North Carolina State University

An Analysis of the North Carolina Wetland Assessment Method (NCWAM) Using Quantitative Metrics

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Submitted to the Graduate Faculty of

North Carolina State University

in partial fulfillment of the
requirements for the Degree of
Master of Natural Resources

Ecological Restoration Technical Option

Raleigh, North Carolina

2013

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Abstract

The purpose of this project is to determine the accuracy of the North Carolina Wetland Assessment Method (NCWAM). NCWAM is a rapid assessment method developed by an interagency team of federal and North Carolina agencies. The purpose of NCWAM is to provide a resource to regulators, planners, and the general public. This resource would aid in project planning, alternatives analysis, compliance, enforcement, mitigation planning, and tracking functional replacement. The successful implementation of NCWAM would allow these agencies to regulate mitigation based on wetland functionality, and therefore value. Because of the intent to use NCWAM in a regulatory capacity, it is important to provide evidence supporting its ability to successfully perform as an accurate evaluator of wetland functionality or find weaknesses so that it can be improved upon. By finding evidence to support or refute the accuracy of NCWAM in this way, this project contributes to the credibility of the NCWAM project. Data were collected which included physical vegetation, macroinvertebrate, amphibian, and physical and chemical data. This project used these data to calculate metrics, which were then examined for relationships between the data and the NCWAM scores.

Introduction

The purpose of this project is to determine the accuracy of the North Carolina Wetland Assessment Method (NCWAM). NCWAM is a rapid assessment method developed by an interagency team of federal and North Carolina agencies.

This assessment was formulated to provide an "accurate, consistent, rapid, observational, and scientifically based field method to determine the level of function of a wetland relative to reference condition for each of the 16 North Caroline general wetland types" (North Carolina, 2010). It is designed to take no more than 15 minutes in the field.

Through the use of NCWAM, significant changes can be made to wetland mitigation in North Carolina. Avoidance and minimization generally means that impacts to wetlands that are lower quality will require less mitigation and in turn will be easier to receive a federal or state permit. Wetlands of a higher quality will require more mitigation and be harder to receive a federal or state permit to impact. Eventually, wetlands can be mitigated in terms of their functionality as opposed to acres. Current rules require a 1:1 ratio of area impacted to area restored in order for restoration or mitigation to achieve no net loss. However, NCWAM could be used to calculate the increase in the ability of the wetland to perform certain functions that would result from enhancement or restoration, such as improving water quality, and use those values to account for net gain of function towards the no net loss policy. Finally, NCWAM could be used in assessment as a comparison of present wetland functionality to future wetland functionalities.

Functional ratings are developed for each wetland assessment area, or the defined area being evaluated based on NCWAM guidance, in comparison to a reference wetland for the wetland type. Within the three major functions, there are ten sub-functions. The functions and their respective sub-functions are:

1. Hydrology
    a. Surface storage and retention
    b. Sub surface storage and retention
2. Water Quality
    a. pathogen change
    b. particulate change
    c. soluble change
    d. physical change
3. Habitat
    a. Physical structure
    b. Landscape patch structure
    c. Vegetation composition

The scores for the function, sub-functions, and overall scores are calculated using 22 field metrics that are provided on the field assessment form. The responses to the metrics are then entered into a calculator which generates scores of High, Medium, or Low for the functions, sub-functions, and the wetlands assessment area. The calculator determines these scores based on iterative Boolean logic.

Because of the intent to use NCWAM in a regulatory capacity, it is important to provide evidence supporting its ability to successfully perform as an accurate evaluator of wetland functionality or find weaknesses so that it can be improved upon. By finding evidence to support or refute the accuracy of NCWAM in this way, this project contributes to the credibility of the NCWAM project.

In a project to support the use of NCWAM as a functional assessment tool, data were collected by NC DWQ from 35 headwater wetland sites presumed to be of varying quality and with differing ability to perform basic functions. Data include:

- Intensive surveys of vegetation, amphibians, and macroinvertebrates
- Water quality parameters: metals, nutrients, pH, dissolved oxygen, fecal coliform, specific conductivity, total suspended solids, total organic carbon, and temperature
- Soil chemistry parameters: plant nutrients, metals, sodium, pH, percent base saturation, percent humic matter, and cation exchange capacity
- Hydrology
- Land covers for each wetland watershed, and 50 meter a 300 meter buffers around the wetland

From these parameters the following metrics were calculated: richness, abundance, diversity, dominance, Land Development Indices, floristic quality assessment index, and water quality pollutant scales, among others.

Using the metrics described above, I examined the relationships between these metrics and MCWAM scores for the overall NCWAM score and the three sub-functions. I used correlation analyses to identify these relationships. In addition, simple analysis of variance models relate NCWAM ratings to the overall NCWAM and function scores.

The North Carolina Wetland Assessment Method (NCWAM)

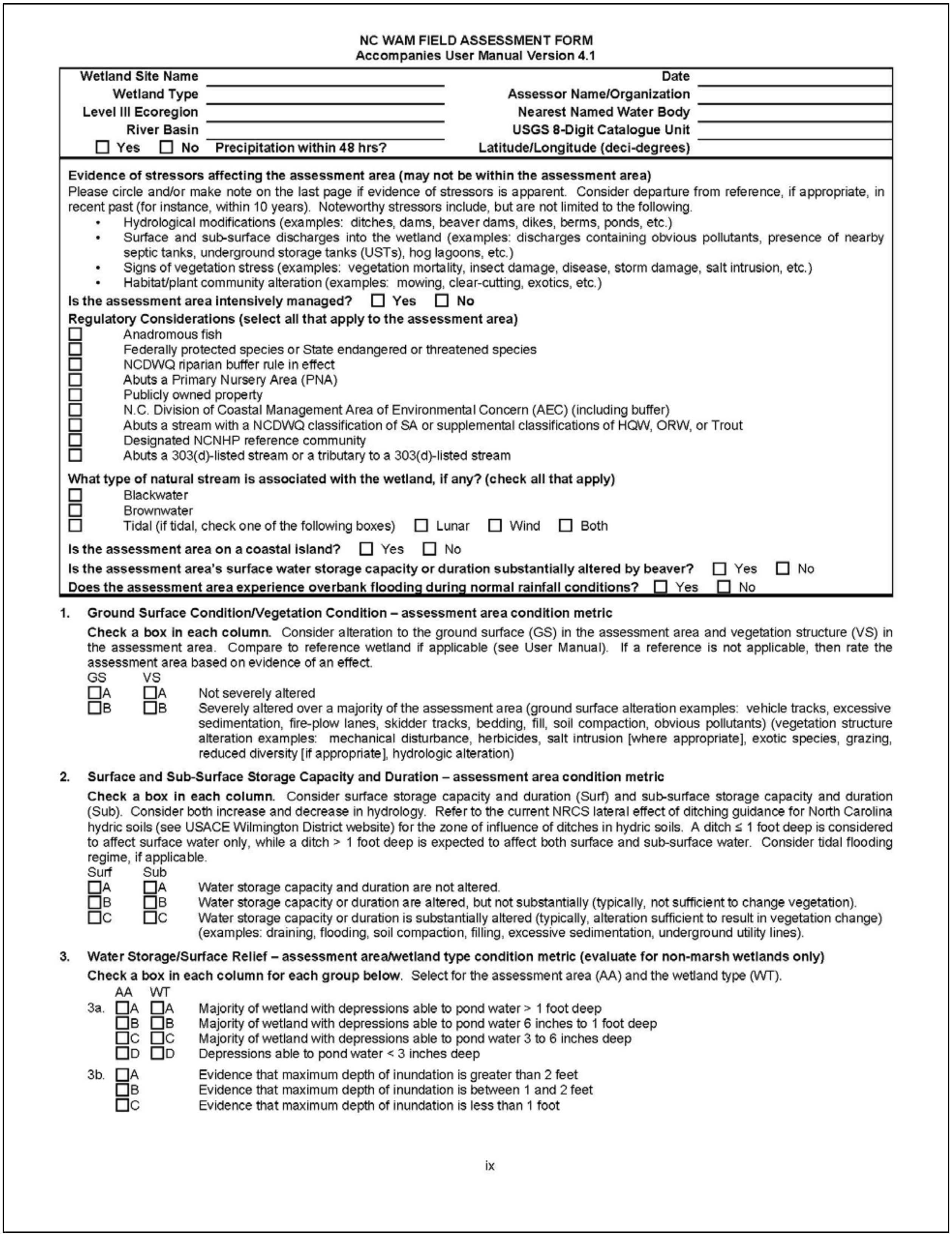
The purpose of NCWAM is to aid in project planning, alternatives analysis, compliance, enforcement, mitigation planning, and tracking functional assessment. In 2003, an interagency team consisting of a variety of federal and state agencies call the North Carolina Wetland Functional Assessment Team (WFAT) began collaboration to develop a field method to determine the level of functionality of a wetland in comparison to a reference wetland of the same type. Sixteen wetlands types were established for the state, and a functional rating was developed for each separate type. **Table 1** below shows the 16 general wetland types as determined by the WFAT (WFAT, 2010).

Table 1. General Wetland Types of North Carolina

16 General Wetland Types of North Carolina	
Salt/Brackish Marsh	Pine Savanna
Estuarine Woody Wetland	Pine Flat
Tidal Freshwater Marsh	Basin Wetland
Riverine Swamp Forest	Bog
Seep	Non-Tidal Freshwater Marsh
Hardwood Flat	Floodplain Pool
Non-Riverine Swamp Forest	Headwater Forest
Pocosin	Bottomland Hardwood Forest

NCWAM develops an overall functional rating of high, medium, or low for a wetland in comparison to the reference for each wetland type. These ratings use indicators of functionality rather than physical measurements and are based on 22 field metrics. Version 4.1 of the NCWAM Field Assessment Form can be seen below. The metric scores are combined to create sub-function scores which use a weighting system that takes into account how important the metric is to the sub-function. These sub-function scores are then used to calculate function ratings, which are then used to produce an overall functional rating (WFAT, 2010). To calculate these ratings, scores from the Field Assessment Form are entered into a calculator, which then develops the scores based on iterative Boolean logic. The functions and their respective sub-functions are as follows:

1. Hydrology
    a. Surface Storage and Retention
    b. Sub-surface Storage and Retention
2. Water Quality
    a. Pathogen Change
    b. Particulate Change
    c. Soluble Change
    d. Physical Change
3. Habitat
    a. Physical Structure
    b. Landscape Patch Structure
    c. Vegetation Composition



NC WAM FIELD ASSESSMENT FORM

Accompanies User Manual Version 4.1

Wetland Site Name		**Date**	
Wetland Type		**Assessor Name/Organization**	
Level III Ecoregion		**Nearest Named Water Body**	
River Basin		**USGS 8-Digit Catalogue Unit**	
☐ **Yes** ☐ **No**	**Precipitation within 48 hrs?**	**Latitude/Longitude (deci-degrees)**	

Evidence of stressors affecting the assessment area (may not be within the assessment area)

Please circle and/or make note on the last page if evidence of stressors is apparent. Consider departure from reference, if appropriate, in recent past (for instance, within 10 years). Noteworthy stressors include, but are not limited to the following.

