United States Environmental Protection Agency

Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-metric Approach

Part B. Ecological Integrity Assessment Protocols for Rapid Field Methods (L2)

EPA/600/R-12/021b
June 2012
www.epa.gov

EPA/600/R-12/021b
June 2012
www.epa.gov

Assessment of Wetland Ecosystem Condition across Landscape Regions: A Multi-metric Approach

Part B. Ecological Integrity Assessment Protocols for Rapid Field Methods (L2)

Don Faber-Langendoen[1], Joe Rocchio[2], Steve Thomas[3], Mike Kost[3], Cloyce Hedge[4], Bill Nichols[5], Kathleen Strakosch Walz[6], Gwen Kittel[1], Shannon Menard[1], Jim Drake[1], and Esteban Muldavin[7]

[1]NatureServe, Conservation Science Division, 4600 N. Fairfax Dr., 7th floor, Arlington, VA 22203

[2] Washington Dept. of Natural Resources, Natural Heritage Program, Olympia WA 98504

[3] Michigan Natural Features Inventory, Michigan State University-Extension, P.O. Box 30444, Lansing, MI 48909

[4] Indiana Natural Heritage Program, Division of Nature Preserves, Department of Natural Resources. 402 West Washington, Rm. W267, Indianapolis, IN 46204

[5] NH Natural Heritage Bureau, Division of Forests & Lands – DRED, PO Box 1856,172 Pembroke Road Concord, NH 03302

[6] Natural Heritage Program, NJDEP MC 501-04, Office of Natural Lands Management. 501 E. State Street, 4th Floor. Trenton, NJ 08625

[7] Natural Heritage Program, New Mexico Division, Museum of Southwestern Biology, Department of Biology, MSC03 2020, 1 University of New Mexico, Albuquerque, NM 87131

U.S. Environmental Protection Agency
Office of Research and Development
Washington, DC 20460

Notice

The United States Environmental Protection Agency (EPA) through its Office of Research and Development funded and managed the research described here via a grant (#R-83377501). It has been reviewed by the EPA and approved for publication.

Foreword

EPA's Environmental Monitoring and Assessment Program (EMAP) is a research program to develop the tools necessary to monitor and assess the status and trends of national ecological resources over broad spatial and temporal scales. Regional EMAP (REMAP) is a partnership between the EPA Regional Offices and EPA's Office of Research and Development (ORD), with the goal of building state and tribal capacity for using statistically valid monitoring data for reporting on the condition of their aquatic resources. ORD works with the Regional Offices to provide funds for projects meeting EMAP criteria that are of importance to the needs within the region. In the REMAP 2007 funding announcement, one of the identified priority focus areas was the "Development and testing of protocols and/or the monitoring and assessment of wetlands in the Region 5 states using a stratified, statistically-valid sample survey design that will allow extrapolation of wetland conditions throughout ecological regions of the Midwest". Under a competitive process, a Cooperative Agreement (R-83377501) was awarded to NatureServe for the proposal they submitted to this focus area. .

This report describes the results of NatureServe's project "Assessment of Wetland Ecosystem Conditions across Landscape Regions – a Multi-metric Approach". The project was conducted in partnership with the Natural Heritage programs of Indiana and Michigan, and included assessment of ~360 wetland sites in those two states. Main elements of the project include examining the suitability of existing spatial datasets and classification systems as the basis for sampling design, developing and assessing metrics for various aspects of wetland condition, and synthesizing the results into an ecological integrity scoring system.

Anett Trebitz (Mid-Continent Ecology Division, Duluth MN), was the EPA Project Officer, providing administrative oversight and technical input and reviews. Other individuals at EPA who provided input or reviews included Sue Elston (Region 5, Chicago IL), Peter Jackson (Region 5, Chicago IL), Mike Scozzafava (Office of Wetlands, Washington DC), and Rich Sumner (Regional liaison for the National Wetlands Program, Corvallis OR). Jo Thompson (REMAP Coordinator, Mid-Continent Ecology Division, Duluth MN) facilitated the funding announcement and selection process and David Ack (Grants Management Division, Washington DC) was the grant specialist for the project.

EPA's Mid-Continent Ecology Division is publishing this report to make these findings more widely available, given their potential significance for EPA's new National Wetlands Condition Assessment, as well as for state or tribal agencies involved in assessments of their wetland resources.

Carl Richards,
Director,
EPA, Office of Research and Development, Mid-Continent Ecology Division

This document is the 2nd of a two part publication.

PART A:

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2012a. *Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part A. Ecological Integrity Assessment overview and field study in Michigan and Indiana.* EPA/600/R-12/021a. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

PART B (this publication):

Faber-Langendoen, D., J. Rocchio, S. Thomas, M. Kost, C. Hedge, B. Nichols, K. Walz, G. Kittel, S. Menard, J. Drake, and E. Muldavin. 2012b. *Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part B. Ecological Integrity Assessment protocols for rapid field methods (L2).* EPA/600/R-12/021b. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Here, in part B of this publication, we are publishing the latest version (version 3.0) of our Ecological Integrity Assessment. See Faber-Langendoen et al. (2012a, Appendix C) for a summary of the various versions. This is an improved version that reflects the results of our Michigan and Indiana study, and has been upgraded for both style and content. The authors of this publication include not only the co-investigators of the Michigan and Indiana study, but also the authors that contributed in substantial ways to the protocols.

ACKNOWLEDGEMENTS

Developing the overall NatureServe methodology for ecological integrity assessments has been a team effort over many years. The protocols presented here were developed through a series of studies, as summarized by Faber-Langendoen et al. (2008, 2011), and through more recent collaboration with Kathleen Walz on a New Jersey wetland assessment (Walz and Domber 2011). These protocols, in turn, drew from NatureServe's Ecological Integrity Assessment Working Group between 2004 and 2007. Members consisted of NatureServe and Network member program staff, including Don Faber-Langendoen and Pat Comer (co-chairs), and David Braun, Elizabeth Byers, John Christy, Greg Kudray, Gwen Kittel, Shannon Menard, Esteban Muldavin, Milo Pyne, Carl Nordman, Joe Rocchio, Mike Schafale, Lesley Sneddon, and Linda Vance. The overall framework for the methodology has been summarized by Unnasch et al. (2009).

Many aspects of the protocols presented here were funded through Cooperative Agreement No. RM-83377501 awarded by the U.S. Environmental Protection Agency (EPA). Although EPA made comments and suggestions on the document, the views expressed are those of NatureServe. EPA does not endorse any products or commercial services mentioned in this publication. We are grateful for support from staff of the EPA, including the project management provided by Anett Trebitz, and ongoing support from Rich Sumner and Mike Scozzafava for their support, and for peer review comments from Rich Sumner, Peter Jackson, and Sue Elston.

We thank Kristin Snow and Mary Harkness for their critical database support for the protocols provided here. They helped design and implement the Ecological Observations database, which houses all information collected using this methodology. In turn, that database can be linked to NatureServe's Biotics databases used by Natural Heritage Programs, who track the many high quality wetlands found across the country.

TABLE OF CONTENTS

NOTICE .... *II*
FOREWORD .... *III*
ACKNOWLEDGEMENTS V
INTRODUCTION 1
INTRODUCTION TO ECOLOGICAL INTEGRITY ASSESSMENT METHODS *1*
- Conceptual Model for Assessing Integrity of Ecosystems 2
- Major Factors: Landscape Context, Size, and Condition 2
- Indicators at Multiple Scales 3
- Rating Ecological Integrity 5

LEVEL 2 ECOLOGICAL INTEGRITY ASSESSMENT METHOD *6*
- Level 2 Metrics 6
- Level 2 Stressor Checklist 6
- Assessment Area (AA) 7
- Field Methods Guidance 8

WETLAND CLASSIFICATION AND LEVEL 2 ASSESSMENTS *8*
VARIATIONS ON THE LEVEL 2 ASSESSMENT *9*
- More Rapid vs. Less Rapid 9
- Assessing Ecosystem Services and Functions 11

OVERVIEW OF WETLAND METRICS *12*
- Main Metrics 12
- Supplemental Metrics 14
- Metric Description Format 15

PROTOCOLS FOR ECOLOGICAL INTEGRITY METRICS 16
LANDSCAPE *16*
- 1. Landscape Connectivity 16
- 2. Land Use Index 21

BUFFER *25*
- 3. Buffer Index 25

SIZE *31*
- 4. Absolute Patch Size 31
- 5. Relative Patch Size 35

VEGETATION *37*
- 6. Vegetation Structure 37
- 7. Woody Regeneration 43
- 8. Native Plant Species Cover 45
- 9. Invasive Plant Species Cover 47
- 10. Vegetation Composition 49

HYDROLOGY *52*

- 11. Water Source 52
- 12. Hydroperiod 56
- 13. Hydrologic Connectivity...61

SOIL / SUBSTRATE...*65*

- 14. Physical Patch Types...65
- 15. Soil Surface Condition 67

STRESSOR CHECKLIST 70

GUIDELINES FOR COMPLETING THE STRESSOR CHECKLIST...*70*

STRESSOR CHECKLIST FORM *72*

GUIDANCE ON COMPLETING THE STRESSOR CHECKLIST FORM...*75*

REFERENCES 78

APPENDIX 1. TEMPLATE FOR METRICS PROTOCOLS..*86*

APPENDIX 2. FIELD METHODS..*87*

- Introduction 87
- Defining the Assessment Area..87
- Guidelines for Field Methods for Ecological Integrity Assessments..............................88

APPENDIX 3. VEGETATION PLOTS *93*

- Plot Size and Design 93
- Plot Data 94

APPENDIX 4. DESCRIPTIONS OF MAJOR WETLAND FORMATIONS IN THE USNVC. *97*

APPENDIX 5. DESCRIPTIONS OF HYDROGEOMORPHIC CLASSES. *101*

INTRODUCTION

Introduction to Ecological Integrity Assessment Methods

Building on the related concepts of biological integrity and ecological health, ecological integrity is a broad and useful endpoint for ecological assessment and reporting (Harwell et al. 1999). Ecological integrity assessments can be defined as "an assessment of the degree to which, under current conditions, an occurrence of an ecosystem matches reference conditions for structure, composition, and function, operating within the bounds of natural or historic disturbance regimes, and is of exemplary size" (adapted from Lindenmayer and Franklin 2002, Parrish et al. 2003). "Integrity" is the quality of being unimpaired, sound, or complete. To have integrity, an ecosystem should be relatively unimpaired across a range of characteristics and spatial and temporal scales. This broad definition can serve as a guide to developing assessment methods, steering us through the related assessment methods for ecological functions and ecosystem services (Jacobs et al. 2010, USFWS 2010).

Our Ecological Integrity Assessment (EIA) method builds on the work of other rapid assessment methods. Methods prior to 2006 are reviewed by Fennessy et al. (2007); more recent methods include the California Rapid Assessment Method or CRAM (Collins et al. 2006, 2007) and USA RAM 2011). Our approach provides a national and international approach that is comprehensive for all wetlands and it is based on ecological integrity concepts, which can be effectively assessed using a suite of rapid assessment metrics, structured around our general ecological model. Although some of our metrics require greater expertise than others, all attributes have at least two metrics that can be evaluated in a relatively straightforward manner, allowing for wide applicability. This wetland EIA is also one part of a larger suite of EIAs for forests, grasslands, etc., that NatureServe and the Natural Heritage Network are developing, and which are being developed for multiple levels of assessment, from remote sensing based (Level 1) assessments to intensive field-based methods (Level 3) (see Faber-Langendoen et al. 2012; http://www1.dnr.wa.gov/nhp/refdesk/communities/eia_list.html). Together, they allow us to assess the entire set of ecosystems across landscapes and watersheds. The EIA methods can also be integrated with a watershed approach to provide an integrated "wetland and watershed" perspective on conservation and restoration goals (Kittel and Faber-Langendoen 2011).

Here, we briefly summarize the overall approach to the development of EIAs, with a focus on Level 2 EIA methods (often referred to as rapid assessment methods or RAMs), but our main purpose is to provide the current metric protocols for Level 2 EIAs of wetlands. A companion document provides a full overview of the EIA method along with a field study in Indiana and Michigan based on the method (Faber-Langendoen et al. 2012). A previous version of that study (Faber-Langendoen et al. 2011) contains the original metric protocols.

- **Conceptual Model for Assessing Integrity of Ecosystems**

Identifying the ecological attributes that need to be assessed involves building a conceptual ecological model of ecological integrity. This model rests on the knowledge of a wetland or upland system, its setting, and similar or associated systems. The result is a set of hypotheses about how the system functions, its defining characteristics and dynamics, and critical environmental conditions and disturbance regimes that may act as drivers of these characteristics and dynamics. These hypotheses both guide management and monitoring, and highlight gaps in knowledge that require additional investigations (Unnasch et al. 2009).

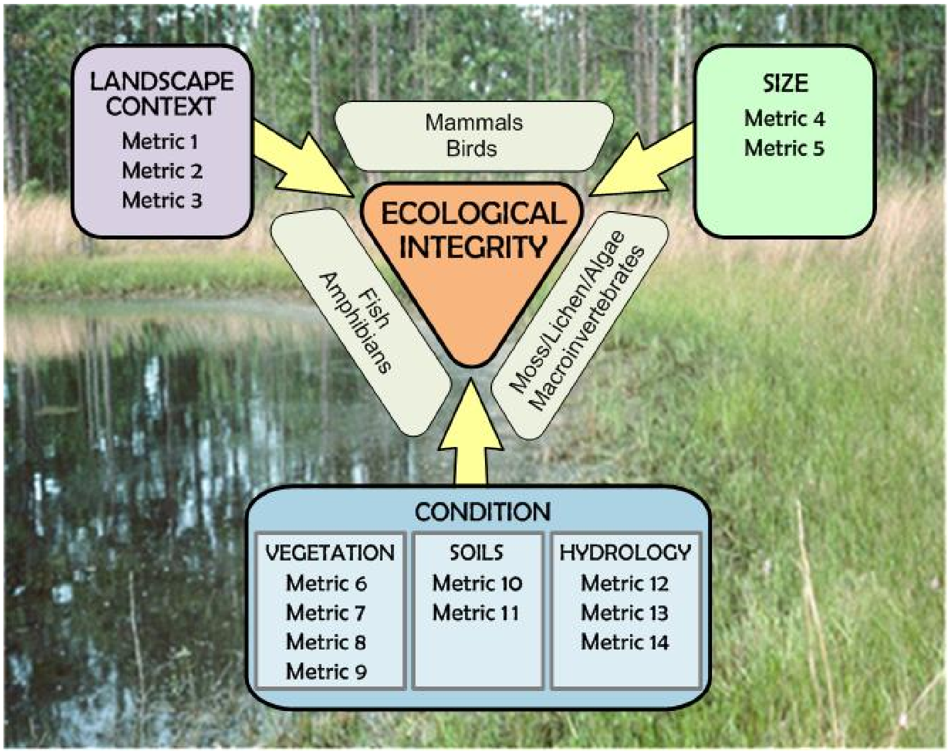
We use a conceptual ecological model that provides a general set of ecological factors common to all terrestrial systems, and then encourage identification of individual key ecological attributes for individual system types. The model also provides a means to correlate stressors or agents of change to the ecological factors (Noon 2003). The terms come from a variety of models available in the literature (e.g., Harwell et al. 1999, Parrish et al. 2003), and our own work (Faber-Langendoen 2009, Faber-Langendoen et al. 2011).

- **Major Factors: Landscape Context, Size, and Condition**

The major components of the model include three primary factors (landscape context, size, and (on-site) condition, subdivided by six major ecological factors of landscape, buffer, size, vegetation, hydrology, and soils. Together these are the components that capture the structure, composition, and processes of a system (Figure I.1). Other major attributes, such as algae, birds, amphibians, and macroinvertebrates, can also be assessed where resources, time, and field sampling design permit. The model can be refined, as needed, based on increasing specificity of ecosystem types, as described by various wetland classifications (e.g., U.S. National Vegetation Classification [FGDC 2008], system classifications from Natural Heritage Programs, National Wetland Inventory [Cowardin et al. 1979], or Hydrogeomorphic classification[Smith et al. 1995]). The model can also be expanded to include more specific key ecological attributes of individual wetland types (e.g., the vegetation factor can be refined into "plant assemblage composition" and "vegetation structure" attributes to ensure that metrics address each of these attributes (Parrish et al. 2003, Unnasch et al. 2009).

The model is fairly intuitive, but a key component is that, to describe how a system "works," one must include both the "inner workings" (condition) and the "outer workings" (landscape context). A third primary factor, the size of an ecosystem patch or occurrence, helps to characterize patterns of diversity, area-dependent species, and resistance to stressors. Addressing all of these characteristics and processes will contribute not only to understanding the current levels of ecological integrity but to the resilience of the ecosystem in the face of climate change and other global causes of stress.

Figure I.1. Example of a conceptual model for Ecological Integrity Assessments of Terrestrial Systems. The three primary factors (landscape context, size, and (on-site) condition) and six major ecological factors (landscape, buffer, size, vegetation, hydrology, and soils of ecological integrity are shown for wetlands and uplands. The model can be expanded to include additional measures of biotic Integrity, such as birds, amphibians, macroinvertebrates, or algae.



- **Indicators at Multiple Scales**

The selection of specific indicators, or metrics, to assess ecological integrity can be executed at three levels of intensity depending on the purpose and design of the data collection effort (Brooks et al. 2004, Tiner 2004, U.S. EPA 2006). This "3-level approach" to assessments allows the flexibility to develop data for many sites that cannot readily be visited or intensively studied, permits more widespread assessment, while still allowing for detailed monitoring data at selected sites.

To ensure that the 3-level approach is consistent across levels in how ecological integrity is assessed, a standard framework or conceptual model for choosing metrics should be used, as described above (Figure I.1). Using this model, metrics are identified that address the three primary factors (landscape context, size, and condition), and six major ecological factors (landscape, buffer, size, vegetation, soils and hydrology).

Level 1 Remote Assessments rely on Geographic Information Systems (GIS) and remote sensing data to obtain information about landscape condition and stressors in and around an occurrence. They can also help assess the distribution and abundance of ecological types in the landscape or watershed. **Level 2 Rapid Assessments** use relatively simple field metrics for collecting data on specific occurrences, and will often require considerable professional judgment. Our approach emphasizes a condition-based rapid assessment, supplemented by information on stressors that may be affecting condition. **Level 3 Intensive Assessments** require more rigorous, field-based methods that provide higher-resolution information on the wetland occurring within an assessment area, often employing quantitative plot-based assessment procedures coupled with a sampling design. Calculations of calibrated indices, such as a vegetation or aquatic based Index of Biological Integrity (IBI), or a Floristic Quality Index (FQI) may also be used (Mack and Kentula2010). This 3-level approach to assessments, summarized in Table I.1, allows for the flexibility of developing data on many occurrences that cannot readily be visited or intensively studied as well as those for which detailed information is desirable. When coupled with standardized procedures for defining occurrences across the landscape, it encourages a widespread application of ecological integrity assessments based on a reasonable and cost-effective approach for programmatic or project needs.

Table I.1. Summary of 3-level approach to conducting ecological integrity assessments (adapted from Brooks et al. 2004, U.S. EPA 2006).

Level 1 – Remote Assessment	Level 2 – Rapid Assessment	Level 3 – Intensive Assessment
General description: Imagery or GIS based assessment of landscapes	**General description:** Rapid site integrity assessment	**General description:** Quantitative site integrity assessment
Evaluates: Integrity of both on and off-site conditions around individual sites/occurrences using • Indicators within occurrences that are visible with remote sensing data • Indicators in the surrounding landscape / watershed	**Evaluates:** Integrity of individual areas/occurrences using relatively simple field indicators • Very rapid assessment (narrative) • Rapid assessment (standard metrics) • Hybrid assessments (rapid + vegetation plot)	**Evaluates:** Integrity of individual areas/occurrences using relatively detailed quantitative field indicators • Choice of metrics may vary, depending on whether they are applied for assessment or monitoring, or both
Based on: • GIS and remote sensing data • Layers typically include: – Land cover, land use, other ecological types • Stressor metrics (e.g., roads and land use)	**Based on:** • On-site condition metrics (e.g., vegetation, hydrology, and soils) • Stressor metrics (e.g., ditching, road crossings, and pollutant inputs)	**Based on:** • On-site condition metrics (e.g., vegetation, hydrology, and soils) • Indicators that have been calibrated to measure responses of the ecological system to disturbances (e.g., indices of biotic or ecological integrity)
Potential uses: • Identifies priority sites • Identifies status and trends of acreages across the landscape • Identifies condition of ecological types across the landscape • Informs targeted restoration and monitoring	**Potential uses:** • Relatively inexpensive field observations across many sites • Informs monitoring for implementation of restoration, mitigation, or management projects • Landscape / watershed planning • General conservation and management planning	**Potential uses:** • Detailed field observations, with repeatable measurements, and statistical sampling design • Identifies status and trends of specific occurrences or indicators • Informs monitoring for restoration, mitigation, and management projects

The 3-level approach is intended to provide increasing accuracy of ecological integrity assessment, recognizing that not all conservation and management decisions need equal levels of accuracy. We discuss all three levels in detail in Faber-Langendoen et al. (2012). Here, we focus on Level 2 rapid assessments.

- **Rating Ecological Integrity**

The choice of individual indicators and their contribution to overall assessments of ecological integrity depends on having a conceptual understanding of integrity. Earlier we stated that ecological integrity assessments can be defined as "an assessment of the degree to which, under current conditions, an occurrence of an ecosystem matches reference conditions for structure, composition, and function, operating within the bounds of natural or historic disturbance regimes, and is of exemplary size." We can expand that definition by providing a narrative set of guidelines on the kinds of structural, compositional, and ecological functions (or processes) that are core to the assessment. Using a scorecard approach (where A = excellent integrity and D = poor integrity), we can define an A-rated example as an…

> "…Occurrence believed to be, across the range of a type, among the highest quality examples with respect to key ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include 1) the landscape context contains natural habitats that are essentially unfragmented (reflective of intact ecological processes) and with little to no stressors; 2) the size is very large or much larger than the minimum dynamic area; 3) vegetation structure and composition, soil status, and hydrological function are well within natural ranges of variation, exotics (non-natives) are essentially absent or have negligible negative impact; and 4) a comprehensive set of key plant and animal indicators are present." (Faber-Langendoen et al. 2012).

A full set of definitions for A – D ratings is provided in Faber-Langendoen et al. (2012). These ratings help guide the recognition of reference wetlands, from reference standards (A-ranked wetlands) to degraded (D-ranked wetlands). Assignment of a rating presumes that a particular type is still recognizable at some level as "the type," despite varying levels of degradation. At some point, a degraded type will "cross the line" (or be "transformed," *sensu* SER 2004) into a separate, typically semi-natural or cultural type. In some state-and-transition models, these examples may be treated as shifts to an "alternative state." As a matter of practicality, the current ecosystem under transformed conditions is considered lost. Using a scorecard approach requires working with a set of diagnostic classification criteria, based on composition, structure, and habitat (see "Wetland Classification and Level 2 Assessments" below) to distinguish "transformed" ecosystem states from degraded conditions of a particular ecosystem type.

A scorecard approach depends on a consistent scaling of the indicators or metrics, such that their ratings are comparable with respect to levels of integrity. It is then reasonable to summarize the metric ratings and roll them into aggregate scores, including an overall Index of

Ecological Integrity, based on a weight of evidence approach (Linkov et al. 2009). Details of the scorecard are provided in Faber-Langendoen et al. (2012).

LEVEL 2 ECOLOGICAL INTEGRITY ASSESSMENT METHOD

Level 2 Metrics

The intent of ecological integrity based rapid assessment methods (RAMs) is to evaluate the complex ecological condition of a selected ecosystem using a specific set of observable field indicators, and to express the relative integrity of a particular occurrence in a manner that informs decision-making, whether for restoration, mitigation, conservation planning, or other ecosystem management goals (Stein et al. 2009). These Level 2 assessments are structured tools combining scientific understanding of ecosystem structure, composition, and processes with best professional judgment in a consistent, systematic, and repeatable manner (Sutula et al. 2006).

Metrics that are chosen should provide information on the integrity or sustainability of the major ecological factors and their relationship to associated stressors (this is sometimes described as the metrics showing a “stressor-dose response” to changes in stressor levels). Sensitivity analyses can be conducted to ensure that metrics are informative (e.g., by assessing how metrics respond to a gradient of stressor levels) (Rocchio 2007; Lemly and Rocchio 2009, Jacobs et al. 2010; Faber-Langendoen et al. 2011, 2012).

Level 2 assessments rely primarily on relatively rapid (ca. 2–4 hours) field-based site visits, but this may vary, depending on the purposes of the assessment. They provide the opportunity to do direct, ground based surveys of ecosystem occurrences. RAMs are widely available for wetlands because of the need for mitigation and restoration tools, and they are used by many state wetland programs (Fennessy et al. 2007). Typically three to five metrics are identified for each of the ecological factors, with each metric designed to assess a major ecological factor or attribute.

Level 2 Stressor Checklist

Stressor checklist can be useful as additional information when evaluating the ecological integrity of an occurrence (Sutula et al. 2006). Typically, they are an aid to further understanding the factors that affect the overall condition of the wetland. The term “stressor” is defined as “the proximate (human) activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity and natural processes” (from Salafsky et al. 2008). Here we restrict our focus to those stressors that have caused, or are causing impacts whenever the effects of the stressors are evident (we exclude potential future threats). For example, a direct stressor may be recent tree removal or mowing. Less recent mowing or tree removal would be included only if the effect of those stressors is still currently evident (e.g., old tree stumps). The term is synonymous with ”direct threats” as defined by Salafsky et al. (2008) or with “stressors” as used by the U.S. EPA (Young and Sanzone 2002).

Stressors may be characterized in terms of scope and severity (Master et al. 2012). **Scope** is defined as the proportion of the occurrence of an ecosystem that is currently affected by the stressor, including stressors that may have occurred in the past, but the effect is still currently evident (e.g., past logging that has removed all large trees from a stand, resulting in a current small tree structure). Within the scope (as defined spatially and temporally in assessing the scope of the stressor**), severity** is the level of damage to the ecosystem from the stressor, based on existing evidence (using a 10 year window).. Severity is typically assessed by known or inferred degree of degradation or decline in integrity to specific major ecological attributes, such as the buffer, vegetation, soils, and hydrology.

