Characterizing Condition in At-Risk Wetlands of Western Utah: Phase II

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Cover:

Leland-Harris Wetland in Snake Valley, Juab County, Utah

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Executive Summary

Snake Valley is a large inter-mountain basin in Utah's West Desert. The valley bottom encompasses a series of springs that support an expanse of critical habitat for rare and endemic wildlife species while providing the principal resources for ranching and other agricultural activity in the area. Snake Valley wetlands have been targeted for shallow groundwater monitoring and wetland condition assessment because of the unique wetland resources supported and because of potential threats to groundwater in the region. Monitoring and assessment of this resource is intended to establish baseline conditions and relationships between spring flow and wetland extent and condition. This study is an extension of a previous study, Characterizing Condition in At-Risk Wetlands of Western Utah: Phase I, that targeted wetlands in the northern reach of Snake Valley associated with a shallow groundwater monitoring network. This report is an expansion of the sample frame to include a broader disturbance gradient in the study area.

There are three major components to this project, each corresponding to the EPA's "three-tier framework" for wetland assessment. First, we conducted rapid wetland condition assessments at sites to obtain information on the condition of emergent wetlands in the study area and to test three rapid assessment protocols to inform on-going development of a state protocol (EPA Level 2 assessment). Then, we obtained detailed information on the distribution and abundance of plant species found at survey plots (EPA Level 3 assessment). Lastly, we conducted a preliminary landscape-scale analysis to determine the types of stressors present in the study area (EPA Level 1 assessment).

We conducted rapid assessment and plant community surveys in 18 sites in Snake Valley. Sites were divided between the northern (n=8) and southern (n=10) reaches in both private (n=11) and publicly (n=7) owned parcels. Surveyed wetlands were all palustrine emergent, slope wetlands supporting wet meadow and marsh ecological systems.

Based on the metrics evaluated for the rapid condition assessment protocols, all sites were surrounded with wide buffers, though many buffers had poor physical condition due to soil disturbances from grazing. Sites predominantly scored high for hydrologic condition metrics with a small number of sites receiving a C or lower due to alteration of surface flows by ditching and diversions. Sites generally scored poorly for topographic complexity, horizontal interspersion, vertical biotic structure, and plant community complexity. These low scores could either be the result of actual impaired conditions or reflect the fact that these metrics may need to be better calibrated to our study system. Sites generally had high aquatic connectivity unless they were isolated springs with a small wetland area or if they were situated on the edge of a larger wetland complex. Physical alterations including soil disturbances varied across all sites. All sites scored high for metrics related to native versus non-native species composition. For overall condition scores, only two sites were rated as A (pristine) in one of the protocols and no sites were rated D, significant deviation from reference. Across all protocols, the majority of sites were rated B, exhibiting slight deviation from reference (CNHP-EIA n=12, USA-RAM n=16, UWAAM n=15).

The most common stressors observed within assessment areas included ditches and channelization and grazing, with grazing observed in moderate to high severity at 10 sites (n=3 north, n=7 south). The mean number of stressors in the 200 m buffer at each site was 7.3, with agricultural and grazing stressors being the most common. Ditching was the most common hydrologic stressor in the buffer and was found in moderate to high severity in 7 sites. Pasture and grazing use was found in the buffer of all sites, while vegetation reflected excessive grazing in 13 sites. Similarly, grazing disturbances were observed in the 500 m envelope around all survey sites.

We recorded 91 unique plant species, with a mean of 24.5 species and a range of 11 to 38 species recorded per site. We found 1 introduced and 14 native species at half of the sites, and *Juncus arcticus* (arctic rush), *Argentina anserina* (silverweed cinquefoil), *Carex nebrascensis* (Nebraska sedge), and *Eleocharis rostellata* (beaked spikerush) were both common and abundant where found. No species encountered are included on Utah’s list of noxious weeds. The mean coefficient of conservatism (C-value) at sites was 3.9. All sites had at least one occurrence of a species with a C-value of 6 or higher. Floristic quality assessment (FQA) metrics were generally higher in northern sites and sites on private land. Percent cover of non-native species in southern sites and on private property was, on average, nearly double that observed in northern and publicly managed sites.

Multiple strong relationship exist between overall wetland condition scores and FQA metrics and multiple measures of stressors, indicating that wetland condition assessment scores appropriately reflect other measures of wetland condition. Overall wetland condition scores had correlations as high as 0.69 with FQA metrics. Total recorded stressors adjusted for extent and severity correlated negatively with overall site scores for all three protocols, correlations were between -0.58 and -0.77.

Field experience, data, and analysis from this Snake Valley wetland assessment project will be used to inform the on-going work to develop a single rapid assessment protocol for use in all Utah wetlands and, potentially, to develop a module specific to the Great Basin ecoregion. We will select a subset of metrics from the three tested protocols and refine the metrics that were difficult to use in the field. New versions of the state protocol will be tested and refined through additional wetland surveys in the Great Basin and across the state. This initial assessment work around Snake Valley has provided a substantial amount of information that will be instrumental as protocol development moves forward.

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1.0 Introduction

1.1 Project Background and Objectives

Wetlands occupy approximately 1% of the landscape in the state of Utah (Dahl, 1990). This relatively uncommon resource occurs in all ecosystems, creating a number of distinct wetland types including marshes, wet meadows, fens, and playas. Though wetlands constitute a minor component of the landscape, they provide diverse ecosystem services including flood attenuation, water quality enhancement, sediment storage, and nutrient cycling, as well as providing critical habitat for biota (Costanza, 1997; Grimm and others, 1997; Mitsch and Gosselink, 2000). Researchers have estimated that Utah has lost approximately 30% of its wetland acreage and many of the remaining wetlands are at risk to loss and degradation due to a diverse number of human activities, making the task of monitoring and assessment of these critical habitats very important (Dahl, 1990; Dahl and Johnson, 1991; Sutula and others, 2006).

Springs and associated wetlands are an important component of desert ecosystems, where they often contribute a disproportionate amount to biodiversity compared to surrounding uplands (Sada and Pohlmann, 2002). In western Utah, these wetlands are located in valley bottoms where groundwater discharges to the surface, forming isolated pockets of highly productive zones in a mosaic of cold-desert uplands. In Snake Valley of the West Desert, the source water for these systems is derived predominantly from regional basin-fill aquifers that are recharged in adjacent mountain ranges (Kirby and Hurlow, 2005; Welch and others, 2007; Hooker and others, 2011). Spring wetlands in the valley serve as critical habitat for two state of Utah sensitive species, Least Chub (*Iotichthys phlegothontis*) and Columbia Spotted Frog (*Rana luteiventris*), as well as other wetland-associated Utah Species of Concern, including several endemic mollusks (Bailey and others, 2005; Sutter and others, 2005; Bailey and others, 2006). These wetlands are also important cultural and agricultural resources for the rural population, supporting the only land suitable for grazing and agriculture. The most significant, potential stress proposed for this area is the development of an interstate groundwater withdrawal network to supply water to southern Nevada (U.S. Bureau of Land Management, 2012).

In 2012, the Utah Geological Survey (UGS), supported by a Wetland Program Development grant from the U.S. Environmental Protection Agency (EPA), undertook an assessment of the current condition and presence of stressors in spring-fed wetlands in Snake Valley to better understand this unique and threatened ecosystem. Data were collected at each survey site using metrics from three rapid condition assessment methods designed to evaluate important indicators of wetland condition using easily observable features that can be assessed in a short field survey. Quantitative vegetation data were collected in the assessment area to inform rapid condition method results and calculate metrics for some rapid condition metrics.

This project is an extension of a previous project *Characterizing Condition in At-Risk Wetlands of Western Utah: Phase I* (Jones and other, 2013) that focused on condition assessment of wetland resources in the northern reach in Snake Valley. The study found that there was an insufficient gradient in condition to support rapid condition assessment development. The current project focused on expanding the sample frame to include sites in the southern reach of Snake Valley that have more intense and varied land use and disturbance.

The primary objective of this study was to collect data to support the development of a rapid assessment protocol for use in wetlands throughout the state. Additionally, these data have been used here to present general trends in wetland condition in the study area. Protocol development will be supported by data from this project, previous work in Great Salt Lake wetlands, and ongoing work in the Upper and Lower Weber River watershed along the Wasatch Front.

Objective 1

Conduct field-based assessment of the condition of spring-fed wetlands in Snake Valley in the West Desert of Utah. Surveyed sites using three rapid assessment protocols to develop a Utah-specific wetland condition assessment methodology. Selected survey sites to capture the variability in land use, management, and wetland type in the study area.

- *Task 1: Collect information on the condition and stressors in wetlands in the northern and southern reaches of Snake Valley and surrounding lands.*
- *Task 2: Use data to inform on-going rapid assessment protocol development, such as determining which tested metrics are difficult to interpret or are not relevant for the study area.*
- *Task 3: Evaluate the relationship between stressors observed in the field and components of wetland condition, such as hydrologic and vegetation condition.*

Objective 2

Obtain detailed plant community data at field sites. *Collected data on the presence and percent cover of all plant species found in survey plots.*

- *Task 1: Contribute data on wetland plant species distribution and abundance to a database for further development of plant-based metrics in the state of Utah, including state-specific coefficient of conservatism values.*
- *Task 2: Evaluate the relationship between plant community metrics and site attributes, including natural and anthropogenic variables and wetland condition.*

1.2 Overview of Wetland Condition Assessments

1.2.1 Definition of Wetland Condition

This project focuses on the evaluation of ecological condition in Snake Valley wetlands. Ecological condition can be defined as "the ability of a wetland to support and maintain its complexity and capacity for self-organization with respect to species composition, physico-chemical characteristics, and functional processes as compared to wetlands of a similar type without human alterations" (Fennessy and others, 2007). Condition is often evaluated in terms of degree of deviation from what is known or expected to occur at sites without any anthropogenic alteration (i.e., reference sites). Condition assessments differ from functional assessments in that the latter specifically focus on the functional aspect of condition, such as the ability of a wetland to attenuate flood waters or provide wildlife habitat, without regard to the overall naturalness of a site.

1.2.2 Environmental Protection Agency Framework

The EPA suggests a three-tiered framework for wetland monitoring and assessment (U.S. Environmental Protection Agency, 2006). Level 1 assessments are generally applied at the landscape scale, using geographic information systems (GIS) and remotely sensed data to evaluate the abundance and distribution of wetlands and surrounding land use. These assessments can provide a coarse estimate of wetland condition based on calculated metrics in the surrounding watershed, such as road density, percent agriculture, and presence of point source discharges. Level 1 assessments are relatively inexpensive and efficient for evaluating broad geographic areas, but cannot provide specific information about the on-site condition of any particular wetland. Level 2 assessments evaluate wetland condition in the field using a rapid assessment approach. These assessments are intended to take two people no more than four hours of field time plus up to half a day in the office for preparation and subsequent analysis and often rely primarily on qualitative evaluation. Level 2 assessments can be used to understand ambient wetland condition, to determine sites appropriate for conservation or restoration, or for regulatory decision making. Level 3 assessments are detailed, quantitative field evaluations that more comprehensively determine wetland condition using intensive measures such as invertebrate or plant community enumeration or water quality measurements. These assessments require the most professional expertise and sampling time, including in some cases repeat visits to a site. Information from Level 3 assessments can be used to develop performance standards for wetland conservation and restoration, support development of water quality standards, determine causes of wetland degradation, and refine rapid assessment methods.

This project analyzed the relationships between data at all three EPA-defined levels using a simplified landscape analysis, rapid assessment, and quantitative plant evaluation. In principal, the detailed Level 3 data can be used to calibrate Level 1 and Level 2 assessments. However, components of the Level 3 analysis often have to be calibrated themselves, such as by developing species-specific coefficient of conservatism values that indicate the ability of species to tolerate disturbance. Level 3 analysis was not the principle focus of this project, and thus we did not collect enough data at that scale to fully develop robust Level 3 metrics. Instead, we used data from all three levels to evaluate the inter-relatedness of the methods and to begin to determine possible approaches for calibration.

1.3 Rapid Assessment Methods

Although several wetland functional assessments have been developed for Utah (Keate, 2005; Johnson and others, 2006), there is currently no widely used condition assessment protocol for the state. As part of a separate project, the UGS is developing a rapid condition assessment method suitable for the state. Development began by applying three methods to wetlands across the state, including the wetlands surveyed for this project. Utah Wetlands Ambient Assessment Method (UWAAM) was recently developed for the state through adaptation primarily of methods used by California and Ohio (Hoven and Paul, 2010). UWAAM altered metrics to specifically address unique aspects of Great Salt Lake and added a habitat component absent from other protocols. However, the method has not been widely adopted for use in the state or validated with landscape or detailed quantitative data. The EPA developed a rapid assessment protocol (USA-RAM) used in conjunction with more detailed surveys carried out as part of the 2011 National Wetland Condition Assessment (www.epa.gov/wetlands/survey). USA-RAM is a standardized method that has been applied to wetlands nationally, but its broad application may limit its ability to properly address issues of local or regional importance. Colorado Natural Heritage Program (CNHP) developed a rapid condition assessment protocol (CNHP-EIA) based on the Ecological Integrity Assessment developed by NatureServe (Faber-Langendoen and others, 2008). CNHP-EIA focuses on evaluating wetland condition within a single ecological system and has been refined through several iterations of field testing (Lemly and Gilligan, 2013). For this project, we evaluated wetlands using a field method based on metrics from CNHP-EIA, USA-RAM, and UWAAM applied during a single field visit.

All three rapid assessment methods are similar in their general structure and interpretation of results. Each method is composed of between 12 and 19 individual metrics that are organized into categories that capture important aspects of wetland condition. Categories evaluated by all three methods include the buffer or landscape context, hydrology, plant community, and physical or physiochemical structure. However, methods differ in the types of metrics included in each category. For example, some methods include structural components of vegetation in the physical structure category while others include it as a plant community metric. UWAAM includes an additional habitat category, and CNHP-EIA evaluates wetland size, though this is not used for final site evaluation. USA-RAM includes two main types of metrics in its evaluation: those that directly evaluate wetland condition and those that tabulate potential stressors in an area. We divided the metrics used by each protocol into the following six categories:

1) **Landscape Context**: Ability of surrounding landscape to buffer wetland from adjacent stressors and provide intact habitat for species.

2) **Hydrologic Condition:** Degree of hydrologic functioning related to water source, connectivity to adjacent areas, hydroperiod, and evidence of water quality degradation.

