Literature Review for Development of Maryland Wetland Monitoring Strategy: Review of Evaluation Methods

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Introduction and Definitions

Functions and Services

Wetland assessment has been defined by Kusler (2004) as "wetland related data-gathering, data analysis, and the presentation of resulting information to regulatory decision makers." Assessment methods directly or indirectly evaluate wetland *functions*, but there is no universally accepted definition of wetland function.

Earlier wetland assessment models were developed for help in wildlife management, and many of these evaluated only habitat (Kusler, 2004). Later, models such as the Wetland Evaluation Technique, or WET (Adamus et al., 1987; Adamus et al.,1991) assessed habitat, hydrologic and biogeochemical functions as well as "functions" such as recreation and uniqueness/heritage. The hydrogeomorphic (HGM) approach to wetland assessment (Brinson, 1993; Smith et al., 1995) and related methods defined functions as ecological processes only.

Federal regulations now define wetland functions as the ecological processes that take in a wetland. However, MDE regulations define functions in terms of services. Wetland *services* are defined as "the benefits that human populations derive, directly or indirectly, from ecosystem functions" (Constanza et al., 1997). In some methods and related literature (Bartoldus, 1999, Fennessy et al., 2004), services are referred to as *values*.

Indicators

It is difficult (and sometimes impossible) to actually measure the exact degree to which a given wetland performs functions and services, so the level of functions and services provided is approximated by *indicators*. Indicators are "easily observed characteristics that are correlated with quantitative or qualitative observations of a function" and "reflect the capacity and opportunity that a wetland has to perform functions" (Hruby, 2006).

Capability, Opportunity, and Functional Capacity

Wetland assessment methods generally evaluate the ecological processes or functions based on one or both of the following factors:

1. The *capability* (also known as *capacity* or *efficiency*) of the wetland to perform the function. Hruby (2006) defines this as the use of "the structural characteristics in a wetland as indicators of the capability of performing a function."
2. The *opportunity* the wetland has to provide the function. Hruby (2006) defines this as "the value that a wetland provides in improving water quality, reducing flooding, or providing habitat."

Functional capacity is a key term used in the hydrogeomorphic (HGM) method and is defined in that method as: "The rate or magnitude at which a wetland ecosystem performs a function." In most HGM methods, the *Functional Capacity Index*, or FCI, is defined as "an index of the capacity of a wetland to perform a function relative to other wetlands within a regional wetland subclass" in the same area.[1]

[1] http://www.epa.gov/wetlands/science/hgm.html.

Hruby (2006) gives the following example to assist in distinguishing between capability (referred to as "efficiency") and opportunity:

> "Consider two wetlands of equal size. The first wetland can remove a maximum of 20 lbs. of pollutants per year and the second can remove 100 lbs. per year. This is their potential. The first wetland has 100 lbs of pollutants coming into it (the opportunity) so it actually removes its maximum potential (20 lbs/year) but lets 80 lbs continue going downstream. The second wetland only has 5 lbs. of pollutants coming in. Though its potential is much higher than that of the first, it actually removes fewer pollutants (only 5 lbs/year), but it removes all pollutants coming in. The first wetland has a low potential but high opportunity and the second has a high potential with a low opportunity."

Bartoldus (1999) notes that upper limits on opportunity levels must be defined to make certain that the wetland will have the capability to provide the measured function. For example, a wetland which receives high nutrient input has a high opportunity for nutrient removal, but may not have the capability to remove all nutrients entering the wetland.

Reference Wetlands

In almost all assessment methods, wetlands are compared to other wetlands with either high functional performance or superior ecological integrity. There are several ways of defining this comparison (Hruby, 1999):

1. Wetlands are compared to an ideal wetland with high performance. However, unless the representation of this ideal wetland is developed using regional data and conditions, the comparison may not be valid.

2. Wetlands are compared by function to wetlands which exemplify the highest performance of each function within a region. This requires a set of reference wetlands for every function.

3. Wetlands are compared to the least altered wetlands within a region. This is the "*reference standard*" approach used in the HGM approach to wetland assessment (Smith et al., 2005). Two definitions for reference standard condition are often used (Sutula et al., 2006):
    - *Culturally unaltered*: implying a wetland that has never been affected by human activities, or
    - *Best attainable condition*: implying or a wetland with the highest functional state that can be obtained given human alteration of the landscape.

The assumption made is that the least altered wetlands have the highest functional level, which is not necessarily true. Stander and Ehrenfeld (2009), in a study in northern New Jersey, found that relatively undisturbed reference wetlands did not have higher rates of nitrogen removal than highly disturbed sites. Hruby (2001) collected data along a gradient of disturbance and proved that undisturbed wetlands in Western Washington state do not have the highest level of function. The HGM approach assumes that disturbed wetlands do not have sustainable functional levels, but this was also disproved in the Washington state study. Thus, the reference standard approach tends to measure wetland *condition* or degree of disturbance, rather than function

Condition

Wetland *condition* is evaluated directly in some, but not all, assessment methods. Fennessy et al. (2004) defines condition as "the extent to which a given site departs from full ecological integrity (if at all)." Methods which measure condition generally provide a score which compares wetlands to a wetland with *reference standard* condition. Assessment methods which evaluate condition only do not measure opportunity because opportunity "does not relate directly to the measurement of ecological condition" (Fennessy et al., 2004).

Assessment Levels

Wetland assessment techniques are classified as Levels 1, 2, or 3 based on the scope and detail required to complete the assessment. The U.S. EPA (2006) and MDE Wetlands and Waterways Program (2008) define these levels as follows:

- *Level 1 Assessment*: Landscape level assessment based on Geographic Information System (GIS) analysis using existing wetland and soil maps, land use and hydrology information. Not a field method, but is often verified by field methods.
- *Level 2 Assessment*: Rapid assessment based on data collection from easily observable field indicators. A Level 2 assessment usually lasts less than four hours in the field, has relatively simple metrics, and results in a single rating for each wetland. Level 2 assessments would be used most often in permit review and watershed assessments. Should be validated by appropriate Level 3 field methods.
- *Level 3 Assessment*: Comprehensive assessment involving collection of data from direct measurements and fewer indicators. Used to validate Level 1 and Level 2 assessments and to develop water quality standards.

Since any field method that takes more than 4 hours can technically be defined as "Level 3," the duration and intensity of Level 3 assessments may be highly variable. Level 1 and Level 2 methods should ideally be validated with Level 3 methods which involve long-term, repeated sampling over at least one year.

Objectives

The objective of this review were to attempt to answer the following series of questions for (1) a list of MDE/MDNR research studies that was designated by MDE, and (2) a list of wetland evaluation methods that have been used in other states. This information was supplemented by compiling and reviewing additional information.

We also determined if the following questions could be answered for the wetland assessment methods in four compilations of methods: Fugro-McClelland East (1993), Bartoldus (1999), Fennessy et al. (2004) and Sutula et al. (2006). This information is presented in the appendix to this report.

The questions to be answered were:

1. Y/N. Can the method be used for Clean Water Act ambient condition monitoring in Maryland?
2. Y/N. Can the method be used for improved wetland regulatory monitoring for permit review and mitigation in Maryland?
3. Y/N. Can the method be used for monitoring for watershed planning efforts in Maryland?
4. Y/N. Can the method be used for monitoring of newly restored wetland restoration sites in Maryland?
5. Y/N. Can the method be used for identifying priority preservation areas in Maryland?
6. Y/N. Is the rationale for the method well developed?
7. What is the vegetation or wetland type(s) (Cowardin, NWI, or HGM), if identified by researchers?
8. For HGM methods only: How were different vegetative communities and plant succession incorporated into the assessment? Do the methods adjust scores for sites based on successional stage?
9. Y/N. Is the model is restricted for use in the studied wetland types or does it say it can be used on other types?
10. In what region was the method was developed?
11. Y/N. Is the model restricted for use in the studied region or does it say it can be used in other areas?
12. Y/N. Was the method able to assess the studied function(s)?
13. Y/N. Are the results supported by or in conflict with other research results?
14. Y/N. Is there a rigorous, valid statistical testing of the method? i.e., was the method validated with an appropriate statistical design or was the study limited to a few sites or limited sampling over time?
15. Y/N. Are the results statistically significant, or accompanied by an explanation for why results are not statistically significant?
16. Are there logistical concerns, such as complex or expensive equipment or supplies needed?
17. Y/N. Are there stated or flaws/limitations for using the method? If so, summarize stated limitations for the method in the paper, not in the table/spreadsheet.
18. How long does it take to conduct the assessment, in the field or office/desktop?
19. How many people are required to assess each site?

Criteria for answering Questions 1 through 5 are outlined below (personal communication, Denise Clearwater):

1. Can the method be used for Clean Water Act ambient condition monitoring in Maryland?

    Assessment methods for Clean Water Act ambient condition monitoring should evaluate chemical, physical, and biological integrity for designated uses – thus the method should evaluate the full suite of functions and services, and should also evaluate condition (ecological integrity).

Question 2. Can the method be used for improved wetland regulatory monitoring for permit review and mitigation in Maryland?

Assessment methods for improved wetland regulatory monitoring should:

- Evaluate hydrologic, biogeochemical (water quality) and habitat functions.
- Evaluate condition.
- Be able to compare one wetland to another wetland, even if the wetlands are of different types.
- Evaluate cultural services, such as recreation, rarity, aesthetics

3. Can the method be used for monitoring for watershed planning efforts in Maryland?

Assessment methods for watershed planning efforts should:

- Evaluate hydrologic, biogeochemical (water quality) and habitat functions.
- Evaluate condition.
- Be able to compare one wetland to another wetland, even if the wetlands are of different types.
- Allow for adjusted scores to highlight wetlands performing specified, preferred functions.

4. Can the method be used for monitoring of newly restored wetland restoration sites?

For voluntary wetland restoration sites, an evaluation method should, at the least, determine if the project was built as designed and meet the landowners and projects objectives. Preferably, the method would evaluate surface water and/or groundwater levels, evaluate vegetation success, make a visual determination of soil organic matter, and list observable problems

5. Can the method be used for identifying priority preservation areas?

Identifying priority preservation areas typically requires a method that evaluates hydrologic, biogeochemical (water quality) and habitat functions. However, local land planners may want to rank certain functions/services higher than others, so in some cases, methods that do not evaluate all the functions above might be suitable.

Because the criteria for some of the questions were similar and/or were flexible, we substituted the following questions:

1. What general categories of functions (hydrologic, biogeochemical/water quality, and habitat) are evaluated? All categories of functions should be evaluated in Clean Water Act, regulatory, watershed planning, and restoration site monitoring in Maryland, and is desirable for identifying priority preservation areas (depending on goals.)
2. Are services evaluated? Services should be assessed in regulatory monitoring in Maryland.
3. Is condition evaluated *directly*? In other words, is a single score that evaluates the ecological condition of the wetland provided? This should be done in Clean Water Act, regulatory, and watershed planning monitoring in Maryland. Although many

methods indirectly assess condition, Fennessy et al (2004) notes "Methods best suited to measure condition reflect this by providing a quantitative measure describing where a wetland lies on the continuum ranging from full ecological integrity (i.e., the least impacted or reference condition) to highly degraded (poor condition)." Some methods which measure functions provide a score for each function evaluated, which makes it difficult to rate condition.

4. Can wetlands be compared to one another, even if they are different types? This is necessary for regulatory monitoring and watershed planning efforts in Maryland.
5. Does the method allow for adjusted scores to highlight wetlands performing specified, preferred functions or services? (These are also known as "value-added metrics.") This should be done for watershed planning efforts in Maryland.
6. Does the method evaluate large scale management goals and priorities for land and/or species conservation? These should be assessed in watershed planning efforts in Maryland, and assessment may be desirable in other types of monitoring.
7. Does the method evaluate whether the area can sustain its ecological integrity over time, given current and projected adjacent land use changes? This should be done for watershed planning efforts in Maryland, and may be desirable for other types of monitoring.

We also added the following question:

8. Is the method Level 1 (landscape), Level 2 (rapid field) or Level 3 (comprehensive field)? Fennessy et al. (2007) defines a rapid (Level 2) assessment as taking no more than two people a half day total in the field and requiring no more than another half day of office preparation and data analysis to obtain a result. We used these criteria to distinguish between Level 2 and Level 3 assessments.

These questions and associated supplemental information were addressed in the text in the following format. Note that some information was not available for certain methods.

Level: Is the method Level 1, Level 2, or Level 3?
Summary: Brief summary of method or study.
Rationale: What is the rationale for the method (if stated)? Is the rationale for the method well developed?
Functions and indicators: List or table of functions and associated indicators (or the equivalent).
Assessment area: What is the assessment area?
Results and validation:

- Are the results supported by or in conflict with other research results? Was the method able to assess the studied function(s)?
- Is there a rigorous, valid statistical testing of the method? i.e., was the method validated with an appropriate statistical design or was the study limited to a few sites or limited sampling over time?
- Are the results statistically significant, or accompanied by an explanation for why results are not statistically significant?

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity: Does the method evaluate large scale management goals, priorities for land and/or species conservation, and whether the area can sustain its ecological integrity over time?

Vegetation successional stage (for HGM methods only): How were different vegetative communities and plant succession incorporated into the assessment? Do the methods adjust scores for sites based on successional stage?

Time required: How long does the method take?

Flaws/Limitations: Are there stated or flaws/limitations for using the method, or logistical concerns, such as complex or expensive equipment or supplies needed?

The following questions are answered in Table 10 (for MDE/MNDR methods) and Table 31 (for other methods); if applicable and/or if required information was available.

- What general categories of functions are evaluated?
- Are cultural services evaluated?
- Is condition evaluated *directly* by providing a single score that evaluates the ecological condition of the wetland?
- Can wetlands be compared to one another, even if they are different types?
- Does the method allow for adjusted scores to highlight wetlands performing specified, preferred functions or services?
- What is the vegetation or wetland type(s) (Cowardin, NWI, or HGM), if identified by researchers?
- Is the model is restricted for use in the studied wetland types or does it say it can be used on other types?
- In what region was the method was developed?
- Is the model restricted for use in the studied region?

Review of MDE/MDNR Methods and Studies

Level 1 Methods

Watershed-based Wetland Characterization for Maryland's Nanticoke River and Coastal Bays Watersheds; *and* Historical Analysis of Wetlands and Their Functions for the Nanticoke River Watershed

References: Tiner et al., 2000; Tiner and Berquist, 2003
Level: Level 1

Summary:
Both studies were Level 1 watershed-level assessments that identified wetlands that perform various functions by using practical and/or observable criteria. National Wetlands Inventory (NWI) maps were combined with newer photography, data on submerged aquatic vegetation from the Virginia Institute of Marine Science (VIMS), hydric soil data from the Natural Resources Conservation Service (NRCS), and data from U.S. Geologic Survey topographic maps to produce an expanded database including:

- Extent and distribution of wetlands by NWI type.
- Extent and distribution of wetlands by Landscape position, Landform, Water flow path, and Waterbody (LLWW) type (see description of this classification system under "Functions and Indicators" below).
- Introductory assessment of wetland functions, both pre-settlement and present.
- List of sites with potential for wetland restoration.
- Description of condition of both wetlands and waterbody buffers.
- Assessment of natural habitat by watershed.
- Assessment of extent of ditching.

Wetland condition was not measured directly, but the condition of the 100 m upland buffer zone around wetlands and water bodies was evaluated using Natural Habitat Integrity Indices (Tiner, 2004). These consist of six habitat extent indices and four habitat disturbance indices:

- Habitat extent indices.
  - The *Natural Cover Index* is of a watershed that has natural vegetation, and may provide wildlife habitat.
  - The *River-Stream Corridor Integrity Index* is the proportion of a riparian corridor that has natural vegetation.
  - The *Wetland Buffer Integrity Index* is the proportion of buffer zone around each wetland that has natural vegetation.
  - The *Pond and Lake Buffer Integrity Index* (added in Tiner, 2004*)* is the proportion of buffer zone around each pond or lake that has natural vegetation.
  - The *Wetland Extent Index* compares the current area of vegetated wetlands to the estimated pre-settlement area.
  - *The Standing Waterbody Extent Index* compares the current area of standing fresh water bodies to the estimated pre-settlement area.

- Habitat disturbance indices
  - The *Dammed Stream Flowage Index* compares the total length of perennial streams impounded by dams to the total length of all perennial streams in the watershed.
  - The *Channelized Stream Flowage Index* compares the total length of channelized streams to the total length of all streams in the watershed.
  - The *Wetland Disturbance Index* compares the area of disturbed or altered wetlands to the total wetland area in the watershed.
  - The *Habitat Fragmentation/Road index* (added in Tiner, 2004) is the area of roads in the watershed compared to total area of the watershed. This Index is a rough estimate of habitat fragmentation and other disturbances (development, water quality issues) caused by roads.

The weighted sum of the four habitat disturbance indices is subtracted from the six habitat extent indices to provide a Composite Natural Habitat Integrity Index. This can be used to compare entire watersheds or sub-basins.

Rationale:
The overall assumption of this functional assessment method is that a wetland's landscape position, geomorphic type and/or size will determine its potential ability to perform certain functions. (The authors emphasize that this needs to be verified by field assessment.) The rationale for the method appears to be based on sound geomorphic and wetland science principles. The reasons for selecting the indicators for each function are supported by numerous references from other research.

Assessment area:
The assessment area is the wetland as delineated on NWI maps.

Functions and indicators:
Functions and indicators are listed in Table 1, and are based on both NWI (Cowardin) and LLWW wetland types. LLLW wetland descriptors are similar but not identical to HGM types. A brief summary of the LLWW system follows (for further information, see Tiner, 2003):

- Landscape types used in the LLWW system are:
  - *Marine*: shores of the ocean and associated embayments.
  - *Estuarine*: along the tidal brackish portion of estuaries.
  - *Lotic*: along freshwater rivers and streams and freshwater portions of tidal rivers.
  - *Lentic*: in lakes, reservoirs, and associated basins
  - *Terrene*: isolated or headwater wetlands; remnants of isolated or headwater wetlands that are joined to downslope wetlands by drainage ditches; wetlands on broad, flat terrain that is cut by streams but not affected by overbank flow.
- Water flow paths are similar to those used in the HGM system, and describe surface water flow paths rather than groundwater connections: bidirectional-tidal, bidirectional-nontidal, throughflow, inflow, outflow, or isolated.

Table 1. Functions and indicators in the Watershed-based Preliminary Assessment of Wetland Functions.

Function	Wetland type (indicator) and probability of performing function
Surface water detention	• Lotic (riparian) floodplain, lotic basin = high • Lotic flat = some potential • Throughflow ponds = high • Terrene 50 acres or more (flats with undulating microtopography) = moderate to high potential; • Terrene 20-50 acres = some potential if not used.
Streamflow maintenance	• Terrene headwater and lotic wetlands along first order streams (also headwater) = moderate to high • Floodplain wetlands on non-sandy soils = important • Headwater wetlands connected to streams by drainage ditches = some
Nutrient transformation	• All lotic wetlands = moderate to high. • Specifically, lotic wetlands on floodplains; or with seasonally flooded or wetter water regime = high • Estuarine vegetated fringe or island wetlands = high. • Lotic flat wetlands and terrene outflow wetlands surrounded by cropland = some
Sediment and particulate retention	• Floodplain wetlands, lotic fringe and basin wetlands = high • Salt and brackish marshes in estuarine fringe or island wetlands = high • Lotic flat wetlands and terrene outflow wetlands surrounded by cropland = some
Coastal storm surge detention and shoreline stabilization	• Estuarine intertidal vegetated and seasonally flooded tidal palustrine vegetated wetlands = high • Nontidal palustrine wetlands bordering the above = moderate to high • Estuarine intertidal non-vegetated = some
Inland shoreline stabilization	• All lotic wetlands except in stream ponds and islands = high
Fish and shellfish habitat	• Based on requirements of fish for feeding and nursery, so does not identify all wetlands that provide fish habitat. • For estuarine fish/shellfish: estuarine submerged aquatic beds, tidal flats, emergent wetlands = high • For freshwater species: palustrine and riverine tidal emergent, tidal flats, semipermanently flooded non-tidal wetlands, palustrine aquatic beds = high
Waterfowl and waterbird habitat	• Estuarine and riverine emergent, estuarine mixed emergent/scrub-shrub, palustrine and riverine tidal emergent, permanently flooded, palustrine and riverine mixed open water-emergent wetlands = high for waterfowl and waterbirds • Seasonally flooded forested/shrub lotic wetlands, tidal freshwater deciduous forest next to estuarine wetlands = high for wood ducks.
Other wildlife habitat (not species specific)	• Potentially significant: wetlands of ≥ 20 acres; 10-20 acre wetlands with multiple cover types; wetlands on stream corridors which connect larger wetlands/wetland complexes = potentially significant.
Conservation of biodiversity	• Forested areas 7410 acres or greater that contain forested wetland and upland areas; large wetlands; wetlands with multiple kinds of vegetative cover; riverine tidal and oligohaline (vegetative diversity); estuarine bay and barrier island fringe wetlands and adjacent tidal freshwater wetlands (uncommon in Maryland) = high.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The method can be used for preliminary identification of wetlands or wetland complexes that have high functional capacity, and/or those which assist in conservation of biodiversity for watershed planning purposes. The method also identifies sites with high restoration potential.

Time required:
Since this is a Level 1 method, the time required would depend on the size of the watershed being surveyed.

Flaws/limitations:
The authors emphasize that this method is designed to be a *preliminary* assessment of wetland function on the watershed level, and should be used as a starting point for planning purposes. It attempts to identify wetlands that have a high capability (potential) for performing certain functions, but site specific evaluations are needed to verify this. An on-site evaluation is particularly recommended for fish/wildlife habitat and biodiversity. Although the method provides a preliminary estimate of capability, the authors state that the method tends not to measure the opportunity a wetland has to provide a certain function because it does not include surrounding land use. The method does not provide a combined functional rating for each wetland.

The method definitely requires expertise at interpreting GIS layers and associated topographic maps to classify wetland types. Although the LLWW system used to interpret wetland functional capacity is similar to HGM, some adjustments would be needed to correlate it with MDE’s draft wetland classification method.

Building Capacity to Perform Wetland Assessments

Reference: CCRM, 2008
Level: Level 1

Summary:
This is a Level 1 assessment which produced a GIS map that estimates "overall condition as related to habitat and water quality functions" (CCRM, 2008) in Maryland's non-tidal wetlands. Estimates of functional capability were derived from surrounding land use and other features, as well as wetland characteristics such as NWI wetland type and wetland size. Each function was rated separately, so a single score for condition was not generated. The method relies heavily on the presence or absence of stressors in estimating functional capability. Despite language in the accompanying text, MDE does not believe it will meet Maryland's needs for regulatory assessment (personal communication, Denise Clearwater).

Rationale:
Overall rationale is explained in a report on the same method used in the Virginia Coastal Plain and Piedmont (CCRM, 2007). The overall model is based on the "Multiple Service" concept, in which each function is presumed to be a product of a different set of wetland properties, and is assessed and rated separately. It assumes that the wetland properties which result in optimum performance of one function (e.g. habitat) may not be the same as those which result in optimum performance of another function (e.g. water quality). [This is opposed to the "Prima Optima model" which "presumes that a wetland is providing optimal benefits when it is in pristine condition" (CCRM, 2007).] The indicators were selected based on either best professional judgment and/or the existing literature. In general, however, the method results in higher scores for wetlands in undisturbed areas. Opportunity is not included in scoring. For example, a wetland providing a water quality service by proximity to pollutant sources receives a lower score for the water quality service than a wetland not close to a pollutant source. There is an extensive list of references for each indicator in the report, but individual rationale for each indicator is not directly explained in the method description.

Assessment area:
Wetlands were identified using Maryland DNR Digital Orthophoto Quarter Quadrangle maps (personal communication, Denise Clearwater). Three buffer zones were used for habitat variables: 3 m, 200 m, and 1000 m around each wetland. Water quality function was based on scores for the three buffers plus those for in the drainage basin surrounding each wetland.

Functions and indicators:
Functions and related variables are presented in Table 2. The variables are similar for both the habitat and water quality functions, except for proximity to other wetlands, which was not used to calculate water quality scores.

Table 2. Functions and associated variables for VIMS Level 1 non-tidal wetland assessment.

Function	Variables
Habitat potential	• Wetland type (NWI) • Wetland size • Land cover type • Proximity to roads • Proximity to highways • Proximity to other wetlands • Wetland hydroperiod (NWI)
Water quality	• Wetland type (NWI) • Wetland size • Land cover type • Proximity to roads • Proximity to highways • Wetland hydroperiod (NWI)

Results and validation:

Results are presented as GIS layers. This portion of the project does not include Level 2 or Level 3 validation. A similar model developed for Virginia's Coastal Plain and Piedmont was calibrated with a Level 2 stressor checklist, and land cover variables and, to some extent, wetland type, were found to be correlated with overall stressor scores (CCRM, 2007). The Virginia model is also in the process of validation via intensive Level 3 sampling, and further details on the Level 3 validation methods follow later in this report [see: Virginia Institute of Marine Science (VIMS) Method: Newer].

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:

The method evaluates wetland condition on a watershed level basis, and can preliminarily identify wetlands with high functional potential for conservation and/or planning purposes.

Time required:

This is a Level 1 method, so time required will depend on the size of the area to be assessed.

Flaws/limitations:

The method does not assess wetland opportunity or services, and does not provide a single score for condition, although it does assess condition for each function. The model information may be misused without field verification. The Maryland version does not have the user-friendly viewer that Virginia has (personal communication, Denise Clearwater).

Level 1 Methods with Level 2 Field Assessment

A Method for the Assessment of Wetland Function (MDE Method)

References: Fugro-McClelland East, Inc., 1995; Maryland Department of the Environment, 1997.
Level: Level 1 with optional Level 2 (possibly Level 3) field assessment.

Summary:
This is a Level 1 method with optional Level 2/3 [1/2 to 1 day, according to Bartoldus (1999) and Fennessy et al. (2004)] field assessment that is designed to evaluate wetland functions and the effect of surrounding landscape on functions. The method can be also be used for evaluating mitigation sites, and has been used for environmental inventories. According to Bartoldus (1999), the method is similar to the Hollands-Magee and Rapid Assessment methods (Hollands and Magee, 1985; Magee, 1998). In this method, wetland classification is based on HGM, but "best professional judgment" rather than reference wetland data is used for assessment. The term "functional capacity index" is used in the model, but the definition is different from that used in HGM. It is defined as an index of both the capability and opportunity that a wetland has to perform a function as compared to the maximum possible (as determined by best professional judgment.)[2]

Rationale:
The method states that indicators are: "Ecosystem characteristics which are quantifiable expressions of wetland function." The indicators that are used measure both wetland functional capability (potential) and wetland functional opportunity. The rationale for each indicator used in the method is explained in the text, and seems to be valid for the most part, but the explanations are not supported by cited references.

Assessment area:
The wetland is the assessment area. The original method suggests separating assessment areas within wetlands by HGM type, stream order, roads, river and stream boundaries, etc. but additional guidance by MDE (Maryland Department of the Environment, 1997) states that wetland assessment area should vary with size of study area. For example, if the study area is small, wetlands along streams can be separated by stream order, but if the study area is large (a watershed), wetlands associated with headwater streams and higher order streams in the same drainage should form one assessment area.

Functions and indicators:
Functions and related indicators are listed in Table 3. In this method, indicators are either (1) "red flag" or direct indicators that confirm that a wetland does or does not perform a function, or (2) contributing or primary indicators that must be combined with other indicators to predict a function.

[2] In HGM, functional capacity index is "an index of the capacity of a wetland to perform a function relative to other wetlands within a regional wetland subclass" in the same area. Opportunity is not measured.

Table 3. Functions and related desktop and field indicators in MDE wetland assessment method.

Function	Indicator: desktop	Indicator: field
Groundwater discharge	• HGM type • Inlet and outlet class (none, intermittent, or perennial) • Presence of springs and seeps • Wetland soil type • Surface water hydrologic connection • Surficial geologic deposit under wetland • Water regime	• Nested piezometer data • Relationship to regional potentiometer surface • Water chemistry • Microrelief of wetland surface • Relationship to steep slopes
Flood flow attenuation	• HGM type • Inlet/outlet class • Degree of outlet restriction • Basin topographic gradient • Wetland water regime • Ratio of wetland area to watershed size • Adjacency to a water body or waterway	• Surface water fluctuations • Stem density • Microrelief of wetland surface • Presence of dead plant material • Occurrence of downcut stream channel • Occurrence of ditching
Modification of water quality (removal of suspended and dissolved solids and nutrients by conversion into other forms)	• Wetland land use • Basin topographic gradient • Degree of outlet restriction • Topographic position in watershed • HGM type • Water regime • Inlet/outlet class • Stream sinuosity • Dominant vegetation type • Occurrence of overbank flooding • % wetland edge bordering sediment source • Occurrence of ditching • Hydric soil type	• Frequency of overbank flooding • Microrelief of wetland surface • Cover distribution • Occurrence of dead plant material
Sediment stabilization (deposition and retention of sediment)	• HGM type • Frequency of overbank flooding • Potential of overland flow from uplands • % wetland edge bordering sediment source • Ratio of wetland area to watershed area	• Evidence of retained sediments • Microrelief • Stem density

Table 3, continued. Functions and related desktop and field indicators in MDE wetland assessment method.

Function	Indicator: desktop	Indicator: field
Aquatic diversity and abundance (includes hydrophytic plant species, and aquatic animal habitat)	• HGM type • Association with open water • Water regime • Water/cover ratio • Stream sinuosity • Dominant vegetation (NWI) • Wetland class richness (# of NWI wetland types occurring within wetland) • Vegetative density • Wetland juxtaposition (location of wetland relative to other wetlands – isolated, connected, or isolated but near other wetlands) • Known habitat for fish • Habitat for aquatic invertebrates, reptiles, amphibians • Wetland land use • Adjacent to undisturbed upland habitat • Adjacent to known upland wildlife habitat • Buffer for water body	• Occurrence of debris dams in wetland stream
Wildlife diversity and abundance	• Wetland size • Wetland class richness (# of NWI wetland types occurring within wetland) • Wetland class rarity • Wetland class edge complexity (degree of irregularity at the upland edge – also number of kinds of edge between two vegetation types) • Surrounding upland habitat • Wetland juxtaposition • Water regime • Wetland land use • Presence of islands • Presence of rare, endangered, or threatened species • Linked to a significant habitat • Connected to a known wildlife corridor • Fragmentation of a once larger wetland • Watershed land use	• Microrelief of wetland surface • Water chemistry • Interspersion of vegetative cover and open water • Number of vertically distributed vegetation types, and percent of each.

Results and validation:
The manuscript says that the method was tested in the Maryland Piedmont and Coastal Plain, and two case studies are presented in the appendix, but statistical testing is not presented.

