NatureServe Ecological Integrity Assessment: Protocols for Rapid Field Assessment of Wetlands. v2

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Don Faber-Langendoen, Bill Nichols, Kathleen Walz, Joe Rocchio, Joanna Lemly, and Laurie Gilligan

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[v2.01-2.03 – minor editorial corrections]
[v2.04.- section 7.0:corrections to stressor checklist calculations and example added]
[v2.05. Change in Size metric was upgraded so that it no longer is averaged against Comparative Size; rather, it lowers that score, based on percentage reduction of wetland size.
[v2.06. Change in LAN2 category "Mature old fields and other fallow lands with natural composition" to "Mature old fields and ruderal forests with natural composition on former fallow lands."

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NatureServe Ecological Integrity Assessment Method

1.0 Introduction

Ecological integrity is a key concept 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, the structure, composition, processes, and connectivity of an ecosystem corresponds to reference conditions, and are within the bounds of natural or historical disturbance regimes" (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 wetland Ecological Integrity Assessment (EIA) method builds on the work of other rapid assessment methods (see Fennessy et al. 2007), including the California Rapid Assessment Method or CRAM (Collins et al. 2006, 2007). Our method provides a national and international approach that is comprehensive for all wetlands. At its core, the method uses a suite of field metrics, guided by a conceptual ecological model. Some of our metrics require greater expertise than others, but all factors have at least two metrics that are relatively straightforward to evaluate by field crews with basic knowledge of wetlands and wetland species, 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 condition; 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).

This document is a second in a series of reports and publications on wetland Ecological Integrity Assessment of wetlands:

1. An Introduction to NatureServe's Ecological Integrity Assessment Method (Faber-Langendoen et al. 2016a)
2. "NatureServe Ecological Integrity Assessment: Protocols for Rapid Field Assessment of Wetlands" (Faber-Langendoen et al. 2016b)
3. Assessing the Conservation Value of Ecosystem Occurrences: Integrating Ecological Integrity Assessments with NatureServe's Core Methodology (Faber-Langendoen et al 2016c)

4. Indicator Selection Process for NatureServe's Wetland Ecological Integrity Assessment Method (Analysis of our metrics, demonstrating their utility in assessing response to stressors of integrity) (Faber-Langendoen et al. 2016d).

A brief overview of our methodology is found in Faber-Langendoen et al. (2016e). Field manuals and forms are available from Colorado (Lemly et al. 2015), New Jersey (K. Walz (pers. comm.), New Hampshire. Nichols and Faber-Langendoen 2012) and Washington (Rocchio 2014, 2016).

Here, we describe the metrics and protocols used to asses wetlands, using our rapid assessment method.

2.0 Conceptual Models and Ecological Integrity Metrics

Conceptual Ecological Model

The major components of the model include three primary rank factors (landscape context, on-site condition, and size), subdivided into six major ecological factors of landscape, buffer, vegetation, hydrology, soils, and size. Together these are the components that capture the structure, composition, processes, and connectivity of a system (Figure 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 the key ecological attributes of "vegetation composition" and "vegetation structure" (Parrish et al. 2003, Unnasch et al. 2009).

A key component of the model is inclusion of landscape context metrics. We include these metrics because ecosystems are structured both by the "inner workings" (condition) and the "outer workings" (landscape context). A third primary rank 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.

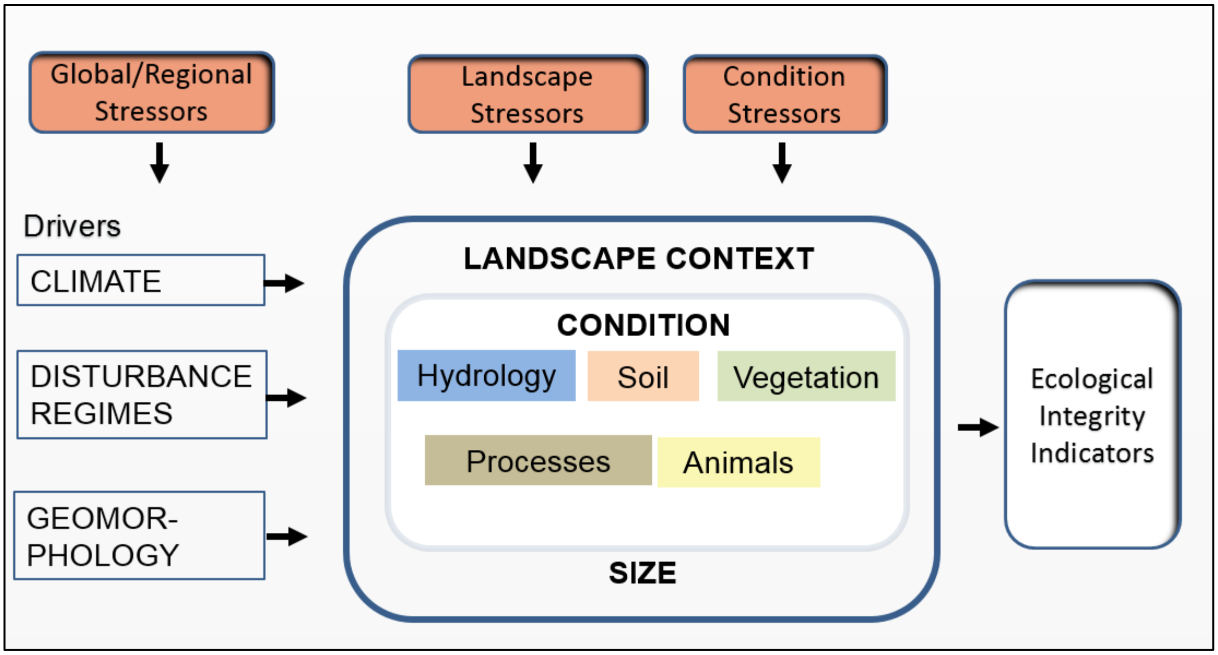

Figure 1. Conceptual ecological model for assessing ecological integrity.

The core ecological factors of ecological integrity are shown for wetlands and uplands. The model can be expanded to include additional measures of biotic Integrity, such as animals (birds, mammals, amphibians, macroinvertebrates, etc.) and ecological processes or functions (water quality, productivity, etc.). Global/regional stressors may indirectly impact the system through impacts to the natural drivers (climate, disturbance regimes, and geomorphology) of the ecosystem; local stressors may more directly impact the ecosystem.

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, USEPA 2006). This ”3-level approach” to assessments allows the flexibility to develop data for many sites that cannot readily be visited or intensively studied, and it permits more widespread assessment, while still allowing for detailed monitoring data at selected sites.

To ensure that the 3-level approach is applied consistently across levels in how ecological integrity is assessed, a standard framework or conceptual model for choosing metrics should be used, as described above (Figure 1). **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 a wetland site. They can also help assess the distribution and abundance of ecological types in the landscape or watershed. **Level 2 Rapid Field Assessments** use relatively simple field metrics for collecting data on specific wetland sites, some of which require expert professional judgment. Our approach emphasizes a condition-based rapid assessment, supplemented by information on stressors that may be affecting condition. **Level 3 Intensive Field Assessments** require more rigorous, field-based methods that provide higher-resolution information on the wetland site, 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 Kentula 2010). This 3-level approach to assessments allows for the flexibility of developing data on many sites 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 wetland sites 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.

3.0 Assessment Area (AA)

The protocols for EIAs are conducted within a wetland site or "occurrence. An occurrence is defined as a wetland type at a site with relatively broadly homogeneous biotic and abiotic composition and structure (see "Wetland Classification and Level 2 Assessments" below). The Assessment Area (AA) is that part of the occurrence that is assessed or evaluated. For small occurrences, the AA and occurrence may be synonymous. But for larger wetland occurrences (perhaps 100s to 1,000s of acres) the AA is much smaller. The AA can be defined as points or small polygons. Discussion of the reasons for choosing points, polygons (entire wetlands), or patches is provided in Faber-Langendoen et al. (2012a, b, 2016a).

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).

For Level 2 assessments, AAs are typically placed within an occurrence of a wetland type. As these occurrences 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 AAs for Level 2 assessments should be limited to areas less than 20 ha; when the polygon is greater than 20 ha (indeed, sometimes much greater), multiple AAs should be completed to address any potential variation in condition across the polygon. If the polygon is large, and there is considerable variation in condition, it is typically advisable to distinguish the various levels of condition.

The approach used to define an AA affects the area included in the surrounding buffer and landscape assessment (Table 1). With a small, fixed area (e.g., the 0.5 ha or 40 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, with multiple AAs for polygons much larger than 20 ha. Potential variation in total area assessed (AA, buffer, and landscape) is between 92 and 330 ha (Table 1). See "Landscape Connectivity" metric for more details.

Table 1. 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	VARIABLE (Polygon) AA		
AA and METRIC	Total Distance From Outer Edge Of AA	FIXED AA (e.g., 40 m radius circle)	Compact Circular (e.g., 40 m to 252 m radius)	Narrow Rectangular (e.g., 10 x 500 m to 100 x 2000 m)	Irregular (see Figure 7 in protocols section)
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
Landscape	100 - 500m	65 ha	20 - 98 ha	36 - 180 ha	shape dependent
TOTAL AREA = AA + Buffer + Landscape		92 ha	92 - 178 ha	152 - 330 ha	92 - 330 ha

4.0 Ecosystem Classifications and Ecological Integrity

The success of developing indicators of wetland ecological integrity depends on an understanding of the structure, composition, processes, and connectivity 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 (Table 2):

- **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, 2012a) (see also Appendices 4 and 5).

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 Nonnative 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 NVC Formation/NWI Class (e.g., Flooded & Swamp Forest / Palustrine Forest versus Salt Marsh / Estuarine Emergent Marsh, among others) (Table 2).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.

Table 2. The inter-relationships among three main wetland classifications: U.S National Vegetation Classification (NVC), National Wetlands Inventory (NWI), and Hydrogeomorphic Classification (HGM).

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

*** NWI** = National Wetland Inventory (Cowardin et al. 1979). E2AB = Estuarine Intertidal Aquatic Bed, E2EM = Estuarine Intertidal Emergent, E2SS = Estuarine Intertidal Scrub-Shrub, E2FO – Estuarine Intertidal Forested, L2AB = Lacustrine Littoral Aquatic Bed, PAB = Palustrine Aquatic Bed, PEM = Palustrine Emergent, PML = Palustrine Moss-Lichens, PSS = Palustrine Scrub-Shrub, PFO = Palustrine Forested, R1AB = Riverine Tidal Aquatic Bed, R1EM = nRiverine Tidal Emergent

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

[1]Includes groundwater slope/riverine or "sliverine" wetlands (e.g., streamside seepage wetlands) 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)

5.0 METRICS AND STRESSORS FOR RAPID ASSESSMENT of WETLANDS

Introduction

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 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 rapid (Level 2) assessments are structured tools combining scientific understanding of ecosystem structure, composition, processes, and connectivity with best professional judgment in a consistent, systematic, and repeatable manner (Sutula et al. 2006).

Metrics that are chosen 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. 2012a, b, Faber-Langendoen et al. 2016d).

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 and the size and complexity of the assessment area. 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 major ecological factors, with each metric designed to assess a component of the ecological factor.

Metrics

- **Main Metrics**

The standard set of rapid assessment metrics for wetlands is provided in Table 3 and each metric is discussed in detail below in the Protocols for Ecological Integrity Metrics section. This version replaces, based on extensive testing, a previous version presented in Faber-Langendoen et al. (2012b). A comparison of what has changed between the two versions is provided in Appendix 9. Results of the tests are available in Faber-Langendoen et al. (2016d).

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. Ten of the metrics (LAN1 and/or LAN2, BUF1, BUF2, VEG1, VEG2, HYD1, HYD3, SOI1, and SIZ1) 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 accurately assess wetland condition (Table 4).

Table 3. The standard set of wetland metrics based on the conceptual model of ecological integrity (see Figure 1).

There are 14 core metrics and three optional metrics. Six metrics have variants based on particular wetland types (NVC Formation or HGM Class). Further information on the metric variants is provided in Table 4.

PRIMARY RANK FACTOR	**MAJOR ECOLOGICAL FACTOR**	**METRIC**			
		NAME		**VAR-IANTS**	**NVC or HGM**
LANDSCAPE CONTEXT	LANDSCAPE	**LAN1**. Contiguous Natural Land Cover			
		LAN2. Land Use Index			
	BUFFER	**BUF1**. Perimeter with Natural Buffer			
		BUF2. Width of Natural Buffer			
		BUF3. Condition of Natural Buffer			
CONDITION	VEGETATION[1]	**VEG1**. Native Plant Species Cover		Y	-
		VEG2. Invasive Nonnative Plant Species Cover			
		VEG3. Native Plant Species Composition			
		VEG4. Overall Vegetation Structure		Y	NVC
		VEG5. Woody Regeneration [opt.]		Y	
		VEG6. Coarse Woody Debris [opt.]		Y	NVC
	HYDROLOGY[1]	**HYD1.** Water Source		Y	HGM
		HYD2. Hydroperiod		Y	HGM
		HYD3. Hydrologic Connectivity		Y	HGM
	SOIL	**SOI1.** Soil Condition		Y	NVC
SIZE	SIZE	**SIZ1.** Comparative Size (Patch Type)[2]			
		SIZ2. Change in Size [opt.]		Y	-

[1]Metrics for Vegetation and Hydrology are best applied when wetlands are classified at more specific levels (e.g., assessing alterations to vegetation composition is improved using NatureServe System or NVC Macrogroup or Group types, rather than at the higher NVC Formation level, even when variants based on Formation or HGM are provided.

[2]This metric is not always used for EIA work, particularly when wetland AAs are based on points rather than polygons. Nonetheless, we recommend that crews routinely estimate the size of the wetland they are working in and provide a scoring for this metric.

Table 4. Metric Variants Based on HGM and NVC Classification.

NVC-based Variants

METRIC	VEGETATION	VEGETATION	SOILS
Metric Variant by NVC Formation Type	**VEG3 Native Plant Species Composition**	**VEG4 Vegetation Structure**	**SOI1 Soil Surface Condition**
Flooded & Swamp Forest	**v1***	**v1**	**v1**
Mangrove		**v2**	**v2**
Freshwater Marsh, Wet Meadow & Shrubland;		**v3**	**v1 (or v2 if freshwater tidal)**
Salt Marsh		**v4**	**v2**
Bog & Fen		**v5**	**v1**
Aquatic Vegetation		**v6**	**v1**

* Only one variant is listed, because future refinement of this metric is best completed at either the USNVC Group or the NatureServe Ecological System level.

HGM-based Variants

METRIC	HYDROLOGY	HYDROLOGY	HYDROLOGY
Metric Variant by HGM Class	**HYD1 Water Source**	**HYD2 Hydroperiod**	**HYD3 Hydrologic Connectivity**
Riverine (Non-tidal)	**v1**	**v1**	**v1**
Depression, Lacustrine, Slope	**v2**	**v2**	**v2**
Organic Soil Flats, Mineral Soil Flats	**v3**	**v3**	**v3**
Estuarine (Tidal)	**v4**	**v4**	**v4**

- ## Supplemental Metrics

Although the EIA Level 2 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 final EIA ratings.

For example, some component of the Floristic Quality Index (FQI) developed for a particular state or region could be used 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). In addition, a rapid FQI (Bourdaghs 2012) can be incorporated as a supplemental L2 vegetation metric.

Metric Ratings and Scorecard

- ### Metric Rating

For each metric, an A, B, C, or D rank is selected, informed by rating criteria descriptions on the Metric Form, the wetland system description and system rank specs (where available), field observations, useful GIS data, and other available data. Field crews are encouraged to assign a single rating, but in some cases, they may be uncertain, and a range rank may be used (i.e., AB, BC, or CD). The range rank does not indicate an intermediate rank or "+/-" rank; it indicates that the metric may be either one or the other. We also discourage the use of intermediate or plus/minus ranks (e.g., A- , B- or C-) at the metric level, because it may generate a false sense of precision for a rapid assessment. The exception to this is when an actual rating with a description has been provided for the intermediate rating (e.g., there are a few metrics, such as Hydroperiod, where we found it helpful to distinguish C+ from C). Table 5 provides guidance for assigning points for the metric ratings.

Table 5. Metric rating and points.
Occasionally, metric ratings are further subdivided (e.g. a B (3.0) and B- (2.5) or a C (2.0) and C- (1.5).

Metric Rating	Points
A	4.0
B	3.0
C	2.0
D	1.0

- ### EIA and Factor Rating

A point-based approach is used to facilitate integration of metrics into an overall rating (Table 6). Undue emphasis should not be placed on the numerical scoring. Rather it is the overall assignment of the grades that matters. When two or more metrics are used to score a major ecological factor, we find that a 7 part scale (A, A-, B, B-, C, C-, D) can be informative. A "rounded" 4 part scale (A, B, C, D) can still be applied (Table 6).

Table 6. Ratings and Points for Ecological Integrity, Primary Rank Factors and Major Ecological Factors.

EIA and Factor Rating*	*7 Part Scale*	*Metric Rating*	*4 Part Scale*
A+	3.8 - 4.00	A (Excellent)	3.5 - 4.0
A-	3.5 - 3.79		
B+	3.0 - 3.49	B (Good)	2.5 - 3.49
B-	2.5 - 2.99		
C+	2.0 - 2.49	C (Fair)	1.5 - 2.49
C-	1.5 - 1.99		
D	1 - 1.49	D (Poor)	1.0 - 1.49

*This scale is applied to the overall EIA, as well as Primary Rank Factors and Major Ecological Factors.

- ### Ecological Integrity Assessment Scorecard

The Ecological Integrity Assessment Scorecard is a summary of factors that are "rolled up" into a final rating for a wetland. Details on the scorecard are provided in Faber-Langendoen et al. (2016c).

