AN ABSTRACT OF THE THESIS OF

Laura Dlugolecki for the degree of Master of Science in Forest Resources presented on February 26, 2010.

Title: A Characterization of Seasonal Pools in Central Oregon's High Desert

Abstract approved:

Ron Reuter

Seasonal wetlands in arid and semi-arid lands provide an important source of surface water in otherwise dry lands. Central Oregon's high desert, located in the Northern Great Basin (NGB) is dotted with hundreds of seasonal pools, locally called playas. The playas hold water or snow during parts of winter and spring but typically dry up during summer months. The mechanisms of seasonal pool hydrology, especially in the NGB, are poorly understood and have not been thoroughly examined. There is high seasonal variability and inter-annual variability in surface water amounts in the playas.

Historical over-grazing and a century of fire suppression have caused serious long-term ecological damage throughout the NGB ecoregion. A large portion of playas located on the Bureau of Land Management (BLM) Prineville District lands have been excavated to capture and retain increased water for livestock use. These dug-out playas exhibit an altered ponding regime, affecting the depth and duration of water on the surface. Playa excavations have affected the hydrologic behavior on the playas, possibly altering the vegetation communities. Playa habitat is important to many different species, including the greater sage-grouse (*Centrocercus urophasianus*), a candidate for protection under the federal Endangered Species Act.

To obtain my objectives of fostering a greater understanding of the ecology of the playa systems and to begin documenting the variability across the landscape I explored various methods to characterize and monitor the playas. I analyzed field data collected by

the BLM, including ecological site inventory. Because of the knowledge gap in playa ecology, I created a method to support and improve data collection to describe these unique wetlands. I created a field manual to characterize playas that will give land managers and scientists a tool to obtain and contribute useful information about the playas. The information can be used to answer a variety of questions concerning subjects such as: the perceived sensitivity of a site for livestock grazing, the relative importance of a playa to various wildlife species, and whether or not the site is appropriate for livestock troughs or wind turbines.

Working with the BLM I helped to develop experimental habitat improvement strategies. To monitor the success of the habitat improvement strategies I used Electromagnetic induction (EMI) to map subsurface soil physical properties, looking specifically at salinity to gain information about hydrologic patterns. I compared hydrologic patterns of playas before and after habitat improvement strategies using EMI data. From initial visual observations of the EMI data, water appears to be distributed across the playas in greater areal extent following habitat improvement strategies.

To further characterize the variability in the playas across Central Oregon's high desert, I examined whether relative ash concentration in the soil samples had an effect on the apparent physical characteristics of a playa. There were no discernable differences in relative ash concentration between any of the soil samples.

Land managers have an inclination towards orchestrating restoration activities on the altered playas aimed at habitat improvement goals. I recommend caution and patience with restoration activities. Attempts to return systems to within their historical range of biotic and abiotic characteristics and processes may not be possible. Management activities directed at removing undesirable features of a system may perpetuate new undesirable systems. Directing management goals towards promoting biological diversity and hydrological functionality may be more successful focus. I recommend continuing to characterize these unique systems to facilitate the understanding of the role of these features in the high desert.

A Characterization of Seasonal Pools in Central Oregon's High Desert

by
Laura Dlugolecki

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented February 26, 2010
Commencement June 2010

Master of Science thesis of Laura Dlugolecki presented on February 26, 2010.

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Laura Dlugolecki, Author

ACKNOWLEDGEMENTS

So many people have helped shape my amazing experience at Oregon State University. I wish to express sincere gratitude to the following people:

- My major advisor Ron Reuter helped greatly in the development of this project through the dozens of permutations, lost funding opportunities and wild ideas without giving up. I really appreciate his dedication and support.
- Bill Dean of the Prineville District BLM not only provided me with welcomed employment, but also helped me have a much needed hands-on experience with the playas in Central Oregon. I appreciate the opportunities he gave me to work with so many talented people and to experience being part of a team to develop a habitat rehabilitation project.
- Jenni Moffitt of the Prineville BLM Distirct is the true playa guru and taught me so much about the playas in Central Oregon. I appreciate her patience in teaching me about all the hard work she and her colleagues have completed.
- Christian Hagan of Oregon Department of Fish and Wildlife gave me a wonderful experience to present my findings at the Oregon Chapter of the Wildlife Society and to meet so many interesting people in my field
- I am very thankful to my committee member Jay Noller for much appreciated and thoroughly enjoyed funding opportunities working as a teaching assistant in the Soils department. I am also thankful for the consultation, advice and lab use for my thesis work.
- I want to extend thanks to my committee member Paul Doescher for introducing me to many fascinating concepts about ecological restoration and for contributing comments on my thesis.
- Thanks to all the much appreciated funding I received throughout my studies, I am honored to the donors for their generous contributions. Thanks to the Oregon Society of Soil Scientists, the Laurels Scholarship, the Mary McDonald Fellowship and the Alfred W. Moltke Fellowship for contributing

to my invaluable educational experience. Thanks to Bob Mason for a teaching opportunity in the Biology Department.

- Thanks to Jim Doolittle and to Paul Pedone from the NRCS for the generous use of their EMI equipment and for joining me in the field to help use the equipment.
- Thanks to all my colleagues in the College of Forestry. You all helped me through this journey! What an intelligent and really fun bunch!
- Last, and in certainly no way least, thanks to my husband Jim. I really don't know where I would be without your encouragement and insight, you are the best.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDIX FIGURES

LIST OF APPENDIX TABLES

CHAPTER 1. AN INTRODUCTION TO SEASONAL POOLS IN CENTRAL OREGON

Global perspective: Seasonal wetland characteristics shared globally

Seasonal wetlands occur in various climate regimes and landforms across the globe. Temporary ponds found in arid lands are of particular interest because of the regionally important water resource they provide in otherwise dry lands. Seasonal wetlands are characterized by the presence of seasonal plant cover and land areas that are submerged by water for only part of the year. Factors such as precipitation, evapotranspiration, infiltration rates and groundwater inflow and outflow contribute to the fluctuations in water levels observed in seasonal pools (Deil 2005). Arid lands that support seasonal pools have a unique seasonal moisture regime associated with the pools.

In the western United States, the Mediterranean-type climate, characterized by dry summers and wet winters, is most commonly associated with seasonal pool features. In arid and semi-arid Mediterranean climates of the Pacific Northwest, the two most common types of seasonal pools are known as vernal pools and playas, which hold water or snow during parts of the winter and spring but typically dry up during the summer months. These pools are considered to be geographically isolated wetlands, meaning that the depressions are completely surrounded by upland (Leibowitz 2003.) Vernal pools occur in surficial depressions that temporarily fill with water during winter and spring rains and desiccate during the dry months. They occur as small poorly drained depressions perched above an impermeable or very slowly permeable soil horizon or bedrock (Smith and Verrill 1998.) Playas are seasonal pools specific to arid and semi-arid regions that are sparsely vegetated with grasses and are surrounded by a ring of shrubs (ODFW(c) 2006). Playas are generally associated with highly saline soils and drier conditions than vernal pools. Playas occur within closed watersheds and only receive water from precipitation and its associated runoff. They are characterized by unpredictable hydroperiods with extended dry periods (Haukos and Smith 2003.)

Seasonally ponded depressions found in the high desert of Central Oregon provide a significant source of surface water in a regionally arid climate. These water features are commonly seen throughout the Northern Great Basin and Range ecoregion of the western United States and they exhibit a wide variety of characteristics. The depressions, locally called playas, provide habitat for a large assortment of vegetation and wildlife. The playas provide important nesting, feeding and stop-over grounds for birds along the Pacific Flyway migratory route. A growing concern for the ecological health of the playas has spurred an investigation into a greater understanding and characterization of these water features.

Available surface water, especially in a hot and dry environment, is critical to the survival of many plant and wildlife species. Most of the playas in Central Oregon are located in year-round sage-grouse (*Centrocercus urophasianus*) habitat. The playas are an important resource for the production and/or rearing of their offspring (BLM 2005.) Many plants have adapted to these unique hydrologic systems and can only grow in or around seasonal wetlands under specific moisture regimes, creating unique vegetative habitats and associations. These wetlands are poorly understood and have not been systematically inventoried, nor have their conditions been consistently assessed. Currently there is no comprehensive management strategy for maintaining or improving the health and function of these wetlands.

Globally, seasonal pools are recognized for hosting diverse and unique plant species due to their unique hydrologic characteristics. Because of the relatively small size of the pools, seasonal moisture regimes and the isolated nature of the wetlands, seasonal pools can support a variety of plants with very specific needs. Plant species are adapted to living amidst seasonal extremes of both inundation and drought. Seasonal pools host plant species that may be regionally unique and often rare or endangered; globally the pools are inhabited by niche-equivalent taxa (Deil 2005).

Zones of vegetation representing varying moisture regimes form in and around seasonal pools. The zones are commonly defined by changes in water depth, duration of inundation, and salinity concentration. The vegetation gradient from zone to zone varies with topography. The most water-tolerant plant species are found in the lowest parts of the pools and the least water-tolerant species are found on the topographic high points in and around the pools. The zones are commonly situated in concentric bands surrounding the low areas of the pool. Species distribution commonly overlaps across vegetative zones because of the high seasonal variability in moisture from precipitation (Crowe et al. 1994.)

Seasonal pools are resilient to the high season-to-season variability of ponding. Seed dormancy is the primary method plants use to cope with temporal variations in climate and resource availability. It provides a means of enduring prolonged unfavorable periods. For plants to succeed they must achieve the difficult task of correctly timing the release of their seeds from dormancy that is suitably hedged against environmental variation (Bliss and Zedler 1998). Seed bank experiments in seasonal pools have shown that soil samples from one vegetation zone in one pool can produce very different plant communities under different flooding regimes (Bliss and Zedler 1998). Rare and endangered species that have not occurred in the apparent vegetation for decades can be recorded in the seed bank (Deil 2006). The ability of plants to stay dormant during unfavorable conditions attributes to the high between-year variability of vegetative expression in seasonal pools and to the difficulty of fully cataloging plant species in the pools.

The mechanisms of seasonal pool hydrology, especially in the Northern Great Basin, are poorly understood and have not been thoroughly examined. There is high seasonal variability and inter-annual variability in surface water amounts. Seasonal inundation can be attributed to the direct result of seasonal rainfall and surface drainage or to the indirect effect of a fluctuating groundwater level, rising above the surface during the wet season. In arid and semi-arid lands, a particular playa may or may not pond at all during a particular year, or it may remain ponded for up to three years due in part to the frequency distribution of precipitation in the desert (Lichvar 2006). Some isolated wetlands interact through subsurface groundwater connections, but in playas, groundwater inflows are minimal due to relatively impermeable clay layers (Leibowitz 2003.)

Studies in Californian vernal pools show that the pools are mostly rain-fed, simulating a mini-catchment system (Deil 2005). Central Oregon seasonal pool hydrology is assumed to operate in a similar manner as the pools in California. A piezometer study in Oregon vernal pools found no free water in the subsoil between 25 and 200 cm, indicating that the subsoils at this depth were never saturated. This supports the hypothesis that water enters the pools through direct precipitation and becomes perched above a shallow, slowly permeable soil horizon (Clausnitzer and Huddleston 2002). Perching layers reduce rates of recharge to underlying regional aquifers. Relatively little is known about how perched aquifers regulate hydrological, biogeochemical, and biological processes in wetland ecosystems in general and vernal pool landscapes in particular. (Rains et al. 2006).

Vernal pools are associated with specific types of geological formations, landforms, and soils. Therefore, vernal pools tend to be clustered at the landscape scale (Rains et al. 2006). California's vernal pools are found in various landforms throughout the central valley. These landforms include basins, basin rims, low terraces, dunes, high terraces, volcanic mudflows and lava flows (Smith and Verrill 1998). Arid and semi-arid desert playa features are found in similar landforms as the pools in California and are additionally associated with relict Pleistocene lakes (Lichvar 2006). Generally, seasonal pool landscapes are characterized by mound-depression microrelief.

Seasonal pools tend to be underlain with an impermeable soil layer that may be a claypan, hardpan, clay-rich soils, or bedrock. In all cases, water perches above the impermeable soil layer (Rains et al. 2006). Studies conducted in both California and eastern Washington have found that finer soil particle sizes increase and sand fractions decrease from outside to the interior of the pool basins (Crowe et al. 1998). Temporary ponding can put finer-textured soil particles in suspension, as the water dries down throughout the year, fine-textured particles settle in the lowest portions of the pools. The accumulation of fine-textured particles can decrease permeability and create a surface-seal effect. Subsoil permeability is very slow in the seasonal pool features and sufficient water can accumulate in low spots to create perched water tables and prolonged seasonal ponding (Thorne 1981.)

Temporary wetlands often shelter extremely rare and isolated taxa. The habitats are sensitive to human impact and they are threatened in many parts of the world (Deil 2005). In many parts of the globe, seasonal pools are subjected to development pressures and landscape modifications. Arid rangelands do not often face the same development pressures of semi-arid climates, but are often impacted by livestock. The stress of grazing, development or alteration to these features has caused a decline in the ecological health, specifically the vegetative diversity, of the pools in California (Bauder and McMillan 1998) and in Oregon (ODFW 2006 (a), (c) and BLM 2005.) Because the rare taxa have specific niche requirements within the seasonal pool habitat, resilience under altered landscapes or climates has the potential to be low.

Local Perspective: Seasonal pools in Central Oregon's High Desert

Regional Site Description

The Northern Great Basin (NGB) encompasses roughly 45 million hectares of the western United States (Pyke and Borman 1993.) The NGB is comprised of the northern half of the great basin desert, including land area in Oregon, Washington and Idaho (Figure 1.) This expanse is part of the Columbia Plateau physiographic province characterized by arid tablelands, intermontane basins, dissected lava plains, and widely scattered low mountains and the sagebrush-steppe plant community (BLM

2009). The NGB is a sparsely inhabited, arid expanse that is characterized by a closed drainage system in which all surface water evaporates or percolates before reaching the ocean. Central Oregon's high desert is located in the Northern Basin and Range Ecoregion, an Environmental Protection Agency (EPA) level 3 designation (Figure 2.) This ecoregion is characterized by flat basins separated by isolated mountain ranges. Oregon's high desert is located in the rain shadow of the Cascade Mountain Range and is a part of the sagebrush-steppe plant community which is part of the largest grassland-type region in North America (Rogers and Rickard 1988.) Sagebrush-steppe vegetation in the NGB is dominated by grasses and forbs with an open shrub layer. Natural fire regimes historically maintained a patchy distribution of shrubs and predominance of grasses (ODFW(b) 2006.)

Figure 1. Extent of the Great Basin region in the intermountain west. The northern half is referred to as the Northern Great Basin (NGB) and coincides with the Columbia Plateau physiographic province. Image courtesy of: NBII Great Basin Information Project, National Biological Information Infrastructure http://www.nbii.gov December 2007.