Standardized checklists of stressors have been developed for a variety of rapid assessment methods (Collins et al. 2006, Faber-Langendoen 2009, Faber-Langendoen et al. 2011). They can be used to create field-based versions of stressor indices. For example, the Human Stressor Index of Rocchio (2007) integrates stressor scores for hydrology, soils, and buffer.

- **Assessment Area (AA)**

The protocols for EIAs are conducted within an Assessment Area (AA), defined by a wetland type with relatively broadly homogeneous biotic and abiotic composition and structure (see "Wetland Classification and Level 2 Assessments" below), and in the buffer and surrounding landscape. These assessment areas can be defined as points, polygons, or patches. A point-based approach typically defines a relatively small area (e.g., 0.5 ha) around a point, within and around which the assessment is conducted. A polygon approach defines a specific ecosystem area that is delineated (using vector or raster methods) to create a mapped area. Pixel (or raster) based approaches, such as from satellites, are perhaps intermediate between points and polygons. Pixels are often smoothed into larger "patches," these patches can be assigned to ecosystem types, and analyses can be performed on these patches. Or these patches can be further aggregated into clusters (e.g., using separation distances between patches, comparable to clustering polygons or patches or as "bounded patches," where a larger landscape or watershed boundary is used, and all patches of the same ecosystem type within that boundary are included as part of the assessment area). The "bounded patch" approach is currently being used by NatureServe to conduct ecological integrity assessments in western U.S. ecoregions (NatureServe 2012, in prep).

For Level 2 assessments, AAs are typically placed within a patch or cluster of patches of a wetland type. As these patches get larger in area, at some point they will exceed the area that is reasonable to survey as part of a rapid assessment. We recommend that Level 2 assessments should be limited to areas less than 20 ha. If the wetland patch or series of patches is larger, and the goal is to establish a rating for the patch or series of patches, then a decision will need to be made as to whether the ratings within the AA can be extrapolated to the larger patch or whether multiple AAs are needed.

The choice of AA affects the area included in the surrounding buffer and landscape assessment (Table 2). With a small, fixed area (e.g., 50 m radius AA), and fixed distances from the AA edge, the buffer area being assessed is 6 ha, and the supporting landscape is 67 ha. With a variable AA, and the same fixed distances from the AA edge, the area of the buffer and landscape assessed depends on the size and shape of AA polygon that is being surveyed (as stated above, we recommend a maximum size of 20 ha for the AA, in order to keep the field work reasonable). Potential variation in total area assessed is between 92 and 330 ha (Table I.2). See "Landscape Connectivity" metric for more details.

Table I.2. Fixed point versus Variable Polygon Assessment Areas (AA) and the changing area of buffer, core and supporting landscape. Minimum AA size is 0.5 ha (5000 m^2); maximum size is 20 ha (200,000 m^2).

METRIC & DISTANCE		FIXED (Point) AA AREA	VARIABLE (Polygon) AA AREA		
AA and METRIC	**Total Distance From Outer Edge Of AA**	**FIXED AA (e.g. 40 m radius circle)**	**Compact Circular (e.g. 40m to 252m radius)**	**Narrow Rectangular (e.g. 10 x 500m to 100 x 2000m)**	**Irregular (see Figure 2.1)**
Assessment Area (ha)		0.5 ha	0.5 - 20 ha	0.5 - 20 ha	0.5 - 20 ha
Buffer	0-100 m	6 ha	6 - 19 ha	14 - 46 ha	shape dependent
Core Landscape	100-250 m	20 ha	20 - 40 ha	36 - 84 ha	shape dependent
Supporting Landscape	250-500 m	65 ha	65 - 98 ha	100 - 180 ha	shape dependent
TOTAL AREA = AA + Buffer + Core & Supporting Landscape		92 ha	92 - 178 ha	152 -330 ha	92-330 ha

- **Field Methods Guidance**

Field methods for applying ecological integrity assessments vary, depending on the purpose of the assessment. We provide general guidance on field methods in Appendix 2.

Wetland Classification and Level 2 Assessments

The success of developing indicators of wetland ecological integrity depends on an understanding of the structure, composition, and processes that govern the wide variety of wetland systems. Ecological classifications can be helpful tools in categorizing this variety. These classifications help wetland managers to better understand natural variability within and among types so that differences between occurrences with good integrity and poor integrity can be more clearly recognized.

We integrate three main classifications into our Level 2 assessments:

- **U.S. National Vegetation Classification (NVC)** (FGDC 2008, Faber-Langendoen et al. 2009a, Jennings et al. 2009).
- **National Wetlands Inventory (NWI)** (Cowardin et al. 1979).
- **Hydrogeomorphic (HGM) classification** (Smith et al. 1995).

A summary of these classifications is provided in Faber-Langendoen et al. (2008, 2011, 2012). Our goal is to apply the classification categories to the degree that they are needed for improving the rapid assessment of ecological integrity. For some metrics (e.g., Invasive Plant Species Cover), we do not require any wetland classification information – the same metric is used for all wetland types. For others, such as Vegetation Structure and Hydrologic Connectivity, the metric varies depending on the wetland type, either by NVC Formation/NWI Class or by HGM class (Table I.3). The NVC Formation level is similar to the NWI Class level, but the formations incorporate key wetland ecological factors reflected in the vegetation. HGM defines classes based on hydrology and geomorphology. Thus it adds an important dimension to the other classifications, but doesn't integrate vegetation with the abiotic factors. A brief description of NVC Formation categories is provided in Appendix 4 and HGM classes in Appendix 5.

Variations on the Level 2 Assessment

▪ More Rapid vs. Less Rapid

We have described what may be called the "Level 2 – standard method." It is worth noting several variants of the Level 2 EIA assessment methods may appeal to different needs. First, there is the "very rapid method," in which, the attributes themselves serve as the general indicators, and field crews complete a structured narrative evaluation of those attributes. This approach has been widely used by the Natural Heritage Network, beginning with the work of White (1978) in Illinois. In this approach, field crews may record observations on the vegetation, soils, and hydrology, and then rate the on-site condition against a general narrative of grades. For example:

> Grade A: Relatively stable or undisturbed communities. — Ideally, a Grade A community has a structure and composition that has reached stability and does not show the effects of disturbance by humans. However, this grade does include a range of conditions: the community may be gradually changing, or it may have been lightly disturbed. Examples: (1) old growth, ungrazed forest, (2) prairie with undisturbed soil and natural plant species composition, (3) wetland with unpolluted water, unaltered water level, and natural vegetation (White 1978, Appendix 22).

While not preferred, it has been a valuable approach for professional ecologists, well-experienced in the range of variation in wetland conditions and degradation, and who need to provide rapid evaluations of many sites. But because it is based on professional judgment, the ratings should be well-documented.

Table I.3. The inter-relationships among three main wetland classifications: NVC, NWI, and HGM.

NVC-NWI-HGM Wetland Classification Crosswalk Table*								
Vegetation Classification		**Hydrogeomorphic Classification**						
		RIVERINE	**DEPRESSION**	**SLOPE[1]**	**MINERAL SOIL FLATS**	**ORGANIC SOIL FLATS**	**ESTUARINE FRINGE[2]**	**LACUSTRINE FRINGE**
NVC FORMATION[4]	**NWI CLASS**	**Palustrine:** *Riverine*	**Palustrine**	**Palustrine**	**Palustrine**	**Palustrine**	**Estuarine:** *Intertidal; Riverine*	**Lacustrine:** *Littoral*
FLOODED & SWAMP FOREST *(Tropical, Temperate, Boreal)*	**Forested (FO)**	PFO	PFO	PFO	PFO	PFO	E2FO	PFO
MANGROVE		-	-	-	-	-	E2FO	-
FRESHWATER MARSH, WET MEADOW & SHRUBLAND *(Tropical, Temperate, Boreal)*	**Scrub-Shrub (SS)**	PSS	PSS	PSS	PSS	PSS	R1SS	PSS
	Emergent (EM)	PEM	PEM	PEM	PEM	PEM	R1EM	PEM
SALT MARSH	**Scrub-Shrub (SS)**	-		-	-	-	E2SS	-
	Emergent (EM)	-	PEM[3]	-	-	-	E2EM	-
BOG & FEN*(Tropical, Temperate, Boreal)*	**Moss-Lichen (ML)**	-	PML, PEM, PSS	PML, PEM, PSS	-	PML, PEM, PSS	-	-
AQUATIC VEGETATION *(Freshwater, Saltwater)*	**Aquatic Bed (AB)**	R1AB	PAB	-	-	-	E2AB	L2AB

* NVC = National Vegetation Classification (FGDC 2008, Faber-Langendoen et al. 2009, Jennings et al. 2009)

* NWI = National Wetland Inventory (Cowardin et al. 1979)

* HGM = Hydrogeomorphic Classification (Smith et al. 1995, NRCS 2008)

[1]Includes groundwater slope/riverine or "sliverine" wetlands (e.g., streamside fens/savannas) and freshwater wetlands on the coast with some tidal influence (e.g., sea level fens)

[2]Includes salt, brackish, oligohaline, and freshwater tidal wetlands

[3]Inland haline marsh

[4] NWI - NVC classification crosswalk details may differ with respect to strata (e.g., NWI tree cover cutoff for PFO is 30% whereas NVC tree cover is 10%; NWI treats sapling stages as Scrub-Shrub whereas in NVC they are treated as part of the Flooded & Swamp Forest)

A second variant may be referred to as the “enhanced rapid method,” in which more quantitatively based Level 2 metrics or a few select level 3 indicators, are added to a Level 2 assessment, because it is important for the goals of the project to better understand some key attributes. A common addition is that of a vegetation plot, or some type of standardized plant species list for an occurrence, referred to as a level 2.5 assessment by Nichols and Faber-Langendoen (2012). The plot may be set up and data collected more or less rapidly (see Appendix 3 for information on vegetation plot sampling). These data can provide sufficient composition information for Level 3 VIBIs or FQIs, or more detailed information on vegetation structure (e.g., old growth or coarse woody debris ratings in forests). As long as the added metrics are guided by the overall conceptual model, there should be little difficulty in producing comparable results to other RAMs.

▪ Assessing Ecosystem Services and Functions

Assessing ecosystem services addresses aspects of wetlands that address human needs (the term “functional assessment” has also been used, but functions can refer broadly to ecological functions in general or to those ecosystem functions that address specific human needs). Ecosystem services include 1) surface water detention, 2) streamflow maintenance, 3) nutrient transformation, 4) sediment and particulate retention, 5) carbon sequestration, 6) shoreline stabilization, 7) coastal storm surge detention, 8) provision of various fish and bird and other animal habitats, etc. To assess these services requires additional models and metrics not discussed here, such as using various landscape, landform and hydrologic attributes in conjunction with HGM classes to predict levels of various ecosystem services (see Tiner 2003, Faber-Langendoen et al. 2008, USFWS 2010). The metrics overlap to some degree with that of the EIA method. We caution that a wetland may be in excellent condition but may not be rated highly for any given ecosystem service. Conversely, a wetland in poor ecological condition may still provide valuable ecosystem services. For example, floodplain forests with high ecological integrity have a range in capacity for providing flood control services; these forests could also be modified to increase those services, but depending on the modification, this may or may not maintain their level of integrity.

OVERVIEW OF WETLAND METRICS

- **Main Metrics**

The standard set of rapid assessment metrics for wetlands is provided in Table I.4. NatureServe, working especially with EPA and state partners, developed these indicators as part of a standard Level 2 Ecological Integrity Assessment method for all wetlands in the U.S. (Faber-Langendoen et al. 2008, Faber-Langendoen 2009). Some metrics have variants for certain ecosystem types (using NVC Formations and Macrogroups) or hydrogeomorphic types (using HGM classes).. Variants are described in the "Protocols" section. Eight of the metrics (1, 3, 5, 8, 9, 11, and 13 and 16) could be considered "basic" metrics; that is, they are based on readily accessible and repeatable office and field information. Other metrics require greater levels of information or expertise to apply. See next section for supplemental metrics. Our approach is straightforward: for each metric, we list the kinds of classification units, either NVC Formation or HGM class, that are needed to more accurately assess wetland condition (Table I.5). This is a work in progress and some metric variants require further testing and refinement.

Table I.4. The standard set of wetland metrics based on the conceptual model of ecological integrity (see Figure I.1). Eight metrics have variants based on particular wetland types (NVC Formation or groupings of HGM Classes) (e.g., tidal vs. non-tidal and riverine vs. non-riverine). Additional details on the metric variants are provided in Table I.5.

RANK FACTOR	ECOLOGICAL FACTOR	METRIC NAME	METRIC VARIANTS	METRIC: NVC or HGM
LANDSCAPE CONTEXT	LANDSCAPE	1. Connectivity (Core, Supporting)		
		2. Land Use Index (Core, Supporting)		
	BUFFER	3. Buffer Index Percent of AA Having Buffer Average Buffer Width Buffer Condition		
SIZE	SIZE	4. Relative Patch Size (ha)		
		5. Absolute Patch Size (ha)	Y	
CONDITION	VEGETATION	6. Vegetation Structure	Y[2]	NVC
		7. Woody Regeneration	(Y)[1]	NVC
		8. Native Plant Species Cover		
		9. Invasive Plant Species Cover		
		10. Vegetation Composition	(Y)[2]	NVC
	HYDROLOGY	11. Water Source	Y	HGM
		12. Hydroperiod	Y	HGM
		13. Hydrologic Connectivity	Y	HGM
	SOIL	14. Physical Patch Types	Y	NVC
		15. Soil Condition		HGM & NVC

[1]Metric is specific to a wetland type (e.g., metric 3 is only used for tidal wetlands), but has no actual variants.
[2]Metric currently has no variants, but is best applied when wetlands are classified at more specific levels (e.g., assessing alterations to vegetation composition is improved using NatureServe System or NVC Group types, rather than at the higher NVC Formation level.

Table I.5. Metric Variants Based on HGM and NVC Classification.

NVC-based Variants

<table>
<tr><th>METRIC</th><th>VEGETATION</th><th>VEGETATION</th><th>VEGETATION</th><th>SOILS</th><th>SOILS</th></tr>
<tr><td>Metric Variant by NVC Formation Type</td><td>7. Vegetation Structure</td><td>8. Woody Regeneration</td><td>11. Vegetation Composition</td><td>15. Physical Patch Types</td><td>16. Soil Surface Condition</td></tr>
<tr><td>FLOODED & SWAMP FOREST</td><td>v1</td><td rowspan="5">v1</td><td rowspan="6">v1*</td><td>v1</td><td>v1</td></tr>
<tr><td>MANGROVE</td><td>v2</td><td>v2</td><td>v2</td></tr>
<tr><td>FRESHWATER MARSH, WET MEADOW & SHRUBLAND</td><td>v3</td><td>v3</td><td>v1</td></tr>
<tr><td>SALT MARSH</td><td>v4</td><td>v3</td><td>v2</td></tr>
<tr><td>BOG & FEN</td><td>v5</td><td>v4</td><td>v2</td></tr>
<tr><td>AQUATIC VEGETATION</td><td>v3</td><td>--</td><td>v5</td><td>v2</td></tr>
</table>

* Metric can be refined at the Macrogroup or Group level of the NVC, or using Ecological Systems.

HGM-based Variants

METRIC	HYDROLOGY	HYDROLOGY	HYDROLOGY
Metric Variant by HGM Class	**12. Water Source**	**13. Hydroperiod**	**14. Hydrologic Connectivity**
Estuarine (Tidal)	v1	v1	v1
Riverine (Non-tidal)	v2	v2	v2
Organic Soil Flats, Mineral Soil Flats	--	v3	v3
Other HGM (Depression, Lacustrine, Slope)	v3	v4	v4

▪ Supplemental Metrics

Although the EIA L2 method covers the basic metrics needed to assess ecological condition, supplemental metrics may be developed for particular wetland types or systems in a specific study, state or region. Customizing the EIA with additional metrics is encouraged as long as the core metrics are not replaced. In addition, it is very important to consider the weighting of the supplemental metrics in the ecological integrity assessment ratings.

For example, using a Floristic Quality Index developed for a particular state or region may be needed to supplement the Level 2 vegetation metric data for wetland mitigation evaluation. While FQI is normally a Level 3 metric, it can be used to augment Level 2 assessments (Rocchio 2007, Lemly et al. 2011). Another example is a supplemental metric for landscape connectivity to evaluate the barriers to landward migration (BLM) of tidal marshes (Jacobs et al. 2010). This connectivity metric would serve to evaluate the ability of a tidal marsh to move inland in the face of sea level rise.

- ### Metric Description Format

All metrics are described using a standard format (see Text Box below). A full explanation of the template is provided in Appendix A.

Text Box. Template for Metric Description

Metric Name:

Definition:

Background:

Metric Type:

Tier:

Rationale for Selection of the Variable:

Measurement Protocol:

Metric Rating:

Metric Rating	***Metric Name & Wetland Type(s) to which it applies***
EXCELLENT (A)	Metric Rating Description
GOOD (B)	Metric Rating Description
FAIR (C)	Metric Rating Description
POOR (D)	Metric Rating Description

Data for Metric Rating:

Scaling Rationale:

Confidence that reasonable logic and/or data support the metric:

PROTOCOLS FOR ECOLOGICAL INTEGRITY METRICS

LANDSCAPE

▪ 1. Landscape Connectivity

Definition: A measure of connectivity assessed using the percent of natural habitat in the surrounding landscape beyond the 100 m buffer, based on an additional 150 m width for the core landscape and an additional 250 m width for the supporting landscape.

Background: This metric addresses the broader landscape beyond the immediate buffer. It addresses ecological dynamics and species that depend on the larger landscape.

Metric Type: Condition.

Tier: 1 (remote sensing).

Rationale for Selection of the Variable: The intensity of human activity in the landscape often has a proportionate impact on the ecological processes of natural systems. The percentage of cultural land use (e.g., agricultural and developed urban/suburban patches) within the surrounding landscape provides an indirect estimate of connectivity among natural ecological systems. Landscapes that retain more connectivity among patches of otherwise isolated wetlands, and therefore have higher levels of connectivity, are assumed to be more likely to maintain populations of various species that inhabit the natural patch. Studies have shown that lack of landscape connectivity reduces pollination and seed dispersal, animal movements, ecological processes, and ultimately genetic diversity (Lindenmayer and Fischer 2006).

The integrity of the landscape context of wetlands can be important to certain biota. Amphibians and reptiles are especially sensitive to the matrix of habitats surrounding a wetland because they spend the majority of their lives foraging, resting, and hibernating in the adjacent terrestrial habitat (Semlitsch 1998). Upland habitats immediately surrounding wetlands serve as important dispersal corridors and are also used as foraging and aestivation areas for many amphibian species (Semlitsch 1998). Total unaltered area around the wetland also seems to be an important landscape component in the maintenance of wetland fauna. Guerry and Hunter (2002) found that wood frogs, green frogs, eastern newts, spotted salamanders, and salamanders of the blue-spotted/Jefferson's complex (*Ambystoma laterale*/*A. jeffersonianum*) were more likely to occupy ponds in unaltered landscapes (i.e., intact forested areas).

In riverine habitats, the floodplain landscape typically comprises a continuous corridor of intact natural vegetation along the stream channel and floodplain. These corridors allow uninterrupted movement of animals to up- and down-stream portions of the riparian zone as well as access to adjacent uplands (Gregory et al. 1991). These corridors also allow for unimpeded movement of surface and overbank flow, which are critical for the distribution of sediments and nutrients as well as recharging local alluvial aquifers. Fragmentation of the riverine corridor can occur as a result of human alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development.

Tests of the Landscape Connectivity metric in conjunction with the Land Use Index metric found a high level of correlation (redundancy), suggesting that perhaps both are not needed (Faber-Langendoen et al. 2011). Landscape Connectivity is a simpler metric to apply. However, the tests were done in a fairly homogeneous region of land uses, and further tests should be conducted across a wider range of land use types.

This metric is sufficient for both Level 1 and many Level 2 assessments, where it is not practical to conduct field surveys in the surrounding landscape. But this metric could be refined by incorporating the idea that some cultural land use types having greater or less degrees of connectivity to natural ecosystems.

Measurement Protocol: The Landscape Connectivity metric is measured by estimating connectivity based on a fixed distance from the edge of the buffer that surrounds the assessment area (AA) (see "Buffer Index," where buffer width is set at 100 m from edge of AA). The core landscape area is set at 100-250 m and the supporting landscape from 250-500 m. The metric is fairly simple, treating the landscape in a binary fashion: all land cover categories are assigned to either a natural or cultural category (see McIntyre and Hobbs 1999). The assessment should be completed in the office using remote sensing imagery, such as aerial photographs or satellite imagery, then, where feasible, verified in the field, at readily accessible points.

The metric could be measured by defining the landscape area based on the watershed or catchment landscape area, rather than the more general landscape area used here, which could include areas outside the watershed. Testing is needed to determine how sensitive the ratings may be to this approach.

Metric Rating:

Table 1.1. Landscape Connectivity Metric Rating.

Metric Rating	***Landscape Connectivity: ALL WETLANDS***
EXCELLENT (A)	Intact: Embedded in 90-100% natural habitat around AA.
GOOD (B)	Variegated: Embedded in 60-90% natural habitat.
FAIR (C)	Fragmented: Embedded in 20-60% natural habitat.
POOR (D)	Relictual: Embedded in <20% natural habitat.

Data for Metric Rating: See McIntyre and Hobbs (1999); also see Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: Less fragmentation increases connectivity between natural ecological systems and thus allow for natural exchange of species, nutrients, and water. The categorical ratings are based on McIntyre and Hobbs (1999). Their scaling rationale is summarized in Table 1.2.

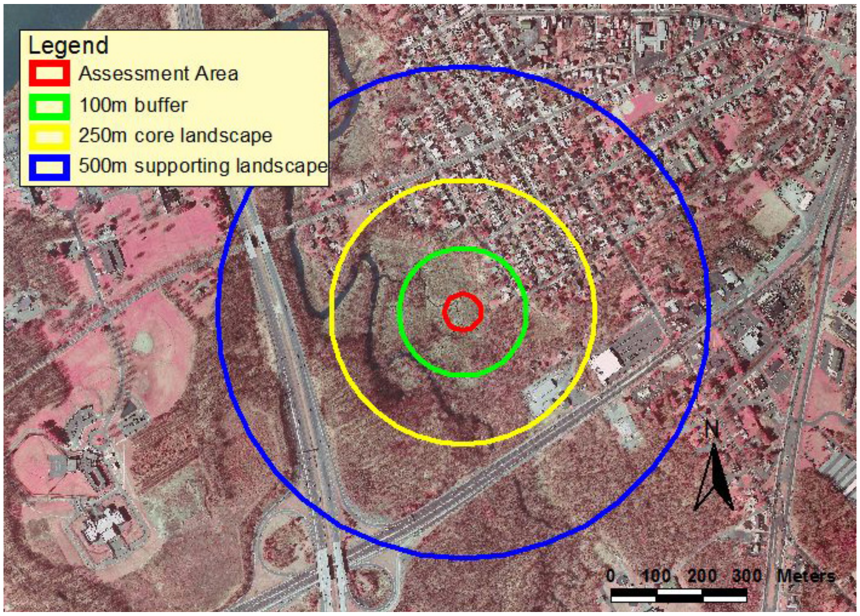
Table 1.2. Landscape Connectivity Scaling Rationale.

Metric Rating	***Landscape Connectivity: Scaling Rationale***
EXCELLENT	Connectivity is expected to be high; remaining natural habitat is in good condition (low modification); and a mosaic with gradients.
GOOD	Connectivity is generally high, but lower for species sensitive to habitat modification; remaining natural habitat with low to high modification and a mosaic that may have both gradients and abrupt boundaries.
FAIR	Connectivity is generally low, but varies with mobility of species and arrangement on landscape; remaining natural habitat with low to high modifications and gradients shortened.
POOR	Connectivity is essentially absent; remaining natural habitat generally highly modified and generally uniform.

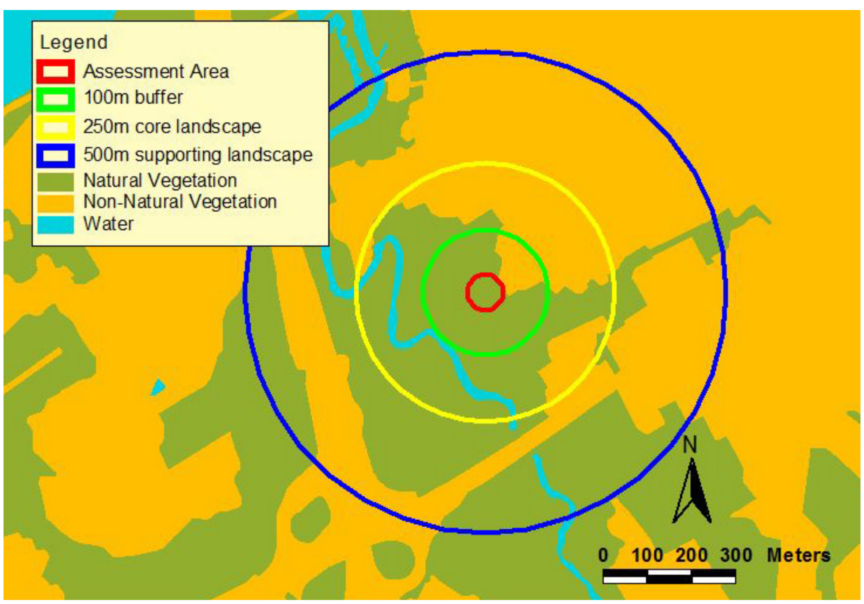
In addition, the Heinz Center (2002) used <10% non-forest as a measure of unfragmented forest (core = 100%; interior=90-99%), and between 10-40% as “connected” forest. The data on which these breakpoints were established needs to be investigated, and depends on whether the forest patches are expected to occur in relatively continuous blocks or naturally occurred in patches (e.g., in prairie or steppe landscapes). The Heinz Center is also investigating the use of a fragmentation index that takes into account roads that occur within the surrounding landscape (Cavender-Bares, pers. comm. 2005).

Confidence that reasonable logic and/or data support the metric: Medium/High.

