Wetland Profile and Condition Assessment of the Goshen Hole Wetland Complex, Wyoming

FINAL REPORT

January 22, 2016

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The Nature Conservancy

WYOMING GAME & FISH DEPARTMENT

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Prepared for:
U.S. Environmental Protection Agency, Region 8
1595 Wynkoop Street
Denver, CO 80202

EPA Assistance ID No. CD-96813601-0

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This document should be cited as follows:

Tibbets, T. M., L. Washkoviak, S.A. Tessmann, G. Jones and H.E. Copeland. 2016. Wetland Profile and Condition Assessment of the Goshen Hole Wetland Complex, Wyoming. Report to the U.S. Environmental Protection Agency. The Nature Conservancy – Wyoming Chapter, Lander, Wyoming. 54 pp. plus appendices.

Cover photographs: Teresa Tibbets and Lindsey Washkoviak

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EXECUTIVE SUMMARY

This report summarizes results of the first basin-wide assessment of wetlands in the Goshen Hole Wetland Complex (GHWC). The study was based on a rigorous field survey protocol applied within a sample of randomly-selected sites. The four objectives were: [1] create a landscape level wetland profile of the Goshen Hole Basin; [2] conduct a statistically valid, field-based assessment of wetland condition; [3] model the distribution of wetland conditions throughout the basin; and [4] determine key wetland habitat features and resources important to wetland-dependent wildlife species.

The landscape profile results demonstrate the importance of understanding linkages between land use, irrigation practices and wetlands in the GHWC. Wetlands and water bodies total 9,669 acres or approximately 3% of the total land area within the GHWC. Sixty-six percent of the wetlands are freshwater emergent wetlands, which include irrigated hayfields. Over 70% of wetlands are privately owned. Coordination with private landowners is essential to maintain the ecological integrity of wetland resources throughout the GHWC.

We developed a multi-level approach to estimate wetland condition within the GHWC. Ecological Integrity Assessment (EIA) methods were supplemented by measurements of anthropogenic and hydrologic disturbance, baseline characteristics of wetland vegetative communities, and hydrologic alteration. Level 2 wetland condition assessments using EIA methods were developed to measure the condition of wetlands in the basin. Metric scores can be used to convey a general overview of the condition of wetlands and to determine where there are large differences in conditions. A and B ranked wetlands indicate high potential for ecological integrity and conservation value. Management of these wetlands should focus on the prevention of further alteration. Lower-ranking wetlands have disturbance across multiple EIA metrics indicating that management would be needed to maintain or restore ecological attributes.

The four wetland subgroups identified within our sample frame were: riparian woodland and shrubland; emergent marsh; wet meadow; and playa and saline depressions. Our study found that all ecological subgroupings were dominated by C-ranked wetlands, meaning there was evidence of moderate levels of disturbance and deviation from reference condition. Two percent of the 68 study sites in the GHWC were A-ranked (no or minimal impact), 21% were B-ranked (slight impact), 69% were C-ranked (moderate impact), and 9% were D-ranked (significant impacted). Playas and saline depressions were the least disturbed wetland type, followed by riparian woodland and shrublands. The highest proportion of D-ranked sites was wet meadows that comprised 10 % of sampled wetlands. We used cumulative distribution function projections to extrapolate our results to the wetland population within the GHWC. Those extrapolations indicate 1.4% of wetlands in the GHWC are A-ranked, 22% B-ranked, 68% C-ranked and 9% D-ranked. These results closely resemble the results obtained from sampled wetlands and indicate approximately 77% of wetlands in the basin are moderately to significantly disturbed.

We collected data documenting stressors that may influence EIA attribute condition. The most widespread anthropogenic disturbances (stressors) identified across all wetland types were presence of invasive plant species surrounding and within the wetland and impacts from grazing by domestic and native herbivores such as soil compaction. Anthropogenic disturbances related to agricultural production and development, such as the presence of unpaved roads and irrigation infrastructure, represent the next most common stressors. Land management policies that discourage further human disturbance and encourage sustainable agricultural practices in and near wetlands will help to maintain wetland function and prevent further declines in condition.

Our results point to the challenge of quantitatively assessing ecological condition of wetlands in irrigated basins because many wetlands, regardless of ecological integrity, are influenced by hydrologic alterations. We developed a Landscape Hydrology Metric (LHM) that identified modified hydrology at 90% of sampled wetlands. Although irrigation and related agricultural activities are generally considered disturbance factors, water availability to wetlands is also enhanced by irrigation, especially in arid regions. Hydroperiod of many wetland basins is extended by nearby irrigation and other wetlands exist solely as a byproduct of irrigation runoff or seepage. These types of created and modified wetlands can provide highly valuable habitat.

Our avian surveys confirm *at least* 126 bird species use wetlands in the GHWC during the breeding season. Interestingly, wetlands with lower landscape attribute scores and higher relative cover of non-native vegetation were correlated with higher bird diversity. In addition, wetlands with hydrologic alterations (lower LHM scores) were associated with greater abundance of birds. Our results suggest that hydrologic modifications can have positive impacts on habitat for some bird species. In general, higher bird diversity and abundance and presence of benthic macroinvertebrates were observed in wetlands with permanent water, such as emergent marshes and riparian woodland and shrublands. Although scores of multiple EIA metrics were consistently low in wet meadows, our data indicate that these wetlands do provide important avian habitat. It is likely that wetlands influenced by hydrologic alterations, including inputs from flood irrigation and ditches, provide a stable water source and adequate habitat for wetland birds during dry summer months. Wetlands supported by irrigation and urban runoff have become recognized as providing critically important habitat within arid and securing these water resources will likely benefit wetland wildlife.

The ecological challenges of conserving and managing hybrid and novel ecosystems are increasingly recognized. This recognition represents a shift from the traditional paradigm that pristine landscapes have the highest ecological value – all wetlands within working landscapes have intrinsic values. The wetland systems we studied constitute a novel or hybrid system resulting from anthropogenic alterations within the GHWC landscape. Understanding the function of entire landscapes, including the spectrum of historic to created wetlands, will be necessary for effective decision-making and management in the basin. Traditional EIA metrics are biased in their assumption that anthropogenic disturbance is always equated with diminished condition and function. Recognizing this broad assumption may not necessarily hold true everywhere (e.g., on arid landscapes modified by agricultural irrigation), we included LHM, floristic quality, and avian richness metrics in our analysis to better understand interrelationships between hydrology and habitat value.

ACKNOWLEDGEMENTS

This project was funded by a Wetland Program Development Grant (#CD-96813601-0) from the U.S. Environmental Protection Agency Region 8. The framework for this study was informed by the State Wildlife Wetlands Conservation Strategy (Wyoming Joint Ventures Steering Committee 2010), the State Wildlife Action Plan (Wyoming Game and Fish Department 2010), and the Wyoming Bird Conservation Habitat Partnership including representatives from Wyoming Game and Fish Department (WGFD), Wyoming Department of Environmental Quality (DEQ), United States Fish and Wildlife Service, The Nature Conservancy, Ducks Unlimited, Intermountain West Joint Ventures, Wyoming Audubon, and Rocky Mountain Bird Observatory.

We would like to thank Chad Reiger at Wyoming DEQ for providing guidance and support for the study proposal. We would also like to thank Matt Reddy from Ducks Unlimited for contributing matching funds for the project. We extend our gratitude to Rich Sumner and Tony Olsen of the U.S. Environmental Protection Agency and Joanna Lemly and Laurie Gilligan of the Colorado Natural Heritage Program for assistance with survey design, method development, and data analysis. We thank our field technician, David Schimelpfenig, for his hard work collecting and entering data. Grant Frost from the WGFD completed the bird surveys, macroinvertebrate identification, and avian database research that were integral to the completion of the wetland habitat component of the project.

This study would not be possible if not for the public land managers and private landowners that granted access to wetlands on their lands. We extend our gratitude to landowners for their support of this project.

1.0 INTRODUCTION

Freshwater wetland ecosystems are highly diverse, productive transitional habitats between aquatic and terrestrial ecosystems. Wetlands provide many vital ecosystem services including flood attenuation, stream flow maintenance, aquifer recharge, sediment retention, water quality improvement, production of food and goods for human use, and maintenance of biodiversity. The global economic value of ecosystem services provided by wetlands is estimated to be higher than that of lakes, streams, forests, and grasslands and second only to services provided by coastal ecosystems (Costanza et al. 1997). Wetland ecosystems support critical habitat for wildlife – more than a third of species listed as threatened or endangered in the United States live solely in wetlands and almost half use wetlands at some point in their life cycle (US EPA 1995). In the Intermountain West, more than 140 bird species, 30 mammals, 36 amphibians, and 30 reptiles are either dependent on or associated with wetlands (Gammonley 2004). Approximately 90% of the wildlife species in Wyoming use wetland and riparian habitats daily or seasonally during their life cycle, and about 70% of Wyoming bird species are considered wetland or riparian obligates (Nicholoff 2003).

Wetlands provide a host of ecosystem services, but remain highly threatened and subjected to pressures from many uses including agricultural, residential, and energy development. Dahl (1990) estimates 38% of wetlands that existed prior to European settlement in Wyoming were lost between 1780 and the mid-1980s. Recent studies identified wetlands as one of the habitat types most vulnerable to impacts of future development and climate change in Wyoming (Copeland et al. 2010, Pocewicz et al. 2014). In light of these threats, and a general lack of information about current status of wetlands in Wyoming, an evaluation of existing wetland conditions was urgently needed to better inform conservation and management priorities.

Recent studies in Colorado (Lemly and Gilligan 2012), Montana (Newlon et al. 2013), and Wyoming (Tibbets et al. 2015) have utilized landscape profiles and rapid assessment methods (RAMs) to draw conclusions regarding the ecological integrity of wetland resources. Landscape profiles primarily utilize digital information or remote sensing data to provide a "desktop analysis" of wetlands at a landscape scale. Landscape profiles are used to quantify the distribution of resources, such as wetland types or area, and to develop strategic goals at a landscape scale (Gwin et al. 1999). RAMs assess the condition of wetlands based on field surveys that measure abiotic and biotic indicators of ecological function and indicators of stress, that have the potential to negatively impact wetlands. Together, landscape profiles and RAMs can be used to establish baseline wetland conditions, assess cumulative impacts, and to prioritize protection and restoration efforts. This project was the third basin-scale wetland condition assessment within Wyoming, and builds upon landscape profiles and RAMs completed within the Laramie Plains Basin (Tibbets et al. 2016), the Upper Green River Basin (Tibbets et al. 2015), and a previous statewide assessment (Copeland et al. 2010).

The Goshen Hole Wetland Complex (GHWC) is one of nine wetland complexes identified as a statewide conservation priority (Copeland et al. 2010) and one of eight focus areas identified by the USFWS Partners Program Strategic Plan (USFWS 2007). Goshen Hole is also among the 48 priority bird habitat conservation areas identified in the Intermountain West Joint Venture's (IWJV) Coordinated Implementation Plan (IWJV 2013) and a key habitat area identified in the State Wildlife Action Plan (SWAP) based on the presence of 46 vertebrate Species of Greatest Conservation Need (WGFD 2010). The GHWC provides important breeding, staging and stopover habitat for waterfowl, waterbirds, and numerous other avian species. Seventeen duck species have been documented in the Goshen Hole area and these wetlands support over 200,000 Canada geese (*Branta Canadensis*), 100,000 Snow (*Chen caerulescens*) and Ross' (*Chen rossii*) geese, and at least 30,000 ducks during fall and spring migration periods (WGFD 2005, 2010, WBHCP 2014). In addition, up to 57,000 Canada geese from the Hi-Line Population overwinter in the Goshen Hole area (Roberts 2013).

1.1 Objectives

The four objectives of this project were: [1] create a landscape profile of the Goshen Hole Wetlands Complex; [2] conduct a statistically valid, field-based assessment of wetland condition, [3] model the distribution of wetland types and their condition throughout the basin, and [4] determine key wetland habitat features and resources important to wetland-dependent wildlife inhabiting the region.

2.0 STUDY AREA

The GHWC study area is a low-lying basin known as "Goshen Hole" located in central Goshen County, southeastern Wyoming. The study area encompasses 314,217 acres (127,159 ha) within the floodplain of the lower North Platte River and a short stretch of the Laramie River at its confluence with the North Platte, as well as the Horse Creek and Cherry Creek Drain watersheds (Figure 1). Elevations range from 4,000 – 4,600 feet and are among the lowest in the State. Recent human population estimates for Goshen County and its largest city, Torrington, were 13,514 and 6,737, respectively (U. S. Census Bureau 2010). Land ownership within the study area is predominantly private and the dominant land use is agriculture. Principal agricultural uses are irrigated and dryland crops and native rangeland.

Average annual precipitation ranges from 12-16 inches, mostly falling as rain during April-July (Curtis and Grimes 2004). Hydrology of the North Platte River, Laramie River and Horse Creek is highly regulated by dams, diversions, and canals upstream and within the study area. Major upstream impoundments include Seminoe, Kortes, Pathfinder, Alcova, Gray Reef, Glendo, Guernsey, and Grayrocks reservoirs, which cumulatively store over three million acre-feet supplying water to generate power and irrigate over 226,000 acres.

The GHWC lies within the High Plains Level III ecoregion (Chapman et al. 2004). Level IV ecoregions within the study area include Platte River Valley and Terraces, and Moderate Relief Rangeland (Chapman et al. 2004). Most of the study area is located within the Platte River

Valley and Terraces ecoregion and includes riparian floodplain habitats that support plains cottonwood (*Populus deltoides*), snowberry (*Symphoricarpos spp*.), wild plum (*Prunus americana*.), and silver buffaloberry (*Shepherdia argentea*). Upland mixed-grass prairie vegetation is dominated by blue gramma (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), June grass (*Koeleria macrantha*), Sandberg bluegrass (*Poa segunda*), needle-and-thread grass (*Hesperostipa comate*), rabbitbush (*Chrysothamnus sp.)*, fringed sage (*Artemisia frigida*), and various grass, forbs, and shrub species.

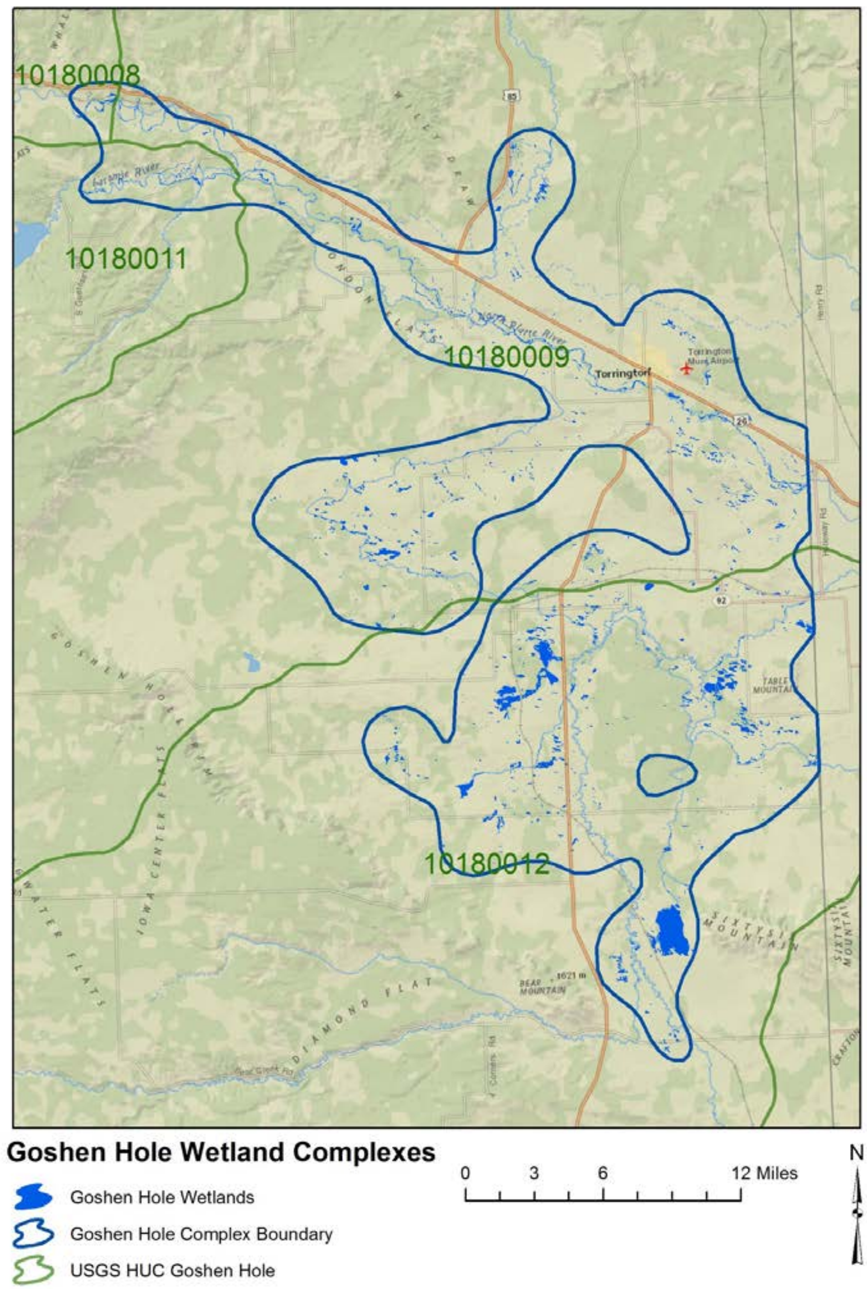

Figure 1. Goshen Hole Wetland Complex study area (HUC 8s: 10180009; 10180012) located in southeast Wyoming.

3.0 METHODS

3.1 Wetland Landscape Profile and Condition Assessment Framework

Wetland landscape profiles and condition assessments can be effective methods to inventory and summarize the distribution and diversity of wetland resources, and can be used to establish baseline conditions, assess cumulative impacts to wetland condition and function, and inform the development of strategic conservation goals (Fennessy et al. 2007, Lemly and Gilligan 2012). A number of sampling methodologies have been developed in the past fifteen years to monitor wetland condition at various spatial scales (Adamus 1993, DeKeyser et al. 2003, Jacobs et al. 2010, U.S. Environmental Protection Agency 2011, Lemly and Gilligan 2012, Vance et al. 2012). Currently, a "three-tiered" approach is recommended by the US Environmental Protection Agency (EPA), with each level increasing in the detail of data and information generated, accompanied by increasing degrees of effort, cost, and resolution:

- Level 1 assessments characterize land uses and distribution of resources such as wetland types over broad geographic areas. These assessments primarily rely on existing digital information or remote sensing data housed in Geographic Information Systems (GISs) to provide a "desktop analysis" of wetlands at the landscape scale.
- Level 2 assessments evaluate the condition of individual wetlands based on field sampling that focuses on easy-to-measure indicators including anthropogenic disturbances, also known as stressors, which are rapid and easy to measure. Level 2 Rapid Assessment Methods (RAMs) are used throughout a number of regions in the US because they provide on-site assessments of wetland condition with comparatively limited effort (Fennessy et al. 2007). Common RAMs estimate the ecological condition of a wetland landscape by integrating metrics that focus primarily on hydrology, and on physical and biological structure. RAM metrics focus on observable stressors and disturbances known or presumed to degrade the ecological integrity of wetlands. Metric scores and stressor identification are incorporated into a wetland profile to provide information about the integrity of wetland resources within a basin.
- Level 3 assessments utilize more intensive methods that require specialized skill sets and usually a full day of measurement and data collection at each site. Example metrics include floristic quality assessments of the plant community, soil characterization, and water quality (Lemly and Gilligan 2012). Level 3 assessments are often utilized to provide more rigorous documentation of Level 2 assessment results and narrative ratings.

Depending on resource availability and study scope, approaches from different assessment levels may be combined to produce the required detail of data and information.

3.1.1. Ecological Integrity Assessment Framework

We assessed wetland condition using protocols from all three levels based on the Ecological Integrity Assessment (EIA) framework. The overarching goal of the EIA framework is to provide a rapid, repeatable, scientifically-defensible evaluation of the ecological condition of a wetland. EIA methods were developed by NatureServe to assess the condition of wetlands across larger landscapes (Faber-Langendoen et al. 2011) and have been refined by several regional wetland programs to specifically address wetland conditions in the Intermountain West (Rocchio 2007, Lemly and Gilligan 2012, Vance et al. 2012).

We developed a Landscape Hydrology Metric (LHM), an assessment of alteration to hydrologic regime. The LHM incorporates Level 1 landscape-scale data on hydrodrologic alterations and water source with Level 3 field data on wetland soils.

We applied Level 2 field metrics based largely on the EIA methods developed by Lemly et al. (2012, 2013). Field indicators or metrics were evaluated at each wetland based on narrative ratings of four attributes: Landscape Context, Hydrologic Condition, Physicochemical Condition, and Biotic Condition. The field metrics were assumed to represent a visible quality of a wetland ecosystem's complex ecological structure and function. Separate stressor metrics focused heavily on identifying the severity of anthropogenic disturbance or "stressors" associated with degradation of wetland ecosystems. Metric scores for each of the four attributes were combined into an overall EIA score that can be used to describe wetlands in relation to a reference condition.

Level 3 field protocols including methods for floristic quality assessments, soil characterization, and water quality were incorporated from Colorado's EIA framework (Lemly and Gilligan 2012).

3.1.2 Wildlife Habitat Assessment

We utilized two field-based methods to identify key habitat features for wetland-dependent avian species: 1) Avian Richness Evaluation Method (AREM – Adamus 1993) and 2) bird surveys. Bird surveys were carried out the year following wetland condition assessments to better understand the relationship between species diversity and wetland condition. In addition, we adapted the AREM for use in Wyoming (Adamus 1993). AREM is a Level 2 assessment of wetland habitat suitability and avian species richness. Information from the bird surveys, AREM, and other field metrics were used to link habitat quality, wetland condition, and avian biodiversity. Invertebrate biomass, densities, and community composition were estimated at selected wetlands with surface water to assess availability of food resources for wetland birds.

3.2 Landscape Profile for Goshen Hole Wetland Complex

A landscape profile was created using digital wetland mapping data compiled from the U.S. Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI). This digital data layer shows wetlands as polygon features, and was produced by digitizing of NWI wetland maps that were drawn in the 1970s and 1980s from aerial photographs. Additional data layers included irrigated lands and land ownership within the GHWC study area. The landscape profile describes water features throughout the study area based on the following attributes: wetland

and waterbody type; hydrologic regime; extent modified/irrigated (Wyoming Wildlife Consultants 2007); and land management/ownership (Bureau of Land Management 2010). The landscape profile identifies all wetland types and waterbodies according to categories based on codes and modifiers defined by Cowardin et al. (1979). The landscape profile provides a broad description of ALL wetland and waterbody features in the GHWC, whereas a subset of NWI codes were used to identify the wetland features that make up the target population for this condition assessment (Section 3.3 or Table 1). We present information in the landscape profile for all wetland and waterbodies, and the target population to capture these differences.

3.3 Survey Design and Site Selection for Wetland Condition Assessment

3.3.1 Target Population

Our wetland target population for the condition assessment included all palustrine wetlands within the GHWC, and excluded non-wetland features such as deepwater lakes and stream channel bottoms. Palustrine wetlands can be situated shoreward of lakes or river channels, on floodplains, in locations isolated from water bodies, in depressions, or on slopes. We also set a minimum size criterion of at least 0.1 hectare and a minimum width of 10 m.

3.3.2 Sample Frame

We used the digital NWI polygon dataset to identify our sample frame (U.S. Fish and Wildlife Service 1984). Table 1 describes the Cowardin hydrologic codes and modifiers used to define the sample frame and exclude non-wetland features from the dataset. NWI polygons that originated in the study area and extended beyond the boundary were included in the sample frame. The study area boundary was re-delineated to include these wetland polygons.

Our sample frame consists of four wetland subgroups based on Cowardin, Hydrogeomorphic (HGM), and Ecological Systems classes: 1) riparian woodland and shrubland; 2) freshwater emergent marsh; 3) wet meadows; and 4) playa and saline depressions. Table 1 provides a detailed description of the 4 wetland subgroups that were included in the study.

Table 1. Wetland subgroups classified by Cowardin, Hydrogeomorphic (HGM), and Ecological Systems used in the Goshen Hole Wetland Complex.

Wetland Subgroups	HGM Class	NWI Cowardin Class	Ecological System
Riparian Woodland and Shrubland	Riverine	PFOA/PFOAh/PFOB/PSSA/PSSAh/PSSB/PSSC/R2UBF/R2UBH/R2USA/R2USC/R4USA	Western Great Plains Riparian, Great Plains Floodplain, Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland, Western Great Plains Wooded Draw and Ravine
Emergent Marshes	Depression	L2ABF/L2ABFh/L2ABGh/L2USAh/L2USCh/PABF/PABFh/PEMCh/PEMF /PEMFh	North American Emergent Marsh, Western Great Plains Closed Depression, Great Plains Open Freshwater Depression Wetland
Wet meadow	Slope	PEMA(irrigated)/PEMAd/PEMAh/PEMB/PEMC/PEMCd	Irrigated wet meadow
Playa and Saline depression	Depression	PUSA/PUSAh/PUSC/PUSCh/L2USA/L2USC/PEMA (not irrigated)	Western Great Plains Saline Depression, Playa

Sample sites were randomly selected from the sample frame by using a generalized random tessellation stratified survey design for a finite resource (Stevens and Olsen 2004, Stevens and Jensen 2007). The target sample size was 60 sites across the four wetland subgroups. After potential sample sites were selected, and prior to field sampling, a desktop site evaluation was performed to determine: 1) whether the presence of a wetland meeting the targeted criteria was likely based on examination of aerial imagery (USDA Farm Service Agency 2009); and 2) land ownership/management status (private, state, federal). Permission was then sought to access sample sites located on private and State lands. Potential sample that met one of the following conditions sites were withdrawn from the sample frame:

1. Size: the wetland area did not meet the minimum area or width requirements for sampling.
2. Minimum distance: the wetland was within 500 meters of another sample location of the same target subpopulation.
3. Access issues: permission by landowner was granted but the point could not be safely accessed at the time of sampling.
4. Depth: the wetland exceeded the maximum depth criterion of 1 meter and the point could not be repositioned to a location that met our size criterion.
5. Hayed before sampling: all of the vegetation was cropped from the site prior to sampling, such that plant identification was not possible.

