marsh versus low marsh in estuarine wetlands is often approximated, since the photo-signature of these zones is not distinctive in many instances.
9. **Water regimes.** Water regimes are identified based on photosignatures coupled with limited field verification; they should be considered approximate. Long-term hydrologic studies are required to accurately describe the hydrology of any particular wetland.
10. **Linear wetlands.** Long, narrow wetlands that follow drainageways and stream corridors may or may not be mapped, depending on project objectives. Most NWI maps identify at least some of these features using a dashed pattern. In most cases, no attempt was made to map all linear wetlands. Users can infer the possible occurrence of these wetlands by looking for pertinent topographic features on the NWI maps.
11. **Farmed wetlands.** In general, only five types of farmed wetlands are shown on NWI maps: cranberry bogs, prairie potholes, pothole-like depressions, playa lakes, and seasonally flooded diked former tidelands in California. This is based on technical considerations and an interagency agreement between the U.S. Fish and Wildlife Service and the U.S.D.A. Natural Resources Conservation Service, developed in the 1970s.
12. **Partly drained wetlands** are mapped based on recognizable photo-signatures. Many of these wetlands may have been missed.
13. **Tundra.** Moist tundra (usually wetland) is often difficult to separate from dry upland tundra due to photo-signatures. This is especially true where wide transition zones exist between the two types.
14. **Map date.** NWI map data are dependent on the date of the photography. Maps do not show losses or gains in wetlands since that date.

Cowardin classification system and were prepared during NWI's operational testing of the system. This also marked the Service's first large-scale application of remote sensing technology for mapping wetlands. These earlier maps generally tend to be far

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more conservative and omit more wetlands than later maps (where 1:40K photos were used). While some of this difference is due to a better technical understanding of the concept of wetland, other differences relate to changes in mapping technology (such as the use of color infrared photos versus black and white photos, and use of larger scale photography) and procedures (such as an increased level of quality control and field review).

Relying on photointerpretation to map wetlands imposes numerous constraints. First and foremost, it must be recognized that wetland identification is not always clearcut. Wetlands have been described as ecotones between water and terrestrial habitats, although this notion is a gross oversimplification. Ecotonal wetlands along the wetland-upland interface are expected to possess a somewhat confusing mix of plants and soils. Wetland identification requires analyzing often subtle changes in vegetation patterns, soil properties, and signs of hydrology, so it is easy to understand why photointerpretation fails to accurately identify subtle wetland-upland boundaries and many of the drier-end wetlands.

Studies have reported significant omissions of wetlands from NWI maps when compared to field delineations in North Carolina, New York, Virginia, and Washington. The latter study erroneously reported significant omissions on NWI maps that were later found to be the result of a digitizing error by the researchers. Forested wetlands, small wetlands, and narrow (linear) wetlands tend to be the major sources of omissions. Also, the fact that NWI maps, by design, do not show many farmed wetlands in most of the country also leads to a significant underestimate of the amount of wetland in agricultural regions, with the Pothole Region being a major exception.

The accuracy of wetland photointerpretation is, in large part, dependent on the landscape setting and wetland type. The National Research Council reported that "mapping wetlands in level landscapes, such as coastal or glaciolacustrine plains, is less precise because boundaries are not as evident." Wetland mapping in more varied terrain is more accurate because boundaries are better defined by abrupt changes in slope. Problems associated with photointerpreting forested wetlands have been reported; Table 1 lists some major limitations of NWI mapping due to reliance on photointerpretation.

NWI maps have a target mapping unit (tmu). A tmu is an *estimate* of the minimum sized wetland that should be consistently mapped. It is *not* the smallest wetland that appears on the map, but it is the size class of the smallest group of wetlands that NWI attempts to map *consistently*. The NWI Project could edit the maps to guarantee that no smaller wetlands are designated, but this would not benefit users, so smaller wetlands are permitted. The tmu is conveyed to photointerpreters working on individual projects, but not to map users, which probably has invited some justified criticism.

Accurately determining an appropriate tmu is somewhat problematic. Some wetland types are more conspicuous and smaller wetlands of these types may be mapped, while other types are more difficult to photointerpret and larger ones will be missed. This is inherent in the use of remote sensing to map wetlands. Despite these difficulties, specifying a tmu can serve as a benchmark or another caution to users. However, at this time, such a note is not anticipated to be added to NWI maps. Users should contact the appropriate Service Regional Wetland Coordinator for specifics. Table 2 presents some examples of tmus across the country.

