North American Arid West Freshwater Marsh Ecological System

Ecological Integrity Assessment

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A. INTRODUCTION

A.1 Classification Summary

CES300.729 North American Arid West Emergent Marsh

<u>Division 300, Herbaceous Wetland</u>
Spatial Scale & Pattern: Small Patch   **Classification Confidence:** High
Required Classifiers: Natural/Semi-natural, Vegetated (>10% vasc.), Wetland
Diagnostic Classifiers: Herbaceous, Mineral: W/ A Horizon >10 cm, Graminoid, Aquatic Herb, Depressional [Lakeshore], Depressional [Pond], Deep (>15 cm) Water, Saturated Soil

Non-Diagnostic Classifiers: Montane [Montane], Montane [Lower Montane], Lowland [Foothill], Lowland [Lowland], Backwater, Drainage bottom (undifferentiated), Floodplain, Marsh, Oxbow, Pond, Temperate [Temperate Continental], Forb, Alga, Clay Subsoil Texture

HGM: Depressional, Riverine

Concept Summary: This widespread ecological system occurs throughout much of the arid and semi-arid regions of western North America. Natural marshes may occur in depressions in the landscape (e.g., ponds, kettle ponds), as fringes around lakes, and along the mainstem and backwater channels of slow-flowing streams and rivers. Marshes are frequently or continually inundated, with water depths up to 2 m. Water levels may be stable, or may fluctuate 1 m or more over the course of the growing season. Marshes have distinctive soils that are typically mineral, but can also accumulate organic material. Soils have characteristics that result from long periods of anaerobic conditions in the soils (e.g., gleyed soils, high organic content, redoximorphic features). The vegetation is characterized by herbaceous plants that are adapted to saturated soil conditions. Common emergent and floating vegetation includes species of bulrushes (*Scirpus* spp.), cattails (*Typha* spp.),rushes (*Juncus* spp.), pondweeds (*Potamogeton* spp.), smartweeds (*Polygonum* spp.), and pond lilies (*Nuphar* spp.). This system may also include areas of relatively deep water with floating-leaf plants such as duckweed (*Lemna* spp.) and submergent and floating plants such as water milfoil (*Myriophyllum* spp.), hornwort (*Ceratophyllum* spp.), and waterweed (*Elodea* spp.).

Ecological Divisions (Bailey): 301, 302, 303, 304, 305, 306
TNC Ecoregions: 11:C, 17:C, 18:C, 19:C, 20:C, 21:C, 23:C, 24:C, 26:C, 27:C, 28:C, 29:C, 30:C, 6:C, 7:C, 8:C, 9:C
Subnations/Nations: AB:c, AZ:c, BC:c, CA:c, CO:c, ID:c, MT:c, MXBC:c, MXCH:c, MXSO:c, ND:c, NE:c, NM:c, NV:c, OK:c, OR:c, SD:c, TX:c, UT:c, WA:c, WY:c

A.2 Ecological System Description

▪ A.2.1. Environment

Climate

A continental climate dominates the Southern Rocky Mountains producing warm, dry summers and cold winters and an overall semi-arid climate. Most precipitation occurs as snowfall (as much as 80% at high elevations) during the winter months and thus is the most important source of water for wetlands and riparian areas in the Southern Rocky Mountains (Laubhan 2004; Windell et. al 1986; Cooper 1990). However, late-summer convective thunderstorms produce slight peaks in runoff in late summer (Baker 1987; Rink and Kiladis 1986). Evaporation generally exceeds precipitation, especially at lower elevations and in the intermountain basins; however, increasing precipitation and lower temperatures at higher elevations tends to reverse this trend, although aspect, topography, and intense solar radiation can moderate these effects on the evaporation/precipitation ratio (Laubhan 2004). The ratio between evaporation and precipitation has a strong influence on the hydrology of wetlands throughout the region.

Climate has a large role in maintenance of marshes since precipitation amounts and the interplay of evapotranspiration and precipitation can dictate water level fluctuation as well as soil chemistry (i.e., evaporative salts in the soil). In general, marshes are tied to the precipitation and runoff characteristics of their contributing basins. During drought years, many marshes may not be inundated to the same degree (or at all) as during normal precipitation years.

Geomorphology

The Southern Rocky Mountains are composed of various igneous, metamorphic, and sedimentary rocks (Mutel and Emerick 1984; Windell et al. 1986). The mountain valleys are relatively young topographical forms created by the erosional effects of flowing water and glacier movement (Windell et al. 1986). Intermountain basins were formed from tectonic and volcanic events which occurred during mountain-forming processes (Windell et al. 1986). The valleys of these basins are now filled with deep alluvial deposits derived from erosional processes in the nearby mountain ranges (Windell et al. 1986). Glaciation has had a large influence on landforms at high elevations through large-scale erosional and depositional processes and thus has a large influence on the presence and distribution of wetlands. Many high elevation river valleys (known locally as “parks”) experienced glaciation during the Pleistocene and terminal moraines extend to about 2550 m in the north and 3000 m in the southern part of the region (Baker 1987, 1989; Windell et al. 1986). High elevation streams which occur in the glaciated valleys (e.g. U-shaped valleys) traverse a flat gradient and are typically dominated by riparian shrublands (e.g., Rocky Mountain Subalpine-Montane Riparian Shrubland), wet meadows (Rocky Mountain Alpine-Montane Wet Meadows), and marshes (North American Arid Freshwater Marsh) while others have a steep gradient (e.g., V-shaped valleys) and are typically dominated by the riparian woodlands (e.g., Rocky Mountain Subalpine-Montane Riparian Woodland) (Baker 1987; Windell et al. 1986). Streams below the extent of glaciation are typically steep although those within intermountain basins often flow through broad valleys where a complex mosaic of wet meadows, riparian woodlands and shrublands form.

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

Hydrology

The interaction of climate and geomorphology has a strong influence on local hydrological processes in a wetland. For example, snowmelt at high elevations contributes a large proportion of water to most wetland types through its influence on groundwater and surface water dynamics (Laubhan 2004). In mountain valleys, snowmelt and geomorphology are major factors controlling the extent, depth, and duration of saturation resulting from high groundwater levels and also exert controls most aspects of the frequency, timing, duration, and depth of flooding along riparian areas (Laubhan 2004). Wetlands in intermountain basins are also affected by snowmelt via its association with the contributing surface water to the valley aquifers.

In riparian areas, 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 and slopes 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 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). Upstream 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, including marshes. 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). Flooding in subalpine-montane streams occurs annually in May and June with the volume and duration affected by snowpack levels (Baker 1987). Occasional September flooding may occur due to intense convective thunderstorms, however these are often very localized (Baker 1987). These thunderstorms can result in sporadic and frequent small-scale flooding in small mountain streams (Hubert 2004). Interannual variation of streamflow can range from 60-150% of the mean annual flow on the west slope, whereas eastern slope streams have less variation (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).