3) **Physical Structure:** Quality of physical structure including complexity of structural features and degree of physical alteration.

4) **Vegetation Structure:** Presence of structural vegetation components, including horizontal and vertical interspersion and natural woody and herbaceous litter accumulation.

5) **Plant Species Composition:** Intactness of plant community based on species richness and presence of desirable and undesirable species.

6) **Habitat:** Presence of threats to wildlife and landscape features that provide habitat for wildlife.

Wetlands can be scored for individual metrics, categories, and overall site condition. Numeric scores can be converted to categories or ranks to ease interpretation. CNHP-EIA uses the letter grades A through D to denote wetland condition ranging from pristine or reference condition to severely altered wetlands that may have little conservation value and be very difficult to restore (Table 1). Similarly, UWAAM divides wetlands into Category I through Category IV designations that reflect rarity, quality of habitat provided, and ecological function of each wetland (Table 1). USA-RAM does not currently have fully developed methods for scoring sites and interpreting scores. For ease and standardization of presentation, we use letter grades (A - D) to portray the results of each method.

Table 1. Definition of assessment ratings from CNHP-EIA and UWAAM. CNHP-EIA values range from A to D and UWAAM categories range from I to IV.

Value/ Category	CNHP-EIA Description[1]	UWAAM Description[2]
A / I	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.	Wetlands are high quality and rare in occurrence. They may provide: primary habitat for federally listed or proposed threatened or endangered species; represent a high quality example of a rare wetland type; provide irreplaceable ecological function; exhibit exceptionally high flood attenuation capability; or score high for all of the metrics assessed.
B / II	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.	Wetlands are more common than Category I wetlands, and can provide habitat for sensitive plants or animals, provide a high level of ecological services for wildlife habitat, are unique to a given region, or score high in many of the metrics assessed.
C / III	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.	Wetlands are more common and generally less diverse than Category I and II wetlands. They can provide many ecological services, but do not score as high in as many metrics as Category I and II wetlands.
D / IV	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.	Wetlands lack vegetative diversity, provide little ecological services to wildlife and are often directly or indirectly disturbed.

[1]From Table 1 in Lemly and others (2011)

[2]From Hoven and Paul (2010)

1.4 Landscape Analysis

Landscape analyses are important tools for assessing wetland condition. These landscape-scale assessments can be used to explore relationships between field observations and landscape stressors and are an efficient means to categorize the potential condition of wetlands in a large area, which can aid in identification of reference sites or sites to target for restoration projects. Recent Landscape Integrity Models developed for Colorado and Montana provide good examples of how landscape models can be developed (Vance, 2009; Lemly and others, 2011; Copeland and others, 2010). First, spatial data for stressors to wetlands such as roads, agriculture, urban development, water diversions, and mines are compiled. Next, each stressor is spatially modeled to capture how the stressor's influence decreases with increasing distance from a wetland, using decay parameters established through literature review, best professional judgment, and/or validation with field sampling data. Last, modeled stressors are combined so that areas close to many stressors receive higher scores to indicate higher levels of potential impairment. Though developing a landscape integrity model for Snake Valley was outside of the scope of this project, a preliminary effort was made to gather the necessary data needed to develop such a model for the area. These data were used to determine potential stressors to wetland resources in the study area.

2.0 Study Area

2.1 Geography

Snake Valley is located in Utah's West Desert, encompassing an area of approximately 8000 km^2 straddling the Utah-Nevada border (Figures 1 and 2). Snake Valley is situated in the eastern half of the Great Basin and the northeastern extent of the Basin and Range physiographic province. The Great Basin extends from the eastern flank of the Sierra Nevada to the Wasatch and Uinta Mountains, and accounts for roughly the western third of Utah. Snake Valley is an example of the broad, low-angle valleys flanked by north-south trending mountain ranges that is characteristic of the Great Basin. Below the valley floors lie deep accumulations of sediment derived from mountain weathering and lake-bed deposits from a series of large, prehistoric pluvial lakes that were trapped in these intermountain basins (Parsons, 1995). These materials, referred to as basin fill, form a mantel over a complex assortment of geologic strata that have been repeatedly folded and faulted over millions of years (Plume, 1996).

2.2 Climate and Hydrology

Utah's West Desert is considered to have a cold desert climate with the majority of precipitation falling during the winter in the form of snow (Barbour and others, 1999). Though the area experiences hot summers, mean temperatures are not as hot as the Mojave and Sonoran Deserts and winters are cooler (California Academy of Sciences, 2013). West Desert wetlands are predominantly located in the topographically low centers of the valleys and receive very little precipitation. The lower elevation Snake Valley basin averages 196 mm annually, while the ranges surrounding the basin receive much higher precipitation, e.g. up to 900 mm in the Snake Range (PRISM Climate Group, 2007). These ranges recharge the valley aquifers which contain large stores of groundwater, the majority of which is over a thousand years old indicating slow recharge rates and long water travel paths through the aquifer (Kirby, 2011). This groundwater is located in two

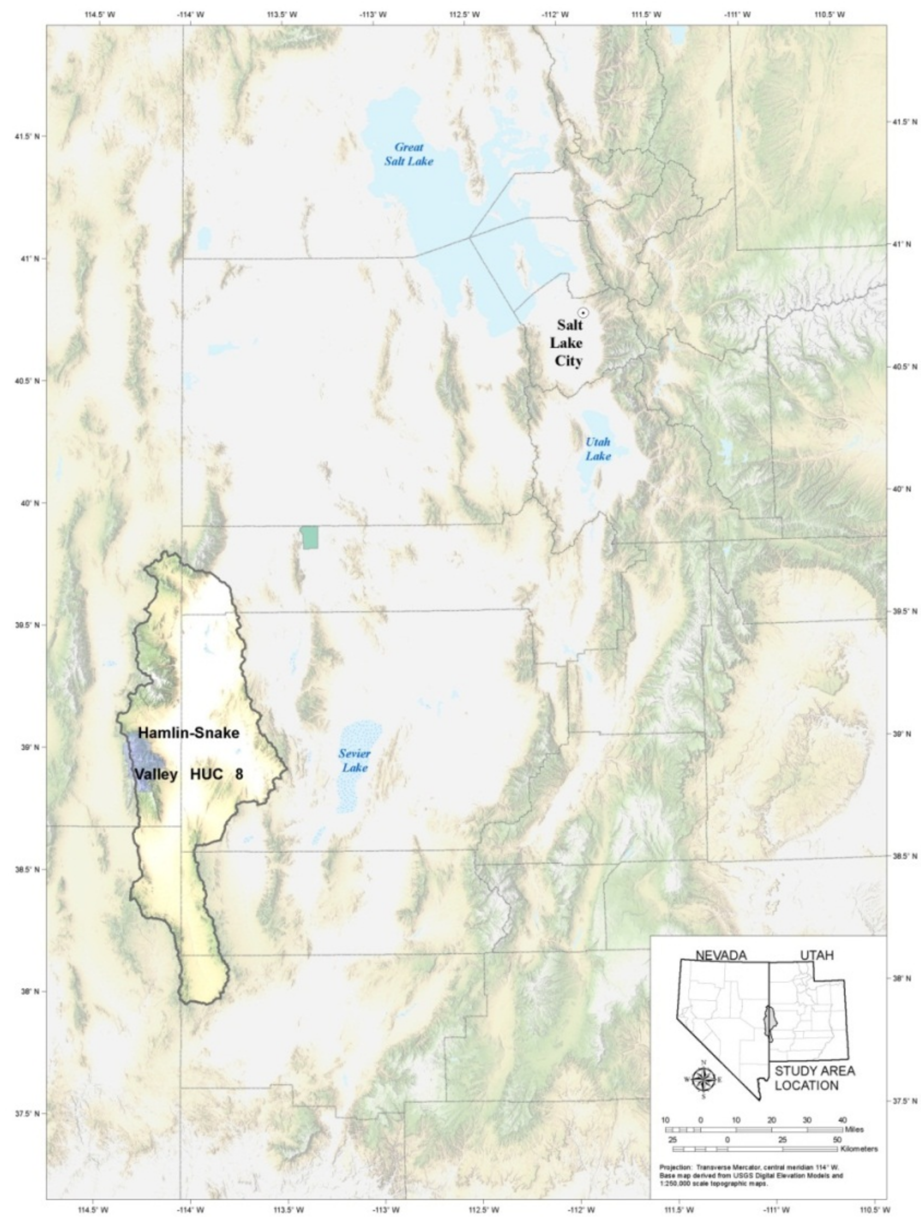

Figure 1. Hamlin and Snake Valleys, located in Utah's West Desert.

main aquifers: an extensive system within Paleozoic carbonate bedrock and local systems of basin fill in lower portions of the valleys (Kirby and Hurlow, 2005). Water is youngest, and most plentiful, in areas where precipitation infiltrates the soil and recharges the aquifer. Recharge is greatest at upper elevations of mountain ranges (where most precipitation falls) and along perennial streams where the mountain flank meets the valley floor. Water flows through pores or fractures in the bedrock, and some of this water enters basin-fill deposits. In general, groundwater flow through the bedrock aquifer is from the south/southwest toward the northeast and Great Salt Lake, based on groundwater potential elevation data derived from the aquifer monitoring network in Snake Valley (Gardner and others, 2011).

Predominant sources of depletion of groundwater include inter-basin flow to adjacent watersheds (towards Great Salt Lake), evapotranspiration where water table elevations are within reach of plant roots, spring flow, and withdrawal for urban and agricultural needs. Areas of groundwater discharge to the surface as springs are common within valleys throughout the West Desert. These springs often support extensive and unique wetland complexes. One well known area is Fish Springs National Wildlife Refuge, where discharge has been impounded to create over 4,000 hectares (10,000 acres) of marsh and other wetlands (U.S. Fish and Wildlife Service, 2013).

2.3 Ecological Context

Snake Valley is part of the Central Basin and Range Ecoregion (Omernik and others, 2009). Valleys are dominated by xeric sagebrush or saltbush-greasewood communities with woodland, forest, and subalpine plant communities ascending into the montane elevations. Wetlands represent isolated pockets of highly productive ecosystems embedded within a mosaic of harsh desert uplands. In Snake Valley and other isolated valleys of the Great Basin, these wetlands serve as vital habitat for many species of wildlife and plants, including dominant hydrophytic (water-tolerant) plant species such as sedges (*Carex* spp.), rushes (*Juncus* spp.), and spikerushes (*Eleocharis* spp.) in extensive wet meadows, as well as bulrush (*Schoenoplectus* spp.) and cattails (*Typha* sp.) in seasonally or semi-permanently flooded marshes (Rocchio, 2006 a,b,c; Three Parameters Plus, 2010). One interesting aspect of these wetland types in Snake Valley is that water sources are primarily derived from older, deeper, regional aquifer systems. Due to the consistency of the water source, there is generally less seasonal variation in the quantity, temperature, and chemical composition of water feeding the wetlands compared to montane springs or riverine systems which rely on local aquifers (Sada and Pohlmann, 2002). These conditions provide stable and consistent wetland habitats supporting the persistence of many wetland specific species within the desert climate context. Spring complexes were described in Phase I of this study (Jones and other 2013).

Many of these wetlands are home to isolated wildlife populations that have endured since Lake Bonneville receded over 10,000 years ago. A spring survey recorded 58 species of previously undescribed hydrobiid snails; 22 species are endemic to (only found in) single locations (Herschler, 1994). These wetlands also serve as critical habitat for “wildlife species of concern”, such as the Least Chub (*Iotichthys phlegothontis*) and Columbia Spotted Frog (*Rana luteiventris*), among others (Utah Division of Wildlife Resources, 2011). Species of concern are species for which there is evidence that population viability is threatened and are at risk of being listed as Threatened or Endangered following protocols outlined by the Endangered Species Act (Utah Administrative Code, R657-48). These species are then targets of Conservation Agreements, where threats to species are identified and conservation actions are prioritized to eliminate or ameliorate the threats as a result of state, federal, and local landowner cooperation (Sutter and others, 2005).

In the southern reach, pastures are flood or sub-irrigated by two ditches that bound the wetlands to the west and east. This may contribute to the higher ratio of wet meadow in the south than the north where 87% and 34% of the wetlands mapped fall into the wet meadow class, respectively. Approximately 98% of the southern reach is influenced by irrigation as opposed to only 10% being irrigated in the northern reach, all near Miller Springs (Figure 3 and 4).

2.4 Land Use and Land Ownership

Snake Valley encompasses a large area that is remote and predominantly unpopulated with less than 250 residents (U.S. Census Bureau, 2010; Utah Automated Geographic Reference Center, 2010). Much of the study area is public and administered by the Bureau of Land Management (77.4%, Figure 2, Table 2). Great Basin National Park in Nevada, two wilderness areas and two wilderness study areas comprise the additional public land area (18.7%). Public lands are mostly managed as open range for sheep and cattle grazing, with the exception of Great Basin National Park. Land ownership in wetlands is mostly public (91%) in the northern reach and mostly private (73%) in the southern reach. Of the private wetland area across the study area, 88% is used for agricultural purposes including grazing and 0.5% is developed. Of the public wetland area across the study area, 81% is managed as natural area and open range, whereas a much smaller area is agriculture (10.4%) or developed (8.3%).

Utilization of water resources is a controversial issue in Snake Valley. Uses and distribution of water resources contribute to the two predominant stresses to wetland permanence and hydrologic condition, hydrological alterations and groundwater development. Hydrologic alterations to surface flows include the creation of ponds, ditches, and diversions in both the northern and southern reaches. These changes are marked in the southern reach where ditches bordering the valley bottom have extensively altered both wetland extent and type (Jones and others, 2013). Though the impacts of these alterations to surface flows are evident in changes to the hydroperiod and wetland area and composition, the key direct anthropogenic threat to permanence of spring-fed wetlands in the valley is excessive groundwater development and potential inter-basin water transfer. One possible wetland response to increased groundwater use is the loss or degradation of habitat and ecosystem function as a consequence of declining water table levels (Bailey and others, 2005, 2006).

