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Field Testing New Plot Designs and Methods for Determining Hydrophytic Vegetation during Wetland Delineations in the United States

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Abstract

Recommendations made by the National Technical Committee on Wetland Vegetation (NTCWV) for vegetation sampling and for assessing hydrophytic vegetation were tested for possible inclusion in the update of the Army Corps of Engineers Wetland Delineation Manual. A new method, the Hydrophytic Cover Index (HCI), was used to determine if vegetation was hydrophytic. Plot shape and size, rectangular (10 × 2 m) vs. nested circular (9 m and 2 m radii used in the Corps 1987 Manual), were tested for differences in hydrophytic vegetation outcomes. HCI determinations produced from calculations using 100%, 90%, and 80% of the total cover in each plot were also tested for differences. Differences in plot size or shape had no effect on the percentage of hydrophytic vegetation determinations produced by the HCI. Calculating the HCI using 100%, 90%, and 80% of the total cover in delineation plots also had no effect on the outcome. Therefore, to determine if hydrophytic vegetation is present, it is not necessary to identify more than 80% of the total cover to the species level. To apply the 80% approach, the NTCWV suggests ranking the species cover in descending order and selecting the 20% from the least common species in the plot. Once 80% of the total cover in a plot has been positively identified, the remaining cover may be disregarded. If the 80% approach determines that the vegetation is nonhydrophytic (≤50%) but hydric soil and wetland hydrology indicators are present, Chapter Five in the appropriate Regional Supplement should be consulted to determine if problematic vegetation is present (e.g., USACE 2007).

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Preface

This research was funded by the Wetlands Regulatory Assistance Program (WRAP) of the US Army Corps of Engineers. Walter Ochs provided the initial idea for evaluating the 80% approach based on differences in the standard deviation. Christy Everett and Jim Godswire provided assistance in selecting sites to collect the CRREL data. Bruce Allen, Lindsey Lefevbre, Walter Ochs, Corinna Photos, Bill Sipple, and Melissa Tarasiewicz provided valuable assistance with field sampling and plant identification. We thank numerous wetland ecologists from Alaska to the Caribbean for collecting the Regional Supplement (RS) data. Jacob Berkowitz is also thanked for managing and compiling the RS data.

The principal investigators were Robert W. Lichvar and Jennifer J. Gillrich, both of the Remote Sensing/Geographic Information Systems (RS/GIS) and Water Resources Branch, US Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH. This study was conducted under the general supervision of Timothy Pangburn, Chief, RS/GIS and Water Resources Branch; Dr. Justin B. Berman, Chief, Research and Engineering Division; Dr. Lance Hansen, Deputy Director; and Dr. Robert E. Davis, Director.

COL Jeffrey R. Eckstein was the Commander of ERDC, and Dr. Jeffery P. Holland was the Director.

Acronyms and Abbreviations

CRREL	US Army Cold Regions Research and Engineering Laboratory
df	Degrees of Freedom
DR	Dominance Ratio
ERDC	Engineer Research and Development Center
FAC	Facultative
FACU	Facultative Upland
FACW	Facultative Wetland
HCI	Hydrophytic Cover Index
NTCWV	National Technical Committee on Wetland Vegetation
NWPL	National Wetland Plant List
OBL	Obligate
PI	Prevalence Index
RS	Regional Supplement
RS/GIS	Remote Sensing/Geographic Information Systems
UPL	Upland
USACE	US Army Corps of Engineers
WRAP	Wetland Regulatory Assistance Program

1 Introduction

This paper is one of two that describe field testing of proposed wetland delineation techniques for possible inclusion in a revised national manual. Wetland boundary field indicators, derived over the last 26 years through national usage and refinement, were recently updated in the regional supplements to the US Army Corps of Engineers (USACE) Wetland Delineation Manual (hereafter referred to as Regional Supplements) (see USACE 2007–2012 for examples). Similarly, wetland delineation procedures first described in the USACE Wetland Delineation Manual (hereafter the 1987 Manual) (Environmental Laboratory 1987) are now being reviewed and updated for a revised national manual. In support of the update to the 1987 Manual, we tested recommendations made by the National Technical Committee on Wetland Vegetation (NTCWV) regarding plot dimensions and the minimum percentage of vegetation that must be identified to the species level to make an accurate hydrophytic vegetation determination for wetland delineation purposes (NTCWV 2011, 2012). Additionally, the NTCWV has proposed a new method for calculating hydrophytic vegetation: the Hydrophytic Cover Index (HCI). Therefore, we tested the HCI to find out whether changes in plot size or the percentage of areal cover of identified plant species used in the calculation affects determination outcomes.

Since 1987, wetlands have been delineated using methods described in the 1987 Manual and field indicators of three wetland factors: hydrophytic vegetation, hydric soils, and wetland hydrology (Environmental Laboratory 1987). To determine whether hydrophytic vegetation is present, the routine delineation method suggests stratifying vegetation by growth forms of trees, shrubs, herbs, and vines and sampling plant communities by using nested circular plots. Trees and woody vines are sampled in large plots with 9 m (30 ft) radii. Saplings, shrubs, and herbs are sampled in nested smaller plots with 2 m (5 ft) radii. To determine if hydrophytic vegetation is present in plots sampled, either the Prevalence Index (PI) or the Dominance Ratio (DR) has traditionally been used. The 1987 Manual requires that the dominant plants must be identified to the species level to make a vegetation determination (Environmental Laboratory 1987) while the Regional Supplements recommend identifying 80% of the vegetation present to the species level (USACE 2007).