Example:



A)



B)

Figure 1.1. Landscape Connectivity evaluation based on percent natural vegetation. A) Raw imagery and B) interpreted natural vegetation versus cultural land cover, with concentric rings for buffer (100 m radius), core landscape (100 - 250 m radius) and supporting landscape (250-500 m radius). The percent natural vegetation within the core and the supporting landscapes determines the Landscape Connectivity rating. In this example, the Core Landscape has an B rating, and the Supporting Landscape has a C rating (see Table 1.1)

▪ 2. Land Use Index

Definition: This metric measures the intensity of human dominated land uses in the surrounding landscape beyond the 100 m buffer, based on an additional 150 m with for the core landscape and an additional 250 m width for the supporting landscape.

Background: This metric is one aspect of the landscape context of specific stands or polygons of ecosystems and is based on Hauer et al. (2002) and Mack (2006)..

Metric Type: Stressor

Tier: 1 (remote sensing).

Rationale for Selection of the Variable: The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural ecosystems. Assessing land use incorporates both the aspect of "habitat destruction" and "habitat modification" (sensu McIntyre and Hobbs 1999), at least for the non-natural habitats. That is, in addition to the effect of converting natural habitat to agricultural, urban and other land use modifications, there is the additional aspect of the intensity of that land use. Human land uses often directly or indirectly alter many natural ecological processes.

Tests of this metric in conjunction with the Landscape Connectivity metric found a high level of correlation (redundancy), suggesting that perhaps both are not needed (Faber-Langendoen et al. 2011). Landscape Connectivity is a simpler metric to apply. However, the tests were done in a fairly homogeneous region of land uses, and further tests should be conducted across a wider range of land use types.

Measurement Protocol: The Land Use Index metric is measured by documenting the surrounding land use(s) within the core and supporting landscape areas. The assessment should be completed in the office using remote sensing imagery, such as aerial photographs or satellite imagery, then, where feasible, verified in the field, using roads or transects to verify land use categories. Ideally, both field data as well as remote sensing tools are used to identify an accurate percent of each land use within the landscape area, but remote sensing data alone can be used.

The metric could be measured by defining the landscape area based on the watershed or catchment landscape area, rather than the more general landscape area used here, which could include areas outside the watershed. Testing is needed to determine how sensitive the ratings may be to this approach.

To calculate a Total Land Use Score, estimate the percent of each Land Use type and then assign the corresponding coefficient (Table 2.1) into the following equation:

Sub-land use score = $\sum LU \times PC/100$

LU = Land Use Score for Land Use Type
PC = % of adjacent area in Land Use Type

Do this for each land use separately within 100 - 250 m core landscape area, and the 250 - 500 m supporting landscape area, then sum Sub-Land Use Score to arrive at a Total Land Use Score for both Core Landscape and Supporting Landscape. For example, if 30% of the Core Landscape area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 60% was a natural area (e.g., no human land use) (1.0 * 0.6 = 0.6), the Total Core Landscape Land Use Score = 0.79 (0.18 + 0.01 + 0.60). The score can then be rated using Table 2.2 (i.e., C or Fair) and combined with the Supporting Landscape Score (with core weighted 2x that of supporting) (Table2.1).

Table 2.1. Current Land Use and Corresponding Land Use Coefficients, modified from Table 21 in Hauer et al. (2002).

Surrounding Land Use Index: Worksheet : Land Use Categories	**Coefficient**	**Core Landscape**		**Supporting L.**	
		% Area	**Score**	**% Area**	**Score**
Paved roads / parking lots	0.00				
Domestic, commercial, or publicly developed buildings and facilities (non-vegetated)	0.00				
Gravel pit / quarry / open pit / strip mining	0.00				
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)	0.10				
Agriculture (tilled crop production)	0.20				
Intensively developed vegetation (golf courses, lawns, etc.)	0.20				
Vegetation conversion (chaining, cabling, roto-chopping, clearcut)	0.30				
Intense recreation (ATV use / camping / popular fishing spot, etc.)	0.40				
Military training areas (armor, mechanized)	0.40				
Heavy grazing by livestock on pastures or native rangeland	0.40				
Agriculture /permanent crop (vineyard, orchard, nursery, hayed pasture, etc.)	0.40				
Logging or tree removal (50-75% of trees >50 cm dbh removed)	0.50				
Commercial tree plantations / holiday tree farms	0.50				
Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species	0.50				
Moderate grazing of native grassland	0.60				
Moderate recreation (high-use trail)	0.70				
Mature old fields and other fallow lands with natural composition	0.70				
Selective logging or tree removal (<50% of trees >50 cm dbh removed)	0.80				
Light grazing or haying of native rangeland	0.90				
Light recreation (low-use trail)	0.90				
Natural area / land managed for native vegetation	1.00				
A ≥95%, B = 80-94%, C = 40 -79%, D = <40%	**Total Land Use Score**	-		-	
	Total Land Use Rating				
Combined Land Use Index Score (Core score x 2) + (Supporting score x 1) / 3)		-			
Combined Land Use Index Rating					

Example:

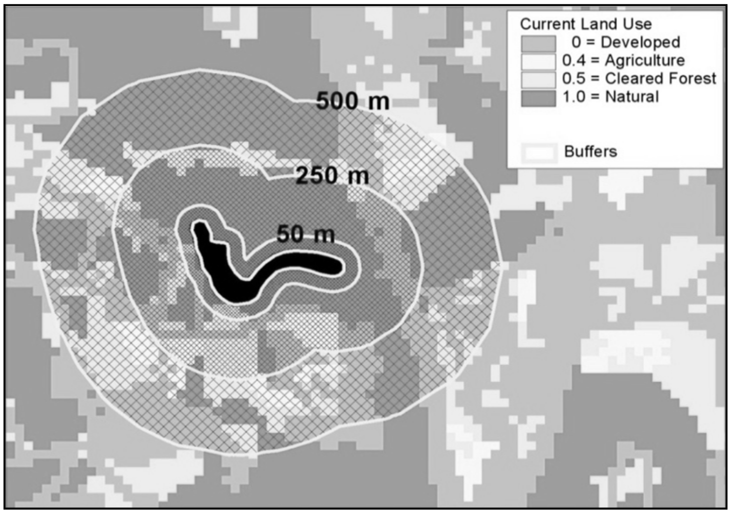


Figure 2.1. Application of land use coefficients to assess the Land Use Index metric in the core and supporting landscapes (Nichols and Faber-Langendoen 2012). In this example, buffer is shown as 50 m (our standard EIA buffer is 100 m). The percent area of each land use is recorded in Table 2.1.

Metric Rating:

Table 2.2. Land Use Index Metric Rating.

Metric Rating	***Land Use Index: ALL WETLANDS***
EXCELLENT (A)	Average Land Use Score = 1.0-0.95
GOOD (B)	Average Land Use Score = 0.80-0.95
FAIR (C)	Average Land Use Score = 0.4-0.80
POOR (D)	Average Land Use Score = <0.4

Data for Metric Rating: The coefficients were assigned according to best scientific judgment regarding each land use's potential impact, and evaluation of tables provided by Hauer et al. (2002) and Mack (2006). See also Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of a variant of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: Land uses have differing degrees of potential impact on ecological patterns and processes. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and low intensity grazing), while other activities (e.g., hay production and agriculture) may replace native vegetation with non-native or cultural vegetation yet still provide potential cover for species movement. Intensive land uses (e.g., urban development, roads, and mining) may completely destroy vegetation and drastically alter ecological processes (Hauer et al. 2002, Mack 2006).

Confidence that reasonable logic and/or data support the metric: Medium.

BUFFER

▪ 3. Buffer Index

Definition: A measure of the overall area and condition of the buffer immediately surrounding the assessment area (100 m radius), using 3 sub-metrics: (a) Percent of AA Having Buffer, (b) Average Buffer Width, and (c) Buffer Condition. Wetland buffers are vegetated, natural areas that surround a wetland.

Background: The buffer of wetlands is important to biotic and abiotic aspects of the wetland. The Environmental Law Institute (2008) has also recently reviewed the critical role of buffers for wetlands. We use a somewhat narrowly defined 100 m buffer, but add a surrounding landscape assessment that extend up to 400 m from the buffer edge (see Table 2 above, and the "Landscape Connectivity" and "Land Use Index" metrics). Here we apply the buffer metric to the assessment area, which may be a subset of the entire wetland polygon, if the AA is restricted to a certain size. An assessment of the buffer around the entire wetland may produce a different rating.

Metric Type: Condition.

Tier: 1 (remote sensing) or 2 (rapid field measure).

Rationale for Selection of the Variable: The Environmental Law Institute (2008) summarizes extensive data on the rationale for the role of buffers in maintaining ecological integrity of wetlands. Many studies have looked at specific effects of buffers on water quality, birds and other attributes of ecosystems. For example, Semlitsch (1998) monitored terrestrial migrations for six Ambystomid salamander species and found that buffers were critical to permitting their passage into uplands. They found that buffer areas 164 m from wetland edges were needed to encompass 95% of population forays.

Measurement Protocol: Metric is adapted from Collins et al. (2006) and USA RAM (2011).

3a. Buffer Metric: Percent of AA Having Buffer

Estimate the length of the AA perimeter contiguous with a natural buffer. Use a 5 m minimum buffer width and length. Perimeter includes open water (see Table 3.1).

Table 3.1. Guidelines for identifying wetland buffers and breaks in buffers (adapted from Collins et al. 2006, Table 3.3).

Examples of Land Covers Included in Buffers	Examples of Land Covers Excluded from Buffers	Examples of Land Covers Crossing and Breaking Buffers
Natural upland habitats and plant communities; open water*; dirt roads not hazardous to wildlife; vegetated levees; rough meadows or greenbelts; swales and ditches; foot trails; horse trails; bike trails; pastures subject to open range grazing pressure; dry-land farming areas; non-intensive plantations†; Conservation Reserve Program pastures	Parking lots; commercial and private developments; gravel or paved roads or very active roadways and bike trails; intensive agriculture; intensive plantations†; orchards; vineyards; railroads; pastures subject to heavy grazing pressure (e.g., horse paddock, feedlot, or turkey ranch); lawns; sports fields; traditional golf courses	Large paved roads (two lanes or larger); residential areas; bridges; culverts; paved creek fords; railroads; sound walls; fences that interfere with movements of water, sediment, or wildlife species that are critical to the overall functions of the wetland

*Open Water: Open water adjacent to the wetland site, such as a lake, large river, or lagoon, is excluded from the buffer by some wetland protocols because the water quality or water disturbance regimes (natural waves vs. boat traffic waves) may or may not be in good condition (e.g., Collins et al. 2006). Here we include open water as part of the buffer, and handle the condition of the open water using the Buffer Condition sub-metric (3c).
†Plantations: These include plantations, in which the overstory is allowed to mature and may regain some native component, and in which the understory of saplings, shrubs, and herbs are native or naturalized species and not strongly manipulated, i.e., they are not "row-crop tree plantings" with little to no vegetation in the understory, typical of intensive plantations.

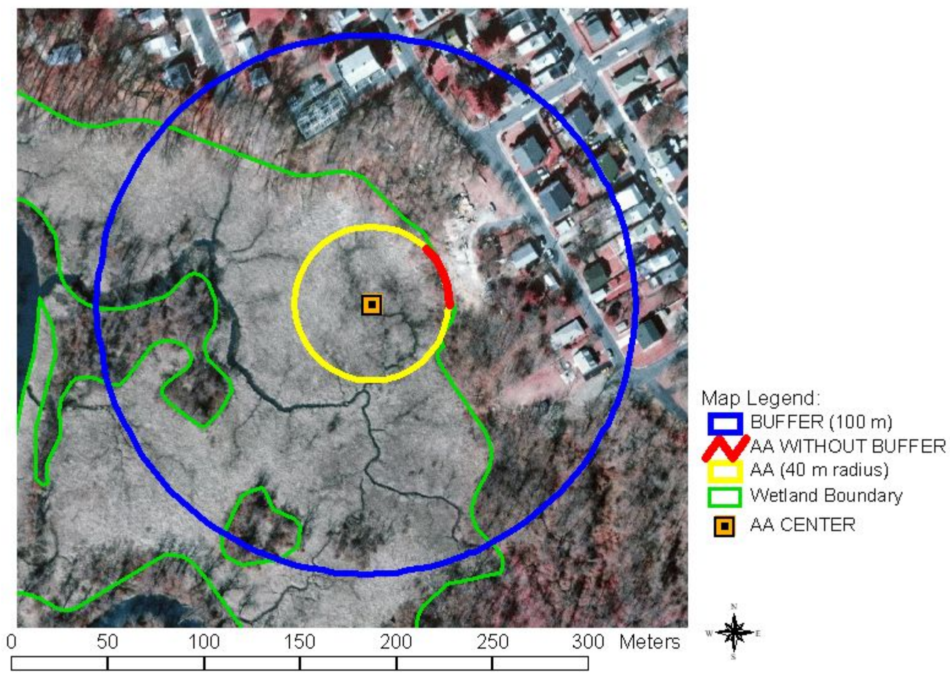


Figure 3.1. Example of calculation for Percent of AA Having Buffer. The wetland boundary is marked by a thin green line. The assessment area (AA) is shown by the inner circle; yellow indicates portions of the AA perimeter that adjoin a buffer land cover (i.e., buffer of at least 5 m width and 5 m in extent). The red indicates that part of AA perimeter lacking a buffer. In this case, about 86% of the AA perimeter has buffer.

3b. Buffer Metric: Average Buffer Width

Assessment Protocol:

1. Determine the areas considered to be buffer.
2. Draw eight straight lines from the edge of the AA out through the buffer area at regular intervals in the portions of perimeter that are considered buffer (see Figure 3.2 below). Drawing the lines on the printed map makes verification and Quality Assurance procedures easier.
3. Measure the buffer width.
4. Assign a metric score based on the average buffer width.

Table 3.2. Measuring Average Buffer Width. See Figure 3.2.

Line	Buffer Width (m) (max = 100 m)
1	63
2	0
3	0
4	100
5	100
6	100
7	100
8	100
Average Buffer Width (m)	70

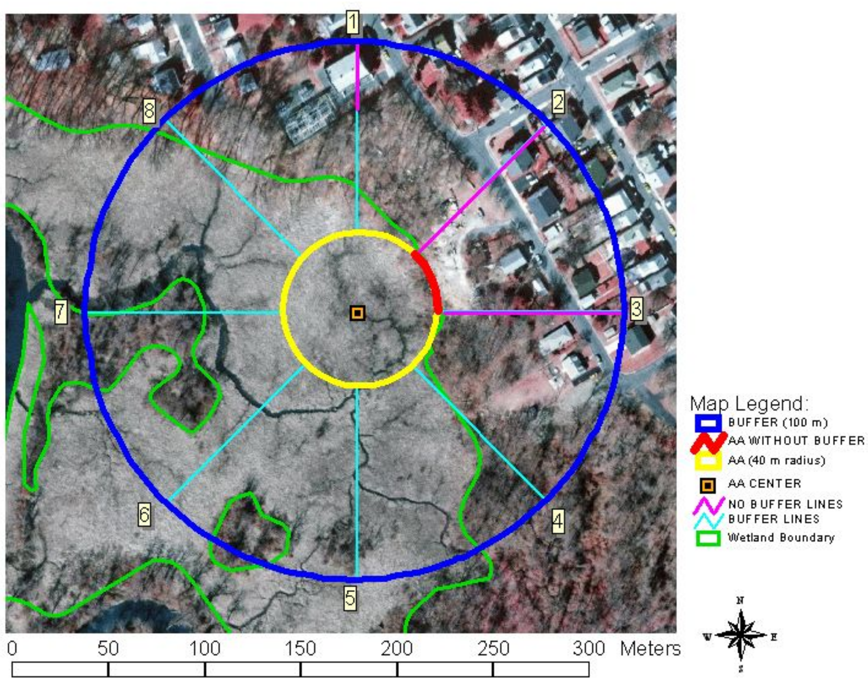


Figure 3.2. Example of Average Buffer Width calculation. The wetland boundary is marked by a thin green line; the AA circular perimeter is yellow; the 100 m buffer assessment area around the AA is dark blue, and the eight transect lines are assessed for the buffer width. The blue segment of each transect indicates buffer is present and the purple segment indicates non-buffer land use. For example, transect 1 (north) has 63 m of buffer (see Table 3.2). An additional level of evaluation may be completed by having field crews walk the four cardinal direction lines to assess buffer condition, if logistically feasible.

There is also value in adjusting the rating of upslope buffer width based on degree of slope. Slope can be estimated in the field or using imagery. The following adjustment should be used for buffers upslope of the AA (Environmental Law Institute 2008, based on data from Island County, Washington).

Table 3.3. Adjusting Rating of Upslope Buffer.

Slope Gradient	Additional Buffer Width Multiplier
5-14%	1.3
15-40%	1.4
>40%	1.5

3c. Buffer Metric: Buffer Condition

Estimate the overall condition of vegetation cover within that part of the perimeter that has a buffer. That is, if buffer length is only 30% of the perimeter, then assess condition within that 30%. Condition is based on cover of native vegetation, disruption to soils, signs of reduced water quality, amount of trash or refuse, and intensity of human visitation or recreation, including from foot or boat traffic. The evaluation can be made by scanning an aerial photograph in the office, followed by ground-truthing, as needed, the eight lines shown in Figure 3.2.

Metric Rating:

Table 3.4. Buffer Index Metric Rating.

	Buffer Sub-metrics: ALL WETLANDS		
Sub-metric Ratings	**a. Percent of AA having Buffer**	**b. Average Buffer Width (m)**	**c. Buffer Condition**
EXCELLENT (A)	Buffer is 90 - 100% of AA	Average buffer width is >95 m, adjusted for slope.	Buffer is characterized by abundant (>95%) cover of native vegetation, with intact soils, no evidence of loss in water quality and little or no trash or refuse.
VERY GOOD (A-)	Buffer is >75 - 89% of AA	Average buffer width is 75 -94 m, after adjusting for slope.	Buffer is characterized by substantial (75-95%) cover of native vegetation, intact or moderately disrupted soils, minor evidence of loss in water quality, moderate or lesser amounts of trash or refuse, and minor intensity of human visitation or recreation.

GOOD (B)	Buffer is 50 - 75% of AA	Average buffer width is 50 -74 m, after adjusting for slope.	Buffer is characterized by a moderate (50-75%) cover of native vegetation, and either moderate or extensive soil disruption, moderate to extensive evidence of loss in water quality, moderate or greater amounts of trash or refuse, and moderate intensity of human visitation or recreation.
FAIR (C)	Buffer is 25-49% of AA	Average buffer width is 25-49 m, after adjusting for slope.	Buffer is characterized by a low (25- 50%) cover of native vegetation, barren ground and highly compacted or otherwise disrupted soils, strong evidence of loss in water quality, with moderate or greater amounts of trash or refuse, and moderate or greater intensity of human visitation or recreation.
POOR (D)	Buffer is <25% of AA	Average buffer width is <25 m, after adjusting for slope.	Very low (<25%) cover of native plants, dominant (>75%) cover of non-native plants, extensive barren ground and highly compacted or otherwise disrupted soils, moderate - great amounts of trash, moderate or greater intensity of human visitation or recreation, OR no buffer at all.

Buffer Index

The buffer index is adapted from Collins et al. (2006). The index integrates the three sub-metrics, but the Buffer Condition is given half the weight of the Percent of AA with Buffer and the Average Buffer Width, as its influence on overall on-site condition is not as strong as the other two. First convert the letter scores to numeric values (e.g., A = 4, A- = 3.5, B = 3, C = 2, D = 1). Then proceed as follows:

1. Percent of AA with Buffer + Average Buffer Width / 2= Average Buffer Score
2. Average Buffer Score + (Average Buffer Condition X 0.5) / 1.5 = Buffer Index

The merit of integrating the submetrics is that they are closely related, and the overall index puts the metric on a comparable level of distinctiveness with other metrics. See Table 3.5 for the ratings for the Buffer Index Metric.

Table 3.5. Example of a Buffer Index Metric Rating.

Metric Rating	***Buffer Index: ALL WETLANDS***
EXCELLENT (A)	3.5-4.0
GOOD (B)	2.5-3.5
FAIR (C)	1.5-2.5
POOR (D)	1- 1.5

Data for Metric Rating: See Environmental Law Institute (2008); also see Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of a variant of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: There is abundant evidence on the value of even narrow buffers between 5 and 25 m (Environmental Law Institute 2008); thus the rating for the "Percent of AA Having Buffer" is extended to have an A-E rating. More generally, setting buffer widths is based on assessing edge effects. The edge effect width of 100 m is based in part on data from Kennedy et al. (2003), who reviewed edge effects for both plants and animals. They recommend a buffer up to 230–300 m as a precautionary threshold. A buffer width of 100 m is also a widely used minimum threshold (e.g., USA RAM). Here we work with 100 m as the "inner buffer" distance, but separately assess the surrounding landscape (core landscape up to 250 m, and supporting landscape to 500 m) (see the "Landscape Connectivity" and "Land Use Index" metrics).

Confidence that reasonable logic and/or data support the metric: Medium/High.

SIZE

▪ 4. Absolute Patch Size[1]

Definition: A measure of the current absolute size (ha) of the entire wetland type polygon or patch. The metric is assessed with respect to expected patch sizes for the type across its range.

Background: This metric is one aspect of the size of specific occurrences of a wetland type. The metric rating is taken from NatureServe's Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008). Assessors are sometimes hesitant of using absolute size as part of an EIA out of concern that a small, high quality example will be down-ranked unnecessarily. We address these concerns to a degree by providing a pattern-type scale, so that types that typically occur as small patches (seepage fens) can use a different rating than types that may occur over large, extensive areas (e.g., marshes or boreal bogs/fens). Size is also more accurately assessed at finer scales of classification (e.g., Systems or Groups). Then, for example, Midwest fens are compared separately from boreal fens.

Metric Type: Condition.

Tier: 1 (remote sensing); 2 (rapid field measure).

Rationale for Selection of the Variable: The role of absolute size in assessing integrity is complex. First, higher ratings for size may not always indicate increased integrity. For some types absolute size can vary widely for entirely natural reasons (e.g., a forest type may have very large occurrences on rolling landscapes, and be restricted in other landscapes to small occurrences on north slopes or ravines).

Second, size overlaps with landscape context as a metric, depending on the scale of the wetland type. Size and landscape context both address spatial aspects of an occurrence. Very large sized, matrix occurrences essentially define the landscape context. Standards for establishing the size metric ratings sometimes can be confounded with criteria for Landscape Context. For example, the use of Minimum Dynamic Area (MDA) as the basis for the Size criteria is misleading, at least at the system or natural community level, because MDA is really assessing the landscape area within which an occurrence is embedded and on which it depends for its persistence (Leroux et al. 2007). MDA is typically applied to types at very broad classification scales (e.g., northern hardwood and boreal forest landscapes).

Nonetheless, size can be an important aspect of integrity. For some types, diversity of animals or plants may be higher in larger occurrences than in small occurrences that are otherwise similar. For occurrences in mosaics, the larger occurrences often have more micro-habitat features. Larger wetlands are more resistant to hydrologic stressors; larger uplands more resistant to invasion by exotics, since they buffer their own interior portions. Thus size can serve as a readily measured proxy for some ecological processes and the diversity of interdependent assemblages of plants and animals.

Note that NatureServe's methodology for evaluation patches or polygons (the "Element Occurrence Rank") integrates integrity and conservation values, so with respect to size, larger occurrences are generally presumed to be more value for conservation purposes, as they provide a better representation of the type being conserved. We keep the Size metrics separate within a Primary "Size Rank Factor" so that users can readily determine the role of these metrics in the overall EIA scores. Some consideration had been given to combining size metrics with a broader "landscape context and size rank factor," so that interactions between size and landscape context could be dealt with first, before considering their joint interaction with condition. Users focused strictly on ecological integrity may find this an appealing option.

Measurement Protocol: The choice of patch type for the particular wetland being assessed is an important first step (see Table 4.1), and should be based on knowledge of the typical sizes of mid to broad scale ecological types (Formations, Groups, Systems) found in excellent sites. Knowledgeable ecologists in the state or region should be consulted. Ecological System and Group types have all been assigned to a pattern type, so if the site is classified to Ecological System or Group, that information can be readily attained (www.natureserve.org/explorer).

Table 4.1. Definitions of various patch types that characterize the spatial patterning of ecosystems (ecological community and system types) (Comer et al. 2003).

PATCH TYPE	*DEFINITION*
Matrix	*Ecosystems that form extensive and contiguous cover, occur on the most extensive landforms, and typically have wide ecological tolerances. Disturbance patches typically occupy a relatively small percentage (e.g., <5%) of the total occurrence. In undisturbed conditions,* ***typical occurrences range in size from 2,000-10,000 ha (100 km²) or more.***
Large Patch	*Ecosystems that form large areas of interrupted cover and typically have narrower ranges of ecological tolerances than matrix types. Individual disturbance events tend to occupy patches that can encompass a large proportion of the overall occurrence (e.g., >20%). Given common disturbance dynamics, these types may tend to shift somewhat in location within large landscapes over time spans of several hundred years. In undisturbed conditions****, typical occurrences range from 50-2,000 ha.***
Small Patch	*Ecosystems that form small, discrete areas of vegetation cover, typically limited in distribution by localized environmental features. In undisturbed conditions,* ***typical occurrences range from 1-50 ha.***
Linear	*Ecosystems that occur as linear strips. They are often ecotonal between terrestrial and aquatic ecosystems. In undisturbed conditions****, typical occurrences range in linear distance from 0.5-100 km.***

Absolute Size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, or other data layers. Size can also be estimated in the field using 7.5 minute topographic quads, NPS Vegetation Mapping maps, National Wetland Inventory maps, or a global positioning system. Wetland boundaries are not delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987); rather, they are delineated by ecological guidelines for delineating the boundaries of the wetland type, based on the International Vegetation Classification, equivalent National Vegetation Classifications, National Wetland Inventory, or other wetland classifications.

Metric Rating:

Two metric ratings may be used. One is based on an absolute patch size rating, in the context of the typical patch type of the wetland (Table 4.2). The other is a comparative rating, based on the known distribution of wetland sizes for a wetland type (Table 4.3). If information on both ratings is available, then the rating that generates the higher rating is used.

Table 4.2. Absolute Patch Size Metric Rating: Area by Patch Type. General guidelines for assessing patch size of wetlands. A determination first needs to be made as to the typical spatial pattern type of the wetland type in the ecoregions or across its entire range.

