Laurentian-Acadian Freshwater Marsh Ecological System

December 15, 2005

Ecological Integrity Assessment

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A. INTRODUCTION

The following description of the Laurentian – Acadian Freshwater Marsh is adapted from the ***North American Arid West Emergent Marsh (CES300.729)****, and will be refined in subsequent editions.*

A.1 ECOLOGICAL SYSTEM DESCRIPTION

A.1.1. Classification Summary

CES201.594 Laurentian-Acadian Freshwater Marsh
(from NatureServe Explorer 2005)

Primary Division: Laurentian-Acadian (201)
Land Cover Class: Herbaceous Wetland
Spatial Scale & Pattern: Large patch
Required Classifiers: Natural/Semi-natural; Vegetated (>10% vasc.)
Diagnostic Classifiers: Depressional [Lakeshore]; Riverine / Alluvial; Graminoid; Shallow (<15 cm) Water; >180-day hydroperiod

Concept Summary: This system encompasses freshwater marshes on mineral soils of the Northeast and upper Midwest. They are often associated with lakes and ponds, but are also found along streams, where the water level does not fluctuate greatly. They are commonly flooded, up to 2 m, for much or all of the growing season. The size of occurrences ranges from small pockets to extensive acreages. The vegetation is characterized by herbaceous plants that are adapted to saturated soil conditions. Common emergent and floating vegetation includes species of *Scirpus* and/or *Schoenoplectus, Typha, Juncus, Potamogeton, Polygonum, Nuphar*, and *Phalaris*. This system may also include areas of relatively deep water with floating-leaved plants (*Lemna, Potamogeton*, and *Brasenia*) and submergent and floating plants (*Myriophyllum, Ceratophyllum*, and *Elodea*). Shrubs and graminoids may be dominant in local patches; typical species include *Salix* spp., *Cornus sericea, Alnus incana, Spiraea alba, Myrica gale, Calamagrostis canadensis*, tall *Carex* spp., and *Juncus effusus*. Trees are generally absent.

Range: New England and northern New York west across the upper Great Lakes to Minnesota, and adjacent Canada, southward to Pennsylvania and Ohio; mostly north of the glacial boundary.
USFS Divisions (Bailey): 201:C, 202:C
TNC Ecoregions: 47:C, 48:C, 49:C, 59:C, 61:C, 63:C, 64:C
Subnations: CT, IL?, IN?, MA, ME, MI, MN, NB, NH, NY, OH?, ON, PA, QC, VT, WI

A.1.2. Environment

Freshwater marshes are wetlands with permanent to semi-permanent standing water, often with a fluctuating water table, that can support submerged, floating, rooted-aquatic, and emergent plants. They occur in depressions, along the fringes of lakes, ponds, and along riparian areas where they may be found near beaver ponds, along the streambanks, and in old channels, oxbows, or sloughs. Thus, the water source for freshwater marshes is associated with surface and/or groundwater which collects in a depression. Marshes always have some area of open water although the amount varies according to the depth of the standing water and vegetation development.

Climate

In this region, the cool temperate climate has a relatively even distribution of precipitation throughout the year, with abundant snowfall in the winter and rainfall throughout the growing season. Climate has a large role in maintenance of marshes since precipitation amounts and the interplay of evapotranspiration and precipitation can dictate water level fluctuation. In general, marshes are tied to the precipitation and runoff characteristics of their contributing basins. During drought years, many marshes may not be inundated to the same degree (or at all) as during normal precipitation years.

Geomorphology

Glaciation has had a large influence on landforms and soils throughout the Laurentian-Acadian region.

Hydrology

The interaction of climate and geomorphology has a strong influence on local hydrological processes in a wetland. Groundwater levels in riparian areas and slopes are dependent on the underlying bedrock, watershed topography, soil characteristics, and season, but in the humid and relatively constant rainfall of this region, marshes typically maintain high water tables through June and into July.

Surface water is a very important formative process in riparian areas, including marshes. In riparian areas, flooding inundates vegetation, can physically dislodge seedlings/saplings, and alter channel morphology through erosion and deposition of sediment. Infrequent, high-powered floods determine large geomorphic patterns that persist on the landscape for hundreds to thousands of years (Hubert 2004). Floods of intermediate frequency and power produce floodplain landforms which persist for tens to hundreds of years while high frequency low-powered floods which occur nearly annually determine short-term patterns such as seed germination and seedling survival (Hubert 2004). Occasional September flooding may occur due to intense convective thunderstorms, however these are often very localized (Baker 1987). These thunderstorms can result in sporadic and frequent small-scale flooding in small higher elevation streams (Hubert 2004).

Marshes can have mineral or, depending on the duration of inundation and frequency of fluctuation, even organic soils. A distinguishing characteristic between fens, another wetland type with organic soils, is the duration and depth of standing water as well as fluctuation of water levels. Fens may have standing water on the soil surface, but typically not more than a few decimeters deep whereas marshes can have up to 2 m of standing water above the soil surface (Cooper 1986, 1990). In addition, the fluctuation of the water table in marshes can be large (> 1 m) whereas water table fluctuations in fens is much less dramatic (occasionally up to 0.5 m) (Cooper 1986, 1990). Because the water table in marshes fluctuates, the soil is periodically aerated allowing organic matter to decompose, preventing the accumulation of peat in many marshes or at least in some zones of a marsh (Cooper 1986). When organic soils do occur in marshes they are typically very local (do not occur over the entire marsh) and are found in those areas which remain permanently inundated or saturated.

Water level fluctuations also support the development of different marsh zones (floating, submergent, emergent, etc.) which vary according to the degree of inundation and eventually grade into the drier wet meadow system (Cooper 1986). Many authors consider marshes and wet meadows as a continuum of site conditions and tend to lump them together. The two types are distinguished based on the duration of saturation and/or flooding, with marshes on the wetter end of this gradient (Cooper 1986). Wet meadows are found some distance from open water areas, and the water table is much lower than in adjacent marshes.

Fluvial geomorphology is an important variable concerning the distribution of marshes. Channel migration and seasonal and episodic flooding create fluvial landforms such as oxbows, sloughs, side channels, and scoured depressions conducive for marsh development. Oxbows, sloughs, and side channels typically remain inundated or saturated due to seasonal flooding as well as groundwater discharge from the local alluvial aquifer. Thus, fluvial dynamics and the seasonal recharge of alluvial aquifers are important for the maintenance of many marshes. Beaver are also an important hydrogeomorphic variable for the formation of freshwater marshes as their activity creates open water ponds which often support small riverine marshes. Thus, geomorphology has a strong influence on the distribution of riparian vegetation, including wet meadows (Baker 1989).

A.1.3. Vegetation and Ecosystem

Vegetation

The freshwater marsh ecological system is comprised of semi-permanently and seasonally flooded herbaceous vegetation types. Marshes are dominated by emergent, rhizomatous, perennial, graminoid species, with a typically dense (40-100%) cover, and heights ranging from 0.5 – 5 m. Floating and submerged aquatic species are also often present. The forb component is typically sparse, ranging from 0-25% cover.

In marshes where cattails (*Typha angustifolia*, *T. latifolia*) or giant reed (*Phragmites australis*) are dominant, nearly monotypic stands of these species may form. Bulrush

(*Schoenoplectus acutus* or *S. tabernaemontani*) dominated sites may also form dense mats with up to 100% cover. Other dominates within this system include prairie cordgrass (*Spartina pectinata*), three square bulrush (*Schoenoplectus pungens*), arrowhead (*Sagittaria* spp.), and others. Other associated species within this system may include water sedge (*Carex aquatilis*), beaked sedge (*C. utriculata*), woolly sedge (*C. pellita*), rushes, spikerushes (*Eleocharis* spp.), mannagrass (*Glyceria* spp.), bentgrass (*Agrostis* ssp.), and cordgrass (*Spartina* ssp.). Forbs associated at these sites are often sparse and may include buttercup (*Ranunculus* spp.), smartweed (*Polygonum* spp.), water plantain (*Alisma gramineum*), and hemlock water-parsnip (*Sium suave*).

Floating and submerged vegetation includes pond lily (*Nuphar lutea*), burreed (*Sparganium* spp.), duckweed (*Lemna* spp.), bladderwort (*Utricularia* spp.), ditchgrass (*Ruppia* spp.), water milfoil (*Myriophyllum* spp.), waterweed (*Elodea* spp.), and quillwort (*Isoetes* spp.).