In vegetation sampling, plot dimensions can affect the ability to adequately measure ecological patterns (Wiens 1989), particularly when describing or quantifying plant distribution (Barbour et al. 1999). To measure plant community attributes, there are methods to determine the best plot size and shape for a specific study's purposes. Plot size is typically adjusted based on the objective of the study and the variance across all plots sampled for a specific community (Barbour et al. 1999; Gage and Cooper 2010). For example, herbaceous species may be sampled in 1.0 m^2 plots when the vegetation community is dense and in continuous but larger plots when the vegetation is patchy or sparse. For general vegetation sampling, the literature provides guidelines for selecting plot sizes based on plant growth forms, community structure, and distribution patterns (Cain and de Oliveiro Castro 1959; Knapp 1984; Kent and Coker 1992). Plot shape affects the precision of the data that are collected. Circular plots are often used to sample plants with large growth forms, such as trees, in areas where the vegetation is relatively homogenous (Gage and Cooper 2010). They are less precise than rectangular plots because they tend to include less heterogeneity. Rectangular plots with the longer side parallel to a major environmental gradient are more precise than circular plots in the same setting (Barbour et al. 1999).

The objective of vegetation sampling during wetland delineations is to determine whether hydrophytic vegetation is present at the wetland boundary. The large, circular plots recommended in the 1987 Manual were designed to sample plant communities across a landscape. These plots were coupled with a sampling scheme that used a process of elimination to determine which plots were closest to the wetland boundary based on three factors: hydrophytic vegetation, hydric soils, and wetland hydrology. At the wetland boundary, large circular plots can be problematic because they encompass vegetation growing up to 18 m (60 ft) away from the actual boundary in areas that may be obvious upland or obvious wetland. The NTCWV proposed replacing the large circular plots designed to sample vegetation at the wetland boundary with rectangular 10 × 2 m (33 × 7 ft) plots. These long linear plots, located adjacent and parallel to an environmental gradient, provide a more precise representation of vegetation at the wetland boundary (Barbour et al. 1999).

During wetland delineations, vegetation determinations are made using the abundance of species in a plot, their wetland indicator status ratings from the National Wetland Plant List (NWPL), and a calculation method.

The year and the version of the NWPL are cited whenever wetland ratings are used because ratings and nomenclature may change with periodic updates. Although wetland indicator status ratings were originally based on the concept of five categories of numerical frequency values (Reed 1988), they have evolved into qualitative descriptions of how often a plant species occurs in wetlands (Lichvar and Minkin 2008; Lichvar and Gillrich 2011; Lichvar et al. 2012). Wetland ratings are determined based on the literature and the field experiences of botanists and wetland ecologists. Plants are rated in five categories that range from Obligate (OBL) to Upland (UPL) (Table 1). Plant species that are not listed on the NWPL are considered UPL.

Table 1. Short qualitative descriptions of the five wetland indicator status ratings used on the National Wetland Plant List.

Designation	Indicator status rating (abbreviation)	Indicator value	Qualitative description (Lichvar et al. 2012)
Hydrophyte	Obligate (OBL)	1	Almost always occur in wetlands.
Hydrophyte	Facultative Wetland (FACW)	2	Usually occur in wetlands, but may occur in non-wetlands.
Hydrophyte	Facultative (FAC)	3	Occur in wetlands and nonwetlands.
Nonhydrophyte	Facultative Upland (FACU)	4	Usually occur in nonwetlands, but may occur in wetlands.
Nonhydrophyte	Upland (UPL)	5	Almost never occur in wetlands.

Two methods, the DR and PI, have traditionally been used to calculate whether hydrophytic vegetation is present in delineation plots, but these methods have been shown to be problematic. The two methods have been the subject of much research because determinations made by the DR and the PI disagree with each other from 16% to 54% of the time (Wakeley et al. 1996; Wakeley and Lichvar 1997; Dewey et al. 2006). Explanations for the highly variable determinations produced by the DR include an odd-hydrophytic/even-nonhydrophytic bias based on the number of dominant species in a plot (Lichvar et al. 2011), the use of strata to pick dominants (Lichvar et al. 2011), and the excessive influence exerted by dominants from low-cover strata in plots containing borderline hydrophytic/nonhydrophytic vegetation (Gillrich et al. 2011). Field data and vegetation simulations show that the PI produces incorrect vegetation determinations 12% (Lichvar and Gillrich 2014) to 14% (R. Lichvar and J. Gillrich, unpublished data) of the time because it assigns nonhydrophytes (FACU and UPL species) larger weighted indicator values (Table 1) than hydrophytes (FAC, FACW, and OBL species), and it mathematically skews the outcome to nonhydrophytic. Most (97% in delineation data and 89% in simulations) of the PI's incorrect vegetation determinations were nonhydrophytic determinations made in plots where more than 50% of the cover was hydrophytic. These discrepancies between the PI and the DR highlight the need for a more precise vegetation assessment method.

In 2012, the NTCWV recommended the HCI as a new method for determining hydrophytic vegetation (NTCWV 2012). The HCI has its origin in the basic vegetation rule described in the 1987 Manual, which states that vegetation is hydrophytic when greater than 50% of the dominant plant species are FAC, FACW, or OBL (Environmental Laboratory 1987). The HCI is calculated by dividing the percent areal cover of the hydrophytes (species rated FAC, FACW, or OBL) by the total cover of all species in the plot. Recent research using data collected along wetland boundaries in nine Corps regions during testing of the Regional Supplements (Berkowitz 2011) shows that the HCI is consistent and accurate, producing hydrophytic vegetation determinations only in plots where hydrophytes compose greater than 50.0% of the vegetative cover. No hydrophytic determinations were made in plots where hydrophytes composed less than or equal to 50.0% of the vegetative cover (Lichvar and Gillrich 2014).