3.0 Methods

3.1 Site Selection

The target population for this project included wetlands associated with large spring complexes in Snake Valley where hydrologic monitoring is proposed or in place. The targeted spring complexes and associated wetland areas as well as wetlands supported by ditched and diverted spring outflows included areas in the northern and southern reaches of the valley in relation to U.S. Route 50 (Figure 2, 3, 4). Though there are additional wetland classes present in the valley, such as open water and playa, the project focused on palustrine emergent wetlands, which are nontidal wetlands characterized by

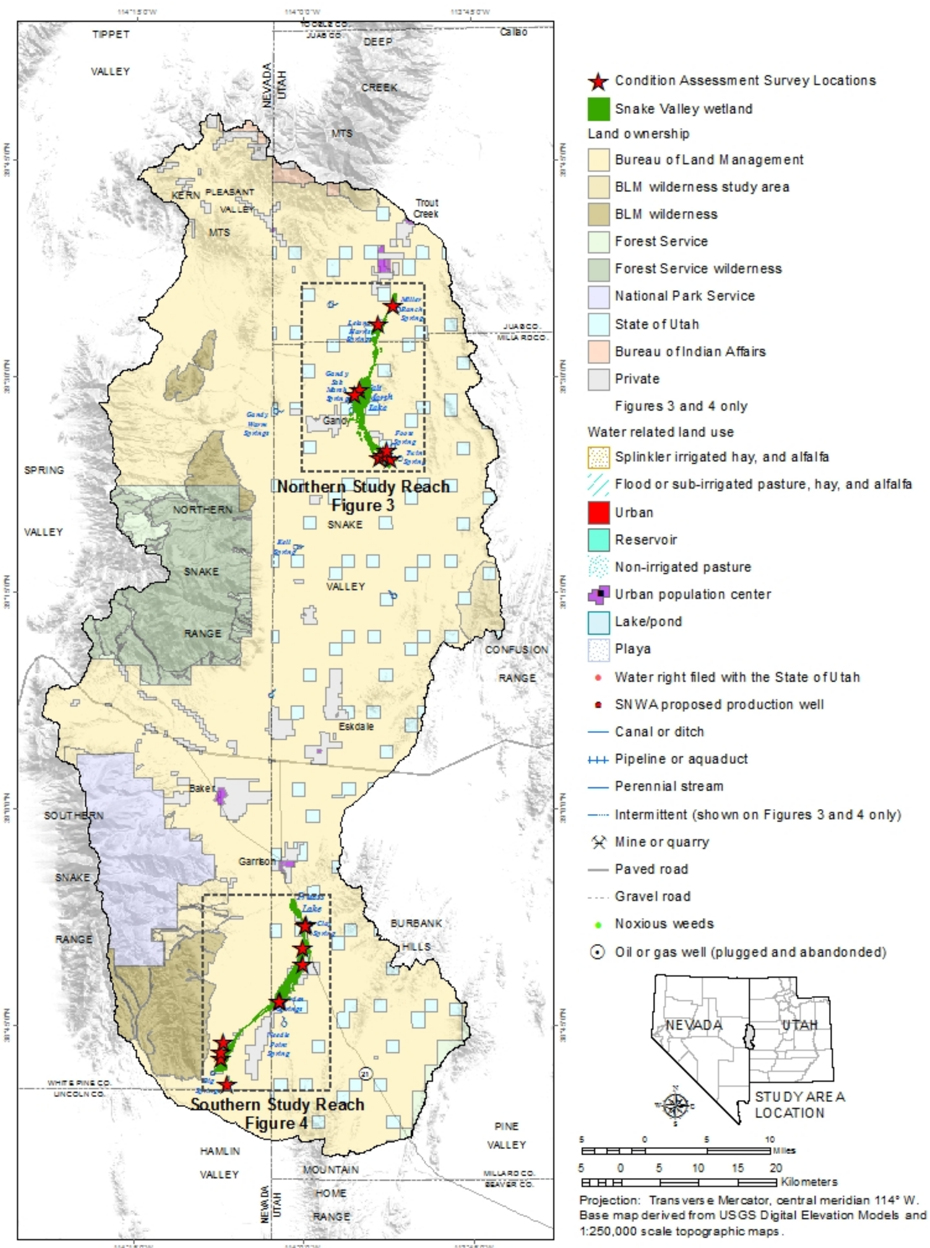

Figure 2. Landscape-scale use and stressor data for the Snake Valley study area. See expanded inset areas in Figures 3 and 4 below.

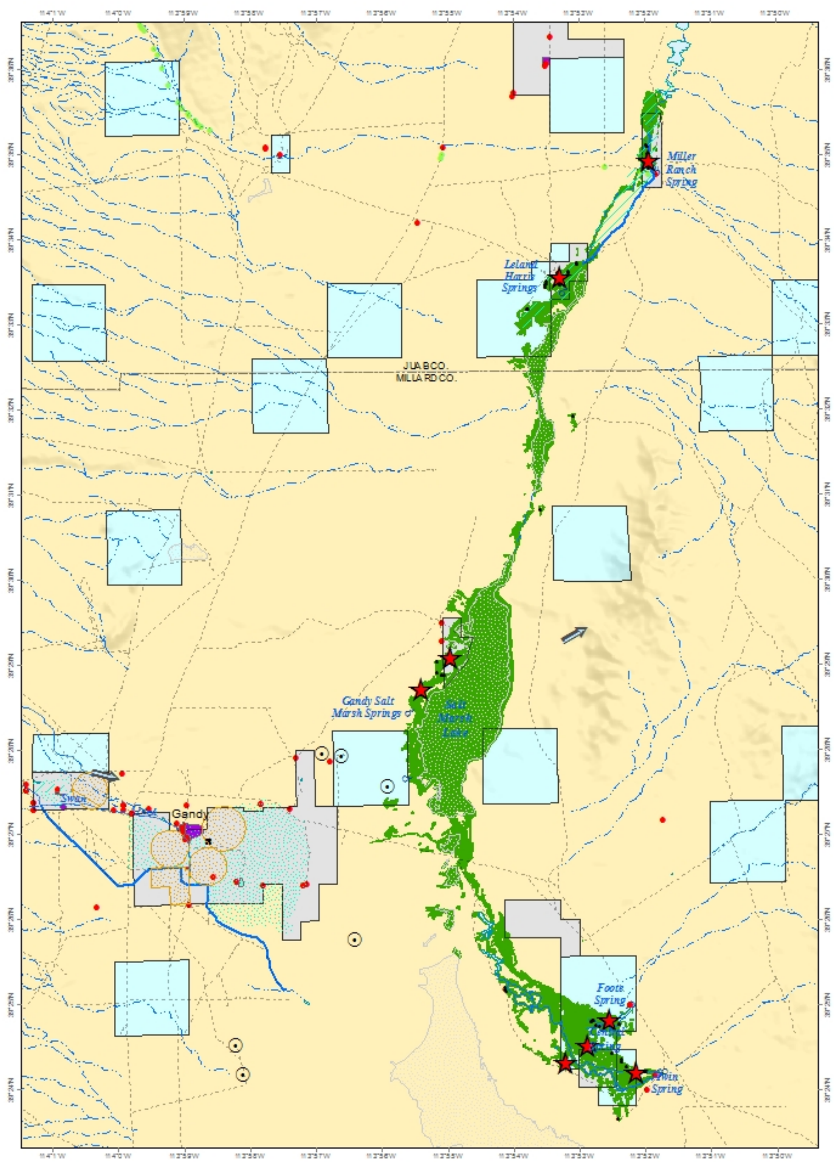

Figure 3. Landscape assessment for the northern reach of the Snake Valley study area. See Figure 2 for legend.

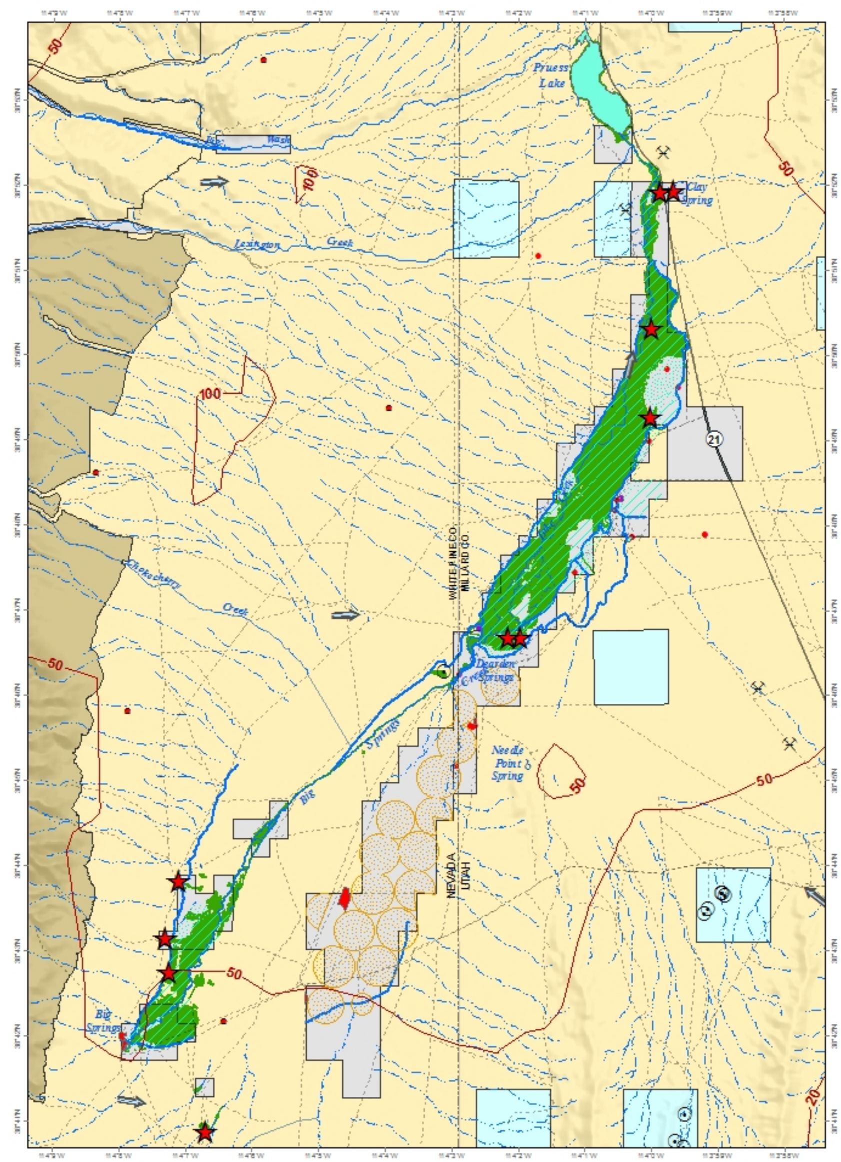

Figure 4. Landscape assessment for the southern reach of the Snake Valley study area. See Figure 2 for legend.

Table 2. Land use in relation to land ownership in the study area.

	Total Land Area					Wetland Area				
	Hectares	% of study area	% Natural	% Agriculture Cultivation/Pasture	% Developed	Hectares	% of wetland study area	% Natural	% Agriculture Cultivation/Pasture	% Developed
Bureau of Land Management	392,238	77.4%	99.8%	0.12%	0.037%	1234	50.7%	80.4%	10.1%	9.5%
US Forest Service	41,274	8.1%	100.0%	-	-	0	-	-	-	-
National Park Service	27,042	5.3%	100.0%	-	0.035%	0	-	-	-	-
Utah Trust Lands (SITLA)	25,035	4.9%	99.9%	0.091%	-	166	6.8%	87.5%	12.5%	0.0%
Bureau of Indian Affairs	1819	0.4%	100.0%	-	-	0	-	-	-	-
Private	19,152	3.8%	64.6%	34.3%	1.1%	1032	42.4%	11.1%	88.4%	0.5%

perennial, erect, rooted, herbaceous, hydrophytic vegetation that is present for most of the growing season (Cowardin and others, 1979).

This study employs surveys of targeted sites to characterize distinct wetland types and evaluate wetland condition assessment tools. Targeted sites included surveys of three of the most common vegetated wetland types: North American Arid West Emergent Marsh (Marsh), Rocky Mountain Alpine-Montane Wet Meadow (Wet Meadow), and Intermountain Basin Alkaline Closed Depression. Intermountain Basin Playa and Open Water wetlands were also present in the study area, but were not surveyed in favor of surveying vegetated wetland types that would better inform rapid assessment metric development. Targeted sampling is often used when a study question does not require a representative sample of the population but rather a focused sample of specific resources.

3.2 Field Methods

3.2.1 Site Screening and General AA Data Collection

Sites were screened in the office prior to visiting based on proximity to existing monitoring locations, wetland area, and ability to obtain landowner permission to survey. We selected 30 potential survey sites with the intention of surveying 18 sites to allow for some sites to be rejected in the field due to access issues or the absence of wetland resources in target areas. Our general field approach, including plot set-up, soil and water chemistry data collection, and vegetation community enumeration, was primarily adapted from CNHP-EIA and is explained in greater detail in *Ecological Integrity Assessment for Colorado Wetlands Field Manual, Version 1.0- Review Draft*, Appendix A (Lemly and Gilligan, 2013). We took four photos at every site, usually facing the center of the AA from points directly to the north, east, south and west at the edge of the AA, but occasionally at other well-spaced locations instead. We collected data on elevation, slope, aspect, wetland origin, representativeness of AA to larger wetland, percent of AA with non-target inclusions, and wildlife encountered. We also determined the Ecological System, Cowardin class, and hydrogeomorphic (HGM) class of each site and assigned a fidelity (high, medium, low) to the class assigned (see Appendix F for keys to each classification) (Cowardin and others, 1979, Smith and others, 1995, Comer and others, 2003). We identified the zone type, dominant species, and percent of AA occupied for major zones within each AA, generally following the guidelines of CNHP-EIA, which stipulate that each zone is a distinct physiognomic class or open water or bare ground that occupies at least 5% of the AA.

3.2.2 Soil and Water Chemistry Data

We used a sharpshooter shovel and an auger to collect soil samples at the center of the AA, whenever possible, or at another representative location in the AA if the center point was not conducive to sampling (e.g., due to deep water). Soil pits were not dug at sites that recently had soil piezometers installed unless no soil data were collected when the well was installed; at these sites water quality data was collected within the piezometer well. Soil pits were dug to a depth of at least 50 cm and often over 70 cm in an attempt to reach the depth of the water table. We described each distinct soil horizon using the guidance of the U.S. Natural Resources Conservation Service (2010) field indicators of hydric soils in the United States and the arid regional supplement (U.S. Army Corps of Engineers, 2008). For each layer, we recorded the depth, color of matrix, and secondary features including redoximorphic concentrations (based on a Munsell Soil Color Chart), soil texture, and concentration of coarse material and roots. We also identified the presence of hydric soil indicators within the entire soil sample.