Snowmelt maintains high water tables through June in many wetland types (wet meadows, fens, riparian areas, etc.), however only those areas with soil saturation or a water table within 30 cm of the soil surface through July and August accumulates peat (Cooper 1990; Chimner and Cooper 2003). Marshes can have mineral or, depending on the duration of inundation and frequency of fluctuation, even organic soils. A distinguishing characteristic between fens, another wetland type with organic soils, is the duration and depth of standing water as well as fluctuation of water levels. Fens may have standing water on the soil surface, but typically not more than a few decimeters deep whereas marshes can have up to 2 m of standing water above the soil surface (Cooper 1990; Cooper 1986). In addition, the fluctuation of the water table in marshes can be large (> 1 m) whereas water table fluctuations in fens is much less dramatic (occasionally up to 0.5 m) (Cooper 1986; Cooper 1990). Because the water table in marshes fluctuates, the soil is periodically aerated allowing organic matter to decompose, preventing the accumulation of peat in many marshes or at least in some zones of a marsh (Cooper 1986). When organic soils do occur in marshes they are typically very local (do not occur over the entire marsh) and are found in those areas which remain permanently inundated or saturated.

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

A.2.2. Vegetation & Ecosystem

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

In marshes where cattails (*Typha domingensis*, *T. latifolia*) or giant reed (*Phragmites australis*) are dominant, nearly monotypic stands of these species may form. Bulrush (*Schoenoplectus acutus* or *S. tabernaemontani*) dominated sites may also form dense mats with up to 100% cover. Other dominates within this system include alkali cordgrass (*Spartina gracilis*), three square bulrush, arrowhead (*Sagittaria* spp.), and sweet coltsfoot (*Petasites sagittatus*). Other associated species within this system may include water sedge (*Carex aquatilis*), beaked sedge (*C. utriculata*), woolly sedge (*C. pellita*), rushes, spikerushes (*Eleocharis* spp.), mannagrass (*Glyceria* spp.), bentgrass (*Agrostis* ssp.), and cordgrass (*Spartina* ssp.). Forbs associated at these sites are often sparse and may include wild licorice (*Glycyrrhiza lepidota*), buttercup (*Ranunculus* spp.), mare's tail (*Hippuris vulgaris*), smartweed (*Polygonum* spp.), water plantain (*Alisma gramineum*), cutleaf waterparsnip (*Berula erecta*), and hemlock waterparsnip (*Sium suave*).

Floating and submerged vegetation includes pond lily (*Nuphar lutea*), burreed (*Sparganium* spp.), duckeweed (*Lemna* spp.). water starwort (*Callitriche* spp.), bladderwort (*Utricularia* spp.), ditchgrass (*Ruppia* spp.), Gmelin's buttercup (*Ranunculus gmelinii*), threadleaf crowfoot (*R. trichophyllus*), water milfoil (*Myriophyllum* spp.), waterweed (*Elodea* spp.), and quillwort (*Isoetes* spp.).

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

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

Marshes associated with riparian areas may also serve as important biogeochemical filters of nutrients and sediment before they enter the stream from adjacent human land uses (Peterjohn and Correll 1984). For example, unconfined riparian areas, such as most occurrences of Rocky Mountain Subalpine-Montane Riparian Shrublands, have been shown to retain more than two times the amount of NH_4^+ than confined riparian areas (e.g., Rocky Mountain Subalpine-Montane Riparian Woodlands) (Gregory et al. 1991). In Colorado, a 10 m riparian wet meadow buffer zone was experimentally shown to reduce applied NO_3^- by 84% and PO_4^{-3} by 79% (Corley et al. 1999).

Productivity

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

Much information regarding productivity of marshes in the Southern Rocky Mountain region is associated with general data from riverine environments, and is thus discussed within the context of riparian areas. In general, productivity in terrestrial environments tends to decline with increasing elevation and aridity (Manley and Schlesinger 2001). Because riparian areas contain perennial or intermittent water and receive periodic influx of nutrients from these waters, they often have higher primary productivity than adjacent upland systems, especially in the semi-arid portions of the Southern Rocky Mountains and thus have been suggested to be the most productive and diverse parts of the western landscape (Gregory et al. 1991; Kattelmann and Embury 1996; Knud-Hansen). In addition, species richness of montane and subalpine riparian areas in the Southern Rocky Mountains was found to be as rich or richer than riparian ecosystems in the southwest, central, and northeast portions of the United States and was found to have higher species richness than most temperate North American forests (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).

Marshes found in other topographic positions likely have higher productivity than nearby upland areas due to increased moisture, organic matter, and nutrients in the marshes.

Animals

The variability in water levels and subsequent vegetation types support a variety of aquatic and terrestrial invertebrates. These invertebrates process detritus, consume vegetation, and provide abundant food resources for other taxa such as birds, mammals, fish, amphibians, and other invertebrate species. Marshes are well known for providing habitat for numerous species of waterbirds. Cattail is known to be important for nesting red-wing, yellow-headed blackbirds, and marsh wrens, and mallards (Foster 1986). Bulrushes are also important for providing potential nesting habitat (Foster 1986).

During drawdown periods, mudflats may provide feeding grounds for shorebirds (Foster 1986). Of course, the amount of open water, density of vegetation, and nearby land use all effect potential habitat for waterbirds in marshes.

Marshes in riparian areas contribute to overall biotic integrity of the riparian zone by increasing species as well as habitat diversity. In general, riparian areas are known to be hot spots of diversity in the arid west. For example, in the Sierra Nevada Mountains, approximately 400 species of vertebrates are dependent on riparian areas for a portion of their life cycle (Kattelmann and Embury 1996). In Colorado, it is estimated that riparian areas, which account for only 1% of the landscape, are used by greater than 70% of the state's wildlife species and that 27% of the breeding bird species depend on riparian habitats for their viability (Knopf 1988; Pague and Carter 1996). Deer, moose, and elk seek out riparian areas for their rich and nutritious grasses and forbs (Foster 1986). Open water areas also provide habitat for numerous invertebrates which in turn provide critical links in local food webs as well as biogeochemical cycling.