Ideally, all plants in a plot should be identified to the species level so that their assigned wetland indicator status and cover values contribute to the vegetation determination. However, the number of plant species that can be identified during delineations is limited by many factors, including, but not limited to, time constraints; lack of flowers or fruit; or extreme disturbance, such as mowing or wildfires. Therefore, Regional Supplements require that 80.0% of the vegetation in a plot be correctly identified to the species level to make a hydrophytic vegetation determination (USACE 2010a). The 80.0% value was developed in 2005 (R. Lichvar and W. Ochs, unpublished data) by analyzing a national set of wetland delineation data and testing various cut-off percentages to find values that did not change the outcome. The analysis determined that using 80%, or one standard deviation of the total cover present, changed the percentage of hydrophytic vegetation in a plot, but it did not change the outcome of vegetation determinations made by the DR and the PI. The NTCWV recommended formal testing of the 80% approach to determine if calculating the HCI using 80% or 90% (instead of 100%) of the total cover affects the outcome of vegetation determinations.

In our study, we had three objectives. The first was to determine if the outcomes of HCI determinations are affected by the proposed changes to plot shape and size at the wetland boundary. To meet this objective, we tested the hypothesis that there is no significant difference in the percentage of hydrophytic vegetation determinations produced by the HCI using percent areal cover data collected in rectangular boundary plots (10 × 2 m) and in nested circular plots (with 9 m and 2 m radii). The second objective was to determine if using 80% or 90% (instead of 100%) of the total cover in a plot to calculate the HCI affects the outcome of vegetation determinations. To meet the second objective, we tested two hypotheses. First, there is no significant difference in the percentage of hydrophytic vegetation determinations produced when the HCI is calculated using 100%, 90%, or 80% of the total cover collected in rectangular boundary plots (10 × 2 m). Second, when the HCI is calculated using 100%, 90%, or 80% of the total cover collected in nested circular plots (with 9 m and 2 m radii), there is no significant difference in (a) the variance among the three groups of HCI determinations or (b) the percentage of hydrophytic vegetation determinations produced. Our last objective was to explore how the use of 80% or 90% (instead of 100%) of the total cover in HCI calculations might affect the outcome of wetland delineations for regulatory purposes. (For a comparison of the HCI, the DR, and the PI, see Lichvar and Gillrich [2014].)

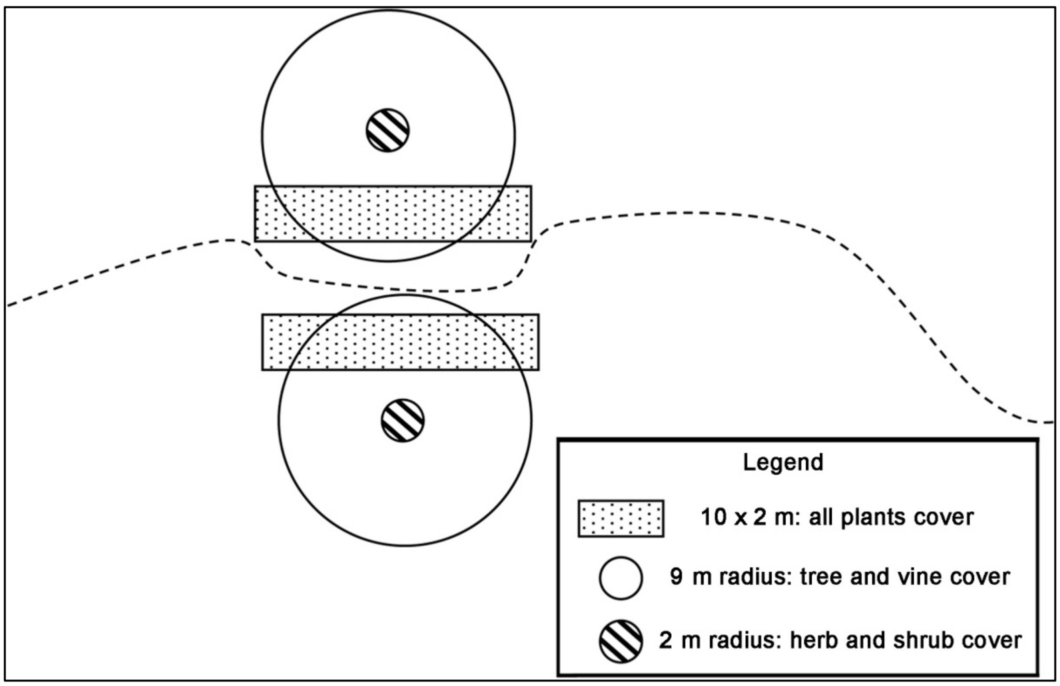
2 Field Methods

To test these hypotheses, we used two data sets. Data collected by the Cold Regions Research and Engineering Laboratory (CRREL) (hereafter CRREL data) were used to test the first two hypotheses regarding nested circular vs. rectangular plots and HCI determinations made based on 100%, 90%, or 80% of the total cover in rectangular plots. A data set collected in nine Corps regions during the Regional Supplement testing (hereafter RS data) was also used because it was very large and covered an extensive geographic area. The RS data were used to test the third hypothesis regarding variation among HCI determinations and the percentage of hydrophytic vegetation determinations made based on 100%, 90%, or 80% of the total cover in nested circular plots. These data were also used to explore our third objective regarding the effect of HCI determinations on wetland delineation outcomes when the HCI calculations were made using 100%, 90%, or 80% of the total cover in a plot.

The CRREL data (n = 66) were collected in 2012 in three Corps regions in three vegetation types: forested, scrub-shrub, and herbaceous meadow. In the Northcentral–Northeast region, data were collected in a total of 24 plots in Salisbury and Enfield, NH, and Norwich and Rochester, VT. In the Western Mountains, Valleys, and Coast region, data were collected in 18 plots near Corvallis, OR. In the Alaska region, data were collected in 24 plots near Fairbanks.

