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EVALUATION OF NATIONAL WETLAND INVENTORY MAPS IN A HEAVILY FORESTED REGION IN THE UPPER GREAT LAKES

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Abstract: National Wetland Inventory (NWI) maps are widely used in the United States but have not been independently evaluated in the Great Lakes region nor in forested areas with level topography. Field data from 148 plots in the Hiawatha National Forest ecological classification and inventory program were combined with an additional review to evaluate NWI mapping accuracy. NWI maps were over 90% accurate in identifying uplands and jurisdictional wetlands. All nonforested wetlands were identified correctly. Uplands were correctly identified 96.9% of the time. The lowest level of accuracy, 90.7%, was achieved in identifying forested wetlands. The most common error was the NWI classification of wetlands on the AuGres soil series, a somewhat poorly drained upland soil that often occurs in complexes with wetland soils in the region. Forested wetlands with a cover type similar to adjacent uplands were also a source of error on NWI maps. The already high accuracy of NWI maps could be improved by the mapping of wetland–upland complexes, a development corresponding to the increased mapping of hydric-nonhydric soil complexes in area soil surveys. The continued refinement of regional lists of hydrophytic vegetation is supported by indicator status discrepancies between an extensive Hiawatha National Forest database and the current NWI list for the region.

Key Words: map accuracy, maps, National Wetland Inventory, plant indicators, soils

INTRODUCTION

The National Wetlands Inventory (NWI) maps and associated digital data are produced by the United States Fish and Wildlife Service (USFWS) and comprise a readily available nationwide data source that is used by local, state, and federal agencies, as well as by private industry and other organizations (Wilen and Pywell 1981, Wilen and Bates 1995). User surveys have documented over 100 different uses of the NWI maps, including regulatory-based activities (Wilen and Bates 1995). Uses have included comprehensive resource management plans, environmental impact assessments, facility and corridor siting, oil spill contingency plans, natural resources inventories, and habitat surveys. The wide availability and use of the NWI products have generated considerable interest and sometimes controversy (Gillis 1996, Tiner 1997a) in the ability of these maps to accurately identify and delineate wetlands. Part of the problem is that the NWI maps were never intended to map wetlands as regulated by various state and federal laws (Cowardin and Golet 1995) but are nevertheless used as a major tool in regulatory activities such as the ''Swampbuster'' provision of the 1985 Food Security Act (Wilen and Bates 1995).

The number of wetlands that meet the regulatory definition of a wetland on NWI maps is unknown (Stolt and Baker 1995). Additionally, wetlands can be missed on NWI maps for various reasons (Tiner 1997a). Remote sensing, the primary tool used to identify and map wetlands in the NWI, cannot easily detect certain wetlands with cover types similar to surrounding uplands, or easily distinguish drier-end wetlands. Small or linear wetlands are often not mapped; neither are most farmed wetlands. The minimum mapping unit (mmu) size on NWI maps has depended on the aerial photographs available. High-altitude photographs at a scale of 1:80,000 were used from 1975 to the early 1980s, with a mmu unit size of 7.5–12.5 ha for early NWI maps (Tiner 1990, Tiner 1997a). In 1980, the U.S. Geological Survey (USGS) initiated a national program of acquiring 1:58,000 scale color infrared (CIR) photographs. The larger scale and CIR emulsion has enabled a current mmu of 0.5–1.2 ha for forested wetlands and a mmu of 0.5 ha for non-forested ponds and pothole marshes.