Level 2 Stressor Checklist

Stressor checklists can be useful as additional information when evaluating the ecological integrity of an occurrence (Sutula et al. 2006), particularly in cases in which restoration may be considered through removal or mitigation of a particular stressor. 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, continued erosion from past logging). 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 or its buffer (0-100 m zone surrounding the wetland) 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, or increased runoff). Within the scope (as defined spatially and temporally in assessing the scope of the stressor), **severity** is the level of damage to the ecosystem or buffer 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 factors, 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. 2012b, see also Section 7 below). 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.

Variations on the Level 2 Assessment

We have described what may be called the "Level 2 standard method." It is worth noting several variants of the Level 2 EIA assessment method may appeal to different needs. First, there is the "very rapid method," in which the major ecological factors themselves serve as the general indicators, and field crews complete a structured narrative evaluation of those factors. 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, and (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.

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 Vegetation Index of Biotic Integrity (VIBI) or Floristic Quality Index (FQI), 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, and the plots are representative of the broader area assessed, there should be little difficulty in producing comparable results to other RAMs.

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. Field manuals and field forms are available from NatureServe and a number of Natural Heritage Programs, including Colorado, New Hampshire, New Jersey, and Washington.

6.0 PROTOCOLS FOR ECOLOGICAL INTEGRITY METRICS

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 1.

Text Box. Template for Metric Description

Metric Name:

Definition:

Background:

Metric Type: 6.0

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:

6.1 LANDSCAPE CONTEXT

LANDSCAPE

For rapid assessments, we assess the larger landscape from 0 to 500 m surrounding the AA, including landscape connectivity (LAN1) and land use (LAN2). Separate from these metrics are the buffer metrics that address specific ecological features of the buffer within a 100 m sub-zone. For AAs based on points, the landscape may largely consist of the same wetland that the point is within, rather than surrounding habitat; preliminary testing has shown that it may be desirable to extend the overall zone to 1000 m to ensure that more of the landscape outside the wetland polygon is accounted for (K. Walz pers. comm. 2016).

- **LAN1. Contiguous Natural Land Cover**

Definition: A measure of connectivity assessed using the percent of natural habitat directly connected to the AA, including options for sub-metrics for the inner zone (0–100 m), and outer zone (100–500 m). For AAs based on points, the landscape may largely consist of the same wetland that the point is within, rather than surrounding habitat; preliminary testing has shown that it may be desirable to extend the zone to 1000 m to ensure that more of the landscape outside the wetland polygon is accounted for (K. Walz pers. comm. 2016).

Background: This metric addresses the broader connectivity of the natural land cover to the AA. The metric assesses the natural habitat that is directly contiguous. Still, not all organisms and processes require directly contiguous habitat, and organisms perceive "connectivity" differently, so this metric may under-estimate contiguous habitat for some organisms. A previous metric "Percent Natural Land Cover" was shown to be highly redundant with this metric (Faber-Langendoen et al. 2016d).

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 estimate of connectivity among natural ecological systems. Landscapes that retain direct 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).

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 have greater (wooded lawns, hay meadows) or lesser (parking lots, corn fields) degrees of connectivity to natural ecosystems.

Measurement Protocol: Select the statement that best describes the **contiguous natural land cover** within the 500 m "zone" and connected to the AA (Figure 2). To determine the rating, identify the percent of natural land cover that is directly connected to the AA within the 500 m zone. Water is included, along with terrestrial natural land cover. Where water may be a degrading factor (e.g., a wetland next to a boat club may be exposed to excessive wave action), it can be scored as such in the Land Use Index metric and Condition of Natural Buffer metric. Well-traveled dirt roads and major canals break unfragmented blocks, but vegetated two-track roads, hiking trails, hayfields, low fences and small ditches can be included. See definitions for natural land cover types in Table 11.

Example:

Figure 2. Contiguous Natural Land Cover evaluation based on percent natural vegetation that is directly connected to the AA.
Raw imagery and example from Colorado Front Range (AA 12473). Yellow line separates contiguous natural land cover within in the 500 m radius zone surrounding the AA boundary (the red polygon). The AA is embedded in a fragmented, natural landscape block, rated at 20–60% of the 500 m zone. In this example, non-natural land cover is predominantly a gravel mining operation and related development. Figure by Joanna Lemly.

Metric Rating:

Table 7. Contiguous Natural Cover Metric Rating.

Metric Rating	*Contiguous Natural Land Cover: ALL WETLANDS*	Total 0–500 m	subzones	
			Inner 0–100 m	Outer 100–500 m
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:

Scaling Rationale: Less fragmentation increases connectivity between natural ecological systems and thus allows 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 8.

Table 8. Contiguous Natural Land Cover Scaling Rationale.

Metric Rating	*Contiguous Natural Land Cover: 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).

Further analysis could show that the metric needs refining. For example, the “Intact” threshold set could be set at 100% (or at least closer to it, perhaps 95-100%)? The B threshold could be set to 75-95%, C= 25-75%, and D<25%.

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

- ### LAN2. Land Use Index

Definition: This metric measures the intensity of human dominated land uses in the surrounding landscape, including options for sub-metrics for the inner sub-zone, or buffer (0–100 m) and outer sub-zone (100–500 m).

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 Natural Land Cover and Contiguous Natural Land Cover metrics found a high level of correlation (redundancy), indicating that all three are not needed (Faber-Langendoen et al. 2012a, Faber-Langendoen et al. 2016d).

Measurement Protocol: The Land Use Index metric is measured by documenting the surrounding land use(s) within the inner and outer 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.

For AAs based on points, the landscape may largely consist of the same wetland that the point is within, rather than surrounding habitat; preliminary testing has shown that it may be desirable to extend the overall zone to 1000 m to ensure that more of the landscape outside the wetland polygon is accounted for (K. Walz pers. comm. 2016).

Surrounding Land Use Index: Worksheet : Land Use Categories	**Land Use Categories- Aggregated**	**Coef- ficient**	**Inner Sub-zone** (0-100 m)		**Outer Sub-zone** (100-500 m)	
			% Area	**Score**	**% Area**	**Score**
Paved roads / parking lots	Developed – High to Moderate Intensity	0				
Domestic, commercial, or publicly developed buildings and facilities (non-vegetated)	Developed – High to Moderate Intensity	0				
Gravel pit / quarry / open pit / strip mining	Developed – High to Moderate Intensity	0				
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive, logging roads)	Developed – High to Moderate Intensity	1				
Agriculture: tilled crop production	Agriculture – Cultivated Crop, Annual	2				
Intensively developed vegetation (golf courses, lawns, etc.)	Developed – Low Intensity	2				
Vegetation conversion (chaining, cabling, roto-chopping, clearcut)	Vegetation – Highly Altered	3				
Agriculture: permanent crop (vineyard, orchard, nursery, hayed pasture, etc.)	Agriculture – Cultivated Crop – Perennial	4				
Intense recreation (ATV use / camping / popular fishing spot, etc.)	Vegetation – Highly Altered	4				
Military training areas (armor, mechanized)	Vegetation – Highly Altered	4				
Heavy grazing by livestock on pastures or native rangeland	Vegetation – Highly Altered	4				
Heavy logging or tree removal (50-75% of trees >30 cm dbh removed)	Vegetation – Moderately Altered	5				
Commercial tree plantations / holiday tree farms	Vegetation – Moderately Altered	5				
Recent old fields and other disturbed fallow lands dominated by ruderal and exotic species	Vegetation – Moderately Altered	5				
Dam sites and flood disturbed shorelines around water storage reservoirs and motorized boating	Vegetation – Moderately Altered	5				
Moderate grazing of native grassland	Vegetation – Moderately Altered	6				
Moderate recreation (high-use trail)	Vegetation – Moderately Altered	7				
Mature old fields and ruderal forests with natural composition on former fallow lands	Vegetation – Moderately Altered	7				
Selective logging or tree removal (<50% of trees >30 cm dbh removed)	Vegetation – Lightly Altered	8				
Light grazing or haying of native rangeland	Vegetation – Lightly Altered	9				
Light recreation (low-use trail)	Vegetation – Lightly Altered	9				
Natural area / land managed for native vegetation	Vegetation – No/ Minimally Altered	10				
A ≥9.5, B = 8.0–9.5%, C = 4.0–7.9%, D = <4.0%		**Total Land Use Score**			-	

	Total Land Use Rating				
	Combined Land Use Index Score (Inner sub-zone score x 0.6)+(Outer sub-zone score x 0.4)			-	
	Combined Land Use Index Rating				

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 9) 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 the inner landscape (inner sub-zone 0–100m) and outer landscape sub-zone (100–500 m), then sum Sub-Land Use Score to arrive at a Total Land Use Score across the two areas. For example, if 30% of the outer Landscape area was under moderate grazing (0.3 * 6.6 = 1.8), 10% composed of unpaved roads (0.1 * 1.0 = 0.1), and 60% was a natural area (e.g., no human land use) (0.6 * 10.0 = 6.0), the Total Outer Landscape Land Use Score = 0.79 (0.18 + 0.01 + 0.60). The score can then be rated using Table 10 (i.e., C or Fair) and combined with the Inner Landscape Score (unweighted is currently preferred, else inner weighted 0.6, outer weighted 0.4 (Table 9).

Table 9. Land Use and Corresponding Land Use Coefficients, modified from Hauer et al. (Table 21, 2002).

See Appendix 7 for application to Landfire Map Legend Types.

*= High to Moderate

Example:

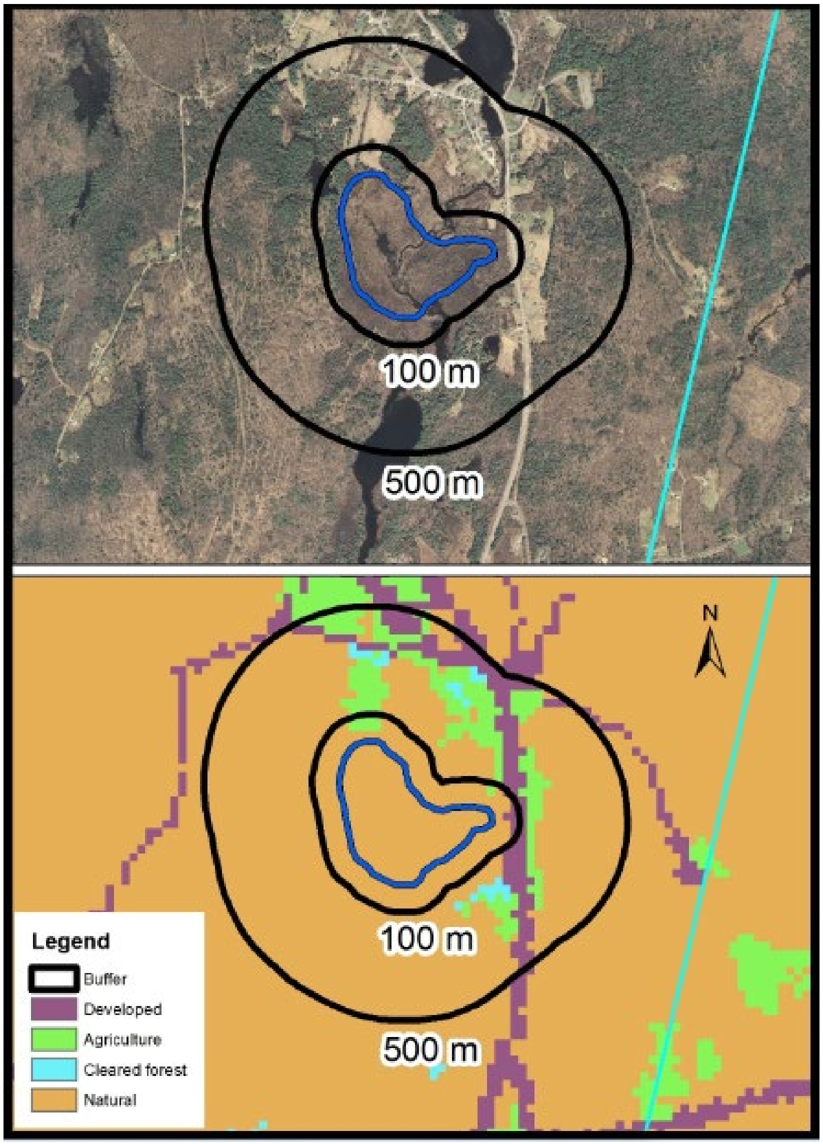

Figure 3. Application of land use coefficients to assess the Land Use Index metric in the core and supporting landscapes (Nichols and Faber-Langendoen 2012).
The Land Use Index is calculated for the inner sub-zone (0–100 m) and the outer sub-zone (100–500 m). The percent area of each land use is recorded in Table 9, and a weight is assigned to the land use based on the degree of non-naturalness. In this case, because the land uses are very general, Developed gets a weight of 1, Agriculture a 3, Cleared Forest a 5, and Natural a 10. Figure by Bill Nichols.

Metric Rating:

Table 10. Land Use Index metric rating.

Metric Rating	*Average Land Use Score: ALL WETLANDS*
EXCELLENT (A)	9.5–10
GOOD (B)	8.0–9.4
FAIR (C)	4.0–7.9
POOR (D)	<4.0

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. (2012b) 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 nonnative 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 important ecological processes related to water filtration, erosion and flow (Hauer et al. 2002, Mack 2006).

Wardrop et al. (2013) developed a Land use index based on forest cover in the Mid-Atlantic states. The thresholds for their Landscape Assessment Score", converted to a scale of 1 to 100, are as follows: A = >8.9, B = 8.2-8.9, C = 4.7-8.2, D = < 4.7. These thresholds are very similar to our thresholds in Table 10.

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

BUFFER

For rapid assessments, we assess the buffer immediately surrounding the assessment area (within a 100 m sub-zone or zone), using 3 metrics: (BUF1) Perimeter with Natural Buffer, (BUF2) Width of Natural Buffer, and (BUF3) Condition of Natural Buffer. This final metric requires a field visit in combination with aerial photography. Wetland buffers are defined as the natural cover that surrounds a wetland. Note that the Land Use Index (LAN2) includes an evaluation of all land uses within the buffer sub-zone (0–100 m), so it addresses the condition of the non-natural part of the buffer. In addition, a condition evaluation of the buffer may be included as part of a Level 3 assessment (e.g., by field walking and recording condition data along transects established for metric BUF2).

- **BUF1. Perimeter with Natural Buffer**

Definition: A measure of the percent of the wetland system perimeter with a vegetated, natural buffer.

Background: The buffer of wetlands is important to biotic and abiotic aspects of the wetland. The Environmental Law Institute (2008) reviewed the critical role of buffers for wetlands. We assess key aspects of buffer within a 100 m sub-zone, but add a surrounding landscape assessment that extends to 500 m from the AA edge (see metrics LAN1 and LAN2 above).

We only include natural habitats as part of the buffer, as these habitats would have been most typical of the historical condition of the buffer (Table 11 below). The definition of natural habitats corresponds with that of the USNVC (i.e., both native habitat and ruderal habitats, including naturally invaded or degraded native habitats), thereby permitting a direct application of NVC and system maps to the evaluation. This definition is also consistent with the use of natural habitats for other EIA metrics.

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). Estimate the length of the AA perimeter contiguous with a natural buffer. Use a 10 m minimum buffer width and length. (Faber-Langendoen et al. (2012b) used a 5 m minimum buffer width and length, but this is difficult to apply with aerial photography, and not possible from remote sensing imagery). Perimeter includes open water (see Table 11). For example, natural buffer is counted if it is at least 10 m width and 10 m in extent. Thus 6 m of buffer + 8 m non-buffer + 7 m buffer = 21 m buffer. When using remote means, high resolution imagery (1-2 m raster) may be necessary to measure the width of natural vegetation in the buffer.

Table 11. Guidelines for identifying wetland buffers and breaks in natural buffers.
(adapted from Collins et al. 2006, Table 3.3).

Examples of Land Covers Included in Natural Buffers	Examples of Land Covers Excluded from Natural Buffers	Examples of Land Covers Crossing and Breaking Natural Buffers
Natural upland habitats and plant communities; open water[1]; vegetated levees; old fields; naturally vegetated rights-of-way; rough meadows; natural swales and ditches; native or naturalized rangeland non-intensive plantations[2]	Parking lots; commercial and private developments; roads (all types), intensive agriculture; intensive plantations†; orchards; vineyards; dry-land farming areas; railroads; planted pastures (e.g., from low intensity to high intensity horse paddock, feedlot, or turkey ranch); planted hayfields; lawns; sports fields; traditional golf courses; Conservation Reserve Program pastures	Bike trails; horse trails; dirt, gravel, or paved roads; 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

[1]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 if desired, the condition of the open water can be assessed using the Buffer Condition metric (metric BUF3).
[2]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.
[3]Land cover that breaks natural buffers: These land covers are added to the land covers excluded from natural buffers, so that, collectively, they may contribute to a 10 m break in the buffer.

