Refinement and validation of a multi-level assessment method for Mid-Atlantic tidal wetlands (EPA #CD-973494-01)

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INTRODUCTION

To monitor the extent and condition of wetland resources across the Mid-Atlantic physiographic region, efforts are currently underway in a number of states, most notably Delaware, Maryland, Pennsylvania and Virginia, to develop and implement wetland monitoring strategies. The purpose of these strategies is to assess the existing condition of wetland resources and to track changes to these systems over time, primarily due to anthropogenically induced alterations to individual systems or the watershed in which they are located. With a solid commitment from US Environmental Protection Agency's Chesapeake Bay Program partners to achieve a net-gain in wetland acreage, an inventory of existing wetland resources and their biological condition, is the necessary first step in a process designed to conduct status and trends analysis over time. In addition to reporting, determining the condition of wetlands improves our ability to protect and restore these resources through both regulatory and non-regulatory programs. State and federal regulatory programs tasked with the implementation of Sections 401 and 404 of the Clean Water Act are in need of methods to assess condition and assign value to wetland resources and to understand how wetlands on the individual site and the landscape levels are impacted through permitted development activities. Collecting information on the condition of wetlands and the associated stressors impacting them will also assist states in better targeting wetland restoration efforts and measuring the success of both compensatory mitigation and voluntary restoration activities. All of these tasks call for an assessment method that provides data for informed management decision-making.

State agencies responsible for tidal and non-tidal wetland regulatory programs across the Mid-Atlantic, and specifically the Delmarva region, are committed to these strategies as evidenced in these States' ongoing involvement with the Mid-Atlantic Wetland Workgroup (MAWWG), funded by the US Environmental Protection Agency (EPA). Substantial contributions have been made by this group in the development of wetland monitoring science over the last few years through efforts focused on wetland assessment methods that can be used in reporting wetland condition as required by Clean Water Act (CWA) Section 305 (b). The efforts of MAWWG have been extremely successful in initiating development of monitoring programs designed to collect critical baseline data to quantify and characterize existing wetland resources. These baseline data can be utilized in the future to programmatically conduct status and trends analysis, determine management program effectiveness, identify restoration opportunities and evaluate the effectiveness of compensatory mitigation projects.

PROJECT OBJECTIVES

Between 1960 and 1990, the Chesapeake Bay watershed experienced the fastest growing population in North America (Culliton et al. 1990) and coastal areas in the Mid-Atlantic are seeing unprecedented growth. As development within the Chesapeake and Delaware Bay watersheds continues to increase, additional anthropogenically induced stress is being placed on tidal and non-tidal wetland resources. Although conscious efforts are underway in Delaware, Maryland, Pennsylvania and Virginia to inventory and assess non-tidal wetlands, no similar effort exists to characterize the regions' tidal wetlands that face continued degradation due to unceasing development of both the riparian area and the surrounding watershed. Therefore, to provide local, state and federal regulatory and resource managers with the current extent and condition of tidal wetland resources, we have developed an inventory and multi-level assessment method for tidal wetlands in the Delmarva region of the Mid-Atlantic.

SCOPE OF WORK

This project is designed to provide the Virginia Marine Resources Commission (VMRC), Virginia Department of Environmental Quality (DEQ), Delaware Department of Natural Resources and Environmental Control (DE DENREC), Maryland Department of Natural Resources (MD DNR) and the Maryland Department of the Environment (MDE) with the ability to report the current extent and condition of estuarine wetlands of three major, tidal river systems of the Delmarva. We have developed a multi-level (Level I, Level II and Level III) tidal wetland inventory and assessment methodology for the Delmarva using the estuarine segments of the York River, Virginia, Nanticoke River, Maryland and the Indian River, Delaware as our project watersheds (Fig. 1). This report outlines the development and implementation of this multi-level approach to tidal wetland inventory and assessment along with the utilization of these data by the aforementioned state environmental programs. It is intended that this multi-level approach can serve as a prototype for expanded investigations into other watersheds in the future.

