Laurentian-Acadian Floodplain Forest Ecological System

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Ecological Integrity Assessment

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Laurentian-Acadian Floodplain Forest

A. INTRODUCTION

The following description of the Laurentian – Acadian Freshwater Marsh is adapted from the **Rocky Mountain Lower Montane Riparian Woodland and Shrubland (CES306.821)**, *and will be refined in subsequent editions.*

A.1 ECOLOGICAL SYSTEM DESCRIPTION

A.1.1. Classification Summary

CES201.587 Laurentian-Acadian Floodplain Forest
(from NatureServe 2005)

Primary Division: Laurentian-Acadian (201)
Land Cover Class: Mixed Upland and Wetland
Spatial Scale & Pattern: Large patch
Required Classifiers: Natural/Semi-natural; Vegetated (>10% vasc.); Upland; Wetland
Diagnostic Classifiers: Forest and Woodland (Treed); Shrubland (Shrub-dominated); Woody-Herbaceous; Herbaceous; Riverine / Alluvial; Flood Scouring; Short (<5 yrs) Flooding Interval [Short interval, Spring Flooding]

Concept Summary: This system encompasses north-temperate floodplains in the northeastern and north-central U.S. and adjacent Canada at the northern end of the range of silver maple. They occur along medium to large rivers where topography and process have resulted in the development of a complex of upland and wetland temperate alluvial vegetation on generally flat topography. This complex includes floodplain forests, with *Acer saccharinum* characteristic, as well as herbaceous sloughs and shrub wetlands. Most areas are underwater each spring; microtopography determines how long the various habitats are inundated. Associated trees include *Acer rubrum* and *Carpinus caroliniana*, the latter frequent but never abundant. On terraces or in more calcareous areas, *Acer saccharum* or *Quercus rubra* may be locally prominent, with *Betula alleghaniensis* and *Fraxinus* spp. *Salix nigra* is characteristic of the levees adjacent to the channel. Common shrubs include *Cornus amomum* and *Viburnum* spp. The herb layer in the forested portions often features abundant spring ephemerals, giving way to a fern-dominated understory in many areas by mid-summer. Non-forested wetlands associated with these systems include shrub-dominated and graminoid-herbaceous vegetation.

Range: Central and northern New England and adjacent Canada west to the Great Lakes.
USFS Divisions (Bailey): 103:C, 201:C
TNC Ecoregions: 47:C, 48:C, 61:?, 63:C, 64:C

Subnations: ME, MI, MN, NB, NH, NY, VT, WI

A.1.2. Environment

Climate, Hydrology and Geomorphology
Riparian vegetation is distributed according to specific climatic, hydrologic, and geomorphic processes (Kattelmann and Embury 1996). The interplay of these three formative processes results in many different types of wetland across the landscape (Laubhan 2004).

Hydrology
The interaction of climate and geomorphology has a strong influence on local hydrological processes in a wetland.

Flooding from the stream channel recharges many alluvial aquifers and as stream flow decreases the trend is reversed as the alluvial aquifer begins to recharge stream flow (Hubert 2004). Groundwater levels in riparian areas are dependent on the underlying bedrock, watershed topography, soil characteristics, and season (Rink and Kiladis 1986). In areas of thin soils, little surface water is retained as groundwater; however, in areas of deep alluvial material surface water collects in alluvial aquifers which support numerous wetlands (Rink and Kiladis 1986). The level of the water table in alluvial aquifers varies temporally and spatially depending on the distance from the stream channel, time since streamflow has increased or decreased (or flooded), geometry of the river valley, and the composition of the alluvium (Hubert 2004). The temporal and spatial variation of the level of the alluvial aquifer is an important determining factor in the distribution and types of riparian habitats present (Hubert 2004).

Surface water flow and flooding is a function of snowmelt, watershed and valley topography and area, late-summer rainfall, and the extent of upstream riparian wetlands (Rink and Kiladis 1986). For example, riparian areas that are steep are not prone to as much flooding as riparian areas in more gently sloped and broad valleys (Mitsch and Gosselink 2000). Watershed area also affects surface flow which has subsequent effects on channel dimensions and varies according to stream discharge, which generally increases with increasing drainage basin area. Upstream lakes and wetlands release water throughout the growing season and are an important contribution to streamflow during later-summer and/or drought periods.

Surface water is a very important formative process 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). Runoff from adjacent hillsides can also contribute to the hydrological regime of riparian shrublands by recharging local alluvial aquifers and supporting wetland vegetation that is otherwise disconnected from stream flow (Cooper 1990).