Vegetation successional stage
The NWI classification is used for vegetation class. Successional stage is considered in the scoring for the modification of water quality function, in which higher scores for modification of water quality are awarded for greater percent vegetative cover and forested dominant vegetation type (forested wetlands > emergent/scrub-shrub >aquatic beds), as well as greater amounts of vegetative cover. The rationale for this is that forested wetlands have longer-term storage of nutrients and contaminants, even though "immature" wetland plant communities tend to have higher levels of nutrient uptake and greater productivity than forested wetlands.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The MDE method identifies rare wetland types, wetlands with rare, threatened, or endangered species, and wetlands which provide significant habitat. The method can identify wetlands with high "relative function" for conservation purposes, and the authors state that the method may be used to predict future wetland condition if questions are answered as if predicted land use changes had already occurred.

Time required:
According to Fennessy et al. (2004) the method takes more than one day to complete in either office or field.

Flaws/limitations:
The method appears to have been primarily designed for watershed scale studies, although it says it can be used on individual wetlands. According to Bartoldus (1999), the method should have upper limits on opportunity variables. (Limits on opportunity levels must be defined to make certain that the wetland will have the capacity to provide the measured function. For example, a wetland which receives high nutrient input has a high opportunity for nutrient removal, but may not have the capacity to remove all nutrients entering the wetland.) Fennessy et al. (2004) feels that the method might be improved if more stressors were considered.

US 301 Waldorf Area Transportation Improvements Project

Reference: Unpublished partial materials and methods document.
Level: Level 1 with Level 2 field assessment

Summary:
In this study, wetlands were first evaluated with a Level 1 landscape analysis for habitat and water quality functions using the VIMS method described earlier (CCRM, 2008: "Building Capacity to Perform Wetland Assessments"). Field verification of the landscape analysis results for 27 wetlands was done using four Level 2 rapid assessment methods: Delaware Rapid Assessment Protocol (DERAP: Jacobs, 2008), Ohio Rapid Assessment Method (ORAM: Mack, 2001), Pennsylvania State University Stressor Checklist (Brooks, 2004), and the Montana Department of Environmental Quality Wetland Rapid Assessment Form (MT DEQ: Apfelbeck and Farris, 2002).

Wetlands were evaluated with the Qualitative Condition Ranking (QCR), a component of the DERAP, which assigns rankings for disturbance levels in wetlands. The ORAM Level 2 method had the best correlation with the QCR, so the researchers recommended use of this method to evaluate wetland condition in the area studied.

A draft Level 2 Wetland Restoration Potential Assessment was also included. To perform this assessment, the area should first be assessed with ORAM. The wetland is then assessed for

- Stressors.
- QCR rating.
- A qualitative estimate of restoration potential, including ease of restoration, access, constraints, potential for restoration success, restoration benefits, and estimated cost.

Rationale:
The overall goal of the project was to select a rapid assessment method to measure condition, as defined by a separate assessment by Qualitative Condition Ranking.

Assessment area:
For the Level 1 method (CCRM, 2008) the assessment area for habitat was the wetland plus three buffer zones: 3 m, 200m, and 1000 m. The assessment area for water quality was the wetland and the three buffers, and the entire drainage basin around the wetland.

Assessment areas for the Level 2 methods varied by method:

- DERAP: The assessment area is a 40 m radius circle around a point generated by a probabilistic sampling design.
- ORAM: The assessment area was the entire wetland, plus an estimated buffer.
- Penn State: The assessment area was the entire wetland, plus a buffer.
- MT DEQ: For large wetlands, a 100 square m assessment area within the wetland is selected. If the wetland is ≤ 100 square m then the entire wetland is the assessment area.

Functions and indicators:
Functions and indicators for the Level 1 method were described earlier (CCRM, 2008). Functions and indicators for the four Level 2 methods varied by method, and are briefly outlined in Table 4. For detailed information on each Level 2 method, see James (2007).

Table 4. Summary of Level 2 (rapid assessment) methods used in the Rt. 301 project. Adapted from James (2007).

Method	Summary
DERAP	• Level 2 method for Coastal Plain flat, riverine, and depression wetlands. • Method assesses wetland condition based on stressors in three categories: habitat/plant community, hydrology, and buffer. Final score is dependent on HGM class. • Method also uses the Qualitative Condition Ranking (QCR) which ranks level of disturbance.
ORAM	• Level 2 method for non-tidal wetlands. • Uses both a narrative ranking to categorize wetland function and restoration potential and a quantitative ranking of metrics related to wetland size; buffer area and condition; hydrology; habitat alteration and development; and vegetative structure. • Uses HGM class, but final scores are not HGM class-dependent. • Provides bonus points for rare wetland types, significant habitat/breeding areas, presence of threatened or endangered species.
Penn State	• Primarily a stressor-based Level 2 method for non-tidal wetlands, but has one Level 1 component: percent forest cover in 1 km buffer. • Level 2 method characterizes buffer type/width, and wetland stressors in three categories: hydrology, water quality, and vegetation. • Scoring based on level of impairment of function.
MT DEQ	• Level 2 method that characterizes ecological integrity of freshwater wetlands. • Uses both HGM and NWI for classification and site characterization. • Method assesses hydrology, vegetation condition, water quality, buffer condition/degree of stress, and wetland restorability. • Method can assess riparian system condition, if applicable.

Results and validation:
This was a partial document so no results were included.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
All the Level 2 methods used can identify wetlands that are in good condition for possible preservation. ORAM specifically identifies rare wetland types, wetlands which provide critical habitat, and wetlands which provide habitat for threatened or endangered species. As stated earlier, the draft Wetland Restoration Potential Assessment provides information on ease of restoration, access, constraints, restoration success potential, restoration benefits, and estimated cost.

Time required:
All methods used were Level 2, and thus would require approximately ½ day per assessment.

Flaws/limitations:
ORAM, the method selected for use, provides bonus scores for "Special Wetland Communities" (rare wetland types, significant habitat/breeding areas, presence of threatened or endangered species). These are specific to Ohio and will need to be adapted for use in Maryland.

Note: The area was also assessed via a DNR Natural Heritage Program survey (Davidson et al., 2008) of rare, threatened, and endangered (RTE), species of Greatest Conservation Need (GCN), and Key Wildlife Habitats (KWH) for identification of Ecologically Significant Areas. Ecologically Significant Areas are "habitat areas and their minimal buffers that need to be conserved and properly managed in order to sustain most of the State's rarest species and natural communities" (Davidson et al., 2008). Maryland has a Green Infrastructure Core Area program that identifies areas that supply important ecological services (Weber, 2003). However, these areas must be at least 100 acres and do not include meadow, grassland, or other "early successional" habitat areas, and thus might not include some Ecologically Significant Areas.

Level 1, 2, and 3 Methods

Wetland Profile of the Nanticoke River Watershed

Reference: Bleil, 2004
Associated references: Weller et al., 2007 (Level 1 method); Whigham et al., 2007 (Level 3 method); Jordan et al., 2007; Jacobs and Bleil, 2008.
Level: Level 1, 2, and 3

Summary: This report assessed the condition of three wetland classes in the Nanticoke River Watershed: flats, riverine and depressions. Each wetland class was assessed with Level 1, 2, and 3 methods, but detailed methodology for all three methods is presented only for the depressional wetland assessment study in Bleil (2004).

The Level 3 method was an HGM functional analysis based on undisturbed reference wetlands. Data for the analysis was collected in a fairly rapid (3-5 hour) site visit. The Level 1 Landscape assessment method was developed using data from the Level 3 HGM assessment. Landscape indicators for wetland condition were chosen based on how well they correlated with the Level 3 HGM assessment. Level 1 Landscape and Level 3 HGM assessment methods for the flat and riverine wetlands are presented in Weller et al. (2007), Whigham et al. (2007), and Jacobs and Bleil (2008), but it is not clear which Level 2 assessment method was used for these areas, although the report states that stressor-based rapid assessment methods were used for all three wetland types. A preliminary version of the Delaware Rapid Assessment Procedure (DERAP: Jacobs, 2005) was used for the Level 2 assessment method in the depressional wetlands. This method assesses stressors on (1) hydrology, (2) habitat and plant community, and (3) the wetland buffer, and produces a final score which quantifies condition. The latest version of this method will be discussed in the review of other assessment methods. Indicators from the Level 3 method were used to develop the Delaware Comprehensive Assessment Procedure (Jacobs et al., 2008).

Rationale:
There was little rationale given for any of the indicators in the Level 3 method, although Whigham et al. (2007) states that the Level 3 flats hydrology model was adapted from that of Rheinhardt et al. (2002). The reference standard sites for "least disturbed" condition were forested wetlands with 50-year old trees. According to Jacobs and Bleil (2008), all the Level 3 model variables were chosen because they were indicators of disturbance. Variables which did not distinguish between disturbed and undisturbed sites were not used.

As stated earlier, the indicators for the Level 1 method was chosen based on how well they correlated with the Level 3 results. The Level 2 method is based on common area stressors.

Assessment area:
The assessment area varied depending on method. Sampling sites for the Level 3 assessment of flats and riverine sites were chosen randomly using the Environmental Monitoring and Assessment Program (EMAP) described in Stevens and Hornsby, 2007. This method results in a point location, and was repeated until enough points in the correct wetland type were found. For flats, the assessment area consisted of a 0.5 ha (40 m) circle around each point; for riverine wetlands, a 1 ha circle was chosen (Whigham et al., 2007). A "near buffer" (<20 m from edge of floodplain) and a "far buffer" (20-100 m) was established for riverine wetlands (Bleil, 2004). For depressions, the wetland map of Tiner et al. (2000) was used, and the entire wetland was the assessment area (Jacobs and Bleil, 2008). For the Level 1 method, land cover in the 240-meter radius buffer (the buffer) around the assessment area was assessed.

Functions and indicators:
Functional Condition Index (FCI) and related indicators for the Level 3 HGM method are presented in Tables 5a and 5b, and functions and variables for the Level 1 method are presented in Tables 6a, 6b, and 6c. FCI is defined in this method as "a mathematical formula developed by expert scientists and constructed of variables that represents the capacity of a wetland to perform a function compared to reference standard condition" (Jacobs and Bleil, 2008)

Results and validation:
The Level 1 and Level 2 methods were extensively tested statistically against the Level 3 methods. The Level 1 model did not accurately predict individual wetland condition but was able to predict average wetland condition across a large area (watershed or county). Scores from the Level 2 method used in the depressions (draft DERAP) correlated reasonably well with the Level 3 assessments of the sites. However, the Level 3 method used to validate both the Level 1 and 2 assessments was a one-time, primarily observational, 3-5 hour assessment.

Jordan et al. (2007) attempted to correlate the biogeochemistry FCI scores produced in the Level 3 HGM assessment to actual measurements of denitrification enzyme activity (an estimate of denitrification potential) and nitrous oxide emissions. They concluded that the biogeochemistry scores did not accurately measure N removal through denitrification potential. They found that denitrification enzyme activity was most accurately predicted by models involving Eh (redox), pH, and % nitrogen (for individual wetlands) or % nitrogen and % waterfilled pore space (for an average across all studied wetlands), and suggested incorporating soil factors in the biogeochemistry HGM model.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The method could be used to identify undisturbed wetlands for possible preservation. It does not identify wetlands with rare, threatened, and endangered species.

Table 5a. Indicators for Functional Condition Indices (FCI) for flats, and riverine wetlands in the Level 3 HGM method used in the Nanticoke River watershed study. [Note: Trees = ≥ 15 cm dbh (diameter at breast height). Saplings = < 15 cm dbh.]

FCI	Indicators
FLATS:	
Hydrology	• Presence and extent of filling and drainage
Biogeochemistry	• Microtopography, • Standing dead trees • Tree basal area (combined dbh of all trees in wetland) • Tree density • Hydrology FCI score
Plant Community	• Tree species • Herb species • Presence of *Rubus* (blackberry: an indicator of disturbance).
Habitat	• Vegetation disturbance (timing and intensity of anthropogenic disturbances) • Tree density • Tree basal area • Shrub density • Standing dead trees
RIVERINE:	
Hydrology	• Stream channel condition (visual assessment of stream channel alteration by humans or livestock) within 100 m of the assessment area • Flood plain condition • Stream channel condition within 500 m of the assessment area
Biogeochemistry	• Tree basal area • Hydrology FCI
Plant Community	• Tree density • Sapling density • Vine density • Presence of invasive species
Habitat	• Tree basal area • Tree density • Shrub density • Vegetation disturbance • Condition of the stream channel within 100 m of the assessment area
Landscape FCI	• Condition of the near buffer • Condition of the far buffer • Condition of the stream within 500 m of the assessment area

Table 5b. Indicators for Functional Condition Indices (FCI) for depression wetlands in the Level 3 HGM method used in the Nanticoke River watershed study. [Note: Trees = ≥ 15 cm dbh (diameter at breast height). Saplings = < 15 cm dbh.]

FCI	Indicators
DEPRESSIONS:	
Hydrology FCI	• Hydraulic alteration • Distance to unnatural land use (not forest or wetland) • Area of buffer in natural vegetation
Biogeochemistry FCI	• Canopy tree density • Tree basal area • Volume of coarse woody debris • Hydrology FCI
Plant Community FCI	• Shrub species richness (presence of indicator shrub species) • Tree species richness • Vine species richness • Native plant percentage • Invasive species percentage.
Habitat FCI	• Tree basal area in buffer • Sapling density • Canopy tree density • Shrub density • Coarse woody debris in the assessment area
Landscape FCI	• Distance to un-natural land use • Percent natural vegetation • Distance to roads.

Table 6a. Level 1 method functions and related variables (positive and negative) for flats wetlands in the Nanticoke River watershed study. Variables were used in multiple regression equations predicting flat, and riverine nontidal wetland FCI scores using landscape indicators (Jacobs and Bleil, 2008).

Flat Function	Variable
Biogeochemistry	• Condition of nearest stream • Distance from assessment point to nearest stream • Stream density Evergreen forest % • Mean % tree cover • Distance from assessment point to nearest stream
Habitat	• Forest % • Deciduous forest • Total stream density • Mixed forest %
Hydrology	• Stream density • Condition of nearest stream • Distance from assessment point to nearest stream • Wooded wetland % • Wetland %
Plant Community	• Deciduous forest % • Mean % tree cover • % with zero tree cover • Mixed forest %

Table 6b. Level 1 method functions and related variables (positive and negative) for riverine wetlands in the Nanticoke River watershed study. Variables were used in multiple regression equations predicting flat, and riverine nontidal wetland FCI scores using landscape indicators (Jacobs and Bleil, 2008).

Riverine Function	Variable
Biogeochemistry	• Stream condition • Distance from assessment point to nearest stream • Mixed % tree cover • Mean % tree cover • Deciduous forest %
Habitat	• Distance from assessment point to nearest stream • Stream condition • Evergreen forest % • Herbaceous wetland % • Natural stream density
Hydrology	• Natural stream density • Stream condition • Distance (m) from assessment point to nearest stream • Herbaceous wetland % • Evergreen forest • Cropland %
Plant Community	• Excavated stream density • Wetland % • Cropland % + grassland % • Evergreen forest %
Buffer Integrity	• Stream condition • Cropland % + grassland % • Total developed land % • Mixed forest % • Distance from assessment point to nearest stream • % with zero impervious • Distance from assessment point to nearest road • Wetland %

Table 6c. Level 1 method functions and related variables (positive and negative) for depressions in the Nanticoke River watershed study. Variables were used in multiple regression equations predicting flat, and riverine nontidal wetland FCI scores using landscape indicators (Jacobs and Bleil, 2008).

Depression Function	Variable
Biogeochemistry	• Total forest % • Open water % • Herbaceous wetland % • Grassland % • Total stream density
Habitat	• Forest % • Evergreen % • Road density • Total developed land %
Hydrology	• Total forest % • Open water % • Herbaceous wetland % • Total stream density
Plant Community	• Total forest % • Open water % • Herbaceous wetland % • Total stream density • Road density

Time required:
The level 3 field assessments required 3-5 hours for 4-5 people. The Level 2 stressor assessment generally requires 1 hour of field work for 2 people (Jacobs, 2008).

Vegetation successional stage
As stated earlier, the level 3 model gives higher scores for the biogeochemistry and habitat function to wetlands with larger trees.

Flaws/limitations:
As stated earlier, the Level 3 method used to validate the Level 1 and Level 2 assessments was a one-time, 3-5 hour assessment. Typically, Level 3 methods used for validation are more intensive: for example, the California Rapid Assessment Method was validated with data on avian diversity, benthic macroinvertebrates, and plant community composition that were collected in independent studies (Stein et al., 2009).

Because indicators that did not distinguish between disturbed and undisturbed sites were discarded, some indicators that were shown to be important to function, such as soil properties (Jordan et al., 2007) were not used. Thus the Level 3 method appears to measures disturbance rather than actual function. The assumption is that no disturbance equals highest functioning, which is not necessarily true. The method also does not distinguish between natural and anthropogenic disturbance. Since the Level 1 model variables were chosen based on the Level 3 method indicators, the Level 1 method will also predict disturbance rather than function.

Refinement and Validation of a Multi-level Assessment Method for Mid-Atlantic Tidal Wetlands; *and* Nanticoke River Tidal Fringe Wetlands Assessment

Reference: O'Brien et al., 2007; McLaughlin, 2007.
Level: Levels 1, 2, and 3.

Summary:
These studies were Level 1 [O'Brien et al. (2007) only], Level 2, and Level 3 assessments of tidal wetlands [both O'Brien et al. (2007) and McLaughlin (2007)]

The Level I method used GIS coverage to determine boundaries of wetlands, salinity, hydrology, bathymetry, land use in surrounding areas, and presence or absence of submerged aquatic vegetation, oyster reefs, and conservations areas.

Three Level 2 methods were used:

- O'Brien et al. (2007) tested a Level 2 method involving a shoreline survey performed from the adjacent river that was designed to evaluate anthropogenic stressors on habitat.
- McLaughlin (2007) used two Level 2 methods for assessing tidal wetlands: the New England Rapid Assessment Method for coastal wetlands (apparently unpublished) and the California Rapid Assessment Method (Collins et al., 2008) for estuarine-saline wetlands, The Level 2 methods were not described in the report, although they were used to create a Mid-Atlantic Tidal Wetland Rapid Assessment Method (Jacobs et al., 2009b), which was developed from the information gained from this project.

The Level 3 method used in both reports was designed to measure "biological habitat condition," and metrics were chosen to reflect this.

Rationale:
All three methods were designed to measure the existing condition of tidal wetlands, particularly the impact of anthropogenic stressors. The metrics for the Level 3 method that was used to test both the Level 1 and Level 2 methods were designed to both "correlate with tidal wetland condition" and "produce variability across the range of ecological conditions" that were sampled (O'Brien et al., 2007).

Assessment area:

- Level 1: Wetlands were identified using NWI and classified by NWI wetland types. The buffer areas for the habitat function were 3 m, 100m, 200m, and 1000 m.
- Level 2: Shoreline only
- Level 3: 40 m radius circle around a center point in the wetland.

Functions and indicators:

Functions and indicators for all three assessment levels are presented in Table 7.

Table 7. Functions and indicators for Level 1, Level 2 shoreline survey, and Level 3 methods described in O'Brien et al. (2007) and McLaughlin (2007).

Function	**Indicator**
LEVEL 1	
Habitat	• Proximity to alternate habitat areas: submerged aquatic vegetation and oyster reefs; other wetlands • Land use around wetland • Stream density around wetland (for access by wildlife) • Located within conservation site (scored by biodiversity rank of site)
Water quality	• Salinity (this was assumed to equal extent of tidal flushing, and therefore water residence time. Lower salinity wetlands received higher scores because the residence time and associated pollutant removal was higher) • % of wetland within 10 m of the wetland side of the upland/wetland interface (lower % wetland = higher scores because more opportunity for pollutant input)
Erosion protection	• Fetch, or area of open water adjacent to wetland (estimates wetland's degree of protection from storm tides and wind-generated waves)
LEVEL 2 (Shoreline Survey)	
Habitat	• Adjacent land-use • Presence or absence of: o Forest buffer o Beach o Man-made shoreline structures o Phragmites
LEVEL 3	
Biological habitat condition	• Wetland NWI subclass • Wetland size • Qualitative ranking of condition using best professional judgment. • Wetland vegetation zones, including invasive species • Structures or features that are barriers to landward migration of marsh • Disturbances that prevent tidal water from entering or leaving site. • Qualitative estimate of alterations to hydrology by noting presence of fill, road, ditch, other. • Pore water pH, dissolved oxygen, electrical conductivity, temperature, and salinity (requires YSI and pH meters) • Soil bearing capacity (with penetrometer) • Root fiber within the root zone (estimate of below-ground biomass) • Macroinvertebrate count [VIMS (2007) only] • eH and soil profile descriptions [McLaughlin (2007) only]

Results and validation:
The Level 1 and Level 2 shoreline survey results are presented as GIS maps (available at http://rmapnt52.wetlan.vims.edu/NantTidal/viewer.htm). The Level 3 method was designed to evaluate the Level 1 and 2 methods, but no results for this or the two rapid assessment methods were presented in either report.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
According to O'Brien et al. (2007), the methods are designed to "assess the existing condition of wetland resources and to track changes to these systems over time." The method should assist in understanding "how wetlands on the individual site and the landscape levels are impacted through permitted development activities" and "in better targeting wetland restoration efforts and measuring the success of both compensatory mitigation and voluntary restoration activities."

Time required:
The Level 2 shoreline survey was a rapid assessment method. No time was given, but we estimate that it was quite rapid since it was performed from a moving boat. The Level 3 field assessment required 10 hours per site for 2 to 3 people.

Flaws/limitations:
This is a condition-based assessment, so will tend to measure disturbance rather than function. Opportunity and services are not evaluated. Some specialized equipment (YSI dissolved oxygen-electrical conductivity-temperature-salinity meter, pH meter, and penetrometer) is needed.

Level 2 Methods

Effectiveness of Maryland Compensatory Wetland Program

Reference: MDE Wetland and Waterways Program, 2007
Level: Level 2 (with some Level 3 and Level 1 validation)

Summary:
The project involved three assessment methods, although the primary method used was a Level 2 assessment method for mitigation sites. This Level 2 method scores four categories: Vegetation, Soils, Hydrology, and Function (Table 8), and gives a final score for each site. Sites can be compared to each other. It was based on a literature review by the University of Maryland Center for Environmental Science (summarized but not included) and criteria from the Interagency Mitigation Task Force Maryland Compensatory Mitigation Guidance[3], and the Fugro-McClelland East, Inc (1995) method. It was used to evaluate 92 mitigation sites during the growing season in 2007.

In addition to the Level 2 method, a Level 3 assessment of a selected subset of 20 mitigation sites was performed:

- Evaluation of hydrology at least twice during the growing season, as evidenced by inundation or saturation in top 12 inches of soil.
- Soil descriptions to evaluate presence of hydric soils or redoximorphic features. 3. Installation of IRIS ("Indicator of Reduction in Soils") tubes to estimate soil reducing potential (necessary because of presence of relic redoximorphic features in soil).
- Soil sampling and analysis for pH and organic matter content.
- A smaller subset was sampled using protocols from the ACOE wetland delineation manual (Environmental Laboratory, 1987)

Two sites were also evaluated using the Fugro-McClelland East, Inc (1995) assessment method (Level 1 with additions from data collected on site.) Note that a 600 m buffer was used for this evaluation.

Rationale:
The Level 2 method was designed to (1) give an overall assessment of the success of a mitigation wetland and (2) specifically identify the particular area(s) in which the site may be deficient. It includes indicators of both capability and opportunity.

Assessment area:
The assessment area for the Level 2 method is the wetland, but it can be separated, if necessary, by areas of different wetland types within the same project.

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[3] http://www.nab.usace.army.mil/Regulatory/Mitigation/MDCompensatoryMitigationGuidance.pdf

Functions and indicators:
Attributes (including functions) and related indicators for the Level 2 method are presented in Table 8.

Table 8. Attributes and indicators for Level 2 evaluation of mitigation sites

Attribute	Indicator
Vegetation	• % cover by native wetland plant species. • % cover by non-native plant species. • Number and cover of native plant species (specific to planned vegetation type of wetland). • Plant density (specific to planned vegetation type of wetland). • Expected growth of species based on age of wetland.
Soils	• % with soils that may be limiting plant growth.
Hydrology	• % of planned vegetated area with wetland hydrology (excluding open water). • % of planned vegetated area with open water. • % of planned vegetated area with wetland hydrology that is too wet or too dry to support the planned wetland vegetative type.
Functional: Biological	• Site contains rare, threatened, or endangered species.* • Habitat for forest-dwelling birds: site is part of larger site with interior forest habitat. • Habitat for non-wetland dependent wildlife: site has high vegetative diversity and other nearby habitat. • Habitat for reptiles/amphibians: site has emergent vegetation, depressions, rocks/logs in open water. • Habitat for wetland dependent wildlife: site has high vegetative diversity and other nearby wetlands. • Habitat for fish and other aquatic wildlife: inundation and/or connection to water bodies.
Functional: Water quality	• Filtering sediments and pollutants: site is adjacent to pollutant/sediment source, and is densely vegetated. • Reducing erosion: site has vegetation along a streambank or pond edge with an elevation difference of more than 6”
Functional: Hydrologic	• Moderation of floodwater flow in headwater wetlands: site should be hydrologically connected with relatively flat topography and depressions with no outlet that store surface runoff but do not receive overbank flooding • Moderation of floodwater flow in floodplain wetlands: site should be hydrologically connected with relatively flat topography and depressions that overbank flooding; ideally no or restricted. • Discharging groundwater: site is large wetland next to lake or stream, or has perennial streams/seeps, or has no inlet/perennial outlet. • Recharging groundwater: no inlet with perennial outlet; hydrologically connected but not permanently inundated.
Functional: Human values	• Providing recreational opportunities: site is known to be used for recreation. • Providing harvestable natural resources: site is known to be used for harvesting timber, fish, or furbearing mammals. • Providing educational opportunities: site is known to be used by groups for environmental education. • Providing aesthetic qualities: site is non-degraded and visible to others. • Representing a rare ecotype within the watershed: site includes this rare ecotype.
*Bonus points if site has habitat for rare plants or animals, or if site creates potential habitat for rare plants or animals that inhabit adjacent land.	

Results and validation:
The overall purpose of the study was to evaluate the effectiveness of Maryland's mitigation program, so development, testing and validation of the Level 2 method was summarized briefly. A draft version of the method was revised and refined after extensive field testing so the method would be fully applicable to situations found on actual mitigation sites. Results of the Level 2 method were presented as averages by type of mitigation site and total overall average score. Individual results for each site evaluated by the Level 3 (20 sites) and Level 1 (2 sites) evaluation were also given. The 20 sites that were assessed by the Level 3 method were also assessed by the Level 2 method so results could be compared, but the comparison is not detailed in the report.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The Level 2 method "allows a high number of sites to be evaluated, making them easy to compare, and gives an overall assessment of the success of the mitigation project" (MDE Wetland and Waterways Program, 2007). It identifies the presence of rare, threatened, or endangered species, and/or of rare wetland ecotypes.

Time required:
The Level 2 method is rapid (< 4 hours).

Flaws/limitations:
Testing of the Level 2 method revealed that evaluation of functions varied depending on the judgment and/or biases of the individual scorer.

Level 3 Methods

The Hydrogeomorphic Approach to Functional Assessment for Piedmont Slope wetlands

Reference: Vasilas, 2006
Level: Level 3

Summary:
This is a Level 3 preliminary HGM model for Piedmont slope wetlands. It is based on reference data collected on 26 slope wetland sites in the Piedmont province of Maryland, Delaware, and Pennsylvania. Data collected and presented in the report included:

- Vegetation: species composition, percent cover, number of strata, presence of alien species.
- Soils: soil classification, textural class, presence/depth O and A horizons, percent organic matter, hydric soil indicators.
- Hydrology: water table depth, presence of surface outflow channel, presence of sub-surface outflow, aquic moisture regime.
- Wetland assessment area: slope, aspect, physical dimensions, surface roughness.
- Landscape/wetland complex: landscape disturbance level, landscape connectivity, landscape complexity, wetland proximity, buffer condition.
- Environmental chemistry: water chemistry, soil chemistry, soil redox potential.

Rationale:
Like all HGM models, this model attempts to rate " functional capacity for a given wetland relative to reference standards-the highest level of functional capacity exhibited by wetlands in the regional subclass" (Vasilas, 2006). However, the reference sites for this model were selected to represent a range of disturbance (both natural disturbance and that resulting from human activity) rather than being chosen from undisturbed sites as is usual in the HGM approach. The reasoning behind this is (1) some "disturbed" wetlands have a higher capacity for certain functions such as removal of sediment and nitrate; and (2) it is very difficult to find a truly "undisturbed" wetland in areas such as the Mid-Atlantic.

The rationale behind most of the model variables for hydrologic and biogeochemical functions is clearly explained (although not referenced) in the text. Further explanation of the variables in the plant community and wildlife habitat would be helpful.

Assessment area:
The assessment area was the wetland, but data on landscape level connectivity and complexity, proximity of the nearest wetland, condition of the catchment area, and subwatershed land use were also used in the model.

Functions and indicators:
The functions assessed were surface and shallow subsurface temporary water storage, organic carbon export, nutrient cycling, removal of elements and compounds,

maintenance of characteristic plant community, and maintenance of characteristic wildlife habitat. Model variables related to each function are presented in Table 9.

Table 9. Model variables for individual functions in the preliminary Piedmont slope HGM model

Function	Model Variables
Temporary water storage	• Surface roughness • Wetland surface slope • Landscape level connectivity • Water source area condition
Organic C export	• Surface water outflow connectivity • Soil organic matter • Woody debris biomass • Leaf litter biomass • Ground cover biomass
Cycling of nutrients	• Soil organic matter • Aquic condition index • Ground cover biomass • Woody debris biomass
Removal of elements and compounds	• Soil organic matter • Soil contact index • Surface roughness
Characteristic plant community	• Plant species composition • Non-native plant index • Vegetation strata index • Water source area condition • Wetland disturbance • Sub-watershed land use
Wildlife habitat	• Wetland disturbance • Landscape level connectivity • Proximity of nearest suitable wetland • Condition of the catchment area • Mast availability index • Plant species composition • Vegetation strata index • Woody debris biomass • Leaf litter biomass

Vegetation successional stage:
Vegetation was incorporated in the plant community (variables: species composition, non-native plant index, and vegetation strata index) and wildlife habitat portions (variables: plant species composition and vegetation strata index) of the model. The model does not result in higher functional capacity indexes for more advanced successional stages.

Results and validation:
This is a preliminary model, so raw data only is presented, with no statistical analysis.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The method could be used to identify wetlands with high functional capacity for preservation. It does not identify wetlands with rare, threatened, and endangered species.

Time required:
Not stated, but we estimate that this is likely a true Level 3 method because it require extended monitoring, as well as laboratory analysis of samples.

Flaws/limitations:
This is a preliminary model and should not be used as is. It is based on measurements from a relatively small number of wetlands. Like all HGM methods, it does not measure opportunity or services. The method requires some specialized equipment, including automated water level monitoring wells and platinum electrodes for redox measurements.

Associated Guidance or Studies

Note: these were not included in Table 10.