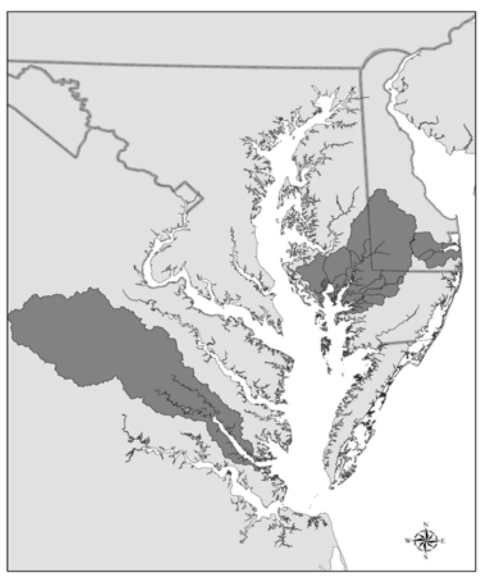

Figure 1. Highlighted watersheds of the York, Nanticoke and Indian Rivers.

METHODS - LEVEL I

The Level I inventory and assessment developed in this study relies extensively upon the use of remotely sensed geographic information systems (GIS)-based datasets, hereafter referred to as a coverage. These data were utilized to determine the boundaries and aerial extent of estuarine and palustrine wetlands, salinity, hydrology, bathymetry, surrounding land use classification, submerged aquatic vegetation, oyster reefs, and conservation sites within the York River, Virginia, Nanticoke River, Maryland, and Indian River, Delaware watersheds. Estuarine and palustrine tidal wetlands as classified by the hierarchical Cowardin system (Cowardin et al., 1979) were identified using the U.S. Department of the Interior's National Wetland Inventory (NWI) coverage. A total of 2,188 tidal wetland polygons were identified in the tidal portion of the York River watershed. Table 1 lists the various tidal wetland types included in this study.

Table 1. NWI wetland types included in Level I assessment of York River, Virginia. Asterick (*) denotes any modifier to: water regime, water chemistry, soil, etc., when applicable.

E2*EM*	Estuarine intertidal emergent
E2*SS*	Estuarine intertidal scrub-shrub
E2*FO*	Estuarine intertidal forested
R1EM	Riverine tidal emergent
PSS*S	Palustrine scrub-shrub temporary-tidal
PSS*R	Palustrine scrub-shrub seasonal-tidal
PSS*T	Palustrine scrub-shrub semi-perm.-tidal
PSS*V	Palustrine scrub-shrub permanent-tidal
PEM*S	Palustrine emergent temporary-tidal
PEM*R	Palustrine emergent seasonal-tidal
PEM*T	Palustrine emergent semi-perm.-tidal
PEM*V	Palustrine emergent permanent-tidal
PFO*S	Palustrine forested temporary-tidal
PFO*R	Palustrine forested seasonal-tidal
PFO*T	Palustrine forested semi-perm.-tidal
PFO*V	Palustrine forested temporary-tidal

Utilizing the most recent versions of available GIS coverages, CCRM scientists identified various metrics to assess every tidal wetland polygon or line feature for three basic ecological functions; habitat, water quality and erosion protection. This census approach to wetland assessment, whereby each wetland is evaluated individually, is one of the strengths and advantages of a methodology based on remotely sensed data. The decision to focus our assessment on these three functions was based on our current scientific understanding of the ecological services provided by these systems. The available scientific literature and the collective best professional judgment of CCRM wetland scientists was used to develop and refine the various metrics that comprise the three functional value scores calculated for each wetland. Reporting functional scores at various resolutions, from an entire NWI wetland class within the three study watersheds to an individual tidal wetland polygon, is facilitated using ArcInfo® GIS software to calculate total wetland size (hectares) and NWI classification.

Although combining the individual function scores to obtain a cumulative functional value score to rank wetlands among one another would appear desirable from a resource management and regulatory perspective, no scientific rationale currently exists that would permit users to attribute or weigh one function more heavily versus another.

Although managing a wetland resource to maximize a specific function has its applications, typically, managing for a suite of functions is the more common resource management practice. Until further research and our scientific understanding support the valuation of one function higher than the others, it is unadvisable to compare scores across ecological functions. Therefore, at this time we do not recommend the cumulative comparison of functional scores for tidal wetlands as a means to rank individual wetland polygons using the assessment methodology described here.