Animals
The variability in water levels and subsequent vegetation types support a variety of aquatic and terrestrial invertebrates. These invertebrates process detritus, consume vegetation, and provide abundant food resources for other taxa such as birds, mammals, fish, amphibians, and other invertebrate species. Marshes are well known for providing habitat for numerous species of waterbirds. Cattail is known to be important for nesting red-wing, yellow-headed blackbirds, and marsh wrens, and mallards (Foster 1986). Bulrushes are also important for providing potential nesting habitat (Foster 1986). During drawdown periods, mudflats may provide feeding grounds for shorebirds (Foster 1986). Of course, the amount of open water, density of vegetation, and nearby land use all effect potential habitat for waterbirds in marshes.

Marshes in riparian areas contribute to overall biotic integrity of the riparian zone by increasing species as well as habitat diversity. Deer, moose, and elk seek out riparian areas for their rich and nutritious grasses and forbs (Foster 1986). Open water areas also provide habitat for numerous invertebrates which in turn provide critical links in local food webs as well as biogeochemical cycling.

Marshes also provide critical habitat for a variety of amphibians, including uncommon and rare species such as wood frog (*Rana sylvatica*) and the boreal toad (*Bufo boreas*), as well as chorus frogs (*Pseudacris triseriata*), leopard frogs (*Rana pipiens*), and tiger salamander (*Ambystoma tigrinum*) (Cooper 1986).

Biogeochemistry
Bedrock geology, soil characteristics, and surface and groundwater discharge of the contributing watershed basin determine the type and amount of nutrient flux in marshes (Knud-Hansen 1986). For example, thin coarse soils associated with granitic bedrock are nutrient poor and tend to be acidic whereas soils derived from limestone or shale outcrops have more nutrients and a higher pH (Knud-Hansen 1986).

Marshes receive much of their nutrients from surface and groundwater inputs and are stored in accumulated organic matter within the soil profile (Knud-Hansen 1986). Nitrogen and phosphorus are thought to be the major limiting nutrients in wetlands (Knud-Hansen 1986, Mitsch and Gosselink 2000). Fluctuating water tables coupled with areas of permanent inundation/saturation leads to a high diversity of aerobic and anaerobic biogeochemical reactions which can occur in marshes resulting in numerous nutrient transformations (Mitsch and Gosselink 2000). These transformations may result in a seasonal pulse of nutrient availability since microbial activity is coupled with the degree of soil aeration and soil temperatures (Knud-Hansen 1986).

Marshes associated with riparian areas may also serve as important biogeochemical filters of nutrients and sediment before they enter the stream from adjacent human land uses (Peterjohn and Correll 1984).

Ecosystem productivity

Mitsch and Gosselink (2000) report that primary productivity of inland marshes is relatively high, ranging from 1,000 g m^{-2} yr^{-1} and is related to species composition, nutrient availability, and the hydrological regime. Many marshes are dominated by just a few species such as broad leaf cattail (*Typha latifolia*), hardstem bulrush (*Schoenoplectus acutus*), and spikerush (*Eleocharis palustris*); thus, productivity is often related to these vitality of these species.

The spatial complexity of patch types in the riparian zone results in a high edge-area ratio creating many ecotones with contrasting environmental processes and habitat types (Knud-Hansen 1986). This spatial heterogeneity supports numerous types of plant communities which provide for abundant secondary productivity of riparian areas (i.e., abundant support of fauna taxa).

A.1.4. Dynamics

Marsh development along riparian areas is driven by the magnitude and frequency of flooding, valley and substrate type, and beaver activity. Seasonal and episodic flooding scour depressions in the floodplain, create side channels and floodplain sloughs, and force channel migration which can result in oxbows. Marsh vegetation establish in these landforms if there is semi-permanent to permanent water contained within them.

Marshes also occur near the fringes of lakes and ponds where their development is dictated by the gradient of the shoreline and fluctuation of lake or pond levels. Relatively flat or gently sloping shorelines support a much larger marsh system than a steep sloping shoreline. The frequency and magnitude of water level fluctuations determine the extent of each marsh zone (floating, submerged, emergent, etc.).

As mentioned above, beaver are an important hydrogeomorphic driver of marsh development. Beavers inhabit streams with a gentle gradient (< 15%) and in wide valleys (at least wider than the stream channel). Beaver dams impound surface water creating open water areas. When dams are initially created, they often flood and thus kill large areas of shrublands. These areas are eventually colonized by marsh vegetation. Depending on the duration of saturation and flooding, these vegetation types are considered marshes or wet meadows. As local food supplies are diminished, beavers tend to abandon their dams and move up or downstream to find additional food supply as well as suitable dam sites (Baker 1987). The abandon beaver ponds eventually fill with sediment and colonize by willows, thus completing the cycle. The presence of beaver creates a heterogeneous complex of wet meadows, marshes and riparian shrublands and increases species richness on the landscape. For example, Wright et al. (2002) note that beaver-modified areas may contribute as much as 25% of the species richness of herbaceous species in Adirondack Mountains of New York. Naiman et al. (1986) note that beaver-influenced streams are very different from those not impact by beaver activity by having numerous zone of open canopy, large accumulations of detritus and nutrients, more wetland areas, having more anaerobic biogeochemical cycles, and in general are more resistance to disturbance. Neff (1957; *in* Knight 1994) estimated that a Colorado valley with an active beaver colony had eighteen times more water storage in the spring and an ability to support higher streamflow in late summer than a drainage where beaver were removed.

It is not known what the density of beaver were throughout the Laurentian-Acadian region; however Naiman et al. (1986) suggest that when beaver are not managed or harvested their activity may influence 20-40% of the total length of 2nd to 5th order streams in the boreal forest of Canada. Regardless, it is apparent that active beaver colonies are very important for ecosystem development in riparian areas, including marshes.

No matter the landform in which a marsh occurs, some general patterns of ecosystem development can be observed. Typically, marshes exhibit distinct bands or zones of vegetation which vary according to the degree of inundation and soil moisture (Mitsch and Gosselink 2000, DeKeyser et al. 2003). Conceptually, from wettest to driest, this includes the following vegetation types (1) aquatic (e.g., submerged and floating species such as duckweed (*Lemna* spp.), pond lily (*Nuphar lutea*), pondweeds (*Potamogeton* spp.), etc.); (2) deep emergent (e.g., cattail (*Typha* spp.), bulrushes (*Schoenoplectu*s spp.), arrowhead (*Sagittaria* spp.), (3) shallow emergent (e.g., spikerush (*Eleocharis* spp.), sedges (*Carex* spp.), and rushes (*Juncus* spp.), and (4) wet meadow (e.g., sedges, rushes, tufted hairgrass (*Deschampsia cespitosa*), reedgrass (*Calamagrostis* spp.), three square bulrush (*Schoenoplectus pungens*), etc.) (Cooper 1986). Of course, not all of these types are always present since shoreline gradient and hydrological regime can essentially exclude some of these zones.

A.1.5. Landscape Condition

It is evident from the hydro-geomorphic setting of marshes that their integrity is partly determined by processes operating in the surrounding landscape and more specifically in the contributing watershed. The quality and quantity of ground and surface water input is almost entirely determined by the condition of the surrounding landscape. Various types of land use can alter surface runoff, recharge of local aquifers, and introduce excess nutrients, pollutants, or sediments.

Marshes are intimately connected to uplands in their upstream watersheds as well as adjacent areas. However, the reverse is also true: marshes provide connectivity between upland systems and between up and downstream riparian patch types (Wiens 2002). Thus, the types, abundance, and spatial distribution of riparian patch types is an important ecological component to these systems as they affect the flow and movement of nutrients, water, seed dispersal, and animal movement (Wiens 2002).

Assessments of marshes have considered the landscape properties of the local watershed to be a critical factor in assessing condition (Mack 2001, 2004, Rondeau 2001, Hauer et al. 2002, DeKeyser et al. 2003).

A.2. ECOLOGICAL INTEGRITY

A.2.1. Threats

Hydrological Alteration
Reservoirs, water diversions, ditches, roads, and human land uses in the contributing watershed can have a substantial impact on the hydrology as well as biotic integrity of marshes (Poff et al. 1997). All these stressors can induce or reduce sedimentation, increase nutrient inputs, lower water tables in floodplains and thus decreases groundwater discharge into riparian marshes, and generate excess surface flow into the marsh (e.g., alter hydrodynamics) (Poff et al. 1997). Response of marsh vegetation varies depending on the stressor, however disturbance to marshes often results in monotypic stands of cattail or giant reed with a corresponding decrease in species diversity in an already depauperata system.

An unaltered hydrologic regime is crucial to maintaining the diversity and viability of marshes.