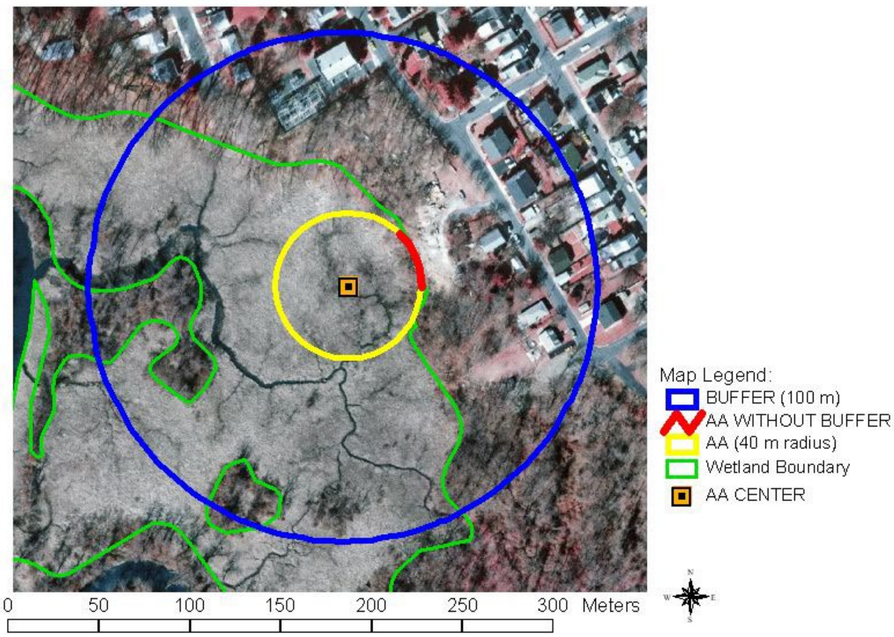

Figure 4. Example of calculation for Perimeter with Natural Buffer, with simple AA.
The wetland boundary is marked by a thin green line. The assessment area (AA) is shown by the inner circle; yellow indicates portions of the AA perimeter that contain buffer land cover (see "Measurement Protocol" text for definitions). The red indicates where AA perimeter lacking a buffer. In this case, about 86% of the AA perimeter has a buffer. Figure by Kathleen Walz.

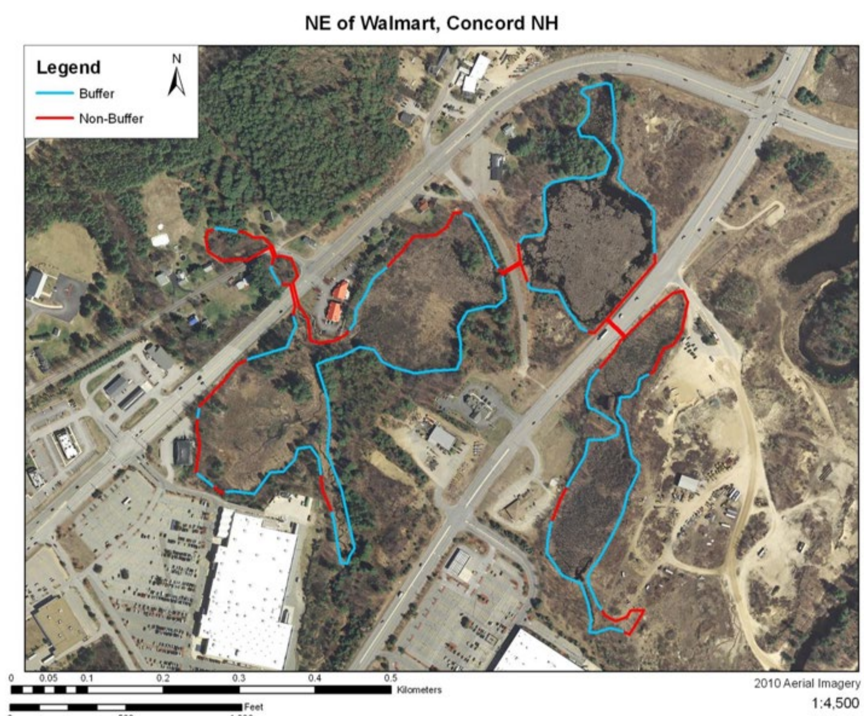

Figure 5. Example calculation of Perimeter with Natural Buffer, with a complex polygon.
In this example, about 65% of the system perimeter has buffer. Figure by Bill Nichols.

Metric Rating:

Table 12. Perimeter with Natural Buffer rating.

Metric Rating	Perimeter with Natural Buffer (%)
EXCELLENT (A)	100%
GOOD (B)	75–99%
FAIR (C)	25–74%
POOR (D)	<25%

Data for Metric Rating: See Environmental Law Institute (2008); also see Faber-Langendoen et al. (2012a) 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 10 and 25 m (Environmental Law Institute 2008); thus the rating for the "Perimeter with Natural Buffer" is extended down to 10 m. Our C rating is fairly broad (25-74% cover), and may need to be refined, as wetlands with as little as 50% buffer may already be in seriously compromised.

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

- ### BUF2. Width of Natural Buffer

Definition: A measure of the average width of natural buffer, extending from the edge of the Assessment Area to a maximum distance of 100 m.

Background: The buffer of wetlands is important to biotic and abiotic aspects of the wetland. The Environmental Law Institute (2008) has reviewed the critical role of buffers for wetlands. We assess key aspects of buffer within a 100 m sub-zone, but add a surrounding landscape assessment that extends to 500 m from the AA edge (see metrics LAN1 and LAN2 above).

We only include natural habitats as part of the buffer, as these habitats would have been most typical of the historical condition of the buffer. The definition of natural habitats corresponds with that of the USNVC (i.e., both native habitat and ruderal habitats, including naturally invaded or degraded native habitats), thereby permitting a direct application of NVC and system maps to the evaluation (see Table 11). This definition is also consistent with the use of natural habitats for other EIA metrics.

BUF4 (Contiguous Natural Buffer), detailed below, is an alternate metric for BUF2 (Width of Natural Buffer), in situations where an automated remote sensing approach is needed; that is, it is difficult to automate the calculation of buffer width from satellite imagery; so BUF4 assesses contiguous natural cover within the 100 m sub-zone.

Metric Type: Condition.

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

Rationale for Selection of the Variable: See "Perimeter with Natural Buffer."

Measurement Protocol: When using remote means, high resolution imagery (1-2 m raster) may be necessary to measure the width of natural vegetation in the buffer.

<u>Circular (more-or-less) AA</u>: Metric is adapted from Collins et al. (2006) and USA RAM (2011).

1. Determine the areas considered to be natural 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 6 below). Drawing the lines on the printed map makes verification and Quality Assurance procedures easier.
3. Measure the buffer width, up to 100 m.
4. Assign a metric score based on the average buffer width.

Note that in the example shown in figure 6, the buffer is applied to the AA rather than the wetland polygon; accordingly, this buffer value may not be indicative of the buffering capacity for the entire wetland if the wetland is large. Extending the landscape metrics from 500 m to 1000m may partially address this issue when assessing the overall role of Landscape Context on onsite condition.

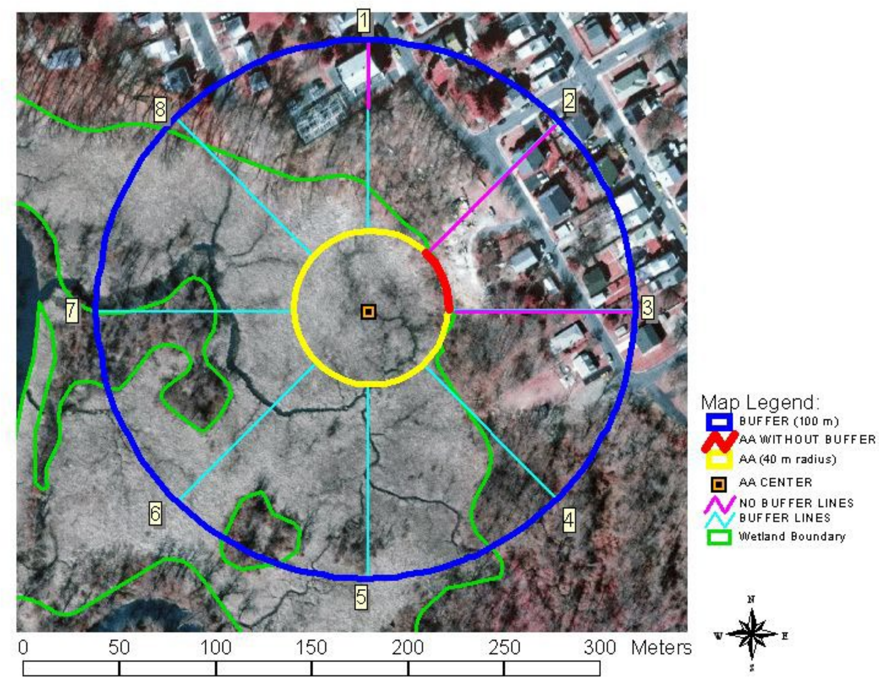

Figure 6. Example of Width of Natural Buffer calculation.
The wetland boundary is marked by a thin green line; the AA circular perimeter is yellow; the 100 m buffer assessment area around the AA is dark blue, and the eight transect lines are assessed for the buffer width. The blue segment of each transect 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 13). 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. Figure by Kathleen Walz.

Table 13. Measuring Width of Natural Buffer.

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

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 contour maps. The following adjustment can be used for buffers upslope of the AA (Environmental Law Institute 2008, based on data from Island County, Washington).

Table 14. Adjusting rating of upslope buffer.

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

__**Polygon-based AA with complex shapes**__

1. Using the most recent aerials, draw on a printout eight straight lines radiating out from the approximate center of the wetland system, each extending 100 m beyond the edge of the system. If the polygon is very long or large, more spokes may be needed to adequately measure the average width of the natural buffer. Additional guidance will be developed in future versions.
2. For wetland polygons lacking a centroid from which eight spokes could reasonably radiate from, draw a line as near to the center of the wetland polygon's long axis as possible where the line follows the broad shape of the polygon, avoiding finer level twists and turns (see figure 7 below). Once you have determined the length of the line along the wetland's long axis, divide the line by five to create four equally spaced points along the axis. At each of the four points, draw a line perpendicular to the axis such that it extends out 100 m beyond each side of the wetland system's perimeter. For some arching wetlands that close back in on themselves, see guidance and figure below to address situations that may arise from interior spokes (i.e., spokes radiating away from the wetland's interior arch):
    - When two spokes cross one another, eliminate the spoke with the longer natural buffer width and locate a new spoke at the more northerly end of the wetland system's long axis; extend the axis 100 m beyond the system perimeter to form new spoke.
    - When a spoke heads back into the wetland system in less than 100 m, eliminate the spoke and locate a new spoke at the more northerly end of the system's long axis.
    - If two spokes need to be relocated, use both ends of the wetland system's long axis.

    For spokes radiating out from the wetland system's exterior arch, if the spoke begins to cross a smaller lobe of the system in less than 100 m then allow the spoke to continue in the same direction through the lobe and measure buffer width where the spoke can be extended beyond the system for 100 m (see figure 7 below).
3. For each of the eight spokes, determine the natural buffer width from the wetland's edge until either a non-buffer land cover is encountered in less than 100 m or 100 m of contiguous natural buffer width is measured.
4. Determine the average width of the buffer (see example below) and evaluate the metric by referencing the A–D rating criteria on the Metric Form.

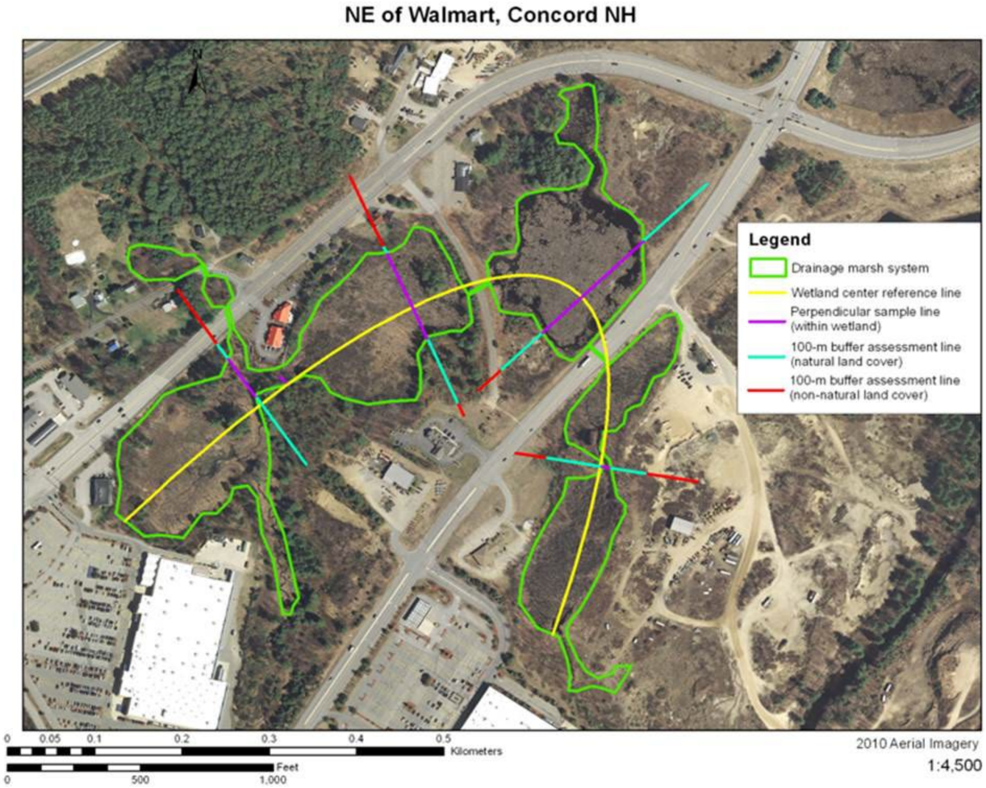

Figure 7. Example calculation of Width of Natural Buffer with polygons.
The entire cluster of polygons for the "drainage marsh - shrub swamp system" (New Hampshire type) is delineated at a site Northeast (NE) of Walmart, in Concord, New Hampshire. The eight spokes or lines are assessed for the buffer width based on the primary central arc that runs through the wetland. Once measured, the eight buffer widths are averaged to calculate the average width of the buffer (see Table 15 below). Figure by Bill Nichols.

Table 15. Example of Measuring Width of Natural Buffer.
See Figures 6, 7 for details.

Spoke or Line	Buffer Width (out to a maximum of 100 m)
West exterior spoke	18
West interior spoke	100
West-central exterior spoke	5
West-central interior spoke	90
East-central exterior spoke	100
East-central interior spoke	69
South-east exterior spoke	35
South-east interior spoke	67
Average Width of Natural Buffer (m)	***61***

Metric Rating:

Table 16. Width of Natural Buffer metric rating.

Metric Ratings	Average Buffer Width (m)
EXCELLENT (A)	≥100 m, adjusted for slope.
GOOD (B)	75–99 m, after adjusting for slope.
FAIR (C)	25–74 m, after adjusting for slope.
POOR (D)	<25 m, after adjusting for slope.

Data for Metric Rating: See Environmental Law Institute (2008); also see Faber-Langendoen et al. (2012a) 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 buffers as narrow as between 10 and 25 m (Environmental Law Institute 2008); thus the rating for the "Perimeter with Natural Buffer" is extended to 10 m within the D rating. More generally, setting buffer width thresholds 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, Brooks et al. 2006). Here we work with 100 m as the "inner buffer sub-zone" distance, but separately link evaluation of this sub-zone with other landscape metrics (See LAN1 and LAN2 metrics above). Some have suggested that even buffers of 10 meters have some value and we may want to introduce a C- rating from 10-25, and a D of < 10 m.

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

- ### BUF3. Condition of Natural Buffer

Definition: A measure of the biotic and abiotic condition of the natural buffer, extending from the edge of the Assessment Area.

Background: The condition of the natural buffer of wetlands is important to biotic and abiotic aspects of the wetland. The Environmental Law Institute (2008) has reviewed the critical role of buffers for wetlands, but less attention has been paid to the condition of the buffer. We assess key aspects of buffer within a 100 m sub-zone.

Metric Type: Condition.

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

Rationale for Selection of the Variable: Assessing the condition of the buffer goes beyond measuring how much natural buffer there is. This metric accounts for the condition or integrity of the natural buffer, by assessing land use pressures, such as grazing, forest harvesting, invasives, etc.

Measurement Protocol:
Estimate the overall condition of vegetation cover within that part of the perimeter that has a natural buffer. That is, if natural buffer length is only 30% of the perimeter, then assess condition within that 30%. Condition is based on percent cover of native vegetation, disruption to soils, signs of reduced water quality, amount of trash or refuse, various land uses, and intensity of human visitation and 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. Ground truthing could be made systematic by using the eight lines used to assess buffer width (Figures 6 and 7 above).

Metric Rating:

Table 17. Condition of Natural Buffer rating.

Metric Ratings	Natural Buffer Condition
EXCELLENT (A)	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.
GOOD (B)	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.
FAIR (C)	Buffer is characterized by a low to moderate (25–75%) cover of native vegetation, and either moderately to highly compacted or otherwise disrupted soils, moderate to 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)	Very low (<25%) cover of native plants, dominant (>75%) cover of nonnative 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.

- **BUF4. Contiguous or Percent Natural Buffer [alternate]**

Definition: A measure of either the contiguous natural habitat directly connected to the AA within 0–100 m or the percent natural habitat within the 0 to 100 m.

Background: This metric addresses the inner connectivity of the natural land cover to the AA. As such, it is also a sub-set of "LAN1. Contiguous Natural Land Cover." This metric is provided because its calculation is readily automated from classified remote sensing imagery, and can be a substitute for BUF2, which is difficult to automate.

Metric Type: Condition.

Tier: 1 (remote sensing).

Rationale for Selection of the Variable: See LAN1 metric for information on the rationale for assessing contiguous or percent natural land cover around the AA. 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 have greater or less degrees of connectivity to natural ecosystems.

Measurement Protocol: Select the statement that best describes the **contiguous or percent natural land cover** within the 100 m sub-zone and connected to the AA. To determine the rating, identify the percent of natural land cover that is directly connected to the AA within the 100 m zone or the overall percent of natural land cover that surrounds the AA within the 100 zone. Water is included, along with terrestrial natural land cover. Where there is evidence that the condition of the water may be a degrading factor (e.g., a wetland next to a boat club may be exposed to excessive wave action), it can be scored as such in Condition of Natural Buffer metric. Well-traveled dirt roads and major canals break unfragmented blocks, but vegetated two-track roads, hiking trails, hayfields, low fences, and small ditches can be included. See definitions of natural land cover type in Table 11.