Level I -Water Quality Scoring

In selecting the most important and valuable ecological functions performed by wetlands it would be difficult to select one more important to general aquatic health than water quality. Tidal wetlands play an important role in removing sediment and nutrients from surface water runoff entering an estuary from the surrounding watershed. Estuaries play an important role in the flushing of toxins, nutrients and suspended sediments from the system. Residence time, a function of freshwater input, currents, and tidal influence, provides a relative rate at which these materials move through the estuarine system. Though it is more desirable to prevent pollutants from entering surface waters than to address the problems associated with eutrophication and turbidity after-the-fact, certain wetlands based on their position within the watershed possess provide more opportunity for these materials to be sequestered in the marsh as opposed to being exported down-estuary then offshore to the continental shelf.

In this study, salinity was used as a proxy for residence time within the estuarine system. Salinity coverage for the York, Nanticoke and Indian Rivers was obtained from the National Oceanic and Atmospheric Administration (NOAA). The salinity coverage is a dataset composite (1986-2000) of seasonally (spring, summer, fall) interpolated data. Salinity was clipped to the three study area boundaries. Average-maximum value was used to group the salinity values into regimes with salinity scores:

Tidal regime	score
Tidal fresh ≤0.5 ppt	1.0
Oligohaline >0.5 – 5.0 ppt	0.75
Mesohaline >5.0 - 18.0 ppt	0.50
Polyhaline >18.0 – 30.0 ppt	0.25
Euhaline >30.0 ppt	0.10

Lines were drawn from the boundaries of the salinity regimes to the edge of the three study area boundaries to create large polygon coverages. These coverages were unioned with the NWI coverage to add salinity values to all tidal wetlands.

Following the stratification of the wetlands by salinity regime, the upland/wetland interface was determined. Wetland polygons were then buffered 10m along the upland/wetland arc. The buffer was then overlaid with the wetland and the percentage of wetland within the wetland side of the buffer was determined. This metric is identified by the name: wtlnd10m. Scores for this metric range from 0.1 to 1.0. All linear tidal wetlands receive a score of 0.1, as do polygons without an upland/wetland interface i.e. surrounded by other wetland polygons.

Level I – Habitat Scoring

Following the water quality benefits provided by tidal wetlands, the provision of habitat for innumerable plant and animal species is arguably the second most important function provided by these systems. Tidal wetlands provide valuable forage, spawning and nursery habitat for many marine and terrestrial species. Many animals important to sustaining ecosystem health spend at least a portion of their life history in tidal marshes. Often, a combination or mosaic of various habitat types can provide a synergism of habitat function not possible when habitats are found separately. Oyster reefs and seagrass beds are examples of habitats that can increase the ecological functional value of an adjacent marsh. For this reason, wetland habitat function is improved through association with submerged aquatic vegetation (SAV), oyster reefs and other wetlands.

The SAV data for the York River used for this study is a 10 year composite of data collected from 1993 to 2003. Other SAV datasets were acquired for the Nanticoke and Indian Rivers. These data are represented as the presence/absence of these habitat types. The percent of SAV within the 100m aquatic buffer and the 200 m aquatic buffer were calculated in hectares (sav1h and sav2h). The 100m buffer score = (area of SAV / aquatic area) X 2 and the 200m buffer score = (area SAV / aquatic area). Area of SAV located within 100m is therefore weighted twice that located between 100-200 m from the wetland. Oyster reefs in the York River watershed are point data obtained from VMRC. The points are buffered 10 m. A wetland with a buffered oyster reef occurring within the 100 m or 200 m aquatic buffer scores a 1.0 (oyster1h or oyster2h). Three buffers, 3 m, 100 m, and 200 m, are used to capture wetland proximity to other wetlands. All wetland types located within the various buffers are used in this scoring, but are differentiated as tidal or non-tidal wetlands. Wetland proximity is scored as follows where only the closest wetland receives a score:

Tidal	score	Non-Tidal	score
3 m	1.0	3 m	0.5
100 m	0.5	100 m	0.25
200 m	0.25	200 m	0.125
1000 m	0.0	1000 m	0.0