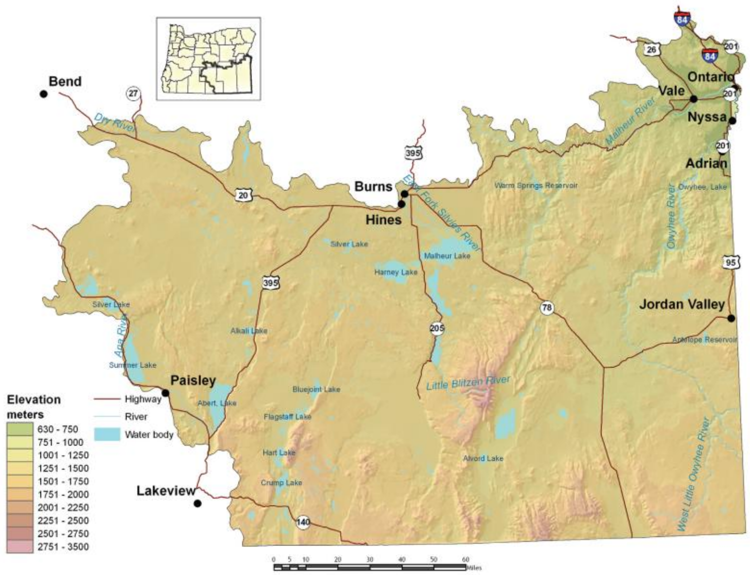

Figure 2. Northern Great Basin and Range Ecoregion of Oregon (Level III Ecoregion, designated by the EPA.) Image Courtesy of Oregon Department of Fish and Wildlife http://www.dfw.state.or.us/conservationstrategy/document_pdf/b-eco_nb.pdf

Sagebrush-steppe plant communities are characterized by a micro-relief pattern commonly referred to as "islands of fertility." (Ravi et. al 2007.) Small "islands" are formed by subtle changes in topography. Sediments loosened through wind erosion accumulate around larger shrubs and create a safe habitat for young grasses and forbs to establish under the shade of the shrubs. The area between these islands is often bare ground or sparsely vegetated ground. Over time a disturbance such as fire may affect the area and subsequent wind erosion will distribute the fertile soil, shifting the location of where new islands of fertility will develop (Ravi et al. 2007). Vesicular or biological crusts locally form on the bare soil, which prevent excessive wind and water erosion (Belknap et al. 2001.)

The sagebrush-steppe community of the Columbia Plateau has been named a "strategy habitat" by the Oregon Department of Fish and Wildlife (ODFW.) A strategy habitat is considered to be a vegetative community that has experienced a high percentage of loss from its 1850 vegetative status and a high degree of fragmentation. The ODFW identifies altered fire regimes, invasive plant encroachment, historic over-grazing and damage to soil macrobiotic crusts as the limiting factors to conservation in this ecoregion (ODFW(b) 2006.) Most of the sagebrush-steppe community in Oregon is managed by public land agencies (Hagan 2005.) A majority of the private and public rural land in the high desert sagebrush-steppe is managed for livestock grazing.

There are hundreds of seasonal pools spread across Central Oregon's sagebrush-steppe. The focus of this investigation lies within the Prineville BLM district specifically south of US Highway 20 between the towns of Millican, Brothers and Hampton, Oregon (Figure 3.) The highest concentration of pools on the Prineville BLM District is found in this area; therefore the BLM identified it as an area for study and inventory to obtain more knowledge about playas in Central Oregon. The Prineville District BLM has mapped over 400 pools within its borders, but there are likely many more that have not been mapped.

Figure 3. Prineville BLM District Boundary. Image courtesy of Bureau of Land Management: http://www.blm.gov/or/districts/prineville/index.php

The seasonal pools in Central Oregon's sagebrush-steppe habitat are locally called playas. However, they are smaller and generally support water for longer durations than the expansive desert playas and salt flats found in southeastern Oregon and Nevada. The limited amount of academic literature published about these water features generally refers to them as vernal pools; however they are not as wet and lush as the vernal pools most commonly characterized in California and southwestern Oregon. The pools in the study area represent a regionally unique wetland habitat of undefined extent.

The regional climate is semi-arid, with long severe winters and short dry summers. Annual precipitation is typically 200 to 300 mm, of which the majority occurs between October 1st and March 31st. Average January temperatures range from 2.1 to -8.7˚C; the average July temperatures range from 30.1 to 11.2˚ C (Clausnitzer et al. 2003.) Temperature and rainfall can be highly variable around these averages from year to year. Central Oregon's high desert frequently experiences fluctuations between extended drought periods and above average precipitation.

The playa study area falls in a geologic region of Oregon known as the High Lava Plains which encompass an expansive region, covered by young lava flows dotted in places by cinder cones and lava buttes. Most of the relief is moderate and the surface geology can be attributed to Pliocene and Pleistocene lavas, tuffs and alluvium (Baldwin 1981). The High Lava Plains province is a middle and late Cenozoic volcanic upland nearly 250 km long and about 80 km wide that extends south-eastward from the Cascade Range to the eastern margin of the Harney Basin. Structurally the province is dominated by a west-northwest-trending zone of en echelon normal faults, generally called the Brothers fault zone, that can be traced for most of the length of the province and perhaps well beyond the province boundaries. (Walker and Nolf 2006.) The Brothers Fault Zone is considered an area of modern volcanic activity.

Large dry lake basins are situated across the high lava plains that once contained considerable expanses of water during the Pleistocene. Evidence of well formed shorelines can be seen on hills and rock walls, some to the height of 200 ft. above the current land surface. The water receded over time as the climate became drier (Baldwin 1981). In very recent geologic history the high lava plains have been volcanically active, but there are two events that have influenced the land surface and subsequently the vegetation and fertility of the soils in the region in the targeted playa study area via ash deposits: the eruption of Mt. Mazama roughly 7,000 years ago and the most recent eruption of Newberry Crater, roughly 1,400 years ago.

The soils of the high lava plains of the Columbia Plateau have parent materials comprised of fine-grained ash, pumice, basalt and alluvium. Most of the playas in the Prineville BLM District exhibit soils mapped as the Swalesilver series, which are classified in the soil subgroup Aquic Palexeralfs. These soils are defined as very deep, somewhat poorly drained soils that formed in alluvium and lacustrine deposits derived from volcanic rocks and volcanic ash. Swalesilver soils are found in depressions on plateaus and lake terraces; they have been found to have seasonally aquic conditions at a maximum depth of 10 inches. Reduced conditions and redoximorphic features can be seen between the soil surface and 6 inches (A1 and A2 horizons) at certain times during normal years (NRCS 2009). The soils in these ponded depressions exhibit weak redoximorphic features indicative of hydric soil conditions (Clausnitzer et. al 2003.)

In the high lava plains, the large volumes of ash and pumice in the soil result in a high water-holding capacity of the soil. In many areas the land can support more vegetation than is typical for the yearly precipitation amounts. Vegetative growth is dependent on stored soil moisture and is generally limited to spring in the sagebrush-steppe plant communities of Central Oregon (Deboodt 2002). In the spring, the playa study area is more productive than would be expected for its climate due to the ash and pumice influence in the soil.

Current Management Jurisdiction and Land Use

Uncontrolled livestock grazing in the decades before enactment of the Taylor Grazing Act of 1934 caused serious long-term ecological damage throughout the NGB ecoregion. Rangeland conditions have improved since that time through active grazing management. However, some areas still show evidence of impact. Sensitive areas, such as riparian habitats and arid areas of sagebrush and salt desert have been slow to recover (ODFW(a) 2006.) In contrast to the short-grass steppe of North America, the current landscapes of the inter-mountain west evolved without the presence of large ungulate herds; therefore, the regional bunchgrasses lack adaptations that increase resilience to surface disturbance. (Fernandez et al. 2008.) There is increasing evidence that intensive grazing leads to widespread changes in the physical properties of the soils, however it is hard to establish because few ungrazed areas remain for reference (Fernandez et al. 2008). Effects due to excrement inputs have not yet been fully investigated, but increased nitrogen inputs likely affect soil fertility and/or water quality.

A large portion of playas on Prineville District BLM administered lands have been altered for livestock watering. The playas were altered by excavating soil from the bottom of the depressions, enlarging them to capture and retain water for livestock use. The excavated soil was piled to the side of the excavation in a pile that is referred to as a berm. Most of the “dug-out” playas are excavated over two meters deep and at least two meters wide, and in most cases, much wider. Most large-sized playas with potential for holding water were excavated in the years between 1950 and 1970. During this time, BLM employees excavated playas on public land. This practice was also common on private land and often administered by the BLM. This was an accepted land management activity of the time; it was seen as beneficial for livestock watering and over time was discovered to provide a surface water source used by big game later into the summer season. Currently, new dug-out activity in playas on BLM land no longer occurs. Concern about the effects of the dug-outs on ecological health and wildlife are drawing attention to the playa habitat. It has been hypothesized that the dug-out playas that collect water in the deeper reservoirs are preventing water from ponding on the surface outside of the excavated area and could be affecting the plant communities because of the change in soil moisture across the playas.

Seasonal pools constitute distinct habitat sites within semi-arid landscapes and, therefore, probably play an important, and so far poorly understood, ecological role in the sagebrush-steppe of Central Oregon (Clausnitzer and Huddleston 2002). Increased localized water availability, ponding depth and duration in the dug-out playas can alter biological communities within pools and on surrounding semi-arid uplands. Little is known about the affects of alteration to the playas in Central Oregon, but there have been studies elsewhere on similar features. In the semi-arid climate of the Little Missouri National Grassland (LMNG) in North Dakota excavation of short hydroperiod wetlands has been a common method of increasing water availability for livestock. A 2004 study by Euliss and Mushet found deeper water depths, increased hydroperiods, increased salt concentrations, and decreased vegetative structure in excavated seasonal wetlands versus intact wetlands of the LMNG. The changed environmental conditions were found to have significant negative impacts on native aquatic macroinvertebrates, amphibian and plant communities. Euliss and Mushet strongly recommend developing programs to restore natural hydroperiods of the wetlands to support native fauna and flora. However, their study does not address the social and economic issues that may arise from these restoration practices. It is possible that restoration of these seasonal pools to their native hydrology will negatively impact the ranching community.

Ram Lake Assessments

In 2005 the BLM conducted a routine assessment process on the Ram Lake grazing allotment located in an area of concentrated playas on the Prineville District (Figure 4.) Using “standards for rangeland health” and “guidelines for livestock grazing", also known as S & G reports, the BLM assessment team examined watersheds, ecological processes, water quality and protected species habitat on the allotment. (For the methodology of the S&G reports see USDI 1997.) The S&G reports found the grazing allotment to be doing poorly in several areas. The failure to meet the standards and guidelines was most pronounced in and around playa habitats. The reports found heavy woody encroachment that is not typical of the seasonal pool habitat and low species diversity. They determined that livestock use is contributing to the failure of the allotment to meet the standards. The report determined that these factors could potentially lead to site xerification and to a decrease in playa size. The report also concluded that the presence of dug-outs in the playas may be preventing sufficient watershed function and could possibly be leading to the failure to meet the standards and guidelines (BLM 2005.)

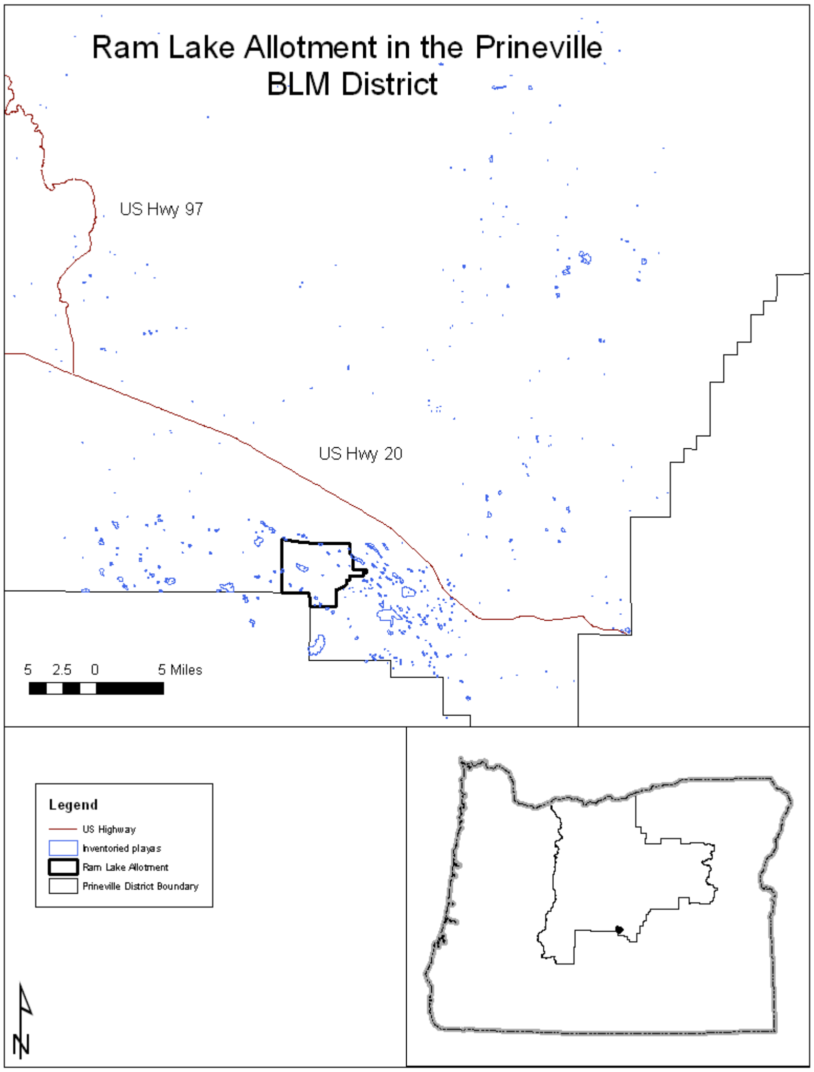

Figure 4. Ram Lake grazing allotment on the Prineville BLM District.

The standards and guidelines for rangeland health assessments were primarily developed as a rapid assessment to determine the physical and biological condition of grazing allotments. This assessment was not intended to be a thorough inventory of each playa's physical, biological and economic condition. However, the inability of these sites to meet the standards of vegetative diversity and protection of desirable habitat for sensitive species raised a red flag that further investigation was needed into this unique habitat system.

Ecological and Wildlife Concerns

The Oregon Department of Fish and Wildlife's "Oregon Conservation Strategy" identifies the playa habitat in Central Oregon as one of the most altered habitats in the Northern Great Basin and Range ecoregion, and an area for future research, specifically in areas of high playa concentration (ODFW 2005.) The playa habitat is important to many different species, but has recently received attention due to its importance to the greater sage-grouse (*Centrocercus urophasianus*) life cycle. The conservation status of the sage-grouse is politically controversial; it is currently under consideration for listing as a federally endangered species. If the sage-grouse were listed, current land management, especially livestock grazing practices and wind energy development projects, could be impacted. The Oregon Wildlife Policy dictates that sage-grouse populations and habitats be actively managed to a level that prevents sage-grouse from being listed on both federal and state endangered species lists. According to ODFW, the largest threats to the sage-grouse populations are habitat loss and fragmentation. Compared to other states that support sage-grouse populations, Oregon has large expanses of contiguous habitat with minimal threats of oil, gas, or coal-bed methane development, which generally threaten sage-grouse habitat. However, there is potential and interest to develop wind-energy grids in most sage-grouse regions in Oregon (Hagan 2005). Sage-grouse researchers are currently examining how wind energy developments may impact sage-grouse habitat.

Sage-grouse are sagebrush obligate species, without sagebrush the species cannot persist. Within the sagebrush habitat of Central Oregon, playas have an important role in sage-grouse breeding and feeding. Sage-grouse breed on sites called leks (strutting grounds). The same lek sites tend to be used annually (Hagan 2005). Playas and old lakebed sites are commonly used as leks as well as other open, flat areas and bluffs. Sage-grouse adults and chicks depend on high quality forage (e.g., forbs) that grows in the playas during the late growing season when upland communities have desiccated. Juvenile chicks also rely on invertebrates, especially insects such as ants and beetles. Diverse forb habitat is needed to support the diverse insect populations that provide high-quality food sources. Shifting hydrologic patterns due to playa excavation may be contributing to a decline in forbs present in playas, and may therefore be decreasing the available food source or the food quality for sage-grouse.

In addition to the sage-grouse, there are many other wildlife species that depend on the playa habitats. Migratory birds such as the long-billed curlew (*Numenius americanus*) and the double-crested cormorant (*Phalacrocorax auritus*) have been observed using the playas in the Prineville District. The playas are located along the Pacific flyway migratory route and could potentially provide areas for nesting, feeding, and resting grounds. In some cases the increased depth of the surface water from playa excavation has attracted different species not historically linked to the playas. Big game such as elk and pronghorn frequent the excavated waterholes. The playas drive the species richness of the high desert by providing islands of biodiversity exploited by a wide range of floral and faunal species with the ability to adapt and respond to the unpredictable playa environment (Haukos and Smith 2003.) Altered playa habitats can affect the species distribution; it is possible that the transformed landscape attracts different bird species and repels others that previously frequented the playas. The altered hydrologic regime in the playa is believed to affect the types of vegetation, aquatic macro-invertebrates and insects in the habitat. These changes affect food sources and nesting needs for birds.