Example:

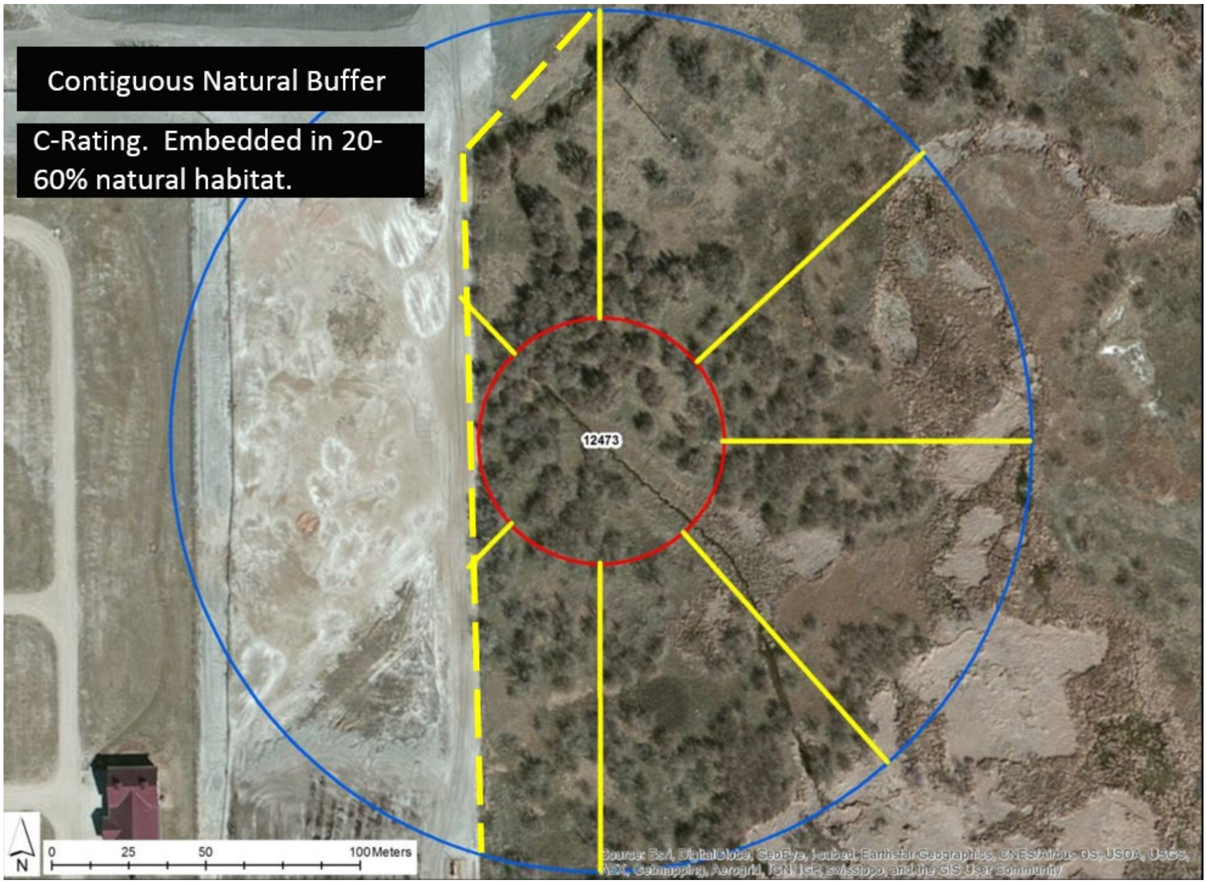

Figure 8. Contiguous Natural Buffer evaluation based on percent natural vegetation that is directly connected to the AA within the inner sub-zone (0-100 m).
The contiguous natural land cover is identified as the land cover to the right of the dashed yellow line cover. Yellow spokes represent the measures for the Width of Buffer Width metric (BUF2) and shows how BUF4 is a proxy for BUF2. The AA is the same as that shown in Figure 2 (AA 12473) on the Colorado Front Range. Figure adapted from Joanna Lemly.

Metric Rating:

Table 18. Contiguous Natural Buffer Metric Rating.

Metric Rating	***Contiguous Natural Buffer Cover: ALL WETLANDS***	***Percent Natural Buffer Cover: ALL WETLANDS***
EXCELLENT (A)	**Intact:** Embedded in 90–100% natural habitat around AA.	**Intact:** Embedded in 90–100% natural habitat around AA.
GOOD (B)	**Variegated:** Embedded in 60–90% natural habitat.	**Variegated:** Embedded in 60–90% natural habitat.
FAIR (C)	**Fragmented**: Embedded in 20–60% natural habitat.	**Fragmented**: Embedded in 20–60% natural habitat.
POOR (D)	**Relictual**: Embedded in <20% natural habitat.	**Relictual**: Embedded in <20% natural habitat.

Data for Metric Rating:

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 8 (see Contiguous Natural Land Cover metric LAN1). Further analysis could show that the metric needs tightening. For example, the "Intact" threshold set could be set at 100% (or at least closer to it, perhaps 95-100%)? The B threshold could be set to 75-95%, C= 25-75%, and D <25%.

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

6.2. CONDITION

VEGETATION

We include six vegetation metrics. For two of these, VEG3 and VEG4, we developed variants based on NVC Formations (Table 19).

Table 19. Metric variants (v) for Vegetation by NVC Formation.

	METRIC	**METRIC**
Metric Variant by NVC Formation Type	**VEG3 Native Plant Species Composition**	**VEG4 Overall Vegetation Structure***
FLOODED & SWAMP FOREST	**v1***	**v1**
MANGROVE		**v2**
FRESHWATER MARSH, WET MEADOW & SHRUBLAND		**v3**
SALT MARSH		**v4**
BOG & FEN		**v5**
QUATIC VEGETATION		**v6**

- **Vegetation Field Data Collection**

We strongly recommend that vegetation field data be collected for vegetation structure (growth forms/strata) and composition, including dominant species and invasive nonnative species. Two examples of field forms are provided (Tables 20 and 21). These tables record the minimum vegetation data needed for EIA purposes. A more expanded vegetation description may be desired for classification or other purposes, as shown in Appendix 6.

Table 20. Simple vegetation profile table for growth form/strata and species.

	VEGETATION GROWTH FORM PROFILE			VEGETATION SPECIES PROFILE BY GROWTH FORM	
	Cover scale: **<1**, 1-4% (**3**) then ±5%, (i.e **10** = 5-14, **20** = 15-24 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 nonnative spp. ≤5% cover. **Optional:** List other characteristic native spp. <5% (1-4%, <1% =T).	
T	**T. Mature (tall) Tree** (>5 m)		—— To nearest 5 m.	*e.g., Acer rubrum – 15%*	
S	**S. Shrub/Sapling/Vine**				
H	**H. Herb (non-aquatic)**				
A	**A. Aquatic**				
	Nonvascular Moss				
N	**Lichen**				

Table 21. Simple vegetation growth form and species profile. See definition of native increasers under metric VEG3.

	Growth Form						
Species	**Tree (>5 m)**	**Shrub/ Sapling/ W. Vine**	**Herb**	**Moss /Lichen**	**Total**	**Nonnative(√)**	**Native Increaser (√)**
Species A							
Species B							
Species C.							
Moss spp.							
Lichen spp.							
SUM							
Total (includes overlapping species)							

Additional data on vegetation patch or structural stage may be collected using a form such as provided in Table 22.

Table 22. Example of a vegetation structural stage profile description.

VEGETATION STRUCTURAL STAGE PROFILE	
Structural Stage: Estimate the % areal 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	

- ### VEG1. 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 within each of the two major strata groups (tree and shrub/sapling + herbaceous) and expressing the total native species cover as a percentage of the total cover. The group with the lowest percentage native cover is used as the basis for the score.

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 Nonnative Plant Species Cover." However, the Native Plant Species Cover metric assesses native species relative to all nonnatives whereas the Invasive Nonnative Plant Species Cover metric includes only invasive nonnative species that are considered to be invasive to the region where the ecosystem is found. Establishing a nonnative list is important because in a given region or state a species may be nonnative compared to other regions or states (e.g., *Typha angustifolia* is invasive in Midwestern and Northeastern interior U.S. marshes, but some occurrences in coastal marshes may be native). See Native Plant Species Composition metric for a discussion of "native increasers." Testing of the redundancy between the two metrics has shown them to be moderately to strongly correlated (Faber-Langendoen et al. 2012a, 2016d) and it may be reasonable to combine these two metrics into a single index. Nonvascular species are not included, desirable as that may be in some wetlands (especially bogs and fens), because many pose identification challenges during rapid assessments and due to lack of information on their use in interpreting ecological integrity.

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, nonnative species increase and can dominate a system.

Measurement Protocol: This metric consists of evaluating the relative percent cover of native species to all species (native and nonnative) for each of the three major strata (tree, shrub, and herb). The protocol is a visual evaluation of native vs. nonnative species cover. A field form should be used that describes species composition by strata or growth form/stage (Jennings et al. 2009) (see Tables 20-22 for data collected 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 using the information from Table 20 or 21. There are two variants, with V1 being the original form of the metric that was in use prior to 2015:

V1. OVERALL: For all the species, each of which has a total cover value, sum the individual species cover values (thus the total could easily exceed 100%), with a separate total for native and nonnative species. Then divide the native species cover by the sum of native and nonnative cover, and multiply by 100.

V2. BY STRATA: Assess the tree stratum separately from shrub/herb stratum. For the tree stratum, sum the individual tree species cover values (thus the total could easily exceed 100%), with a separate total for native and nonnative trees. Then divide the native tree species cover by the sum of native and nonnative trees, and multiply by 100. Repeat this for all shrub and herb species (i.e., summing both native shrubs and herbs separately from nonnative shrubs and herbs). If desired, the shrubs could be treated separately from the herbs and then an average of the two can be taken (though this may give a slightly different result).

Table 23. VEG1.Native Plant Species Cover (Relative) metric rating.

Metric Rating	*Native Plant Species Cover: ALL WETLANDS*	*Native Plant Species Cover: ALL WETLANDS*
	v1. OVERALL	v2. BY STRATA: Tree _ Shrub/Herb
EXCELLENT (A)	>99% relative cover of native vascular plant species across strata.	>99% relative cover of native vascular plant species in either the tree stratum or shrub/herb stratum, whichever value is lower.
GOOD (B)	95–99% relative cover of native vascular plant species across strata.	95–99% relative cover of native vascular plant species in either the tree stratum or shrub/herb stratum, whichever value is lower.
FAIR (C)	85–94% relative cover of native vascular plant species across strata.	85–94% relative cover of native vascular plant species in either the tree stratum or shrub/herb stratum, whichever value is lower.
FAIRLY POOR (C-)	60–84% relative cover of native plant species across strata.	60–84% relative cover of native plant species in either the tree stratum or shrub/herb stratum, whichever value is lower.
POOR (D)	<60% relative cover of native vascular plant species cover across strata.	<60% relative cover of native vascular plant species cover in either the tree stratum or shrub/herb stratum, whichever value is lower.

Data for Metric Rating: See Faber-Langendoen et al. (2012a) 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.

- ### VEG2. Invasive Nonnative Plant Species Cover

Definition: The absolute percent cover of nonnative species that are considered invasive to the ecosystem being evaluated. Although generally an invasive species is defined as "*a species that is nonnative to the ecosystem under consideration and whose introduction causes or is likely to cause …environmental harm…*" (Executive Presidential Order 1999, Richardson et al. 2000), thus potentially including species native to a region but invasive to a particular ecosystem in that region, here we restrict invasive species to nonnatives. We treat "native invasives" as "native increasers" under the Native Plant Species Composition metric. Nonvascular species are not included, desirable as that may be in some wetlands (especially bogs and fens), because many pose identification challenges during rapid assessments and due to lack of information on their use in interpreting ecological integrity.

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 Nonnative Plant Species Cover" includes only invasive nonnatives, not all nonnatives. Even here, judgment is required, because some species are native to a small part of a region, or have mixed genotypes of both native and nonnative forms, and are widely invasive (e.g., *Phalaris arundinacea* and *Typha angustifolia* in the Northeastern U.S.). Field crews must be provided with a definitive list of what is considered a nonnative invasive to their project area.

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 with the potential to spread over a considerable area) from "transformers" (a subset of invasive plants that change the character, condition, form, and/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, *Dennstaedtia punctilobula,* a native fern in northeastern U.S. northern hardwoods forests, is a native increaser because it responds favorably to heavy deer browse (de la Crétaz and Kelty 2006). Another example is *Typha latifolia*, a native cattail that increases in response to eutrophication. Native increasers are treated under the "Native Plant Species Composition" metric.

Metric Type: Stressor/Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: As viable populations of nonnative 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 nonnative invasive species must be established for any given project, in order to make the application of the metric as consistent as possible (Table 24). A definitive list should be constructed for each state or region, so field crews have specific guidance, and can be trained to recognize these species.

Table 24. State or regionally based invasive nonnative species list for wetland ecosystems. The list of species is for illustration only; it is not comprehensive.

Region	Invasive Nonnative Species
Northeast:	flowering rush (*Butomus umbellatus*) yellow iris (*Iris pseudacorus*) purple loosestrife (*Lythrum salicaria*) Chinese privet (*Ligustrum sinense*) exotic biotype of giant reed (*Phragmites australis*) exotic biotype of reed canary grass (*Phalaris arundinacea*) Japanese knotweed (*Fallopia japonica*) (=*Polygonum cuspidatum*) water chestnut (*Trapa natans*) Chinese tallow tree (*Triadica sebifera*) exotic biotype of narrow-leaf cattail (*Typha angustifolia*) white cattail (*Typha x glauca* [= *T. latifolia x T. angustifolia*])
Southeast:	water hyacinth (*Eichhornia crassipes*)
Midwest:	purple loosestrife (*Lythrum salicaria*) reed canary grass (*Phalaris arundinacea*) giant reed (*Phragmites australis*) flowering rush (*Butomus umbellatus*) glossy buckthorn (*Frangula alnus*) narrow-leaved cat-tail (*Typha angustifolia*) hybrid cat-tail (*Typha* x *glauca*) Japanese barberry (*Berberis thunbergii*)
West:	purple loosestrife (*Lythrum salicaria*) Brazilian waterweed (*Egeria densa*) hydrilla (*Hydrilla verticillata)* parrotfeather (*Myriophyllum aquaticum*) Eurasian water-milfoil (*Myriophyllum spicatum*) reed canary grass (*Phalaris arundinacea*) cordgrasses (*Spartina alterniflora*, *S. anglica*, *S. densiflora*, and *S. patens*)

This metric consists of evaluating the absolute percent cover of invasive nonnative species.

Field survey method for estimating nonnative 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, the strata cover and the cover of non-native invasive 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). If plot data are used for this metric, it is important that the plot is representative of the larger system being assessed. In patchy types, more than one plot may be desirable.

Metric Rating:

Table 25. Invasive Nonnative Plant Species Cover Rating.
See Table 24 for examples of state and/or regional lists of the invasive nonnative species.

Metric Rating	***Invasive Nonnative Plant Species Cover*: ALL WETLANDS**
EXCELLENT (A)	Invasive nonnative plant species apparently absent.
GOOD (B)	Invasive nonnative plant species in any stratum present but sporadic (1–3% cover).
FAIR (C)	Invasive nonnative plant species in any stratum somewhat common (4–10% cover).
FAIRLY POOR (C-)	Invasive nonnative plant species in any stratum common (10–30% cover).
POOR (D)	Invasive nonnative plant species in any stratum abundant (>30% cover).

Data for Metric Rating: See Faber-Langendoen et al. (2012a) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. Studies by DeBerry (2006) indicate that nonnative species in the shrub and herbaceous strata provide the best assessment of current condition since they are shorter lived than trees.

Scaling Rationale: Establishment of invasive nonnative plant species 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 (see Fig 6.12 in Rejmánek et al. 2005). Thus the metric sets the A-ranked threshold at 0%, and is scaled to be sensitive to relatively small levels of nonnative invasive cover (e.g., 1–3% cover receives a "B" rating). The D rating of 30% allows stands that are between 70 and 90% native to still receive a C rating. Although their long term integrity may be seriously compromised when invasives reach 30%, their current condition still warrants a C rating.

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

- ### VEG3. Native Plant Species Composition

Definition: An assessment of the overall vascular plant species composition and diversity, including by layer, of native diagnostic and native increasers (including the "native invasives" of Richardson et al. 2000), 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). This metric evaluates the degree of degradation to the native plant species, including both decline in native species diversity and loss of key diagnostic species, as well as shifting dominance caused by positive response of some species to stressors, i.e., native increasers (or "native invasives", aggressive natives, successful competitors), such as *Smilax rotundifolia, Cornus foemina* var. *racemosa*, etc.). In regional FQI Coefficient of Conservatism (CoC) scores (Swink and Wilhelm 1979), these species most often correspond to CoC scores of 1, 2, or 3. Native decreasers are those species that decline rapidly from stressors (sometimes referred to as "conservative species"). CoC scores for native decreasers would most often be 7, 8, 9, or 10.

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 plant species composition 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 requires experienced ecological judgment in the field in combination with good vegetation descriptions of the wetland type being evaluated. Its intent is similar to more formal methods of evaluating floristic quality, such as the Floristic Quality Index (FQI), either using the original version based either on a comprehensive species list (Mack and Kentula (2010), or a rapid version using dominant species (Bourdaghs 2012).