The land use surrounding a wetland can dramatically influence its ability to provide and sustain habitat function. A wetland surrounded by undisturbed forested land typically provides excellent habitat function to the wetland whereas urban and industrial surrounding land use types can limit the ability for the wetland to provide significant habitat. To identify land use classifications within the three study watersheds, National Land Cover Data (NLCD) 1992 and NLCD 2001 were used. The methodology we developed for use with non-tidal wetlands (EPA #CD-983380-01) was also employed in this study. Wetlands are buffered with four distances (3 m, 100 m, 200 m, 1000 m). These buffers are combined into one polygon coverage. Buffer coverage is intersected with the landuse coverage. A frequency is run to determine the landuse types within the buffers. Total area is determined for each buffer width (0-3 m, 3-100 m, 100 m-200 m, and 200 m-1000 m). The percentage of each landuse type within each buffer was then calculated. Functional values are calculated by multiplying the percentage of each landuse type within the buffer by the value assigned for each landuse type. Land cover types and initial habitat value scores are listed below. Functional values for each buffer width are then summed for each wetland.

Landuse type	score
Wetland (woody and emergent)	1.0
Forest (deciduous, evergreen, and mixed)	1.0
Open water	1.0
Pasture	0.7
Cropland	0.5
Bare rock/sand, transitional	0.5
Residential (low den. res. & urban/rec. grass)	0.2
Urban/Industrial	0.0

Adjacency to open water and access to the marsh interior directly affects the quality of the marsh habitat by affording access onto the marsh surface for refuge and feeding during high water levels. To evaluate the availability of the marsh to aquatic species, stream density is measured for each wetland using Virginia Base Map Program (VBMP) arcs (coded level = 44 streams/rivers). Other coverages were obtained for the Nanticoke and Indian Rivers. NWI polygons were used to clip the VBMP arcs. Minor errors associated with clipping the arcs were unavoidable due to alignment offsets. All stream segments were assigned a default width of 1 m. Stream density is expressed as a percentage of the total area where ((total stream length x 1 m) / area of wetland polygon) x 10.

Wetlands often provide valuable or even critical habitat for rare, threatened and endangered species of plants and animals. Because of the importance of protecting these species and the habitats that support them, conservation sites were identified in the York River watershed using the Virginia Department of Conservation and Recreation, Division of Natural Heritage coverage. Tidal wetlands that fall within conservation sites are identified and are scored based upon the biodiversity rank (B1-B5) of the conservation site they overlay. If a wetland overlaps more than one conservation site, the wetland score represents the highest-ranking site.

Biodiversity Rank:	B1	B2	B3	B4	B5
Score:	2.0	1.5	1.0	0.75	0.5

Level I - Erosion Protection Scoring

Miles of Mid-Atlantic tidal shoreline is hardened each year by property owners seeking to provide their property with erosion protection. Although structural solutions to shoreline protection such as rock revetments and breakwaters have application in high wave energy environments, often a more environmentally sensitive approach that utilizes wetland vegetation to buffer wave energy is more appropriate and desirable in lower energy environments. Though all vegetated wetlands afford some protection to typical wind generated waves and boat wakes, marshes can also provide considerable buffering of tidal shorelines when subject to storm tides and large wind generated waves over large expanses of open water (fetch). We assessed the erosion protection afforded by tidal wetlands in the three study rivers using the NWI shoreline and the 2m-depth contour based on NOAA bathymetry available through the Chesapeake Bay Program. Mid-point of the arc(s) were determined for wetlands intersecting the shoreline. COGO (coordinate geometry) is used to create short arcs in 16 directions (N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW). Arcs are extended to intersect the bathymetry and shoreline. Directions and distances are then written back to the wetland. If there are two midpoints, the midpoint with the longest fetch is identified and that data written data back to the wetland. If there are three or more shoreline segments for a single wetland polygon, the maximum fetch and direction for each midpoint is determined. The 16 directions are then condensed into four quadrants (NE, SE, SW, NW). The predominant fetch direction is then determined based upon the number of points in each quadrant. The longest fetch is selected from the predominant quadrant and data written to the wetland. If two or more quadrants have an equal number of points, then the longest fetch is selected from among those quadrants.

The assessment of wetland islands, where a single wetland is completely surrounded by open water, requires a slightly different analysis. A centroid point is established within the wetland. Arcs are created from this point and radiate out in 16 directions to intersect with the wetland's perimeter. From each of these intersection points, 16 additional arcs are created and extended to the nearest shoreline and 2m bathymetric contour. The arc with the longest fetch is written back to the wetland. The direction of the arc with the longest fetch is then used to determine the distance to the 2m contour.