Metric Rating	***Absolute Size Metric (hectares): ALL WETLANDS, BY PATTERN TYPE***						
	MATRIX	***LARGE PATCH***		***SMALL PATCH***		***LINEAR***	
	Matrix (ha)	**Very Large Patch (ha)**	**Large Patch (ha)**	**Medium-Small Patch (ha)**	**Small Patch (ha)**	**Very Small Patch (ha)**	**Linear (length in km)**
EXCELLENT (A)	>25,000	>500	>125	>50	>10	>2	>5 km
GOOD (B)	500-25,000	100-500	25-125	10 - 50	2 - 10	0.5 - 2	1-5 km
FAIR (C)	50-500	20 -100	5 -25	2 -10	0.5-2	0.1-0.5	0.1-1 km
POOR (D)	<50	<20	<5	<2	0.5	0.1	<0.1 km

OR

Metric Rating	***Absolute Size Metric (acres): ALL WETLANDS, BY PATTERN TYPE***						
	MATRIX	***LARGE PATCH***		***SMALL PATCH***		***LINEAR***	
Spatial Pattern Type	**Matrix (ac)**	**Very Large Patch (ac)**	**Large Patch (ac)**	**Medium-Small Patch (ac)**	**Small patch (ac)**	**Very Small Patch (ac)**	**Linear (mi)**
EXCELLENT (A)	>6,000	>1,250	>300	>125	>25	>5	>3 mi
GOOD (B)	1,250-6,000	250 - 1,250	60-300	25 - 125	5 - 25	1 -5	0.6 - 3 mi
FAIR (C)	125 - 1,250	50 - 250	12 -60	5 -25	1 - 5	0.25 - 1.25	0.06 - 0.6 mi
POOR (D)	<125	<50	<12	<5	1	0.25	<0.06 mi

Table 4.3. Absolute Patch Size Metric Rating: Comparative.

Metric Rating	***Absolute Patch Size: ALL WETLANDS***
EXCELLENT (A)	Patch size is very large compared to other examples of the same type (i.e., top 10% based on known and historic occurrences; most area-sensitive indicator species very abundant within occurrence).
GOOD (B)	Patch size is large compared to other examples of the same type (i.e., within 10-30% based on known and historic occurrences; many area-sensitive indicator species moderately abundant within occurrence).
FAIR (C)	Patch size is medium to small compared to other examples of the same type, (i.e., within 30-70% of known or historic sizes; some area-sensitive indicator species are able to sustain a minimally viable population; many characteristic species are of low abundance but present).
POOR (D)	Patch size is small to very small; occurrence too small to sustain full diversity and function of the type (e.g., smallest 30% of known or historic occurrences; both key area-sensitive indicator species and characteristic species are sparse to absent).

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: Scaling criteria are based on the NatureServe Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008). Our scaling has been informed by considerations of spatial pattern types, but no general guidelines have yet been established to assess wetland patch size. Tables 4.2 and 4.3 provide some standard guidance.

Confidence that reasonable logic and/or data support the metric: Medium.

▪ 5. Relative Patch Size

Definition: A measure of the current size of the wetland (in hectares) divided by the historic wetland size (within most recent period of intensive settlement or 200 years), multiplied by 100.

Background: This metric is one aspect of the size of specific occurrences of a wetland type. The metric rating is adapted from Rondeau (2001) and Faber-Langendoen et al. (2008), where it is referred to as "Patch Size Condition."

Metric Type: Condition.

Tier: 1 (remote sensing); 2 (rapid field measure).

Rationale for Selection of the Variable: Relative size is an indication of the amount of the wetland change caused by human-induced disturbances. It provides information that allows the user to calibrate the current size to the historic area of the wetland. For example, if a wetland has a current size of 1 hectare but the historic size was 2 hectares, this indicates that half (50%) of the original wetland was lost or severely degraded. Complicating the use of this metric is that in some cases, wetland size increases due to human disturbances.

Measurement Protocol: Relative size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, or other data layers. Field assessments of current size may be required since it can be difficult to discern the historic area of the wetland from remote sensing data. However, use of old aerial photographs may also be very helpful, as they may show the historic extent of a wetland.

Relative size can also be estimated in the field using 7.5 minute topographic quads, NPS Vegetation maps, National Wetland Inventory maps, or a global positioning system.

Wetland boundaries are not delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987); rather, they are delineated by ecological guidelines for delineating the boundaries of the wetland type, based on a standard wetland classification.

The definition of the "historic" timeframe will vary by region, but generally refers to the intensive Euro-American settlement that began in the 1600s in the eastern United States and extended westward into the 1800s. If the historic time frame is unclear, use a minimum of a 50 year time period, long enough to ensure that the effects of wetland loss are well-established, and the wetland has essentially adjusted to the changes in size.

Metric Rating:

Table 5.1. Relative Patch Size Metric Rating:

Metric Rating	***Relative Patch Size: ALL WETLANDS***
EXCELLENT (A)	Occurrence is at, or only minimally reduced (<5%) from its full original, natural extent, and has not been artificially reduced in size. See note below for interpretation of "reduction."
GOOD (B)	Occurrence is only modestly reduced (5-20%) from its original natural extent. See note below for interpretation of "reduction."
FAIR (C)	Occurrence is substantially reduced (20-50%) from its original, natural extent. See note below for interpretation of "reduction."
POOR (D)	Occurrence is heavily reduced (>50%) from its original, natural extent See note below for interpretation of "reduction." .

***Note**: Reduction in size for metric ratings A-D can include conversion or disturbance (e.g., changes in hydrology due to roads, impoundments, development, human-induced drainage; or changes caused by recent cutting). Assigning a metric rating depends on the degree of reduction.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: Scaling criteria are based on Rondeau (2001), NatureServe Ecological Integrity Assessment Working Group (2008) and best scientific judgment.

Confidence that reasonable logic and/or data support the metric: Medium.

VEGETATION

For various aspects of the vegetation metrics, we rely on variants based on NVC Formations (see also Table 5 above).

Table 6.1. Metric Variants (v) for Vegetation and Soils by NVC Formation.

METRIC	VEGETATION	VEGETATION	VEGETATION	SOILS	SOILS
Metric Variant by NVC Formation Type	**6. Vegetation Structure**	**7. Woody Regeneration**	**10. Vegetation Composition**	**14. Physical Patch Types**	**15. Soil Surface Condition**
FLOODED & SWAMP FOREST	**v1**			**v1**	**v1**
MANGROVE	**v2**			**v2**	**v2**
FRESHWATER MARSH, WET MEADOW & SHRUBLAND	**v3**	**v1**	**v1***	**v3**	**v1**
SALT MARSH	**v4**			**v3**	**v2**
BOG & FEN	**v5**			**v4**	**v2**
AQUATIC VEGETATION	**v3**	--		**v5**	**v2**

* Metric can be refined at the Macrogroup or Group level of the NVC, or using Ecological Systems.

- ### 6. Vegetation Structure

Definition: An assessment of the overall structural complexity of the vegetation layers and growth forms, including presence of multiple strata, age and structural complexity of canopy layer, and evidence of the effects of disease or mortality on structure.

Background: This metric has been drafted by NatureServe's Ecological Integrity Assessment Working Group (Faber-Langendoen et al.2008).

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: In wetlands, vegetation structure can have an important controlling effect on composition and processes. The patch structure is an important reflection of vegetation dynamics and for creating heterogeneity within the community. Plants strongly influence the quantity, quality, and spatial distribution of water and sediment within wetlands. For example, vascular plants entrap suspended sediment and contribute organic matter to the sedimentary layers. Plants reduce wave energy and decrease the velocity of water flowing through wetlands, potentially reducing flooding or erosion further down in a watershed. Vascular and non-vascular plants and large patches of macro algae function as habitat for wetland wildlife (Collins et al. 2006, Rocchio 2007).

The patch structure is often homogenized by disturbance such as logging of wetland forests, soil compaction, or heavy grazing by livestock and geese in fresh and salt marshes. In general, beaver-caused disturbances are treated as part of the range of variability expected within minimally-disturbed stands. Impacts from beavers can affect almost all wetland types, but they are most commonly associated with wetlands along streams and ponds Beaver dams create impoundments that typically kill woody plants and drastically alter structure, species composition, and hydrology. These natural disturbances generally occur in cycles that span decades. As the beaver deplete their woody food supply they abandon dam maintenance and move to other suitable habitat. Eventually, when the dam fails, and the beaver pond drains, the resulting wet mud flats are quickly colonized by annuals, then herbaceous perennials, and finally woody plants after several years. Without further disturbance over subsequent decades, succession will progress toward a more mature natural community. Wetland communities that are commonly associated with drainages used by beaver include aquatic beds, emergent marshes, wet meadows, shrub thickets, and forested wetlands, but peatlands in drainages are influenced by beaver activity as well (Tiner 1998, Thompson and Sorenson 2000). The cycle of natural disturbances caused by beaver can be difficult to interpret, because beaver were heavily trapped and eliminated from large parts of the landscape in the 19th century, then subsequently reintroduced. Thus the watersheds and landscapes may still be recovering from the absence of beaver.

Measurement Protocol: This metric consists of evaluating the horizontal and vertical structure of the vegetation relative to the reference condition of structural heterogeneity of the dominant growth forms. The protocol is a visual evaluation of variation in overall structure (e.g., age, size, and density), overall canopy cover, frequency of canopy gaps with regeneration, and number of different age/size patches represented. A field form should be used, as shown in Table 7.1, which describes structure using either strata or growth forms (Jennings et al. 2009). For the strata method, list all major strata – tree, shrub, herb, non-vascular, floating, submerged – then estimate strata cover and cover of dominant (>5% cover), characteristic, and exotic species. For the growth form method, list major growth forms – tree (subdivided into overstory and regeneration), shrub (subdivided by tall and medium/low), herb, non-vascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of dominant (>5%), characteristic, and exotic species. The prevailing height of a stratum or growth form is used to determine its height class. For example, although the tree canopy may vary from 10 to 30 m, the prevailing height may be 25 m. For particular field applications, it can be helpful for field crews to create a standard list of vine / liana species, or even tree species.

Table 6.1. An example of a vegetation structure/growth form vertical profile.

VEGETATION GROWTH FORM PROFILE			VEGETATION SPECIES PROFILE BY GROWTH FORM	
Cover scale: 0, 1-4%, then ±5% (10, 15, 20, etc.)				
Growth forms / strata	Cover (%)	Ht (m)	Dominant Species: List all species and their absolute cover if ≥5% cover, to ± 5% (e.g., 10% = 5-14 etc.). List all exotic spp. <5% cover. Optional: List other characteristic native spp. <5% (1-4%, <1% =T).	
Tm. Mature (tall) Tree (>5 m)		____ To nearest 5 m.	*e.g., Acer rubrum – 15%*	
Ts. Sapling (medium) Tree (2-5 m)				
Te. Seedling (small) Tree (<2 m)				
S1. Tall Shrub (≥2 m)				
S2. Short/ Dwarf-shrub (<2 m)				
H1. Herbaceous				
A1. Floating-leaved Aquatic		X		
A2. Submerged Aquatic		X		
N. Non-vascular - Moss		X		
- Lichen		X		
- Algae		X		
V. Vine / Liana				

Table 6.2. Example of a vegetation structure spatial profile description.

VEGETATION PROFILE	
Structural Stage: Estimate the % aerial cover of all trees in each structural stage to nearest 10%. Evaluate only the top canopy layer (i.e. view canopy from above, but canopy might be sapling layer). Total should add to 100%. [dbh ranges – eastern N.A. temperate]	
_____% woody stages **absent** or **seedlings** (i.e. stems < 2m)	_____%**Large**: stems 30—50 cm (12-20") dbh
_____% **Sapling**: stems < 10 cm (< 4") dbh	_____ %**Very Large:** stems >50 cm (20") dbh
_____ %**Pole:** stems 10-30 cm (4 – 12") dbh	

Field survey method for estimating structure may be either 1) qualitative data where the observers walks the entire AA and make notes on vegetation strata, their cover, and exotic species, using tables such as shown in Table 6.1 or 6.2 above or2) quantitative data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken (Appendix 3).

Metric Rating:

Metric ratings can be assigned using Table 6.3 based on variants by NVC Formation class. The metric can be further improved by using a mid-scale classification unit, such as Ecological System or NVC Group.

Table 6.3. Vegetation Structure Metric Rating: Variants are provided in six separate tables by NVC Vegetation Formation (V1: Flooded & Swamp Forest, V2: Mangrove, V3: Freshwater Marsh, Wet Meadow & Shrubland, V4: Salt Marsh, V5: Bog & Fen, and V6: Aquatic Vegetation.

Metric Rating	***V1: Vegetation Structure Variant: FLOODED & SWAMP FOREST***
EXCELLENT (A)	**FLOODED & SWAMP FOREST**: Canopy a mosaic of small patches of different ages or sizes, including old trees and canopy gaps containing regeneration, AND number of live stems of medium size (30-50 cm / 12-20"dbh) and large size (>50 cm / >20" dbh) well within expected range.
GOOD (B)	**FLOODED & SWAMP FOREST:** Canopy largely heterogeneous in age or size, but with some gaps containing regeneration or some variation in tree sizes, AND number of live stems of medium and large size within or very near expected range.
FAIR (C)	**FLOODED & SWAMP FOREST:** Canopy somewhat homogeneous in age or size, AND number of live stems of medium and large size below but moderately near expected range.
POOR (D)	**FLOODED & SWAMP FOREST:** Canopy very homogeneous, in size or age OR number of live stems of medium and large size well below expected range.

Metric Rating	*V2: Vegetation Structure Variant: MANGROVE: [metric variant under development]*
EXCELLENT (A)	**MANGROVE**: Canopy heterogeneous, with patches of different ages or sizes, including old trees and young saplings. No evidence of human impacts.
GOOD (B)	**MANGROVE:** Canopy largely heterogeneous in age or size, but with some gaps containing regeneration or some variation in tree sizes. Negative human impacts to structure (such as cutting) are minor.
FAIR (C)	**MANGROVE:** Canopy somewhat homogeneous in age or size. Negative human impacts to structure (such as cutting) are moderate.
POOR (D)	**MANGROVE:** Canopy very homogeneous, in size or age. Negative human impacts to structure (such as cutting) are major.

Metric Rating	*V3: Vegetation Structure Variant: FRESHWATER MARSH, WET MEADOW & SHRUBLAND [metric variant under development]*
EXCELLENT (A)	**FRESHWATER MARSH, WET MEADOW & SHRUBLAND**: Vegetation structure is at or near minimally disturbed natural conditions. Little to no structural indicators of degradation evident.
GOOD (B)	**FRESHWATER MARSH, WET MEADOW & SHRUBLAND**: Vegetation structure shows minor alterations from minimally altered from minimally disturbed natural conditions. Structural indicators of degradation are minor (e.g. levels of grazing, mowing).
FAIR (C)	**FRESHWATER MARSH, WET MEADOW & SHRUBLAND:** Vegetation structure is moderately altered from minimally disturbed natural conditions. Structural indicators of degradation are moderate (e.g. levels of grazing, mowing).
POOR (D)	**FRESHWATER MARSH, WET MEADOW & SHRUBLAND**: Vegetation structure is greatly altered from minimally disturbed natural conditions. Structural indicators of degradation are strong (e.g. levels of grazing, mowing).

Metric Rating	*V4: Vegetation Structure Variant: SALT MARSH (salt/brackish marsh & shrubland) [Metric variant under development]*
EXCELLENT (A)	**SALT MARSH:** Vegetation structure is at or near minimally disturbed natural conditions. Little to no structural indicators of degradation evident.
GOOD (B)	**SALT MARSH:** Vegetation structure shows minor alterations from minimally disturbed natural conditions. Structural indicators of degradation are minor.
FAIR (C)	**SALT MARSH:** Vegetation structure is moderately altered from minimally disturbed natural conditions. Structural indicators of degradation are moderate.
POOR (D)	**SALT MARSH:** Vegetation structure is greatly altered from minimally disturbed natural conditions. Structural indicators of degradation are strong.

Metric Rating	***V5: Vegetation Structure Variant: BOG & FEN***
EXCELLENT (A)	**BOG & FEN**: Peatland is supporting structure with little to no evident influence of negative anthropogenic factors. Some very wet peatlands may not have any woody vegetation or only scattered stunted individuals. Woody vegetation mortality is due to natural factors. The site meets near minimally disturbed condition.
GOOD (B)	**BOG & FEN**: Generally, peatland structure has only minor negative anthropogenic influences present or the site is still recovering from major past human disturbances. Mortality or degradation due to grazing, limited timber harvesting or other anthropogenic factors may be present although not widespread. The site can be expected to meet minimally disturbed condition in the near future if negative influences do not continue.
FAIR (C)	**BOG & FEN**: Peatland structure has been moderately influenced by negative anthropogenic factors. Expected structural classes are not present. Human factors may have diminished the condition for woody vegetation. The site will recover to minimally disturbed condition only with the removal of degrading influences and moderate recovery times.
POOR (D)	**BOG & FEN:** Expected peatland structure is absent or much degraded due to anthropogenic factors. Woody regeneration is minimal and existing structure is in poor condition, unnaturally sparse, or depauperate. Recovery to minimally disturbed condition is questionable without restoration or will take many decades.

Metric Rating	***V6: Vegetation Structure Variant: AQUATIC VEGETATION [Metric variant under development]***
EXCELLENT (A)	**AQUATIC VEGETATION**: Vegetation structure is at or near minimally disturbed natural conditions. No structural indicators of degradation evident.
GOOD (B)	**AQUATIC VEGETATION:** Vegetation structure shows minor alterations from minimally disturbed natural conditions. Structural indicators of degradation are minor.
FAIR (C)	**AQUATIC VEGETATION**: Vegetation structure is moderately altered from minimally disturbed natural conditions. Structural indicators of degradation are moderate.
POOR (D)	**AQUATIC VEGETATION**: Vegetation structure is greatly altered from minimally disturbed natural conditions. Structural indicators of degradation are strong.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana.

Scaling Rationale: This metric has been scaled based on scientific judgment of NatureServe's Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008) and survey work in Michigan and Indiana wetlands (Faber-Langendoen et al. 2012). The metric is scaled based on the similarity between the observed vegetation structure and what is expected based on reference (or minimally disturbed natural) conditions. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources. The basis for assigning the ratings should be documented on the field forms.

Assessing structure is challenging in herbaceous and shrub wetlands, e.g., freshwater marshes vary in their complexity. Some marshes are structurally simple, such as the Everglades sawgrass types, or freshwater bulrush marshes. Others may have combinations of high, medium, or low structure. For example, in peatlands in the western U.S., some woody species (e.g., *Spiraea douglasii*, *Myrica gale*, and *Pinus contorta*) may expand rapidly in degraded examples caused by hydrologic change, nutrient loading, and fire suppression (J. Christy pers. comm. 2008), and increased woody structure means increased degradation. Thus, down-rating based on simplicity of structure, per se, should be avoided.

Confidence that reasonable logic and/or data support the metric: Medium.

- ### 7. Woody Regeneration

Definition An assessment of tree regeneration.

Background: This metric was developed by NatureServe and Natural Heritage Program staff, and applied in a study in Michigan and Indiana (Faber-Langendoen et al. 2012). It combines both structural and compositional information, in that regeneration abundance is assessed with respect to native tree and shrub species.

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: The tree regeneration and shrub layers provide independent information on the structural characteristics, ecological processes, and stressors (such as herbivore browsers) found at the site, and indicate potential future canopy composition. We rely on a qualitative evaluation for our rapid assessment, which may only detect substantial degradation. We recognize that a more rigorous approach is often necessary to accurately assess this metric (e.g., Tierney et al. 2009).

Measurement Protocol: This metric consists of evaluating the tree regeneration layer (tree seedlings less than 1.3 m tall and saplings 1.3+ m tall and up to 10 cm dbh), and/or the shrub regeneration layer. The protocol is a visual evaluation of abundance of tree seedlings and saplings and/or younger shrub growth. Information on this metric can be gained from tables that describe composition using strata or growth forms (Jennings et al. 2009) (see "Vegetation Structure" metric, Table 6.1). For the growth form method, list major growth forms – tree (subdivided into overstory and regeneration), shrub (subdivided by tall and medium/low), herb, non-vascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of dominant (>5%), characteristic, and exotic species.

The field survey method for estimating woody regeneration may be either a (1) Site Survey (semi-quantitative) method where the observers walk the entire AA, and make notes on vegetation strata, their cover, and native vs. exotic species or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken (Appendix 3).

Metric Rating:

Table 7.1. Woody Regeneration Metric Rating. The metric is typically applied in forested wetlands, but can be used for shrublands or any other wetland with woody vegetation.

Metric Rating	***Woody Regeneration: ALL WETLANDS (except for Aquatic Vegetation)***
EXCELLENT (A)	Native tree saplings and/or seedlings or shrubs common to the type present in expected amounts and diversity; obvious regeneration.
GOOD (B)	Native tree saplings and/or seedlings or shrubs common to the type present but less amounts and diversity than expected.
FAIR (C)	Native tree saplings and/or seedling or shrubs common to the type present but low amounts and diversity; little regeneration.
POOR (D)	No, or essentially no regeneration of native woody species common to the type.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of a variant of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: The metric is scaled based on field judgments of expected natural regeneration within the AA, and evidence of heavy browsing or grazing of the woody layers. The metric also addresses situations where native diversity of the tree regeneration layer or shrub layer is reduced through anthropogenic disturbance or increased native herbivory.

Confidence that reasonable logic and/or data support the metric: Medium.

- ### 8. Native Plant Species Cover

Definition: A measure of the relative percent cover of all plant species in the AA that are native to the region. The metric is typically calculated by estimating total absolute cover of all vegetation (summing total cover by major strata), subtracting total exotic species cover, and expressing the total native species cover as a percentage of the total vegetative cover.

Background: This metric has been developed by NatureServe's Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008). To a certain degree this metric is the converse of the "Invasive Plant Species Cover." However, the Native Plant Species Cover metric only includes native species, whereas the Invasive Plant Species Cover metric includes both native and exotic species that are considered to be invasives to the ecosystem under study (e.g., *Typha angustifolia* in Midwestern and Northeastern U.S. marshes). Testing in the Midwest showed the two metrics to be moderately strongly correlated (Faber-Langendoen et al. 2011) and it may be reasonable to combine these two metrics into a single Index.

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: Native species dominate an ecosystem when it has excellent ecological integrity. This metric is a measure of the degree to which native ecosystems have been altered by human disturbance. With increasing human disturbance, non-native species increase and can dominate a system.

Measurement Protocol: This metric consists of evaluating the exotic and native species composition of the vegetation. The protocol is a visual evaluation of native vs. exotic species cover. A field form should be used that describes species composition by strata or growth forms (Jennings et al. 2009) (see Table 6.1. for the Vegetation Structure metric).

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walk the AA and make notes on vegetation strata, their cover, and the cover of native vs. exotics or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken (see Appendix 3).

The metric can be calculated in three ways (Table 6.1 can be used to record the information needed for all three way):

1. **Where species cover is available by growth form or strata:**
   First estimate the total cover of the vegetation, across strata and growth forms (e.g., cover of the tree, shrub, herb, and non-vascular growth forms are combined, thus the total could easily exceed 100%), then estimating the total cover of each of the exotic species, by growth form or strata. Divide the total vegetation cover by the

total exotics cover, multiply by 100, and subtract from 1. This method can be used when all species, or only dominant species, are listed.

2. **Where species cover is available only as total cover:**
   If cover is recorded for each species, but not by strata or growth form (e.g., tree species cover combines cover across sapling and tree layer), then sum the cover across all species, and divide it by the sum of the cover across all exotic species, multiply by 100, and subtract from 1. This method can be used when all species, or only dominant species, are listed.

3. **Where species cover is only available for exotic species, and total cover is available:**
   Where a complete or dominant species list and cover is not available, but total cover or total cover by growth form or strata is available, and exotic species cover is available, then sum the total cover, and divide it by the sum of the cover across all exotic species, multiply by 100, and subtract from 1. This third option is less accurate than the first two, but allows field crews with less botanical skills to apply the metric.

Metric Rating:

Table 8.1. Native Plant Species Cover Metric Rating.

Metric Rating	***Native Plant Species Cover: ALL WETLANDS***
EXCELLENT (A)	>99% relative cover of native plant species.
VERY GOOD (A-)	95-99% relative cover of native plant species
GOOD (B)	85-95% relative cover of native plant species.
FAIR (C)	60-85% relative cover of native plant species.
POOR (D)	<60% relative cover of native plant species.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: The criteria are based on best scientific judgment and the extensive knowledge of native and introduced floras across the country. These criteria need further validation. Scaling of this metric using native vs. exotic species richness rather than cover is an alternative approach (Miller et al. 2006).

Confidence that reasonable logic and/or data support the metric: High.

- ## 9. Invasive Plant Species Cover

Definition: The percent cover of a selected set of exotic (or more rarely native) species that are considered invasive to the ecosystem being evaluated. An invasive species is defined as "*a species that is non-native to the ecosystem under consideration and whose introduction causes or is likely to cause …environmental harm…*" (Executive Presidential Order 1999, Richardson et al. 2000).

Background: This metric has been drafted by NatureServe's Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008), based in part on work by Tierney et al. 2008) and Miller et al. (2006). This metric is a counterpart to "Native Plant Species Cover," but "Invasive Plant Species Cover" includes all invasives, whether exotic or not. That is, this metric includes plants native to a region that may be invasive in a particular ecosystem (e.g., *Phalaris arundinacea* and *Typha angustifolia* in the Northeastern U.S.), so it is not a direct mirror of the previous metric.

The definition of invasive used here is related to the perceived impact that invasives have on ecosystem condition, or what Richardson et al. (2000) refer to as "transformers". They distinguish invasives (Naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from parent plants and thus have the potential to spread over a considerable area) from "transformers" (A subset of invasive plants that change the character, condition, form, or nature of ecosystems over a substantial area relative to the extent of that ecosystem). Although our definition is essentially equal to that of "transformers" in that we are concerned with those naturalized plants that cause ecological impacts, we retain the term "invasive" as the more widely used term. Our use of the term also equates to "harmful non-indigenous plants" of Snyder and Kaufman (2004):

> "Invasive species that are capable of invading natural plant communities where they displace indigenous species, contribute to species extinctions, alter the community structure, and may ultimately disrupt the function of ecosystem processes."