Several studies have evaluated the accuracy of NWI maps in various regions (Swartwout et al. 1981, Crowley et al. 1988, Kuzila et al. 1991, Nichols 1994, Stolt and Baker 1995, K. Klemow and M. Mohseni pers. comm.). One approach was to evaluate accuracy by overlaying NWI maps with soils maps (Kuzila et al. 1991, K. Klemow and M. Mohseni pers. comm.). In Nebraska, an overlay of a 1981 soil survey and a 1981 NWI map found 94.2% agreement in wetland and non-wetland designations based on considering hydric soils as wetlands (Kuzila et al. 1991). The soil survey classified more areas as wetlands than did the NWI. Klemow and Mohsehi (K. Klemow and M. Mohseni pers. comm.) found a very different result in Pennsylvania. They found that 66% of the hydric soil areas were not marked as wetlands on the NWI maps. In addition, 97% of subhydric soil areas, which they described as often being jurisdictional wetlands, and 26% of open water areas were left off NWI maps. The map overlay approach has been criticized because of the lack of field verification for either source and the difference between hydric soil and NWI wetland designations (Tiner 1997a). Discrepancies between hydric soil mapping and NWI wetland types can be due to the inclusion of up to 40% of a nonhydric soil within a hydric soil mapping unit. In addition, soil maps generally do not distinguish between undrained hydric soils and drained or recently filled hydric soils (Tiner 1997a). Reasons for differences also include the fact that most somewhat poorly drained soils are not jurisdictional wetlands and that drier wetlands are difficult to photointerpret and are mapped conservatively by the NWI (Tiner 1997a).

Other evaluation methods, however, have included field verification. Swartwout et al. (1981) used this technique and found NWI maps to be very accurate, over 95% correct, in differentiating wetland and upland types. A similar accuracy level was determined in Vermont (Crowley et al. 1988) and Maine (Nichols 1994). In Virginia, Stolt and Baker (1995) found that 91% of palustrine wetlands identified on NWI maps met the criteria as a jurisdictional wetland. In evaluating the effectiveness of the NWI maps to inventory all the jurisdictional wetlands, they found that the NWI often underestimated the size of wetlands; most wetlands in this area were linear features along watercourses and difficult to delineate accurately. Small wetlands with forest cover were often missed entirely. Some of the wetlands identified were below the mmu size recognized on the NWI maps. Small wetlands and those obscured by dense forest cover have been recognized by the NWI as problem areas with a printed disclaimer on each NWI map.

The ability of the NWI to accurately identify wetlands depends on the landforms involved. The published verification studies all occurred in predominantly upland landscapes located in the eastern United States (Swartwout et al. 1981, Crowley et al. 1988, Nichols 1994, Stolt and Baker 1995, K. Klemow and M. Mohseni pers. comm.) with one midwestern exception in Nebraska (Kuzila et al. 1991). No verification studies have been reported for the wetland-rich upper Great Lakes area. The objective of our study was to evaluate how well the NWI identified jurisdictional wetlands in a landscape dominated by forested wetlands, the most difficult wetland type to identify from aerial photographs (Dahl 1992). The predominant landform is a low and level glacial lake plain with upland–wetland boundaries that are difficult to accurately photointerpret (National Research Council 1995). The study area is mostly coniferous wetlands, recognized as a difficult cover type to accurately photointerpret because of year-round canopy retention preventing the observation of saturated soils (Tiner 1990). This cover type is often similar to adjacent uplands, presenting another difficulty to the photointerpreter. Plot data from the Hiawatha National Forest ecosystem mapping and inventory program were used to evaluate NWI data. Since wetland boundaries need to be field-verified for jurisdictional purposes, this study focused on evaluating what the NWI attempts to achieve: an inventory of wetlands at a scale and level of detail achievable with the remote sensing methods used.

STUDY AREA

The Hiawatha National Forest is about 400,000 ha in area and is located in the eastern half of the Upper Peninsula of Michigan. The Forest is divided into two separate units, an eastern half and western half. All of the work for this study was completed in the western half (Figure 1). A regional landscape ecosystem classification (Albert 1995) places this area in two ecological sub-subsections. Most of the study area is the Seney sand lake plain sub-subsection with landforms of lacustrine origin containing the largest expanse of wetlands in Michigan (Albert 1995). It is further characterized as having very poorly or excessively drained sand lake plains, transverse dunes, outwash with shallow paludified peatlands (many patterned), jack pine barrens, and hardwood-conifer and conifer swamps (Albert 1995). The Grand Marais sandy end moraine and outwash sub-subsection contains the rest of the study area. Albert (1995) describes this landscape as having sandy end-moraine ridges and outwash aprons, Lake Superior shoreline features, transverse dunes,