We collected water chemistry data in soil pits whenever possible and occasionally at surface water locations, either as supplementary data or because soil pit groundwater data were not possible to collect. Settling time varied depending on total AA survey time but was generally between 60 and 150 minutes. If water was evident after the settling period, we recorded the depths to saturated soil and free water and then used a bailer to obtain a water sample from just below the surface level of water in the pit. We used low and high range HANNA waterproof combo testers to measure pH, electroconductivity (EC), and temperature of the water sample. We also obtained a value for total-dissolved-solids (TDS) based on the default meter conversion factor of 0.5 between EC and TDS. Occasionally we could not take EC/TDS measurements in one or both devices because the values were out of range for the meters. We tested meter accuracy in known EC and pH solutions and calibrated them as needed.

3.2.3 Vegetation Community and Ground Cover Data

We recorded a list of all plant species found within the AA after thoroughly searching the area for no more than one hour. For each species found, we recorded predominant height as one of six cover classes, aerial cover as one of ten cover classes, and phenology as vegetative, flowering, fruiting, or standing dead (from current year only). Plants not recorded to species in the field were collected for later identification in the office or at local herbaria.

We recorded ground cover data for each major zone within the AA as well as for the AA overall. Ground cover data collected include bare ground, litter, and water cover at different depths and with different types of vegetation cover. We also recorded litter depth, water depth, and the cover of bryophytes, lichens, algae, and various types of woody debris.

3.2.4 Rapid Assessment Metrics

We based our rapid condition assessment metrics on metrics collected by CNHP-EIA, USA-RAM, and UWAAM. We combined metrics from the three protocols into a single form organized by metric category rather than by protocol to facilitate efficient data collection in the field. We use the following categories throughout this report: Landscape Context, Hydrologic Condition, Physical Structure, Vegetation Structure, Species Composition, Habitat, and Size. We also modified metrics in order to (1) increase field efficiency by combining similar metrics from different protocols into a single metric, (2) address the fact that some metrics were designed to be evaluated across entire wetlands instead of fixed area plots, (3) establish a scale to use when evaluating metrics, and (4) better capture conditions of importance in our study region. In some cases metrics or metric options were split for ease of use in the field and then recombined for scoring purposes. Some USA-RAM metrics are formed through tabulation of stressors particular to specific features, such as stressors to the buffer or stressors to physical structure. We supplemented the USA-RAM list of stressors with additional stressors from the CNHP-EIA protocol and from stressors witnessed in the field in order to have a more complete list of stressors at sites, though we evaluated USA-RAM stressor metrics only using the USA-RAM specific stressors. For each stressor present, we recorded the extent of the evaluated area where the stressor was present as well as the degree of severity as one of three qualitative categories (low, moderate, high).

The best reference for each metric evaluated in this study is the source protocols developed for the original metric (Appendices A, B, and D). These protocols describe aspect of wetland condition captured by each metric as well as the field procedure for evaluation. Table 3 provides a crosswalk between metric name and category used in the source protocol and metric name and category that will be used in this report. It is important to note that none of the metrics evaluated in this report should be assumed to be identical to those in any of the source protocols because field personnel did not receive protocol-specific training and many metrics can be interpreted in multiple ways, though an effort was made to ascertain the original intention whenever possible. Specific details about protocol changes are described in Appendix E. Field forms used by the UGS can be found in Appendix F. The most significant changes in the protocols were:

- Assessment areas were fixed plots of 0.5 ha whenever possible, as stipulated by USA-RAM and CNHP-EIA, instead of whole wetland as used by UWAAM.
- Buffer width and condition were evaluated up to 200 m from AAs for all protocols, but scored using width thresholds specific to each protocol.
- UWAAM habitat data were evaluated within the AA and in buffer 200 m from sites in order to account for the fact that we used a fixed area and not whole wetland AA.
- EIA and UWAAM hydrologic connectivity was evaluated in buffer 200 m from sites instead of immediately adjacent to the site’s edge.
- For some metrics in the UWAAM protocol, playas and areas managed for wildlife habitat objectives automatically receive the highest possible score regardless of underlying condition. We instead scored all UWAAM metrics based on the actual condition regardless of wetland type..

Table 3. Rapid wetland condition assessment metrics collected by Utah Geological Survey and their protocol of origin. Utah Metric Name and Utah Category are names and categories that will be used throughout this report to refer to the metric. Original Metric Category and Original Metric Name are taken from Table 4 in Appendix A, Table 1 in Appendix B, and Table 1.1 in Appendix D. Metric Description briefly describes each metric as collected by the Utah Geological Survey.

Utah Metric Name	Source	Original Metric Category	Original Metric Name	Metric Description
Utah Category: Landscape Context				
Percent Buffer- EIA	CNHP-EIA	Landscape Context	Buffer Extent	percent of area on the edge of AA with buffer land cover
Percent Buffer- USA-RAM	USA-RAM	Buffer	Percent of AA Having Buffer	percent of area on the edge of AA with buffer land cover
Percent Buffer- UWAAM	UWAAM	Buffer	Percent Buffer	percent of area on the edge of AA with buffer land cover
Buffer Width- EIA	CNHP-EIA	Landscape Context	Buffer Width	mean width of buffer land cover surrounding AA, evaluated up to 200 m
Buffer Width- USA-RAM	USA-RAM	Buffer	Buffer Width	mean width of buffer land cover surrounding AA, evaluated up to 100 m
Buffer Width- UWAAM	UWAAM	Buffer	Buffer Width	mean width of buffer land cover surrounding AA, evaluated up to 200 m
Buffer Condition- Vegetation[1]	CNHP-EIA	Landscape Context	Buffer Condition- Vegetation	condition of vegetation in buffer, with particular focus on nativity of species
Buffer Condition- Soil[1]	CNHP-EIA	Landscape Context	Buffer Condition- Soil	condition of soil in buffer
Buffer Condition- UWAAM	UWAAM	Buffer	Intactness	condition of vegetation and soil in buffer
Landscape Fragmentation	CNHP-EIA	Landscape Context	Landscape Fragmentation	size of unfragmented landscape within which AA is embedded, evaluated in 500 m radius area around site
Stressor Checklist- Buffer	USA-RAM	Buffer	Stress to the Buffer Zone	checklist of stressors to the buffer zone
Utah Category: Hydrologic Condition				
Water Source- EIA	CNHP-EIA	Hydrologic Condition	Water Source	forms or places of direct inputs of water into AA
Water Source- Hydrologic Alterations[2]	UWAAM	Hydrology	Water Source	degree of hydrologic alterations affecting flow
Water Source- Water Quality[2]	UWAAM	Hydrology	Water Source	naturalness and potential for water quality degradation of incoming water
Hydrologic Connectivity- EIA[3]	CNHP-EIA	Hydrologic Condition	Hydrologic Connectivity	extent to which rising waters within AA have access to adjacent areas

Utah Metric Name	Source	Original Metric Category	Original Metric Name	Metric Description
Hydrologic Connectivity- UWAAM[3]	UWAAM	Hydrology	Downstream Connectivity	extent to which rising waters within AA have access to adjacent areas
Upstream Connectivity[4]	UWAAM	Hydrology	Upstream Connectivity	potential value of hydrologic connectivity given the landscape context
Hydroperiod- EIA[5]	CNHP-EIA	Hydrologic Condition	Alterations to Hydroperiod	degree of alteration to hydroperiod
Hydroperiod- UWAAM	UWAAM	Hydrology	Hydroperiod/Stability	naturalness of hydroperiod in respect to patterns of inundation and drawdown
Aquatic Connectivity	UWAAM	Hydrology	Landscape Connectivity	percent of area within 500 m of sites with aquatic features (e.g., other wetlands, stream channels)
Turbidity/ Pollutants	CNHP-EIA	Physiochemical Condition	Turbidity/ Pollutants	visual evidence of water quality degradation at site, for sites with water present
Algal Growth	CNHP-EIA	Physiochemical Condition	Algal Growth	extent of algal growth at site, for sites with water present
Stressor Checklist- Water Quality	USA-RAM	Hydrology	Stress to Water Quality	checklist of stressors affecting water quality
Stressor Checklist- Hydroperiod	USA-RAM	Hydrology	Alterations to Hydroperiod	checklist of stressors affecting hydroperiod
Utah Category: Physical Structure				
Topographic Complexity- USA-RAM	USA-RAM	Physical Structure	Topographic Complexity	presence of macro- and micro- relief structural features within AA (e.g., animal burrows, hummocks, soil cracks)
Topographic Complexity- UWAAM	UWAAM	Structural Integrity	Structural Patch Richness	presence of macro- and micro- relief structural features within AA (e.g., animal burrows, hummocks, soil cracks)
Substrate/ Soil Disturbance	CNHP-EIA	Physiochemical Condition	Substrate/ Soil Disturbance	degree of alteration of soil within AA
Physical Alteration	UWAAM	Structural Integrity	Physical Alteration	degree of alteration to physical intactness of AA
Stressor Checklist- Substrate Alterations	USA-RAM	Physical Structure	Habitat/ Substrate Alterations	checklist of alterations to substrate in AA
Utah Category: Vegetation Structure				
Horizontal Interspersion- EIA[6]	CNHP-EIA	Vegetation Condition	Horizontal Interspersion/ Complexity	complexity of abiotic and biotic patches within AA
Horizontal Interspersion- USA-RAM[6]	USA-RAM	Physical Structure	Patch Mosaic Complexity	complexity of abiotic and biotic patches within AA
Horizontal Interspersion- UWAAM[6]	UWAAM	Structural Integrity	Horizontal Interspersion	complexity of abiotic and biotic patches within AA
Vertical Biotic Structure- USA-RAM	USA-RAM	Biological Structure	Vertical Complexity	number of plant strata (defined by functional class and height breaks) covering at least 10% of AA

Utah Metric Name	Source	Original Metric Category	Original Metric Name	Metric Description
Vertical Biotic Structure-UWAAM	UWAAM	Structural Integrity	Vertical Biotic Structure	number and extent of overlapping plant layers
Litter Accumulation	CNHP-EIA	Vegetation Condition	Litter Accumulation	naturalness of litter accumulation (compared to excessive or little litter)
Woody Debris[7]	CNHP-EIA	Vegetation Condition	Coarse and Fine Woody Debris	degree of woody debris input at site, if woody species are not unnaturally uncommon or absent
Woody Species[7] Regeneration	CNHP-EIA	Vegetation Condition	Regeneration of Native Woody Species	age class structure of woody species at site, if not unnaturally uncommon or absent
Stressor Checklist- Vegetation	USA-RAM	Biological Structure	Vegetation Disturbance	checklist of stressors to vegetation
Utah Category: Plant Species Composition				
Plant Community Complexity-USA-RAM	USA-RAM	Biological Structure	Plant Community Complexity	number of species with at ≥10% relative cover within strata (for species in strata with ≥10% cover)
Plant Community Complexity-UWAAM	UWAAM	Plant Community	Plant Layers/ Species Richness	number of plant strata present (submerged/floating and height classes) and species richness
Relative Cover Native Species	CNHP-EIA	Vegetation Condition	Relative Cover of Native Plant Species	relative percent cover of native species in AA
Absolute Cover Aggressive Species	CNHP-EIA	Vegetation Condition	Absolute Cover Aggressive Native Species	absolute cover of aggressive native species as defined by CNHP-EIA
Absolute Cover Noxious Weeds	CNHP-EIA	Vegetation Condition	Absolute Cover Noxious Weeds	absolute cover of species listed as noxious in the state of Utah
Absolute Cover Invasive Species	USA-RAM	Biological Structure	Percent Cover of Invasive Species	cover of species listed as invasive in USA-RAM protocol
Relative Cover Invasive/ Introduced Species	UWAAM	Plant Community	Vegetative Condition	representation of native, introduced, and invasive species within AA
Mean C	CNHP-EIA	Vegetation Condition	Mean C	mean coefficient of conservatism value for all species encountered at a site
Utah Category: Habitat				
Water Presence	UWAAM	Habitat	Water Presence	percent of AA with aquatic habitat features in place and functioning
Ecological Services	UWAAM	Habitat	Ecological Services	number of ecological services (primarily defined as habitat features) provided within AA
Threats	UWAAM	Habitat	Threats	presence of threats to wildlife (e.g., American bullfrog, common carp, Chytrid fungus)
Utah Category: Size[8]				

Utah Metric Name	Source	Original Metric Category	Original Metric Name	Metric Description
Relative Size	CNHP-EIA	Size	Relative Size	percent reduction in natural wetland size due to human modification
Absolute Size	CNHP-EIA	Size	Absolute Size	absolute size of wetland within a single Ecological System

[1] CNHP-EIA aggregates separate evaluations of soil and vegetation conditions into a single buffer condition metric.
[2] UWAAM has a single metric that considers both aspects of water source; Utah created two separate metrics and took the mean between them for the final scoring.
[3] EIA and UWAAM connectivity were recorded in the field and score identically and will be reported only once as Hydrologic Connectivity.
[4] Utah excluded this metric from evaluation because it is based on a checklist of ecological services rather than wetland condition.
[5] Utah split metric into metric for heavily managed sites and metric for more natural sites, but scores were recombined for final scoring.
[6] Interspersion was recorded and scored identically for all three protocols and will be reported only once as Interspersion.
[7] Study sites naturally lacked woody inputs and all were scored as Not Applicable for both metrics.
[8] Data not used by CNHP-EIA for site scoring and not included in this repor

- The species list obtained from the vegetation community data was used to calculate most of the species composition data and some of the vegetation structure data. In some cases, limitations of percent cover and plant height classes prohibited us from calculating anything more than approximate versions of the original metrics

3.3 Landscape Profile

We compiled available land use and stressor layers that we considered relevant to wetland and groundwater resources in the study area (see Appendix I for description of data sources). We assessed an area within the Snake-Hamlin Valley hydrologic unit code (HUC) 8, which is divided into 15 HUC 10 units and 85 HUC 12 units. Each smaller unit represents a smaller hydrologic catchment, with HUC 12 representing 'watershed' units or the smallest unit available in the United States Geological Survey coding system. To assess landscape-scale disturbance, we selected those HUC 10 level watersheds contiguous with wetlands in the study area. Those watersheds removed for the analysis do not directly contribute to wetland hydrologic resources. Because the initial phase of this project indicated that there may be important differences in stress and wetland condition between the northern and southern reaches of the study area, the landscape profile components were analyzed separately between the two areas to evaluate how stressors may account for differences observed in wetland condition.