CHAPTER 2. AN ECOLOGICAL ASSESSMENT OF SEASONAL WETLANDS IN CENTRAL OREGON'S HIGH DESERT AND HABITAT IMPROVEMENT STRATEGIES

Introduction

The Prineville BLM, in partnership with Oregon State University and the Oregon Department of Fish and Wildlife developed the Playa Habitat Rehabilitation Project to address concerns over the ecological health of the playas in Central Oregon's high desert. The partnership project examines habitat rehabilitation strategies aimed at benefiting playa vegetation that is favorable to the greater sage-grouse population and other wildlife. Plans for active restoration activities on the playa habitat were preceded by an exhaustive inventory process by the BLM to gather much needed data about the ecology of the playa habitat.

The inventory process primarily focused on the playas assessed in the Ram Lake allotment S & G reports. The main component of the inventory process was conducted using ecological site inventory (ESI) on as many playas in the allotment as time would allow. Additionally, botany, mammal, macro-invertebrate, bird and management status inventories were completed on several playas. Inventory data were collected over three field seasons spanning the years 2006 through 2008.

Ecological Site Inventory

Ecological site inventory allows land managers to break up components of the landscape by vegetation communities into ecological sites. Ecological sites are used to describe variation across a landscape in regard to vegetation; changes in vegetative communities or associations across a landscape roughly indicate a change in ecological site type. Ecological site types are approved for major land resource areas (MLRA) within individual states; each site has an official description and a generalized state and transition model in a database created by the Natural Resource Conservation Service (NRCS). Sites are approved for a specific location based on observation and description of an ecological site within a MLRA. The official NRCS ecological site description (ESD) describes the potential natural community (PNC) for a site. The PNC is developed based on information about historic pre-settlement vegetation, current and historical disturbance regimes. PNCs are described by the percent composition of plant community assemblages and species dominance; variability in vegetative expression and site productivity is considered when the PNCs are developed for a site. Two playa ecological sites of interest in the inventory process are Ponded Clay and Lakebed sites.

Ponded Clay Ecological Sites

Ponded Clay ecological sites (referenced as Ponded Clay 023XY200OR in the NRCS ESD) occur in lake basins and small depressions in upland areas(See photo in Appendix A.) The annual precipitation range for this site is 20-30.5 cm and these sites experience short duration ponding in the spring from direct precipitation. The soils for this site are poorly drained and have a silt loam to clay surface texture. The reference site identifies the PNC as being dominated by Nevada bluegrass (*Poa nevadensis*), creeping wildrye (*Leymus triticoides)*, and silver sagebrush (*Artemesia cana*). At PNC, the composition by plant form should be: 10% Shrubs, 85% Grasses, and 5% Forbs (NRCS (a) 2005.)

Ponded Clay sites are easily damaged by grazing activity when the soils are wet. Animal or vehicle tracks left in wet soil create deep holes, sometimes exceeding a depth of one foot. These tracks persist after the soil dries in the late spring and early summer. Fine textured soils, as are typical in this site, are very susceptible to compaction when wet. Site impact is minimized in the late summer and early fall when soils are dry. Heavy disturbance causes increase of undesirable grasses, silver sagebrush, creeping wildrye, and povertyweed (*Iva axillaris* Pursh.) With continued disturbance, silver sagebrush has the potential to eventually dominate the site (NRCS(a) 2005.)

Silver sagebrush is an important species in the Ponded Clay ecological site. There are three subspecies of silver sage in the United States; the playa habitat is home to the subspecies bolanderi. Subspecies *bolanderi* is only found in Oregon, Idaho, California, and Nevada (Winward, 2004). *Artemisia cana* ssp. *bolanderi* is able to survive in the Ponded Clay site because, unlike other species of sagebrush, it can withstand over one month of ponding (Winward 2007). Silver sagebrush is unique from other sagebrush types because it is a sprouter and a layerer. When a branch makes contact with the ground it has the potential to root from the stem. The plant can also sprout and reestablish after a disturbance, such as fire or flooding (Winward 2007.)

Silver sagebrush has multiple stems that are generally smaller than one inch in diameter, because of its sprouting characteristic. Silver sagebrush is subject to a black fungus that can kill branches or the whole plant. Susceptibility to the fungal outbreak is a natural occurrence (Winward 2007.) Throughout the ESI process it was common to find a higher decadence level among shrubs in the lower elevations of the playas or closest to the Lakebed ecological site (described below). This is probably due to the variable interval of inundation from year to year. During high water years these areas may stay ponded longer than the time frame that silver sagebrush can survive submerged, resulting in the death of the plant.

Lakebed Ecological Sites

Lakebed ecological sites (referenced as Lakebed 023XY100OR in the NRCS ESD) occur in small to large lake basins that receive moisture from runoff (See photo in Appendix A.) These sites occur in areas that receive 20 to 30.5 cm of annual precipitation. The soils at these sites are generally deep, exhibit very low permeability and have a high water table that restricts rooting depth (NRCS(b) 2005.) In the targeted study area, Lakebed sites were found in playas that held water for the longest duration. These playas were generally larger than the Ponded Clay playas observed in the project area. An outer ring of Ponded Clay vegetation surrounds most of the Lakebed playas observed in the study area, which necessitated that the field technician create two ESI write-ups. Long-duration ponding in the spring and early summer prevents the growth of shrubs on the Lakebed playa. Silver sage is not seen in these playa sites except in the outer rings of Ponded Clay vegetation.

The Lakebed reference site identifies the PNC as being dominated by spikerush (*Eleocharis R. Br*.), baltic rush (*Juncus balticus (Syn)*), and dock (*Rumex L*.) Mat muhly (*Muhlenbergia richardsonis*) and squirreltail (*Elymus elymoides ssp. hordeoides*) are common. But, variation in the plant composition is dependent upon the depth and duration of standing water. Similar to the Ponded Clay ecological site, the Lakebed ecological site is vulnerable to disturbance when wet. The ESD claims that lakebed sites are suited to grazing in the late summer and fall as the soil dries and becomes more stable. The suitability was likely identified for low impact and low density grazing; there are an abundance of grasses and forbs at these sites in the summer, but these playas stay moist through much of the summer, remaining sensitive to disturbance. Heavy disturbance on this site causes a decrease in spikerush, mat muhly, and dock. Squirreltail, povertyweed and knotweed (*Polygonum L.*) increase with disturbance (NRCS(b) 2005.) The observed Lakebed and the Ponded Clay plant communities shared several common plant species, especially grasses, but diverged in species composition based on the tolerance of long-term ponding.

Methods

The ESI data collection methods were consistent with the protocols outlined in *Ecological Site Inventory*, BLM Technical Reference 1734-7 (2001.) To conduct an ESI assessment on a playa, an observer visits a site, creates an exhaustive plant species list of all plants found on the site, estimates the foliar cover of each species, converts the cover to pounds of production through set weight units established for each plant species occurring in that area and being examined, then calculates the percent weight composition of each species to the nearest whole number. This data is then compared to the NRCS ESD best correlated to the site visited on the ground; in most cases of this inventory the best-correlated sites were either Ponded Clay or Lakebed. A number of factors are used to determine the best ecological site in addition to the percent weight composition of each plant species including: soil type, climate, elevation, slope, landscape position, and dominant vegetation.

When choosing the appropriate reference ecological site on the ground, the observer looks for plants on their PNC species list for the assumed ecological site type, even if these species are not dominant at the site at the time of the evaluation. The percent weight composition of the plants found on the ground is compared to the values provided in the reference description to determine the condition class, or ecological status, of the site. The resulting value is between zero and 100; zero signifies that the plant composition of the site had nothing in common with the reference, and a score of 100 means that the site contained all the plants in the same proportions as depicted in the reference description on the PNC. Table 1 shows how the numerical ratings are used to determine the condition class, or seral state, of the site. The ESI process equates seral state with a qualitative condition class that uses outdated terminology. If a playa is rated as having a poor condition class, it does not necessarily mean that its ecological health is poor. These qualitative ratings should not be interpreted as such. When referencing ESI condition classes in this document, the terminology concerning seral states (early, middle, late or PNC) was chosen over the terms poor, fair, good or excellent, to avoid connotations of quality.

Table 1. Ecological site inventory (ESI) ratings and their corresponding condition classes and ecological statuses.

Rating	Condition Class	Ecological Status (Seral State)
0-25	Poor	Early
26-50	Fair	Middle
51-75	Good	Late
76-100	Excellent	PNC

When evaluating a site, an ESI technician may determine that more than one ecological site is expressed at a particular playa, or that different sections of a large playa express multiple seral states. In these cases, more than one ESI write up was completed for a playa.

In addition to ESI data collection, several other inventories were completed. After ESI was completed on a site, the field technician recorded any visual observations concerning the management status of the playa. The possible management statuses included: presence of grazing or livestock, presence and location of roads, presence and location of roads, and evidence of recreational activities. Based upon availability of technician expertise, a portion of the playas received wildlife inventories. Non-bat mammal and bird inventories were completed through visual observations. Before conducting ESI on a playa, the trained field technicians approached quietly to avoid disturbance and recorded species and noted evidence of species (i.e. scat.)

Aquatic macro-invertebrate inventories were completed by scientists from the National Aquatic Monitoring Center in the Department of Aquatic, Watershed, & Earth Resources from Utah State University in 30 playas. The playas were chosen based on their ability to hold water during the inventory period. To inventory aquatic macro-invertebrates, a technician waded into the standing water and cast a mesh net for a duration of no less than 15 minutes. Bat inventories were completed in 15 playas. Trained bat field technicians visited the playas at dusk and at night. They identified and recorded bat calls. For each wildlife inventory the species richness was calculated by counting the number of each species observed in a category (i.e. bird, non-bat mammal, bat, aquatic macro-invertebrate.) The species richness was also tallied for the botanical species observed through ESI. Overall species richness for all playas was examined along with individual playa, ecological site and ecological condition species richness. Comparisons were made to see if trends in playa type by ecological site or condition could be identified.

Results and Discussion

The ESI process completed as of 2008 inventoried 79 ecological sites and found that the majority (76 %) of Ponded Clay sites received a mid-seral condition rating and the majority (85%) of Lakebed sites received a late-seral condition rating. These findings may not directly represent the distribution of condition classes of the ecological sites across the entire playa habitat rehabilitation area, but could relay trends. ESI's were completed on far less than half of the known playas in the district. The Prineville District is dotted with several very small playas; ESI was prioritized for playas that covered over 5 acres in size. It is possible that these condition classes are a better representation of seral conditions seen at playas with greater acreage.

Four different ecological sites were observed during the playa inventory process (Table 2.) Lakebed and Ponded Clay ecological sites were the two most common ecological sites observed in the playas in the study area. Analysis of the ESI inventories focused on these two ecological sites because they represent the majority of the playas observed in the Prineville BLM District. The Ponded Clay and Lakebed ecological sites are wetland sites, while the Dry Lakebed 10-12 PZ and Pumice Claypan 9-12 PZ sites are upland sites that do not support wetland vegetation; therefore, management of these sites is incorporated with the management of the surrounding upland area and out of the scope of the playa habitat rehabilitation project. However, it is important to note that these two upland ecological sites temporarily hold limited amounts of water and are likely important to wildlife species.

Table 2. Ecological status (determined through ESI) observed at various playa types and the number of playa types observed during the playa inventory period.

Playa Type (Ecological Site)	Number Of ESI Ratings Designated To Ecological Status				Total # of playas seen at each ecological site
	PNC	Late	Middle	Early	
Ponded Clay	0	12	48	3	63
Lakebed	0	11	0	2	13
Dry Lake 10-12 PZ	0	0	2	0	2
Pumice Clay Pan 10-12 PZ	0	0	1	0	1
				Total	**79**

Fewer Lakebed sites were inventoried than Ponded Clay sites, so it is difficult to make comparisons about the condition classes between the two ecological sites. However, based on local knowledge and satellite imagery, it appears that there are many more Ponded Clay sites than Lakebed sites in the Prineville District and some generalizations about the playa types can be made. Ponded Clay sites tend to be drier and therefore support a greater variety of shrubs. Also, due to the highly variable seasonal soil moisture in Ponded Clay sites, a larger number of taxa were observed throughout the field season, with especially high species richness in forbs (Figure 5.) But comparisons of species richness across ecological sites may not be appropriate for interpretation due to the uneven sample sizes and temporally variable sampling times. With more frequent sampling of the ecological sites inventoried, the relative species richness could change drastically.

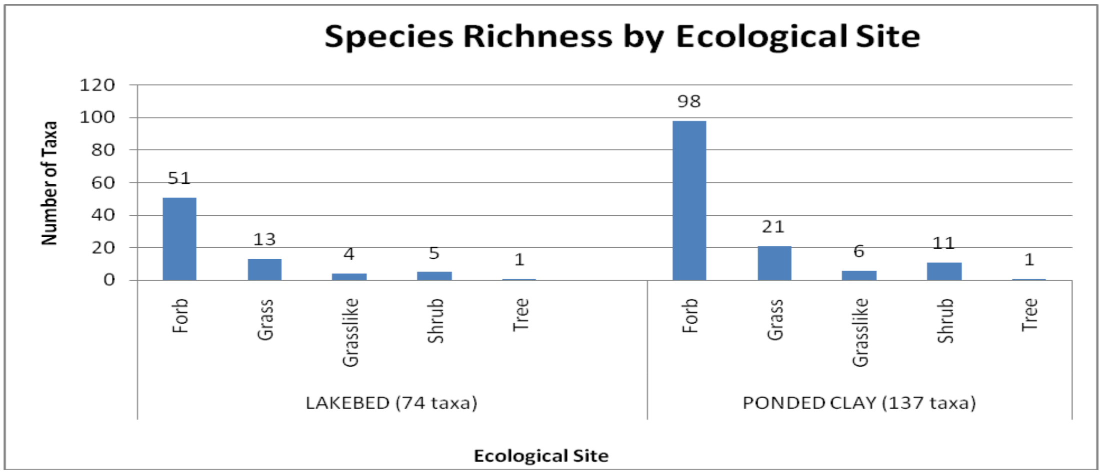

Figure 5. Vegetative species richness in two ecological sites observed in playas on the Prineville BLM District. (Lakebed n=13, Ponded Clay n=63)

Based on vegetative trends identified in the state and transition models described in the ESDs, it is possible that the seral state of a playa affects the species richness observed in a playa. During the BLM's inventory process, plant species richness was recorded at each playa by totaling the number of plant species seen at each site visited. The data show that in Ponded Clay sites, mid-seral conditions express the greatest species richness out of the three seral states observed (Figure 6). In Lakebed sites, the data show the highest species richness in late-seral playas (Figure 7). However, in both cases the data may not be an accurate representation of the landscape; it could be a product of sampling size. The probability of observing more species in a specific seral state increases with playas visited. The observed seral states may show trends related to species richness and other ecological metrics, but because of the annual and seasonal variability seen in the playas, it is difficult to use this information to characterize the playas across the district. The condition class information is valuable for analyzing a "snapshot in time" and for monitoring a particular playa over time. The condition class rating may not necessarily be useful for habitat restoration or rehabilitation goals. A more appropriate focus for habitat rehabilitation goals may be identifying thresholds of plant species richness, or functional plant groups that are required to meet targeted wildlife needs at particular playa types.