Fetch	score
≥ 1000m	1.0
< 1000m	0.5
= 0 m	0

Distance to 2m contour	score
≤ 100m	1.0
> 100m	0.5
= 0 m	0
= fetch (shallow water)	0.25

Level I – Example scores

The tidal portion of the York River, Virginia, and its two main tributaries the Mattaponi and Pamunkey Rivers, was used as the prototype watershed in developing of the Level I tidal wetland assessment utilized in this study. Scoring for each of the 2,188 wetlands evaluated in this study for the York River, as well as the Nanticoke River, Maryland and Indian River, Delaware are available for viewing at http://ccrm.vims.edu The output of the Level I assessment is provide via interactive maps depicting wetland habitat, water quality and erosion protection scores. Examples of scores for each function calculated for three York River wetlands are depicted in Appendix A (Figures 2 through 10). The three different wetland polygons are examples that illustrate the range of the individual metric scores that comprise the overall scores for water quality, habitat and erosion protection functions.

METHODS - LEVEL II

In order to provide resource management with the site-specific information necessary to accurately assess condition of specific, individual tidal wetlands, a field-based sampling protocol has been used here to provide additional site-specific data. The Level II assessment also helps to calibrate the Level I landscape-scale assessment. Consequently, it is important for the on-site assessment to be relatively quick while providing easy access to individual sites. We have employed a census-based approach to Level II sampling whereby access to all estuarine tidal wetlands within the three study watersheds is provided via the river. Using this approach, thousands of tidal wetlands across a large area (three Mid-Atlantic watersheds) have been surveyed relatively quickly, thereby providing a continuous data set for each of the three tidal rivers that were sampled.

Level II - Data Collection Methodology

The Level II Tidal Wetlands Assessment protocol is derived from data development and collection techniques established by the VIMS Comprehensive Coastal Inventory Program (CCI) for mapping tidal shoreline condition in Virginia. These protocols are discussed in further detail in following sections of this report. The shoreline inventory uses a multi-tiered assessment approach for mapping and cataloging conditions along tidal shores. Data collection is performed in the field from a small, shoal draft vessel navigating slowly and parallel to the shoreline. Trimble® hand-held global positioning systems (GPS) are used to log conditions and attributes observed from the boat.

The Level II tidal wetland assessment refines (calibrates) the Level I assessment through a spatially explicit examination of the landscape adjacent tidal wetlands within the three study watersheds. Specifically, the Level II assessment is intended to evaluate anthropogenic stressors adjacent tidal wetlands and to qualify the degree to which these stressors have affected specific wetlands functions. The Level II assessment considers landscape characteristics of the immediate riparian zone and how these enhance or impact wetland function. The assessment methodology derives a set of spatial rules in order to score each wetland polygon based on the collection of observable site conditions. Shoreline inventory data was collected in the Indian River, Delaware during the summer of 2006 using methods previously described. Existing shoreline inventory datasets collected by CCI have been utilized herein to conduct the Level II analysis of tidal wetlands within the Nanticoke and York River watersheds.

Level II– Shoreline Attributes

Geographic Information System (GIS) has been used to model the wetland assessment methodology we have developed here. Similar approaches have been utilized in nontidal wetland assessment projects (Havens et al. 2004; Havens et al. 2002) that apply point systems to rank geographic features based upon specific use. This assessment approach uses observations that can be made from a shallow draft vessel underway. A GPS survey captures descriptive measurements that characterize conditions (attributes) using a methodology developed by Berman and Hershner (1999). The GPS provides positional data for the attributes and conditions to within 5 meters of the true shoreline position.

The GPS data collection protocol applies a three-tiered assessment approach to characterize condition related to riparian land use, bank stability, and shoreline modifications (structures). Because this protocol was originally developed to collect information necessary in support of enhanced shoreline management decisions, the data collected has significant relevance to this condition assessment. The specific attributes we recorded using GPS are described below.

Level II -Riparian Land Use

Land use immediately adjacent to the bank is classified into one of nine different categories (Table 1). These categories provide a simple assessment of land use and assume that various land management practices may be anticipated based on this classification. The width of the landuse zone varies along the shoreline, and is determined by what field personnel can observe from the vessel. The actual width of the zone is not measured or estimated, but the linear extent of the shore along which the land use condition is observed is measured using GPS. These land use classes provide insight into potential adverse effects on wetland function.