Riparian areas can generally be referred to as confined or unconfined streams. Gregory et al. (1991) have defined confined streams as those whose valley floors are less than twice the width of the active stream channel. Confined streams typically have relatively straight, single channels flowing through narrow valley floors (Gregory et al. 1991). Flooding in confined streams increases stream depth and flow velocity increases rapidly as discharge increases due to minimal lateral floodplain areas (Gregory et al. 1991). Confined streams typically have shallow soils with minimal alluvium deposition (Hubert 2004). Unconfined streams lack lateral constraint and are typically found in low-gradient, lowland areas or in glaciated valleys and intermountain basins in the mountainous regions. Meandering occurs in unconfined streams where the gradient is low (Hubert 2004). The meander process leads to the formation of a complexity of geomorphic surfaces which support a diverse array of riparian habitats such as point bars, oxbows and backchannels, natural levees, ridges and swales, and pools and riffles in the stream channel, etc. (Gregory et al. 1991, Hubert 2004). These geomorphic surfaces support many different types of vegetation communities such as early seral plant communities, emergent vegetation associated with oxbows and backwater areas, decadent stands of vegetation (Gregory et al. 1991, Hubert 2004). Due to the diversity of abiotic and biotic patches created by the meander process, perennial, low-gradient streams support the most extensive riparian habitat in the Intermountain West (Hubert 2004).

Laurentian-Acadian Floodplain Forests are found along confined as well as unconfined streams.

A.1.3. Vegetation and Ecosystem

Vegetation

This system consists of temporarily, seasonally and intermittently flooded woodlands and shrublands comprised of broad leaved deciduous species, both in the tree and shrub canopy, as well as occasional conifers.

The spatial complexity of riparian areas support numerous vegetation types such wet meadows and marshes. These community types are associated with this floodplain forest type, but they may be large enough (i.e., meet the minimum size criteria) to classify as other Ecological System types (e.g., wet meadows or marshes).

Biogeochemistry

Bedrock geology, soil characteristics, and discharge of the contributing watershed basin determine the type and amount of nutrient flux in riparian forests (Windell et al. 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). Groundwater can also contribute nutrients via subsurface hillside runoff into riparian areas (Cooper 1990).

Periodic flooding is an important contributor of nutrients to riparian areas as it deposits organic material and fine-sediment (Hubert 2004).

Riparian areas are also important nutrient sources as they provide sources of particulate and dissolved carbon (e.g., detritus) to the stream which are crucial food sources for aquatic invertebrates in local environments as well as downstream areas (Gregory et al. 1991, Kattelmann and Embury 1996).

Ecosystem productivity
Because riparian areas contain perennial or intermittent water, they often have higher primary productivity than adjacent upland systems.

In Colorado, Baker (1990) found that species richness was highest in subalpine riparian forests (mean of 57.8 species/0.1 ha) on the West Slope while Peet (1978) found that montane riparian forests on the East Slope was highest (mean of 60.3 species/0.1 ha). Undisturbed montane riparian forests on the West Slope had an average of 47.4 species/0.1 ha (Baker 1990).

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, Manley and Schlesinger 2001). 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). Riparian vegetation also shades streamside aquatic habitat and therefore regulates stream temperatures which as large implications on habitat quality for aquatic invertebrates and fish.

A.1.4. Dynamics

Ecosystem development
Development of floodplain forests is driven mostly by the magnitude and frequency of flooding, valley type, and beaver activity. Seasonal and episodic flooding erode and/or deposit sediment resulting in complex patterns of soil development which subsequently have a strong influence on the distribution of riparian vegetation (Gregory et al.1991, Poff et al. 1997). Bare alluvium also provides suitable substrate for the germination of seedlings of cottonwood, willow and other tree species, and is thus a critical patch type for continued regeneration of riparian vegetation (Poff et al. 1997, Woods 2001). Alluvial soils are of variable thickness and texture and often exhibit wetland soil features such as mottling, indicating a fluctuating water table.

Valley geomorphology, flooding regime, and substrate dictate the types of riparian vegetation which develops. For example, this ecological system contains early seral, mid- and late seral riparian plant associations as well as a diversity of wet meadow and emergent wetland communities. The distribution and extent of these communities is determined by valley type (confined vs. unconfined), flooding regime, and beaver activity. Forest communities are early, mid- or late seral, depending on the age class of the trees and the associated species of the stand (Kittel et al. 1998). In very dynamic rivers, forest types do not regenerate in place, but regenerate by "moving" up and down a river reach by establishing on "new ground" created by seasonal and episodic flooding. Overtime a healthy riparian area supports all stages of these communities (Kittel et al. 1998).

Beavers typically inhabit streams with a gentle gradient (< 15%) and in wide valleys (at least wider than the stream channel) (Bierly 1972). Beaver dams impound surface water creating open water areas. When dams are initially created, they often flood and kill large areas of shrublands or trees. These areas are eventually colonized by herbaceous emergent and submergent vegetation. 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 (Phillips 1977, Baker 1987). The abandoned beaver ponds eventually fill with sediment and are colonized by willows and saplings, thus completing the cycle. The presence of beaver creates a heterogeneous complex of floodplain forests, wet meadows 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 impacted by beaver activity by having numerous zones of open water and vegetation, 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 in the Laurentian-Acadian region prior to European settlement; 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 2^{nd} to 5^{th} order streams in the boreal forest of Canada. It is apparent that active beaver colonies are very important for ecosystem development in riparian areas.

A.1.5. Landscape Condition

It is evident from the hydrogeomorphic setting of floodplain forests 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 into riparian areas 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.

Riparian areas are intimately connected to uplands in their upstream watersheds as well as adjacent areas. However, the reverse is also true: riparian areas 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 riparian areas have considered the landscape properties of the local watershed to be a critical factor in assessing condition (Costick 1996, Richter et al. 1996, Poff et al. 1997, Hauer and Smith 1998, Moyle and Randall 1998, Rondeau 2001, Hauer et al. 2002).