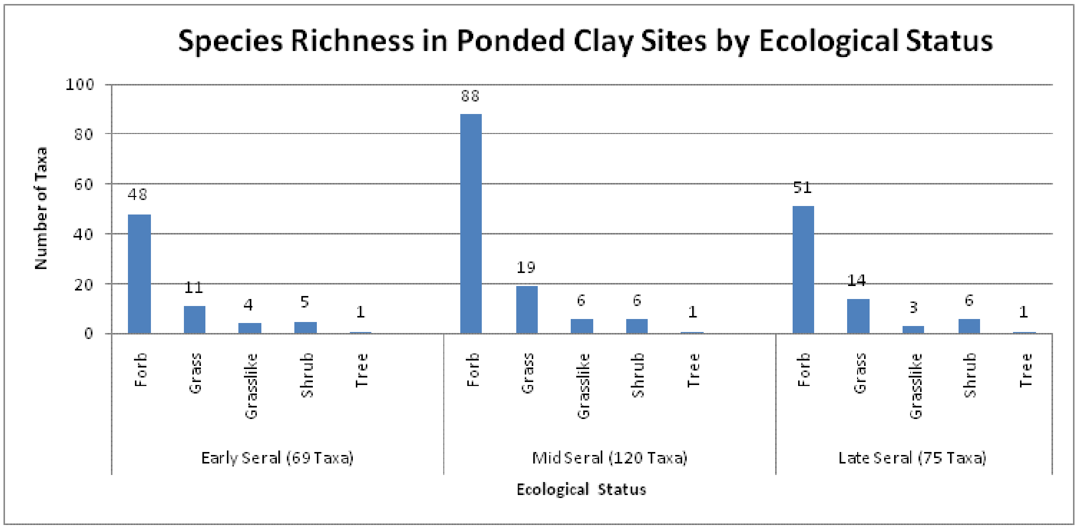

Figure 6. Vegetative species richness by ecological status of observed playas on the Prinveille BLM District that were rated as ponded clay ecological sites. (Early seral n= 3, mid-Seral n=48, late-Seral n=12, PNC, n=0)

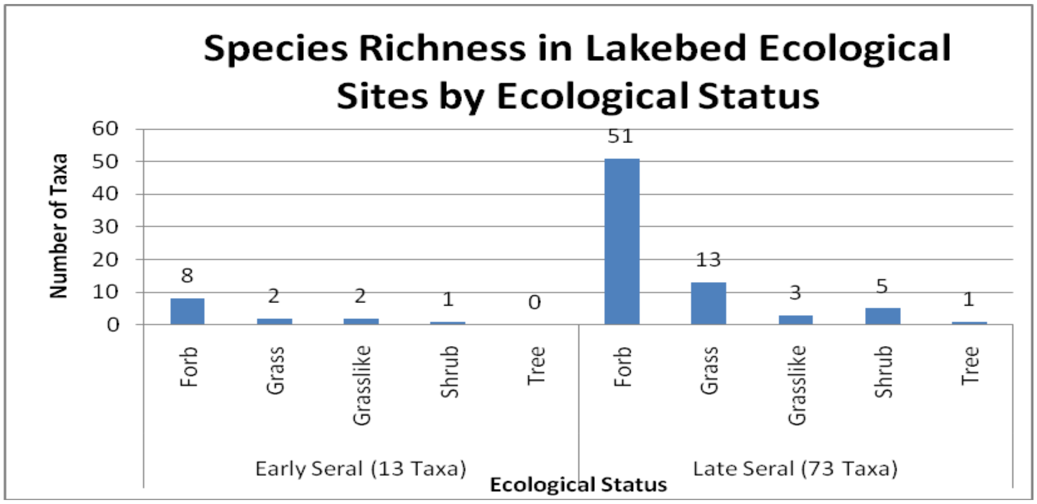

Figure 7. Vegetative species richness by ecological status of observed playas on the Prineville BLM District that rated as Lakebed ecological sites. (PNC n=0, late-seral n= 11, early seral n=2. (There were no mid-seral Lakebed playas observed.))

Even though the condition class may not be the most comprehensive characterization of the playa vegetation, it is interesting to note that none of the observed playas rated out to a PNC condition class for its ecological site during the inventory. Several hypotheses were proposed by those working the playa habitat rehabilitation project to describe the lack of playas seen at PNC: (1) long-term grazing has changed the plant communities from how they were described in the ESD, (2) dug-outs in the playas have altered the hydrologic regime and thereby the plant communities, (3) low rainfall inputs during the inventory field season years restricted potential plant growth that only occurs in wetter years, or (4) the PNC's described do not accurately correspond to the playas in the Prineville District because they are unique and do not match a current site description. Regardless of the observed seral state, the inventoried playas express different proportions of plant functional groups than are expressed in the PNC. (Figures 8 and 9.) The Ponded Clay sites show a dramatic shift from grass-dominated vegetation to shrub-dominated vegetation. Shrub encroachment is a ubiquitous concern in the sage-brush steppe, and may be indicative of drier conditions at the playa sites.

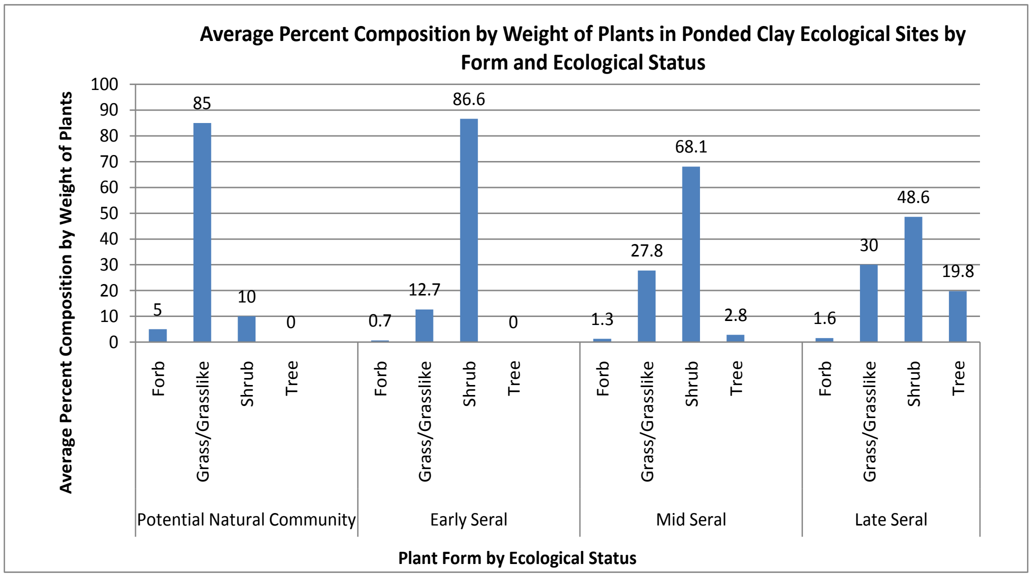

Figure 8. Average percent composition by weight of plants in Ponded Clay sites by form and ecological status. Number of Ponded Clay playas in ecosites. PNC n=0, early- seral n=3, mid-seral n= 48, late-seral n=12.

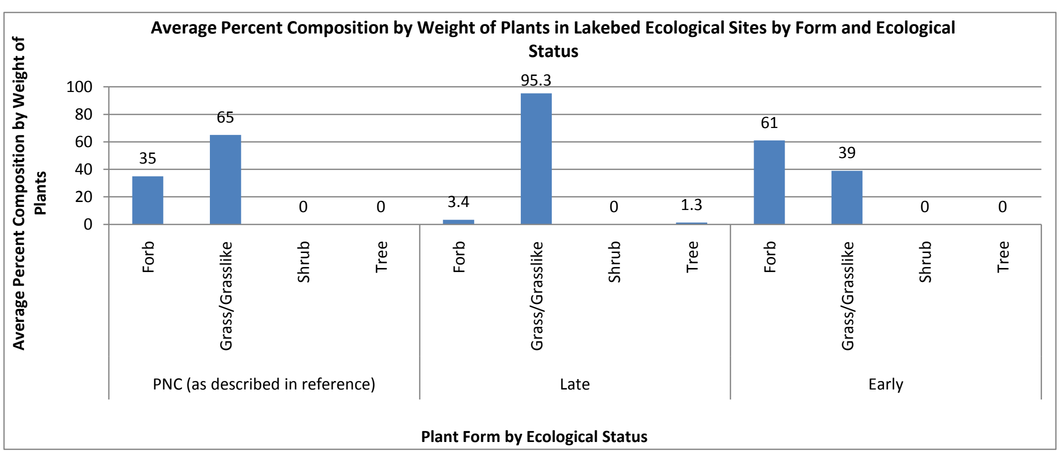

Figure 9. Average percent composition by weight of plants in Lakebed sites by form and ecological status. Number of playas observed in Each seral state: PNC n=0, late seral n=11, early-seral n=2. (There were no mid-seral Lakebed playas observed).

The terminology used in the ESI is no longer aligned with current scientific thought. The BLM uses this outdated method to gather data about rangeland habitats. ESI is not only outdated because of their qualitative assessment of condition class, but also because of their use of seral state terminology. The scientific community no longer describes changes in plant communities along linear successional pathways. Currently scientists talk about changes in ecosystems as changes between states. The states can transition into other states due to disturbance and can oscillate between states. Unlike linear succession, there is no end-point or climax community in the ecological state and transition theory. However, because this is the method of data collection used by the BLM, I analyzed it while being aware of its limitations.

Beyond ESI inventory, field technicians recorded observations of 159 vascular plant species in 70 playas, 51 bird species in 59 playas, 13 non-bat mammal species in 57 playas, 12 bat species in 15 playas and 62 species of aquatic macro-invertebrates in 30 playas (Full species list in Appendix B.) Upon analysis of the aquatic macro-invertebrate inventories, scientists from the National Aquatic Monitoring Center in the Department of Aquatic, Watershed, & Earth Resources from Utah State University documented phenomena of increased taxa observation with increased time spent at a particular playa and with increased sampling from additional playas (Vinson 2007). They found taxa rarity to be high, indicating that the observed number of species was likely much lower than the actual number of species present. The macro-invertebrate observations concerning species richness have the potential to be analogous to other plant and wildlife observations in the playas. The completed inventories show just a small portion of the diversity across a vast landscape with hundreds more playas. Since only a small portion of the playas were inventoried, it is possible that only a small amount of the diversity was documented. Because of the variation among playas, biodiversity in the high desert is not related to species richness of individual playas, but rather the cumulative richness associated with playas across the landscape. Therefore, because of the extensive alteration of playas and their associated watersheds, we may never completely understand the role of playas in the disappearing grassland ecosystems. (Haukos and Smith 2003.)

Current and Future Directions: BLM Habitat Rehabilitation Strategies

In an effort to test whether or not the dug-outs in playas are contributing to a decline in water availability for vegetation, some playas were identified for rehabilitation activities. The playas selected for these activities were chosen based on their proximity to sage-grouse leks and lack of conflict with livestock watering needs. In October and November of 2008 two dug-out playas were filled in with the soil berm piled to the side of the playa. A back-hoe moved the soil into the excavated area and graded the earth to create a shallow-bowl shape. Over time, the playas will be monitored to see if filling in the playas has restored the hydrologic function that is believed to have been altered by the presence of the dug-out. With the intended return of the unaltered hydrologic regime, the playa should be able to support vegetation that is desirable to the sage-grouse. A five-acre exclusion fence was built on the playas that were filled in. The exclosures cover half of the reclaimed area, a portion of the playa surrounding the reclaimed area, and a small piece of uplands adjacent to the playa. These areas have been fenced to exclude livestock activity in the reclaimed area to minimize disturbance during a sensitive recovery time. The fences installed exclude cattle, but allow wildlife through. Half of the reclaimed area was left unfenced to provide a comparison of playa recovery with and without livestock grazing.

In another effort to enhance water availability to the playas and benefit a variety of wildlife species, cutting and thinning of young juniper has occurred on the landscapes surrounding some of the targeted playas. Western juniper (*Juniperus occidentalis*) is native to Central Oregon's high desert. In arid and semi-arid lands, its population has expanded rapidly throughout the last century (Miller and Wigand 1994.) The expansion is attributed to anthropogenic activities such as fire suppression and over-grazing that began after European settlement in the late 1800's (Miller and Tausch 2001.) Increased western juniper density and extent across the high desert negatively affects plant communities through restricting understory growth (Miller and Wigand 1994) and by altering the water balance within the plant communities (Owens 2008.) A paired watershed study in Central Oregon looking at the effects of thinning young juniper found that more water is available in the system when trees are thinned, making it available as increased soil moisture, ground water, and/or spring flow (Deboodt et al., 2009). Based on this research, it is expected that increased water availability from juniper cutting and thinning projects will be available to remaining shrub-steppe vegetation and associated playas. An increase in available water for playas could extend the duration of ponding, extending the duration of forage availability for sage-grouse and other wildlife. Two 1000-acre juniper cuts for the Playa Habitat Rehabilitation Project were completed in 2009. The playas chosen for the cutting activity were playas with heavy juniper encroachment and documentation of sage-grouse use.

The active rehabilitation techniques are experimental and continued monitoring is necessary to determine the results of these activities. The BLM has plans to continue these rehabilitation activities into the future. However, it is important to note that even if large-scale active rehabilitation is successful, it may not be feasible to conduct these activities across the entire playa habitat. Many altered playas are in very remote locations that are difficult to get to. Additionally, many playas are actively used by ranchers for livestock watering; limiting or revoking that use could potentially cause conflict. After implementation of these rehabilitation techniques, time should be taken to see if they are effective in restoring the hydrology and in turn supporting sensitive species of interest before any long-term decisions are made.

CHAPTER 3. MONITORING REHABILITATION ACTIVITIES WITH ELECTROMAGNETIC INDUCTION

Introduction

Electromagnetic induction (EMI) has been used to map a variety of subsurface soil physical properties that correlate with EMI measurements (e.g., salinity, moisture, and clay contents.) EMI is a tool that can be used to collect data to monitor subsurface conditions that can provide information about hydrologic patterns (Nogues et al. 2006.) Water moves through soil by gravitational and matric forces, however, it is difficult to get a clear picture of how water moves below the surface over time without exhaustive information about soil physical conditions. Some methods to understand subsurface water movement involve leaving equipment sensors in place to monitor water over time or require using expensive dyes or tracers (Robinson et al. 2009.) Electromagnetic induction is a noninvasive, portable method that can take measurements instantaneously in the field. Because of the remote geographic locations of many of the playas, EMI is a practical tool; frequent visits to the field sites to check monitoring equipment was not practical.

Originally, EMI techniques were developed for oil and well exploration. In the late 1970's EMI practices were used to examine agricultural fields for salinity concentrations. EMI has also been used to find buried utilities, leakage from buried pipes (Lee et al. 2006) and to map the subsurface movement of agrochemicals (Yoder et al. 2001.) More recently, hydrologists have used EMI to delineate watershed boundaries and to identify subsurface hydrological spatial patterns (Abdu et al. 2008.) EMI readings are sensitive to soluble salts. In the playas, EMI readings of the subsurface concentration of soluble salts in a specific location can be used as an indirect measurement indicating a relative degree of saturation for that location.

EMI uses electromagnetic energy to measure the near-surface (1-m depth) apparent conductivity of the soil substrate (EC_a) (Lee et al. 2006.) EC_a values are a proxy for subsurface physical properties and are defined as the ratio between current density and electrical field with a unit of millisiemens per meter (mSm^{-1}) (Abdu et al. 2008.) The EM device can measure more than one depth at once depending on the orientation of the coils with respect to the ground. A transmitting coil in one end of the EMI meter creates a primary magnetic field. This field creates current loops in the ground. The current loops induce a secondary magnetic field. This induced magnetic field is superimposed on the primary magnetic field and measured in a receiving coil at the other end of the instrument. The measured response is a function of ground conductivity, and is linear under conditions of low induction numbers (Nogues et al. 2006.). The EMI meter records values of EC_a as it is manually passed over the soil surface. The values of EC_a vary due to changes in soluble salts, water content and clay contents. Some conductivity meters can sync with a GPS unit and the EC_a data can be spatially referenced instantaneously. Geo-referenced data collected from EMI can be transformed into map imagery that can be used to assess site conditions. EMI information was collected as a hydrological monitoring tool on two playas before and after habitat improvement activities were conducted to determine the effectiveness of filling in the excavated playas.