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 20). 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” (Faber-Langendoen et al. 2014), are typically native plant species whose relative constancy or abundance differentiates one type from another. Characteristic or diagnostic species 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, eutrophication, or browse pressure (Daubenmire 1968), but where sites typically do not have substantial soil profile disturbances. For example, *Dennstaedtia punctilobula,* a native fern in temperate northeastern North American forests, responds favorably to heavy deer browse (de la Crétaz and Kelty 2006). *Typha latifolia*, a native cattail, increases in wetlands following eutrophication. Degrading conditions that lead to presence of invasives species are treated in the “Invasive Nonnative 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 regions and wetland types being evaluated. For example, red maple in some upland habitats in the Northeast may be considered an ‘increaser’ (CoC = 2), but it is a native and differential species in red maple swamps.

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).). It is important that the plot is representative of the larger wetland being assessed. In patchy types, more than one plot may be desirable.

Table 26. Example of a native increaser list: Wetland/riparian native increaser species in Washington State (From Rocchio 2014).

Alnus rubra (past soil disturbance/hydro alteration/nutrient)	*Artemisia tridentata* (can increase in drying wetlands)
Argentina anserina (grazing)	*Carex douglasii* (grazing)
Carex obnupta (various)	*Carex pellita* (various; in western WA prairies)
Deschampsia cespitosa (soil disturbance in salt marsh)	*Juncus arcticus ssp. littoralis* (=*Juncus balticus*) (grazing)
Schoenoplectus acutus/tabernaemontani (nutrient/sediment/hydro alterations)	*Spiraea douglasii* (nutrient/hydro alterations)
Typha latifolia (nutrient/sediment/hydro alterations)	*Iris missouriensis* (grazing)

Metric Rating

Table 27. Native Plant Species Composition metric ratings.
See text ("Measurement Protocol") for definitions of diagnostic, increaser, and ruderal species terms.

Metric Rating	*Native Plant Species Composition: ALL WETLANDS*
EXCELLENT (A)	**Native plant species composition (species abundance and diversity) with expected natural conditions:** i) Typical range of native diagnostic species present; AND, ii) Native species sensitive to anthropogenic degradation (native decreasers) all present, AND iii) Native species indicative of anthropogenic disturbance (i.e., increasers, weedy or ruderal species) absent to minor.
GOOD (B)	**Native plant species composition with minor disturbed conditions:** i) Some native diagnostic species absent or substantially reduced in abundance, OR ii) At least some native species sensitive to anthropogenic degradation (native decreasers) present, OR iii) Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present with low cover.

FAIR (C)	**Native plant species composition with moderately disturbed conditions:** i) Many native diagnostic species absent or substantially reduced in abundance, OR ii) No native species sensitive to anthropogenic degradation (native decreasers) present, OR iii) Native species indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present with moderate cover.
POOR (D)	**Native plant species 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 indicative of anthropogenic disturbance (increasers, weedy or ruderal species) are present in high cover).

This metric requires good ecological expertise and integrates a number of aspects of native species composition. It's possible that a series of sub-metrics that focus on particular aspects of this metric could be helpful in scoring this metric. Table 28 provides a suggested worksheet to guide the assessment.

Table 28. Worksheet within the Native Plant Species Composition (V3) metric.
This worksheet could be helpful in rating the overall metric. The FQA metric would benefit from a reference gradient of FQI scores for a particular wetland type.

	Native Increasers (stressor tolerant, weedy natives) (~CoC=1,2,3)	**Native Decreasers (stressor intolerant) (~CoC=8,9,10)**	**Diagnostic Species (characteristic spp., including dominants)**	**Floristic Quality Index (rapid)**
A				Top 25% of scores for the wetland type
B				Upper 25-50%
C				Lower 25-50%
D				<25%
Comment				

Data for Metric Rating: See Faber-Langendoen et al. (2012a) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. See Nichols and Faber-Langendoen (2015) for Ecological System approach with system specific descriptions for six of the EIA metrics; i.e. creating metric variants based on each of the 27 System types (e.g., drainage marsh - shrub swamp system and major river silver maple floodplain system).

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 historical sources.

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

- **VEG4. Overall 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. This metric may either be used on its own or integrated with metrics VEG5 and VEG6 into a Vegetation Structure Index.

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 provides heterogeneity within the community. Plants strongly influence the quantity, quality, and spatial distribution of water and sediment within wetlands, and their structure can influence faunal diversity. 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, impoundment of water flow, or heavy grazing by livestock and geese in fresh and salt marshes. In general, beaver-caused disturbances are treated as a natural 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 19^{th} century, then subsequently reintroduced. Thus, the watersheds and landscapes in some areas 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 Tables V.2, V.3 and V.4 above, which describes structure using either strata or growth forms (Jennings et al. 2009). For the <u>strata method</u>, 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 <u>growth form method</u>, 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.

The 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 21 or 22 above, or 2) walking an entire AA and recording an entire species list or all dominant species, e.g. the timed meander method (Bourdaghs 2012) or 3) 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 29 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 29. Overall 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: Overall 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.

* Acidic conifer swamps may typically have smaller average stem sizes than hardwood swamps.

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, recreational vehicles, limited timber harvesting, peat mining 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, such as peat mining. 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. (2012a) 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 (condition). 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 historical 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.

- **VEG5. Woody Regeneration [optional]**

Definition An assessment of tree or tall shrub regeneration.

Background: This metric was developed by NatureServe and Natural Heritage Program staff and applied in a study in Michigan and Indiana (condition). 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 Table 20 above). 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 30. 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. (2012a) 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. Note that in some cases, however, limited regeneration may reflect natural rather than anthropogenic processes. In floodplain forests of the northeast, for instance, regeneration patterns may reflect infrequent stand-replacing floods that are part of a natural but long-term flooding dynamics.

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

- ### VEG6. Coarse Woody Debris [optional]

Definition An assessment of the coarse woody debris (or downed woody material), standing or fallen.

Background: Woody debris plays a critical role in a variety of systems, but its importance for ecological integrity is most clearly documented in forested types. Evaluation in shrub and herb types is optional, because coarse woody debris is much less likely to occur and levels of fine litter are very variable and difficult to interpret in terms of ecological integrity.

Metric Type: Condition.

Tier: 2 (rapid field measure).

Rationale for Selection of the Variable: In forested systems, there is extensive documentation of the importance of in-stream wood for altering channel form and characteristics, enhancing aquatic and riparian habitat, retention of organic matter and nutrients (Wohl 2011, Richmond and Fausch 1995). Large fallen stems can also provide important nurse logs for tree regeneration. In particular, large diameter woody material is often lacking in forests that have been harvested. Prior to European settlement, many streams likely had greater amounts of woody debris, but these volumes were reduced through widespread logging and trapping of beaver.

Measurement Protocol:

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 20 or 21 above or 2) 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). Note, however, that fixed plots are often not sufficient to tally widely scattered, large diameter coarse woody debris.

Forested wetlands
In forested wetlands, pay special attention to the amount of coarse woody debris when surveying the AA. Select the statement on the form that best describes the amount of woody debris within the AA. Riverine wetlands that have incised banks, no longer experience flooding, experience overgrazing, or are no longer at a dynamic equilibrium may lack coarse woody debris. If scoring as a sub-metric, it is scored a N/A in naturally herbaceous wetlands; keeping in mind that many wetlands surrounded by forest may be expected to have some coarse woody debris.

Shrub and Herb wetlands [optional]
During the vegetation survey or while walking through the AA, note the quantity and distribution of coarse woody debris and litter compared with a baseline that may be expected in the landscape. Playas are typically low in litter; densely vegetated wetlands can be high in litter. Overgrazing, woody vegetation removal, and the presence of exotic earthworms, can reduce and compact litter and aggressive plant colonization or artificially reduced water levels can result in excessive litter. Excessive litter can choke out new growth and inhibit animal movement.

Metric Rating:

Metric ratings can be assigned using Table 31 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 31. Coarse Woody Debris metric rating.

Metric Rating	*V1: Coarse Woody Debris variant: FLOODED & SWAMP FOREST*
EXCELLENT/GOOD (A/B)	• Wide size-class diversity of standing snags and CWD (downed logs).* • Larger size class (>30 cm dbh/12" dbh and >2 m/6' long) present with 5 or more snags per ha (2.5 ac), but not excessive numbers (suggesting disease or other problems).* • CWD in various stages of decay.
FAIR (C)	• Moderate size-class diversity of standing snags or downed CWD; • Larger size class present with 1–4 snags per ha, or moderately excessive numbers (suggesting disease or other problems). • CWD in various stages of decay.
POOR (D)	• Low size-class diversity of downed CWD and snags. • Larger size class present with <1 snag per ha, or very excessive numbers (suggesting disease or other problems). • CWD mostly in early stages of decay.

* Acidic conifer swamps may typically have smaller average stem sizes than hardwood swamps.

Metric Rating	*V2: Coarse Woody Debris variant: FRESHWATER MARSH, WET MEADOW & SHRUBLAND, BOG & FEN, SALT MARSH [metric variant under development]*
EXCELLENT (A)	Litter, coarse woody debris, and other organic inputs are typical of the system (i.e., playas should have low litter, whereas meadows and marshes have moderate amounts of litter).
GOOD (B)	Litter, standing snags, dead shrubs, and downed woody debris show minor alterations to system.
FAIR (C)	Litter, standing snags, dead shrubs, and downed woody debris show moderate alterations to system.
POOR (D)	Litter, standing snags, dead shrubs, and downed woody debris show substantial alterations to system.

Data for Metric Rating: See Faber-Langendoen et al. (2012a) for an evaluation of the discriminatory power of this metric, based on an assessment of 277 wetlands in Michigan and Indiana. In that study this metric had low discriminatory power in distinguishing a gradient of stressors based on a Human Stressor Index. That said, this metric may reflect past stressors that are no longer clearly evident (e.g. logging), and could be missed or rated low by stressor evaluations.

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 (condition). This metric has often proven difficult to apply in the field, particularly for non-forested wetlands.

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

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). We use three metrics, Water Source, Hydroperiod, and Hydrologic Connectivity (Table 32).

Table 32. Hydrology metric variants by HGM Class.

	METRIC	METRIC	METRIC
Metric Variant by Hydrogeomorphic (HGM) Class	**HYD1 Water Source**	**HYD2 Hydroperiod**	**HYD3 Hydrologic Connectivity**
Riverine (Non-tidal)	**v1**	**v1**	**v1**
Depression, Lacustrine, Slope	**v2**	**v2**	**v2**
Organic Soil Flats, Mineral Soil Flats	**v3**	**v3**	**v3**
Estuarine Fringe (Tidal)	**v4**	**v4**	**v4**

The three metrics are not strictly independent. Hydrology is a complicated ecological factor to measure during a rapid assessment, and users will find that their evaluation of one metric partly relates to another. A simple way to portray the primary focus of each metric is as follows:

- Water Source: water coming into the wetland.
- Hydroperiod: water patterns within the wetland, regardless of source.
- Connectivity: water exchange between wetland and surrounding systems, regardless of patterns within the wetland.

- **HYD1. 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 Source encompasses 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 an impact to natural water sources 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, groundwater 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, California 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. Field surveys should assess the primary water sources (see field form) and HGM class:

_____Overbank flooding	_____Irrigation via direct application
_____Alluvial aquifer	_____Irrigation via seepage

_____Groundwater discharge
_____Natural surface flow
_____Precipitation
_____Snowmelt
_____Other:
_____Irrigation via tail water run-off
_____Urban run-off / culverts
_____Pipes (directly feeding wetland)
_____Tidal (bi-directional)

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 identification of unnatural water sources, such as adjacent intensive development or irrigated agriculture, nearby wastewater treatment plants, and nearby reservoirs. These sources identified in the office can then be checked in the field.

Metric Rating:

Table 33. Water Source metric rating.
Separate metric ratings are provided for Riverine (Non-tidal); Depression, Lacustrine, Slope; Organic and Mineral Soil Flats; and Estuarine Fringe (Tidal).

Metric Rating	***v1: Water Source variant: RIVERINE (Non-tidal) Wetlands***
EXCELLENT (A)	Water source is natural, site hydrology is dominated by precipitation, groundwater, or overbank flow. There is no indication of direct artificial water sources. Land use in the local drainage area of the wetland 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 wetland directly receives occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic input include developed or agricultural land (<20%) in the immediate drainage area of the wetland, some road runoff, small storm drains or other minor point source discharges emptying into the wetland.
FAIR (C)	Water source is moderately impacted by anthropogenic sources. Indications from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage basin or moderate point source discharges into or adjacent to the site, such as many small storm drains or a few large ones.
POOR (D)	Water source is substantially impacted by anthropogenic sources. Indications of anthropogenic sources include >60% developed or agricultural land adjacent to the wetland, and major point source discharges into or adjacent to the wetland.

Metric Rating	***v2: Water Source variant: DEPRESSION, LACUSTRINE, SLOPE***
EXCELLENT (A)	Water source is natural: site hydrology is dominated by precipitation, groundwater, natural runoff from an adjacent freshwater body. 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, small storm drains or other local discharges emptying into the site, or some road runoff. No large point sources discharge into or adjacent to the site.
FAIR (C)	Water source is moderately impacted by anthropogenic sources, but is still a mix of natural and non-natural sources. Indications of moderate contribution from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage basin or many small storm drains or a few large ones, or moderate road runoff.
POOR (D)	Water source is substantially impacted by anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or other artificial hydrology). Indications of substantial artificial hydrology include >60% developed or agricultural land adjacent to the site, and the presence of major point sources that discharge into or adjacent to the site, or large amounts of road runoff.

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 anthropogenic sources, but are still a mix of natural and non-natural sources. Indications of moderate contribution from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage basin, the presence of many small storm drains or a few large ones, or moderate amounts of road runoff.
POOR (D)	Water source is substantially impacted by anthropogenic sources, indications of anthropogenic sources include >60% developed or agricultural lands in the immediate drainage basin, large amounts of road runoff, impoundments or diversions of water or other input into or withdrawals directly from the site and its encompassing wetland, or from areas adjacent to the site or its wetland.

Metric Rating	*v4: Water Source: ESTUARINE FRINGE (Tidal) Wetlands*
EXCELLENT (A)	Tidal and non-tidal water sources are natural with no artificial alterations to natural salinity; no indication of direct artificial water sources (e.g., no tide gates, land use in the local drainage area of the wetland is primarily open space or low density, passive uses). Lacks point source discharges into or adjacent to the wetland.
GOOD (B)	Tidal and non-tidal water sources are mostly natural with minor alterations to natural salinity. Site directly receives occasional or small continuous amounts of inflow from anthropogenic sources; indicators include <20% of core landscape is agricultural or developed land, road runoff, storm drains, or other minor discharges emptying into the wetland.
FAIR (C)	Tidal and non-tidal water sources are moderately impacted by human activity; indicators of anthropogenic input include 20–60% developed or agricultural land adjacent to the site, including direct irrigation, or pumped water, moderate amounts of road runoff, moderately sized storm drains, and/or moderate point source discharges into or adjacent to the wetland.
POOR (D)	Tidal and non-tidal water sources are substantially impacted by human activity. Indicators of anthropogenic input include >60% developed or agricultural land adjacent to the site, large amounts of road runoff, large-sized storm drains, and major point source discharges into or adjacent to the wetland.

Data for Metric Rating: See Faber-Langendoen et al. (2012a) 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.

- ### HYD2. 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 streams and rivers.

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, mosquito control, etc.

Measurement Protocols for Non-Tidal Wetlands

Riverine (non-tidal): To score this metric, visually survey the AA for field indicators of aggradation or degradation (listed in Table 34). 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 34. Suggested field indicators for evaluating the Hydroperiod metric for Riverine Wetlands (adapted from Table 4.8 in Collins et al. 2006).

Condition	Hydroperiod Field Indicators for Evaluating Riverine Wetlands
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 (Erosion)	- 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 (Sedimentation)	- 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 35).

Table 35. Suggested field indicators for evaluating the Hydroperiod metric for Non-Riverine, Non-tidal Freshwater Wetlands (adapted from Table 4.8 in Collins et al. 2006).

Condition	Hydroperiod Field Indicators for Evaluating Non-Riverine, Non-tidal Freshwater Wetlands
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 reduced 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. Surface removal of vegetation through peat mining may also alter the hydrology of the remainder of the bog by reducing evapotranspiration.

Table 36. Suggested field indicators for evaluating the Hydroperiod metric for Organic Soil Flat Wetlands (Bog & Poor Fen).

Condition	Hydroperiod Field Indicators for Evaluating Organic Soil Flat Wetlands (Bog and Poor Fen)
Reduced Extent and Duration of Saturation	- Upstream spring boxes, diversions, impoundments, pumps, ditching, or draining from the wetland. - Water withdrawal (regional or local wells) - Evidence of aquatic wildlife mortality. - Encroachment of terrestrial vegetation. - Stress or mortality of hydrophytes. - Drying or mortality of non-vascular species (e.g., *Sphagnum*) - Compressed or reduced plant zonation. - Organic soils occurring well above contemporary water tables.
Increased Extent and Duration of 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 (e.g., beaver created impoundment) - Removal of vegetation for peat mining

Metric Rating:

Table 37. Hydroperiod metric rating.
Separate metric ratings are provided for Riverine (Non-Tidal), Organic and Mineral Soil Flats, other HGM (Depression, Lacustrine, Slope) and Estuarine Fringe (Tidal) variants.