1. Forest	stands greater than 5.5m in height
2. Scrub-shrub	stands less than 5.5m in height
3. Grass	includes fields and pasture land
4. Agriculture	active cropland only
5. Residential	includes single or multi-family residences
6. Commercial	includes industrial, business
7. Nonvegetated	cleared to bare soil
8. Timbered	silviculture clear-cuts
9. Unknown	land use undetectable from the vessel

Table 1. Riparian land use classes collected using GPS during shoreline inventory

Level II -Bank Condition

The bank of the shoreline typically extends from the fastland and acts as protection for the immediate upland area. The protection offered by a bank is dependent on several attributes such as height, slope, evidence of erosion, sediment composition and the presence of channelward buffers that help absorb wave energy prior to impacting the bank itself. Banks are also a source of nutrient and sediment fluxes from the fastland, affecting water quality, and the formation of beaches and marshes. Highly eroding banks contribute high sediment loads to receiving waters. Eroding banks adjacent to agricultural lands may also include high nutrient loads in the sediments. Therefore, the condition of the bank, in combination with the adjacent land practice, can identify areas where erosion and sediment control practices may be beneficial to help meet water quality goals. The water quality and sediment control benefits provided by tidal wetlands adjacent to agricultural land use or eroding bank conditions are obvious. The three major characteristics of the bank recorded during the inventory include bank height, bank cover and bank stability. The presence of natural buffers at the toe of the bank is also recorded. These buffers include fringe marsh and supratidal beaches that act to dissipate wave energy and filter upland runoff. Although the physical condition of these buffers is often a function of the shoreline orientation and exposure, they may be indicative of the site's overall ecological condition. The presence/absence of common reed (*Phragmites australis*), an invasive species of the Mid-Atlantic, is also recorded because of its reported adverse effect on the habitat diversity of vegetated wetlands.

Level II - Shoreline Features

Features on or along the shoreline installed by property owners are recorded using GPS during the inventory. These features include shoreline defense structures constructed for erosion control, offensive structures designed to accumulate sand in longshore transport and recreational structures built to enhance recreational access to the water. The location of these features with respect to tidal wetlands can have a significant impact on the functions of wetlands with respect to water quality and habitat value. Structures are collected as either GPS point or line features along the tidal shoreline. For example, structures such as riprap revetments and bulkheads are line features, whereas features such as docks and boat ramps are point features.

Level II - Data Processing

Field data collected using GPS was processed using Trimble Pathfinder® GPS software. Differential correction was applied as necessary to achieve the established accuracy limit (+/- 5 meters). Base stations maintained by the United States Coast Guard and/or the National Geodetic Survey are used to complete differential correction when required. Data was then converted into ESRI® shape files for GIS processing using the ArcGIS® software.

A baseline shoreline of the three study rivers was developed from Digital Orthophoto Quarter Quadrangles (DOQQ). This shoreline represents the land-water interface as observed on the imagery. The shoreline was not corrected relative to any tidal datum. GIS techniques are employed to translate the data to the digital shoreline coverage using onscreen digitizing techniques. A series of new points and arcs are created on the digital shoreline and coded appropriately. Digital imagery of the site is displayed on the screen as background to assist in data translation. This step ensures a rigorous sequence of quality assurance checks to insure the positional translation of attributes is as accurate as possible. The final products are GIS coverages that delineate riparian land use, bank and buffer conditions, and shoreline features. CCI quality assurance and quality control measures for these steps are documented as a component of the QA/QC manual prepared and administered for all CCRM data collection, processing and analysis.