Vegetation near wetland boundaries was sampled in circular plots according to the routine delineation method described in the 1987 Manual (Environmental Laboratory 1987) and in rectangular plots according to the boundary plot method recommended by the NTCWV (Figure 1). For both methods, the abundance of all plant species in each plot was estimated using absolute percent areal cover. To sample vegetation by using the routine delineation method, percent areal cover was estimated by vegetative strata for all trees and woody vines in 9 m (30 ft) radius plots and saplings, shrubs, and herbaceous species in 2 m (5 ft) radius plots. In herbaceous meadows, only the 2 m (5 ft) radius plots were used because trees and vines were not present. In contrast, the boundary plot method uses a strata-less approach to estimate areal cover by species. Each species has the potential to have a cover value up to 100% within the plot. This includes areal cover estimates for all plant species that had stems in or were overhanging a linear 10 × 2 m (33 × 7 ft) plot. The botanical nomenclature follows Kartesz (2009). Wetland indicator status ratings are from the NWPL 2012 (Lichvar 2012).

Figure 1. Example of the plot arrangement for sampling forested and scrub-shrub vegetation types by using the routine method described in the USACE Wetland Delineation Manual (Environmental Laboratory 1987) and the boundary plot method recommended by the NTCWV. The dashed line represents the wetland boundary.



We determined the location of wetland boundaries by the presence of hydrophytic vegetation, hydric soil indicators, and wetland hydrology indicators as described in the 1987 Manual and in the appropriate Regional Supplement (Environmental Laboratory 1987; USACE 2007, 2010a, 2011). Using the information in the appropriate Regional Supplement, we documented the presence of hydric soils and wetland hydrology indicators for each plot. A Munsell Soil Color Chart was used to describe the hue, value, and chroma of each soil layer when appropriate (Gretag/Macbeth 2000) and to determine if hydric soil indicators as described in the appropriate Regional Supplement were present.

The RS data (n = 637) were collected between 2004 and 2009 during the testing of the Regional Supplements. Teams of wetland resource professionals representing USACE, the Environmental Protection Agency, the US Fish and Wildlife Service, the Natural Resources Conservation Service, and state and local agencies collected data in nine Corps regions, from the Caribbean to Alaska. Most of the data were collected along freshwater, nontidal, wetland boundaries in either forested or meadow plant communities. Saline and tidal wetlands are represented in the data less frequently. Using procedures described in the 1987 Manual and in the appropriate Regional Supplement, the regional teams collected vegetation data at 232 sites. At each site, plots were located on either side of the wetland boundary or along a wetland-to-upland transect. Most often, nested circular plots with 9 m (30 ft) and 2 m (5 ft) radii were used to collect percent areal cover data. Occasionally, herb cover was collected in nested 1 m^2 plots as described in the appropriate Regional Supplement (e.g., USACE 2012a). Vegetation was identified to species, and wetland indicator status ratings were assigned according to the National List of Plant Species that Occur in Wetlands (Reed 1988). Plots were not used if the percent cover was not recorded or if more than 20% of the vegetation was not identified to species. For more information on these data, see Berkowitz (2011).

3 Data Analysis

To test the first hypothesis regarding plot shape, we made vegetation determinations using wetland ratings, the CRREL percent areal cover data from the nested circular (n = 33) and rectangular (n = 33) plots, and the following equation for the HCI:

$$HCI = (S_{obl} + S_{facw} + S_{fac}) / (S_{obl} + S_{facw} + S_{fac} + S_{facu} + S_{upl}) \times 100$$

where *S* is the summed percent areal cover. Plots in which the cover of species rated FAC, FACW, and OBL was greater than 50% of the total cover were determined to contain hydrophytic vegetation. Plots in which the cover of species rated FAC, FACW, and OBL was less than or equal to 50% of the total cover were determined to contain nonhydrophytic vegetation. Pearson chi-square tests and SYSTAT 12 software (SYSTAT 2007) were used to determine if the HCI produced different percentages of hydrophytic vegetation determinations in the circular and the rectangular plots.

To test the second hypothesis regarding HCI determinations made from calculations based on 100%, 90%, and 80% of the total cover in rectangular boundary plots, we made three sets of calculations using the CRREL data (n = 33). In the first set, the HCI was calculated using 100% of the cover data in each of the 33 plots. In the second set, 10% of the total cover in each plot was randomly selected and removed using a random number generator and an Excel spreadsheet. The remaining 90% of the total cover was used to calculate the HCI in each of the 33 plots. In the third set of calculations, 20% of the total cover in each plot was randomly selected and removed. The remaining 80% of the total cover was used to calculate the HCI in each of the 33 plots. Pearson chi-square tests were used to test for differences in the percentage of hydrophytic vegetation determinations produced when the HCI was calculated based on 100%, 90%, and 80% of the total cover in a plot.

To test the third hypothesis regarding HCI determinations made from calculations based on 100%, 90%, and 80% of the total cover in nested circular plots, we used the RS data (n = 637) and the previously described procedure to make three sets of calculations. Histograms and descriptive statistics were used to examine the distribution of HCI determinations when the HCI was calculated based on 100%, 90%, and 80% of the total cover in a plot. Levene's test, a test of the homogeneity of variance, was used to determine if the variance among these three groups of HCI determinations differed significantly. Pearson chi-square tests were used to determine if the HCI produced different percentages of hydrophytic vegetation determinations when it was calculated based on 100%, 90%, and 80% of the total cover in a plot.

To explore the effect of HCI determinations on wetland delineation outcomes when calculations were made using 100%, 90%, or 80% of the total cover in a plot, we examined characteristics of two types of plots. The first type consisted of plots in which the outcome of vegetation determinations (nonhydrophytic or hydrophytic) produced when the HCI was calculated using 100% cover conflicted with the outcome produced when the HCI was calculated using 90% or 80% of the total cover. The second type consisted of plots in which vegetation was nonhydrophytic when the HCI was calculated using 80% of the total cover. Characteristics examined included HCI values, wetland ratings of the most abundant plant species (Reed 1988), and the presence or absence of hydric soil and wetland hydrology indicators.