Maps produced by photointerpretation will never be as accurate as a detailed on-the-ground delineation. This is not to say that photointerpretation cannot produce accurate boundaries at a fraction of the cost of field delineation. For some types in certain landscapes (such as marshes, fens, bogs, wetter swamps surrounded by upland, and seasonally flooded bottomland swamps), photointerpretation works well for locating the boundary of these types. For other types in different situations (such as certain evergreen forested wetlands, drier-end wetlands in relatively flat landscapes, and significantly drained wetlands), it does not work well and the boundaries are more generalized.

NWI wetlands versus regulated wetlands

The NWI maps were never intended to show the limits of regulated wetlands. A "Special Note" that appears on the map clearly points this out: "Federal, state and local regulatory agencies with jurisdiction over wetlands may define and describe wetlands in a different manner than that used in this inventory. There is no attempt, in either the design or products of this inventory, to define the limits of proprietary jurisdiction of any federal, state or local government or to establish the geographical scope of the regulatory programs of government agencies. Persons intending to engage in activities involving modifications within or adjacent to wetland areas should seek the advice of appropriate federal, state or local agencies concerning specified agency regulatory programs and proprietary jurisdictions that may affect such activities." After reading this statement, it should be evident to a map user that he or she should contact the regulatory agencies regarding the extent of regulated areas and not rely on a NWI map for this information.

Within the limitations of NWI photointerpretation tech-

niques, the Service attempts to map all types of wetlands without regard to their jurisdictional status. As a result, NWI maps also depict nonregulated wetlands. Besides policy guidelines (such as wetland size, location, and artificial hydrology), the extent of nonregulated wetlands is a product of the amount of proof required to identify a regulated wetland. In 1991, the burden of proof was increased when the federal government shifted from using the 1989 interagency manual to the 1987 Corps manual. The former manual assumes the presence of wetland hydrology when positive indicators of hydrophytic vegetation and hydric soils were found *in the absence of any signs or knowledge of significant drainage*, which is consistent with the National Research Council's findings. In contrast, the Corps manual requires more proof of wetland hydrology and has a more restrictive vegetation requirement. Corps districts also were given discretion for using the facultative neutral rule and interpreting the length of the growing season, which can significantly affect wetland determinations. (The facultative neutral rule compares better wetland indicator plants against species that are better indicators of upland, giving no weight to species that occur nearly equally in both wetlands and uplands.) Now, many drier-end wetlands do not meet the requirements for federal regulation because they either: 1) have plant communities dominated by FAC- or FACU species (species with a frequency of occurrence in wetlands of less than 50 percent), 2) possess wet soils that do not display typical hydric soil field indicators, 3) lack currently accepted wetland hydrology indicators, or 4) are not wet enough during the Corps-defined growing season to qualify as a regulated wetland, despite significant wetness during the rest of the year.

NWI maps versus soil survey maps

Using GIS technology, some researchers have reported on digital data comparisons between NWI maps and soil survey maps. These types of studies cannot assess the accuracy of either source in wetland identification unless field verification is performed. Researchers also must ensure accurate digitizing of data sources since this can be a significant source of error.

Significant discrepancies between wetlands identified on NWI maps and "hydric soil map units" of soil surveys usually exist. The soil survey focuses on management, while NWI is concerned strictly with wetland identification. Soil map units often contain both hydric and nonhydric soils if the management of those soils is similar. This approach leads to more Type II errors (commissions) for wetland determinations while NWI maps tend to make more Type I errors (omissions). This difference in design can lead to enormous differences in estimating the extent of wetlands.

Several other reasons also cause notable contradictions between NWI maps and hydric soil map units. Soil maps have a minimum map unit tied to the final map scale, which reflects the

level of effort given. When a 1:24,000 scale map is desired, a minimum map unit of 5.7 acres is the typical target according to the *Soil Survey Manual*. Yet most map units are much larger than this, especially in forested areas. For example, the *Soil Survey of Umatilla County Area, Oregon* identifies a five-acre minimum for strongly contrasting soils, a 40-acre minimum for small grain-fallow and annual cropping areas, and a 100-acre minimum for rangeland and woodland. This can result in large units of mixed soil types, since soil map units often contain more than one type of soil.