A.1.6. Size

The size of a wetland, whether very small or very large, is a natural characteristic defined by a site's topography, soils, and hydrological processes. The natural range of sizes found on the landscape varies for each wetland type. As long as a wetland has not been reduced in size by human impacts or isn't surrounded by areas which have experienced human disturbances, then size isn't very important to the assessment of ecological integrity. However, if human disturbances have decreased the size of the wetland or if 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. Under such circumstances, size may be an important factor in assessing ecological integrity.

Size is often very important when the conservation or functional value of a wetland is considered. For example, larger wetlands tend to have more diversity, often support larger populations of component species, are more likely to support sparsely distributed species, and may provide more suitable wildlife habitat as well as more ecological services derived from natural ecological processes (e.g. sediment/nutrient retention, floodwater storage, etc.) than smaller wetlands. Thus, when conservation or functional values are of concern, size is almost always an important component to the assessment.

In the context of regulatory wetland mitigation, size is always important whether mitigation transactions are based on function or integrity "units" and thus should be used to weight such transactions.

The size of riparian shrublands can vary greatly depending on their topographic location, underlying soil texture, and driving hydrological processes. Some are very small (> 8 linear km) while others can be very large (< 1.5 linear km).

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 riparian areas (Baker 1987, Kattelmann and Embury 1996, Poff et al. 1997, Woods 2001). All these stressors can induce downstream erosion and channelization, reduce changes in channel morphology, reduce base and/or peak flows, lower water tables in floodplains, and reduce sediment deposition in the floodplain (Poff et al. 1997). Vegetation responds to these changes by shifting from wetland and riparian dependent species to more mesic and xeric species typical of adjacent uplands and/or encroaching into the stream channel. Without periodic disturbance by flooding, riparian areas become dominated by late-seral communities due to the inability of pioneer species (e.g., cottonwood and willow) to regenerate. These late-seral communities are dominated by more upland species, or other, more drought tolerant species. Floodplain width and the abundance and spatial distribution of various patch types also typically decline. In addition, the spatial complexity of riparian and wetland habitat is greatly reduced due to alteration of the flooding regime.

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

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. Altered hydrology can disrupt nutrient cycles by eliminating normal flushing cycles and lack of deposition of organic material from floodwaters.

Exotics

Non-native plants or animals can have wide-ranging impacts. Non-native plants can increase dramatically under the right conditions and essentially dominate a previously natural area. Woody species of concern in this system include honeysuckle (*Lonicera morrowii, Lonicera tartarica*) and buckthorn (*Rhamnus cathartica*).

Common aggressive non-native species in floodplain forests include Japanese knotweed (*Polygonum cuspidatum*), Canada thistle (*Cirsium canadensis*), multiflora rose (*Rosa multiflora*), alfalfa (*Medicago sativa*), sweet clover (*Melilotus alba*; *M. officinalis*), reed canarygrass (*Phalaris arundinacea*), barnyard grass (*Echinochloa crus-galli*), cocklebur (*Xanthium strumarium*), red top (*Agrostis gigantea*), and Kentucky bluegrass (*Poa pratensis*).

Fragmentation

Human land uses both within the riparian area as well as in adjacent and upland areas can fragment the landscape and thereby reduce connectivity between riparian patches and between riparian and upland areas. This can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. Roads, bridges, and development can also fragment both riparian and upland areas. Intensive grazing and recreation can also create barriers to ecological processes.

A.2.2. Justification of Metrics

Measures selected need to include

- Landscape condition, given the critical role of the contributing watershed of riparian areas.
- Biotic condition, as measured by the species composition and diversity, and tree regeneration
- Floodplain and hydrologic characteristics.
- Invasion of exotics could alter species composition.
- Degree of fragmentation in the riparian as well as upland areas.

A.2.3 Ecological Integrity Metrics

A synopsis of the ecological metrics and ratings is presented in Table 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).

The Scorecard (see Tables 1 & 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 & 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 & 2.

For each metric, a rating is developed and scored as A – (Excellent) to D – (Poor). The background, methods, and rationale for each metric are provided in section B. Each metric is rated, 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 Floodplain Forest. Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. Shaded metrics are core metrics. Unshaded are supplementary metrics.

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**
LANDSCAPE CONTEXT	Landscape Composition	Adjacent Land Use	1
		Buffer Width	1
		Percentage of unfragmented landscape within 1 km.	1
		Riparian Corridor Continuity	1
BIOTIC CONDITION	Community Composition	Percent of Cover of Native Plant Species	2
		Floristic Quality Assessment (Mean C)	3
		Saplings/seedlings of Native Woody Species	2
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland	2
		Sediment Loading Index	1
	Hydrological Regime	Upstream Surface Water Retention	1
		Upstream/Onsite Water Diversions	1
		Floodplain Interaction	2
		Surface Water Runoff Index	1
		Bank Stability	2
		Index of Hydrological Alteration NOTE: When data are available, this metric should be used in lieu of Upstream Surface Water Retention, Upstream/Onsite Water Diversions, Floodplain Interactions, Surface Water Runoff Index, and Bank Stability.	3
		Beaver Activity	2
	Chemical /Physical Processes	Nutrient/ Pollutant Loading Index	1
		Soil Organic Carbon	3
		Soil Bulk Density	3