Invasives are distinguished from "increasers," which are native species present in an ecosystem that respond favorably to increasing human stressors. For example, *Dennstaedia punctilobula,* a native fern in northeastern U.S. northern hardwoods forests, responds favorably to heavy deer browse (de la Crétaz and Kelty 2006).

Metric Type: Stressor/Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: As viable populations of invasive plants become established in novel habitats, they can have a number of ecological impacts including loss of habitat; loss of native biodiversity; decreased nutrition for herbivores; competitive dominance; overgrowth and shading; resource depletion; and alteration of biomass, energy cycling, productivity, and nutrient cycling (Dukes and Mooney 1999). Invasive plant species can also affect hydrologic function and balance, making water scarce for native species.

Measurement Protocol: A comprehensive list of invasive species should be established for any given project, in order to make the application of the metric as consistent as possible. Examples of wetland invasive plant species in different regions of the United States are listed below, but these are for illustration only:

<u>Northeast</u>: purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), Japanese knotweed (*Polygonum cuspidatum*), water chestnut (*Trapanatans*), flowering rush (*Butomus umbellatus*), yellow iris (*Iris pseudacorus*), Chinese tallow tree (*Triadica sebifera*), Chinese privet (*Ligustrum sinense*), and exotic biotype of giant reed (*Phragmites australis*). Narrow-leaf and white cattail (*Typha angustifolia* and *T. x glauca* [= *T. latifolia x T. angustifolia*]) are also an increasing problem.

<u>Southeast</u>: water hyacinth (*Eichhornia crassipes*).

<u>Midwest</u>: reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), and giant reed (*Phragmites australis*).

<u>West</u>: reed canary grass (*Phalaris arundinacea*), purple loosestrife (*Lythrum salicaria*), parrotfeather (*Myriophyllum aquaticum*), cordgrasses (*Spartina alterniflora*, *S. anglica*, *S. densiflora*, and *S. patens*), hydrilla (*Hydrilla verticillata)*, Brazilian waterweed (*Egeria densa*), and Eurasian water-milfoil (*Myriophyllum spicatum*).

This metric consists of evaluating the percent cover of invasive plant species. The protocol is a visual evaluation of invasive plant species cover. A field form should be used that describes species composition using either strata or growth forms (Jennings et al. 2009) (see Table 6.1, Vegetation Structure metric). The cover of those species identified as non-native invasives and native plant increasers is summed to produce the total cover of invasive plant species.

Field survey method for estimating structure may be either a (1) Site Survey (semi-quantitative) method where the observers walk the entire occurrence, or assessment area within the occurrence, and make notes on vegetation strata, their cover and the cover of native vs. exotics or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a “rapid” plot, but a single intensive plot can also be taken (see Appendix 3).

Metric Rating:

Table 9.1. Invasive Plant Species Cover Metric Rating. A specific list of invasive (transformer) species should be provided with this metric.

Metric Rating	*Invasive Exotic Plant Species Cover*: ALL WETLANDS
EXCELLENT (A)	Invasive plant species absent or cover is very low (<1% absolute cover).
VERY GOOD (A-)	Invasive plant species present but sporadic (1-3 % cover).
GOOD (B)	Invasive plant species somewhat abundant (4-10% cover).
FAIR (C)	Invasive plant species abundant (10-30% cover).
POOR (D)	Invasive plant species very abundant (>30% cover).

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana.

Scaling Rationale: Establishment of invasives at a site can be followed by rapid increases, with the potential for exponentially increasing levels of abundance and effects on other species and ecological processes (Rejmánek et al. 2005, Figure 6.12). Thus the metric is scaled to be sensitive to relatively small levels of invasive cover (e.g., 1-3% cover receives an “A-” rating).

Confidence that reasonable logic and/or data support the metric: Medium/High.

▪ 10. Vegetation Composition

Definition: An assessment of the overall species composition and diversity, including by layer, and evidence of species specific diseases or mortality.

Background: This metric has been drafted by NatureServe’s Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008).

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: Trees, shrubs, herbs, and alga play an important role in providing wildlife habitat, and they are the most readily surveyed aspect of wetland biodiversity. Vegetation is also the single, largest component of net primary productivity. The integrity of ecosystems is optimized when a characteristic native flora dominates the plant community, and suitable habitat exists for multiple animal species. Much of the natural microbial, invertebrate, and vertebrate species of wetlands respond to overall vegetation composition. Vegetation composition also reflects the interactions between plants and physical processes, especially hydrology. A change in vegetation composition, as a result of invasive and exotic plant invasions for example, can have cascading effects on system form, structure, and function (Collins et al. 2006, Rocchio 2007).

We use overall composition, emphasizing key diagnostic species typical of a wetland type, rather than species diversity or richness (which is also more typically a Level 3 metric). This metric can be thought of as a rapid version of a Level 3 Floristic Quality Index (FQI) or Index of Biotic Integrity (VIBI), requiring experienced ecological judgment in the field in combination with good vegetation descriptions of the wetland type being evaluated (Mack and Kentula (2010).

Measurement Protocol: This metric consists of evaluating the species composition of the vegetation. The protocol is a visual evaluation of variation in overall composition. This metric requires the ability to recognize the major-dominant aquatic, wetland, and riparian plants species of each layer or stratum. When a field team lacks the necessary botanical expertise, voucher specimens will need to be collected using standard plant presses and site documentation. This can greatly increase the time required to complete an assessment.

A field form should be used that describes composition using either strata or growth forms (Jennings et al. 2009) (see "Vegetation Structure**"** metric, Table 6.1). For the strata method, list all major strata – tree, shrub, herb, non-vascular, floating, submerged – then estimate strata cover and cover of dominant (>5% cover), characteristic, and exotic species. For the growth form method, list major growth forms – tree (subdivided into overstory and regeneration), shrub (subdivided by tall and medium/low), herb, non-vascular, floating, submerged, epiphyte, and liana – then estimate strata cover and cover of dominant (>5%), characteristic, and exotic species.

The metric refers to species which are diagnostic, increaser, or ruderal. Diagnostic species, or the characteristic combination of species, are typically native plant species whose relative constancy or abundance differentiates one type from another, including character species (strongly restricted to a type), differential species (higher constancy or abundance in a type as compared to others), constant species (typically found in a type, whether or not restricted), and dominant species (high abundance or cover) (FGDC 2008). Together these species also indicate certain ecological conditions, typically that of minimally disturbed sites. Information on diagnostic species for USNVC types is available for the USNVC Group level and below (alliance and association), and many state Natural Heritage Programs maintain natural community classifications where lists of diagnostic species are provided (see "Wetland Classification" above).

Increaser species are native species in the wetland whose dominance is indicative of degrading ecological conditions, such as heavy grazing or browse pressure (Daubenmire 1968), but where sites typically do not have substantial soil profile disturbances. For example, *Dennstaedia punctilobula,* a native fern in northeastern U.S. northern hardwood forests, responds favorably to heavy deer browse (de la Crétaz and Kelty 2006). Degrading conditions that lead to presence of invasives species are treated in the "Invasive Plant Species Cover" metric. Ruderal species are either native or exotic species whose presence or dominance is indicative of disturbed soils, such as disturbances caused by grading, plowing, or vehicular ruts; that is, they are especially dominant native increasers or invasive exotic species on heavily disturbed sites, and where strongly dominant, they may cause a wetland to be "transformed" to a different type (e.g., a native sedge meadow type could be transformed to a reed canary grass type). Guidance on typical "increaser" species is helpful for field crews, but needs to be developed in the context of diagnostic species that are specific to the wetlands being evaluated.

Field survey method for estimating vegetation composition may be either a (1) Site Survey (semi-quantitative) method where the observers walk the AA, and make notes on vegetation strata, their cover, and native vs. exotic species or (2) Quantitative Plot Data, where a fixed area is surveyed, using either plots or transects. The plot or transect is typically a "rapid" plot, but a single intensive plot can also be taken (see Appendix 3).

Metric Rating

Table 10.1. Vegetation Composition Metric Ratings. See text ("Measurement Protocol") for definitions of diagnostic, increaser, and ruderal species terms.

Metric Rating	***Vegetation Composition: ALL WETLANDS***
EXCELLENT (A)	**Vegetation composition minimally to not disturbed:** i) Typical range of native diagnostic species present, including those native species sensitive to anthropogenic degradation, AND ii) Native species indicative of anthropogenic disturbance (i.e., increasers, weedy or ruderal species) absent to minor.
GOOD (B)	**Vegetation composition with minor disturbed conditions:** i) Some native diagnostic species absent or substantially reduced in abundance, AND ii) Some native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present but minor in abundance.
FAIR (C)	**Vegetation composition with moderately disturbed conditions:** i) Many native diagnostic species absent or substantially reduced in abundance, AND ii) Species are still largely native and characteristic of the type, but they also include increasers, weedy or ruderal species.
POOR (D)	**Vegetation composition with severely disturbed conditions:** i) Most or all native diagnostic species absent, a few may remain in very low abundance, OR ii) Native species from entire strata may be absent or species are dominated by ruderal ("weedy") species, or comprised of planted stands of non-characteristic species, or unnaturally dominated by single species.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana.

Scaling Rationale: The metric is scaled based on the similarity between the described species composition of the vegetation and what is expected based on reference condition. Reference conditions reflect the accumulated experience of field ecologists (as recorded in detailed wetland type descriptions – see "Wetland Classification" section above), studies from sites where natural processes are intact, regional surveys and historic sources.).

Confidence that reasonable logic and/or data support the metric: Medium/High.

HYDROLOGY

For various aspects of the hydrology metrics, we have benefitted from the work of the Ohio Rapid Assessment Method (Mack 2001) and California Rapid Assessment Method (Collins et al. 2006).

Table 11.0 Hydrology Metric Variants by HGM Class.

METRIC	HYDROLOGY	HYDROLOGY	HYDROLOGY
Metric Variant by Hydrogeomorphic Class	**12. Water Source**	**13. Hydroperiod**	**14. Hydrologic Connectivity**
Estuarine Fringe (Tidal)	**V1**	**V1**	**V1**
Riverine (Non-tidal)	**V2**	**V2**	**V2**
Organic Soil Flats, Mineral Soil Flats	**V3**	**V3**	**V3**
Other HGM (Depression, Lacustrine, Slope)	**V4**	**V4**	**V4**

- ### 11. Water Source

Definition: An assessment of the extent, duration, and frequency of saturated or ponded conditions within a wetland, as affected by the kinds of direct inputs of water into, or any diversions of water away from, the wetland.

Background: Water Sources encompass the forms, or places, of direct inputs of water to the AA as well as any unnatural diversions of water from the AA. Diversions are considered a water source because they affect the ability of the AA to function as a source of water for other habitats while also directly affecting the hydrology of the AA. The metric is adapted from Collins et al. (2006), but the variants are modified for national and international application, and the role of wetland plant indicators is de-emphasized (their role is assessed by the Vegetation Composition metric). Collins et al. (2006) state:

> “A water source is direct if it supplies water mainly to the AA, rather than to areas through which the water must flow to reach the AA. Natural, direct sources include rainfall, ground water discharge, and flooding of the AA due to high tides or naturally high riverine flows. Examples of unnatural, direct sources include storm drains that empty directly into the AA or into an immediately adjacent area. For seeps and springs that occur at the toe of an earthen dam, the reservoir behind the dam is an unnatural, direct water source. Indirect sources that should not be considered in this metric include large regional dams or urban storm drain systems that do not drain directly into the AA but that have systemic, ubiquitous effects on broad geographic areas of which the AA is a small part. For example, the salinity regime of an estuarine wetland near Napa is affected by dams in the Sierra Nevada, but these effects are not direct. But the same wetland is directly affected by the nearby discharge from the Napa sewage treatment facility. Engineered hydrological controls, such as tide gates, weirs, flashboards, grade control structures, check dams, etc., can serve to demarcate the boundary of an AA…, but they are not considered water sources.”

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: Natural inflows of water to a wetland are important to its ability to persist as a wetland. The flow of water into a wetland also affects sediment processes and the physical structure/geometry of the wetland (Collins et al. 2006).

Measurement Protocol: This metric can be assessed initially in the office using available imagery, and then revised based on the field visit. The metric focuses on direct sources of tidal and non-tidal water, comparing the natural sources to unnatural sources. Permanent or semi-permanent features that affect water source at the overall watershed or regional level should not be considered in the evaluation of this metric (Collins et al. 2006).

The office assessment can work outward from the AA, to include landscape indicators of unnatural water sources, such as adjacent intensive development or irrigated agriculture, nearby wastewater treatment plants, and nearby reservoirs. These indicators identified in the office can then be checked in the field.

Metric Rating:

Table 11.1. Water Source Metric Rating. Separate metric ratings are provided for Estuarine Fringe (Tidal), Riverine (Non-tidal), Organic and Mineral Soil Flats,, and Other HGM – (Depression, Lacustrine, Slope).

Metric Rating	***V1: Water Source: ESTUARINE FRINGE (Tidal) Wetlands***
EXCELLENT (A)	Tidal water source is natural with no artificial alterations to natural salinity. Non-tidal source (alluvial) is natural; no indication of direct artificial water sources (e.g., land use in the local drainage area of the site is primarily open space or low density, passive uses. Lacks point source discharges into or adjacent to the site.
GOOD (B)	Tidal water source is mostly natural with minor alterations to natural salinity. Non-tidal source is mostly natural, but site directly receives occasional or small continuous amounts of inflow from anthropogenic sources (indicators include <20% of core landscape is agricultural or developed land, storm drains etc.)
FAIR (C)	Tidal water source is somewhat impacted by human activity. Non-tidal source is primarily urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology (indicators include >20% of core landscape is agricultural or developed land, major point sources of discharge, etc.).
POOR (D)	Tidal water source is substantially impacted by human activity. Non-tidal water flow has been substantially diminished by human activity.

Metric Rating	***V2: Water Source variant: RIVERINE (Non-tidal) Wetlands***
EXCELLENT (A)	Water source is natural, site hydrology is dominated by precipitation, groundwater, and natural runoff from an adjacent freshwater body. System may naturally lack water at times, such as in the growing season. There is no indication of direct artificial water sources. Land use in the local drainage area of the site is primarily open space or low density, passive uses. Lacks point source discharges into or adjacent to the site.
GOOD (B)	Water source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic input include developed land or agricultural land (<20%) in the immediate drainage area of the site, or the presence of small storm drains or other local discharges emptying into the site, road runoff, or the presence of scattered homes along the wetland that probably have septic systems. No large point sources discharge into or adjacent to the site.
FAIR (C)	Water source contains a large component of urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology. Indications of substantial artificial hydrology include >20% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site.
POOR (D)	Water flow exists but has been substantially diminished by known impoundments or diversions of water or other withdrawals directly from the site, its encompassing wetland, or from areas adjacent to the site or its wetland, OR water source has been severely altered to the point where it no longer supports much vegetation (e.g., flashy runoff from impervious surfaces).

Metric Rating	***V3: Water Source variant: ORGANIC SOIL FLATS, MINERAL SOIL FLATS***
EXCELLENT (A)	Water source is natural, and site hydrology is dominated by precipitation. There is no indication of direct artificial water sources. Land use in the local drainage area of the site is primarily open space or low density, passive uses. Lacks point source discharges into or adjacent to the site.
GOOD (B)	Water source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources, or is ditched, causing peatland to dry out more quickly. Indications of anthropogenic input include developed land or agricultural land (<20%) in the immediate drainage area of the site; or the presence of small storm drains, ditches, or other local discharges emptying into the site; road runoff; or the presence of scattered homes along the wetland that probably have septic systems. No large point sources discharge into or adjacent to the site.
FAIR (C)	Water source is moderately impacted by increased inputs into the peatland, artificially impounded water, or other artificial hydrology. Indications of substantial artificial hydrology include >20% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site.
POOR (D)	Water source is substantially impacted by impoundments or diversions of water or other input into or withdrawals directly from the site, its encompassing wetland, or from areas adjacent to the site or its wetland.

Metric Rating	***V4: Water Source variant: OTHER HGM (DEPRESSION, LACUSTRINE, SLOPE)***
EXCELLENT (A)	Water source is natural: site hydrology is dominated by precipitation, groundwater, natural runoff from an adjacent freshwater body, or the system naturally lacks water in some periods. There is no indication of direct artificial water sources. Land use in the local drainage area of the site is primarily open space or low density, passive uses. Lacks point source discharges into or adjacent to the site.
GOOD (B)	Water source is mostly natural, but site directly receives occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic input include developed land or agricultural land (<20%) in the immediate drainage area of the site, or the presence of small storm drains or other local discharges emptying into the site, road runoff, or the presence of scattered homes along the wetland that probably have septic systems. No large point sources discharge into or adjacent to the site.
FAIR (C)	Water source is primarily urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology. Indications of substantial artificial hydrology include >20% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site.

POOR (D)	Water source exists but has been substantially diminished by known impoundments or diversions of water or other withdrawals directly from the site, its encompassing wetland, or from areas adjacent to the site or its wetland, OR water sources has been severely altered to the point where they no longer support much vegetation (e.g., flashy runoff from impervious surfaces).

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana.

Scaling Rationale: Metric ratings are adapted from Collins et al. (2006).

Confidence that reasonable logic and/or data support the metric: Medium/High.

12. Hydroperiod

Definition: An assessment of the characteristic frequency and duration of inundation or saturation of a wetland during a typical year.

Background: Metric is adapted from Collins et al. (2006), and modified to include other hydroperiod variants outside of California. Hydroperiod integrates the inflows and outflows of water and varies by major wetland types (Mitsch and Gosselink 2000). For tidal wetlands, there are many hydroperiod cycles that correspond to different periodicities in the orbital relationships among the earth, moon, and sun, creating a variety of tidal patterns at semi-daily, daily, semi-weekly, monthly, seasonal, and annual timeframes. For non-tidal wetlands, with fluctuating hydroperiods such as depressional, lacustrine, riverine, and mineral flats wetlands, cycles are governed by seasonal or annual patterns of rainfall and temperature. For non-tidal wetlands with more stable, saturated hydroperiods, such as groundwater-fed slope wetlands, these seasonal patterns are often over-ridden by groundwater flows. Lagoons can be episodically subjected to tidal inundation, but may otherwise have similar hydroperiods to lacustrine systems (Collins et al. 2006).

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: For all non-riverine wetlands, hydroperiod is the dominant aspect of hydrology. Hydroperiod, or the pattern and balance of inflows and outflows, is a major determinant of wetland functions. The patterns of import, storage, and export of sediment and other water-borne materials are functions of the hydroperiod. In most wetlands, plant recruitment and maintenance are dependent on hydroperiod. The interactions of hydroperiod and topography are major determinants of the distribution and abundance of native wetland plants and animals (Mitsch and Gosselink 2000).

For riverine wetlands, hydroperiod is assessed through the patterns of water flow associated with rainfall, snowmelt, dams, and long term weather patterns, i.e. the flow regime (Poff et al. 1997). The natural flow regime of a river can be characterized in terms of the magnitude, frequency, duration, and timing of extreme high flows and low flows (Poff et al. 1997, 2007). Flow regime has an important impact on sediment movement and sinuosity of the stream and river.

Measurement Protocol: This metric evaluates recent changes in the hydroperiod, and the degree to which these changes affect the structure and composition of the wetland plant community. Common indicators are presented for the different wetland classes. This metric focuses on changes that have occurred in the last 20-30 years.

A basic understanding of the natural hydrology or channel dynamics of the type wetland being evaluated is needed to apply this metric. For example, high gradient riparian areas in mountainous areas have very different dynamics from those in flat coastal plains, especially in terms of aggradation or degradation (Poff et al. 1997).

<u>Measurement Protocols for Tidal Wetlands (Estuarine)</u>

Collins et al. (2006) describe the hydroperiod of estuaries:

> "The volume of water that flows into and from an estuarine wetland due to the changing stage of the tide is termed the "tidal prism". This volume of water consists of inputs from both tidal (i.e., marine) and non-tidal (e.g., fluvial or upland) sources. The timing, duration, and frequency of inundation of the wetland by these waters is termed the tidal hydroperiod. Under natural conditions, increases in tidal prism result in increases in sedimentation, such that increases in hydroperiod do not persist. For example, estuarine marshes tend to build upward in quasi-equilibrium with sea level rise. A decrease in tidal prism usually results in a decrease in hydroperiod. In lagoons, freshwater inputs are substantial and tidal prisms are altered by barriers to tidal inputs, which may occasionally be breached by occasional winds driving overwash across the tidal barrier or by seepage through the tidal barrier, etc."

Collins et al. (2006) provide indicators of alterations to the estuarine hydroperiod (i.e., a change in the tidal prism):

- Changes in the relative abundance of plants indicative of either high or low marsh.
- A preponderance of shrink cracks or dried pannes is indicative of decreased hydroperiod.
- Inadequate tidal flushing may be indicated by algal blooms or by encroachment of freshwater vegetation.

- Dikes, levees, ponds, ditches, and tide control structures are indicators of an altered hydroperiod resulting from management for flood control, salt production, waterfowl hunting, boating, etc.

<u>**Measurement Protocols for Non-Tidal Wetlands**</u>

Riverine (non-tidal): To score this metric, visually survey the AA for field indicators of aggradation or degradation (listed in Table 12.1). After reviewing the entire AA and comparing the conditions to those described in the table, determine whether the AA is in equilibrium, aggrading, or degrading, then assign a metric rating. Groundwater-fed wetlands in a riverine context are treated with non-riverine (e.g., New Jersey's groundwater-fed riverine pine barrens). See Collins et al. (2006) for additional guidance.

Table 12.1. Suggested field indicators for evaluating the Hydroperiod Metric for Riverine Wetlands (adapted from Collins et. al. 2006, Table 4.8).

Condition	**Field Indicators**
Indicators of Channel Equilibrium	- The channel (or multiple channels in braided systems) has a well-defined usual high water line, or bankfull stage that is clearly indicated by an obvious floodplain, topographic bench that represents an abrupt change in the cross-sectional profile of the channel throughout most of the site. - The usual high water line or bankfull stage corresponds to the lower limit of riparian vascular vegetation. - The channel contains embedded woody debris of the size and amount consistent with what is available in the riparian area. - There is little or no active undercutting or burial of riparian vegetation.
Indicators of Active Degradation	- Portions of the channel are characterized by deeply undercut banks with exposed living roots of trees or shrubs. There are abundant bank slides or slumps, or the banks are uniformly scoured and unvegetated. - Riparian vegetation may be declining in stature or vigor, and/or riparian trees and shrubs may be falling into the channel. - The channel bed lacks any fine-grained sediment. - Recently active flow pathways appear to have coalesced into one channel (i.e., a previously braided system is no longer braided).

Indicators of Active Aggradation	- The channel through the site lacks a well-defined usual high water line. - There is an active floodplain with fresh splays of sediment covering older soils or recent vegetation. - There are partially buried tree trunks or shrubs. - Cobbles and/or coarse gravels have recently been deposited on the floodplain. - There are partially buried, or sediment-choked, culverts.

Non-Riverine (non-tidal): Assessment of the hydroperiod for all non-riverine wetlands should be initiated with an office-based review of diversions or augmentations of flows or alteration of saturated conditions to the wetland. Field indicators for altered hydroperiod include pumps, spring boxes, ditches, hoses and pipes, encroachment of terrestrial vegetation, excessive exotic vegetation along the perimeter of the wetland, and desiccation during periods of the year when comparable wetlands are typically inundated or saturated (Table 12.2).

Table 12.2. Suggested field indicators for evaluating the Hydroperiod Metric for Non-Riverine, Non-tidal Freshwater Wetlands (adapted from Collins et. al. 2006, Table 4.8).

Condition	Field Indicators
Reduced Extent and Duration of Inundation or Saturation	- Upstream spring boxes, diversions, impoundments, pumps, ditching, or draining from the wetland. - Evidence of aquatic wildlife mortality. - Encroachment of terrestrial vegetation. - Stress or mortality of hydrophytes. - Compressed or reduced plant zonation. - Organic soils occurring well above contemporary water tables.
Increased Extent and Duration of Inundation or Saturation	- Berms, dikes, or other water control features that increase duration of ponding (e.g., pumps). - Diversions, ditching, or draining into the wetland. - Late-season vitality of annual vegetation. - Recently drowned riparian or terrestrial vegetation. - Extensive fine-grain deposits on the wetland margins.

Organic Soil Flats. Bog and Poor Fen: Bogs (and poor fens) have a very stable, saturated hydroperiod, or a much damped cycle of saturation and partial drying. Because drying is limited to the upper layers of peat, bogs are rarely subject to fires, which can burn woody vegetation and upper peat layers when they do occur. The hydroperiod can be altered by ditches, which further increase drying of the peat layer, or by increased runoff into the system, which if weakly minerotrophic (and not truly ombrotrophic), as occurs in poor fens, can lead to nutrient enrichment.

Metric Rating:

Table 12.3. Hydroperiod Metric Rating. Separate metric ratings are provided for Estuarine Fringe (Tidal), Riverine (Non-Tidal), Organic and Mineral Soil Flats, other HGM (Depression, Lacustrine, Slope) variants.

Metric Rating	***V1: Hydroperiod variant: ESTUARINE FRINGE (Tidal*)**
EXCELLENT (A)	Area is subject to the full tidal prism, with two daily tidal minima and maxima. Lagoons: Area subject to natural inter-annual tidal fluctuations (range may be severely muted or vary seasonally), and is episodically fully tidal by natural breaching due to either fluvial flooding or storm surge.
GOOD (B)	Area is subject to reduced, or muted, tidal prism, although two daily minima and maxima are observed. Lagoons: Area is subject to full tidal range more often than would be expected under natural circumstances, because of artificial breaching of the tidal barrier.
FAIR (C)	Area is subject to muted tidal prism, with tidal fluctuations evident only in relation to extreme daily highs or spring tides. Lagoons: Area is subject to full tidal range less often than would be expected under natural circumstances due to management of the breach to prevent its opening.
POOR (D)	Area is subject to muted tidal prism, plus there is inadequate drainage, such that the marsh tends to remain flooded during low tide. Lagoons: Area appears to have no episodes of full tidal exchange.