- Hydrological modifications (examples: ditches, dams, beaver dams, dikes, berms, ponds, etc.)
- Surface and sub-surface discharges into the wetland (examples: discharges containing obvious pollutants, presence of nearby septic tanks, underground storage tanks (USTs), hog lagoons, etc.)
- Signs of vegetation stress (examples: vegetation mortality, insect damage, disease, storm damage, salt intrusion, etc.)
- Habitat/plant community alteration (examples: mowing, clear-cutting, exotics, etc.)

Is the assessment area intensively managed? ☐ **Yes** ☐ **No**

Regulatory Considerations (select all that apply to the assessment area)

☐ Anadromous fish
☐ Federally protected species or State endangered or threatened species
☐ NCDWQ riparian buffer rule in effect
☐ Abuts a Primary Nursery Area (PNA)
☐ Publicly owned property
☐ N.C. Division of Coastal Management Area of Environmental Concern (AEC) (including buffer)
☐ Abuts a stream with a NCDWQ classification of SA or supplemental classifications of HQW, ORW, or Trout
☐ Designated NCNHP reference community
☐ Abuts a 303(d)-listed stream or a tributary to a 303(d)-listed stream

What type of natural stream is associated with the wetland, if any? (check all that apply)

☐ Blackwater
☐ Brownwater
☐ Tidal (if tidal, check one of the following boxes) ☐ Lunar ☐ Wind ☐ Both

Is the assessment area on a coastal island? ☐ Yes ☐ No

Is the assessment area's surface water storage capacity or duration substantially altered by beaver? ☐ Yes ☐ No

Does the assessment area experience overbank flooding during normal rainfall conditions? ☐ Yes ☐ No

1. Ground Surface Condition/Vegetation Condition – assessment area condition metric

Check a box in each column. Consider alteration to the ground surface (GS) in the assessment area and vegetation structure (VS) in the assessment area. Compare to reference wetland if applicable (see User Manual). If a reference is not applicable, then rate the assessment area based on evidence of an effect.

GS	VS	
☐A	☐A	Not severely altered
☐B	☐B	Severely altered over a majority of the assessment area (ground surface alteration examples: vehicle tracks, excessive sedimentation, fire-plow lanes, skidder tracks, bedding, fill, soil compaction, obvious pollutants) (vegetation structure alteration examples: mechanical disturbance, herbicides, salt intrusion [where appropriate], exotic species, grazing, reduced diversity [if appropriate], hydrologic alteration)

2. Surface and Sub-Surface Storage Capacity and Duration – assessment area condition metric

Check a box in each column. Consider surface storage capacity and duration (Surf) and sub-surface storage capacity and duration (Sub). Consider both increase and decrease in hydrology. Refer to the current NRCS lateral effect of ditching guidance for North Carolina hydric soils (see USACE Wilmington District website) for the zone of influence of ditches in hydric soils. A ditch ≤ 1 foot deep is considered to affect surface water only, while a ditch > 1 foot deep is expected to affect both surface and sub-surface water. Consider tidal flooding regime, if applicable.

Surf	Sub	
☐A	☐A	Water storage capacity and duration are not altered.
☐B	☐B	Water storage capacity or duration are altered, but not substantially (typically, not sufficient to change vegetation).
☐C	☐C	Water storage capacity or duration is substantially altered (typically, alteration sufficient to result in vegetation change) (examples: draining, flooding, soil compaction, filling, excessive sedimentation, underground utility lines).

3. Water Storage/Surface Relief – assessment area/wetland type condition metric (evaluate for non-marsh wetlands only)

Check a box in each column for each group below. Select for the assessment area (AA) and the wetland type (WT).

	AA	WT	
3a.	☐A	☐A	Majority of wetland with depressions able to pond water > 1 foot deep
	☐B	☐B	Majority of wetland with depressions able to pond water 6 inches to 1 foot deep
	☐C	☐C	Majority of wetland with depressions able to pond water 3 to 6 inches deep
	☐D	☐D	Depressions able to pond water < 3 inches deep
3b.	☐A		Evidence that maximum depth of inundation is greater than 2 feet
	☐B		Evidence that maximum depth of inundation is between 1 and 2 feet
	☐C		Evidence that maximum depth of inundation is less than 1 foot

4. Soil Texture/Structure – assessment area condition metric

Check a box from each of the three soil property groups below. Dig soil profile in the dominant assessment area landscape feature. Make soil observations within the top 12 inches. Use most recent guidance for National Technical Committee for Hydric Soils regional indicators.

4a. ☐A Sandy soil
☐B Loamy or clayey soils exhibiting redoximorphic features (concentrations, depletions, or rhizospheres)
☐C Loamy or clayey soils not exhibiting redoximorphic features
☐D Loamy or clayey gleyed soil
☐E Histosol or histic epipedon

4b. ☐A Soil ribbon < 1 inch
☐B Soil ribbon ≥ 1 inch

4c. ☐A No peat or muck presence
☐B A peat or muck presence

5. Discharge into Wetland – assessment area opportunity metric

Check a box in each column. Consider surface pollutants or discharges (Surf) and sub-surface pollutants or discharges (Sub). Examples of sub-surface discharges include presence of nearby septic tank, underground storage tank (UST), etc.

Surf	Sub	
☐A	☐A	Little or no evidence of pollutants or discharges entering the assessment area
☐B	☐B	Noticeable evidence of pollutants or discharges entering the wetland and stressing, but not overwhelming the treatment capacity of the assessment area
☐C	☐C	Noticeable evidence of pollutants or discharges (pathogen, particulate, or soluble) entering the assessment area and potentially overwhelming the treatment capacity of the wetland (water discoloration, dead vegetation, excessive sedimentation, odor)

6. Land Use – opportunity metric

Check all that apply (at least one box in each column). Evaluation involves a GIS effort with field adjustment. Consider sources draining to assessment area within entire upstream watershed (WS), within 5 miles <u>and</u> within the watershed draining to the assessment area (5M), <u>and</u> within 2 miles and within the watershed draining to the assessment area (2M).

WS	5M	2M	
☐A	☐A	☐A	≥ 10% impervious surfaces
☐B	☐B	☐B	< 10% impervious surfaces
☐C	☐C	☐C	Confined animal operations (or other local, concentrated source of pollutants)
☐D	☐D	☐D	≥ 20% coverage of pasture
☐E	☐E	☐E	≥ 20% coverage of agricultural land (regularly plowed land)
☐F	☐F	☐F	≥ 20% coverage of maintained grass/herb
☐G	☐G	☐G	≥ 20% coverage of clear-cut land
☐H	☐H	☐H	Little or no opportunity to improve water quality. Lack of opportunity may result from hydrologic alterations that prevent drainage or overbank flow from affecting the assessment area.

7. Wetland Acting as Vegetated Buffer – assessment area/wetland complex condition metric

7a. Is assessment area within 50 feet of a tributary or other open water?
☐Yes ☐No If Yes, continue to 7b. If No, skip to Metric 8.
Wetland buffer need only be present on one side of the open water. Make buffer judgment based on the average width of wetland. Record a note if a portion of the buffer has been removed or disturbed.

7b. How much of the first 50 feet from the bank is wetland?
☐A ≥ 50 feet
☐B From 30 to < 50 feet
☐C From 15 to < 30 feet
☐D From 5 to < 15 feet
☐E < 5 feet <u>or</u> buffer bypassed by ditches

7c. Tributary width. If the tributary is anastomosed, combine widths of channels/braids for a total width.
☐≤ 15-feet wide ☐> 15-feet wide ☐ Other open water (no tributary present)

7d. Do roots of assessment area vegetation extend into the bank of the tributary/open water?
☐Yes ☐No

7e. Is the tributary or other open water sheltered or exposed?
☐Sheltered – open water width < 2500 feet and no regular boat traffic.
☐Exposed – open water width ≥ 2500 feet or regular boat traffic.

8. Wetland Width at the Assessment Area – wetland type/wetland complex condition metric (evaluate for riparian wetlands only)

Check a box in each column. Select the average width for the wetland type at the assessment area (WT) and the wetland complex at the assessment area (WC). See User Manual for WT and WC boundaries.

WT	WC	
☐A	☐A	≥ 100 feet
☐B	☐B	From 80 to < 100 feet
☐C	☐C	From 50 to < 80 feet
☐D	☐D	From 40 to < 50 feet
☐E	☐E	From 30 to < 40 feet
☐F	☐F	From 15 to < 30 feet
☐G	☐G	From 5 to < 15 feet
☐H	☐H	< 5 feet

x

9. Inundation Duration – assessment area condition metric

Answer for assessment area dominant landform.

☐A Evidence of short-duration inundation (< 7 consecutive days)
☐B Evidence of saturation, without evidence of inundation
☐C Evidence of long-duration inundation or very long-duration inundation (7 to 30 consecutive days or more)

10. Indicators of Deposition – assessment area condition metric

Consider recent deposition only (no plant growth since deposition).

☐A Sediment deposition is not excessive, but at approximately natural levels.
☐B Sediment deposition is excessive, but not overwhelming the wetland.
☐C Sediment deposition is excessive and is overwhelming the wetland.