In the arid climates typical of these playas, EC_a readings are interpreted as identifying the concentration of soluble salts in the soil, which serve as a proxy for seasonal hydrological patterns. Soluble salts remain in solution until water evaporates from the system and the salts become stationary. Greater amounts of salt are concentrated where water remains for the longest period of time. Undisturbed playas are expected to have various low points of water collection and drier high points. Altered or dug-out playas are expected to have one very deep low point that holds all the water. EC_a readings reflect the changes in the concentration of soluble salts. If rehabilitation of the hydrologic regime in the playas is successful, water is expected to behave as it does in the undisturbed playas.

Materials and Methods

Electrical conductivity data was collected on two separate occasions on two playas referenced as playa #295 and Ram Lake NE. The first series of data collection occurred on two dug-out playas in September of 2008. In October of 2008 the two playas were filled in with soil as a habitat improvement strategy; a five-acre fence was installed on each playa to reduce livestock impacts. The second series of data collection occurred on the same 2 playas in November of 2009.

Due to equipment availability, two different conductivity units were used to collect data. In 2008 the EM-38 was used and in 2009 the EM-31 was used. Both units measure apparent conductivity in millisiemens per meter (mS/m) and the in-phase ratio of the secondary to primary magnetic field in parts per thousand (ppt). Both instruments have measurement resolution of ± 0.1 % of full scale, but the EM-38 has a measurement accuracy of ± 5 % at 30 mS/m and the EM-31 has a measurement accuracy of ± 5% at 20 mS/m. The most pronounced difference between the models is that the EM-38 is newer, has increased portability and can be connected to a GPS unit. Data collected from the EM-31 had to be recorded by hand or with a data logger. Each EM unit generated data output for a "deep" reading (up to 1 meter under the soil) and a "shallow" reading (up to .5 meter under the soil.)

In 2008, EMI data collection was completed with the use of a Trimble GPS unit that was connected to the EM-38. Data was collected at over 1,000 GPS points throughout each playa. To collect data, the EM-38 was traversed across the area of interest while holding the unit evenly one-half meter above the soil surface. When data collection was completed at each playa, the geo-referenced in-phase and EC_a data at both depths were automatically entered into a spreadsheet format by the EM-38's software.

In 2009, EMI data collection was completed with the EM-31 in concert with a hand-held Trimble GPS unit. Each GPS point was differentially corrected. Because the EM-31 was not synched to the GPS unit, data logging was done manually. At each playa, a grid was flagged across the filled-in and re-graded portion of the playa. The flags were placed at 6-meter intervals. At each flag in-phase and EC_a data at 50-cm and 1-m depths were logged in a notebook and a GPS coordinate was recorded. The EM-31 was placed on the ground to take the readings. Data was collected at fewer than 150 GPS points in each playa. The data was manually entered into a spreadsheet format upon return from the field.

The data points were entered into ArcGIS. To create map imagery showing the distribution of EC_a values across the playas, the inverse distance weighted function in the spatial analyst tools was used to interpolate the readings between point values. A linear relationship was assumed for this analysis process over a polynomial relationship. Because EC_a is collected as a linear measurement, it was assumed that the data have a linear relationship to each other. Due to gradual drying and short-duration ponding that observed in the playas, a linear relationship between soluble salt concentrations was appropriate. When presenting the data in map imagery, the 2009 data-collection grid was included in the maps for both years to serve as a reference for comparisons between the two playas over the time.

Results and Discussion

In both years of data collection there was no standing water in either of the playas. In both dug-out playas measured in 2008 (playa #295 and Ram Lake NE), the EC_a is highest for both the deep and shallow readings in the excavated part of the playa, with small amounts of variation in the surrounding playa area (Figures 10 and 11.) This signifies that most of the playa water collects in the excavated area and this low-point remains wet for the longest period of time throughout the season. EMI data collected in November of 2009 shows that water appears to be distributed differently across the playas than it was in 2008. From initial visual observations of the EC_a data, the water appears to be distributed across the playa in greater extent post rehabilitation.

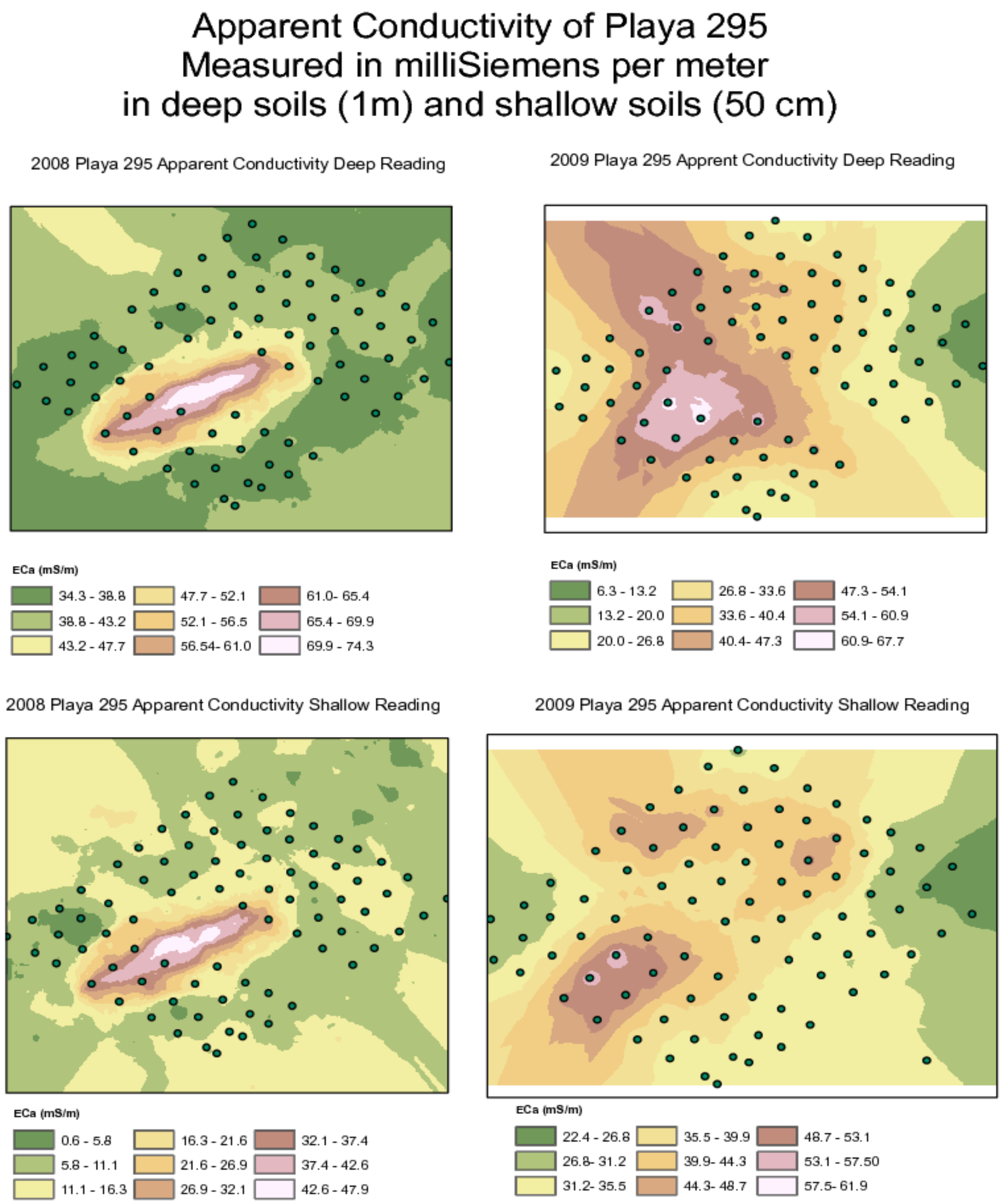

Figure 10. Apparent conductivity (EC_a) readings in milliSiemens per meter (mS/m) from EMI on playa # 295 in the year 2008, before rehabilitation activities and in 2009 after rehabilitation activities. In each year, EC_a readings were taken at a shallow depth of 50cm and a deep level of 1 meter. The dots represent sampling points from 2009 and are displayed in all images for reference purposes.

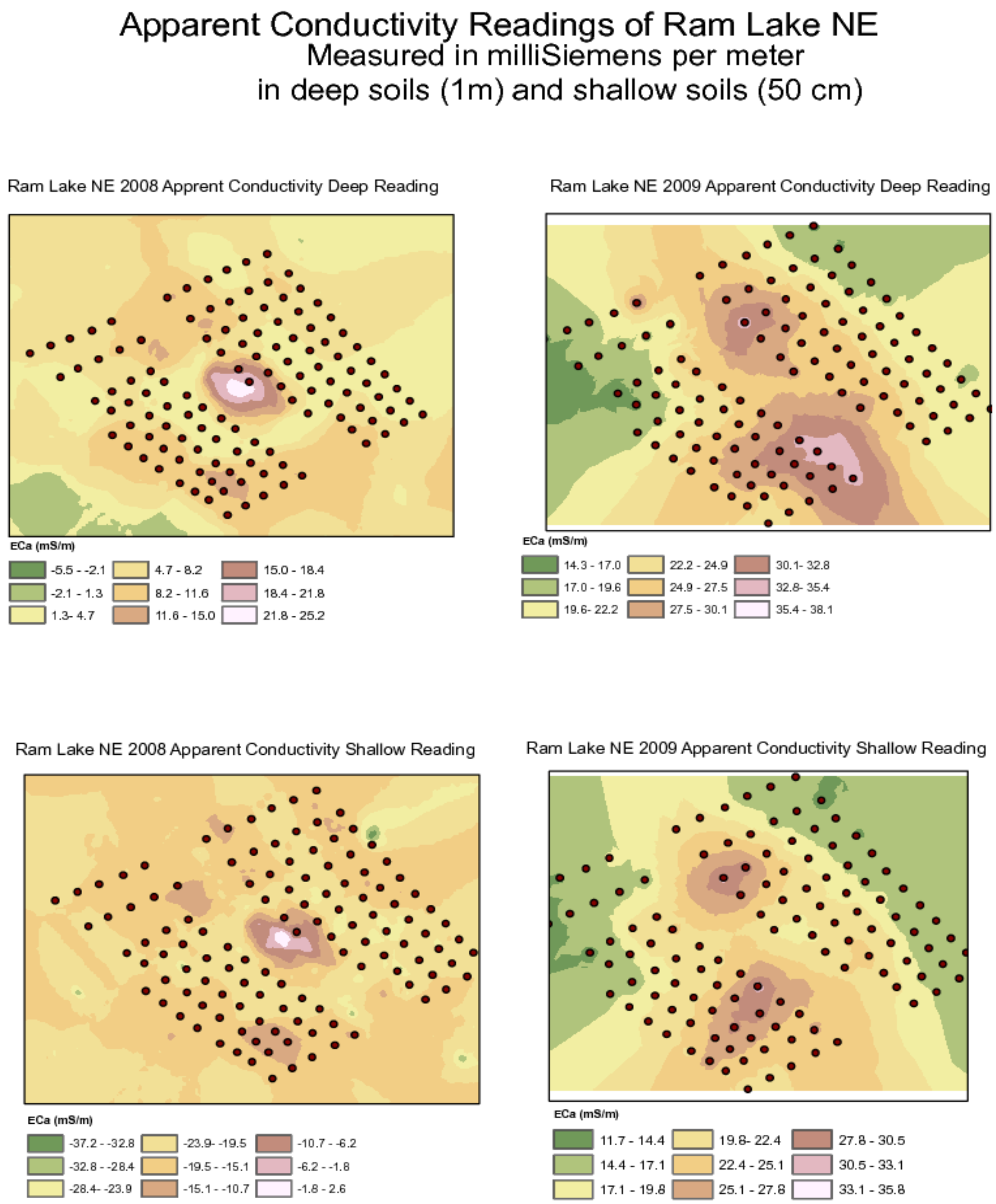

Figure 11. Apparent conductivity (EC_a) readings in milliSiemens per meter (mS/m) from EMI on Ram Lake NE playa in the year 2008, before rehabilitation activities and in 2009 after rehabilitation activities. In each year, EC_a readings were taken at a shallow depth of 50cm and a deep level of 1 meter. The dots represent sampling points from 2009 and are displayed in all images for reference purposes.

The data gathered from both years was compared to see if the rehabilitation activities have had any immediate effects on the distribution of water across the playa areas. Observing a more evenly distributed salt concentration in the soil subsurface instead of a central concentration point would be identified as an achievement for this rehabilitation activity. Shifting patterns in ECa data, or soluble salt concentrations, were examined to interpret the presence of changes to hydrologic activity in the playa over time. Through this preliminary analysis, it appears that ECa data shows that the hydrologic pattern has changed. The concentric circles of different ECa values radiating from the playa center seen in the 2008 data seem to be wider and more irregular in the 2009 data, perhaps suggesting a more gradual drying process. It is possible that a more gradual drying process will affect the vegetation growth and type in the playa.

When comparing a playa between the two years of data collection in Figures 10 and 11, the absolute EC_a values are not comparable, only the observable spatial patterns are comparable. EC_a values can spike rapidly due to precipitation and be greatly affected by soil moisture, which was not recorded in this study. It is impossible to control for moisture conditions at the site. When future EMI data is collected on the playas, it is recommended that soil samples are measured for moisture content so that a reference of the current conditions is available.

In 2009 a fence line was constructed through the center of the filled-in playas as part of the rehabilitation efforts. The presence of the metal fence greatly skewed the EM readings in some locations by causing interference in the apparent conductivity readings. Any data point that was recorded within 6 meters of the fence line was removed from the analysis. The data points adjacent to the fences were generally recorded as having 4 to 10 times the EC_a value as other data points. Because there were fewer data points taken in 2009 due to the equipment type and because of the omission of points due to fence interference, it was difficult to get high quality information about the EC_a reading in the center of the filled-in playas. Additionally, with so few data points taken in 2009, the interpolation between the points is not as refined as the interpolation between the points collected in 2008.

The comparison between the two years of data collection is intended to serve as an initial look only. The two sites have unequal data quality because in 2008 there were many more data points from which to interpolate the imagery in Figures 10 and 11 than in 2009, so inferences may not be appropriate. From the images created through the interpolated data, it appears that in 2009, post rehabilitation activities, soluble salts are concentrating in more than one area unlike the images from 2008, indicating a change in hydrologic distribution. It is important to note that the "shallow surface" of the playa from 2008, and likely the "deep surface" represent different soil than in 2009; the dugout area is now under a few meters of soil that was placed there from the berm. Differences in how water moves through the soil observed between the data collection years may be attributed to different-textured surface soil. The difference may affect soil physical characteristics.

Conclusion

After intensive earth-moving activities were conducted on these playas it is reasonable to observe a novel drainage pattern in the playa area. However, the drainage patterns may continue to change and adjust over time due to changes in soil composition or settling. A more descriptive representation of changes in the playa's hydrology will likely be seen over several years of EMI monitoring. In combination with other monitoring practices such as vegetation surveys, the EC_a data can be used to assess the viability of this ecosystem rehabilitation practice. The noninvasive nature of EMI is beneficial for monitoring the rehabilitation of these playas and could be useful in future research to continue monitoring practices and to delineate the extent of relict playas that may have been lost due to agriculture or development.

CHAPTER 4. DOES ASH CONCENTRATION CORRELATE WITH PLAYA CHARACTERISTICS?

Introduction

The playas on the Prineville BLM District generally express an observable trend in size, vegetative characteristics and relative amounts of surface water across a directional gradient. The playas in the northern end of the district tend to be smaller, more likely to express the vegetation of a Ponded Clay ecological site, and tend to be drier earlier in the season. The playas in the southern end of the district and over the southern border of the district onto the Lakeview BLM District generally tend to be larger, express vegetation of Lakebed ecological sites, and to hold larger amounts of water later into the season.

Soils derived from volcanic ash are light and porous and tend to accumulate organic matter rapidly which can contribute to increased soil fertility. Volcanic ash deposits can increase the water holding capacity in soils due to their high porosity and mineralogy. Generally, volcanic ash weathers rapidly into clay-size minerals that form strong bonds with humus (Brady and Weil 2008.) The influence of ash concentration on soils in the playa habitat area may explain the changes in playa characteristics over the directional gradient.