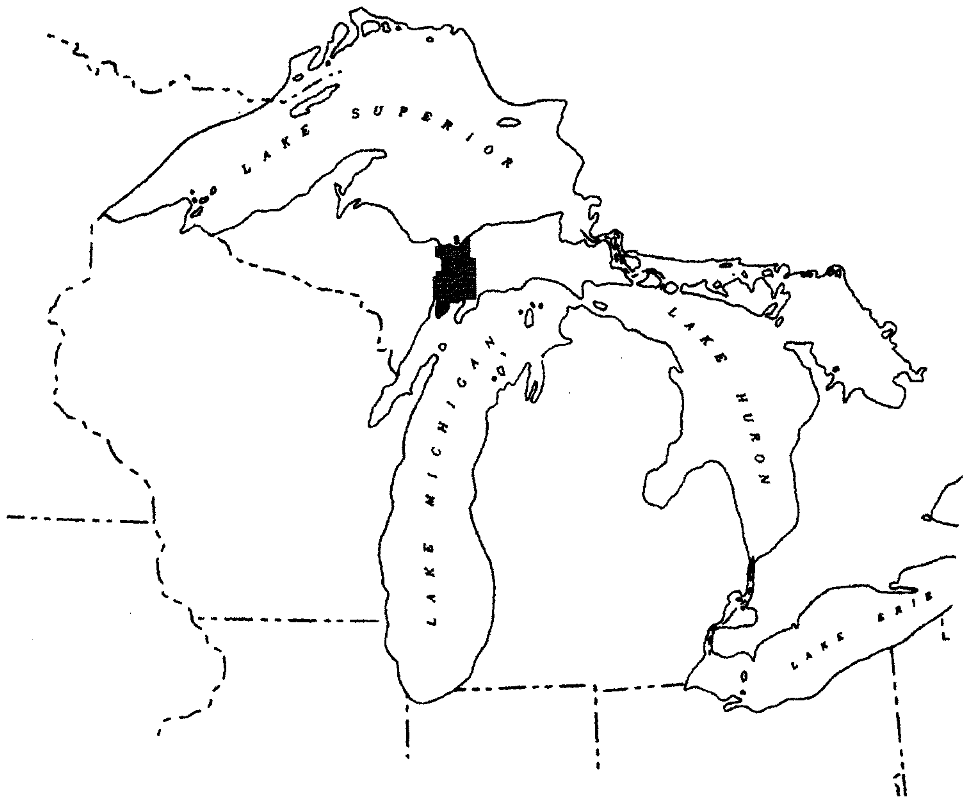

Figure 1. Location of the study area in the Upper Peninsula of Michigan, USA.

sand spits with white pine-red pine forests, jack pine barrens, red pine forests, northern hardwood forest, and patterned peatlands. Forested, conifer-dominated wetlands are the most common wetland vegetation type; mixed conifer-deciduous forested wetlands are also widespread.

Histosols composed of incompletely decayed organic material are common wetland soils in the lowest parts of topographic depressions. At the edges of organic filled basins, the soils typically transition into mineral soils, Entic or Typic Haplaquods, which are wet Spodosols with an iron, aluminum and humus-enriched B horizon. Entic and Typic Haplorthods are the most common upland soils. Some of the area has Aquic Eutroboralfs soils, formed in fine-textured lacustrine deposits.

Table 1. Hiawatha National Forest ecosystem classification summary at the landtype level. Included are wetland and near-wetland types.