Comprehensive Nontidal Wetland Watershed Management Plan: A Guide for Local Governments

Reference: Clearwater et al., 1998

Summary:
This is not a wetland assessment method, but it (1) describes the components and outlines procedures necessary for Level 1 assessment and (2) includes case studies where watershed plans were prepared using combination of Level 1 and Level 2 or 3 assessment methods. It also includes detailed guidance for preparing a watershed management plan with the following components: wetland assessment, identification and location of mitigation sites, protection of non-tidal wetlands, limitation of cumulative impacts, water supply consideration, and flood management consideration.

Watershed management plans must address how wetlands protect water supply, and include flood/floodplain management strategies. Important indicators are described briefly and are taken from those in "A Method for the Assessment of Wetland Function" (Table 3). Functions to be measured include wildlife habitat, aquatic habitat, groundwater discharge, water quality, sediment stabilization (either water quality or bank stabilization), flood attenuation A tabular summary of other methods is also included. Advice on how to modify methods for the purposes of individual assessments is given.

The following case studies which involved Level 2 or 3 assessment methods were presented.

- *Big Annemessex River Watershed Management Plan- Somerset County (for non-tidal wetlands only).*

This study used the WET 2.0 (Adamus et al., 1897) groundwater discharge and production export models modified to give numerical rankings (so that wetlands could be compared), and the New Hampshire method (Amman and Stone, 1991) for others. The methods were modified to fit the needs of the watershed planners. The highest score for each wetland was considered the "reference standard" and other wetlands were compared to that. High ranked wetlands had one of the following attributes: at least 20 acres in size, an infrequently occurring water regime, an association with perennial stream, or a record of rare and endangered species.

- *Parker Creek Watershed, Clarksburg Wetlands, and Hunting Creek Watershed - Calvert County.*

This field portion of these studies used WET 2.0 converted to give numerical scores and the New Hampshire method in the office, except for wildlife habitat assessment. Unless a threatened or endangered species was present, wildlife habitat index was calculated from total watershed minus urban area, plus forest area, wetland class, wetland size, and water regime.

- *Middle River Neck Peninsula Special Area Management Plan – Baltimore County*.

This was a small area where an intensive field assessment was desired. Combinations of methods were used: the New Hampshire method modified to: (1) evaluate fewer functions, and (2) place less emphasis on waterbirds. A modified version of EPA's rapid bioassessment procedure (Barbour et al., 1999) was used for aquatic habitat. WET 2.0 was used for flood control function. Wetlands within the Chesapeake Bay Critical Area received higher rankings.

Flaws/limitations

Since this document provides guidelines for choosing a method rather than an actual method, there are no stated limitations. However, since the document was published in 1998, it would likely benefit from an updating of the methodology and case studies portion portions.

Monitoring and Assessing the Nutrient Status and Overall Health of Fresh Water Wetlands

Reference: Vasilas et al., 2008

Summary:
This was a study to determine sampling techniques and possible indicators, rather than a method. The objectives of the project were to (1) quantify nutrient (nitrogen and phosphorus) dynamics in wetlands (2) investigate protocols for monitoring wetlands for nutrient (nitrogen and phosphorus) levels and (3) examine whether nutrient transformation in wetlands could be evaluated by using rapid assessment indicators. The authors examined 12 freshwater wetlands: six Piedmont slope wetlands and six Coastal Plain flats or depressions. Wetlands with differing hydrologic systems and nutrient loading potential were chosen. Sites were monitored for three years.

Results and validation:
Results were presented in the form of figures and tables with extensive statistical analysis, and were discussed in the text. Conclusions were:

- In the Piedmont wetlands, less disturbed wetlands had a greater capacity to remove nitrate, but degree of disturbance did not affect nitrate levels. In the Coastal Plain, less disturbed wetlands had a lower capacity to remove nitrate. Less disturbed Coastal Plain sites had lower nitrate levels. Disturbance was not a reliable indicator of phosphorus (orthophosphate) enrichment or removal.

- One water sampling will probably give a general idea of nutrient levels in the groundwater of a wetland, but since there was unpredictable seasonal variation in wetland nutrient content, three water samples are recommended in order to fully characterize wetland nutrient content.

- Water quality within a wetland was not correlated with wetland nutrient transformation. Nitrate and orthophosphate levels in wetlands are correlated in Coastal Plain flat wetland but not in Coastal Plain depression or Piedmont slope wetlands. Nitrate and orthophosphate removal capacity were correlated in Piedmont slope wetlands, but not necessarily in Coastal plain wetlands.

- Hydroperiod, specifically water table depth and number of wet/dry cycles, fluctuation was the primary factor affecting wetland water quality and nutrient transformation. Hydric soil indicators were accurate indicators of hydroperiod in both Piedmont and Coastal Plain sites. Hydric soil indicators depleted matrix (F3) and a depleted zone below a dark surface (A11) were found to be indicators of denitrification potential in the Piedmont.

Flaws/limitations:
Only 6 sites were chosen from each physiographic province. This was likely necessary given the complexity of the study, but further research may be required to validate the results, and/or to extend the results to other physiographic provinces.

Formation of New Redoximorphic Features under Hydric Soil Conditions

Reference: Rabenhorst and Orr, 2009.

Summary:
This is a study, not a method**,** although results from the study could be used as a starting point to develop indicators for assessment of constructed and other wetlands.
Soil redoximorphic features are one indicator of the presence of hydric soil conditions, and their presence can be used as a gauge to measure the success of mitigation wetlands. This study sought to quantify the time needed for soil redoximorphic features to form under hydric conditions in different soil types and under different vegetation.

Results and validation:
Visible redoximorphic features formed in soil surface horizons in as little as 8 weeks after soils were saturated. Percentage of redoximorphic features in soil increased with repeated wetting and drying cycles. Almost all the redoximorphic features were faint fine iron oxide concentrations on root channels, pore linings and structural surfaces. Vegetation affected the type and location of features, but not the number of features present. High organic matter content in soils promoted the development of redoximorphic features. Results were presented as figures and tables and appear to have undergone rigorous statistical analysis. Findings were statistically significant.

Flaws/limitations:
Discernment of faint redoximorphic features would likely require soils expertise or training.

Baseline Assessment of Water Quality in Maryland's Wetlands

References: Tilley et al., 2008a; 2008b.

Summary:
This was a study, not a method, but the methods used in the study could be adapted to Level 3, and possibly Level 1, assessment. The study examined *Escherichia coli* and total coliform concentrations and antibiotic resistance of *E. coli* as well as vegetation, soil characteristics, and surrounding land use in 13 constructed wetlands. It also included a short review of methods used to monitor nutrient levels in wetlands. Sampling in each wetland was done in three "representative" plots, with subplots chosen for intensive sampling. Vegetative cover, plant species and percent cover by species was quantified for the subplots (approximately 3 per site). Two soil samples were taken in each plot: one for on-site soil description and one for laboratory analysis for carbon, nitrogen, and phosphorus. Water samples were taken from both surface (if possible) and subsurface of each plot for nutrient analysis and E. coli antibiotic resistance testing. Dissolved oxygen and Eh were also measured. The rationale for the sampling methods is extensively referenced and appears to be quite sound. Buffer zones of 1000 and 2000 m around the wetland were used to determine the Landscape Development Index (Brown and Vivas, 2005) and a general characterization of land use around each wetland.

Results and validation:
The results were presented in tables and figures and discussed in the report. Extensive statistical testing was performed but sample size was small (n=13) so few statistically significant relationships were found, and only broad conclusions could be made. The study found that most of the mitigation sites appeared to be functioning well. The authors recommended including surrounding land use practices in any wetland assessment; in this particular study, surrounding agricultural land-use predicted high nutrient concentrations in a wetland. They also found that wetland with high carbon and nitrogen levels had lower populations of antibiotic resistant bacteria.

Flaws/limitations:
The authors define a number of "wetland health" characteristics, including many which are based on high nutrient levels in either soil or water. "Wetland health" may be a misnomer since some natural wetlands are low-nutrient environments, and nutrient overloads may negatively affect wetland ecosystems.

Tabular Comparison of Assessment Methods Used in MDE/MDNR Studies.

Table 10. Comparison of wetland assessment methods used in MDE/MDNR studies.

Method or study	**Reference**	**Level 1, 2, or 3?**	**Which categories of functions are evaluated?**	**Are cultural services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Adjusted scored for preferred functions**	**Wetland and/or vegetation type**	**Restricted for use in studied wetland type?**	**Region where method was developed**	**Can it be used in other regions?**
Watershed-based wetland characterization for Maryland's Nanticoke River and Coastal Bays watersheds *and* Historical analysis of wetlands and their functions for the Nanticoke River watershed	Tiner et al., 2000; Tiner and Berquist, 2003	Level 1	Hydrologic, biogeochemical, habitat	Conservation of biodiversity only	No	Yes	No	NWI and LLWW (Landscape position, Landform, Water flow path, and Waterbody)	No	Maryland Coastal Plain	Yes, if adapted
Building capacity to perform wetland assessments	CCRM, 2008	Level 1	Water quality, habitat	No	Performance of each function is scored separately.	Yes	No	NWI	Non-tidal only	Maryland Coastal Plain and Piedmont	If adapted
A method for the assessment of wetland function	Fugro-McClelland East, Inc. 1995	Level 1 and 2	Hydrologic, biogeochemical, habitat	No	No	Designed to directly compare wetlands of same class/stream order.	Yes, for rare species.	HGM wetland class with NWI vegetation type	Palustrine non-tidal only	Maryland Coastal Plain and Piedmont	If adapted

Table 10 (continued). Comparison of assessment methods used in MDE/MDNR studies.

Method or study	**Reference**	**Level 1, 2, or 3?**	**Which categories of functions are evaluated?**	**Are cultural services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Adjusted scored for preferred functions**	**Wetland and/or vegetation type**	**Restricted for use in studied wetland type?**	**Region where method was developed**	**Can it be used in other regions?**
US 301 Waldorf Area Transportation Improvements project	unpublished materials and methods document	Level 1 (same method as CCRM, 2008) and Level 2 (4 rapid assessment methods)	Hydrologic, biogeochemical, habitat	Depends on method	Yes, in all Level 2 methods.	Yes, for all methods	Depends on method	Depends on method	N/A	Depends on method	All methods used were developed in other regions
Wetland profile for the Nanticoke River watershed	Bleil, 2004	Level 1, 2, 3	Hydrologic, biogeochemical, habitat	No	Yes - for Level 2 method(s). For HGM model, performance of each function is scored separately (although this was combined to produce an overall score).	Only by HGM type	No	HGM	Yes	Maryland and Delaware Nanticoke River watershed	No

Table 10 (continued). Comparison of assessment methods used in MDE/MDNR studies.

Method or study	**Reference**	**Level 1, 2, or 3?**	**Which categories of functions are evaluated?**	**Are cultural services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Adjusted scored for preferred functions**	**Wetland and/or vegetation type**	**Restricted for use in studied wetland type?**	**Region where method was developed**	**Can it be used in other regions?**
Refinement and validation of a multi-level assessment method for Mid-Atlantic tidal wetlands *and* Nanticoke River tidal fringe wetlands assessment	VIMS, 2007; McLaughlin, 2007	Level 1, 2, 3	Level 1 and Level 2: Habitat, water quality, erosion protection; Level 3: Habitat	No	Performance of each function is scored separately.	Yes (tidal wetlands only)	No	NWI (Level 1) and HGM (Level 3)	Tidal wetlands only	Nanticoke River (Maryland), Indian River (Delaware), and York River (Virginia) watersheds	Possibly can be used In other Chesapeake Bay area watersheds, if adapted
Effectiveness of Maryland compensatory mitigation program.	MDE Wetland and Waterways Program, 2007	Level 2	Assesses success in establishing wetland vegetation, soil, and hydrology as well as hydrologic, biogeochemical, and habitat functions	Yes	No (mitigation success is evaluated rather than condition)	Yes (mitigation sites only)	Yes, for rare species.	NWI vegetation types	Mitigation sites	Maryland	Not stated, but method could be adapted.
The hydrogeomorphic approach to functional assessment for Piedmont slope wetlands	Vasilas, 2006	Level 3	Hydrologic, biogeochemical, habitat	No	Performance of each function is scored separately.	No	No	HGM	Yes	Mid-Atlantic Piedmont slope wetlands	Not stated, but method could be adapted.

Review of Other Methods and Studies

Level 1 Methods with Level 2 or 3 Field Assessment

Mid-Atlantic Regional Wetland Assessment Procedure

References: Brooks, 2006; Brooks et al., 2009
Level: 1 and 2 (Level 3 is proposed)

Summary:
This is an on-going study (2008-2012). Its goal is to develop Level 1, 2, and 3 methods for determining wetland condition and dominant stressors in the Mid-Atlantic Region. Specific objectives for each level are (Brooks, 2006):

- Level 1:
  - Examine landscape and land use around all Mid-Atlantic around all non-tidal, NWI-mapped wetlands with existing datasets.
  - Develop and test Level 1 functional models (ongoing).
- Level 2:
  - Combine existing stressor checklist methods from Pennsylvania, Delaware and Virginia to produce a Mid-Atlantic Rapid Assessment Method.
  - Sample 400 sites over 2 field seasons: 200 with the existing methods and 200 with the combined method.
- Level 3 (proposed; if funding allows)
  - Use intensive data to validate Level 1 and Level 2 models.

Rationale
The Mid-Atlantic Regional Wetland Assessment Project is designed to combine methods currently used in the Mid-Atlantic to "generate a protocol that can be used for probabilistic sampling and characterization of wetlands in each of the major eco-regions of the mid-Atlantic" (Brooks, 2006). Specifically, the goals of the project method are to:

- Characterize wetland condition in the Mid-Atlantic region using probabilistic sampling.
- Determine which stressors have the most influence on wetland condition in the Mid-Atlantic.
- Produce a Level 1 landscape-scale evaluation of Mid-Atlantic wetland condition.
- Assist in determining objectives for wetland restoration and creation in the mid-Atlantic.

Assessment area
The assessment area for the combined stressor checklist method (Unified Mid-Atlantic Rapid Assessment Procedure) is a 0.5 ha (40m) radius circle. The buffer is a 100 m ring around the assessment area (Brooks et al., 2009)

Functions and indicators:
The Level 1 method used is the VIMS Level 1 method described earlier (CCRM, 2008: "Building Capacity to Perform Wetland Assessments"). It assesses habitat and water

quality condition. Note that the variables shown in Table 11 were slightly adapted by removal of some of the metrics after calibration and validation tests[4] (personal communication, Kirk Havens). Scoring and non-scoring factors using in the Unified Mid-Atlantic Rapid Assessment Procedure were briefly described in Brooks et al. (2009), and are presented in Table 12.

Table 11. Functions and indicators for the VIMS Level 1 method (CCRM, 2007; 2008)

Function	Variables
Habitat potential	• Wetland type (NWI) • Wetland size • Land cover type • Proximity to roads • Proximity to highways • Proximity to other wetlands • Wetland hydroperiod (NWI)
Water quality	• Wetland type (NWI) • Wetland size • Land cover type • Proximity to roads • Proximity to highways • Wetland hydroperiod (NWI)

Table 12. Variables for Unified Mid-Atlantic Rapid Assessment Procedure (adapted from Brooks et al., 2009).

Factor type	Variable
Non-scoring factors	• HGM class • Wetland successional stage • Buffer successional stage: dominant land use plus forest age • Qualitative Condition Rating (used to check stressor checklist score)
Scoring factors (stressor checklist)	• Hydrologic modification: ditch, fill, dead trees, stormwater, roads • Sedimentation: deposits, intensive grazing, active construction, etc. • Vegetation alteration: mowing, moderate grazing, brush cutting, etc. • Eutrophication: discharges, heavy algal mats, etc. • Contaminants or toxicity: point discharges, severe vegetation stress, chemical odor.

Results and validation:

In 2009, 200 sites in five physiographic provinces in the Mid-Atlantic were assessed with the Mid-Atlantic Rapid Assessment Procedure, although results have not been published. Sites were selected with a probabilistic survey sampling design, which randomly chooses sites from all possible sampling sites. According to Brooks et al. (2009), a subset of the

[4] For example (personal communication, Kirk Havens): “For habitat condition assessment, the following landscape metrics were found to have significant relationship with the ecoservice endpoints of avian and amphibian community structure: % developed land within 200m, proximity to other wetlands within 200m, road density within 200m, % developed land within contributing drainage (200m), % row crops within 200m, %row crops within drainage (200m), % natural land within drainage, %pasture land, and [wetland] size.”

sites sampled with the Mid-Atlantic Rapid Assessment Procedure will undergo comprehensive assessment in order to validate the rapid protocols.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
As stated earlier, the completed project will be used to produce a Level 1 evaluation of wetland condition in the Mid-Atlantic Region. It may also be used to set objectives for wetland restoration and creation in the region.

Time required:
Not stated, but the Unified Mid-Atlantic RAP should require less than half a day.

Limitations:
The Level 1 and Level 2 methods do not evaluate opportunity or services. Results from the Level 2 assessments are compromised because sites were chosen with a probabilistic survey sampling design and the field crews did not verify that they were actually in a wetland (personal communication, Denise Clearwater).

Penn State Landscape/Rapid Assessment Method

Reference: Brooks et al., 2004a (Level 1); Brooks et al., 2004b and Wardrop et al., 2007a (Level 1 and 2)
Level: Combines Levels 1 and 2

Summary:
The Penn State method (also known as the Penn State Stressor Checklist) is designed to assess wetland condition. It combines one factor from a Level 1 landscape assessment with a Level 2 field stressor assessment. The Level 1 factor is percent forest within 1 km of the wetland. Two assumptions are made here: "(1) forested land cover is the reference standard condition (i.e., ecological condition in the absence of stressors associated with human land use) and (2) non-forested land cover is a surrogate for the stressors that affect wetland condition" (Brooks et al., 2004a). Since forest is the primary reference land cover type in Pennsylvania, the Level 1 provides an estimate of human disturbance in areas adjacent to the wetland. However, Brooks et al., (2004a) notes that this metric may not apply to other regions.

The Level 2 portion of the method is a field survey of stressors. Field data are combined with the Level 1 assessment to produce a "human disturbance score." The score for each wetland is calculated using the following formula:

100 - [(% forest x weighting factor) + buffer score – buffer hits) x 100]

Where:
% forest = % forest in a 1-km radius landscape circle centered on the wetland

- Weighting factor = (10 - # of stressor categories) / 10 (see Table 13).
- Buffer score = numeric value associated with adjacent buffer vegetation type and width.
- buffer hits = five possible stressors which can directly break a continuous buffer:
    - Active plowing, etc.
    - Direct discharges of organic wastewater, etc.
    - Adjacent to industrial sites, etc.
    - Direct discharges from agricultural feedlots, etc.
    - Adjacent to spoil piles.

Rationale:
The landscape portion of the method was chosen based on average reference standard condition for wetlands in Pennsylvania and assumes that sites that are located in forested areas are in higher condition (Brooks et al., 2004a). The stressor based portion of the method is based on the assumptions that:

1. More stressors equal more disturbance, and lower condition.
2. The negative effect of stressors on condition can detract from the positive effect of surrounding forest cover.

3. Wide buffers and/or buffers in natural vegetation can lessen the effects of nearby disturbance on a wetland, unless the buffer itself is broken by surrounding land use practices (Wardrop et al., 2007).

Assessment area:
Wardrop et al (2007) defined the assessment area for the Penn State method as either (1) the entire wetland, if wetland size was less than 5 ha, or (2) a 1-2 ha area centered around a sampling point for wetlands larger than 5 ha.

Functions and indicators:
Stressors by stressor category are presented in Table 13.

Results and validation:
The adjusted Floristic Quality Assessment Index (FQAI) of Miller and Wardrop (2006), which also assesses condition, was used to test and refine the Penn Sate method (Wardrop et al., 2007). The results from assessments of 80 sites with the method were compared to FQAI results using Classification and Regression Tree (CART) analysis. In general, the method was able to predict wetland condition as evaluated by the FQAI, but scoring break points for condition categories (highest, high, medium, low, and lowest) were adjusted based on FQAI results. Penn State has also developed other Level 3 method besides the FQAI (Brooks, 2004), including several HGM models and indices of biological integrity (IBI)[5], but we were unable to determine if the stressor checklist had been validated with these methods.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The Penn State Method can be used to "target areas needing attention or protection, prioritize sites for restoration, design restoration projects, and choose appropriate best management practices" (Wardrop et al., 2007). Periodic monitoring of previously assessed wetlands could assist in quantifying the effects of restoration and/or management practices. The method does not identify wetlands with rare, threatened, and endangered species.

Time required:
Although this method is technically not "rapid" because it involves some Level 1 landscape analysis, Fennessy et al., (2004) estimates that it would require less than 4 hours.

[5] An index of biological (or biotic) integrity (IBI) is a condition measurement. Bartoldus (1999) defines an IBI as "a multimetric index indicating the ability of a habitat to support and maintain a balanced, integrated, adaptive biological system having the full range of elements expected in a region's natural habitat." Indicators used should be sensitive to varying degrees of stress on ecological integrity. IBI's may be developed using vascular plants, amphibians, birds, algae, or macroinvertebrates (EPA, 1998).

Table 13. Stressors used in the Penn State assessment method.

Stressor category	Stressor
Hydrologic modification	• Ditch • Tile drain • Dike • Weir/dam • Stormwater inputs • Point source (non stormwater) • Filling, grading, dredging • Road/railroad • Dead/dying trees • Other
Sedimentation	• Sediment deposits/ plumes • Eroding banks/ slopes • Active or recently active adjacent construction, plowing, heavy grazing, or forest harvesting • Siltiness on ground or vegetation • Urban/road stormwater input/culvert • 50% presence of sediment tolerant plants (from list) • Other
Lack of dissolved oxygen	• Excessive density of aquatic plants or algal mats in water column • Excessive deposition or dumping of organic waste • Direct discharges of organic wastewater or material
Contaminant toxicity	• Severe vegetation stress • Obvious spills, discharges, plumes, odors • Wildlife impacts • Adjacent industrial sites, proximity of railroad • Other
Vegetation alteration	• Mowing • Grazing • Tree cutting • Brush cutting • Removal of woody debris • Aquatic weed control • Excessive herbivory • Dominant presence of exotic or aggressive plant species • Evidence of chemical defoliation • Other
Eutrophication	• Direct discharges from agriculture feedlots, manure pits • Direct discharges from septic or sewage treatment systems • Heavy or moderately heavy formation of algal mats • Dominant presence of nutrient tolerant species • Other (dead fish, methane odor, etc.)
Acidification	• Acid mine drainage • Adjacent mined lands/ spoil piles • Excessively clear water • Absence of expected biota • Turbidity • Other (such as abnormally low pH)
Turbidity	• High concentration of suspended solids in water column • Moderate concentration of suspended solids in water column • (Check both stressors if there is a high concentration)
Thermal alteration	• Significant increase in water temperature • Moderate increase in water temperature • (Check both stressors if there is a significant increase)
Salinity	• Obvious increase in dissolved salts

Flaws/limitations:

The Penn State method does not evaluate services. Like all stressor-based methods, it assumes wetland is in good condition unless stressors are visible, which may not account for non-point source stressors (Fennessy et al., 2004) or management practices designed to combat on or off-site stressors (Sutula et al., 2006), although it does modify the stressor score based on surrounding forested buffer areas. The Level 1 portion and some of the Level 2 stressors may be specific to Pennsylvania.

Virginia Institute of Marine Science (VIMS) Method: Older

Reference: Bradshaw, 1991.
Level: Combines Levels 1 and 2/3

Summary: The older Virginia Institute of Marine Science (VIMS) method was designed to assess wetlands on the basis of both (1) opportunity to perform each function or service and (2) effectiveness in performing the function/service. Wetlands are ranked as having a "High, Moderate, or Low" probability for opportunity plus effectiveness for each function. The data used is collected from desktop analysis of maps and other data, and from site visits. The field portion of the method requires 1/2 to 1 day, according to Bartoldus (1999) and Fennessy et al. (2004). The method does not assess condition, and does not provide an overall score for each wetland. It was primarily adapted from the Wetland Evaluation Technique for Bottomland Hardwood Functions (Adamus et al., 1990), and the Connecticut/New Hampshire methods (Ammann et al., 1986; Ammann et al., 1991).

Rationale:
The method was meant to be "a research tool which evaluates the relationships between vegetation structure, wetland function, and landscape position" (Bradshaw, 1991). Indicators were developed from a review of literature, rather than from reference wetland data. The rationale behind each indicator is clearly explained and referenced. The method does not measure condition. However, for the wildlife habitat function, the rationale is that all wetlands provide habitat, and that habitat value is lessened by human disturbance, so some indicators are similar to those for stressor-based condition assessment.

Assessment area: The assessment area is "the entire contiguous wetland of similar topography and vegetation structure" (Bradshaw, 1991).

Functions and indicators:
Functions and indicators for the older VIMS method are presented in Table 14. Note that some of the indicators for the hydrologic/biogeochemical functions are the same.

Results and validation:
This is a method only: no results or validation data is given.

Table 14. Functions and indicators for the Virginia Institute of Marine Science method (Bradshaw, 1991)

Function	**Indicator**
Flood storage and storm flow modification	• Proportion of 2-year, 24-hour storm volume stored in wetland • Average watershed slope
Nutrient retention and transformation	• Potential source of excess nutrients • Proportion of land with nutrient runoff that is not treated prior to entering wetland • Average runoff in 2-year 24-hour storm • Average slope of watershed • Proportion of 2-year 24-hour storm volume stored in wetland • Retention/ detention of storm water within wetland
Sediment and toxicant trapping	• Potential sources of sediments • Potential sources of nutrients • Proportion of land with sediment source that is not treated prior to entering wetland • Proportion of land with toxicant source that is not treated prior to entering wetland • Average runoff in 2-year 24-hour storm • Average slope of watershed • Proportion of 2-year 24-hour storm volume stored in wetland • Retention/ detention of storm water within wetland
Sediment stabilization	• Erodibility of soils within the wetland • Erosive conditions present (includes some stressors) • Flooding • Wetland roughness
Wildlife habitat	• Surrounding land use • Wildlife access to other wetlands over land • Disturbance within wetland • Potential sources of toxic inputs to wetlands • Regional biodiversity (rare wetland types, or presence of rare species) • Food sources and special habitat features such as snags, large trees, exposed sandbars, etc. (This was a test indicator and was not rated or scored).
Aquatic habitat	• Permanent water • Accessibility of wetland to fish • Water quality stresses present • Channel modification • % cover
Public use of wetland	• Public access to wetland
Other factors (these are not used in ranking, but may used to analyze collected data)	• Disturbance in surrounding landscape • Disturbance within wetland • Landscape position • Stream order

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The method identifies the presence of rare wetland types and rare, threatened, and endangered species. It could be used to identify wetlands that should be preserved, or might be candidates for restoration.

Time required:
Bartoldus (1999) estimated that the method would require approximately 4 hours for a 1 acre site, while Fennessy et al. (2004) estimated that the method would take more than 1 day.

Flaws/limitations:
The author noted the following limitations:

1. At the time of publication, the method was still under development. (It appears to have been replaced by the newer VIMS methods.)
2. The method is, by necessity, somewhat subjective.
3. Assessment of groundwater relationships is not included (the author felt that this was not appropriate for a rapid assessment method.)
4. Wildlife habitat is assessed for “wildlife” in general, rather than specific species.
5. Aquatic habitat is primarily designed to assess fish habitat.
6. The method does not assess production export.
7. Indicators were designed to assess the probability of a wetland’s opportunity to perform a function and effectiveness in performing a function, and were not meant to be actual measures of opportunity and effectiveness.

Level 1, 2, and 3 Methods

Virginia Institute of Marine Science (VIMS) Method: Newer

References: CCRM, 2007; personal communication, Kirk Havens
Level: Levels 1, 2, and 3

Summary:
The newer VIMS method (CCRM, 2007) assesses "overall condition as related to habitat and water quality functions" via Level 1, 2, and 3 methods. The Level 1 method estimates habitat and water quality functional capability from surrounding land use and other features, as well as wetland characteristics such as NWI wetland type and wetland size. The Level 2 method evaluates a list of stressors in and around each wetland.

The Level 3 method uses intensive sampling and observation to validate the water quality and habitat capability scores from the Level 1 method. The method is in review for publication so complete information on method techniques and validation is not yet available.

Rationale:
The overall model is based on the "Multiple Service" concept, in which each function is presumed to be a product of a different set of wetland properties, and is assessed and rated separately. It assumes that the wetland properties which result in optimum performance of one function (e.g. habitat) may not be the same as those which result in optimum performance of another function (e.g. water quality). [This is opposed to the "Prima Optima model" which "presumes that a wetland is providing optimal benefits when it is in pristine condition" (CCRM, 2007).] The indicators were selected based on either best professional judgment and/or the existing literature. In general, however, the method results in higher scores for wetlands in undisturbed areas. Opportunity is not included in scoring. For example, a wetland providing a water quality service by proximity to pollutant sources receives a lower score for the water quality service than a wetland not close to a pollutant source. There is an extensive list of references for each indicator in the report, but individual rationale for each indicator is not directly explained in the method description.

Assessment area:
For the Level 1 method, three buffer zones were used for habitat variables: 3 m, 200 m, and 1000 m around each wetland. Water quality function was based on scores for the three buffers plus those for in the drainage basin surrounding each wetland. For the Level 2 method, stressors were determined for (1) 30m radius circle from a center point, and (2) a 30m to 100m radius circle from a center point.

Functions and indicators:
Functions and related variables for the Level 1 method are presented in Table 15, and stressors used in the Level 2 method are presented in Table 16.

Table 15. Functions and associated variables for VIMS Level 1 method.

Function	Variables
Habitat potential	• Wetland type (NWI) • Wetland size • Land cover type • Proximity to roads • Proximity to highways • Proximity to other wetlands • Wetland hydroperiod (NWI)
Water quality	• Wetland type (NWI) • Wetland size • Land cover type • Proximity to roads • Proximity to highways • Wetland hydroperiod (NWI)

Table 16. Stressors assessed in the VIMS Level 2 method.

Stressor
Sediment deposits
Eroding banks
Active construction
Other sedimentation
Potential source discharge
Potential non-point source discharge
Other hydrologic alterations
Active agriculture
Unfenced cattle
Active timber harvesting (within 1 yr)
Active clear cutting (within 1 yr)
Other toxic inputs
Drain/ditch
Filling/grading
Dredging/excavation
Stormwater inputs/culverts/input ditches
$\geq$ 4 lane paved road
2 lane paved road
1 lane paved road
Gravel road
Dirt road
Railroad
Other roadways (parking lots)
Utility easement maintenance
Herbicide application
Dike/weir/dam
Beaver dam
Mowing
Brush cutting
Excessive herbivory
Timber harvesting (1-5yrs)
Clear cutting (1-5 yrs)
Invasive species present
Other vegetative alteration

Results and validation:
The Level 1 model was calibrated with the Level 2 stressor checklist on 1,326 sites in the Virginia Coastal Plain and 602 sites in the Virginia Piedmont. Land cover variables and, to some extent, wetland type, were found to be correlated with overall stressor scores (CCRM, 2007).