4 Results

With regard to plot dimensions, the CRREL data suggest that there was no significant difference between the percentages of hydrophytic determinations produced from cover data collected in circular (70%) and rectangular (82%) plots (Table 2). The p-value (hereafter p) of 0.25 showed that there was little evidence against the null hypothesis. Likewise, there were no significant differences among the percentages of hydrophytic determinations produced (82%, 79%, and 82%) when 100%, 90%, or 80% of the total cover in the rectangular boundary plots was used to calculate the HCI ($p = 0.94$).

Table 2. Results of Pearson chi-square tests comparing the percentage of hydrophytic vegetation determinations produced by the Hydrophytic Cover Index (HCI) when using the CRREL data collected in three Corps regions. df represents degrees of freedom. X^2 is the chi-squared test statistic.

Hypotheses 1 and 2 tested using CRREL data	Circular plots	Rectangular plots			n	df	Test statistic	p-value
	100% cover	100% cover	90% cover	80% cover				
$\%Hydrophytic_{rectangular} = \%Hydrophytic_{circular}$	70	82	na*	na	66	1	$\chi^2 = 1.32$	0.25
$\%Hydrophytic_{100\%\ cover} = \%Hydrophytic_{90\%\ cover} = \%Hydrophytic_{80\%\ cover}$ in rectangular plots	na	82	79	82	33	2	$\chi^2 = 0.13$	0.94

* na = not applicable.

Histograms and statistics describing the RS data showed that there were very few differences among HCI determinations when 100%, 90%, or 80% of the total cover in a plot was used in the calculations. Vegetation in most (485–490) plots was strongly hydrophytic (≥61%) regardless of the percentage of cover used to calculate the HCI (Figure 2; Table 3). Accordingly, statistics showed that the distribution of HCI determinations were skewed left (−1) regardless of the percentage of cover used to calculate the HCI. When HCI calculations were based on 100% cover, the standard deviation among the 637 determinations was 30 (Table 3), and the variance was 915 (Table 4). When HCI calculations were based on 90% and 80% of the total cover data, the standard deviation increased slightly to 31 and 32, and the variance increased to 973 and 1011, respectively. However, increases in the variance were not significant ($p = 0.97$). The RS data also suggested that there was no significant difference in the percentage of hydrophytic determinations produced by the HCI (80% and 81%) in nested circular plots when the HCI was calculated using 100%, 90%, or 80% of the total cover ($p = 1.00$).

Table 3. Statistics describing the distribution of Hydrophytic Cover Index (HCI) determinations when the HCI is calculated using 100%, 90%, and 80% of the total cover in a plot from RS data collected in nine Corps regions (n = 637) (Berkowitz 2011).

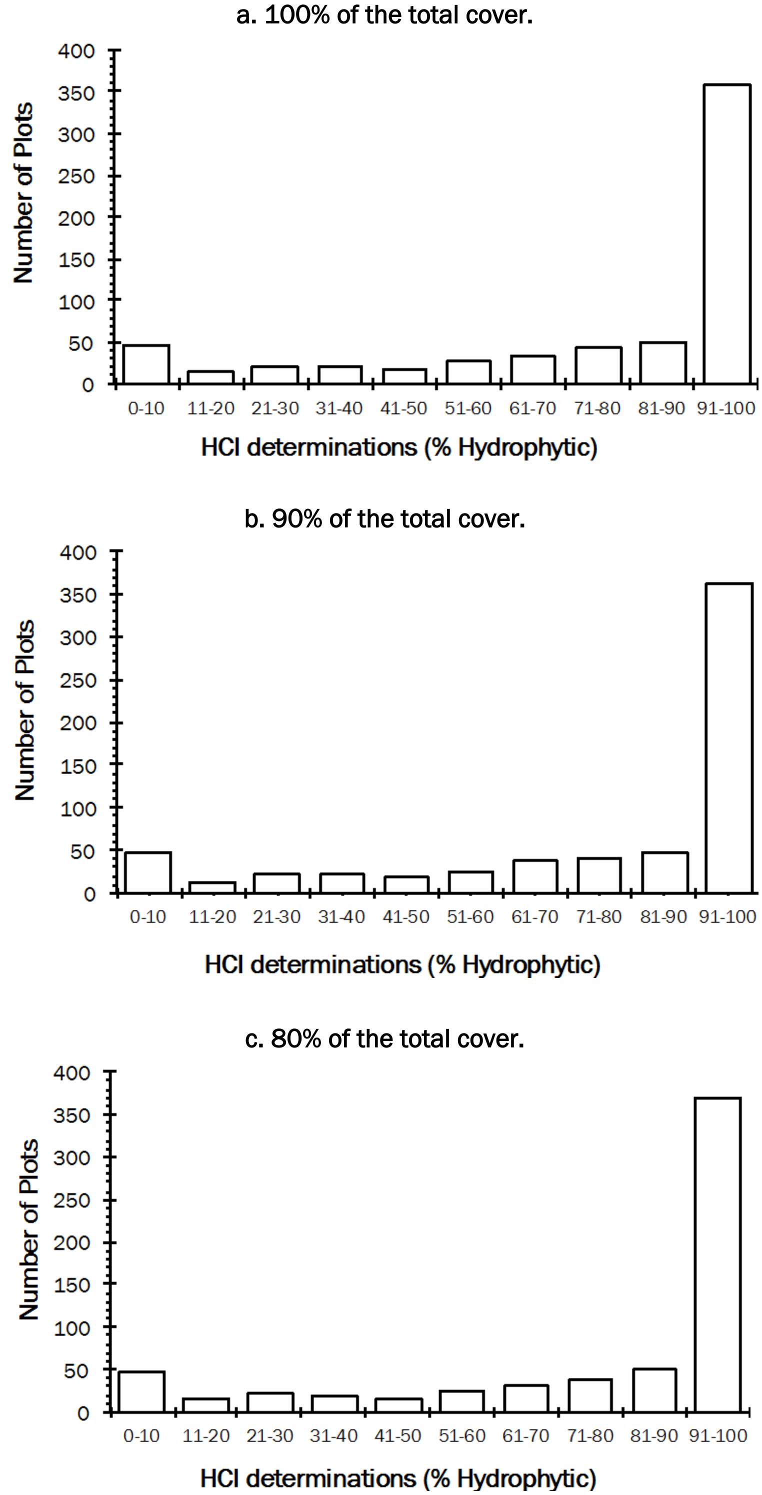
Descriptive statistics (RS data)	100% cover	90% cover	80% cover
Skewness of HCI determinations	−1	−1	−1
Standard deviation of HCI determinations	30	31	32
Number of plots where HCI ≥ 61%	485	488	490
Number of plots where HCI ≤ 50%	125	124	123
Number of plots where HCI ≤ 50% and hydric soil, wetland hydrology indicators, or both are absent	109	108	107
Percent of plots where the HCI outcome (hydrophytic or nonhydrophytic) is unaffected by using 90% or 80% cover in calculations	na*	99%	99%
Percent of plots where the HCI outcome (hydrophytic or nonhydrophytic) produced by 100% cover conflicts with the outcome produced by 90% or 80% of the total cover	na	1%	1%
Percent of plots where HCI ≤ 50% and both hydric soil and wetland hydrology indicators are present	3%	3%	3%