Land Use
Since marshes tend to inundated for much of the year, land use impacts typically result from those occurring in adjacent wetland or upland areas. Galatowitsch et al. (2000) found that the intensity and types of land use within 500 m of a wet meadow had a significant affect on plant community composition. Livestock management can impact wet meadows by compacting soil, pugging (creation of pedestals by hooves) on the soil surface, altering nutrient concentrations and cycles, changing surface and subsurface water movement and infiltration, and shifting species composition (Kauffman et al. 2004).

Nutrient enrichment
Adjacent and upstream land uses all have the potential to contribute excess nutrients into riparian areas. Increased nutrients can alter species composition by allowing aggressive, invasive species to displace native species (Zedler and Kercher 2004). In Montana

peatlands, beaked sedge was found to be positively correlated to concentrations of ammonium (NH_4^+) and negatively associated with diversity of vascular plants (Jones 2003). Most marshes affected by nutrient enrichment tend to have monotypic stands of *Typha* or *Phragmites*.

Exotics

Non-native species can displace native species, alter hydrology, alter structure, and affect food web dynamics by changing the quantity, type, and accessibility to food for fauna (Zedler and Kercher 2004). Wetlands dominated by non-native, invasive species typically support fewer native animals (Zedler and Kercher 2004). Marshes are susceptible to invasion by many non-native species including *Typha angustifolia*, purple loosestrife (*Lythrum salicaria*), barnyard grass (*Echinochloa crus-galli*), and reed canary grass (*Phalaris arundinacea*). Pasture grasses such as Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis gigantea*), and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*) may be invade the peripheral margins of marshes. However, increases in native species such as *Typha latifolia* and *Phragmites australis* are often more problematic in marshes than exotics.

Fragmentation

Human land uses both within the wetland as well as in adjacent and upland areas can fragment the landscape and thereby reduce connectivity between wetland and upland areas. This can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. Gravel mining can have a direct effect on riparian marshes by physically removing vegetation and substrate thereby creating large gaps in connectivity in the floodplains. Roads, bridges, and development can also fragment both wetland and upland areas. Intensive grazing and recreation can also create barriers to ecological processes.

A.2.2. Justification of Metrics

As reviewed above, the literature suggests that the following attributes are important measures of the ecological integrity of this system:

- Landscape condition, given the critical role of the contributing watershed.
- Biotic condition, as measured by the species composition and diversity
- Impacts on nutrient status could have effects on species diversity and decomposition.
- Invasion of exotics could alter species composition.
- Degree of fragmentation in the wetland and upland areas.

A.2.3. Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Tables 1 and 2. The three tiers refer to levels of intensity of sampling required to document a metric. Tier 1 metrics are able to be assessed using remote sensing imagery, such as satellite or aerial photos. Tier 2 typically require some kind of ground sampling, but may require only qualitative or semi-quantitative data. Tier 3 metrics typically require a more intensive plot sampling or other intensive sampling approach. A given measure could be assessed at multiple tiers, though some tiers are not doable at Tier 1 (i.e., they require a ground visit). A given metric could be assessed at multiple tiers, though some metrics cannot be measured at Tier 1 (i.e., they require some kind of ground visit). The focus for this System is primarily on metrics using both Tier 1 and Tier 2 metrics.

The Scorecard (see Tables 1 and 2) contains two types of metrics: Core and Supplementary. Separating the metrics into these two categories allows the user to adjust the Scorecard to available resources, such as time and funding, as well as providing a mechanism to tailor the Scorecard to specific information needs of the user.

Core metrics are shaded gray in Tables 1 and 2 and represent the minimal metrics that should be applied to assess ecological integrity. Sometimes, a Tier 3 Core metric might be used to replace Tier 2 Core Metrics. For example, if a Vegetation Index of Biotic Integrity is used, then it would not be necessary to use similar Tier 2 Core metrics such as Percentage of Native Graminoids, Percentage of Native Plants, etc.

Supplementary metrics are those which should be applied if available resources allow a more in depth assessment or if these metrics add desired information to the assessment. Supplementary metrics are those which are not shaded in Tables 1 and 2.

For each metric, a rating is developed, scored as A – (Excellent) to D – (Poor). The background, methods, and rationale for each metric are provided in section B. Each metric is rated, and then various metrics are rolled together into one of four categories: Landscape Context, Biotic Condition, Abiotic Condition, and Size.

Table 1. Overall Set of Metrics for the Laurentian-Acadian Freshwater Marsh. Tier: 1 = Remote Sensing, 2 = Rapid or Extensive, 3 =Intensive. Shaded metrics are core metrics. Unshaded are supplementary metrics.

Category	**Essential Ecological Attribute**	**Indicator & Metric**	**Tier**
LANDSCAPE CONDITION	Landscape Composition	Adjacent Land Use	1
		Buffer Width	1
	Landscape Pattern	Fragmentation of Cover within 1 km	1
		Distance to Nearest Road	1
BIOTIC CONDITION	Community Composition	Percent Cover of Native Plant Species	2
		Invasive Species – Plants	2
		Floristic Quality Assessment (Mean C)	3
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland	2
		Sediment Loading Index	1
	Hydrology	Flashiness Index	2
		Hydrological Alterations	2
		Surface Water Runoff Index	1
	Chemical/Physical Processes	Soil Organic Carbon	3
		Soil Bulk Density	3
		Nutrient/ Pollutant Loading Index	1
SIZE	Absolute Size	Absolute Size	1,2
	Relative Size	Relative Size	1,2

Table 2. Overall Set of Metrics for the Laurentian-Acadian Freshwater Marsh System, with Definition and Metric Ratings. Tier: 1 = Remote Sensing, 2 = Rapid or Extensive, 3 =Intensive. Shaded metrics are core metrics. Unshaded are supplementary metrics.

Category	Essential Ecological Attribute	Indicator & Metric	Tier	Definition	*Metric Rating Criteria*			
					Excellent	**Good**	**Fair**	**Poor**
LANDSCAPE CONDITION	Landscape Composition	Adjacent Land Use	1	Addresses the intensity of human dominated land uses within 100 m of the wetland.	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
		Buffer Width	1	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	Wide > 100 m	Medium. 50 m to <100 m	Narrow. 25 m to 50 m	Very Narrow. < 25 m
	Landscape Pattern	Fragmentation of Cover within 1 km	1	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	Embedded in 90-100% cover unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% cover unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60% cover unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% cover unfragmented natural landscape. Internal fragmentation high
		Distance to nearest road	1	Addresses the potential impacts to the site of roads or major trails, which are a specific type of altered habitat effect.	Very Far > 300 m	Far. 100 m to 300 m	Near. 50 m to 99 m	Very Near. < 50m
BIOTIC CONDITION	Community Composition	Percent Cover of Native Plant Species	2,3	Percent cover of the plant species that are native, relative to total cover (sum by species)	100% cover of native plant species	85-< 100% cover of native plant species	50-85% cover of native plant species	<50% cover of native plant species
		Invasive Species – Plants	2,3	Percent of marsh which is dominated by invasive, aggressive plants.	Native species such as *Typha* and *Phragmites*, if present, do not dominate wetland	Native species such as *Typha* and *Phragmites* and/or other non-native invasive species present but occupy less < 25% of wetland;	Native species such as *Typha* and *Phragmites* and/or other non-native invasive species present and occupy 25-75% of wetland;	Native species such as *Typha* and *Phragmites* and/or other non-native invasive species present and occupy >75% of wetland;
		Floristic Quality Assessment (Mean C)	3	The mean conservatism of all the native species growing in the wetland.	Mean C > 4.5	Mean C = 3.5-4.5	Mean C = 3.0 – 3.5	Mean C < 3.0

Category	Essential Ecological Attribute	Indicator & Metric	Tier	Definition	*Metric Rating Criteria*			
					Excellent	**Good**	**Fair**	**Poor**
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland	2	Addresses the intensity of human dominated land uses within the wetland.	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
		Sediment Loading Index	1	A measure of the varying degrees to which different land uses contribute excess sediment via surface water runoff and overland flow into a wetland.	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
	Hydrology	Flashiness Index	3	Measures the variability of water table fluctuations and rates it compared to a reference standard	Flashiness Index = 1.0 - 2.0	Flashiness Index = 1.0 - 2.0	Flashiness Index = between 2.0 -3.0 if wetland is NOT associated with riverine	Flashiness Index = > 3.0 if wetland is NOT associated with riverine environment
		Hydrological Alterations	2	The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.	No alterations. No dikes, diversions, ditches, flow additions, or fill present in wetland that restricts or redirects flow	Low intensity alteration such as roads at/near grade, small diversion or ditches (< 1 ft. deep) or small amount of flow additions	Moderate intensity alteration such as 2-lane road, low dikes, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions.	High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions
		Surface Water Runoff Index	1	A measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland.	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
	Chemical / Physical Processes	Soil Organic Carbon	3	Measures the amount of soil organic carbon present in the soil.	Soil C is equivalent to natural range of variability	Soil C is nearly equivalent to natural range of variability	Soil C is significantly lower than natural range of variability	Soil C is significantly lower than natural range of variability