3.4 Data Analysis

3.4.1 Rapid Condition Assessment Scoring

We scored metrics and overall site condition using scoring procedures outlined by each protocol. However, we report metric category scores based on categories used in this report rather than the categories used in the original protocols. For CNHP-EIA, each individual metric is assigned a score between 1 and 5. Metric scores are then combined into category-specific scores using metric weighting. To calculate overall CNHP-EIA site scores, we used metric weights from Table 6 of CNHP's *Ecological Integrity Assessment for Colorado Wetlands Field Manual, Version 1.0- Review Draft*, Appendix A (Lemly and Gilligan, 2013) and the following category weights (L. Gilligan, CNHP, written communication, 2013): 0.2 for landscape context, 0.3 for hydrologic condition, 0.1 for physiochemical condition, and 0.4 for vegetation condition. Cut-offs between A and B, B and C, and C and D sites were, respectively, 4.5, 3.5, and 2.5.

Individual UWAAM metrics are assigned a minimum score of 1 and a maximum score between 5 and 7, depending on the specific metric. Final site scores are based on the summation of all scores minus 2 points for each threat to wildlife detected at a site. Because we did not evaluate one of the UWAAM metrics, upstream connectivity, we subtracted that metric's maximum value (6) from the overall site evaluation cut-offs so that final cut-offs between A and B, B and C, and C and D sites were, respectively, 84, 59, and 29.

The final procedure for USA-RAM scoring is currently in the process of development through analysis of data from the *National Wetland Condition Assessment* (G. Serenbertz, EPA, written communication, 2013). We used provisional scoring developed by the EPA and documented in 2012 datasheets used by the state of Wyoming to score each USA-RAM metric (Appendix C). Individual metrics were assigned a score between 3 and 12. USA-RAM also does not have thresholds developed to evaluate overall site scores. We set preliminary thresholds that, in order for a site to receive a particular grade, required the site to have an overall score equivalent to receiving that grade on at least seven metrics and the grade one below that grade on the remaining five metrics. In other words, in order to receive an overall A, a site must have the number of points equivalent to seven A scores (7 x 12) and five B scores (5 x 9), or 129 points. Similarly, we used a cut-off of 93 between B and C and 57 between C and D. Development of USA-RAM scoring for Utah data will be further explored in an upcoming report on the development of URAP.

3.4.2 Rapid Assessment and Stressor Results

We summarize rapid assessment scores for each metric and lists of stressors at sites by presenting the number of sites with each score and with each stressor. We acknowledge, however, that rapid assessment metrics have not yet been verified and calibrated for the study area. Verification is a general assessment of whether metrics are measuring wetland condition as intended, and calibration is the determination of the scientific validity of metrics through correlation with more intensive measures of condition (Sutula and others, 2006). Aspects of verification that must be conducted on a regional basis include determining whether metrics and statements within metrics comprehensively capture all wetland states found in the region, determining if metrics are sensitive to the disturbance gradient particular to the region, and adjusting the scaling of individual metrics based on data obtained in regional high and low quality wetlands. Calibration further refines metrics through the use of independent and more intensive wetland condition data (e.g., plant or invertebrate index of biotic integrity). Due to lack of regional metric verification and calibration, it is important to note that site scores presented in this report do not necessarily indicate true site condition, though they can provide a general understanding of the conditions and stressors to condition present in the study area. We will also use the data to indicate which metrics may not be appropriately developed for our study region, which will inform the associated project of developing a final rapid assessment method for use in Utah.

Sampling targeted sites without a random sample design prevents us from extrapolating our findings to the entire study area and from conducting statistical tests of differences between, for example, wetlands in the northern versus southern reaches. We do present information on interesting trends observed in our results in a qualitative manner in order to provide the basis for hypotheses in future research.

3.4.3 Characterization of Wetland Vegetation

Plant species that were not able to be identified in the field were pressed in newspaper, brought to the office, and dried in a drying oven set to approximately 38°C for at least 24 hours. We used a dissecting microscope, standard set of plant dissection tools, and several plant treatments to aid with identification, including *A Utah Flora* (Welsh and others, 2003), all volumes of the *Intermountain Flora* series (see introductory volume, Cronquist and others, 1972), *Field Guide to Intermountain Sedges* (Hurd and others, 1998), and *Flora of North America* (http://floranorthamerica.org). Specimens that were particularly difficult to identify were taken to Utah State University's Intermountain Herbarium for comparison with known specimens and for consultation with herbarium staff. We used species scientific names as listed in U.S. Natural Resources Conservation Service's *Plants Database* (http://plants.usda.gov). Species identification problems are detailed in Appendix G.

Plant community composition data from this study are a first step towards better understanding the distribution of wetland plant species and their relationship to different wetland and landscape conditions. We provide summary information on the distribution and abundance within our study area of common plant species and species of management concern. We also present summary values from a Floristic Quality Assessment (FQA) similar to that developed by CNHP (Lemly and Gilligan, 2013). An important aspect of the FQA method is the use of "coefficients of conservatism" (C-values). Species are each assigned a C-value between 0 and 10, with low values indicating high tolerance and high values indicating low tolerance to disturbance. The value of 0 is assigned to all non-native species. C-values from all species present at a site can then be summarized in a variety of ways to estimate site integrity. We present FQA values including species richness, mean C value across species, Floristic Quality Index (FQI) and adjusted FQI. FQI incorporates information about both degree of conservatism and species richness into a single measure so that, all else being equal, sites with more species receive a higher rating. Adjusted FQI calculates a measure of site conservatism that only slightly weights species richness and adjusts values based on nativity of species present. Values for all species and native-species-only as well as cover-weighted values were calculated for many of these attributes. See Rocchio (2007)and Rocchio and Crawford (2013) for a more in-depth discussion of FQA metrics and their specific formulae.

Ideally, C-values are developed for individual states or regions to capture the regional variability in how species respond to disturbance. However, the development of state-specific C-values requires substantial time and effort from a panel of experts and is ideally supported by qualitative field data that span the whole area of interest across a broad range of conditions. There are no C-values currently developed for the state of Utah. We instead contacted botanists and wetland scientists in surrounding states to determine which states had assigned C-values to species. We received C-value lists from Colorado (Rocchio, 2007), Montana (Jones, 2005), and Idaho [C-values used by the state of Idaho are from values developed for eastern Washington's Columbia Basin region (Rocchio and Crawford, 2013)]. We assigned Utah species the mean C-value of the three states' lists. We then made sure that every non-native species, and no native species, had a C-value of 0. Ten species with a total of 21 occurrences were not assigned C-values. Most of these occurrences were of species with 2% or less cover, though one occurrence each of *Nitrophila occidentalis* (borarxweed) and *Solidago spectabilis* (Nevada goldenrod) occupied approximately 7.5% cover and an occurrence of *Phragmites australis* ssp. *americanus* occupied approximately 37.5% cover.

We used non-metric multidimensional scaling (NMDS) with the "vegan" package (Oksanen and others, 2013) in R 3.0.0 (R Core Development Team, 2013) to explore plant community composition data. NMDS can be used to reduce complex multivariate data, such as plant abundance values, to a few primary axes that describe most of the variation found among sites. Axes can then be overlain with vectors showing the strength (represented by vector length) and direction (represented by vector orientation) of correlation between environmental variables of interest and species composition data. We used the wrapper function metaMDS within vegan to transform and standardize data, calculate a dissimilarity matrix using Bray-Curtis distance, run NMDS multiple times with random starts to avoid local optima, and rotate the axes of the final configuration so that the variance of points was maximized on the first dimension. Plant abundance data were transformed using a Wisconsin-style double standardization where taxa are normalized to percent abundance and then abundances are normalized to the maximum for each species. Species that occurred at only one site and species only identified to genus were dropped from analysis. We determined the appropriate number of axes to use by obtaining stress values for ten replicate NMDS runs for each number of dimensions between one and ten. We set the maximum number of random starts for each run at 500. We selected as the final number of dimensions the lowest number of axes that had a stress value ≤0.20, based on rules of thumb for the threshold of usable results (McCune and Grace, 2002).

We fit site attribute data to the species NMDS axes using the envfit function in the vegan package. We looked at the mean site elevation for each site (which is strongly correlated with temperature and precipitation gradients) and the total area of the assessment area surveyed. We also looked at whether sites were located in the northern or southern areas of Snake Valley and whether they were on land publically or privately owned. We also looked at several variables obtained from site visits, including total CNHP-EIA, USA-RAM, and UWAAM site scores, CNHP-EIA individual category scores, and site stressor scores. Site stressor scores were calculated as the summation of the extent category (1 to 5) of each stressor times the severity category (except that stressors in category 3 were multiplied by 4 instead of 3). We looked at hydrologic stressors, buffer stressors, within-site physical, vegetation, and water quality stressors, and all stressors combined together. We tested the strength of evidence for each site attribute variable and each species using 10000 permutations in envfit.

3.4.4 Relationships between Condition, Stressors, and Vegetation

A wetland condition score ideally is calibrated to reflect the degree to which important components of a wetland have been affected by stressors and unnatural processes. Accordingly, we can evaluate the relationship between wetland condition scores and information on nearby stressors in order to gauge the degree to which scores are capturing that stressor information. Wetland condition can also be affected by historic stressors that are no longer evident on the landscape and by stressors that are not readily apparent to observers. Plant community composition data can potentially provide insight into otherwise invisible processes that have affected wetlands because plant composition can be indicative of both past and on-going disturbances such as hydrological alterations, sedimentation, vegetation removal, nutrient enrichment, and physical disturbance (Rocchio and Crawford, 2013).

We analyzed the relationships between stressors and wetland condition, stressors and plant FQA metrics, and FQA metrics and wetland condition by examining Pearson correlations between variables (Stein and others, 2009). Our assumption is that stressors affect both wetland condition and wetland vegetation and that true wetland condition affects wetland vegetation, though measures of plant community composition may better capture true wetland condition if wetland condition scores are not calibrated. Correlation analysis cannot provide information about cause and effect, but can provide insight into the degree to which stressors, plant community composition, and wetland condition are interrelated. Analysis is somewhat circular, since, for example, USA-RAM wetland condition scores are heavily influenced by values on stressor checklists and plant community composition data is a component of wetland condition scores for all three protocols. Nonetheless, this preliminary analysis provides a quick check of the degree to which wetland condition scores reflect other measures of potential wetland condition and a starting point for further protocol development and calibration. Stressor scores in each subcategory [buffer, hydrologic, site-specific (site physical, vegetation, and water quality stressors), and total stressors] were calculated as the summation of the extent category (1 to 5) of each stressor times the severity category (except that stressors in category 3 were multiplied by 4 instead of 3). We looked at overall wetland condition scores from all three protocols and individual category scores for CNHP-EIA. We did not look at USA-RAM and UWAAM category scores for the sake of simplicity and because scoring within categories is not emphasized in these protocols.

4.0 Results

4.1 Sites Surveyed

4.1.1 Sites Selected for Survey

We surveyed a total of 18 sites in the Snake Valley basin between July 16 and July 22, 2013. Surveyed sites included 13 40-m-radius circular plots, 4 freeform plots, and 1 rectangular plot. All of the circular plots had an area of 5027 m², the freeform plots ranged in area from 1021 to 4996 m², and the rectangular plot had an area of 5402 m². We surveyed 8 sites in the northern reach of the study area and 10 sites in the southern reach. Sampled sites were located on both private land (n=11) and public lands managed by the BLM or the Trust Lands Administration (n=7). There were 4 sites surveyed in Nevada, two on private land and two on public land managed by the BLM Ely Ranger District.

4.1.2 Classification

Despite consistency of landscape context and water source within Snake Valley wetlands, surveyed sites varied in regards to their classification within any of the three systems used: Cowardin, Hydrogeomorphic (HGM), and Ecological Systems. All sites were classified as palustrine emergent in the Cowardin Classification System, with the majority of sites described as having a saturated water regime (n=11) and all others being temporarily (n=2), seasonally (n=1), or semi-permanently (n=4) flooded. Though water regime is difficult to determine in a single visit, these determinations provide a general description about water table depth and variability based on that site visit. The HGM system classifies wetlands based on geomorphic position and characteristics of hydrology that support the wetland. Though in the larger landscape context, the valley bottom is geomorphically depressional, local-scale context and groundwater source designated the majority of sites as slope wetlands (n=15) with the exception of three sites that were classified as novel (irrigation-fed). These sites appeared to be sustained by groundwater outflows that had been ditched or channelized, and the sites would likely not be wetland if that source was removed or altered. We had high confidence in the majority of determinations in both the Cowardin and HGM classification systems, but the Ecological System classification was more difficult. Sites were classified as either the Rocky Mountain Alpine-Montane Wet Meadow(n=12) or North American Arid West Emergent Marsh (n=6) Ecological Systems. All sites classified as Emergent Marsh had high fidelity to characteristics of that class, whereas sites classified as Wet Meadow were given low (n-3), medium (n=3), and high (n=6) fidelity. Those sites with low fidelity were the sites classified as novel (irrigation-fed) in the HGM classification system and therefore have unnatural water sources. Wet Meadow sites typically had high fidelity to the class based on vegetation and soil characteristics, though the landscape context of Snake Valley may be better described as an inter-mountain basin. One alternative Ecological System, Inter-Mountain Basins Alkaline Closed Depression, may be more appropriate for the landscape context, but this class is typified by depressional geomorphology, poorly developed alkaline soils, and salt-tolerant species. Additional data on wetlands across the state will provide a chance to assess the appropriateness of each of the classification systems and available classes in Utah wetlands.

4.1.3 General Attributes of Surveyed Sites

All soil profiles exhibited hydric soil indicators (U.S. Army Corps of Engineers, 2008) except for two). The two sites that did not show evidence of hydric soils were in areas where there are intense hydrological modifications including spring diversion and major channelization of surface water flows. The remaining sites had between one and three indicators. Sites in the north had a median of two indicators and sites in the south had a median of one indicator. Hydrogen sulfide (A4) was the most common indicator, found at six sites in each the north and south. All of the northern sites had at least one indicator related to accumulated organic matter, including Histosols (A), Histic Epipedon (A2), Black Histic (A3), and Loamy Mucky Mineral (F1), whereas only three sites in the south exhibited these indicators. Only southern sites had Thick Dark Surface (A12) and Depleted Matrix (F3). Water levels were recorded at or above the surface of soil pits or peizometers at five sites (two north, three south) and within 30 cm of the surface at four sites (two north, two south). Of the remaining sites, five soil pits were saturated two the surface, three were saturated within 17 cm of the surface, and one appeared dry.