11. Wetland Size – wetland type/wetland complex condition metric

Check a box in each column. Involves a GIS effort with field adjustment. This metric evaluates three aspects of the wetland area: the size of the wetland type (WT), the size of the wetland complex (WC), and the size of the forested wetland (FW) (if applicable, see User Manual). See the User Manual for boundaries of these evaluation areas. If assessment area is clear-cut, select "K" for the FW column.

WT	WC	FW (if applicable)	
☐A	☐A	☐A	≥ 500 acres
☐B	☐B	☐B	From 100 to < 500 acres
☐C	☐C	☐C	From 50 to < 100 acres
☐D	☐D	☐D	From 25 to < 50 acres
☐E	☐E	☐E	From 10 to < 25 acres
☐F	☐F	☐F	From 5 to < 10 acres
☐G	☐G	☐G	From 1 to < 5 acres
☐H	☐H	☐H	From 0.5 to < 1 acre
☐I	☐I	☐I	From 0.1 to < 0.5 acre
☐J	☐J	☐J	From 0.01 to < 0.1 acre
☐K	☐K	☐K	< 0.01 acre <u>or</u> assessment area is clear-cut

12. Wetland Intactness – wetland type condition metric (evaluate for Pocosins only)

☐A Pocosin is the full extent (≥ 90%) of its natural landscape size.
☐B Pocosin is < 90% of the full extent of its natural landscape size.

13. Connectivity to Other Natural Areas – landscape condition metric

13a. **Check appropriate box(es) (a box may be checked in each column).** Involves a GIS effort with field adjustment. This metric evaluates whether the wetland is well connected (Well) and/or loosely connected (Loosely) to the landscape patch, the contiguous naturally vegetated area and open water (if appropriate). Boundaries are formed by four-lane roads, regularly maintained utility line corridors the width of a four-lane road or wider, urban landscapes, maintained fields (pasture and agriculture), or open water > 300 feet wide.

Well	Loosely	
☐A	☐A	≥ 500 acres
☐B	☐B	From 100 to < 500 acres
☐C	☐C	From 50 to < 100 acres
☐D	☐D	From 10 to < 50 acres
☐E	☐E	< 10 acres
☐F	☐F	Wetland type has a poor or no connection to other natural habitats

13b. **Evaluate for marshes only.**

☐Yes ☐No Wetland type has a surface hydrology connection to open waters/tributary or tidal wetlands.

14. Edge Effect – wetland type condition metric (skip for all marshes)

May involve a GIS effort with field adjustment. Estimate distance from wetland type boundary to artificial edges. Artificial edges include non-forested areas ≥ 40 feet wide such as fields, development, roads, regularly maintained utility line corridors, and clear-cuts. Consider the eight main points of the compass.

☐A No artificial edge within 150 feet in all directions
☐B No artificial edge within 150 feet in four (4) to seven (7) directions
☐C An artificial edge occurs within 150 feet in more than four (4) directions <u>or</u> assessment area is clear-cut

15. Vegetative Composition – assessment area condition metric (skip for all marshes and Pine Flat)

☐A Vegetation is close to reference condition in species present and their proportions. Lower strata composed of appropriate species, with exotic plants absent or sparse within the assessment area.

☐B Vegetation is different from reference condition in species diversity or proportions, but still largely composed of native species characteristic of the wetland type. This may include communities of weedy native species that develop after clearcutting or clearing. It also includes communities with exotics present, but not dominant, over a large portion of the expected strata.

☐C Vegetation severely altered from reference in composition. Expected species are unnaturally absent (planted stands of non-characteristic species or at least one stratum inappropriately composed of a single species). Exotic species are dominant in at least one stratum.

16. Vegetative Diversity – assessment area condition metric (evaluate for Non-tidal Freshwater Marsh only)

☐A Vegetation diversity is high and is composed primarily of native species (< 10% cover of exotics).
☐B Vegetation diversity is low or has > 10% to 50% cover of exotics.
☐C Vegetation is dominated by exotic species (> 50% cover of exotics).

17. Vegetative Structure – assessment area/wetland type condition metric

17a. Is vegetation present?

☐Yes ☐No If Yes, continue to 17b. If No, skip to Metric 18.

17b. Evaluate percent coverage of assessment area vegetation **for all marshes only**. Skip to17c for non-marsh wetlands.

☐A ≥ 25% coverage of vegetation
☐B < 25% coverage of vegetation

17c. **Check a box in each column for each stratum.** Evaluate this portion of the metric **for non-marsh wetlands**. Consider structure in airspace above the assessment area (AA) and the wetland type (WT) separately.

	AA	WT	
Canopy	☐A	☐A	Canopy closed, or nearly closed, with natural gaps associated with natural processes
	☐B	☐B	Canopy present, but opened more than natural gaps
	☐C	☐C	Canopy sparse or absent
Mid-Story	☐A	☐A	Dense mid-story/sapling layer
	☐B	☐B	Moderate density mid-story/sapling layer
	☐C	☐C	Mid-story/sapling layer sparse or absent
Shrub	☐A	☐A	Dense shrub layer
	☐B	☐B	Moderate density shrub layer
	☐C	☐C	Shrub layer sparse or absent
Herb	☐A	☐A	Dense herb layer
	☐B	☐B	Moderate density herb layer
	☐C	☐C	Herb layer sparse or absent

18. Snags – wetland type condition metric

☐A Large snags (more than one) are visible (> 12 inches DBH, or large relative to species present and landscape stability).
☐B Not A

19. Diameter Class Distribution – wetland type condition metric

☐A Majority of canopy trees have stems > 6 inches in diameter at breast height (DBH); many large trees (> 12 inches DBH) are present.
☐B Majority of canopy trees have stems between 6 and 12 inches DBH, few are > 12 inch DBH.
☐C Majority of canopy trees are < 6 inches DBH or no trees.

20. Large Woody Debris – wetland type condition metric

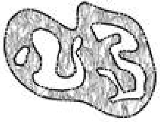
Include both natural debris and man-placed natural debris.

☐A Large logs (more than one) are visible (> 12 inches in diameter, or large relative to species present and landscape stability).
☐B Not A

21. Vegetation/Open Water Dispersion – wetland type/open water condition metric (evaluate for Non-Tidal Freshwater Marsh only)

Select the figure that best describes the amount of interspersion between vegetation and open water in the growing season. Patterned areas indicate vegetated areas, while solid white areas indicate open water.

☐A



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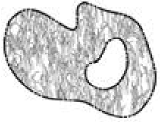
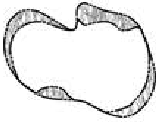
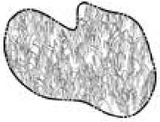


☐C



☐D



22. Hydrologic Connectivity – assessment area condition metric (evaluate for riparian wetlands only)

Examples of activities that may severely alter hydrologic connectivity include intensive ditching, fill, sedimentation, channelization, diversion, man-made berms, beaver dams, and stream incision.

☐A Overbank and overland flow are not severely altered in the assessment area.
☐B Overbank flow is severely altered in the assessment area.
☐C Overland flow is severely altered in the assessment area.
☐D Both overbank and overland flow are severely altered in the assessment area.

Notes

Through the use of NCWAM, significant changes can be made to wetland mitigation practices in North Carolina. When impacts are going to be made to a wetland, such as a road or other development being constructed, the entity that will be making the impact must apply for a permit from the state and from the USACE in North Carolina. In order to receive this permit, the applicant must demonstrate that it has made efforts to avoid making an impact to the best of their ability. It must also demonstrate that they have made efforts to minimize the effects of any impacts they cannot avoid making. Finally, it must mitigate for any impacts that cannot be avoided or minimized. Currently, mitigation for wetland impacts is a 1:1 ratio of the area impacted to the area that is restored for restoration or mitigation in North Carolina. However, NCWAM could be used to calculate the functionality of the wetland to be impacted and allow a recalculation of the mitigation ratio to account for the functionality of the wetland being impacted. A high functioning wetland would require more mitigation than a low functioning wetland. NCWAM could also be used in mitigation to calculate track functional uplift in mitigation sites over time as a method of evaluating mitigation success. A third possible use of NCWAM could be to compare functionality between different wetlands of the same wetland type (Dorney, 2009).

Methods

Metrics

North Carolina Division of Water Quality (NCDWQ) staff collected physical, chemical, and biological data from 36 wetlands with varying degrees of development in their watersheds, including sites in agricultural, urban, and natural areas. The physical and chemical data collected included water quality and soils. The biological monitoring was conducted by surveying the amphibian, macroinvertebrate, and vegetation populations. Using GIS, data were collected on surrounding land use as a measure of anthropogenic disturbance. From this data, metrics were calculated to aid in the comparison between the data and the NCWAM scores. More information about how these metrics were calculated can be found in **Appendix A**.

Macroinvertebrate Metrics

While there is significant research linking macroinvertebrate populations to water quality based on their sensitivity to pollutants, there is little research to determine which macroinvertebrates are found in headwater wetlands (NCDWQ, 2006). Macroinvertebrates are used to assess the condition of wetlands for a variety of reasons; they are commonly and widely distributed in wetlands, they have a wide range of sensitivities depending on the species of macroinvertebrate, they have partial or complete life cycles that result in them being exposed to any physical, chemical, or biological stressor in the wetland, and they play an important role in the food chain (U.S. EPA, 2002b). Many macroinvertebrates complete their life cycle in an aquatic ecosystem. In a wetland that is infrequently flooded, seasonal, or temporary, the macroinvertebrates might have a shorter life cycle. Populations of these organisms respond quickly to stressors in their environment, but they also recover more quickly than other organisms such as plants (U.S. EPA, 2002b). **Table 2** contains a complete listing of the macroinvertebrate metrics used in this analysis. The metrics are categorized by metric type. These metrics were selected through the use of a literature review of other stream and wetland studies with the assistance of a

NCDWQ biologist specializing in macroinvertebrates (NCDWQ, 2008). The metrics also have designations of H, WQ, or Ha. These designations indicate which of the three functions; Hydrology (H), Water Quality (WQ), or Habitat (Ha); the metric is intended to predict. All of the macroinvertebrate metrics could be used to predict both hydrology and water quality.