Landtype	Criteria for Inclusion	Jurisdictional Wetland?
Landtype 60	Water table or soil redoxyimorphic features >60 cm and <100 cm	No
Landtype 70	Water table or soil redoxyimorphic features <60 cm, soil organic horizon <30 cm	Variable
Landtype 80	Soil organic horizon ≥30 cm	Yes

METHODS

Field work was conducted during a 1994 ecological classification and inventory (ECI) program that mapped approximately 20,000 ha in the Hiawatha National Forest. The ECI data included information on soil organic depth, depth to water table, depth to redoxymorphic features, and vegetation composition. ECI types were determined with a key based on water chemistry, depth to water table and soil and vegetation indicators (Kudray 1995). Previous mapping had occurred prior to the development of the ECI wetland classification (Kudray 1995), with wetland and upland types based on U.S. Department of Agriculture (USDA) soil taxonomy drainage classes. To maintain consistency with the earlier mapping, the same criteria were used in the 1994 mapping. Upland types were identified through the location of redoximorphic features or water tables at least 60 cm or deeper in the soil profile. Two main wetland groups, called landtypes, were recognized (Table 1). Landtype 80 included

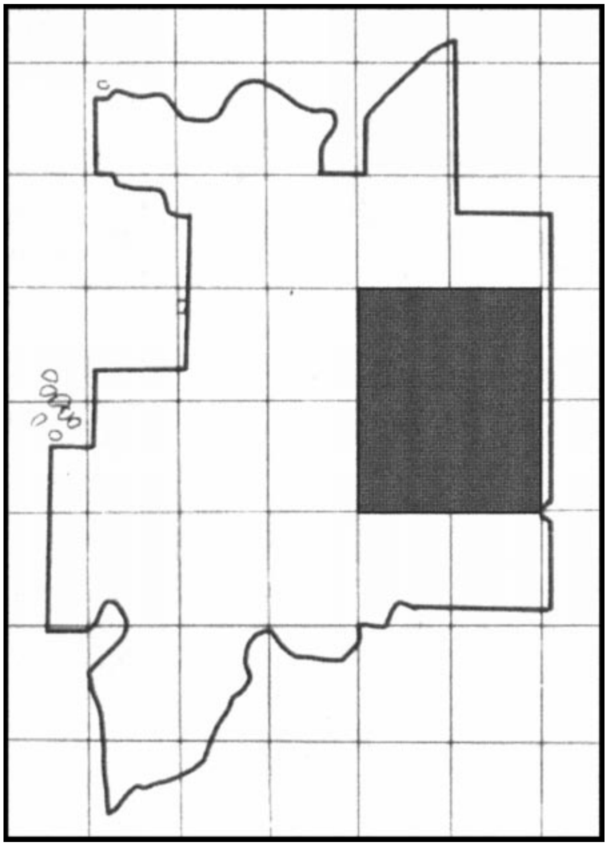

Figure 2. Location of the NWI maps (Steuben SW, Steuben NW, Corner Lk. NE. and Corner Lk. SE quadrangles) that contained the study plots within the western half of the Hiawatha National Forest, Michigan, USA.

all wetlands with an organic soil depth 30 cm or greater. Landtype 70 included all other types with a water table or soil redoxymorphic features shallower than 60 cm. Landtype 70 could then be either a jurisdictional wetland (Environmental Laboratory 1987) or an upland.

Plot location Universal Transverse Mercator (UTM) coordinates were recorded in the field using a Trimble Pathfinder Basic Global Positioning System (GPS) receiver. The data were post-processed using differential correction software to maximize locational accuracy to a probable accuracy level of a few meters. Plots were marked on CIR aerial photographs. Plot UTM coordinates were plotted manually on NWI draft 1:24,000 scale maps and coded with either a NWI wetland type designation or as upland. The NWI maps evaluated were the Steuben SE, Steuben NW, Corner Lk. NE, and Corner Lk. NW quadrangles (Figure 2). Although final versions of the NWI maps became available during the project, there were no differences between the draft and final versions. A total of 148 plots comprised this data set.