6. Not a wetland: The sample location did not contain a wetland due to mapping error, or a wetland may have been present but the location no longer met our operational definition of a wetland.

The operational definition of wetlands used in this project is based on the definition adopted by the U.S. Fish and Wildlife Service (USFWS) and used in the National Wetland Inventory (Cowardin et al. 1979):

> *"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."*

However, it is important to note that standard wetland delineation techniques are based on a different definition used by the U.S. Army Corps of Engineers (ACOE) and the Environmental Protection Agency (EPA) for regulatory purposes under Section 404 of the Federal Clean Water Act :

> *"[Wetlands are] those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."*

The primary difference between the two definitions is the ACOE/EPA definition requires positive identification of all three wetland parameters (hydrology, vegetation, and soils), whereas the USFWS definition requires only one characteristic must be present. We used the USFWS definition of a wetland for this survey. Non-vegetated areas and deep water habitats that would be considered wetlands under the USFWS definition were excluded.

If a site was withdrawn, it was replaced with an "oversample" site from the random survey design. Additional reference wetlands were hand-selected as sites representing "least disturbed" condition based on professional judgment of regional wildlife managers.

3.4 Field Methods

In June-August 2014, 68 wetlands (61 randomly selected and 7 reference) were sampled to assess ecological condition and wildlife habitat value. Field methods were based on EIA protocols developed by Lemly et al. (2013). In addition, we collected data on soils, water quality, vegetation, and avian diversity and habitat suitability to supplement the EIA protocol.

These assessments required a half a day or less to complete at each site. Detailed field data forms are included in Appendix B. Bird surveys were also conducted at 66 of the 68 wetland study sites in April-June 2015. Field methods are described in detail in the following sections.

3.4.1 Wetland Assessment Area (AA)

The field crew applied the EPA's National Wetland Condition Assessment methodology for selecting and the assessment area (AA) at each wetland site (U.S. Environmental Protection Agency 2011). When possible a standard 40 m radius circular AA was established. If the site configuration did not accommodate a circular AA of this size, the crew adjusted the AA to a rectangular or irregular shape of at least 1000 m^2 and 10 m wide. The AA boundary was marked with flagging to aid with data collection. A 500-m buffer was established from the perimeter of each AA. Standard descriptions of each wetland included: UTM coordinates, wetland classification, presence or signs of wildlife, and photos of the buffer and AA.

3.4.2 Ecological Integrity Assessment (EIA)

After the AA was established, each wetland was assessed based on the EIA manual and field forms adapted from Lemly et al. (2013). A copy of the field forms is included in Appendix B and the manual can be obtained on request. The principal attributes and metrics that were measured in this study are summarized in Table 2.

Table 2. EIA attributes and field metrics used for wetland assessments in the Goshen Hole Wetland Complex.

Attributes	Indicators and Metrics
Landscape Context	• Landscape Fragmentation • Buffer Extent • Buffer Width • Buffer Condition
Hydrologic Condition*	• Water Source • Hydrologic Connectivity • Alteration of Hydroperiod
Physicochemical Condition	• Water Quality • Algal Growth • Substrate/soil Disturbance
Biological Condition	• Relative Cover of Native Plant Species • Absolute Cover of Noxious Weeds • Absolute Cover of Aggressive Native Species • Mean C • Structural Complexity

*Field data for hydrology metrics were collected, however, scores for the Landscape Hydrologic Metric were used in place of the field scores for EIA scoring.

3.4.3 Plant Community

We used a plotless sample design to collect vegetation data using methods described in Lemly et al. (2012). Species searches were limited to no more than 1 hour at each site. Vascular plant species were identified using Dorn (2001) and regional keys including Johnston (2001), Skinner (2010), and Culver and Lemly (2013). Species names are taken from the U.S. Department of Agriculture (USDA) Plants database. Unknown plant specimens were pressed in the field and cataloged for later identification. The percent cover of each species, including that of unidentified specimens, was estimated over the entire AA.

3.4.4 Soils

We dug 2-4 soil pits within each AA. One pit was placed within each community type excluding those covered completely by water. We recorded a GPS waypoint at each soil pit and then marked the location on a map. Pits were dug to a depth of 40 cm (about one shovel length) when possible. The core was removed and laid next to the pit, ensuring all horizons were intact and in order. We recorded the following information about each horizon: 1) color (based on a Munsell Soil Color Chart) of the matrix and any redoximorphic concentrations (mottles and oxidized root channels) and depletions; 2) soil texture; and 3) any other specifics about the concentration of roots, the presence of gravel or cobble, or other unusual soil features. Hydric soil indicators were identified based on guidance from the Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region (2008) and the National Resources Conservation Service (NRCS) Field Indicators of Hydric Soils in the United States and Hydric Soil Indicators in the Mountain West (NRCS 2010).

3.4.5 Water Quality

We estimated percent cover and interspersion (patch complexity) of open water within the AA. The water depth range and average were recorded within the AA. Common water chemistry parameters (pH, salinity, conductivity, total dissolved solids and temperature) were recorded from permanent, undisturbed standing water closest to the center point of the AA.

3.4.6 Avian Richness Evaluation Method

We assessed habitat characteristics of all wetlands by completing the Avian Richness Evaluation Method (AREM) field forms (Appendix B). Habitat characteristics were assessed within 200 m buffer surrounding the AA (Adamus 1993).

3.4.7 Bird Surveys

During April-June, 2015, a Wyoming Game and Fish Department (WGFD) biologist conducted bird surveys at 66 of the wetland study sites sampled in 2014. Data were used to describe bird diversity and abundance. Each location was visited once in the evening and once in the morning during the breeding season. The observer walked to the center point (or close to it) and noted species and numbers of all birds seen or heard for a total of 25 minutes. The observer then relocated 40 meters north, and walked in a 40-m radius around the center point noting all bird species observed. Surveys were suspended under any of the following conditions: rain, fog, or smoke impaired visibility; wind velocity exceeded 12 mph (18 mph in open regions); or cold or wet weather that inhibited bird song activity. Survey methods were adjusted in open habitats (those lacking forested vegetation structure) because birds tended to flush from afar. Surveys in open habitats were done from the best available vantage point and at varying distances that did not disturb the birds present. In a number of instances, the surveys were done from a vehicle.

3.4.8 Benthic Invertebrate Surveys

We sampled benthic wetland habitats for macroinvertebrate density, biomass, and diversity in each wetland with surface water present. Five core samples were collected per site using a 5-cm diameter cylindrical plastic core pushed 5 cm into the benthos (Sherfy et al. 2000). Benthic core samples were collected haphazardly within the AA in habitats with concentrations of surface water. Each sample was immediately preserved in 95% ethanol in a labelled 500 mL Whirl-pak bag. At time of analysis, each sample was washed through a 500 µL sieve and invertebrates were sorted from organic matter. An observer then identified invertebrates to the level of family, with the exception of Oligochatea, Megaloptera, and Odonata. The observer counted the number of individuals in each taxonomic group to get estimates of density. We estimated total dry biomass by drying all individuals from all taxonomic groups in each core sample for at least 24h and weighing to the nearest 0.0001 g.

3.5 Data Management

All field data were entered into relational databases that were developed using Microsoft Access and/or ArcGIS 10.1 platforms. Data were then proofed to correct any errors prior to analysis. The data are housed on a TNC data server that is backed up nightly and stored off-site weekly.

3.6 Data Analysis

3.6.1. Ecological Integrity Assessment

To be effective tools, ecological assessment metrics should provide information about the integrity of major ecological attributes in relation to a gradient of disturbance or stressors. We evaluated performance of each EIA metric based on methods used to refine aquatic condition indices (Stoddard et al. 2006, Jacobs et al. 2010, Faber-Langendoen et al. 2011). Evaluation of EIA methods and scoring was a vital step to ensure the EIA methods we selected were relevant and effective for assessing wetland condition in Wyoming. The applicable range of each metric was determined by examining histograms depicting ranges and distributions of scores. We evaluated metric redundancy by calculating Spearman's rank correlation coefficients among all metrics. None of the metrics within an attribute category were found to be highly correlated (as determined by a coefficient value of $r > 0.8$).

3.6.2. Landscape Hydrology Metric (LHM)

Hydrology is broadly characterized as the movement, distribution, timing, and quality of water across the landscape. Hydrology is the primary driver of the processes that establish and maintain wetlands, including ecological, physical, and chemical processes that sustain ecosystem functions and associated services and values to people (Mitch and Gosselink 2000). Therefore, it is important to identify alterations to the natural hydrologic regime that may detrimentally affect the structure and function of a wetland. Identifying alterations to natural wetland hydrology can be a challenge because significant alterations such as major dams or ditches may not be evident during a single site visit or are located outside the 500m buffer surrounding the AA. In addition, it can be difficult to identify a wetland's water source when the wetland is supported or created by hydrologic alterations, such as leaky dams or canals.

We based the hydrology component of the EIA scoring formula on scores from the Landscape Hydrology Metric (LHM), an assessment of alteration to hydrologic regime. LHM incorporates landscape-level data identifying alterations to hydroperiod and water source, along with field data characterizing wetland soils. Tibbets et al. (2015) found that the LHM was more effective at identifying features potentially affecting wetland hydrology such as ditches and small dams or impoundments compared to field site visits. Moreover, LHM scoring provides more specific information about how a wetland is influenced by anthropogenic water sources because it estimates the proportions of natural versus human-mediated water inputs. In contrast, EIA Hydrology subscores combine several field RAM metrics, which eliminates the capability to categorize wetlands based on specific types of hydrologic alteration. LHM relies on descriptive criteria from submetrics (see below) to assign a total point rating from 5 to 0. Historic wetlands (score = 5) were defined in this study as wetlands without evidence of hydrologic alteration, whereas created wetlands (score = 0) are dependent on hydrologic alteration.

LHM Submetric 1: Hydroperiod alteration

We used high-resolution (0.3 meter) satellite imagery obtained from Digital Globe to conduct a desktop assessment of potential stressors to hydrology and hydroperiod alterations affecting each wetland AA. We recorded evidence of hydroperiod alteration such as the presence of irrigation ditches and canals, dams and berms, or points of diversion at a higher position in the watershed from each AA. Major dams or reservoirs were noted if they were located upstream or near a site. A major dam is defined as one that's located on the main-stem of a river, 50 feet tall, and having a storage capacity of at least 5,000 acre feet, or a dam of any height with a storage capacity of at least 25,000 acre feet (ACOE 2006). Mapped GIS data from the US Geological Survey's National Hydrologic Dataset (USGS NHD high-resolution version) were used to confirm or support satellite imagery interpretations.

LHM Submetric 2: Evidence of a natural water source

We used GIS data available from USGS NHD, and satellite imagery to conduct a desktop evaluation of natural surface water sources that could influence the hydrology at each sampled site. A site was considered to have a natural water source if a permanent or intermittent stream was within 50 meters or the site was within a natural playa. We also evaluated the likelihood of groundwater influence by identifying locations where groundwater is within 20 feet from the surface based on an existing GIS model of depth to groundwater (Wyoming Department of Environmental Quality 2005). The site was also considered to have a natural water source if histic soils were identified in the field.

LHM Submetric 3: Calculation of wetness

We applied the Compound Topographic Index (CTI) to identify wet areas. CTI is a steady state wetness index model available in a toolbox provided with ArcGIS 10.1 (Evans et al. 2014). The CTI is a function of both the slope and ratio of the upstream contributing area to width measured at right angle to the flow direction. CTI was derived for the entire study area based on a "filled" 30-m National elevation dataset (U.S. Geological Survey 2009). We applied a 90m x 90m smoothing focal mean filter to the resulting CTI model and then partitioned model results into ten equal area classes. Final CTI pixel values were assigned to sample sites (0=driest and 10=wettest).

LHM Submetric 4: Evidence of historic saturated conditions from soils data

Soil profile data were collected in the field and used to identify sites with a histic epipedon (surface organic matter ≥ 20 cm thick) or a histosol (organic soil, with ≥ 40 cm of organic matter). Presence of these organic soil layers indicates long-term saturated conditions and provides hydrologic evidence that the site historically supported wetland conditions.

LHM Scoring Criteria

Based on the LHM criteria outlined above, we identified four categories of wetland hydrology ranging from low to high degrees of alteration: historic, hybrid, supported and created. Hybrid and supported wetlands were further classified based on influence from local and basin-wide alterations including major dams and diversion structures. Wetlands were assigned to a hydrologic category and given a LHM score based on the metric criteria outlined in Table 3.

Table 3. Landscape Hydrology Metric scoring criteria.

Hydrologic Category	LHM Score	Landscape Hydrology Metric Criteria
Historic Wetland	5	No alterations to hydrology identified, natural water source or no observed natural water source but histic layer present.
Hybrid Wetland in landscape with site-level hydrologic alterations	4	Site-level hydrologic alteration, natural water source identified or no observed natural water source but histic layer present.
Hybrid Wetland in landscape with basin-wide hydrologic alterations	3	Basin-wide hydrologic alteration (major dam present) and direct hydrologic connectivity to natural water source observed. No histic layer observed.
Supported Wetland with natural water source	2	Basin-wide hydrologic alteration (major dam present), landscape position is in depression with natural water source potential, however, dominant water source is unclear due to presence of large canals. No histic layer observed.
Supported Wetland- Irrigation Dependent Depression	1	Hydrologic alteration identified, landscape position is in depression. Irrigation is likely dominant water source. No histic layer observed.
Created Wetland - Irrigation Dependent	0	Hydrologic alteration identified, no natural water source identified. Irrigation is exclusive water source. No histic layer observed.

3.6.3. Floristic Quality Assessment (FQA)

Floristic Quality Assessment (FQA) uses plant community composition as an indicator of ecological condition. The FQA method assesses the degree of human caused disturbance based on the proportion of “conservative” plants present. “Coefficients of conservatism” (C-values) are the foundation of FQA. C values range from 0 to 10 and represent an estimated probability that a plant is likely to occur in a landscape relatively unaltered from conditions that existed before European settlement (Swink and Wilhelm 1979, 1994). A C-value of 10 is assigned to plant species obligate to high-quality natural areas and having low tolerance for habitat degradation, whereas a 0 is assigned to plant species with a wide tolerance to human disturbance (Rocchio 2007). Once C-values have been assigned for a given region or area, they can then be used to calculate a number of FQA indices such as the average C-value of a site (Mean C) and the Floristic Quality Assessment Index (FQAI) (Swink and Wilhelm 1979, 1994). Formalized C-values are not currently available for Wyoming. TNC staff developed a series of rules to assign surrogate C-values to species on the USDA list of wetland plants in Wyoming (~1500 species) based on existing C-value data from Colorado, Nebraska, the Dakotas and Montana (Appendix C).

We calculated Mean C, total species richness, and the numbers of native and non-native species based on the species lists compiled at each wetland site. Mean C is calculated by summing the C-values of the plant species found at each site, and then dividing by the number of species. We also calculated Spearman's rank correlation coefficients to evaluate relationships among FQA metrics, disturbance indices, and stressors metrics.

3.6.3. Ecological Integrity Assessment Scores

We calculated EIA scores and thresholds based on EIA methods used in Colorado (Lemly and Gilligan 2012, 2013). Refer to Appendix D for a detailed description of scoring formulas and thresholds used to rank from A-D. Ideally, wetlands that are ranked "A" are those in minimally disturbed condition (MDC), representing the best approximation of naturalness or a high degree of biological integrity on the landscape (Stoddard et al. 2006). Reference wetland condition in the GHWC is defined as least disturbed condition (LDC), meaning "in the best available physical, chemical and biological habitat conditions given today's state of the landscape" (Stoddard et al. 2006). Because LDC can differ from MDC, the biological integrity of our A-ranked sites may not reflect the sites' fullest potential for biological integrity.

Cumulative distribution function (CDF) analysis was used to estimate the percent of the target population (i.e., all wetlands in the GHWC) that is less than or equal to a particular EIA score (Whittier et al. 2002). A site weight was calculated from the probability sample design to estimate the number of wetlands each sample site represented across the total target population. Percent and standard error of number of wetlands within each ranking category were calculated. We generated CDF estimates using R software package version 3.1.0 (R Development Core Team 2014) and the spsurvey library.

3.6.4. Assessment of Wildlife Habitat

The AREM database and models were migrated from the MS-DOS platform to Microsoft Access. Habitat indicators for 261 wetland and riparian bird species were entered. The list of birds included all species (excluding rare species) that use wetlands, riparian areas and irrigated lands in Wyoming (Wyoming Game and Fish Department 2008). The final list was further narrowed by considering professional opinion of WGFD nongame bird biologists (S. Patla, personal communication), regional abundance information, and checklists (WGFD 2008, Faulkner 2010). Data were analyzed using the AREM database and models for birds present during the breeding season in SE Wyoming (WGFD 2008). The model assigns "habitat suitability" scores, ranging from 0 (least suitable) to 1 (most suitable), for each species potentially present based on site-specific habitat data collected at each wetland. A bird species is included in a list of species for each site based on thresholds of habitat suitability scores defined by the AREM user. For example, if the habitat suitability threshold is set at 0.75, a bird species with a habitat suitability score of 0.65 would not be included in the list of species for consideration. Species richness estimates for the GHWC were also calculated at each wetland site based on the 0.75 threshold, because this threshold successfully predicted presence of wetland bird species on the Colorado Plateau (Adamus 1993).

3.6.5 Benthic Invertebrate biomass and density

We calculated estimates of mean invertebrate biomass (g/m^2) and density ($individuals/m^2$) among all cores at each wetland sampled. Descriptive data analyses were calculated among wetlands.

4.0 RESULTS

4.1 Landscape Profile for Goshen Hole Wetland Complex

The exterior boundary of the GHWC encompasses 314,217 acres within southeast Wyoming. All wetlands and water bodies total 9,669 acres or approximately 3% of the GHWC (Table 4). This figure includes non-wetland features such as deep lakes and excavated water features totaling 962 acres. The remaining 8,707 acres is comprised of wetlands, representing slightly less than 3% of the study area.

Freshwater Emergent wetlands are the most common wetland type, totaling 5,752 acres or 66% of total wetland area (Table 4). Freshwater Emergent wetlands include irrigated hayfields, wet meadows, and emergent vegetation zones around more permanent water features such as rivers and ponds. Lakes are the second most common wetland type and cover 1,147 acres and 13% of wetland area. Wetlands mapped as lakes include freshwater emergent zones along permanent water sources or intermittently flooded playas.

Seasonally and temporarily flooded wetlands are the two most common hydrologic regimes in the study area and account for 35% and 38% of the wetland area respectively (Table 5). Seasonally flooded wetlands hold surface water for extended periods during the growing season, but are dry by the end of the growing season in most years. They include wetlands with hydrology dependent on alluvial groundwater and seasonal flooding along the North Platte River and its tributaries. Temporarily flooded wetlands hold surface water for relatively shorter periods during the growing season. Semi-permanently flooded water bodies, such as playa lakes and river oxbows, total 2,297 acres or 22% of the wetland area.

Water bodies influenced by man-made and natural alterations are identified by modifier codes on NWI maps. No modifier codes are identified for 70% of mapped wetlands in the GHWC (Table 6). Impoundments and dikes are the most prevalent anthropogenic modifications influencing over 28% of the wetland area. In addition, many modified wetlands in the GHWC were purposely created to provide waterfowl habitat or exist as a coincidence of irrigation runoff or retention. Riverine wetlands include the highest proportion of wetlands influenced by anthropogenic modifications. Excavated riverine wetlands total 821 acres, representing 72% of this wetland type. The main purpose of excavations is to divert water for irrigation.

Irrigation was not explicitly identified as a wetland modifier in the NWI mapping codes, even though much of the land within the GHWC is irrigated for agricultural production. Thirty-three percent of the GHWC study area (104,498 acres) is mapped as irrigated lands (Wyoming

Wildlife Consultants 2007) (Table 7). Although more than a third of the basin is receiving direct irrigation inputs, only 1% of irrigated acres are mapped as wetlands. The most common wetland type receiving irrigation inputs is freshwater emergent wetlands – 1,339 acres (23%) (Table 7). Many of these wetlands are associated with irrigation runoff or were created as retention ponds for cattle use.

Over 92% (289,182 acres) of the GHWC study are is private (Fig. 2). The majority of wetlands, water bodies and irrigated lands are located on private lands (Table 8). Approximately 35% of private lands are irrigated and contain over 70% of the wetland area. Lands managed by the Bureau of Land Management (BLM) and the Wyoming Game and Fish Commission (WGFC) contain the second largest proportion of targeted wetland area (~6% each). Reservoirs and wetlands at Table Mountain and Springer WHMAs provide wildlife habitat and recreational benefits within the basin. The National Park Service manages Fort Laramie National Historic Site, which includes a 787-acre tract of riparian habitat along the Laramie River.

Table 4. Surface areas of wetlands based on NWI classifications in the GHWC.

NWI Code	NWI Wetland and Waterbody Type	Area of Wetlands and Waterbodies Identified by the NWI (Acres)	% of Study Area	Area of Wetlands in the GHWC Sample Frame (Acres)	% of Study Area	% Wetlands in the GHWC Sample Frame
PFO	Forested Wetland	257	0.08%	257	0.08%	2.95%
PEM	Freshwater Emergent Wetland	5,760	1.83%	5,752	1.83%	66.06%
PAB	Freshwater Pond	535	0.17%	488	0.16%	5.61%
L1/2	Lake	1,147	0.37%	1,147	0.37%	13.18%
R2/3/4	Riverine	1,138	0.36%	317	0.10%	3.64%
PSS	Shrub Wetland	447	0.14%	447	0.14%	5.13%
PUB/US	Unconsolidated Bottom/Shore	385	0.12%	299	0.10%	3.43%
	Total	9,669	3.08%	8,707	2.77%	100.00%

Table 5. Surface areas of wetlands and waterbodies classified according to NWI water regimes in the GHWC.

NWI Code	NWI Water Regime	Area of Wetlands and Waterbodies Identified by the NWI (Acres)	% of Study Area	Wetland Acres in the GHWC Sample Frame (Acres)	% of Study Area	% Wetlands of GHWC Sample Frame
A	Temporarily Flooded	3,013	0.96%	3,013	0.96%	34.60%
B	Saturated	50	0.02%	50	0.02%	0.57%
C	Seasonally Flooded	3,318	1.06%	3,311	1.05%	38.02%
F	Semi-permanently Flooded	2,297	0.73%	1,878	0.60%	21.57%
G	Intermittently Exposed	905	0.29%	417	0.13%	4.79%
H	Permanently Flooded	40	0.01%	38	0.01%	0.44%
	Total	45	0.01%	-	-	-

Table 6. Surface areas of wetland and waterbody types classified according to NWI modifiers in the GHWC.

NWI Wetland and Waterbody type	No Modifier		Excavated		Impounded/diked		Drained	
	Acres	% of NWI wetland and Waterbody type	Acres	% of NWI wetland and Waterbody type	Acres	% of NWI wetland and Waterbody type	Acres	% of NWI wetland and Waterbody type
Forested Wetland	106	41.16%	-	-	151	58.84%	-	-
Freshwater Emergent Wetland	4,507	78.25%	8	0.14%	1,049	18.21%	195	<0.01%
Freshwater Pond	295	55.19%	47	8.73%	193	36.08%	-	-
Lake	246	21.47%	-	-	901	78.53%	-	-
Shrub Wetland	396	88.51%	-	-	51	11.49%	-	-
Riverine	317	27.88%	821	72.12%	-	-	-	-
Unconsolidated Bottom/Shore	238	61.83%	86	22.39%	61	15.78%	-	-
All Water bodies	6,106	63.15%	962	9.95%	2,406	24.89%	195	2.02%
Wetlands	6,106	70.12%	-	-	2,406	27.64%	195	2.24%

Table 7. Surface areas of irrigated wetlands and water bodies based on NWI classifications in the GHWC.

NWI Wetland and Waterbody type	Acres	% of NWI Wetland and Waterbody type	% of irrigated lands
Forested Wetland	3	1.26%	0.00%
Freshwater Emergent Wetland	1,339	23.25%	1.28%
Freshwater Pond	20	3.69%	0.02%
Lake	11	0.95%	0.01%
Riverine	15	1.30%	0.01%
Shrub Wetland	7	1.66%	0.01%
Unconsolidated Bottom/Shore	34	8.77%	0.03%
All Water Bodies	1,429	14.78%	1.37%
Wetlands	1,403	16.11%	1.34%

Table 8. Landownership/management of irrigated lands, all wetlands, and target wetlands in the GHWC.