Newberry Crater and Mt Mazama (Crater Lake) are located to the south and west of the playas in the Prineville District. Both of these volcanoes have been active in recent geologic time and are considered to be the prominent ash sources for the soils in the Prineville BLM district. From aerial photo observations and from playa site visits, the playas in closest proximity to the ash sources appear to hold greater quantities of water for a longer period of time. Due to the increased water holding capacity, vegetative growth continues later into the summer. The perceived playa productivity increase across a directional gradient could be a function of the distance of the playa from the source of volcanic ash. I questioned whether increased ash concentration was correlated with increased playa productivity. To investigate the presence of a link between ash concentration and playa type or productivity, soil samples were collected from playas along a directional transect and examined for qualitative differences in the amount of ash concentration in the playas.

Methods

Five playas were selected from aerial photos along a north-south transect of nearly 30 km in length. The transect bisected a section of the Prineville BLM District with a high density of playas. Playas did not fall exactly on the transect line, but were chosen based on their proximity to the transect. The three northern sampling sites were inventoried as Ponded Clay ecological sites and the two southern sites were inventoried as Lakebed ecological sites (Figure 12.) Two of the three Ponded Clay sites were altered. The Lakebed sites were larger than the other Ponded Clay playas and were both holding water in their dug-outs. The Ponded Clay sites were smaller than the Lakebed playas and were not holding any water.

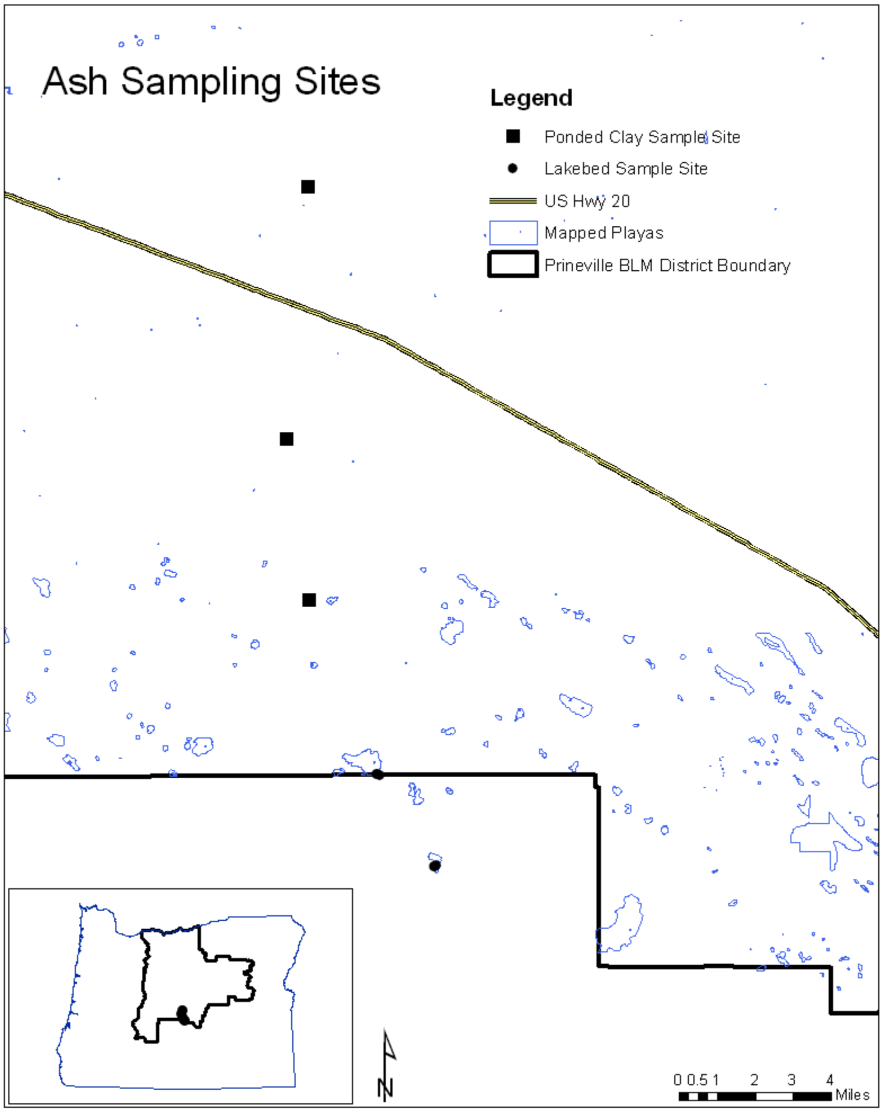

Figure 12. Ash Sample locations in the Prineville BLM District sites along a 30-km transect. The three northern sites are Ponded Clay playas and the two southern sites are Lakebed playas.

At each of the 5 sampling sites several soil samples were taken at various locations and depths. Within each playa, samples were taken from three locations identified as locations a, b and c. The playa center, which is devoid of vegetation, was labeled location a. Location b included the transition between bare ground and vegetation; "b" was referred to as the vegetation edge. Location c was referred to as the topographic edge; "c" was the visible transition from the flat or gently sloping playa interior to the surrounding upland. At each location (a, b, or c) in the playa an auger was used to examine the soil profile (Appendix C.) We observed changes in color and texture in the profile and identified soil horizons at each location. Using a hammer-driven soil probe, we took a soil sample from each horizon we observed up to a depth of 2 meters. There were a total of 69 individual soil samples from the 5 playas.

Each soil sample was examined in the laboratory for relative ash content. Each sample received a qualitative assessment rating; the assessment ratings used for ash content were: very high, high, medium, low, trace and none. To determine the qualitative amount of ash material in a sample, a pinch of soil was placed on a glass microscope slide with 1 drop of benzyl benzoate. The slide was viewed under a polarizing microscope and a qualitative judgment was made concerning the relative ash content.

Benzyl benzoate is an oil with a high refractive index (1.56.) Volcanic glass (ash) has a refractive index of 1.499 to 1.501. Because benzyl benzoate has a higher refractive index than volcanic glass, a shadow effect is created and the grain stands out in the oil (Bloss 1961.) The benzyl benzoate also allows light to pass through the volcanic glass if organic matter coatings are present, making identification possible. The refractive indices of quartz and feldspar are much closer to that of the oil, so the shadowed relief is not apparent with other mineral grains seen in the samples.

Each soil sample was examined individually for a qualitative assessment and for comparisons between samples. Of special interest were differences between the relative ash amounts in the northernmost Ponded Clay playa and the southernmost Lakebed playa. Additionally, a comparison between samples from location "a" across all the playas was of interest. We questioned whether a higher concentration of ash would be found in the center of the playas associated with longer-duration ponding.

Results and Discussion

There were no discernable differences in relative ash concentration between soil samples. Every sample was assessed as having very-high ash content. There were no observable changes in ash content between soil depths, locations within the playas, or between playas. These findings do not support our idea that ash content in soil may drive physical characteristics of the playas. It is possible that the type of ash may have influenced playa characteristics, but that was beyond the scope of this investigation. However, the geologic landscape may still explain some of the differences in the playa characteristics; the Brothers Fault Zone trends from northwest to southeast and runs through the densest playa habitat on Prineville BLM District. It is possible that the fault zone has an effect on the shape and size of the playas through topographic influence on the landscape.

Although the results did not show any differences between ash concentration within the soil on the five playas, it is possible that differences were too subtle to perceive. By increasing the scope of this study to include playas along a longer north-south transect and by including an east-west transect of similar length, differences in ash concentration, if they exist, may be more apparent. A more advanced process of examining the soil samples for ash concentration that is less qualitative and more quantitative may give more insight into the influence of ash concentration on playa characteristics.

Conclusion

Whether the proximity of ash sources influences playa characteristics is unknown. The southern playas that exhibit longer duration ponding and more abundant vegetation differ greatly from the northern playas. There are numerous other factors that could be affecting these differences, such as microclimatic influences, geography or soil properties that affect water holding capacity or fertility. Because so many species rely on the playas in Central Oregon, understanding how the playas function and retain water can assist land managers in conservation and rehabilitation activities.

CHAPTER 5. DEVELOPMENT OF A FIELD BOOK FOR PLAYA CHARACTERIZATION

Justification of Field Book Need

When the Prineville BLM inventoried playas on the Ram Lake Allotment, they documented a failure of the playas to meet the standards and guidelines for rangeland health. The BLM attributed the failure to the effects of long-term grazing and to modification of the playas. In recognition of the failure to meet the standards and guidelines, the BLM, in partnership with ODFW and Oregon State University, worked on creating objectives to rehabilitate playa habitat across the district. However, the lack of baseline information about the playa habitat proved to be a hindrance toward developing or implementing rehabilitation goals. To better understand the effects of the stresses on the system, a better understanding of the system as a whole is necessary. In literature referring to the playas in Central Oregon, a common theme converges on the fact that little is known about the role of the seasonal pools in the greater ecosystem. It is certain that they are an important source of water for a myriad of wildlife and vegetation, and that they are critical for the success of the livestock grazing on rangelands.

The Bureau of Land Management has taken an active role in initiating the process of gathering information about the playa habitat through vegetation, wildlife and management surveys. The vegetation surveys completed through the NRCS ESI format yield a description of the ecological site of an observed playa and the site's current condition or seral state. This inventory process is useful for categorizing the various types of ecological sites observed in playas on the district and for describing their apparent seral state. The categorization of the playas has the potential to allow land managers to see broad similarities and differences across playa types and to eventually lead to a better understanding of the characteristics of playas. However, the inventory is only able to relay information about a snapshot in time and due to the high seasonal and yearly variability documented in the playas, the ESI data may not always represent an accurate characterization of the seral state of the playas. The ESI system compares how similar the site on the ground is to an idealized climax community. The climax communities described by the NRCS may not serve as an exact analog to the playas in Central Oregon, especially because they are based on historic pre-settlement vegetation. ESI data is useful for characterizing and documenting the conditions of the playas. However, using ESI data to focus rehabilitation goals on driving vegetative plant communities towards an upwardly successional pathway to the potential climax plant communities described for the ecological sites may not be successful, possible or result in desirable outcomes.

When Prineville BLM field technicians completed ESI on a particular playa, they recorded any evidence of the types of current land use on the playas, namely roads, livestock grazing, fencing and recreation. Soil descriptions were completed on many of the playas using the *NRCS Field Book for Describing and Sampling Soils Version 2.0.* Many of the playas received bird, mammal and macro-invertebrate inventories that tallied the number and type of species observed, or in some cases, evidence of a particular species using the playa. The NRCS manuals for ESI and for describing soils give field technicians the ability to collect information that the scientific community and land managers have deemed important and to record it in a manner that allows it to be easily entered into a database and/or characterized. The wildlife and management information collected without official data recording systems was useful for an initial glance at the playa habitat, but was often not detailed enough to be useful for analysis or database entry due to the type and manner in which the data were collected. Although vital to a preliminary characterization of the playas, the initial field collection data lacked consistency and methodical repetition. A standardized process of describing playa characteristics will increase the utility of the data and drive the type of information gathered at the sites.

An approach to achieving the goal of methodical data collection across Central Oregon's playas is to propose the creation and use of a field manual to characterize playas. The proposed manual would describe how to systematically collect information on these features and would allow the user to record data in a useful manner that can later be entered into a playa database. The information in the database would be used by land and wildlife managers to answer a variety of questions concerning subjects such as: the perceived sensitivity of a site for livestock grazing, the relative importance of a playa to various wildlife species, and whether or not the site is appropriate for livestock troughs or wind turbines.

The proposed field manual is intended to be used in concert with the NRCS Field Book for Describing and Sampling Soils and the ESI vegetation monitoring system. The combination of these three data gathering techniques can be used to amass the baseline data much needed for understanding the seasonal pools in Central Oregon and to gather baseline information to be used for long-term and near-term monitoring, planning and land management directives. The process of inventorying each playa for several different ecological aspects is arduous and may be limited due to costs, training and labor. However, a process to collect more in-depth data about the playas beyond apparent vegetation and soils may be useful for the long-term study of these areas, especially for habitat rehabilitation goals. With more detailed information collected at the sites, connections and associations can be made concerning the effects of dug-outs, recreation, wildlife usage, and water availability.

In California, a field manual was proposed for describing vernal pool features in the Central Valley that is now used by the NRCS. The premise of the data collection system was based on the idea that the location of pools can be correlated with specific soils, geologic formations and landforms, and that these soil-geomorphic relationships provide a hierarchical framework for classification and identification of vernal pools in CA (Smith and Verrill 1998). Smith and Verrill provide a clear, concise and persuasive justification for a classification system like the one proposed here in their publication introducing the California manual:

> This system provides a natural physical basis for pool classification that is a framework for understanding modes of landscape origin and geomorphic evolution, relative landform and land surface age, vernal pool hydrologic and chemical characteristics, active landscape and biogeochemical processes, distribution of vernal pools by size and shape, and the landscape density and geographic distribution of vernal pools.
>
> This system allows for a detailed determination of the historical versus present distribution of the pools. Correlation of the microtopographic and hydrologic descriptions in historical soil surveys with the detailed mapping of modern soil surveys would allow for the eventual production of 1:24,000 scale maps of historical vernal pool distribution throughout the Central Valley for comparison with present distribution. This approach also identifies which pool types and landforms are presently most or least abundant.
>
> This system provides a framework for a vernal pool database that will allow for the identification of correlations between vernal pool plant and invertebrate distributions and landform soil characteristics. Such correlations could be used to predict other occurrences of species, best locations for mitigation of habitat loss, and could provide a tool for conservation planning.
>
> This system provides an increasingly specific screening tooling to identify potential vernal pool landscapes, and a basis for both site-specific evaluation and comprehensive planning of vernal pool preserves and mitigation banks that will allow preservation and restoration of vernal pool landscapes that approximate their natural diversity and distribution.

The advantages outlined above cover a larger scope than is applicable to the playas in central Oregon. The vernal pools of California occupy a wide range of landforms and are geographically more expansive than the playas in Central Oregon. California's pools have faced development pressures not seen in Oregon's playa habitats. The California goals concerning the identification of potential vernal pool habitat are not currently applicable in Central Oregon. But, by using a classification or characterization system similar to the one used in California, it is possible that similarities within Central Oregon, across Oregon and even across states may be observed based on landforms and pool characteristics. Understanding the environmental components that contribute to playa habitat will improve how the playas are understood ecologically and could assist in understanding which types of playas are preferred for specific wildlife species.

A Field Manual for Characterizing Central Oregon's Playas

The hierarchical framework proposed by Smith and Verrill describes the landscape from general to specific in the following order: landforms, geologic formations, soil great groups, soil series, phases of soil series. Smith and Verrill emphasize looking at the hierarchical landscape to find relationships between types of vernal pools and their landscape. Important information pertaining to reference conditions for restoration goals can be inferred through the classification process. Information about the in-tact pools of a specific landscape can be compared with human-modified sites that potentially can provide or have provided the correct conditions for a specific type of vernal pool. The proposed "Field Manual for Describing Central Oregon's Playas" uses aspects of Smith and Verrill's methods for describing vernal pools in the central valley in California and additionally contains sections pertaining to regional concerns in Central Oregon. If the field manual for Oregon's playas is a successful tool, it has the potential to be expanded upon to include ways to characterize seasonal pool features throughout the Pacific Northwest.

The objectives of implementing a new field manual for describing Central Oregon's playas are:

1. To provide a basis for categorizing various types of playas beyond the scope of ecological site inventory. The playas will be categorized based on landform, geographic coordinates, pool size and shape, wildlife usage,

vegetation, extent of alteration, current land use, amount of seasonal water present and duration of ponding.

2. To create a user-friendly categorization process that will provide the data necessary to for a complete playa database. Through the database, relationships between playa characteristics will be revealed or predicted. The database can be used to identify areas of concern and for land management planning.
3. To provide the tools necessary for long-term monitoring. The information gathered and analyzed over time through this system will be able to be used to assess areas that have been targeted for rehabilitation, or that are suspected to be under stress. Individual playas will be able to be monitored for changes over time and how they change in relation to adjacent or similar playas.