For each plot, the NWI type was compared to the ECI Landtype. If the plot was coded upland for both systems, the NWI map was considered correct for that plot. If a plot was coded as Landtype 80 and also coded as a NWI wetland, the NWI map was considered correct for that plot. Since Landtype 70 plots could be either jurisdictional wetlands (Environmental Laboratory 1987) or uplands, these plots were identified as needing further review. Other plots with ECI–NWI coding that did not agree as to wetland–upland typing were also identified as needing further review.

Questionable plots were further reviewed by relocating these plots on NWI maps. Five plots were located within 100 m of a wetland–upland boundary and removed from the analysis since the objective was not to evaluate fine resolution jurisdictional wetland boundaries. The methods used were intended to capture broader scale NWI type misclassifications. The plots were then examined using the ECI data, CIR photos, and the local USDA soil survey (Berndt 1977). If the ECI data and the soil survey clearly indicated that the plot was a wetland or an upland, no additional field visit was made. If the data were considered ambiguous, the plot was revisited.

The nine plots that needed to be reexamined on the ground were relocated by using the GPS and aerial photographs. A routine wetland determination procedure (Environmental Laboratory 1987) was then conducted to determine if the plot met the jurisdictional wetland requirement. This determination procedure consists of a stepwise evaluation of wetland indicators. If hydrophytic vegetation is not dominant, the area is not a wetland. If the vegetation is inconclusive, further steps evaluating the presence of wetland hydrology and hydric soils are undertaken. All wetland indicators were recorded during our evaluation.

RESULTS AND DISCUSSION

Of the 143 plots in the final data set, seven (5%) were considered misclassified by the NWI based on field verification through the Hiawatha National Forest ecosystem mapping and additional review (Table 2). Jurisdictional wetlands were correctly identified on NWI maps at 93.7% of the sampled points. A high level of accuracy was also achieved in differentiating uplands from wetlands; only 2 of 64 (3.1%) NWI-mapped upland points were true jurisdictional wetlands. All nonforested wetlands were correctly identified. The lowest level of accuracy was achieved in identifying forested wetlands; however, they were correctly identified at an accuracy rate of 90.7%. The misclassified polygons were substantially larger in size than the NWI target mmu size, which is .4 to 1.2 ha for this region (Tiner 1997b). Tiner (1997a) states that NWI maps tend to err more by omission than com-

Table 2. Classification matrix comparing NWI maps to jurisdictional wetlands identified through Hiawatha National Forest ECI mapping and additional review.

NWI Category	Number of Plots Sampled	Number Correct	Percent Correct
All	143	136	95.1
Upland	64	62	96.9
Wetland	79	74	93.7
Forested wetland*	54	49	90.7
Non-forested wetland	25	25	100.0

* Forested wetland includes forested and forested/nonforested mixed types.

Table 3. Typing summary of plots misclassified by the NWI based on Hiawatha N.F. ECI mapping and additional review.

NWI type*	SCS mapped soil series	Hydric soil	Wetland Hydrology**	Hydrophytic Vegetation***	Jurisdictional Wetland
Upland	Bruce	Yes	Yes	Yes	Yes
Upland	Roscommon	Yes	Yes	Yes	Yes
PSS/EMB	Au Gres	No	No	Yes	No
PFO4/1Y	Au Gres	No	No	Yes	No
PFO4/1Y	Au Gres	No	No	No	No
PFO4B	Au Gres	No	No	No	No
PFO4/1B	Tawas	Yes	No	Yes	No

* PSS/EMB = Palustrine Scrub/Shrub–Emergent Saturated. PFO4/1Y = Palustrine Forested Needle-Leaved Evergreen–Broad-Leaved Deciduous Saturated Semipermanent. PFO4B = Palustrine Forested Needle-Leaved Evergreen Saturated. PFO4/1B = Palustrine Forested Needle-Leaved Evergreen–Broad-Leaved Deciduous Saturated.
** Wetland hydrology based on visual observation of soil saturation within 30 cm.
*** Hydrophytic vegetation is present if more than 50% of the dominant species in the trees, sapling/shrub, herb vegetation layers have an indicator status of OBL, FACW, and/or FAC. Wetland indicator status if from the North Central region of the national list of plant species that occur in wetlands: 1996 national summary (Reed 1997).

mission: a conservative approach indicating that areas mapped as wetlands are usually true wetlands. A more common error would then involve the omission of true wetlands. That was not the case here, although the error rate was still quite low. These misclassifications represent more inclusive mapping of uplands or upland-wetland complexes as wetlands by the NWI.