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

▪ A.2.3. Dynamics

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

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

As mentioned above, beaver are an important hydrogeomorphic driver of marsh development. Beavers inhabit streams with a gentle gradient (< 15%) and in wide valleys (at least wider than the stream channel) (Bierly 1972). Beaver dams impound surface water creating open water areas. When dams are initially created, they often flood and thus kill large areas of shrublands. These areas are eventually colonized by marsh vegetation. Depending on the duration of saturation and flooding, these vegetation types are considered marshes or wet meadows. As local food supplies are diminished, beavers tend to abandon their dams and move up or downstream to find additional food supply as well as suitable dam sites (Baker 1987; Phillips 1977). The abandon beaver ponds eventually fill with sediment and colonize by willows, thus completing the cycle. The presence of beaver creates a heterogeneous complex of wet meadows, marshes and riparian shrublands and increases species richness on the landscape. For example, Wright et al. (2002) note that beaver-modified areas may contribute as much as 25% of the species richness of herbaceous species in Adirondack Mountains of New York. Naiman et al. (1986) note that beaver-influenced streams are very different from those not impacted by beaver activity by having numerous zone of open canopy, large accumulations of detritus and nutrients, more wetland areas, having more anaerobic biogeochemical cycles, and in general are more resistance to disturbance. Neff (1957; *in* Knight 1994) estimated that a Colorado valley with an active beaver colony had eighteen times more water storage in the spring and an ability to support higher streamflow in late summer than a drainage where beaver were removed.

It is not known what the density of beaver were in the Southern Rocky Mountains prior to the fur trade (Baker 1987), 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. Regardless, it is apparent that active beaver colonies are very important for ecosystem development in riparian areas, including marshes.

No matter the landform in which a marsh occurs, some general patterns of ecosystem development can be observed. Typically, marshes exhibit distinct bands or zones of vegetation which vary according to the degree of inundation and soil moisture (Dekeyser et al. 2003; Cooper and Severn1992; Mitsch and Gosselink 2000). Conceptually, from wettest to driest, this includes the following vegetation types (1) aquatic (e.g., submerged and floating species such as duckweed (*Lemna* spp.), pond lily (*Nuphar lutea*), pondweeds (*Potamogeton* spp.), etc.); (2) deep emergent (e.g., cattail (*Typha* spp.), bulrushes (*Schoenoplectu*s spp.), arrowhead (*Sagittaria* spp.), sweet coltsfoot (*Petasites sagittata*, etc.), (3) shallow emergent (e.g., spikerush (*Eleocharis* spp.), sedges (*Carex* spp.), and rushes (*Juncus* spp.), and (4) wet meadow (e.g., sedges, rushes, tufted hairgrass (*Deschampsia cespitosa*), reedgrass (*Calamagrostis* spp.), three square bulrush (*Schoenoplectus pungens*), etc.) (Cooper 1986). Of course, not all of these types are always present since shoreline gradient and hydrological regime can essentially exclude some of these zones.

- **A.2.4. Landscape**

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

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

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

- **A.2.5. 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.

Of course, 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 marshes can vary greatly depending on their topographic location, underlying soil texture, and driving hydrological processes. Some are very small (< 1 hectare) while others can be very large (> 20 hectares).

A.3 Ecological Integrity

- ### A.3.1. Threats

Hydrological Alteration: Reservoirs, water diversions, ditches, roads, and human land uses in the contributing watershed can have a substantial impact on the hydrology as well as biotic integrity of marshes (Windell et. al. 1986; Woods 2001; Kattelmann and Embury 1996; Poff et al. 1997; Baker 1987). All these stressors can induce or reduce sedimentation, increase nutrient inputs, lower water tables in floodplains and thus decreases groundwater discharge into riparian marshes, and generate excess surface flow into the marsh (e.g., alter hydrodynamics) (Windell et al. 1986; Poff et al. 1997). Response of marsh vegetation varies depending on the stressor, however disturbance to marshes often results in monotypic stands of cattail or giant reed with a corresponding decrease in species diversity in an already depauperata system.

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

Land Use
Since marshes tend to inundated for much of the year, land use impacts typically result from those occurring in adjacent wetland or upland areas. Galatowitsch et al. (2000) found that the intensity and types of land use within 500 m of a wet meadow had a significant affect on plant community composition. Livestock management can impact wet meadows by compacting soil, pugging (creation of pedestals by hooves) on the soil surface, altering nutrient concentrations and cycles, changing surface and subsurface water movement and infiltration, and shifting species composition (Kauffman and Krueger 1984; Elmore and Kauffman 1984; Weixelman et al. 1997; Flenniken et al. 2001; Kauffman et al. 2004).

Nutrient enrichment
Adjacent and upstream land uses all have the potential to contribute excess nutrients into riparian areas. Increased nutrients can alter species composition by allowing aggressive, invasive species to displace native species (Zedler and Kercher 2004). In Montana peatlands, beaked sedge was found to be positively correlated to concentrations of ammonium (NH_4^+) and negatively associated with diversity of vascular plants (Jones 2003). Most marshes affected by nutrient enrichment tend to have monotypic stands of *Typha* or *Phragmites*.

Exotics
Non-native species can displace native species, alter hydrology, alter structure, and affect food web dynamics by changing the quantity, type, and accessibility to food for fauna (Zedler and Kercher 2004). Wetlands dominated by non-native, invasive species typically support fewer native animals (Zedler and Kercher 2004). Marshes are susceptible to invasion by many non-native species including *Typha angustifolia*, purple loosestrife (*Lythrum salicaria*), barnyard grass (*Echinochloa crus-galli*), and reed canary grass (*Phalaris arundinacea*). Pasture grasses such as Kentucky bluegrass (*Poa*

pratensis), redtop (*Agrostis gigantea*), and timothy (*Phleum pratense*) as well as exotics species common to other wetland types such as Canada thistle (*Cirsium arvense*) and dandelion (*Taraxacum officinale*) may be invade the peripheral margins of marshes. However, increases in native species such as *Typha latifolia* and *Phragmites australis* are often more problematic in marshes than exotics.

Fragmentation: Human land uses both within the wetland as well as in adjacent and upland areas can fragment the landscape and thereby reduce connectivity between wetland and upland areas. This can adversely affect the movement of surface/groundwater, nutrients, and dispersal of plants and animals. Gravel mining can have a direct effect on riparian marshes by physically removing vegetation and substrate thereby creating large gaps in connectivity in the floodplains (Baker 1987). Roads, bridges, and development can also fragment both wetland and upland areas. Intensive grazing and recreation can also create barriers to ecological processes.

▪ A.3.2. Justification of Metrics

As reviewed above, the literature suggests that the following attributes are important measures of the ecological integrity of North American Arid West Freshwater Marshes:

- Landscape Context: Land use within the contributing watershed has important effects on the connectivity and sustainability of many ecological processes critical to this system.
- Biotic condition: Species composition and diversity, presence of conservative plants, and invasion of exotics are important measures of biological integrity.
- Abiotic Condition: Hydrological integrity is the most important variable to measure, however land use within the wetland can have detrimental impacts on other important abiotic processes such as nutrient cycling.
- Size: Absolute size is important for consideration of conservation values as well as ecosystem resilience. Relative size is also very important as it provides information regarding historical loss or degradation of wetland size.

▪ A.3.3. 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 metrics are not doable at Tier 1 (i.e., they require a ground visit).

Core and Supplementary Metrics

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 metric*s* 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.