The field manual will be divided into major subject areas that relate to sections to be filled out on the official field manual sheet for describing playas (Figure 13.) Each subject area provides descriptive information needed to equip the user to fill out the field sheet. Many of the playas in the Prineville BLM district express more than one ecological site, unlike the ESI write-ups, two separate playa field manual description sheets should not be filled out. Conjoined playas should not be separated into more than one field sheet because it is too difficult to separate wildlife, livestock and recreational usage into sections of a large playa association.

The field manual is comprised of the nine following major sections: introduction to playas in Central Oregon, site description, soils, water, vegetation, alterations, management, wildlife and playa habitat management strategies. A detailed summary and example text from the manual sections is provided in Appendix D. Users of this manual and of the data generated from the collection method will be invited to critique and improve upon the type and quality of the data collected to eventually create an improved version.

Field Data Collection Sheet for Playa Description		
Date:	Weather:	Describer:
NRCS Ecological Site Type:	Latitude: Longitude: Sec: T: R:	Annual PPT:
MLRA#	Topo Quad	Parent Material
Microrelief:	Ponding Present:	Comments Regarding Evidence of Ponding:
Recreation Evidence:		Biological/Physical Crusts:

Dugouts/Alterations/Impacts				Management Conditions		
Water	Depth	Shape	Berm	Roads	Fences	Livestock
Comments and Sketch of Dugout Location:				Additional Comments:		

Vegetation Cover		Miscellaneous Field Notes:	Evidence of Wildlife Presence
	Percent Cover		Sage-grouse
Tree			Other Birds
Shrub			Mammals
Herbaceous			Additional Comments:
Bare Soil			

Figure 13. Sample field data collection sheet for the Field Guide for Characterizing Central Oregon's Playas.

CHAPTER 6. GENERAL CONCLUSIONS AND OBSERVATIONS

Isolated wetlands, like those observed on the Prineville BLM District, are not entirely isolated from other aquatic systems. The playas in Central Oregon's high desert have biotic connections through wildlife usage and as a source of vegetative genetic diversity passed through seed dispersal. The spatial variability in the extent of isolation as well as the temporal variability and variation between specific processes and organisms results in a juxtaposition of isolation and connectivity (Leibowitz and Nadeau 2003.) The complex biotic and abiotic interactions in playas are poorly understood, compared to other wetland systems, creating many challenges in designing and applying rehabilitation and conservation techniques.

Rangeland ecosystems have an extended history of exposure to long-term grazing and human-influenced modifications. These systems are slow to recover from disturbance and are susceptible to invasive species. Rangeland systems are less understood than more inhabitable and less-remote ecosystems. The hydrology of the Northern Great Basin wetlands has not been intensely studied and the overall importance of these geographically isolated wetlands is difficult to quantify. Currently no baseline information exists concerning how to restore or preserve these features.

Land managers frequently have an inclination towards orchestrating restoration activities on the altered playas. We recommend caution and patience with restoration activities. Monitoring the progress of the filled-in playas may give insights about the effectiveness of playa restoration in the future. Immediately, to improve playa health, actions to minimize impact from livestock grazing and motorized recreation can be implemented. Looking into the success of off-site watering troughs may potentially minimize playa over-use by livestock grazing. Thoughtful planning must be involved in rehabilitation activities. Because the playa habitat may have transitioned into a new state, or may be in a state at risk, large-scale engineering activities may not be productive in the rehabilitation of the habitat. Attempts to return systems to within their historical range of biotic and abiotic characteristics and processes may not be possible. Management activities directed at removing undesirable features of a system may perpetuate new undesirable systems. A focus on methods to restore hydrology and functional groups, genetic and species diversity to the habitat may be an approach that yields the greatest success (Seastedt et. al 20008.) This may include filling in the dug-outs, but this can only be determined after long-term monitoring.

Livestock grazing in Central Oregon's high desert has been interwoven in the culture as a part of subsistence and the economy since European settlement in the 1800's. The playas were altered to provide for large-scale livestock grazing, filling them all in, or restricting use on all playas has the potential to negatively impact grazing viability. For a successful habitat rehabilitation effort, a balance between habitat protection and grazing has to be found. Oregon's public land policy dictates that is required to protect sage-grouse habitat, which includes playas. It is up to land managers and ranchers to cooperate in finding methods to provide habitat protection and conservation while still including responsible grazing in the long-term future.

Using the Field Manual for Describing Central Oregon's Playas will engage land managers in the practice of examining and recording playa characteristics and help contribute to our understanding of these unique wetlands systems. There are multitudes of opportunities for continued research on the playas of Central Oregon and the field manual will assist in laying the ground work for any future research. It is not certain how climate change will affect Oregon's high desert, but in the decades to come the weather patterns may change and it has been hypothesized that the frequency and duration of drought conditions will increase. By monitoring the playas now, we will be better equipped to manage the playas for resilience in the face of a changing environment.

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APPENDICES

Appendix A: Playa Photos

Figure 14. Typical Ponded Clay site: presence of silver sagebrush surrounding a small, shallow depression.

Figure 15. Typical Lakebed playa with dug-out activity.

Figure 16. A dry “dug-out” alteration in a Lakebed playa. (Note: ring of silver sagebrush surrounding playa low point.)

Appendix B: Playa Inventory Species Lists

Table 3. Full botanical species list. Complete list of all plant species observed during 2007 ecological site inventory period and their relative frequencies of occurrence in playa features inventoried.

Scientific Name	Family	Common Name	Life Form	Frequency
Elymus elymoides	Poaceae	squirreltail	Grass	97%
Artemisia cana	Asteraceae	silver sagebrush	Shrub	97%
Castilleja sp.	Scrophulariaceae	Indian paintbrush	Forb	91%
Carex douglasii	Cyperaceae	Douglas' sedge	Grasslike	82%
Chrysothamnus viscidiflorus	Asteraceae	yellow rabbitbrush	Shrub	79%
Collinsia parviflora	Scrophulariaceae	maiden blue eyed Mary	Forb	75%
Camissonia tanacetifolia	Onagraceae	tansyleaf evening-primrose	Forb	71%
Eleocharis sp.	Cyperaceae	spikerush	Grasslike	68%
Poa secunda	Poaceae	Sandberg bluegrass	Grass	63%
Muhlenbergia richardsonis	Poaceae	mat muhly	Grass	60%

Juniperus occidentalis	Cupressaceae	western juniper	Tree	51%
Festuca idahoensis	Poaceae	Idaho fescue	Grass	50%
Achillea millefolium	Asteraceae	common yarrow	Forb	47%
Lupinus sp.	Fabaceae	lupine	Forb	43%
Iva axillaris	Asteraceae	povertyweed	Forb	38%
Polyctenium fremontii	Brassicaceae	desert combleaf	Forb	38%
Ceratocephala testiculata	Ranunculaceae	curveseed butterwort	Forb	38%
Poa sp.	Poaceae	bluegrass	Grass	38%
Antennaria sp.	Asteraceae	pussytoes	Forb	34%
Cryptantha sp.	Boraginaceae	cryptantha	Forb	32%
Eriogonum umbellatum	Polygonaceae	sulphur-flower buckwheat	Forb	32%
Microsteris gracilis	Polemoniaceae	Slender phlox	Forb	31%
Erigeron sp.	Asteraceae	fleabane	Forb	28%
Potentilla newberryi	Rosaceae	Newberry's cinquefoil	Forb	28%
Navarretia leucocephala	Polemoniaceae	whitehead navarretia	Forb	26%
Bromus tectorum	Poaceae	cheatgrass	Grass	26%
Koeleria macrantha	Poaceae	prairie Junegrass	Grass	26%
Eriophyllum lanatum	Asteraceae	common woolly sunflower	Forb	25%
Descurainia sp.	Brassicaceae	tansymustard	Forb	22%
Lepidium perfoliatum	Brassicaceae	clasping pepperweed	Forb	22%
Polygonum sp.	Polygonaceae	knotweed	Forb	22%
Leucocrinum montanum	Liliaceae	common starlily	Forb	21%
Epilobium sp.	Onagraceae	willowherb	Forb	21%
Astragalus curvicarpus	Fabaceae	curvepod milkvetch	Forb	19%
Eriogonum ovalifolium	Polygonaceae	cushion buckwheat	Forb	19%
Arnica sp.	Asteraceae	arnica	Forb	18%
Achnatherum thurberianum	Poaceae	Thurber's needlegrass	Grass	18%
Astragalus purshii	Fabaceae	woollypod milkvetch	Forb	16%
Astragalus sp.	Fabaceae	milkvetch	Forb	16%
Phlox longifolia	Polemoniaceae	longleaf phlox	Forb	16%
Lomatium sp.	Apiaceae	desertparsley	Forb	15%
Epilobium minutum	Onagraceae	chaparral willowherb	Forb	15%
Eriogonum sp.	Polygonaceae	buckwheat	Forb	15%
Carex sp.	Cyperaceae	sedge	Grasslike	15%
Crepis sp.	Asteraceae	hawksbeard	Forb	13%
Oenothera sp.	Onagraceae	evening-primrose	Forb	13%

Poa secunda	Poaceae	Sandberg bluegrass (Nevada bluegrass)	Grass	13%
Juncus sp.	Juncaceae	rush	Grasslike	13%
Erigeron poliospermus	Asteraceae	purple cushion fleabane	Forb	12%
Psilocarphus sp.	Asteraceae	woollyheads	Forb	12%
Taraxacum sp.	Asteraceae	dandelion	Forb	12%
Agropyron cristatum	Poaceae	crested wheatgrass	Grass	12%
Taraxacum officinale	Asteraceae	perennial forb	Forb	10%
Cardaria pubescens	Brassicaceae	hairy whitetop	Forb	10%
Artemisia arbuscula	Asteraceae	little sagebrush	Shrub	10%
Psilocarphus brevissimus	Asteraceae	short woollyheads	Forb	9%
Eriastrum sparsiflorum	Polemoniaceae	Great Basin woollystar	Forb	9%
Polemonium micranthum	Polemoniaceae	annual polemonium	Forb	9%
Penstemon sp.	Scrophulariaceae	beardtongue	Forb	9%
Deschampsia danthonioides	Poaceae	annual hairgrass	Grass	9%
Carex rossii	Cyperaceae	Ross' sedge	Grasslike	9%
Artemisia longiloba	Asteraceae	early sagebrush	Shrub	9%
Ericameria nauseosa	Asteraceae	rubber rabbitbrush	Shrub	9%
Agoseris sp.	Asteraceae	agoseris	Forb	7%
Chorispora tenella	Brassicaceae	crossflower	Forb	7%
Rumex sp.	Polygonaceae	dock	Forb	7%
Collinsia rattanii	Scrophulariaceae	sticky blue eyed Mary	Forb	7%
Blepharipappus scaber	Asteraceae	rough eyelashweed	Forb	6%
Erigeron bloomeri	Asteraceae	scabland fleabane	Forb	6%
Plagiobothrys leptocladus	Boraginaceae	finebranched popcornflower	Forb	6%
Draba verna	Brassicaceae	spring draba	Forb	6%
Lepidium sp.	Brassicaceae	pepperweed	Forb	6%
Holosteum umbellatum	Caryophyllaceae	jagged chickweed	Forb	6%
Phlox hoodii	Polemoniaceae	musk phlox	Forb	6%
Phlox sp.	Polemoniaceae	phlox	Forb	6%
Ranunculus aquatilis	Ranunculaceae	whitewater crowfoot	Forb	6%
Leymus triticoides	Poaceae	beardless wildrye	Grass	6%
Muhlenbergia asperifolia	Poaceae	scratchgrass	Grass	6%
Artemisia tridentata	Asteraceae	mountain big sagebrush	Shrub	6%
Myosotis stricta	Boraginaceae	strict forget-me-not	Forb	4%
Arabis sp.	Brassicaceae	rockcress	Forb	4%
Descurainia sophia	Brassicaceae	herb sophia	Forb	4%

Downingia bacigalupii	Campanulaceae	Bach's calicoflower	Forb	4%
Lupinus alpestris	Fabaceae	Great Basin Lupine	Forb	4%
Trifolium macrocephalum	Fabaceae	largehead clover	Forb	4%
Allium sp.	Liliaceae	onion	Forb	4%
Allium tolmiei	Liliaceae	Tolm's onion	Forb	4%
Linum sp.	Linaceae	flax	Forb	4%
Gayophytum sp.	Onagraceae	groundsmoke	Forb	4%
Leptodactylon pungens	Polemoniaceae	granite prickly phlox	Forb	4%
Ruppia cirrhosa	Ruppiaceae	spiral ditchgrass	Forb	4%
Danthonia intermedia	Poaceae	timber oatgrass	Grass	4%
Artemisia tridentata	Asteraceae	Wyoming big sagebrush	Shrub	4%
Dasiphora fruiticosa	Rosaceae	shrubby cinquefoil	Shrub	4%
Lomatium triternatum	Apiaceae	nineleaf biscuitroot	Forb	3%
Agoseris glauca	Asteraceae	pale agoseris	Forb	3%
Antennaria dimorpha	Asteraceae	low pussytoes	Forb	3%
Antennaria luzuloides	Asteraceae	rush pussytoes	Forb	3%
Aster sp.	Asteraceae	aster	Forb	3%
Erigeron linearis	Asteraceae	desert yellow fleabane	Forb	3%
Ionactis alpina	Asteraceae	Lava aster	Forb	3%
Pyrrocoma carthamoides	Asteraceae	largeflower goldenweed	Forb	3%
Senecio crassulus	Asteraceae	thickleaf ragwort	Forb	3%
Senecio integerrimus	Asteraceae	lambstongue ragwort	Forb	3%
Senecio sp.	Asteraceae	ragwort	Forb	3%
Tragopogon dubius	Asteraceae	yellow salsify	Forb	3%
Downingia yina	Campanulaceae	cascade calicoflower	Forb	3%
Linum lewisii	Linaceae	prairie flax	Forb	3%
Epilobium brachycarpum	Onagraceae	tall annual willowherb	Forb	3%
Orobanche sp.	Orobanchaceae	broomrape	Forb	3%
Montia linearis	Portulacaceae	narrowleaf minerslettuce	Forb	3%
Delphinium nuttallianum	Ranunculaceae	twolobe larkspur	Forb	3%
Mimulus nanus	Scrophulariaceae	dwarf purple monkeyflower	Forb	3%
Achnatherum occidentale	Poaceae	western needlegrass	Grass	3%
Agropyron sp.	Poaceae	wheatgrass	Grass	3%
Elymus lanceolatus	Poaceae	streambank wheatgrass	Grass	3%

Leymus cinereus	Poaceae	basin wildrye	Grass	3%
Juncus balticus	Juncaceae	Baltic rush	Grasslike	3%
Artemisia tridentata	Asteraceae	basin big sagebrush	Shrub	3%
Cardaria chalapensis	Brassicaceae	lenspod whitetop	Shrub	3%
Eriogonum sphaerocephalum	Polygonaceae	rock buckwheat	Shrub	3%
Lomatium macrocarpum	Apiaceae	bigseed biscuitroot	Forb	1%
Cirsium arvense	Asteraceae	Canada thistle	Forb	1%
Cirsium sp.	Asteraceae	thistle	Forb	1%
Cirsium scariosum	Asteraceae	meadow thistle	Forb	1%
Crepis occidentalis	Asteraceae	largeflower hawksbeard	Forb	1%
Erigeron filifolius	Asteraceae	threadleaf fleabane	Forb	1%
Lygodesmia sp.	Asteraceae	skeletonplant	Forb	1%
Cryptantha intermedia	Boraginaceae	Clearwater cryptantha	Forb	1%
Brassica sp.	Brassicaceae	mustard	Forb	1%
Descurainia pinnata	Brassicaceae	western tansymustard	Forb	1%
Astragalus misellus	Fabaceae	pauper milkvetch	Forb	1%
Zigadenus sp.	Liliaceae	deathcamas	Forb	1%
Zigadenus venenosus	Liliaceae	meadow deathcamas	Forb	1%
Collomia sp.	Polemoniaceae	trumpet	Forb	1%
Eriastrum sp.	Polemoniaceae	woollystar	Forb	1%
Gilia sp.	Polemoniaceae	gilia	Forb	1%
Phlox gracilis	Polemoniaceae	slender phlox	Forb	1%
Phlox gracilis	Polemoniaceae	slender phlox	Forb	1%
Polemonium sp.	Polemoniaceae	Jacob's-ladder	Forb	1%
Eriogonum heracleoides	Polygonaceae	parsnipflower buckwheat	Forb	1%
Montia sp.	Portulacaceae	Springbeauty	Forb	1%
Geum triflorum	Rosaceae	old man's whiskers	Forb	1%
Lithophragma parviflorum	Saxifragaceae	smallflower woodland-star	Forb	1%
Collinsia sp.	Scrophulariaceae	blue eyed Mary	Forb	1%
Achnatherum hymenoides	Poaceae	Indian ricegrass	Grass	1%
Agrostis sp.	Poaceae	bentgrass	Grass	1%
Alopecurus geniculatus	Poaceae	water foxtail	Grass	1%
Distichlis spicata	Poaceae	inland saltgrass	Grass	1%
Elymus glaucus	Poaceae	blue wildrye	Grass	1%
Hesperostipa comata	Poaceae	needle and thread	Grass	1%
Pseudoroegneria spicata	Poaceae	bluebunch wheatgrass	Grass	1%
Vulpia octoflora	Poaceae	sixweeks fescue	Grass	1%

Rosa sp.	Rosaceae	rose	Shrub	1%

Table 4. Complete list of all bird species observed during the 2007 inventory period and the frequency that these species were seen in the playas inventoried.