Table 2. Macroinvertebrate Metrics

Metric Type	Candidate Metric			
Taxonomic Richness	Species Richness	H, WQ	EPT Richness	H, WQ
	Genera Richness	H, WQ	OET Richness	H, WQ
	Family Richness	H, WQ	POET Richness	H, WQ
	Chironomidae Richness	H, WQ		
Taxonomic Composition	Percent Decapoda	H, WQ	Percent Orthocladiinae	H, WQ
	Percent Oligochaetes	H, WQ	Percent Terrestrial	H, WQ
	Percent Chironomidae	H, WQ	Percent Tricoptera	H, WQ
	Percent Coleoptera	H, WQ	Percent Trombidiformes	H, WQ
	Percent Corixidae	H, WQ	Percent EPT	H, WQ
	Percent Crustacea	H, WQ	Percent OET	H, WQ
	Percent Diptera	H, WQ	Percent POET	H, WQ
	Percent Dytiscids	H, WQ	Percent of Top 3 Dominants	H, WQ
	Percent Hemiptera	H, WQ	Evenness	H, WQ
	Percent Leech	H, WQ	Simpson's Index of Diversity	H, WQ
	Percent Microcrustaceans	H, WQ	Site Abundance	H, WQ
	Percent Mollusk	H, WQ		
Trophic Structure	Percent Predators	H, WQ		
	Predator Richness	H, WQ		
Tolerance/ Sensitive	Percent Sensitive	H, WQ	Sensitive : Tolerant	H, WQ
	Percent Tolerant	H, WQ	Biotic Index Score	H, WQ

Vegetation Metrics

Vegetation indicators are considered to be one of the most telling of wetland quality as a result of the number of ways in which vegetation influences the wetland. As the base of the food chain in a wetland, wetland plants serve as the intermediary between the inorganic and the organic environments. Wetland vegetation provides habitat for many other organisms, such as macroinvertebrates, amphibians, and mammals. As such, vegetation cover, diversity, and composition influence the populations of these organisms. Strong links have been found between vegetation and environmental factors such as water quality. Through the uptake of nutrients, metals, and other contaminants, vegetation has been found to improve water quality in many ways (U.S. EPA, 2002c). Vegetation influences chemical and physical water traits through respiration, photosynthesis, and shading and through the uptake of pollutants such as metals or sediments. During the summer, evapotranspiration dries wetlands. Wetland vegetation helps to filter sediments from the water by slowing currents and allowing sediments and other pollutants to settle (U.S. EPA, 2002c; NCDWQ, 2008).

As a result of the wide variety of ways in which vegetation influences the wetland, wetland vegetation is also heavily impacted by wetland condition. Many anthropogenic alterations to wetlands and their watersheds have been shown to cause changes in vegetation community composition that can be directly measured. Because individual species respond differently to stressors, vegetation communities are altered accordingly. Vegetation communities have been shown to respond to hydrologic alterations, nutrient enrichment, sediment loading, metals, and other pollutants. Due to the extensive research that has been completed on wetland vegetation, these responses can be tracked to diagnose wetland impacts (U.S. EPA, 2002c).

The NCDWQ determined that there should be metrics from a variety of categories. These categories should include (NCDWQ, 2008):

1. Community balance metrics (ex. Species richness, diversity, or evenness)
2. Community structure metrics (ex. Sapling density)
3. Auto-ecological metrics that explore previously described relationships between taxa and environmental gradients
4. Quality or tolerance metrics (ex. Floristic quality index, percent tolerant species, average site coefficient of conservation scores)
5. Functional groups (ex. Annual to perennial ratio, moss coverage)
6. Wetness characteristics metric that utilize wetland indicator status (ex. Percent obligate species)

Of these categories, five are represented in the metrics selected in this study, which are shown in **Table 3** below. The vegetation metrics used in this study were selected based on a literature review of stream and wetland assessments using vegetation as a metric of function or disturbance (NCDWQ, 2008). The metrics also have designations of H, WQ, or Ha. These designations indicate which of the three functions; Hydrology (H), Water Quality (WQ), or Habitat (Ha); the metric is intended to predict. While all vegetation metrics could be used to predict habitat, there are some that could also reasonably predict hydrology.

Table 3: Vegetation Metrics

Metric Type	Candidate Metric			
Community Balance Candidate Metric	Simpson's Diversity Index Metric	Ha	Species Richness Metric	Ha
	Evenness Metric	Ha	Native Species Richness Metric	Ha
	Native Species Evenness Metric	Ha	Vascular Plant Genera Richness Metric	Ha
	Dominance Metric	Ha	Plant Family Richness Metric	Ha
	Herb and Shrub Dominance Cover Metric	Ha		
Floristic Quality Candidate Metrics	FQAI Metric	Ha	Invasive Species Coverage Metric	Ha
	Average C of C Metric	Ha	Invasive Shrub Coverage Metric	Ha
	Percent Tolerant Metric	Ha	Invasive Grass Coverage Metric	Ha
	Percent Sensitive Metric	Ha		
Wetness Characteristic Metrics	FAQWet Equation 3 Metric	Ha, H	Wetland Plant Cover Metric	Ha, H
	FAQWet using Cover Metric	Ha, H	Wetland Shrub Species Richness Metric	Ha, H
	Wetland Plant Species Richness Metric	Ha, H	Wetland Shrub Cover Metric	Ha, H
Functional Groups	Cryptogram Richness Metric	Ha	Carex Coverage Metric	Ha
	Cryptogram Coverage Metric	Ha	Cyperaceae Poaceae, and Juncaceae Metric	Ha
	Annual: Perennial Metric	Ha	Cyperaceae Poaceae, and Juncaceae Coverage Metric	Ha
	Bryophyte Coverage Metric	Ha	Dicot Richness Metric	Ha
	Carex Richness Metric	Ha	Dicot Coverage Metric	Ha
Community Structure	Native Herb Species Richness Metric	Ha	Large Tree Density Metric	Ha
	Native Herb Cover Metric	Ha	Pole Timber Density Metric	Ha
	Total Herb Richness (native and exotic) Metric	Ha	IV Canopy Importance Metric	Ha
	Total Herb Species Cover (native and exotic) Metric	Ha	IV Average Importance Shrub Metric	Ha
	Shade Metric	Ha	Standing Snag Importance Metric	Ha
	Sapling Density Metric	Ha		

Amphibian Metrics

Headwater wetlands serve as critical habitat for many species of amphibians. In the past few decades, it has been noted that amphibian populations are declining. This decline has been attributed to habitat loss and degradation, acid deposition, increases in UV radiation, climate warming, pollutants, introduction of predators, and pathogens such as the chytrid fungus (U.S. EPA, 2002a). Due to their thin, highly permeable skin; jellied and unshelled eggs; their life cycle that requires both terrestrial and aquatic phases; restrictions in habitat; and their limited ability to disperse and colonize other habitats, amphibians are considered indicators of ecosystem health (U.S. EPA, 2002a; NCDWQ, 2006). North Carolina has 96 species of amphibians, 53 of which are known to use habitats such as headwater wetlands during their breeding seasons. These species require areas with high water quality and no predatory fish (EPA, 2002a). The hydrological connection of headwater wetlands does not allow predatory fish to enter the wetland areas and therefore provides breeding habitat for amphibians within the area. Headwater wetlands with characteristics such as deeper pools that can perform the same functions as vernal pools are ideal habitat for many amphibian species. The seepage areas that saturate the wetland soils also provide habitat for many amphibian species (NCDWQ, 2008). For these reasons, data on amphibian populations are considered to be an important indicator of a wetland's functionality.

The amphibian metrics were selected through an additional literature review of stream and wetland studies that use amphibian data to create an Index of Biological Integrity (IBI) (NCDWQ, 2008). These metrics are outlined in **Table 4** shown below. The metrics also have designations of H, WQ, or Ha. These designations indicate which of the three functions; Hydrology (H), Water Quality (WQ), or Habitat (Ha); the metric is intended to predict.

Table 4. Amphibian Metrics

Amphibian Disturbance Scales			
Candidate Metrics			
Percent Tolerant Metric	WQ, Ha	AQAI Metric	WQ, Ha
Percent Sensitive Metric	WQ, Ha	Species Richness Metric	WQ, Ha
% EW-HW-IW Metric	WQ , H, Ha	Abundance Metric	WQ, Ha
Percent Urodela Metric	WQ, Ha		

Physical and Chemical Metrics

In addition to biotic characteristics, abiotic characters, such as water quality and soil properties were determined. Due to the intrinsic relationships between the abiotic and biotic characteristics, it is important to also examine the relationships these factors have with the other metrics calculated. The Land Development Index (LDI) scores were also included in this category.

Water quality is important because of the impact that it has on all other metrics. Headwater streams drain approximately 55-85% of a watershed (U.S. FWS, 2000), illustrating the importance of surrounding land use on water quality in a headwater wetland. As discussed in previous sections, amphibians are sensitive to pollutants such as metals or pesticides and are reliant upon water during various stages of their life cycle. Macroinvertebrates have varying sensitivities to pollutants as well and are also reliant on water during various stages of their life cycle. Vegetation is also sensitive to environmental characteristics such as pH or metals. Sediment pollution can harm populations of macroinvertebrates (NCDWQ, 2008).

LDI scores provide a measure of the level of development surrounding the wetland. **Table 5** displays the metrics that are related to water quality, soils, and land development. These metrics were determined using results from previous NCDWQ studies and a literature review of additional stream and wetland studies (NCDWQ, 2008). The metrics also have designations of H, WQ, or Ha, indicating which of the three functions - Hydrology (H), Water Quality (WQ), or Habitat (Ha) - the metric is intended to predict.