Table 1. Overall Set of Metrics for the North American Arid West Freshwater Marsh System. Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses is reference to the metric ID and corresponds to the section in which the metric is described)

Category	**Essential Ecological Attribute**	**Indicators/Metrics**	**Tier**	**Field Value**	**Rating (E,G,F,P)**
LANDSCAPE CONTEXT	Landscape Context	Adjacent Land Use (B.1.1)	1		
		Buffer Width (B.1.2)	1		
		Percentage of unfragmented landscape within 1 km. (B.1.3)	1		
BIOTIC CONDITION	Community Composition	Percent of Cover of Native Plant Species (B.2.1)	2		
		Invasive Species – Plants (B.2.2)	2		
		Invasive Species – Amphibians (B.2.3)	2		
		Floristic Quality Index (Mean C) (B.2.4)	3		
	Patch Diversity	Biotic Patch Richness (B.2.5)	2		
		Interspersion of Biotic Patches (B.2.6)	2		
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland (B.3.1)	2		
		Sediment Loading Index (B.3.2)	1		
	Hydrological Regime	Flashiness Index (B.3.3)	3		

Category	Essential Ecological Attribute	Indicators/Metrics	Tier	Field Value	Rating (E,G,F,P)
		Surface Water Runoff Index (B.3.4)	1		
		Hydrological Alterations (B.3.5)	2		
	Chemical/ Physical Processes	Litter Cover (B.3.6)	2		
		Nutrient/ Pollutant Loading Index (B.3.7)	1		
		Nitrogen Enrichment (C:N) (B.3.8)	3		
		Phosphorous Enrichment (C:P) (B.3.9)	3		
		Soil Organic Carbon (B.3.10)	3		
		Soil Bulk Density (B.3.11)	3		
SIZE	Size	Absolute Size (B.4.1)	1		
		Relative Size (B.4.2)	1		

Table 2. Metric Ranking Criteria. Tier: 1 = Remote Sensing, 2 = Rapid, 3 =Intensive. (Alpha-numeric codes in parentheses is reference to the metric ID and corresponds to the section in which the metric is described). Confidence column indicates that reasonable logic and/or data support the index.

Category	**Essential Ecological Attribute**	**Indicators /Metrics**	**Tier**	**Definition**	**Confidence**	*Metric Ranking Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
LANDSCAPE CONTEXT	Landscape Context	Adjacent Land Use (B.1.1)	1	Addresses the intensity of human dominated land uses within 100 m of the wetland.	Medium	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 (B.1.2)	1	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	Medium/High	Wide > 100 m	Medium. 50 m to <100 m	Narrow. 25 m to 50 m	Very Narrow. < 25 m
		Percentage of unfragmented landscape within 1 km. (B.1.3)	1	An unfragmented landscape has no barriers to the movement and connectivity of species, water, nutrients, etc. between natural ecological systems.	Medium	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
BIOTIC CONDITION	Community Composition	Percent of Cover of Native Plant Species (B.2.1)	2	Percent of the plant species which are native to the Southern Rocky Mountains.	High	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

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Ranking Criteria* Excellent (A)	Good (B)	Fair (C))	Poor (D)
		Invasive Species – Plants (B.2.2)	2	Percent of marsh which is dominated by invasive, aggressive plants.	High	Native species such as *Typha* and *Phragmites*, if present, do not dominate wetland	Native species such as *Typha* and *Phragmites* and/or other non-native invasive species present but occupy less < 25% of wetland;	Native species such as *Typha* and *Phragmites* and/or other non-native invasive species present and occupy 25-75% of wetland;	Native species such as *Typha* and *Phragmites* and/or other non-native invasive species present and occupy >75% of wetland;
		Invasive Species – Amphibians (B.2.3)	2	Number of bullfrogs found in the marsh.	High	No bullfrogs present; Only native amphibians present	No bullfrogs present; Only native amphibians present	Bullfrogs as well as some native amphibians present.	Bullfrogs have displaced all native amphibians
		Floristic Quality Index (Mean C) (B.2.4)	3	The mean conservatism of all the native species growing in the wetland.	High	Mean C > 4.5	Mean C = 3.5-4.5	Mean C = 3.0 – 3.5	Mean C < 3.0
	Patch Diversity	Biotic/Abiotic Patch Richness (B.2.5)	2	The number of biotic/abiotic patches or habitat types present in the wetland.	Medium	> 75-100% of the possible patch types are evident in the wetland	> 50-75% of the possible patch types are evident in the wetland	25-50% of the possible patch types are evident in the wetland	< 25% of the possible patch types are evident in the wetland
		Interspersion of Biotic Patches (B.2.6)	2	The spatial arrangement of biotic/abiotic patch types within the wetland, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).	Medium	Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Ranking Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
ABIOTIC CONDITION	Energy/ Material Flow	Land Use Within the Wetland (B.3.1)	2	Addresses the intensity of human dominated land uses within the wetland.	Medium	Average Land Use Score = 1.0-0.95	Average Land Use Score = 0.80-0.95	Average Land Use Score = 0.4-0.80	Average Land Use Score = < 0.4
		Sediment Loading Index (B.3.2)	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.	Medium	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
	Hydrological Regime	Flashiness Index (B.3.3)	3	Measures the variability of water table fluctuations and rates it compared to a reference standard.	Medium	Flashiness Index = 1.0 - 2.0	Flashiness Index = 1.0 - 2.0	Flashiness Index = between 2.0 - 3.0 if wetland is NOT associated with riverine	Flashiness Index = > 3.0 if wetland is NOT associated with riverine environment
		Surface Water Runoff Index (B.3.4)	1	A measure of the varying degrees to which different land uses alters surface water runoff and overland flow into a wetland.	Medium	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	Confidence	*Metric Ranking Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Hydrological Alterations (B.3.5)	2	The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.	Medium	No alterations. No dikes, diversions, ditches, flow additions, or fill present in wetland that restricts or redirects flow	Low intensity alteration such as roads at/near grade, small diversion or ditches (< 1 ft. deep) or small amount of flow additions	Moderate intensity alteration such as 2-lane road, low dikes, roads w/culverts adequate for stream flow, medium diversion or ditches (1-3 ft. deep) or moderate flow additions.	High intensity alteration such as 4-lane Hwy., large dikes, diversions, or ditches (>3 ft. deep) capable to lowering water table, large amount of fill, or artificial groundwater pumping or high amounts of flow additions
	Chemical/ Physical Processes	Litter Cover (B.3.6)	2	The percent cover of plant litter or detritus covering the soil surface.	Low/Medium	Litter cover 75-125% of Reference Standard (Litter > 50% cover)	Litter cover 25-75% of Reference Standard (Litter 10-50% cover)	Litter cover 0-25% of Reference Standard (Litter cover present but sparse < 10%)	No litter present.
		Nutrient/ Pollutant Loading Index (B.3.7)	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.	Medium	Average Score = 0.9 – 1.0	Average Score = 0.8 – 0.89	Average Score = 0.75 – 0.79	Average Score = < 0.7
		Nitrogen Enrichment (C:N) (B.3.8)	3	The carbon to nitrogen (C:N) ratio in the aboveground biomass or leaves of plants. .	Medium/High	Leaf tissue C:N is equivalent to natural range of variability	Leaf tissue C:N is slightly less and outside of natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability

Category	Essential Ecological Attribute	Indicators /Metrics	Tier	Definition	Confidence	*Metric Ranking Criteria*			
						Excellent (A)	**Good (B)**	**Fair (C))**	**Poor (D)**
		Phosphorous Enrichment (C:P) (B.3.9)	3	The carbon to phosphorous (C:P) ratio in the aboveground biomass or leaves of plants.	Medium/High	Leaf tissue C:P is equivalent to natural range of variability	Leaf tissue C:P is slightly less and outside of natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability
		Soil Organic Carbon (B.3.10)	3	Measures the amount of soil organic carbon present in the soil.	Medium/High	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
		Soil Bulk Density (B.3.11)	3	A measure of the compaction of the soil horizons.	Medium/High	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.
SIZE	Size	Absolute Size (B.4.1)	1	The current size of the wetland	High	> 20 hectares	8 to 20 hectares	1 to 8 hectares	< 1 hectares
		Relative Size (B.4.2)	1	The current size of the wetland divided by the total potential size of the wetland multiplied by 100.	High	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.4 Scorecard Protocols

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. 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.

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

- #### A.4.1. 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) roll up the metrics into an overall Landscape Context rating.

Rationale for Scoring: Adjacent land use and buffer width 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 (B.1.1)	Addresses the intensity of human dominated land uses within 100 m of the wetland.	1	5	4	3	1	0.40	
Buffer Width (B.1.2)	Wetland buffers are vegetated, natural (non-anthropogenic) areas that surround a wetland.	1	5	4	3	1	0.40	

Measure	Definition	Tier	A	B	C	D	Weight	Score (weight x rating)
Percentage of unfragmented landscape within 1 km. (B.1.3)	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	0.20	
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.4.2. 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 Index (FQI) metric is judged to be more important than cover of native species and invasive species metric. The latter two provide very useful information, but the FQI provides a more reliable indicator of biotic condition.

Scoring for Biotic Condition is a bit more complex. For example, the Floristic Quality Index (FQI) 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 FQI 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 (B.2.1)	Percent of the plant species which are native to the Southern Rocky Mountains.	2	5	4	3	1	0.30 (0.55)	
Invasive Species – Plants (B.2.2)	Percent of marsh which is dominated by invasive, aggressive plants.	2	5	4	3	1	0.20 (0.45)	
Floristic Quality Index (Mean C) (B.2.4)	The mean conservatism of all the native species growing in the wetland.	3	5	4	3	1	0.50 (N/A)	
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.2.4 is not used.

▪ A.4.3. Abiotic Condition Rating Protocol

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

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

Table 5. Abiotic Condition Rating Calculation.

Measure	Definition	Tier	A	B	C	D	Weight*	Score (weight x rating)
Land Use Within the Wetland (B.3.1)	Addresses the intensity of human dominated land uses within the wetland.	2	5	4	3	1	0.25 (0.40)	
Hydrological Alterations (B.3.3)	The degree to which onsite or adjacent land uses and human activities have altered hydrological processes.	2	5	5	0	0	0.30 (0.60)	
Flashiness Index (B.3.5)	Measures the variability of water table fluctuations and rates it compared to a reference standard.	3	5	5	0	0	0.45 (N/A)	
Abiotic Condition Rating	A = 4.5 - 5.0 B = 3.5 – 4.4 C = 2.5 – 3.4 D = 1.0 – 2.4							**Total =** (sum of N scores

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

▪ A.4.4. 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.

▪ A.4.5. Overall Ecological Integrity Rating Protocol

If an Overall Ecological Integrity Score is desired for a site, then a weighted-point system should be used with the following rules:

1. If Landscape Context = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]** **Note:** For this calculation ONLY consider Relative Size for Size Score

2. If Landscape Context is *B*, *C*, or *D* AND Size = *A* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Size Score * (0.25)] + [Landscape Context Score * (0.15)]**

3. If Landscape Context is *B*, *C*, or *D* AND Size = *B* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.20)] + [Size Score * (0.20)]**

4. If Landscape Context is *B*, *C*, or *D* AND Size = *C* or *D* then the Overall Ecological Integrity Rank = **[Abiotic Condition Score *(0.35)] + [Biotic Condition Score *(0.25)] + [Landscape Context Score * (0.25)] + [Size Score * (0.15)]** **Note:** For this calculation use both Absolute and Relative Size for Size Score.

The Overall Ecological Rating is then assigned using the following criteria:

A = 4.5 - 5.0
B = 3.5 – 4.4
C = 2.5 – 3.4
D = 1.0 – 2.4

B. PROTOCOL DOCUMENTATION FOR METRICS

B.1 Landscape Context Metrics

▪ B.1.1. 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 and riparian 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* = $\sum$ LU x PC/100
>
> where**:** LU = Land Use Score for Land Use Type; PC = % of adjacent area in Land Use Type.

Do this for each land use within 100 m of the wetland edge, then sum 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.

- ### B.1.2. 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 and riparian 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 in the Southern Rocky Mountains.

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

▪ B.1.3. 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 and riparian 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.

B.2 Biotic Condition Metrics

- **B.2.1. Percent of Cover of Native Plant Species**

Definition: Percent of the plant species which are native to the Southern Rocky Mountains.

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

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

Measurement Protocol: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the marsh system should be walked and a qualitative ocular estimate of the total cover of native species growing in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. 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 Utah, Wyoming, and Montana (NRCS 2005), data and descriptions in Cooper (1990), Windell et al. (1996), CNHP (2005), and best scientific judgment. These are tentative hypotheses as they have not been validated with quantitative data. The Colorado Natural Heritage Program is currently developing a Vegetation Index of Biotic Integrity. Data from this project will likely provide the necessary information to confirm, validate, and improve the criteria.

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

▪ B.2.2. Invasive Species - Plants

Definition: Percent of marsh which is dominated by invasive plants.

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

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

Measurement Protocol: A qualitative, ocular estimate of cover is used to calculate and score the metric. The entire occurrence of the marsh system should be walked and a qualitative ocular estimate of the total cover of invasive species growing in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is calculated by dividing the total cover of invasive species by the total cover of all species and multiplying by 100. The metric is calculated by dividing the total cover of invasive species by the total cover of all species and multiplying by 100.