Category	Essential Ecological Attribute	Indicator & Metric	Tier	Definition	*Metric Rating Criteria* Excellent	Good	Fair	Poor
		Soil Bulk Density	3	A measure of the compaction of the organic soil horizons.	Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. (same as Very Good)	Bulk density for wetland is between 0.2 to 0.1 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density for wetland is = or > than Root Restricting Bulk Density value for the soil texture found in the wetland.
		Nutrient/ Pollutant Loading Index	1	the varying degrees to which different land uses contributed excess nutrients and pollutants via surface water runoff and overland flow into a wetland.	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
SIZE	Absolute Size	Absolute Size	1,2	The current size of the wetland	> 25 acres	5 to 25 acres	1 to 5 acres	< 1 acre
	Relative Size	Relative Size	1,2	The current size of the wetland divided by the total potential size of the wetland multiplied by 100.	Wetland area = onsite Abiotic Potential	Wetland area < Abiotic Potential; Relative Size = 90 – 100% ; (< 10% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc.	Wetland area < Abiotic Potential; Relative Size = 75 – 90%; 10-25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc	Wetland area < Abiotic Potential; Relative Size = < 75%; > 25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc

A.3 SCORECARD PROTOCOLS

A point-based approach is used to roll up the metrics into Category scores. Points are assigned for each rating level (A, B, C, D) within a measure. The default set of points are A = 5.0, B = 4.0, C = 3.0, D = 1.0. Sometimes, within a category, one measure is judged to be more important than the other(s). For such cases, each metric will be weighted according to its perceived importance. Points for the various measures are then added up and divided by the total number of metrics. The resulting score is used to assign an A-D rating for the category. After adjusting for importance, the Category scores could then be averaged to arrive at an Overall Ecological Integrity Score, but this approach has not yet been developed for this system.

It is not always possible to develop a four grade rating system for each metric, because we lack sufficient detail on how the metric changes or what the thresholds might be. In some cases, the ratings may combine A and B. The point scoring approach is A/B = 5, C=3, D = 1.

At this time, roll-ups are provided for each of the four categories, but they are not rolled up into an overall Ecological Integrity Index.

Supplementary metrics are not included in the Rating Protocol. However, they could be incorporated if the user desired.

A.3.1. Landscape Context Rating Protocol

Rate the Landscape Context metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 3) to roll up the metrics into an overall Landscape Context Rating.

<u>Rationale for scoring table:</u> Adjacent land use, buffer width, and distance to nearest road are judged to be more important than the amount of fragmentation within 1 km of the wetland since a wetland with no other natural communities bordering it is very unlikely to have a strong biological connection to other natural lands at a further distance.

Table 3. Landscape Context Metrics and Ratings for this System. Scores for the ratings are show in each cell.

Measure	**Tier**	**A**	**B**	**C**	**D**	**Weight**	**Score** (weight x rating)
Adjacent Land Use	1	5	4	3	1	0.3	
Buffer Width	1	5	4	3	1	0.3	

Measure	Tier	A	B	C	D	Weight	Score (weight x rating)
Fragmentation of Cover within 1 km	1	5	4	3	1	0.1	
Distance to nearest road or major trail	1	5	4	3	1	0.3	
Landscape Context Rating A=4.5 - 5.0 B=3.5 - 4.4 C=2.5 - 3.4 D=1.0 – 2.4							**Total = sum of N scores**

A.3.2. Biotic Condition Rating Protocol

Rate the Biotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 4) to roll up the metrics into an overall Biotic Condition rating.

Rationale for Scoring: The Floristic Quality Assessment (FQA) metric is judged to be more important than cover of native species and invasive species metric. The latter two provide very useful information, but the FQA provides a more reliable indicator of biotic condition.

Scoring for Biotic Condition is a bit more complex. For example, the Floristic Quality Assessment (FQA) may or may not be assessed, depending on resources (since it is a Tier 3 metric). If it is included then the weights without parentheses apply to the Biotic Condition metrics. If FQA is not included then the weight in parentheses is used for the Tier 2 metrics.

Table 2. Biotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Percent Cover of Native Plant Species	Percent of the plant species which are native to the region	2	5	4	3	1	0.30 (0.55)	
Invasive Species – Plants	Percent of marsh which is dominated by invasive, aggressive plants.	2	5	4	3	1	0.20 (0.45)	
Floristic Quality Assessment (Mean C)	The mean conservatism of all the native species growing in the wetland.	3	5	4	3	1	0.50 (N/A)	

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Biotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when FQA metric is not used.

A.3.3 Abiotic Condition Rating Protocol

Rate the Abiotic Condition metrics according to their associated protocols (see Table 2 and details in Section B). Use the scoring table below (Table 5) to roll up the metrics into an overall Abiotic Condition rating.

Rationale for Scoring: Quantitative water table data are judged to more reliable than the other metrics for indicating Abiotic Condition (shaded metric in Table 5). However, if such data are lacking then stressor related metrics (Land Use & Hydrological Alterations) are perceived to provide more dependable information concerning Abiotic Condition.

Table 3. Abiotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Land Use Within the Wetland	Addresses the intensity of human dominated land uses within the wetland.	2	5	4	3	1	0.25 (0.40)	
Hydrological Alterations	The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.	2	5	5	0	0	0.30 (0.60)	
Flashiness Index	Measures the variability of water table fluctuations and rates it compared to a reference standard.	3	5	5	0	0	0.45 (N/A)	
Abiotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when metric B.2.9 is not used.

A.3.4 Size Rating Protocol

Rate the two measures according to the metrics protocols (see Table 2 and details in Section B). Use the scoring table below (Table 6) to roll up the metrics into an overall Size rating.

Rationale for Scoring: Since the importance of size is contingent on human disturbance both within and adjacent to the wetland, two scenarios are used to calculate size:

(1) When Landscape Context Rating = "A":
Size Rating = Relative Size metric rating (weights w/o parentheses)
(2) When Landscape Context Rating = "B, C, or D".
Size Rating = (weights in parentheses)

Table 4. Size Rating Calculation.

Measure	**Definition**	**Tier**	**A**	**B**	**C**	**D**	**Weight***	**Score** (weight x rating)
Absolute Size	The current size of the wetland	1	5	4	3	1	0.0 (0.70)	
Relative Size	The current size of the wetland divided by the total potential size of the wetland multiplied by 100.	1	5	4	3	1	1.0 (0.30)	
Size Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total = sum of N scores**

* The weight in parentheses is used when Landscape Context Rating = B, C, or D.

B. DOCUMENTATION FOR METRICS

B.1 LANDSCAPE CONDITION METRICS

Adjacent Land Use

Definition: This metric addresses the intensity of human dominated land uses within 100 m of the wetland. Each land use type occurring in the 100 m buffer is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the target wetland (Hauer et al. 2002).

Background: This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The intensity of human activity in the landscape has a proportionate impact on the ecological processes of natural systems.

Measurement Protocol: This metric is measured by documenting surrounding land use(s) within 100 m of the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge. To calculate a Total Land Use Score estimate the % of the adjacent area within 100 m under each Land Use type and then plug the corresponding coefficient (Table 7; the coefficients in this table are derived from Hauer et al. (2002)) with some manipulation to account for regional application) into the following equation:

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

where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 100 m of the wetland edge, then sum Sub-Land Use Score to arrive at a Total Land Score. For example, if 30% of the adjacent area was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Table 7. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer et al. (2002))

Current Land Use	**Coefficient**
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95

Natural area / land managed for native vegetation	1.0

Scaling Rationale: Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and 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 (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes. The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002).

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

Buffer Width

Definition: Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland. This includes forests, grasslands, shrublands, lakes, ponds, streams, or another wetland. Some land uses such as light grazing and recreation may occur in the buffer, but other land uses should be considered the buffer boundary. Irrigated meadows may be considered a buffer if the area appears to function as a buffer between the wetland and nearby, more intensive land uses such as agricultural row cropping, fenced or unfenced pastures, paved areas, housing developments, golf courses, mowed or highly managed parkland, mining or construction sites, etc. (Mack 2001).