For some hydric soil map units, hydric soils comprise 60 percent of the unit and nonhydric soils as much as 40 percent, although inclusions of other soils may usually represent less than 20 percent. Thus, only 60-80 percent of any hydric soil map unit may actually contain hydric soils and have a *potential* for being a wetland or regulated wetland. Also some map units are associations of two or more series. Hydric and nonhydric soils can comprise a single association. If the acreage of potential wetlands is estimated by the sum total of hydric soil map units and any association including a hydric soil component, the projected figure could be vastly inflated. It would be prudent to use an appropriate percentage of these units to estimate historic wetland acreage.

Soil maps generally do not distinguish between undrained or

Table 2
Examples of target mapping units

| REGION | TARGET MAPPING UNIT |
|---------------|---|
| Northeast | varies with photo scale: 1:80,000 = 3-5 acres 1:58,000 = 1-3 acres 1:40,000 = 1 acre |
| Southeast | Same as Northeast |
| Midwest | 1-3 acres (in general) 1/4-1 acre in pothole region and other agricultural areas |
| Interior West | None; attempts to map all wetlands |
| Northwest | Same as Northeast |
| Southwest | 1-3 acres |
| Alaska | 2-5 acres |

In all cases, user must recognize basic limitations of NWI mapping.

partly drained hydric soils (wetlands) and effectively drained or filled hydric soils (nonwetlands), so both types are designated as "hydric soil map units." Translating hydric soil acreage to wetland usually leads to a significant overestimate of current wetland acreage. Again, since former wetlands are not designated on the NWI maps, this too accounts for significant "wetland" acreage discrepancies.

Finally, the series level of soil classification was never intended to separate hydric soils from nonhydric soils. Some series are so broadly characterized that they include both hydric and nonhydric members. This situation applies to most, if not all, of the soils with an aquic suborder (saturated soils with reducing conditions due to a lack of free oxygen) and an "aeric" subgroup (soils that are drier in the upper part of the soil). When these soils occur lower in the landscape, they often have hydric soil properties, whereas when they are upslope, they do not. These types of series need to be subdivided into two series, one that has hydric soil morphology (poorly drained) and another that does not (somewhat poorly drained). In the meantime, considering map units with such series as wetlands also adds to exaggerating wetland acreage.

Future options

The NWI Project could design a product that could attempt to map more wetlands by changing the basic inventory design to favor Type II errors over Type I. This would require mapping certain landscapes that favor wetland formation. These areas could be labelled with a unique code to separate them from the photointerpretable wetlands to maintain data integrity. These additions could be called "areas potentially supporting some wetlands," for example. A map like this may be more valuable than the current NWI maps, especially to regulatory agencies and the regulated community, since it may better inform landowners and developers on where regulated wetlands may exist.

Another option involves assembling information from field delineations to update and enhance NWI maps. If regulatory agencies required applicants to approximate verified wetland boundaries on a USGS topographic map or on a NWI map and provided such information to the Service, future updates of NWI maps could incorporate this valuable site-specific information. This

would make more use of the work of professional wetland delineators and help enhance the existing national wetland map database. Environmental consultants and regulators alike are encouraged to provide the NWI Project with this information.

In the meantime, people with an interest in knowing whether regulated wetlands are on their property should be advised to do the following:

1. Consult both NWI maps and soil surveys to get an idea of where wetlands may be located on their properties. Also learn to interpret maps to identify landscapes where wetlands tend to form (such as floodplains, drainageways, toes of slopes, flats, depressions, and saddles between mountains). Considering these sites as potential wetland areas is also good practice. These landscapes can be seen on the NWI maps by interpreting topographic contours.
2. Learn how to identify wetland plants and hydric soils. Numerous easy-to-use wetland plant field guides and at least one hydric soil guidebook are available for the nonscientist.
3. Contact the appropriate regulatory agency.

While regulations and the criteria employed by regulators may change and how they are interpreted on the ground may vary, the average person, using a variety of sources of information including NWI maps and once familiar with wetland plants and soils, should be able to recognize wetlands or questionable areas that might be regulated wetlands on their property. ■

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*A complete list of references can be obtained from the author by written request: U.S. Fish and Wildlife Service, Ecological Services (NWI), Region 5, 300 Westgate Center Drive, Hadley, MA 01035.