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

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

Data: N/A

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

- **B.2.3. Invasive Species - Amphibians**

Definition: Number of bullfrogs found in the marsh.

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

Rationale for Selection of the Variable: Bullfrogs are non-native to the Southern Rocky Mountain and Central Shortgrass Prairie region (Hammerson 1999). Bullfrogs are also known to be tolerant of disturbances (Micacchion 2002) and will displace other native amphibians (Hammerson 1999). When present, bullfrogs indicate a disruption to the native amphibian community.

Measurement Protocol: Bullfrogs can be easily observed or heard during a site visit due to their large size and recognizable vocalizations. Walk the wetland, including submerged areas along the shoreline to observe the present of bullfrogs and their immature forms.

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

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
No bullfrogs present; Only native amphibians present	No bullfrogs present; Only native amphibians present	Bullfrogs as well as some native amphibians present.	Bullfrogs have displaced all native amphibians

Data: N/A

Scaling Rationale: The criteria are based on and best scientific judgment. Data are not available to distinguish between Excellent and Good, thus these are lumped into one category. These are tentative hypotheses as they have not been validated with quantitative data.

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

- **B.2.4. Floristic Quality Index (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 and riparian 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 personal communication, 2005).

The Floristic Quality Index (FQI), originally developed for the Chicago region (Swink and Wilhelm 1979, 1994) is a vegetative 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). FQI 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).

The Colorado Floristic Quality Assessment Panel is currently assigning coefficients of conservatism to the Colorado flora. Initial testing of the Colorado FQI should begin in 2006 and available for use shortly thereafter. However, calibration of the FQI will likely occur over many years of use and thus this metric will need to be updated accordingly.

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 wetland 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 (Mack 2004; Peet et al. 1998).

The metric is calculated by referencing only native species C value from the Colorado FQI Database (*in development*; *expected to be completed in 2006*), summing the C values, and dividing by the total number of native species (Mean C).

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

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

Data: Colorado FQI Database (*in development*; *expected to be completed in 2006*)

Scaling Rationale: In the Midwest, field studies using FQI 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). 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 (Wilhelm and Masters 1995). 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 FQI literature. Although it is not know if these same thresholds are true for the Southern Rocky Mountains, they have been used to construct the scaling for this metric. As the FQI is applied in this region, the thresholds may change.

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

- ### B.2.5. Biotic/Abiotic Patch Richness

Definition: The number of biotic/abiotic patches or habitat types present in the wetland. The metric is not a measure of the spatial arrangement of each patch.

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

Rationale for Selection of the Variable: Ecological diversity of a site is correlated with biotic/abiotic patch richness (Collins et al. 2004). Unimpacted sites have an expected range of biotic/abiotic patches. Human-induced alterations can decrease patch richness.

Measurement Protocol: This metric is measured by determining the number of biotic/abiotic patches present at a site and dividing by the total number of possible patches for the specific wetland (see Table 4). This percentage is then used to rate the metric 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**
> 75-100% of the possible patch types are evident in the AA	> 50-75% of the possible patch types are evident in the AA	25-50% of the possible patch types are evident in the AA	< 25% of the possible patch types are evident in the AA

Data:

Table 8. Biotic/Abiotic Patch Types in Wet Meadows

Patch Type
Open water –stream
Oxbow/backwater channels
Tributary or secondary channels
Open water – beaver pond
Active beaver dams
Occasional trees
Occasional shrubs
Adjacent or onsite hillside seeps/springs
Beaver canals
Submerged/floating vegetation
Emergent vegetation

TOTAL = 11

Scaling Rationale: The scaling criteria are based on Collins et al. (2004); however, best scientific judgment was used to modify patch types to correspond with Southern Rocky Mountain wetlands.

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

- **B.2.6. Interspersion of Biotic/Abiotic Patches**

Definition: Interspersion is the spatial arrangement of biotic/abiotic patch types within the wetland, especially the degree to which patch types intermingle with each other (e.g. the amount of edge between patches).

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

Rationale for Selection of the Variable: Spatial complexity of biotic/abiotic patches is indicative of intact ecological processes (Collins et al. 2004). Unimpacted sites have an expected spatial pattern of biotic/abiotic patches. Human-induced alterations can decrease this complexity and homogenize patch distribution.

Measurement Protocol: This metric is measured by determining the degree of interspersion of biotic/abiotic patches present in the wetland. This can be completed in the field for most wetlands, however aerial photography may be beneficial for larger sites (Collin et al. 2004). The metric is rated by matching site interspersion 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**
Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type	Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches,	Horizontal structure consists of one dominant patch type and thus has relatively no interspersion

Data: See B.2.5 for list and definitions of Biotic Patches.

Scaling Rationale: The scaling criteria are based on Collin et al. (2004), however best scientific judgment was used to modify criteria to correspond with Southern Rocky Mountain wetlands.

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

B.3 Abiotic Condition Metrics

▪ B.3.1. 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 and riparian 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 6) with some manipulation to account for regional application) into the following equation:

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

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

Do this for each land use, 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 9. Current Land Use and Corresponding Land Use Coefficients (based on Table 21 in Hauer ete 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.

- ### B.3.2. 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 and riparian 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 (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 restoreable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

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

- ### B.3.3. Flashiness Index

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

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

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

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

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

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

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

Water levels can be read with a steel measuring tape marked with a water-soluble marker. The only equipment needed is the tape, marker, and a rag to wipe the tape dry after each reading. The height of the well above the ground surface should be noted every time the instrument is read because pipes are known to move (U.S. Army Corps of Engineers). Another simple measuring tool for measuring water levels is that described in Henszey (1991). This instrument is attached to a meter tape, lowered into the well, and beeps when it contacts water, at which point a measurement is taken from the tape and subtracted from the height of the well above the soil surface to give the depth of the water table.

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

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

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

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

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

Data: Appendix B.

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

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

- ### B.3.4. 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 and riparian 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 (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 restoreable (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.

▪ B.3.5. Hydrological Alterations

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

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

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

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

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

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

Data: N/A

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

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

▪ B.3.6. Litter Cover

Definition: The percent cover of plant litter or detritus covering the soil surface.

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

Rationale for Selection of the Variable: Litter cover provides an indication of the amount of organic matter produced and recycled in the wetland. Disturbed wetlands often have different amounts of litter cover than reference sites due to a change in species composition, productivity, and decomposition.

Measurement Protocol: Litter cover is measured using the same protocols as vegetation. A qualitative, ocular estimate of litter cover is used to calculate and score the metric. The entire occurrence of the marsh system should be walked and a qualitative ocular estimate of the total cover of litter in the wetland should be made. Alternatively, if time and resources allow a more quantitative determination of species presence and cover such methods (i.e. Peet et al. 1998) are encouraged to be used. The metric is scored by comparing current litter cover values to those of reference or baseline conditions.