NWI misclassification errors fell into two types: 1) somewhat poorly drained uplands with a mixed conifer-deciduous forest cover similar to nearby wetlands and 2) wetlands with an unusual cover type more similar to uplands than the majority of forested wetlands in the area. The first error type was the most common, occurring in 71% of the misclassified plots. Most of these were on the same somewhat poorly drained but nonhydric (U.S. Department of Agriculture Soil Conservation Service 1993) Au Gres soil type (Table 3). Au Gres soils are sandy mixed, frigid Entic Endoaquods: somewhat poorly drained sandy soils characterized by a leached gray albic horizon over a dark reddish-brown spodic horizon.

The wetland plots that were misidentified by the NWI as uplands were both large (>50 ha) species-rich forested wetlands with a tree cover dominated by aspen (*Populus* spp.) with a substantial conifer component. This is a cover type similar to the surrounding uplands and much less common in the study area than conifer-dominated forested wetlands. These plots were clearly wetlands and probably misinterpreted as uplands on aerial photographs due to the similarity of the cover type to the surrounding upland types. The correct NWI type for these polygons should have been PFO1/4B, Palustrine Forested Broad-leaved Deciduous–Needle-leaved Evergreen Saturated.

Of the five upland plots misidentified as wetlands, one was a small (6 ha) upland ridge in a predominant wetland matrix mapped as an Au Gres soil type (Berndt 1977) but field-verified during ECI mapping as a Croswell series, (topographically a slightly higher soil). The remaining four were larger (>12 ha) areas of somewhat poorly drained soils, three mapped as Au Gres soil types and one incorrectly mapped as a hydric organic soil (Berndt 1977). The correct NRCS soil type based on the ground truth would also have been an Au Gres soil. The forested cover type on all these plots was similar to adjacent wetlands. The NWI mapped four of these areas as palustrine forested needle-leaved evergreen dominated wetlands. The fifth was mapped as a scrub/shrub–emergent, a misinterpretation due to young tree regrowth after a recent timber harvest on the site.

With one exception, the existing soil survey (Berndt 1977) correctly identified the misclassified plots as a hydric or nonhydric soil. While the NWI relies heavily on soil surveys and reports for ground-truth information (Dahl 1993), Tiner (1997b) cautions that hydric soil mapping in soil surveys cannot be directly compared with NWI map units. He suggests that the mapping of hydric soils on survey maps may tend to overestimate the occurrence of wetlands for several reasons, including nonhydric inclusions and soil series that were not designed to strictly adhere to the definition of a hydric soil. The Au Gres soil series that was most commonly incorrectly mapped as wetland by the NWI is a somewhat poorly drained soil that is now often mapped in Upper Peninsula of Michigan soil surveys in complexes with hydric soils (L. Carey, pers. comm.). In this area with subtle topographic changes, wetlands often occur in complexes with uplands and cannot be accurately mapped exclusively as upland or wetland. As a future option, Tiner (1997b) suggests that the NWI could map some areas as ''potentially supporting some wetlands.'' This approach could be usefully applied to regions with landforms similar to our study area. The increased mapping of hydric-nonhydric soil complexes in soil surveys is a corresponding development.

The procedure used to determine wetland/upland identity in this study is the current federal jurisdictional wetland definition (Environmental Laboratory 1987), which is more restrictive and requires more proof than other current or proposed wetland definitions (e.g., Cowardin et al. 1979, Federal Interagency Committee for Wetland Delineation 1989). The primary difference between the current federal jurisdictional wetland definition and the USFWS definition (Cowardin et al. 1979) is that a USFWS wetland can be identified with a positive indicator for any one of the three vegetation, soil, or hydrology parameters, while all parameters must be positive to identify a jurisdictional wetland.