* na = not applicable.

Table 4. Results of Levene's test (comparing the variance among HCI determinations) and Pearson chi-square tests (comparing the percentage of hydrophytic determinations produced by the HCI) using the RS data collected in nine Corps regions (Berkowitz 2011).

Hypothesis 3 tested using RS data	Circular plots			n	df	Test statistic	p-value
	100% cover	90% cover	80% cover				
Variance $HCI_{100\% cover}$ = Variance $HCI_{90\% cover}$ = Variance $HCI_{80\% cover}$ in circular plots	915	973	1011	637		$F = 0.03$	0.97
$\%Hydrophytic_{100\% cover}$ = $\%Hydrophytic_{90\% cover}$ = $\%Hydrophytic_{80\% cover}$ in circular plots	80	81	81	637	2	$\chi^2 = 0.01$	1.00

Figure 2. Distribution of Hydrophytic Cover Index (HCI) determinations when the HCI is calculated using 100%, 90%, and 80% of the total cover in a plot. Data were collected in nine Corps regions during Regional Supplement testing (n = 637) (Berkowitz 2011).



Using either 90% or 80% of the total cover (instead of 100% cover) to calculate the HCI did not affect the outcome (hydrophytic or nonhydrophytic) of HCI determinations in 99% of the plots (Table 3). However, in 1% of the plots (first seven plots in Table 5) outcomes conflicted when the HCI was calculated using 90% and 100% of the total cover. Outcomes also conflicted in 1% of the plots (last eight plots in Table 5) when the HCI was calculated using 80% and 100% of the total cover. Plots in which HCI outcomes conflicted had two commonalities. Vegetation consisted of similar percentages of hydrophytes and nonhydrophytes (49%–57% hydrophytic). Also, hydric soil indicators, wetland hydrology indicators, or both were absent.

Table 5. Plots in which Hydrophytic Cover Index (HCI) determinations calculated using 100% cover conflicted with those calculated using 90% or 80% of the total cover in each plot. Data were collected in nine Corps regions during Regional Supplement testing (n = 637) (Berkowitz 2011).

Plot	USACE region*	HCI determination			Hydric soil indicator	Wetland hydrology indicator
		100% cover	90% cover	80% cover		
BWA#45	GP	52	47	NC†	A	A
LdC14-6	AW	50	56	NC	A	A
WCo#1	WMVC	50	52	NC	A	A
LC2-6	AW	53	48	42	A	P
WI_1-upl	NCNE	52	50	46	A	A
BSP_4b	AW	50	52	53	A	P
PT-2Dry	AGCP	49	53	56	P	A
MF#2	WMVC	57	NC	49	P	A
BWA#43	GP	45	NC	53	A	A
W-1up	NCNE	50	NC	51	A	A
A-Dry	AGCP	49	NC	53	A	A

* The full name of each USACE region and its corresponding acronym are shown in Appendix A.

†NC = no conflict with 100% cover result, P = present, A = absent.

The HCI produced nonhydrophytic determinations in 125 plots (20% of the RS data) when calculated using 100% cover (Table 3). The HCI produced nonhydrophytic determinations in 123 plots (19% of the RS data) when calculated using 80% of the total cover. Of these 123 plots, 107 lacked a hydric soil indicator, a wetland hydrology indicator, or both. In the remaining 16 plots (3% of the RS data), both soil and hydrology indicators were present (Table 6). The most abundant plant species in these 16 plots were either rated FACU or were not on the 1988 list (Reed 1988). All of these plots represent difficult wetland situations described in the appropriate Regional Supplement.

Table 6. Sixteen plots in which the Hydrophytic Cover Index (HCI) determined that vegetation was nonhydrophytic (HCI ≤ 50%) and hydric soil and wetland hydrology indicators were present. Data were collected in nine Corps regions during Regional Supplement testing (n = 637) (Berkowitz 2011). Wetland ratings are from the *National List of Plant Species that Occur in Wetlands* (Reed 1988).