Landowner/ Manager	Total		Irrigated Lands			All Wetlands and Water Bodies			Wetlands			
	Acres	% of Basin Area	Acres	% of Landowner Area	% of Basin Area	Acres	% of Landowner Area	% of Basin Area	Acres	% of Landowner Area	% of Basin Area	% of Wetland Acres
Bureau of Land Management	5,141	1.64%	170	3.31%	0.05%	555	10.80%	0.18%	524	10.20%	0.17%	6.02%
Bureau of Reclamation	419	0.13%	22	5.21%	0.01%	23	5.60%	0.01%	5	1.29%	< 0.01%	0.06%
DOE	87	0.03%	-	-	-	6	6.86%	< 0.01%	6	6.86%	< 0.01%	0.07%
National Park Service	787	0.25%	205	26.09%	0.07%	25	3.17%	0.01%	21	2.61%	0.01%	0.24%
Private	289,182	92.03%	101,277	35.02%	32.23%	6,932	2.40%	2.21%	6,090	2.11%	1.94%	69.94%
State	12,355	3.93%	1,946	15.75%	0.62%	469	3.79%	0.15%	409	3.31%	0.13%	4.70%
Water	2,911	0.93%	9	0.32%	0.00%	1,111	38.17%	0.35%	1,109	38.11%	0.35%	12.74%
WY Game and Fish Commission	3,336	1.06%	868	26.02%	0.28%	548	16.44%	0.17%	542	16.26%	0.17%	6.23%
Total	314,217	100.00%	104,498	33.26%	33.26%	9,669	3.08%	3.08%	8,707	2.77%	2.77%	100.00%

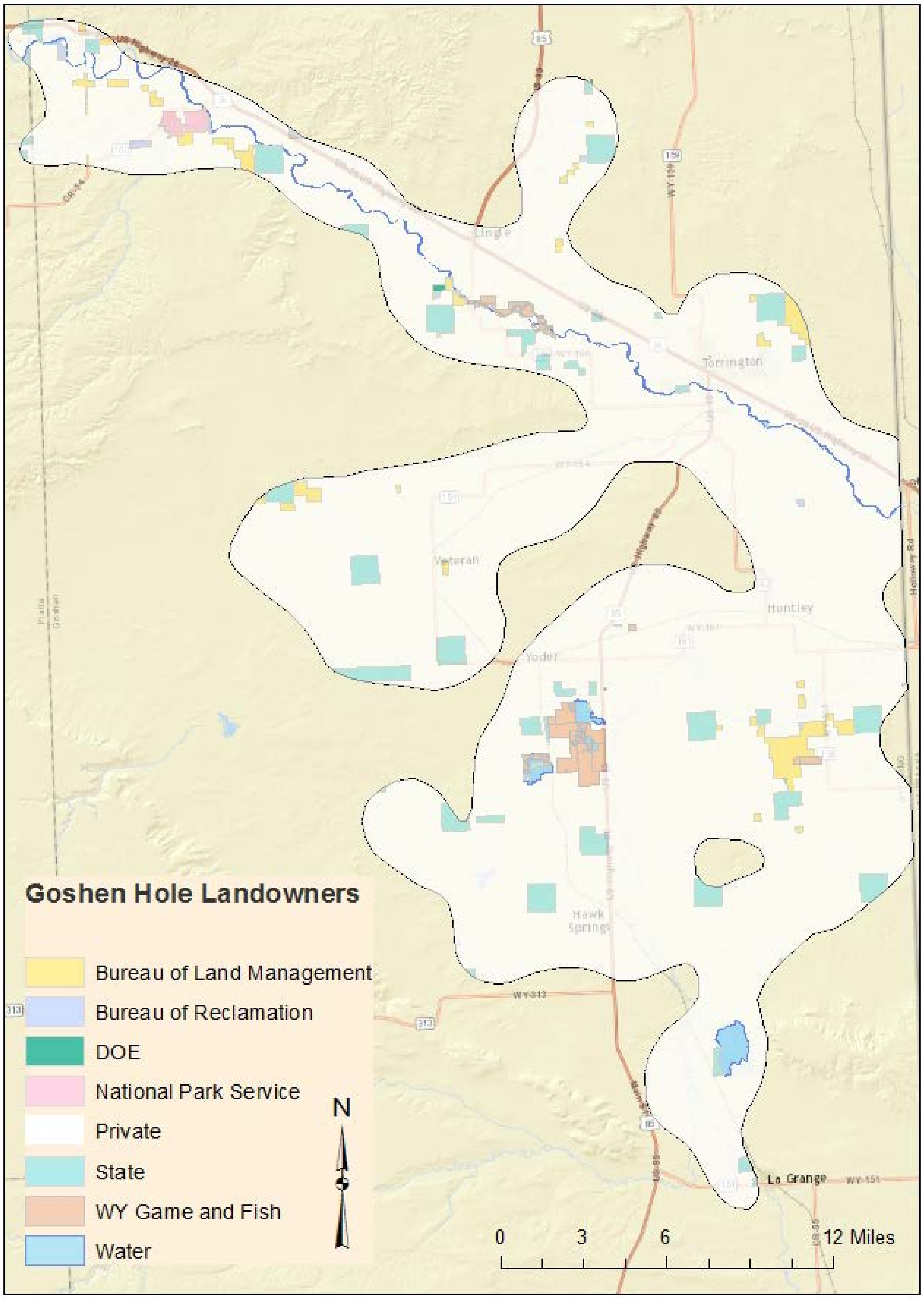

Figure 2. Spatial distribution of land ownership/management within the GHWC study area.

4.2 Description of Sampled Wetlands

4.2.1 Implementation of the Survey Design

We sampled 68 wetlands (including 7 reference wetlands) in 2014. Seventy-one percent of sampled wetlands were located on private lands. Lands managed by the Wyoming Game and Fish Commission (WGFC) contained 12% of sampled wetlands, followed by the BLM (9%), State of Wyoming Trust Lands (6%), and the National Park Service (3%).

We obtained permission to access 33% of the sites selected from the random survey design. The actual proportion of sample points on private lands (71%) was similar to the proportion intended based on the random sample design (70%). We sampled a higher proportion of wetlands managed by WGFC and BLM compared to their area represented in GHWC (Tables 8 & 9). One hundred twenty-two sites evaluated from the original sample design were rejected due to access denial (n = 97) or classified as not sampleable (n = 25).

Table 9. Land ownership/management of sampled study sites in the GHWC.

Wetland subgroups	BLM	NPS	WGFC	State	Private
Riparian Woodland and Shrubland	1	1	4	1	16
Freshwater Emergent Marsh	3	1	4	2	17
Playa and Saline Depression	1			1	9
Wet Meadow	1				6
Total	6	2	8	4	48

4.2.2 Description of Sampled Wetland Subgroups

A field key (Appendix A) was used to classify sampled wetlands and riparian sites according to ecological system. The sites were then classified into wetland subgroups based on these ecological systems (Table 1). Characteristics of the four subgroups are summarized below:

Riparian Woodland and Shrubland

Riparian shrublands are distributed along rivers and streams within the GHWC. Many are associated with historic floodplains and receive water from overbank flooding and the alluvial aquifer. Riparian shrublands typically occur in narrow bands along intermittent streams or are intermixed cottonwood galleries along the North Platte River. Several sites along the North Platte River are on sand and gravel bars within the active river channel. These sites are dominated by a woodland tree/shrub overstory consisting of *Populus* and *Salix* sp. Understory vegetation is dominated by mesic to hydric meadow species consisting of graminoides, forbs, and woody saplings, often including non-native species such as *Phalaris arundinaceae, Cirsium arvense, Elaeagnus angustifolia* and *Tamarix* sp.

Freshwater Marshes and Ponds
Freshwater marshes and ponds include riverine oxbows, created ponds and semi-permanently flooded wetlands receiving irrigation inputs, and along edges of major reservoirs. These systems are dominated by herbaceous vegetation. Many freshwater marshes and ponds on WGFC lands and some private lands are actively managed to provide waterfowl habitat. Marshes often have a central area that is frequently flooded and surrounded by increasingly drier concentric zones. Central areas are dominated by hydrophytic species such as *Eleocharis palustris, Typha* spp., *Schoenoplectus pungens*, and *Schoenoplectus tabernaemontani*. Dominant species in the surrounding zones include *Hordeum jubatum, Distichlis spicata,* and *Cirsium arvense.* Many marshes and ponds are surrounded by a tree/shrub overstory consisting of *Populus* and *Salix* spp.

Wet meadows
Wet meadows are large herbaceous wetlands associated with a high water table. In the GHWC, these are typically located within a floodplain. Hydrology is often modified by artificial overland flow (irrigation). These sites typically lack prolonged standing water. Vegetation is dominated by native or non-native herbaceous species with graminoids accounting for the most canopy cover. Common species include *Hordeum jubatum, Distichlis spicata, Juncus arcticus ssp. littoralis and Carex praegracilis*. Patches of emergent marsh vegetation (e.g., *Schoenoplectus pungens, Carex nebrascensis, Eleocharis palustris, and Typha spp*) and standing water less than 0.1 ha may be present, but are not the predominant cover types.

Playa and Saline Depressions
Playas and saline depressions are seasonally to semi-permanently flooded. These depressions occur in alkaline basins and swales and along the drawdown zones of lakes and ponds. Vegetation cover generally exceeds 10% and is typically comprised of salt-tolerant species such as *Distichlis spicata*, *Puccinellia* spp., *Schoenoplectus maritimus, Schoenoplectus pungens, Triglochin maritima,* and *Salicornia rubra*. Saline depressions generally have thick unvegetated salt crusts over clay soils surrounded by zones of vegetation. Many seasonal playas and saline depressions are associated with springs, irrigation seepage, or are located in large basins with internal drainage. Seasonal drying exposes mudflats colonized by annual wetland vegetation.

4.3 Wetland Soil Profiles and Water Chemistry
Soil pits were dug at all wetland sites except 6 that were completely flooded at the time of sampling. Hydric soils were documented in 94% of the wetlands where soils were sampled (Table 10). The highest proportions of sites with hydric soil indicators were in emergent marshes and in riparian woodland and shrublands. The most common hydic soil indicators were found in mineral soils. Those indicators are created by a reduction, translocation or accumulation of iron and other reducible elements. Organic soils resulting from the accumulation of organic matter under a more stable water regime were found at 16 sampled wetlands. Mucky mineral soils were the most common organic soil indicators found in

freshwater emergent marshes, riparian woodland and shrubland sites, and wet meadows. One riparian woodland and shrubland site had peat accumulation deep enough to qualify as a histisol or a histic epipedon.

Table 10. Wetland soil characteristics in the GHWC study area.

Wetland Subgroup	# of Sites	# with Hydric Soil	# Hydric with Mineral Soil	# with Mucky Mineral	# Hydric with Organic Soil	# Histosols and Histic Epipedons
Riparian Woodland and Shrubland	23	22	17	5	5	1
Freshwater Emergent Marsh	21	20	12	8	8	0
Wet Meadow	7	7	4	3	3	0
Playa and Saline Depression	11	9	9	0	0	0
Total	62	58	42	16	16	1

Surface water was present at 64% of wetlands at the time of sampling (Table 11). Surface water was observed at 44% of riparian woodland and shrubland sites, 89% of emergent marshes, 57% of wet meadows, and 55% of playas and saline depressions. Conductivity, Total Dissolved Solids (TDS) and salinity values varied among wetlands within the basin. Emergent marsh sites included the largest number of wetlands with oligosaline conditions (Cowardin et al. 1979), however 100% of wet meadows were also classified as oligosaline (Table 12). One of the playas with a salinity value of 7500 ppm was classified as mesosaline.

Table 11. Mean water chemistry measurements and standard deviations at sampled wetlands with surface water present.

Wetland Subgroup	n	Temperature (ºC)	Conductivity (µS/cm)	pH	Total Dissolved Solids (ppm)	Salinity (ppm)
Riparian woodland and shrubland	10	19.9 ± 5.6	836 ± 240	7.9 ± 0.3	593 ± 166	446 ± 131
Emergent Marsh	24	24.3 ± 4.1	1485 ± 1225	8.3 ± 0.8	1050 ± 852	808 ± 700
Wet Meadow	4	20.6 ± 3.3	960 ± 104	8.0 ± 0.2	682 ± 73	506 ± 51
Playa and saline depression	6	24.3 ± 6.4	2606 ± 2569	9.2 ± 0.7	3110 ± 3131	2636 ± 2815

Table 12. Salinity classifications of sampled wetlands with surface water present (Cowardin et al. 1979).

	Cowardin Salinity Class		
Wetland subgroup	Fresh (<500 ppm)	Oligosaline (500-5000 ppm)	Mesosaline (5000-18000 ppm)
Riparian woodland and shrubland	8	2	0
Emergent Marsh	7	17	0
Wet Meadow	0	3	0
Playa and saline depression	1	4	1

4.4 Landscape Hydrology Metric

Based on LHM analyses, only 9% of wetlands were categorized as historic (Fig. 3). Almost half the wetlands sampled were categorized as altered-hybrid, and over 90% had altered hydrology of some form, indicating wide-spread hydrologic modification throughout the basin. Almost half (46%) of sampled wetlands were dependent on water sources linked to irrigation and other hydrologic alterations.

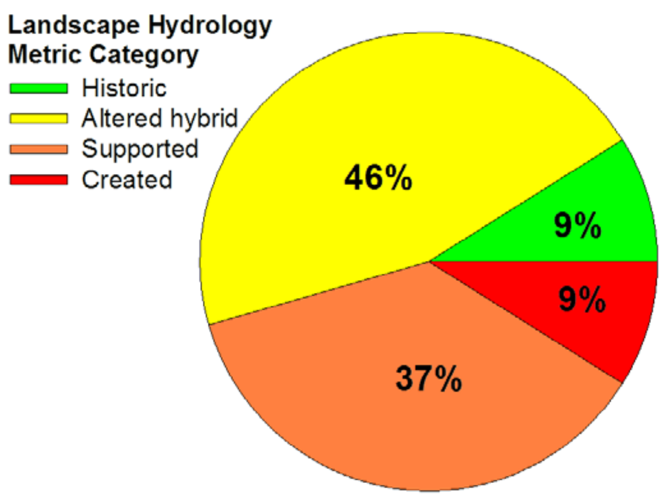

Figure 3. Proportion of total wetland sites in each category based on the Landscape Hydrology Metric.

We observed hydrologic alterations in all wetland types (Fig. 4). The hydrology of sites classified as riparian woodland and shrublands was largely in the altered-hybrid category (87% of sites) and only 4% were categorized as historic. The wet meadows subgroup included the highest proportion of sites with hydrologic alteration – 71% were categorized as supported, and 29% were created. None of the wet meadows we sampled were categorized as altered-hybird or historic. Approximately two-thirds of emergent marshes were categorized as supported or created, and only 4% were categorized as historic. The playa and saline depressions subgroup included the largest proportion of historic wetlands in the study, however 47% of those sites were categorized as supported or created.

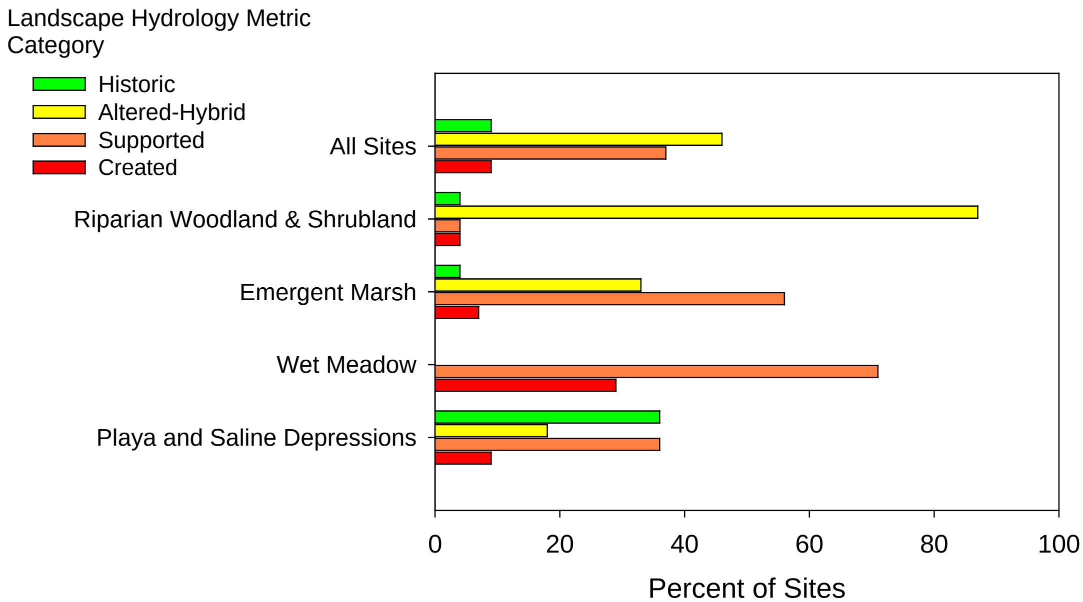

Figure 4. Landscape Hydrology Metric categories for all wetland study sites by wetland subgroups.

4.5 Characterization of Wetland Vegetation

4.5.1 Species Diversity of Wetland Vegetation

One hundred sixty-six taxa of vascular plants were identified at the 68 sample sites. Seven taxa could only be identified to genus because diagnostic plant parts were absent at the time of sampling. One hundred fifty-nine taxa were identified to the species level. These represent 4% of the total number of plant species that have been documented in Wyoming (Dorn 2001). Forty-four taxa were encountered only once and 26 were encountered twice. Since 43% of the species were only encountered once or twice, it is probable that more species would be found with additional survey effort. One hundred-two taxa identified to the species level (64%) were native and 53 (33%) were non-native.

The three most common species, fox-tail barley (*Hordeum jubatum*), common spike-rush (*Eleocharis palustris*), and three-square (*Schoenoplectus pungens*), were detected at 53 (78%), 40 (59%), and 38 (56%) of the sampled wetlands, respectively (Tables 13 &14). They also occurred in all four wetland subgroups. The most common non-native species were Canadian thistle (*Cirsium arvense*), Reed canary grass (*Phalaris arundinacea*), Russian-olive (*Elaeagnus *angustifolia*) encountered at 32 (47%), 35 (37%), 24 (35%), and 24 (35%) of the sampled sites, respectively (Table 13). These species were often found in riparian wetlands along the North Platte River and its tributaries.

Table 13. Frequencies of native and non-native species encountered at study sites in the GHWC.

Native		Non-Native	
Species	% of Sites	Species	% of Sites
Hordeum jubatum	78%	*Cirsium arvense*	47%
Eleocharis palustris	59%	*Phalaris arundinacea*	37%
Schoenoplectus pungens	56%	*Elaeagnus angustifolia*	35%
Distichlis spicata	49%	*Melilotus officinalis*	32%
Salix amygdaloides	43%	*Typha angustifolia*	31%
Ambrosia psilostachya	41%	*Lactuca serriola*	26%
Salix exigua	38%	*Juncus compressus*	25%
Populus deltoides	37%	*Poa pratensis*	24%
Conyza canadensis	35%	*Rumex stenophyllus*	24%
Schoenoplectus tabernaemontani	34%	*Bromus tectorum*	24%

Table 14. Ten most common plant species documented at sampled wetland in the GHWC.

Species	% of Sites	Wetland Status	Nativity	WY C Value	Common Name
Hordeum jubatum	78%	FACW	Native	2	Fox-Tail Barley
Eleocharis palustris	59%	OBL	Native	4	Common Spike-Rush
Schoenoplectus pungens	56%	OBL	Native	5	Three-Square
Distichlis spicata	49%	FACW	Native	4	Coastal Salt Grass
Cirsium arvense	47%	FACU	Non-native	0	Canadian Thistle
Salix amygdaloides	43%	FACW	Native	5	Peach-Leaf Willow
Ambrosia psilostachya	41%	FACU	Native	2.25	Perennial Ragweed
Salix exigua	38%	FACW	Native	3	Narrow-Leaf Willow
Populus deltoides	37%	FAC	Native	4	Eastern Cottonwood
Phalaris arundinacea	37%	FACW	Non-native	0	Reed Canary Grass
Elaeagnus angustifolia	35%	FACU	Non-native	0	Russian-Olive
Schoenoplectus tabernaemontani	34%	OBL	Native	3	Soft-stem club-rush

4.5.2 Floristic Quality Assessment

Riparian woodland and shrublands had the highest mean species richness as well as the largest numbers of native and non-native plants observed per site (Table 15). This subgroup was the most influenced by the presence of non-native species. The second highest mean total species and native species richness values were documented in wet meadows. Playas and saline depressions had lower mean species richness values, but also had the smallest number of non-native species. Playas and saline depressions are naturally bare areas where soil chemistry greatly restricts the number and type of plant species present.

The overall mean C ($\overline{C}_{all}$) measured across sites in the GHWC was 2.60 and ranged from 3.5-1.73 (Table 15). Overall mean C based on native species ($\overline{C}_{n}$) was slightly higher at 3.72. Playas and saline depressions had the highest $\overline{C}_{all}$ as well as the highest relative percent cover of native species. Wet meadows had the highest $\overline{C}_{n}$ (4.07). Riparian woodland and shrublands had the lowest $\overline{C}_{all}$ and $\overline{C}_{n}$. Mean C values for riparian woodland and shrublands reflect the high mean absolute cover of noxious species, and the high relative cover of aggressive natives (such as *Typha spp*.) observed across sites.

Table 15. Floristic quality assessment indices calculated for wetlands in the GHWC.

FQA Indices	Riparian Woodland and Shrubland		Emergent Marsh		Wet Meadow		Playa and Saline Depression		Overall	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Total species richness	27.09	9.69	15.81	9.47	20.00	5.77	8.91	4.89	18.94	10.75
Native species richness	15.87	6.01	10.89	5.92	12.29	5.02	6.09	2.51	11.94	6.33
Non-native species richness	10.96	4.58	4.74	4.49	6.71	2.50	2.73	2.94	6.72	5.19
Mean C of all species	2.11	0.51	2.83	0.94	2.60	0.66	3.06	1.04	2.60	0.87
Mean C of native species	3.52	0.57	3.72	0.62	4.07	0.27	3.93	0.47	3.72	0.57
FQI of all species	10.85	3.86	10.16	3.07	11.68	3.91	8.33	2.12	10.25	3.40
FQI of native species	13.94	4.37	11.77	3.40	14.12	3.52	9.50	1.74	12.38	3.87
Relative % cover native species	72.27	21.66	82.50	21.72	80.56	15.97	91.61	17.00	80.31	21.17
Absolute % cover noxious species	12.90	16.77	1.76	3.84	0.06	0.05	0.00	0.00	5.07	11.42
Absolute % cover aggressive natives	24.55	26.29	15.20	24.91	1.23	1.64	0.00	0.00	14.46	23.57

4.6 Wetland Condition Assessment

4.6.1 Ecological Integrity Assessment of Sampled Wetlands

EIA scores from 68 sampled wetlands ranged between 1.9 – 4.8 out of a possible range of 1.0-5.0. We established 4 wetland condition categories based on threshold values defined in Appendix D:

- A = At or near reference condition
- B = Level of disturbance indicates slight departure from reference condition
- C = Level of disturbance indicates moderate departure from reference condition
- D = Level of disturbance indicates severe departure from reference condition

Two percent of the 68 study sites in the GHWC were ranked “A,” 21% were ranked “B,” 69% were ranked “C,” and 9% were ranked “D” (Fig. 5). All 4 ecological subgroupings were dominated by C-ranked wetlands. Playas and saline depressions were the only subgroup with A-ranked wetlands (one site) and no D-ranked sites, indicating overall lower disturbance. The wet meadows subgroup included the highest proportion of D-ranked sites. Scores at nearly a third of those sites indicated significant departure from reference condition.

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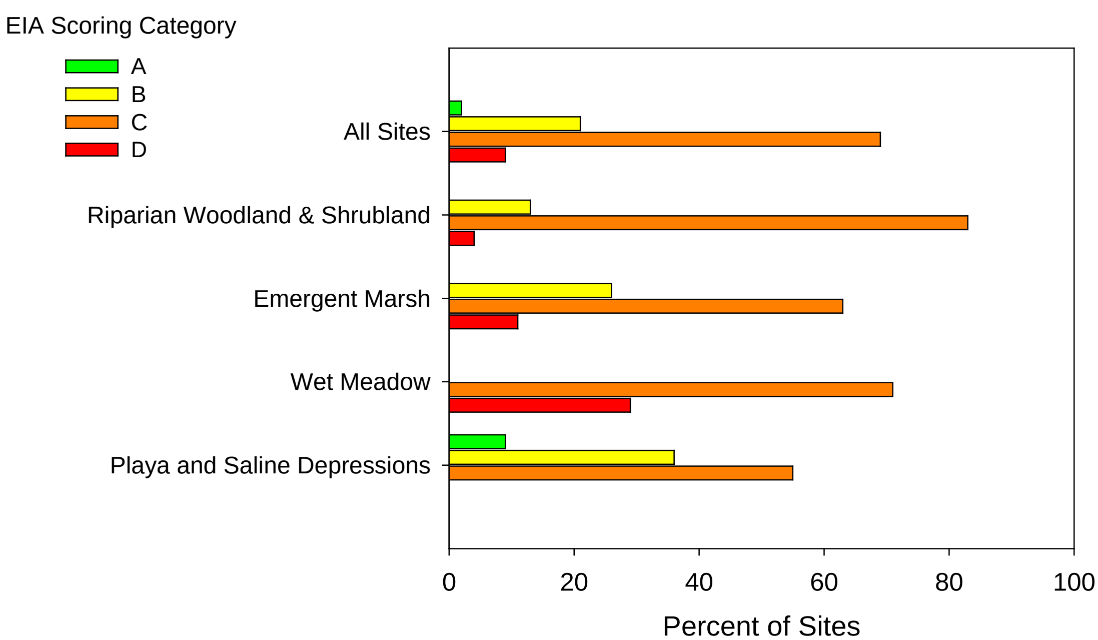

Figure 5. EIA condition categories for all wetland study sites by wetland subgroups

EIA scores were derived from 4 attributes: landscape context, biotic condition, physicochemical condition, and the Landscape Hydrology Metric. The landscape context rankings mainly ranged from A – B, with the exception of 2 C-ranked and 3 D-ranked emergent marshes (Table 16). Biotic condition ranks were relatively lower than other attribute categories, with 77% of wetlands receiving a rank of C or lower. Riparian woodland and shrublands received the lowest biotic condition scores compared to the other wetland subgroups – 91% of sites were D-ranked. Only one sample site, a playa and saline depression, received a biotic condition ranking of A. Most wetlands received relatively high physicochemical condition ranks, with the exception of the playas and saline depressions subgroup, which included the largest proportion of C-ranked wetlands. Detailed results from our analysis are provided in Section 4.4.3. Frequencies of LHM classifications within wetland subgroupings are shown at the bottom of Table 16 for comparison to the other EIA attribute ranking frequencies.