Category	Essential Ecological Attribute	Indicators /Metrics	Tier
SIZE	Absolute Size	Tier 0/1 - Absolute Size	1
	Relative Size	Tier 0/1 - Relative Size	1

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

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**	**Definition**	*Metric Ranking Criteria*			
					Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
LANDSCAPE CONTEXT	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	Percentage of unfragmented landscape 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% unfragmented, roadless natural landscape; internal fragmentation absent	Embedded in 60-90% unfragmented natural landscape; internal fragmentation minimal	Embedded in 20-60%% unfragmented natural landscape; Internal fragmentation moderate	Embedded in < 20% unfragmented natural landscape. Internal fragmentation high

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	*Metric Ranking Criteria*			
					Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
		Riparian Corridor Continuity	1	Indicates the degree to which the riparian area exhibits an uninterrupted vegetated riparian corridor.	< 5% of riparian reach with gaps / breaks due to cultural alteration	> 5 - 20% of riparian reach with gaps / breaks due to cultural alteration	>20 - 50% of riparian reach with gaps / breaks due to cultural alteration	> 50% of riparian reach with gaps / breaks due to cultural alteration
BIOTIC CONDITION	Community Composition	Percent of Cover of Native Plant Species	2	Percent of the plant species which are native to the region	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
		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
		Saplings/seedlings of Native Woody Species	2	Estimates the amount of regeneration of native woody plants.	Saplings/seedlings of native woody species (floodplain hardwoods) present in expected amount; Obvious regeneration.	Saplings/seedlings of native woody species (floodplain hardwoods) present but less than expected; Some seedling/saplings present.	Saplings/seedlings of native woody species (floodplain hardwoods) present but in low abundance; Little regeneration by native species.	No reproduction of native floodplain hardwood species
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

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	*Metric Ranking Criteria* Excellent (A)	Good (B)	Fair (C)	Poor (D)
		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
	Pattern of Surface Flow	Upstream Surface Water Retention	1	Measures the percentage of the contributing watershed which drains into water storage facilities capable of storing surface water from several days to months	< 5% of drainage basin drains to surface water storage facilities	>5 - 20% of drainage basin drains to surface water storage facilities	>20 - 50% of drainage basin drains to surface water storage facilities	> 50% of drainage basin drains to surface water storage facilities
		Upstream/Onsite Water Diversions	1	Measures the number of water diversions and their impact in the contributing watershed and in the wetland.	No upstream or onsite water diversions present upstream of the riparian area	Few diversions present upstream of the riparian area relative to contributing watershed size. Onsite diversions, if present, do not appear to have only minor impact on local hydrology.	Many diversions present upstream of the riparian area relative to contributing watershed size. Onsite diversions, if present, appear to have a major impact on local hydrology.	Water diversions are very numerous upstream of the riparian area relative to contributing watershed size. Onsite diversions, if present, have drastically altered local hydrology.

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	*Metric Ranking Criteria*			
					Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
		Floodplain Interaction	2	Indicates the amount of interaction between the stream and floodplain by assessing whether any geomorphic modifications have been made to the stream channel.	Floodplain interaction is within natural range of variability. There are no geomorphic modifications (incised channel, dikes, levees, riprap, bridges, road beds, etc.) made to contemporary floodplain.	Floodplain interaction is disrupted due to the presence of a few geomorphic modifications. Up to 20% of streambanks are affected.	Floodplain interaction is highly disrupted due to multiple geomorphic modifications. Between 20 – 50% of streambanks are affected.	Complete geomorphic modification along river channel. The channel occurs in a steep, incised gulley due to anthropogenic impacts. More than 50% of streambanks are affected.
	Pattern of Surface Flows	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

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	*Metric Ranking Criteria*			
					Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
		Bank Stability	2	Assesses the stability and condition of the streambanks.	Banks stable; evidence of erosion of bank failure absent or minimal; little potential for future problems. < 5% of bank affected. Streambanks dominated (> 90% cover) by Stabilizing Plant Species (OBL & FACW)	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion. Streambanks have 75-90% cover of Stabilizing Plant Species (OBL & FACW)	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods. Streambanks have 60-75% cover of Stabilizing Plant Species (OBL & FACW)	Unstable; many eroded areas; "raw" AREAS frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars. Streambanks have < 60% cover of Stabilizing Plant Species (OBL & FACW)
		Index of Hydrological Alteration NOTE: When data are available, this metric should be used in lieu of Upstream Surface Water Retention, Upstream/Onsite Water Diversions, Floodplain Interactions, and Surface Water Runoff Index.	3	Uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.	No significant change from Reference Hydrographs	Slight change from Reference Hydrographs	Moderate change from Reference Hydrographs	Large change from Reference Hydrographs