Model validation via intensive Level 3 sampling is complete for Virginia's Coastal Plain, although results are not yet published. Level 3 validation of Level 1 land cover variables and Level 2 stressors was conducted on 27 randomly selected sites. Functional capability as related to water quality and habitat was evaluated as follows (personal communication, Kirk Havens):

- Water quality was assessed by measuring total dissolved N, total dissolved phosphate, and total suspended solids in wetland surface water. Water was sampled monthly and after rainfall, and these data were compared to the Level 1 variables. Water quality condition assessment scores were also independently evaluated by comparing scores for wetlands in drainages that supplied impaired waterways versus wetlands in drainages that supplied unimpaired waterways (as determined by VA Department of Environmental Quality).

- Habitat was assessed using variables that evaluated avian and amphibian communities (personal communication, Kirk Havens). Avian communities were assessed via "three rounds of stratified point count surveys. Surveys were conducted from 0.5 and 4.5 hours after sunrise between late May and mid July. Data collected at each point include, site, date, start time, species of birds detected, distance from point center (within 50m, and >50m) of each detection, time period of detection (0-3, 3-5, 5-7, 7-10, and 10-15min), and detection method (visual, aural, both)." The number of birds that were either wetland priority species, on the Partners in Flight[6] index, and/or neotropical migrants was then compared to the Level 1 variables. Amphibian communities were assessed by "by early and late spring 1 m sweeps of a D-ring dip net. Visual encounter surveys (VES), at night and daytime and nighttime frog call surveys were also conducted." Number of amphibian species was then compared to the Level 2 land cover variables.

- If the wetlands were adjacent to a stream, stream incision ratios (bank height / bank full height), in-stream woody debris abundance, and plant community composition were also evaluated. Relationship between plant community and stream incision was determined by comparing stream incision ratio to the ratio of tree wetland indicator status and wetland indicator status.

- Habitat condition assessment scores were also independently evaluated by comparing scores for wetland sites that were prioritized by the Nature

[6] http://www.partnersinflight.org/

Conservancy, the Audubon Society, and/or were Virginia Priority Conservation Areas[7] to scores for non-priority wetland sites.

Preliminary results from the Coastal Plain (CCRM, 2007) showed that (1) percent pasture or row crops surrounding a wetland was correlated with total dissolved N; (2) developed land use in the contributing drainage of a wetland was correlated with incision ratio (a measure of stream condition) in headwater streams; (3) surrounding developed land use were correlated with habitat stressors (as measured by sound analysis). The method is in review for publication and additional validation results should be available after publication.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The method evaluates wetland functional capability and condition, and can preliminarily identify wetlands with high functional potential for conservation and/or planning purposes.

Time required:
The Level 2 method, so time required will depend on the size of the area to be assessed. Time required for the Level 2 method is not stated, but it appears to be rapid (< 4 hours). The Level 3 avian assessment methods require several site visits.

Flaws/limitations:
The methods do not assess wetland opportunity or services. The Level 1 and 3 methods do not provide a single score for condition, although they do assess condition for each function. The Level 2 method may provide a single score that approximates condition.

[7] http://www.dgif.virginia.gov/gis/MOM.asp

West Virginia Wetland Assessment Methods (Proposed)

References: Kordek, 2008; Kordek, 2009, and personal communication, Walt Kordek.
Level: 1, 2, and 3

Summary:
All three levels of this method are still under development. The proposed Level 1 assessment will assess integrity, function and HGM class, land cover classes in the contributing watershed and in 500 m and 200 m buffers, and nearby highway and structure density (Kordek, 2009). The proposed Level 2 method (West Virginia Rapid Assessment Procedure) assesses services, functional capability, and stressors in the assessment area. Stressors and land use in the buffer are also determined. Condition is evaluated by a "qualitative rating of anthropogenic disturbance" for both the assessment area and the buffer. The Level 3 method consists of intensive data taken on randomly located small plots within the wetland using an adapted version of the method of Vanderhorst et al. (2008).

Rationale:
At this point, work on the methods continues, so a detailed rationale is not available.

Assessment area:
The assessment area is the wetland. The buffer is 50 m wide.

Functions and indicators:
Data required for the draft West Virginia Rapid Assessment Procedure are presented in Table 17a (overall information), Table 17b (assessment area information), and Table 17c (buffer information). Data collected for the Level 3 method is presented in Table 18.

Results and validation:
Since the methods are still under development, validation data is not available. The Level 3 method was used to evaluate 1251 individual plots on 262 sites (Kordek, 2008).

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The Level 2 method could be used to identify wetlands that are in good condition, wetlands that provide services, or wetlands with superior functional capability for preservation or restoration purposes. It also identifies "Wetland of Special Interest": bogs, fens, mature forested wetlands, wetlands on karst topography, wetland that provide habitat for threatened and endangered species, and wetlands that provide habitat for migratory songbirds and waterfowl.

Time required:
Approximations of time required are not included in the methods. We estimate, however, that the current version of the Level 2 method would take much longer than 4 hours per site.

Limitations:
Work on the methods is ongoing, but at this point, two limitations are apparent. First, the Rapid Assessment Procedure appears not to be a rapid (<4 hours) method. Secondly, the data collected for the Level 3 procedure, although quite extensive, requires only one site visit.

Table 17a. Draft West Virginia Wetland Rapid Assessment Procedure (WVWRAP).

Category	**Data collected**
General information	• Purpose of assessment • HGM class • Landform/landscape/water flow/water body • Cowardin class(es) present
Aesthetic, educational, recreational value	• Site visible from public roadway. • Wetland is accessible to public without landowner permission. • Parking for access to site is safe and off roadway (a pull out is considered off of road). • Parking and access is of size that will accommodate a school bus. • There is a clear and unobstructed path to the wetland. • There is a boardwalk or observation deck/ blind designated for viewing the wetland. • The wetland has self-guided information available. • Wetland is not a monotypic stand of vegetation. • Wetland has evidence of signs of fishing and/or hunting. • Wetland has portions of open water. • Wetland is in a naturalized setting with no signs of dumping, filling, or draining.
Wetland of Special Interest?	• Bog • Fen • Mature forested wetland • Karst topography • Known T& E species, Natural Heritage Species • Significant migratory songbird/ waterfowl habitat • Less than one acre, hydrologically isolated, dominated by invasive species • Acidic pond created on mined land with little vegetation
Qualitative rating of hydrologic stressors in area (AA, buffer, and adjacent)	• Road bed/ railroad track • Ditch • Borrow ditch • Weir/ dam • Beaver dam • Groundwater or surface water pumps • Perched culvert or dam downstream of wetland • Perched culvert or dam upstream of wetland • Stormwater input • Impervious surfaces (including road ditches) • Tile • Dike/ levee • Stream channelization • Other

Table 17b. Assessment area information: West Virginia Wetland Rapid Assessment Procedure.

Category	Information
Assessment area detailed information (by transect)	• Vegetation o Cover of non-woody vegetation o Cover and average height of woody vegetation o Basal Area Factor of each canopy cover class o Cover of indicator vegetation (invasive, nutrient tolerant, sediment tolerant) • Water regime o Upland inclusion o Stream channel o Entrenched stream channel o Permanently flooded o Semi permanently flooded o Seasonally flooded o Saturated o Temporarily flooded o Artificially flooded • Presence of structural patches: vegetated hummocks, sediment deposits, macro-depression, coarse woody debris, standing snags, filamentous mats, parallel high water marks, soil cracks, perennial drainage patterns, intermittent swales, beaver dam or lodge
Assessment area stressors (details are the same as buffer stressors)	• Vegetation alteration • Filling, excavation • Presence of micro-alterations (tracks, plowing, etc.) • Aquatic imbalances • Garbage/ isolated dumping
Qualitative rating of anthropogenic disturbance in assessment area	• Anthropogenic alteration of: o Vegetation structure o Vegetation composition o Soil condition o Microtopography o Habitat connectivity
Flow characteristics of the assessment area	• Flow: o No surface water inlet o Non-relatively permanent waterway o Relatively permanent waterway-seasonal o Relatively permanent waterway o Man-made ditch o Sheet flow from impervious surfaces o Other groundwater o No surface water flows o Non-channelized flow o No surface water outlet • Flow modifiers/ descriptors: o Impounding effect o Beaver-induced impounding effect o Overflow flooding from RPW o Adjustable water control structures o Non-adjustable water control structure o Man-made spillway o Evidence of AMD o Culvert spans bankfull channel o Constricted culvert o Perched culvert above wetland o Perched culvert below wetland o Entrenched o Drainage patterns adjacent to stream, but no direct outlet to stream • List of inflows and outflows

Table 17b (continued). Assessment area information: West Virginia Wetland Rapid Assessment Procedure.

<table>
<tr><th>Category</th><th>Information</th></tr>
<tr><td>Assessment area soil measurements (for each non-flooded Cowardin class at 5 and 20 cm depth.)</td><td>Matrix color
Texture
Mottle color
Mottle quantity
Mottle contrast
Overall soil color properties (reduced gleyed, reduced fluctuating, oxidized fluctuating, oxidized)</td></tr>
<tr><td>Evidence of stressors or function</td><td>Evidence of hydrologic effects and stress
Increase in water level or hydroperiod
Widening of wetland upstream of impoundment
Deepening of wetland upstream of impoundment
Abrupt wetland edge along impoundment or fill
Dead or dying vegetation due to hydrologic conditions
Perched culvert or dam downstream of wetland
Decrease in water level or hydroperiod
Flowing drainage ditch or tiles
Perched culvert or dam upstream of wetland
Unnatural water fluctuations obvious
Exposure of normally submerged roots
Soil fissures
Uncharacteristic ground cover
Change in velocity or flashiness
Bank erosion or undercutting
Floodplain erosion
Water quality indicators
Filamentous algae
Submerged rooted vascular vegetation
Rotten egg smell from sediments
Obvious discharges, plumes, or spills
Chemical smell
Aquatic communities: presence of snails, or remains of; presence of bivalves, or remains of; presence of fish or newts; presence of tadpoles; presence of frogs or toads; presence of salamanders; presence of waterfowl; presence of herons or other predatory wading birds; presence of shorebirds; presence of turtles; presence of snakes
Flooding
Obvious evidence of flooding
Human structures and/ or natural resources downstream that are susceptible to flooding
AA lacks man-made structures that would speed the flow of water from wetland (tiles, culverts, ditches)
Nutrients and toxicants
Wetland has contributing basin with waterways lusted listed on state 303(d) list.
Power boats or diesel engines used on adjacent waterways
Impervious surfaces drain into wetland
Wetland receives nutrient inputs or shows signs of nutrient inputs (including nutrient tolerant vegetation)
Managed right-of-way within assessment area
Groundwater
Presence of permanent outlet, but no permanent inlet
Standing water typically present at wetland
Sediment stabilization: structural complexity in wetland is sufficient to reduce velocity of water entering wetland, and or wetland receives sediment inputs or shows signs of sediment inputs (including sediment tolerant vegetation)</td></tr>
<tr><td>Indicator plant checklist</td><td>Presence of specific indicator plants</td></tr>
</table>

Table 17c. Buffer information: West Virginia Wetland Rapid Assessment Procedure.

<table>
<tr><th>Category</th><th>Information</th></tr>
<tr><td>Buffer analysis (by segment)</td><td>

Natural system
Natural open water (lake or large river)
Natural wetland / riverine
Recreational/ open space (low intensity)
Pasture
Orchards
Row crops / Occasional intensive use
Recreational/ open space (high intensity)
High intensity agriculture (e.g. dairy farm)
Single family residential (specify units per acre: <4, 4-8, >8 units)
Two-lane road/parking lot
Low intensity commercial
Length and type of roads and trails in buffer and assessment area
Length of buffer segment with unrestricted flood access in buffer
</td></tr>
<tr><td>Buffer stressors</td><td>

Vegetation alteration:

Mowing
Livestock
Tree cutting
Brush cutting (mechanized removal of shrubs/ saplings)
Removal of woody debris
Aquatic weed control (mechanical or herbicide)
Herbivory (e.g. deer, insect, muskrat, geese, carp)
Burned
Presence of invasive herb, shrub, or tree layers
Chemical spraying
Catastrophic disturbance (e.g. beaver, ice, wind, insect)

Sedimentation:

Sediment deposits/ plumes
Eroding banks/ slopes
Active/ recent adjacent construction.
Presence of sediment tolerant vegetation
Non-elevated crossings (road or ATV)
Other

Filling, excavation:

Fill or excavation
Riprap

Presence of micro-alterations (tracks, plowing, etc.)
Aquatic imbalances:

Impervious surface runoff (including via ditches)
Point-source input
Direct discharges (e.g. straight pipe, gray water)
Agricultural impacts (e.g. fertilizer, manure, aquaculture)
Formation of algal mats
Presence of nutrient indicator vegetation
Dumping of organic wastes (e.g. wood, grass, leaves)
Spills, discharges, plumes, odors
Adjacent industrial sites
Acid mine drainage discharges
Adjacent mined lands/ spoil piles
Other

Garbage/ isolated dumping
</td></tr>
<tr><td>Qualitative rating of anthropogenic disturbance in buffer</td><td>

Anthropogenic alteration of:

Vegetation structure
Vegetation composition
Soil condition
Microtopography
Habitat connectivity

</td></tr>
</table>

Table 18. West Virginia Level 3 method metrics (Kordek, 2008).

Category	**Data collected**
Ecological community	• Leaf type (broad, needle, etc.) leaf, needle leaf • Leaf phenology (evergreen, deciduous, etc.) • Physiognomic class (forest, shrubland, etc.) • Floristic Quality Index
Soil	• Hydric soil descriptors: Hue, value, chroma, depth to mottling, depth to water table, stoniness, drainage assessment, texture, pH, depth of organic layers, and soil profile description • Von Post peat decomposition scale (for bogs and fens only) • Pore water pH • Pore water conductivity • Pore water temperature • Soil mapping unit • Soil chemistry: organic matter (% humus), total exchangeable cations, pH, estimated nitrogen release, total N, nitrates, P, S, Ca, K, Na, B, Fe, Mn, Cu, Zn, and Al
Landscape	• Elevation • Slope • Slope shape • Aspect • Landform
Hydrology	• Evidence: hydrophytic plants, standing water, saturated soil, flotsam, soil features, and other (crayfish chimneys, etc.) • Hydrologic regime
Wetland classification	• HGM • Cowardin • National Vegetation Classification System (for plots)
Vegetation	• Height and/or %cover for trees, shrubs, herbaceous, non-vascular, and floating vegetation • Plant species by number, stratum, diameter at breast height, and % cover
Hummocks	• % hummocks, % hollow, height, type, peat, tussocks, roots, tip mounds, downed wood, woody stem clusters
Disturbance	• Clearing, logging, fire, insects, disease, exotic plants, grazing, browsing, wind/ice damage, ditching/hydro-alteration, deer trails, other
Invasive plants	• Identification from list
Narrative	• Representativeness, environmental condition, landscape context.
Vertebrates	• Breeding bird point and call-back counts, species x number, evenness, diversity. • Frog and toad call counts, species diversity, abundance. • Habitat descriptive data and Habitat Suitability Indices for snapping turtle, muskrat, mink, great blue heron, red-spotted newt, red-winged blackbird, and beaver
Invertebrates	• Number of Benthos x family, number of Nektons x family, number of Odonata (adults) x species, familial diversity, richness, evenness

Level 2 Methods

California Rapid Assessment Method (CRAM)

Reference: Collins et al., 2008
Associated references: Sutula et al., 2006; Stein et al., 2009; CWMW, 2009. Electronic versions of the CRAM user's manual, associated documents, and electronic data entry tools can be downloaded at http://www.cramwetlands.org/
Level: Level 2

Summary:

Summary: The California Rapid Assessment Method (CRAM) evaluates landscape context, hydrology, physical structure, and biotic structure as compared to undisturbed reference wetlands in order to assess ecological condition. Wetlands are evaluated by HGM class (riverine, lacustrine, depressional, slope, playas, and estuarine) and cannot be compared between classes. A stressor checklist is also included, but stressor checklist results are not included in the final CRAM score. They are used to determine possible reasons for low scores. The developers of CRAM chose to remove any metrics which indicated either anthropogenic or natural stressors from the method because they felt that stressor based metrics did not account for on or off-site management of stressors.

Rationale:

CRAM was developed to measure overall ecological condition by evaluation of selected physical and biological attributes of each wetland (Sutula et al., 2006). The basic assumption of the method is that the ecological integrity (or condition) of a wetland equals the sum of hydrology plus physical and biological structure plus landscape context. The rationale for each metric used is discussed in the CRAM User's Manual (Collins et al., 2008).

Assessment area:

The assessment area is based on (1) breaks in surface hydrology, sediment supply, or geomorphology within a wetland area (including some resulting from man-made structures), then (2) a preferred assessment area size for wetland type. Assessment area size is specified because CRAM gives higher scores for structural complexity and larger wetlands tend to be more complex. If the wetland is much larger than the preferred assessment area size, then multiple assessment areas are used.

Functions and indicators:

Attributes and associated metrics for CRAM are presented in Table 19. Note that specifics of some metrics may vary by wetland type.

Table 19. Overall attributes and metrics for the California Rapid Assessment Method (adapted from Collins et al., 2008).

Attributes		**Metrics**
Buffer and Landscape Context		• Landscape connectivity: spatial association with other areas of aquatic resources* • Percent of assessment area with buffer* • Average buffer width* • Buffer condition: extent and quality of vegetative cover and condition of substrate
Hydrology		• Water source* • Hydroperiod (or channel stability for riverine wetlands) • Hydrologic connectivity*
Structure	Physical	• Structural patch richness (number of different physical habitat surfaces or features). • Topographic complexity
	Biotic	• Number of plant layers present or native species richness (vernal pools only) • Number of co-dominant (≥10% relative cover) plant species • % invasive species • Horizontal interspersion and zonation in plant community • Vertical biotic structure

* Preliminary scores can be determined in office before site visit.

Results and validation:
The riverine module of CRAM was used to assess 41 sites with existing data on riparian bird diversity, abundance, and reproductive index and 54 sites with existing index of biological integrity data for benthic macroinvertebrates (Stein et al., 2009). The estuarine module of CRAM was used to assess 38 sites with existing U.S. EPA Environmental Monitoring and Assessment Program (EMAP) plant community composition data. Results generally showed that CRAM condition scores correlated well with these independent measures of condition. Some problems with repeatability of results were encountered, but adjustments to the CRAM method resolved most of these. CRAM scores from riverine and estuarine sites were also negatively correlated with the Landscape Development Index (Brown and Vivas, 2005), which indicates lower wetland condition.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
CRAM is designed to "assess existing conditions, without regard for past, planned, or anticipated future conditions" but information that is derived from the method may be used to plan for future wetland protection or restoration (Collins et al., 2008). Although the stressor checklist included in CRAM is not used to calculate the wetland's condition score, Klimas (2008) notes that it could be useful in determining whether a specific wetland is a possible candidate for restoration. CRAM does not identify wetlands with rare, threatened, and endangered species.

Time required:
The CRAM assessment method requires less than four hours in the field for two people, plus ½ day of office time.

Flaws/limitations:
The California Wetlands Monitoring Workgroup (CWMW, 2008) specifically notes that CRAM is for ecological condition assessment only and cannot be used to assess services. CRAM also requires a model for each wetland HGM class, which makes it more complex to implement.

In a peer review by the U.S. Army Engineer Research and Development Center, Klimas (2008) noted some potential limitations of CRAM:

1. It may not clearly distinguish condition gradients when wetlands of intermediate condition are compared.
2. Correct user implementation may require more than one CRAM training session, since some of the metrics appear to require specialized field experience (for example, field assessment of stream entrenchment or characterization of grazing programs used in vernal pool landscapes).

Delaware Rapid Assessment Procedure (DERAP)

Reference: Jacobs, 2008
Level: Level 2

Summary:
The Delaware Rapid Assessment Procedure (DERAP) evaluates wetland condition based on the presence or absence of stressors that affect hydrology, habitat, biogeochemical cycling, and the surrounding landscape. Function is inferred based on whether stressors are present or not. Scores for stressors are multiplied by weighting factors based on wetland HGM class, and scores can only be compared by HGM type. DERAP is ultimately intended for use in all non-tidal wetlands in the Outer Coastal Plain regions of Maryland and Delaware, but currently, the procedure is only fully developed for flat and riverine wetlands.

Rationale:
DERAP is used to gather information on stressors that is then correlated to more intensive condition data obtained through the Delaware Comprehensive Assessment Procedure (DECAP) to "determine the general condition of wetlands on a watershed scale" (Jacobs, 2008). The first version of DERAP was developed during the Nanticoke River watershed study (Bleil, 2004; Jacobs and Bleil, 2008) and was based on a list of stressors that could be easily assessed in the field. Later versions were refined via regression analysis with site scores from the Delaware Comprehensive Assessment Procedure (DECAP), which is based on the HGM model from the Nanticoke River watershed study. Stressors were adjusted or eliminated and weighting of certain stressors for each HGM class were formulated in order to correlate DERAP scores with DECAP scores. We believe that the rationale for the original DERAP stressor checklist seems logical and that stressors may have different levels of effects on certain HGM classes. However, the rationale for some of the metrics used to evaluate functions in the Nanticoke River watershed study (and in DECAP) was not clear, and thus we believe that the attempts to correlate DERAP with DECAP by function weighting may be clouding the rationale for DERAP.

Assessment area:
The assessment area is a 40 m radius circle centered a "random point located in a mapped wetland that has been selected using a probabilistic sampling design for a watershed scale study" (Jacobs, 2008). Buffer size is 100 m.

Functions and indicators:
Stressor categories and stressors for DERAP are presented in Table 20.

Table 20. Stressors used in the Delaware Rapid Assessment Procedure.

Stressor category	Stressor
Habitat/plant community	• Forest harvesting within 50 years • Dominant forest age • Tree basal area (test variable) • Converted from natural forest • Presence of invasive species • Chemical defoliation • Excessive herbivory (insects, nutria) • Burned • Garbage or dumping • Increased nutrients (either algal mats, or, *for depressions only*, presence of >50% nutrient indicator species • Trails or roads • Other
Hydrology	• Ditching • Stream channelization • Weir/dam/road presence • Stormwater inputs • Non-stormwater point source inputs • Filling, excavation • Microtopography alteration (plowing, tracks, etc.) • Excessive sedimentation • Soil subsidence/root exposure • Tidal restriction • Other
Buffer stressors (in 100 m surrounding the assessment area	• Development density • Type of sewage disposal • Roads • Stormwater drains • Landfill/waste disposal • Channelized streams or ditches • Nearby agriculture • Forest harvesting within 15 years • Piers/docks • Golf Course • Mowed area • Sand/ gravel operation • Other

Results and validation:

DERAP has been extensively tested against DECAP (Jacobs, 2008; Jacobs et al., 2009a). DERAP was also used to assess 92 wetlands in Delaware, Maryland, Ohio, and Oregon to quantify repeatability with different users (Herlihy et al., 2009). The researchers found that training was more important in obtaining repeatability than experience. After statistical analysis of scores, they concluded that if the same wetland is assessed by different trained personnel, DERAP scores that differ by ≥4 points most likely indicate an actual difference in condition, while scores that differ by ≤ 2 points likely indicate differences between evaluators.

Vegetation successional stage:
DERAP gives higher condition scores for forested wetlands which have not been harvested for 50 years, older forests, and, potentially, to tree basal area, which is currently a test variable.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
According to Jacobs (2008) "The State of Delaware uses DERAP in conjunction with DECAP to assess and report on the condition of wetlands by watershed and to assess status and trends over time. The presence of stressors can also provide information on potential impacts on wetland condition and function and inform restoration and protection efforts." DERAP does not identify wetlands with rare, threatened, and endangered species.

Time required:
The method should take 2 people no more than 1 hour of field work.

Flaws/limitations:
DERAP does not evaluate services. Like all stressor-based methods, it assumes that the wetland is in good condition unless stressors are visible, which may not account for non-point source stressors (Fennessy et al., 2004) or management practices designed to combat on or off-site stressors (Sutula et al., 2006).

Eastern and Western Washington Wetland Rating Systems

References (both methods have been recently revised)**:**

- Eastern Washington: Hruby, 2007. Rating form (updated 2008) available at: http://www.ecy.wa.gov/programs/sea/wetlands/ratingsystems/pdf/EWA_RatingForm.pdf
- Western Washington: Hruby, 2006. Rating form (updated 2008) available at: http://www.ecy.wa.gov/programs/sea/wetlands/ratingsystems/pdf/WWA_RatingForm.pdf

Level: Level 2.

Summary:

Both the Eastern and Western Washington State Wetland Rating Systems are designed to determine the level of regulatory protection for individual wetlands in the state of Washington. Wetlands are classified as Category I, II, III, or IV (Table 21) based on special characteristics (rare wetland types or wetlands which contain threatened or endangered species) and/or functional ability (based on both potential and opportunity).

To categorize each wetland, the assessor determines:

1. Whether the wetland will require additional regulatory protection (e.g. habitat for threatened and endangered species, etc.)
2. Wetland HGM class.
3. Functional evaluation:
   - Potential and opportunity for performance of hydrologic functions, such as reducing flooding and erosion. Questions for this portion are specific for each HGM class.
   - Potential and opportunity for improving water quality. Questions for this portion are specific for each HGM class.
   - Potential and opportunity for providing habitat for many species. Questions for this portion are the same for all HGM classes.
4. Whether the wetland possesses special characteristics that will place it in a higher regulatory category than that determined by functional evaluation alone.

Rationale:

According to Hruby (2006), the rating system is "designed to differentiate between wetlands based on their sensitivity to disturbance, rarity, the functions they provide, and whether we can replace them or not." Because functional rates and processes cannot be measured directly in a rapid assessment method, the method characterizes functions by both *potential* (the structural characteristics of a wetland which indicate its capability of performing a function) and *opportunity* (the "degree the wetland's position in the landscape will allow it to perform a specific function"). The rationale for the selection of indicators is documented and referenced in the method.

Table 21. Definition of categories for Eastern and Western Washington methods.

Category	Definition	Eastern Washington	Western Washington
I	Wetlands that either: "1) represent a unique or rare wetland type; or 2) are more sensitive to disturbance than most wetlands; or 3) are relatively undisturbed and contain ecological attributes that are impossible to replace within a human lifetime; or 4) provide a high level of functions." (Hruby, 2006)	• Alkali wetlands • Natural heritage wetlands (high quality undisturbed or contains threatened and endangered species) • Bogs • Mature and old-growth forested wetlands >0.25 acre with slow-growing trees • Forests with stands of aspen • Wetlands which perform many functions very well (≥70 on function related questions)	• Undisturbed estuarine wetlands larger than 1 acre • Natural heritage wetlands (high quality undisturbed or contains threatened and endangered species) • Bogs • Mature and old growth forested wetlands >1 acre • Wetlands in coastal lagoons • Wetlands that perform many functions very well (≥70 on function related questions)
II	Wetlands that are difficult to replace, or perform high levels of some functions	• Forested wetlands in floodplains of rivers • Mature and old-growth forested wetlands >0.25 acre with fast-growing trees • Non-isolated vernal pools • Wetlands that perform functions very well (51-69) on function-related questions	• Undisturbed estuarine wetlands <1 acre or disturbed estuarine wetlands >1 acre • Interdunal wetlands > 1 acre • Wetlands that perform functions very well (51-69) on function-related questions
III	Wetlands that are either more disturbed, less diverse, or more isolated than Category II	• Isolated vernal pools • Wetlands with moderate functional levels (30-50 points)	• Interdunal wetlands between 0.1 and 1 acre Wetlands with moderate functional levels (30-50 points)
IV	Wetlands with low functional levels that may be fairly disturbed	• Wetlands with low levels of functions (< 30 points)	• Wetlands with low levels of functions (< 30 points)

Assessment area:

The assessment area is generally the wetland. Adjustments are made to this based on wetland hydrology and spatial orientation. For example, large connected areas of wetlands are divided by changes in water regime (volume, flow, or velocity), and wetland complexes are mapped as one wetland if wetlands are small (< 1 acre) and close together (< 100 ft apart).

Functions and indicators:
Indicators for water quality and hydrology functions for both Washington State rating methods are specific for HGM class. Table 22 is an example of the indicators used to rate functional opportunity and potential in depressions and flats in Western Washington.

Table 22. Functions and indicators for depressional and flat wetlands in the Western Washington Rating method (Hruby, 2006)

Function	**Potential or opportunity?**	**Indicators**
Water quality	Potential	• Inlet and outlet characteristics • Clay or organic soil 2" below surface • % cover of persistent ungrazed vegetation • Area of the wetland with seasonal ponding or inundation
	Opportunity	• YES, if there are of pollutants in groundwater or surface water coming into the wetland that would otherwise reduce water quality in streams, lakes or groundwater downgradient from the wetland
Hydrologic: reduction of flooding and erosion	Potential	• Inlet and outlet characteristics • Depth of storage during wet periods (height of ponding above the bottom of the outlet)
	Opportunity	• YES, if wetland is in a location in the watershed where the flood storage or reduction in water velocity that it provides helps protect resources from flooding or excessive and/or erosive flows • NO, if the water coming into the wetland is controlled by a structure such as flood gate, tide gate, flap valve, reservoir etc. or more than 90% of the water in the wetland is from groundwater in areas where damaging groundwater flooding does not occur
Habitat	Potential	• Vegetation structure (number of Cowardin classes) • Number of water regimes (hydroperiods) present within the wetland • Number of plant species in the wetland • Degree of interspersion of vegetation classes and unvegetated areas • Presence of special habitat features: woody debris, standing snags, undercut banks, overhanging vegetation, suitability for beaver/muskrat habitat, thin-stemmed persistent vegetation or woody branches in permanently or seasonally inundated areas, less than 25% invasive plants in each stratum.
	Opportunity	• Size and condition of buffer: • Wetland is part of a relatively undisturbed and unbroken vegetated corridor (either riparian or upland) • Wetland is near estuary, large field or pasture, or large lake

Results and validation:
The rating system was tested and calibrated in over 200 wetlands in both eastern and western Washington using reference sites that were chosen to exemplify the "full range of characteristics and functions" (Hruby, 1999; Hruby, 2006). The assessment methodology was also peer reviewed by other wetland scientists.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
Both Washington State Rating methods are specifically designed to identify wetlands which are entitled to a high level of regulatory protection: wetlands which provide critical habitat, wetlands which provide habitat for threatened or endangered species, rare wetland types, etc.

Time required:
Fennessy et al. (2004) estimated that an earlier version of the method would require less than half a day per wetland.

Flaws/limitations:
Rare wetland types, and some functional indicators, are specific to Washington State. The method does not measure condition.