Background: This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

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. Buffers reduce potential impacts to wetlands by alleviating the effects of adjacent human activities (Castelle et al. 1992). For example, buffers can moderate stormwater runoff, reduce loading of sediments, nutrients, and pollutants into a wetland as well as provide habitat for wetland-associated species for use in feeding, roosting, breeding and cover (Castelle et al. 1992).

Measurement Protocol: This metric is measured by estimating the width of the buffer surrounding the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. Measure or estimate buffer width on four or more sides of the wetland then take the average of those readings (Mack 2001). This may be difficult for large wetlands or those with complex boundaries. For such cases, the overall buffer width should be estimated using best scientific judgment.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Wide > 100 m	Medium. 50 m to <100 m	Narrow. 25 m to 50 m	Very Narrow. < 25m

Data: N/A

Scaling Rationale: Increases in buffer width improve the effectiveness of the buffer in moderating excess inputs of sediments, nutrients, and other pollutants from surface water runoff and provides more potential habitat for wetland dependent species (Castelle et al. 1992). The categorical ratings are based on data from Castelle et al. (1992), Keate (2005), Mack (2001), and best scientific judgment regarding buffer widths. Note that Kennedy et al. (2003) recommend a minimum buffer width of 230 to 300 m.

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

Fragmentation of Cover Within One Kilometer

Definition: An unfragmented landscape is one in which human activity has not destroyed or severely altered the landscape. In other words, an unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems. Fragmentation results from human activities such as timber clearcuts, roads, residential and commercial development, agriculture, etc.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

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 fragmentation provides an estimate of connectivity among natural ecological systems. Although related to other landscape metrics, this metric differs by assessing the spatial interspersion of human land use as well as considering a much larger area.

An alternative to using a fixed 1 km area is to define the local watershed area around the marsh, the natural vegetation area within watershed, and different kinds of agricultural use in watershed (row crop vs. pasture). In NY state, watershed area ranged from 13 to 4,500 ha (median 119 ha) (Godwin et al. 2002). It may also be of interest to estimate wetland area within water shed. But watersheds can be very difficult to define.

Measurement Protocol: This metric is measured by estimating the amount of fragmentation in a one km buffer surrounding the wetland and dividing that by the total area. This is best completed in the office using aerial photographs or GIS.

Alternatively, if local watersheds are of interest, establish a local watershed boundary by using a contour map method, where from a single point at the upgradient mark of the marsh draw a line perpendicular to topography isopleths (identified on USGS topo maps) to the top of ridges. Godwin (pers. comm. 2005) indicated that this method wasn't extremely precise, and there could be large differences (~10-20%) between two people. ARCVIEW now has a script that will create a local watershed from a Digital Elevation Map. Alternatively, we could use HUC watersheds (M. Tuffly pers. comm. 2005). We can identify the entire watershed that is down stream from a fen and exclude it from the watershed population. We need only know the marsh location (point, polygon, or coordinate info), the watershed data set (polygon), and DEM.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Embedded in 90-100% cover unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% cover unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60% cover unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% cover unfragmented natural landscape. Internal fragmentation high

Data: N/A

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 Rondeau (2001).

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

Distance to Road or Major Trail

Definition: This metric addresses the potential impacts to the forest plot of roads or major trails, which are a specific type of altered habitat effect.

Background: This metric is one aspect of the landscape context of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The nearness to roads has an impact on the ecological processes of natural systems. Roads may be the source of invasives, affect mortality of amphibians and other animals that migrate to and from the wetland, or cause surface water flow and associated nutrients and sediments to contaminate the wetland.

Measurement Protocol: Calculate distance from plot center to road or major trail using GIS.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor Rating.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Very Far > 300 m	Far. 100 m to 300 m	Near. 50 m to 99 m	Very Near. < 50m

Data: Watkins et al. (2003) found that unpaved roads in managed forests caused an increase in exotic plant species and a decrease in native plant species diversity within 150 meters from the road. Edge effects have often been reported between 100 to 300 m (Mladenoff et al. 1994).

Scaling Rationale: Scaling is approximately logarithmic, presuming that edge effects become increasingly pronounced as distance to road or major trail decreases. A minimum threshold of 50 m was established, based on the many edge effects demonstrated to occur within the 50 m range (Kennedy et al. 2003, Harper et al. 2005). Edge effects seem to decline rapidly after 100m, and few edge effects are reported at over 500 m (Kennedy et al. 2003, Harper et al. 2005). Kennedy et al. (2003) recommend a road distance of 300 m as a precautionary threshold, which we use here as the A/B threshold.

Confidence that reasonable logic and/or data support the index: MEDIUM/HIGH

B.2. BIOTIC CONDITION METRICS

Percent Cover of Native Plant Species

Definition: Percent of the plant species which are native.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Native species dominate wet meadows and shrub swamps that have excellent ecological integrity. This metric is a measure of the degree to which native plant communities have been altered by human disturbance. With increasing human disturbance, non-native species invade and can dominate the wetland.

Measurement Protocol: Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make a qualitative ocular estimate of the total cover of each species growing in the wetland. The cover classes identified in Peet et al. (1998) are recommended (solitary/few, 0-1%, 1-2.5%, 2.5-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-90%, 90-95%, 95-99%) but any cover class system can be used as long as they same system remains consistent when comparing data with time or different site. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004). See section A.2.2 for further information regarding plot establishment.

The metric is calculated by dividing the total cover of native species by the total cover of all species and multiplying by 100.

Once qualitative or quantitative cover data are collected, these values are then used to determine the metric status in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
100% cover of native plant species	85-< 100% cover of native plant species	50-85% cover of native plant species	<50% cover of native plant species

Data: N/A

Scaling Rationale: The criteria are based on extrapolated thresholds from ecological site descriptions from a variety of sources, including (NRCS 2005), Cooper (1990), Windell et al. (1986), CNHP (2005), and best scientific judgment. These thresholds need further validation.

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

Invasive Species - Plants

Definition: Percent of marsh species which are comprised by invasive plants.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Non-native species or native increasers can displace other native species, alter hydrology, alter structure, and affect food web dynamics by changing the quantity, type, and accessibility to food for fauna (Zedler and Kercher 2004). Wetlands dominated by non-native, invasive species typically support fewer native animals (Zedler and Kercher 2004). Marshes are susceptible to invasion by many non-native species including purple loosestrife (*Lythrum salicaria*), barnyard grass (*Echinochloa crus-galli*), and somewhat ambiguous natives, such as narrowleaf cattail (*Typha angustifolia*), reed canary grass (*Phalaris arundinacea*). Pasture grasses such as Kentucky bluegrass (*Poa pratensis*), redtop (*Agrostis gigantea*), and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*) may be invade the peripheral margins of marshes. However, increases in native species such as broad leaf cattail (*Typha latifolia*) and giant reed (*Phragmites australis*) are often more problematic in marshes than exotics.

Measurement Protocol: Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make a qualitative ocular estimate of the total cover of each invasive species growing in the wetland. This is typically a very easy task in marshes, since invasive species tend to develop monocultures in disturbed marshes. The cover classes identified in Peet et al. (1998) are recommended (solitary/few, 0-1%, 1-2.5%, 2.5-5%, 5-10%, 10-25%, 25-50%, 50-75%, 75-95%, > 95%) but any cover class system can be used as long as they same system remains consistent when comparing data with time or different site. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004).

The metric is calculated by dividing the total cover of invasive species by the total cover of all species and multiplying by 100.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Native species such as *Typha angustifolia* and *Phragmites*, if present, do not dominate wetland	Native species such as *Typha angustifolia* and *Phragmites* and/or other non-native invasive species present but occupy less < 25% of wetland;	Native species such as *Typha angustifolia* and *Phragmites* and/or other non-native invasive species present and occupy 25-75% of wetland;	Native species such as *Typha angustifolia* and *Phragmites* and/or other non-native invasive species present and occupy >75% of wetland;

Data: N/A

Scaling Rationale: The criteria are based on and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data.

Floristic Quality Assessment (Mean C)

Definition: The mean conservatism of all the native species growing in the wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Plants grow in habitats in which they are adapted to, including biotic and abiotic fluctuations associated with that habitat (Wilhelm and Masters 1995). However, when disturbances to that habitat exceed the natural range of variation (e.g. many human-induced disturbances), only those plants with wide ecological tolerance will survive and conservative species (e.g. those species with strong fidelity to habitat integrity) will decline or disappear according to the degree of human disturbance (Wilhelm and Master 1995; Wilhelm pers. comm. 2005).