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	*Metric Ranking Criteria*			
					Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
	Beaver Activity	Beaver Activity	2	Assesses the presence and degree of beaver activity.	New, recent, and/or old beaver dams present. Beaver currently active in the area.	Recent and old beaver dams present. Beaver may not be currently active but evidence suggests that have been within past 10 years.	Only old beaver dams present. No evidence of recent or new beaver activity despite available food resources and habitat.	
	Nutrient Enrichment	Nutrient/ Pollutant Loading Index (B.2.16)	1	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.	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
		Soil Organic Carbon (B.2.20)	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
	Compaction	Soil Bulk Density (B.2.21)	3	A measure of the compaction of the soil horizons.	Bulk density is within natural range of variability	Bulk density is slightly higher than natural range of variability	Bulk density is higher than natural range of variability	Bulk density is much higher than natural range of variability
SIZE	Absolute Size	Absolute Size (B.3.1)	1	The current size of the wetland	> 8.0 linear km (minimum of 10 m wide)	5.0 to 8.0 linear km (minimum of 10 m wide)	1.5 to 5.0 linear km (minimum of 10 m wide)	< 1.5 linear km (minimum of 10 m wide)

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	*Metric Ranking Criteria*			
					Excellent (A)	**Good (B)**	**Fair (C)**	**Poor (D)**
	Relative Size	Relative Size (B.3.2)	1	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 various metrics into Category Scores. Points are assigned for each rating level (A, B, C, D) within a metric. 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. This is described in more detail in Section A.3.

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.

Rationale for Scoring: Adjacent land use, buffer width, and connectivity of the riparian corridor 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.

Thus, the following weights apply to the Landscape Context metrics:

Table 3. Landscape Context Rating Calculation.

Measure	**Definition**	**Tier**	**A**	**B**	**C**	**D**	**Weight**	**Score** (weight x rating)
Adjacent Land Use	Addresses the intensity of human dominated land uses within 100 m of the wetland.	1	5	4	3	1	0.30	
Buffer Width	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	1	5	4	3	1	0.30	
Percentage of unfragmented landscape within 1 km.	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	1	5	4	3	1	0.10	
Riparian Corridor Continuity	Indicates the degree to which the riparian area exhibits an uninterrupted vegetated riparian corridor.	1	5	4	3	1	0.30	

Measure	Definition	Tier	A	B	C	D	Weight	Score (weight x rating)
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 the other metrics as 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 4. Biotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Percent of Cover of Native Plant Species	Percent of the plant species which are native to the region	2	5	4	3	1	0.20 (0.55)	
Floristic Quality Assessment (Mean C)	The mean conservatism of all the native species growing in the wetland.	3	5	4	3	1	0.60 (N/A)	
Saplings/seedlings of Native Woody Species	Estimates the amount of regeneration of native woody plants.	2	5	4	3	1	0.20 (0.45)	
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 metric B.2.2 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) roll up the metrics into an overall Abiotic Condition rating.

<u>Rationale for Scoring</u>: 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 5. 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.	1	5	4	3	1	0.20	
Upstream Surface Water Retention	Measures the percentage of the contributing watershed which drains into water storage facilities capable of storing surface water from several days to months	1	5	4	3	1	0.20	
Upstream/Onsite Water Diversions	Measures the number of water diversions and their impact in the contributing watershed and in the wetland.	1	5	5	0	0	0.20	
Floodplain Interaction	Indicates the amount of interaction between the stream and floodplain by assessing whether any geomorphic modifications have been made to the stream channel.	2	5	5	0	0	0.20	
Bank Stability	Assesses the stability and condition of the streambanks.	2	5	4	3	1	0.20	
Index of Hydrological Alteration	Uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.	3					N/A *1.0*	
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**

* Index of Hydrologic Alteration (IHA) is a more accurate and reliable measure than the other metrics. Thus, if IHA is used, no other metrics are needed for the assessment.

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 6. Size Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Absolute Size (B.3.1)	The current size of the wetland	1	5	4	3	1	0.0 (0.70)	
Relative Size (B.3.2)	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. PROTOCOL 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.

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. 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 wetland (Hauer et al. 2002).

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 3) 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 within 100 m of the wetland edge, then sum the Sub-Land Use Score(s) 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.

Measure (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.

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. Buffer boundaries extend from the wetland edge to intensive human land uses which result non-natural areas. Some land uses such as light grazing and recreation may occur in the buffer, but other more intense 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).

Measurement 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.

Measure (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 and their effectiveness.

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

Percentage of Unfragmented Landscape 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, mining, utility lines, railroads, 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 (e.g., anthropogenic patches) provides an estimate of connectivity among natural ecological systems. Although related to metric B.1.1 and B.1.2, this metric differs by addressing the spatial interspersion of human land use as well as considering a much larger area.

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

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

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

Riparian Corridor Continuity

Definition: This metric indicates the degree to which the riparian area exhibits an uninterrupted naturally vegetated riparian corridor.

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: Riparian areas are typically comprised of a continuous corridor of intact natural vegetation along the stream channel and floodplain (Smith 2000). These corridors allow uninterrupted movement of animals to up- and down-stream portions of the riparian zone as well as access to adjacent uplands (Gregory et al. 1991). These corridors also allow for unimpeded movement of surface and overbank flow, which are critical for the distribution of sediments and nutrients as well as recharging local alluvial aquifers. Fragmentation of the riparian corridor can occur as a result of human alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development (Smith 2000).