Plot	USACE region*	HCI determination			Most abundant species	1988 wetland rating
		100% cover	90% cover	80% cover		
C24_#1	GP	50	44	38	*Glycine max* (L.) Merr.	NOL†
A1	CB	30	30	25	*Calophyllum antillanum* Britt.	NOL
2Wet-PT	AGCP	49	45	38	*Quercus alba* L.	FACU
8-1 WET	MW	47	42	46	*Rhamnus cathartica* L.	FACU
TSP2B	EMP	40	37	31	*Acer saccharum* Marsh.	FACU
M_1-low	NCNE	36	35	40	*Betula papyrifera* Marsh.	FACU
MC_B	AK	35	35	31	*Picea sitchensis* (Bong.) Carr.	FACU
SP_#5	GP	33	35	28	*Pascopyrum smithii* (Rydb.) A. Löve (= *Agropyron smithii* Rydb.)	FACU
MRF_#1	GP	21	19	1	*Poa pratensis* L.	FACU
E01	CB	20	17	6	*Bidens pilosa* L. (= *Bidens alba* (L.) DC)	FACU
WT_#13	GP	19	9	17	*Pascopyrum smithii* (Rydb.) A. Löve (= *Agropyron smithii* Rydb.)	FACU
1-Mfrd	AGCP	13	10	8	*Carya ovata* (P. Mill) K. Koch	FACU
WCo #2	WMVC	10	5	12	*Avena sativa* L.	NOL
SB-2A	EMP	9	10	11	*Tsuga canadensis* L. (Carr.)	FACU
PC_2	WMVC	0	0	0	*Ammophila arenaria* (L.) Link	FACU
A_1-low	NCNE	0	0	0	*Festuca rubra* L.	FACU

* The full name of each USACE region and its corresponding acronym are shown in Appendix A.

† NOL = Not on the 1988 List.

5 Discussion

These results suggest that for wetland delineation purposes, plot dimensions have no effect on the percentage of hydrophytic vegetation determinations produced by the HCI. The concept of hydrophytic vegetation is based on differences in plant species composition in wetlands (species rated FAC, FACW, or OBL) and in uplands (species rated FACU or UPL). Data collected from upland plots of different sizes near a wetland boundary should reflect these differences in species composition, resulting in different percentages of hydrophytic vegetation determinations. Circular plots on the upland side of the wetland boundary should produce fewer hydrophytic determinations than linear rectangular plots placed in the same location because of the size of the circular plots and because circular plots extend farther into the upland and potentially contain more species rated FACU and UPL. Rectangular plots on the upland side of the boundary are narrower than the circular plots and are adjacent to the wetland boundary, so they are likely to contain more hydrophytes. However, the CRREL data show that the difference in the percentage of hydrophytic vegetation determinations produced by the circular (70%) and rectangular (82%) plots is not significant ($p \geq 0.25$) (Table 2).

These results also support the NTCWV recommendation to use the 80% approach for vegetation sampling, which is described in the Regional Supplements. Ideally, all plants in a plot should be identified to the species level so that their assigned wetland rating and cover values contribute to determining if hydrophytic vegetation is present. However, any viable sampling approach for regulatory purposes must be pragmatic, recognizing that the time available for plant identification and vegetation assessment is limited (Gage and Cooper 2010). The 80% approach acknowledges this limitation, requiring that at least 80% of the cover be identified to species for a vegetation determination to be made (USACE 2010a). The CRREL data show that calculating the HCI by using 80% of the total cover in a plot, rather than 100% cover, does not significantly affect the outcome of hydrophytic vegetation determinations when cover data were collected in rectangular plots (82%–79%; $p = 0.94$) (Table 2).

The RS data collected in nested circular plots along wetland boundaries in nine Corps regions show similar results. Calculating the HCI using 90% or

80% of the total cover, instead of 100% cover, had no effect on the percentage of hydrophytic vegetation determinations produced (81%–80%; $p = 1.00$) (Table 4). The outcome of vegetation determinations (hydrophytic or nonhydrophytic) was unaffected in 99% of these delineation plots (Table 3). There are two explanations for these consistent results. First, the basic rule in determining hydrophytic vegetation is that greater than 50% of the vegetation present consists of wetland plant species. HCI calculations are based on this rule. Since there is no manipulation of the data used in the calculation, the HCI produces consistent results when evaluated over large data sets. Second, HCI determinations were consistent because the vegetation in most plots in the RS data was strongly hydrophytic. For instance, when 100% cover was used to calculate the HCI, the vegetation in 485 of the 637 plots was 61%–100% hydrophytic (Figure 2a; Table 3). In these plots, the outcome (hydrophytic) could not change when 80% of the total cover was used to calculate the HCI. Even if all of the species that could not be identified were hydrophytes, these plots would still be 51%–100% hydrophytic ($61 - 20 = 41$; $41 / (41 + 39) \times 100 = 51$). Other research conducted along wetland boundaries in Virginia, Indiana, and New York has produced similar results (Gillrich et al. 2011). In that study, vegetation was so strongly hydrophytic that manipulations of cover thresholds and wetland ratings affected only a small percentage of plots containing borderline hydrophytic/nonhydrophytic vegetation.

However, plots containing borderline vegetation are of particular concern during delineations because when similar percentages of hydrophytes and nonhydrophytes are present (49%–57% hydrophytic), the outcomes of HCI determinations calculated from 90% or 80% of the total cover may conflict with outcomes calculated from 100% cover. Such conflicts occurred in 1% of the RS data (Table 3). For instance, the HCI calculated using 90% of the total cover differed from the HCI calculated using 100% of the cover in seven plots (Table 5). Likewise, the HCI calculated using 80% of the total cover differed from the HCI calculated using 100% of the cover in eight plots. All of these plots lacked either a soil or a hydrology indicator, or both, meaning that they were located in uplands. So, even though using 90% or 80% of the total cover to calculate the HCI affected the outcome of vegetation determinations in 1% of the plots in this study, it did not affect wetland boundary determinations because all of the affected plots were located in uplands as they lacked hydric soil, wetland hydrology indicators, or both.