Ohio Rapid Assessment Method (ORAM)

References: Mack, 2001; Mack, 2000; Ohio EPA, 2001
Level: Level 2

Summary:
The Ohio EPA classifies wetlands based on “quality” and this classification is used to determine the level of regulatory protection for individual wetlands (Mack, 2001). The Ohio Rapid Assessment Method (ORAM) is designed to determine whether wetlands will be defined Category 1, 2, or 3, as follows:

- Category 1 wetlands are defined by the Ohio Administrative Code (OAC) as wetlands which “...support minimal wildlife habitat, and minimal hydrological and recreational functions," and as wetlands which “...do not provide critical habitat for threatened or endangered species or contain rare, threatened or endangered species.” According to Mack (2001), Category 1 wetlands “are often hydrologically isolated, and have some or all of the following characteristics: low species diversity, no significant habitat or wildlife use, limited potential to achieve beneficial wetland functions, and/or a predominance of non-native species” or “have been seriously degraded by human-caused disturbances such that the wetland's species diversity and functionality has been significantly compromised.”

- Category 2 wetlands, according to the OAC, either (1) “...support moderate wildlife habitat, or hydrological or recreational functions," and are "...dominated by native species but generally without the presence of, or habitat for, rare, threatened or endangered species and/or are (2) "...wetlands which are degraded but have a reasonable potential for reestablishing lost wetland functions." Basically, these are “moderate quality” wetlands (Mack, 2001)

- Category 3 wetlands are defined by the OAC those which possess “...superior habitat, or superior hydrological or recreational functions.” According to Mack (2001) Category 3 wetlands are “typified by high levels of diversity, a high proportion of native species, and/or high functional values. Category 3 wetlands include wetlands which contain or provide habitat for threatened or endangered species, are high quality mature forested wetlands, vernal pools, bogs, fens, or which are scarce regionally and/or statewide.”

ORAM is a rapid assessment method which evaluates condition by rating wetlands on habitat connectivity, average buffer width, percent of wetland with buffer, buffer condition, water sources, hydroperiod, hydrologic connectivity, physical patch types, topographic complexity, organic matter accumulation, biotic patch types, vertical structure, interspersion and zonation, native plant species richness, and percent invasive plant species. The method does assess condition, but since it adds points for rare wetland types the final score produced may not be an accurate reflection of relative condition.

Although this is a Level 2 method, Mack (2001) notes that the assessment could be performed in the office with a short visit to the wetland to confirm or add further data.

Rationale:
As described in the summary ORAM is designed to categorize wetlands based on "quality." According to Mack (2006), ORAM can also be used as a "wetland disturbance scale." Although some questions do not specifically address condition, the score from the condition-related questions in ORAM correlates very strongly with the overall ORAM score. Scientific rationale for the indicators used in the method is explained (although not referenced) in the ORAM Users Manual (Mack, 2001).

Assessment area:
The assessment area is determined using a "scoring boundary" which is either (1) the jurisdictional wetland boundary, or (2) a boundary based on breaks in hydrologic conditions.

Functions and indicators:
ORAM consists of two parts: narrative and qualitative. Both sections must be completed for accurate evaluation. The narrative part of the ranking has questions which will determine if the wetland is Category 3 or Category 1, but classification based on this section may be overruled by scoring on the qualitative portion.

The narrative questions are:

1. Critical habitat (as defined by USFWS)? If yes, Category 3.
2. Threatened or endangered species known to be present? - If yes, Category 3.
3. Classified as high quality natural wetland in Ohio Natural Heritage database - If yes, Category 3.
4. Documented significant bird habitat? If yes, Category 3.
5. Is the wetland less than 1 acre in size and hydrologically isolated and either (1) comprised of vegetation that is dominated (greater than eighty per cent areal cover) by *Phalaris arundinacea* (reed canary grass), *Lythrum salicaria* (purple loostrife), or P*hragmites australis*, or (2) an acidic pond created or excavated on mined lands that has little or no vegetation? If yes, Category 1.
6. Is the wetland a bog? If yes, Category 3.
7. Is the wetland a fen? If yes, Category 3.

8a. Is the wetland an old growth forest? If yes, Category 3.
8b. Is the wetland a mature forested wetland If yes, evaluate for Category 3; may also be 1 or 2.
9a. Is the wetland a Lake Erie coastal and tributary wetland? If so, see questions 9b-9d.
9b. For Lake Erie wetlands: partially restricted by dams/dikes, etc.? If yes, evaluate for Category 3; may also be 1 or 2.
9d. For Lake Erie wetlands: unrestricted? If yes, Category 3 unless 9e applies.
9e. For Lake Erie wetlands: unrestricted with invasive plants? If yes, evaluate for Category 3; may also be 1 or 2.
10. Is the wetland an oak opening? If yes, Category 3.

11. Is the wetland a relict wet prairie? If yes, evaluate for Category 3; may also be 1 or 2.

Properties and indicators for the qualitative portion of ORAM are presented in Table 23.

Table 23. Ohio Rapid Assessment Method version 5.0 qualitative portion: properties and indicators.

Property	**Indicator**
Wetland area	• Wetland size (larger wetlands receive higher scores)
Upland buffer and surrounding land use	• Average buffer width • Intensity of predominant surrounding land use
Hydrology	• Sources of water (groundwater and perennial surface water wetland score highest; precipitation-fed wetlands lowest) • Connectivity to water sources and other wetlands/habitat • Maximum water depth • Duration of standing water/ saturation • Modifications to natural hydrologic regime
Habitat development and alteration	• Substrate/soil disturbance • Qualitative evaluation of how well-developed the wetland is in comparison to other ecologically or hydrogeomorphically similar wetlands • Stressor checklist, plus qualitative evaluation of the degree to which the stressors have affected the wetland.
Special wetland communities	• Rare wetland types and/or good wildlife habitat
Vegetation, interspersion, microtopography	• Number of wetland plant communities • Horizontal community interspersion • Coverage of invasive species (%) • Microtopography

Results and validation:
The ORAM method has extensively tested and subsequently refined through several versions to correct biases and improve accuracy of results (Mack, 2000). Scoring for ORAM was calibrated using interim Vegetation Indices of Biotic Integrity (VIBIs) for developed for emergent, forested, and scrub-shrub wetland vegetation classes. [Note that work continues on VIBIs for Ohio (Mack, 2007; Mack, 2009).] ORAM has been positively correlated with bird species richness (Stapanian et al., 2004) and an amphibian index of biological integrity (Micacchion, 2002), and has been negatively correlated with the Landscape Development Index of Brown and Vivas (2005), which is a Level 1 predictor of human disturbance (Mack, 2006).

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The method specifically identifies wetlands which are entitled to a high level of regulatory protection under Ohio law (e.g. wetlands which provide critical habitat, wetlands which provide habitat for threatened or endangered species, rare wetland types, etc.)

Time required:
Small wetlands may require only minutes for assessment, while large wetlands or wetland complexes may require several hours (Mack, 2001). Fennessy et al. (2004) estimates that assessing a wetland with ORAM would require less than ½ day.

Limitations:
ORAM is specifically designed to classify wetlands into categories for Ohio regulatory purposes. The author notes that the method is not designed to "determine a particular wetland's ecologic or human value" (Mack, 2000). ORAM does not assess opportunity or services, except for rare ecosystem types (i.e. "special wetland communities"), almost all of which are specific to Ohio.

Maryland State Highway Administration (MD-SHA) assessment method

Reference: U.S. Corps of Engineers (1999), plus rating form and list of functions and considerations/qualifiers provided by Denise Clearwater.
Level: Level 2

Summary: The Maryland State Highway Administration (MD-SHA) wetland assessment method is slightly adapted from the Descriptive Approach developed by the Corps of Engineers in New England (U.S. Corps of Engineers 1999) The method identifies the presence or absence of 13 functions and values using best professional judgment for projects reviewed under section 404 (Bartoldus, 1999). Evaluation consists of three parts:

- A brief description of wetland characteristics.
- A list of wetland functions and values to which the evaluator gives yes or no answers.
- The rationale, from a list of possible indicators, for the presence or absence of each function.

The SHA method is a very rapid qualitative evaluation (approximately 2 hours per site). Wetlands within the region can be directly compared to each other.

Rationale: By design, the method does not produce a final overall score. According to the original method (U.S. Corps of Engineers, 1999), results from other methods that numerically weight, rank, or average different functions may be difficult to interpret because the indicators used for the ranking are not readily apparent. Thus, this method was designed specifically not to produce a final overall score, or to rank functions against each other. The rationale for each indicator seems logical, but references are not given.

Assessment area:
The assessment area is the jurisdictional wetland.

Functions and indicators:
Functions and indicators are presented in Table 24. Since the purpose of the assessment is to determine whether each function is present or absent, some indicators are repeated under different functions.

Table 24. Maryland State Highway Administration method functions and indicators.

Function	Possible indicators (or "considerations/qualifiers")
Groundwater recharge/discharge	• Wells downstream • Potential for wells downstream • Gravel or sandy soils in/around wetland • No fragipan in wetland • Presence of fragipan, impervious soils, or bedrock under wetland • Wetland associated with watercourse • Signs of groundwater recharge present, or piezometer data demonstrates recharge • Wetland is associated with watercourse, but lacks defined or unconstricted outlet • Wetland contains outlet but no inlet • Good water quality in wetland • Signs of groundwater discharge present • Water temperature suggests discharge
Floodflow alteration	• Area of wetland is large compared to watershed • Wetland is in upper part of watershed • Little to no flood storage upslope/above wetland • Watershed has high percentage of impervious surface • Wetland contains hydric soils which can absorb/detain water • Wetland is in flat area with flood storage potential • Wetland has intermittent outlet, ponded water, or variable water level • Wetland appears to be able to retain more water than produced by average rainfall • Wetland retains overland flow from uplands • Wetland may detain flood waters from nearby watercourse • Valuable resources are located in floodplain downstream from wetland • Watershed has history of economic loss due to flooding • Wetland is associated with watercourse • Wetland watercourse is sinuous or diffuse • Wetland outlet is constricted • Wetland affects channel flow velocity • Wetland protects land use downstream • High vegetation density in wetland.
Fish and shellfish habitat	• Forest land dominant in watershed above wetland • Abundance of cover • If wetland is associated with watercourse, then: o Wetland is large enough to support fish/shellfish o Wetland retains open water during winter o Stream width is >50 feet o Water quality of associated watercourse is good o Streamside vegetation provides shade o Spawning areas present o Food available in wetland o Barriers (dams, etc.) are absent from stream associated with wetland o Evidence of fish is present o Wetland is stocked with fish o Watercourse is persistent o Man—made streams are absent o Water velocity is not excessive o Defined stream channel is present

Table 24 (continued) Maryland State Highway Administration method functions and indicators.

Function	Possible indicators (or "considerations/qualifiers")
Sediment and toxicant retention	• Watershed above wetland has potential sources of excess sediment • Watershed above wetland has potential or known sources of toxicants • Wetland has opportunity for sediment trapping by slow moving water or deepwater habitat • Fine grained mineral or organic soils are present • Wetland has long duration water retention time. • Wetland edge is broad and intermittently aerobic • Wetland is known to have existed for more than 50 years • Drainage ditches have not been constructed in the wetland • If wetland is associated with watercourse, then: o Wetland is associated with an intermittent or perennial stream or a lake o Channelized flows have visible velocity decreases in the wetland o Effective floodwater storage in wetland is occurring with areas of impounded open water present o No indicators of erosive forces or high water velocities are present o Diffuse water flows are present in wetland o Wetland has a high degree of water and vegetation interspersion. o Dense vegetation provides opportunity for sediment trapping
Nutrient removal	• Wetland is large relative to the size of its watershed • Wetland has deep water or open water habitat exists • Wetland has overall potential for sediment trapping • Potential sources of excess nutrients are present in the watershed above the wetland • Wetland saturated for most of the season. • Wetland has deep organic/sediment deposits • Wetland has slowly drained fine grained mineral or organic soils • Wetland has dense vegetation • Emergent vegetation and/or dense woody stems are dominant. • Opportunity for nutrient attenuation exists. • Vegetation diversity/abundance sufficient to utilize nutrients • If wetland is associated with watercourse, then: o Water flow through this wetland is diffuse. o Water retention/detention time in wetland is increased by constricted outlet or thick vegetation. o Water moves slowly through wetland
Production export	• Wildlife food sources grow within wetland • Detritus development present within wetland • Economically or commercially used products found in wetland • Evidence of wildlife use within wetland • Higher trophic level consumers are utilizing wetland • Fish or shellfish in wetland • High vegetation density present • Wetland has high degree of plant community structure/species diversity • High aquatic vegetative diversity/abundance in wetland • Nutrients exported in wetland watercourses: permanent outlet present • "Flushing" of relatively large amounts of organic plant material occurs from wetland • Wetland contains flowering plants used by nectar-gathering insects • Indications of export are present • High production levels occurring but no visible signs of export

Table 24 (continued) Maryland State Highway Administration method functions and indicators.

Function	Possible indicators (or "considerations/qualifiers")
Sediment/shoreline stabilization	• Indications of erosion or siltation present • Topographical gradient present in wetland • Potential sediment sources up-slope • Potential sediment sources present upstream • No distinct shoreline or bank between the waterbody and the wetland or upland • There is a distinct step (i.e., sharp bank) between the open waterbody or stream and the adjacent land with dense roots throughout • Wetland is wide wetland (>10') and borders watercourse, lake, or pond • High flow velocities in the wetland • Watershed is of sufficient size to produce channelized flow • Open water fetch is present • Boating activity is present • Dense vegetation borders watercourse, lake, or pond • High percentage of energy-absorbing emergents and/or shrubs border watercourse, lake, or pond • Vegetation is comprised of large trees and shrubs that withstand major flood events or erosive incidents and stabilize the shoreline on a large scale (feet) • Vegetation is comprised of a dense resilient herbaceous layer that stabilizes sediments and the shoreline on a small scale (inches) during minor flood events or potentially erosive events
Wildlife habitat	• Wetland is not degraded by human activity • Wetland is not fragmented by development • Upland surrounding wetland is undeveloped • More than 40% of wetland edge is bordered by upland wildlife habitat ≥500 feet wide • Wetland is connected with other wetland systems by watercourse or lake • Wildlife overland access to other wetlands is present • Wildlife food sources are within or near wetland • Wetland exhibits a high degree of interspersion of vegetation classes and/or open • water • Two or more islands or inclusions of upland within the wetland are present • Dominant wetland class includes deep or shallow marsh or wooded swamp. • More than three acres of shallow permanent open water (<6.6 feet deep) is present • High density of wetland vegetation • Wetland has high degree of plant species diversity • Wetland has high degree of diversity in plant community structure • Plant/animal indicator species are present (list species) • Animal signs observed • Wetland appears to support varied population diversity/abundance during different seasons • Wetland contains or has potential to contain a high population of insects • Wetland contains or has potential to contain large amphibian populations • Wetland has or has potential for high avian utilization • Indications of less disturbance-tolerant species are present • Signs of wildlife habitat enhancement are present

Table 24 (continued) Maryland State Highway Administration method functions and indicators.

Function	Possible indicators (or "considerations/qualifiers")
Recreation	• Wetland is part of recreation area, park, forest, or refuge • Fishing available within or from the wetland • Hunting permitted in the wetland • Hiking occurs or has potential to occur within the wetland • Wetland is a valuable wildlife habitat • Watercourse, pond, or lake associated with the wetland is unpolluted • High visual/aesthetic quality for potential recreation site • Access to water available for boating, canoeing, or fishing • Watercourse associated with this wetland is wide and deep enough for non-powered boating • Off-road public parking available • Accessibility and travel ease • Wetland is within a short drive or safe walk from highly populated areas
Educational and scientific value	• Wetland contains threatened, rare, or endangered species • Little or no disturbance in this wetland • Contains a diversity of wetland classes which are accessible or potentially accessible • Wetland is undisturbed and natural • Wetland is considered to be valuable wildlife habitat • Wetland is located within a nature preserve or wildlife management area • Signs of wildlife habitat enhancement present • Off-road parking suitable for school bus access in or near wetland • Within safe walking distance or a short drive to schools • Within safe walking distance to other plant communities • Direct access to perennial stream available. • Direct access to pond or lake available • No known safety hazards exist within site • Public access is controlled • Handicapped accessibility is available • Site is currently used for educational or scientific purposes

Table 24 (continued) Maryland State Highway Administration method functions and indicators.

Function	Possible indicators (or "considerations/qualifiers")
Uniqueness/heritage	• Upland surrounding wetland is primarily urban • Upland surrounding wetland is developing rapidly • More than 3 acres of shallow permanent open water (<6.6 feet deep) in wetlands • Three or more wetland classes present • Deep and/or shallow marsh or wooded swamp dominant • High degree of interspersion of vegetation and/or open water in wetland • Well-vegetated stream corridor (15 feet on each side) occurs in wetland • Potential educational site is within a short drive or a safe walk from schools • Off-road parking at potential educational site is suitable for school buses • No known safety hazards exist within this potential educational site • Direct access to perennial stream or lake exists at potential educational site • Two or more wetland classes are visible from viewing locations • Low-growing wetlands (marshes, scrub-shrub, bogs, open water) are visible • Half an acre of open water or 200 feet of stream is visible • Wetland is dominated by flowering plants or plants with seasonal color change • General visible appearance of the wetland is unpolluted and/or undisturbed • Overall view of the wetland is available from the surrounding upland • Quality of the water associated with the wetland is high • Opportunities for wildlife observations are available • Historical buildings are found within the wetland • Presence of pond or pond site and remains of a dam occur within the wetland • Wetland is within 50 yards of the nearest perennial watercourse • Visible stone or earthen foundations, berms, dams, standing structures, or associated features occur within the wetland • Wetland contains critical habitat for endangered species • Wetland is known to be a study site for scientific research • Wetland is a natural landmark or recognized by the state natural heritage inventory authority as an exemplary natural community • Wetland has local significance because it serves several functional values • Wetland has local significance because it has biological, geological, or other features that are locally rare or unique • Wetland is known to contain an important archaeological site • Wetland is hydrologically connected to a state or federally designated scenic river • Wetland is located in an area experiencing a high wetland loss rate
Visual quality/aesthetics	• Multiple wetland classes visible from viewing locations • Emergent marsh and/or open water visible from viewing locations • Diversity of vegetative species is visible from viewing locations • Wetland is dominated by flowering plants or plants with seasonal color change • Visible land use surrounding the wetland is undeveloped • Visible surrounding land use contrasts with wetland • No visible trash, debris, and signs of disturbance • Wetland considered to be a valuable wildlife habitat • Wetland is easily accessed • Low noise level at viewing locations • No unpleasant odors at primary viewing locations • Relatively unobstructed sight line exists through wetland
Endangered species	• Wetland contains or is known to contain threatened or endangered species • Wetland contains critical habitat for threatened or endangered species

Results and validation:

This is a method only: no results are presented.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
According to the U.S. Corps of Engineers (1999), the method should be used for describing wetland resources when necessary for Section 404 permit requirements It can be used to "compare project alternatives, avoid and minimize project impacts, determine significance of impacts, weigh environmental impacts against project benefits, and design and monitor compensatory mitigation." Rare, threatened, or endangered species and/or habitat thereof are specifically identified in the method.

Time required:
Bartoldus (1999) estimates that the Descriptive Approach would require 2 hours per 1 acre site (including office work).

Flaws/limitations:
Some subjective decisions are required. There is no upper limit on opportunity values for functions (Bartoldus, 1999).

Mid-Atlantic Tidal Wetland Rapid Assessment Method (MidTRAM)

Reference: Jacobs et al., 2008b
Level: Level 2

Summary:
The Mid-Atlantic Tidal Wetland Rapid Assessment Method (MidTRAM) Version 2.0 is a rapid assessment method for estuarine emergent tidal wetlands in Delaware, Maryland, and Virginia. It provides a single score that represents condition as compared to regional reference wetlands. The format of MidTRAM was adapted from CRAM, and involves metrics that estimate the condition of the wetland buffer, hydrology, and habitat properties.

Rationale:
MidTRAM is designed to assess condition, so the indicators were chosen because they correlated with tidal wetland ecological condition.

Assessment area:
The assessment area is a 50-m radius circle centered on either (1) a randomly located point determined by using a probabilistic sampling design or (2) a subjectively chosen point based on the needs of the user.

Functions and indicators:
Functions and associated indicators for MidTRAM are presented in Table 25.

Table 25. Attributes and metrics for MidTRAM 1.0 (adapted from Jacobs et al., 2009b.)

Attributes	Metrics
Buffer/landscape	• % of assessment area perimeter with ≥ 5m of natural/semi-natural land cover. • Average width of buffer with that is in natural or semi-natural condition • Quality of vegetation, substrate and extent of human visitation (landscape condition) within 250 m buffer • % of developed land within 250 m buffer • Number of different habitats found within 250 m buffer • % of assessment area with physical barriers preventing marsh migration inland
Hydrology	• Presence and functionality of ditches in the AA • Presence of fill or marsh fragmentation from anthropogenic sources in the AA • Presence of dikes or other restrictions • Presence of localized (point) sources of pollution
Habitat	• Bearing capacity of soil • Volume of plant fragments in the upper soil horizon • Interspersion and complexity of the vegetation community • Number of plant layers (based on plant height). • % co-dominant (≥10% relative cover) non-native species • % invasive species

Results and validation:
Rogerson et al. (2009) attempted to correlate MidTRAM scores for 50 randomly selected estuarine emergent tidal wetlands in Delaware's Inland Bays watershed to a marsh bird index of biological integrity and above-ground and below-ground biomass data. Results were inconclusive, likely because of the relatively small number of wetlands sampled. MidTRAM was able to identify wetlands with different condition levels (as evaluated independently), but this was mainly a result of the score for the buffer metrics. As a result of this, the method was re-evaluated, and two metrics which did not accurately evaluate anthropogenic disturbance were removed. The hydrology and habitat metrics will continue to be evaluated.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
MidTRAM method could be used to identify undisturbed wetlands that should be preserved and/or possible restoration sites. It does not identify wetlands with rare, threatened, and endangered species.

Time required:
The method should require approximately 2 hours for 2 people.

Flaws/limitations:
MidTRAM is a condition assessment only, and does not measure opportunity or services. The method might be more useful if it could be adapted to estimate tidal wetland sustainability: whether the rate of vertical accretion via sediment deposition and organic matter accumulation in the wetland would be able to match the rate of sea level rise. Cahoon and Guntenspergen (2010) have proposed a method for doing this. Details are presented in the section "The Effect of Climate Change on Wetlands."

Wisconsin Rapid Assessment Method (WIRAM)

Reference: Wisconsin Department of Natural Resources, 2001.
http://dnr.wi.gov/wetlands/documents/RapidWetlandAssessment.pdf
Level: Level 2

Summary:
The Wisconsin Rapid Assessment Method (WIRAM) evaluates the ability of a wetland to perform the following functions and services: floral diversity; wildlife habitat; fishery habitat; flood/stormwater attenuation; water quality protection; shoreline protection; groundwater; and aesthetics/recreation/education.

Specifically, the method consists of:

1. A site description: wetland type and size, hydrologic setting, vegetation, soils, surrounding land use.
2. Special features or "red flags:" is the wetland is an area of special natural resource interest, does it contains RTE species, or does it requires a Coastal Zone Management Plan?
3. A functional assessment: qualitative rating of Low, Medium, High, or exceptional for each function or service. This is based on answers to questions about the indicators

Rationale: There is no apparent background information associated with the method and we were not able to obtain additional information from the Wisconsin Department of Natural Resources. The State of Wisconsin appears to be developing Level 1, 2, and condition-based assessment methods that may supersede WIRAM[8].

Assessment area: The assessment area is the wetland.

Functions and indicators:
Functions/services and related indicators for WIRAM are presented in Table 26.

Results and validation: There is no apparent background information associated with the method.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
This is a rapid assessment method that is not designed to address overall goals, but some of the indicators used address these topics (e.g. wetland contains rare species; wetland is in priority watershed; wetland is important for flood water storage, etc.).

Time required:
4 hours per site (Bartoldus, 1999).

[8] http://dnr.wi.gov/wetlands/methods.html

Flaws/limitations:
According to Bartoldus (1999), the rating system for WIRAM is quite subjective. There is no upper limit on opportunity values for functions. The method does not provide an overall score for condition.

Table 26. Functions and indicators used in the Wisconsin Rapid Assessment Method.

Function	Indicators
Floral diversity	• Supports diversity of native plants • Contains rare plant community
Wildlife habitat Fishery habitat	• Species observed • High vegetation diversity and interspersion • Ratio of open water to cover between 30-70% • Surrounding upland habitat value • Provides wildlife corridor • Part of a large tract of habitat for species that require it • Near other wetlands • Adjacent to permanent water body or inundated • Food base for fish and wildlife • Wetland is in priority watershed • Provides habitat that is scarce in region
Flood/stormwater attenuation	• Presence of steep slopes, large impervious area, moderate slopes with row cropping or overgrazing in watershed (opportunity) • Wetland has properties that will reduce run-off velocity • Evidence of flashy water level response to storms • Natural or man-made drainage impediment • Estimated water storage capacity • Wetland is important for flood water storage (i.e. located in mid-lower watershed).
Water quality protection	• Wetland receives overland flow or stormwater • Surrounding land is nutrient and sediment source • Wetland performs flood/ stormwater attenuation • Vegetative density for suspended sediments retention • Landscape position indicates runoff detention/filtering. • Visible indicators of nutrient loading
Shoreline protection (not applicable unless wetland is in lacustrine or riverine setting)	• Subject to wave action • Presence of submerged and emergent vegetation • Stream bank is prone to erosion • Stream bank is vegetated
Groundwater recharge discharge	• Presence of groundwater springs • For discharge: contribution to base flow in stream • For recharge: located on or near groundwater divide.
Aesthetics/recreation/education	• Visibility of wetland • Nearness to population centers • Public/conservation ownership • Ease of access • Free from obvious human influences • Viewshed free from obvious human influences • Diversity within wetland • Wetland adds to diversity of landscape • Encouragement of exploration (views, edges, etc.) • Potential for recreational activities • Potential for education or research

Level 3 Methods

Delaware Comprehensive Assessment Method (DECAP)

Reference: Jacobs et al., 2008, and unpublished scoring documents supplied by Amy Jacobs, Delaware Department of Natural Resources and Environmental Control.
Level: Level 3

Summary:
The Delaware Comprehensive Assessment Procedure (DECAP) is an HGM-based method with that assesses wetland condition as compared to relatively undisturbed[9] reference sites. Some Level 1 landscape analysis is involved. The method attempts to quantify the condition of wetlands as compared to relatively undisturbed wetlands of the same HGM type for five functional categories: buffer integrity, wildlife habitat integrity, plant community integrity, hydrologic flux and storage, and biogeochemical cycling and storage. An Index of Wetland Condition (IWC) is also calculated using weighted variables chosen from the indicator list, and is used to combine the HGM variables into a single score to rate overall wetland condition. The method is currently being used to assess Coastal Plain flat, riverine, and depressional wetlands in Delaware, but scoring protocols are continually being updated with new data (personal communication, Amy Jacobs).

Rationale:
DECAP was developed from the HGM model used in the Nanticoke River watershed study (Bleil, 2004; Jacobs and Bleil, 2008), and shares many of the same functional indicators. All indicators were selected because they were indications of disturbance from reference standard condition. The rationale for some indicators is detailed in the scoring documents but these are still a work in progress, so rationale justification is incomplete, and the citations do not have associated references. However, as mentioned earlier, we feel that the rationale was unclear for some of the metrics for functions in the Nanticoke River watershed HGM model, and this appears to be true

Assessment area:
The assessment area is a 40 m radius circle centered on "a random point located in a mapped wetland that has been selected using a probabilistic sampling design" (Jacobs et al., 2008), plus a buffer of 240 m radius from the center of assessment area. (Note: for some variables, the buffer is 200 m from the edge of assessment area.)

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[9] DECAP flat and riverine reference standard site criteria (adapted from DECAP scoring procedures):

1. Less then 1% of the species are non-native or invasive.
2. Less than 10% of the 200 meter buffer from the edge of the AA contains anthropogenic alterations.
3. For flat wetlands: No ditches within the AA and no ditches within 200m of the edge of the AA that have hydrologic impact on the AA. For Riverine wetlands, no channelization or stream alteration within the AA or 500 meters upstream or downstream of site.
4. No vegetation disturbance in the AA such as forestry activity or mowing within the past 50 years.

Functions and indicators:
Functions and variables for DECAP are presented in Table 27a (flat wetlands) and Table 27b (riverine wetlands). The information on depressions from Amy Jacobs had scoring only rather than the entire model, so functions and indicators for depressions are not shown.

Table 27a. Functions and indicators for flat wetlands in the Delaware Comprehensive Assessment Procedure. [Note: Trees = ≥ 7.5 cm dbh (diameter at breast height) and >1m high.]

Function	**Indicators**
Hydrologic flux and storage	• Presence and extent of filling and drainage
Biogeochemical cycling and storage	• Microtopography, • Standing dead trees • Tree basal area (combined dbh of all trees in wetland) • Tree density • Hydrology FCI score
Plant community integrity	• Wetland indicator status of tree species • Herb species • Presence of *Rubus* (blackberry: an indicator of disturbance). • Shrub species
Wildlife habitat integrity	• Vegetation disturbance (timing and intensity of anthropogenic disturbances) • Tree density • Tree basal area • Shrub density • Standing dead trees
Buffer integrity	• Percent surrounding landscape (240 m radius from center of assessment area) in natural land use • Canopy tree basal area in buffer plot (240 m radius from center of assessment area) • Percent cover of roads in buffer (240 m radius from center of assessment area) • Impervious surface surrounding site (200 m from edge of assessment area)
Index of wetland condition	Sum of: • Habitat = 50% * (vegetation disturbance + herbaceous vegetative composition + presence of Rubus + tree basal area + tree density + wetland indicator status of tree species + shrub density) • Hydrology = 40% * (microtopography + filling + drainage) • Buffer integrity = 10% * (percent surrounding landscape in natural land use)

Table 27b. Functions and indicators for riverine wetlands in the Delaware Comprehensive Assessment Procedure. [Note: Trees = ≥ 7.5 cm dbh (diameter at breast height) and >1m high.]

Function	Indicators
Hydrologic flux and storage	• Stream incision and alterations within assessment area • Degree of channelization outside of the assessment area • Large hydrologic alterations outside the assessment • Floodplain alterations
Biogeochemical cycling and storage	• Tree basal area • Microtopography • Hydrology FCI
Plant community integrity	• Invasive species abundance • Wetland indicator status of tree species • Floristic Quality Assessment (Miller and Wardrop, 2006) • Presence of *Rubus*
Wildlife habitat integrity	• Tree basal area • Microtopography • Shrub density • Vegetation disturbance
Buffer integrity	• Distance to roads • Basal area of trees in forested buffer • Land use within 200 m buffer
Index of wetland condition	Sum of: • Habitat = 50% * (presence of Rubus + invasive species abundance disturbance + wetland indicator status of tree species + tree basal area) • Hydrology = 40% * (degree of channelization outside of the assessment area + floodplain alterations) • Buffer integrity = 10% * (percent surrounding landscape in natural land use)

Results and validation:
The Index of Wetland Condition of DECAP was tested in the Nanticoke River watershed (54 riverine wetlands; 89 flats; 48 depressions) and the Inland Bays Watershed (25 riverine; 24 flats) [Jacobs et al., 2009a, Jacobs et al. (in press)]. The HGM variables used to calculate the Index of Wetland Condition were "screened and scored based on a range check, responsiveness, and metric redundancy" using the method of Stoddard et al. (2008), which is used to develop indexes of biological integrity [Jacobs et al. (in press)]. Final scores for the IWC were tested against "best professional judgment" evaluation of wetland condition.