4.2 Rapid Assessment Results

As stated in the methods, it is important to note that the following discussion of site rapid condition scores is based on metrics that are not fully developed and calibrated for the study area. Site scores are assumed to be indicative of site condition because they are based on other well-tested methods, but some metrics may require further refinement in order to accurately capture wetland condition for the study area and other wetlands in the state of Utah.

4.2.1 Landscape Context

Every site received an A for the percent of the site surrounded by land considered to act as a buffer to wetland resources, and no sites received a score lower than A- for buffer width (Table 4). Half of the sites received A- for buffer width for the CNHP-EIA metric because that protocol does not consider unpaved roadways to be buffer, whereas UWAAM does and USA-RAM allows narrow areas of non-buffer to interrupt the buffer land cover. Sites were generally surrounded by wetland or rangeland, which are both considered a buffer by all three protocols. There was more variability in scoring for buffer condition metrics. Though only one site scored lower than A for vegetation condition in the buffer, the majority of sites scored B or lower for the two metrics that considered soil disturbance as a component of buffer condition. The Landscape Fragmentation metric that is evaluated in a 500 m buffer around each AA showed moderate variability, with 2/3rd of surveyed sites scoring a B or C. All sites received C or D for the Stressor Checklist metric due to the spatial extent of stressors such as rangeland, ditching, and extensive soil disturbance from grazing that were ubiquitous, though not consistently severe across the study area.

Table 4. Number of sites by score (converted to a letter grade) for each rapid condition assessment metric in the Landscape Context category for 18 sites in Snake Valley.

Protocol	Metric Name	A	A-	B	C	D
CNHP-EIA	Percent Buffer- EIA	18	*NA*	0	0	0
USA-RAM	Percent Buffer- USA-RAM	18	*NA*	0	0	0
UWAAM	Percent Buffer- UWAAM	18	*NA*	0	0	0
CNHP-EIA	Buffer Width- EIA	9	9	0	0	0
USA-RAM	Buffer Width- USA-RAM	18	*NA*	0	0	0
UWAAM	Buffer Width- UWAAM	18	*NA*	0	0	0
CNHP-EIA	Buffer Condition- Soil	4	*NA*	8	6	0
CNHP-EIA	Buffer Condition- Vegetation	17	*NA*	0	1	0
UWAAM	Buffer Condition- UWAAM	4	*NA*	13	1	0
CNHP-EIA	Landscape Fragmentation	6	*NA*	8	4	0
USA-RAM	Stressor Checklist- Buffer	0	0	0	4	14

4.2.2 Hydrologic Condition

The majority of sites scored A or B for all hydrologic metrics, though only for the Algal Growth and Turbidity/Pollutants metrics did all sites score B or higher (Table 5). No more than three sites scored C or lower for any of the other hydrologic-specific metrics. Sites that received a C- and D for hydroperiod metrics were those sites that were either supported by or completely created by irrigation. The two sites that scored D for hydroperiod stressors had high severity ditching/channelization, diverted water, or undercut/slumping banks in the buffer. Small springs surrounded by upland or sites at the edge of larger wetland complexes received low scores for Aquatic Connectivity, which evaluates the proximity of an AA to other aquatic features within 500 meters of the site.

4.2.3 Physical Structure, Vegetation Structure, and Habitat

Sites scored poorly for several of the metrics related to physical and vegetation structure, including topographic complexity and vertical biotic structure (Table 6). Low scores were driven in part by (1) UWAAM scoring applied to fixed-area AAs rather than whole wetland as intended, and (2) lack of appropriate calibration of metrics to the study area. Scores related to soil disturbances and physical alteration, which takes into account recovery from past or ongoing disturbances, varied across all sites. Horizontal interspersion was also variable suggesting that a range of habitat and vegetation zones were captured within the limited number of wetland classes sampled. The two vertical biotic structure metrics varied because the USA-RAM metric considers the number of layers, while the UWAAM metric considers the overlap of vertical vegetation strata. Potential threats to wildlife observed included crayfish (n=1), American bullfrog (*Lithobates catesbeianus* , n=1), largemouth bass (*Micropterus salmoides*, n=1), and mammalian predators (n=2). Actual threats present were probably more common but not observed during field surveys.

Table 5. Number of sites by score (converted to a letter grade) for each rapid condition assessment metric in the Hydrologic Condition category for 18 sites in Snake Valley.

Protocol	Metric Name	A	B	C	C-	D
CNHP-EIA	Water Source - EIA	12	3	2	1	0
CNHP-EIA/UWAAM	Hydrologic Connectivity	15	2	1	*NA*	0
CNHP-EIA	Hydroperiod - EIA	10	4	1	3	0
UWAAM	Hydroperiod - UWAAM	14	1	0	*NA*	3
UWAAM	Aquatic Connectivity	13	1	2	*NA*	2
EIA	Algal Growth[1]	7	6	0	*NA*	0
EIA	Turbidity/Pollutants[1]	11	2	0	*NA*	0
USA-RAM	Stressor Checklist - Hydroperiod	14	2	0	*NA*	2
USA-RAM	Stressor Checklist - Water Quality	13	4	1	*NA*	0

[1]Only scored at sites with surface water present

4.2.4 Plant Species Composition

All sites scored A or B for the majority of metrics related to cover of invasive, noxious, or aggressive species (Table 7). Three sites scored C for relative cover of native species because the relative native cover was less than 95%, though native plant cover was still very high at these sites (between 93% and 94.5%). Mean C scores were well distributed, though the majority of sites scored a C or lower and no scores received an A. Sites scored poorly for Plant Community Complexity because most surveyed areas typically encompassed one wetland class with minimal variability in vegetation or habitat composition throughout.

4.2.5 Overall Scores

For overall site scores, no sites received the lowest possible score of D, with the majority of sites scoring B for all three protocols (Table 8, Figure 5). Boxplots of overall scores show that USA-RAM had the smallest range of scores of the three protocols (Figure 5). The only sites to score an A in any of the protocols were two sites on public land in the northern reach near Twin Springs. Sites in the northern reach of the study area generally scored higher in all protocols, with all northern sites receiving a B for both the UWAAM and USA-RAM protocols, and A or B for the CNHP-EIA protocol (Table 8, Figure 6). Pearson correlations were significant (≤0.05) among overall site scores for all three protocols, with CNHP-EIA and USA-RAM the most related (correlation coefficient 0.77), followed by CNHP-EIA and UWAAM (0.75) and then USA-RAM and UWAAM (0.57). Overall scores for sites in the northern reach were generally higher for all protocols, while differences in overall scores for sites on public versus private land were less pronounced (Figure 6, 7).

Table 6. Number of sites by score (converted to a letter grade) for each rapid condition assessment metric in the Physical Structure, Vegetation Structure, and Habitat categories for 18 sites in Snake Valley.

Protocol	Metric Name	A	B	C	D
Physical Structure					
USA-RAM	Topographic Complexity	0	2	9	7
UWAAM	Topographic Complexity	0	0	3	15
CNHP-EIA	Substrate/Soil Disturbance	4	8	4	2
UWAAM	Physical Alteration	6	6	2	4
USA-RAM	Stressor Checklist - Substrate Alterations	5	11	2	0
Vegetation Structure					
all three	Horizontal Interspersion	2	5	8	3
USA-RAM	Biotic Structure	0	0	4	14
UWAAM	Biotic Structure	2	7	0	9
CNHP-EIA	Litter Accumulation	12	0	5	1
USA-RAM	Stressor Checklist - Vegetation	9	7	2	0
Habitat					
UWAAM	Presence of Water	3	5	5	5
UWAAM	Ecological Services	13	5	0	0
UWAAM	Threats to Wildlife	13	4	1	0

Table 7. Number of sites by score (converted to a letter grade) for each rapid condition assessment metric in the Plant Species Composition category for 18 sites in Snake Valley.

Protocol	Metric Name	A	B	C	C-	D
USA-RAM	Plant Community Complexity	0	0	7	*NA*	11
UWAAM	Plant Community Complexity[1]	0	*NA*	18	*NA*	*NA*
CNHP-EIA	Relative Cover Native Species	8	7	3	0	0
CNHP-EIA	Absolute Cover Aggressive Species	18	0	0	*NA*	0
CNHP-EIA	Absolute Cover Noxious Weeds	12	6	0	*NA*	0
USA-RAM	Absolute Cover Invasive Species	18	0	0	*NA*	0
UWAAM	Relative Cover Invasive/ Introduced Species	16	2	0	*NA*	0
CNHP-EIA	Mean C	0	2	10	4	2

[1]Sites are given one of only two possible scores for this metric.

Table 8. Proportion of sites in north (n=8) versus south (n=10) and public (n=7) versus private (n=11) ownership receiving each overall site score (converted to a letter grade) for CNHP-EIA, USA-RAM, and UWAAM rapid condition assessment protocols.

Protocol	Location/ Management	A	B	C	D
	Public	0	0.86	0.14	0
	Private	0	0.82	0.18	0
UWAAM	North	0	1	0	0
	South	0	0.7	0.3	0
	Overall	0	0.83	0.17	0
	Public	0.29	0.71	0	0
	Private	0	0.64	0.36	0
EIA	North	0.25	0.75	0	0
	South	0	0.6	0.4	0
	Overall	0.11	0.67	0.22	0
	Public	0	1	0	0
	Private	0	0.82	0.18	0
USA-RAM	North	0	1	0	0
	South	0	0.8	0.2	0
	Overall	0	0.89	0.11	0

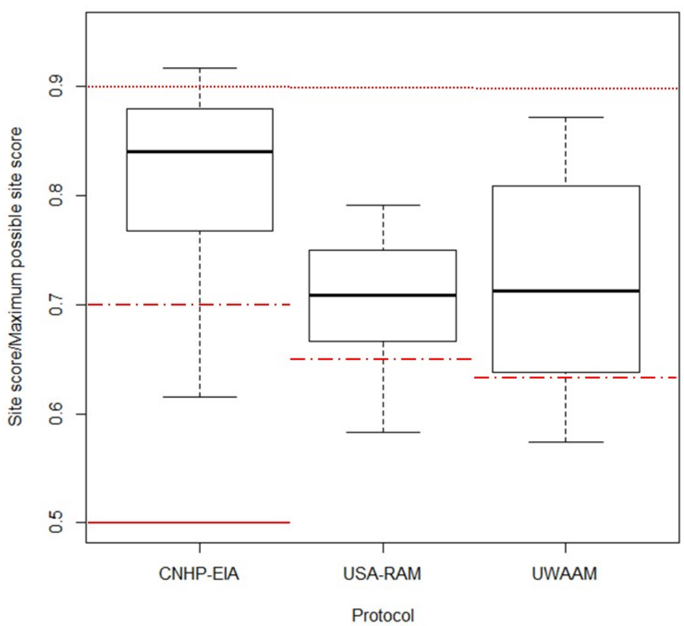

Figure 5. Overall site wetland condition scores, shown as site score divided by maximum possible site score, by rapid assessment protocol. Values used as thresholds between A and B, B and C, and C and D scores for each protocol are shown by the dotted, dashed, and solid red lines, respectively. The C and D cut-off for USA-RAM (0.40) and UWAAM (0.31) are below the scale of the y-axis and therefore not shown.

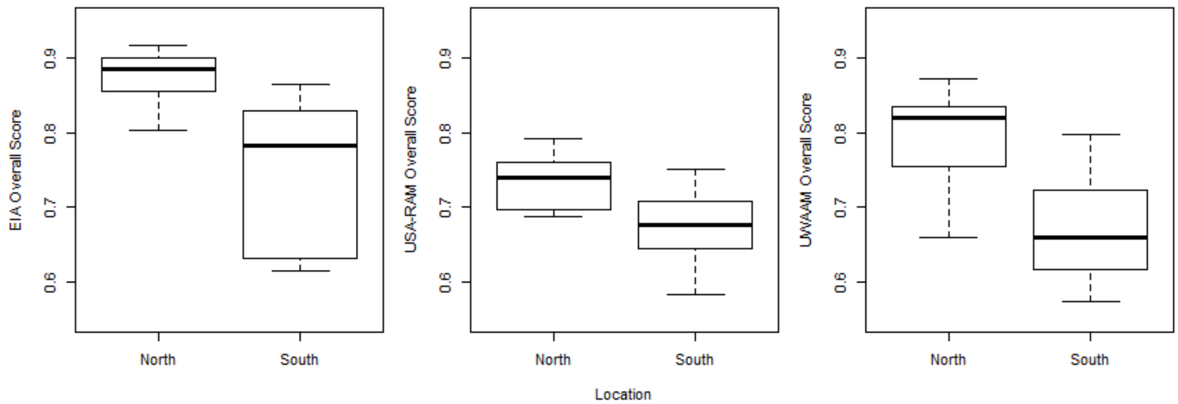

Figure 6. Boxplots of overall site scores calculated from the three protocols by location, North (n=8) versus South (n=10).

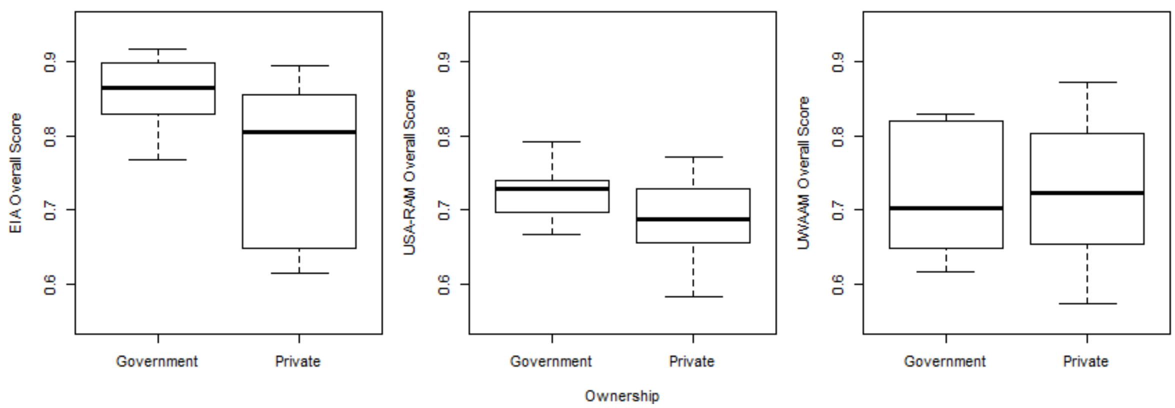

Figure 7. Boxplots of overall site scores calculated from the three protocols by ownership, Government (n=7) versus Private (n=11).