Characteristics of plots in which the HCI produced nonhydrophytic vegetation determinations are also of interest because these plots could affect delineation outcomes. These data show that nonhydrophytic vegetation determinations made by the HCI were almost always located in uplands. When calculated using 80% cover, the HCI produced nonhydrophytic vegetation determinations in 123 plots in the RS data (Table 3). Most of these plots (107) were located in uplands because they lacked either a hydric soil or wetland hydrology indicator or both; this type of plot will have no effect on wetland boundary determinations.

However, 3% of the time, regardless of whether 100% or 80% of the total cover were used in the calculations, the HCI made nonhydrophytic determinations in plots that might be located in wetlands (Table 3). In 16 plots, the HCI determined that the vegetation was nonhydrophytic, but both hydric soil and wetland hydrology indicators were present (Table 6). These plots represent problematic wetland situations described in Chapter Five of the Regional Supplements. Chapter Five describes wetlands that are difficult to identify because indicators of hydric soils, wetland hydrology, or hydrophytic vegetation are absent. Vegetation from difficult wetland types warrants further consideration because plant communities may not display hydrophytic indicators at the time of sampling. Some examples from the RS data include wetlands dominated by FACU plant species, such as *Tsuga canadensis* L. (Carr.) in the Eastern Mountains and Piedmont region (USACE 2012); wetlands dominated by exotic invasive plant species, such as *Rhamnus cathartica* L. in the Midwest (USACE 2010b); or wetlands with temporal shifts in vegetation, such as *Ammophila arenaria* (L.) Link in the Western Mountains, Valleys, and Coast region (USACE 2010a). In these plots and thirteen others, the HCI determined that the vegetation was nonhydrophytic (0%–50% hydrophytic), regardless of whether HCI calculations were made using 100%, 90%, or 80% of the total cover. But, because both hydric soil and wetland hydrology indicators were present, these plots may be reexamined using the procedures for difficult wetland types in Chapter Five.

6 Conclusions

Given these results, we conclude that the use of the rectangular plot size of 10 × 2 m proposed by the NTCWV and the use of absolute percent areal cover data collected without stratifying vegetation by growth form is an accurate method for wetland boundary delineations. The simple HCI formula precisely captures the presence of hydrophytic vegetation. These results also suggest that the percentage of hydrophytic vegetation determinations produced by the HCI is not affected by the use of a smaller, rectangular plot at the wetland boundary. Finally, the use of rectangular plots placed parallel to the wetland boundary is more representative of the vegetation occurring at the boundary and focuses the investigation on the area thought to be the wetland boundary.

The most accurate hydrophytic vegetation determinations use 100% cover of all species present. However, the data presented in this report suggest that there is no significant difference in the percentage of hydrophytic determinations produced when 100%, 90%, or 80% of the total vegetative cover is used to calculate the HCI, and there is no difference in the variance among these groups of HCI determinations. Therefore, we recommend that at least 80% of the total cover be identified to species when making a vegetation determination for wetland delineation purposes. To apply the 80% approach, the NTCWV suggests ranking the species cover in descending order and selecting the 20% from the least common species in the plot. If 80% of the total cover cannot be identified, investigators should collect and press specimens and ask a botanist or a local herbarium for help. Once 80% of the total cover has been positively identified, the remaining cover may be disregarded, because it will not change the outcome. If the 80% approach determines that the vegetative cover is nonhydrophytic (≤50%) but hydric soil and wetland hydrology indicators are present, investigators should consult Chapter Five in the appropriate Regional Supplement to determine if problematic vegetation is present.

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Appendix A: US Army Corps of Engineers Regions and Acronyms

Region	Acronym
Atlantic and Gulf Coastal Plain	AGCP
Alaska	AK
Arid West	AW
Caribbean Islands	CB
Eastern Mountains and Piedmont	EMP
Great Plains	GP
Hawaii and Pacific Islands	HI
Midwest	MW
Northcentral and Northeast	NCNE
Western Mountains, Valleys, and Coast	WMVC

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14. ABSTRACT

Recommendations made by the National Technical Committee on Wetland Vegetation (NTCWV) for vegetation sampling and for assessing hydrophytic vegetation were tested for possible inclusion in the update of the Army Corps of Engineers Wetland Delineation Manual. A new method, the Hydrophytic Cover Index (HCI), was used to determine if vegetation was hydrophytic. Plot shape and size, rectangular (10 × 2 m) vs. nested circular (9 m and 2 m radii used in the Corps 1987 Manual), were tested for differences in hydrophytic vegetation outcomes. HCI determinations produced from calculations using 100%, 90%, and 80% of the total cover in each plot were also tested for differences. Differences in plot size or shape had no effect on the percentage of hydrophytic vegetation determinations produced by the HCI. Calculating the HCI using 100%, 90%, and 80% of the total cover in delineation plots also had no effect on the outcome. Therefore, to determine if hydrophytic vegetation is present, it is not necessary to identify more than 80% of the total cover to the species level. To apply the 80% approach, the NTCWV suggests ranking the species cover in descending order and selecting the 20% from the least common species in the plot. Once 80% of the total cover in a plot has been positively identified, the remaining cover may be disregarded. If the 80% approach determines that the vegetation is nonhydrophytic (≤50%) but hydric soil and wetland hydrology indicators are present, Chapter Five in the appropriate Regional Supplement should be consulted to determine if problematic vegetation is present (e.g., USACE 2007).

15. SUBJECT TERMS

Hydrophytic Cover Index
Hydrophytic vegetation
Vegetation sampling
Wetland delineation
Wetland vegetation

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