Table 5. Physical and Chemical Metrics

Physical and Chemical Metrics		
Metric Type	Candidate Metrics	
Land Development Intensity	LDI Watershed Value	Ha, WQ
	LDI 300m Buffer Value	Ha, WQ
	LDI 50m Buffer Value	Ha, WQ
Water Quality	Water Quality Pollutant Scale	WQ
Soils	Average Soils pH	Ha, WQ
	Average Soils Zinc	Ha, WQ

Headwater Wetlands as the Test System

Headwater wetlands are wetlands found in the highest reaches of a watershed. These wetlands are associated with first order intermittent and perennial streams. Headwater wetlands grade into the first order stream channels through braided channels or seepage areas. In the Piedmont, these wetlands tend to be bowl shaped, while wetlands in the Coastal Plain tend to be broader and more flattened. These wetlands are very diverse and rarely exceed more than one acre in size, especially in the Piedmont and Mountain regions in North Carolina (NCDWQ, 2008). These wetlands generally contain the first order stream which they feed, but their primary sources of water are precipitation overland runoff, and groundwater discharge from a source such as a seep (Whigham, et al., 1998). Headwater wetlands with minimal disturbance are forested with mature trees. These trees are usually hardwoods such as *Acer rubrum*, *Liquidambar styraciflua*, and *Liriodendron tulipifera*. These trees tend to dominate these wetlands in both the Coastal Plain and the Piedmont. However, headwater wetlands in the Coastal Plain generally have a denser understory of shrubs and trees while the headwater wetlands in the Piedmont generally have a more diverse and denser coverage of the herbaceous layer (NCDWQ, 2008).

Headwater wetlands are very vulnerable to disturbance from actions such as road crossings or ditches that can in turn alter the hydrology, water quality, or habitat structure. Urbanization and agriculture can decrease the quality of water entering the headwater wetland. This can result in an increase in pollutants such as oil, fertilizers, pesticides, and sediments. Headwater wetlands serve as a filtration system to remove these pollutants. Because these wetlands serve as the water source for first order streams, this can have a significant impact on the entirety of the watershed (NCDWQ, 2006). Several studies (Whigham, et al., 1998; NC-CREWS, 1999; NCDWQ, 2006) have shown that headwater wetlands are critical in removing nonpoint source pollutants. As a result, these studies indicate that the higher in the watershed the wetland is located, the more significant it is in removing nonpoint source pollution.

Statistical Analyses

Multivariate Correlation Analysis: A multivariate correlation analysis was conducted using the JMP statistical program. This analysis produced a standard correlation table. A correlation was considered significant if it had a p-value <0.05. Only correlations between the Overall NCWAM score and the three functions (hydrology, water quality, and habitat) were explored in this analysis. The strength ranges of the correlations are outline in **Table 6** below.

Table 6. Correlation Relationship Strength Table

Relationship Strength	Positive Relationship Range	Negative Relationship Range
Negligible	0.01 to 0.19	-0.01 to -0.19
Weak	0.20 to 0.29	-0.20 to -0.29
Moderate	0.30 to 0.39	-0.30 to -0.39
Strong	0.40 to 0.69	-0.40 to -0.69
Very Strong	0.70 to 1.00	-0.70 to -1.00

A modeling tool called screening modeling used a fitting standard least squares modeling procedure to create the best model to predict the Overall NCWAM scores, Hydrology function, Habitat function, and the Water Quality function using the biological, physical, and chemical metrics. Only metrics with a p-value <0.05 were considered significant and used in the models.

An additional model was created using the screening model procedure to determine the role that the function scores play in predicting the Overall NCWAM scores. These outputs created a standard least squares report with a standard regression report, which included an Analysis of Variance

Only linear relationships between the metrics and NCWAM scores were examined in this analysis.

Results

Correlations

First, the metrics were tested for a pairwise correlation to the Overall NCWAM Score, the Hydrology Function, the Water Quality Function, or the Habitat Function. The significant correlations are outlined in **Table 7**. Of the 92 metrics that were tested for their correlation to the NCWAM scores, only 18 were significantly correlated, which is 20% of the total metrics.

The Water Quality Function has the fewest significant correlations. It is only significantly correlated the LDI 50m Buffer Metric, the LDI Watershed Metric, and the Percent Terrestrial Metric.

There are no metrics that are common to the Overall NCWAM score and the three functions. However, there are a number of metrics that are common to the Overall NCWAM score and the Hydrology and Habitat Functions. These metrics are as follows: Annual: Perennial Metric, Average C of C Metric, Fern Richness Metrics, FQAI Cover and Species Count Metrics, and the Grass-Sedge-Rush Metric. Outlined in **Table 7** are the relationships that are expected for each of the metrics to the NCWAM scores. While the majority of these relationships followed the trend expected of them, there were several that did not. The majority of the metrics did not have strong R values, although the Annual: Perennial Metric and the Average C of C Metric did have high R values.

Table 7. Correlations and their Expected Relationships

Metric	Habitat		Hydrology		Water Quality		Overall NCWAM Score		
	R	P-value	R	P-value	R	P-value	R	P-value	Expected Relationship
Amphibian Abundance	0.52	0.0017							positive
Amphibian Species Richness							0.36	0.039	positive
Annual: Perennial Metric	-0.56	0.0007	-0.78	<.0001			-0.75	<.0001	negative
Average Soils pH			-0.41	0.016			-0.38	0.0252	variable
Average Soils Zinc			-0.36	0.0341					variable
Average C of C Metric	0.59	0.0003	0.63	<.0001			0.65	<.0001	positive
Carex Richness Metric	-0.50	0.0257					-0.45	0.0482	positive
Herbaceous and Shrub Cover Dominance-Metric			**0.36**	0.0374					negative
Fern Cover Metric			0.56	0.0008			0.56	0.0007	positive
Fern Richness Metric	0.37	0.0345	0.36	0.0406			0.39	0.0255	positive
FQAI Cover Metric	0.60	0.0002	0.45	0.0094			0.52	0.0017	positive
FQAI Species Count Metric	0.53	0.0014	0.48	0.0046			0.51	0.0023	positive
Grass-Sedge-Rush Metric	**-0.35**	0.0476	**-0.48**	0.005			**-0.42**	0.0153	positive
LDI 300 m Buffer Value							-0.45	0.0078	negative
LDI 50 m Buffer Value					-0.35	0.0448	-0.55	0.0008	negative
LDI Watershed Value					-0.52	0.0018	-0.61	0.0001	negative
Native Herb Richness Metric							**-0.37**	0.0344	positive
Percent Terrestrial Metric					-0.57	0.0007			variable

*correlation coefficient values highlighted in red are R values that did not match the expected positive or negative relationship

Linear Least Squares Model Results

Table 8. ANOVA Summary: Overall NCWAM vs. Function

r-square: 0.96				
Source	DF	Sum of Squares	F Ratio	Prob > F
Hydrology	1	4.9438456	138.3525	<0.0001
Water Quality	1	1.3220029	36.9960	<0.0001
Habitat	1	0.7490359	20.9616	<0.0001
Error	30	1.072010		

Table 9. ANOVA Summary: Overall NCWAM vs. Wetland Metrics

r-square : 0.85				
Source	DF	Sum of Squares	F Ratio	Prob > F
LDI Watershed Value	1	1.1613175	8.3718	0.0080
Predator Richness Metric	1	3.1409957	22.6431	<.0001
Annual: Perennial Metric	1	1.2730868	9.1775	0.0058
Predator Richness Metric*LDI Watershed Value	1	1.3898967	10.0196	0.0042
Annual: Perennial Metric*Predator Richness Metric	1	0.7852323	5.6607	0.0256
Error	24	3.329223		

Table 10. ANOVA Summary: Habitat Score vs. Wetland Metrics

r-square: 0.96				
Source	DF	Sum of Squares	F Ratio	Prob > F
Average C of C Metric	1	4.1866904	75.9779	<0.0001
Large Tree Density Metric	1	3.2725007	59.3877	<0.0001
Carex Richness Metric	1	2.9981651	54.4092	<0.0001
Percent Sensitive Metric	1	1.1895641	21.58766	0.0004
Amphibian Species Richness Metric	1	1.1016428	19.9920	0.0005
Error	14	0.771454		

Table 11. ANOVA Summary: Water Quality Score vs. Wetland Metrics

r-square: 0.55				
Source	DF	Sum of Squares	F Ratio	Prob > F
LDI Watershed Value	1	2.2262543	11.4112	0.0022
LDI 50 m Buffer value	1	0.8571624	4.3936	0.0456
Percent Terrestrial Metric	1	1.7854541	9.1518	0.0054
Error	27	5.267545		

Table 12. ANOVA Summary: Hydrology Score vs. Wetland Metrics

r-square = 0.61				
Source	DF	Sum of Squares	F Ratio	Prob > F
Annual: Perennial Metric	1	0.04941308	47.7741	0.0001
Error	31	0.03206353		

Discussion

Correlation Discussion

Amphibian Abundance

This metric has a strong positive relationship with the Habitat Function of NCWAM. Because habitat loss and fragmentation are among the greatest threats to amphibian populations (Cushman, 2005), it is not surprising that amphibian richness would have a positive correlation with habitat scores. Studies described in the research by Cushman (2005) found that factors such as increased forest cover, proximity of a pond to forested habitat, and the area of forest in a landscape have positive relationships with amphibian richness, while factors such as increasing urban development result in negative relationships with amphibian richness. Additional studies (NC DWQ, 2006; NC DWQ, 2008) have shown that because of the "biphasic life history" of amphibians, amphibians populations are dependent on abundant wetlands distributed within the forested terrestrial habitats that allows for the dispersion of juvenile amphibian populations (Cushman, 2005; NC DWQ, 2008). High quality headwater wetlands are ideal habitat for amphibians due to the interspersion of aquatic and terrestrial habitats for their biphasic life cycle and the lack of predatory fish in the streams to protect larvae and eggs (DWQ, 2008).The results of these studies support the finding of a strong positive relationship with the Habitat Function.

Amphibian Species Richness

This metric has a moderate positive relationship with the Overall NCWAM score. Because of physical characteristics exhibited by amphibians and their diverse needs in terms of habitats, amphibians are considered bioindicators of wetland and water quality (NC DWQ, 2008). As a result, it is logical that amphibian species richness would be positively correlated with the Overall NCWAM score.

Annual: Perennial Metric

This metric had strong to very strong negative relationships with the Habitat Function, Hydrology Function), and Overall NCWAM score.