4.3 Stressors on the Landscape

4.3.1 Stressors Recorded in the Field

Between 3 and 13 stressors were recorded at each site for the 200 meter buffer; the mean number of stressors was 7.3 (Table 9). Agriculture and grazing stressors were the most common with the presence of pasture/rangeland and soil disturbance from grazing being recorded at all surveyed sites and excessive grazing reflected in vegetation cover found in 13 sites. Other substrate disturbance from human use, e.g. off-road vehicle use and trash was found in over half the sites (n=11). Cover of non-native or invasive species was also a common stressor in the 200 m buffer (n=10), but was observed in only low to moderate severity. The most common hydrologic stressor observed in the buffer, ditching, was recorded at eight southern and three northern sites. Three sites in the northern reach of the study area were located close to BLM-administered vegetation removal projects for *Elaeagnus angustifolia* (Russian olive) that had formed dense thickets around springs and outflow areas. Removal disturbances included cutting, burning, and chemical application to stems.

Table 9. Stressors present in the 200 meter buffer around wetland assessment sites, with the degree of severity and extent of area covered by the stressor.

Stressor	Extent	≤10			>10 - 50			>50 - 100			Total
	Severity	Low	Mod.	High	Low	Mod.	High	Low	Mod.	High	
Hydrologic Stressor											
Dikes, dams, levees, railroad or road beds		1	0	2	0	0	0	0	0	0	**3**
Direct input from impervious surface		0	1	0	0	0	0	0	0	0	**1**
Ditches, drains, channelization		2	5	2	0	0	0	0	0	0	**9**
Excavation, dredging		0	1	1	0	0	0	0	0	0	**2**
Formation of filamentous algae		4	3	0	0	0	0	0	0	0	**7**
Inlets and outlets		0	2	1	0	0	0	0	0	0	**3**
Development and Human Use											
Road – 1 or 2 lane paved		0	1	1	0	0	0	0	0	0	**2**
Road – gravel		6	0	0	0	0	0	0	0	0	**6**
Substrate disturbance (off-road vehicles)		9	2	0	0	0	0	0	0	0	**11**
Trash/ dumping		11	0	0	0	0	0	0	0	0	**11**
Agriculture and Grazing											
Pasture / rangeland		0	0	0	1	1	0	8	6	2	**18**
Heavily grazed grasses, excessive grazing		1	1	0	0	2	2	1	5	1	**13**
Trampling, soil disturbance from grazing		1	1	0	2	0	1	4	8	1	**18**
Irrigation (irrigated land)		1	0	0	0	0	0	0	0	3	**4**
Fallow field		1	0	0	0	0	0	0	0	0	**1**
Other Stressors											
Chemical vegetation control		0	1	0	0	0	0	0	0	0	**1**
Cover of non-native or invasive species		4	0	0	1	0	0	3	2	0	**10**
Recently burned grassland		0	0	1	0	0	0	0	0	0	**1**
Removal of large woody debris		2	1	0	0	0	0	0	0	0	**3**
Rural residential		2	0	0	0	0	0	0	0	0	**2**
Sediment input		0	0	1	0	0	0	0	0	0	**1**
Shrub cutting (brush hogging)		1	0	2	0	0	0	0	0	0	**3**
Shrub layer browsed		0	1	0	0	0	0	0	0	0	**1**
	Total	**46**	**20**	**11**	**4**	**3**	**3**	**16**	**21**	**7**	**131**

Stressors were also considered in a 500 m envelope around each AA. Light to moderate recreation or human visitation was observed in the 500 m envelope around all sites, though this use was recorded to be in less than 50% of the buffer in all sites. Light to heavy grazing was also observed in all 500 m envelopes, and three sites exhibited heavy grazing in more than 50% of the buffer area. Unpaved roads were noted in all envelopes except in two sites, both publicly managed lands in the northern portion of the study area.

We recorded stressors present directly in the AA in four categories: hydroperiod, water quality, vegetation, and physical structure (Table 10). All sites had three or more stressors at the AA scale except for one site that had only one stressor. The most common stressors were ditching and undercut banks or slumping in channels in the wetland. Hydroperiod stressors were generally uncommon at the AA scale in all sites, though four stressors rated high severity were found at the same two sites that did not exhibit hydric soil indicators. The most common physical and vegetation stressors detected were related to grazing which was seen to impact both vegetation and soils. Grazing disturbances were observed in moderate to high severity in a total of 10 assessment areas (n=3 north, n=7 south). The most common indications of water quality stress included debris/silt lines on vegetation, algal or *Lemna* spp. surface mats, and concentrations of dissolved salts of which none were found to occur in high severity.

Table 10. Stressors present within AA and their associated severity (low, medium, and high). Number following each stressor category indicates the number of sites with at least one stressor recorded in that category.

Stressor/Stressor Severity	**Low**	**Mod.**	High	**Total**
Hydroperiod (n=6)				
Channels have deeply undercut banks and/or bank slumps or slides	3	0	1	**4**
Ditches/channelization	1	0	2	**3**
Spring box diverting water from wetland	0	0	1	**1**
Upland plant species encroaching into AA (due to drying of wetland)	1	1	0	**2**
Physical (n=16)				
Dredging or other prominent excavation	2	1	0	**3**
Dumping of garbage or other debris	3	0	0	**3**
Grazing by domesticated/ feral animals	6	5	4	**15**
Grazing by native ungulates	1	0	0	**1**
Soil subsidence, scour or surface erosion	0	1	0	**1**
Vegetation (n=13)				
Evidence of intentional burning	0	1	0	**1**
Excessive wildlife herbivory	1	0	0	**1**
Grazing by domestic or feral animals	3	7	2	**12**
Recreation/human visitation	1	1	0	**2**
Water Quality (n=11)				
Debris lines on plants, trees or silt-laden vegetation	6	0	0	**6**
Formation of heavy algal or *Lemna* sp. surface mats	4	2	0	**6**
Increased concentration of dissolved salts	3	2	0	**5**
Turbidity in the water column	1	0	0	**1**
Total	**36**	**21**	**10**	**67**

4.3.2 Stressors Determined at the Landscape Scale

Site elevations ranged from 1451 to 1697 m, with a mean of 1461 m for sites in the northern reach and 1666 m for sites in the southern reach. In the northern reach, only two sites had anthropogenic water-related land use within one kilometer of the site. This land use, sub-irrigated pasture, comprised no more than 23% of the surrounding 1 km land area at these sites, though the activity of irrigation in one of the sites is uncertain. Water-related land use in the southern reach was divided between irrigated, sub-irrigated, and non-irrigated agricultural land, and natural upland or wetland. There was only one site in the southern reach with no active agricultural use within 1 km and all other sites had between 7.2% and 68% (mean 32.3%) of the surrounding 1 km landscape in agricultural use. There was no development within 1 km of any of the survey sites. Development makes up a small portion of the land use within 5 km of seven sites, but these developed areas include very small parcels around homesteads in both the northern and southern reaches. There was agricultural land use within 5 km of all sites in the southern reach and half of the sites in the northern reach. Site were generally far from roads with a mean distance to road of 253 m. One site abutted an unimproved road and three sites had no roads within 500 m. There were no Pollutant Discharge Elimination Systems operating or active mines in the study area.

4.4 Wetland Vegetation

We recorded 404 occurrences of 91 unique plant species in the 18 surveyed areas. Of those, 23 species were encountered only once across all sites. An additional 39 plants encountered were not identified to species level, including 31 identified to genus and 8 that were not identified. Of the 31 plants identified to genus, 10 occurrences were *Carex* spp. that either had insufficient samples or we were unsure about consistent naming across sites. Other unidentified species typically lacked the flower or fruit structures needed for identification. Because of the limited sampling period for this data collection and distance to the study area, we were unable to recollect species at various times during the growing season to facilitate species' determinations. The number of species per site, including unidentified species, ranged from 11 to 38, with a mean of 24.5. Fifteen species were found in over half of the sites (Table 11). Only a few of the commonly encountered species were also abundant where they were found, including *Juncus arcticus* (arctic rush), *Argentina anserina* (silverweed cinquefoil), *Carex nebrascensis* (Nebraska sedge), and *Eleocharis rostellata* (beaked spikerush). All other common species occurred with a mean cover of 1.7% or less. Five potentially aggressive or invasive species were detected, though none are listed as species of concern by the state of Utah (Table 12).

Table 11. Plant species found at ≥50% of surveyed wetland sites with number of sites, mean cover where detected, and plant characteristics. Wetland indicator status is taken from the U.S. Army Corps of Engineers National Wetland Plant List for the Arid West.

Scientific Name (Common Name)	Nativity	C-Value	Arid West Wetland Indicator Status	# Sites	Mean Cover (%)
Juncus arcticus (arctic rush)	Native	1	FACW	17	14.9
Argentina anserina (silverweed cinquefoil)	Native	2	OBL	14	3.9
Distichlis spicata (saltgrass)	Native	4	FAC	13	1.5
Hordeum jubatum (foxtail barley)	Native	2	FAC	13	1.1
Glaux maritima (sea milkwort)	Native	7	FACW	13	0.8
Ranunculus cymbalaria (alkali buttercup)	Native	4	OBL	13	0.5
Carex nebrascensis (Nebraska sedge)	Native	5	OBL	11	11.6
Mimulus guttatus (seep monkeyflower)	Native	5	OBL	11	0.6
Eleocharis rostellata (beaked spikerush)	Native	7	OBL	10	24.2
Carex (sedge)	-	-	-	10	1.5
Polypogon monspeliensis (annual rabbitsfoot grass)	Introduced	0	FACW	10	0.3
Schoenoplectus pungens (common threesquare)	Native	5	OBL	9	1.7
Cirsium scariosum (meadow thistle)	Native	6	FAC	9	1.3
Epilobium ciliatum (fringed willowherb)	Native	4	FACW	9	0.4
Centaurium exaltatum (desert centaury)	Native	6	FACW	9	0.3

Table 12. Plant species of concern detected during wetland field surveys, with number of sites and mean cover where detected. Species of concern include those on state noxious species lists for Utah (UT) or surrounding states, including Arizona (AZ), Colorado (CO), Idaho (ID), Nevada (NV), and Wyoming (WY), and/or species specifically listed in CNHP-EIA or USA-RAM protocols as species of concern. State listings are followed by state-specific designation, if available.

Scientific Name **Common Name**	**Species Status**	**# Sites**	**Mean Cover (%)**
Bromus tectorum cheatgrass	**States:** CO List C **Protocols:** USA-RAM	1	0.5
Cicuta douglasii western water hemlock	**States:** NV **Protocols:** none	1	0.5
Elaeagnus angustifolia Russian olive	**States:** CO List B, WY **Protocols:** CNHP-EIA, UWAAM	3	0.7
Sonchus arvensis field sowthistle	**States:** AZ, CO List C, ID control, NV, WY **Protocols:** none	1	0.5
Typha latifolia Broadleaf cattail	**States:** None **Protocols:** CNHP-EIA	6	2

The majority of floristic quality metrics were similar or marginally higher in sites in the northern reach and sites on private land (Table 13). Total species richness was not considerably different by location or management, though there were more non-native species encountered in southern and privately owned sites. Also, percent of species that were non-native in southern sites and on private property was nearly double on average what was observed in northern and publicly managed sites. Cover-weighted mean C values and cover weighted FQI for all species was higher in private than in publicly managed areas, but these values were similar between northern and southern sites.

The optimal NMDS solution consisted of two axes, with a stress value of 0.17 (Appendix H, Figure H-1, H-2). Visual representation of plot location along the resulting axes show grouping of northern and southern sites based on plant community composition, with one southern site grouped with the northern sites (Figure 8). This site is located near a groundwater discharge point and just outside of a fence that excluded intensive grazing.

Eleven species were strongly related to the final axes suggesting high fidelity with sites also situated along the axis (Appendix H, Table H-1). The herbaceous species *Argentina anserina, Sisyrinchium demissum, Carex nebrascensis, Ranunculus cymbalaria, Poa pratensis, Agrostis stolonifera* and *Rumex crispus* are associated with sites in the southern reach (Figure 8). The last three of these species are introduced. *Berula erecta*, *Epilobium leptophyllum*, *Schoenoplectus americanus*, and *Polypogon monspeliensis* (introduced) are associated with sites in the northern reach.

Overlays of environmental and condition variables indicate that plant community composition exhibits a strong relationship with hydrologic, buffer, and local stressors (Appendix H, Table H-2). Overall scores for each protocol, as well as the CNHP landscape and hydrologic category scores, are related to the study reach and in turn to plant species composition. Sites in the north were related to higher overall and buffer scores, sites in the south were associated with higher overall and buffer stress, and hydrological stress was associated with a subset of both northern and southern sites.

Table 13. Floristic Quality Assessment (FQA) metrics mean and standard deviation (sd) by location and land ownership for wetland sites surveyed in Snake Valley.