These observations can be combined into a "conservatism" (or C) index, whereby species with strong fidelity to habitat integrity are scored 10 and those with a very low integrity are scored 1. Exotics are either scored 0 or excluded. The average C value (xC) is then multiplied by the square root of site or total plot (or native) richness ($\sqrt{S}$) to produce the Floristic Quality Assessment Index (FQA) index, (also called the Floristic Quality Index, or FQI). The FQA index, originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a plant community index designed to assess the degree of "naturalness" of an area based on the presence of species whose ecological tolerance are limited (U.S. EPA 2002). FQA methods have been developed and successfully tested in Illinois (Swink and Wilhelm 1979), Missouri (Ladd 1993), Ohio (Andreas and Lichvar 1995), southern Ontario (Oldham et al. 1995), Michigan (Herman et al. 1996), Indiana (Coffee Creek Watershed Conservancy 2001), and North Dakota (Northern Great Plains Floristic Quality Assessment Panel 2001), but the exact form of the equation is still debated. Various authors have criticized the approach of combining the C value with the square root of richness (Bowles and Jones 2006), and recommend treating each separately, as done here.

Measurement Protocol: Species presence/absence data need to be collected from the wetland. Although, quantitative measurements are preferred, depending on time and financial constraints, this metric can be measured with qualitative or quantitative data. The two methods are described as follows: (1) Site Survey (semi-quantitative): walk the entire occurrence of the wetland system and make notes of each species encountered. A thorough search of each macro- and micro-habitat is required. (2) Quantitative Plot Data: The plot method described by Peet et al. (1998) is recommended for collecting quantitative data for this metric. This method uses a 20 x 50 m plot which is typically established in a 2 x 5 arrangement of 10 x 10 m modules. However, the array of modules can be rearranged or reduced to meet site conditions (e.g. 1 x 5 for linear areas or 2 x 2 for small, circular sites). The method is suitable for most types of vegetation, provides information on species composition across spatial scales, is flexible in intensity and effort, and compatible with data from other sampling methods (Peet et al. 1998, Mack 2004). See section A.2.2 for further information regarding plot establishment.

The metric is calculated by referencing only native species C value from a given state FQA Database, summing the C value, and dividing by the total number of native species (Mean C).

The Mean C is then used to determine the metric status in the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
> 4.5	3.5-4.5	3.0 – 3.5	< 3.0

Data: Various state and provincial FQA Databases (*in development*)

Scaling Rationale: In the Midwest, field studies using FQA have determined that a site with a Mean C of 3.0 or less is unlikely to achieve higher C values thus this value was used as the Restoration Threshold (between Fair and Poor) (Wilhelm and Masters 1995). In other words, those sites have been disturbed to the degree that conservative species are no longer able to survive and or compete with the less conservative species as a result of the changes to the soil and or hydrological processes on site. Sites with a Mean C of 3.5 or higher are considered to have at least marginal quality or integrity thus this value was used as the Minimum Integrity Threshold (between Good and Fair) (Wilhelm and Masters 1995). The threshold between Excellent and Good was assigned based on best scientific judgment upon reviewing the FQA literature. As the FQA is applied in this region, the thresholds may change.

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

B.3 ABIOTIC CONDITION METRICS

Land Use Within the Wetland

Definition: This metric addresses the intensity of human dominated land uses within the wetland. Each land use type is assigned a coefficient ranging from 0.0 to 1.0 indicating its relative impact to the wetland (Hauer et al. 2002).

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The intensity of human activity in the wetland often has a proportionate impact on the ecological processes occurring onsite.

Measurement Protocol: This metric is measured by documenting land use(s) within the wetland. This should be completed in the field then verified in the office using aerial photographs or GIS. However with access to current aerial photography and/or GIS data a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use within 100 m of the wetland edge. To calculate a Total Land Use Score estimate the % of the wetland area under each Land Use type and then plug the corresponding coefficient (Table 8; the coefficients in this table are derived from Hauer et al. (2002)) with some manipulation to account for regional application) into the following equation:

> *Sub-land use score* = ∑ LU x PC/100
>
> where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use, then sum Sub-Land Use Score to arrive at a Total Land Score. For example, if 30% of the wetland was under moderate grazing (0.3 * 0.6 = 0.18), 10% composed of unpaved roads (0.1 * 0.1 = 0.01), and 40% was a natural area (e.g. no human land use) (1.0 * 0.4 = 0.4), the Total Land Use Score would = 0.59 (0.18 + 0.01 + 0.40).

Based on the Total Land Use Score, assign the Metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4

Data:

Table 8. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer et al. (2002))

Current Land Use	Coefficient
Paved roads/parking lots/domestic or commercially developed buildings/gravel pit operation	0.0
Unpaved Roads (e.g., driveway, tractor trail) / Mining	0.1
Agriculture (tilled crop production)	0.2
Heavy grazing by livestock / intense recreation (ATV use/camping/popular fishing spot, etc.)	0.3
Logging or tree removal with 50-75% of trees >50 cm dbh removed	0.4
Hayed	0.5
Moderate grazing	0.6
Moderate recreation (high-use trail)	0.7
Selective logging or tree removal with <50% of trees >50 cm dbh removed	0.8
Light grazing / light recreation (low-use trail)	0.9
Fallow with no history of grazing or other human use in past 10 yrs	0.95
Natural area / land managed for native vegetation	1.0

Scaling Rationale: The coefficients were assigned according to best scientific judgment regarding each land use's potential impact (Hauer et al. 2002). Land uses have differing degrees of potential impact. Some land uses have minimal impact, such as simply altering the integrity of native vegetation (e.g., recreation and 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 (i.e., urban development, roads, mining, etc.) may completely destroy vegetation and drastically alter hydrological processes.

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

Sediment Loading Index

Definition: The sediment loading index is a measure of the varying degrees to which different land uses contribute excess sediment via surface water runoff and overland flow into a wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The type and amount of each land use in the wetland and contributing watershed affects the amount of sediment that enters into a wetland. Excess sediment can change nutrient cycling, bury vegetation, suppress regeneration of plants, and carry pollutants into the wetland.

Measurement Protocol: Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Sediment Loading coefficient found for each land use in Appendix B, then sum for the Sediment Loading Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was multi-family residential, 20% had a dirt/local roads, and 30% natural vegetation the calculation would be (0.5 * 0.61) + (0.2 * 0.97) + (0.3* 1.0) = 0.79 (Sediment Loading Index Score). Referring to the scorecard, this would give the metric a "Fair" rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7

Data: Appendix B.

Scaling Rationale: The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which loading impacts were considered to not be restorable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

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

Flashiness Index

Definition: This metric measures the variability of water table fluctuations and rates it compared to a reference standard.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: A wetland's hydrologic regime is the most important ecological processes given its affect on the wetland's soils and flora and fauna communities (Mitsch and Gosselink 2000). The natural variability of water level fluctuations (e.g., hydroperiod) has a strong impact on the floristic composition, nutrient dynamics, and fauna distributions in a wetland. Thus, alterations to the hydroperiod can have negative impacts to ecological processes, including a shift in species composition and an alteration of biogeochemical cycling.

Measurement Protocol: To measure a change in the hydroperiod, a "flashiness" index, developed by Fennessey et al. (2004) for Ohio wetlands is used. The Flashiness Index is calculated by averaging the absolute value of the differences between ground water measurements from the measurement just preceding it. Thus, long-term well or staff-gauge data are needed to calculate the metric.

Staff gauges should be placed in deep open water areas whereas shallow groundwater monitoring wells should be placed in less deep water.

If quantitative vegetation data are being collected, monitoring wells should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), wells would be located within each of the intensive modules (See section A.2.2 for further information regarding plot establishment).

Monitoring wells are set vertically in the ground to intercept the groundwater passively. Shallow monitoring wells should be installed according the protocol identified in the technical note, *Installing Monitoring Wells/Piezometers in Wetlands* (U.S. Army Corps of Engineers 2000). To summarize, 3.8 cm PVC pipe is perforated from just below the ground surface to the bottom of the pipe. Using a soil auger, a hole is dug to at least 40 cm. Sand is placed in the bottom of the well, the pipe is placed in the hole which is then backfilled with the excavated soil. Bentonite clay is then used to seal the opening of the hole and to ensure surface water does not infiltrated freely into the hole. Water levels inside the pipe result from the integrated water pressures along the entire length of perforations.