Measurement Protocol: This metric is measured as the percent of anthropogenic patches within the riparian corridor. For example, fenced heavily grazed pastures, roads, bridges, urban/industrial development, agriculture fields, and utility right-of-ways are cultural breaks in the riparian corridor. The riparian corridor itself is defined at the width of the geomorphic floodplain.

The percent of anthropogenic patches is estimated based on field observations, aerial photographs, and GIS sources observed within the system.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
< 5% of riparian reach with gaps / breaks due to cultural alteration	> 5 - 20% of riparian reach with gaps / breaks due to cultural alteration	>20 - 50% of riparian reach with gaps / breaks due to cultural alteration	> 50% of riparian reach with gaps / breaks due to cultural alteration

Data: N/A

Scaling Rationale: As fragmentation increases the continuity of natural vegetated patches in the riparian decreases, along with corresponding changes in species, sediment, nutrient, and water movement. The categorical ratings are based on Smith (2000).

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

B.2. BIOTIC CONDITION METRICS

Percent of Cover of Native Plant Species

Definition: Percent of the plant species which are native to the region.

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 this system when it has 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 10 point cover classes identified in Peet et al. (1998) are recommended, 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 native 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.

Measure (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 NRCS (2005), Cooper (1990), Windell et al. (1996), CNHP (2005), and best scientific judgment. These criteria need further validation.

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

Saplings/seedlings of Native Woody Species

Definition: This metric estimates the amount of regeneration of native woody 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: Intensive grazing by domestic livestock and/or alteration of natural flow regime can reduce to eliminate regeneration by native woody plants (Elmore and Kauffman 1994). Species such as cottonwoods, willows, silver maple, and other lowland hardwood species depend on episodic flooding to create new bare surfaces suitable for germination of willow seedlings (Woods 2001). In addition, base flows following flooding need to be high enough to maintain soil water content in these areas at or above 15% through July and August in order for these seedlings to survive long enough to establish a deep root system (Woods 2001). Beaver dams also create bare areas suitable for regeneration of woody species, especially as they accumulate silt and/or there is a breach in the dam. Lack of regeneration is indicative of altered ecological processes and has adverse impacts to the biotic integrity of the riparian area.

Measurement Protocol: This metric is measured by determining the degree of regeneration of native woody species present along the streambank and edges of beaver ponds/dams. This is completed in the field and ocular estimates are used to match regeneration with the categorical ratings in the scorecard.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Saplings/seedlings of native woody species (floodplain hardwoods) present in expected amount; Obvious regeneration.	Saplings/seedlings of native woody species (floodplain hardwoods) present but less than expected; Some seedling/saplings present.	Saplings/seedlings of native woody species (floodplain hardwoods) present but in low abundance; Little regeneration by native species.	No reproduction of native floodplain woody species

Data: N/A. Additional study is needed to establish a specific set of floodplain hardwoods on which to base the metric

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

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

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 (√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.

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. 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).

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 5) 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 the Sub-Land Use Score(s) 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).

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

Measure (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.

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 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.

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.

Upstream Surface Water Retention

Definition: This metric measures the percentage of the contributing watershed which drains into water storage facilities (e.g., reservoirs, sediment basins, retention ponds, etc.) that are capable of storing surface water from several days to months (Smith 2000).

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

Rationale for Selection of the Variable: Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991, Poff et al. 1997). The amount of water retained in upstream facilities has a direct effect on these flows and subsequent effects on the continued biotic and physical integrity of the riparian area (Poff et al. 1997). For example, retention of surface water can decrease or eliminate episodic, high intensity flooding, decrease seasonal high flows (e.g., spring snowmelt) and increase base flows during seasonal dry periods causing a shift in channel morphology and altering the dispersal capabilities, germination, and survival of many plant species dependent on those flows (Poff et al. 1997; Patten 1998).

Measurement Protocol: This metric is measured as the percent of the contributing watershed to the riparian area that occurs upstream of a surface water retention facility. First the total area of the contributing watershed needs to be determined. Next, the area of the contributing watershed which is upstream of the surface water retention facility furthest downstream is calculated for each stream reach (e.g., main channel and/or tributaries) then summed, divided by the total area of the contributing watershed, then multiplied by 100 to arrive at the metric value. For example if a dam occurs on the main channel, then the entire watershed upstream of that dam is calculated whereas if only small dams occur on tributaries then the contributing watershed upstream of each dam on each of the tributaries would be calculated then summed.

These calculations can be conducted using GIS themes of surface water retention facilities, USGS 7.5 minute topographic maps, and/or Digital Elevation Models. The contributing watershed can be calculated or digitized using Digital Elevation Models in a GIS. The percentage of the contributing watershed upstream of surface water retention facilities is simply “cut” from the original contributing watershed layer and its area is then calculated then compared to the total area.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
< 5% of drainage basin drains to surface water storage facilities	>5 - 20% of drainage basin drains to surface water storage facilities	>20 - 50% of drainage basin drains to surface water storage facilities	> 50% of drainage basin drains to surface water storage facilities

Data: A GIS layer of surface water retention facilities can be downloaded from the Colorado Division of Water Resource's Decision Support Systems website: http://cdss.state.co.us/

Scaling Rationale: The scaling is based on Smith (2000) and best scientific judgment. Additional research may suggest changes to the scaling criteria.