Metric Rating	***V1: Hydroperiod variant: RIVERINE (Non-tidal)***
EXCELLENT (A)	Hydroperiod (flood frequency, duration, level, and timing) is characterized by natural patterns, with no major hydrologic stressors present. The channel/riparian zone is characterized by equilibrium conditions, with no evidence of severe aggradation or degradation indicative of altered hydroperiod (see field indicators table).
GOOD (B)	Hydroperiod inundation and drying patterns (flood frequency, duration, level, and timing) deviate slightly from natural conditions due to presence of stressors such as: flood control dams upstream or downstream, small ditches or diversions; berms or roads at/near grade; minor trampling by livestock; or minor flow additions. If wetland is artificially controlled, the management regime closely mimics a natural analog (it is very unusual for a purely artificial wetland to be rated in this category). 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 (see field indicators table).
FAIR (C)	Hydroperiod filling or inundation and drying patterns (flood frequency, duration, level, and timing) deviate moderately from natural conditions due to presence of stressors such as: flood control dams upstream or downstream

	moderately affect Hydroperiod; ditches or diversions 1–3 ft. deep; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible. If wetland is artificially controlled, the management regime approaches a natural analog. Site may be passively managed, meaning that the hydroperiod is still connected to and influenced by natural high flows timed with seasonal water levels. The channel/riparian zone is characterized by severe aggradation or degradation (see field indicators table).
POOR (D)	Hydroperiod filling or inundation and drawdown (flood frequency, duration, level, and timing) deviate substantially from natural conditions because of high intensity alterations such as: flood control dams upstream or downstream moderately to substantially affect hydroperiod; a 4-lane highway; diversions >3 ft. deep that withdraw a significant portion of flow; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be substantially constricted, blocking most flow. If wetland is artificially controlled, the site is actively managed and not connected to any natural season fluctuations, but the hydroperiod supports natural functioning of the wetland. The channel is concrete or artificially hardened (see field indicators table).

Metric Rating	***V2: Hydroperiod variant: DEPRESSION, LACUSTRINE, SLOPE (including Playas)***
EXCELLENT (A)	Hydroperiod characterized by natural patterns associated with inundation – drawdown, saturation, and seepage discharge. There are no major hydrologic stressors that impact the natural hydroperiod (see field indicators table).
GOOD (B)	Hydroperiod filling or inundation patterns deviate slightly from natural conditions due to presence of stressors such as: small ditches or diversions; berms or roads at/near grade; minor pugging by livestock; or minor flow additions. Outlets may be slightly constricted. Playas are not significantly impacted pitted or dissected. If wetland is artificially controlled, the management regime closely mimics a natural analog (it is very unusual for a purely artificial wetland to be rated in this category).
FAIR (C)	Hydroperiod filling or inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as: ditches or diversions 1–3 ft. deep; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; shallow pits within playas; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible. If wetland is artificially controlled, the management regime approaches a natural analog. Site may be passively managed, meaning that the hydroperiod is still connected to and influenced by natural high flows timed with seasonal water levels.

POOR (D)	Hydroperiod filling or inundation and drawdown of the AA deviate substantially from natural conditions from high intensity alterations such as: a 4-lane highway; large dikes impounding water; diversions > 3ft. deep that withdraw a significant portion of flow, deep pits in playas; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be substantially constricted, blocking most flow. If wetland is artificially controlled, the site is actively managed and not connected to any natural season fluctuations, but the hydroperiod supports natural functioning of the wetland.

Metric Rating	***V3: Hydroperiod variant: ORGANIC SOIL FLATS, MINERAL SOIL FLATS***
EXCELLENT (A)	Hydroperiod is characterized by natural patterns of filling, inundation saturation and drying or drawdowns. There are no major hydrologic stressors that impact the natural Hydroperiod (see field indicators table)
GOOD (B)	Hydroperiod filling or inundation patterns deviate slightly from natural conditions due to presence of stressors such as: small ditches or diversions; berms or roads at/near grade; minor pugging by livestock; or minor flow additions. Outlets may be slightly constricted. If wetland is artificially controlled, the management regime closely mimics a natural analogue (it is very unusual for a purely artificial wetland to be rated in this category).
FAIR (C)	Hydroperiod filling or inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as: ditches or diversions 1–3 ft. deep; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible. If wetland is artificially controlled, the management regime approaches a natural analogue. Site may be passively managed, meaning that the hydroperiod is still connected to and influenced by natural high flows timed with seasonal water levels.
POOR (D)	Hydroperiod filling or inundation and drawdown deviate substantially from natural conditions from high intensity alterations such as: a 4-lane highway; large dikes impounding water; diversions >3ft. deep that withdraw a significant portion of flow; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be significantly constricted, blocking most flow. If wetland is artificially controlled, the site is actively managed and not connected to any natural season fluctuations, but the hydroperiod supports natural functioning of the wetland. Hydroperiod is dramatically different from natural. Upstream diversions severely stress the wetland. If wetland is artificially controlled, hydroperiod does not mimic natural seasonality.

Metric Rating	*V4: Hydroperiod variant: ESTUARINE FRINGE (Tidal)*
EXCELLENT (A)	Area is subject to the full tidal prism, with two daily tidal minima and maxima. Storm tides, tidal river flooding and onshore wind-maintained high tides causing short-term changes in tidal amplitude are within the expected norm. 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 or overwash due to fluvial flooding, storm surge or wind-driven tides (extreme highs or lows).
GOOD (B)	Area is subject to minor 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 due to artificial breaching of the tidal barrier.
FAIR (C)	Area is subject to moderately 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 substantially muted tidal prism; 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.

*Kathleen Walz. Should we specify natural coastal lagoon? (as opposed to inland salt or fresh lagoon) – RAMSAR wetland classification definitions: Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea. Coastal freshwater lagoons; includes freshwater delta lagoons. Salinity can range from hypersaline to fresh.

Data for Metric Rating: See Faber-Langendoen et al. (2012a) for an evaluation of the discriminatory power of this metric based on an assessment of 277 wetlands in Michigan and Indiana. See Colorado field manual for documentation of their approach to artificial hydrology for assessing hydroperiod. For beaver impacted wetlands, be sure that the rating of this Hydroperiod metric is in sync with Metric VEG4 Overall Vegetation Structure.

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

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

▪ HYD3. 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. 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). Connectivity can be difficult to evaluate for both surface and subsurface hydrologic connections (including connections with shallow aquifers and zones beneath and alongside stream beds, where surface water and groundwater mix).

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, or impairments caused by rivershore rip-rap, 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 38. Hydrologic Connectivity metric rating.
Separate variants are provided for Riverine (Non-Tidal), Depression, Lacustrine, and Slope, Organic and Mineral Soil Flats, and Estuarine Fringe (Tidal).

Metric Rating	***V1: Hydrologic Connectivity variant: RIVERINE (Non-tidal)***
EXCELLENT (A)	Completely connected to floodplain (backwater sloughs and channels). No geomorphic modifications made to contemporary floodplain. Channel is not unnaturally entrenched.
GOOD (B)	Minimally disconnected from floodplain. Up to 25% of stream banks are affected due to dikes, rip rap and/or elevated culverts. Channel is somewhat entrenched (overbank flow occurs during most floods).
FAIR (C)	Moderately disconnected from floodplain due to multiple geomorphic modifications. Between 25 and 75% of stream banks are affected (e.g., dikes, tide gates, rip rap, concrete, and elevated culverts). Channel is moderately entrenched (overbank flow only occurs during moderate to severe floods).
POOR (D)	Channel is severely entrenched and entirely or extensively disconnected from the floodplain; >75% of stream banks are affected due to dikes, tide gates, rip rap, concrete, and elevated culverts. Channel is substantially entrenched (overbank flow never occurs or only during severe floods).

Metric Rating	***V2: Hydrologic Connectivity variant: DEPRESSION, LACUSTRINE*, SLOPE including Playa variant***
EXCELLENT (A)	No unnatural obstructions to lateral or vertical movement of ground or surface water. 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. If perched water table, then impermeable soil layer (fragipan or duripan) intact. <u>Playa</u>: Surrounding land cover / vegetation does not interrupt surface flow. No artificial channels feed water to playa.
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. 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. If perched then impermeable soil layer partly disturbed (e.g., from drilling or blasting). <u>Playa</u>: Surrounding land cover / vegetation does not interrupt surface flow. Artificial channels may feed minor amounts of excess water to playa.
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. Flood flows may exceed the obstructions, but drainage back to the wetland is incomplete

	due to impoundment. If perched, then impermeable soil layer moderately disturbed (e.g., by drilling or blasting). Playa: Surrounding land cover / vegetation may interrupt surface flow. Artificial channels may feed moderate amounts of excess water to playa.
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. Playa: Surrounding land cover / vegetation may dramatically restrict surface flow. Artificial channels may feed significant amounts of excess water to playa.

*Great Lakes Hydrologic Connectivity variant in development.

Metric Rating	***V3: Hydrologic Connectivity variant: ORGANIC SOIL FLATS (especially bogs and poor fens), MINERAL SOIL FLATS***
EXCELLENT (A)	No or very little direct connectivity to groundwater. Precipitation is the dominant or only source. Surrounding land cover / vegetation does not interrupt surface flow. No artificial channels feed water to wetland.
GOOD (B)	Minor hydrological connectivity, as caused by human activity (e.g., ditching). Surrounding land cover / vegetation does not interrupt surface flow. Artificial channels may feed minor amounts of excess water to wetland.
FAIR (C)	Moderate connectivity caused by human activity (e.g., ditching). Surrounding land cover / vegetation may interrupt surface flow. Artificial channels may feed moderate amounts of excess water to wetland.
POOR (D)	Substantial to full connectivity caused by human activity. Surrounding land cover / vegetation may dramatically restrict surface flow. Artificial channels may feed significant amounts of excess water to wetland.

Metric Rating	***V4: 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.

Data for Metric Rating: See Faber-Langendoen et al. (2012a) 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). See Colorado (Lemly 2014) for detail on Playa variant metric ratings.

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 that include brackish to fresh tidal marshes. 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). Great Lakes coastal marshes may also need a variant to account for their exposure to large, decadal lake level fluctuations.

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

SOIL

Conducting rapid assessment of soil condition in wetlands is challenging, and here we limit the assessment to visible evidence of soil surface or soil profile alterations that degrade the soil structure.

Wetlands naturally have varying water quality states, including a range of natural pH and salinity. Their water quality can also differ dramatically over the course of the growing season as runoff increases or decreases and water levels rise and fall. The EIA method evaluates water quality with two metrics: surface water turbidity/pollutants and algal growth. Both of these metrics are experimental and therefore optional; quantitative variants of these methods might be appropriate for Level 3 analyses. Earlier versions were not entirely successful (Faber-Langendoen et al. 2012a). The Colorado Natural Heritage Program (Lemly and Gilligan 2013) is actively seeking funding opportunities to expand their understanding of the natural range of variation for water quality measurements.

▪ SOI1. Soil Condition

Definition: An indirect measure of soil condition based on stressors that increase the potential for erosion of the soils or sedimentation, 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's Ecological Integrity Assessment 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 39. Soil Surface metric rating.
Separate variants are provided by NVC Formation for all freshwater, non-tidal wetlands (including Flooded & Swamp Forest, Freshwater Marsh, Wet Meadow & Shrubland, Bog & Fen, Aquatic Vegetation) and for estuarine, tidal wetlands (including Mangrove and Salt Marsh).

Metric Rating	***v1: Soil Condition variant: ALL FRESHWATER NON-TIDAL WETLANDS*** (FLOODED & SWAMP FOREST, FRESHWATER MARSH, WET MEADOW & SHRUBLAND, BOG & FEN, AQUATIC VEGETATION)
EXCELLENT (A)	Little bare soil, OR bare soil and soil disturbed areas are limited to naturally caused disturbances such as flood deposition or game trails, OR soil is naturally bare (e.g., playas). No disturbances are evident from trampling, erosion, soil compaction, ruts, sedimentation, invasive earthworms, or boat traffic.
GOOD (B)	Small amounts of bare or disturbed soil are present, but the extent and impact is minimal. Examples include disturbance from cattle (trampling or heaving grazing that leads to erosion), compaction or trampling by machinery, ruts or other disturbances from ATV or other vehicular activity, sedimentation due to human causes, invasive earthworms, or effects of boat traffic. The depth of disturbance is limited to only several centimeters (a few inches) and does not show evidence of ponding or channeling of water.
FAIR (C)	Moderate amounts of bare or disturbed soil are present, and the extent and impact is moderate. Examples include disturbance from cattle (trampling or heaving grazing that leads to erosion), compaction or trampling by machinery, ruts or other disturbances from ATV or other vehicular activity, sedimentation due to human causes, invasive earthworms, or effects of boat traffic. The

	depth of disturbance may extend 5–10 cm (2–4 inches), or localized deeper ruts, and shows some evidence of ponding or channeling of water.
POOR (D)	Substantial amounts of bare or disturbed soil are present, with extensive and long lasting impacts. Examples include disturbance from cattle (trampling or heaving grazing that leads to erosion), compaction or trampling by machinery, ruts or other disturbances from ATV or other vehicular activity, sedimentation due to human causes, invasive earthworms, or effects of boat traffic. The depth of disturbance extends > 10 cm (4 inches), or deeper ruts are widespread, and show some evidence of extensively altering hydrology, e.g., ponding or channeling of water.

Metric Rating	***v2: Soil Condition variant: ESTUARINE WETLANDS*** (MANGROVE, SALT MARSH, and tidal variants of FRESHWATER MARSH, WET MEADOW & SHRUBLAND)
EXCELLENT (A)	Excluding mud flats, bare or disturbed soils are naturally occurring and largely limited to salt pannes.
GOOD (B)	Small amounts of bare or disturbed soil areas caused by rafts of anthropogenic debris (killing marsh vegetation and creating artificial pannes), ditch spoils impounding water and forming artificial pannes, trampling by livestock, and erosion of marsh and channel banks due to excavation by marine traffic and/or altered current/tidal patterns resulting from deficient culverts (leading to erosion).
FAIR (C)	Moderate amounts of bare or disturbed soil areas caused by rafts of anthropogenic debris (killing marsh vegetation and creating artificial pannes), ditch spoils impounding water and forming artificial pannes, trampling by livestock, and erosion of marsh and channel banks due to excavation by marine traffic and/or altered current/tidal patterns resulting from deficient culverts (leading to erosion).
POOR (D)	Substantial amounts of bare or disturbed soil areas caused by rafts of anthropogenic debris (killing marsh vegetation and creating artificial pannes), ditch spoils impounding water and forming artificial pannes, trampling by livestock, and erosion of marsh and channel banks due to excavation by marine traffic and/or altered current/tidal patterns resulting from deficient culverts (leading to erosion).

Data for Metric Rating: See Faber-Langendoen et al. (2012a) 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.

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6.3 SIZE

The role of size in ecological integrity assessments varies depending on the application. Inventory or monitoring programs that focus on the condition of wetlands across watersheds or jurisdictions, with an emphasis on statistical design, often rely on a point based sampling approach (e.g. a 0.5 ha AA). In this case, the overall wetland size is typically not used to evaluate the wetland. Conversely, programs that focus on identifying wetlands as entire polygons, with an emphasis on the condition of the polygon, more typically consider the size of the wetland as important to its overall integrity. Size does interact with landscape context, such that small wetlands embedded in entirely natural landscapes should not be treated as having lower size rating for ecological integrity than a larger example of the same wetland in a fragmented landscape. Thus a scorecard should give careful consideration to how to score size in the context of other factors.

- ### SIZ1. Comparative Size (Patch Type)

Definition: A measure of the current absolute size (ha) of the entire wetland type polygon or patch. The metric is assessed with respect to a comparison of patch-type 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 to use patch 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 an absolute patch-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). For example, with this approach, Midwest prairie 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 patch size in assessing integrity is complex. First, higher ratings for size may not always indicate increased integrity. For some types, patch size can vary widely for entirely natural reasons, particularly across its entire range (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; a peatland type may have very large occurrences at the north end of its range and have small occurrences at the south end).

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, patch 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. Similarly, large occurrences may be more likely to sustain viable populations of rare or area-dependent plants and animals. For example, species richness of wet meadow grassland birds in Nebraska was highest in patches greater than 50 ha (Helzer and Jelinski 1999). Other birds, such as the Greater Prairie Chicken (*Tympanuchus cupido*) may require 4,000 to 8,000 ha of unfragmented native prairie (Bidwell et al. 2003). Larger wetlands are more resistant to hydrologic stressors. Larger uplands are 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 evaluating 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 (Faber-Langendoen et al. 2016c). 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:
Patch 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 (GPS) receiver. 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:

Metric ratings are based on the Spatial Pattern patch size rating, in the context of the typical patch type of the wetland. The kind of spatial patterns that is typical of particular wetland being assessed is an important first step (see Table 40), 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 spatial pattern type, so if the site is classified to Ecological System or Group, that information can be readily attained (www.natureserve.org/explorer).

Table 40. 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 km^2) (5000 – 25,000 ac) 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 (125-5,000 ac).**
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 (3 – 125 ac).**
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 (1 – 60 mi).**

After assigning the wetland type to a typical spatial pattern type (or types), the patch size can be rated based on Comparative Size (patch type) using Table 41 and Table 42. This metric addresses size from an ecological process perspective; that is, D ratings are given to smaller sizes based on lower diversity, lower ability to maintain area-dependent species, etc.

Table 41. Comparative Size (Patch Type) metric rating: Area by spatial pattern of type.
General guidelines for assessing size of wetlands. A determination first needs to be made as to the typical spatial pattern of the wetland type in the ecoregions or across its entire range.