According to Miller, et al. (2006), this negative relationship is expected because studies have found annual and biennial plants to have a negative relationship with site disturbance (van der Valk, 1981; Gross & Werner, 1982; McIntyre et al., 1995; Gernes & Helgen, 1999; Kleyer, 1999; Schippers et al., 2001; Chapin, 1991). The more disturbed the site, the greater the number of annual and biennial plants. Miller et al. (2006) explain that an explanation for this could be that annual plants have traits that support their growth in disturbed habitats such as rapid growth or a short life cycle. Additional studies (Ehrenfield and Schneider, 1993; Pyle, 1995) have supported this by finding that annual plant species are associated with urban development and forest fragmentation.

Because this metric has such strong significant relationships with two of the three function scores, it is not surprising that it also has a strong relationship with NCWAM. In the screening model results, it was determined that the Annual: Perennial Metric was the only metric that could predict the Hydrology Score with significant results. The Annual: Perennial Metric was able to predict 65% of the Hydrology scores. Because the Hydrology function was found to explain 67% of the Overall NCWAM score, it follows that the Annual: Perennial Metric would both have a significant correlation with the Overall NCWAM score and would play a significant role in predicting the Overall NCWAM score.

Average Soils pH

The Average Soils pH Metric was only significantly correlated with the Hydrology Function scores and was not used in any of the predictive models. However, the correlation for this metric and the Hydrology Function was strong and negative.

Average Soils Zinc

The Average Soils Zinc Metric was also only significantly correlated with the Hydrology Function, but only had a moderate negative relationship.

Average C of C Metric (Coefficient of Conservation)

Plants with high C of C values are considered to typically occur in areas of high habitat integrity while plants with low C of C values are typically found in a wide variety of habitats and are tolerant to disturbance (NCDWQ, 2008; Wilhem and Masters, 1995). It would be expected that this metric would have a positive relationship with the NCWAM scores since a higher score would indicate higher quality plants, which would be desirable in a higher quality wetland.

The Average C of C Metric was found to be strongly correlated with the Habitat Function, Hydrology Function, and the Overall NCWAM Metric. This Metric was also found to be significantly helpful in predicting the Habitat score with a p-value <0.0001. The relationships between the Average C of C value and the Habitat Function, Hydrology Function, and Overall NCWAM Metric were positive, which was expected.

Carex Richness Metric

In this study, Carex Richness was found to have a strong negative relationship with the Habitat Function scores and the Overall NCWAM score. Galatowitsch, et al., (2000) reported that sedges are poorly recruited in restored wetlands, which suggests that these plants have a low tolerance to environmental stress. Therefore, it would be expected that high carex richness would indicate lower levels of disturbance. This is supported by several studies (Galatowitsch et al., 2000; Mack, 2004; Miller et al., 2006). However, the Carex Richness Metric was found to have strong negative relationships with the Habitat Function and the Overall NCWAM scores. This was not expected.

Dominance- herb-shrub Cover Metric

This metric is a community balance metric, meaning that it is testing how much of the sampled wetland is composed of the top three dominant species across the herbaceous and shrub strata. Studies have shown that increased biodiversity is important to wetland quality in a variety of ways. Increased diversity in wetland vegetation has been linked to increased habitat for macroinvertebrates, mammals, and other animals (Tews et al., 2003). Increased vegetation diversity has also been shown to improve the ability of a wetland to remove sediments and other pollutants since multiple species have a better likelihood to withstand various sediment loading rates and can remove a wider variety of pollutants than a wetland with decreased vegetation diversity (Thurston, et al., 2001). It was expected that this metric would have a negative relationship with the NCWAM scores. However, this metric had a moderate positive relationship with the Hydrology Function. It is not known why the metric had a significant correlation with the Hydrology Function as opposed to the Habitat Function, especially with a positive correlation.

Fern Cover and Fern Richness Metrics

According to Miller et al. (2006), the individual and species richness of vascular cryptograms (ferns) decrease with the intensity of the site disturbance. This relationship also is true of the percent cover of ferns. The study by Miller et al. (2006) and others cited within that article have found that high percent cover of ferns is associated with high habitat integrity. Finally, ferns and other fern allies have been found to be forest species that generally have high C of C values. This suggests that they have specific habitat requirements and are more sensitive to disturbance (Miller et al., 2006). This supports our expectations that there will be a positive relationship between the fern cover and fern richness metrics and the NCWAM function and overall scores. The Fern Richness Metric was found to have a strong positive relationship with the Habitat, Hydrology, and Overall NCWAM scores. The Fern Cover Metric was found to have a moderate positive relationship between the Habitat Function, Hydrology Function, and the Overall NCWAM score.

FQAI Cover and Species Count Metric

FQAI stands for Floristic Quality Assessment Index. A higher index score indicates that there is a low probability of the plant species of a site being found in a disturbed site (Lopez and Fennessy 2002). Studies have found the FQAI metric to be useful in evaluating wetland quality (NCDWQ, 2008; Lopez and Fennessy, 2002, Cohen et al., 2004; Miller et al., 2006). Based on the results of this study, the strong positive relationships that were found for both the FQAI species count and cover metrics with the Habitat Function, the Hydrology Function, and the Overall NCWAM scores.

”Studies utilizing the FQAI metric have proven this method to be useful for evaluating wetland integrity (Andreas *et al*. 2004, Cohen *et al*. 2004, Lopez and Fennessy 2002, Mushet *et al*. 2002); however, flaws do exist in the FQAI metric that could result in a misrepresentation of wetland quality.” FQAI is strongly influenced by species richness (Ervin *et al*. 2006). Species richness can be affected by habitat heterogeneity, wetland size, and survey effort, therefore, survey methods must be standardized in wetland studies that use FQAI (Taft *et al*. 1997). The influence of species richness on the FQAI equation could result in a lower FQAI score for more natural and pristine sites with a lower number of native species than more disturbed sites that are heterogeneous and have a higher number of native weedy species. The limitation that species richness has on FQAI is a clear reason why this metric should not be used solely as a wetland evaluation method. Additionally, FQAI mathematically neglects non-native species in calculation of the equation (Ervin 2005). Invasive exotics are assigned a C of C value of zero” (NCDWQ, 2008).

Grass-Sedge-Rush Metric

This metric had a moderate negative relationship with Habitat and strong negative relationships with Hydrology and the Overall NCWAM scores. This relationship followed the trend expected for the metric.

LDI 300m, 50m and Watershed Value Metrics

A Land Development Index, or LDI, is a measure of human disturbance in a designated region. LDI has been found to be an effective indicator of a human disturbance gradient in an ecosystem or watershed (Mack, 2006). This study found that the LDI 300m Buffer Metric had a strong negative relationship with the Overall NCWAM score. The LDI 50m Buffer had a moderate negative relationship with the Water Quality Function and a strong negative relationship with the Overall NCWAM score. The LDI Watershed Value Metric had a strong negative relationship with the Water Quality Function and the Overall NCWAM score. Because a higher LDI score is indicative of increased disturbance in the study area, LDI was expected to have a negative relationship with the NCWAM scores. Studies have found that increased development within a watershed will result in increased sediment loading and increased pollutant levels such as nutrients, pesticides, and other pollutants associated with increased development (Lenat and Crawford, 1994). Therefore, a negative relationship between the LDI scores, which become higher with increased watershed development, and the NCWAM scores, which increase with quality, is expected. A relationship between water quality and LDI scores should be expected due to the strong influence of increased development on water quality in a receiving wetland such as a headwater wetland. Because of the role that land development has on the conditions in a headwater wetland, a relationship between LDI scores and the Overall NCWAM score is also expected.

Native Herb Richness Metric

This metric was expected to have a positive relationship with the NCWAM scores, but has a moderate negative relationship with the Overall NCWAM score instead. One study (Onaindia, et al., 2004) found that herb richness is greatest following periods of intense disturbance and in landscapes that have not been disturbed. Another study (Schmidt, 2005) found that vascular plant richness was greatest in managed forests that experienced some disturbance than in forests that were not managed and had regenerated. The negative relationship that the metric had with the Overall NCWAM metric could be explained by the non-linear relationship of the herb richness metric with varying levels of disturbance.

Screening Model Discussion

Overall NCWAM Scores and the NCWAM Functions Model

The three functions (Habitat, Hydrology, and Water Quality) were able to predict 96 percent of the Overall NCWAM score. Of the three functions, the Hydrology Function was able to explain the most variability in the Overall NCWAM score, predicting approximately five times more of the variability in the Overall NCWAM score than the Habitat or Water Quality functions. Because the Hydrology Function is capable of explaining such a large proportion of the Overall NCWAM score, it is logical to assume that the metrics that are significantly correlated with the Hydrology Function would also contribute significantly to the Overall NCWAM score.

Overall NCWAM and Metrics Model

This model predicted 85 percent of the Overall NCWAM score. The Overall NCWAM score is reliant upon three main metrics; the Annual: Perennial Metric, the LDI Watershed Value, and the Predator Richness Metric. These metrics come from three of the four major categories; vegetation, physical/ chemical, and macroinvertebrates. This model was the only model to contain a macroinvertebrate metric. Of the three metrics in this model, only Predator Richness was not discussed as to its significance in the Correlation section as a result of it not being significantly correlated to the Overall NCWAM score or any of the functions. Of all the metrics in the model, Predator Richness contributed approximately three times more than the other metrics to the Overall NCWAM score based on the Sum of Squares values.

Predator Richness is a measure of the percent of the predators, one of the functional feeding groups of macroinvertebrates in the site. According to studies, the proportion of predators is expected to decrease as impairment increases (U.S. EPA, 2002b). Because headwater wetlands lack predators for macroinvertebrates such as fish, these ecosystem are often dominated by macroinvertebrate predators. Of the functional feeding groups, the two that were found in studies to decrease with increasing human disturbance are the proportions of grazers and the proportions of predators (Kerans and Karr, 1994). Of the metrics described by the U.S. EPA in their Methods for Evaluating Wetland Condition (2002b), predator richness was mentioned several times for its importance in their ability to predict human disturbance levels. Therefore, it is not surprising that this metric was found to be a significant predictor of the Overall NCWAM score, although it is surprising that this metric did not have a significant correlation with the Overall NCWAM score during the correlation analysis.