Table 16. EIA and LHM ranking frequencies for sampled wetlands within targeted wetland subgroups.

	EIA Landscape context rank			
Wetland Subgroup	A	B	C	D
Riparian woodland and shrubland	6	17	0	0
Emergent Marsh	7	15	2	3
Wet Meadow	4	3	0	0
Playa and Saline Depression	7	4	0	0
Total	24	39	2	3

	EIA Biotic condition rank			
Wetland Subgroup	A	B	C	D
Riparian woodland and shrubland	0	0	2	21
Emergent Marsh	0	9	12	6
Wet Meadow	0	0	4	3
Playa and Saline Depression	1	6	3	1
Total	1	15	21	31

	EIA Physicochemical condition rank			
Wetland Subgroup	A	B	C	D
Riparian woodland and shrubland	19	3	1	0
Emergent Marsh	15	8	3	1
Wet Meadow	6	1	0	0
Playa and Saline Depression	3	2	6	0
Total	43	14	10	1

	LHM Hydrology classification			
Wetland Subgroup	Historic	Hybrid	Supported	Created
Riparian woodland and shrubland	1	20	1	1
Emergent Marsh	1	9	15	2
Wet Meadow	0	0	5	2
Playa and Saline Depression	4	2	4	1
Total	6	31	25	6

4.6.2 Estimate of Wetland Condition for the Wetland Population in GHWC

Cumulative Distribution Function (CDF) analysis was used to estimate the percent of wetlands within the target population with EIA scores less than or equal to a particular score. Figure 6 displays a cumulative distribution plot of wetland EIA scores estimated for the targeted wetland population in the GHWC.

The CDF plot is not linear, indicating that scores are not evenly distributed across the target population (Fig. 6). Confidence intervals vary along the plot and are widest at the lowest and highest scores. Based on CDF analysis, 1.4% of wetlands in the GHWC would be A-ranked, 22% B-ranked, 68% C-ranked and 9% D-ranked. An assumption of the CDF analysis is that sample wetland data were obtained from a random sample that is representative of the wetland population in the GHWC study area. Our sample violated this assumption because 51% of wetlands in the sample design could not be sampled due to landowners denying permission and 27% due to other rejection criteria

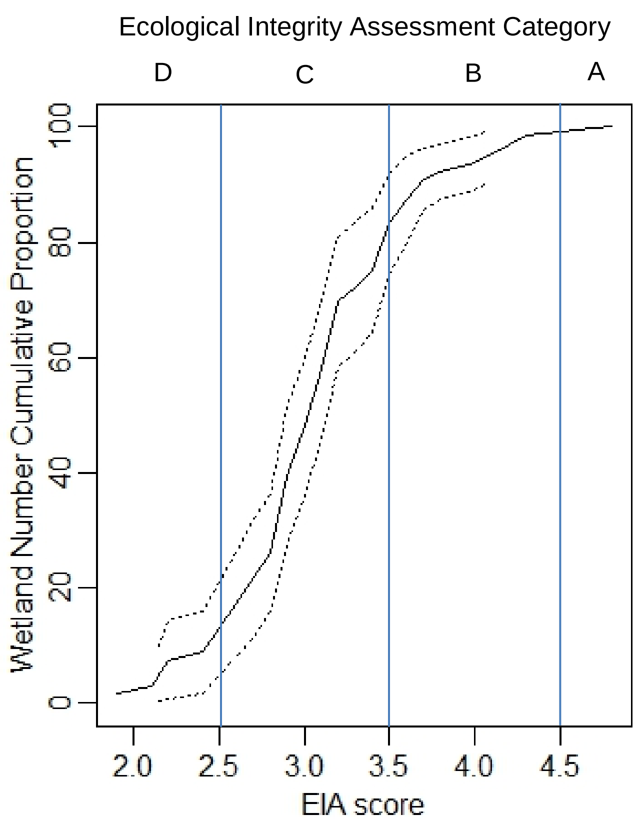

Figure 6. Cumulative distribution function of wetland EIA scores with 95% CI shown. Graph is the cumulative proportion of wetlands (y-axis) with EIA scores at or below values on the x axis. Center solid line indicates the estimate and is surrounded by dashed lines indicating the upper and lower 95% confidence limits

4.6.3 Indicators of disturbance

The EIA stressor metrics provided detailed information about the presence of different stressors within and surrounding each wetland study site. Non-native invasive plant species were observed in the buffers surrounding 75% of sampled wetlands (Fig. 7). The next most common stressors indicated landscape fragmentation by roads, nearby crop production, and buildings. These types of stressors were observed in buffers surrounding over half of the sampled wetlands. Potential hydrologic stressors related to irrigation were also observed in buffers surrounding over half of the sampled sites. The most common stressors observed within the wetlands themselves included the presence of invasive plant species and soil compaction by domestic and native herbivores (Table 17).

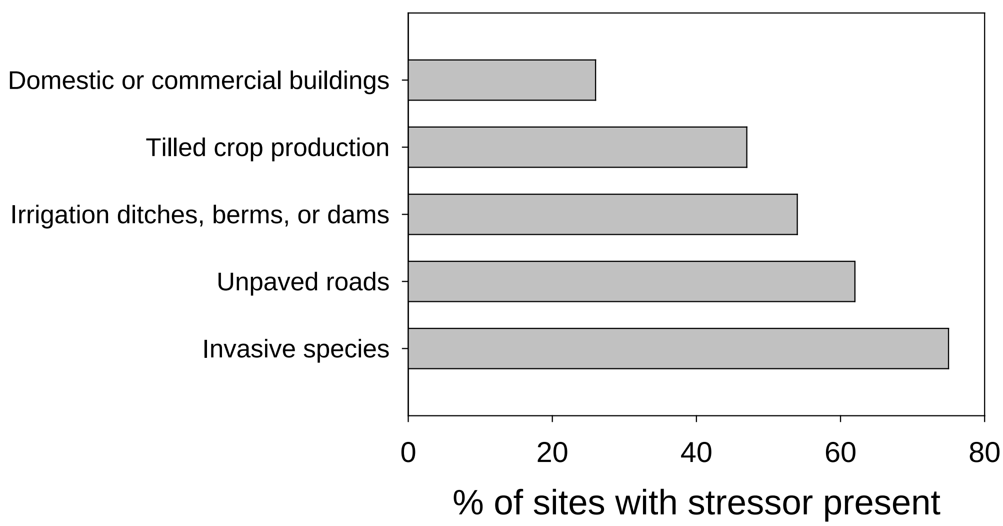

Figure 7. Five stressors observed most frequently in the 500 m buffers surrounding wetland sample site assessment areas in the GHWC.

Table 17. Prevalent stressors affecting physicochemical, vegetation, and hydrology attributes of wetlands

EIA Attribute Category	Rank of Stressor Indicator and % of sites present					
	Most Common		2nd Most Common		3rd Most Common	
Physicochemical	Compaction and soil disturbance by livestock or native ungulates	44.1%	Sedimentation	20.6%	Agricultural runoff	10.3%
Biotic	Invasive species	50.0%	Light grazing by livestock or native ungulates	17.6%	Moderate grazing by livestock or native ungulates	10.3%
Hydrology	Pugging or trails that affect water flow	11.7%	Dam/reservoir	10.2%	Pumps, diversions, ditches that move water into wetland	4.4%

4.6.5 Correlations between EIA Attribute Scores and Level 3 Floristic Metrics

Level 2 measures of wetland condition (EIA attributes) were compared with more intensive Level 3 floristic quality measures to assess potential relationships. The objectives of this project did not include calibration and validation of EIA methods, however the following results may provide information that can be used to improve future wetland assessment methods in Wyoming.

EIA biotic condition scores were negatively correlated with physicochemical condition scores (r[s] = -0.45, P = 0.0001). Significant relationships were found between EIA attributes and level 2 floristic quality metrics (Table 18). Plant species richness was negatively correlated with biotic condition scores and EIA scores, but positively correlated with physicochemical condition scores. EIA scores and non-native species richness were also negatively correlated, indicating that a higher number of non-native plant species tended to be present at sites with lower biotic condition and EIA scores. Interestingly, sites with higher physicochemical scores had both a higher number of total species and non-native species. Mean-C values were not correlated with EIA attribute scores. Disturbance to hydrology, as measured by LHM was also not correlated with other metrics.

Table 18. Analysis of potential relationships between floristic quality metrics and EIA attribute scores based on Spearman's rank correlation coefficient. Significant correlations (P < = 0.05) are shown in bold.

	Landscape context		Biotic condition		Physicochemical condition		Landscape Hydrology Metric		EIA total score	
	[r]s	*P*	[r]s	*P*	[r]s	*P*	[r]s	*P*	[r]s	*P*
Species richness	-0.13	0.289	-0.68	<0.0001	0.32	0.0066	0.12	0.331	-0.35	0.0033
Non-native species richness	-0.21	0.11	-0.67	<0.0001	0.31	0.0148	0.16	0.215	-0.29	0.0248
Mean C - all species	0.19	0.1277			-0.23	0.0562	0.19	0.1277		
Mean C - native	0.18	0.1448			-0.02	0.8788	-0.19	0.1309		

4.6.6 Evaluation of Avian Habitat

Bird Surveys

Bird surveys conducted at 66 wetland sites detected 6,035 birds belonging to 126 species within the GHWC (Appendix E). Sites classified as emergent marshes had the highest mean species richness (Fig. 8a). Mean species richness was lowest for wet meadows, but was highly variable between sites and ranged from 11-39 species. Approximately double the mean numbers of birds were observed at emergent marshes compared to the other wetland subgroups. Fifteen species from the "Bird Species of Concern" list for Wyoming (WYNDD 2015) were observed during surveys (Appendix E).

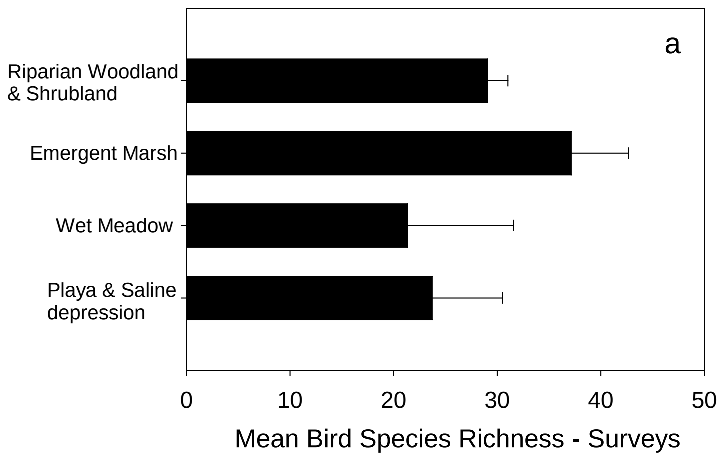

Figure 8a. Mean number per site of different bird species (species richness) observed in wetland subgroups in the GHWC.

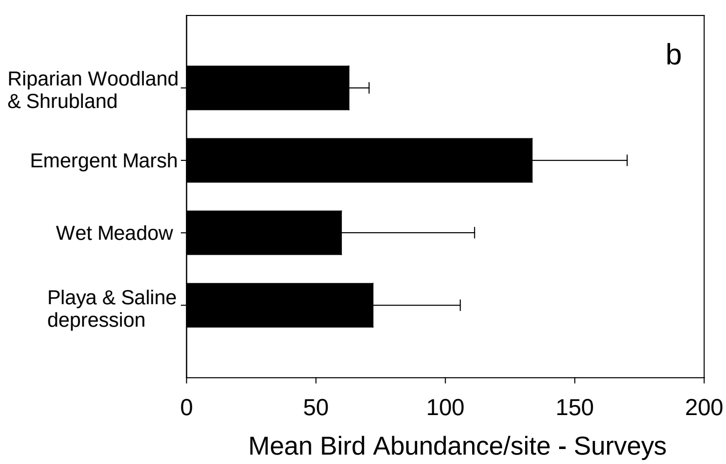

Figure 8b. Mean bird abundance (number of individuals per site) observed in wetland subgroups in the GHWC.

Analysis of EIA Attribute Scores and Bird Surveys

An objective of this study is to determine key wetland habitat features and resources that influence presence and abundance of wetland-dependent wildlife species. In light of this objective, we examined relationships between EIA scores and bird species richness and abundance. EIA attribute scores for landscape context were negatively correlated with bird species richness (r[s] = -0.33, $P = 0.0065$) and LHM scores were negatively correlated with bird abundance (r[s] = -0.26, $P = 0.0325$). The percent cover of non-native plants species was positively correlated with number of bird species detected at wetlands (r[s] = 0.29, $P = 0.0278$). In summary, wetlands with lower buffer condition and higher relative cover of non-native species supported a higher diversity of birds. In addition, wetlands with hydrologic alterations were associated with a higher number of birds detected.

Avian Habitat - AREM

AREM habitat suitability models predict that wetlands within the GHWC could provide suitable breeding habitat for 136 bird species. Riparian woodland and shrublands are predicted to provide suitable habitat for an average of 76 (range = 12-112 species) bird species per site (Fig. 9). Emergent marshes potentially provide suitable habitat for 51 (range = 15-106) avian species per site. The mean number of species predicted at wet meadows is 23 (range = 10-38) avian species per site and 17 (range = 7-32) at playas and saline depressions.

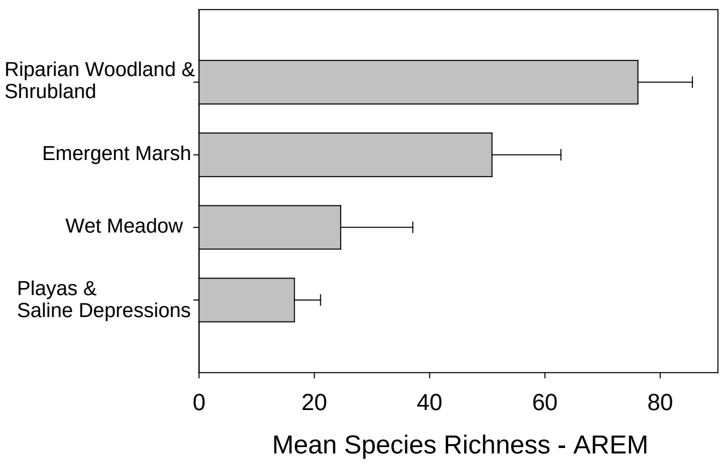

Figure 9. Mean bird richness predicted by AREM models.

Predicted bird species richness based on AREM models differed significantly from observed values (Mann-Whitney-Wilcoxon Test, $P = 0.001$). For riparian woodland and shrubland sites, AREM predicted substantially higher species richness per site than was observed. AREM also predicted higher-than-observed species richness for emergent marsh sites and playa and saline depression sites, although the differences between predicted and observed values were less than for the woodland and shrubland sites. The AREM prediction for wet meadow sites was closer to the observed value than for the other wetland groups. In addition, the Spearman's rank correlation test did not reveal a significant correlation between AREM predicted richness values and observed richness (r[s] = 0.23, $P = 0.0559$), which means that the AREM model did not correctly predict how the wetland groups rank relative to one another for bird species richness per site.

Of the 136 species AREM predicted could be present based on suitable habitat, 92 were observed during bird surveys, and 34 of the species predicted by AREM models were not detected. The overall lack of accuracy and evidence of error suggest improvements in AREM models are needed. Similarity of observed and predicted species composition were not analyzed for individual sites because data were insufficient. The model could be improved by adjusting scoring related to habitat requirements of each species. By lowering the habitat suitability threshold to 0.50, AREM predicts suitable habitat conditions could exist for 146 species across all sites in the GHWC. At this threshold level, the AREM-predicted species richness values are positively correlated with observed values (r[s] = 0.27, $P = 0.0289$). This result indicates that presence of suitable habitat may be indicated by a score lower than the 0.75 threshold, and adjustment to habitat requirements defined for each species could improve AREM performance. Further site-specific comparisons of observed and predicted species, and adjustments to scoring for birds breeding in the region, could improve the utility of AREM for predicting presence of wetland bird species.

Benthic invertebrates

Benthic invertebrates were present at all of wetlands with surface water, mainly emergent marsh and riparian woodland and shrubland wetlands (Table 19). The mean benthic invertebrate biomass and densities were highest for emergent marshes, and lowest for wet meadows, although only one site was sampled from each of the wet meadow and playa and saline depression subgroups. Benthic invertebrate communities were dominated by air-breathing freshwater snails from the families Planorbidae, Lymnaeidae, and Physidae, followed by Chironomidae, Culicidae, and Tabanidae from the Order Diptera (Table 20).

Table 19. Biomass and density of benthic invertebrates (all taxonomic groups combined) at 23 wetland sites.

Wetland subgroup	n	Mean (SD) benthic invertebrate biomass (g/m^2)	Mean (SD) benthic invertebrate density ($indiv./m^2$)
Riparian woodland and shrubland	5	10 (8)	2433 (1323)
Emergent Marsh	16	139 (208)	6375 (8942)
Wet Meadow	1	2	1274
Playa and Saline Depression	1	290	2140

Table 20. Mean densities (individuals/m^2) and community composition (average proportion of total invertebrate density among sites) for benthic invertebrate taxonomic groups observed at 23 wetland sites.

Taxonomic group	Common name	Mean density (#/m^2)	Proportion of total
Planorbidae	Ram's horn snails	3088	45.1
Lymnaeidae	Pond snails	1743	28.7
Physidae	Bladder snails	1050	12.5
Chironomidae	Midge	827	12.1
Culicidae	Mosquito	238	0.65
Tabanidae	Horsefly	203	0.19
Oligochaeta	Aquatic worm	102	0.19
Hydrophilidae	Water scavenger beetles	102	0.09
Megaloptera	Alderfly, dobsonfly, or Fishfly	102	0.09
Odonata	Dragonfly	102	0.09
unknown	unknown	102	0.28

5.0 DISCUSSION

This study provides the first basin-wide assessment of wetlands in Goshen Hole, southeast Wyoming. Results from our study provide a baseline assessment of the landscape profile, condition, and habitat potential of wetland resources in the GHWC. This information provides a reference point for wetland condition monitoring, which will help inform conservation planning and project design and implementation efforts.

The landscape profile demonstrates the importance of recognizing linkages between land use, irrigation practices and wetlands in the GHWC. Wetlands and water bodies total 9,669 acres or approximately 3% of the total land area within the GHWC. Sixty-six percent of the wetlands are freshwater emergent wetlands, which include irrigated hayfields. Over 70% of wetlands are privately owned. Understanding land use patterns and coordination with private landowners is essential to maintain the ecological integrity of wetland resources throughout the GHWC.

Level 2 wetland condition assessments using EIA methods were developed to measure the condition of wetlands in the basin. A and B ranked wetlands indicate high potential for ecological integrity and conservation value. Management of these wetlands should focus on the prevention of further alteration. Lower-ranking wetlands have disturbance across multiple EIA metrics indicating that management would be needed to maintain or restore ecological attributes. All wetland subgroupings were dominated by C-ranked wetlands. Two percent of the 68 study sites in the GHWC were ranked “A,” 21% were ranked “B,” 69% were ranked “C,” and 9% were ranked “D”. Playas and saline depressions were the least-disturbed wetland type, followed by riparian woodland and shrublands. The highest proportion of D-ranked sites were wet meadows that comprise 10 % of sampled wetlands.

Based on the CDF analysis, we estimate that 1.4% of wetlands in the GHWC are A-ranked, 22% B-ranked, 68% C-ranked and 9% D-ranked. These results suggest that a high proportion (77%) of wetlands in the basin are moderately to highly altered from reference condition. These inferences are based on the assumption that our data come from a random sample of study sites. Unfortunately, that assumption was weakened when we had to remove sites from our original sampling frame due to landowner denial for access and other rejection criteria. We don't know how much this affected our inferences about wetlands in the GHWC. It is impossible to know the condition of unsampled wetlands.

EIA attribute condition scores (Landscape Context, Hydrologic Condition, Physicochemical Condition, and Biotic Condition) provide key information about the distribution of factors influencing ecological integrity. EIA helps identify general patterns of disturbance in the basin, and managers can use the condition attributes to identify disturbances that might be affecting specific locations. Landscape context ranks were generally in the A-B range, indicating presence of wide buffers and landscape connectivity surrounding most wetlands. Biotic condition scores were relatively low across all wetland subgroups (76% C & D-ranked) which is consistent with results from prior studies done in irrigated basins in Colorado (Lemly and Gilligan 2012). Lower scores are mainly due to the presence of non-native species, which influences multiple EIA biotic metrics. In contrast, most wetlands received relatively high physicochemical condition rankings in the A-B range. Soil disturbance from livestock and native ungulates and sedimentation were common stressors observed at wetlands.

It is important to point out the general contrast between physicochemical and biotic attribute scores across all wetland types, but especially for riparian woodland and shrublands. Riparian woodlands and shrublands had the lowest biotic attribute scores, with 91% of sites ranked as D, resulting in a negative correlation between physicochemical and biotic attribute scores. In addition, LHM analyses categorized 87% of riparian woodlands and shrublands as altered-hybrid, largely due to hydrologic alterations of the North Platte and Laramie Rivers. These combined results suggest hydrologic alterations at the basin-scale (LHM) can be more important than local disturbances (i.e. physicochemical or landscape context) in affecting the ecological integrity of riparian wetlands (Junk et al. 1989, Rood et al. 2005, Stromberg et al. 2007).

We collected data documenting potential stressors that may influence EIA attribute condition scores. Correlations between wetland condition and potential stresses can be used to direct management efforts. The most widespread signs of disturbances (stressors) identified across all wetland types were presence of invasive plant species surrounding and within the wetland (which causes lower biotic condition scores) and impacts from grazing by domestic and native herbivores such as soil compaction (which relates to lower physical-chemical scores) (Table 17). Anthropogenic disturbances related to agricultural production and development such as the presence of unpaved roads and irrigation infrastructure represent the next most common stressors. Land management policies that discourage further human disturbance and encourage sustainable agricultural practices in and near wetlands will help to maintain wetland function and prevent further declines in condition.

Our results point to the challenge of quantitatively assessing ecological condition of wetlands in irrigated basins because many wetlands, regardless of ecological integrity, are influenced by hydrologic alterations. For example, according to NWI data, wetlands in the GHWC make up less than 2% of the irrigated landscape, and most (70%) have no hydrologic modifications. However, our LHM analyses identified modified hydrology at 90% of sampled wetlands. Almost half (46%) of sampled wetlands were dependent on water sources linked to irrigation and other hydrologic alterations. All wet meadows and 67% of emergent marshes were supported by hydrologic and anthropogenic disturbances. Eighty-seven percent of riparian woodland and shrublands were in the altered-hybrid LHM category due to basin scale hydrologic alteration of the North Platte and its tributaries. In some cases (9% of sampled wetlands), hydrologic alterations have created wetlands that did not historically exist. Playas and saline depressions had the largest proportion of historic wetlands absent of hydrologic alterations, likely because of their position in the landscape distant from floodplain agricultural development.

Our bird surveys confirm that *at least* 126 bird species use wetlands in the GHWC during the breeding season (April-May). Interestingly, wetlands with lower landscape attribute scores and higher relative cover of non-native vegetation were correlated with higher bird diversity. In addition, wetlands with hydrologic alterations (lower LHM scores) were associated with greater abundance of birds. Although correlations between EIA metric scores and bird species richness and abundance were low (<0.3), p-values suggest that hydrologic modifications can have positive impacts on habitat for some bird species. In general, higher bird diversity and abundance and presence of benthic macroinvertebrates were observed in wetlands with permanent water, such as emergent marshes and riparian woodland and shrublands. Although scores of multiple EIA metrics were consistently low in wet meadows, our data indicate that these wetlands do provide important bird habitat. It is likely that wetlands influenced by hydrologic alterations, including inputs from flood irrigation and ditches, provide a stable water source and adequate habitat for wetland birds during dry summer months. Wetlands supported by irrigation and urban runoff have become recognized as providing critically important avian habitat within otherwise arid regions (Trammell et al. 2011, Bateman et al. 2015) and securing these water resources will likely benefit wetland wildlife.