Metric Rating	***V2: Hydroperiod variant: RIVERINE (Non-tidal)***
EXCELLENT (A)	Most of the channel/riparian zone is characterized by equilibrium conditions, with no evidence of severe aggradation or degradation (based on the field indicators listed in Table 12.1).
GOOD (B)	Most of the channel/riparian zone is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form (based on the field indicators listed in Table 12.1).
FAIR (C)	Most of the channel/riparian zone is characterized by severe aggradation or degradation (based on the field indicators listed in Table 12.1).
POOR (D)	Most of the channel is concrete or artificially hardened (see field indicators in Table 12.1).

Metric Rating	*V3: Hydroperiod variant: ORGANIC SOIL FLATS, MINERAL SOIL FLATS*
EXCELLENT (A)	Stable, saturated hydrology, or naturally damped cycles of saturation and partial drying.
GOOD (B)	Minor altered inflows or drawdown/drying (e.g., ditching).
FAIR (C)	Moderately altered by increased runoff, or drawdown and drying (e.g., ditching).
POOR (D)	Substantially altered by increased inflow from runoff, or significant drawdown and drying (e.g., ditching).

Metric Rating	*V4: Hydroperiod variant: OTHER HGM (DEPRESSION, LACUSTRINE, SLOPE)*
EXCELLENT (A)	Natural patterns associated with inundation – drawdown, saturation, and seepage discharge.
GOOD (B)	Some alteration to the natural patterns associated with inundation – drawdown, saturation, and seepage discharge.
FAIR (C)	Moderate alteration to the natural patterns associated with inundation – drawdown, saturation, and seepage discharge.
POOR (D)	Significant alteration to the natural patterns associated with inundation – drawdown, saturation, and seepage discharge.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana.

Scaling Rationale: Metric ratings are adapted from Collins et al. (2006), except for Bog &Poor Fen, were drafted by the NatureServe Ecological Integrity Assessment Working Group (Faber-Langendoen et al. 2008).

Confidence that reasonable logic and/or data support the metric: Medium/High.

- ### 13. Hydrologic Connectivity

Definition: An assessment of the ability of the water to flow into or out of the wetland, or to inundate adjacent areas.

Background: Metric is adapted from Collins et al. (2006, CRAM manual 4.0), with additional metric variants added.

Metric Type: Condition.

Tier: 1 (remote sensing); 2 (rapid field measure).

Rationale for Selection of the Variable: Hydrologic connectivity between wetlands and adjacent uplands supports key ecologic processes, such as the exchange of water, sediment, nutrients, and organic carbon. Connectivity of both surface and subsurface hydrologic connections, including connections with shallow aquifers and hyporheic zones (zones beneath and alongside stream beds, where surface water and groundwater mix), is a challenging and often poorly understood aspect of connectivity. Many animal species, such as amphibians, depend on the connectivity between streams and their floodplains, or ponds and surrounding habitats (Poff et al. 1997, Amoros and Bornette 2002).

The number of junctions in tidal channels (Adamus 2005; 2006, Appendix A, code 54A) provides a measure of the number of branches in typically dendritic networks of channels in tidal marsh, and provides an indication of existing tidal connectivity or potential connectivity at proposed restoration sites. Occurrences are determined by channels visible in 1:24,000 aerial photographs. Tidal channel sinuosity can be quantified, but more work is needed to determine whether general metrics of sinuosity can be established. Time elapsed since restoration of tidal circulation and extent of restoration (Adamus 2005, 2006) provides a measure of rate and extent of sediment accretion.

Measurement Protocol:
Scoring of this metric is based solely on field indicators (see Collins et al. 2006). No office work is required. The metric is assessed in the field by observing signs of alteration to overbank flooding, channel migration, channel incision, and geomorphic modifications present within the assessment area.

For riverine wetlands and riparian habitats, Hydrologic Connectivity is assessed in part based on the degree of alteration of flooding regimes (e.g., channel entrenchment). Entrenchment varies naturally with channel confinement. Channels in steep canyons naturally tend to be confined, and tend to have small entrenchment ratios indicating less hydrologic connectivity. Assessments of hydrologic connectivity based on entrenchment must therefore be adjusted for channel confinement based on the geomorphic setting of the riverine wetlands. Prevention of river flooding by human-created levees and dikes are other ways in which changes to hydrological connectivity can be assessed (Collins et al. 2006). Natural levees may form as part of river dynamics, and may be breached during natural flooding events, also altering connectivity. Their form is distinctive enough from human-created levees, helping to minimize misidentification.

We do not present an “isolated wetland” variant, as it is difficult to verify this category in the field. Depressional wetlands often have outlets, as well as subsurface connectivity.

Metric Rating:

Table 13.1. Hydrologic Connectivity Metric Rating. Separate Estuarine Fringe (Tidal), Riverine (Non-Tidal), Organic and Mineral Soil Flats), Other HGM (Depression, Lacustrine, Slope) variants are provided.

Metric Rating	*V1: Hydrologic Connectivity variant: ESTUARINE FRINGE (Tidal)*
EXCELLENT (A)	Tidal channel sinuosity reflects natural processes; absence of channelization. Marsh receives unimpeded tidal flooding. Total absence of tide gates, flaps, dikes culverts, or human-made channels.
GOOD (B)	Tidal channel sinuosity minimally altered: marsh receives essentially unimpeded tidal flooding, with few tidal channels blocked by dikes or tide gates, and human-made channels are few. Culvert, if present, is of large diameter and does not significantly change tidal flow, as evidenced by similar vegetation on either side of the culvert.
FAIR (C)	Tidal channel sinuosity moderately altered: marsh channels are frequently blocked by dikes or tide gates. Tidal flooding is somewhat impeded by small culvert size, as evidenced in obvious differences in vegetation on either side of the culvert.
POOR (D)	Tidal channel sinuosity extensively altered: tidal channels are extensively blocked by dikes and tide gates; evidence of extensive human channelization. Tidal flooding is totally or almost totally impeded by tidal gates or obstructed culverts.

Metric Rating	*V2: Hydrologic Connectivity variant: RIVERINE (Non-tidal)*
EXCELLENT (A)	Completely connected to floodplain (backwater sloughs and channels). No geomorphic modifications made to contemporary floodplain.
GOOD (B)	Minimally disconnected from floodplain. Up to 25% of stream banks are affected.
FAIR (C)	Moderately disconnected from floodplain due to multiple geomorphic modifications (e.g., dikes, tide gates, and elevated culverts); 25-75% of stream banks are affected.
POOR (D)	Extensively disconnected from floodplain; >75% of stream banks are affected.

Metric Rating	*V3: Hydrologic Connectivity variant: ORGANIC SOIL FLATS, MINERAL SOIL FLATS*
EXCELLENT (A)	No or very little direct connectivity to groundwater. Precipitation is the dominant or only source.
GOOD (B)	Minor hydrological connectivity, as caused by human activity (e.g., ditching).
FAIR (C)	Moderate connectivity caused by human activity (e.g., ditching).
POOR (D)	Substantial to full connectivity caused by human activity.

Metric Rating	*V4: Hydrologic Connectivity variant: OTHER HGM (DEPRESSION, LACUSTRINE, SLOPE)*
EXCELLENT (A)	No unnatural obstructions to lateral or vertical movement of ground or surface water, or if perched water table then impermeable soil layer (fragipan or duripan) intact. Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows.
GOOD (B)	Minor restrictions to the lateral or vertical movement of ground or surface waters by unnatural features, such as levees or excessively high banks. Less than 25% of the site is restricted by barriers to drainage. If perched then impermeable soil layer partly disturbed (e.g., from drilling or blasting). Restrictions may be intermittent along the site, or the restrictions may occur only along one bank or shore. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment.
FAIR (C)	Moderate restrictions to the lateral or vertical movement of ground or surface waters by unnatural features, such as levees or excessively high banks. Between 25-75% of the site is restricted by barriers to drainage. If perched then impermeable soil layer moderately disturbed (e.g., by drilling or blasting). Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete due to impoundment.
POOR (D)	Essentially no hydrologic connection to adjacent wetlands or uplands. Most or all water stages are contained within artificial banks, levees, sea walls, or comparable features. Greater than 75% of wetland is restricted by barriers to drainage. If perched then impermeable soil layer strongly disturbed.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of a variant of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: Metric ratings are adapted from Collins et al. (2006), except for Bog & Poor Fen. Use of a "wide salinity gradient and connectivity" metric could be helpful in assessing the hydrologic connectivity of mangroves, and it could be applicable to many estuaries. But it does not apply to salt marsh lagoons on the U.S. west coast that may have restricted tidal access in summer and restricted salinity gradients, so a lagoon variants may need to be addressed at lower levels of classification, such as NVC Group or Ecological System, where Atlantic or Pacific salt marshes are treated as separate types (J. Christy pers. comm. 2008).

Confidence that reasonable logic and/or data support the metric: Medium/High.

SOIL / SUBSTRATE

- ### 14. Physical Patch Types

Definition: A checklist of the number of different physical surfaces or features that may provide habitat for species.

Background: This metric is adapted from Collins et al. (2006), but has been rescaled by NatureServe's Ecological Integrity Assessment Working Group to emphasize condition rather than functional complexity (Faber-Langendoen et al. 2008).

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: The rationale for this variable as used by Collins et al. (2006) emphasizes the connection between increasing physical complexity and increasing ecological functions, beneficial uses, as well as overall condition. Here we revise the metric to primarily emphasize condition. For each wetland class, there are visible patches of physical structure that typically occur at multiple points along the hydrologic gradient. But not all patch types will occur in all wetland types. Therefore, the rating is based on the percent of total expected patch types for a given wetland class at a site.

Measurement Protocol: Prior to fieldwork, the imagery of the site should be reviewed to survey the major physical features or patch types present. The office work must be field-checked using a descriptive list of patch types, as summarized in the Physical Patch Type Worksheet below (Table 14.1), by noting the presence/absence of patch types expected for a particular example of a given wetland type, and calculating the percentage of expected patch types actually found at the site.

Table 14.1. Physical Patch Type Worksheet.

FLOODED & SWAMP FOREST		FRESHWATER MARSH, WET MEADOW & SHRUBLAND		BOG& FEN	
Open water - Oxbows / Backwater channels / Pools / Tributaries	FS1	Open water - ponds or lakes	M1	Open water margin - Moats / Laggs	BF1
Seeps / Springs - onsite or adjacent	FS2	Open water - pools	M2	Inlet / Outlet Stream (fens)	BF2
Depositional or erosional features, e.g., point bar, flats, bare ground, undercut banks	FS3	Open water - streams	M3	Rivulets	BF3
Debris jams / Woody debris on-site or in adjacent channel	FS4	Seeps / Springs: adjacent or onsite	M4	Springs / Seeps / Shallow open water (fen)	BF4
Tip up mounds / Pits	FS5	Non-vegetated areas (e.g., Bare ground / Mudflat / Sand)	M5	Moss / Aquatic hollows / Bog pools	BF5
Beaver dams / Canals	FS6	Beaver dams / Canals	M6	Floating mats	BF6
Terraces	FS7	Debris jams / Woody debris	M7	Beaver dams / Canals	BF7
Natural levees	FS8	Topographic gradient	M8	Peat flats (bog) / Marl flats (fens)	**BF8**
Upland pockets in floodplain or swamp	FS9	Swale topography	M9	Flarks / Strings	**BF9**
Plant hummocks and hollows	FS10	Plant hummocks / Hollows	M10	Plant hummocks / Hollows	BF10
Animal mounds and burrows	FS11	Animal mounds and burrows	M11	Animal mounds and burrows	BF11
MANGROVE		**SALT MARSH**		**AQUATIC VEGETATION**	
Open water (tidal)	M1	Natural tidal creeks/Creeklets	SM1	Shallow open water (<2 m deep)	AV1
Non-vegetated flats or bare ground	M2	Pannes or Pools	SM2	Non-vegetated flats or bare ground	AV2
Topographic gradient	M3	Mudflats / Sandflats	SM3	Woody debris	AV3
Marl levee	M4	Deposition or erosional features e.g., sand or mud fans, edge sloughing, intertidal rocky shore	SM4	Boulders, rocks, or bedrock	AV4
Prop roots, drop roots, pneumatophores, aerial rootlets, viviparous propagules	M5	Topographic and/or Salinity gradient	SM5	Topographic gradient	AV5
Intertidal barnacle or oyster colonies	M6	Detrital mats	SM6		
Fiddler crab burrows	M7	Intertidal mussel colonies	SM7		
		Fiddler crab burrows	SM8		
OTHER:					

Metric Rating:

Table 14.2. Physical Patch Type Metric Rating.

Metric Rating	***Physical Patch Types: ALL WETLAND TYPES***
EXCELLENT (A)	Expected physical patch types for a particular example of wetland type are present (see worksheet for examples).
GOOD (B)	One or two of the expected physical patch types are lacking (give evidence).
FAIR (C)	Several of the expected physical patch types are lacking (give evidence).
POOR (D)	Most or the entire expected physical patch types are lacking (give evidence).

Data for Metric Rating: See table from Collins et al. (2006, Physical Patch Type Worksheet). Refinement is ongoing as we apply this to a variety of wetlands. Also see Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Lemly and Rocchio (2009) tested user variability and the performance of a variant of this metric in relation to a Level 3 EIA (e.g., vegetation index of biotic integrity).

Scaling Rationale: Scaling rationale focuses more on a characteristic set of physical patch types, appropriate to the site rather than a presumption that more physical patch types are better than fewer patch types. But assessing a characteristic set of patch types may not be a particularly sensitive metric (Faber-Langendoen et al. 2011). Further testing is needed.

Confidence that reasonable logic and/or data support the metric: Low.

▪ 15. Soil Surface Condition

Definition: An indirect measure of soil condition based on stressors that increase the potential for erosion or sedimentation of the soils, assessed by evaluating intensity of human impacts to soils on the site.

Background: This metric is partly based on a metric developed by Mack (2001) and the NatureServe Ecological Integrity Working Group (Faber-Langendoen et al. 2008). This metric has also been called “Substrate / Soil Disturbance.”

Metric Type: Condition/Stressor.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: Soils are a key feature of wetlands, providing the medium in which plants grow and storing filtrate water. Assessment of soils is challenging for rapid assessments; surface condition is the most visible aspect that can be assessed. The attributes for this metric describe surface conditions that affect a site's biological and physical characteristics and functions (Page-Dumroese et al. 2000, 2009a).

Measurement Protocol: Prior to fieldwork, aerial photography of the site can be reviewed to determine if any soil alterations have occurred, but the primary assessment is based on field observations of the AA.

Metric Rating:

Table 15.1. Soil Surface Metric Rating. Separate variants are provided by NVC Formation for all freshwater wetlands (non-tidal) including Flooded & Swamp Forest, Freshwater Marsh, Wet Meadow & Shrubland, Bog & Fen, Aquatic Vegetation versus estuarine wetlands (tidal) including Mangrove and Salt Marsh.

Metric Rating	***V1: Soil Surface Condition variant: ALL FRESHWATER NON-TIDAL WETLANDS*** (FLOODED & SWAMP FOREST, FRESHWATER MARSH, WET MEADOW & SHRUBLAND, BOG & FEN, AQUATIC VEGETATION)
EXCELLENT (A)	Bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails.
GOOD (B)	Small amounts of bare soil areas due to human causes are present but the extent and impact is minimal. The depth of disturbance is limited to only several centimeters (a few inches) and does not show evidence of ponding, channeling water, or effects of boat traffic. Any disturbance is likely to recover within a few years after the disturbance is removed.
FAIR (C)	Moderate amounts of bare soil areas due to human causes. Soil trampling by livestock can cause 5-10 centimeters (several inches) of soil disturbance. Off-road-vehicles or other machinery may have left some shallow ruts or erosion. Damage is not excessive and the site will recover to potential with the removal of degrading human influences and moderate recovery times.
POOR (D)	Bare soil areas substantial and contribute to altered hydrology or other long-lasting impacts. Deep ruts from Off-road-vehicles or machinery may be present, or livestock soil trampling and/or trails are widespread. Water will be channeled or ponded. The site will not recover without restoration and/or long recovery times.

Metric Rating	***V2: Soil Surface Condition variant: ESTUARINE WETLANDS*** (MANGROVE, SALT MARSH, and tidal variants of FRESHWATER MARSH, WET MEADOW & SHRUBLAND)
EXCELLENT (A)	Excluding mud flats, bare soils are limited to salt pannes.
GOOD (B)	Limited exposure of bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic.
FAIR (C)	Frequent exposure of bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic.
POOR (D)	Extensive bare soils caused by erosion of marsh and channel banks due to excavation by marine traffic.

Data for Metric Rating: See Faber-Langendoen et al. (2011) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Also see Page-Dumroese et al. (2009b) for a summary of data for forests.

Scaling Rationale: Page-Dumroese et al. (2009a) summarize how increasing levels of soil impacts in forests lead to changes in hydrology and other ecological processes.

Confidence that reasonable logic and/or data support the metric: Medium/High.

STRESSOR CHECKLIST

GUIDELINES FOR COMPLETING THE STRESSOR CHECKLIST

Definition: A stressor is an anthropogenic perturbation within the AA or surrounding landscape that can negatively affect the condition and function of the wetland.

Background: The term "stressor" is defined as "the proximate (human) activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity and natural processes" (from Salafsky et al. 2008). Here we restrict our focus to those stressors that have caused or are causing impacts, whenever the effects of the stressors are evident. For example, a stressor may be recent tree removal or mowing. Less recent mowing or tree removal would be included only if the effect of those stressors is still currently evident (e.g., old tree stumps). The term is synonymous with" *direct threats*" as defined by Salafsky et al. (2008) or with "stressors" as used by the U.S. EPA (Young and Sanzone 2002). The checklist is taken from Faber-Langendoen et al. (2011). See also Collins et al. (2006). For guidance on completing the stressors checklist form, see section below.

Rationale: The overarching purpose of this checklist is to identify likely anthropogenic causes for diminished wetland conditions. A list of potential stressors corresponds to each of the major ecological attributes of wetland condition. Thus, relationships between stressors, attributes, and their component metrics might be surmised. In some cases, a single stressor may cause deviation from "good" condition, but in most cases multiple stressors interact to affect wetland condition (EPA, 2002).

There are four underlying assumptions about the presumed correlation between ecological condition or integrity and the stressors: (1) deviation from a "good" condition can be explained by a single stressor or multiple stressors acting on the wetland; (2) increasing the number of stressors acting on the wetland causes a decline in its condition [there is no assumption as to whether this decline is additive (linear), multiplicative, or is best represented by some other non-linear mode]; (3) increasing either the intensity or the proximity of the stressor results in a greater decline in condition; and (4) continuous or chronic stress causes further declines in condition. We rate stressor levels and condition levels separately so that we test these assumptions, by exploring correlations between the stressor levels and the levels of integrity, including the use of a Human Stressor Index (Rocchio 2007, Faber-Langendoen et al. 2011). Some wetlands may be very resistant to change in the face of high levels of stress, which is informative. Some of the condition metrics used to assess ecological integrity include stressors to a certain degree (e.g., surrounding land use is a guide to rating alterations to water source), so care must be taken in how these correlations are developed.

Seasonality: The Stressor Checklist is not particularly sensitive to seasonality, except for Vegetation stressors.

Office and Field Indicators: The assessment of this attribute is the same across all wetland classes. For each attribute, a variety of human actions that are likely sources of stress are listed, and their presence, and likelihood of affecting the AA (assessment area) in question, are recorded in the table. Stressors associated with Vegetation, Soil / Substrate, and Hydrology are assessed within the AA itself. Adjacent land uses are scored only for those land uses in the 100 meter Buffer surrounding the AA.

Stressor Checklist Form

A complete set of stressors is presented in Table 16.1 below.

Table 16.1 Level 2 Stressor Checklist.

Stressors: *direct threats*; "the proximate (human) activities or processes that have caused, are causing the destruction, degradation, and/or impairment of biodiversity and natural processes."

Important Points about Stressors Checklists.

1. Stressors checklists must be completed for all 4 categories (B, V, S, H).
2. Buffer Perimeter is the entire perimeter **around the AA,** up to a distance of 100 m. Rely on imagery in combination with what you can field check.
3. Assess Buffer Perimeter stressors and their effects within the Buffer Perimeter (**NOT how buffer stressors may impact the AA**).
4. Stressors for Vegetation, Soils, and Hydrology are assessed across the **assessment area; AA**.
5. Some stressors may overlap (e.g., 10 [Passive recreation] may overlap with 24 [Trampling]); choose only 1 and note overlap.

Assess for up to next 20 yrs.	Threat Scope (% of AA affected)	Assess for up to next 20 yrs.	Threat Severity within the Scope(degree of degradation of AA)
A = Small	Affects a small (1-10%) proportion	A = Slight	Likely to only slightly degrade/reduce
B = Restricted	Affects some (11-30%)	B = Moderate	Likely to moderately degrade/reduce
C = Large	Affects much (31-70%)	C = Serious	Likely to seriously degrade/reduce
D = Pervasive	Affects most or (71-100%)	D = Extreme	Likely to extremely degrade/destroy or eliminate

				ASSESSMENT AREA						
		Buffer(100 m)		Vegetation		Soil / Subs		Hydrology		
	STRESSORS CHECKLIST	**Scope**	**Sever**	**Scope**	**Sever**	**Scope**	**Sever**	**Scope**	**Sever**	**Comments (circle stressor #)**
D	1. Residential, recreational buildings, associated pavement									1
E	2. Industrial, commercial, military buildings, associated pavement									2
V	3. Utility/powerline corridor									3
E	4. Sports field, golf course, urban parkland, lawn									4
L	5. Row-crop agriculture, orchard, nursery									5
O	6. Hay field									6
P	7. Livestock, grazing, excessive herbivory									7
	8. Roads (gravel, paved, highway), railroad									8
	9. Other (specify):									9
R	10. Passive recreation (bird-watching, hiking, trampling, camping)									10
E	11. Active recreation (ATV, mountain biking, hunting, fishing, boats)									11
C	12. Other (specify):									12
	13a. Tree resource extraction (e.g., clearcut, selective cut)									13
	13 b. Shrub/herb resource extraction (e.g., medicine, horticulture)									
V	14. Vegetation management(cutting, mowing)									14
E	15. Excessive animal herbivory, insect pest damage									15
G	16. Invasive exotic plant species									16
	17. Pesticide or vector control, chemicals (give onsite evidence)									17
	18. Other (specify):									18

CONTINUED

	STRESSORS CHECKLIST	Buffer [100 m]			Vegetation [AA]			Soil / Subst. [AA]			Hydrology [AA]			
		Scope	Sever		Scope	Sever		Scope	Sever		Scope	Sever		Comments (circle stressor(s)
Nat	19. Altered natural disturbance regime (specify expected regime)													19
Dis	20. Other (specify):													20
	21. Excessive sediment or organic debris (recently logged sites), gullying, erosion													21
S	22. Trash or refuse dumping													22
O	23. Filling, spoils, excavation													23
I	24. Soil disturbance (trampling, vehicle, livestock, skidding, etc.)													24
L	25. Grading, compaction, plowing, discing, fire lines													25
	26. Physical resource extraction (rock, sand, gravel, etc.)													26
	27. Other (specify):													27
H	28. Point source discharge (treatment water, non-storm discharge, septic)													28
Y	29. Non-point source discharge (urban runoff, farm drainage)													29
D	30. Dam, ditch, diversion, dike, levee, unnatural inflow, reservoir													30
R	31. Groundwater extraction (water table lowered)													31
O	32. Flow obstructions (culverts, paved stream crossings)													32
L	33. Engineered channel (riprap, armored channel bank, bed)													33
O	34. Actively managed hydrology (e.g., lake levels controlled)													34
G	35. Tide gate, weir/drop structure, dredged inlet/channel													35
Y	36. Other (specify):													36

	Stressors Very Minimal or Not Evident (check box, if true)	☐		☐		☐		☐		

***Hydrology stressors will often cross between buffer and AA. For example, ditches in the buffer may directly impact hydrology of the AA. Minimize listing in both columns unless you are sure of the impacts. If ditches occur in both the buffer and the AA, then both should be listed.**

Guidance on Completing the Stressor Checklist Form

Stressors are rated if they are observed or inferred to occur in the present (i.e. within a 10 year timeframe), or occurred anytime in the past with effects that persist into the present. Stressors are not assessed if they are projected to occur in the near term, but do not yet occur.[1] It may be of interest to assess stressors that are projected to occur in the near or long term (e.g., projected sea level rise and its impact on salt marshes, but they should be scored separately).

[1] Thus listing of stressors for an AA differs from a Threats Impact approach used to assess overall threats that influence the conservation status of an ecosystem type (see Master et al. 2012).

Stressors may be characterized in terms of ***scope*** and ***severity***. Scope is defined as the proportion of the AA that can reasonably be expected to be affected by the stressor with continuation of current circumstances and trends. Severity is the degree of degradation within the scope from the stressor, which can reasonably be expected to occur now or in the near term (within 10 years) with continuation of current circumstances and trends.

The following guidance is under review, and is adapted from Master et al. (2012).

1. Record an estimate of the scope and severity for applicable individual stressors to the wetland (Table 16.2).

Table 16.2. Ratings for Stressor Scope and Severity

Stressor Scope (typically assessed within a 10-year time frame)
Pervasive = Affects all or most (71-100%) of total AA
Large = Affects much (31-70%) of the total AA
Restricted = Affects some (11-30%) of the total AA
Small = Affects a small (1-10%) proportion of the total AA
Unknown
Stressor Severity – within the scope(assessed within max of 10 years)
Extreme = Likely to extremely degrade/destroy or eliminate AA (71-100%)
Serious = Likely to seriously degrade/reduce AA (31-70%)
Moderate = Likely to moderately degrade/reduce AA (11-30%)
Slight = Likely to only slightly degrade/reduce AA (1-10%)

2. The impact of each stressor is scored automatically from the scope and severity values, and a letter grade is assigned (Table 16.3).

Table 16.3. Stressor Impact Scoring.

Stressor Impact Calculation		**Scope**			
		Pervasive	Large	Restricted	Small
Severity	Extreme	Very High	High	Medium	Low
	Serious	High	High	Medium	Low
	Moderate	Medium	Medium	Low	Low
	Slight	Low	Low	Low	Low

Stressor Impact
A = Very High
B = High
C = Medium
D = Low

3. After impact has been recorded for all applicable stressors, use these impact values to calculate an overall stressor impact for the major ecological attributes (buffer, vegetation, soils, and hydrology) according to the guidelines in Table 16.4 below.