Habitat Score and Metrics Model

Ninety-six percent of the Habitat Score was predicted by a total of five metrics. Of these five, two were not discussed in the correlation discussion section. Four of the five metrics were vegetation metrics and one was an amphibian metric. Of the metrics that would significantly impact the Habitat score of NCWAM, it is plausible that the vegetation metrics would constitute the majority of the Habitat score. It is very significant that these five metrics could predict such a large percentage of the Habitat score. This would suggest that instead of measuring so many metrics, it would be possible to use these metrics alone to predict the Habitat score. Two of the metrics used in this model did not have correlations with the Overall NCWAM score or the three functions.

The Large Tree Density Metric measures the relative density of the trees ≥25cm DBH. This metric helps to evaluate the maturity of the wetland's tree population. A lack of large trees may indicate human disturbance in a site, which would in turn impact habitat quality.

Finally, the Percent Sensitive Metric is a measurement of the total relative coverage of all species, including non-natives, with a C of C value ≥ 7. As previously discussed, a high C of C value indicates a high quality plant species. A high percentage of vegetation with high C of C values would indicate a wetland with high quality habitat. Because C of C values were strongly correlated with the Habitat and Overall NCWAM scores and explained the highest prediction of variability in the Habitat score, the Percent Sensitive Metric is a logical metric to contribute to the Habitat score due to the inherent relationship between the two.

Hydrology Score

Only one metric, the Annual: Perennial Metric, was used in the Hydrology model. However, this single metric predicted 61percent of the Hydrology score. Because the Hydrology score predicted such a high percent of the Overall NCWAM score, it follows to reason that the Annual: Perennial Metric was also a significant predictor of the Overall NCWAM score. It is uncertain why the Annual: Perennial Metric has such a significant impact on the Hydrology score.

Water Quality Score

Finally, there were three metrics that predicted 55 percent of the Water Quality score. These metrics are the LDI Watershed Value Metric, the LDI 50m Buffer Metric, and the Percent Terrestrial Metric. All of these metrics had significant correlations with the Water Quality score. Because the LDI metrics measure levels of development within the watershed and a 50m buffer around the wetland, these metrics would show significant correlations with water quality for the reasons discussed in the Correlation Discussion section earlier in the report. While the LDI metrics are similar in their function, the Watershed metric predicted twice the amount of the variability in the Water Quality score as the 50m buffer metric. As previously discussed, the Percent Terrestrial Metric may be an indicator of the short term hydrology. However, because the correlation noted in the Correlation Discussion section was negative and could not be explained, it is unknown why this metric so significantly predicts the Water Quality score.

Conclusion

In conclusion, significant relationships were found between the metrics and the NCWAM scores. However, only 18 of the 94 metrics were correlated, which is only 19% of the total metrics. Therefore, NCWAM scores do not reflect the functions of a wetland as defined by the metrics selected for this study. Some of the lack of correlations may be attributed to the fact that the analysis only looked for linear relationships between the metrics and the NCWAM scores while non-linear relationships may have additional relationships that this study did not find. In addition, it is plausible that all of the metrics are not equally significant as an indicator of functionality. For example, the Pole Timber Density Metric may not be as significant of an indicator of habitat functionality as the Large Tree Metric.

Another consideration may be the inherent difficulty in capturing an accurate measure of functionality from a rapid assessment method, and based on the inherent difficulty, the success found in this study may be sufficient to be deemed successful. In addition, it is important to consider the large percentages of the NCWAM scores that could be predicted by the metrics. The metrics were able to predict 55 percent of the Water Quality Function, 61 percent of the Hydrology Function, 96 percent of the Habitat Function, and 85 percent of the Overall NCWAM score.

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Appendix A:
Calculations of Field Metrics

Metric Calculations

Vegetation Metrics

Annual: Perennial Metric:

The Annual: Perennial Metric is calculated by adding the number of annual and biennial plants together and dividing the sum by the number of perennial plants at a site. Biennials are categorized in the same functional group as the annual plants due to their being monocarpic like annuals and mostly being ruderal species (Rhodes & Klein, 2000).

Average C of C Metric:

The Average C of C Metric, or Coefficient of Conservation, is the average of the Coefficient of Conservation values for plants within the site. A Coefficient of Conservation is a ranking that is assigned to a plant based on the likelihood of that plant occurring in a landscape that has relatively undisturbed. These scores vary across different regions of the country. These rankings vary from 0-10 with 0 representing non-native species that are adapted to high levels of disturbance and 10 representing a plant species with the "highest fidelity" to natural areas. Plants with high C of C values are considered to typically occur in areas of high habitat integrity while plants with low C of C values are typically found in a wide variety of habitats and are tolerant to disturbance (NCDWQ, 2008; Wilhem and Masters, 1995).

Bryophyte Coverage Metric:

This metric is the total relative coverage of bryophytes, or mosses.

Carex Coverage Metric:

This metric is the total relative coverage of *Carex* species, or grasses.

Carex Richness Metric:

The Carex Richness Metric is the total number of *Carex* species found at the site.

Cryptogram (Fern) Cover Metric:

The Cryptogram Cover Metric is a measure of the total relative cover of ferns and fern allies.

Cryptogram (Fern) Richness Metric:

The Cryptogram Richness Metric is the total number of fern or fern ally species.

Simpson's Diversity Index using Cover Metric (Dcov-Simpsons Metric):

$\mathrm{D}_{cov} = 1 - [\, \sum n_{icov} (n_{icov} - 1) / N_{cov} (N_{cov} - 1) \,]$

D_{cov} – Simpson's Diversity Index using Cover
N_{cov} – Total cover for all species

n_{icov} - Total cover for species $_i$

Dicot Coverage Metric:

This metric is the relative percent cover of native Dicot herb stratum species

Dicot Richness Metric:

This metric is the total number of native Dicot herb species.

Dominance Metric:

$D = (Cov_{a+b+c} / N cov)$

Cov_{a+b+c} - Total herb or shrub cover species *a, b*, or *c*
*N*cov – Total cover for all herb and shrub species

Evenness Metric:

$E_s = D_s / D_{max}$

E_s - Evenness
D_s – Simpson's Diversity Index
D_{max} – Maximum D_s

FAQ Wet Cover Metric

FAQWet Cover = $\sum WC/\sqrt{S} * \sum Cov_{nat}/\sum Cov_{tot}$

WC = Wetness Coefficient
F = Frequency of all species
S = All species
f = Frequency of native species
N = Native Species
Wetland coefficient values in the above equations are calculated as follows: OBL = + 5, FACW = + 3, FAC = 0, FACUP = -3, UPL = - 5

FAQ Wet Equation 3 Metric:

FAQWet equation 3 $= \sum WC/\sqrt{S} * N/S$

WC = Wetness Coefficient
F = Frequency of all species
S = All species
f = Frequency of native species

N = Native Species
Wetland coefficient values in the above equations are calculated as follows: OBL = + 5, FACW = + 3, FAC = 0, FACUP = -3, UPL = - 5

Floristic Quality Assessment Index (FQAI) Metric:
FQAI stands for Floristic Quality Assessment Index. This index was designed to minimize the subjectivity and to develop a tool that can be used by an individual with basic botanical skills. The FQAI Metric is a "weighted index of species richness, the arithmetic product of the average coefficient of conservation, and the square root of species richness" of a site and is calculated using the following equation (Taft, Wilhelm, Ladd, & Masters, 1997): The metric used in this study also includes non-natives in the species total. A second FQAI metric, FQAI_{cov}, which incorporates species cover into the equation, was also tested.

$$\text{FQAI} = \sum C_i / \sqrt{N} \qquad \text{FQAI}_{cov} = \sum C_i * Cov_i / \sqrt{N} * \text{Cov}_{tot}$$

C_i - Coefficient of Conservatism for species i

N - Species richness (including non-natives)

Cov_i - Cover of species i

Cov_{tot} – Total Coverage including non-native species

A higher index score indicates that there is a low probability of the plant species of a site being found in a disturbed site (Lopez and Fennessy 2002).

Grass-Sedge-Rush Metric

Total number of native grasses, sedges and rushes (Poaceae, Cyperaceae, and Juncaceae).

Grass-Sedge-Rush Cover Metric

Total relative cover of native grasses, sedges and rushes (Poaceae, Cyperaceae, and Juncaceae).

Dominance- herb-shrub Cover Metric:

This metric incorporates the distribution or concentration of the three most dominant species cover class values for all individuals, "D", and shrub and herb classified individuals "D(hs)"(ferns, grass, sedge, rush, forbs, herbaceous vines, shrubs, and small trees). This metric is calculated as follows (IWC 2012):

$$D = (\text{Cov}_{a+b+c} / N\text{cov})$$

Cov_{a+b+c} - Total most dominant species a, b, or c.

Ncov – Total cover for all species

$$D(hs) = (\text{Cov}(hs)_{a+b+c} / N\text{cov}(hs))$$

Cov(hs) $_{a+b+c}$ - Total most dominant herb or shrub cover species *a, b*, or *c*.

*N*cov(hs) – Total cover for all herb and shrub species

Invasive Grass Coverage Metric:

Total relative cover of all non-native invasive grass species.

Invasive Shrub Coverage Metric:

Total relative cover of all non-native invasive shrub species.

Invasive Species Coverage Metric:

Total relative cover of all non-native invasive species.

IV Average Importance Shrub Metric:

This metric is the sum of the average importance value for native shrubs and small trees. The average importance values for all native shade shrubs and small trees and all native partial shade shrubs and small trees were calculated separately. The relative importance value is equal to the sum of the relative density, relative dominance, and relative frequency. Relative density for each species was calculated by dividing the total number of shrub and small tree stems per species by the total number of shrub and small tree stems for all species. Species dominance per size class was calculated by multiplying the number of shrub and small tree stems in each species size class by the midpoint of the size class. The dominance of each size class was then summed to equal total species dominance. Relative species dominance was calculated by dividing total dominance of each native shrub and small tree species by the total dominance of all shrub and small tree species. Relative species frequency was calculated by dividing the number of size classes each native shrub or small tree species occurred in by the total number of size classes, which were 10.