Water levels can be read with a steel measuring tape marked with a water-soluble marker. The only equipment needed is the tape, marker, and a rag to wipe the tape dry after each reading. The height of the well above the ground surface should be noted every time the instrument is read because pipes are known to move (U.S. Army Corps of Engineers

2000). Another simple measuring tool for measuring water levels is that described in Henszey (1991). This instrument is attached to a meter tape, lowered into the well, and beeps when it contacts water, at which point a measurement is taken from the tape and subtracted from the height of the well above the soil surface to give the depth of the water table.

Water levels should be checked weekly during the summer months. Automatic recording devices record water levels with down-well transducers or capacitance-based sensors are efficient for season-long monitoring but these cost much more than manually read instruments (U.S. Army Corps of Engineers 2000). However, automatic recorders may be less expensive than total travel costs and salaries. In addition, the credibility of monitoring data is enhanced by automatic wells (U.S. Army Corps of Engineers 2000). Automatic water-level recorders should be periodically checked and recalibrated as necessary (U.S. Army Corps of Engineers 2000).

Consideration of annual precipitation (or more specifically, annual snowpack) and its deviation from long-term averages from the closest weather station are needed to assess the reliability of this metric. During years of average precipitation (e.g. average snowpack) this metric is a reliable rapid metric of the integrity of groundwater levels in the marsh. Long-term monitoring of ground water in the wetland coupled with an analysis of climatic variation during that time-frame will provide the most reliable information.

Water table averages should be calculated for each month and hydrographs should be constructed to visually inspect trends.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Flashiness Index = 1.0 - 2.0	Flashiness Index = 1.0 - 2.0	Flashiness Index = between 2.0 -3.0 if wetland is NOT associated with riverine environment	Flashiness Index = > 3.0 if wetland is NOT associated with riverine environment

Data: See Fennessey et al. (2004).

Scaling Rationale: Data are not available to distinguish between Excellent and Good; thus, they are lumped into one category. These criteria are tentative hypotheses as they have not been validated with quantitative data throughout the range of this type. The scaling is based on best scientific judgment and on Fennessey et al. (2004) who found that Ohio wetlands with very strong depressional hydrology (vertical hydrologic pathway driven by precipitation and evapotranspiration) had flashiness scores of 1.0 to ~2.0 while riverine marshes had scores of between 2 and 3. Wetland with small to moderate stormwater inputs were also found to have scores between 2-3 while Scores greater than 3 were indicative of high stormwater inputs disrupting the natural hydroperiod. Scaling criteria are only provided for non-riverine marshes. Additional research needs to be conducted for riverine marshes. This metric could also be used to monitor site-specific changes if long-term baseline, as well as post-impact, data are available.

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

Hydrological Alterations

Definition: The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Land uses within or near a wetland can reduce soil permeability, affect surface water inflows, impede subsurface flow, and lower water tables.

Measurement Protocol: This metric is measured by evaluating land use(s) and human activity within or near the wetland which appear to be altering the hydrological regime of the site. Data collected in the field as well as from aerial photograph and GIS should be used. The ratings in the scorecard reflect various degrees of hydrological alteration.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
No alterations. No dikes, diversions, ditches, flow additions, or fill present in wetland that restricts or redirects flow	Low intensity alteration such as roads at/near grade, small diversion or ditches (< 1 ft. deep) or small amount of flow additions	Moderate intensity alteration such as 2-lane road, low dikes, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions.	High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions

Data: N/A

Scaling Rationale: The criteria are based on Keate (2005) and best scientific judgment.

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

Surface Water Runoff Index

Definition: The surface water runoff index is a measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The type and amount of each land use in the wetland and contributing watershed affects the timing, duration, and frequency of surface water runoff and overland flow into a wetland. These flows alter the hydrological regime of the wetland and can result in degradation of biotic integrity, change nutrient cycling, and potentially affect peat integrity.

Measurement Protocol: Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Surface Water Runoff coefficient found for each land use in Appendix B, then sum for the Surface Water Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was under heaving grazing, 10% had a dirt road, and 40% natural vegetation the calculation would be (0.5 * 0.76) + (0.1 * 0.71) + (0.4* 1.0) = 0.85 (Surface Water Index Score). Referring to the scorecard, this would give the metric a "Fair" rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating

Excellent	Good	Fair	Poor
Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7

Data: Appendix B.

Scaling Rationale: The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which runoff impacts were considered to not be restorable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

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

Soil Organic Carbon

Definition: This metric measures the amount of soil organic carbon present in the soil.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Soil organic matter or carbon generally refers to the organic fraction of the soil, including plant and animal residues at various stages of decomposition, as well as substances synthesized by the soil organisms (Neue 1984). Organic matter plays an extremely important role in the soil environment, including increases water holding capacity, encouraging soil structure, has a high cation exchange capacity, and supplies essential nutrients (Brady 1990).

Soil organic carbon is strong metric of soil quality due to its sensitivity to environmental disturbance (NRC 2000 *in* Fennessy et al. 2004). Given that soil organic carbon contributes to critical hydrologic, biogeochemical, and physical processes (Hall et al. 2003), a reduction in soil organic carbon from reference conditions serves as a strong metric of loss of soil quality.

Measurement Protocol: Multiple soil pits should be dug in the wetland to a depth of at least 40 cm (deeper pits are suggested…up to 120 cm). If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located within each of the intensive modules (See section A.2.2 for further information regarding plot establishment). At least five replicate soil samples should be taken within the top 10 cm of the soil surface in each pit. The replicates are mixed together as “one” sample from the site. Each soil sample should be placed in their own individual plastic bag, packed on ice, and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer).

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Soil C is equivalent to natural range of variability	Soil C is nearly equivalent to natural range of variability	Soil C is significantly lower than natural range of variability	Soil C is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference soil organic carbon levels need to be established in undisturbed fens. Thereafter, the scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established. Alternatively, if “baseline” soil organic carbon levels are known (from “pre-impact” conditions or from adjacent unaltered sites) then this metric can be used to determine change of soil organic carbon with time.

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

Soil Bulk Density

Definition: Soil bulk density is a ratio of the mass/volume of the soil. This metric is a measure of the compaction of the soil horizons.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Bulk density is a measure of the weight of the soil divided by its volume and provides and indication of the level of compaction. Compaction can results from any activity which compresses soil particles thereby increasing the weight to volume ratio. This can reduce the soil’s water holding capacity, infiltration, water movement through the soil, and limit plant growth by physically restricting root growth (NRCS 2001). Bulk density of organic soils are typically much less than those of mineral soils, however as decomposition increases and/or organic soils are compacted from human activity, bulk density of organic soils will increase. This has corresponding negative impacts on ecological processes such as water movement through the peat body, decomposition, and nutrient cycling.

Measurement Protocol: Multiple soil pits should be dug in the wetland to a depth of at least 40 cm. If quantitative vegetation data are being collected, soil pits should be located within these plots to allow correlations with vegetation data. For example, if using the 20 x 50 m plots described by Peet et al. (1998), soil pits would be located and samples collected within each of the intensive modules (See section A.2.2 for further information regarding plot establishment).

The samples are collected by taking a core sample within the top 15 cm of the soil. A cylinder of known volume should be used to collect samples. A PVC pipe of known dimensions will suffice. The cylinder is simply inserted into the peat profile, extracted, then shaved to eliminate any peat which is not contained within the cylinder. The soil remaining in the cylinder can then be placed into a plastic bag and then sent to a laboratory for analysis. Bulk density and soil texture (e.g., particle distribution) should analyzed. Alternatively, texture can be determined in the field using the "field hand method", however lab analysis is preferable.

Once texture and bulk density are determined, use the information below to determine whether the soil's bulk density is less than, equal to, or greater then the minimum root-restricting bulk density values listed for the corresponding texture of the soil and assign the metric rating accordingly in the scorecard.

There are no root restricting values given for organic soils, thus if the riparian shrubland is dominated by organic soil, reference bulk density measurements need to be established in undisturbed areas.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density value for wetland is at least 0.2 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland. (same as Very Good)	Bulk density for wetland is between 0.2 to 0.1 (g/cm3) less than Root Restricting Bulk Density value for the soil texture found in the wetland.	Bulk density for wetland is = or > than Root Restricting Bulk Density value for the soil texture found in the wetland.