Metric Rating	***COMPARATIVE SIZE BY PATCH TYPE (hectares)***						
Spatial Pattern Type	***MATRIX***	***LARGE PATCH***			***SMALL PATCH***		***LINEAR***
	Matrix (ha)	**Large Patch - high (ha)**	**Large Patch - typic (ha)**	**Large Patch - low (ha)**	**Small Patch - typic (ha)**	**Small Patch - low (ha)**	**Linear (length in km)**
EXCELLENT (A)	>5,000	>500	>125	>50	>10	>2	>5 km
GOOD (B)	500–5,000	100–500	25–125	10– 50	2–10	0.5–2	1–5 km
FAIR (C)	100–500	20–100	5–25	2–10	0.5–2	0.1–0.5	0.1–1 km
POOR (D)	<100	<20	<5	<2	0.5	0.1	<0.1 km

OR

Metric Rating	***COMPARATIVE SIZE BY PATCH TYPE (acres)***						
Spatial Pattern Type	***MATRIX***	***LARGE PATCH***			***SMALL PATCH***		***LINEAR***
	Matrix (ac)	**Large Patch - high (ac)**	**Large Patch - typic (ac)**	**Large Patch - low (ac)**	**Small Patch - high (ac)**	**Small Patch - typic (ac)**	**Linear (length in mi)**
EXCELLENT (A)	>12,500	>1,250	>300	>125	>25	>5	>3 mi
GOOD (B)	1,250–12,500	250–1,250	60–300	25–125	5–25	1–5	0.6–3 mi
FAIR (C)	250–1,250	50–250	12–60	5–25	1–5	0.25–1.25	0.06–0.6 mi
POOR (D)	<250	<50	<12	<5	1	0.25	<0.06 mi

From a conservation perspective, larger examples of types may have more conservation value, and for that reason, we have developed a conservation-value based rating that incorporates these size ratings, referred to as an Element Occurrence Rank (EORANK) in NatureServe's core methodology (Faber-Langendoen et al. 2016d). We first calculate an EIA Score based on Landscape Context and Condition ratings, then add or subtract points using Table 42 based on the Size Rating from Table 41.

Table 42. [DRAFT] A point-based approach for assessing Size ratings with Landscape Context and Condition.
An EIA score is first produced based on weighted averages of Landscape Context and Condition, then points are added or subtracted based on the Size rating from Table 41 (See Faber-Langendoen et al. 2016d). **Points are under review**.

	Matrix	**Large Patch**	**Small Patch**
A	+1.5	+ 1.0	+ 0.75
B	+0.5	+ 0.33	+ 0.25
C	-0.5	- 0.33	- 0.25
D	-1.5	-1.0	- 0.75

An alternative view of comparing size is to look at it from the point of view of the distribution of sizes that a type had historically, and to rate those at the largest end of the distribution as an A and those at the smallest end as a D. Table 43 provides an example of this approach. We note again that inclusion of size introduces other conservation values to our assessment of the point or polygon beyond that of ecological integrity.

Table 43. Comparative Size (Distribution) metric rating.

Metric Rating	***Comparative Size By Size Distribution: ALL WETLANDS***
EXCELLENT (A)	Very large size compared to other examples of the same type, based on current and historical spatial patterns (and meeting the requirements for all or almost all of the area-sensitive indicator species dependent on the system, if within range)
GOOD (B)	Large size compared to other examples of the same type, based on current and historical spatial patterns (and not meeting the requirements for some of the area-sensitive indicator species; i.e., they are likely to be absent, if within range[1]).
FAIR (C)	Medium to small size compared to other examples of the same type, based on current and historical spatial patterns (and not meeting the requirements for several to many of the area-sensitive indicator species, if within range[1]).
POOR (D)	Small to very small size, based on current and historical spatial patterns; (and not meeting the requirements for most to all area-sensitive indicator species, if within range[1]).

[1] If known, record the area-dependent species that are missing.

Data for Metric Rating: See Faber-Langendoen et al. (2012a) 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's 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 Z1.2 and Z1.3 provide some standard guidance.

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

▪ SIZ2. Change in Size [optional]

Definition: A measure of the current size of the wetland (in hectares) relative to its historical extent.

Background: This metric is one aspect of the size of specific occurrences of a wetland type. The metric rating is adapted from Faber-Langendoen et al. (2008), where it is referred to as "Patch Size Condition." Scoring of this metric was revised in 2018, based on suggestions from Bill Nichols. In its 2016 form, it was averaged with SIZ1, but this produced counterintuitive results. For example, when Comparative Size is C+ and Change in Size is B, the averaging approach produces an improved overall Size rating, from C to B- even though there has been a reduction in size (wetland loss/impact). Bill Nichols suggests that this metric be used in tandem with Comparative Size, such that reduction in a wetland further lowers the Comparative Size rating. For example, if Comparative Size is C+ and Change in Size is B, then the Comparative Size rating is lowered from C+ to C.

Metric Type: Condition.

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

Rationale for Selection of the Variable: Change in 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 historical area of the wetland. For example, if a wetland has a current size of 1 hectare but the historical size was 2 hectares, this indicates that half (50%) of the original wetland was lost or severely degraded.

Change in Size should only be used if the user is reasonably confident a change in size has occurred, based on GIS data layer(s), etc. There are limitations in our ability to detect degree of change and historical extent. Given this, Change in Size should be scored based on what can reasonably be detected and limitations should otherwise be noted in the metric comment field.

Complicating the use of this metric is that in some cases, wetland size increases due to human disturbances. Note that increases in wetland size resulting from beaver flooding should not be considered here, unless the beaver flooding is associated with blockage of a culvert or other artificial structure.

Measurement Protocol: Change in Size can be measured using a combination of digital imagery, maps and field evaluation, including aerial photographs, orthophoto quads, and National Wetland Inventory maps. Use of old aerial photographs may also be very helpful, as they may show the historical extent of a wetland. Field assessments of current size is typically required to confirm photo interpretation. The metric is calculated as follows:

$$\text{Change in Size} = \text{Current Size} / \text{Historical Size} * 100$$

The definition of the “historical” timeframe for assessing Change in Size 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 historical 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 44. Change in Size metric rating.

Metric Rating *(change in rating of Comparative Size)*	***Change in Size: ALL WETLANDS*** *Required for small AAs of large-patch/matrix ecosystems; optional for all other small AAs*
No change to Comparative Size rating	Occurrence has not been artificially reduced (0%) or increased from its original, natural extent; any detectable change in size is due to natural fluctuations. *See note[1] below for interpretation of "reduction."* No change in scoring of Comparative Size (SIZ1)
-1/3 letter grade	Occurrence is minimally reduced (1–5%) or increased from its original natural extent. Lower the Comparative Size (SIZ1) rating by one-third (e.g., B+ to B).
-2/3 letter grade	Occurrence is moderately reduced (5–30%) or increased from its original, natural extent. Lower the Comparative Size (SIZ1) rating by two-thirds (e.g., B+ to B-).
-1 letter grade	Occurrence is substantially reduced (>30%) or increased from its original, natural extent. Lower the Comparative Size (SIZ1) rating by one (e.g., B+ to C+)."

[1]**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. (2012a) 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). Nichols (2018) is applying this metric to a variety of wetland sites.

Scaling Rationale: Scaling criteria are based on Faber-Langendoen et al. (2008) and best scientific judgment.

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

7.0 STRESSOR CHECKLIST

Stressors and Stressor Ratings

A stressor is an anthropogenic perturbation within the AA or surrounding landscape that can negatively affect the condition and function 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. 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 modified from Faber-Langendoen et al. (2012b). See also Collins et al. (2006) and Brooks et al. (2006) for parallel approaches to the use of stressor checklists as part of wetland condition assessments. For guidance on completing the stressors checklist form, see section below.

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 factors of wetland condition. Thus, relationships between stressors, ecological factors, 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. 2012a). 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.

Guidelines and Calculations for the Stressor Checklist

The stressor checklist form is provided at the end of this section. The form is embedded in EcoObs and after entering data from Step 1, the database automatically completes Steps 2 – 4.

Step 1. Rate Scope and Severity of Stressors: Stressors are rated if they are observed or inferred to occur, but are not assessed if they are projected to occur in the near term, but do not yet occur. Record and estimate the scope and severity, as defined in Table 45, of applicable stressors in the AA or its buffer. Things to consider when filling out the form:

- Stressors checklists must be completed for all 4 categories (Buffer, Vegetation, Soils/Substrate, Hydrology).
- 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.
- Assess Buffer Perimeter stressors and their effects within the Buffer Perimeter (NOT how buffer stressors may impact the AA).
- Stressors for Vegetation, Soils, and Hydrology are assessed across the AA.
- Some stressors may overlap (e.g., 10 [Passive recreation] may overlap with 24 [Trampling]); choose the one with the highest impact and note overlap.
- 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.
- 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.
- A number of stressors have a single pre-assigned severity number as a highly recommended severity assignment for that stressor. But if this recommendation appears to be inappropriate for your wetland, you may fill in another number.

Table 45. Stressor Scoring Categories: Scope and Severity.

SCOPE of Threat (% of AA or Buffer affected by direct threat)	
1 = Small	Affects a small (1-10%) proportion of the AA or Buffer
2 = Restricted	Affects some (11-30%)
3 = Large	Affects much (31-70%)
4 = Pervasive	Affects all or most (71-100%)
SEVERITY of Threat within the defined Scope (degree of degradation to AA or Buffer)	
1 = Slight	Likely to only slightly degrade/reduce
2 = Moderate	Likely to moderately degrade/reduce
3 = Serious	Likely to seriously degrade/reduce
4 = Extreme	Likely to extremely degrade/destroy or eliminate

Step 2. Assign Impact Rating of Each Stressor: The impact rating of each stressor is based on the combination of its scope and severity score (Table 46). Enter the score in the "Impact" cell for each stressor.

Table 46. Stressor Impact Rating, based on assigned values of Scope and Severity.

Threat Impact Calculator		Scope			
		4 = Pervasive	3 = Large	2 = Restricted	1 = Small
Severity	4 = Extreme	Very High = 10	High = 7	Medium = 4	Low = 1
	3 = Serious	High = 7	High = 7	Medium = 4	Low = 1
	2 = Moderate	Medium = 4	Medium = 4	Low = 1	Low = 1
	1 = Slight	Low = 1	Low = 1	Low = 1	Low = 1

Example: (note that stressor 2 has a preassigned severity score on the field sheet, but it was not encountered at the site, so no impact score is assigned).

	BUFFER (0-100 m)		
STRESSORS CHECKLIST	Scope	Severity	IMPACT
1. Residential, recreational buildings, associated pavement	3	3	H=7
2. Industrial, commercial, military buildings, associated pavement		4	
3. Oil and gas wells and surrounding footprint	1	4	L=1

Step 3. Calculate Overall Stressor Impact Rating for each of the Major Ecological Factors (MEF): For each MEF (i.e., Buffer, Vegetation, Hydrology, and Soils), sum the total impact scores and enter the value in the appropriate cell at the bottom of the field form. Assign a Rating for each MEF, using Table 47.

Example:

	BUFFER (0-100 m)		
STRESSORS CHECKLIST	Scope	Severity	IMPACT
1. Residential, recreational buildings, associated pavement	3	3	H=7
2. Industrial, commercial, military buildings, associated pavement		4	
3. Oil and gas wells and surrounding footprint	1	4	L=1
Overall Buffer Impact Score | Rating			**8 | High**

Table 47. Stressor Impact Scores and Ratings.

MEF Sum of Impact Scores	MEF / Site Stressor RATING
10+	**Very High**
7 – 9.9	**High**
4 – 6.9	**Medium**
1 – 3.9	**Low**
0 – 0.9	**Absent**

Step 4. Calculate an Overall Stressor Impact Rating for AA: Next, using the algorithms on the field form, calculate overall impact scores based on each categories score.

Using the four MEF Stressor "Sum of Scores" for Buffer, Vegetation, Hydrology, and Soils, apply the following weights to calculate the HSI score. After the HSI score is calculated, use Table 48 to determine the HSI rating for the wetland system.

Example:

MEF	Buffer	Vegetation	Soil	Hydrology	HSI
Weight	0.3	0.3	0.1	0.3	
score x weight	8 x 0.3= 2.4	4 x 0.3= 1.2	1 x 0.1= 0.1	6 x 0.3= 1.8	5.5 Medium

Table 48. Overall Site Rating for Human Stressor Index Score.

HSI Score	HSI Rating
10+	Very High
7 – 9.9	High
4 – 6.9	Medium
1 – 3.9	Low
0 – 0.9	Absent

Stressor Checklist Form

Stressors: *direct threats*; "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" or altered disturbance regime (e.g. flooding, fire, or browse).

AA = Assessment Area

Some Important Points about Stressors Checklists:

1. The Stressors Checklist must be completed for the AA (Veg, Soils, Hydro) and the Buffer (0-100m)
2. Assessment is of stressors found only within the AA and in the buffer, not outer landscape. Rely on imagery in combination with what you can field check.
3. *Assess Buffer stressors and their effects within the Buffer 0-100m (NOT how buffer stressors may impact the AA)*
4. Stressors for Vegetation, Soils, and Hydrology are assessed across the full AA.
5. Some stressors may overlap. E.g. 10 (low impact recreation) may overlap with 24 (Trampling).Choose only 1, note overlap
6. **Severity has been pre-assigned for many stressors. If the severity differs from the pre-assigned rating, cross it out and note the true severity. If there is more than one pre-assigned value, circle the appropriate value.**

		BUFFER (100 m)			ASSESSMENT AREA (AA)									
					Vegetation MEF			Soil / Subs MEF			Hydrology MEF			
	STRESSORS CHECKLIST	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Comments (circle stressor #)
	1. Residential, recreational buildings, associated pavement		4											1
D	2. Industrial, commercial, military buildings, associated pavement		4											2
E	3. Utility/powerline corridor		1,2,3			1,2,3								3
V	4. Sports field, golf course, urban parkland, expansive lawns		2											4
E	5. Row-crop agriculture, orchard, nursery		3											5
L	6. Hay field		2,3											6
O	7. Livestock grazing (low=2, mod=3, high=4), excessive herbivory (deer =3)		2,3,4			2,3,4								7
P	8. Roads (gravel = 2, paved=3, highway=4), Railroad=3		2,3,4											8
	9. Other [specify]:													9
R	10. Low impact recreation (hunting, fishing, camping, hiking, bird-watching, canoe/kayak)		1			1								10
E	11. High impact recreation (ATV, mountain biking, motor boats)		3			3								11
C	12. Other [specify]:													12
	13a. Tree resource extraction (e.g., Clearcut = 3 for Buffer or =4 for AA; Selective cut = 2 or 3)		2,3,4			2,3,4								13a
	13 b. Shrub / Herb resource extraction (e.g. medicine, horticulture)		2,3			2,3								13b
V	14. Vegetation management: cutting, mowing		2			2								14
E	15. Excessive animal herbivory or insect pest damage		1,2,3			1,2,3								15
G	16. Invasive plant species (SEE LIST)		3,4			3,4								16
G	17. Pesticide or vector control, chemicals (give onsite evidence)		2,3			2.3								17
	18. Other [specify]:													18
Nat	19. Altered natural disturb regime [specify expected regime]		1,2,3			1,2,3								19
Dis	20. Other [specify]:													20

		BUFFER (100 m)			ASSESSMENT AREA (0.5 ha)									
					Vegetation MEF			Soil / Subs MEF			Hydrology MEF			
	STRESSORS CHECKLIST	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Scope	Severity	IMPACT*	Comments (circle stressors)
	21. Excessive sediment or organic debris (recently logged sites), gullying, excessive erosion, excessive loss of organic matter		3						3					21
S	22. Trash or refuse dumping													22
O	23. Filling, spoils, excavation													23
I	24. Soil disturbance: trampling (2), livestock (3), skidding (3), Vehicle (4)		2,3,4						2,3, 4					24
L	25. Grading, compaction, plowing, discing, fire lines		4						4					25
	26. Physical resource extraction: rock, sand, gravel, etc		3						3					26
	27. Other [specify]: e.g. landfill, soil loss/root exposure													27
H	28. PS discharge (waste water treatment water, non-storm discharge, septic)		3									3		28
Y	29. NPS discharge (urban/storm water runoff, agricultural drainage or excess manure, mine runoff, oil/gas discharge)		3									3		29
D	30. Dam, ditch, diversion, dike, levee, unnatural inflow, reservoir		3,4									3,4		30
R	31. Groundwater extraction (small well=2,several wells=3, extensive extraction causing significant lowering of water table =4)		2,3,4									2,3, 4		31
O	32. Flow obstructions (culverts, paved stream crossings)		4									4		32
L	33. Engineered channel (riprap, armored channel bank, bed)		4									4		33
O	34. Actively managed hydrology (e.g. lake levels controlled)		3									3		34
G	35. Tide gate, weir/drop structure, dredged inlet/channel		3									3		35
Y#	36. Other [specify]: e.g. wall/ riprap, impervious surface													36
Stressors Very Minimal or Not Evident (check box, if true)		☐			☐			☐			☐			
SUM OF Stressor IMPACTS -- Score & Rating by MEF (Buffer, Veg, Soils, Hydro) and for Site (from Table 46). See Table 47, for MEF Rating,		Sum Score:	MEF Rating:		Sum Score:	MEF Rating:		Sum Score:	MEF Rating:		Sum Score:	MEF Rating:		
TOTAL (Site) HSII: Multiply each MEF Impact Score by the following weights then sum them to calculate the HSI Rating. See Table 48 for HSI Site Rating.		_____ x 0.3 =			_____ x 0.3 =			_____ x 0.1 =			_____ x 0.3 =			HSI Total Score: _____ HSI Total Rating:_____

*For impact score, see Table 46

Hydrology stressors may cross between buffer and AA. E.g., ditches in the buffer may directly impact hydrology of the AA. Minimize listing in both columns unless you are sure of the impacts.

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9.0 APPENDICES

APPENDIX 1. Template for Metrics Protocols

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 species, 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 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 and the ecosystems being assessed. 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) when polygon is much larger than 20 ha, use multiple AAs to document variability in condition.
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 (factor in step 2 when mapping). Locations may be based on office information, or from previous field visits. Establish a preliminary Assessment Area (AA).

2. Classify the wetland type(s). 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. Use the Protocols for each metric, as described in the main document. 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. For forested wetlands, it is useful to have some knowledge of basic forest measurements (i.e., basal area, tree age, canopy cover).

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 (including historic imagery if available)
- Satellite imagery
- LIDAR
- Digital Orthophoto Quadrangles (1 m resolution)
- GIS layers - ecological maps (e.g., National Land Cover Dataset, National Wetland Inventory, Landfire NVC/Ecological Systems maps)
- GIS layers - other (e.g., roads, utility lines, trails, mines, wilderness areas, 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. (n.b. additional guidance is needed for large wetlands with potentially multiple AAs).