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

Upstream/Onsite Water Diversions

Definition: This metric measures the number of water diversions and their impact in the contributing watershed and in the wetland relative to the size of the contributing watershed.

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

Rationale for Selection of the Variable: Ecological processes of riparian areas are driven to a large degree by the magnitude and frequency of peak flows and the duration and volume of base flows (Poff et al. 1997). The biotic and physical integrity of riparian areas are dependent on the natural variation associated with these flow characteristics (Gregory et al. 1991, Poff et al. 1997). The amount of water imported, exported, or diverted from a watershed can affect these processes by decreasing episodic, high intensity flooding, seasonal high flows (e.g., spring snowmelt), and base flows (Poff et al. 1997, Patten 1998).

Measurement Protocol: This metric can be measured by calculating the total number of water diversions occurring in the upstream contributing watershed as well as those onsite. The number of diversions relative to the size of the contributing basin is considered and then compared to the scorecard to determine the rating.

Since the riparian area may occur on a variety of stream orders and since the corresponding upstream or contributing watershed differs in area, it is difficult to set standard guidelines. Thus, the user must use their best scientific judgment regarding the number of diversions and their impact relative to the size of the contributing watershed. If available, attributes such as capacity (cubic feet/second) of each diversion can be considered in the assessment.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No upstream or onsite water diversions present	Few diversions present or impacts from diversions minor relative to contributing watershed size. Onsite diversions, if present, appear to have only minor impact on local hydrology.	Many diversions present or impacts from diversions moderate relative to contributing watershed size. Onsite diversions, if present, appear to have a major impact on local hydrology.	Water diversions are very numerous or impacts from diversions high relative to contributing watershed size. Onsite diversions, if present, have drastically altered local hydrology.

Data: A GIS layer of surface water diversions can be downloaded from the Colorado Division of Water Resource's Decision Support Systems website: http://cdss.state.co.us/

Scaling Rationale: The scaling is based on best scientific judgment. Additional research is needed and may suggest changes to the scaling criteria.

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

Floodplain Interaction

Definition: This metric indicates the amount of interaction between the stream and floodplain by assessing whether any geomorphic modifications have been made to the stream channel.

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

Rationale for Selection of the Variable: Overbank flooding is a critical ecological process in riparian areas as it replenishes floodplain aquifers, deposits and/or removes sediment, detritus, and nutrients in the floodplain. Stream channels affected by geomorphic modifications (e.g., channel incision, dikes, levees, roads, bridges, rip-rap, etc.) lose their connection to the adjacent floodplain and the ability to migrate (Poff et al. 1997). The biotic and physical integrity of riparian areas are partially dependent on the natural variation associated with overbank flows (Gregory et al. 1991, Poff et al. 1997).

Measurement Protocol: This metric is estimated in the field by observing signs of overbank flooding, channel migration, and geomorphic modifications that are present within the riparian area. From these observations, best scientific judgment is used to assign the metric rating in the scorecard.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Floodplain interaction is within natural range of variability. There are no geomorphic modifications (incised channel, dikes, levees, riprap, bridges, road beds, etc.) made to contemporary floodplain.	Floodplain interaction is disrupted due to the presence of a few geomorphic modifications. Up to 20% of streambanks are affected.	Floodplain interaction is highly disrupted due to multiple geomorphic modifications. Between 20 – 50% of streambanks are affected.	Complete geomorphic modification along river channel. The channel occurs in a steep, incised gulley due to anthropogenic impacts. More than 50% of streambanks are affected.

Data: N/A

Scaling Rationale: The scaling is based on best scientific judgment. Additional research is needed and may suggest changes to the scaling criteria.

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

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 runoff 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: Medium.

Bank Stability

Definition: This metric assesses the stability and condition of the streambanks.

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

Rationale for Selection of the Variable: Unstable or eroding banks are often the results of local and/or upstream impacts associated with channel incision induced by over grazing and/or upstream alterations in the hydrological and/or sediment regimes. The local impact from eroding or unstable banks is typically a drop in the local water table along with a change in composition of plant species growing along the streambanks.

Measurement Protocol: This metric is measured by walking along the streambanks in the riparian area and observing signs of eroding and unstable banks. These signs include crumbling, unvegetated banks, exposed tree roots, exposed soil, as well as species composition of streamside plants (Prichard et al. 1998, Barbour et al. 1999). Stable streambanks are vegetated by native species that have extensive root masses (*Alnus incana*, *Salix* spp., *Populus* spp., *Betula* spp., *Carex* spp., *Juncus* spp., and some wetland grasses) (Prichard et al. 1998). In general, most plants with a Wetland Indicator Status of OBL (obligate) and FACW (facultative wetland) have root masses capable of stabilizing streambanks while most plants with FACU (facultative upland) or UPL (upland) do not (Reed 1988, Prichard et al. 1998).