5.1 Wetland Priorities for Conservation and Restoration

The GHWC has been extensively modified by agriculture since being settled in the 1800s. It is likely that, as elsewhere in the US, some natural wetlands were drained and converted to cropland or grazing land. Clearly, stream hydrology has been altered by impoundments, diversions, and channel modifications (Dahl 1990). More significant changes in the GHWC, though, likely have been the creation of wetlands and the enhancement of hydrology in existing wetlands. Both resulted from the development of the irrigation infrastructure in this region in the early 20th century, and both created novel or hybrid wetland ecosystems. The ecological challenges of conserving and managing hybrid and novel ecosystems are increasingly recognized (Hobbs et al. 2014). Understanding the function of all types of wetlands along a spectrum of unaltered historic to novel wetlands, will be necessary for effective decision-making and management. To maintain or improve wetland conditions within the GHWC, conservation and restoration efforts need to focus on implications of climate change, changes to water availability, and land use practices when prioritizing wetland management.

Climate change was identified as an extreme threat in the Goshen Wetlands Complex Regional Wetlands Conservation Plan (WBHCP 2014) and wetlands were identified as highly vulnerable to climate change in a recent statewide report (Pocewicz et al. 2014). For example, recent drought conditions in southeastern Wyoming from 2000-2008 had a major impact on wetlands in the GHWC (WBHCP 2014). During that drought, irrigation inputs ceased or were substantially curtailed, leading to low or no water available to many wetlands.

Water shortages due to potential climate alteration and predicted drought (Cook et al. 2004), and increased human population (Hansen et al. 2002) may place pressure on agricultural producers to convert to center-pivot irrigation methods. According to the Goshen wetlands conservation plan (WBHCP 2014), flood irrigation is the prevalent method currently used to irrigate. Temporary and seasonal wetlands are especially vulnerable to loss from conversion to sprinklers or residential development (Copeland et al. 2010, Pocewicz et al. 2014). Approximately 46% of wetlands sampled were created or supported by irrigation. Conversion to center pivot irrigation could potentially affect an estimated 1,403 acres of wetlands in the basin, as well as the wildlife habitat they provide. Conservation strategies aimed at protecting wetlands may fall short of their intended purpose if water quantity and timing crucial to wetland function are not also maintained (Downard and Endter-Wada 2013).

Hydrology is the principal driver of ecological processes that sustain wetland ecosystem functions (Barker and Maltby 2009). Seasonal flood pulses and late summer periods of low flow are vital for maintaining structure and function of wetlands linked to streams (Junk et al. 1989). Presence of dams and diversions alter the timing and quantity of water available within the basin, and this directly or indirectly affects the quantity and types of wetlands present. Basin-level and local hydrologic alterations observed at a majority of the sampled sites within the GHWC have likely impacted the ecological integrity of most wetlands. Best management practices that focus on maintenance and improvement of the ecological integrity of wetlands, irrespective of historic versus novel status, will have the greatest conservation benefit.

There is increasing recognition of the ecosystem services provided by agriculturally influenced wetlands (Tanner et al. 2013) for pesticide de-contamination (Tournebize et al. 2013), reduction of nitrogen transport from agricultural catchments, and support of species diversity (Strand and

Weisner 2013). Many studies have begun to quantify the importance of irrigation-influenced wetlands for birds and other wildlife (Chester and Robson 2013, Moulton et al. 2013, Patla 2015, Donnelly et al. In press). Many avian species have adapted to, and benefitted from these systems, and have likely altered migration patterns in response to changes in wetland habitat availability (Nichols et al. 1983, Sutherland 1998, Abraham et al. 2005). However, research is still needed to fully explore and better quantify ecosystem services and wildlife values associated with irrigation-influenced and created wetlands.

6.0 CONCLUSION

The ecological challenges of conserving and managing hybrid and novel ecosystems are increasingly being recognized. This recognition represents a shift from the traditional paradigm that pristine landscapes have the highest ecological value – all wetlands within working landscapes have intrinsic values (Hobbs et al. 2014). The wetland systems we studied constitute novel or hybrid systems resulting from anthropogenic alterations within the GHWC landscape. The same type of novel systems appear to be prevalent on other western arid landscapes (Peck and Lovvorn 2001, Trammell et al. 2011, Bateman et al. 2015). Understanding the functionality of entire landscapes, including the spectrum of historic to created wetlands, will be necessary for effective decision-making and management of these novel systems. Traditional EIA metrics are biased in their assumption that anthropogenic disturbance is always equated with diminished condition and function. Recognizing that this broad assumption may not hold true everywhere (e.g., on arid landscapes modified by agricultural irrigation), we included LHM, floristic quality, and avian richness metrics in our analysis. These data provide a baseline for beginning to understand the complex interrelationships between anthropogenic disturbances, hydrologic modifications, and wildlife values of wetlands in the GHWC.

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Appendix A: Field Key to Wetland and Riparian Ecological Systems of Wyoming
Last Updated April 7, 2015

1b. Wetlands and riparian areas of the Western Great Plains. *[If on the edge of the foothills, try both Key A and Key B]* .... **KEY A**: **WETLANDS AND RIPARIAN AREAS OF THE WESTERN GREAT PLAINS**

1b. Wetland and riparian areas west of the Great Plains **2**

2a. Wetlands and riparian areas with alkaline or saline soils within the inter-mountains basins of the Rocky Mountains (Upper Green River basin, Wind River basin, ect.) *[If the site does not match any of the descriptions within Key B, try Key C as well. Wetlands and riparian areas of the Rocky Mountains transition into the inter-mountain basins.]* .... **KEY B: WETLANDS AND RIPARIAN AREAS OF THE INTER-MOUNTAIN BASINS**

2b. Wetlands and riparian areas of the Rocky Mountains, including the Snowy Mountains, the Wind Rivers, the Absorakas and the Bighorns.. .... **KEY C: WETLANDS AND RIPARIAN AREAS OF THE ROCKY MOUNTAINS**

Ecological Systems of Wyoming

- Black Hills
- Inter-mountain Basins
- Rocky Mountains
- Western Great Plains

KEY A: WETLANDS AND RIPARIAN AREAS OF THE WESTERN GREAT PLAINS

1a. Low stature shrublands dominated by species such as *Sarcobatus vermiculatus, Atriplex* spp., *Ericameria nauseosa*, *Artemisia sp.* Vegetation may be sparse and soils may be saline. Sites may be located on the edge alkali depressions, or in flats or washes not typically associated with river and stream floodplains. *[These systems were originally described for the Inter-Mountain Basins, but may extend to the plains.]* **2**

1b. Wetland is not a low stature shrub-dominated saline wash or flat. **3**

2a. Shrublands with sparse (<20%) vegetation cover, located on flats or in temporarily or intermittently flooded drainages, or on the edge of playas and alkali depressions. They are typically dominated by *Sarcobatus vermiculatus* and *Atriplex* spp. with inclusions of *Sporobolus airoides, Pascopyrum smithii, Distichlis spicata, Puccinellia nuttalliana,* and *Eleocharis palustris* herbaceous vegetation ……………………………………………………………………………………………….**Inter-Mountain Basins Greasewood Flat**

2b. Sites with > 20% total vegetation cover and restricted to temporarily or intermittently flooded drainages with a variety of sparse or patchy vegetation including *Sarcobatus vermiculatus*, *Ericameria nauseosa*, *Artemisia sp., Grayia spinosa*, *Distichlis spicata*, and *Sporobolus airoides.* .... ……….**Inter-Mountain Basins Wash**

3a. Sites located within the floodplain or immediate riparian zone of a river or stream. Vegetation may be entirely herbaceous or may contain tall stature woody species, such as *Populus* spp. or *Salix* spp. Water levels variable. Woody vegetation that occurs along reservoir edges can also be included here.... **4**

3b. Herbaceous wetlands of the Western Great Plains that are isolated or partially isolated from floodplains and riparian zones, often depressional with or without an outlet. **8**

4a. Herbaceous wetlands within the floodplain with standing water at or above the surface throughout the growing season, except in drought years. Water levels are often high at some point during the growing season, but managed systems may be drawn down at any point depending on water management regimes. Vegetation typically dominated by species of *Typha, Scirpus, Schoenoplectus*, *Carex*, *Eleocharis*, *Juncus*, and floating genera such as *Potamogeton*, *Sagittaria*, and *Ceratophyllum*. The hydrology may be entirely managed. Water may be brackish or not. Soils are highly variable. This system includes natural warm water sloughs and other natural floodplain marshes as well as a variety of managed wetlands on the floodplain (e.g., recharge ponds, moist soil units, shallow gravel pits, etc.)……… .... **Western North American Emergent Marsh**

4b. Not as above. Wetland and riparian vegetation that typically lacks extensive standing water. Vegetation may be herbaceous or woody. Management regimes variable.. **5**

5a. Large herbaceous wetlands within the floodplain associated with a high water table that is controlled by artificial overland flow (irrigation). Sites typically lack prolonged standing water. Vegetation is dominated by native or non-native herbaceous species; graminoids have the greatest canopy cover. Species composition may be dominated by non-native hay grasses such as *Poa spp., Alopecurus sp, Phleum pretense, and* Bromus inermis spp. inermis. There can be patches of emergent marsh vegetation and standing water less than 0.1 ha in size; these are not the predominant vegetation. .... **Irrigated Wet Meadow (not an official Ecological System)**

5b. Predominantly natural vegetation (though may be weedy and altered) within the floodplain or immediate riparian zone of a river or stream, dominated by either woody or herbaceous species. Not obviously controlled by irrigation. **6**

6a. Riparian woodlands and shrublands of the Rocky Mountain foothills on the very western margins of the Great Plains. Woodlands are dominated by *Populus* spp. (mainly *Populus angustifolia*,). Common native shrub species include *Salix* spp., *Alnus incana*, *Betula occidentalis, Cornus sericea*, and *Crataegus* spp. Sites are most often associated with a stream channel, including ephemeral, intermittent, or perennial streams (Riverine HGM Class). This system can occur on slopes, lakeshores, or around ponds, where the vegetation is associated with groundwater discharge or a subsurface connection to lake or pond water, and may experience overland flow but no channel formation (Slope, Flat, Lacustrine, or Depressional HGM Classes). It is also typically found in backwater channels and other perennially wet but less scoured sites, such as floodplain swales and irrigation ditches. .... **Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland**

6b. Riparian woodlands, shrublands and meadows of Wyoming's Western Great Plains. Common native trees are *Populus deltoides*, *Salix amygdaloides, Acer negundo, Fraxinus* pennsylvanica., and *Ulmus* americana. Common native shrubs include *Salix* spp., Rosa spp, and Symphoricarpos spp. Common non-native trees and shrubs are *Tamarix* spp. and *Elaeagnus angustifolia.* **7**

7a. Riparian woodlands, shrublands, and meadows along medium and small rivers and streams. Sites have less floodplain development and flashier hydrology than the next, and all streamflow may drawdown completely for some portion of the year. Water sources include snowmelt runoff (more common in Wyoming), groundwater (prairie streams), and summer rainfall. Dominant species include *Populus deltoides, Salix* spp., *Fraxinus pennsylvanica, Pascopyrum smithii, Panicum sp., Carex* spp., *Tamarix* spp., *Elaeagnus angustifolia,* and other non-native grasses and forbs…………………………………… ……………………………………………………………………………………………………….W**estern Great Plains Riparian**

7b. Woodlands, shrublands, and meadows along large rivers (the North Platte and its larger tributaries) with extensive floodplain development and periodic flooding that is more associated with snowmelt and seasonal dynamics in the mountains than with local precipitation events. Hydroperiod alterations from major dams and reservoirs alter historic flooding patterns. Dominant communities within this system range from floodplain forests to wet meadow patches, to gravel/sand flats dominated by early successional herbs and annuals; however, they are <u>linked by underlying soils and the flooding regime</u>. Dominant species include *Populus deltoides* and *Salix* spp., *Panicum sp.* and *Carex* spp. *Tamarix* spp., *Elaeagnus angustifolia,* and non-native grasses.…………………………….**Western Great Plains Floodplain**

8a. Natural shallow depressional wetlands in the Western Great Plains with an impermeable soil layer, such as dense hardpan clay that causes periodic ponding after heavy rains. Sites generally have closed contour topography and are surrounded by upland vegetation. Hydrology is typically tied to precipitation and runoff but lacks a groundwater connection; however some of these sites are receiving increased water from irrigation seepage. Ponding is often ephemeral and sites may be dry throughout the entire growing season during dry years. Species composition depends on soil salinity, may fluctuate depending on seasonal moisture availability, and many persistent species may be upland species. *[The wetlands within this group are collectively referred to* ***playas or playa lakes****. Ecological systems listed below separate playas based on the level of salinity and total cover of vegetation.]* **9**

8b. Herbaceous wetlands in the Western Great Plains not associated with hardpan clay soils. Sites may or may not be depressional and may or may not be natural. **10**

9a. Shallow depressional wetlands with less saline soils than the next. Dominant species are typically not salt-tolerant. Sites may have obvious vegetation zonation of tied to water levels, with the most hydrophytic species occurring in the wetland center where ponding lasts the longest. Common native species include *Pascopyrum smithii, Iva axillaris, , Eleocharis* spp., *Oenothera canescens, Plantago* spp., *Polygonum* spp., *Conyza canadensis* ,and *Phyla cuneifolia.* Non-native species are very common in these sites, including *Salsola australis, Bassia sieversiana, Verbena bracteata,* and Polygonum aviculare. Sites have often been affected by agriculture and heavy grazing. Many have been dug out or “pitted” to increase water retention and to tap shallow groundwater.. ....**Western Great Plains Closed Depression Wetland**

9b. Shallow depressional herbaceous wetlands with saline soils. Salt encrustations can occur on the surface. Species are typically salt-tolerant, including *Distichlis spicata*, *Puccinellia nuttalliana, Salicornia rubra, Schoenoplectus maritimus, Schoenoplectus americanus, Suaeda calceoliformis, Spartina* spp., *Triglochin maritima,* and occasional shrubs such as *Sarcobatus vermiculatus .[This system resembles the Inter-Mountain Basins Alkaline Closed Depression but occur in the Great Plains ecoregion. Note: Low stature shrub-dominant wetlands key in the flats and wash systems above.]* ....**Western Great Plains Saline Depression Wetland**

10a. Herbaceous wetlands with standing water at or above the surface throughout the growing season, except in drought years. Water levels are often high at some point during the growing season, but managed systems may be drawn down at any point depending on water management regimes. Vegetation typically dominated by species of *Typha, Scirpus, Schoenoplectus*, *Carex*, *Eleocharis*, *Juncus*, and floating genera such as *Potamogeton*, *Sagittaria*, and *Ceratophyllum*. The isolated expression of this system can occur around ponds, as fringes around lakes, and at any impoundment of water, including irrigation run-off. The hydrology may be entirely managed or artificial. Water may be brackish or not. Soils are highly variable... **Western North American Emergent Marsh**

10b. Herbaceous wetlands associated with a high water table that is controlled by artificial overland flow (irrigation) or artificial groundwater seepage (including from leaky irrigation ditches). Sites typically lack prolonged standing water. Vegetation is dominated by native or non-native herbaceous species; graminoids have the greatest canopy cover. s. Patches of emergent marsh vegetation and standing water are less than 0.1 ha in size and not the predominant vegetation... ....**Irrigated Wet Meadow (not an official Ecological System)**

KEY B: WETLANDS AND RIPARIAN AREAS OF THE INTER-MOUNTAIN BASINS

1a. Depressional, herbaceous wetlands occurring within dune fields of the inter-mountain basins (e.g. Great Divide basin)..**Inter-Mountain Basins Interdunal Swale Wetland**

1b. Wetlands not associated with dune fields **2**

2a. Depressional wetlands. Soils are typically alkaline to saline clay with hardpans. Salt encrustation typically visible on the soil surface or along the water edge. Water levels various. Cover of vegetation variable, can be extremely sparse (<10% cover) or moderate to high (30–60% cover). Typically herbaceous dominated, but may contain salt-tolerant shrubs on the margins... **3**

2b. Non-depressional wetlands on flats or in washes, with alkaline to saline soils. Cover of vegetation variable, can be extremely sparse (<10% cover) or moderate to high (30–60% cover). Typically shrub dominated. Most common species are *Sarcobatus vermiculatus* and *Atriplex* spp.................................... **4**

3a. Depressional, alkaline wetlands that are seasonally to semi-permanently flooded, usually retaining water into the growing season and drying completely only in drought years. Many are associated with irrigation seepage, springs, or located in large basins with internal drainage. Seasonal drying exposes mudflats colonized by annual wetland vegetation. This system can occur in alkaline basins and swales and along the drawdown zones of lakes and ponds. They generally have thick unvegetated salt crusts over clay soils surrounded by zones of vegetation transitioning to the uplands. In these zones vegetation cover is generally >10% and species are typically salt-tolerant such as *Distichlis spicata*, *Puccinellia* spp., *Leymus* sp., *Schoenoplectus maritimus, Schoenoplectus americanus, Triglochin maritima,* and *Salicornia* spp. ....**Inter-Mountain Basins Alkaline Closed Depression**

3b. Barren and sparsely vegetated playas (generally <10% plant cover. Could be more if annuals or upland vegetation are encroaching). Salt crusts are common throughout, with small saltgrass beds in depressions and sparse shrubs around the margins. These systems are intermittently flooded. The water generally comes from precipitation and is prevented from percolating through the soil by an impermeable soil sub horizon and is left to evaporate. Soil salinity varies with soil moisture and greatly affects species composition. Characteristic species may include *Sarcobatus vermiculatus, Distichlis spicata,* and/or *Atriplex* spp. .... **Inter-Mountain Basins Playa**

4a. Shrublands with >10% total vegetation cover, located on flats. Vegetation dominated by *Sarcobatus vermiculatus* and *Atriplex* spp. with inclusions of *Artemisia tridentata ssp. Tridentate, Sporobolus airoides, Pascopyrum smithii, Distichlis spicata, Puccinellia nuttalliana,* and.herbaceous vegetation. .... **Inter-Mountain Basins Greasewood Flat**

4b. Sites with < 10% total vegetation cover and restricted to temporarily or intermittently flooded drainages with a variety of sparse or patchy vegetation including *Sarcobatus vermiculatus*, *Ericameria nauseosa*, *Artemisia cana*, *Artemisia tridentata*, *Distichlis spicata*, and *Sporobolus airoides.* .... **Inter-Mountain Basins Wash**

KEY C: WETLANDS AND RIPARIAN AREAS OF THE ROCKY MOUNTAINS

1a. Wetland defined by groundwater inflows and organic soil (peat) accumulation of at least 40 cm in the upper 80 cm. Vegetation can be woody or herbaceous. If the wetland occurs within a mosaic of non-peat forming wetland or riparian systems, then the patch must be at least 0.1 hectare (0.25 acre). If the wetland occurs as an isolated patch surrounded by upland, then there is no minimum size criterion. .... **Rocky Mountain Subalpine-Montane Fen**

1b. Wetland does not have at least 40 cm of organic soil (peat) accumulation or occupies an area less than 0.1 hectares (0.25 acres) within a mosaic of other non-peat forming wetland or riparian systems ... 2

2a. Total woody canopy cover generally 25% or more within the overall wetland/riparian area. Any purely herbaceous patches are less than 0.5 hectare and occur within a matrix of woody vegetation. *[Note: Relictual woody vegetation such as standing dead trees and shrubs are included here.] 3*

2b. Total woody canopy cover generally less than 25% within the overall wetland/riparian area. Any woody vegetation patches are less than 0.5 hectare and occur within a matrix of herbaceous wetland vegetation 5

3a. Riparian woodlands and shrublands of the foothill and lower montane zones on the Rocky Mountains. Woodlands are dominated by *Populus* spp. (*Populus angustifolia*, or the hybrid *P. acuminate*. At higher elevations Picea engelmannii, Abies lasiocarpa, Pseudotsuga menziesii, and Pinus ponderosa can be found. Common native shrub species include *Salix* spp., *Alnus incana*, *Betula occidentalis, Cornus sericea*, and *Crataegus* spp. Sites are most often associated with a stream channel, including ephemeral, intermittent, or perennial streams (Riverine HGM Class). This system can occur on slopes, lakeshores, or around ponds, where the vegetation is associated with groundwater discharge or a subsurface connection to lake or pond water, and may experience overland flow but no channel formation (Slope, Flat, Lacustrine, or Depressional HGM Classes). It is also typically found in backwater channels and other perennially wet but less scoured sites, such as floodplain swales and irrigation ditches. (this system is also found in the inter-mountain basin ecoregion).. ....
…………………………………………..**Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland**

3b. Riparian woodlands and shrublands of the montane or subalpine zone 4

4a. Montane or subalpine riparian woodlands (canopy dominated by trees). This system occurs as a narrow streamside forest lining small, confined low- to mid-order streams. Common tree species include *Abies lasiocarpa*, *Picea engelmannii*, ,and *Populus tremuloides* (The overstory consists of Picea engelmannii, often with some Abies lasiocarpa and Populus tremuloides. These riparian areas generally occur at elevations where the uplands support upper montane and subalpine forests -- Pinus contorta, Picea engelmannii, Abies lasiocarpa. The common riparian trees in this type -- Picea engelmannii, Abies lasiocarpa, Populus tremuloides -- also grow in riparian zones in the lower montane, but there they are joined by Populus angustifolia, sometimes Populus acuminata, Populus balsamifera (mostly in NW Wyoming), Picea pungens (NW Wyoming : Snake River drainage, and the Wind River around Dubois), Pseudotsuga menziesii, Pinus ponderosa (eastern half of WY). Then, with decreasing elevation, the conifer drop out, Populus acuminata increases, and Populus deltoides becomes a major species.) ....
.... **Rocky Mountain Subalpine-Montane Riparian Woodland**

4b. Montane or subalpine shrub wetlands (canopy dominated by shrubs with sparse or no tree cover). This system is most often associated with streams (Riverine HGM Class), occurring as either a narrow band of shrubs lining streambanks of steep V-shaped canyons (straight, with boulder and cobble substrate)*or* as a wide, extensive shrub stand on alluvial terraces in low-gradient valley bottoms (more sinuous, with finer-textured substrates. Sometimes referred to as a *shrub carr*). Beaver activity is common within the wider occurrences. In addition, this system can occur around the edges of fens, lakes, seeps, and springs on slopes away from valley bottoms. This system can also occur within a mosaic of multiple shrub- and herb-dominated communities within snowmelt-fed basins. In all cases, vegetation is dominated by species of *Salix*, *Alnus*, or *Betula* but their composition varies depending on stream gradient. Alnus incana is a dominant or co-dominant along high-gradient streams; Betula occidentalis often co-dominates. Willows are present, as is Cornus sericea, but rarely dominate. In contrast, along the lower-gradient streams in wide valleys, the willows dominate; Betula and Cornus often are present but secondary to the willows; Alnus usually is a minor component. . ...
....**Rocky Mountain Subalpine-Montane Riparian Shrubland**

5a. Herbaceous wetlands with water present throughout all or most of the year. Water is at or above the surface throughout the growing season, except in drought years. This system can occur around ponds, as fringes around lakes, and along slow-moving streams and rivers. The vegetation is dominated by common emergent and floating leaved plants, including species of *Scirpus*, *Schoenoplectus*, *Typha*, *Juncus*, *Carex*, *Potamogeton*, *Polygonum*, and *Nuphar*...
.... **Western North American Emergent Marsh**

5b. Herbaceous wetlands that typically lack extensive standing water. Patches of emergent marsh vegetation and standing water are less than 0.1 ha in size and not the predominant vegetation............. **7**

6a. Herbaceous wetlands associated with a high water table or overland flow, but typically lack standing water. Sites with *no channel formation* are typically associated with snowmelt or groundwater and not subjected to high disturbance events such as flooding (Slope HGM Class). Sites *associated with a stream channel* are more tightly connected to overbank flooding from the stream channel than with snowmelt and groundwater discharge. Vegetation is dominated by herbaceous species; typically graminoids have the highest canopy cover including *Carex* spp., *Calamagrostis* spp., and *Deschampsia caespitosa*.............
.... **Rocky Mountain Alpine-Montane Wet Meadow**

6b. Large herbaceous wetlands associated with a high water table that is controlled by artificial overland flow (irrigation). Sites typically lack prolonged standing water, but may have standing water early in the season if water levels are very high. Vegetation is dominated by native or non-native herbaceous species; graminoids have the highest canopy cover ....
. ... **Irrigated Wet Meadow (not an official Ecological System)**

Appendix B: Goshen Hole Wetland Assessment Field Form

LOCATION AND GENERAL INFORMATION

Point Code __________ Date: __________________________Surveyors:____

Directions to Point:

Access Comments (note permit requirement or difficulties accessing the site):

GPS COORDINATES OF TARGET POINT AND ASSESSMENT AREA

Original Point WP #: _______ Cowardin Code: ________ Target?: ___ Yes ___ No Relation to AA: ___Centered ___Included ___Outside

Dimensions of AA:	
____40 m radius circle	Elevation (m):
____Rectangle, width________ length:_________	Slope (deg):
____Freeform, describe and take a GPS Track	Aspect (deg):

AA-Center WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________
(Circle AAs Only)

AA-1 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-2 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-3 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-4 WP #: __________ UTM E: ___ ___ ___ ___ ___ ___ UTM N: ___ ___ ___ ___ ___ ___ ___ Error (+/-): ______________

AA-Track Track Name: ____ Area: ____

PHOTOS OF ASSESSMENT AREA(Taken at four points on edge of AA looking in.