Vegetation successional stage:
DECAP gives higher scores for biogeochemical cycling and storage, wildlife habitat integrity, and buffer integrity, and wetland condition to wetlands with larger trees, which in turn results in a higher Index of Wetland condition. For plant community integrity, the assumption was made that plant species commonly found in open habitat were indicators of disturbed sites.

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
DECAP is used with DERAP to "assess and report on the condition of wetlands by watershed and to assess status and trends over time" (Jacobs, 2008). If rare or threatened plant species are present, they are identified as part of the DECAP procedure, but are not included in scoring.

Time required:
DECAP requires about 4 hours per site for a team of 3-4 people.

Flaws/limitations:
Like the Nanticoke River HGM study from which it is adapted, DECAP assesses condition based on comparison with relatively undisturbed reference wetlands, and thus omits some indicators that reflect wetland function (Jordan, 2007). It does not assess opportunity or services. Although DECAP is technically a Level 3 method, it is performed with one relatively short site visit, and thus may not be as intensive as is necessary to accurately assess wetland condition.

A Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Hardwood Flats on Mineral Soils in the Coastal Plain of Virginia.

Reference: Havens et al., 2001.
Level: Level 3

Summary: This project is a proposed HGM model for functional assessment of hardwood mineral flats in Virginia's Coastal Plain. This is a method only. It contains detailed information on sampling, and example data sheets. Data from 24 reference sites is presented but not analyzed in the report.

Rationale: This is a typical HGM assessment model in which optimum functioning levels are derived from the characteristics and properties of undisturbed reference wetlands. The rationale for each function and indicator is clearly explained but not referenced in the guidebook. The hydrologic function is adapted from a draft version of Rheinhardt et al. (2002).

Assessment area: The assessment area is the wetland, but is divided into two or more partial assessment areas if altered vegetation, hydrology or soils are present in a portion the wetland. Three or more randomly selected subplots (10 m radius) are used for intensive data collection in each wetland.

Functions and indicators:
Functions and model variables for the draft mineral hardwood flats HGM model are presented in Table 28.

Results and validation:
Data from 24 wetlands is presented, but is not analyzed. The final report on the project is not expected to be completed until the end of 2010 (personal communication, Kirk Havens).

Vegetation successional stage:
The Functional Capacity Index (FCI) for the function "Maintain site quality for characteristic plant community" is calculated by adding the following:

- Presence of plants which indicate lack of site disturbance
- Number and species of canopy trees
- Number and species of saplings
- Number and species of mid-story trees
- Shrub density

Each factor is modified by the presence of exotic/invasive species in that particular vegetative substratum. Scores are calculated to give preference to wetlands with a mixture of hardwood trees and saplings and a dense shrub layer. The authors suggest using the wet pine flat model of Rheinhardt et al. (2002) if the wetland has a predominance of pines.

Table 28. Functions and model variables for the draft HGM model for mineral hardwood flats in the Coastal Plain of Virginia.

Function	Model Variables
Maintain characteristic water level regime	• Impediment to flow (roads) • Lateral drainage effect (removal of water by ditches and drains) • Addition or excavation of material • Evapotranspiration potential • Importation of water from elsewhere (via ditches, surface runoff, etc.) • Microtopographic features • Soil porosity
Maintain site quality for characteristic plant community	• Presence of plants which indicate lack of site disturbance • Number and species of canopy trees • Number and species of saplings • Number and species of mid-story trees • Shrub density • Presence of exotic/invasive species
Maintain site quality for characteristic animal community	• Site quality for plant community (from function above) • Plant structure (number of types of vegetation present) • Number of food producing plants present, plus modifier for plants which produce winter food. • Mass of organic matter in woody debris • Number of standing dead trees • Presence and abundance of tree cavities • Alteration of natural microtopography • Alteration of 200 m buffer surrounding wetland (can be determined by GIS) • Land use in 1000 m buffer surrounding wetland (can be determined by GIS)
Maintain characteristic biogeochemical functions	• Site quality for plant community (from function above) • Presence of redoximorphic features • Amount of carbon (calculated from mass of organic matter in woody debris and number of standing dead trees • Soil porosity

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
The method could be used to identify wetlands with high functional capacity for preservation. It does not identify wetlands with rare, threatened, and endangered species.

Time required:
According to the method, two people can collect field data on a site with three subplots in 3-4 hours. Although this would technically classify the method as Level 2, the U.S. EPA (2006) classifies HGM methods as Level 3, possibly because of the time required for model development.

Flaws/limitations:

This is a draft model only. VIMS is currently working on a finalized regional HGM guidebook for Mid-Atlantic flats (see http://ccrm.vims.edu/publications/completed_projects/index.html for more information.) Like all HGM models, the model does not address opportunity or services. Field data is collected on one relatively short site visit.

Virginia Department of Environmental Quality Floristic Quality Index

Reference: http://www.deq.virginia.gov/wetlands/calculator/main.php
Level: Level 3

Summary:
The Virginia Department of Environmental Quality Floristic Quality Assessment Index assesses the relative condition of wetlands. A floristic quality assessment is developed by assigning a numerical rating known as the "coefficient of conservatism" to each type of plant. Coefficients of conservatism or "C-values" correspond to the approximate probability that a plant will occur in an unaltered landscape (pre-settlement). Higher C-values mean that a plant is more "conservative" or more likely to occur in unaltered areas.

A floristic quality survey is done by identifying each plant present in a representative area, determining the C-value for each plant and calculating:

1. The *mean coefficient of conservatism*. This is the sum of the coefficients of conservatism for all plants in the area divided by the total number of plant taxa.
2. The *floristic quality index*. This is the mean coefficient of conservatism multiplied by the square root of the total number of plants. This allows relative comparison of sites with large and small numbers of species.

The Virginia DEQ has an on-line calculator for this process at http://www.deq.virginia.gov/wetlands/calculator/main.php

Rationale: The basic rationale behind floristic quality assessment is that of species conservatism, defined as "the degree to which a species can tolerate disturbance and its fidelity to undegraded conditions" (Herman et al., 2001). The method does not measure species rarity. Some rare or endangered species have a high coefficient of conservatism but some do not.

Assessment area: At least 100 meters square.[10]

Functions and indicators: N/A

Results and validation:
Although results and validation are not presented for the Virginia DEQ method, the FQAI has been widely used to assess the degree of disturbance in wetlands. Studies in Pennsylvania show that a slightly adapted version of Pennsylvania's FQAI was highly correlated with disturbance in headwater wetlands (Miller and Wardrop, 2007).

[10] http://www.deq.virginia.gov/wetlands/wetlands.html

Evaluation of management goals, priorities for land and species conservation, and sustained ecological integrity:
According to Taft et al. (1997) and Miller and Wardrop (2007) the floristic quality index can be used to monitor changes in wetland restoration sites and to identify high quality wetlands. The method is not specifically designed to identify rare plant species, but they will be assessed if present.

Time required: Not stated.

Flaws/limitations:
The method is specifically designed to assess ecological integrity and does not assess functions or services. Floristic quality assessments may give higher scores to sites with larger numbers of native species, and thus may not give the highest score to the site with highest percentage of conservative species. The adjusted FQAI of Miller and Wardrop (2006) is an attempt to rectify this issue. The Virginia DEQ notes that assessments should be performed in mid-July for optimum identification of grass and sedge species.

Development of a floristic quality assessment index and assignment of coefficients of conservatism to plant species requires extensive botanical knowledge.

Associated Methods, Guidance, or Studies

Note: these were not included in Table 31.

Maryland Natural Heritage Program Classification Systems: Plant Communities and Key Wildlife Habitats

References: Harrison, 2004 (plant communities); Maryland Department of Natural Resources, 2005 (key wildlife habitats)

Summary:
The Maryland Natural Heritage Program Plant Community and Key Wildlife Habitat classification systems are an attempt to **"**partition the biophysical landscape into reasonable units for conservation."[11]

1. *Plant Communities*
Harrison (2001) defines plant communities as "physiognomically uniform assemblages of plants which are ecologically related to each other and their physical environment, and predictably found under similar habitat conditions." The goals of Maryland's plant community classification system are to:

- List and describe all vegetation types at the community level.
- Identify plant communities that are in need of preservation.

The rationale behind the preservation of entire plant communities is that it results in protection of entire ecosystems. Rare vegetation communities often provide habitat for rare, threatened, or endangered plant and animal species (Harrison, 2001). In Maryland, these are termed "Rare Natural Communities."[12]

Surveys of plant communities have been performed on Maryland's Eastern Shore forested tidal wetlands (Harrison et al., 2004); Eastern Shore shrubland tidal wetlands Harrison and Stango, 2003); and Eastern Shore herbaceous wetlands Harrison, 2001). These surveys have produced detailed descriptions of regional vegetation communities and have identified community reference types.

2. *Key Wildlife Habitats*
Maryland's list of Key Wildlife Habitats was developed from a simplified version of Harrison's (2004) vegetation community classification (Maryland Department of Natural Resources, 2005.) This was combined with other classification systems to provide a list of 35 significant wildlife habitat types. Each habitat type was then associated with a previously identified list of over 500 wildlife species of "Greatest Conservation Need." These species included declining and vulnerable species as well as rare, threatened and endangered species. GIS layers were then developed for every Key Wildlife Habitat (except forested seepage wetlands, for which not enough information was available).

[11] http://www.dnr.state.md.us/wildlife/nhpnatcomm.asp
[12] http://www.dnr.state.md.us/wildlife/divplan/rarenc-v2-abbreviated-final.pdf

Ten wetland wildlife habitat types are identified under this system:

- Floodplain forests
- Upland depressional swamps
- Carolina Bays
- Vernal pools
- Forested seepage wetlands
- Bog and fen wetland complexes
- Nontidal shrub wetlands
- Tidal shrub wetlands
- Nontidal emergent wetlands
- Tidal marshes

Key Wildlife Habitats have been coordinated with the appropriate wetland classes in MDE's draft wetland classification system (MDE Wetlands and Waterways Program, 2008).

Flaws/limitations:
Key Wildlife Habitat GIS layers were derived from both field data and predictive models, so will likely require field verification.

U.S. EPA Methods for Evaluating Wetland Condition

Reference: U.S. EPA, 2002.

Summary:
Most of the modules in this document consist of detailed guidance for using biological assessments or indices of biological integrity (IBI's) to evaluate wetland condition. The assumption behind bioassessment procedures is that plant and animal communities reflect wetland health, and anthropogenic stressors will change biological attributes.

Biological attributes are defined as "measurable components of a biological system," and usually fall into four classes: species richness and composition, tolerance and intolerance to human disturbances, trophic composition, and the health/condition of the population and/or individual organisms. Ideally, biological assessment provides a way to estimate the cumulative impact of all anthropogenic stressors (as opposed to trying to measure each stressor individually). Bioassessment can assist in planning protection and restoration efforts, and may be used to protect or restore determine the success of wetland restoration. They can also be used to develop water quality standards for wetlands, and to track changes in wetland water quality.

Indices of biological integrity (IBI's) are developed by:

1. Classifying wetlands into regional types.
2. Identifying characteristic regional flora and fauna.
3. Determining habitat and land use characteristics.
4. Selecting sites within each wetland type that encompass a gradient of human disturbance.
5. Selecting biological attributes to sample. The attributes selected should be ones that are thought to predict biological response to human disturbance.
6. Sampling the wetland.
7. Analyzing data to identify and select metrics that actually do predict disturbance.
8. Scoring metrics and calculating an IBI for all sites sampled.

Detailed information is given on developing IBI's for plants (including floristic quality assessments), algae, birds, amphibians, and fish. The document also contains sections on:

- Selecting indicators of nutrient enrichment, such as changes in vegetation composition with time, stem height, and plant tissue chemical analysis, biomass, nutrient uptake efficiency, and identification of nutrient tolerant and intolerant species.
- Estimating nutrient and sediment loading rates from GIS analysis of land use.
- Selecting chemical analyses for determining wetland nutrient status.
- Modeling nutrient loading rates.

Numerous case studies are included, with information on which biological assemblages were sampled, methods of sampling and analysis, and lessons learned. The case studies would be quite valuable for practical advice on developing specific IBI's once the desired biological communities are chosen.

Limitations:
The objective of the methods in the publication is to find way to quantify human disturbance of wetlands. In other words, all methods aim to measure condition rather than function or opportunity, although some of the methods could be adapted to measure function. Several of the modules have been moved to the newer EPA document "Nutrient Criteria Technical Guidance Manual: Wetlands" (U.S. EPA, 2008) which is summarized below.

U.S. EPA Nutrient Criteria Technical Guidance Manual: Wetlands

Reference: U.S. EPA, 2008.

Summary:
This manual is designed to provide "technical guidance to assist States in assessing the nutrient status of their wetlands by considering water, vegetation, and soil conditions, and to provide technical assistance for developing regionally-based, scientifically defensible, numeric nutrient criteria for wetlands" (U.S. EPA, 2008). It provides very detailed explanations of classification, sampling, metrics, statistical analysis, and development of numeric criteria.

According to the manual, the overall goals for a nutrient monitoring program are to:

- Detect and characterize the condition of existing wetlands.
- Describe whether wetland conditions are improving, degrading, or staying the same.
- Define seasonal patterns, impairments, and deviations in status of wetland conditions.

Specifically, the manual discusses:

1. Sampling designs for monitoring programs:
    - Probabilistic sampling: a random sampling of regional wetlands.
    - Targeted/tiered sampling: sampling wetlands of different levels of impairment, from non-impacted to most impacted.
    - BACI (Before/After, Control/Impact) sampling: sampling a site before and after a known impact. This also requires a non-impacted control site so that both the control and the impacted site can be sampled after impact.

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2. Possible variables (metrics) to use when establishing nutrient standards
    - Causal variables: used to characterize nutrient availability. Some examples are nutrient loading rates, land use, extractable and total soil N and P, and water N and P.
    - Response variables: used to characterize biological response to nutrient loading. Examples are vegetation nutrient content, above-ground biomass, stem height, and structure and composition of plant and macroinvertebrate communities.
    - Supporting variables: used to categorize wetlands and interpret causal and response variables. Examples are electrical conductivity, soil pH, soil bulk density, soil organic matter content, and hydrologic variables such as seasonal water level variation hydroperiod.

3. Development of numeric criteria for nutrients based on:
    - Reference wetlands that exemplify the least disturbed wetlands in a region.
    - "Multimetric indices" such as a Tiered Aquatic Life Use model to identify various levels of impairment.
    - A review of published data on nutrients, vegetation, algae, and soil.

There are also extensive discussions on wetland classification schemes and methods for appropriate statistical analysis of data, as well as a wetland science review.

Flaws/limitations:
The manual has useful guidance on setting up a Level 3 nutrient monitoring program. Almost all the methods described, however, are likely to be time-consuming and costly.

USDA Conservation Effects Assessment Project (CEAP): Mid-Atlantic Wetlands

Reference: Unpublished draft materials and methods documents from Dr. Megan Lang/USDA-ARS. (*Please note: according to Dr. Lang, these methods have not been finalized and should **not** be distributed*
Level: Level 3.

Summary: This is a level 3 study, not a method. The overall goal of the entire Mid-Atlantic Wetland Conservation Effects Assessment Project is to quantify ecosystem services provided by wetlands established through USDA conservation practices. Specifically, this project will be a detailed study on control of nutrient and sediment pollution, control of greenhouse gas emissions, and ecological diversity of both amphibians and native plants in Coastal Plain non-tidal depressional wetlands. Study sites will include 16 wetlands that have been converted to cropland, 16 hydrologically restored wetlands, and 16 relatively undisturbed wetlands. (Nine of the forty-eight sites are also being studied as part of the Choptank CEAP-Wetland project, which is an assessment of water quality services and ecological functioning across a wetland alteration gradient in the Choptank River Watershed.) Proposed functions and metrics are detailed in Table 29.

The CEAP project has also developed an extensive bibliography: "Wetlands in Agricultural Landscapes" that provides references and abstracts for literature concerning "(1) the effect of conservation practices (and other agricultural activities) on wetlands and (2) the environmental effects of wetlands as conservation practices (including constructing and restoring wetlands)." [13]

Note: Dr. Lang's group is interested in using the results of this study and the associated Choptank River study to validate Level 2 rapid assessment methods.

[13] http://www.nal.usda.gov/wqic/ceap/05CEAP.shtml

Table 29. Proposed wetland functions and metrics for the CEAP Mid-Atlantic wetlands project.

Function	Metrics
Nutrient control	• *Landscape level metric:* Identification of "Hydrologic-landscape Regions:" areas with similar hydrologic properties which affect wetland water movement and nutrient transport. • Soil nitrate, C, N, and denitrification potential • Forms of N and P in water inflow and outflow, plus other chemical constituents in water.
Sedimentation control	• Soil organic carbon, bulk density, texture • Sedimentation and erosion rates/trends via Cesium 137 levels and soil profile descriptions
Control of greenhouse gas emissions	• Flux of carbon dioxide, methane, and nitrous oxide at surface • Soil organic carbon, bulk density, texture • Sedimentation and erosion rates/trends
Amphibian biodiversity and habitat support	• Amphibian species richness, diversity, and biomass • Water presence and level (hydroperiod) • Water basin topography • % cover and location of emergent vegetation • Presence of algae, organic matter, invertebrates (food) • % of wetland edge with vegetation • Presence or absence of fish • % vegetative canopy cover
Plant community biodiversity	• Plant species and density

Wetland Evaluation Technique (WET)

References: Adamus et al., 1987; Adamus et al., 1991

Summary:
WET is an older wetland assessment method that "which uses the presence or absence of a large set of wetland characteristics as correlative predictors of wetland functions" (Thiesing, 1998). It combines both Level 1 and Level 3 evaluation. WET is designed to predict the qualitative likelihood (high, medium or low) that a wetland will perform a certain function. Eleven functions and services are assessed.

- Landform types used in the system are basin, flat, floodplain, fringe, island, slope, and interfluve.
- Ground-water recharge
- Ground-water discharge
- Floodflow alteration
- Sediment stabilization
- Sediment/toxicant retention
- Nutrient removal/transformation
- Production export
- Wildlife diversity/abundance
- Aquatic diversity/abundance
- Recreation
- Uniqueness/heritage

WET produces a "high/middle/low" ranking for each function, but does not result in an overall score. It evaluates both capability and opportunity for almost all functions. It also includes species-specific habitat assessments for wildlife.

Flaws/limitations:
WET was developed as a national method for use in all regions of the U.S., and thus may not be sensitive enough to distinguish differences between wetlands. Originally, the authors intended to develop several regionally specific methods, such as the WET for Bottomland Hardwood Functions (Adamus et al., 1990), from which the VIMS method was adapted (Novitski et al., 1996). Dr. Adamus, the method's developer, does not plan to update the method and has stated that he finds regionally specific methods based on reference wetlands to be a great improvement (Hatfield et al., 2004).

NatureServe: Ecological Integrity Assessment and Performance Measures for Wetland Mitigation.

Reference: Faber-Langendoen et al., 2006

Summary: This report is a template of proposed methodology for wetland ecological integrity assessment. Despite the title, it is primarily oriented towards natural wetland assessment. The methodology has not been field-tested.

First, the authors recommend that wetlands be classified to the "terrestrial ecosystem" level of Comer et al. (2003). Faber-Langendoen (2007) defines a terrestrial ecosystem as a group of plant community types that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients." Then, ecological attributes and related indicators (metrics) of condition are chosen for each ecological system. Both landscape and field level indicators are used. Reference wetlands are used to develop metrics. (The authors define reference condition as representing "the state of the ecosystem prior to European settlement" or "the best condition that can be obtained.") The metrics are then combined into an overall score or rank.

Separate reports detail proposed ecological integrity assessments for 18 U.S. wetland ecosystems[14], none of which occur in Maryland. Metrics are proposed for each ecosystem in four categories: landscape context, biotic condition, abiotic condition, and size. Although metrics are specific to each ecosystem, the authors have identified a set of 12 indicators that applied to numerous ecosystems (Table 30).

Table 30. Core indicators that are widely shared among wetland ecological systems in the proposed NatureServe methodology. [S = supplementary metric "which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment" (Faber-Langendoen et al., 2006).]

Category	**Metric**
Landscape context	• Adjacent land use • Buffer width • Percentage of unfragmented landscape within 1 km.
Biotic condition	• % cover of native plant species • Floristic Quality Assessment
Abiotic condition:	• Land use within wetland • Hydrologic alterations • Soil organic carbon (S) • Soil bulk density (S)
Size	• Absolute size • Relative size

[14] http://www.natureserve.org/getData/eia_integrity_reports.jsp

Flaws/limitations:
This is a condition-based method that measures ecological integrity as compared to undisturbed wetlands. It does not measure opportunity or services. Although the authors do propose a list of common metrics, their proposed method would entail defining a different set of metrics for each ecological community type, which would be time-consuming and difficult.

The Effect of Climate Change on Wetlands

References: This is a review of several studies and compilations on wetlands and climate change. References are listed in the text.

Summary:

Recent projections of the effects of climate change (IPCC, 2007; Karl et al., 2009) suggest that the northeast U.S. (from Maryland northward) and southeast U.S. (from Virginia southward) may experience:

- Increased sea level rise, resulting in increasing coastal erosion, loss of coastal wetlands, and increasing probability of high storm surges.
- Increased air and water temperatures.
- More heavy downpours during rainfall events, resulting in increased flooding and runoff.
- Northward shifts in the ranges of plant and animal species.
- Possible changes in rainfall patterns (for the Southeast: decreasing summer rainfall and increasing fall rainfall.)

Freshwater non-tidal wetlands may become drier if temperatures increase, even if precipitation levels remain the same, because of increasing evapotranspiration levels (Burkett and Kusler, 2000; Kusler, 2006b). Nontidal wetlands where the primary source of water is groundwater are less likely to be affected by climate change than wetlands where the primary source of water is precipitation (Moore et al., 1997; Winter, 2000). Lower water tables coupled with rising temperatures will increase organic matter decomposition rates, resulting in higher rates of CO_2 release to the atmosphere (Burkett and Kusler, 2000).

Increasing rates of sea level rise will primarily affect tidal wetlands. As stated earlier, tidal wetlands accumulate material at the surface via tidal or storm sedimentation, peat accumulation, and fluvial sediment supply. They lose surface elevation via compaction, tidal sediment export, decomposition, and subsidence (FitzGerald et al., 2009). Tidal wetlands can only survive if they accumulate material at the surface at a rate equivalent to compaction, export, decomposition and sea level rise. In the past, marsh surfaces have generally been able to keep up with sea level rise (often by migrating inland, if possible) but the recent rapid increases in sea level may mean that many of these wetlands will not be able to sustain surface levels, and will "drown" or be transformed into mud flats (Brinson et al., 1995; FitzGerald et al., 2009).

According to Cahoon and Guntenspergen (2010), the time required for a tidal marsh to become subtidal can be estimated from rate of sea level rise and the elevation of the marsh relative to low and high tide. They outline four steps for evaluating the susceptibility of both individual wetland and regional wetland areas to sea level rise:

1. Determine *elevation capital*. Elevation capital is "the position of the wetland relative to the lowest elevation at which plants can survive," and can be approximated by determining tidal range and wetland surface elevation relative to

sea level. Tidal marshes with substantial vertical tidal range have more elevation capital, as do marshes which are located at an elevation that is in the upper portion of the range at which marsh plants can survive. Marshes with higher elevation capital are more resistant to sea level rise.

2. Determine trends in elevation relative to sea level, or whether the rate of vertical accretion via sediment deposition and organic matter accumulation in a tidal marsh is keeping pace with sea level rise. If vertical accretion is not keeping pace with local sea level rise, this results in an *elevation deficit*. Quantification of an elevation deficit requires measuring changes in local sea level and in marsh surface elevation with time. Changes in marsh surface elevation can be determined with a piece of equipment called a Surface Elevation Table (Cahoon et al., 1995), which is a "portable mechanical leveling device for measuring the relative elevation change of wetland sediments."[15]

3. Determine which processes and factors affect changing marsh elevation relative to sea level rise. Tidal fringe wetlands accrete material at the surface through several processes, including tidal sedimentation, storm sedimentation, peat accumulation from wetland vegetation, and fluvial sediment supply. They lose surface elevation through other processes, including compaction, tidal sediment export, organic matter decomposition, and subsidence (FitzGerald et al., 2009). It will require further research to determine which processes are most directly connected with elevation change.

4. Determine future wetland response to sea level rise. This will require models that simulate the processes governing wetland elevation change, and these are currently being developed.

Rising sea levels may also increase salinity in upstream areas of tidal rivers, resulting in the conversion of tidal forested freshwater wetlands to brackish marshes A model by Craft et al (2009) which simulates the effect of sea level rise on the Georgia coast, predicts that tidal marshes on the low and high ends of the salinity range will be the most affected by sea level rise. Salt marshes along the oceans will be unable to accrete sediments at a rate which will prevent inundation, and freshwater tidal marshes will be affected by the intrusion of saline water and will be converted to brackish marshes.

Poff et al. (2002), Kusler (2006b), and ASWM (2009) have summarized the effects of projected climate change in wetlands as:[16]

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[15] http://www.pwrc.usgs.gov/set/ Further details on the Surface Elevation Table are available at this website.

[16] Kusler (2006b) also includes increased plant productivity resulting from elevated CO_2 levels but Poff et al. (2002) notes that this is hard to predict.

- Changes in hydrology due to increased or decreased precipitation, sea level rise, changes in stream flow patterns, and higher evaporation/transpiration resulting from increasing temperatures.
- Changes due to an increase number of storms: increased runoff and erosion into wetlands and stress on wetland systems due to storm related flooding.
- Disruption in present habitat for many plants or animals, including particular problems species which are sensitive to temperature/hydrology changes but cannot migrate because of wetland fragmentation.
- Increased eutrophication in nutrient enriched wetlands and adjacent aquatic ecosystems.
- Increasing stress on wetlands that are already affected by anthropogenic stressors.

Recommendations for planning for the effects of climate change on wetlands (Poff et al.., 2002; Kusler, 2006b) include (but are not limited to):

- Identification of wetland types and wetland-dependent species that are most vulnerable to climate change, and development of strategies to protect them.
- Reduction of nutrient loading to prevent increased eutrophication.
- Location of new reservoirs off-channel to maintain flow of water and sediment to riverine ecosystems and estuarine wetlands.
- Curtailment of groundwater withdrawals that affect wetlands.
- Protection of upland areas surrounding estuarine wetlands so that they can migrate after sea level rise.
- Maintenance of forested wetlands that provide shade to waterbodies.
- Preventing wetland fragmentation to help maintain plant and animal migration corridors.
- Increasing buffer area around wetlands to help alleviate the effects of runoff and sedimentation.

ASWM (2009) particularly recommends that wetlands with high carbon levels be protected or restored to maintain or increase existing carbon sequestration. He recommends that "regulatory agencies at all levels of government should amend regulations to better protect wetland carbon stores." For example, estimation of carbon impacts could be included in wetland-related regulatory permits.

Tabular Comparison of Assessment Methods Used in Other Areas

Table 31. Comparison of wetland assessment methods used in other areas.

Method or study	**Reference**	**Level 1, 2, or 3?**	**Which categories of functions are evaluated?**	**Are cultural services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Adjusted scores for preferred functions**	**Wetland and/or vegetation type**	**Restricted for use in studied wetland type?**	**Region where method was developed**	**Can it be used in other regions?**
Mid-Atlantic Regional Wetland Assessment Procedure	Brooks, 2006; Brooks et al., 2009	Level 1 and 2 (Level 3 is proposed)	Level 1: Water quality and habitat Level 2: Evaluates stressors on hydrologic, biogeochemical and habitat functions	No	Yes (for Level 2)	Yes	No	Level 1: NWI Level 2: N/A	Non-tidal wetlands in the Mid-Atlantic only	Mid-Atlantic region	If adapted.
Penn State Method	Brooks et al., 2004a; Brooks et al., 2004 b; Wardrop et al., 2007	Level 1 and 2	Evaluates stressors on hydrologic, biogeochemical and habitat functions	No	Yes	Yes	No	N/A	Non-tidal wetlands in Pennsylvania only	Pennsylvania	If adapted.
VIMS method (older)	Bradshaw, 1991	Level 1 and 2/3	Hydrologic, biogeochemical, habitat	Yes	No	Yes	No	N/A	Non-tidal wetlands in Virginia Coastal Plain	Virginia	If adapted
VIMS method (newer)	CCRM, 2007; CCRM, 2008	Level 1, 2, and 3	Water quality and habitat	No	Performance of each function is scored separately	Yes	No	NWI	Non-tidal wetlands	Virginia Coastal Plain and Piedmont	If adapted

Table 31 (continued). Comparison of wetland assessment methods used in other areas.

Method or study	**Reference**	**Level 1, 2, or 3?**	**Which categories of functions are evaluated?**	**Are cultural services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Adjusted scores for preferred functions**	**Wetland and/or vegetation type**	**Restricted for use in studied wetland type?**	**Region where method was developed**	**Can it be used in other regions?**
West Virginia wetland assessment methods (proposed)	Kordek, 2008; Kordek, 2009	Level 1, 2, and 3			Yes – as "Qualitative ranking of anthropogenic disturbance"	Yes	No	HGM wetland type and NWI (Cowardin) vegetation type	Non-tidal only	West Virginia	If adapted
California Rapid Assessment Method (CRAM)	Collins et al., 2008	Level 2	Hydrologic, habitat (plus buffer/landscape context)	No	Yes	By HGM type only	No	HGM wetland type	Wetlands in California only	California	If adapted.
Delaware Rapid Assessment Procedure (DERAP)	Jacobs, 2008	Level 2	Evaluates stressors on hydrologic, habitat, and buffer	No	Yes	Yes	No	HGM wetland type	Flat, riverine, and depressional wetland only (depressional model is not fully developed yet)	Delaware	Designed for use in Outer Coastal Plain of Delaware and Maryland; can be used in other regions if adapted
Eastern and Western Washington State Methods	Hruby, 2007; Hruby, 2006	Level 2	Hydrologic, biogeochemical, habitat	Rare wetland types and habitat for rare, species only.	No	Yes	Yes, for rare wetland types and habitat for rare, threatened, endangered species	HGM wetland type with Cowardin vegetation type	Wetlands in Eastern or Western Washington only (depending on method)	Washington State	If adapted.

Table 31 (continued). Comparison of wetland assessment methods used in other areas.