Since the NWI was never intended to directly map jurisdictional wetlands and jurisdictional definitions change over time, the characteristics of the upland plots misclassified as wetlands were further examined. Many wetland definitions require hydrophytic vegetation; three of the misclassified plots had hydrophytic vegetation but lacked hydric soils or wetland hydrology. It can be expected that in the continuum of ecosystems, some may have one wetland factor and lack others, but a further examination of the vegetation data suggested that local variability in the indicator status of wetland plants could be considered as the cause. For example, in the North Central region, balsam fir (*Abies balsamea* (L.) P. Mill.) has an indicator status of FACW—facultative wetland, usually occurring in wetlands (estimated probability 67%− 99%) but occasionally found in non-wetlands (Reed 1997). A review of the Hiawatha N.F. ECI database indicated that the species is just as likely to occur in uplands. Of the 1466 plots in the ECI database that could be considered wetlands based on soil or hydrologic characteristics, balsam fir was found in 56%, but it also occurred in 71% of 1258 upland plots. Some other species commonly found also differed from the regional list in wetland indicator status. This finding confirms the National Research Council (1995) recommendation to continue the refinement of regional hydrophytic vegetation lists and to rely on other indicators when the vegetation community is near a hydrophytic–nonhydrophytic threshold.

The characteristics of this study area make it a particularly difficult landscape to accurately photointerpret wetland types. Much of the area is a lacustrine plain with forested wetlands on subtle topography. The National Research Council (1995) reported that ''mapping wetlands in level landscapes, such as coastal or glaciolacustrine plains, is less precise because boundaries are not as evident.'' Dahl (1992) considers forested wetlands the most difficult wetland type to identify from aerial photographs. Additionally, the dominant wetland type in the study area, evergreen forested wetland, is among the most difficult forested wetlands to identify due to canopy retention (Tiner 1990). This cover type occurs both in the wetland areas and the surrounding uplands, a situation recognized by Tiner (1990) to represent the biggest problem in detecting forested wetlands. Despite these difficulties, the high level of NWI classification accuracy in our area agrees with studies in other regions (Swartwout et al. 1981, Crowley et al. 1988, Nichols 1994, Stolt and Baker 1995). All of these studies have indicated that NWI maps correctly identify wetlands at an accuracy level of over 90%. Although regional evaluations of NWI maps should continue due to the unique problems each regional landscape presents in the photointerpretation of wetlands, the growing body of evidence supports the ability of NWI maps to accurately identify wetland areas throughout the nation. The only work suggesting that NWI maps do not accurately map wetlands (K. Klemow and M. Mohseni pers. comm.) should be either considered a notable exception in the overall quality of NWI maps or reevaluated due to the map-comparison methodology used and the lack of ground-truth verification. NWI maps cannot be evaluated directly with hydric soils areas on soil survey maps for a variety of reasons (Tiner 1997a), but using soil surveys and hydric soils lists to provide additional information can help identify areas that will require a more intensive examination.

Despite the fact that the USFWS wetland definition is an ecological, not a regulatory, definition and that the NWI maps do not directly define jurisdictional wetlands, it is obvious that NWI maps are used as tools in many activities that do involve regulated wetlands. It is important to know how accurately NWI maps identify and delineate wetlands regulated by the federal definition (Environmental Laboratory 1987) but only with the realization that the NWI program goal is neither to set absolute boundaries on regulated wetlands nor to map wetlands smaller than their minimum target size. Final regulatory wetland identification and delineation must remain an on-the-ground activity. Since small wetlands less than the current NWI mmu unit size of about .5 ha (Tiner 1990) are not within the scale of NWI mapping, an accuracy assessment using no minimum size criterion is informational but not a valid criticism of NWI products. A more appropriate question is how accurately the NWI identifies wetlands within its operational limits and across varying regions, landforms, soils, and cover types.

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