AA-1 Photo #: _____________ Aspect: _____________

AA-2 Photo #: _____________ Aspect: _____________

AA-3 Photo #: _____________ Aspect: _____________

AA-4 Photo #: _____________ Aspect: _____________

Additional AA Photos and Comments:
(Note range of photo numbers and explain particular photos of interest)

Wildlife:

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA

Non-target Inclusions:

% AA with > 1m standing water: ______________

% AA with upland inclusions: _________________

Wetland origin (if known):

____ Natural feature with minimal alteration

____ Natural feature, but altered or augmented by modification

____ Non-natural feature created by passive or active management

____ Unknown

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA(CONTINUED)

Ecological System: (see manual for key and rules on inclusions and pick the *best match*) Fidelity: High Med Low

Cowardin Classification (pick *one each that best represents AA*)

Fidelity: High Med Low

System and Class:		Water Regime:		Modifier (optional):	
____ PEM	____ PAB	____ A	____ F	____ b	____ h
____ PSS	____ PUB	____ B	____ G	____ x	____ f
____ PFO	____ PUS	____ C	____H	____ d	
____ L2AB	____ L2US				

HGM Class (pick *only one that best represents AA*)

Fidelity: High Med Low

____Riverine* ____Lacustrine Fringe

____Depressional ____ Slope

____ Flats ____ Irrigated (choose additional class)

**Specific classification and metrics apply to the Riverine HGM Class*

RIVERINESPECIFIC CLASSIFICATION OF THE ASSESSMENT AREA

Confined vs. Unconfined Valley Setting

______ Confined Valley Setting (valley width < 2x bankfull width)

______ Unconfined Valley Setting (valley width ≥ 2x bankfull width)

Stream Flow Duration

______ Perennial

______ Intermittent

______ Ephemeral

AA Proximity to Channel

______ AA includesthe channel and both banks

______ AA is adjacent to or near the channel (< 50 m) and evaluation includes one or both banks

______ AA is > 50 m from the channel and banks were not evaluated

Stream Depth at Time of Survey (if evaluated)

______ Wadeable

______ Non-wadeable

MAJOR ZONES WITHIN THE ASSESSMENT AREA (See manual for rules and definitions. Mark each zone on the site sketch.)

Zone 1 Description ______________________________ Dom spp: ____ % of AA: ___________

Zone 2 Description ______________________________ Dom spp: ____ % of AA: ___________

Zone 3 Description ______________________________ Dom spp: ____ % of AA: ___________

Zone 4 Description ______________________________ Dom spp: ____ % of AA: ___________

Zone 5 Description ______________________________ Dom spp: ____ % of AA: ___________

AA REPRESENTATIVENESS

Is AA the entire wetland? ___ Yes ___ No If no, is AA representative of larger wetland? ___ Yes ___ No

Provide comments:

ASSESSMENT AREA DRAWING AND COMMENTS

Add north arrow and approx. scale bar. Document **Community types and abiotic zones** (particularly open water), inflows and outflows, and indicate direction of drainage. Include sketch of soil pit placement. If appropriate, add a **cross-sectional diagram** and indicate slope of side.

ASSESSMENT AREA DESCRIPTION AND COMMENTS

Overall site description and details on site hydrology, soil, and vegetation.

AA GROUND COVER AND VERTICAL STRATA			
Ground Cover		**AA**	
(A) Cover of water (any depth, vegetated or not, standing or flowing)			
Set 1 B+C = A	**(B)**Cover of shallow water <20cm / average depth shallow water (cm)	/	
	(C) Cover of deep water >20 cm / average depth deep water (cm)	/	
Set 2 D+E+F = A	**(D)**Cover of open water with no vegetation		
	(E) Cover of water with submergent or floating aquatic vegetation		
	(F) Cover of water with emergent vegetation		
Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95% **(Unless otherwise noted)**			
Cover of exposed bare ground* – soil / sand / sediment			
Cover of exposed bare ground* – gravel / cobble (~2–250 mm)			
Cover of exposed bare ground* – bedrock / rock / boulder (>250 mm)			
Cover of litter (all cover, <u>including under water or vegetation</u>)			
Depth of litter (cm) – average of fournon-trampled locations where litter occurs			
Predominant litter type (C = coniferous, E = broadleaf evergreen, D = deciduous, S = sod/thatch, F = forb)			
Cover salt crust (all cover, <u>including over vegetation or litter cover</u>)			
Cover of standing dead trees (>5 cm diameter at breast height)			
Cover of standing dead shrubs or small trees (<5 cm diameter at breast height)			
Cover of downed coarse woody debris (fallen trees, rotting logs, >5 cm diameter)			
Cover of downed fine woody debris (<5 cm diameter)			
Cover bryophytes (all cover, <u>including under water, vegetation or litter cover</u>)			
Cover lichens (all cover, <u>including under water, vegetation or litter cover</u>)			
Cover algae (all cover, <u>including under water, vegetation or litter cover</u>)			
Height Classes 1:<0.5 m **2:** 0.5–1m **3:** 1–2 m **4:** 2–5 m **5:** 5–10 m **6:** 10–15 m **7:** 15–20 m **8:** 20–35 m **9:** 35–50 m **10:**>50 m			
Vertical Vegetation Strata(live or very recently dead)	**Cover / Height →**	**C**	**H**
(T1) Dominant canopy trees (>5 m and > 30% cover)			
(T2) Sub-canopy trees (> 5m but < dominant canopy height) or trees with sparse cover			
(S1) Tall shrubs or older tree saplings (2–5 m)			
(S2) Short shrubs or young tree saplings (0.5–2 m)			
(S3) Dwarf shrubs or tree seedlings (<0.5 m; included short *Vaccinium* spp., etc.)			
(HT) Herbaceous total			
(H1) Graminoids (grass and grass-like plants)			
(H2) Forbs (all non-graminoids)			
(H3) Ferns and fern allies			
(AQ) Submergent or floating aquatics			

Vegetation Species List

Walk through the AA and identify as many plant species as possible beginning with the most dominant species first. Spend *no more* than 1 hour compiling the species list. Once the species list is compiled, use the first module column on the form to estimate cover for the entire AA

Cover Classes 1: trace 2: <1% 3: 1–<2% 4: 2–<5% 5: 5–<10% 6: 10–<25% 7: 25–<50% 8: 50–<75% 9: 75–<95% 10: >95%

Scientific Name or Pseudonym	% Cover	Coll #	Photos

Walk through the AA and identify as many plant species as possible beginning with the most dominant species first. Spend *no more* than 1 hour compiling the species list. Once the species list is compiled, use the first module column on the form to estimate cover for the entire AA

Cover Classes 1: trace 2: <1% 3: 1–<2% 4: 2–<5% 5: 5–<10% 6: 10–<25% 7: 25–<50% 8: 50–<75% 9: 75–<95% 10: >95%

Scientific Name or Pseudonym	% Cover	Coll #	Photos

SOIL PROFILE DESCRIPTION – SOIL PIT ☐ **Representative Pit?** **Photo #s** _________

GPS Waypoint ___________ UTM E: ___ ___ ___ ___ ___ ___UTM N: ___ ___ ___ ___ ___ ___ ___	Temp_________ pH ________ EC _______ TDS ________ Salinity ________

Settling Time: ___________ Depth to saturated soil (cm): ____________Depth to free water (cm): _____________ ☐ Not observed, if so: ☐Pit is filling slowly OR ☐Pit appears dry

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Dominant Redox Features Color (moist)	Dominant Redox Features %	Secondary Redox Features Color (moist)	Secondary Redox Features %	Texture	% Roots	% Gravel	Remarks
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

SOIL PROFILE DESCRIPTION – SOIL PIT 2 ☐ **Representative Pit?** **Photo #s** ________

GPS Waypoint ___________ UTM E: ___ ___ ___ ___ ___ ___UTM N: ___ ___ ___ ___ ___ ___ ___	Temp_________ pH ________ EC _______ TDS ________ Salinity ________

Settling Time: ___________ Depth to saturated soil (cm): ____________Depth to free water (cm): _____________ ☐ Not observed, if so: ☐Pit is filling slowly OR ☐Pit appears dry

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Dominant Redox Features Color (moist)	Dominant Redox Features %	Secondary Redox Features Color (moist)	Secondary Redox Features %	Texture	% Roots	% Gravel	Remarks
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________
________	_______	______________	______________	________	_____________	________	______________	_________	_________	_______________________________

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____HisticEpipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

Point Code__________________

SOIL PROFILE DESCRIPTION – SOIL PIT 3 ☐ **Representative Pit** **Photo #s _______**

GPS Waypoint ___________ UTM E: ___ ___ ___ ___ ___ ___UTM N: ___ ___ ___ ___ ___ ___ ___ | Temp_________ pH ________ EC _______ TDS ________ Salinity ________

Settling Time: ___________ Depth to saturated soil (cm): ____________Depth to free water (cm): _____________ ☐ Not observed, if so: ☐Pit is filling slowly OR ☐Pit appears dry

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Dominant Redox Features Color (moist)	Dominant Redox Features %	Secondary Redox Features Color (moist)	Secondary Redox Features %	Texture	% Roots	% Gravel	Remarks

Hydric Soil Indicators: See field manual for descriptions and check all that apply to pit.

____Histosol (A1)
____HisticEpipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Concentrations (S5/F6/F8)
____Redox Depletions (S6/F7)

Comments:

WATER QUALITY

Site 1: GPS Waypoint _______________ E: ___ ___ . ___ ___ ___ ___ ___ ___ N: ___ ___ . ___ ___ ___ ___ ___ ___ **Standing OR Flowing**

Temp_____________ pH _____________ EC _____________ TDS ___________________ Salinity ___________________

Site 2: GPS Waypoint _______________ E: ___ ___ . ___ ___ ___ ___ ___ ___ N: ___ ___ . ___ ___ ___ ___ ___ ___ **Standing OR Flowing**

Temp_____________ pH _____________ EC _____________ TDS ___________________ Salinity ___________________

Water quality measurement comments:

LEVEL 2 ECOLOGICAL INTEGRITY ASSESSMENT

1. *LANDSCAPE CONTEXT METRICS – Check the applicable box.*

1a. LANDSCAPE FRAGMENTATION		
Select the statement that best describes the **landscape fragmentation** with in a 500 m envelope surrounding the AA. To determine, identify the largest unfragmented block *that includes the AA* within the 500 m envelope and estimate its percent of the total envelope. Well-traveled dirt roads and major canals count as fragmentation, but hiking trails, hayfields, fences and small ditches can be included in unfragmented blocks (see definitions).	Intact: AA embedded in >90–100% unfragmented, natural landscape.	
	Variegated: AA embedded in >60–90% unfragmented, natural landscape.	
	Fragmented: AA embedded in >20–60% unfragmented, natural landscape.	
	Relictual: AA embedded in ≤20% unfragmented, natural landscape.	

1b. RIPARIAN CORRIDOR CONTINUITY*(RIVERINE WETLANDS ONLY)*		
For riverine wetlands, select the statement that best describes the **riparian corridor continuity** within 500 m upstream and downstream of the AA. To determine, identify any non-buffer patches (see definitions) within the potential riparian corridor (natural geomorphic floodplain) both upstream and downstream of the AA. Estimate the percentage of the riparian corridor they occupy. *For AAs on one side of a very large river channel (~20 m width),* only consider the riparian corridor on that side of the channel.	Intact: >95–100% natural habitat within the riparian corridor both upstream and downstream.	
	Variegated: >80–95% natural within the riparian corridor both upstream and downstream.	
	Fragmented: >50–80% natural habitat within the riparian corridor both upstream and downstream.	
	Relictual: ≤50% natural habitat within the riparian corridor both upstream and downstream.	

Landscape fragmentation and riparian corridor continuity comments:

1c. BUFFER EXTENT		
Select the statement that best describes the **extent of buffer land cover** surrounding the AA. To determine, estimate the percent of the AA surrounded by buffer land covers (see definitions). Each segment must be ≥ 5 m wide and extend along ≥ 10of the AA perimeter.	Buffer land covers surround >100% of the AA.	
	Buffer land covers surround >75–<100% of the AA.	
	Buffer land covers surround >50–75% of the AA.	
	Buffer land covers surround >25–50% of the AA.	
	Buffer land covers surround ≤25% of the AA.	

1d. BUFFER WIDTH		
Select the statement that best describes the **buffer width**. To determine, estimate width (up to 200 m from AA) along eight lines radiating out from the AA at the cardinal and ordinal directions (N, NE, E, SE, S, SW, W, NW).		
1: _____________ 5: _____________	Average buffer width is >200 m	
2: _____________ 6: _____________	Average buffer width is >100–200 m	
3: _____________ 7: _____________	Average buffer width is >50–100 m	
4: _____________ 8: _____________	Average buffer width is >25–50 m	
Average width: _________________________	Average buffer width is ≤25 m OR no buffer exists	

1e. BUFFER CONDITION			
Select the statement that best describes the **buffer condition**. Select one statement per column. Only consider the actual buffer measured in metrics 1c and 1d.			
Abundant (≥95%) relative cover native vegetation and little or no (<5%) cover of non-native plants.		Intact soils, little or no trash or refuse, and no evidence of human visitation. Light grazing can be present.	
Substantial (≥75–95%) relative cover of native vegetation and low (5–25%) cover of non-native plants.		Intact or moderately disrupted soils, moderate or lesser amounts of trash, light grazing to moderate grazing OR minor intensity of human visitation or recreation	
Moderate (≥50–75%) relative cover of native vegetation.		Moderate or extensive soil disruption, moderate or greater amounts of trash, moderate to heavy grazing OR moderate intensity of human use.	
Low (<50%) relative cover of native vegetation OR no buffer exists.		Barren ground and highly compacted or otherwise disrupted soils, moderate or greater amounts of trash, moderate or greater intensity of human use, very heavy grazing OR no buffer exists.	
Buffer comments:			

LANDSCAPE STRESSORS	
Using the table below, estimate the independent and cumulative percent of each **landscape stressor / land use within a 500 m envelope** of the AA. Stressors can overlap and do not need to total 100% (e.g., light grazing and moderate recreation can both be counted in the same portion of the envelope). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***	
Landscape stressor/ land use categories	*Scope*
Paved roads, parking lots, railroad tracks	
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)	
Domestic or commercially developed buildings	
Gravel pit operation, open pit mining, strip mining	
Mining (other than gravel, open pit, and strip mining), abandoned mines	
Resource extraction (oil and gas wells and surrounding footprint)	
Agriculture – tilled crop production	
Agriculture – permanent crop (hay pasture, vineyard, orchard, tree plantation)	
Recent old fields and other lands dominated by non-native species (weeds or hay fields)	
Intensively managed golf courses, sports fields, urban parks, expansive lawns	
Vegetation conversion (chaining, cabling, rotochopping, or clear-cutting of woody veg)	
Heavy grazing by livestock or native ungulates	
Moderate grazing by livestock or native ungulates	
Light grazing by livestock or native ungulates	
Heavy browse by livestock or native ungulates	
Moderate browse by livestock or native ungulates	
Light browse by livestock or native ungulates	
Heavy recreation or human visitation (ATV use / camping / popular fishing spot, etc.)	
Moderate recreation or human visitation (high-use trail)	
Light recreation or human visitation (low-use trail)	
Logging or tree removal with 50-75% of trees	
Selective logging or tree removal with <50% of trees	
Evidence of recent fire (<5years old, still very apparent on vegetation, little regrowth)	
Dam sites and flood disturbed shorelines around water storage reservoirs	
Beetle-killed conifers	
Irrigation ditches, berms, dams, head gates that change how water moves	
Invasive species:	
Other:	
Other:	
Landscape stressor comments:	

2. VEGETATION CONDITION METRICS – Check the applicable box.

2A-D. VEGETATION COMPOSITION
Vegetation compositions metrics can be calculated out of the field based on the species list and cover values. To aid data interpretation, provide comments on composition and **list noxious species identified in field.**

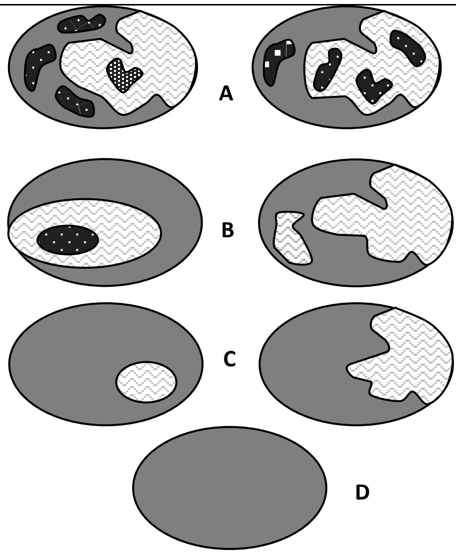
2e. REGENERATION OF NATIVE WOODY SPECIES	
Select the statement that best describes the **regeneration of native woody species** within the AA.	
Woody species are naturally uncommon or absent.	**N/A**
All age classes of desirable (native) woody riparian species present.	
Age classes restricted to mature individuals and young sprouts. Middle age groups absent.	
Stand comprised of mainly mature species OR mainly evenly aged young sprouts that choke out other vegetation.	
Woody species predominantly consist of decadent or dying individuals OR woody layer is dominated by Russian olive and/or Salt Cedar	
Regeneration comments and photo #'s:	

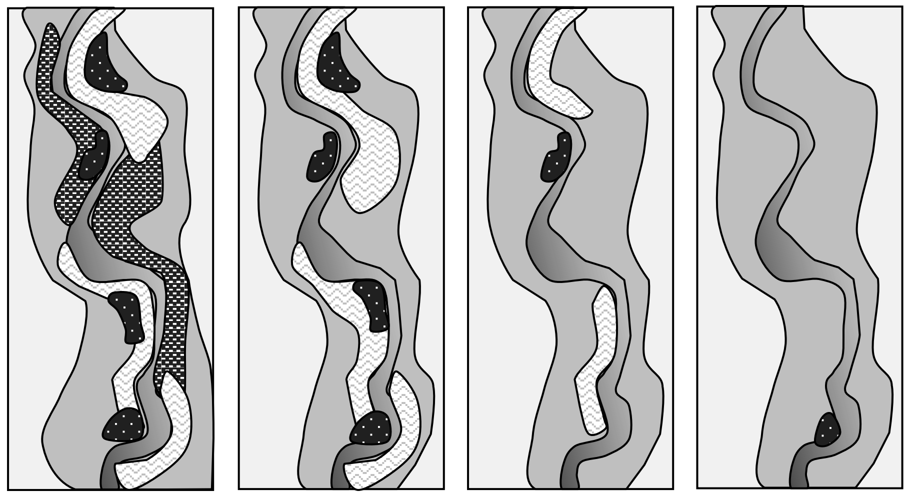
2f. COARSE AND FINE WOODY DEBRIS	
Select the statement that best describes c**oarse and fine woody debris** within the AA.	
There are no obvious inputs of woody debris or wood species are naturally abscent	**N/A**
AA characterized by moderate amount of coarse and fine woody debris, relative to expected conditions. For riverine wetlands, debris is sufficient to trap sediment, but does not inhibit stream flow. For non-riverine wetlands, woody debris provides structural complexity, but does not overwhelm the site.	
AA characterized by small amounts of woody debris OR debris is somewhat excessive. For riverine wetlands, lack of debris may affect stream temperatures and reduce available habitat.	
AA lacks woody debris, even though inputs are available OR debris is extensive and limits new growth	
Woody debris comments and photo #'s:	

2g. HERBACEOUS / DECIDUOUS LEAF LITTER ACCUMULATION	
Select the statement that best describes **herbaceous and/or deciduous leaf litter accumulation** within the AA. Think about what the site should look like. If there is evidence of haying or grazing there is probably a reduction in the amount of litter. If site is dominated by cattails or other aggressive species there is probably an excess of litter.	
AA characterized by moderate amount of herbaceous and/or deciduous leaf litter, relative to expected conditions. New growth is more prevalent than previous years'. Litter and duff layers in pools and topographic lows are thin. Organic matter is neither lacking nor excessive.	
AA characterized by small amounts of litter with little plant recruitment OR litter is somewhat excessive. (Light to Moderate grazing)	
AA lacks litter OR litter is extensive and limiting new growth. (Moderate to heavy grazing, haying, thick cattails limiting new growth)	
Herbaceous / deciduous litter accumulation comments and photo #'s:	

2h. HORIZONTAL INTERSPERSION OF BIOTIC AND ABIOTIC ZONES

Refer to diagrams below and select the statement that best describes the **horizontal interspersion of biotic and abiotic zones** within the AA. Rules for defining zones are in the field manual. Include zones of open water when evaluating interspersion.		
	High degree of horizontal interspersion: AA characterized by a very complex array of nested or interspersed zones with no single dominant zone.	
	Moderate degree of horizontal interspersion: AA characterized by a moderate array of nested or interspersed zones with no single dominant zone.	
	Low degree of horizontal interspersion: AA characterized by a simple array of nested or interspersed zones. One zone may dominate others.	
	No horizontal interspersion: AA characterized by one dominant zone.	





A B C D

Horizontal interspersion comments (note if lack of interspersion is not related to wetland integrity such as in *Carex*-dominated fens):

2i. STRUCTURAL PATCH TYPES WITHIN THE ASSESSMENT AREA

Using the following worksheet, mark all structural patch types that occur within or adjacent to the AA. For those that occur in the AA, estimate the % cover. For those adjacent, mark with ***adj***. Record photo numbers if taken. See the field manual for patch type definitions.

Patch type	*% AA*	*Photos*	*Patch type*	*% AA*	*Photos*
Open water - river / stream			Point bar / sand bar		
Open water - tributary / secondary channel			Interfluve on floodplain		
Open water - oxbow / backwater channel / slough			Bank slumps or undercut banks		
Open water - rivulets / streamlet / small channel			Adjacent or onsite seep / spring		
Open water - ditch or canal			Animal mounds or burrows		
Open water – pond / lake (>1,000 m^2)			Mudflat		
Open water – pools / pits (<1,000 m^2)			Salt flat / alkali flat		
Open water - beaver pond			Hummock / tussock (naturally formed, not pugging)		
Active beaver dam			Water tracks / hollow (mostly found in fens)		
Beaver canal			Floating mat (mostly found in fens)		
Debris jams / woody debris in channel			Marl / Limonite bed		
Pools in stream			Other:		
Riffles in stream			Other:		

Structural patch types comments:

2k. VEGETATION STRESSORS WITHN THE AA	
Using the table below, estimate the independent scope of each vegetation stressor within the AA. Independent scopes can overlap (e.g., light grazing can occur along with moderate recreation). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***	
Vegetation stressor categories	*Scope*
Unpaved Roads (e.g., driveway, tractor trail, 4-wheel drive roads)	
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	
Logging or tree removal with 50-75% of trees >50 cm dbh removed	
Selective logging or tree removal with <50% of trees >50 cm dbh removed	
Heavy grazing by livestock or native ungulates	
Moderate grazing by livestock or native ungulates	
Light grazing by livestock or native ungulates	
Heavy browse by livestock or native ungulates	
Moderate browse by livestock or native ungulates	
Light browse by livestock or native ungulates	
Intense recreation or human visitation (ATV use / camping / popular fishing spot, etc.)	
Moderate recreation or human visitation (high-use trail)	
Light recreation or human visitation (low-use trail)	
Recent old fields and other lands dominated by *non-native* species (weeds or hay)	
Haying of *native* grassland (*not* dominated by non-native hay grasses)	
Beetle-killed conifers	
Invasive Species	
Other:	
Vegetation stressor comments and photo #'s:	

3. HYDROLOGY METRICS – Circle the applicable letter.

4a. WATER SOURCES / INPUTS		
Select the statement below that best describes the **water sources** feeding the AA during the growing season. Check off all *major* water sources in the table to the right. If the dominant water source is evident, mark it with a star (*).	_____ Overbank flooding _____ Alluvial aquifer _____ Groundwater discharge _____ Natural surface flow _____ Precipitation _____ Snowmelt	_____ Irrigation via direct application _____ Irrigation via seepage _____ Irrigation via tail water run-off _____ Urban run-off / culverts _____ Pipes (directly feeding wetland) _____ Other:

Water sources are precipitation, groundwater, natural runoff, or natural flow from an adjacent freshwater body. The system may naturally lack water at times, such as in the growing season. There is no indication of direct artificial water sources, either point sources or non-point sources. Land use in the local watershed is primarily open space or low density, passive use with little irrigation.	
Water sources are mostly natural, but also include occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic sources include developed land or irrigated agriculture that comprises < 20% of the immediate drainage basin, the presence of a few small storm drains or scattered homes with septic system. No large point sources control the overall hydrology.	
Water sources are moderately impacted by anthropogenic sources, but are still a mix of natural and non-natural sources. Indications of moderate contribution from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage basin or the presence of a many small storm drains or a few large ones. The key factor to consider is whether the wetland is located in a landscape position supported wetland before development and whether the wetland is still connected to its natural water source (e.g., modified ponds on a floodplain that are still connected to alluvial aquifers, natural stream channels that now receive substantial irrigation return flows).	
Water sources are primarily from anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or another artificial hydrology). Indications of substantial artificial hydrology include developed or irrigated agricultural land that comprises > 60% of the immediate drainage basin of the AA, or the presence of major drainage point source discharges that obviously control the hydrology of the AA. The key factor to consider is whether the wetland is located in a landscape position that likely never supported a wetland prior to human development. The reason the wetland exists is because of direct irrigation, irrigation seepage, irrigation return flows, urban storm water runoff, direct pumping, or landscape modifications for water storage.	
Natural sources have been **eliminated** based on the following indicators: impoundment of all wet season inflows, diversions of all dry-season inflows, predominance of xeric vegetation, etc. The wetland is in steady decline and may not be a wetland in the near future.	