If the value for one or more impacts is a range, evaluate the highest (single and range) values for every threat and then evaluate the lowest values to determine the range of overall stressor impact. For example, three Medium–Low impacts could indicate an overall stressor impact of High–Low, and four Medium–Low impacts indicate an overall stressor impact of High–Medium.

Table 16.4. Guidelines for assigning an overall impact value.

Impact Values of Stressor Categories	OVERALL STRESSOR IMPACT
1 or more Very High, OR 2 or more High, OR 1 High + 2 or more Medium	Very High
1 High, OR 3 or more Medium, *OR* 2 Medium + 2 Low, *OR* 1 Medium + 3 or more Low	High
1 Medium, or 4 or more Low	Medium
1 to 3 Low	Low

4. After impact has been recorded for the major ecological attributes, use these impact values to assign an overall stressor impact to the AA, again using Table 16.4 above (e.g., if Vegetation and Soils have a High Rating, then Overall Stressor Impact is Very High). Ratings can be summarized using Table 16.5.

If the value for one or more major ecological attributes is a range, evaluate the highest (single and range) values for every major attribute and then evaluate the lowest values to determine the range of overall threat impact. For example, three Medium–Low impacts indicate an overall threat impact of High–Low, and four Medium–Low impacts indicate an overall threat impact of High–Medium.

Table 16.5. Stressor Summary Form

Major Ecological Attribute	Impact
Landscape Context	
Vegetation	
Soil	
Hydrology	
Overall Stressor Impact	

REFERENCES

Adamus, P.R. 2005. Science review and data analysis for tidal wetlands of the Oregon coast. Hydrogeomorphic guidebook, Part 2. Report to Coos Watershed Association, US Environmental Protection Agency, and Oregon Department of State Lands, Salem. 216 pp.

Adamus, P.R. 2006. Hydrogeomorphic (HGM) assessment guidebook for tidal wetlands of the Oregon coast, Part 1: Rapid assessment method. Report to Coos Watershed Association, U.S. Environmental Protection Agency, and Oregon Department of State Lands, Salem. 85 pp.

Amoros, C. and G. Bornette. 2002. Connectivity and bio-complexity in water bodies of riverine floodplains. Freshwater Biology 47:761-776.

Brooks, R.P., D.H. Wardrop, and J.A. Bishop. 2004. Assessing wetland condition on a watershed basis in the Mid-Atlantic region using synoptic land-cover maps. Environmental Monitoring and Assessment 94:9–22.

Brown, J. 1974. Handbook for inventorying downed woody material of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 24 pp.

Carlisle, B. K., A. L. Hicks, J. P. Smith, S. R. Garcia, and B. G. Largay. 1999. Plants and aquatic invertebrates as metrics of wetland biological integrity in Waquoit Bay watershed, Cape Code. Environment Cape Code 2: 30–60.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2006. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas. Version 4.2.3. 136 pp.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2007. California Rapid Assessment Method (CRAM) for Wetlands and Riparian Areas. Version 4.5.2. Riverine Field Book.

Cooper, D.J. 1990. Ecology of Wetlands in Big Meadows, Rocky Mountain National Park, Colorado. U.S. Fish and Wildlife Service, Biological Report 90(15).

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of the wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Daubenmire, R.F. 1968. Plant communities: A textbook of plant synecology. Harper and Row, NY.

de la Crétaz, A. L. and M.J. Kelty. 2006. Control of Hay-Scented Fern by Mowing. Northern Journal of Applied Forestry 23: 149-154.

Dukes, J.S. and H.A. Mooney. 1999. Does global change increase the success of biological invaders? Trends in Evolution and Ecology 14: 135–139.

Environmental Law Institute. 2008. Planner's Guide to Wetland Buffers for Local Governments. Washington, DC. 25 pp.

Executive Presidential Order. 1999. Executive Order 13112 of February 3, 1999: Invasive Species. Federal Register 64 (25):6183–6186.

Faber-Langendoen,D., G. Kudray, C. Nordman, L. Sneddon, L. Vance, E. Byers, J. Rocchio, S. Gawler, G. Kittel, S. Menard, P. Comer, E. Muldavin, M. Schafale, T. Foti, C. Josse, and J. Christy. 2008. *Ecological Performance Standards for Wetland Mitigation based on Ecological Integrity Assessments.* NatureServe, Arlington, VA. + Appendices.

Faber-Langendoen, D. 2009. A freshwater wetlands monitoring and assessment framework for the Northeast Temperate Network, National Park Service. Natural Resource Report PS/NETN/NRR–2009/143. National Park Service, Fort Collins, CO.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2011. *Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach.* NatureServe, Arlington VA.+ Appendices.

Faber-Langendoen, D., C. Hedge, M. Kost, S. Thomas, L. Smart, R. Smyth, J. Drake, and S. Menard. 2012. *Assessment of wetland ecosystem condition across landscape regions: A multi-metric approach. Part A. Ecological Integrity Assessment overview and field study in Michigan and Indiana.* EPA/600/R-12/021a. U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Federal Geographic Data Committee. 2008. Vegetation Classification Standard, version 2 FGDC-STD-005, v2. Washington, DC.

Fennessy, M.S., A.D. Jacobs, and M.E. Kentula. 2007. An evaluation of rapid methods for assessing the ecological condition of wetlands. Wetlands 27:543–560.

Gregory, S.V., F.J. Swanson, W.A. McKee, and K.W. Cummins.1991. An Ecosystem Perspective of Riparian Zones. BioScience 41: 540–551.

Guerry, A. D. and M. L. Hunter. 2002. Amphibian Distributions in a Landscape of Forests and Agriculture: An Examination of Landscape Composition and Configuration. Conservation Biology 16:745–754.

Harwell, M.A., V. Myers, T. Young, A. Bartuska, N. Gassman, J. H. Gentile, C. C. Harwell, S. Appelbaum, J. Barko, B. Causey, C. Johnson, A. McLean, R. Smola, P. Templet, and S. Tosini. 1999. A framework for an ecosystem integrity report card. BioScience 49: 543–556.

Hauer, F.R., B.J. Cook, M.C. Gilbert, E.J. Clairain Jr., and R.D. Smith.2002. A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Riverine Floodplains in the Northern Rocky Mountains. U.S. Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory, Vicksburg, MS. ERDC/EL TR-02-21.

Heinz Center. 2002. The State of the Nation's Ecosystems: Measuring the Lands, Waters and Living Resources of the United States. Cambridge University Press, NY.

Jacobs, A., E. McLaughlin, and K. Havens. 2010. Mid-Atlantic Tidal Wetland Rapid Assessment Method Version 3.0. June 2010. Delaware Department of Natural Resources and Environmental Control. Dover, DE.

Jennings, M.D., D. Faber-Langendoen, R.K. Peet, O.L. Loucks, M.G. Barbour, and D. Roberts. 2009. Guidelines for characterizing associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs 79: 173–199.

Kittel, G. and D. Faber-Langendoen. 2011. Watershed Approach to Wetland Mitigation: A Conceptual Framework for Juneau, Alaska. Prepared by NatureServe, Arlington VA

Lemly, J.M. and Rocchio, J.R. 2009. Field Testing and Validation of the Subalpine-Montane Riparian Shrublands Ecological Integrity Assessment (EIA) Scorecard in the Blue River Watershed, Colorado. Report prepared for the Colorado Division of Wildlife and US EPA Region 8 by the Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Online: http://www.cnhp.colostate.edu/download/reports.asp

Lemly, J, L. Gilligan, M. Fink, B. Sullivan, G. Wilcox, and C. Johnson. 2011. Statewide Strategies to Improve Effectiveness in Protecting and Restoring Colorado's Wetland Resource *Including* the Rio Grande Headwaters Pilot Wetland Condition Assessment. Report prepared for the Colorado Division of Wildlife and US EPA Region 8 by the Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Online: http://www.cnhp.colostate.edu/download/reports.asp

Leroux, S.J., F.K.A. Schmiegelowa, R. B. Lessard, and S. G. Cumming. 2007. Minimum dynamic reserves: A framework for determining reserve size in ecosystems structured by large disturbances. Biological Conservation 138: 464–473.

Lindenmayer, D.B. and J.F. Franklin. 2002. Conserving forest biodiversity: A comprehensive multiscaled approach. Island Press, Washington, DC.351 pp.

Lindenmayer, D. B. and Fischer, J. (2006). Habitat fragmentation and landscape change: an ecological and conservation synthesis. Island Press, Washington, DC.

Linkov, I., D. Loney, S. Cormier, F. K. Satterstrom and T. Bridges. 2009. Weight-of-evidence evaluation in environmental assessment: Review of qualitative and quantitative approaches. Science of the Total Environment 407:5199-5205.

Mack, J.J. 2001. Ohio rapid assessment method for wetlands v. 5.0, user's Manual and scoring forms. Ohio EPA Technical Report WET/2001-1. Ohio Environmental Protection Agency, Division of Surface Water, Wetland Ecology Group, Columbus, OH.

Mack, J.J. 2006. Landscape as a predictor of wetland condition: An evaluation of the Landscape Development Index (LDI) with a large reference wetland dataset from Ohio. Environmental Monitoring and Assessment 120: 221–241.

Mack, J. J. and M.E. Kentula. 2010. Metric Similarity in Vegetation-Based Wetland Assessment Methods. EPA/600/R-10/140. U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C.

Master, L. L., D. Faber-Langendoen, R. Bittman, G. A. Hammerson, B. Heidel, L. Ramsay, K. Snow, A. Teucher, and A. Tomaino. 2012. NatureServe Conservation Status Assessments: Factors for Evaluating Species and Ecosystem Risk. NatureServe, Arlington, Virginia, U.S.A.

McIntyre S. and R. Hobbs. 1999. A framework for conceptualizing human effects on landscapes and its relevance to management and research models. ConservBiol 13:1282–1292.

McRae, B.H., B.G. Dickson, T.H. Keitt, and V.B. Shah. 2008. Using circuit theory to model connectivity in ecology and conservation. Ecology 10: 2712-2724.

Miller, S.J., D.H. Wardrop, W.M. Mahaney, and R.P. Brooks. 2006. A plant-based index of biological integrity (IBI) for headwater wetlands in central Pennsylvania. Ecological Indicators 6: 290–312.

Miller, S.J. and D.H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. Ecological Indicators 6(2): 313–326.

Mitsch, W.J. and J. G. Gosselink.2000. Wetlands, 3rd edition. J. Wiley & Sons, Inc. 920 pp.

NatureServe. 2012. Central Basin and Range. Rapid Ecoregional Assessments, Final Memorandum I-3-C (March 4, 2011). Department of the Interior, Bureau of Land Management, Rapid Ecoregional Assessments, Denver, Colorado. NatureServe, Washington DC.

Nichols, W. F. and D. Faber-Langendoen. 2012. Level 2.5 Ecological Integrity Assessment Manual: Wetland Systems. New Hampshire Natural Heritage Bureau & NatureServe, Concord, NH. +Appendices.

Noon, B. R. 2003. Conceptual issues in monitoring ecological systems. Pages 27–71 *in* D. E. Busch and J. C. Trexler, editors. Monitoring ecosystems: Interdisciplinary approaches for evaluating ecoregional initiatives. Island Press, Washington, DC., USA 447 pp.

NRCS [Natural Resource Conservation Service]. 2005. Ecological Site Descriptions for Utah, Wyoming, and Montana. These can be found online at http://www.nrcs.usda.gov/technical/efotg/.

NRCS [Natural Resources Conservation Service]. 2008. Hydrogeomorphic Wetland Classification System: An Overview and Modification to Better Meet the Needs of the Natural Resources Conservation Service. USDA Technical Note No. 190–8–76.

Page-Dumroese, D, M. Jurgensen, W. Elliot, T. M. Rice, J. Nesser, T. Collins, and R. Meurisse. 2000. Soil quality standards and guidelines for forest sustainability in northwestern North America. Forest Ecology and Management 138: 445–462.

Page-Dumroese, D., A. M. Abbott, and T. M. Rice. 2009a. USDA Forest soil disturbance monitoring protocol, Volume 1: Rapid assessment. FS-WO-82a. Moscow, ID: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 29 pp.

Page-Dumroese, D., A. M. Abbott, and T. M. Rice. 2009b. Forest soil disturbance monitoring protocol, Volume 2: Supplementary methods, statistics, and data collection. FS-WO-82b. Moscow, ID: U.S. Department of Agriculture, Forest Service. 64 pp.

Parrish, J.D., D. P. Braun, and R.S. Unnasch. 2003. Are we conserving what we say we are? Measuring ecological integrity within protected areas. BioScience 53: 851–860.

Patten, D.T. 1998. Riparian ecosystems of semi-arid North America: Diversity and human impacts. Wetlands 18:498–512.

Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Presegaard, B.D. Richter, R.E. Sparks, and J.C. Stromburg. 1997. The natural flow regime: A paradigm for river conservation and restoration. BioScience 47:769–784.

Poff, N.R., J.D. Olden, D. M. Merritt, and D. M. Pepin. 2007. Homogenization of regional river dynamics by dams and global biodiversity implications. PNAS 104: 5732–5737.

Reed, P.B., Jr. 1988. National list of plant species that occur in wetlands: Intermountain (Region 8). Biological Report 88(26.8), U.S. Department of Interior, Fish and Wildlife Service, Fort Collins, CO.

Rejmánek, M., D. M. Richardson, S. I. Higgins, M.J. Pitcairn, and E. Grotkopp. 2005. Ecology of invasive plants: State of the art. Pp 104–161 *In* H. Mooney, R.N. Mack, J.A. McNeely, L.E. Neville, P.J. Schei, and J.K. Waage. Invasive alien species: A new synthesis. SCOPE 63. Island Press, Washington, DC.

Richardson, D.M., P. Pysek, M. Rejmánek, M.G. Barbour, F.D. Panetta, and C.J. West. 2000. Naturalization and invasion of alien plants: Concepts and definitions. Diversity and Distributions 6:93–107.

Rocchio, J. 2007. Assessing Ecological Condition of Headwater Wetlands in the Southern Rocky Mountain Ecoregion Using a Vegetation Index of Biotic Integrity. Colorado Department of Natural Resources, and U.S. Environmental Protection Agency, Region VIII. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Online: http://www.cnhp.colostate.edu/reports.html.

Rondeau, R. 2001. Ecological system viability specifications for Southern Rocky Mountain ecoregion. First Edition. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. 181 pp.

Salafsky, N., D. Salzer, A. J. Stattersfield, C. Hilton-Taylor, R. Neugarten, S. H. M. Butchart, B. Collen, N. Cox, L. L. Master, S. O'Connor, and D. Wilkie. 2008. A standard lexicon for biodiversity conservation: unified classifications of threats and actions. Conservation Biology 22:897-911.

Semlitsch, R. D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding amphibians. Conservation Biology 12:1113–1119.

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. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS, USA. Technical Report TR WRP-DE-10.

Snyder, D. and S.R. Kaufman. 2004. An overview of nonindigenous plant species in New Jersey. New Jersey Department of Environmental Protection, Division of Parks andForestry, Office of Natural Lands Management, Natural Heritage Program, Trenton, NJ.107 pp.

Society for Ecological Restoration (SER) International Science & Policy Working Group. 2004. *The SER International Primer on Ecological Restoration*. www.ser.org & Tucson: Society for Ecological Restoration International. 13 p.

Stein, E.D., A. E. Fetscher, R. P. Clark, A. Wiskind, J. L. Grenier, M. Sutula, J. N. Collins, and C. Grosso. 2009. Validation of a wetland rapid assessment method: Use of EPA's level 1-2-3 framework for method testing and refinement wetlands. Wetlands 29: 648–665.

Stevenson, R.J. and F.R. Hauer. 2002. Integrating Hydrogeomorphic and Index of Biotic Integrity approaches for environmental assessments of wetlands. J. N. Am Benthol. Soc. 21:502-513

Sutula, M.A., E.D. Stein, J.N. Collins, A.E. Fetscher, and R. Clark. 2006. A practical guide for development of a wetland assessment method: The California experience. J. Amer. Water Resources Association 42:157–175.

Tierney, G.L., D. Faber-Langendoen**,** B.R. Mitchell, W.G. Shriver, and J.P. Gibbs. 2009. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment 7:308–316.

Thompson, E.H. and E.R. Sorenson. 2000. Wetland, Wildland, Woodland. A guide to the natural communities of Vermont. Vermont Department of Fish and Wildlife and The Nature Conservancy. University Press of New England, Hanover.

Tiner, R.W. 1998. In search of swampland: A wetland sourcebook and field guide. Rutgers University Press, New Brunswick, NJ.

Tiner, R.W. 2003. Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors. U.S. Fish and Wildlife Service, National Wetlands Inventory Program, Northeast Region, Hadley, MA. http://library.fws.gov/Wetlands/dichotomouskeys0903.pdf.

Tiner, R.W. 2004. Remotely-sensed indicators for monitoring the general condition of "natural habitat" in watersheds: An application for Delaware's Nanticoke River watershed Ecological Indicators 4 (2004) 227–243.

Unnasch, R.S., D. P. Braun, P. J. Comer, and G. E. Eckert. 2009. The Ecological Integrity Assessment Framework: A Framework for Assessing the Ecological Integrity of Biological and Ecological Resources of the National Park System**.** Report to the National Park Service.

U.S. EPA. 2011. USA RAM Manual, Version 11. (co-authors, Josh Collins, Siobhan Fennessy). U.S. Environmental Protection Agency, Washington, DC.

U.S. Army Corps of Engineers. 1987. *Corps of Engineers Wetlands Delineation Manual*. Environmental Laboratory, U.S. Army Corps of Engineers Waterways Exp. Stn. Tech. Rep. Y-87-1.

U.S. EPA. 2006. Application of Elements of a State Water Monitoring and Assessment Program For Wetlands, Wetlands Division, Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, DC, April 2006.

U.S. Fish and Wildlife Service (USFWS). 2010. NWIPlus: Geospatial Database for Watershed-level Functional Assessment. April 2010 Factsheet. http://www.fws.gov/northeast/wetlands/factsheets/NWIPlus_FactSheet.pdf.

Walz, K.S. and S. Domber. 2011. Developing a Wetland Condition Monitoring Network for New Jersey: Application of New Assessment Methods. New Jersey Department of Environmental Protection, Trenton, NJ.

White, J. (ed.). 1978. Illinois Natural Areas Inventory Technical Report. Vol. 1. Survey Methods and Results. Report Prepared for Illinois Department of Conservation, Springfield, Illinois.

Windell, J.T., B.E. Willard, and S.Q. Foster.1996. Introduction to Rocky Mountain wetlands. Pages 1–41 *in* J.T. Windell, B.E. Willard, D.J. Cooper, S.Q. Foster, C.F. Knud-Hansen, L.P. Rink, and G.N. Kiladis, editors. An ecological characterization of Rocky Mountain montane and subalpine wetlands. U.S. Fish and Wildlife Service, Biological Report 86.

Young, T.F. and S. Sanzone (editors). 2002. A framework for assessing and reporting on ecological condition. Prepared by the Ecological Reporting Panel, Ecological Processes and Effects Committee. EPA Science Advisory Board. Washington, DC. 142 p.

APPENDIX 1. Template for Metrics Protocols

Text Box. Template for Metric Description

Metric Name: A brief descriptive name for the metric

Definition: A brief explanation of the metric.

Background: Information on the origin and development of the metric.

Metric Type: Types include:

Condition metric: Emphasizes assessment of an aspect of the ecosystem's "inherent" attributes, and which is relevant to ecological integrity (e.g. diagnostic native pecies, hydrologic connectivity).
Stressor metric: Emphasizes assessment of stressors to ecosystem (e.g., invasive species, ditches).

Tier: Metrics may belong on one of more "tiers," referring to levels of intensity of effort required to document a metric. Tier 1 metrics use relatively simple, often qualitative, levels of information, such as may be available from relatively basic interpretations of remote sensing imagery. Tier 2 typical requires qualitative or semi-quantitative data, such as is gathered through rapid field assessments. Tier 3 typically requires intensive quantitative analysis, either from remote sensing or field data, or both.

Example: Landscape Connectivity

Tier 1: Metric based on classifying land cover into natural vs cultural (McIntyre and Hobbs 1999).
Tier 2: Metric based on modeling connectivity. For example, Circuitscape represents landscapes as conductive surfaces, with resistance levels assigned to habitats that vary in their permeability to ecological processes (McRae et al. 2008).
Tier 3: Metric based on integrating field observations in the landscape with remote sensing imagery to assess landscape connectivity.

Rationale for Selection of the Variable: A brief explanation of the merits of the metric

Measurement Protocol: A summary of the methods used to assess the metric, including use of remote sensing imagery and field collection methods.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***Metric Name & Wetland Type(s) to which it applies***
EXCELLENT (A)	Metric Rating Description
GOOD (B)	Metric Rating Description
FAIR (C)	Metric Rating Description
POOR (D)	Metric Rating Description

Data for Metric Rating: Published data that support the basis for the metric rating

Scaling Rationale: A brief summary of the rationale for how the A through D ratings were developed.

Confidence that reasonable logic and/or data support the metric: Confidence rating is based on the level of data supporting the rating and its scaling. High, Medium, Low, Provisional.

APPENDIX 2. Field Methods

Introduction

Field methods for applying ecological integrity assessments vary, depending on the purpose of the assessment. Field methods depend, in part on the sampling design of the project; however, discussions of sampling design are beyond the scope of this report.

Defining the Assessment Area

AA: 0.5 ha (minimum) to 20 ha (maximum).
AA: Flexible area based on all or part of a polygon.

Observations and Guidelines: What follows are a series of observations and guidelines that may be helpful for designing a field survey protocol for ecological integrity assessments.

First, the level of inference must be established. Most commonly, for ecological surveys, this is an occurrence of a wetland, at the scale of a site. We refer to this as the "Assessment Area" (AA). Accordingly, we may define the AA as "the entire area, sub-area, or point of an occurrence of a wetland type."

Described below are three possible sampling strategies if the occurrence at a site is the focus:

1) Conduct an assessment survey of the entire area of the occurrence, e.g., a rapid qualitative assessment.
2) Conduct an assessment survey of a typical sub-area(s) of the occurrence.
3) Collect data using one or more plots, placed in a representative or un-biased location(s), in the assessment area or sub-area (see Appendix 3).

In all three cases, the intent is to assess the ecological integrity of a particular wetland occurrence.

But the level of inference could also be the entire wetland area of a jurisdictional area (e.g., national park, natural area, state, or nation). The intent of an assessment may be to evaluate the ecological integrity of "the park's wetlands," rather than any one particular wetland occurrence. In this case, several options exist. For example, one could first identify all occurrences of wetlands, and map their areal extent. Then one could either sample:

1) A subset of the occurrences, and infer the condition of the park's wetlands from this survey.
2) A series of points across the entire wetland area irrespective of the occurrences, and infer the overall condition of the park's wetlands.

Various combinations of these two approaches are also possible. What is lost in the latter approach is a site-specific ecological assessment area, since the park boundaries determine the area being considered. But if individual wetlands are ecologically delineated and assessed, then averaged together across the park, it would still be possible to think of such an assessment as being comprised of AAs within the park.

Here, our primary focus is working at the level of an occurrence; that is, an entire local wetland polygon or cluster of polygons of a particular type. The goal is to assess the integrity of this occurrence, irrespective of property type, management regime, or size.

▪ Guidelines for Field Methods for Ecological Integrity Assessments

A few guidelines are provided for conducting wetland assessments:

1. Locate, and if desired, map (see step 5 below) the occurrence of a wetland type. Locations may be based on office information, or from previous field visits. Establish a preliminary Assessment Area (AA).

2. Classify the wetland type. Wetlands can be classified using a variety of classifications. Examples of classifications include the U.S. National Vegetation Classification (USNVC, FGDC 2008, Faber-Langendoen et al. 2009), National Wetland Inventory types (Cowardin et al. 1979), Ecological Systems (Comer et al. 2003), Hydrogeomorphic (HGM) type (Smith et al. 1995), or individual state classifications. Knowing the USNVC Formation, NWI type, and HGM type is helpful in applying some of the metrics, as some have variants based on these categories. For example, assessing the Hydrologic Connectivity metric of a freshwater marsh found along a river corridor requires a different form of the metric than for marshes found in depressions.

3. Provide standard office and field data collection protocols, regardless of the intent of the survey, since the fundamental metrics of ecological integrity need to be included. Protocols for how to measure the metrics are all briefly described above. In many cases the metrics can be documented from remote sensing/aerial photographs imagery; in other cases, by walking an assessment area (site); yet in others, by taking a few relatively simple field measures.

4. A field crew (usually two people) should be able to complete a rapid field assessment within two to four hours (excluding travel time to or from the site), plus two hours preparation time assessing the imagery (see #4 below). After the crew leaves the field, the field forms are essentially complete. Field crew expertise should be akin to that needed for wetland delineation; that is, field crews should have some knowledge of hydrology, soils, and vegetation, sufficient to assess hydrologic dynamics, perhaps examine a soil core for mottling and other features, and be able to identify all prominent native and exotic species.

5. Where metrics can be assessed, at least preliminarily from the office, compile the needed information for the office part of the assessment. Many sources of information can help determine the condition and threats to a site (see Rocchio 2007):

- Aerial photographs
- Satellite imagery
- Digital Orthophoto Quadrangles (1 m resolution)
- GIS layers (e.g., roads, utility lines, trails, mines, wilderness areas, National Land Cover Dataset, irrigation, ditches, and groundwater wells),
- Element occurrence records from Natural Heritage Programs
- State or Federal Agency surveys
- Soils map
- Etc.

6. It is helpful to map the extent of the occurrence as part of the field survey (see Rocchio 2007), using the following steps.

A. Estimation of Wetland Boundaries
The first step is to map the wetland area. Readily observable ecological criteria such as vegetation, soil, and hydrological characteristics are used to define wetland boundaries, regardless of whether they meet jurisdictional criteria for wetlands regulated under the Clean Water Act.

B. Delineating Wetland Type Boundaries
The second step is to delineate the targeted type present within the wetland boundary. Type descriptions can be used to guide the delineation of the type boundaries in the field. A minimum map size criterion should be specified, and each patch of a wetland type would be considered separate potential AAs or sub-AAs. If a patch is less than the minimum map size then it would be considered to be associated with internal variation of the type in which it is embedded.