Each bank is evaluated separately then averaged to assign the metric rating.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Banks stable; evidence of erosion or bank failure absent or minimal; < 5% of bank affected. Streambanks dominated (> 90% cover) by Stabilizing Plant Species (OBL & FACW)	Mostly stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion. Streambanks have 75-90% cover of Stabilizing Plant Species (OBL & FACW)	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods. Streambanks have 60-75% cover of Stabilizing Plant Species (OBL & FACW)	Unstable; many eroded areas; "raw". Areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars. Streambanks have < 60% cover of Stabilizing Plant Species (OBL & FACW)

Data:
Wetland Indicator Status: U.S. Fish and Wildlife Service, National Wetlands Inventory website: http://www.nwi.fws.gov/plants.htm or USDA PLANTS Database: http://plants.usda.gov/

The Colorado Floristic Quality Assessment Database will also have Wetland Indicator Status information.

Scaling Rationale: The scaling is based on Barbour et al. (1999), Prichard et al. (1998), and best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

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

Index of Hydrological Alteration

Definition: This metric uses daily streamflow data to determine trends at one site or determine differences between pre- and post-impacts of sites.

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 Index of Hydrological Alteration (IHA) is an easy to use tool for calculating the characteristics of natural and altered hydrologic regimes using any type of daily hydrologic data, such as streamflows, river stages, ground water levels, etc. Rather that review the entire method here, please refer to http://www.freshwaters.org/tools to download the IHA software as well as supporting documentation, including numerous published papers.

Measurement Protocol: Long-term daily streamflow data are required for this metric. If those are not available daily flow data may be generated using a hydrologic model or other simulation method (see Richter et al. 1997). The IHA statistics will be meaningful only when calculated for a sufficiently long hydrologic record. The length of record necessary to obtain reliable comparisons is currently being researched, however it is recommended that at least twenty years of daily records be used (see Richter et al. 1997).

Some lake level and ground water well data are also available from the USGS, but much of this type of data is collected and managed by other local governmental entities.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
No significant change from Reference Hydrographs	Slight change from Reference Hydrographs	Moderate change from Reference Hydrographs	Large change from Reference Hydrographs

Data:
Index of Hydrologic Alteration Software and Supporting Documentation:
http://www.freshwaters.org/tools

U.S. Geological Survey Streamflow Data: http://water.usgs.gov/usa/nwis. (data can be imported directly in the IHA)

The U.S. Forest Service, U.S. Bureau of Land Management, and local government agencies may have streamflow data for some of the streams located on the lands they manage.

Scaling Rationale: The scaling is based on best scientific judgment of deviation from the reference standard. Additional research may suggest changes to the scaling criteria.

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

Beaver Activity

Definition: This metric assesses the presence and degree of beaver activity.

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

Rationale for Selection of the Variable: Beaver are an important hydrogeomorphic variable in riparian areas. The presence of beavers creates a heterogeneous complex of floodplain forests, wet meadows and riparian shrublands and increases species richness on the landscape. Beaver-influenced streams differ from those not impacted by beaver activity by having numerous zones of open water and vegetation, large accumulations of detritus and nutrients, more wetland areas, having more anaerobic biogeochemical cycles, generate more stable streamflow throughout summer months, and in general are more resistance to disturbance (Neff 1957, Naiman et al. 1986).

Measurement Protocol: This metric is measured by walking through the riparian area and observing signs of beaver activity (beavers, dams, canals, food harvesting (e.g., gnawing of willows, cottonwoods, and aspens). Aerial photography can be used as well either as a means of assessing this metric remotely or to confirm field observation regarding the number and activity of beaver dams present on the site. Both current, recent, and old beaver dams and canals should be searched for.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Active, recent, and/or old beaver dams present. Beaver currently active in the area.	Recent and old beaver dams present. Beaver may not be currently active but evidence suggests that have been within past 10 years.	Only old beaver dams present. No evidence of recent or new beaver activity despite available food resources and habitat.	No beaver dams present when expected (in unconfined valleys).

Data: Aerial photographs and/or digital orthophotos.

Scaling Rationale: It is not known what the density of beaver were in this region prior to European settlement. 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 floodplains. The scaling is based on best scientific judgment.

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

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.

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, a reduction in soil organic carbon from reference conditions serves as a strong indicator of loss of soil quality.

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 within each of the intensive modules. 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.

Measure (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 wetlands. 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 an indication of the level of compaction. Compaction can result from any activity which compresses soil particles thereby increasing the weight to volume ratio. This can reduce the soil's water holding capacity, infiltration rate, 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.

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 soil profile, extracted, then shaved to eliminate any soil 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 be 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 wetland 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 areas) 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.

B.3 SIZE METRICS

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. Regardless, absolute size 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 for delineating the boundaries of the wetland ecological system type.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
> 8.0 linear km (minimum of 10 m wide)	5.0 to 8.0 linear km (minimum of 10 m wide)	1.5 to 5.0 linear km (minimum of 10 m wide)	< 1.5 linear km (minimum of 10 m wide)

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 the abiotic potential of the wetland from remote sensing data. However, the reverse may also be true since old or historic aerial photographs may indicate a larger wetland than observed in the field. 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 for delineating the boundaries of the wetland ecological system type.

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

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