4b. HYDROPERIOD	
Select the statement below that best describes the **hydroperiod** within the AA (extent and duration of inundation and/or saturation). Search the AA and 500 m envelope for hydrologic stressors (see list below). Use best professional judgment to determine the overall condition of the hydroperiod. For some wetlands, this may mean that water is being channelized or diverted away from the wetland. For others, water may be concentrated or increased.	
Hydroperiod is characterized by natural patterns of filling or inundation and drying or drawdowns. There are no major hydrologic stressors that impact the natural hydroperiod.	
Hydroperiod filling or inundation patterns deviate slightly from natural conditions due to presence of stressors such as: small ditches or diversions; berms or roads at/near grade; minor pugging by livestock; or minor flow additions. Outlets may be slightly constricted. Playas are not significantly impacted pitted or dissected. *If hydrology is artificially controlled,* the management regime closely mimics a natural analogue (it is very unusual for a purely artificial wetland to be rated in this category).	
Hydroperiod filling or inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as: ditches or diversions 1–3 ft. deep; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; shallow pits within playas; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible. *If hydrology is artificially controlled,* the management regime approaches a natural analogue. Site may be passively managed, meaning that the hydroperiod is still connected to and influenced by natural high flows timed with seasonal water levels.	
Hydroperiod filling or inundation and drawdown of the AA deviate substantially from natural conditions from high intensity alterations such as: a 4-lane highway; large dikes impounding water; diversions > 3ft. deep that withdraw a significant portion of flow, deep pits in playas; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be significantly constricted, blocking most flow. *If hydrology is artificially controlled,* the site is actively managed and not connected to any natural season fluctuations, but the hydroperiod supports natural functioning of the wetland.	
Hydroperiod is dramatically different from natural. Upstream diversions severely stress the wetland. Riverine wetlands may run dry during critical times. *If hydrology is artificially controlled,* hydroperiod does not mimic natural seasonality. Site is actively managed for filling or drawing down without regard for natural wetland functioning.	
Water source and Hydroperiod comments:	

4c. HYDROLOGIC CONNECTIVITY

Select the statement below that best describes the **hydrologic connectivity**.

Rising water has unrestricted access to adjacent areas without levees or other obstructions to the lateral movement of flood waters. Channel, if present, is not entrenched and is still connected to the floodplain (see entrenchment ratio in optional riverine metrics).	
Unnatural features such as levees or road grades limit the amount of adjacent transition zone or the lateral movement of floodwaters, relative to what is expected for the setting, but limitations exist for <50% of the AA boundary. Restrictions may be intermittent along the margins of the AA, or they may occur only along one bank or shore. Channel, if present, is somewhat entrenched. If playa, surrounding vegetation does not interrupt surface flow.	
The amount of adjacent transition zone or the lateral movement of flood waters to and from the AA is limited, relative to what is expected for the setting, by unnatural features for 50–90% of the boundary of the AA. Features may include levees or road grades. Flood flows may exceed the obstructions, but drainage out of the AA is probably obstructed. Channel, if present, may be moderately entrenched and disconnected from the floodplain except in large floods. If playa, surrounding vegetation may interrupt surface flow.	
The amount of adjacent transition zone or the lateral movement of flood waters is limited, relative to what is expected for the setting, by unnatural features for >90% of the boundary of the AA. Channel, if present, is severely entrenched and entirely disconnected from the floodplain. If playa, surrounding vegetation may dramatically restrict surface flow.	

Hydrologic connectivity comments:

4d. HYDROLOGY STRESSORS WITHIN A 500 M ENVELOPE

Using the table below, mark the severity of each **hydrology stressor within a 500 m envelope of the AA**. Mark whether the stressor is present upstream/slope or downstream/slope of the AA. If known alteration occurs further upstream than 500 m, please explain in comments below.

Hydrology stressor categories	*Within AA*	*Upstream / Upslope*	*Downstream / Downslope*
Dam / reservoir			
Impoundment / stock pond			
Spring box diverting water from wetland			
Extensive groundwater wells in the surrounding area			
Pumps, diversions, ditches that move water *out of* the wetland			
Pumps, diversions, ditches that move water *into* the wetland			
Berms, dikes, levees that hold water in the wetland			
Deeply dug pits for holding water			
Weir or drop structure that impounds water and controls energy of flow			
Observed or potential agricultural runoff			
Observed or potential urban runoff			
Flow obstructions into or out of wetland (roads without culverts)			
Dredged inlet or outlet channel			
Engineered inlet or outlet channel (e.g., riprap)			
Pugging or trails that change water flow *into/out* of the wetland			
Other:			
Other:			

Hydrology stressor comments:

4. PHYSIOCHEMICAL METRICS – *Circle the applicable letter.*

3a. WATER QUALITY - SURFACE WATER TURBIDITY / POLLUTANTS	
Select the statement that best describes the **turbidity or evidence or pollutants** in surface water within the AA.	
No open water in AA	
No visual evidence of degraded water quality. No visual evidence of turbidity or other pollutants.	
Some negative water quality indicators are present, but limited to small and localized areas within the wetland. Water is slightly cloudy, but there is no obvious source of sedimentation or other pollutants.	
Water is cloudy or has unnatural oil sheen, but the bottom is still visible. Sources of water quality degradation are apparent (identify in comments below). *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution. Riverine wetlands can be turbid if flood waters are high*	
Water is milky and/or muddy or has unnatural oil sheen. The bottom is difficult to see. There are obvious sources of water quality degradation (identify in comments below). *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution. Riverine wetlands can be turbid if flood waters are high*	
Surface water turbidity / pollutants comments and photo #'s:	

3b. WATER QUALITY - ALGAL GROWTH	
Select the statement that best describes **algal growth** within surface water in the AA.	
No open water in AA or evidence of open water.	
Water is clear with minimal algal growth.	
Algal growth is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.	
Algal growth occurs in moderate to large patches throughout the AA. Water may have a moderate greenish tint or sheen. Sources of water quality degradation are apparent (identify in comments below).	
Algal mats are extensive, blocking light to the bottom. Water may have a strong greenish tint and the bottom is difficult to see. There are obvious sources of water quality degradation (identify in comments below).	
Algal growth comments and photo #'s: Algal growth may be natural and not necessarily indicative of poor water quality. If algal growth appears natural, describe and record % of total algae that is due to natural processes.	

3c. SUBSTRATE / SOIL DISTURBANCE

Select the statement below that best describes disturbance to the substrate or soil within the AA. For playas, the most significant substrate disturbance is sedimentation or unnaturally filling, which prevents the system's ability to pond after heavy rains. For other wetland types, disturbances may lead to bare or exposed soil and may increase ponding or channelization where it is not normally. For any wetland type, consider the disturbance relative to what is expected for the system.

No soil disturbance within AA. Little bare soil OR bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails OR soil is naturally bare (e.g., playas). No pugging, soil compaction, or sedimentation.	
Minimal soil disturbance within AA. Some amount of bare soil, pugging, compaction, or sedimentation present due to human causes, but the extent and impact are minimal. The depth of disturbance is limited to only a few inches and does not show evidence of altering hydrology. **Any disturbance is likely to recover within a few years after the disturbance is removed**.	
Moderate soil disturbance within AA. Bare soil areas due to human causes are common and will be slow to recover. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts. Sedimentation may be filling the wetland. Damage is obvious, but not excessive**. The site could recover to potential with the removal of degrading human influences and moderate recovery times.**	
Substantial soil disturbance within AA. Bare soil areas substantially degrade the site and have led to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Sedimentation may have severely impacted the hydrology. **The site will not recover without active restoration and/or long recovery times.**	

Substrate / soil comments and photo #'s:

3d. PHYSIOCHEMICAL STRESSORS WITHIN THE AA

Using the table below, estimate the independent scope of each physiochemical stressor within the AA. Independent scopes can overlap (e.g., soil compaction can occur with trash or refuse). ***Scope rating: 1 = 1–10%, 2 = >10–25%, 3 = >25–50%, 4 = >50–75%, 5 = >75%.***

Physiochemical stressor categories	*Scope*
Erosion	
Sedimentation	
Current plowing or disking	
Historic plowing or disking (evident by abrupt A horizon boundary at plow depth)	
Substrate removal (excavation)	
Filling or dumping of sediment	
Trash or refuse dumping	
Compaction and soil disturbance by livestock or native ungulates	
Compaction and soil disturbance by human use (trails, ORV use, camping)	
Mining activities, current or historic	
Obvious point source of water pollutants (discharge from waste water plants, factories)	
Agricultural runoff (drain tiles, excess irrigation)	
Direct application of agricultural chemicals	
Discharge or runoff from feedlots	
Obvious excess salinity (dead or stressed plants, salt encrustations)	
Other:	
Other:	

Physiochemical stressor comments:

5. SIZE METRICS – Circle the applicable letter.

5a. RELATIVE SIZE		
Estimate the potential size of the wetland containing the assessment area and compare this to the actual size. Wetland area can be lost due to human disturbance such as roads, impoundments, development, ditching, draining, mining, flooding for reservoirs, etc. Estimate using best available information (maps, air photography, etc.).	Wetland area ≈ onsite abiotic potential; <5% of wetland has been reduced. OR Wetland area > onsite abiotic potential because of anthropogenic inputs	
	Wetland area < abiotic potential; 5–25% of wetland has been reduced.	
	Wetland area < abiotic potential; 25–50% of wetland has been reduced.	
	Wetland area < abiotic potential; >50% of wetland has been reduced.	
Relative size comments:		

5b. ABSOLUTE SIZE
Absolute size of the wetland will be determined in GIS. To aid data interpretation, please describe any **significant boundaries** to the targeted **Ecological System** that are not evident from aerial photography, such as break in hydrologic flow, change in soil type, or land use changes since aerial photography was flown.

OPTIONAL RIVERINE HYDROLOGY METRICS (use when channel is within ~50 m)

6a. RIVERINE CHANNEL AND BANK STABILITY

Select the statement below that best describes **channel and bank stability** within or near the AA. To determine, visually survey the AA for field indicators of channel equilibrium, aggradation or degradation listed in the table below. Check is the statement is true. Use best professional judgment to determine the overall channel and bank stability.

Condition	*Field Indicators*
Indicators of Channel Equilibrium / Natural Dynamism	Check if True ☐ The channel (or multiple channels in braided systems) has a well-defined usual high water line or bankfull stage that is clearly indicated by an obvious floodplain, topographic bench that represents an abrupt change in the cross-sectional profile of the channel throughout *most* of the site. ☐ The usual high water line or bank full stage corresponds to the lower limit of riparian vascular vegetation. ☐ Leaf litter, thatch, wrack, and/or mosses exist in most pools. ☐ The channel contains embedded woody debris of the size and amount consistent with what is available in the riparian area. ☐ Active undercutting of banks or burial of riparian vegetation is limited to localized areas and not throughout site. ☐ There is little evidence of recent deposition of cobble or very coarse gravel on the floodplain, although recent sandy deposits may be evident. ☐ There are no densely vegetated mid-channel bars and/or point bars, indicating flooding at regular intervals. ☐ The spacing between pools in the channel tends to be 5-7 channel widths, if appropriate. ☐ The larger bed material supports abundant periphyton.
Indicators of Active Aggradation / Excessive Sediment	☐ The channel through the site lacks a well-defined usual high water line. ☐ There is an active floodplain with fresh splays of sediment covering older soils or recent vegetation. ☐ There are partially buried tree trunks or shrubs. ☐ Cobbles and/or coarse gravels have recently been deposited on the floodplain. ☐ There is a lack of in-channel pools, their spacing is greater than 5-7 channel widths, or many pools seem to be filling with sediment. ☐ There are partially buried, or sediment-choked, culverts. ☐ Transitional or upland vegetation is encroaching into the channel throughout most of the site. ☐ The bed material is loose and mostly devoid of periphyton.
Indicators of Active Degradation / Excessive Erosion	☐ The channel through the site is characterized by deeply undercut banks with exposed living roots of trees or shrubs. ☐ There are abundant bank slides or slumps, or the banks are uniformly scoured and unvegetated. ☐ Riparian vegetation declining in stature or vigor, and/or riparian trees and shrubs may be falling into channel. ☐ Abundant organic debris has accumulated on what seems to be the historical floodplain, indicating that flows no longer reach the floodplain. ☐ The channel bed appears scoured to bedrock or dense clay. ☐ The channel bed lacks fine-grained sediment. ☐ Recently active flow pathways appear to have coalesced into one channel (i.e. a previously braided system is no longer braided). ☐ There are one or more nick points along the channel, indicating headward erosion of the channel bed.

RATING CRITERIA FOR ALL RIVERINE WETLANDS	
Most of the channel within or near the AA is characterized by naturally dynamic equilibrium conditions, with little evidence of excessive aggradation or degradation. Streambanks typically dominated (>90% cover) by stabilizing plant species, including trees, shrubs, herbs.	
Most of the channel within or near the AA is characterized by some aggradation or degradation, none of which is severe, and the channel seems to be approaching an equilibrium form. Streambanks may have 70–90% cover of stabilizing plant species, but some bare areas occur.	
There is evidence of severe aggradation or degradation of most of the channel within or near the AA or the channel is artificially hardened through less than half of the AA. Streambanks may have 50–70% cover of stabilizing plant species within several bare areas.	
The channel is concrete or otherwise artificially hardened through most of the AA. Streambanks have <50% cover of stabilizing plant species.	

Channel stability comments (note if channel is unstable due to beaver or natural processes):

6b. RIVERINE ENTRENCHMENT RATIO (optional guide for if stream may be entrenched)				
Using the following worksheet, calculate the average **entrenchment ratio** for the channel. The steps should be conducted for each of three cross sections located in or adjacent to the AA at the approximate mid-points along straight riffles or glides, away from deep pools or meander bends. *Do not attempt to measure this for non-wadeable streams!*				
Steps	*Replicate cross-sections* ⟶	*1*	*2*	*3*
1. Estimate bankfull width.	If the stream is entrenched, the height of bankfull flow is identified as a scour line, narrow bench, or the top of active point bars well below the top of apparent channel banks. If the stream is not entrenched, bankfull stage can correspond to the elevation of a broader floodplain with indicative riparian vegetation. Estimate or measure the distance between the right and left bankfull contours.			
2. Estimate max bankfull depth.	Imagine a line between right and left bankfull contours. Estimate or measure the height of the line above the thalweg (the deepest part of the channel).			
3. Estimate flood prone height.	Double the estimate of maximum bankfull depth from Step 2.			
4. Estimate flood prone width.	Imagine a level line having a height equal to the flood prone depth from Step 3. Note the location of the new height on the channel bank. Estimate the width of the channel at the flood prone height.			
5. Calculate entrenchment.	Divide the flood prone width (Step 4) by the max bankfull width (Step 1).			
6. Calculate average entrenchment	Average the results of Step 5 for all three cross-sections and enter it here.			

RATING CRITERIA FOR CONFINED RIVERINE WETLANDS		**RATING CRITERIA FOR UNCONFINED RIVERINE WETLANDS**	
Entrenchment ratio >2.0.		Entrenchment ratio >2.2.	
Entrenchment ratio 1.6–2.0.		Entrenchment ratio 1.9–2.2.	
Entrenchment ratio 1.2–1.5.		Entrenchment ratio 1.5–1.8.	
Entrenchment ratio <1.2.		Entrenchment ratio <1.5.	

Entrenchment ratio comments:

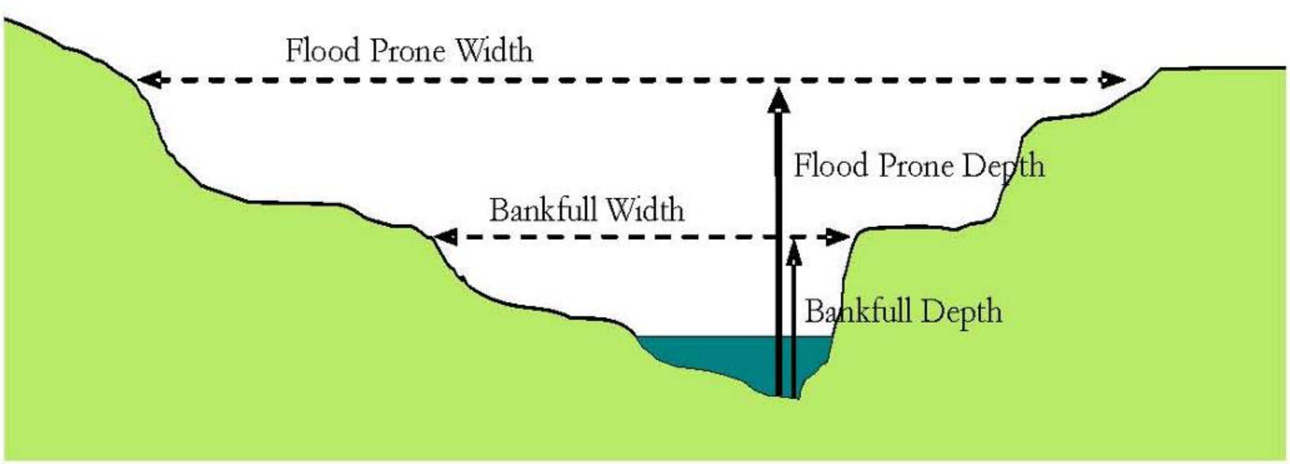


Illustration from Collins *et al.* 2008. California Rapid Assessment Method for Wetlands v 5.0.2

AREM Long Form

Please evaluate the wetland or riparian habitat within the **200 meter** buffer when answering the below questions. Do not consider upland habitat except for questions 16 – 21. For each numbered item, check only one response unless noted otherwise. Then proceed to the next question unless noted otherwise. Parenthetical names are the names of fields in the supporting software database (WHRBASE). If a field name is lacking, the information is not used directly.

Note: 1 Acre = .5 hectares

1. Season: Migratory__________ Breeding__________Winter__________
2. LOCATION. Is the area part of, or is it within 0.5 mile of, a major* river or lake?
   ** river channel wider than 100 ft, or lake larger than 40 acres*
   ____ Yes (field BigWater)   ____ No
3. SURFACE WATER. During this season, does the area contain at least 0.1 acre* of surface water, either obscured by vegetation or not?
   ** See Figure B-1 for guidance in estimating acreage categories.*
   ____ Yes (field AnyWater). Go to next question.
   ____ No. **Skip to question #5.**
4. OPEN WATER. During this season, how much open* water is present in the area?
   ** water deeper than 2 inches and mostly lacking vegetation (except submerged plants).*
   ____ > 20 acres and it is mostly wider than 500 ft (field OpenBig)
   ____ < 1 acre, or, >1 acre but mostly narrower than 3 ft (field OpenSmall)
   ____ Other conditions (field OpenOther)
5. SPECIFIC AQUATIC CONDITIONS
   Check all that apply during this season:
   ____ > 0.1 acre of the surface water is still, i.e., usually flows at less than 1 ft/s (field StillWater)
   ____ The evaluated area can be assumed to contain fish (field Fish)
   ____ The evaluated area can be assumed to contain frogs, salamanders, and/or crayfish (field Amphibs)
   ____ Water transparency in the deepest part of the area is (or would be, if depth is shallow) sufficient to see an object 10 inches below the surface, and the area is not known to have problems with metal contamination (field Clear)
   ____ The evaluated area is highly enriched by direct fertilizer applications, water from nearby feedlots, or other sources (field Enriched)
   ____ Most of the normally-flooded part of the area goes dry at least one year in five, or, is subject to flooding from a river at least as often (field Drawdown)
6. BARE SOIL. Is there at least 0.1 acre of mud*, alkali flat, gravel/sand bar, recently tilled soil, and/or heavily grazed open (grassy, non-shrubby) areas during this season?
   ** includes soil that is continually saturated up to the surface, or which was previously covered by water but has become exposed to the air during this period*
   ____ Yes (field Bare). Go to next question.
   ____ No. **Skip to question #7.**
7. LARGE MUDFLAT. Does the area at this season contain mud that has all these features?:
   - At least 1 acre in size
   - Maximum dimension is greater than 100 ft
   - Salt crust or salt stains are not apparent
   - Not recessed within a wash or canal whose depth (relative to surrounding landscape) is greater than half its width.

   ____ Yes (field MudBig) ____ No

8. TREES. Are there at least 3 trees*:
   ** woody plants taller than 20 ft.*
   ____ in the evaluation area? (field TreeIn).
   ____ within 1000 ft of the evaluation area? (field TreeNear). **Go to #8.**
   ____ neither of the above. **Skip to #11.**
9. TREE COVER. Check one or more responses below that describe the maximum cumulative acreage of various conditions of tree cover in the evaluation area. Also include areas within 300 ft:
   ____ >1 acre, dense*, and wide** (field ForestDens)
   ____ >1 acre and open; or, dense but narrow (field ForestOpen)
   ____ 0.1-1 acre, dense* (field WoodDens)
   ____ 0.1-1 acre, open (field WoodOpen)
   ____ <0.1 acre
   ** Dense= the tree canopy, viewed from the ground during midsummer, appears at least 50% closed, as averaged across an area that is at least as large as the acreage specified.*
   *** Wide= the wooded area is wider than 300 ft (average).*
10. BIG TREES. Are there at least three trees whose trunk diameter 20 ft above the ground is >12 inches?
    ____ Yes (field TreesBig) ____ No
11. SNAGS. Are there at least three snags, or trees with dead limbs with diameter >5 inches?
    ____ Yes (field Snags) ____ No
12. SHRUBS. Is there at least 0.1 acre of shrubs*:
    ** woody plants 2-20 ft in height.*
    ____ in the evaluation area? (field ShrubIn).
    ____ within 1000 ft of the wetland (including the wetland itself)? (field ShrubNear). **Go to #12.**
    ____ Neither of the above. **Skip to #13.**
13. SHRUB SPECIES AND DENSITY. Check one or more responses below that describe the maximum cumulative extent of various types and conditions of shrub cover in the evaluation area. Also include areas within 300 ft.
    Willow:
    ____ >1 acre, dense*, and wide** (field WwMuchDens)
    ____ >1 acre and open; or, dense but narrow (field WwMuchOpen)
    ____ 0.1-1 acre, dense* (field WwSomeDens)
    ____ 0.1-1 acre, open (field WwSomeOpen)
    ____ <0.1 acre; or larger area but height mostly <4 ft and openly spaced

    Greasewood or other tall desert shrubs:
    ____ >1 acre, dense*, and wide** (field GrMuchDens)
    ____ >1 acre and open; or, dense but narrow (field GrMuchOpen)
    ____ 0.1-1 acre, dense* (field GrSomeDens)
    ____ 0.1-1 acre, open (field GrSomeOpen)
    ____ <0.1 acre

    Russian olive, sumac, buffaloberry, wild rose, or others with fleshy fruit:
    ____ >1 acre, dense*, and wide** (field FrMuchDens)
    ____ >1 acre, open; or, dense but narrow (field FrMuchOpen)
    ____ 0.1-1 acre, dense (field FrSomeDens)
    ____ 0.1-1 acre, open (field FrSomeOpen)
    ____ <0.1 acre; or larger area but height mostly <4 ft

Tamarisk (salt cedar):
____ >1 acre, dense*, and wide** (field TmMuchDens)
____ >1 acre, open; or, dense but narrow (field TmMuchOpen)
____ 0.1-1 acre, dense (field TmSomeDens)
____ 0.1-1 acre, open (field TmSomeOpen)
____ <0.1 acre; or larger area but height mostly <4 ft

** Dense= the shrub canopy, as viewed from a height of 100 ft during midsummer, appears to be >50% closed, as averaged across an area that is at least as large as the acreage specified.*
*** Wide= the shrub area is wider than 300 ft (average).*

14. HERBACEOUS VEGETATION. Is there at least 0.1 acre of herbaceous vegetation*:
    ** Nonwoody plants such as cattail, bulrush, sedges, grasses, and forbs.*
    ____ in the evaluation area? (field HerbIn).
    ____ within 1000 ft? (field HerbNear). **Go to #14.**
    ____ Neither of the above. **Skip to #15.**
15. HERBACEOUS SPECIES. Check one or more responses below that describe the maximum cumulative extent of various types and conditions of shrub cover in the evaluation area. Also include areas within 300 ft.