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 Amount	Slight change from Reference Amount	Moderate change from Reference Amount	Large change from Reference Amount

Data: The Colorado Vegetation Index of Biotic Integrity project will likely provide the necessary data to establish the range of litter cover found in undisturbed examples.

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

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

- ### B.3.7. 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 and riparian 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 (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 restoreable (based on the land uses that have coefficients below 0.7). Additional research may suggest changes to the scaling criteria.

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

▪ B.3.8. Nutrient Enrichment (C:N)

Definition: The carbon to nitrogen (C:N) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess N in the system (compared to reference standard). Increasing leaf N decreases the C:N ratio and indicates nitrogen enrichment.

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

Rationale for Selection of the Variable: Nitrogen enrichment causes vegetation to increase uptake and storage of nitrogen in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996 *in* U.S. EPA 2002). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996 *in* U.S. EPA 2002) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999 *in* U.S. EPA 2002). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002). See U.S. EPA (2002) for additional information.

Nitrogen is typically measured by dry combustion using a CHN analyzer. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:N is equivalent to natural range of variability	Leaf tissue C:N is slightly less and outside of natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability	Leaf tissue C:N is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:N ratios 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 nutrient enrichment. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established.

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

- **B.3.9. Nutrient Enrichment (C:P)**

Definition: The carbon to phosphorous (C:P) ratio in the aboveground biomass or leaves of plants is used to determine whether there is excess P in the system (compared to reference standard). Increasing leaf P decreases the C:P ratio and indicates phosphorous enrichment.

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

Rationale for Selection of the Variable: Phosphorous enrichment causes vegetation to increase uptake and storage of phosphorous in plant tissue and generally results in increased productivity (Craft et al. 1995, Bridgham et al. 1996 *in* U.S. EPA 2002). These changes affect ecosystem processes including decomposition (Valiela et al. 1982, Davis 1991, Rybczyk et al. 1996 *in* U.S. EPA 2002) and accumulation of soil organic matter (Craft and Richardson 1993, 1998, Morris and Bradley 1999 *in* U.S. EPA 2002). Floristic composition may change as aggressive, competitive species take advantage of increased nutrients and displace less competitive species. All of these changes degrade the ecological integrity of the wetland by altering energy flow, nutrient cycling, and potential habitat for fauna assemblages (U.S. EPA 2002).

Measurement Protocol: Herbaceous plants are preferentially sampled because they respond to nutrient enrichment quicker than woody species (U.S. EPA 2002). Two or three dominant species should be selected for sampling. Samples should be collected from plants of a similar age and clipped from nodes a similar distance below the terminal bud (U.S. EPA 2002). The plants should be growing in similar habitats. If habitat is heterogeneous, then it is best to sample from each dominant habitat type. Multiple samples should be collected from several individual plants (5-10) to capture variability within the population. It is important to make collections from the same species at each site so that variation in leaf tissue nutrient concentrations is minimized (U.S. EPA 2002). See U.S. EPA (2002) for additional information.

Phosphorous is typically measured by spectrophotometry in acid (H_2SO_4-H_2O_2) digests. Each clipped sample should be placed in their own individual paper bag and sent to a laboratory for analysis of soil organic carbon (e.g., CHN Analyzer). Do not put the sample in a plastic bag as this could induce decomposition of the sample.

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

Measure (Metric) Rating			
Excellent	**Good**	**Fair**	**Poor**
Leaf tissue C:P is equivalent to natural range of variability	Leaf tissue C:P is slightly less and outside of natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability	Leaf tissue C:P is significantly lower than natural range of variability

Data: N/A

Scaling Rationale: Reference C:P ratios 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 nutrient enrichment. If data are collected from wetlands across a disturbance gradient, quantitative criteria could be established.

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

- ### B.3.10. 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 and riparian 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.

- ### B.3.11. 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 and riparian 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.4 Size Metrics

- **B.4.1. 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 and riparian 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.

Metric Rating			
Excellent	**Good**	**Fair**	**Poor**
> 20 hectares	8 to 20 hectares	1 to 8 hectares	< 1 hectares

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.

▪ B.4.2. 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 and riparian 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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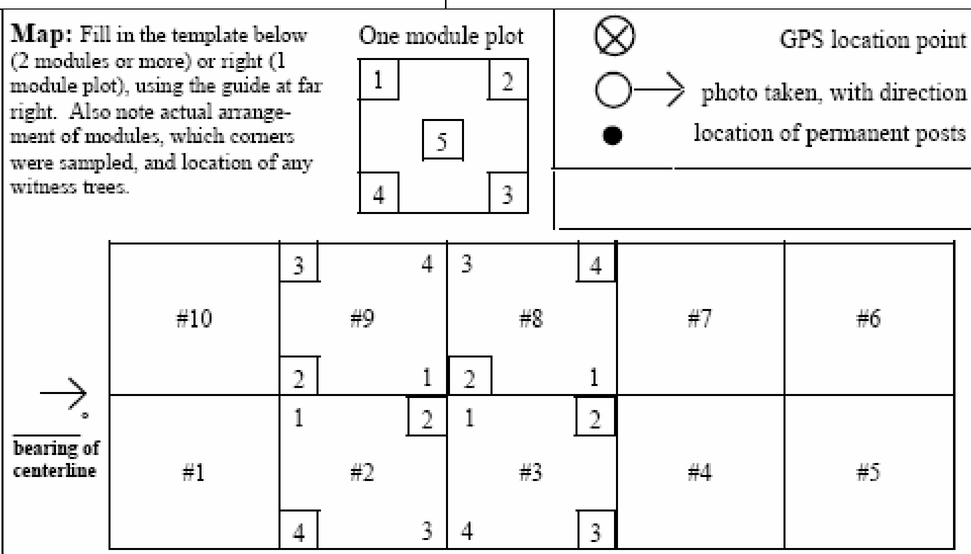
APPENIDX A: FIELD FORMS

Scorecard Field Form, pg 1 of 5

General Information	Location		Site Characteristics	
Project	General:		Elevation (m/ft):	
Team:	County:		Slope (deg):	
Plot:	USGS quad:		Aspect (deg):	
Date (Start): / /	Ownership:		Compass: magnetic /corrected	
Date (End): / /	GPS location in plot: x= y=		Buffer width:	
	UTM Zone: 13		% unfragmented area of wetland:	
Plot Documentation	Uncorrected	UTM-E:		
Cover method:		UTM-N:	**Land use w/in 100m of wetland**	
		Coord. Accuracy (m radius):	Types:	Relative %:
Photos				
Film roll: /Frame(s)	GPS File Name:			
Focal length:	T: R: S:			



Land use in contributing watershed	
Ground watershed	
Surface watershed	

Physiognomic Class*
- __ I Forest
- __ II Woodland
- __ III Shrubland
- __ IV Dwarf Shrubland
- __ V Herbaceous
- __ VI Nonvascular
- __ VII Sparsely vegetated