Data: The data below are derived from a Natural Resource Conservation Service, Soil Quality Information Sheet — Compaction which can be found online at: http://soils.usda.gov/sqi/publications/sqis.html

Theses texture classes have the following Root Restricting Bulk Density values (g/cm3):

1. Coarse, medium, and fine sand AND loamy sand other than loamy very fine sand = 1.8 g/cm3

2. Very fine sand, loamy very find sand = 1.77 g/cm3
3. Sandy loam = 1.75 g/cm3
4. Loam, sandy clay loam = 1.7 g/cm3
5. Clay loam = 1.65 g/cm3
6. Sandy clay = 1.6 g/cm3
7. Silt, silt loam = 1.55 g/cm3
8. Silty clay loam = 1.5 g/cm3
9. Silty clay = 1.45 g/cm3
10. Clay = 1.4 g/cm3

Scaling Rationale: The scaling is based on best scientific judgment and an assumed linear relationship of the amount of deviation from the reference standard to level of disturbance. However, no distinction was made between Excellent and Good as there is no information to suggest that threshold. Alternatively if "baseline" bulk density levels are known (from "pre-impact" conditions or from adjacent unaltered sites) then this metric can be used to determine change of bulk density with time.

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

Nutrient/Pollutant Loading Index

Definition: The nutrient/pollutant loading index is a measure of the varying degrees to which different land uses contributed excess nutrients and pollutants via surface water runoff and overland flow into a wetland.

Background: This metric is one aspect of the condition of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: The type and amount of each land use in the wetland and contributing watershed affects the amounts and types of nutrients and pollutants that enter into a wetland. Excess nutrients can result in degradation of biotic integrity, change nutrient cycling, and potentially affect peat integrity.

In a functional assessment of slope and depressional wetlands associated with the Great Salt Lake, Keate (2005) developed a HGM assessment model primarily based on land use as a surrogate for human impacts on wetland functions. Coefficients from Nnadi and Bounvilay (1997) were used to represent the sediment, nutrient loading, runoff, and wildlife impacts associated with various land uses. The functions considered included hydrologic, geochemical and habitat characteristics. The same coefficients used in the Keate (2005) method are used for this metric.

Measurement Protocol: Identify and estimate the percentage of each land use within the wetland and the contributing watershed (within 100 m of the wetland). This is best completed in the field, however with access to current aerial photography a rough calculation of Land Use can be made in the office. Ideally, both field data as well as remote sensing tools are used to identify an accurate % of each land use. Once the percentage of each land use is identified, multiply it by the corresponding Nutrient/Pollutant Loading coefficient found for each land use in Appendix B, then sum for the Nutrient/Pollutant Loading Index Score.

For example, if 50% of the wetland and contributing watershed (within 100 m of the wetland) was under heaving grazing, 10% had a dirt road, and 40% natural vegetation the calculation would be (0.5 * 0.87) + (0.1 * 0.92) + (0.4* 1.0) = 0.93 (Surface Water Index Score). Referring to the scorecard, this would give the metric a "Good" rating.

The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. Surface water divides are determined using topography and although groundwater divides do not always coincide with these same hydrological divides, groundwater movement is assumed to do so, unless other data for the site is available

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7

Data: Appendix B.

Scaling Rationale: The scaling is based on best scientific judgment. Scores below 0.7 are assumed to have crossed a threshold in which loading impacts are considered to not be restorable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

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

B.4 SIZE

Absolute Size

Definition: Absolute size is the current size of the wetland

Background: This metric is one aspect of the size of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Absolute size is pertinent to ecological integrity if the surrounding landscape is impacted by human-induced disturbances. When the surrounding landscape is impacted and has the potential to affect the wetland, larger sized wetlands are able to buffer against these impacts better than smaller sized wetlands due to the fact they generally possess a higher diversity of abiotic and biotic processes allowing them to recover and remain more resilient. However, when the landscape is unimpacted (i.e. has an "Excellent" rating), then absolute size has little impact on ecological integrity since there are no adjacent impacts to buffer. Of course, larger wetlands tend to have more diversity (MacArthur and Wilson 1967), however this is a metric more pertinent to functional or conservation value than ecological integrity. Thus, absolute size is included as a metric but is only considered in the overall ecological integrity rank if the landscape is impacted (See Section A.3.3). Regardless if absolute size is considered in the overall ecological integrity rank, it provides important information to conservation planners and land managers.

Measurement Protocol: Absolute size can be measured easily in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. Absolute size can also be estimated in the field using 7.5 minute topographic quads, National Wetland Inventory maps, or a global positioning system. Wetland boundaries aren't delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987) rather by the guidelines identified elsewhere [need to specify where] for delineating the boundaries of this system. Size is then calculated in hectares.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
> 25 acres	5 to 25 acres	1 to 5 acres	< 1 acre

Data: N/A

Scaling Rationale: Scaling criteria are based on best scientific judgment.

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

Relative Size

Definition: Relative size is the current size of the wetland divided by the total potential size of the wetland multiplied by 100.

Background: This metric is one aspect of the size of specific occurrences of wetland or terrestrial ecological systems.

Rationale for Selection of the Variable: Relative size is an indication of the amount of the wetland lost due to human-induced disturbances. It provides information allowing the user to calibrate the Absolute Size metric to the abiotic potential of the wetland onsite. For example, if a wetland has an Absolute Size of 2 hectares but the Relative Size is 50% (1 hectare), this indicates that half of the original wetland has been lost or severely degraded. Unlike Absolute Size, the Relative Size metric is always considered in the ecological integrity rank.

Measurement Protocol: Relative size can be measured in GIS using aerial photographs, orthophoto quads, National Wetland Inventory maps, etc. However, field calibration of size is required since it can be difficult to discern potential wetland boundaries with current potential boundaries. Relative size can also be estimated in the field using 7.5 minute topographic quads, National Wetland Inventory maps, or a global positioning system. Wetland boundaries aren't delineated using jurisdictional methods (U.S. Army Corps of Engineers 1987) rather by the guidelines identified elsewhere [need to specify where] for delineating the boundaries of this system. Relative size is then calculated in hectares.

Metric Rating: Assign the metric an Excellent, Good, Fair, or Poor rating on the scorecard.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
Wetland area = onsite Abiotic Potential	Wetland area < Abiotic Potential; Relative Size < 10% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc.	Wetland area < Abiotic Potential; 10-25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc	Wetland area < Abiotic Potential; > 25% of wetland has been reduced, destroyed or severely disturbed due to roads, impoundments, development, human-induced drainage, etc

Data: N/A

Scaling Rationale: Scaling criteria are based on Rondeau (2001) and best scientific judgment.

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

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APPENDIX A: FIELD FORM REQUIREMENTS

APPENDIX B: SUPPLEMENTARY DATA:

Coefficient Table (coefficients were calculated from numerous studies throughout the U.S. (Keate 2005)

Land Use	Surface Water Runoff	Nutrient/ Pollutant Loading	Suspended Solids
Natural area	1.00	1.00	1.00
Dirt Road (dirt or crushed or loose gravel, unpaved roads, local traffic)	0.71	0.92	0.90*
Field Crop (actively plowed field)	0.95	0.94	0.85**
Clearcut forest	0.83	0.93	0.98
Golf Course (area manipulated for golf, manicured grass)	0.75	0.86	0.94
High Intensity Commercial (area is entirely of commercial use and paved - shopping malls, construction yards)	0.13	0	0
High Traffic Highway (4 lanes or larger, railroads)	0.26	0.43	0.48
Industrial (intense production activity occurs on a daily basis - oil refineries, auto body and mechanic shops, welding yards, airports)	0.25	0.54	0
Feedlot, Dairy	0.62	0	0.81
Heavy grazing - Non-rotational grazing (year-round or mostly year-round grazing, vegetation is sparse and area trampled)	0.76	0.87	0.85***
Rotational Grazing (grazing is for short periods during the year, vegetation is allowed to recover)	0.96	0.95	0.98
Light Intensity Commercial (businesses have large warehouses and showrooms - large patches of vegetation occur between buildings)	0.19	0.64	0.02
Low Density Rural Development (areas of small structures in a farm or ranch setting - silos, barns)	0.87	0.92	0.98
Low Traffic Highway (2-3 lane paved highways)	0.26	0.69	0.16
Multi-family Residential (subdivisions with lots ½ acre or less)	0.38	0.55	0.61
Nursery (business where the production of nursery grade vegetation occurs including greenhouses, outbuildings and sales lots)	0.86	0.94	1.00
Orchards	0.86	0.93	0.99
Waterfowl Management Areas	0.86	0.91	0.98
Single Family Residential (residential lots are greater than ½ acre with vegetation between houses)	0.75	0.86	0.94
Surface Solid Waste (landfills and waste collection facilities)	0.71	0.87	0.61
Sewage Treatment Plants and Lagoons	0.60	0.61	0.71
Mining	0.76	0.94	0.80

* changed value from 0.97; ** changed value from 1.00; *** changed value from 0.98