	North (n=8)		South (n=10)		Public (n=7)		Private (n=11)		Overall (n=18)	
FQI Metric	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Total species richness	24.9	7.5	24.3	6.3	23.1	6.4	25.5	7	24.6	6.7
Native species richness	21	6	17.9	3.8	19.3	5.6	19.3	4.9	19.3	5
Non-native species richness	2	1.3	4.2	3.5	2	1.4	4	3.4	3.2	2.9
Percent non-native Species	8	5.1	17.6	12.8	8.9	6.5	16.2	12.6	13.4	11
Mean C of all species	4.1	0.3	3.8	0.8	4	0.4	3.8	0.7	3.9	0.6
Mean C of native species	4.5	0.3	4.6	0.4	4.4	0.3	4.6	0.4	4.5	0.3
Cover-weighted mean C, all species	4	1.4	4	1.5	3.1	0.9	4.7	1.4	4	1.4
Cover-weighed mean C, native species	4.1	1.4	4.2	1.6	3.1	0.9	4.8	1.4	4.1	1.4
FQI of all species	18.6	3.5	16.9	3.3	17.6	3.5	17.7	3.5	17.7	3.4
FQI of native species	19.5	3.8	18.7	3	18.6	3.6	19.4	3.2	19.1	3.3
Cover-weighted FQI, all species	18.2	7.2	18.4	7.2	13.3	3.7	21.5	6.8	18.3	7
Cover-weighted FQI, native species	17.6	6.8	17	6.9	12.9	3.6	20.1	6.7	17.3	6.7
Adjusted FQI	42.8	3.1	41.4	5.5	42.1	2.9	42	5.5	42	4.6
Adjusted cover-weighted FQI	39	13	37.5	14.6	29.8	8.8	43.5	13.6	38.2	13.5

4.5 Relationships among Stressors, Plant Community Data, and Wetland Condition

Few plant community metrics were significantly ($p \leq 0.05$) correlated with overall or specific scores for CNHP-EIA hydrologic, landscape, or physiochemical categories (Table 14). Non-native species richness, percent cover non-native species, mean C of all species, and adjusted FQI were correlated with CNHP-EIA vegetation scores and USA-RAM overall scores. Native species richness was correlated with both USA-RAM and UWAAM overalls scores. Interestingly, the CNHP-EIA landscape component was negatively related to two non-native species metrics, indicating that non-native species may accurately reflect disturbed buffer around sites. No trend was detected in the correlations except that both non-native species metrics had the highest number of significant correlations to condition scores and, of the three protocols' total scores, USARAM had the strongest and the most significant correlations. Six of the evaluated plant community metrics had no correlations with any of the condition categories or overall condition scores including three of the mean C metrics and total species richness.

All stressors values were correlated with at least two condition scores (Table 15). CNHP-EIA landscape and vegetation scores were not significantly correlated with any stressor values. Hydrologic stressor values were only correlated with CNHP-EIA hydrologic condition scores and with USA-RAM overall scores. All other stressor values were correlated with the CNHP-EIA hydrologic and physiochemical condition scores as well as overall scores for all three protocols. Evaluation of correlations between vegetation metrics and stressors found that the only significant correlation was between buffer stressor values and FQI of all species (p=0.03).

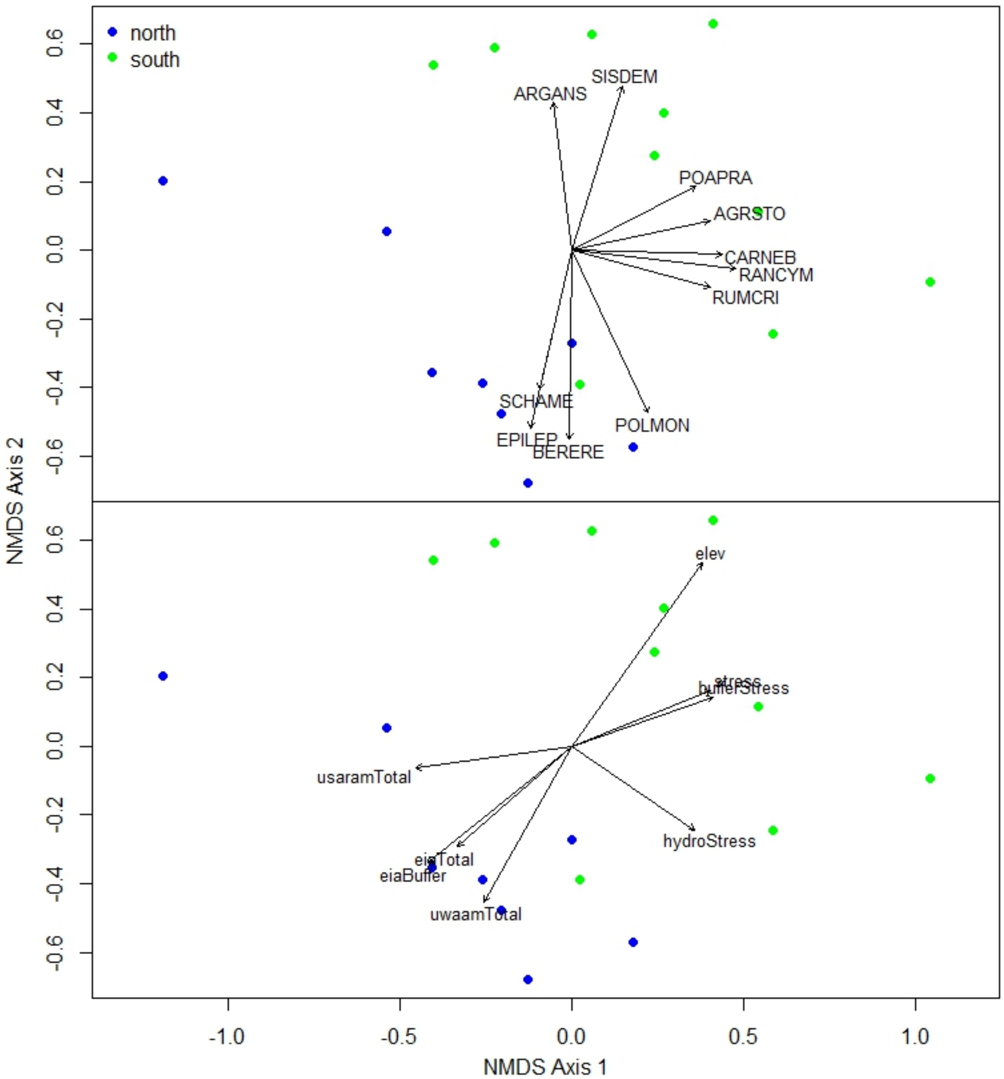

Figure 8. Plot of sites and species scores (top, for species p ≤0.05) and site variables (bottom, for variables p ≤0.05) for first two axes of the plant community composition NMDS. Species and site variables are plotted as vectors proportional to their strength of correlation with the axes. Sites are plotted as points colored by location, North (blue) versus South (green). Species identities and variable names are explained in Appendix H.

Table 14. Significant (p≤0.05) Pearson correlation coefficients between plant community composition metrics and wetland condition scores. CNHP-EIA scores include both overall site score and score in hydrologic (hydro.), landscape, physiochemical (physio.), and vegetation (veg.) categories.

Plant Community Metric	CNHP-EIA					USARAM	UWAAM
	Hydro.	Landscape	Physio.	Veg.	Total	Total	Total
Total species richness	-	-	-	-	-	-	-
Native species richness	-	-	-	-	-	0.6	0.48
Non-native species richness	-	-0.53	-	-0.77	-	-0.47	-
Percent non-native species	-	-0.52	-	-0.79	-0.56	-0.58	-
Mean C of all species	-	-	-	0.69	-	0.58	-
Mean C of native species	-	-	-	-	-	-	-
Cover-weighted mean C, all species	-	-	-	-	-	-	-
Cover-weighed mean C, native species	-	-	-	-	-	-	-
FQI of all species	-	-	-	-	-	0.69	0.5
FQI of native species	-	-	-	-	-	0.57	-
Cover-weighted FQI, all species	-	-	-	-	-	-	-
Cover-weighted FQI, native species	-	-	-	-	-	-	0.48
Adjusted FQI	-	-	-	0.56	-	0.53	-
Adjusted cover-weighted FQI	-	-	-	-	-	-	-

Table 15. Significant (p≤0.05) Pearson correlation coefficients between aggregated site stressor values and wetland condition scores. CNHP-EIA scores include both overall site score and score in hydrologic (hydro.), landscape, physiochemical (physio.), and vegetation (veg.) categories.

Stressor	CNHP-EIA					USARAM	UWAAM
	Hydro.	Landscape	Physio.	Veg.	Total	Total	Total
Buffer	-0.79		-0.69		-0.77	-0.64	-0.74
Hydrologic	-0.54					-0.58	
Site Veg., Physical, Water Quality	-0.62		-0.70		-0.71	-0.60	-0.78
All stressors combined	-0.76		-0.71		-0.77	-0.65	-0.77

5.0 Discussion

This study is an extension of a previous study (Phase I) that employed two rapid assessment methods and targeted wetlands in the northern reach of Snake Valley that were associated with a long term hydrologic monitoring network (Jones and others 2013). Phase I of this project found that there was an insufficient condition gradient sampled to support rapid assessment development and that the inclusion of sites in the southern reach would better support project and program goals. This report represents an expansion of the sample frame to include a broader disturbance gradient and a continuing effort to develop wetland condition assessment tools at the ecoregion and state scale.

5.1 General Trends in Wetland Condition

The majority of sites surveyed in Snake Valley fell into the B or C categories for all three protocols, and two sites received a score of A for the CNHP-EIA protocol and no sites scored D for any of the protocols. Though scores are preliminary until metrics are calibrated for the region, these results are within the range expected for the study area. There were 5 sites (CNHP-EIA n=4, USA-RAM n=2, UWAAM n=3) with an overall score of C in at least one of the protocols. These sites were all located in the southern reach and experience intense grazing pressure. These results suggest that there are few or no wetlands in the study area that significantly deviate from reference condition with little or no conservation value and that the majority of sites only exhibit slight alteration from natural or undisturbed conditions. The ubiquitous agriculture and grazing use in the valley make it difficult for any areas to be considered pristine using the tested protocols. Snake Valley is generally remote and sees limited use and, while landscape context scores indicate buffering land around wetlands is adequate, buffer condition is affected by grazing stresses throughout the area and particularly in sites in the southern reach where grazing use is more intense.

Several components of Physical Structure, Vegetation Structure, and Species Composition metrics indicate that Snake Valley wetlands may have less structural and biotic complexity than wetlands targeted by the tested protocols. The majority of sites received C or D scores on measures of the complexity of topographic features at sites as well as interspersion of plant zones, vertical biotic structure, and plant community complexity. Without appropriate reference sites, it is difficult to determine whether low complexity is a natural condition of Snake Valley wetlands or is driven by current and historic land use, water use, or other stressors. For example, woody species and species in different height categories may be naturally uncommon or absent from wetlands in the region. Additional data for the region will support the reevaluation of these metrics to determine thresholds and weighting appropriate for Great Basin wetlands in Utah.

Though few sites were entirely pristine, it is likely that some wetlands in the northern reach of Snake Valley wetlands may be considered reference or least disturbed condition for the Great Basin ecoregion in Utah. In order to determine reference for the region, additional sampling will need to be conducted at the regional scale. This additional sampling will also aid in expanding the data available for characterization of wetland resources in the region and calibrating metrics to the range of conditions present.

5.2 Key Threats to Wetland Resources

The overall score of the majority of surveyed sites indicates that wetlands in Snake Valley deviate slightly from reference condition and would not warrant any immediate restoration action. However, the presence of sites that deviate moderately from reference indicate that there are a number of pervasive stresses to wetland condition that could be addressed to increase condition as well as productivity. The primary stresses observed at surveyed sites in Snake Valley that drove condition scores were impacts from intensive grazing and other agriculture-related uses. The establishment of best management practices may provide some relief for these disturbances.

Though existing disturbances are the site characteristics that most impact condition site scores, the potential threat of excessive groundwater development and inter-basin water transfer is a significant concern for the future ecological and economic stability of the wetland resources in Snake Valley. The importance of these key threats has been heightened by the proposed development of water supply wells and an interconnecting pipeline system within the far western portion of Snake Valley in eastern Nevada by the SNWA (Southern Nevada Water Authority, 2011). Their current plan involves pumping and removal of approximately 176,000 acre-feet per year of groundwater from the eastern Great Basin to the Las Vegas metropolitan area, including over 50,000 acre-feet per year from Snake Valley. The SNWA project, if developed, would likely represent an acute impact to groundwater resources in Snake Valley. It is anticipated that under this level of withdrawal, groundwater levels will decline and there will be substantial reductions in spring discharge (Schaefer and Harrill, 1995; Kirby and Hurlow, 2005). However, additional threats to spring-fed wetlands and groundwater resources exist, involving increased agricultural consumption of groundwater both within and beyond Snake Valley's hydrographic boundaries. These projects could move forward before the SNWA project in Snake Valley is activated. As such, cumulative groundwater removal could be greater than anticipated. At the present time, it remains unclear if and how further development of Snake Valley's groundwater resources would affect water table elevations and ultimately spring-fed wetlands in the valley.

5.3 Development of Wetland Condition Protocol

Our experience testing three rapid wetland condition assessment protocols in Snake Valley wetlands will make an important contribution to the development of the statewide URAP protocol and ecoregional modules that may be needed for the Great Basin. Wetlands in Snake Valley comprise a unique and understudied wetland resource in the western portion of the state. These resources provide critical habitat for wildlife species and will act as gauges for changes in climate and water resource utilization. Though these wetlands are representative of many wetlands in the Great Basin, future sampling should include isolated wetlands across the western region of the state to expand the frame of reference and insure that the range and variability in Great Basin wetlands in the state has been captured.

This project highlights multiple issues to consider while we develop URAP. For example, we found it easier to think of land as existing on a continuum between non-buffer and buffer rather than having to assign each land cover type to a category. It was particularly difficult to decide whether some low-use roads should be considered non-buffer and landscape fragmenting features. We may be able to use coefficients, such as those adopted by Keate (2005), to relate land cover types to their relative degree of contribution to runoff, nutrient and sediment loading, and habitat quality. We could then calculate scores in each category for each site and establish thresholds to distinguish between condition categories. This may more accurately detail the specific types and severities of disturbances around sites.

Development of URAP requires selection of a subset of metrics from the three tested protocols and calibration to determine appropriate thresholds between condition classes. We find it encouraging that overall site scores between all three protocols were significantly correlated with one another and that condition scores were correlated with landscape measures of condition, with stressors values, and with plant community composition data evaluated by NMDS. USA-RAM showed the least range of scores and was not as strongly correlated with the other protocols or other measures of condition. This is not surprising because scoring and evaluation of this protocol is still under development; however, due to these factors, USA-RAM metrics will be the most difficult and least advised to adapt into the URAP protocol at this time. Based on work around Snake Valley, we have three recommendations for URAP development. Firstly, we should reword some metric statements to make them more easily understood and consistently scored between observers. Secondly, we should make sure that site scores capture the range of variability present across the state *and* within Snake Valley wetlands. Lastly, we should calibrate metrics in a manner that strengthens the relationship between stressors, landscape data, FQA metrics, and the wetland condition scores. With this approach, we will move closer to developing a rapid condition assessment tool that is user-friendly and informative of true wetland condition.

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