IV Canopy Importance Metric:

This metric is the average relative importance value of native canopy species. The relative importance value is equal to the sum of relative density, relative dominance, and relative frequency. Relative density for each species was calculated by dividing the total number of canopy (Canopy = "Tree" see Table B-3) stems per species by the total number of canopy stems for all species. Species dominance per size class for size classes 0-1 cm to 30-35 cm DBH was calculated by multiplying the number of canopy stems in each species size class by the midpoint of the size class. The 0-1 cm to 30-35 cm dominance size class for each species was calculated by summing the dominance for size classes 0-1 cm to 30-35 cm. The species dominance for size classes >35 cm DBH was calculated by summing the total DBH for each canopy species >35 cm. Therefore, if two red maples each equal to 45 cm DBH and one red maple equal to 60 cm DBH were recorded during the woody vegetation survey the >35 dominance size class would be equal to 150 cm. The total dominance for each species was calculated by summing the 0-1 cm to 30-35 cm dominance and > 35 cm species dominance species size classes. Relative dominance was calculated by dividing total dominance of each canopy species by the total dominance of all canopy species. Relative frequency was calculated by dividing the number of size classes each canopy species occurred in by the total number of size classes, which were 10 (0-1, 1-2.5, 2.5-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-35, and ≥35).

Large Tree Density Metric:

Relative density of native trees > 25 cm DBH.

Native Evenness Metric:

Evenness is the distribution of individuals among species. If all species are equal in distribution, then evenness is high. The first equation (E_s) is the standard Evenness equation and the second equation (E_{cov}) uses coverage instead of abundance and was used as a candidate metric in this study. *Native Evenness* was calculated with solely native species.

$E_s = D_s / D_{max}$

$E_{cov} = D_{cov} / D_{max\text{-}cov}$

$D_{max} = (s - 1 / s) * (N / N - 1)$ $D_{max\text{-}cov} = (s - 1 / s) * (N_{cov} / N_{cov} - 1)$

E_s - Evenness

D_{max} – Maximum D_s

$D_{max\text{-}cov}$ – Maximum D_s using cover

s - number of species

N – Total Individuals

D_s – Simpson's Diversity Index

N_{cov} – Total cover for all species

Native Herb Coverage Metric:

Relative herbaceous cover for native species.

Native Herb Richness Metric:

Total number of native herb species.

Native Species Richness Metric:

Total number of native species.

Percent Sensitive Metric:

Total relative coverage of all species, including non-natives, with a C of C value $\geq$ 7.

Percent Tolerant Metric:

Total relative coverage of all species, including non-natives, with a C of C value $\leq$ 2.

Plant Family Richness Metric:

Total number of plant families.

Pole Timber Density Metric:

Relative density of trees in the 10-15, 15-20, and 20-25 cm DBH size class. Relative density of pole timber trees was calculated for each pole timber size class (10-15, 15-20, 20-25) by dividing the total number of stems per pole timber size class for canopy and small tree species by all stems for canopy and small tree species.

Sapling Density Metric:

Relative density of canopy and small tree sapling species and small tree species in the <1 cm, 1-2.5 cm, 2.5-5 cm, and 5-10 cm DBH size classes. Relative density was calculated for each sapling size class by dividing the total number of stems per size class for canopy and small tree species by all stems for canopy and small tree species. The relative density of the four sapling size classes (<1 cm, 1-2.5 cm, 2.5-5 cm, and 5-10 cm) was then summed to equal the *Sapling Density Metric*.

Shade Metric:

Number of native species (not including adventives or trees) with a shade rating of “shade” or “partial shade”.

Simpson’s Diversity Index:

$$D_s = 1 - [\sum n_i (n_i - 1) / N (N - 1)]$$

D_s – Simpson’s Diversity Index
n_i –Total individuals of species $_i$
N – Total individuals

Species Richness Metric:

Total number of species.

Standing Snag Importance Metric:

Snags ≥ 5cm DBH were counted for this metric.

Total Herb Cover Metric:

Total herb cover for both native and exotic species.

Total Herb Richness Metric:

Total herb richness for both native and exotic species.

Vascular Plant Genera Richness:

Total number of vascular plant genera.

Wetland Plant Cover Metric:

Coverage of native species with a FACW or OBL wetland indicator status.

Wetland Plant Species Richness Metric:

Number of native species with a FACW or OBL wetland indicator status.

Wetland Shrub Cover Metric:

Coverage of native wetland shrubs with a FACW or OBL wetland indicator status.

Wetland Shrub Species Richness Metric:

Number of native wetland shrubs with a FACW or OBL wetland indicator status.

Macroinvertebrate Metrics

Abundance Metric:

The total number of individuals.

Family Richness Metric:

The total number of macroinvertebrate families.

Generic Richness Metric:

The total number of macroinvertebrate genera.

Species Richness Metric:

The total number of macroinvertebrate species.

Chironomidae Richness Metric:

The total number of Chironomidae.

EPT Richness Metric:

Total number of Ephemeroptera, Plecoptera, and Trichoptera

OET Richness Metric:

Total number of Odonata, Ephemeroptera, and Trichoptera

POET Richness Metric:

Total number of Plecoptera, Odonata, Ephemeroptera, and Trichoptera

Macroinvertebrate Biotic Index Score Metric:

$MBI=(\sum Tv_iN_i)/N$

Tvi= tolerance value of ith taxa
Ni= abundance of ith taxa
Total number of individuals collected

Per Top 3 Dominant Metric:

The percent of the sample that consisted of the top three genera.

Percent Decapoda Metric:

Percent of the sample that are Decapoda

Percent Oligochaeta Metric:

Percent of the sample that are Oligiochaeta

Percent Chironomidae Metric:

Percent of the sample that are Chironomidae

Percent Coleoptera Metric:

Percent of the sample that are Coleoptera

Percent Corixidae Metric:

Percent of sample that are Corixidae

Percent Crustacea Metric:

Percent of sample that are Crustacea

Percent Diptera Metric:

Percent of sample that are Diptera

Percent Dyticidae Metric:

Percent of sample that are Dyticidae

Percent Hemiptera Metric:

Percent of sample that are Hemiptera

Percent Leech Metric:

Percent of sample that are leeches

Percent Microcrustacea Metric:

Percent of sample that are microcrustacae

Percent Mollusk Metric:

Percent of sample that are mollusks

Percent Orthocladinae Metric:

Percent of sample that are Orthocladinae

Percent Terrestrial Metric:

Percent of sample that are terrestrial species only

Percent Trichoptera Metric:

Percent of sample that are Trichoptera

Percent Trombidiformes Metric:

Percent of sample that are Trombidiformes

Percent EPT Metric:

Percent of sample that are Ephemeroptera, Plecoptera, or Trichoptera

Percent OET Metric:

Percent of sample that are Odonata, Ephemeroptera, or Trichoptera

Percent POET Metric:

Percent of sample that are Plecoptera, Odonata, Ephemeroptera, or Trichoptera

Percent Predator Metric:

Percent of the sample that are in the predator functional feeding group

Percent Sensitive Metric:

Total relative coverage of all species, including non-natives, with a C of C value $\geq$ 7.

Percent Tolerant Metric:

Total relative coverage of all species, including non-natives, with a C of C value $\leqq$ 2.

Sensitive: Tolerant Ratio Metric:

The ratio of sensitive (C of C value $\geq$ 7) to tolerant (C of C value $\leqq$ 2)

Simpson's Diversity Metric:

$$\mathrm{D}_s = 1 - \left[\sum n_i (n_i - 1) / N (N - 1) \right]$$

D_s – Simpson's Diversity Index
n_i –Total individuals of species $_i$
N – Total individuals

Evenness Metric:

$$E_s = D_s / D_{max}$$

E_s - Evenness
D_s – Simpson's Diversity Index
D_{max} – Maximum D_s

Amphibian Metrics

AQAI Metric:

A higher Amphibian quality Assessment Index (AQAI) score indicates there is a higher abundance of sensitive species or a high number C of C species at the site.

$$\mathrm{AQAI} = \sum \mathrm{S}_i * \mathrm{S}_{i\,\mathrm{c\ of\ c}}$$

$$
\begin{array}{c}
\text{----------------}\\
N
\end{array}
$$

Where:

S_i = Adult number of species i
$S_{i\ c\ of\ c}$ = C of C value for species i
N = Total number of adults.

Percent Tolerant Metric:

Percent of amphibians with C of C score ≤ 3

Percent Sensitive Metric:

Percent of amphibians with C of C ≥ 6

% EW-HW-IW Metric:

Percent of amphibians requiring Isolated, Ephemeral, Seepage, or Headwater wetland conditions

Percent Urodela Metric:

Percent of sample that are Urodela (salamanders)

Species Richness Metric:

Total number of species at the site

Abundance Metric:

Relative number of species at the site

Physical/ Chemical Metrics

LDI 50m Buffer, 300m Buffer, and Watershed Values:

A Land Development Index, or LDI, is a measure of human disturbance in a designated region. To calculate this metric, land use in the wetland's watershed, 300 meter buffer, and 50 meter buffer was designated as one of ten land use cover types (see Table 1) and the acreage of the digitized land parcel was determined for each land use cover type. A coefficient was then assigned to each of these land use cover types, which can also be seen in Table 1. Finally, the following equation was used to calculate the Land Use Index vale for each site.

$\mathrm{LDI}_{Total} = \sum \%\mathrm{Lu}i * \mathrm{LDI}i$

LDI_{Total} = LDI ranking for landscape unit

$\%Lu_i$ = percent of the total area of influence in the land use i

LDI_i = landscape development intensity coefficient for land use i

Table 1. Headwater Wetland Land Cover Type and Index Values

Land Cover Types for wetland study site watersheds and one-mile buffers	LDI Coefficient
Natural Areas	1
Water Bodies	1
Unmanaged Herbaceous Upland	2
Unmanaged Herbaceous Wetland	2
Managed Herbaceous Upland	3
Pine Plantation	3
Unconsolidated Sediment	4
Cultivated	5
Low Intensity Developed	6
High Intensity Developed	8

Average Soils pH:

The Average Soils pH Metric was calculated by averaging the pH values from the samples collected at each site.

Average Soils Zinc

The Average Soils Zinc Metric was calculated by averaging the zinc levels from the samples collected at each site.

Water Quality Pollutant Scale:

Water Quality Pollutant Disturbance measurement = Sum of Relative Average Values by Region for Nutrients+Metals+Fecal Coliform+TSS+Specific Conductivity (surface water only)