Robust emergents (e.g., cattail, phragmites)
____ >1 acre, dense*, and wide** (field RbMuchDens)
____ >1 acre, open; or dense but narrow (field RbMuchOpen)
____ 0.1-1 acre, dense (field RbSomeDens)
____ 0.1-1 acre, open (field RbSomeOpen)

Other wet** emergents (e.g., bulrush, sedge)
____ >1 acre, dense*, wide**, and tall*** (field WEMuchDens)
____ >1 acre, tall, open; or dense but narrow (field WEMuchOpen)
____ >1 acre, dense or open, and short (field WEMuchShrt)
____ 0.1-1 acre, tall, dense (field WESomeDens)
____ 0.1-1 acre, tall, open; or dense but narrow (field WESomeOpen)
____ 0.1-1 acre, dense or open, and short (field WESomeShrt)

Drier emergents (e.g., saltgrass, other grasses
____ >1 acre, dense*, wide**, and tall*** (field DEMuchDens)
____ >1 acre, tall, open; or dense but narrow (field DEMuchOpen)
____ >1 acre, dense or open, and short (field DEMuchShrt)
____ 0.1-1 acre, tall, dense (field DESomeDens)
____ 0.1-1 acre, tall, open; or dense but narrow (field DESomeOpen)
____ 0.1-1 acre, dense or open, and short (field DESomeShrt)

Broad-leaved Forbs (e.g., milkweed, thistle, alfalfa)
____ >1 acre (field ForbMuch)
____ 0.1-1 acre (field ForbSome)

Aquatic plants (e.g., watercress, sago pondweed, duckweed)
____ >10 acres (field AqMuch)
____ 0.1-10 acres (field AqSome)

** Dense= plants are so close together that the duff layer or soil beneath the plants is mostly obscured by foliage, when looking down from just above the plant tops.*

*** Wet= water is visible at or above the soil surface during most of the growing season.*

**** Wide= the shrub area is wider than 300 ft (average).*

***** Tall= taller than 1 ft.*

16. SURROUNDING LAND COVER (includes wetland and upland habitat). Check one:
    Within 0.5 mi of the wetland, >60% of the land cover is:
    ____ Pasture, alfalfa, grain crops, row crops, other wetlands, grass lawns, and/or weed fields (field SurAgwet)
    ____ Desert shrubs (e.g., sagebrush, shadscale, rabbitbrush)(field SurDesrt)
    ____ Pinyon-juniper (field SurPJ)
    ____ Oak scrub (e.g., Gambel oak, serviceberry, skunkbrush)(field SurOak)
    ____ Other, or none of the above comprise >60%
17. LOCAL LAND COVER (includes wetland and upland habitat). Check one:
    Within 3 mi of the wetland, > 60% of the land cover is:
    ____ Pasture, alfalfa, grain crops, row crops, other wetlands, grass lawns, and/or weed fields (field LocAgWet)
    ____ Desert shrubs (e.g., sagebrush, shadscale, rabbitbrush)(field LocDesrt)
    ____ Pinyon-juniper (field LocPJ)
    ____ Oak scrub (e.g., Gambel oak, serviceberry, skunkbrush)(field LocOak)
    ____ Other, or none of the above comprise >60%
18. VISUAL SECLUSION
    Check only one:
    ____ Both of the following:
    (a) wetland is seldom visited by people on foot or boat (less than once weekly), (b) there are no paved roads within 600 ft, or if there are, wetland is not visible from the roads (field SeclusionH).
    ____ Either (a) or (b) above (field SeclusionM).
    ____ Other condition.
19. PREDATION POTENTIAL
    Check only one. The evaluation area:
    ____ is linear*, adjoins a heavily-traveled road (usual maximum of >1 car/minute), and/or is in a high-density housing area (>1 house/5 acres) (field PredHPot)
    ____ adjoins a less-traveled road, and/or is in an area with sparser housing density but is closer than 1000 ft to a normally-occupied building (field PredMPot)
    ____ Other condition.
    ** at least 90% of the area being evaluated is within 25 ft of a canal, road, railroad tracks, or other artificially linear feature.*
20. GRAZED, BURNED, MOWED. Is the area mowed, burned, or grazed intensively (i.e., with clearly visible effects on vegetation) during this season?
    ____ Yes (field GrazBurnMo)
    ____ No
21. NESTING LOCATIONS
    Check all that apply:
    ____ Semi-open structures (bridges, barns) suitable for nesting swallows are present within 300 ft (field SwallNest)
    ____ Platforms suitable for nesting geese are present in the wetland or along its perimeter (field GooseNest)
    ____ Vertical, mostly bare dirt banks at least 5 ft high are present within 0.5 mi., of potential use to nesting kingfishers, barn owls, and swallows (field Banks

Appendix C. Wetland Plants Found in Goshen Hole with Surrogate C-values

Scientific Name	# of Occurrences	Life Form	Nativity	Wetland Status	WY Surrogate C-Value	Common Name
Agrostis stolonifera	11	Graminoid	Non-native	FACW	0	Spreading Bent
Alisma gramineum	1	Forb	Native	OBL	3	Narrow-Leaf Water-Plantain
Alisma triviale	2	Forb	Native	OBL	3	Northern Water-Plantain
Alopecurus aequalis	5	Graminoid	Native	OBL	4	Short-Awn Meadow-Foxtail
Alopecurus arundinaceus	9	Graminoid	Non-native	FACW	0	Creeping Meadow-Foxtail
Alopecurus pratensis	14	Graminoid	Non-native	FACW	0	Field Meadow-Foxtail
Ambrosia psilostachya	28	Forb	Native	FACU	2.25	Perennial Ragweed
Apocynum cannabinum	6	Forb	Native	FAC	3.2	Indian-Hemp
Arctium minus	2	Forb	Non-native	FACU	0	Lesser Burrdock
Argentina anserina	4	Forb	Native	FACW	3	Common Silverweed
Asclepias speciosa	17	Forb	Native	FAC	3	Showy Milkweed
Asparagus officinalis	1	Forb	Non-native	FACU	0	Asparagus
Atriplex argentea	1	Forb	Native	FAC	6	Silverscale
Bassia scoparia	2	Forb	Non-native	FACU	0	Mexican-Fireweed
Beckmannia syzigachne	3	Graminoid	Native	OBL	4	American Slough Grass
Berula erecta	3	Forb	Native	OBL	7	Cut-Leaf-Water-Parsnip
Bromus arvensis	1	Graminoid	Non-native	FACU	0	Field Brome
Bromus inermis	6		Non-native	UPL	0	Smooth Brome
Bromus tectorum	16	Graminoid	Non-native		0	
Callitriche palustris	1	Forb	Native	OBL	5	Vernal Water-Starwort
Capsella bursa-pastoris	1	Forb	Non-native	FACU	0	Shepherd's-Purse
Carduus nutans	9	Forb	Non-native	FACU	0	Nodding Plumeless-Thistle
Carex aquatilis	2	Graminoid	Native	OBL	6	Leafy Tussock Sedge
Carex brevior	1	Graminoid	Native	FAC	4	Short-Beak Sedge
Carex canescens	1	Graminoid	Native	OBL	8	Hoary Sedge
Carex lenticularis	2		Native	OBL	9	Lakeshore Sedge

Carex nebrascensis	14	Graminoid	Native	OBL	4	Nebraska Sedge
Carex pellita	18	Graminoid	Native	OBL	5	Woolly Sedge
Carex praegracilis	13	Graminoid	Native	FACW	5	Clustered Field Sedge
Carex sp.	1					
Ceratophyllum demersum	2	Forb	Native	OBL	1	Coon's-Tail
Chenopodium album	15	Forb	Non-native	FACU	0	Lamb's-Quarters
Chenopodium rubrum	2	Forb	Native	OBL	2.5	Red Goosefoot
Cirsium arvense	32	Forb	Non-native	FACU	0	Canadian Thistle
Clematis ligusticifolia	2	Vine	Native	FACU	4	Deciduous Traveler's-Joy
Cleome serrulata	4	Forb	Native	FACU	2	Rocky Mountain Beeplant
Conyza canadensis	24	Forb	Native	FACU	0	Canadian Horseweed
Cynoglossum officinale	5	Forb	Non-native	FACU	0	Gypsy-Flower
Cyperus squarrosus	4	Graminoid	Native	OBL	5	Awned Flat Sedge
Descurainia sophia	5	Forb	Non-native		0	
Distichlis spicata	33	Graminoid	Native	FACW	4	Coastal Salt Grass
Echinochloa crus-galli	8	Graminoid	Non-native	FAC	0	Large Barnyard Grass
Elaeagnus angustifolia	24	Shrub	Non-native	FACU	0	Russian-Olive
Eleocharis acicularis	1	Graminoid	Native	OBL	5	Needle Spike-Rush
Eleocharis palustris	40	Gaminoid	Native	OBL	4	Common Spike-Rush
Eleocharis parvula	1	Graminoid	Native	OBL	4	Little-Head Spike-Rush
Elymus repens	9	Graminoid	Non-native	FACU	0	Creeping Wild Rye
Epilobium sp.	1					
Equisetum arvense	1	Forb	Native	FAC	3	Field Horsetail
Equisetum laevigatum	8	Forb	Native	FAC	4	Smooth Scouring-Rush
Eragrostis cilianensis	1	Graminoid	Non-native	FACU	0	Stink Grass
Eragrostis pectinacea	1	Graminoid	Native	FAC	1	Purple Love Grass
Fragaria virginiana	1		Native	FACU	5	Virginia Strawberry
Fraxinus pennsylvanica	8	Tree	Native	FAC	0	Green Ash
Galium aparine	1	Forb	Non-native	FACU	0	Sticky-Willy
Geum macrophyllum	1		Native	FACW	6	Large-Leaf Avens
Glaux maritima	1	Forb	Native	OBL	7	Sea-Milkwort

Glyceria grandis	3	Graminoid	Native	OBL	7	American Manna Grass
Glyceria striata	2	Graminoid	Native	OBL	6	Fowl Manna Grass
Glycyrrhiza lepidota	12	Forb	Native	FACU	3	American Licorice
Grindelia squarrosa	4	Forb	Native	UPL	1.5	Curly-Cup Gumweed
Helianthus annuus	11	Forb	Native	FACU	0.5	Common Sunflower
Heliotropium curassavicum	1		Non-native	OBL	0	Seaside Heliotrope
Hippuris vulgaris	2	Forb	Native	OBL	6	Common Mare's-Tail
Hordeum brachyantherum	5		Native	FAC	5	Meadow Barley
Hordeum jubatum	53		Native	FACW	2	Fox-Tail Barley
Iva axillaris	1	Forb	Native	FAC	3	Deer-Root
Juncus arcticus ssp. Littoralis	16	Graminoid	Native	FACW	4	Arctic Rush
Juncus compressus	17	Graminoid	Non-native	FACW	0	Round-Fruit Rush
Juncus interior	1	Graminoid	Native	FACW	4.5	Inland Rush
Juncus longistylis	1	Graminoid	Native	FACW	6	Long-Style Rush
Juncus nodosus	2	Graminoid	Native	OBL	6	Knotted Rush
Juncus torreyi	9	Graminoid	Native	FACW	5	Torrey's Rush
Koeleria macrantha	1	Graminoid	Native		6	
Lactuca serriola	18	Forb	Non-native	FAC	0	Prickly Lettuce
Lemna turionifera	5	Forb	Native	OBL		Turion Duckweed
Lepidium densiflorum	2	Forb	Non-native	FAC	0	Miner's Pepperwort
Lepidium latifolium	4	Forb	Non-native	FACW	0	Broad-Leaf Pepperwort
Lepidium perfoliatum	5	Forb	Non-native	FAC	0	Clasping Pepperwort
Limosella aquatica	2	Forb	Native	OBL	7	Awl-Leaf Mudwort
Lycopus americanus	7	Forb	Native	OBL	6	Cut-Leaf Water-Horehound
Lycopus asper	3	Forb	Native	OBL	5.2	Rough Water-Horehound
Maianthemum stellatum	1	Forb	Native	FACU	7	Starry False Solomon's-Seal
Medicago lupulina	4	Forb	Non-native	FACU	0	Black Medick
Melilotus officinalis	22	Forb	Non-native	FACU	0	Yellow Sweet-Clover
Mentha arvensis	12	Forb	Native	FACW	4	American Wild Mint
Mimulus floribundus	2	Forb	Native	OBL	10	Purple-Stem Monkey-Flower

Monarda fistulosa	1		Native	UPL	6	Oswego-Tea
Muhlenbergia asperifolia	6	Graminoid	Native	FACW	4	Alkali Muhly
Nasturtium officinale	2	Forb	Non-native	OBL	0	Watercress
Nepeta cataria	11	Forb	Non-native	FACU	0	Catnip
Panicum capillare	5	Graminoid	Native	FAC	0	Common Panic Grass
Parthenocissus vitacea	4	Vine	Native	FAC	2	Thicket-Creeper
Pascopyrum smithii	13	Graminoid	Native	FACU	5	Western-Wheat Grass
Persicaria pensylvanica	9			FACW		Pinkweed
Phalaris arundinacea	25	Graminoid	Non-native	FACW	0	Reed Canary Grass
Plantago major	15	Forb	Non-native	FAC	0	Great Plantain
Poa compressa	1	Graminoid	Non-native	FACU	0	Flat-Stem Blue Grass
Poa pratensis	16	Graminoid	Non-native	FACU	0	Kentucky Blue Grass
Polygonum amphibium	7		Native	OBL	5	Water Smartweed
Polygonum aviculare	4	Forb	Non-native	FACU	0	Yard Knotweed
Polygonum persicaria	3		Non-native	FACW	0	Lady's-Thumb
Polygonum ramosissimum	2	Forb	Native	FACW	2	Yellow-Flower Knotweed
Polypogon monspeliensis	2	Graminoid	Non-native	FACW	0	Annual Rabbit's-Foot Grass
Populus deltoides	25		Native	FAC	4	Eastern Cottonwood
Portulaca oleracea	1	Forb	Non-native	FAC	0	Little-Hogweed
Potentilla paradoxa	13	Forb	Native	FACW	5	Bushy Cinquefoil
Potentilla sp.	1					
Puccinellia nuttalliana	14	Graminoid	Native	OBL	6	Nuttall's Alkali Grass
Ranunculus cymbalaria	6	Forb	Native	OBL	4	Alkali Buttercup
Ranunculus inamoenus	1	Forb	Native	FACW	7	Graceful Buttercup
Ranunculus sceleratus	1		Native	OBL	2	Cursed Buttercup
Rhus aromatica	1			UPL	7	Fragrant Sumac
Ribes aureum	2	Shrub	Native	FACU	5.5	Golden Currant
Rorippa sinuata	2	Forb	Native	FACW	4	Spreading Yellowcress
Rosa arkansana	1	Shrub	Native	FACU	4	Prairie Rose
Rudbeckia laciniata var. ampla	1	Forb	Native	FAC	5.33	Green-Head Coneflower
Rumex crispus	15	Forb	Non-native	FAC	0	Curly Dock

Rumex sp.	1				7	
Rumex stenophyllus	16	Forb	Non-native	FACW	0	Narrow-Leaf Dock
Ruppia cirrhosa	1	Forb	Native	OBL	6	Spiral Ditch-Grass
Sagittaria cuneata	5	Forb	Native	OBL	7	Arum-Leaf Arrowhead
Salix amygdaloides	29	Tree	Native	FACW	5	Peach-Leaf Willow
Salix exigua	26	Shrub	Native	FACW	3	Narrow-Leaf Willow
Schendonorus pratensis	2					
Schoenoplectus acutus	10		Native	OBL	3	Hard-Stem Club-Rush
Schoenoplectus maritimus	12	Graminoid	Native	OBL	5.66	Saltmarsh Club-Rush
Schoenoplectus pungens	38	Graminoid	Native	OBL	5	Three-Square
Schoenoplectus tabernaemontani	23	Graminoid	Native	OBL	3	Soft-Stem Club-Rush
Scirpus atrocinctus	1			OBL	10	Black-Girdle Bulrush
Scirpus nevadensis	1	Graminoid	Native	OBL	8	Nevada Bulrush
Scirpus pallidus	1	Graminoid	Native	OBL	5	Pale Bulrush
Scutellaria galericulata	2	Forb	Native	OBL	7	Hooded Skullcap
Setaria pumila	2		Non-native	FACU	0	Yellow Bristle Grass
Sisymbrium altissimum	2	Forb	Non-native	FACU	0	Tall Hedge-Mustard
Sonchus asper	4	Forb	Non-native	FAC	0	Spiny-Leaf Sow-Thistle
Sonchus sp.	1					
Spartina gracilis	1	Graminoid	Native	FACW	6	Alkali Cord Grass
Spartina pectinata	11	Graminoid	Native	FACW	5.8	Freshwater Cord Grass
Sporobolus airoides	4	Graminoid	Native	FAC	5	Alkali-Sacaton
Stachys pilosa	11		Native	FACW		Hairy Hedge-Nettle
Stuckenia filiformis	4		Native	OBL	5.5	Slender-Leaf False Pondweed
Stuckenia pectinata	15	Forb	Native	OBL	4	Sago False Pondweed
Suaeda calceoliformis	3	Forb	Native	FACW	3	Paiuteweed
Symphoricarpos occidentalis	4	Shrub	Native	UPL	4	Western Snowberry
Symphorocarpus sp.	3					
Tamarix chinensis	11	Shrub	Non-native	FACW	0	Five-Stamen Tamarisk

Taraxacum officinale	10	Forb	Non-native	FACU	0	Common Dandelion
Teucrium canadense	3		Native	FACW	3	American Germander
Thinopyrum ponticum	6	Graminoid	Non-native		0	
Thlaspi arvense	1	Forb	Non-native	FACU	0	Field Pennycress
Toxicodendron rydbergii	6	Shrub	Native	FACU	3.5	Western Poison-Ivy
Tragopogon dubius	6	Forb	Non-native		0	
Trifolium pratense	1	Forb	Non-native	FACU	0	Red Clover
Trifolium repens	2	Forb	Non-native	FACU	0	White Clover
Triglochin maritima	4	Graminoid	Native	OBL	7	Seaside Arrow-Grass
Typha angustifolia	21	Forb	Non-native	OBL	0	Narrow-Leaf Cat-Tail
Typha latifolia	14	Forb	Native	OBL	3	Broad-Leaf Cat-Tail
Urtica dioica	7		Native	FAC	3	Stinging Nettle
Verbascum thapsus	15	Forb	Non-native	UPL	0	Great Mullein
Verbena hastata	8	Forb	Native	FACW	4.33	Simpler's-Joy
Veronica americana	2	Forb	Native	OBL	6	American-Brooklime
Veronica anagallis-aquatica	5	Forb	Native	OBL	0	Blue Water Speedwell
Veronica sp.	1					
Vitis riparia	2	Vine	Native	FAC	4	River-Bank Grape
Zannichellia palustris	10	Forb	Native	OBL	2	Horned-Pondweed

APPENDIX D. Scoring formulas and definitions for Ecological Integrity Assessment wetland condition scores.

Table D.1. EIA ranks and definitions adapted from (Lemly and Gilligan 2013).

Rank	*Condition Category*	*Interpretation*
A	**Excellent / Reference Condition (No or Minimal Human Impact)**	Wetland functions within the bounds of natural disturbance regimes. The surrounding landscape contains natural habitats that are essentially unfragmented with little to no stressors; vegetation structure and composition are within the natural range of variation, nonnative species are essentially absent, and a comprehensive set of key species are present; soil properties and hydrological functions are intact. Management should focus on preservation and protection.
B	**Good / Slight Deviation from Reference**	Wetland predominantly functions within the bounds of natural disturbance regimes. The surrounding landscape contains largely natural habitats that are minimally fragmented with few stressors; vegetation structure and composition deviate slightly from the natural range of variation, nonnative species and noxious weeds are present in minor amounts, and most key species are present; soils properties and hydrology are only slightly altered. Management should focus on the prevention of further alteration.
C	**Fair / Moderate Deviation from Reference**	Wetland has a number of unfavorable characteristics. The surrounding landscape is moderately fragmented with several stressors; the vegetation structure and composition is somewhat outside the natural range of variation, nonnative species and noxious weeds may have a sizeable presence or moderately negative impacts, and many key species are absent; soil properties and hydrology are altered. Management would be needed to maintain or restore certain ecological attributes.
D	**Poor / Significant Deviation from Reference**	Wetland has severely altered characteristics. The surrounding landscape contains little natural habitat and is very fragmented; the vegetation structure and composition are well beyond their natural range of variation, nonnative species and noxious weeds exert a strong negative impact, and most key species are absent; soil properties and hydrology are severely altered. There may be little long term conservation value without restoration, and such restoration may be difficult or uncertain.

Table D.2. EIA methods for scoring.

1. The score for each EIA submetric was calculated using the equations below.

<u>Landscape Context Score</u>:
(Landscape Fragmentation * 0.4) + ([(Buffer Width * Buffer Extent)$^{1/2}$ * ((Buffer Condition + Buffer Natural Cover)/2)]$^{1/2}$ * 0.6)

<u>Biotic Condition Score:</u>
(Relative Cover Native Plant Sp. * 0.2) + (Absolute Cover Noxious Weeds * 0.2) + (Mean C * 0.4) + (Horizontal Interspersion * 0.2)

<u>Hydrologic Condition Score:</u>
Landscape Hydrology Metric score

<u>Physicochemical Condition Score</u>:
(Surface Water Quality * 0.25) + (Algal Growth * 0.25) + (Substrate/Soil Disturbance * 0.5)
If no standing water was present, score = Substrate/Soil Disturbance.

3. EIA score was calculated using submetric scores:
<u>EIA Score:</u>
(Landscape Context * 0.2) + (Biotic Condition * 0.4) + (Hydrologic Condition * 0.3) + (Physicochemical Condition * 0.1)

4. Score to rank conversion:

A = 4.5 – 5.0
B = 3.5 – <4.5
C = 2.5 - <3.5
D = 1.0 - <2.5

Appendix E: Species detected across all wetlands during bird surveys within the Goshen Hole Wetland Complex.

Table E.1. List of species detected, species of concern or potential concern, and number of occurrence records across all sampled wetlands in the Goshen Hole Wetland Complex. If a species was on the "Bird Species of Concern" list (WYNND 2015), Heritage Ranking codes were included.

Bird species observed	Species of Concern	Species of Potential Concern	# of Occurances
American Avocet		G5/S3B	10
American Bittern	G4/S3B		1
American Coot			17
American Goldfinch			20
American Kestrel			7
American Robin			35
American White Pelican	G4/S1B		1
American Wigeon			11
Bald Eagle	G5/S2B, S5N		5
Bank Swallow			10
Barn Swallow			32
Belted Kingfisher			5
Black Tern	G4/S1		3
Black-billed Cuckoo			1
Black-billed Magpie			7
Black-capped Chickadee			7
Black-headed Grosbeak			6
Blue Jay			25
Blue-winged Teal			40
Brewers Blackbird			2
Brown Thrasher			12
Brown-headed Cowbird			24
Bufflehead		G5/S2B	3
Bullock's Oriole			21
Canada Goose			21
Canvasback			1
Cedar Waxwing			1
Chestnut-sided Warbler			1
Chimney Swift		G5/S3B	1
Chipping Sparrow			4
Cinnamon Teal			8
Cliff Swallow			27

Bird species observed	Species of Concern	Species of Potential Concern	# of Occurances
Common Grackle			37
Common Merganser			7
Common Nighthawk			12
Common Yellowthroat			28
Cormarant			4
Downy Woodpecker			8
Eared Grebe			1
Eastern Kingbird			32
English Sparrow			2
Eurasian Collared Dove			23
European Starling			28
Forster's Tern	G5/S1		2
Franklins Gull			1
Gadwall			16
Grasshopper Sparrow		G5/S4	12
Gray Catbird			2
Great Blue Heron			21
Great-horned Owl			8
Great-tailed Grackle			8
Green-tailed Towhee			1
Green-winged Teal			25
Hairy Woodpecker			2
Horned Grebe			2
Horned Lark			18
House Wren			27
Killdeer			41
Lark Bunting			6
Lark Sparrow			12
Lazuli Bunting			1
Least Flycatcher			8
Least Sandpiper			1
Lesser Scaup			5
Lesser Yellowlegs			4
Lincoln's Sparrow			4
Long-billed Dowitcher			2
Magpie			1
Mallard			43
Marbled Godwit			1
Marsh Wren			3
Mourning Dove			54

Table E.1.

Bird species observed	Species of Concern	Species of Potential Concern	# of Occurances
Northern Flicker			23
Northern Harrier			5
Northern Pintail			19
Northern Rough-winged Swallow			9
Northern Shoveler			28
Orange-crowned Warbler			14
Orchard Oriole			26
Osprey		G5/S3B	1
Peregrine Falcon	G4/S2		2
Pheasant			20
Pied-billed Grebe			8
Red-breasted Nuthatch			1
Redhead			6
Red-headed Woodpecker			2
Red-tailed Hawk			7
Red-winged Blackbird			48
Ring-billed Gull		G5/S2	2
Ring-necked Duck		G5/S4B	5
Rock Pigeon			5
Ruddy duck			10
Sandhill Crane		G5/S3B,S5N	2
Snow Goose			4
Solitary Sandpiper			1
Song Sparrow			2
Sora			5
Spotted Sandpiper			5
Spotted Towhee			11
Swainson's Hawk			4
Swainson's Thrush			5
Tree Swallow			12
Turkey			5
Turkey Vulture			2
Unknown gull			2
Unknown sandpiper			3
Upland Sandpiper			2
Violet-green Swallow			3
Warbling Vireo			7
Western Grebe			9
Western Kingbird			27
Western Meadowlark			49

Bird species observed	Species of Concern	Species of Potential Concern	# of Occurances
Western Tanager			1
Western Wood Peewee			9
White-breasted Nuthatch			2
White-crowned Sparrow			3
White-faced Ibis	G5/S1B		2
White-rumped Sandpiper			1
Willet			5
Wilson's Phalarope			19
Wilson's Snipe			10
Wood Duck			28
Yellow Warbler			33
Yellow-breasted Chat			5
Yellow-headed Blackbird			14
Yellow-rumped Warbler			5