Method or study	**Reference**	**Level 1, 2, or 3?**	**Which categories of functions are evaluated?**	**Are cultural services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Adjusted scores for preferred functions**	**Wetland and/or vegetation type**	**Restricted for use in studied wetland type?**	**Region where method was developed**	**Can it be used in other regions?**
Maryland State Highway Administration method (MD-SHA)	USCOE, 1999, plus additional MD specific documents	Level 2	Hydrologic, biogeochemical, habitat	Yes	No	Yes	No	N/A	No	New England; adapted to Maryland	If adapted
Mid Atlantic Tidal Rapid Assessment Method (MidTRAM)	Jacobs et al., 2008b	Level 2	Hydrologic, habitat (plus buffer/landscape context)	No	Yes	Yes (estuarine emergent only)	No	N/A (method is for estuarine emergent wetlands only)	Estuarine emergent wetlands in the Mid-Atlantic	Delaware, Maryland, Virginia	If adapted
Ohio Rapid Assessment Method (ORAM)	Mack, 2001; Mack, 2000, Ohio EPA, 2001	Level 2	Hydrologic, habitat	Rare wetland types or rare species only.	No, but overall score has been shown to correlate with condition.	Yes	Yes, for rare wetland types or rare species	Cowardin vegetation classes are used for some indicators	Wetlands in Ohio only	Ohio	If adapted.
Wisconsin Rapid Assessment Method (WIRAM)	Wisconsin Department of Natural Resources, 2001	Level 2	Hydrologic, biogeochemical, habitat	Yes	No	Yes	No	N/A	Wetlands in Wisconsin only	Wisconsin	If adapted

Table 31 (continued). Comparison of wetland assessment methods used in other areas.

Method or study	Reference	Level 1, 2, or 3?	Which categories of functions are evaluated?	Are cultural services evaluated?	Is condition evaluated directly?	Can method compare wetlands of different classes/types?	Adjusted scores for preferred functions	Wetland and/or vegetation type	Restricted for use in studied wetland type?	Region where method was developed	Can it be used in other regions?
Delaware Comprehensive Assessment Procedure (DECAP)	Jacobs et al., 2008a	Level 3	Hydrologic, biogeochemical, habitat	No	Yes. An "Index of Wetland Condition" is calculated	By HGM type only	No	HGM wetland type	Mid-Atlantic Coastal Plain flat, riverine, depressional wetlands only	Delaware	If adapted
Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Hardwood Flats on Mineral Soils	Havens et al., 2001	Level 3	Hydrologic, biogeochemical, habitat	No	Performance of each function is scored separately.	No	No	HGM	Mineral hardwood flats only	Virginia Coastal Plain	Some indicators might be adaptable to other regions.
Virginia DEQ Floristic Quality Assessment index	VA DEQ website	Level 3	No functions - condition only	No	Yes	Yes	No	N/A	All FQAI's are region-specific	Virginia	No

Summary

MDE/MDNR Methods: Summary

1. Many of the MDE/MDNR methods assessed ecological condition (often using disturbance-based metrics) rather than attempting to predict function.

2. To date, none of the MDE/MDNR methods has successfully validated with a long-term study, although the VIMS method "Building Capacity to Perform Wetland Assessments" (CCRM, 2008) is currently undergoing validation in Virginia. Some of the Level 1 and 2 methods were not validated, and several were validated with one relatively short-term "Level 3" (3-5 hour) site visit. The only MDE/MDNR method that that was based on repeated site visits was the Hydrogeomorphic Approach to Functional Assessment for Piedmont Slope Wetlands (Vasilas, 2006).

3. Cultural services (excepting biodiversity-related services) and opportunity were specifically evaluated only in the two methods designed for MDE: "A method for the assessment of wetland function" (Fugro-McClelland East, Inc., 1995) and "Effectiveness of Maryland compensatory mitigation program" (MDE Wetlands and Waterways Program, 2007).

Other Methods: Summary

1. Many of the other methods evaluated (e.g. Penn State method, CRAM, DERAP, MidTRAM, DECAP, the Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Hardwood Flats on Mineral Soils, and the Virginia DEQ Floristic Quality Assessment Index) were condition evaluations only. These methods did not assess services or opportunity.

2. Only a few of the methods (MD-SHA, WIRAM, West Virginia Level 2, and the older VIMS method) assessed any services apart from rare wetland types or habitat for rare species, which were assessed in the ORAM and Washington State methods.

3. Opportunity was evaluated in the MD-SHA, WIRAM, older VIMS, and Washington State methods only.

4. Five Level 3 methods were included: the newer VIMS Level 3 method, the West Virginia Level 3 method, DECAP, the Draft Regional Guidebook for Applying the Hydrogeomorphic Approach to Wet Hardwood Flats on Mineral Soils, and the Virginia DEQ Floristic Quality Assessment Index. All Level 3 methods except the VIMS method required one site visit only.

Some Recommendations for Developing a Wetland Assessment Method

Rationale and Indicators

As stated earlier, indicators are "easily observed characteristics that are correlated with quantitative or qualitative observations of a function" (Hruby, 2006). The overall level and goal of the method must be formulated before indicators are chosen. Will the method measure condition or function? Will opportunity be evaluated? Sutula et al. (2006) points out that many indicators used to assess function and condition are the same, but that evaluation of indicators will vary depending on the desired objective of the method. The level of function of disturbed wetlands cannot be accurately assessed without including opportunity variables in the assessment method. Thiesing (1998) gives the example of a wetland in an urban area which is actually be removing more sediment and providing more water quality benefits than an undisturbed reference standard wetland because of its location. Wetlands such as these would receive a low rating in a typical HGM or condition-based assessment method because of their disturbance level.

Indicators can be chosen by several methods:

- Characteristics of an ideal wetland, as based on literature.
- Characteristics of regional wetlands which exemplify the highest performance of each function. This may be based on literature or actual measurements.
- Characteristics of the least altered wetlands within a region, as in the HGM approach and other methods which measure condition/ecological integrity.

Many of the methods described in this review use the third approach because it is likely to be the easiest to implement. Undisturbed (or relatively undisturbed) reference standard wetlands are chosen, and certain characteristics are chosen that are thought to exemplify the highest level of function. There are two issues with this approach:

- Use of an undisturbed reference wetland as the standard method results in measures of disturbance or condition, rather than function. It has been shown that condition does not necessarily equal function (Hruby, 2001; Kusler, 2006a; Stander and Ehrenfeld, 2009). Thus, models based on reference standard wetlands do not effectively assess the actual performance of disturbed wetlands because they do not account for the opportunity a wetland may have to perform a function, regardless of its level of disturbance.
- It is unlikely that any wetland will perform all functions equally well (Hruby, 2006; Kusler, 2006).

The rationale for the indicators used in the method should be clearly stated and referenced with appropriate literature. It is quite difficult to adapt a method when necessary if rationale for indicators is not given (Hatfield et al., 2004). In particular, Many indicators for Level 2 methods are simplified assumptions chosen so that the assessment can be rapid (Kusler, 2006a). If this is the case, the assumptions should be as transparent as possible, and should be explained in the supporting literature for the method.

Selecting Assessment Areas

The assessment areas defined in the methods in this review varied. In many methods, the entire jurisdictional wetland was the assessment area. Some methods select a defined portion of the wetland for assessment (for example, DERAP and DECAP use a 40 m radius circle around a center point). ORAM uses a "scoring boundary" which is either (1) the jurisdictional wetland boundary, or (2) a boundary based on breaks in hydrologic conditions. The original MDE method suggests separating assessment areas within wetlands by HGM type, stream order, roads, river and stream boundaries, etc. but additional guidance by MDE (Maryland Department of the Environment, 1997) states that wetland assessment area should depend on the size of the entire area being assessed. For example, if the study area is small, wetlands along streams can be separated by stream order, but for watershed-level assessment, wetlands associated with headwater streams and higher order streams in the same drainage should form one assessment area. Fennessy et al. (2004) notes that assessing the entire wetland can lead to problems when the wetland being assessed is either especially large, or is part of a large wetland complex, so policies governing the selection of an assessment area in these instances should be developed. Kusler (2006a) points out that the assumption behind any method used to choose an assessment area is that the functions and services of the wetland are consistent throughout the specified area.

Rules for definition of the assessment area should consider (Fennessy et al., 2004):

- Will the definition work when choosing sites for sampling? For example, can it be used with GIS?
- Is the definition easy to apply in the field? For example, can different users select a consistent assessment area?
- Does the assessment area reflect dominant ecological conditions in the wetland?
- Are the results produced consistent with the goals of the monitoring program? For example, the goals of a watershed level monitoring program may be different than those of a monitoring program which seeks to identify rare species or ecotypes.

If a probabilistic survey, other random sampling design, and/or NWI maps are used to choose assessment sites, field verification that the site is actually a wetland is necessary.

Method Levels and Method Validation

In general, Level 1 landscape level methods are most useful in large-scale (e.g. watershed level) wetland assessments. They can assist in determining wetland connectivity and hydrologic connections. Level 1 methods may also provide an estimate of opportunity by determining how close wetlands are to sediment or nutrient sources, waterways, and alternate habitat areas. They may also be able to provide a rough idea of factors needed for some services such as accessibility to the public. Future conditions and cumulative impacts may be approximated by inputting projected data into Level I methods (Kusler, 2006).

Level 2 rapid assessment methods are useful because they provide an inexpensive and accurate method of assessing wetlands of many different kinds. As such, they can be used for condition assessments, screening, and performance evaluations. Level 2 methods do not provide detailed functional assessments and cannot predict changing conditions (Kusler, 2006a; Stein et al., 2009). As Klimas (2008) states, "The challenge in designing a comprehensive [rapid] assessment tool is to maintain an acceptable level of technical rigor and precision while meeting the time restrictions."

Both Level 1 and Level 2 methods must be validated by Level 3 intensive assessments. Level 3 methods used to validate Level 1 and Level 2 methods should involve repeated sampling over at least one year. Although the U.S. EPA (2006) considers HGM to be a Level 3 method, almost all the HGM-based methods reviewed in this study [with the exception of Vasilas (2006)] involved a one-time relatively short site visit. Some of these short-term Level 3 assessments methods, such as the method used in the Wetland Profile of the Nanticoke River Watershed (Bleil, 2004), were then used to verify Level 2 methods. Many of the indicators were visual assessments or on-site measurements which are derived from reference wetland characteristics and may or may not be related to actual function (Cole, 2006). For example, Stander and Ehrenfeld (2009) found that a one-time HGM site assessment was not sufficient to assess the hydrologic and nitrogen cycling functions, and recommended that water table levels be assessed for at least one year to account for seasonal changes in hydrology and subsequent differences in rates of biogeochemical processes. Jordan et al. (2007) found that the biogeochemistry FCI scores produced in the Level 3 HGM assessment in the Wetland Profile of the Nanticoke River Watershed (Bleil, 2004) did not correspond to actual biogeochemical measurements and recommended that soil laboratory data be included.

Information on method validation should be accessible. It was difficult to locate validation information for many of the methods reviewed in this study. In some cases, the information is in journal articles that are not accessible to the public. The developers of the California Rapid Assessment methods have a website devoted to the method which includes a documentation page where full copies literature related to the method is linked.[17] This approach is recommended.

[17] http://www.cramwetlands.org/documents/

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Appendix: Review of Compilations

Introduction

For this review of compilations, we determined whether the questions in the "Objectives" portion of the main report could be adequately answered by the four methods compilations: Fugro-McClelland East (1993), Bartoldus (1999), Fennessy et al. (2004) and Sutula et al. (2006). We also supplemented the information given in the compilations with information from Adamus (1992), Kusler (2004a and 2006) and Fennessy et al. (2007)

Although the compilations provided a basic overview of many methods, we were not able to answer all the questions for the methods described in the compilations for several reasons:

- The compilations generally did not contain detailed information on field data collection, data analysis, and statistical evaluation.
- The compilations often did not supply detailed information on which indicators were used for functions and services for each method.
- The compilations did not usually summarize the original research on which each method was based.
- There was very little information available on some of the methods.
- The version of the method reviewed was not always the latest available, even in the newer compilations.

We determined that we could answer the following questions for most of the methods listed in the compilations:

1. What general categories of functions are evaluated? (For example, hydrologic, biogeochemical/water quality, and habitat.)
2. Are services evaluated?
3. Is condition evaluated?
4. Can wetlands be compared to one another, even if they are different types?
5. Is the method Level 1 (landscape), Level 2 (rapid field) or Level 3 (comprehensive field)? Note that estimates of time required for performance of some methods varied widely among compilations.
6. In what region was the method was developed?
7. Is the model restricted for use in the studied physiographic region or does it say it can be used in other areas?
8. Are there stated or flaws/limitations for using the method? (Note: this was answered in the text rather than Table A-2)
9. How long does it take to conduct the assessment, in the field or office/desktop? [Again, when different estimated times to complete the method were given in two or more compilations, we used the estimated time given in Fennessy et al. (2004; 2007).]

Compilation Overview

We reviewed 37 methods from the four compilations (Table A-1). Fugro-McClelland East (1993) reviewed 12 wetland assessment methods for their suitability for landscape level assessment. Several of the methods reviewed have been superseded by newer methods and/or appear to never have been used extensively. Bartoldus (1999) reviewed 40 assessment methods in detail, including the current MDE method. Again, several methods are outdated or appear never to have been used extensively. Fennessy et al. (2004) briefly reviewed 16 assessment methods, including the current MDE method, in a survey of rapid assessment methods and chose seven methods to review in detail. (Fennessy et al., however, did not interview MDE regarding its method.) The methods selected were those that (a) measured condition (b) were truly rapid (c) were on-site assessments and (d) were verifiable through level 3 assessment. The study was updated in Fennessy et al. (2007), and one of the seven “rapid” methods (the Penn State Stressor Checklist) was eliminated because it was not truly rapid. Sutula et al. (2006) described the development of the California Rapid Assessment Method (CRAM), and explained decisions that may need to be made while developing other rapid assessment methods.

Table A-1. List of methods reviewed in this report with associated references.

Method	Reviewed by	References
Avian Richness Evaluation Method	Bartoldus, 1999	Adamus, P.R. 1993a. User's Manual: Avian Richness Evaluation Method (AREM) for lowland wetlands of the Colorado Plateau. EPA/600/R-93/240. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.
CRAM - California Rapid Assessment Method	Sutula et al., 2006	Collins, J., E. Stein, M. Sutula, 2004. Draft California Rapid Assessment Method for Wetlands (Version 2.0). San Francisco Estuary Institute and the Southern California Coastal Water Research Project, Westminster, CA.
Delaware Rapid Assessment Protocol	Fennessy et al., 2004	Jacobs, A. D. 2003. Delaware Rapid Assessment Procedure, Version 1.2. Delaware Department of Natural Resources and Environmental Control. Dover, DE. **Note:** this has apparently been superseded by: Jacobs, A.D. 2005. Delaware Rapid Assessment Procedure, Version 2.0. Delaware Department of Natural Resources and Environmental Control, Dover, DE.
Descriptive Approach	Bartoldus, 1999	U.S. Army Corps of Engineers. 1995. The highway methodology workbook supplement. Wetland functions and values: A descriptive approach. U.S. Army Corps of Engineers, New England Division. NENEP-360-1-30a. Available on-line at http://www.nae.usace.army.mil/reg/hwsplmnt.pdf
Evaluation for Planned Wetlands (EPW)	Bartoldus, 1999	Bartoldus, C.C., E.W. Garbisch, and M.L. Kraus. 1994. Evaluation for Planned Wetlands (EPW). Environmental Concern Inc., St. Michaels, MD. Bartoldus, C. C. 1994. EPW: A procedure for the functional assessment of planned wetlands. Water, Air and Soil Pollution, 77:533-541.
Florida Wetland Quality Index	Bartoldus, 1999; Fennessy et al., 2004	Lodge, T.E., H.O. Hillestad, S.W. Carney, and R.B. Darling. 1995. Wetland Quality Index (WQI): A method for determining compensatory mitigation requirements for ecologically impacted wetlands. Proceedings of the American Society of Civil Engineers South Florida Section Annual Meeting, Sept 22-23, 1995, Miami, FL.
Florida Wetland Rapid Assessment Procedure	Bartoldus, 1999; Fennessy et al., 2004	Miller, R.E., Jr. and B.E. Gunsalus. 1999. Wetland Rapid Assessment Procedure. Technical Publication REG-001. Natural Resource Management Division, Regulation Department, South Florida Water Management District, West Palm Beach, FL. Available on-line at: http://www.sfwmd.gov/org/reg/nrm/wrap99.htm

Table A-1 (continued). List of methods reviewed in this report with associated references.

Method	Reviewed by	References
Habitat Assessment Technique (HAT)	Fugro-McClelland East, 1993; Bartoldus, 1999	Cable, T.T., V. Brack, Jr., and V.R. Holmes. 1989. Simplified method for wetland habitat assessment. Environmental Management 13:207-213
Habitat Evaluation Procedure (HEP)	Fugro-McClelland East, 1993; Bartoldus, 1999	USFWS. 1980. Habitat Evaluation Procedure manual. 102 ESM. U.S. Fish and Wildlife Service, Washington, DC. Available on-line at: http://www.fws.gov/policy/ESMindex.html USFWS. 1981. Standards for the development of Habitat Suitability Index models. 103 ESM. U.S. Fish and Wildlife Service, Washington, DC.
Hydrogeomorphic Approach (HGM)	Bartoldus, 1999	Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Wetlands Research Program Technical Report WRP-DE-9. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.
Index of Biological Integrity (IBI)	Bartoldus, 1999	Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6(6): 21-27. Karr, J.R. and E.W. Chu. 1997. Biological monitoring and assessment: Using multimetric indexes effectively. EPA 235-R97-001. University of Washington, Seattle, WA. Danielson, T.J. 1998. Wetland bioassessment fact sheets. EPA 843-F-001. U.S. Environmental Protection Agency. Office of Wetlands, Oceans, and Watersheds, Wetlands Division, Washington, D.C.
Interim HGM (HGM Light)	Bartoldus, 1999	Whited, M. 1997. The NRCS interim hydrogeomorphic approach to functional assessment: what should it entail? USDA Natural Resources Conservation Service, Washington, DC. Available on-line at: ftp://ftp-fc.sc.egov.usda.gov/WLI/1212OldWLIfromUSGS/wli/WAIS1.htm
Larson-Golet Method	Fugro-McClelland East, 1993; Bartoldus, 1999	Larson, J.S. (ed). 1976. Models for assessment of freshwater wetlands. Publication No. 32, Water Resources Research Center, University of Massachusetts, Amherst, MA. Golet, F.C. 1976. Wildlife wetland evaluation model. p. 13-34 *In* Larson, J.S. (ed). Models for assessment of freshwater wetlands. Publication No. 32, Water Resources Research Center, University of Massachusetts, Amherst, MA. Golet, F.C., and J.S. Larson. 1974. Classification of freshwater wetlands in the glaciated Northeast. Resource Publication 116, U.S. Fish and Wildlife Service, Washington, D.C.

Table A-1 (continued). List of methods reviewed in this report with associated references.

Method	Reviewed by	References
Massachusetts Coastal Zone Management Method	Fennessy et al., 2004	Hicks, A. L. and B. K. Carlisle. 1998. Rapid habitat assessment of wetlands. Macro-invertebrate survey version: Brief description and methodology. Massachusetts Coastal Zone Management Wetland Assessment Program, Amherst, MA.
MNRAM - Minnesota Routine Assessment Method	Bartoldus, 1999; Fennessy et al., 2004; Fugro-McClelland East, 1993 (earlier version)	Minnesota Board of Water and Soil Resources. 2003. Minnesota Routine Assessment Method for Evaluating Wetland Functions (MNRAM) Version 3.0. Minnesota Board of Water and Soil Resources, St. Paul, MN. **Note:** Fugro-McClelland East (1993) lists the Minnesota method as WEM (similar to WET), with the following reference*:* U.S. Army Corps of Engineers. 1988. The Minnesota Wetland Evaluation Methodology for the North Central United States. U.S. Army Corps of Engineers, St. Paul District, St. Paul, MN.
Montana Wetland Assessment Method	Bartoldus, 1999; Fennessy et al., 2004	Berglund, J. 1999. Montana wetland assessment method. Montana Department of Transportation and Morrison-Maierle, Inc., Helena, MT
New Hampshire Coastal Method	Bartoldus, 1999; Fennessy et al., 2004	Cook, R.A., A.J. Lindley Stone, and A.P. Ammann. 1993. Method for the evaluation and inventory of vegetated tidal marshes in New Hampshire. Audubon Society of New Hampshire, Concord, NH.
New Hampshire/Connecticut Method	Bartoldus, 1999; Fugro-McClelland East, 1993 Fennessy et al., 2004; (lists only NH method)	Ammann, A.P. and A. Lindley Stone. 1991. Method for the comparative evaluation of nontidal wetlands in New Hampshire. NHDES-WRD-1991-3. New Hampshire Department of Environmental Services, Concord, NH. Ammann, A.P., R.W. Frazen, and J.L. Johnson. 1986. Method for the evaluation of inland wetlands in Connecticut. DEP Bulletin No. 9. Connecticut Department of Environmental Protection, Hartford, CT.
North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS)	Bartoldus, 1999	Sutter, L.A. and J.R. Wuenscher. 1996. NC-CREWS: A wetland functional assessment procedure for the North Carolina coastal area (Draft). Division of Coastal Management, North Carolina Department of Environment and Natural Resources, Raleigh, NC
North Carolina Guidance - Guidance for Rating the Values of Wetlands in North Carolina	Bartoldus, 1999	North Carolina Department of Environment and Natural Resources. 1995. Guidance for rating the values of wetlands in North Carolina. Raleigh, NC.

Table A-1 (continued). List of methods reviewed in this report with associated references.

Method	Reviewed by	References
Ohio Rapid Assessment Method (ORAM)	Fennessy et al., 2004	Mack, J.J. 2001. Ohio rapid assessment method for wetlands v. 5.0: User's Manual and Forms. Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency Division of Surface Water, Columbus, OH.
Ontario Wetland Evaluation Guide	Fugro-McClelland East, 1993	Bond, W.K., K.W. Cox, T. Heberlein, E.W. Manning, D.R. Witty, and D.A. Young. 1992. Wetland evaluation guide: Final report of the 'wetlands are not wastelands' project. Sustaining Wetlands Issues Paper No. 1992-1. North American Wetlands Conservation Council (Canada). Ottawa, Ontario.
Ontario Wetland Evaluation System	Fugro-McClelland East, 1993	Euler, D.L., F.T. Carreriro, G.B. McCullough, G.B. Snell, V. Glooschenko, and R.H. Spurr. 1983. An evaluation system for wetlands of Ontario south of the Precambrian Shield. Ontario Minstry of Natural Resources and Canadian Wildlife Service, Ontario Region. **Note:** This has apparently been superseded by**:** Ontario Ministry of Natural Resources. 1993. Ontario Wetland Evaluation System Southern Manual. NEST Technical Manual TM-002.
Oregon Freshwater Wetland Assessment Methodology (OFWAM)	Bartoldus, 1999; Fennessey et al., 2004	Roth, E., R. Olsen, P. Snow, and R. Sumner. 1996. Oregon freshwater wetland assessment methodology. Wetlands Program, Oregon Division of State Lands, Salem, OR.
Penn State Stressor Checklist	Fennessy et al., 2004	Brooks, R.P., D.H. Wardrop, and J.A. Bishop. 2002. Watershed-based protection for wetlands in Pennsylvania: Levels 1 & 2 - Synoptic maps and rapid field assessments. Report No. 2002-1. Penn State Cooperative Wetlands Center, University Park, PA.
Process for Assessing Proper Functioning Condition (PFC)	Bartoldus, 1999	Prichard, D., H. Barrett, J. Cagney, R. Clark, J. Fogg, K. Gebhart, P.L. Hansen, B. Mitchell, and D. Tippy. 1993. Riparian area management: Process for assessing proper functioning condition. TR 1737-9 (Revised 1998). Bureau of Land Management BLM/SC/ST-93/003+1737+REV95+REV98, Service Center, CO. Prichard, D., C. Bridges, R. Krapf, S. Leonard, and W. Hagenbuck. 1994. Riparian area management: Process for assessing proper functioning condition for lentic riparian-wetland areas. TR 1737-11. Bureau of Land Management, BLM/SC/ST-94/008+1737, Service Center, CO

Table A-1 (continued). List of methods reviewed in this report with associated references.

Method	Reviewed by	References
Rapid Assessment Procedure (Hollands-Magee)	Bartoldus, 1999, Fugro-McClelland East, 1993 (earlier version)	Magee, D.W. 1998. A rapid procedure for assessing wetland functional capacity. Normandeau Associates, Bedford, NH. Association of State Wetland Managers, Berne, NY. ***Note:*** The precursor to this method is listed in both Bartoldus (1999) and Fugro-McClelland East (1993) as Hollands, G.G., and D.W. Magee. 1985. A method for assessing the functions of wetlands. Pages 108-118. *In* J. Kusler and P. Riexinger (eds.), Proceedings of the National Wetland Assessment Symposium. Association of Wetland Managers, Berne, NY.
Synoptic Approach	Fugro-McClelland East, 1993; Bartoldus, 1999	Liebowitz, Scott G., B.S. Abbruzzese, P.S. Adamus, L.E. Huges, and J.T. Irish, 1992. A synoptic approach to cumulative impact methodology. EPA-600-R92-167. U.S. Environmental Protection Agency Environmental Research Laboratory, Corvallis, OR. Abbruzzese, B., and S.G. Leibowitz. 1997. A synoptic approach for assessing cumulative impacts to wetlands. Environmental Management 21(3):457-475
VIMS method	Bartoldus, 1999; Fennessy et al., 2004	Bradshaw, J.G. 1991. A technique for the functional assessment of nontidal wetlands in the Coastal Plain of Virginia. Special Report No. 315 in Applied Marine Science and Ocean Engineering. Virginia Institute of Marine Science, College of William and Mary, Gloucester Point, VA.
Washington State Wetland Rating System - Eastern	Fennessy et al., 2004	Hruby, Thomas. 2004. Washington State wetland rating system for eastern Washington. Revised and annotated version. Ecology Publication # 04-06-15. Washington State Department of Ecology, Olympia, WA.
Washington State Wetland Rating System - Western	Fennessy et al., 2004; Bartoldus, 1999 (earlier version)	Hruby, Thomas. 2004. Washington State wetland rating system for western Washington. Ecology Publication # 04-06-025. Washington State Department of Ecology, Olympia, WA. **Note:** This is listed in Bartoldus (1999) as the Washington State Wetland Function Assessment Method (Hruby, T., T. Granger, K. Brunner, S. Cooke, K. Dublanica, R. Gersib, L. Reinelt, K. Richter, D. Sheldon, A. Wald, and F. Weinmann. 1998. Methods for assessing wetland functions. Volume I: Riverine and depressional wetlands in the lowlands of Western Washington. Washington State Department of Ecology Publication #98-106, and Hruby, T. and T. Granger. 1998. Methods for assessing wetland functions. Volume II: Procedures for collecting data in the lowlands of Western Washington. Washington State Department of Ecology Publication #98-107.)

Table A-1 (continued). List of methods reviewed in this report with associated references.

Method	Reviewed by	References
WET - Wetland Evaluation Technique	Fugro-McClelland East, 1993; Bartoldus, 1999	Adamus, P. R., E. J. Clairain Jr., R. D. Smith, and R. E. Young. 1987. Wetland Evaluation Technique (WET). Volume II. Methodology. Report FHWA-IP-88-029. Federal Highway Administration, Office of Implementation. McLean, VA Adamus, P.R., L.T. Stockwell, E.J. Clairain, M.E. Morrow, L.D. Rozas, and R.D. Smith. 1991. Wetland Evaluation Technique (WET). Volume I. Literature review and evaluation rationale. Technical Report WRP-DE-2. U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.
WEThings	Bartoldus, 1999	Whitlock, A.L., N.M. Jarman, J.A. Medina, and J.S. Larson. 1994a. WEThings: Wetland Habitat Indicators for nongame species. Volume I. TEI Publication 94-1. The Environmental Institute, University of Massachusetts, Amherst, MA Whitlock, A.L., N.M. Jarman, and J.S. Larson. 1994b. WEThings: Wetland Habitat Indicators for nongame species. Volume II. TEI Publication 94-2. The Environmental Institute, University of Massachusetts, Amherst, MA.
Wetland Value Assessment (WVA)	Bartoldus, 1999	Environmental Work Group. 1998. Wetland value assessment methodology and community models. Report of the Coastal Wetlands Planning, Protection, and Restoration Act Technical Committee, U.S. Fish and Wildlife Service, Lafayette, LA Louisiana Department of Natural Resources. 1994. Habitat assessment models for fresh swamp and bottomland hardwoods within the Louisiana Coastal Zone. Louisiana Department of Natural Resources, Baton Rouge, LA.
Wildlife Community Habitat Evaluation (WCHE)	Bartoldus, 1999	Schroeder, R.L. 1996a. Wildlife community habitat evaluation: A model for deciduous palustrine forested wetlands in Maryland. Technical Report WRP-DE-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS
Wildlife Habitat Appraisal Procedure (WHAP)	Bartoldus, 1999	Frye, R. 1995. Wildlife Habitat Appraisal Procedure (WHAP). Texas Parks and Wildlife Department, Austin, TX.
Wisconsin Rapid Assessment Method (WIRAM)	Bartoldus, 1999; Fennessy et al., 2004; Fugro-McClelland East, 1993 (earlier version)	Wisconsin Department of Natural Resources. 1992. Rapid assessment methodology for evaluating wetland functional values. Wisconsin Department of Natural Resources, Madison, WI. **Note:** Fugro-McClelland East (1993) lists the Wisconsin method as WEM (similar to WET), with the following reference: US Army Corps of Engineers. 1983. Wetland evaluation methodology. Prepared for Wisconsin Department of Natural Resources, Bureau of Water Regulation and Zoning. U.S. Army Corps of Engineers, Rock Island, IL.

We eliminated some methods from the review process for various reasons:

- The New England Freshwater Wetlands Invertebrate Biomonitoring Protocol (Hicks, 1997) reviewed in Bartoldus (1999) was eliminated because it was a subset of the Index of Biological Integrity method.
- The Maine Tidal Method (Bryan et al., 1997) and the Narragansett Bay Method (Lipsky, 1997), which were listed separately in Bartoldus (1999) were eliminated because they were so similar to the New Hampshire Coastal Method.
- We eliminated the Pennsylvania Modified 1980 Habitat Evaluation Procedure (Palmer et al., 1993) and the Pennsylvania Wildlife Habitat Assessment and Management System (Palmer et al., 1993), both reviewed in Bartoldus (1999), because they were both versions of the Habitat Evaluation Procedure (HEP).
- We eliminated the Regulatory Assessment Method that was reviewed in Bartoldus (1999) but was never published. It appears to be a precursor to Kusler (2004b), which compiles recommendations for developing assessment methods.
- We also eliminated the Indicator Value Assessment (Hruby et al., 1995) that was reviewed in Bartoldus (1999) because it appears to be a tool for planning methods tool rather than an actual model.
- Since the Rapid Assessment method is an improved version of the Hollands-Magee method (Bartoldus, 1999), we did not review the Hollands-Magee method that was reviewed in both Fugro-McClelland East (1993) and Bartoldus (1999) separately.
- We eliminated the New Jersey Watershed Method (Zampella et al., 1994) reviewed in Bartoldus (1999) because it was a Level 1 demonstration project that was never used and/or revised, and the method author recommended revision prior to implementation.
- Two studies reviewed in Fugro-McClelland East (1993) were not reviewed because they did not appear to be assessment methods. The Croonquist and Brooks study (1991) that was reviewed in Fugro-McClelland East (1993) was a research project that assessed the effects of human activities on bird and mammal communities of wetlands and associated riparian areas in Pennsylvania. The Palustrine-Emergent Conceptual Model (Rosen et al., 1995: cited in the compilation as Rosen et al., 1993, but apparently never published as such) was described in Rosen et al. (1995) as a conceptual framework that could be used in the development of an assessment method for prairie potholes.