C. Size of Occurrence
Once the targeted type boundaries are delineated, then size can be used to further refine AA boundaries. For example, depending on the size or variation of the wetland area, the AA may consist of the entire site or only a portion of the wetland/riparian area. For small wetlands or those with a clearly defined boundary (e.g., isolated fens or wet meadows) this boundary is almost always the entire wetland. In very large wetlands or extensive and contiguous riparian types, a sub-sample of the area can be defined as the AA for the project. For other project purposes such as regulatory wetland projects, there may be multiple AAs in one large wetland (see *Land Use Related Boundaries below*).

D. Land Use Related Boundaries

Significant change in management or land use may result in distinct ecological differences. If such changes are large-scale, they could require two separate evaluations (two AAs) within the occurrence. If the two AAs differ strongly in ecological integrity, they could be considered separate occurrences or a "range-rating" could be applied to the occurrence (e.g., A/C). Some examples follow:

- A heavily grazed wetland on one side of a fence line and ungrazed wetland on the other could result in separate AAs.
- Natural changes in hydrology occur across a broadly defined wetland. For example, a drastic change in water table levels or fluctuations or confluence with a tributary could dictate using sub-AAs, and, perhaps a change in type.
- Anthropogenic changes in hydrology. For example, ditches, water diversions, irrigation inputs, and roadbeds that substantially alter a site's hydrology relative to adjacent areas could require sub-AAs, if ecological integrity varies substantially.

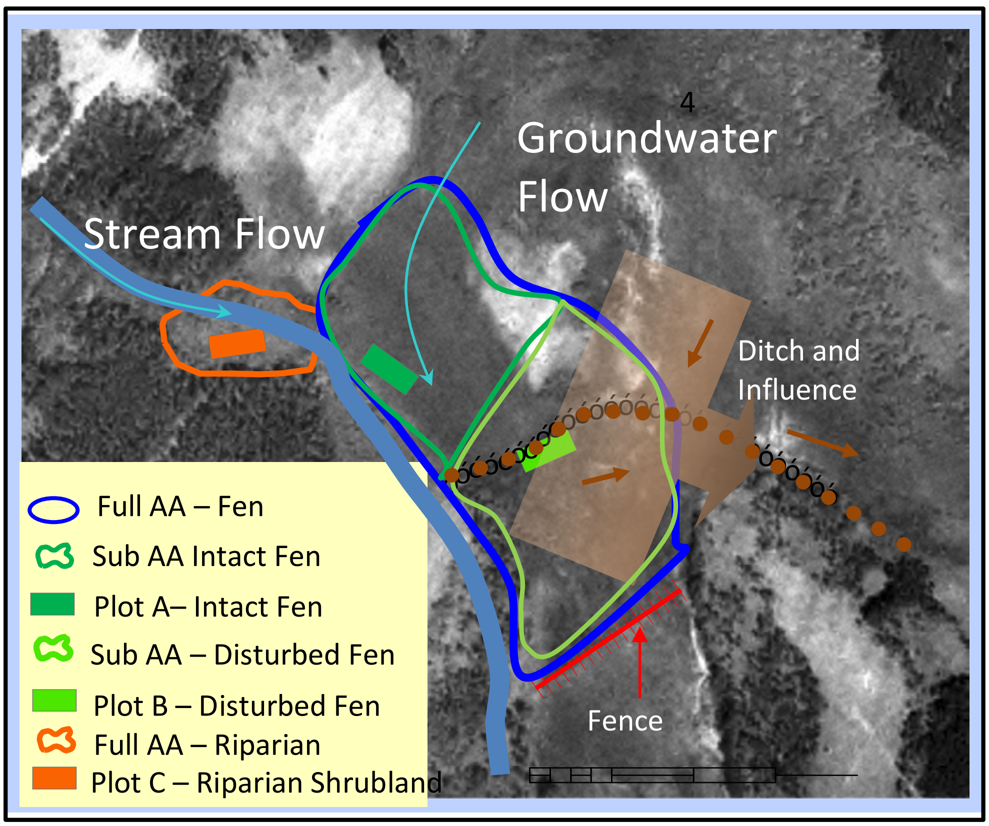


Figure A2.1. Example of delineated Assessment Areas (AAs). Although contiguous with each other, the fen and riparian shrubland were delineated as distinct AAs because they were distinct wetland types (e.g., fen vs. riparian shrubland). The fen was divided into sub-AAs due to a human-induced disturbance (e.g., ditching) which could significantly alter a large portion of an otherwise contiguous wetland type (e.g., intact vs. disturbed fen). A decision as to whether to formally recognize two sub AAs within a larger AA or to simply incorporate the variation into a single evaluation depends on the observed differences in integrity and the size of the AA versus sub-AAs (adapted from Rocchio 2007).

7. For rapid assessments, the entire AA should be assessed, including, as much as is feasibly possible, the 100 m buffer around the AA (typically aided by aerial photography or other imagery). Assessment will consist of a walk-around, scoring metrics based on visual observations.

8. For intensive assessments, vegetation plots can be subjectively placed within the AA to maximize capturing abiotic / biotic heterogeneity within the AA, or randomly placed (see Appendix 3). Capturing heterogeneity within the plot ensures adequate representation of local, micro-variations produced by such things as hummocks, water tracks, side-channels, pools, wetland edge, and micro-topography in the floristic data. Plots can also be placed objectively, if enough plots are laid.

The following guidelines can be used to determine plot locations within the AA:

- The plots can be located using a series of unbiased selected points in the AA or sub-AA.
- Large upland areas and other substantial inclusions which differ from the targeted type should be excluded from plots; however, mesic micro-topographic features such as hummocks, if present, can be included in the plots.
- Localized, small areas of human-induced disturbance can be included in the plot according to their relative representation of the AA. Large areas of human-induced disturbance should be delineated as a separate sub-AA.

References for Appendix 2

Comer, P., D. Faber-Langendoen, R. Evans, S. Gawler, C. Josse, G. Kittel, S. Menard, M. Pyne, M. Reid, K. Schulz, K. Snow, and J. Teague. 2003. Ecological Systems of the United States: A Working Classification of U.S. Terrestrial Systems. NatureServe, Arlington, VA.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of the wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Faber-Langendoen, D., D.L Tart, and R.H. Crawford. 2009. Contours of the revised U.S. National Vegetation Classification standard. Bulletin of the Ecological Society of America 90:87-93.

Federal Geographic Data Committee.2008. Vegetation Classification Standard, version 2 FGDC-STD-005, v2. Washington, DC.

Rocchio, J. 2007. Assessing Ecological Condition of Headwater Wetlands in the Southern Rocky Mountain Ecoregion Using a Vegetation Index of Biotic Integrity. Colorado Department of

Natural Resources, and U.S. Environmental Protection Agency, Region VIII. Colorado Natural Heritage Program, Colorado State University, Fort Collins, CO. Online: http://www.cnhp.colostate.edu/reports.html.

Smith, R. D., A. Amman, C. Bartoldus, and M. M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices. Technical report TR WRP-DE-10, and operational draft. U.S. Army Engineers Waterways Experiment Station, Vicksburg MS.

APPENDIX 3. Vegetation Plots

Although vegetation plots are not typically included in Level 2 assessments, they may be added as part of an "enhanced" Level 2, and they are part of the standard approach for Level 3 assessments. Here we describe the key considerations in choosing a vegetation plot approach (adapted from Jennings et al. 2009). We note that the 0.1 ha hybrid plot approach, typically with one or more 100 to 400 m^2 subplots, contains many desirable features for sampling vegetation, including for EIA purposes (see especially Mack 2007). The method is fully described in Peet et al. 1998; however, their nested methodology below the 100 m^2 level is typically not needed for EIA purposes.

- ### Plot Size and Design

Two fundamentally different approaches are commonly used for recording vegetation: (a) data is recorded from a single large plot, and (b) data is recorded from a set of smaller plots distributed within the stand. Both types of plot designs provide adequate data for vegetation classification, but each method has its own requirements and advantages.

Data from a single large plot: This is an efficient, rapid method for collecting floristic and physiognomic data. The plot size is chosen to ensure that it is small enough to remain relatively uniform in habitat and vegetation, yet is large enough to include most of the species that occur within the community or wetland type. This approach permits statistical assessment of variation among stands but not within stands. Recommended plot size varies depending on the structure of vegetation (such as the size of individual plants, their spacing, and the number of canopy layers) and the need to capture an adequate proportion of the stand's species composition and structure. In most temperate hardwood or conifer forests, plots of between 200 and 1,000 m^2 are adequate for characterizing both the herb and the tree strata, while in many tropical forests, plots between 1,000 and 10,000 m^2 are required. Grassland and shrubland vegetation may require plots between 100 and 400 m^2, while vegetation containing very sparse vascular vegetation (sometimes dominated by non-vascular vegetation), such as open cliff, talus, or desert vegetation may require plots between 1,000 and 2,500 m^2 (McAuliffe 1990; see Chytrý and Otýpková 2003 for plot sizes used by European phytosociologists). We do not recommend any particular plot shape; indeed shape may depend on the local environment and wetland type (e.g., riparian stands tend to be linear).

Data from a set of subplots: Taking multiple subplots within a community or wetland type is an alternative to the single large plot sampling method. This approach yields data that can assess the internal variability within the AA and can more precisely estimate the average abundance of each species across the AA. It is often used to measure responses to experimental manipulations of vegetation. Investigators using the multiple subplot method may locate subplots randomly or systematically within the stand. The observation unit can be a quadrat, line-transect, or point-transect, and can be of various sizes, lengths, and shapes. Quadrats for ground layer vegetation typically range from 0.25 to 5.0 m^2 and anywhere from 10 to 50 quadrats may be placed in the stand. Although subplots may be distributed through a large portion of the stand, the total area from which data are recorded may be smaller than that from a single large plot.

Finally, the choice between a single large plot vs. multiple subplots must consider the tradeoff between a better ability to estimate the precision of species abundance values obtained from small, more widely distributed subplots compared to the more complete species list and more realistic assessment of intimate co-occurrence obtained using the single large plot. A disadvantage of relying on subplots to characterize the stand is that a large number of small sample units may be needed to characterize the full floristic composition of the stand. Yorks and Dabydeen (1998) describe how reliance on subplots can result in a failure to assess the importance of many of the less abundant species in a plot. Consequently, whenever subplots or transects are used, a list of "additional species present" within a larger part of the stand, such as some fixed area around the subsamples, should be included. For example, the California Native Plant Society protocol uses 50-meter point transects supplemented with a list of all the additional species in a surrounding 5x50 m area (Sawyer and Keeler-Wolf 1995).

Hybrid approaches: A hybrid sampling method combines advantages from the above approaches. Indeed, the 1,000 m^2 (50 x 20 m) Whittaker plot approach comes as close to a standard method for vegetation sampling as any (Whittaker 1960, Naveh and Whittaker 1979, Stohlgren et al. 1995, Peet et al. 1998, Mack 2007). Sometimes, several somewhat large subplots (e.g., >100 to 400 m^2 in a forest) are established within the full plot to capture internal variability. An alternative plot method uses a series of nested plots to describe the different layers, with the largest plot for the tree layer, and progressively smaller subplots for the shrub, herb, and nonvascular strata. Although efficient with respect to measures of abundance for the common species, this method risks under-representing the floristic richness of the lower strata which are often more diverse than the upper strata, and may contain many diagnostic species. This problem can be ameliorated by listing all species found within the largest plot used to sample the upper stratum.

Still, no one plot size is correct *a priori*: The widely applied 1,000 m^2 Whittaker plot method noted above and the 375 m^2 Daubenmire (1968) plot method both contain a series of subplots for herbaceous vegetation. With adequate documentation, the hybrid approach can yield data compatible with many other types of sampling while providing data on compositional variation as a function of the scale of observation.

▪ Plot Data

Three types of plot data are needed for effective vegetation classification: vegetation data, site data, and metadata. Of these, vegetation data on floristics and physiognomy are the primary focus. Site or habitat data, such as soil attributes, topographic position, and disturbance history, are also important, but because environmental variables that are significant in one region may be insignificant in another region, the selection of such variables will vary by vegetation type. Floristic composition and cover estimation requires direct estimation of the canopy cover for each plant species. It is preferable to estimate the cover of each species in each vertical canopy stratum or by major growth forms. To assess vegetation structure, the total canopy cover should also be determined for each stratum or major growth form of vegetation (i.e., tree, shrub, herb layer or growth form). These measurements of species and stratum/growth form cover allow for a three-dimensional representation of the vegetation in a plot in order to characterize the vegetation.

References for Appendix 3

Chytrý, M. and Z. Otýpková. 2003. Plot sizes used for phytosociological sampling of European vegetation. Journal of Vegetation Science 14: 563–570.

Daubenmire, R.F. 1968. Plant communities: A textbook of plant synecology. Harper and Row, New York.

Jennings, M.D., D. Faber-Langendoen, O.L. Loucks, R.K. Peet, and D. Roberts.2009. Standards for associations and alliances of the U.S. National Vegetation Classification. Ecological Monographs 79: 173–199.

Mack, J.J. 2007. Developing a wetland IBI with statewide application after multiple testing iterations. Ecological Indicators 7: 864—881.

McAuliffe, J. R. 1990. A rapid survey method for the estimation of density and cover in desert plant communities. Journal of Vegetation Science 1:653–656.

Naveh, Z. and R.H. Whittaker. 1979. Structural and floristic diversity of shrublands and woodlands in northern Israel and other Mediterranean areas. Vegetatio 41:171–190.

Peet, R. K., T. R. Wentworth, and P. S. White. 1998. The North Carolina Vegetation Survey protocol: A flexible, multipurpose method for recording vegetation composition and structure. Castanea 63:262–274.

Sawyer, J. O. and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento, CA.

Stohlgren, T.J., M.B. Falkner, and L.D. Schell. 1995. A modified-Whittaker nested vegetation sampling method. Vegetatio 117:113–121.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs 30:279–338.

Yorks, T.E. and S. Dabydeen. 1998. Modification of the Whittaker sampling technique to assess plant diversity in forested natural areas. Natural Areas Journal 18:185–189.

APPENDIX 4. Descriptions of Major Wetland Formations in the USNVC.

Major wetland categories used to guide formation distinctions are described below (from Faber-Langendoen et al. 2012). Types, definitions, environmental features, and growth forms are adapted from the National Wetlands Working Group (1997) in Canada and Mackenzie and Moran (2004), with linkage to major wetland types described by Mitsch and Gosselink (2000) and by the National Wetland Inventory (NWI, Cowardin et al. 1979).

Wetland Category	**Definition**	**Environmental features**	**Growth forms**	**Mitsch & Gosselink (2000) type**	**NWI Wetland Class**
Bog	Bogs are shrubby, nutrient-poor peatlands with distinctive communities of ericaceous shrubs and hummock-forming *Sphagnum* species, sometimes with sedges, adapted to high acid and oxygen-poor soil conditions. Trees >2 m have <10% cover (rarely, raised bogs may contain some forested stands). Vegetation of bogs and poor fen often overlap and are sometimes treated together as "acid peatland."	+/- ombrotrophic pH <4.5 >40 cm fibric/mesic peat	Stunted needle-leaved tree, low shrub, dwarf shrub (ericaceous), sphagnum	Peatland	Palustrine Moss-Lichen (PML)*+/- Palustrine Emergent (PEM) Palustrine Scrub-Shrub (PSS)

Fen	Fens are peatlands where groundwater or stream inflow maintains relatively moderate to high mineral content within the rooting zone. Sites are characterized by non-ericaceous shrubs, sedges, grasses, reeds, and brown mosses. Trees >2 m have <10% cover. Forested fen included under Swamp Forest. Ranges from poor fen to rich fen. Poor fens overlap with bogs and are sometimes together as "acid peatland" separate from "alkaline peatland."	Groundwater-fed pH >4.5(approximate ranges include poor fen 4.5-5.5, medium or intermediate fen 5.5-6.5, rich fen 6.5-7.5 and extremely rich fen > 7.5). >40 cm fibric/mesic peat (including marly peat)	Low shrub (often non-ericaceous), sedge (often fine), grass, reed, and brown moss, with or without sphagnum	Peatland	Palustrine Moss-Lichen (PML)+/- Palustrine Emergent (PEM) Palustrine Scrub-Shrub (PSS)
Freshwater Marsh, Wet Meadow & Shrubland ***(non-tidal and tidal)***	A marsh-wet meadow is a shallowly flooded or saturated wetland dominated by emergent grass-like, forb or shrub vegetation. A fluctuating water table is typical in marshes and wet meadows, with early season high water tables and some flooding dropping through the growing (or dry) season, and exposure of the substrate or drying of the profile possible in late (or high of dry) season or drought years. Shrub wetlands (shrub carrs) occupy similar sites to wet meadows. Trees >2 m have <10% cover.	Mineral soils or well-humified peat, or rarely marl or rocky substrates. Protracted shallow flooding (0.1 to 2.0 m), prolonged soil profile saturation, or freshwater or oligohaline tidal inundation.	Grass, sedge (often coarse), forb, low shrub, tall shrub	Freshwater marsh (emergent), Tidal freshwater marsh, Riparian ecosystems (wetland, herb/shrub)	Palustrine Emergent (PEM) Palustrine Scrub-Shrub (PSS) Riverine Tidal Emergent (non-persistent) (R1EM2)

Salt Marsh	Salt marshes are intertidal to supratidal ecosystems that are flooded diurnally (or less), sometimes with freshwater inputs, and has communities dominated by salt-tolerant emergent graminoids and succulents. Trees >2 m have <10% cover.	Intertidal and supratidal zones, semi-diurnal to diurnal, flooding by brackish or saltwater [n.b. inland non-tidal saline wet meadows may also be placed here]	Grass, sedge, forb, halophytic (succulent) forb, halophytic shrub	Salt marsh, [Inland saline marsh]	Estuarine Intertidal Emergent (E2EM) Estuarine Intertidal Scrub-Shrub (E2SS)
Flooded & Swamp Forest *(non-tidal and tidal)*	A swamp forest is a tree-dominated mineral or peat wetland, on sites with a flowing/flooded or fluctuating semi-permanent, near or at surface water table. A flooded forest occur on sites where flooding varies from temporary (<7 days) to semi-permanent (>180 days). Trees >2 m have >10% cover.	Mineral soils or well-humified peat. Temporary to semipermanent flooding (0.1 to 2 m deep), or freshwater or oligohaline tidal inundation.	broad-leaved tree, needle-leaved tree, tall shrub, forb, graminoid, hydromorphic herb (rarely)	Freshwater swamps, Riparian ecosystems (wetland, tree)	Palustrine Forested (PFO) Estuarine Intertidal Forested (E2FO) (mainly freshwater)
Mangrove	Mangroves occur in the inter-tidal and brackish backwater of estuarine areas in tropical regions. Mangroves include tree and shrub forms of mangrove of all heights.	Intertidal and supratidal zones, semi-diurnal to diurnal, flooding by brackish or saltwater	Mangrove, halophytic shrub, halophytic (succulent) forb, graminoids	Mangrove	Estuarine Intertidal Forested (E2FO)
Aquatic Vegetation *(non-tidal and tidal)*	Aquatic wetlands are shallow waters dominated by rooted, submerged and floating aquatic plants. They are associated with permanent still or slow-moving waters, such as shallow potholes, ponds, rivers and lakes. Aquatic plants may occur in mineral or in well-humified sedimentary peat. Emergent growth forms <10% cover, hydromorphic growth forms >1% cover.	+/-Permanent deep flooding (0.5 – 2 m), substrate can be muck, sand, marl or rocky substrates	Hydromorphic (aquatic) herb	Freshwater marsh (aquatic)	Palustrine Aquatic Bed (PAB) Riverine Tidal Aquatic Bed (R1AB) Lacustrine Aquatic Bed (L2AB)

**NWI PML= mosses or lichens cover substrates other than rock (emergents, shrubs, or trees make up less than 30% of the areal cover)*

References for Appendix 4

National Wetlands Working Group. 1997. Wetlands of Canada. C. D. A Rubec, editor. Ecological Land Classification Series No. 24. Environment Canada, Ottawa, and Polyscience Publications, Inc., Montreal. 452 pp.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of the wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Faber-Langendoen, D., C. Josse, G. Navarro, T. Keeler-Wolf, D. Meidinger, E. Helmer, B. Hoagland, G. Fults, S. Ponomarenko, J.-P. Saucier, D. Tart, A. Weakley. 2012b. Classification and description of world formation types. Federal Geographic Data Committee, FGDC Secretariat, U.S. Geological Survey. Reston, VA, and NatureServe, Arlington, VA.

MacKenzie, W.H. and J.R. Moran. 2004. Wetlands of British Columbia: a guide to identification. Research Branch, B.C. Ministry of Forestry, Victoria, B.C. Land Management Handbook. No. 52.

Mitsch, W. J. and J. G. Gosselink. 2000. Wetlands, 3rd edition. J. Wiley & Sons, Inc. 920 pp.

APPENDIX 5. Descriptions of Hydrogeomorphic Classes.

See hydrogeomorphic class definitions below from NRCS (2008). Table 1 provides a full definition; Table 2 (Smith et al. 1995) provides a brief tabular overview.

Table 1 Definitions of hydrogeomorphic wetland classes (modified from Brinson et al. 1995)	
HGM CLASS	**Definition**
RIVERINE	Riverine wetlands occur in flood plains and riparian corridors in association with stream channels. Dominant water sources are often overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. However, sources may be interflow and return flow from adjacent uplands, occasional overland flow from adjacent uplands, tributary inflow, and precipitation. At their headwater, RIVERINE wetlands often are replaced by SLOPE or DEPRESSIONAL wetlands where the channel morphology may disappear. They may intergrade with poorly drained flats or uplands. Perennial flow in the channel is not a requirement.
DEPRESSIONAL	Depressional wetlands occur in topographic depressions. Dominant water sources are precipitation, ground water discharge, and both interflow and overland flow from adjacent uplands. The direction of flow is normally from the surrounding uplands toward the center of the depression. Elevation contours are closed, thus allowing the accumulation of surface water. Depressional wetlands may have any combination of inlets and outlets or lack them completely. Dominant hydrodynamics are vertical fluctuations, primarily seasonal. Depressional wetlands may lose water through intermittent or perennial drainage from an outlet, by evapotranspiration and, if they are not receiving ground water discharge, may slowly contribute to ground water. Peat deposits may develop in depressional wetlands. Prairie potholes are a common example of depressional wetlands.
SLOPE	Slope wetlands normally are found where there is a discharge of ground water to the land surface. They normally occur on sloping land; elevation gradients may range from steep hillsides to slight slopes. Slope wetlands are usually incapable of depressional storage because they lack the necessary closed contours. Principal water sources are usually ground water return flow and interflow from surrounding uplands, as well as precipitation. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if ground water discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturation subsurface and surface flows and by evapotranspiration. SLOPE wetlands may develop channels, but the channels serve only to convey water away from the SLOPE wetland. Fens are a common example of slope wetlands.
MINERAL SOIL FLATS	Mineral soils flats are most common on interfluves, extensive relic lake bottoms, or large historic flood plain terraces where the main source of water is precipitation. They receive no ground water discharge, which distinguishes them from DEPRESSIONAL and SLOPE wetlands. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, saturation overland flow, and seepage to underlying ground water. They are distinguished from flat upland areas by their poor vertical drainage, often due to spodic horizons and hardpans, and low lateral drainage, usually due to low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become the class ORGANIC SOIL FLATS. Pine flatwoods with hydric soils are a common example of MINERAL SOIL FLAT wetlands.
ORGANIC SOIL FLATS	Organic soil flats, or extensive peatlands, differ from mineral soil flats, in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation,

	while water loss is by saturation overland flow and seepage to underlying ground water. Raised bogs share many of these characteristics, but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are common examples of organic soil flat wetlands.
ESTUARINE FRINGE	Estuarine Fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with Riverine wetlands where tidal currents diminish and riverflow becomes the dominant water source. Additional water sources may be ground water discharge and precipitation. The interface between the estuarine fringe and Riverine classes is where bidirectional flows from tides dominate over unidirectional ones controlled by flood plain slope of Riverine wetlands. Because estuarine fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, estuarine fringe wetlands seldom dry for significant periods. Estuarine fringe wetlands lose water by tidal exchange, by saturated overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. *Spartina alterniflora* salt marshes are common examples of estuarine fringe wetlands.
LACUSTRINE FRINGE	Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and ground water discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or SLOPE wetlands. Surface water flow is bidirectional, usually controlled by water-level fluctuations such as seiches in the adjoining lake. Lacustrine fringe wetlands are indistinguishable from depressional wetlands where the size of the lake becomes so small relative to fringe wetlands that the lake is incapable of stabilizing water tables. Lacustrine fringe wetlands lose water by flow returning to the lake after flooding, by saturation surface flow, and by evapotranspiration. Organic matter normally accumulates in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are a common example of lacustrine fringe wetlands.

Table 2 (Smith et al. 1995)
Hydrogeomorphic Classes of Wetlands Showing Dominant Water Sources, Hydrodynamics, and Examples of Subclasses

Hydrogeomorphic Class	Water Source (dominant)	Hydrodynamics (dominant)	Examples of Regional Subclass	
			Eastern USA	Western USA and Alaska
Riverine	Overbank flow from channel	Unidirectional and horizontal	Bottomland hardwood forests	Riparian forested wetlands
Depressional	Return flow from groundwater and interflow	Vertical	Prairie pothole marshes	California vernal pools
Slope	Return flow from groundwater	Unidirectional, horizontal	Fens	Avalanche chutes
Mineral soil flats	Precipitation	Vertical	Wet pine flatwoods	Large playas
Organic soil flats	Precipitation	Vertical	Peat bogs; portions of Everglades	Peat bogs
Estuarine fringe	Overbank flow from estuary	Bidirectional, horizontal	Chesapeake Bay marshes	San Francisco Bay
Lacustrine fringe	Overbank flow from lake	Bidirectional, horizontal	Great Lakes marshes	Flathead Lake marshes

References for Appendix 5

Smith, R. D., Ammann, A., Bartoldus, C., and M.M. Brinson. 1995. An approach for assessing wetland functions using hydrogeomorphic classification, reference wetlands, and functional indices, Technical Report WRP-DE-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Natural Resources Conservation Service. 2008. Hydrogeomorphic Wetland Classification System: An Overview and Modification to Better Meet the Needs of the Natural Resources Conservation Service. USDA Technical Note No. 190–8–76.