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 substantial and occur over large areas, 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.

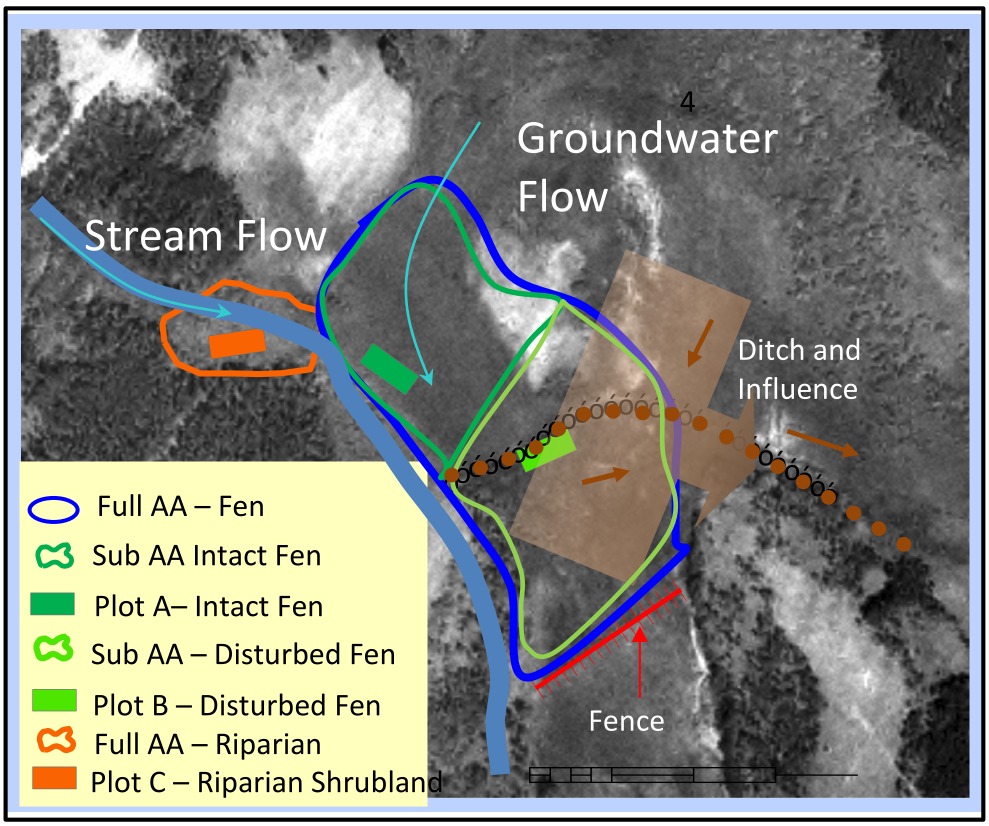

Figure A2.1. Example of delineated Assessment Areas (AAs). Although contiguous with each other, the fen and riparian shrubland were delineated as distinct AAs because they were distinct wetland types (e.g., fen vs. riparian shrubland). The fen was divided into sub-AAs due to a human-induced disturbance (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 (or use of multiple plots) ensures adequate representation of local, micro-variations produced by such things as hummocks, water tracks, side channels, pools, wetland edge, and microtopography in the floristic data. Plots can also be placed objectively, if enough plots are laid. Invasive plants are often very patchy, and surveyors should be cautious that plots may over or under represent the actual cover of invasive plants in a wetland polygon.

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.

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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 largely distinct approaches are commonly used for recording vegetation: (a) data are recorded from a single large plot, and (b) data are recorded from a set of smaller plots distributed within the AA. 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, whereas vegetation containing very sparse vascular vegetation, and 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). Chytrý and Otýpková (2003) provide a range of plot sizes used by European vegetation ecologists. 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 multiple small plots: Taking multiple small plots within a community or wetland type is an alternative to the single large (100, 400 or1000 m^2) nested 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 plot method may locate these plots 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 shrub and herb vegetation typically range from 0.25 to 5.0 m^2 and anywhere from 10 to 50 quadrats may be placed in the stand.

Finally, the choice between a single larger plot vs. multiple smaller plots must consider the tradeoff between a better ability to estimate the precision of species abundance values obtained from smaller more widely distributed plots compared to the more complete species list and the assessment of nested richness obtained using the single large plot. A disadvantage of relying on multiple small plots or quadrats to characterize the stand is that a large number of small plots may be needed to characterize the full floristic composition of the stand. Yorks and Dabydeen (1998) describe how reliance on smaller plots can result in a failure to assess the importance of many of the less abundant species in a larger plot. Consequently, whenever smaller plots 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. 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), especially when conducting extensive surveys across widely separated stands. Sometimes, several somewhat large subplot or modules (e.g., >100 to 400 m^2 in a forest) are established within the full plot to capture internal variability, especially where the goal is to more intensively assess or monitor a particular stands. An alternative plot method uses a series of nested plots to describe the different strata, with the largest plot for the tree stratum, 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 Stratum 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. Other measurements of forest structure, such as basal area, diameter distribution, and density or regeneration, provide valuable data for comparison to reference conditions (i.e., old growth) for forested wetlands.

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

Major wetland categories used to guide formation distinctions are described (see also Faber-Langendoen et al. 2012b). 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 or low-statured treed, 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 between 5- 10 m typically 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)

Wetland Category	Definition	Environmental features	Growth forms	Mitsch & Gosselink (2000) type	NWI Wetland Class
Fen	Fens are peatlands where groundwater or stream inflow maintains relatively moderate to high mineral content within the rooting zone. Sites are characterized by both ericaceous and non-ericaceous shrubs, sedges, grasses, reeds, and brown mosses. Trees 5-10 m typically have <10% cover. Ranges from poor fen to rich fen. Poor fens overlap with bogs and are sometimes treated 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. Less commonly, short trees.	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 > 5 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)

Wetland Category	Definition	Environmental features	Growth forms	Mitsch & Gosselink (2000) type	NWI Wetland Class
Salt Marsh	Salt marshes are intertidal to supratidal ecosystems that are flooded diurnally (or less), sometimes with freshwater inputs, and have communities dominated by salt-tolerant emergent graminoids and succulents. Trees > 5 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 occurs on sites where flooding varies from temporary (<7 days) to semi-permanent (>180 days). Trees > 5 m have >10% cover.	Mineral soils or well-humified peat. Temporary to semi-permanent 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.

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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.

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APPENDIX 5. Description of Hydrogeomorphic Classes.

See hydrogeomorphic class definitions below from NRCS (2008). Smith et al. (1995) provides a brief tabular overview.

Table A5.1 Definitions of hydrogeomorphic wetland classes (modified from Brinson et al. 1995)	
HGM CLASS	**Definition**
RIVERINE	Riverine wetlands occur in floodplains 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, groundwater 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 groundwater discharge, may slowly contribute to groundwater. 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 groundwater 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 groundwater 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 groundwater 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 historical floodplain terraces where the main source of water is precipitation. They receive no groundwater 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 groundwater. 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 groundwater.

	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 groundwater discharge and precipitation. The interface between the estuarine fringe and Riverine classes is where bidirectional flows from tides dominate over unidirectional ones controlled by floodplain 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 groundwater 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 A5.2 (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.

APPENDIX 6. Vegetation Profile for Structure and Composition.

EIAs typically require only basic information on vegetation structure, along with species composition. This information is also suitable for vegetation classification and description. However, where more detailed information is desired, the table below may be more useful.

	VEGETATION GROWTH FORM PROFILE			**VEGETATION SPECIES PROFILE BY GROWTH FORM**	
	Cover scale: 0, 1-4%, then ±5% (10, 20, etc.)				
	Growth forms / Stratum	**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 nonnative spp. <5% cover. **Optional:** List other characteristic native spp. <5% (1-4%, <1% =T).	
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)				
S	**St. Tall Shrub** (≥2 m)				
	Ss. Short/ Dwarf-shrub (<2 m)				
H	**Hn. Herb (non-aquatic)**				
A	**Af. Floating-lvd Aquatic**		X		
	As. Submerged Aquatic		X		
N	**Nonvascular: Nm Moss**				
			X		
	Nl. Lichen		X		
	Na. Algae		X	e.g., *Chara*	
V	**Vine/Liana*: Vt. Tall (> 5m)**		X		
	*woody				
	Vl. Low (< 5 m)		X		

APPENDIX 7. Application of Land Use Index to Landfire Map Legend.

The "LU class-aggregated" matches the column in Table L2.1. This table needs to be updated to Latest Landfire Systems map legend.

note	OBJECTID	ESLF	Land Use Class	LU categories_ aggregated	LU_coefficient	Natural (1) Cultural (0)	buffer_ int	Note
new in 3.0	9	31	Urban	Developed - High to Moderate Intensity	0	0	0	
	5	23	Developed-Medium Intensity	Developed - High to Moderate Intensity	0	0	0	
	6	24	Developed-High Intensity	Developed - High to Moderate Intensity	0	0	0	
	35	32	Quarries/Strip Mines/Gravel Pits	Developed - High to Moderate Intensity	0	0	0	
	4	22	Developed-Low Intensity	Developed - Low Intensity	1	0	0	
	3	21	Developed-Open Space	Developed - Low Intensity	2	0	0	
	8	82	Agriculture-Cultivated Crops and Irrigated Agriculture	Agriculture - Cultivated Crop, Annual	2	0	0	
	37	80	Agriculture-General	Agriculture - Cultivated Crop, Perennial	3	0	0	
	59	8508	Clearcut - Grassland/Herbaceous	Vegetation - Highly Altered	3	1	1	
new in 3.0	414	8603	Harvested forest-grass regeneration	Vegetation - Highly Altered	4	1	1	
	7	81	Agriculture-Pasture/Hay	Agriculture - Moderate Intensity	4	0	0	

	21	8509	Successional Shrub/Scrub (Clear Cut)	Vegetation - Highly Altered	4	1	1	
	23	8602	Recently Logged Timberland	Vegetation - Highly Altered	4	1	1	
	24	8604	Harvested forest-herbaceous regeneration	Vegetation - Highly Altered	4	1	1	
	34	10	Recently Logged Areas	Vegetation - Highly Altered	4	1	1	
	36	61	Orchards/Vineyards	Agriculture - Cultivated Crop, Perennial	4	0	0	
	43	2191	Recently Logged Timberland-Herbaceous Cover	Vegetation - Highly Altered	4	1	1	
	58	8503	Harvested Forest-Grass Regeneration	Vegetation - Highly Altered	4	1	1	
new in 3.0	399	8406	Introduced Riparian and Wetland Vegetation	Vegetation - Moderately Altered	5	1	1	
new in 3.0	404	8502	Recently burned grassland	Vegetation - Moderately Altered	5	1	1	
new in 3.0	411	8517	Semi-natural / Altered Vegetation and Conifer Plantations	Vegetation - Moderately Altered	5	1	1	
	1	1	Non-Specific Disturbed	Vegetation - Moderately Altered	5	1	1	
	19	8401	Introduced Upland Vegetation - Treed	Vegetation - Moderately Altered	5	1	1	
	20	8490	Introduced Wetland Vegetation	Vegetation - Moderately Altered	5	1	1	

	22	8514	Managed Tree Plantation	Vegetation - Moderately Altered	5	1	1	
	32	2	Recently Burned	Vegetation - Moderately Altered	5	1	1	
	33	8	Introduced Upland Vegetation - Annual Grassland	Vegetation - Moderately Altered	5	1	1	
	38	2181	Introduced Upland Vegetation-Annual Grassland	Vegetation - Moderately Altered	5	1	1	
	39	2182	Introduced Upland Vegetation - Perennial Grassland and Forbland	Vegetation - Moderately Altered	5	1	1	
	40	2183	Introduced Upland Vegetation - Perennial Grassland and Forbland	Vegetation - Moderately Altered	5	1	1	
	42	2185	Introduced Wetland Vegetation	Vegetation - Moderately Altered	5	1	1	
	46	2195	Recently Burned Herbaceous	Vegetation - Moderately Altered	5	1	1	
	47	2196	Recently Burned Shrubland	Vegetation - Moderately Altered	5	1	1	
	50	8310	Ruderal Upland - Old Field	Vegetation - Moderately Altered	5	1	1	Ruderal old fields are given a 5 in the context of a forested landscape. They could be given a 7 in the context of prairie/shrub

								landscapes, because their structure is similar to native prairies.
	51	8402	Introduced Upland Vegetation - Shrub	Vegetation - Moderately Altered	5	1	1	
	52	8403	Introduced Upland Vegetation - Annual and Biennial Forbland	Vegetation - Moderately Altered	5	1	1	
	53	8404	Introduced Upland Vegetation - Annual Grassland	Vegetation - Moderately Altered	5	1	1	
	54	8405	Introduced Upland Vegetation - Perennial Grassland and Forbland	Vegetation - Moderately Altered	5	1	1	
	55	8412	Introduced Wetland Vegetation - Treed	Vegetation - Moderately Altered	5	1	1	
	56	8480	Introduced Riparian Vegetation	Vegetation - Moderately Altered	5	1	1	
	57	8501	Recently Burned Forest and Woodland	Vegetation - Moderately Altered	5	1	1	
	60	8512	Recently Burned Forbland	Vegetation - Moderately Altered	5	1	1	
	61	8513	Managed Tree Plantation	Vegetation - Moderately Altered	5	1	1	
	18	8311	Ruderal Forest	Vegetation - Lightly Altered	7	1	1	Ruderal Forest is given a 7 rather than a 5 in forested

								environments, because it is much closer to structure of native forests.
	44	2192	Recently Logged Timberland-Shrubland Cover	Vegetation - Lightly Altered	7	1	1	
	48	8301	Successional Shrub/Scrub (Other)	Vegetation - Lightly Altered	7	1	1	
	49	8304	Ruderal Forest - Southeast Hardwood and Conifer	Vegetation - Lightly Altered	7	1	1	
	63	8601	Harvested forest-tree regeneration	Vegetation - Lightly Altered	7	1	1	
	45	2193	Recently Logged Timberland-Woodland Cover	Vegetation - Lightly Altered	8	1	1	
	62	8516	Modified/Managed Southern Tall Grassland	Vegetation - Lightly Altered	9	1	1	
new in 3.0	393	8313	Great Lakes Sandy Beach System	Vegetation - No/Minimally Altered	10	1	1	
	2	11	Open Water		10	1	0	

APPENDIX 8. Ecological Integrity Assessment Ratings

See Faber-Langendoen et al. (2016c) for details.

Metric Rating	
EXCELLENT (A)	3.5 – 4.0
GOOD (B)	2.5 – 3.5
FAIR (C)	1.5 – 2.5
POOR (D)	1.0 – 1.5

OR

Factor Rating	
A+	3.8 – 4.0
A -	3.5 – 3.79
B+	3.0 – 3.49
B-	2.5 – 2.99
C+	2.0 – 2.49
C-	1.5 – 1.99
D	1.0 –1.49

APPENDIX 9. Comparison of Level 2 Metrics between 2012 (v1.0) and 2016 (v2.0).

Metrics from 2012 (v1.0) are described in Faber-Langendoen et al. (2012b). Two metrics from 2012 were dropped: “**Landscape Connectivity”** (which was redundant with “Contiguous Natural Land Cover” and “**Physical Patch Types**,” which was hard to apply consistently in the field. A detailed comparison is available as a separate word document (Faber-Langendoen et al. 2016d).

RANK FACTOR	ECOLOGICAL FACTOR	2015 METRIC NAME	2012 Metric Name	2015 CHANGE
LANDSCAPE CONTEXT	LANDSCAPE	LAN1. Contiguous Natural Land Cover	New	New metric.
		LAN2. Land Use Index	Land Use Index	Simple change from a 0 – 1.0 scale to 1 – 10 scale. But note some modifications to land use categories in worksheet table.
	BUFFER	BUF1. Perimeter with Natural Buffer	Percent of AA Having Buffer	The A is given a stricter threshold, A- becomes an expanded B and C is also expanded to include 2012 B.
		BUF2. Width of Natural Buffer	Buffer Width	The A is given a stricter threshold, A- becomes an expanded B, and C is also expanded to include 2012 B.
		BUF3. Condition of Natural Buffer	Buffer Condition	The A- becomes a B, and C is expanded to include the 2012 B.
CONDITION	VEGETATION	VEG1. Native Plant Species Cover	Same	Text in yellow (cover overall or cover of key stratum) under review.
		VEG2. Invasive Nonnative Plant Species Cover	Invasive Plant Species Cover	Same thresholds, but A- now a B, B now a C, and C is now a C-.
		VEG3. Native Plant Species Composition	Vegetation Composition	Threshold same; rating text improved.
		VEG4. Overall Vegetation Structure	Same	Thresholds same; rating text improved.
		VEG5. Woody Regeneration (opt.)	Same	No change.
		VEG6. Coarse Woody Debris (opt.)	Same	New since 2012 (taken from 2010 version).
	HYDROLOGY	HYD1. Water Source	Same	Thresholds largely same. See improvement to B and C ratings. Question of a C-.
		HYD2. Hydroperiod	Same	Thresholds basically same; text improved. See additional text in B and C ratings. D rating for Riverine and Depression etc., variants appear to have an error.
		HYD3. Hydrologic Connectivity	Same	Thresholds basically same; text greatly improved.
	SOIL	SOI1. Soil Condition	Soil Surface Condition	Thresholds basically same; text greatly improved.
SIZE	SIZE	SIZ1. Comparative Size (Patch Type)	Absolute Size	Thresholds same. Error fixed on matrix A and B ratings.
		SIZ2. Change in Size (opt)	Relative Patch Size	A, B, C and D ratings narrowed, with A = 0%, D now > 30%, rather than > 50%.