Results of Compilation Review

Results from the review of the compilations are presented in two parts. First:

1. A list of methods we reviewed sorted by assessment level with both a brief description and the associated limitations (if stated in the compilations).
2. An alphabetical tabular comparison of the wetland assessment methods from the compilations (Table A-2). This summarizes answers to the specific questions about each method.

Level 1 Methods

North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS)
Reviewed in Bartoldus, 1999
Summary: This is a GIS-based landscape level method that predicts the relative ecological significance of wetlands at the watershed level.
Limitations: Not appropriate for small projects. Does not evaluate services. No upper limit on opportunity values for functions.

Synoptic Approach
Reviewed in Fugro-McClelland East, 1993; Bartoldus, 1999
Summary: The Synoptic Approach is a Level 1 method that uses watershed maps to evaluate natural functions (habitat, water quality and hydrologic), services, functional loss, and restoration potential of wetlands in a large geographic area. Individual wetlands are not ranked.
Limitations: Cannot rate or compare individual wetlands. Months to years required to develop and complete assessment.

Level 1 Methods with Level 2 or 3 Field Assessment

Ontario Wetland Evaluation Guide (combines Level 1 with either Level 2 or 3 evaluations, depending on user needs)
Reviewed in Fugro-McClelland East, 1993
Summary: The Ontario Wetland Evaluation Guide was designed to evaluate seven functions and services in three categories: life support (regulation/absorption, ecosystem health) social/cultural (aesthetic/recreation, cultural/psychological) and production (both natural and commercial). The method involves a decision tree which includes three stages, each requiring progressively more input from the user.
Limitations: Very time consuming, especially at later stages. Functions/services are different from those used in most other wetland assessment methods.

Penn State Stressor Checklist – 2002 version (combines Level 1 and Level 2 methods)
Reviewed in Fennessy et al., 2004
Summary: The Penn State Stressor Checklist combines a Level 1 landscape assessment with a Level 2 field assessment. It is an inventory of stressors at a site with adjustments for surrounding buffer areas. According to Fennessy et al. (2004), newer versions of the method will not require a landscape level assessment.
Limitations: Does not evaluate services. Assumes wetland is in good condition unless stressors are visible, which may not account for non-point source stressors.

Process for Assessing Proper Functioning Condition (PFC) (combines Level 1 and Level 2 methods)
Reviewed in Bartoldus, 1999
Summary: The Process for Assessing Proper Functioning Condition was designed by the U.S. Bureau of Land Management in order to evaluate whether of riparian-wetland areas on BLM-managed lands are functioning properly. Proper functioning condition is defined as follows (Bartoldus, 1999): "Riparian-wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to dissipate stream energy associated with high water flows, thereby reducing erosion and improving water quality; filter sediment, capture bedload, and aid floodplain development; improve flood-water retention and ground-water recharge; develop root masses that stabilize streambanks against cutting action; develop diverse ponding, and channel characteristics to provide the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; and support greater biodiversity."
Limitations: The method is designed to assess riparian-wetland areas, not individual sites.

VIMS method (combines Level 1 and Level 2/3 methods)
Reviewed in Bartoldus, 1999; Fennessy et al., 2004
Summary: The VIMS method is primarily designed to assess wetlands on the basis of their opportunity to perform flood storage and storm flow modification, nutrient retention and transformation, sediment and toxicant trapping, sediment stabilization, wildlife

habitat, aquatic habitat, public use, and other factors. It is mainly a desktop method. The field portion requires between 4-8 hours (1/2 to 1 day).
Limitations: Opportunity is a large factor in scoring. No upper limit on opportunity values for functions. No overall score calculated for site.

WET - Wetland Evaluation Technique (combination of Level 1 and Level 3)
Reviewed in Fugro-McClelland East, 1993; Bartoldus, 1999
Summary: WET assesses habitat, hydrologic and biogeochemical functions as well as services such as recreation and uniqueness/heritage. The method involves three levels of evaluation, each requiring progressively more input from the user. WET uses "high/middle/low" ranking but no overall ranking,
Limitations: Time-consuming (according to Kusler, 2004a). May not be sensitive enough to distinguish differences between wetlands.

Level 2 Methods

Avian Richness Evaluation Method

Reviewed in: Bartoldus, 1999

Summary: This Avian Richness Evaluation Method estimates number and species of birds in wetlands and riparian areas in the Colorado Plateau area of western Colorado, eastern Utah, and southwestern Wyoming. Information can then be input into the associated computer program to determine to determine how suitable each area is for specific species habitat.

Limitations: Evaluates habitat potential only. No direct evaluation of hydrological and biogeochemical functions.

California Rapid Assessment Method (CRAM)

Reviewed in Sutula et al., 2006

Summary: The California Rapid Assessment Method evaluates landscape context, hydrology, physical structure, and biotic structure as compared to undisturbed reference wetlands in order to assess ecological condition. Wetlands are evaluated by HGM class and cannot be compared between classes. A stressor checklist is included, but is scored independently.

Limitations: Does not measure services. Requires model for each type of wetland.

Delaware Rapid Assessment Protocol

Reviewed in Fennessy et al., 2004

Summary: This is a rapid assessment method evaluates wetland condition based on the presence or absence of stressors that affect hydrology, habitat, biogeochemical cycling, and the surrounding landscape. Function is inferred based on whether stressors are present or not.

Limitations: Does not evaluate services. Assumes wetland is in good condition unless stressors are visible, which may not account for non-point source stressors.

Descriptive Approach

Reviewed in: Bartoldus, 1999

Summary: The Descriptive Approach was developed by the Corps of Engineers New England Division, and is a very rapid qualitative evaluation of the presence or absence of 13 functions and values, including ground water recharge/discharge; flood flow alteration; fish and shellfish habitat; sediment/toxicant/pathogen retention; nutrient removal, retention, and transformation; production export; sediment and shoreline stabilization; wildlife habitat; recreation; educational or scientific value; uniqueness/heritage; visual quality/aesthetics; and threatened or endangered species habitat. Functions and values are evaluated using best professional judgment. Wetlands within the region can be directly compared to each other.

Limitations: Some subjective decisions required. No upper limit on opportunity values for functions.

Evaluation for Planned Wetlands (EPW)

Reviewed in Bartoldus, 1999

Summary: The Evaluation for Planned Wetlands is a rapid procedure for evaluating function and services when comparing planned wetlands to other wetlands, but can also be used in restoration, permit review, or watershed inventor. It evaluates five functions: shoreline bank erosion control, sediment stabilization, water quality, wildlife habitat, and fish habitat; plus one service: uniqueness/heritage. It has some features of HGM but does not use a reference standard.

Limitations: Cannot directly compare wetlands from different classes (e.g., tidal vs. non-tidal, or non-tidal stream/river vs. non-tidal pond/lake.) Limited number of functions/services evaluated.

Florida Wetland Rapid Assessment Procedure

Reviewed in Bartoldus, 1999; Fennessy et al., 2004

Summary: The Florida Rapid Wetland Assessment procedure was designed to evaluate freshwater wetlands that were created, enhanced, preserved, or restored by the South Florida Water Management District. It evaluates six functions: wildlife utilization; overstory/shrub canopy of desirable species; wetland vegetative ground cover of desirable species; adjacent upland/wetland buffer; field indicators of wetland hydrology; and water quality input and treatment.

Limitations: Scores weighted towards wildlife habitat. Many variables require subjective judgment.

Massachusetts Coastal Zone Management Method

Reviewed in Fennessy et al., 2004

Summary: This is a rapid assessment method was primarily designed to evaluate macroinvertebrate habitat, but includes landscape features and stressors that would affect habitat. It results in a single score that can be used to evaluate condition.

Limitations: Stressors caused by human activities are combined into one category.

Minnesota Routine Assessment Method (MNRAM)

Reviewed in Bartoldus, 1999; Fennessy et al., 2004; Fugro-McClelland East, 1993 (earlier version)

Summary: MNRAM evaluates 12 hydrologic, biochemical and habitat functions, as well as services, relative to reference wetlands. A computer program is used to score each function.

Limitations: Can only directly compare wetlands of same type. Does not directly evaluate condition. May require GIS to answer some questions. No upper limit on opportunity values for functions.

<u>Montana Wetland Assessment Method</u>
Reviewed in Bartoldus, 1999; Fennessy et al., 2004
Summary: The Montana Wetland Assessment Method was specifically developed to find wetlands which provide unique and valuable functions or services. Evaluates 12 hydrologic, biochemical and habitat functions, and also evaluates services. It provides a single score that can represent condition.
Limitations: No upper limit on opportunity values for functions.

<u>North Carolina Guidance - Guidance for Rating the Values of Wetlands in North Carolina</u>
Reviewed in Bartoldus, 1999
Summary: The North Carolina Guidance assesses the following functions: water storage, bank and shoreline stabilization, pollutant removal, wildlife habitat. It also assesses services such as recreational and educational value. It can directly compare all freshwater wetlands.
Limitations: The method produces an overall score, but recreational/educational values are included in that score, so it does not directly assess condition. No upper limit on opportunity values for functions.

<u>Ohio Rapid Assessment Method (ORAM) - 2001 version</u>
Reviewed in Fennessy et al., 2004
Summary: ORAM is a rapid assessment method which evaluates condition by rating wetlands on habitat connectivity, average buffer width, percent of wetland with buffer, buffer condition, water sources, hydroperiod, hydrologic connectivity, physical patch types, topographic complexity, organic matter accumulation, biotic patch types, vertical structure, interspersion and zonation, native plant species richness, and percent invasive plant species. The method adds points for rare wetland types.
Limitations: None stated in compilations.

<u>Washington State Wetland Rating System – Eastern</u>
Reviewed in Fennessy et al., 2004
Summary: The Eastern version of the Washington State Wetland Rating System Method assesses wetlands for (1) functions performed and (2) special characteristics. It evaluates wetlands based on HGM type. Extra points are awarded for rare wetland types.
Limitations: Does not measure condition. Some wetlands are rated higher based on opportunity. Function score is doubled for wetlands which have the opportunity to perform a certain functions.

<u>Washington State Wetland Rating System - Western</u>
Reviewed in Fennessy et al., 2004; Bartoldus, 1999 (earlier version)
Summary: The Western version of the Washington State Wetland Rating System Method assesses wetlands based on (1) sensitivity to disturbance (2) rarity, and (3) functions performed. Extra points are awarded for rare species, rare wetland types, and "irreplaceable areas."
Limitations: Some wetlands are rated higher based on opportunity.

Wetland Value Assessment (WVA)
Reviewed in Bartoldus, 1999.
Summary: The Wetland Value Assessment method was designed to assess habitat quantity and quality in Coastal Louisiana fresh, salt, and brackish wetlands. It was adapted from HEP.
Limitations: Evaluates habitat potential only. No direct evaluation of hydrological and biogeochemical functions.

WEThings (Can be Level 2 or Level 3, depending on wetland complexity)
Reviewed in Bartoldus, 1999
Summary: WEThings is a computer program developed to evaluate wildlife habitat potential in New England wetlands for impact assessment and resource management. It Measures habitat suitability for several species of amphibians, reptiles, and mammals, and can be used with WET.
Limitations: Evaluates habitat potential for a limited number of species only. No direct evaluation of hydrological and biogeochemical functions.

Wildlife Community Habitat Evaluation (WCHE) (Can be either Level 2 or Level 3 depending on user needs)
Reviewed in Bartoldus, 1999
Summary: The Wildlife Community Habitat Evaluation was developed to evaluate wildlife habitat potential in deciduous palustrine forested wetlands in Maryland. It measures habitat suitability for birds, reptiles and amphibians and can be used with WET.
Limitations: Evaluates habitat potential only. No direct evaluation of hydrological and biogeochemical functions.

Wisconsin Rapid Assessment Method (WIRAM)
Reviewed in Bartoldus, 1999; Fennessy et al., 2004; Fugro-McClelland East, 1993 (earlier version)
Summary: WIRAM evaluates the ability of a wetland following functions and services: floral diversity; wildlife habitat; fishery habitat; flood/stormwater attenuation; water quality protection; shoreline protection; groundwater; and aesthetics/recreation/education. Sites are then rated low, medium, high, exceptional, or N/A for each function or service.
Limitations: No overall score for site. No upper limit on opportunity values for functions

Level 3 Methods

Florida Wetland Quality Index

Reviewed in Bartoldus, 1999; Fennessy et al., 2004

Summary: The Florida Wetland Quality Index was designed to evaluate wetland mitigation areas. It assesses 17 hydrologic, biogeochemical and habitat functions, but its primary focus is wildlife habitat. The method requires a year of water level data, plus 1-2 hours of field work.

Limitations: Designed for mitigation sites so might not be suitable for some natural wetlands. Scores weighted towards wildlife habitat.

Habitat Assessment Technique (HAT)

Reviewed in Fugro-McClelland East, 1993; Bartoldus, 1999

Summary: The Habitat Assessment Technique assesses bird habitat in wetlands and other areas. It requires direct species surveys with at least three visits.

Limitations: Evaluates habitat potential only. No direct evaluation of hydrological and biogeochemical functions. A model must be developed for each state.

Habitat Evaluation Procedure (HEP)

Reviewed in Fugro-McClelland East, 1993; Bartoldus, 1999

Summary: The Habitat Evaluation Procedures assesses habitat potential for wildlife, fish, invertebrates for wetlands and other landscapes based on structural features. It requires a model for each species and type of wetland being evaluated, and site visits to confirm the model. It can directly compare habitats within the range of the species being evaluated.

Limitations: Evaluates habitat potential only. No direct evaluation of hydrological and biogeochemical functions.

Hydrogeomorphic Approach (HGM)

Reviewed in Bartoldus, 1999

Summary: The Hydrogeomorphic Approach measures wetland hydrologic, biogeochemical, and habitat functional capacity by comparing wetlands within regional subclasses to reference wetlands of the same subclass.

Limitations: Complicated, time consuming, expensive. Does not directly evaluate condition because no overall score is calculated. Does not evaluate services.

Interim HGM (HGM Light)

Reviewed in Bartoldus, 1999

Summary: Interim HGM is used by the NRCS. It is based on the HGM Approach, but models are calibrated using best professional judgment and literature values rather than reference wetlands. (Note that HGM models may be developed from the Interim HGM models after they are calibrated using reference wetlands.)

Limitations:

Model development is time-consuming. Does not address services. Does not directly evaluate condition because no overall score is calculated.

Index of Biological Integrity (IBI)
Reviewed in Bartoldus, 1999
Summary: The Index of Biological Integrity evaluates biological condition using data on plant and animal habitat and hydrology. Sites with various levels of disturbance are compared to a reference site, and then indicator species are used to assess condition.
Limitations: Time consuming and expensive. Difficult to create index that is accurate in every season/year. Cannot directly compare different habitats within a region or similar habitats across regions. Biological integrity does not necessarily relate to other functions and services such as flood storage, etc.

Larson-Golet Method
Reviewed in Fugro-McClelland East, 1993; Bartoldus, 1999
Summary: The Larson-Golet method was one of the first relatively rapid assessment methods. It assesses wildlife, groundwater potential and visual/cultural value. It was used to develop several newer assessment methods.
Limitations: Measures only a limited number of functions or services. Some of the assumptions that the method is based on are outdated

New Hampshire Coastal Method
Reviewed in Bartoldus, 1999; Fennessy et al., 2004
Summary: The New Hampshire Coastal Method evaluates hydrologic, biogeochemical, and habitat functions, and several services. According to Fennessy et al., 2004, this method does not directly evaluate condition. However, it does provide a score for ecological integrity, which we feel is equivalent to condition.
Limitations: Time-consuming (according to Kusler, 2004a). Does not provide overall score for each wetland.

New Hampshire/Connecticut Methods
Reviewed in Bartoldus, 1999; Fennessy et al., 2004; Fugro-McClelland East, 1993
Summary: The New Hampshire and Connecticut methods are very similar, with slight regional adjustments for each method. Both methods assess hydrologic, biogeochemical, and habitat functions, plus services. Evaluation of both functions and services results in a numerical score output that can be used to compare wetlands.
Limitations: Time-consuming (according to Kusler, 2004a). No upper limit on opportunity values for functions. Uses ordinal values in mathematical calculations.

Ontario Wetland Evaluation System
Reviewed in Fugro-McClelland East, 1993
Summary: The Ontario Wetland Evaluation System addresses hydrologic, biogeochemical, and habitat functions, along with services such as recreation, aesthetics, educational value, etc. It is similar to the Rapid Assessment (improved Hollands-Magee) method.
Limitations: Depends on expertise of users so can be biased. Time consuming. Uses ordinal values in mathematical calculations.

Oregon Freshwater Wetland Assessment Methodology (OFWAM)
Reviewed in Bartoldus, 1999; Fennessy et al., 2004
Summary: OFWAM evaluates 9 functions and services: wildlife habitat; fish habitat; water quality; hydrologic control; sensitivity to impact; enhancement potential; education; recreation; and aesthetic quality. It allows for increased scores for wetlands performing preferred functions or services.
Limitations: Time-consuming (according to Kusler, 2004a). Some questions are not clearly defined. May result in higher scores for larger or wetter wetlands. No upper limit on opportunity values for functions.

Rapid Assessment Procedure (improved Hollands-Magee)
Reviewed in Bartoldus, 1999, Fugro-McClelland East, 1993 (earlier version)
Summary: The Rapid Assessment Procedure is an improved version of the Hollands-Magee method. It is both (1) a specific assessment procedure for assessing functions in wetlands in glaciated areas of the U.S. Northeast and Midwest and (2) a template for developing procedures for other areas. The method measures both functions and services with numerical ranking. It has some features of HGM but does not use a reference standard. Despite the name of the method, it is not rapid since model development can take weeks (Bartoldus, 1999).
Limitations: Depends on expertise of users so can be biased. Time consuming, and requires expertise in geology/hydrology/botany/ecology. Uses ordinal values in mathematical calculations.

Wildlife Habitat Appraisal Procedure (WHAP)
Reviewed in Bartoldus, 1999
Summary: The Wildlife Habitat Appraisal Procedure is a procedure for assessing wildlife habitat in wetlands, bottomlands, and uplands in Texas. It evaluates vegetative cover and other habitat elements as well as protected/endangered species.
Limitations: Evaluates habitat potential only. No direct evaluation of hydrological and biogeochemical functions.

Tabular Comparison of Assessment Methods Reviewed in Compilations

Table A-2. Comparison of wetland assessment methods from compilations.

Method	**Compilation**	**Which categories of functions are evaluated?**	**Are services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Level 1, 2, or 3?**	**Region in which method was developed**	**Can it be used in other areas?**	**How long does it take (either in field or in office)?**
Avian Richness Evaluation Method	Bartoldus, 1999	Bird habitat	No	No	Yes	Level 2	Colorado Plateau	Not as is	2 hours in field after wetland delineation plus additional time for plus data entry
California Rapid Assessment Method (CRAM)	Sutula et al., 2006	Hydrologic, biogeochemical, habitat	No	Yes	Wetlands can only be compared within regional subclasses	Level 2	California	Not as is	2.1 ± 0.9 hours (for two people)
Delaware Rapid Assessment Protocol	Fennessy et al., 2004	Effects of stressors on hydrologic, biogeochemical, habitat functions	No	Yes	No, because scoring is different for different subclasses	Level 2	Delaware	Not as is	<1/2 day
Descriptive Approach	Bartoldus, 1999	Hydrologic, biogeochemical, habitat	Yes	No	Yes	Level 2	New England	Not as is	2 hours per 1 acre site
Evaluation for Planned Wetlands (EPW)	Bartoldus, 1999	Hydrologic, biogeochemical, habitat	Yes	No	Can only compare wetlands of same general type (tidal, non-tidal stream/river, non-tidal pond/lake)	Level 2	National method	National method	1 hour per 1 acre site in field plus variable amounts of office time.

Table A-2 (continued). Comparison of wetland assessment methods from compilations.

Method	**Compilation**	**Which categories of functions are evaluated?**	**Are services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Level 1, 2, or 3?**	**Region in which method was developed**	**Can it be used in other areas?**	**How long does it take (either in field or in office)?**
Florida Wetland Quality Index	Bartoldus, 1999; Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	No	No	Yes, but only within the Everglades	Level 3	Florida Everglades	Not as is	1 day in field, but requires 1 year of water level data
Florida Wetland Rapid Assessment Procedure	Bartoldus, 1999; Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	No	Yes	No	Level 2	Freshwater wetlands in Florida	Not as is	<1 day
Habitat Assessment Technique (HAT)	Fugro-McClelland East, 1993; Bartoldus, 1999	Bird habitat	No	No	Yes	Level 3 after model development	National method	Models must be developed for each state	Requires at least 3 visits of 1 hour per 1 acre site after breeding bird numbers for state are compiled.
Habitat Evaluation Procedure (HEP)	Fugro-McClelland East, 1993 (HEP only); Bartoldus, 1999	Wildlife habitat	No	No	Yes	Level 3 after model development (possibly Level 2 if site is very simple)	National method	Models must be developed for each species	1 day or more for 1 acre site.
Hydrogeomorphic Approach (HGM)	Bartoldus, 1999	Hydrologic, biogeochemical, habitat	No	No	Wetlands can only be compared within regional subclasses	Level 3, according to U.S. EPA (2006)	National method	Models must be developed for each regional subclass	2 months or more to develop model, then 1-2 hours per 1 acre site for assessment.

Table A-2 (continued). Comparison of wetland assessment methods from compilations.

Method	**Compilation**	**Which categories of functions are evaluated?**	**Are services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Level 1, 2, or 3?**	**Region in which method was developed**	**Can it be used in other areas?**	**How long does it take (either in field or in office)?**
Interim HGM (HGM Light)	Bartoldus, 1999	Hydrologic, biogeochemical, habitat	No	No	Wetlands can only be compared within regional subclasses	Level 3, according to U.S. EPA (2006)	National method	Models must be developed for each regional subclass	1 month or more to develop model, then 1-2 hours per 1 acre site for assessment.
Index of Biological Integrity (IBI)	Bartoldus, 1999	Biological condition	No	Yes	Wetlands can only be compared if they are similar habitat types within the same geographic region.	Level 3	National method	Model must be developed for each state	2 months or more to develop model, then 4 hours field and 4 hours lab per site.
Larson-Golet Method	Fugro-McClelland East, 1993; Bartoldus, 1999	Wildlife habitat, groundwater potential	"Visual-cultural" only	No	Yes	Level 3	Freshwater non-tidal wetlands in glaciated Northeast U.S.	Not as is	9-18 hours
Massachusetts Coastal Zone Management Method	Fennessy et al., 2004	Designed to evaluate macroinvertebrate habitat	No	Yes	Method has two versions - tidal and non-tidal: wetlands cannot be compared across versions.	Level 2	Tidal and non-tidal wetlands in Massachusetts	Not as is	1/2 day

Table A-2 (continued). Comparison of wetland assessment methods from compilations.

Method	**Compilation**	**Which categories of functions are evaluated?**	**Are services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Level 1, 2, or 3?**	**Region in which method was developed**	**Can it be used in other areas?**	**How long does it take (either in field or in office)?**
Minnesota Routine Assessment Method (MNRAM)	Bartoldus, 1999; Fennessy et al., 2004; Fugro-McClelland East, 1993 (earlier version)	Hydrologic, biogeochemical, habitat	Yes	No	No	Level 2	Freshwater wetlands in Minnesota	Not as is	1/2 day
Montana Wetland Assessment Method	Bartoldus, 1999; Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	Yes	Yes	Yes	Level 2	Freshwater wetlands in Montana	Not as is. Parts of this method were used to develop CRAM.	1/2 day
New Hampshire Coastal Method	Bartoldus, 1999; Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	Yes	Yes - as ecological integrity.	Tidal wetlands only	Level 3	Tidal wetlands in New Hampshire	Not as is. Has been adapted for use in Maine and Rhode Island	More than 1 day
New Hampshire/ Connecticut method	Bartoldus, 1999; Fugro-McClelland East, 1993; Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	Yes	Possibly, if adapted to area	Possibly, if adapted to area	Level 3	Non-tidal wetlands in New Hampshire and Connecticut	Not as is. Used as a template for OFWAM method; portions were adapted for VIMS method.	More than 1 day

Table A-2 (continued). Comparison of wetland assessment methods from compilations.

Method	**Compilation**	**Which categories of functions are evaluated?**	**Are services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Level 1, 2, or 3?**	**Region in which method was developed**	**Can it be used in other areas?**	**How long does it take (either in field or in office)?**
North Carolina Coastal Region Evaluation of Wetland Significance (NC-CREWS)	Bartoldus, 1999	Hydrologic, biogeochemical, habitat - on landscape level.	No	Yes - as overall ecological significance	Yes	Level 1	Tidal and non-tidal wetlands in coastal North Carolina	Not as is	Approx. 3-9 days per watershed
North Carolina Guidance (Guidance for Rating the Values of Wetlands in North Carolina	Bartoldus, 1999	Hydrologic, biogeochemical, habitat	Yes	No	Yes (freshwater only)	Level 2	Freshwater wetlands in North Carolina	Not as is	Approx. 1 hour per 1 acre site in field.
Ohio Rapid Assessment Method (ORAM)	Fennessy et al., 2004	Hydrologic, habitat	Extra points are awarded for rare wetland types.	Yes	Yes	Level 2	Ohio	Not as is. Parts of this method were used to develop CRAM.	1/2 day
Ontario Wetland Evaluation Guide	Fugro-McClelland East, 1993	Hydrologic, biogeochemical, habitat	Yes	Unclear	Unclear	Level 1, 2, or 3 depending on user needs	Ontario	Possibly in glaciated areas of the U.S. if adapted	Not directly stated, but appears to be more than 1 day.
Ontario Wetland Evaluation System	Fugro-McClelland East, 1993	Hydrologic, biogeochemical, habitat	Yes	Unclear	Yes	Level 3	Ontario	Not as is	"Hours to days" (Adamus, 1992)

Table A-2 (continued). Comparison of wetland assessment methods from compilations.

Method	Compilation	Which categories of functions are evaluated?	Are services evaluated?	Is condition evaluated directly?	Can method compare wetlands of different classes/types?	Level 1, 2, or 3?	Region in which method was developed	Can it be used in other areas?	How long does it take (either in field or in office)?
Oregon Freshwater Wetland Assessment Methodology (OFWAM)	Bartoldus, 1999; Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	Yes	No	Yes	Level 3	Freshwater wetlands in Oregon	Not as is. Parts of this method were used to develop ORAM.	More than 1 day
Penn State Stressor Checklist	Fennessy et al., 2004	Effects of stressors on hydrologic, biogeochemical, habitat functions	No	Yes	Yes	Combination of Level 1 and Level 2	Freshwater wetlands in Pennsylvania	Not as is. Parts of this method were used to develop CRAM.	More than 1/2 day
Process for Assessing Proper Functioning Condition	Bartoldus, 1999	Hydrologic, biogeochemical, habitat	No	Yes	Yes, but within riparian-wetland areas only.	Combination of Level 1 and Level 2	Riparian-wetland areas managed by U.S. BLM	Yes, but some portions will require regional adaptation.	Approx. 8-24 hours for each study area
Rapid Assessment Procedure (Hollands-Magee)	Bartoldus, 1999, Fugro-McClelland East, 1993 (earlier version)	Hydrologic, biogeochemical, habitat	Yes - depending on regional model.	No	No. Can only directly compare wetland from the same regional class.	Level 3 (including model development)	Glaciated Northeast and Midwest U.S.	Yes, if adapted. This method was used to develop the MDE method.	Weeks for model development, then 1-2 hours/site
Synoptic Approach	Fugro-McClelland East, 1993; Bartoldus, 1999	Hydrologic, biogeochemical, habitat	Yes	Unclear	Can only compare geographic areas - not individual wetlands.	Level 1	National method	National method	Several months per geographic area

Table A-2 (continued). Comparison of wetland assessment methods from compilations.

Method	**Compilation**	**Which categories of functions are evaluated?**	**Are services evaluated?**	**Is condition evaluated directly?**	**Can method compare wetlands of different classes/types?**	**Level 1, 2, or 3?**	**Region in which method was developed**	**Can it be used in other areas?**	**How long does it take (either in field or in office)?**
VIMS Method	Bartoldus, 1999; Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	Yes	No	Yes	Combination of Level 1 and Levels 2/3	Virginia Coastal Plain	Not as is	Over 1 day
Washington State Wetland Rating System - Eastern	Fennessy et al., 2004	Hydrologic, biogeochemical, habitat	Extra points are awarded for rare wetland types.	No	No. Wetlands can only be compared by HGM class.	Level 2	Eastern Washington State	Not as is	1/2 day
Washington State Wetland Rating System - Western	Fennessy et al., 2004; Bartoldus, 1999 (earlier version)	Hydrologic, habitat	Extra points are awarded for rare species, rare wetland types, etc.	Yes	Yes	Level 2	Western Washington State	Not as is	1/2 day
WET: Wetland Evaluation Technique	Fugro-McClelland East, 1993; Bartoldus, 1999	Hydrologic, biogeochemical, habitat	Yes	No	Yes	Combination of Level 1 and Level 3	National method	Yes, if adapted. This method was used to develop part of the VIMS method.	Approx. 14-42 hours.
WEThings	Bartoldus, 1999	Habitat	No	No	Yes	Level 2 or 3 - depending on wetland complexity	New England	Possibly, if similar species are present.	1-2 hours per wildlife cover type.

Table A-2 (continued). Comparison of wetland assessment methods from compilations.

Method	Compilation	Which categories of functions are evaluated?	Are services evaluated?	Is condition evaluated directly?	Can method compare wetlands of different classes/types?	Level 1, 2, or 3?	Region in which method was developed	Can it be used in other areas?	How long does it take (either in field or in office)?
Wetland Value Assessment (WVA)	Bartoldus, 1999	Habitat	No	No	No, except for restoration projects	Level 2	Coastal Louisiana	Not as is	1 hour per 1 acre site.
Wildlife Community Habitat Evaluation (WCHE)	Bartoldus, 1999	Habitat	No	No	Can only compare deciduous palustrine forested wetlands within Maryland.	Level 2 or 3 depending on user needs	Maryland	Not as is	Variable depending on user needs
Wildlife Habitat Appraisal Procedure (WHAP)	Bartoldus, 1999	Habitat	No	No	Yes	Level 3	Texas	Not as is	8 hours per study area
Wisconsin Rapid Assessment Method (WIRAM)	Bartoldus, 1999; Fennessy et al., 2004; Fugro-McClelland East, 1993 (earlier version)	Hydrologic, biogeochemical, habitat	Yes	No	Yes	Level 2	Wisconsin	Not as is. Was used to develop MNRAM.	1/2 day

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