Leaf Type*
- __ B Broad-leaved
- __ N Needle-leaved
- __ M Microphyllous
- __ G Graminoid
- __ F Forb
- __ P Pteridophyte

Leaf Phenology*
- __ EG Evergreen
- __ CD Cold-deciduous
- __ DD Drought- deciduous
- __ MC Mixed evergreen- cold deciduous
- __ MD Mixed evergreen- drought deciduous

Soil Chemistry*
- ____ pH
- ____ Conductivity
- ____ Temperature

Cowardin System*
- __ UPL Upland
- __ EST Estuarine
- __ RIP Riparian
- __ PAL Palustrine
- __ LAC Lacustrine

Community Classification*
- CNHP Type ___________________
- Cowardin ____________________
- HGM________________________
- Classifier ___________________
- Date ________________________

** Definitions and/or values are in the Reference section of the Pulse Field Guide

Scorecard Field Form, pg 2 of 5

Present?	Biotic/abiotic patch type	√ one	Interspersion of patches
	Open water –stream		**Excellent:** Horizontal structure consists of a very complex array of nested and/or interspersed, irregular biotic/abiotic patches, with no single dominant patch type.
	Open Water - Pools		
	Open Water – Rivulets/Streams –fen		
	Open water – beaver pond		**Good:** Horizontal structure consists of a moderately complex array of nested or interspersed biotic/abiotic patches, with no single dominant patch type.
	Oxbow/backwater channels		
	Tributary or secondary channels		
	Streams – pool/riffle complex		**Fair:** Horizontal structure consists of a simple array of nested or interspersed biotic/abiotic patches.
	Active beaver dams		
	Wet meadows		**Poor:** Horizontal structure consists of one dominant patch type and thus has relatively no interspersion.
	Occasional trees		
	Point bars		**Abundance of willows/cottonwoods**
	Adjacent hillside seeps/springs		**Excellent:** Saplings/seedlings present in expected amount; obvious regeneration
	Beaver canals		
	Interfluves on floodplain		**Good:** Saplings/seedlings present but less than expected; some seedling/saplings present
	Debris jams (woody debris) in stream		
	Mudflats		**Fair:** Saplings/seedlings present but in low abundance; Little regeneration by native species
	Saltflats		
	Submerged/floating vegetation		**Poor:** No reproduction of native woody species
	Emergent vegetation		**Beaver Activity**
	Moss bed		**Excellent:** New, recent, and/or old beaver dams present. Beaver currently active in the area.
	Occasional shrubs		
	Emergent vegetation		**Good:** Recent and old beaver dams present. Beaver may not be currently active but evidence suggests that have been with past 10 years.
	Hummock/tussock - fen		
	Water Tracks/Hollows - fen		
	Lawns - fen		**Fair:** Only old beaver dams present. No evidence of recent or new beaver activity despite available food resources and habitat.
	Floating Mat - fen		
	Spring fen		**Poor:** No beaver dams present when expected (in unconfined valleys).
	Shrubs - fen		
	Marl/Limonite beds - fen		

Ground Cover (%)

Bryo/lichen:	Sand/soil:
Decaying wood:	Water:
Bedrock/boulder:	Litter/OM:
Gravel/cobble:	Other

Cover by Strata

Canopy height (m):

Abr.	Stratum	Height range (m)	Total Cover (%)
S	Shrub		
F	Forb		
G	Graminoid		
T	Tree		
FL	Floating		
A	Aquatic submerged		

Landform type*: ______________________________

√ one	Relative Size
	Excellent: Wetland area = outside abiotic potential
	Good: Wetland area < abiotic potential; Relative size = 90 – 100%; (<10% of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.
	Fair: Wetland area < abiotic potential; Relative size = 75 – 90%; (10-25% of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.
	Poor: Wetland area < abiotic potential; Relative size = <75 – > 25 %; of wetland has been reduced, destroyed or severly disturbed due to roads, impoundments, development, human-induced drainage, etc.

** Definitions and/or values are in the Reference section of the Pulse Field Guide

Scorecard Field Form, pg 3 of 5

<table>
<tr><td rowspan="5">Diversions in/near wetland?</td><td colspan="2">Water Source (√ one)</td></tr>
<tr><td>Ground water</td><td></td></tr>
<tr><td>Seasonal surface water</td><td></td></tr>
<tr><td>Permanent surface</td><td></td></tr>
<tr><td>Precipitation</td><td></td></tr>
<tr><td>Layout Notes: (anything unusual about plot layout and shape)</td><td colspan="2" rowspan="2">Hydro Regime*

__ SP Semipermanently flooded
__ SE Seasonally flooded
__ ST Saturated
__ TM Temporarily flooded
__ IN Intermittently flooded
__ PR Permanently flooded
__ TD Tidally flooded
__ IR Irregularly flooded
__ IE Irregularly exposed
__ UN Unknown
__ RD Rapidly drained
__ WD Well drained
__ MW Moderately well drained
__ SP somewhat poorly drained
__ PD Poorly drained
__ VP Very poorly drained</td></tr>
<tr><td>Location Notes: (include why location was chosen and a small map, more space on reverse)</td></tr>
<tr><td>Vegetation Notes: (characterization of community, dominants, and principle strata)</td><td colspan="2" rowspan="2">Topographic Position *

__ H interfluve (crest,summit,ridge)
__ E High slope (shoulder, upper, convex)
__ M High level
__ D Mid slope
__ F Back slope (cliff)
__ C Low slope (lower, foot, colluvial)
__ B Toeslope
__ G Low level (terrace)
__ J Channel wall (bank)
__ K Channel bed (valley bottom)
__ I Basin floor (depression)</td></tr>
<tr><td>Additional Notes:</td></tr>
</table>

** Definitions and/or values are in the Reference section of the Pulse Field Guide

Scorecard Field Form, pg 4 of 5

Soils Data

Horizon	Range (depth cm)	Texture	Soil & Mottle Color	Depth to water table (cm)	Depth to Saturated Soils (cm)	Depth of Peat (cm)	Structure	% Coarse (Est.% per horizon by type- gravel, cobble, boulder)	Comments (90% root depth, charcoal, etc.) Mottle Abundance(few <2%, common 2-20%, many >20%), Size (fine <5 mm dia., medium 5-15 mm, large >15 mm) and Contrast (faint-similar to matrix, distinct-contrast slightly, prominent-mottles vary by several units of hue, value or chroma)

Scorecard Field Form, pg 5 of 5

Vegetation Plot data (see Carolina Vegetation Survey for digital versions of their data forms: http://www.bio.unc.edu/faculty/peet/lab/CVS/)

Species Code	2	2	2	4	3	2	3	3	8	2	8	4	9	2	9	3	R	R

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