Level II – Habitat Scoring

Attributes collected in during the Level II shoreline survey previously described here were evaluated as to their individual ability to influence or affect wetland habitat function. Of the various attributes collected during the survey, it was determined to utilize five attributes including adjacent land use, and the presence/absence of the following four attributes; forest buffer, *Phragmites australis*, beach, and structures. The nine land use categories collected during the shoreline survey were condensed into three included natural (forested, scrub-shrub, wetlands), agriculture (grass, row crop, pasture), and developed (residential, commercial, industrial, paved). The three resulting land use categories were assigned values relative to their ability to affect a wetlands ability to provide habitat. Natural was given an initial core of 6, Agriculture the score of 4, and Developed the initial score of 2. From these initial scores, the presence or absence of the four attributes were scored as follows:

attribute	presence	absence
forest buffer	+1	0
Phragmites	-1	0
beach	+1	0
structure	-1	0

Individual attribute scores were added to the initial land use score to produce a function score for each individual land use segment of the wetland. The various function scores based on land use were then weighted based on their percentage composition of the wetland to produce an overall wetland polygon score for habitat. A complete description of the programming written in Arc Macro Language (AML) to perform the manipulations described here is provided by the metadata for the Level II wetland assessment and is available at http://www.ccrm.vims.edu

METHODS – LEVEL III

Specific biological endpoint data are important not only to design and implement restoration strategies, set mitigation requirements and evaluate individual project impacts, but also to help calibrate and validate less intensive landscape level (Level I) and inventory (Level II) assessment methods (Fennessy et al. 2004). In this project we sampled sites across each of the three projects watershed that represented the continuum of wetland conditions found within each specific watershed based on the Level I scores and best professional judgment.

In developing the metrics to be used in the Level III sampling we conducted an extensive review of the existing scientific literature to identify the current methodologies being employed to measure biological habitat function. It was our intention to select attributes known to correlate with tidal wetland condition and that would produce variability across the range of ecological conditions (pristine to highly disturbed) that we were sampling. We reviewed the considerable research that has been conducted in tidal wetlands in the Mid-Atlantic and Northeast regions of the US to select metrics that we felt would be relatively simple to measure, but would be indicative of wetland condition.

Level III – Selection of Reference Sites

Biological sampling of sites across the range of disturbance and ecological variation present within a domain or sampling frame serves to help design, calibrate and validate less intensive Level I and Level II monitoring and assessment protocols. For each of the three study watersheds, we identified a set of approximately twenty potential sampling sites using the results of the Level I analysis. From the list of potential sites, ten were selected within each watershed that best represented the existing range of ecological condition. Our goal was to sample across a range of anthropogenic disturbances, from undisturbed to highly disturbed. In our study of the three study watersheds, wetlands of the Nanticoke River, Maryland were the least disturbed, while wetlands of the Indian River, Delaware exhibited the most disturbance. Wetlands in the York River, Virginia watershed displayed the continuum of conditions between these two end members. For the ten sample sites selected in each sample watershed, aerial photographs and Level I scores were reviewed to determine the anticipated relative condition of the wetland. Site reconnaissance of the Nanticoke River watershed was conducted prior to sampling to help identify the easiest access (from land or water) to some of the selected sample sites. Our goal for the Level III sampling was to collect field data for specific metrics that would provide condition of biological endpoints that would provide the ability to measure condition and that could be used to calibrate and validate the Level I and Level II assessments.

Level III - Field data collection

Detailed Level III sampling was conducted on between eight and ten individual wetlands in each of the three study watersheds. The metrics selected for this study were based on those developed by others conducting tidal wetland condition and assessment work or are metrics and methods generally accepted and supported in the scientific literature. The specific metrics used in this study include sampling vegetative and macroinvertebrate communities, sediments, and an estimate of below ground biomass. In each wetland sampled, an assessment area (AA) was established, 80m in diameter. Pictures looking in the four cardinal directions were taken from the centroid. Vegetative sampling was conducted along two perpendicular transects totaling sixteen $1m^2$ plots that identified the plant species present and estimated percent cover for each species. Any invasive plant species were specifically noted. Within the AA, four $1/10^{th}$ m^2 plots were also established to sample macroinvertebrates, soil bearing capacity, and an estimate of below ground biomass. In addition, soil and pore water quality data (temperature, pH, dissolved oxygen, conductivity, and salinity) were also collected at each of these four sampling locations. A quick guide to the field protocols developed and utilized in this study along with a full description of the metrics, data collection methods, and field datasheets are provided in Appendixes B, C, and D. Data collected in the field was reviewed for transcription errors following input to a computer spreadsheet. These data are provided in Appendix E in their raw form. Data analysis of the Level III data is currently being conducted to identify any correlations among variables. If regression is unable to discern any relationships among variables, a principal components analysis may be required.