Scientific Name	Common Name	Frequency
Eremophila alpestris	Horned Lark	61%
Spizella breweri,	Brewers Sparrow	58%
Pooecetes gramineus	Vesper Sparrow	48%
Sialia currucoides	Mountain Bluebird	38%
Amphispiza belli	Sage Sparrow	36%
Turdus migratorius	American Robin	34%
Branta canadensis	Canada Goose	34%
Euphagus cyanocephalus	Brewer's Blackbird	31%
Molothrus ater	Brown-Headed Cowbird	27%
Sturnella neglecta	Western Meadowlark	27%
Corvus corax	Common Raven	25%
Colaptes auratus	Northern Flicker	22%
Charadrius vociferus	Killdeer	20%
Centrocercus urophasianus	Sage Grouse	17%
Oreoscoptes montanus	Sage Thrasher	16%
Falco sparverius	American Kestrel	14%
Buteo regalis	Ferruginous Hawk	13%
Circus cyaneus	Northern Harrier	11%
Buteo jamaicensis	Red-Tailed Hawk	11%
Anas platyrhynchos	Mallard	8%
Zenaida macroura	Mourning Dove	8%
Passerculus sandwichensis	Savannah Sparrow	8%
Ardea herodias	Great Blue Heron	6%
Numenius americanus	Long-Billed Curlew	6%
Falco mexicanus	Prairie Falcon	6%
Actitis macularia	Spotted Sandpiper	6%
Junco hyemalis	Dark-Eyed Junco	5%
Carpodacus mexicanus	House Finch	5%
Poecile gambeli	Mountain Chickadee	5%
Buteo swainsoni	Swainson's Hawk	5%
Hirundo rustica	Barn Swallow	3%
Spizella passerina	Chipping Sparrow	3%
Sturnus vulgaris	European Starling	3%
Ardea alba	Great Egret	3%
Anas carolinensis	Green-Winged Teal	3%

Sitta canadensis	Red-Breasted Nuthatch	3%
Agelaius phoeniceus	Red-Winged Blackbird	3%
Melospiza melodia,	Song Sparrow	3%
Tachycineta bicolor	Tree Swallow	3%
Cathartes aura	Turkey Vulture	3%
Zonotrichia leucophrys	White-Crowned Sparrow	3%
Anas americana	American Wigeon	2%
Callipepla californica	California Quail	2%
(Anas cyanoptera	Cinnamon Teal	2%
Ammodramus savannarum	Grasshopper Sparrow	2%
Chondestes grammacus	Lark Sparrow	2%
Lanius ludovicianus	Loggerhead Shrike	2%
Pica hudsonia	Magpie	2%
Mimus polyglottos	Northern Mockingbird	2%
Sialia mexicana	Western Bluebird	2%
Aix sponsa	Wood Duck	2%

Table 5. Complete list of all non-bat mammals observed during the 2007 inventory period and the frequency that these species were seen in the playas inventoried.

Scientific Name	Common Name	Frequency
Canis latrans	Coyote	81%
Antilocapra americana	Pronghorn Antelope	77%
Odocoileus hemionus)	Mule Deer	45%
Taxidea taxus	American Badger	27%
Lepus californicus	Black-Tailed Jackrabbit	20%
Cervus canadensis	Rocky Mountain Elk	19%
Thomomys talpoides	Northern Pocket Gopher	16%
Spermophilus beldingi	Belding's Ground Squirrel	16%
Brachylagus idahoensis	Pygmy Rabbit	6%
Tamias minimus	Least Chipmunk	5%
Lynx rufus	Bobcat	3%
Puma concolor	Mountain Lion	3%
Perognathus parvus	Great Basin Pocket Mouse	2%

Table 6. Complete list of all bats observed during 2007 inventory period.

Scientific Name	Common Name
Eptesicus fuscus	Big brown bat
Myotis californicus	California bat

Myotis thysanodes	Fringed bat
Tadarida brasiliensis	Brazillian free-tailed bat
Myotis lucifugus	Little brown bat
Antrozous pallidus	Pallid bat
Lasionycteris noctivagans	Silver-haired bat
Corynorhinus townsendii (Plecotus townsendii)	Townsend's big-eared bat
Myotis evotis	Western long-eared bat
Myotis ciliolabrum	Western small-footed bat
Myotis volans	Western long-legged bat
Myotis yumanensis	Yuma bat

Table 7. Complete List of aquatic macro invertebrates observed during the 2007 inventory period and the frequency of observation at a playa

Order	Family	Subfamily (when applicable)	Genus	species	Frequency
Rhynchobdellida	Glossiphoniidae		Helobdella	stagnalis	3%
Rhynchobdellida	Glossiphoniidae		Placobdella	parasitica	3%
Trombidiformes					40%
Anostraca	Artemiidae		Artemia	salina	3%
Diplostraca	Cyzicidae		Cyzicus	setosa	17%
Diplostraca	Lynceidae		Lynceus	brachyurus	10%
Notostraca	Triopsidae		Lepidurus	couesii	20%
Coleoptera	Dytiscidae		Agabus		3%
Coleoptera	Dytiscidae		Colymbetes	densus	7%
Coleoptera	Dytiscidae		Colymbetes	sculptilis	17%
Coleoptera	Dytiscidae		Coptotomus	longulus	33%
Coleoptera	Dytiscidae		Dytiscus	marginicollis	3%
Coleoptera	Dytiscidae		Dytiscus		10%
Coleoptera	Dytiscidae		Graphoderus	occidentalis	7%
Coleoptera	Dytiscidae		Hydroporus		3%
Coleoptera	Dytiscidae		Hygrotus		63%
Coleoptera	Dytiscidae		Laccophilus	maculosus	27%
Coleoptera	Dytiscidae		Laccophilus		7%
Coleoptera	Dytiscidae		Rhantus	consimilis	3%

Coleoptera	Dytiscidae		Rhantus	sericans	7%
Coleoptera	Dytiscidae		Stictotarsus		20%
Coleoptera	Dytiscidae				13%
Coleoptera	Gyrinidae		Gyrinus		7%
Coleoptera	Haliplidae		Haliplus		10%
Coleoptera	Haliplidae		Peltodytes	callosus	3%
Coleoptera	Helophoridae		Helophorus		10%
Coleoptera	Hydrophilidae		Berosus		33%
Coleoptera	Hydrophilidae		Hydrophilus		7%
Coleoptera	Hydrophilidae		Tropisternus		50%
Coleoptera	Hydrophilidae				7%
Diptera	Ceratopogonidae	Ceratopogoninae	Probezzia		3%
Diptera	Chironomidae	Chironominae			27%
Diptera	Chironomidae	Orthocladiinae			23%
Diptera	Chironomidae	Tanypodinae			47%
Diptera	Chironomidae				13%
Diptera	Tabanidae				17%
Ephemeroptera	Baetidae		Callibaetis		30%
Heteroptera	Belostomatidae		Lethocerus	americanus	3%
Heteroptera	Corixidae		Cenocorixa		53%
Heteroptera	Corixidae		Corisella		10%
Heteroptera	Corixidae		Hesperocorixa		40%
Heteroptera	Corixidae				40%
Heteroptera	Gerridae		Gerris		3%
Heteroptera	Nepidae		Ranatra	fusca	7%
Heteroptera	Notonectidae		Notonecta	kirbyi	63%
Heteroptera	Notonectidae		Notonecta		47%
Odonata	Aeshnidae		Aeshna		3%
Odonata	Aeshnidae		Anax	junius	3%
Odonata	Aeshnidae		Rhionaeshna	californica	3%
Odonata	Coenagrionidae		Enallagma		7%
Odonata	Coenagrionidae				13%
Odonata	Lestidae		Lestes		17%
Odonata	Libellulidae		Libellula	pulchella	3%

Odonata	Libellulidae		Libellula	saturata	3%
Odonata	Libellulidae		Libellula		7%
Odonata	Libellulidae		Sympetrum		3%
Odonata	Libellulidae				3%
Amphipoda	Hyalellidae		Hyalella		3%
Anura	Hylidae		Pseudacris	triseriata	3%
Basommatophora	Lymnaeidae		Lymnaea		20%
Basommatophora	Physidae		Physa		3%
Basommatophora	Planorbidae		Helisoma		33%

Appendix C: Characteristics of Soil Samples

Table 8. General observations of soil samples collected for ash characterization. Playas 1 through 5 correlate to the playas in Figure 12. Playa 1 is the northern-most playa in Figure 12, and playa 5 is the southernmost playa in Figure 12. The subscripts refer to location of sampling within the playa: a is the vegetation-free lowpoint, or playa center; b is the vegetation edge, where vegetation establishes around the playa center; c is the topographic edge, where the playa transitions into the upland. Samples were taken at depth ranges that captured horizon differences. The ash content was recorded is the lab as Very high (VH), High (H), Medium (M), Low(L), Trace (T), or none (N).

Playa	Depth (cm)	Ash Content	Comments
1a	0-8	VH	Ponded Clay playa, no standing water
1a	19-36	VH	
1a	42-50	VH	clay increase
1a	59-65	VH	Redox features, gleying, no free water
1b	0-5	VH	
1b	19-35	VH	
1b	35-45	VH	
1b	47-56	VH	
1c	0-9	VH	
1c	20-29	VH	
1c	47-60	VH	
1c	82-87	VH	
1c	100-110	VH	Clay films, no free water
2a	0-6	VH	Ponded Clay playa, no standing water, mud cracks

2a	19-30	VH	Clay increase
2a	60-72	VH	Clay becomes less dense
2a	92-100	VH	
2a	130-135	VH	
2b	0-7	VH	
2b	18-30	VH	
2b	32-50	VH	clay increase
2b	62-69	VH	
2b	80-86	VH	
2c	0-7	VH	
2c	25-37	VH	
2c	50-60	VH	
2c	90-95	VH	
2c	105-113	VH	
3a	0-8	VH	Ponded Clay playa, no standing water
3a	12-26	VH	
3a	33-40	VH	Clay increase
3a	53-61	VH	Less clay
3a	78-83	VH	Color change, clay increase
3b	0-8	VH	
3b	16-27	VH	Very ashy
3b	40-56	VH	
3b	58-68	VH	Less clay
3b	78-89	VH	Pumice
3b	120-124	VH	Silty
3c	0-7	VH	
3c	27-34	VH	Pumice
3c	50-56	VH	Clay layer
4a	0-1	VH	Lakebed playa, 2 dug-outs with ~1.5m standing water, very hard surface
4a	1-4	VH	
4a	7-20	VH	Clay layer, hard
4a	30-47	VH	Silty
4a	57-71	VH	
4a	91-97	VH	
4b	0-5	VH	
4b	8-11	VH	Clay layer

4b	19-26	VH	
4b	36-49	VH	Silty
4c	0-10	VH	
4c	7-14	VH	
4c	16-32	VH	
4c	58-69	VH	
5a	0-5	VH	Lakebed playa, 2 dug-outs with ~1.5m standing water
5a	2-7	VH	Ashy until ~8cm, clay layer
5a	36-49	VH	
5a	88-94	VH	Silty
5a	117-123	VH	Yellowish clay layer
5b	0-5	VH	
5b	3-7	VH	
5b	26-40	VH	Clay layer@ 17cm
5b	58-65	VH	
5c	0-3	VH	
5c	17-38	VH	Clay layer @ 15cm
5c	39-48	VH	
5c	50-60	VH	

Appendix D : Field manual for Characterizing Central Oregon's Playas

The following sections in the field manual are developed to give the user enough information to confidently complete the field guide observation sheet with useful information and to increase the understanding the ecological significance of playas in central Oregon.

Introduction to playas in Central Oregon

This section describes some of the major components of playa ecosystems and major differentiating characteristics between playa types. It also discusses the compatibility of the field manual with the NRCS ESI and the *Field Book for Describing and Sampling Soils*. The introduction will also provide ecological context concerning known significance of playas in the high desert.

The following sections detail the methods of how to fill out information in the field data collection sheet. The sections will include shorthand notation or abbreviations so that detailed information can be entered in the small spaces.

Site Description

This section details instructions on how to fill out the top lines of the field sheet. Maps of central Oregon's high desert and lists of appropriate topographic quads and MLRAs will be included so that the user can pinpoint their general location in addition to providing exact GPS points. A detailed list of weather conditions and corresponding abbreviations will be listed so that abbreviations can be entered into the field sheet.

Soils

This section will discuss possible parent materials in the area and provide abbreviations for the parent materials. Evidence of biological crusts and the degree to which (if any) that they are eroding or damaged will be recorded through a series of pictures linked to abbreviations that can be filled into the field sheet.

Water

Varying degrees of ponding will be recorded in the field sheet based on a numerical representation of the amount of water present. Comments regarding evidence of ponding (i.e. mudcracks or moist surface soil) are to be included in the sheet. Any additional comments about the appearance of the water can be included in the "miscellaneous comments" section.

Vegetation

This section is to provide a brief ocular estimation of the percent cover of different plant types. Drawings will be provided that give examples of how different proportions of plant forms will appear. Using the drawings as a guide, general observations can be made about the approximate plant cover types and the amount of bear ground

Alterations

In this section the user should sketch a playa with the approximate locations and shapes of the dugout(s) relative to the playa. They also will include details concerning the shape and apparent functionality of the dug-out. They will also describe the soil berm, measure its length and height, and estimate its extent of erosion and plant cover.

Management

This section provides a place for the manual user to describe the presence of roads, fences and livestock usage. This will give an idea of how frequently the playa is used by livestock. Any evidence of recreation (OHV use, target practice, etc.) should be listed in the additional comments portion. Condition of the roads should be noted and the extent of use (if able to discern)

Wildlife

This section specifically addresses sage-grouse usage, but provides areas for recording other wildlife usage. The manual will provide information on how to identify sage-grouse droppings. Additionally a list of palatable forbs and other known landscape characteristics that are favorable to the sage-grouse.

The following section may be eventually broken into many sections. This will provide information on how the data will be used to further research the playa habitats. This section will also include past, current and future playa habitat management strategies.

Data Utilization and Playa Habitat Management Strategies

This section provides detailed playa habitat management strategies, current knowledge about resilience of playas to different types of disturbance and monitoring playa habitats. This section will detail how monitoring project shave been executed with success in the past and tips for monitoring current conditions.